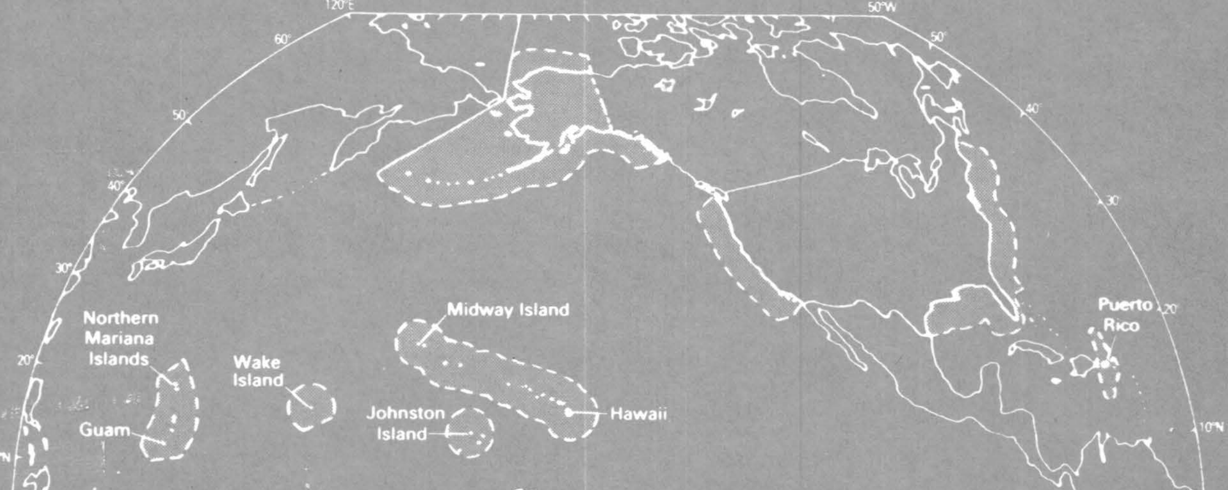
SYMPOSIUM PROCEEDINGS

A National Program for the Assessment and Development of the Mineral Resources of the United States Exclusive Economic Zone



Symposium sponsored by the United States Department of the Interior

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A National Program for the Assessment and Development of the Mineral Resources of the United States Exclusive Economic Zone

November 15, 16, 17, 1983

U.S. GEOLOGICAL SURVEY CIRCULAR 929

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INTRODUCTION

On March 10, 1983, President of the United States Ronald Reagan signed a proclamation establishing the Exclusive Economic Zone, an area contiguous to the territorial sea of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands, and the U.S. overseas territories and possessions extending 200 nautical miles from the coastline. The area of the EEZ encompasses 3.9 billion acres, which is one and two-thirds times larger than the total land area of the United States and its territories.

As an aid in organizing a national program for the assessment and development of the mineral resources of the recently proclaimed Exclusive Economic Zone, a symposium was held in Reston, Virginia, at the U.S. Geological Survey National Center, November 15-17, 1983. The 3-day symposium was sponsored by the Geological Survey, the Minerals Management Service, and the Bureau of Mines, all in the U.S. Department of the Interior. The EEZ Symposium was held to plan a coordinated government, academic, and industry program to evaluate the mineral-resource potential in this new economic zone. Approximately 240 people participated in the symposium; 58 percent of the attendees were from government agencies (Federal, state, local, and foreign), 25 percent from private industry, and 17 percent from academia.

The objectives of the symposium were to examine, through presentations and workshop groups, the status of current and proposed activities among academic institutions, the private sector, and government agencies involved in evaluating, leasing, exploring, and developing mineral resources of the EEZ; to identify future research and data needs and program objectives and priorities of mutual interest to all three sectors; and to define the best course of action by the government, the private sector, and academia in the EEZ in order to evaluate this vast national domain within a framework of mutual cooperation.

Invited speakers from academic institutions, petroleum and mineral mining companies, and government agencies presented from their various viewpoints the state of knowledge and significance of the EEZ. These presentations constitute the first part of this volume and set the stage for the important workshop discussion groups.

Six workshop panels were designated, and the panel chairmen prepared a preliminary report as a starting point for discussion in the workshop by the participants. Panels I-A and I-B addressed the science and resource evaluation of (A) oil and gas, and (B) hard minerals. The reports for these panels: (1) assessed the present status of knowledge and future research requirements; (2) identified critical data and information needs including priorities for data acquisition; and (3) recommended appropriate program roles, a schedule of actions, and resource requirements to implement an effective national program. Panels II-A and II-B addressed the engineering and technology assessment of (A) oil and gas, and (B) hard minerals. The report for these panels: (1) assessed the present status of research and development activities; (2) identified present technological limitations and major obstacles to overcome; and (3) recommended appropriate program roles, a schedule of actions, and resource requirements to implement an effective national program. Panels III-A and III-B addressed the management as well as the legal and leasing framework of (A) oil and gas, and (B) hard minerals. The reports for these panels: (1) assessed present status of the legal and leasing framework for U.S. marine mineral resources; (2) identified problem areas associated with present programs for exploration and development of domestic marine minerals; and (3) recommended conditions and actions necessary to promote a national program for growth of the domestic marine mineral industries. Each of these preliminary documents is included in the second part of this volume.

Discussions by the participants in each of the six workshop panels resulted in a series of recommendations that are being and will be used to formulate and implement a national program for assessment and development of the resources of the EEZ. These panel recommendations are also included with each panel report.

PART A. VARIED PERSPECTIVES OF THE IMPORTANCE OF THE EEZ

Chapter 1

IMPORTANCE OF THE EEZ PROCLAMATION

by

William P. Pendley
Department of the Interior

Welcome. I want to thank you, Dr. Peck, for having us here at the home of the Geological Survey, and I want to thank you and your tremendous staff for the incredibly fine display that we saw on the way in this afternoon. What a marvelous piece it is and how, in so little space, you have really summarized where we are: at the edge of a new frontier in oceans' exploration. It's a credit to the Geological Survey, to the Minerals Management Service, and to the Bureau of Mines, that you were able to put together such a fine display. I thank you, Dr. Peck.

On behalf of the Secretary of the Interior, I welcome you to this gathering of minds for the purpose of meeting the challenges of America's Exclusive Economic Zone. I wish Judge Clark could be here today to stand where I'm standing, and welcome you. Unfortunately, the United States Senate was not able to move as quickly as we had expected. It looks as though the confirmation vote will take place either late today or early tomorrow.

We, at the Department of the Interior, are exceedingly proud of the role that we played in the initial phase of the establishment of an Exclusive Economic Zone: It began with a memo from Secretary James Watt to the Cabinet in August of 1982, suggesting the establishment of a national oceans policy, including the Presidential proclamation of an Exclusive Economic Zone. That initial effort was carried to fruition by Secretary of the Interior-Designate Judge William P. Clark, then acting as the National Security Adviser to the President.

Those of you who have followed the confirmation process over the past couple of weeks and have read the transcript of Judge Clark's confirmation hearings will know that he does not take lightly America's national security interests relating to strategic and critical minerals and our energy resources. Sprinkled throughout the confirmation hearings, in response to numerous queries from Senators across the country, are Judge Clark's remarks on the need to be strong as a nation by having those essential natural resources available to us.

Thus, it is with a great deal of pride that I welcome you here today. You are the essential contributors needed to meet the challenges ahead. Our Nation has been built on a free enterprise system based on a unique marriage of the vast natural resources that we have and the resources of the human spirit.

Our ocean resources are vast and diverse. If we are to succeed in the wise use of our oceans, we must obtain a better scientific understanding of their resources and prepare for a development program that will provide environmental protection and safeguards. We will succeed only if we cooperate and diligently strive together to apply our talents and use our resources in the most effective way possible. Only by close cooperation can we meet the challenges offered by this 3.9-billion-acre new frontier. Prior to the President's signature on this proclamation, we were looking at a billion acres of offshore territory. Today, we are looking at nearly four times that amount.

Today marks the beginning of a new phase of progress in the Exclusive Economic Zone. We see it as a phase of action undertaken in a spirit of cooperation and commitment. The work ahead truly captures the imagination. Among us already are the present and future explorers, prospectors, and discoverers. We will enter a new region of uncharted rivers, canyons, volcanoes, and geysers. We will face a hostile climate unlike any other yet experienced by man. Crossing the West or going to the Moon posed dangers to man not unlike the hazards, the unique climates and situations that we face deep under the oceans. We will work in an atmosphere of rushing currents and pressures of 4 tons per square inch. As yet unimagined technology will support us, and the goals of scientific understanding and free enterprise will once again merge to the benefit of the Nation.

I think we need only to look at the development that has taken place in just 20 to 30 years in Outer Continental Shelf (OCS) activity with regard to oil and gas in order to understand how technology, when given the opportunity, and free enterprise, when availed the chance, will respond. Where were we just 30 years ago in the OCS? We thought that 600 feet was the technological limit of Outer Continental Shelf activity. Just a few months ago, private industry placed a platform on the Outer Continental Shelf in 1,080 feet of water, a unique, previously untested platform, that will allow us to take a production platform into 6,000 feet of water. As we look to the OCS oil and gas, we know that the private sector and America's great human resources can respond and meet the challenge.

We will learn volumes from the ocean and the rich natural resources as we explore these new regions like pioneers of the past. Yet, as in every new frontier, we will gain a new appreciation for and understanding of the land from whence we came. Understanding the geology of the oceans will help us understand the geology of the land and the rich resources still hidden from our view. I think this is the link upon which many have not yet focused. As we go into this unique land area, covered by the world's water, we will find many of the answers that have eluded us here on the continents.

President Reagan made a historic contribution to the future of this Nation by issuing his March 10, 1983, proclamation creating an Exclusive Economic Zone. By redrawing our sovereign boundaries 200 miles out from our Nation's shorelines, he underscored the Government's commitment to preserving mineral opportunities on the sea floor and advancing marine scientific research. By one single act, the President quadrupled the area in which the United States exercises ocean jurisdiction. It demonstrated the President's will in aggressively asserting our rights over mineral resources in the region, and it advanced the goals of his national minerals policy while responding to a fatally flawed Law of the Sea Treaty.

The President's commitment to national minerals interest is long standing. In September 1980, Governor Ronald Reagan became the first presidential candidate in history to make national minerals policy a part of a presidential campaign when he recognized not only the critical link that minerals have to national defense, but their imperative relationship to economic recovery. In his second month in the White House, the President ordered the Government to once again begin purchasing materials for the strategic and critical stockpile, the first purchases in over 20 years. On April 5, 1982, the President issued the first National Minerals Policy in nearly three decades, second only to President Eisenhower's proclamation in 1954.

The National Minerals Policy is the foundation of the Exclusive Economic Zone initiative. President Reagan rejected the Law of the Sea Convention in large part because of his commitment to this policy. The President's words were: "It is the policy of this administration to decrease America's minerals vulnerability by taking positive action that will promote our national security, help ensure a healthy and vigorous economy, create American jobs, and protect America's natural resources and environment." Here again, we see the wedding of natural resources and human resources to build America, to cause that new beginning that the President committed himself to in January 1981. The President's policy statement is reflected in the Exclusive Economic Zone proclamation of March 10th of this year. Within the Exclusive Economic Zone, the United States has sovereign rights for the purposes of exploring, exploiting, conserving and managing natural resources, both living and nonliving, of the seabed.

The wealth of our Nation and her industrial and military strength is founded on minerals. There can be no doubt about that. The only way to meet our material needs and sustain our standard of living is to have secure access to minerals, to dig them from the earth, or to take them from the sea. Over 40,000 pounds of new minerals are needed each year for every American. Each citizen will require, over a lifetime, a half a ton of lead, half a ton of zinc, 2 tons of aluminum, and 45 tons of iron and steel.

Yet, we have become complacent as a nation about the role of minerals in our economy, our national defense and our lifestyle. Our collective dependence on minerals has grown, while our supply, security, and industrial productivity have declined. As a people, we have grown so far removed from our extractive industries that few recognize the threat posed by the current trend toward increasing minerals vulnerability.

Our dependence on certain imported minerals is irrefutable. For some strategic minerals, such as chromium, manganese, cobalt, and nickel, U.S. dependence on foreign sources ranges from 80 to 100 percent. Cobalt, for example, which is not mined domestically, is imported, 100 percent, from foreign sources, 73 percent of the total coming from central and southern Africa. Nickel is mined in America, but more than 80 percent of our stock is imported. We're virtually 100 percent dependent on foreign sources for manganese. Most of that supply originates in central and southern Africa, with a substantial amount from Gabon and Brazil. But, projections are that by the end of the century, the Soviet Union and South Africa will control all of the world's supply of manganese.

The importance of these minerals to our national defense, to essential civilian and industrial use in times of war, and to sustaining economic growth is well established. Manganese is fundamental to the production of virtually all steels and most cast iron. Cobalt is a critical hardener of steel for wear resistance and super alloys in cutting steels and manufacturing engine parts. Nickel, principally used in alloys to resist corrosion, is widespread in its use for aircraft and shipbuilding.

These special-property minerals form the basis of many developing technologies in the areas of defense, energy, and our space programs. At no time in our Nation's history are we more conscious, more aware, more concerned about international threats and the need for a strong military.

Our import dependence imparts maximum vulnerability when we deal with politically, economically, and socially unstable producer nations and long, unprotected shipping lanes. Whether we talk about energy resources that come around southern Africa, or whether we talk about strategic minerals that come out of South Africa and central Africa, we must have grave concerns about our vulnerability and our ability to sustain ourself as a nation in times of war.

The Soviet Union, on the other hand, has reached self-sufficiency in a great majority of strategic minerals and has secure supplies for the remaining few from Soviet Bloc countries. The possibility that the Soviet Union could engage in what some call a "resource war" by disrupting world markets and limiting availability of strategic minerals is supported by that nation's political positions on deep ocean mineral issues and the Law of the Sea negotiations, as well as by the Soviet hand, which through proxy forces reaches out for domination whether in southern Africa or Grenada. The strategic importance of deep seabed minerals containing cobalt, manganese, and nickel is not lost on the Soviet Bloc. The structure of an international deep-ocean mineral regime that is a collectivist system of production and allocation designed to protect land-based mineral producers and to deprive nations having market economies of their legal rights and freedoms, is an inspired effort, frankly, when viewed from the Soviet perspective.

No free-market enterprise could accept the risk of dealing with an independently financed, highly discretionary, intensely political agency such as the International Seabed Authority. That was the President's response. We are thankful that he had the courage to reject the Treaty that was 10 years in the making and yet still fatally flawed. By reaffirming his commitment to mineral security and by declaring a rational legal basis for mineral exploration within the Exclusive Economic Zone, the President has today opened the door to new opportunities for those of us who gather here. As we enter the new phase of activity related to exploration of this region, we can proceed, confident of our footing. We are supported by the national priority placed on our endeavor.

The speakers today and tomorrow, and those of you who will be participating in the panel sessions, are leaders in science, industry, academia, and government. You are the men and women of science, of industry, and of the sea who have been first off the starting blocks. You provide inspiration to others. You are the pioneers; you are the Neal Armstrongs, the Henry Comstocks, and the John Wesley Powells. You will be asked to examine the broad scope of work to be achieved in the EEZ, and the specialized needs of each of your communities. You will collectively shape the emerging path of progress in this vital, exciting area called the Exclusive Economic Zone. The Department of the Interior is institutionally committed to supporting the goals of the President in the Exclusive Economic Zone. We didn't just start the ball rolling from the standpoint of seeing something that needed to be done, but we had a tremendous cadre of career professionals behind us who gave us the inspiration for it.

I will relate to you a story that I think is illustrative of the way the government can work when government works best. We had our first session on this concept of an Exclusive Economic Zone and the National Oceans Policy in a conference room at the Department of the Interior headquarters. We had gathered around the table participants from various agencies--from the Department of Energy, the Environmental Protection Agency, the State Department, and the Department of Commerce--and we began the meeting with a discussion of an Exclusive Economic Zone. We had prepared in September 1982, rather optimistically, a press release for the President and a Presidential proclamation. We were really looking ahead.

We also led off the meeting by having two of the career scientists with the Geological Survey stand up and talk about a recent discovery in the Pacific, near the Hawaiian Islands, of something you've all heard about--the cobalt-rich manganese crusts. We passed around samples, and our career scientists answered questions. When it was over, it was as if the issue had been settled. There was no further discussion. Finding this vast resource within 200 miles of the Hawaiian Islands answered the question for many of us. The issue then became: How do we do this? How do we go about making this happen?

I think that the Exclusive Economic Zone originated from two events. It came out of the failure of the Law of the Sea Treaty to answer our questions and answer our needs and our plans for the future. Frankly, that's what we're after in this Nation, to protect our national interests into the foreseeable future. The notion of the EEZ came out of something else, too. It came out of the good, raw, solid scientific work of the Geological Survey, which, in cooperation with the West German government, had made these vital discoveries. These fascinating discoveries, the spreading centers off our Pacific Coast, allowed us to say: There is a reason to do this; there is a rationale. They allowed us to move--less than 7 months later--a document to the President's desk for signature proclaiming the Exclusive Economic Zone.

The Secretary of the Interior has the benefit of the support and experience of respected agencies, such as the Geological Survey, the Bureau of Mines, and our newly created Minerals Management Service. The Minerals Management Service, now a little more than a year old, has inherited the regulatory responsibilities of our 30-year-old ocean mining program. They have acquired in that new organization the expertise of the past, with the new leadership and the dedication of this Administration in its view of the future. The Bureau of Mines has been engaged in deep-seabed mining-technology assessment for over a decade, and is the world's foremost authority on global mineral supply-and-demand information, as well as minerals processing and metallurgy. As you look at the Bureau of Mines seal--I suggest that you read what's on the seal--it says, "Minerals Industries." We know what our commitment is and the responsibility of that 60-year-old agency. The U.S. Geological Survey is an internationally acknowledged leader in earth sciences and has historically included marine geology and sea-floor processes in its scope of work. As Dr. Ballard has said many times before, geology is geology whether you cover it with trees or you cover it with water. We look to the Survey for the answers.

We are eager to work together with you to apply the full weight of our influence, our abilities and our assets to meet the challenges and the opportunities of this Exclusive Economic Zone. We want an active program to make things happen. We want to make resources available. We want to learn all that we can learn, together--as industry, as academia, as government--to help America in the future. Will these resources be mined in the next decade, or in the next century? We can't provide the answers. But we've got to start now, as we plan for the future, to have that new beginning, to have that golden future that we've all held out to our children and to the American people.

I thank you for coming today, and I look forward to your participation and the results of this symposium.

Chapter 2

SCIENTIFIC ADVANCES IN OUR KNOWLEDGE OF THE SEA FLOOR

by

Robert D. Ballard
Woods Hole Oceanographic Institute

Within the last two decades, our concept of the sea floor has undergone a tremendous change. In fact, the term "ocean floor" is poorly applied when used to characterize the 71 percent of our planet which lies beneath the sea. The ocean bottom is dominated by a tremendous mountain range which covers 23 percent of Earth's total surface area. Despite the fact that this mid-ocean ridge stretches for a continuous distance of 72,000 kilometers, not until 1960 did we first recognize its total dimensions. Not until 1973 did we first begin to map its rugged slopes with manned submersibles in the Atlantic as a part of the joint U.S. and French program called "Project Famous."

This great mountain range system is only one example of the various geologic settings beneath the sea which now hold out promise as bedrock terrain for future heavy-metal exploration. The importance of this underwater terrain lies in its relationship to the crustal processes of earth, which shape its form and renew its resources.

The axial summit of the mid-ocean ridge, unlike the mountain ranges on land, is characterized by crustal separation, the upwelling of heat and magma material which lead to the formation of hydrothermal circulation and the outpouring of mineralized fluids. These fluids subsequently form potentially important heavy-metal deposits.

It is important to realize that our discovery of high-temperature venting of hydrothermal fluids within the mid-ocean ridge did not occur until 1979--less than 4 years ago. Since that time, we have discovered similar processes occurring not only along the mid-ocean ridge, but on isolated seamounts and in back arc basins, and more recently we have discovered cobalt-rich crusts on the seamounts around Hawaii. Although the black smokers of the mid-ocean ridge have galvanized our attention, these other settings may in the long run prove more important.

Let us now review our present status and place these discoveries in a larger global context. In 1970, the United States was unchallenged in the field of deep-submergence technology. Except for the aging French bathyscaph, Archimede, we were the only Nation which could routinely place scientific explorers in the deep abyss. We were the only Nation which possessed sophisticated sonar mapping systems capable of delineating the rugged mountainous terrain beneath the sea. We were the only Nation which possessed the deep sea drilling technology. As a result, our scientists dominated deep sea research as other nations looked on with envy.

During the intervening years all of this has changed. First, France, then England, then Germany, and now Japan and Canada have not only met our challenge, but in the area of deep-sea mineral exploration, have passed us. The loss of this clear and undisputed lead is not only the result of their resolve but the direct result of our lack of purpose. France, then Germany, and most recently, Japan and Canada, have followed a course of action now becoming routine in their competitive interactions with our country. Recognizing our position and size, they separately concluded that a serious response could come about only by each of them focusing their national talent.

In France, CNEXO took the lead, organizing an impressive group of engineers, scientists, and administrators, who themselves are highly qualified professionals. This talent base in France was drawn from industry, academia, and government. France moved quickly to acquire the first commercially available SEABEAM sonar mapping system from General Instruments in Massachusetts. CNEXO installed it in their first and their best research ship, the Jean Charcot, and had the system operational and in the field 3 years ahead of the United States.

France developed cooperative technology exchanges, and while we emphasized the political significance, they concentrated on assessing our technology and quickly developed a comparable capability, in large part through purchasing American technology. While our scientists struggled to justify the exploration for mineral deposits purely on scientific significance, as they were forced to do, France organized cruises specifically focused upon the assessment of potential commercial significance of these deposits. While we added basic researchers in biology and chemistry to our team, they added mining engineers and economic geologists to theirs.

Germany's response came through Preussag. Lacking deep submersible technology, they began cooperative discussions with CNEXO at the highest levels to gain access to their submersible technology. They also quickly acquired a SEABEAM sonar and began looking beyond manned submersibles to robotic vehicles. Their field programs took on a massive scale and a sense of urgency. While they toured our country, reviewing our previous cruise results, their data became proprietary.

Canada's approach, carried out by their Geological Survey, was to invite U.S. scientists to help them formulate their own national program. In 1983, a major symposium was sponsored by the Canadian government in Victoria, British Columbia, to carry out their planning effort. That summer, Canada mounted a major program on their western coast, which centered around the use of their submersible *Pisces* and rented U.S. assets.

More recently, Japan, through the leadership of JAMSTEC, has formed a group to assess the massive sulfide issue with members of Mitsubishi Metal, Mitzui Mining, Mitsubishi Heavy Industry, Sumitom Metal Mining, Toshiba, NEC, and Deep Ocean Mineral Associations.

And what has been the United States' program to date? It has been characterized by indecisiveness, or by maneuvering within the Government while our talent base looks on, frustrated by the lack of a focused, coordinated national program, and the lack of funding incentives or funding mechanisms to encourage cooperation among academia, industry, and government. To date, our industries have sat on the sidelines while their Canadian counterparts have actively helped their national program. Those industries which could benefit from a national program, but which do not necessarily care if mining proves profitable, are the only ones we're hearing from.

What should be our response? We should take this opportunity to shape a national program which draws upon a tremendous resource of talent; for, if we do, we will quickly regain the unchallenged position of leadership which we held only a decade ago. Like Canada and Japan, let our EEZ program provide a focus for our short-term objectives, but like France and Germany, let us not lose sight of the long-term goal of assessing the potential of the entire ocean basins.

Within our Government, the largest resource of talent resides within the U.S. Geological Survey. But they should also take good advantage of the assets, both human and technical, within NOAA. But more important, the Department of the Interior should draw upon industry and academia; for here lies the critical mass of expertise and technology necessary to meet this challenge.

Chapter 3

REQUIREMENTS FOR PRIVATE SECTOR INVESTMENT

by

Clifford E. McLain
SPC Venture Corporation

I feel very honored to be here today to discuss a subject in which I have a strong interest. I have some new thoughts to present to you, primarily relating to the question of investment in ocean hard minerals. Figure 1 shows some of these mineral deposits of interest and where they occur within the new Exclusive Economic Zone (EEZ).

I know that I have a tendency to be optimistic in this area. There are those who say, "We can never do things that fast." But the fact is, I've sometimes found that we can surprise ourselves if we actually just plunge in and try. However, even in "plunging in," a strategy is essential. The most important strategic element, which I think Bob Ballard described explicitly to us in the past few minutes, is that of a partnership of all of us to make these things happen. In order to bring about an effective partnership, government, academia, and the private sector need to work together. The principal private sector role is investment and operations. I've been particularly interested in the conditions necessary to encourage private investment in the ocean hard-minerals area. Such investment will ultimately be necessary if we're ever going to develop these assets.

The thoughts that I'm going to present to you this afternoon are mine. I would be most happy if they would be in any way productive as food for thought in this workshop, which is most timely.

The ocean hard minerials in which we're interested, shown in figure 1, are primarily those which fall within the area which we now have available to us under the President's EEZ proclamation, an area almost three times the size of the Louisiana Purchase. This is an enormous new region for development and for stewardship, and we want to be careful in what we do with it. We have said that we're going to use the EEZ to improve our economic situation, but it is an asset that interacts with all elements of our society.

The various authorities which were in place before the EEZ proclamation are somewhat fancifully sketched out in figure 2, which shows an artist's rendition of a cross section through the Gorda Ridge with a suggestion of the continuation to the Juan de Fuca Ridge. None of

EXCLUSIVE ECONOMIC ZONE MINERALS

Polymetallic sulfides Zn, Cu, Cd, Ag	Gorda, Juan de Fuca Ridge Systems
Placer Deposits	Alaska, Pacific NW coasts
Phosphorites	CA, FL, S. Atlantic coasts
Crusts Co, Ni, Mn	Gorda, Juan de Fuca seamounts, Pacific Islands
Manganese Nodules Mn, Co, Ni, Cu	S. Atlantic Coasts, Pacific Islands

Figure 1.

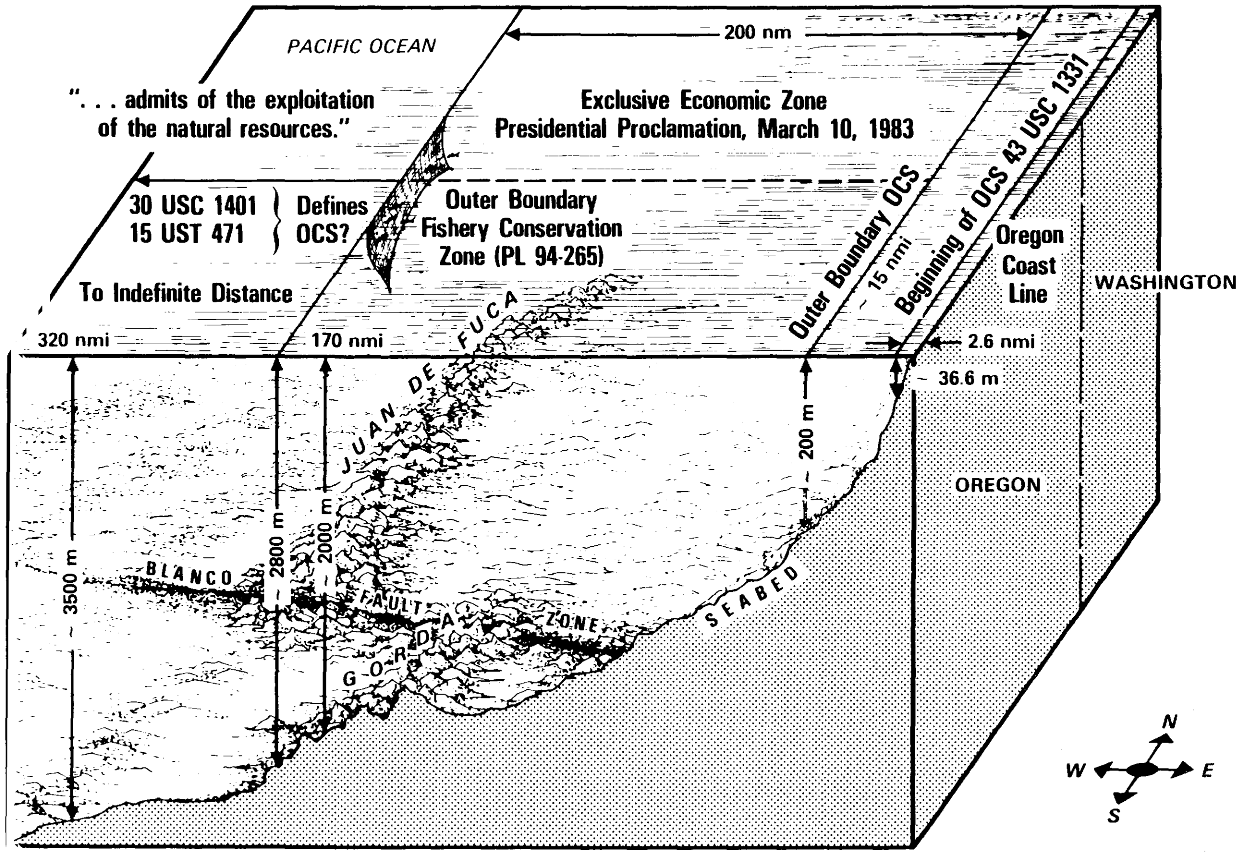
PACIFIC OCEAN
". . . admits of the exploitation of the natural resources."
200 nm
Exclusive Economic Zone
Presidential Proclamation, March 10, 1983
30 USC 1401
15 UST 471
Defines OCS?
Outer Boundary
Fishery Conservation
Zone (PL 94-265)
To Indefinite Distance
Outer Boundary OCS
15 nmi
Beginning of OCS 43 USC 1331
Oregon
Coast
Line
WASHINGTON
320 nmi
170 nmi
2.6 nmi
36.6 m
JUAN DE FUCA
200 m
2000 m
2800 m
3500 m
OREGON
BLANCO FAULT ZONE
GORDA
SEABED
N
W
E
S

Figure 2.

these authorities, however, were deemed quite adequate for dealing with the problems of developing the polymetallic sulfide deposits, which we have discovered over the past very few years, even though they did provide a mechanism for certain other economic developments such as fisheries, petroleum, and manganese nodules.

The 200-mile EEZ is interesting in that it encompasses basically all of the assets that we might wish to work with; however, there are still some areas of interest that fall outside of the EEZ; for example, the Juan de Fuca Ridge itself.

It should be noted that the Geneva Treaty, 15 U.S.T.-471, provided that nations could exploit ocean-bottom assets as far as they were technologically able to do so. Such provisions obviously transcend 200-mile zone borders, but would now appear to be superseded by the Law of the Sea Treaty, to which the United States is not a signatory. In addition, we have the OCS Lands Act, 43 USC 1331, and the Deep Sea Bed Hard Minerals Act, 30 USC 1401, which are actually in place, and which provide umbrellas for certain kinds of operations. However, our initial studies of the requirements for investment in the new ocean hard-mineral assets, particularly those off the Pacific Northwest coast, indicated that some action, such as the declaration of an EEZ, would be a necessary prelude to the development of assets that are not specifically addressed by these prior acts.

I want to address what the requirements might be, in the minds of the private sector, for investment in ocean hard minerals. I emphasize "requirements for investment." What kind of things does one think about as a private investor, if one is thinking about putting real money into doing something with these ocean hard-mineral assets? Figure 3 notes some of the requirements of importance.

Rules of the Game

If one is going to invest in something, one wants to know what the rules of the game are that are going to govern how that investment will work. This is a very important issue. The declaration of the EEZ, the legislation or regulatory instruments which cover what one does within the EEZ, and the tax structure related to investment, all determine these rules.

Protection of Investment

One needs mechanisms for protecting an investment after it is made. A particular mechanism may be that of claim staking. If one invests in exploration and finds something that has economic significance, one ought to have some kind of a right or mechanism, as an investor, to derive benefit from that finding.

OCEAN MINERALS
REQUIREMENTS FOR INVESTMENT

- Predictable rules of the game
- Mechanisms to protect investment
- Favorable economics
- Risk sharing
- Cooperative environment

Bottom line: ROI, ROR

Figure 3.

Economic Situation

A favorable economic situation has to be present; that is to say, one's business plan as an investor has to be based on a reasonable chance that one might actually make some money. While it is true that there are those who observe that some of the things I start tend to be nonprofit foundations, I think that one would insist that profitability would at least be evident in the basic economic equation for investment.

Risk Sharing

An important element in considering whether to put money into something from the private sector is whether or not there is a mechanism that allows one to share risks, so that one doesn't have to take all the lumps alone. (Perhaps there are some others that may throw in with one in the proposed venture.)

Cooperation

A cooperative environment is important. And by that I mean that any investment in a major economic area has to be made in what I like to call the socio-political/economic environment. If one is going to build a factory; if one is going to have a processing plant; if one is going to dig things up out of the ocean; one is, perforce, affecting all elements of the society that share the affected assets. And if there is an environmental factor that may be inimical to the venture -- in the present or future -- there's naturally a great reluctance to invest because of that factor. The private sector today recognizes that it must build a solid foundation on which to accomplish its objectives in order to establish its desired place in society.

Return on Investment, Rate of Return

The bottom line is that if anyone from the private sector is going to invest in any of these new operations, there has to be a calculable return on investment. Further, this return must be balanced with the perceived elements of risk. In addition, for the viability of the investment as a business venture, an effective rate of return must be achieved which will allow the business to operate.

Now I'd like to discuss a few of these ideas in a little more detail.

First, just a brief note on the rules of the game, relative to the development of ocean hard-mineral assets (fig. 4). The overall rule, or umbrella, has in fact been put in place. That's why we've met here today. The proclamation of the EEZ was essential, particularly in the context of the existing Law of the Sea Treaty and the fact that the United States is not a signatory to that treaty. Many people might argue, I would submit, that even if we had been a signatory to the Treaty, we would still have required the EEZ proclamation because of the unsatisfactory current nature of the provisions under the Law of the Sea for ocean-bed hard-mineral mining.

RULES OF THE GAME

OVERALL POLICY: The EEZ

LEGISLATION: OCS Lands Act 43 USC 1337 DoI
Deep Seabed Act 30 USC 1401 DOC/NOAA
Others needed?

REGULATION: Leasing/claim staking
Environmental requirements
On and off shore operations

FISCAL AND TAX POLICY: Investment tax credits
State and local tax policy for on shore
Syndications and joint ventures
Federal subsidies and assistance
State loans and matching funds

Figure 4.

In any event, the EEZ is now in place. And we have 43 USC 1337 and 30 USC 1401 which might be expanded or extended to cover specific problems. There has been some discussion as to whether or not we need other legislative vehicles. I'm not prepared to discuss requirements for further legislation here. John Norton Moore's Center for Ocean Law and Policy at the University of Virginia, Charlottesville, hosted an excellent discussion of this subject at the November 3 Ocean Policy Forum in Washington, D.C. My personal conclusion at the end of the November 3 Forum was that discussions were essentially moot as to the need for additional legislation.

Regulation, however, is also important. The reason for its importance is that we need some vehicle for protecting the investment and for guiding the operations of the people, institutions, and industries desiring to develop some of these assets. Leasing and claim-staking are two mechanisms that have been traditionally employed and proven effective in protecting hard-mineral exploration and development investments.

Regulation obviously has to also address the question of environmental requirements. These requirements affect both onshore and offshore operations. For example, regulations relative to the operation of processing facilities onshore (such as smelters) would be a most important part of the investment environment.

Finally, there is the very important area of fiscal and tax policy--some of the important considerations listed in Figure 4. The United States has a long history of using its tax policy to encourage investment. The current tax laws, particularly those providing R&D tax credits, depletion allowances, investment tax credits, and other credits such as those now in place with respect to the oil and gas industry, are important elements in encouraging investment.

Figure 5 lists some of the important aspects of protecting the investment itself. First, I want to point out that private investments resulting in mineral asset discoveries need to be rewarded. That is to say, if private sector, rather than Federal or State Government support, is going to be applied to the discovery and characterization of assets, those who invest in that area need to know that there is a reasonable expectation of return. Currently, this is generally accomplished by granting lease areas and the ability to stake claims. Some protection mechanism such as this must be in place if the private sector is going to invest in the mineral recovery area. It's also clear, however, that we first have to determine that there are adequate assets there to work with in the first place. There must be enough deposits to run the smelter or another type of processing activity for a reasonable period of time in order to allow the amortization of the recovery facility investment. Typical amortization schedules for such facilities might be set at a maximum period of 10 years.

PROTECTING INVESTMENTS

MINERAL DISCOVERIES	Leased areas Claim staking
MINERAL RECOVERY	Adequate deposits
MINERAL PROCESSING	Integration with local and regional aims Steady labor pool
MARKET	Adequate margin for a typically unstable market Volume a small fraction of total market

Figure 5.

The whole processing area is one that has to be carefully addressed and studied. Investors need to understand processing facility requirements in terms of integrating such facilities within the local area in which it will operate. That is, it's an industry development that must be accepted by those that will live and work there. The best insurance for regional and local acceptance is that such investments should match regional and local goals and plans for growth and development. If the type of installation proposed is contrary to regional and state growth objectives, it probably will not take place. It will have serious regulatory restrictions. There will be local opposition groups. Thus a broad basis of regional and local community interest has to be laid down beforehand. The development must be seen as an economic asset. A steady labor pool needs to be assured as an important element in validating the investment.

Finally, the market situation has to be addressed. The minerals market has been a difficult one. Over the past 10 years, metals have been up and down, but the recent metals market has been generally characterized by depression. The investor must look at the situation from an investment standpoint and ask: Will my investment pay off, understanding what I do about the ups and downs of the market. And, in fact, when making the investment calculation, one should always take the minimum dips as the "worst case" profit scenario. I, at least, would want to make a few percent even at that low level. One of the ways to insure that market assumptions will hold is to consider whether or not the entry of a new source into the market will, in fact, affect the price.

The investor, then, looks for a favorable economic situation. Figure 6 lists some of the factors that would contribute to a favorable economic situation. It is desirable that there be a continuing demand for the metals, and that metals of interest have a very high assay value compared to their recovery and processing costs. (High potential assay value is one of the fascinating considerations about some of these ocean hard-mineral deposits).

The investor also looks for some separation of the recovery and processing costs from the minerals market itself. That is to say, one wants to be able to not only predict costs, but also to seek as large a gap as possible between these costs and the probable market price, as insurance against an uncertain market. That is, one seeks to protect the investment on the down side.

As a final important element in the investment equation, it is probably a good rule that the production volume required to make money should be only a small fraction of the total market requirement in order to minimize any effect the new production might have on market prices. One of the problems encountered in processing manganese nodules was that, because of the large amounts required for profitability (Ref. "Report on Marine Hydrothermal Metal Deposits," the Congressional Research Service report No. 97-D, July 1, 1982), the output would have

FAVORABLE ECONOMICS

- High assay value compared to recovery and processing costs/ton
- Recovery and processing costs decoupled from metals market
- Lowest market values determine basic profit margin
- Production volume for profitability small with respect to world market

Figure 6.

constituted a significant fraction of the total world consumption of manganese, thereby significantly depressing the price.

As an example of the data which might be considered in such market questions, figure 7 extracts stockpile information from a 1972 report by the Federal Emergency Management Agency (FEMA) on the status of the stockpile. Figure 7 shows that many of the elements found in the polymetallic sulfide, placer, and crustal deposits are important elements in our stockpile. As far as the stockpile goals are concerned, there are still large stockpile requirements for all of these metals except silver. This stockpile picture has not changed significantly since 1981. Although the stockpile shows a surplus of silver, it is still an important recovery metal, because it does have a reasonable continuing world market.

Figure 8 shows the assay results of polymetallic sulfide recoveries that were obtained from 1980-81 surveys of the Juan de Fuca Ridge which show that, in fact, these deposits have high recovery values. More recent recoveries from Juan de Fuca show similar high assay values.

Figure 9 illustrates some very rough calculations I've made, which, frankly, although based on such cost data as used in the Breaux report (Ref. "Report on Marine Hydrothermal Metal Deposits," the Library of Congress Report No. 97-D, July 1, 1982), should be taken only as a gross indication of the profitability calculation. The numbers indicate that a pilot plant operation would amortize its capital investment (on the order of $400 million) within a period of about 10 years by processing aproximately 200,000 tons of ore a year assuming it all met the assay average of samples recovered from the Juan de Fuca Ridge. I would urge that these are not "real" numbers, but are offered as illustrative of the type of investment calculation that must be made -- and viewed as probable -- by the prospective private investor.

Next, I'd like to address the question of risk-sharing, illustrated in figure 10. There are various mechanisms available for risk-sharing. Syndications of industries and private investors constitute one important mechanism for risk-sharing, and, in fact, may form an excellent mechanism for early industrial and private sector investment in this area.

Joint ventures and cooperative teams similarly provide such a mechanism. Because of the importance of laying a basis of regional and local acceptance of the development, we are particularly interested in a cooperative team that consists of State and local as well as Federal Government interests. This may be further facilitated by the inclusion of academia through appropriate universities and institutions having the technological know-how to meet operational requirements and environmental concerns. The wise private investor should seek every opportunity to validate the investment opportunity. One of the best methods of validation is to obtain the very best people. Hence, one can see the value of incorporating the scientific, technical, and

STOCKPILE INVENTORY
MARCH 1981
IN POTENTIAL POLYMETALLIC SULFIDE ORES

	INVENTORY (UNITS)	FEMA GOALS	EXCESS/ DEFICIT	VALUE ($1000s)
Cadmium	6,328,809	11,700,000	– 5,371,191	– 10,743
Cobalt	40,802,393	85,400,000	– 44,597,607	– 1,114,940
Copper	28,444	1,000,000	– 971,556	– 1,915,923
Lead	601,026	1,100,000	– 498,974	– 359,262
Manganese	2,409,377	2,700,000	– 290,623	– 21,236
Silver (Troz)	139,500,000	0	139,500,000	1,848,375
Tin	200,112	42,000	158,112	2,291,839
Zinc	375,970	1,425,000	– 1,049,030	– 894,297

Source: Report to Congress: National Materials and Minerals Program Plan, April 1982
The White House, April 5, 1982

Figure 7.

EXAMPLE MASSIVE ORES
S. PORTION OF JUAN D FUCA RIDGE
(USGS – U of Wash, Seattle – UCSB Surveys 1980-81)

	WF-22D-1	WF-22D-2	WF-22D-3
Zinc	54%	29.7%	59.2%
Silver	290 ppm	124 ppm	230 ppm
Cadmium	490 ppm	–	1060 ppm

Value of Metal/Ton of Ore

Zinc	432.00	237.60	473.60
Silver	71.80	30.70	56.90
Cadmium	1.00	–	2.10
Total/ton	504.80	268.30	532.60

Fall 1982 Metals Prices/Lb

Copper .75 Silver 123.80 Zinc .40 Cadmium 1.00

Figure 8.

SCOPE OF PILOT OPERATIONS

- Assuming operations to support $400 M investment
  - 15% ROI for investors
  - Current metal market prices (Fall 1982)
  - Ores equalling samples from Gorda and Juan de Fuca ridges
- 250 operating days/year
- 1000 tons/day – 200,000 tons/year
- 200 yd^3/day – 40,000 yd^3/year
- Average assay: $300-500/ton recoverable metals
- 10 year amortization of capital investment

Figure 9.

RISK SHARING

- **Syndications**
  - Risks, profits, tax benefits
  - Tax and antitrust considerations
- **Joint ventures**
  - Pooled talent, resources
  - Shared investment
- **Cooperative teams**
  - Private/government/academic
  - Validation of technology and plans
- **Shared technology**
  - Multiple markets for technology
  - Investments

Figure 10.

planning talent available from both public and private institutions, and in the government, as a part of the cooperative team.

Finally, the idea of shared technology can provide another important mechanism for encouraging private investment. As an example of the opportunity for shared technology, private investment in developing new exploratory technologies, new assessment technologies, and new recovery and processing technologies for the development of U.S. assets can be backed up through the sale of such technology to other markets in the world. There are other countries and markets that are interested in these technology areas. The investment program can draw on its very competent and leading technological resources to meet some of these other market opportunities. In other words, the investor will be more interested in a program which provides an opportunity for returns not only on its own mining applications, but also from other shared markets with like requirements.

Now I'd like to shift gears a little bit and talk about some specific things that we might do. Building the cooperative environment is, I think, an important first step. I have suggested that achieving a cooperative environment for doing things in the ocean hard-minerals area provides a solid basis for both private and more vigorous public investment in the development of these resources. In taking such a step I would like to suggest some points for consideration (see fig. 11):

1. We should regard these ocean resources as a stewardship opportunity. And, by stewardship, I mean that we're not only planning to use these resources, but that we're also going to take care of them and take care of the other ocean assets as well -- the fisheries, the ocean as a natural environment, its preservation as an international waterway -- and yet permit the intelligent development of new economic areas.

2. I have already mentioned the important role that state, regional, and local planning goals play in establishing a sound investment basis. Local planning provides an important background. State and national economic objectives need to be well served. National strategic and trade objectives are also a most important element. The integration of such plans and objectives into the ocean hard-minerals development plan is an important first product of the cooperative team.

3. We should seek to establish formal ways in which the academic community can become a part of the development team. One mechanism, which I would like to suggest for consideration, is that of using R&D Limited Partnerships as a supporting mechanism for applied research and development centers or activities at colleges and universities. This mechanism is based on the work of Dr. D. Bruce Merrifield, Assistant Secretary of Commerce for Productivity, Technology, and Innovation, and his staff. This type of device is illustrated in figure 12.

COOPERATIVE ENVIRONMENT

- Stewardship of resources
- State/regional/local goals
- Local operations a part of accepted local planning
- National economic objectives
- National strategic and trade objectives

Figure 11.

A MECHANISM FOR COOPERATIVE DEVELOPMENT

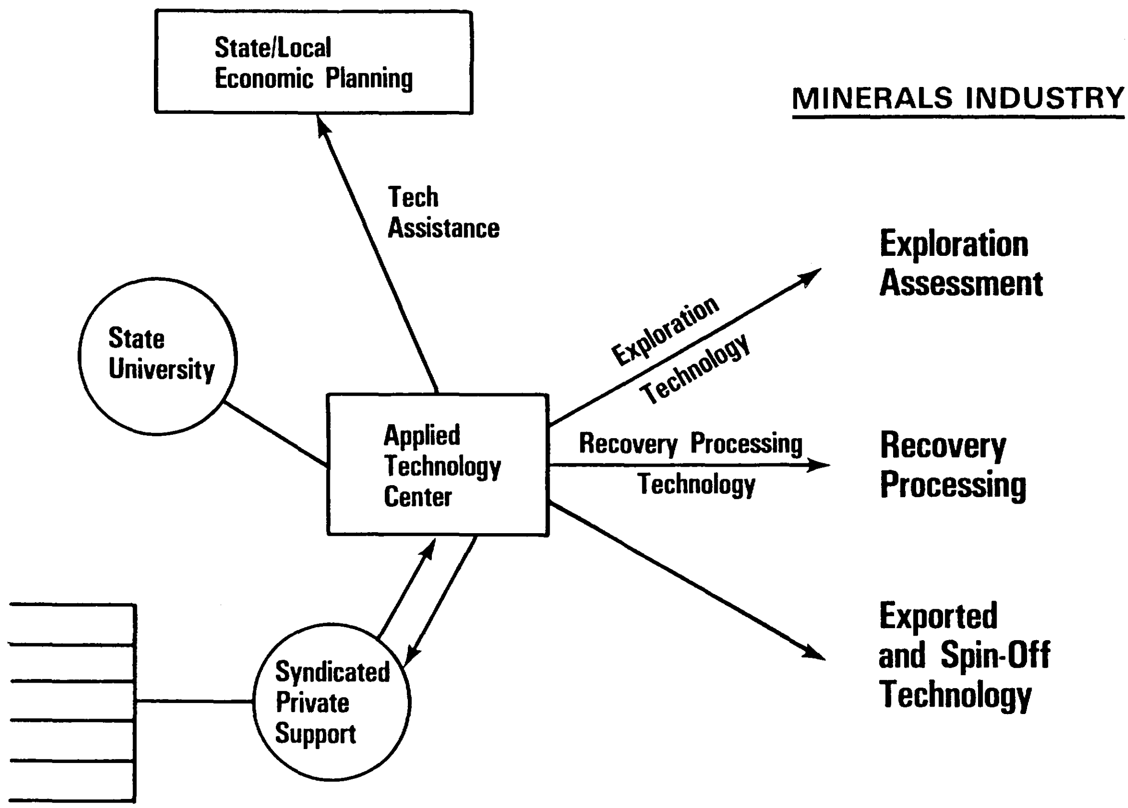

Figure 12.

In this particular mechanism, it is suggested that a syndication of investors can provide support for an applied technology center, connected with a major university or another institution, and that such a center might be an ideal vehicle for developing a number of technological assets that we need for ocean mineral development:

a. those assets for necessary exploration and characterization of deposits;

b. technology and assets for recovery and processing;

c. a focus for cooperative development, consistant with the state and local economic plan, with appropriate interest groups and state and local government.

4. After we have established an appropriate cooperative environment for planning and action, the actual stages of development can be undertaken. Figure 13 illustrates an oversimplified view of these stages: exploration, assessment, and utilization. Although there may be some arguments about the bars indicating current progress in figure 13, they do attempt to suggest where our present developmental stage is. For most of the ocean hard minerals of interest, we're now in the basic exploration stage, perhaps getting to the point where we can do some detailed exploration. There's obviously a lot of room for R&D investment here. In some of the mineral areas, we might be ready to test a pilot plant. But the real question as to whether we should do so or not relates not to technology but to economics and the need to characterize the resources. We will have to go through these stages if these mineral resources are to be developed. The question is: At what point and to what objectives will private investment appear appropriate?

5. Figure 14 suggests some current or near term opportunities for private investment. The first opportunity, which may in fact be with us now, is for the development of tools and facilities for exploration and characterization. This is the first step beyond the current federally supported program for basic R&D and exploratory activity. We may also wish to encourage private investment in the actual discovery and characterization of assets that lie in a particular place. Such encouragement for private investment may be in the form of leasing mechanisms which provide for the establishment of mineral rights through these exploratory efforts.

I would suggest that we are at this first stage with most of the potential mineral assets that we are going to be discussing in the workshop, and that this first stage constitutes the present opportunity for private investment. The second stage provides the first requirement for major capital investments, involving test operations of the planned operational facilities and new recovery and processing techniques which must be developed. The third stage, full-scale operations, may take

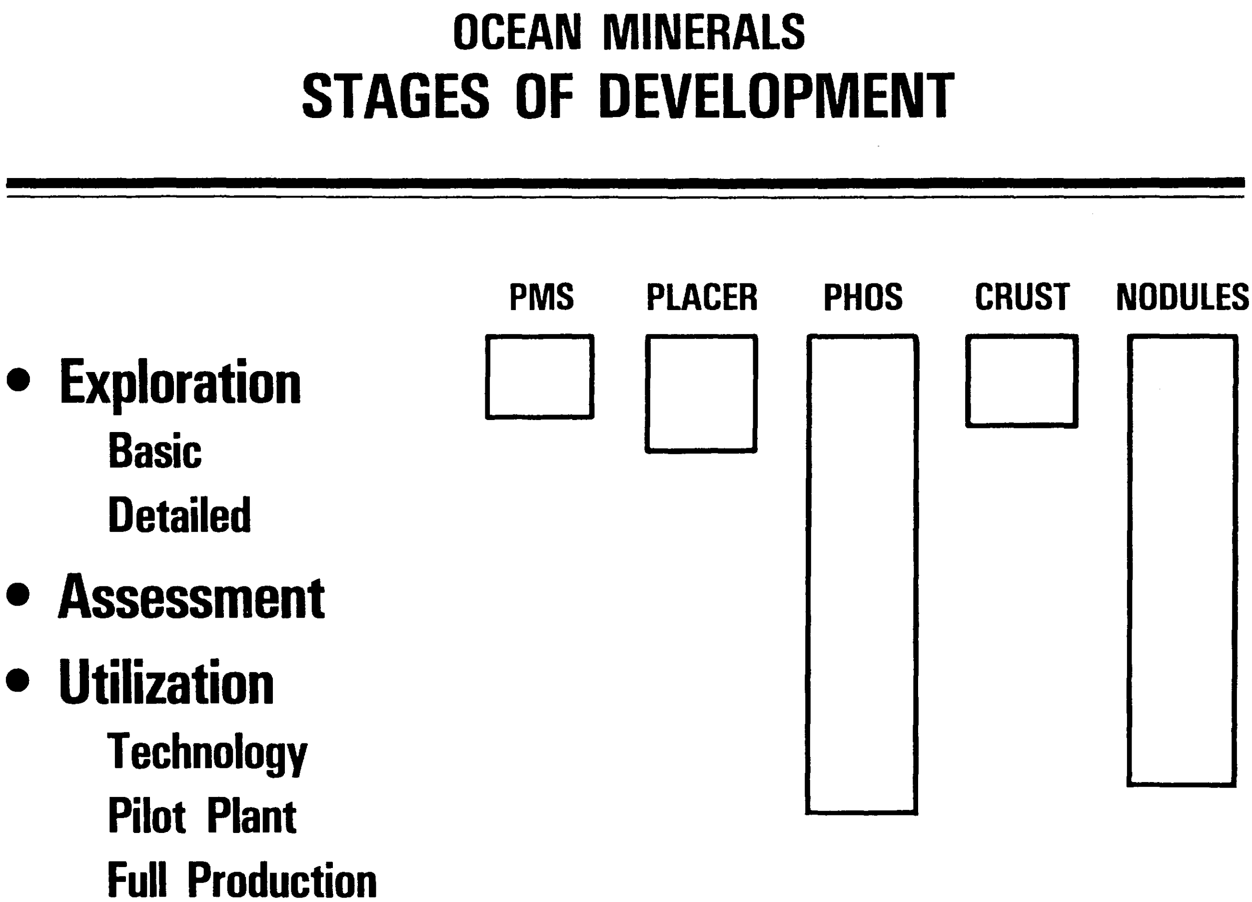
OCEAN MINERALS
STAGES OF DEVELOPMENT
PMS
PLACER
PHOS
CRUST
NODULES
• Exploration
Basic
Detailed
• Assessment
• Utilization
Technology
Pilot Plant
Full Production

Figure 13.

MINERAL RESOURCES
EXCLUSIVE ECONOMIC ZONE

Opportunities for private investment

► First stage
- Development of exploratory tools and facilities
- Acquisition of mineral rights through exploratory finds

► Second stage
- Pilot plant operations
- New recovery and processing techniques

► Third stage
- Full scale operations

Figure 14.

place in the 1990's or perhaps sooner in some areas, later in others. Finally, figure 15 illustrates some appropriate next steps which I would suggest can be taken in the development of ocean hard-mineral resources. The primary step is our need to develop tools and acquire facilities for exploration and characterization of the ocean hard-mineral assets. We also need to establish appropriate regulations and mechanisms (such as leasing) to encourage those in the private sector who may wish to invest in exploration and characterization efforts, by providing a mechanism for rewards for their investment. We also certainly need to initiate long-range planning efforts, particularly at the state and local level, to take into account the potential growth and societal impact that will result from these investments.

And, finally, I would again strongly suggest that a teamwork operation of industry, federal, state and local governments, and academia is the basic underlying requirement for assuring the success of such ventures as a private investment opportunity.

In summary, I would suggest that it is not unreasonable to expect initial private investment in certain ocean hard mineral assets within the next 2 years if we set up the right supporting framework. Starting with the EEZ declaration, and perhaps without any further legislation, we need to seek the establishment of the type of regulatory and other mechanisms which can be put in place to reward research through private investment. I believe that those instruments, to be attractive and effective, will inevitably have to encourage the type of teamwork support for ocean hard-mineral development that has been suggested in a very cursory form in this discussion.

MINERAL RESOURCES

EXCLUSIVE ECONOMIC ZONE

Next steps for PMS, crusts, placers

- ► Develop improved exploratory tools and facilities
- ► Develop and establish appropriate regs and instruments for private exploration
- ► Planning efforts at state and local level for industrial operations
- ► Teamwork operations
  - Industry
  - Federal, state, local governments
  - Academia

Figure 15.

Chapter 4

PETROLEUM EXPLORATION AND PRODUCTION IN THE EEZ

by

Joel S. Watkins
Gulf Oil Company

It is a pleasure to join this distinguished group of speakers here at the USGS' home and to have the opportunity to meet and visit with so many of my friends, both old and new.

Resource assessment is a big subject and I obviously can't encompass the whole thing in a short discussion such as this. So what I want to do is to speak briefly about four issues. First, I want to talk a bit about the exploration sequence and how it's related to resource assessment. While talking about this, I will emphasize the importance of exploratory drilling in the sequence and what we learn from exploratory drilling. Then I want to review the status of resource assessment for major offshore basins in a rather simplistic way. Third, I will say a few words about problems; these are mainly costs and assessment in the deep water. And, finally, I have a couple of ideas that I would like to suggest to you as possible steps we can take to speed up resource assessment.

First, let's talk about exploration assessment and its relationship to the exploration sequence. Resource assessment and exploration are very closely related. In fact, one finds that they are identical during the early phases. The first phase, as shown on figure 1, is the research phase. The length that I've shown is variable.

On the east coast of the United States, relevant research for resource assessment began in the late thirties with Maurice Ewing's studies and continues even today in some parts. In some of the Alaskan basins, on the other hand, the research phase may last 5 years or less. I point this out to illustrate the fact that the phase length in years is elastic and varies from area to area.

The time scale in figure 1 represents an off-the-cuff average for the U.S. Atlantic, Gulf of Mexico and west coast basins. The elasticity of the time scale doesn't affect the sequence order; the sequence order is the important thing.

During the research phase, academic and government vessels are found plying the offshore waters. They collect data about a number of things.

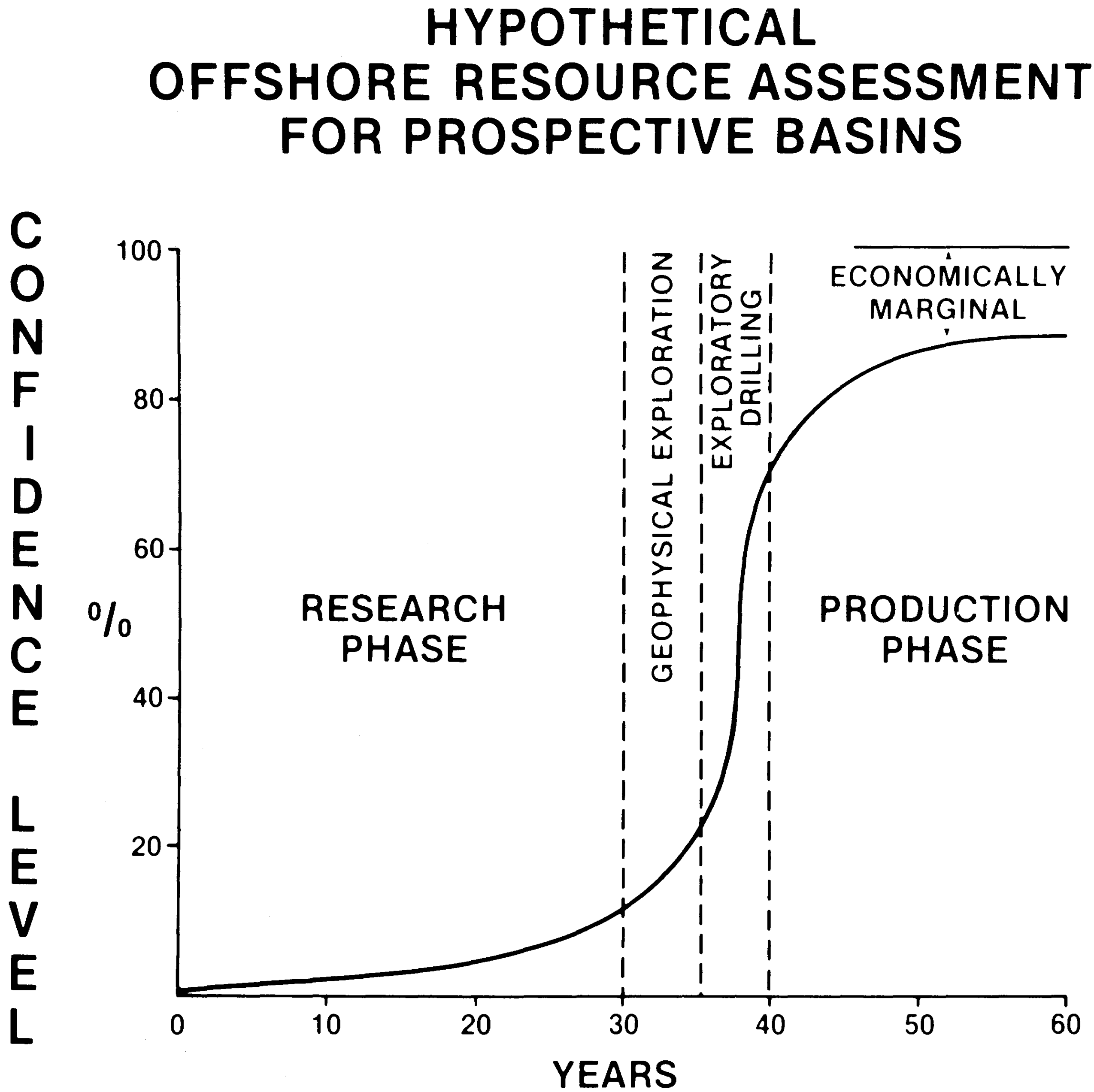
HYPOTHETICAL
OFFSHORE RESOURCE ASSESSMENT
FOR PROSPECTIVE BASINS
CONFIDENCE LEVEL
%
100
80
60
40
20
0
10
20
30
40
50
60
YEARS
RESEARCH PHASE
GEOPHYSICAL EXPLORATION
EXPLORATORY DRILLING
ECONOMICALLY MARGINAL
PRODUCTION PHASE

Figure 1.

They map the sea floor. They measure the depth of the floor. They measure the intensity of the Earth's magnetic and gravity fields. They take samples of the sea floor to determine the sediment character and composition, and they collect seismic data in order to obtain information about the Earth's crust and composition. In the early days, the seismic data consisted mainly of seismic refraction, which gave us a rather gross overview of the Earth's crustal structure. In recent years, the introduction of industry-grade reflection seismic systems has produced good regional subsurface coverage in some areas.

Geophysical exploration is the second phase of the sequence. This phase consists mainly of detailed seismic reflection surveys by oil companies and their contractors. Whereas research produced good regional subsurface coverage, in geophysical exploration we're getting to the point where we're looking for subsurface coverage in considerable detail necessary for the mapping of individual prospects. Regional seismic coverage might consist of lines 20-50 miles apart; while during geophysical exploration phase, line spacing would drop down to 2-10 miles apart, or even closer in some instances. Large parts of the Gulf of Mexico--the most intensely explored part of the U.S. offshore--are covered at 1- to 2-mile intervals. Most other basins are less densely covered.

The third phase in the sequence is the exploratory drilling phase, and this is the one I want to emphasize. This phase often begins with the drilling of stratigraphic tests, the so-called COST wells, to establish the general rock sequence and to provide data we need for the proper interpretation of the seismic data collected in previous phases, and, in general, to guide further exploration.

The important part of this phase follows COST well drilling. That is the drilling of the wildcat wells. It is during the drilling of the wildcat wells that resources are really assessed. I want to repeat: it's during the drilling of the wildcat wells that we really get the essential information we need to assess our hydrocarbon resources. Everything up to this point has relied a great deal on inferrence and speculation. After the exploratory drilling phase is completed, we are largely filling in gaps in our information.

The last phase, shown on the right side of figure 1, requires no explanation. This is the production-drilling phase. I point out here that the hydrocarbon resources of a basin are never entirely known because we reach a point where exploration is no longer economically feasible. We must stop drilling even though we know that there are reserves that remain undiscovered. During the next decade, we hope we will find new technologies, new ways of locating hydrocarbons, that will push this barrier back, for the remaining undiscovered hydrocarbons represent a significant national resource.

Before going on to an elaboration of the exploratory drilling phase, I want to point out that the phases overlap, sometimes to a large extent; thus, exploration, or even research, may be going on in one part of a basin while drilling activities and production are being carried out in another part. The phases as I've described them are greatly simplified, of course, and represent the dominant activity at a given point in time as I haven't attempted to describe all the activities going on.

Now, let's talk a little bit about the importance of exploratory drilling. I've said earlier that the assessment occurs mainly during this phase. I will use two examples. In 1974, the USGS estimated oil and gas reserves beneath the Atlantic Shelf, a range that would be between 10-20 billion barrels of oil, and the gas between 55-110 trillion cubic feet of gas. In the ensuing decade, the industry has drilled out virtually all the major structures in this area and come up with almost nothing. On the west coast, on the other hand, the USGS estimated reserves at 3.8 billion barrels of oil. Recent discoveries suggest that the Santa Maria Basin alone may have reserves of 4 billion barrels. Additional discoveries in other California basins suggest that the reserves may ultimately climb as high as 30 billion barrels.

These examples clearly show the lack of accuracy in the predrilling results. The geologists that made these estimates were good geologists. They used all the information that they had at hand, and they did the best job that they could at the time. But they lacked the information that you get from the actual drilling in the basin areas.

There are reasons why the bad estimates are made. First, no geophysical tool consistently predicts sediment fluid content in advance of the drill. Many of you have heard of bright-spot technology and other techniques that are being researched in every oil company lab in the country, and how some of these have predictive ability in the finding of hydrocarbons. "Bright spots" and this general class of technology work well in Tertiary deltas and certain deposition environments, but they are not always hydrocarbon indicators. Drilling on them has led to some very expensive dry holes. We also know from the physics of seismology and from the information content of seismic data that there is a limit to achievable results in this field. To sum up, we know that drilling will continue to be required to prove the existence of hydrocarbons in frontier basins for the foreseeable future.

On the other end of the curve, where it climbs rather abruptly, basin reserves tend to be well established because most of the reserves are found in the giant and super-giant fields which typically contain up to 80-90 percent of the total basin reserves. They are also the largest and most obvious prospects in seismic data, so we drill them first.

The cumulative reserves of small fields never exceed those of the few giants; hence, the giant field distribution largely determines the total reserves in a basin. There are mathematical methods of infilling the few gaps.

Giant fields are discovered, of course, during production phases, as, for example, the Eugene Island 330 Field offshore Louisiana. But these fields are exceptions. Most large discoveries were made early in the Gulf of Mexico exploration. The North Sea discoveries follow the same pattern. And it seems likely that Alaska will follow the pattern as well with the discovery in Prudhoe Bay of the Kuparuk fields. When one looks at other areas in the world, one sees that this pattern persists. Thus, as we see in figure 1, our confidence level rises slowly through research and geophysical exploration phases, but remains relatively low until we reach the exploratory drilling phase.

As we get the information from the wells, as we actually get the rock in hand, as we get the cuttings, as we get the test results from the wells, our confidence rises. By the end of exploratory drilling phase, we have a pretty good idea of what the reserves are. Clearly, if we are serious about assessing resources--hydrocarbon resources, that is, in the offshore--we must carry through the drilling exploratory phase. The research and the geophysical exploration phases are essential and must be strongly supported in order to optimize the assessment. But, in the end, we've got to drill the wells.

Figure 2 shows the status of assessment in the Exclusive Economic Zone basins. Assessment phases overlap to some extent, and in this figure the overlap is indicated by the dash lines. There's been some simplification here, obviously, and my apologies to those scientists doing research in the areas where I show solid black lines indicating the research phase as largely completed. Research is never done, but it is necessary to simplify this somewhat and to make some judgments regarding this phase. The point here is that a great deal remains to be done if we are to adequately assess the reserve potential of the Exclusive Economic Zone.

Only one area in the United States, the Louisiana Shelf, can be considered adequately surveyed from the assessment point of view. There are a couple of other areas, such as the Baltimore Canyon Shelf and the Gulf of Alaska that may be adequately assessed. But, on the whole, in most of the basin areas we have a long way to go.

Figure 3 shows a generalized and simplified view of the cost of exploring a small to medium-sized basin or sub-basin in the Gulf of Mexico or California, offshore in water depths somewhere in the range of 1,500-2,000 feet. It ignores leasing costs which vary widely depending on location. I estimate that there are somewhere in the neighborhood of 25 equivalent sized plays in the EEZ. This gives us some idea of what a comprehensive assessment program is going to cost. For research, we are looking at about $10 million per basin. This aggregates into perhaps $250 million for all of the U.S. EEZ.

Geophysical exploration costs are somewhat variable. Aggregate cost through the geophysical exploration phase might be $50 million for a single basin, and as much as a billion or a billion and a quarter

MAJOR BASIN
EXPLORATION STATUS

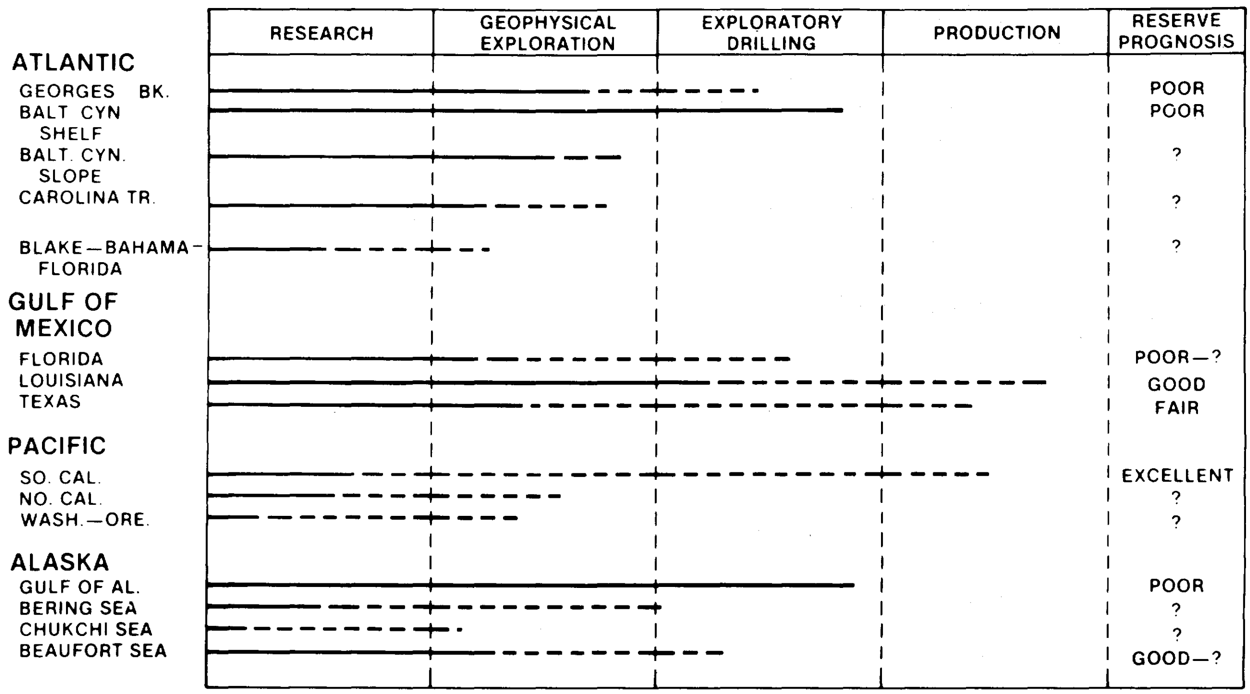

Figure 2.

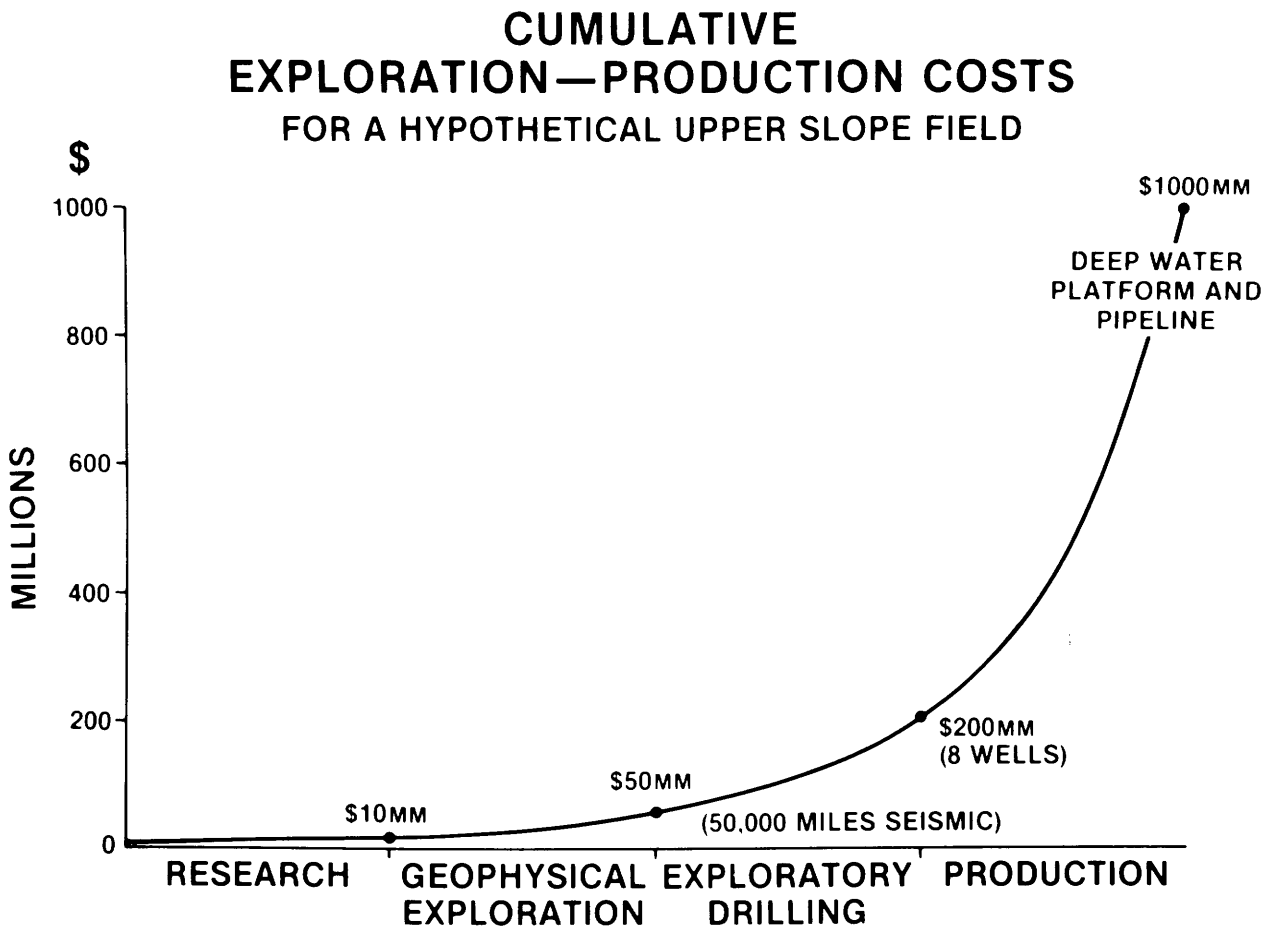
CUMULATIVE
EXPLORATION—PRODUCTION COSTS
FOR A HYPOTHETICAL UPPER SLOPE FIELD
$
MILLIONS
1000
800
600
400
200
0
$1000MM
DEEP WATER
PLATFORM AND
PIPELINE
$200MM
(8 WELLS)
$50MM
(50,000 MILES SEISMIC)
$10MM
RESEARCH
GEOPHYSICAL
EXPLORATION
EXPLORATORY
DRILLING
PRODUCTION

Figure 3.

for all the U.S. EEZ. When we get into the exploratory drilling phase, taking eight wells at a cost of about $16-20 million each to assess a basin, the cost would run about $5 billion. These amounts are possibly a little high for some of the mainland U.S. offshore waters, but they're low for Alaska. On the whole, my aggregate numbers are probably conservative.

Industry is going to do a certain amount of this on its own. We are already drilling. There are a couple of fields in the Gulf of Mexico in water depths of 1,000 feet or more, and industry is going to continue to pursue looking at this part of the world. But we reach a barrier somewhere in the range of 1,500-3,000 feet where the present-day crude-oil prices and production costs make it uneconomic to go out very much farther. The expected return from reservoirs beyond this range makes them excessively risky in today's economic climate.

Where do we go from here? What can we do about all this? We've seen that there are no magic wands. There are no dousing rods we can use. There are no black boxes that tell us how much oil and gas we have. We have seen that assessment is going to be expensive. If we want to know how much oil and gas there is out there, we must drill and we must find the money to do so.

I believe, and I think that most of you believe, that resource assessment is vital to the U.S. policy and strategy. To paraphrase my good friend, Hollis Hedberg, how much longer are we going to continue driving around without checking the fuel level in our gas tank?

I suggest the following: To start, we need to ensure that research is adequately supported. Research is like a flashlight, and it's a murky world out there in the subsurface. With all the modern technology we have to peer into the subsurface and look for oil and gas, it's still very dark. Research is a beam in the night that guides the way and shows us the direction we need to follow to understand subsurface geology and the distribution of hydrocarbons. Without research, we are wandering around in the dark.

We especially need to support academic research. Most innovative ideas have originated in academia, and I believe that this will continue to be the case for the foreseeable future. We've also got to protect academic research, because academic research is where most of the scientists get their basic training, where the researchers get their basic training, and where the explorationists get their basic training. Academic research unfortunately lacks a direct constituency to provide money and, consequently, it's vulnerable to arbitrary cost-cutting from both industry and government funding sources.

We must also establish a frontier drilling program in those areas lying beyond this economic wall imposed by high production cost. Industry can and will do this if certain steps are taken. First, I think we need to take a good look at this 200-mile boundary and perhaps make some modifications. At the moment, the 200-mile boundary cuts across potentially hydrocarbon rich structures. So I think we need to take a look at this and maybe make some asjustments here and there.

Second, we need larger lease blocks in deep water. The risks are too great, the costs are too high, in proportion to the reserves that are likely to be found beneath the single block.

Then, and most important, we need some incentives; the incentives we have right now are largely disincentives. Canada, on the other hand, has pursued a program of incentives for exploration in the entire country. And this has resulted in the exploration and resource assessment of the Beaufort Sea and the Arctic Islands, which is going on today. We can do something like this in the United States.

And, fourth, I think industry has got to be willing to join the team. We've got to make public a lot of information, the fundamental proprietary data from frontier areas that we've kept private in the past. Canada has done this, and my Canadian colleagues tell me it hasn't affected them. I would suggest to my U.S. colleagues that we can survive this, too. The result has been that the geology and reserves of Canada, particularly the northern and more obscure parts of Canada, are becoming rapidly well known. Making these data available within the United States would be a tremendous boon to academic and government researchers as well, of course.

The benefits accruing from these actions will be many. First, and most important, the EEZ assessment will be dramatically speeded up. Second, the overall cost to the taxpayers will be minimized, since it will cost less in terms of incentives to drill than will outright government drilling of the wells. Third, U.S. research dollar will be greatly stretched because of the data that will be made available both to academia and government sources that are now being kept confidential.

In conclusion, I think this plan can work, and I hope you'll give it serious consideration.

Chapter 5

GEOPOLITICAL VIEW OF MINERAL RESOURCES

by

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It is a pleasure to be at the USGS today to take part in this historic conference on the Exclusive Economic Zone of the United States.

The objective of my participation in this conference is to place the EEZ in the larger picture which is a product of an ancient and honorable craft, almost obscure now in graduate studies of mining and mineral economics or natural-resource management; that is, the geopolitical view of mineral resources.

Accordingly, I would disagree with a statement on page 2 of the Geological Survey Circular 912 that the EEZ is "a vast new frontier to study and understand." The accumulation of knowledge goes only part of the way, at least from the perspective of discussions I have had in Japan and Western Europe. The industrialized world regards the United States and its EEZ proclamation not merely as "a vast new frontier to study and understand" but as a vast new frontier in which to develop, extract, and recover mineral resources, as the old American frontier of public land is prematurely (before mineral exploration and production) closed or delimited.

With the partial exception of Alaska, the land (onshore) frontier of mineral resources has been artificially diminished by a complex of social and political policy which I have described elsewhere as a Congressional edict of resource freeze. Many of you are familiar with the legislative history of public lands policy since 1964. No one in this audience, certainly, is unaware of its implications. The proclamation of the EEZ then, given the withdrawals of potentially valuable mineral resource land--a withdrawal which in its aggregate is incomprehensible to the mining and minerals departments of foreign governments--is an effort to restore balance. With the EEZ proclamation one can reasonably say that in spite of the absence of a consensus in Congress and in public opinion which enabled President Truman to proclaim a Continental Shelf four decades ago, the Reagan Administration, while losing on land to a Congress which has adopted a *de facto* resource freeze, nonetheless has in the national interest achieved a victory at sea.

The United States EEZ is important in the global equation of potential mineral-resource supply. It offers strategic, unrestricted, market-centered access to allies who require or who will require a secure source of some mineral resources in the future. Supply-source risk is the cutting edge of geopolitical natural-resource analysis. According to the U.S. ocean mining industry, it will not be possible to recover EEZ minerals at competitive costs in the immediate future, but it is good to know what is out there and that it's under the flag.

Security of supply, apart from business cycles, is the central property of the geopolitical nature of minerals. MITI of Japan has concluded: "The availability of mineral resources could pose a short-term sporadic threat, or a protracted institutional menace to the economic security of Japan." Japan is fully dependent on foreign sources of mineral supplies, with the exception of some dwindling non-ferrous reserves.

For most of the 20th century, access to raw materials has been associated with wars and military conflict. It is no less true in the 1980's. Although the language of the cost-effective approach prevails in peace, emergency mobilization planning and war itself supersede such models and their authority over decisions of national security. So decisive are mineral resources in these higher-than-cost-effective moments in international politics, that an argument was made in 1945 to the effect that the combined mineral reserves and resources of the British Empire and the United States, together with control of the sea and air, was the very fabric and basis of world control of peace and war. This power, it was recommended, could be used as a framework of collective action to prevent future wars. But four decades later, the British Empire has vanished, the public lands of the United States have been placed in a <u>resource freeze</u>, in which a process of declaratory de-access to land (onshore) mineralization has terminated the growth of the domestic mineral-resource base. The control of the sea and air partially awaits the outcome of the resolve of the Western alliance. Nonetheless, it is this vast change in the availability and control of minerals that has revived the anxiety over security of supply. And it is this change that is the context for the proclamation of the EEZ.

Although the COMEX settlement price for copper this afternoon was only 62 cents a pound, in an economic recovery cycle, deliberations here on the EEZ, similar to those on the Continental Shelf in the 1950's, will have much to do with security, recovery, and supply in decades to come. No longer are Anglo-American mining and metals companies the prevailing influence on markets through reasonable prices and assured deliveries to worldwide industrial consumers. Indeed, recent history is replete with nationalization and staged renegotiation in which national governments have progressively diminished the ownership and control of such companies over minerals on a massive scale. The intervention of State producers in world mineral markets has escalated the apprehension over security of supply. The relationship of the future of the American copper industry to the International Monetary Fund (the funding of expansion outside the United States) reflects this decisive historic change of ownership.

It is precisely this state of affairs that the EEZ proclamation, and the associated science and technology support from the Federal Government, will partially correct because the future privatization of natural resources requires an expanding base as a countervailing strategy against the shift towards nationalization and the "Group 77" target of state ownership and control or the "permanent sovereignity over natural resources." The fixed reality of the geopolitics of minerals is the universal inequality of the distribution of natural resources. National policy begins from the assumption that if conquest or annexation is ruled out and a given mineral is necessary to industrial progress and security, a strategy to obtain a source of secure supply is obligatory.

The EEZ has not gone unnoticed as an element of such a strategy by the Soviet Union. The USSR conducted a review of the Watt-Reagan mineral policy early last year. The observations of the Soviet Union are pertinent to this conference.

> It should be pointed out, however, that the current U.S. dependence on foreign sources for various kinds of minerals is not explained so much by geologic as by socio-economic factors. Possessing political reserves of scarce materials, the United States has also confronted social policies and elements of its own foreign policies which is moving its supply sources offshore. There is a similarity in the approaches used by the Truman and Reagan Administration in resolving the raw materials problem. However, there's a new important element. This is the politization of the problem in its advancement to the fore of government policy.

Now remember, this is the view of a Soviet analyst quoting the former Secretary of Interior:

> "To rebuild this great country, we must know what our resources are. We must make an inventory of our lands. At present, we don't know what the potential of our mineral resources is. Neither do we know the extent of our petroleum and gas resources."

The Soviet comment:

> This was Secretary Watt's evaluation of the state of affairs in this sphere one year after he was appointed Secretary of the Department of Interior, which oversees the natural resources of the United States.

The article goes on:

> Obviously, this evaluation contains an element of intentional dramatization of the situation which the Administration apparently needs for its own political reasons. It should also be pointed

out that just during the '70's, the U.S. Geological Survey prepared approximately 400 classification maps showing the amount of mineral resources in the continental United States. This almost completed the geological charting of the country.

Now a most interesting insight:

However, a study of an inventory of the mineral resources of the Continental Shelf presents another picture to the United States. The mineral potential of these lands is indeed almost unknown. The United States owns one billion acres of the Continental Shelf. In 1953 the Federal Government began leasing portions of the Shelf to private companies for mineral exploration and development. It is actually at least about 9 percent of all petroleum, 23 percent of all gas in the U.S. comes from these areas.

The conclusion of this review for Soviet mineral and foreign policy-makers is that:

American ruling circles understand that it is impossible to preserve and strengthen the leadership of the United States in the capitalist world without: 1) stabilizing and reviving the country's economy, and 2) this, in turn, requires resolving the raw materials problem.

Not surprisingly, it is that raw-materials problem which is perceived by the Soviet Union as the element of highest policy in the United States. Moreover, in the last 3 years, Moscow observes that the resolution of the problem is reaching what it calls "the fore of highest government policy."

The last Communist Party Congress of the USSR declared a 5-year plan with a massive program to develop natural resources in the north. This was entitled "Conquer the North." Europeans pay very close attention to such statements. "Conquer the North" consists of massive capital outlays for Arctic and sub-Arctic hard-rock exploration and for Arctic Sea, oil, gas, and mineral exploration and development. This is a second stage of the historic decision of the Soviet Union to allocate the equivalent of 2 billion U.S. dollars in 1967 to the Norilsk nickel and PGM complex. One investment choice of that scale was apparently available to the Soviet Union at the end of the 1960's. The investment was made in the north near the maximum USSR EEZ area. In contrast, the Soviets, no less than the Europeans and Japanese, are astounded by the recent domestic setback of the administration's mineral policy by Congress, which has halted further coal-leasing and development and slowed minerals-directed entry into public land.

To the Japanese, the proclamation of the EEZ is a signal that a new and expanded mineral and energy base of the United States would be open to commercial development as a source of supply to themselves and the Pacific rim. The Japanese now assume that "the mineral base of the United States now does not stop at its ocean's edge." In a discussion with me in July, a senior advisor to Sumitomo said, "We have a high priority to survive. We have no mineral future. We must go to the sea. We are even looking seriously at the extraction of gold from seawater, and we will pay the price to do it."

One component of the Soviet Union mineral strategy is to support counter-trade and barter around the world, and to progressively remove minerals from trade dominated by the United States dollar; that is, to weaken the dollar as the international currency of commodity exchange. Counter-trade has struck hard at mining and energy companies which must compute their costs in dollars and which do not have the capability to take counter-supply of products from the East or from the Third World and then sell them in markets in the United States. The barter counter-trade expansion, which consists of the Eastern Bloc mineral export potential and the state owners in the Third World, poses another threat in addition to state ownership in terms of the trade and availability of mineral resources.

The Soviet Union has also expanded its role as a buyer while expending great sums of money and investment in new development. This pattern of buying and selling is confusing--perhaps deliberately so. They are net buyers of copper this year. They will buy large amounts of lead, zinc, and tin. They are the largest state importers of foreign silver in the world.

And they will buy across the board. The buying in the Soviet Union signals, in some cases--particularly manganese--the failure of geological exploration to find reserves and the depletion of their high-grade reserves. But it also suggests a potential interest in supplies outside the Soviet Union and the integration of a natural resource bloc tied to the industrial output of the same bloc with respect to producers outside Eastern Europe. It must not be forgotten that the showcase of Cuba is not its army. Neither is it sugar, because the long-term prospect of sugar is very bleak. But it is Ponta Gorda, a showcase of a new Cuban nickel complex, and its nickel laterite reserves; a showcase for all visitors from other South and Central American countries with mining potential.

It is no secret that the government of Korea is moving very close to a 5 percent Alaska supply commitment, the first of which is Alaskan coal. This will extend to the EEZ in the future, because Korea and Japan, as industrialized countries, are mineral dependent and vulnerable. The Pacific rim, including its ocean with an EEZ under U.S. flag protection, offers great promise that some share of diversification of supply in the future will be EEZ-derived.

Finally, I will conclude that the geopolitics of natural resources is a history of conflict over raw materials: wars actually began over raw materials and access. Any contribution to freedom of access to a new supply, regardless of the economic or econometric models of the long-term price of the product, is understood clearly as a contribution to peace.

Chapter 6

THE U.S. GEOLOGICAL SURVEY PROGRAM AND PLANS IN THE EEZ

by

Dallas L. Peck
U.S. Geological Survey

The U.S. Geological Survey (USGS) marine geology branch offices in Woods Hole, Massachusetts, and Menlo Park, California, have a commitment to the EEZ as well as other existing marine programs. But it is not just a USGS commitment--academia, industry, and several other Federal bureaus and agencies are every bit as interested and involved. I hope that this symposium, as its title indicates, will produce a design for a full-scale assault on the fascinating research problems and resource prospects by Government, industry, and academia. I encourage all of us to use this time to find areas and avenues of mutual interest and cooperation. We can also offer support of joint cruises and opportunities for cooperative studies.

The USGS marine program and our efforts and plans in the EEZ are well described in recent publications that are available at this symposium. The marine geology program of the Survey has three elements. The first consists of regional geologic framework studies aimed at developing a basic understanding of the geologic setting and history and of the habitat of potential energy and mineral resources. These studies generate maps and cross sections, histories of continental margin evolution, and understanding of framework matters such as structure, stratigraphy, seismicity, volcanism, and plutonism.

A second element is focused on marine deposits and sedimentary dynamics. These studies lead to an understanding of depositional and erosional processes and how the sedimentary units outlined and dissected in framework studies came to be. Geologic history obtained by unraveling sequences of events as the continental margins evolve is important in this program element as well.

The third element is formation, location, and extent of marine energy and mineral deposits. This element focuses on processes by which oil and gas and mineral deposits occur and through which they are generated, mobilized, destroyed, or preserved. Studies also evaluate the actual area resource potential generated by those processes. Obviously, all three elements interrelate, and each of our scientists tends to work on problems that relate to all three program elements.

This division of labor is designed to produce results. So I would like to present some recent results, some current investigations, and our plans for the immediate future. Because of the main purpose of this symposium, I have chosen to focus on studies and results directly related to resources.

USGS marine scientists have for many years been working in the EEZ (fig. 1) studying the offshore areas of the United States proper. Much less effort has been aimed at the vast Pacific EEZ, now known to have some interesting possibilities for resources both in seabed metal deposits and hydrocarbons.

The offshore basins around the conterminous United States have been outlined in large part through Survey program efforts (fig. 2). Some basins, which have never been drilled, have major thicknesses of sedimentary rock (e.g., 39,000 feet in the Carolina trough, 43,000 feet in the Blake Plateau basin). Virtually all of these basins are very incompletely known with respect to the nature of their sedimentary sequences, their detailed structure, their thermal histories as the continental margins evolved, and most especially the possibilities for the generation and trapping of petroleum in economic amounts.

The geologic information for basins around Alaska (fig. 3) is even more rudimentary. Areas are vast, and sea conditions are often difficult. In the Arctic portion, even in a good ice year, it is hard to make the badly needed geophysical surveys. This year, supposedly a good ice year, we were forced out of the Arctic; next year we hope to use a Coast Guard icebreaker for a brief geophysical survey. Some of the basins are spectacular in size and thickness of the sedimentary sequence, but we know little concerning their histories, sedimentation or structural patterns, and their resource potential. Where the ocean plate is subducting beneath the continent south of the Aleutians and Alaska Range, an enormous wedge of sediment has been trapped. High heat flow there may have caused maturation of organic material to form natural gas, and we have a small effort with the Department of Energy to investigate that notion.

A tectonic map of the Atlantic margin shows major basins and throughgoing structures (fig. 4). Seismic lines on which this type of mapping is based are typically spaced 30 to 50 miles apart. However, few lines extend oceanward across the rise, where we very much need to gather more data. A typical seismic line (fig. 5) shows an integrated paleoshelf edge, a feature that could be of great importance in the search for oil. One such feature, a Jurassic reef on a paleoshelf edge, is now being drilled in deep water on the Atlantic margin.

From the seismic data and the even scarcer drill holes available, geologic cross sections are constructed (fig. 6). These are typical products of our geologic framework program, and provide a basis for interpretation by our scientists in the sedimentary processes and resource processes programs as well.

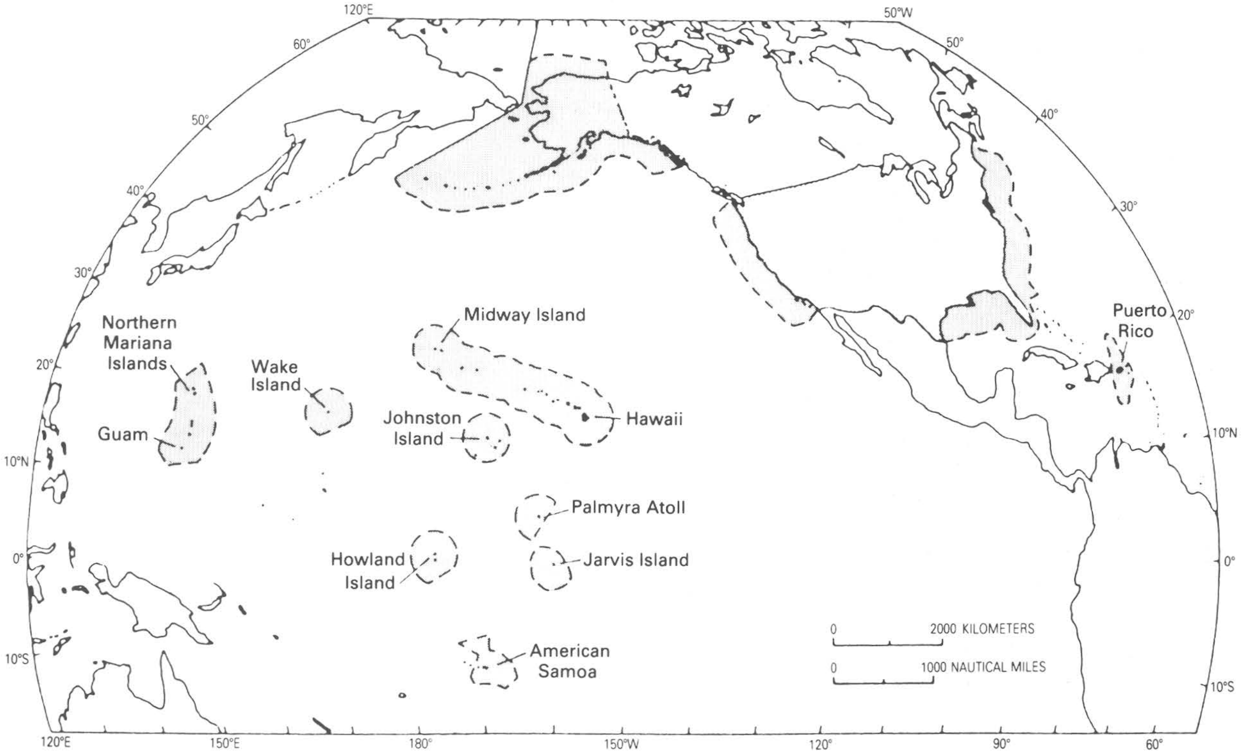


Figure 1. Exclusive Economic Zone (EEZ) of the United States, Commonwealth of Puerto Rico, Commonwealth of the Northern Mariana Islands, and the United States overseas territories and possessions (outlines of map are approximate).

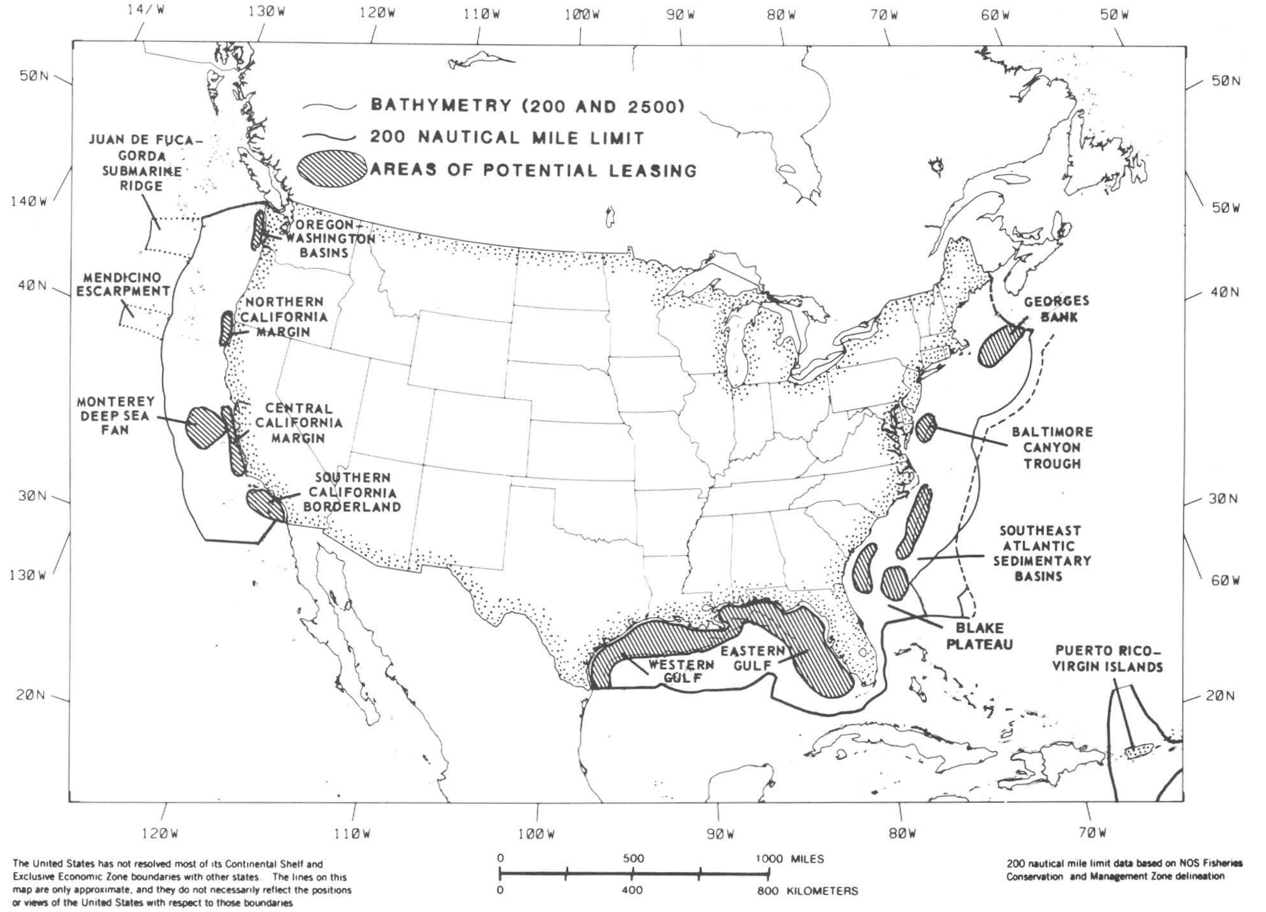
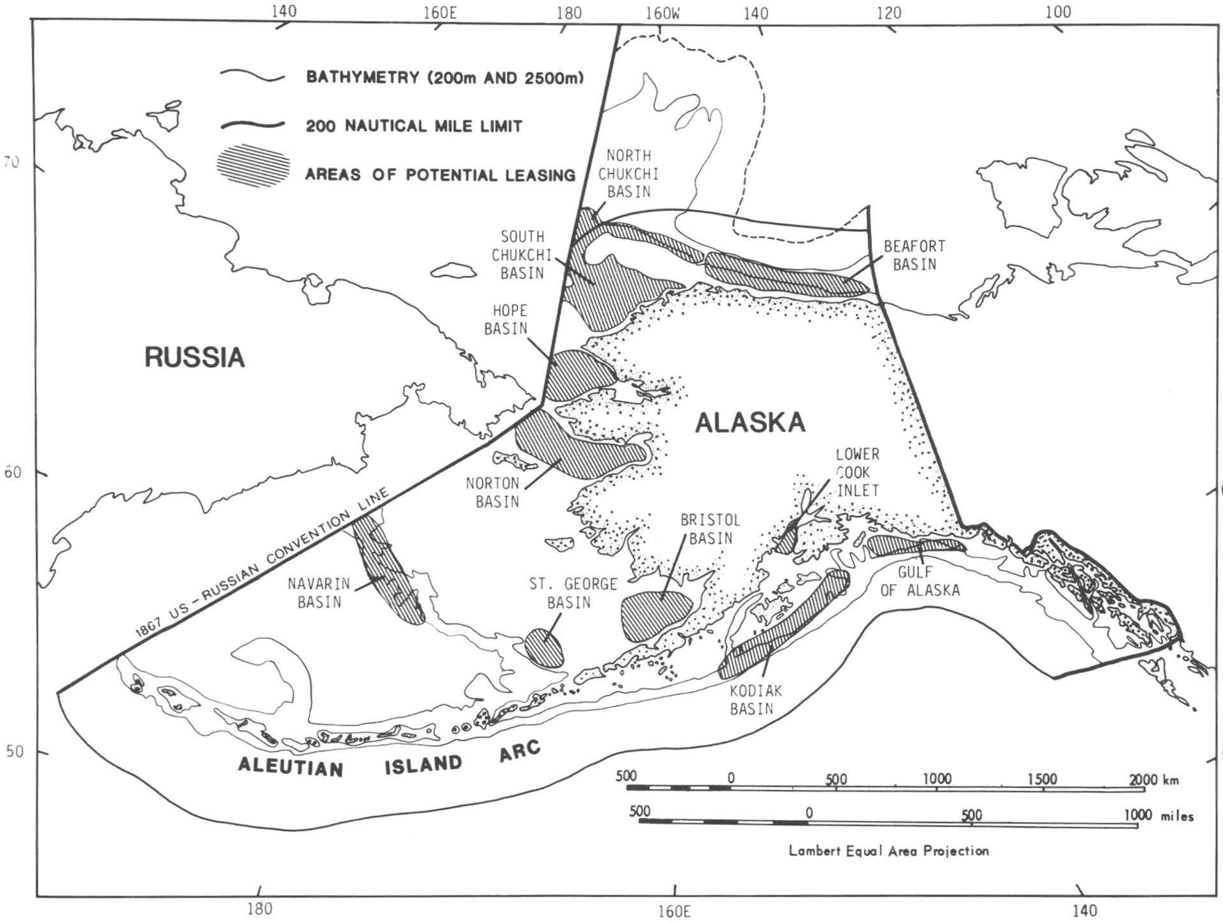


Figure 2. Location of basins with oil and gas potential within the EEZ.



The United States has not resolved most of its Continental Shelf and Exclusive Economic Zone boundaries with other states. The lines on this map are only approximate, and they do not necessarily reflect the positions or views of the United States with respect to those boundaries

200 nautical mile limit data based on NOS Fisheries Conservation and Management Zone delineation

Figure 3. Location of basins around Alaska with oil and gas potential within the EEZ.

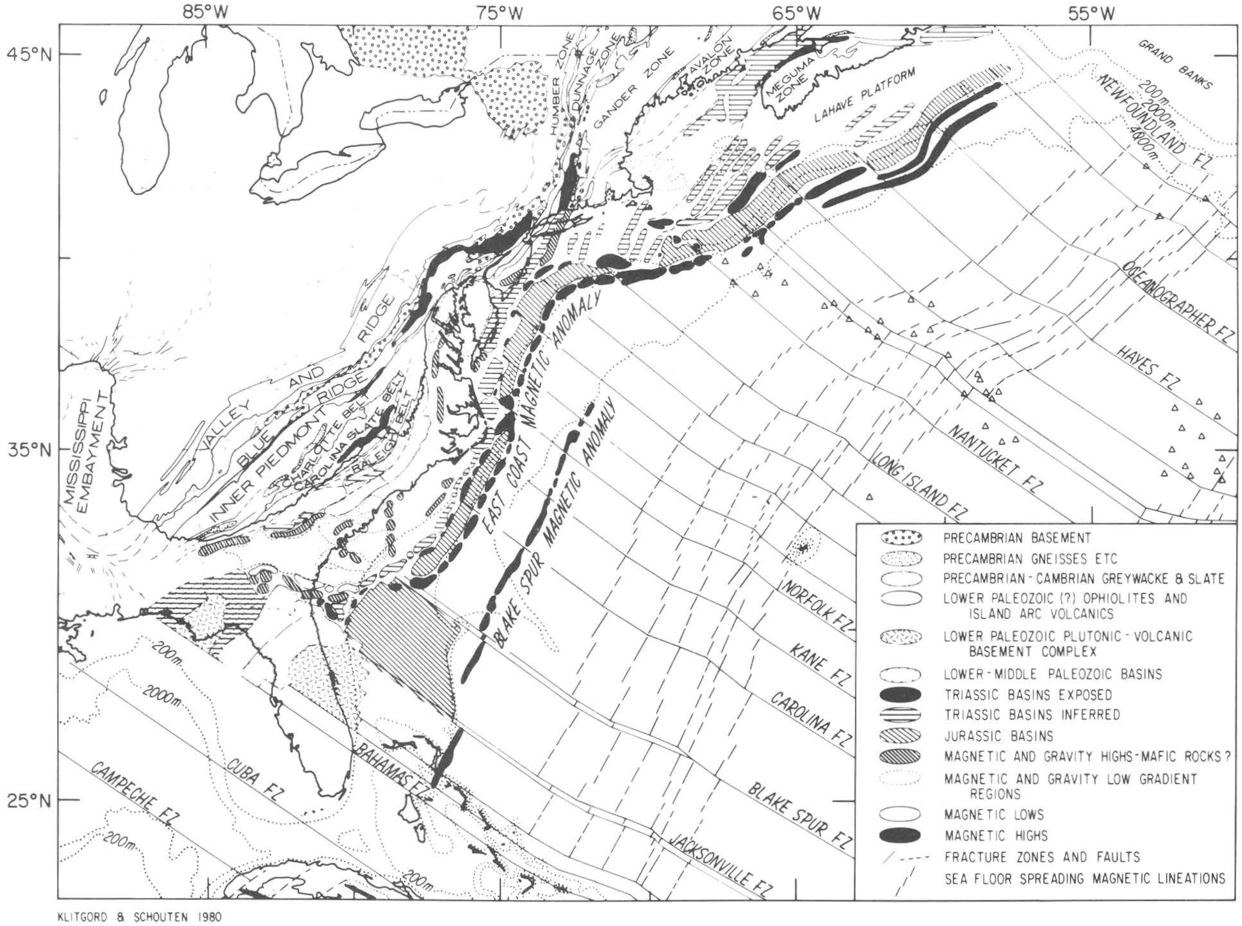


Figure 4. Tectonic map of the U.S. Atlantic continental margin.

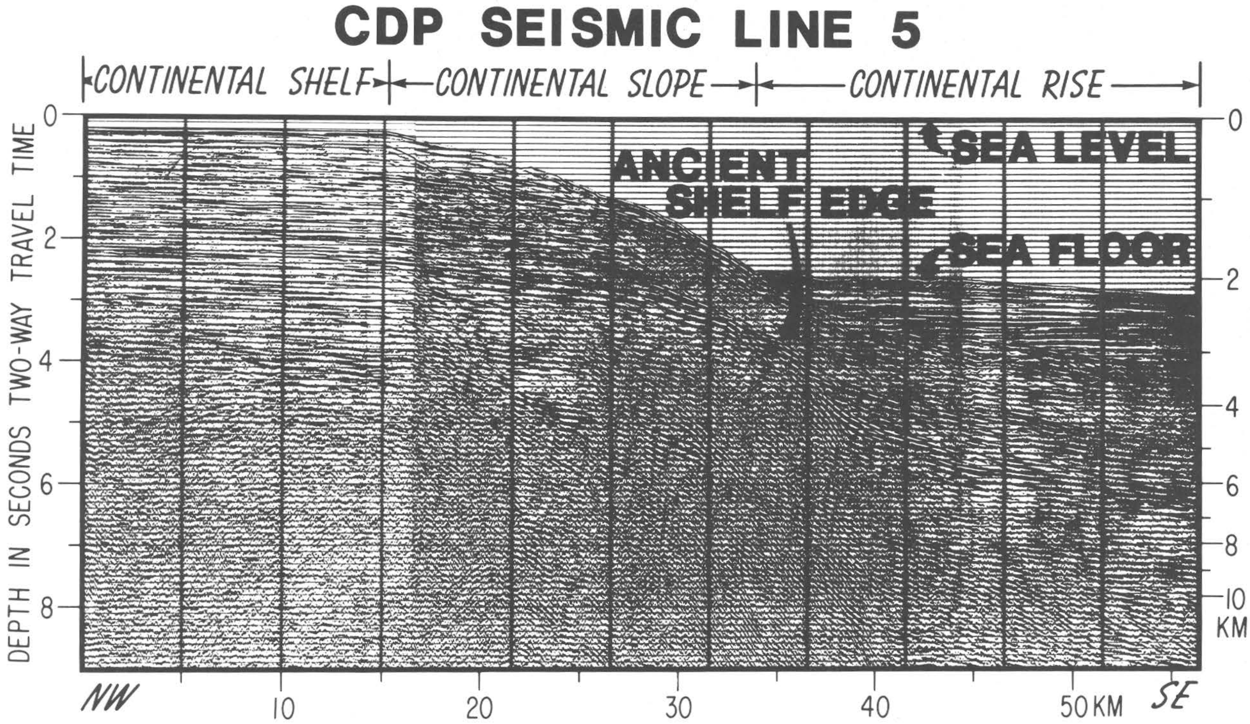


Figure 5. Seismic reflection profile across the U.S. Atlantic Continental Shelf, Slope, and Rise.

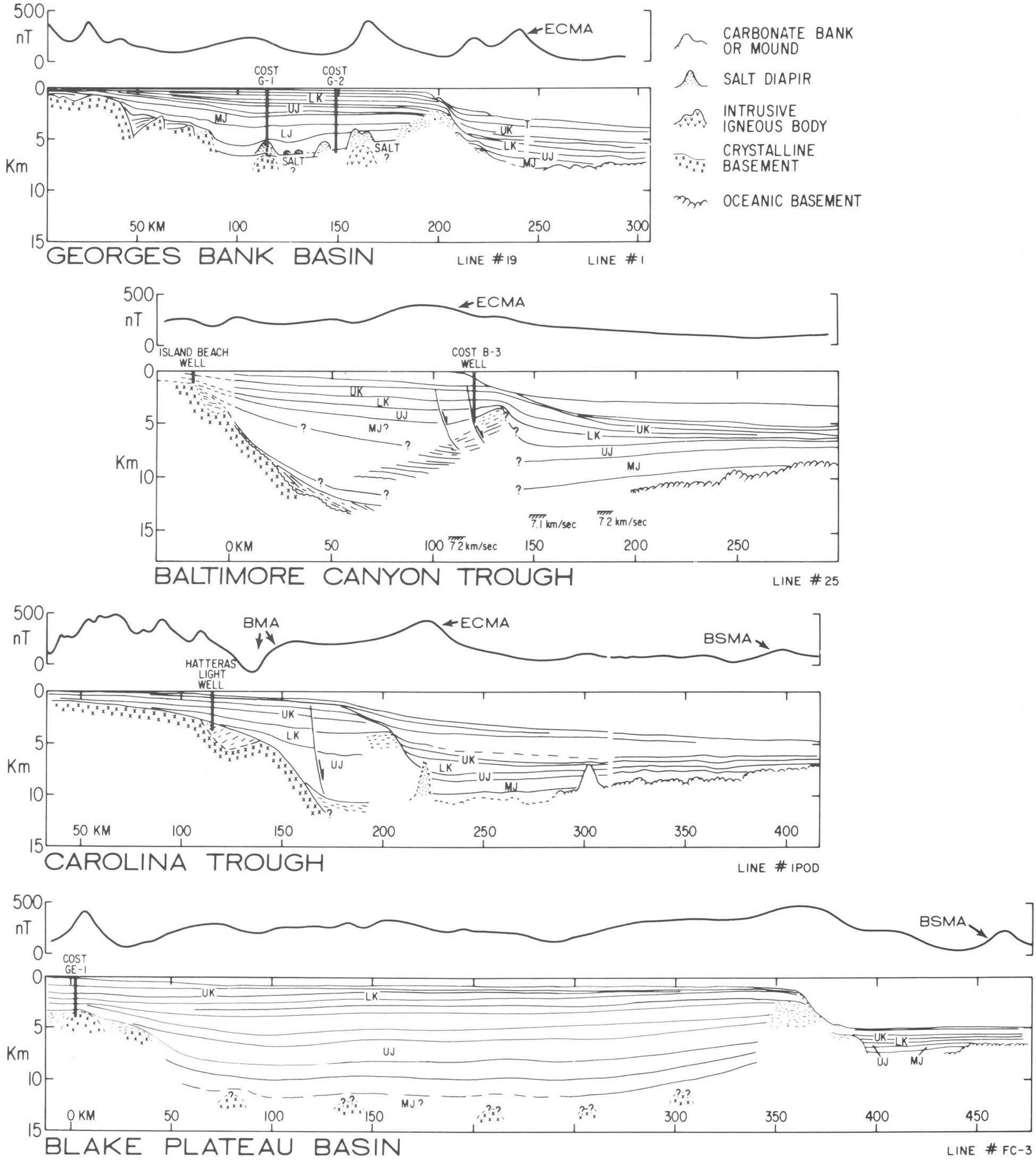


Figure 6. A series of cross sections across the U.S. Atlantic continental margin.

On the west coast, folios of maps and cross sections of the Pacific margin are being constructed in an effort to provide the basic data on geologic framework and processes (fig. 7). This effort must go with any exploration for resources in order to draw together a complete picture of our knowledge of structure and sedimentation during the evolution of an active plate margin.

We also are focusing attention on the potential for sea-floor mineral deposits. Some of the most surprising scientific finds in recent years have been the polymetallic sulfide deposits along the axial zones of oceanic spreading centers (fig. 8). There, seawater descends along cracks into the hot rocks of new ocean crust. The water is heated and boils up to the surface, where it may have such force that it literally geysers into the ocean. Such geysers commonly are called "black smokers" because they carry enough sulfide to be black. Some of the sulfide stays at the mouth of the sea-floor vent and builds up a massive sulfide deposit much like many deposits we have been studying onshore for years. These, too, were once on the sea floor. New finds in the ocean give us a laboratory in which we can come to an understanding of the processes by which the deposits form. We have a team of onshore economic geologists and marine geologists now exchanging information and insights. Some of these efforts involve scientists from academia, NOAA, and the Bureau of Mines, and we are always interested in discussing the geologic problems with industry geologists as well. The sulfide deposits, of course, may offer resource potential as well as a laboratory for studies, and we are pursuing the resource aspects. Figure 8 shows the location of the Juan de Fuca Ridge and the Gorda Ridge off the west coast. Although the Juan de Fuca Ridge lies outside the EEZ, we are studying it because we and the University of Washington have found sulfide deposits there, some still actively forming, some inactive.

This past summer, we joined forces with the Canadians to use the Bedford Institute sea-floor drill to try to sample the third dimension of some of the known deposits along the Juan de Fuca (fig. 9). Unfortunately, we weren't able to maintain the drill on the sloping surfaces of the sulfide deposits, so we recovered only samples of extremely fresh basalt from the lower relief volcanic rocks around the vents. Another important part of this summer's fieldwork involved bottom photography using Bob Ballard's Woods Hole ANGUS camera and our own camera system as well (fig. 10). The bottom photographs revealed blocky basalts, hydrothermally derived sediments, vent deposits, and numerous organisms (figs. 11, 12, and 13). Our summer work also suggests that the vent deposits may be coalesced and nearly continuous through a zone about 300 meters long and up to 50 meters wide. But we have no idea about their depth.

Samples of sulfides have been recovered from the sea floor, as oxidized massive sulfide (fig. 14) and fresh sulfides (fig. 15). The samples contain some pyrite, but mostly zinc sulfide, approximately 55 percent zinc. We are exchanging sulfide samples with other institutions in order to have our experts look at samples from different localities

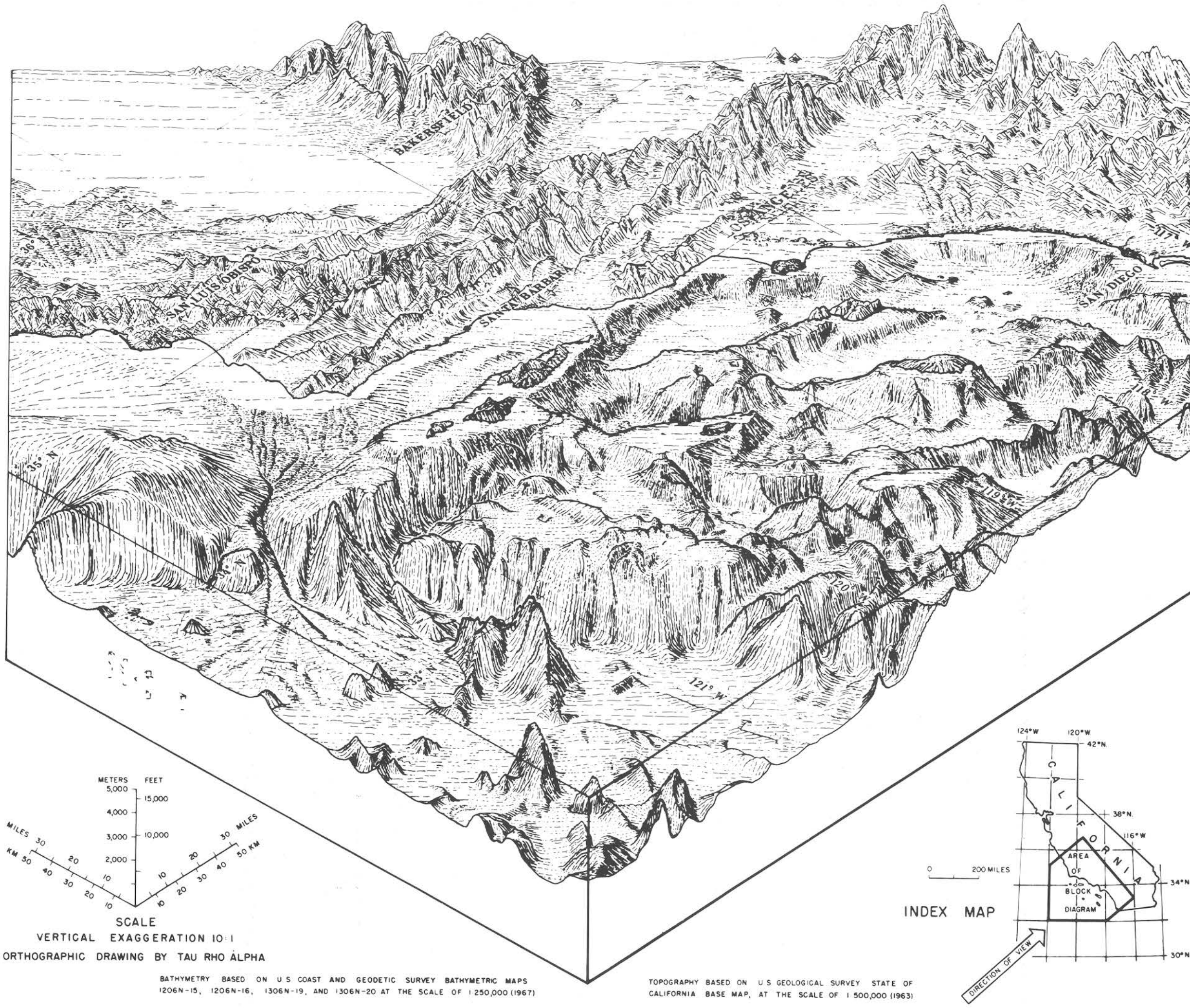


Figure 7. Block diagram of the continental borderland of southern California. The borderland is composed of many banks, islands, and basins. These basins trap sediments and may have potential oil reservoirs.

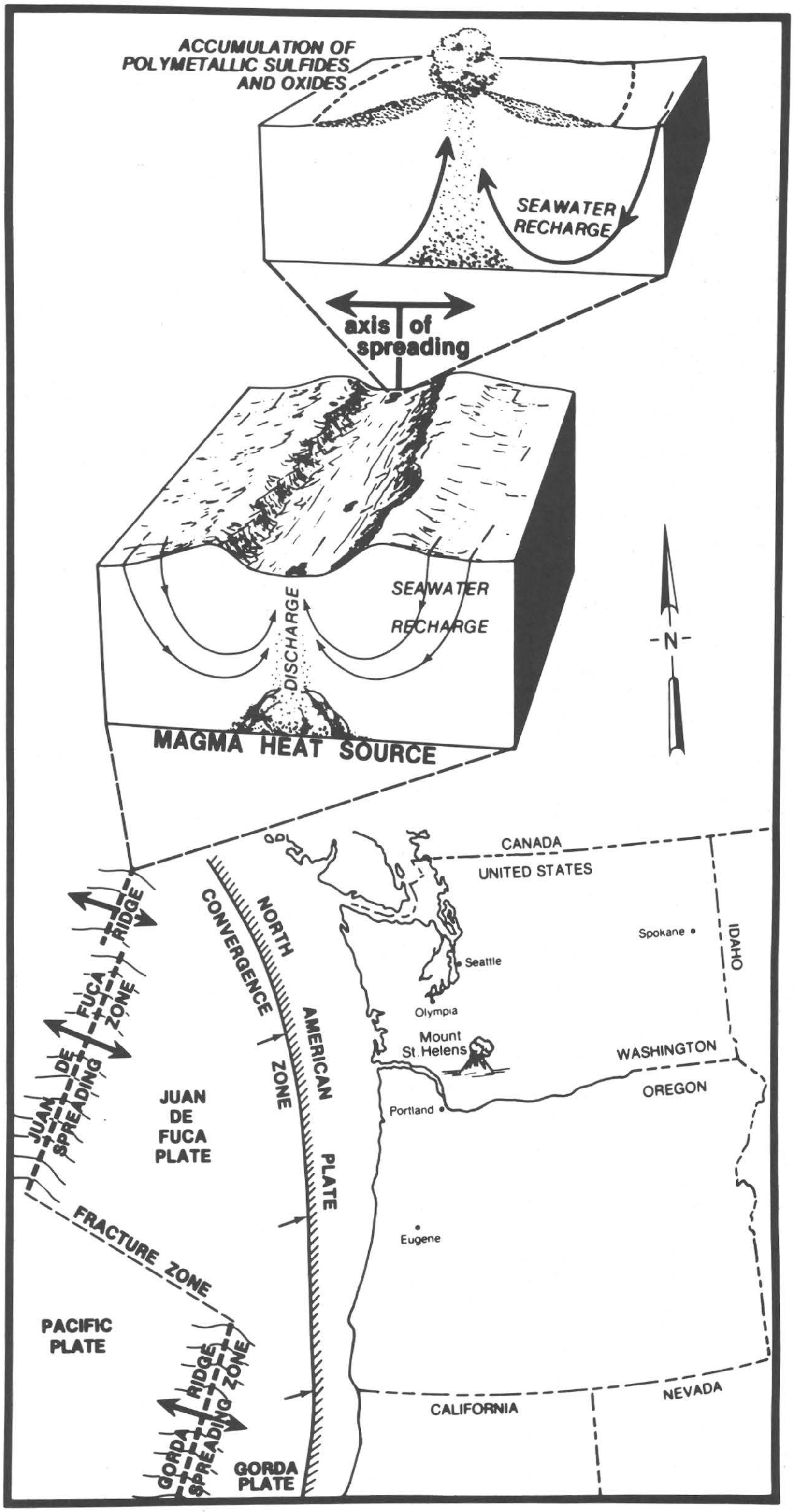


Figure 8. Polymetallic sulfide deposits form at vents along the axis of a spreading ridge. The Gorda and Juan de Fuca Ridges are spreading centers off the U.S. Pacific coast.

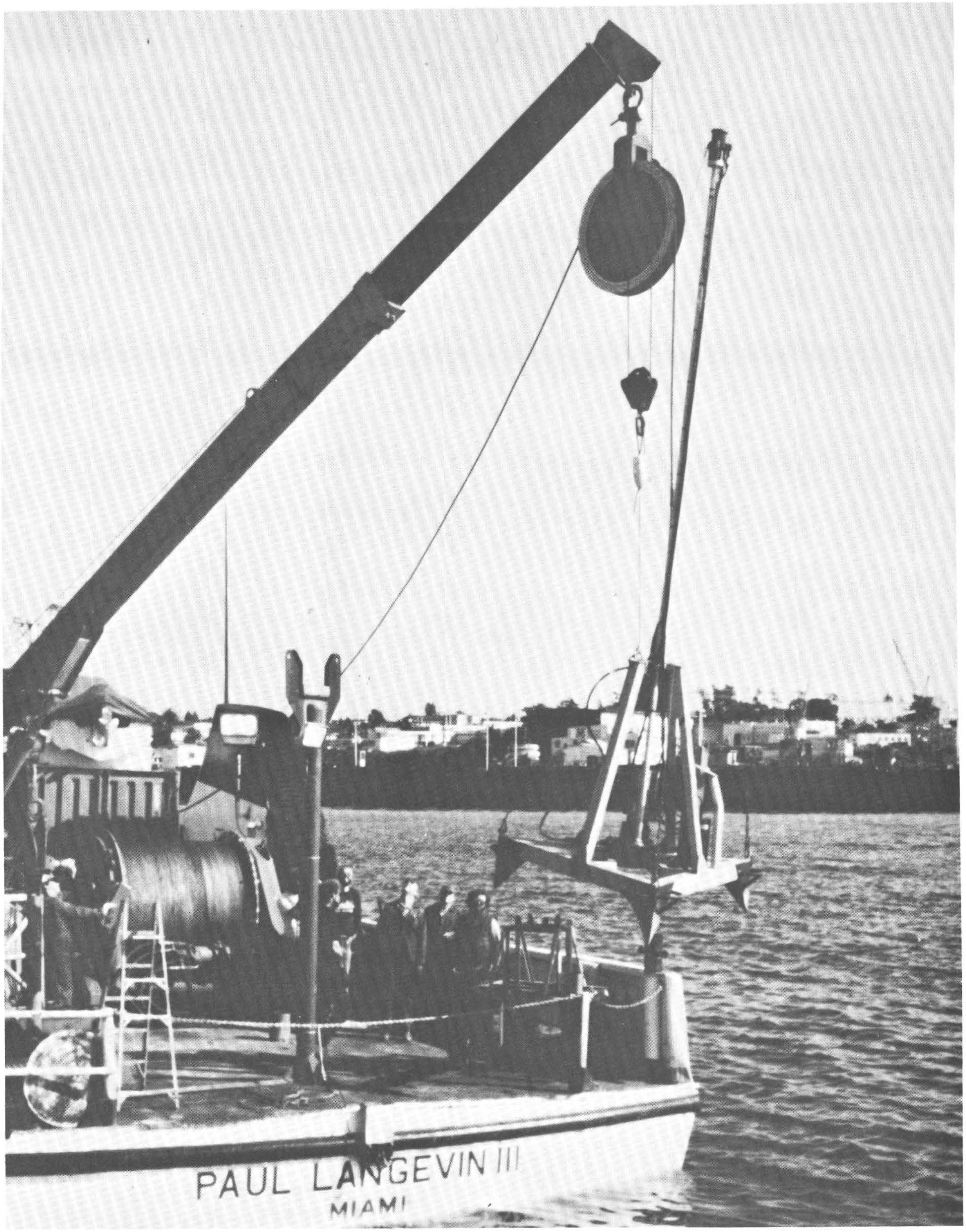


Figure 9. Photograph of Canada's Bedford Institute sea-floor drill which was used to obtain rock cores from the Juan de Fuca Ridge. (Photo by William R. Normark).

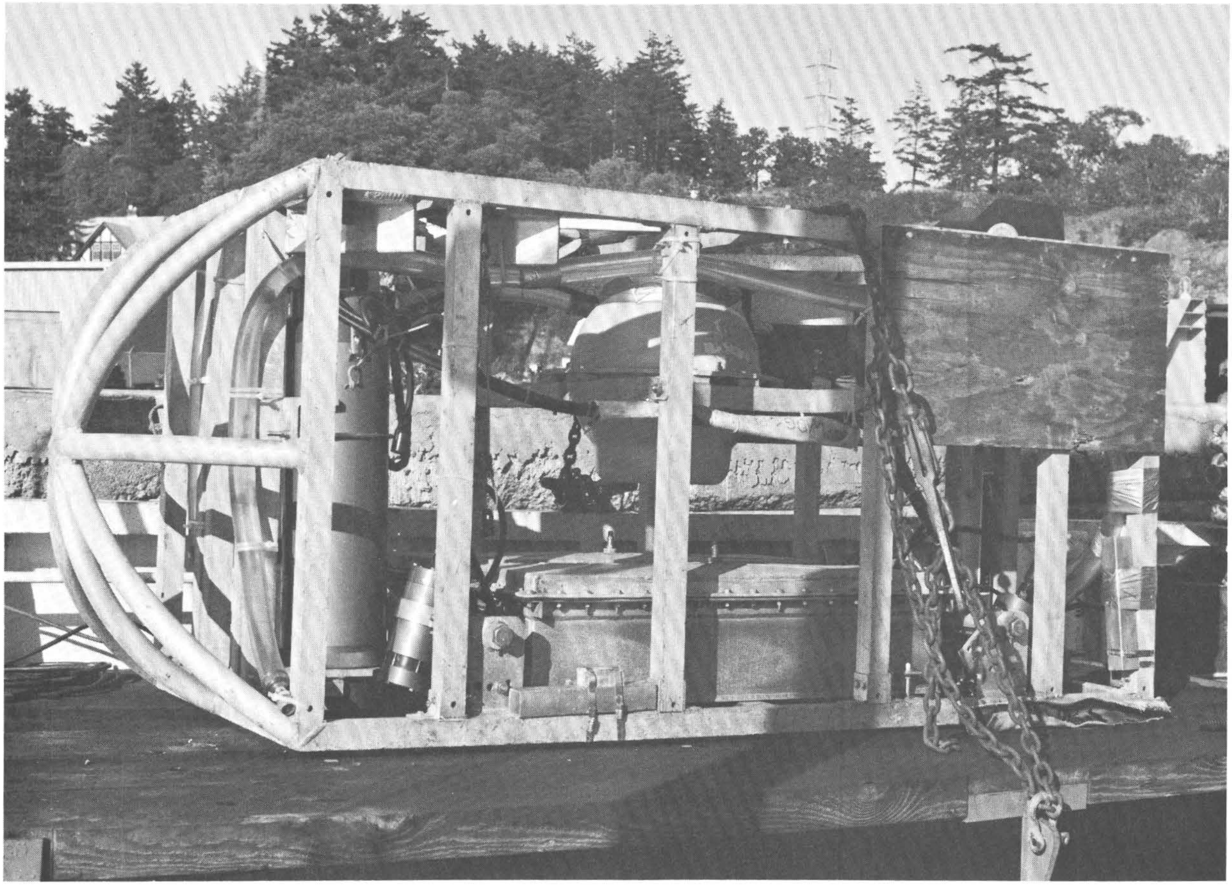


Figure 10. USGS deep-sea camera and color video system which is used to photograph polymetallic sulfide deposits on the sea floor. (Photo by Hank Chezar).

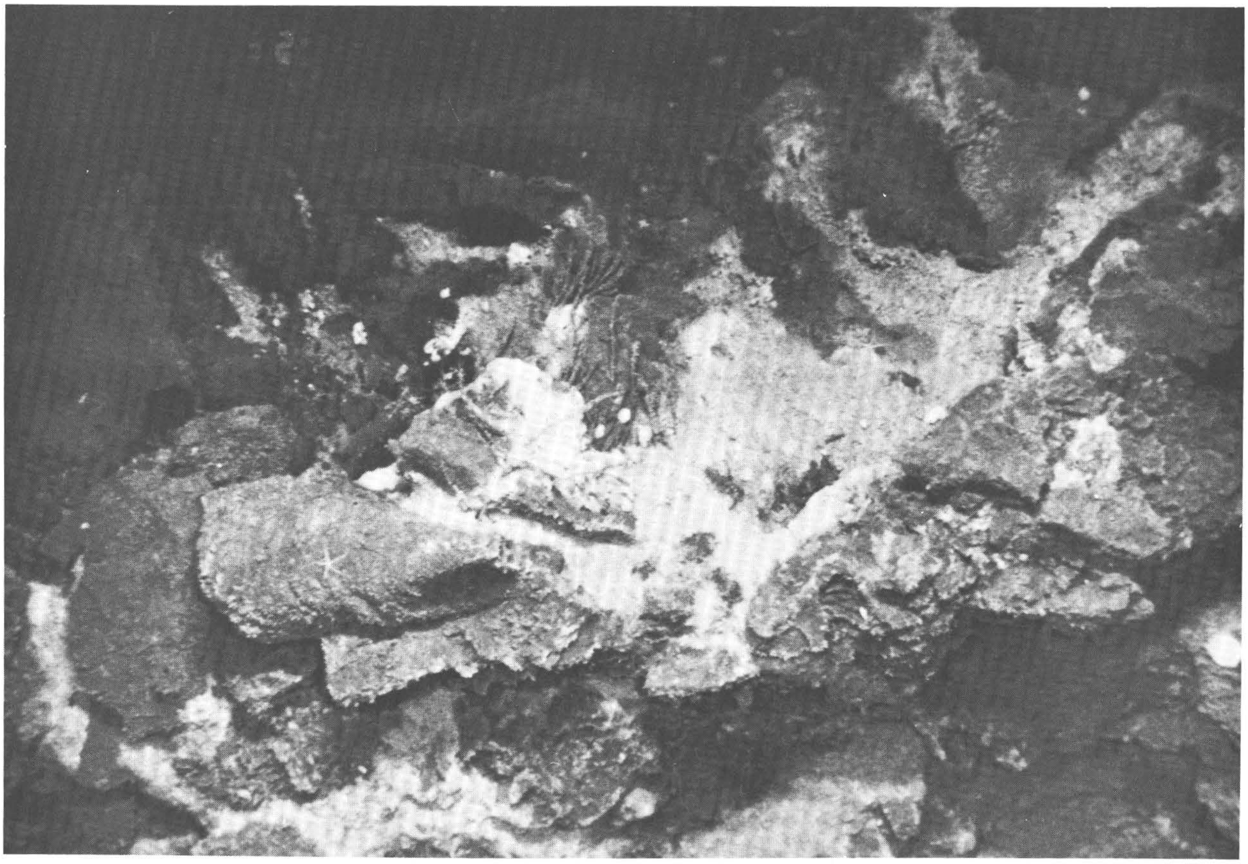


Figure 11. Underwater photograph of clusters of tube worms and polymetallic sulfide deposits around a hydrothermal vent on the Juan de Fuca Ridge. Field of view is approximately 5 meters across. (Photo courtesy of William Normark).

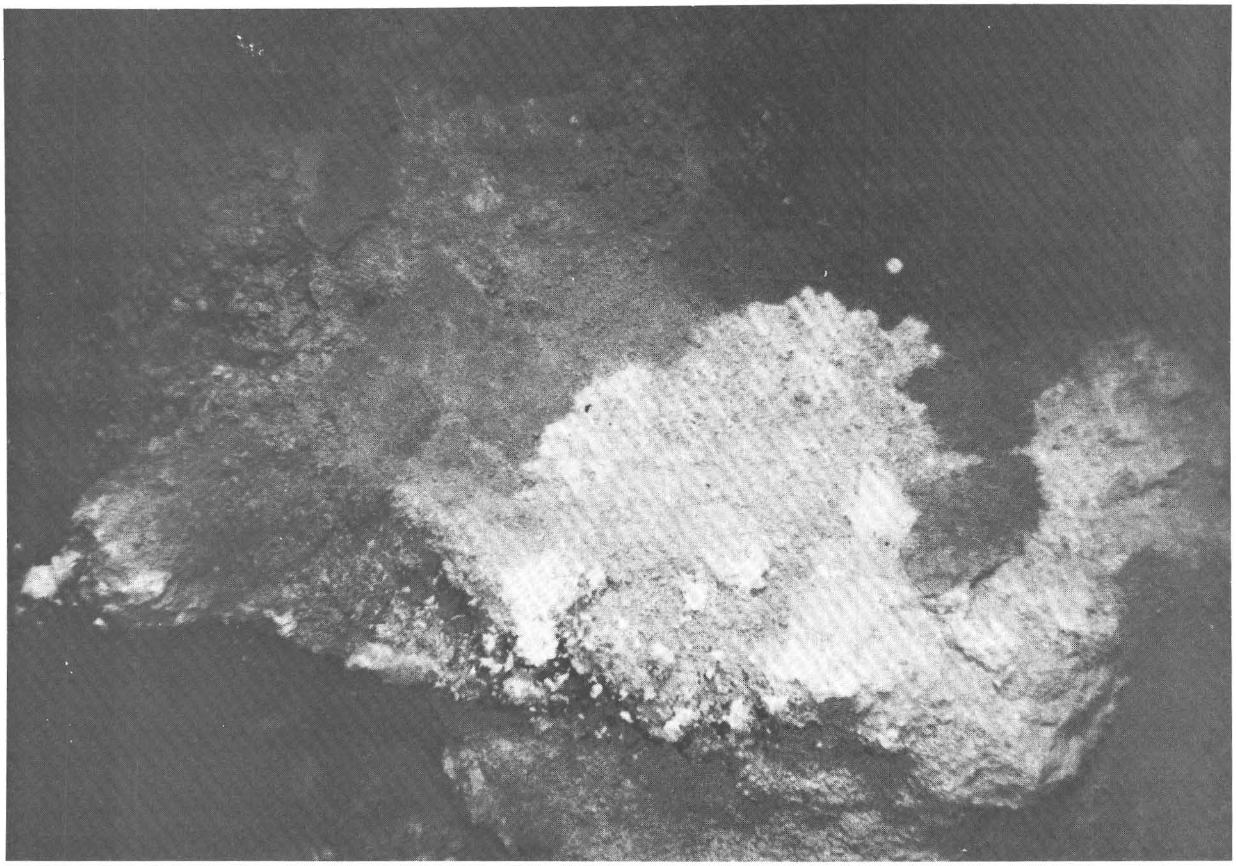


Figure 12. Underwater photograph of weathered sulfide mound on the Juan de Fuca Ridge. The white patches represent bacterial mats or hydrothermally derived sediment. Field of view is approximately 5 meters across. (Photo courtesy of William Normark).

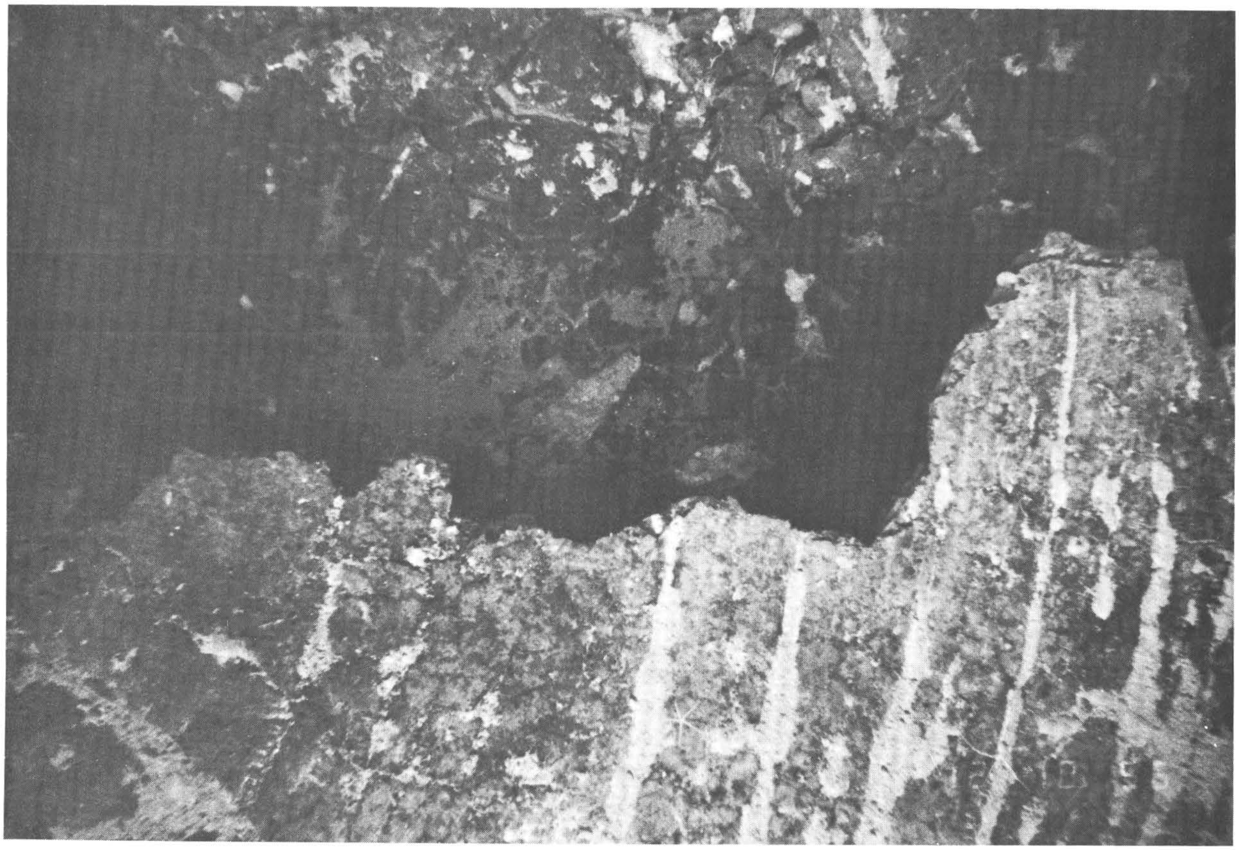


Figure 13. Underwater photograph of the rim of a lava-lake collapse pit on the Juan de Fuca Ridge. Glassy sheet flows are present and small patches of sediment, possibly of hydrothermal origin. Field of view is approximately 5 meters. (Photo courtesy of William Normark).

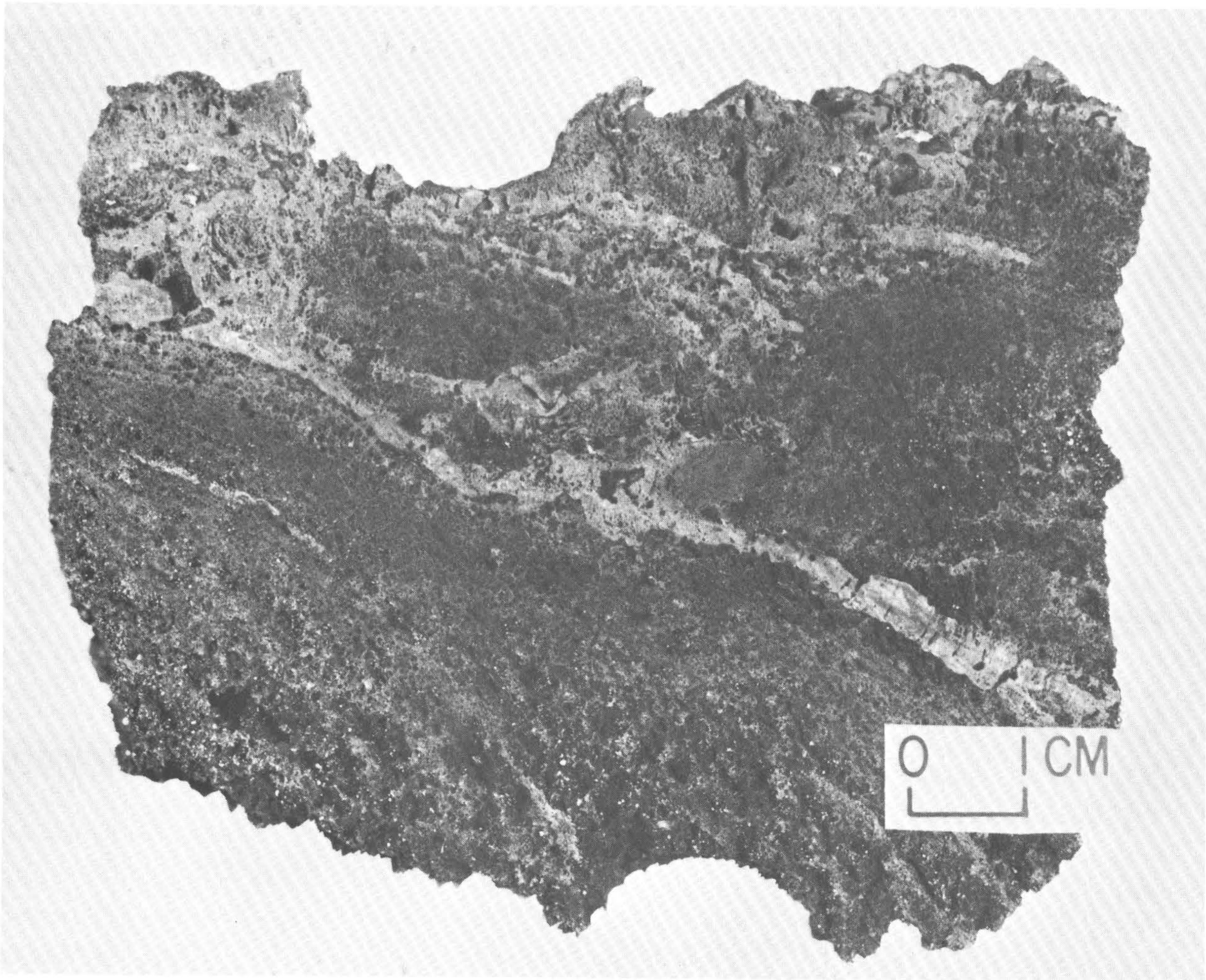


Figure 14. A sample of a polymetallic sulfide deposit from a hydrothermal vent. Sample is mostly zinc sulfide with light streaks of pyrite.

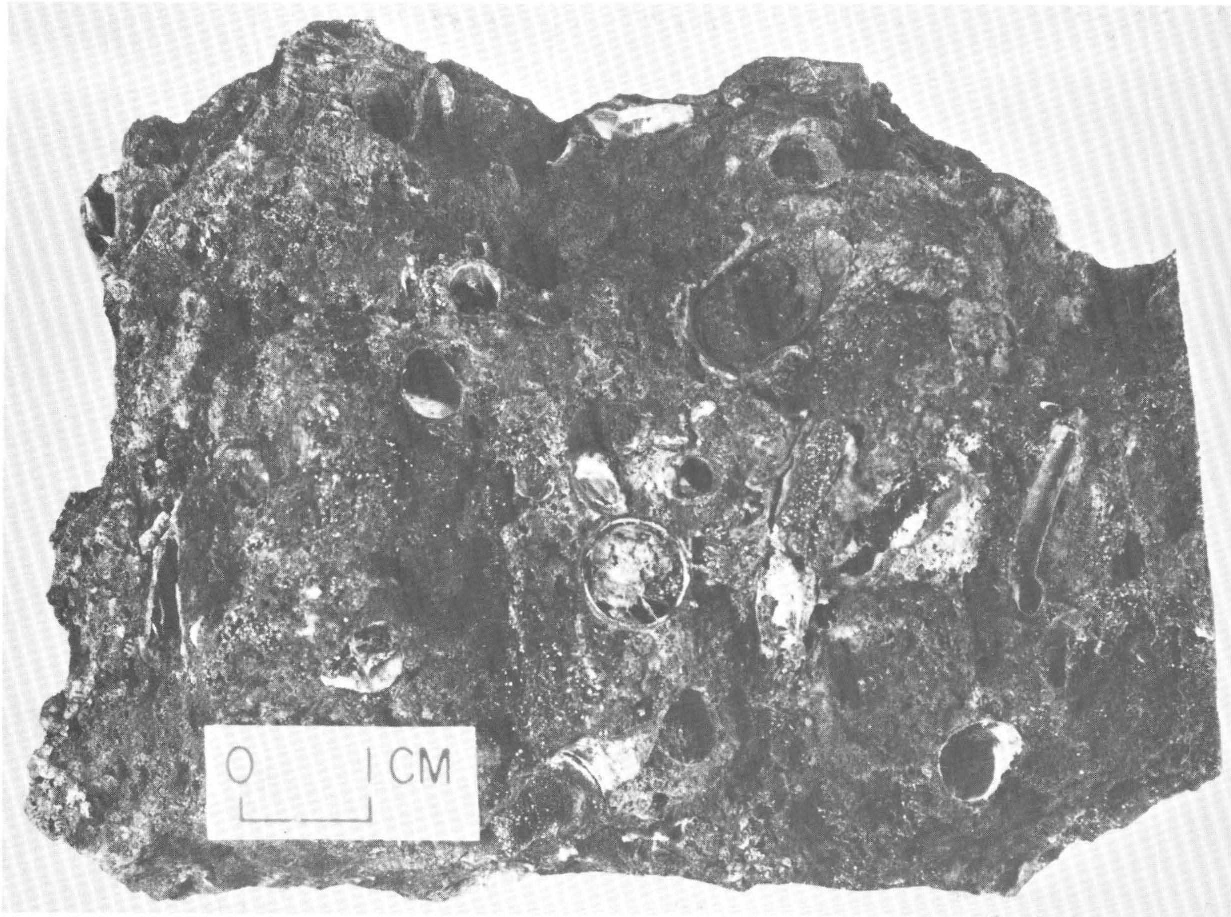


Figure 15. A sample of a polymetallic sulfide deposit from a hydrothermal vent. The holes were made by tube worms. The sample contains some pyrite, but is mostly zinc sulfide.

on the East Pacific Rise which differ somewhat in mineralogy and chemistry. These analyses will improve our insight into the hydrothermal process and its chemical and geologic controls. We hope to add some ALVIN dives in 1984 for closeup observation and sampling.

This past summer, the USGS, MMS, NOAA, and the Hawaii Institute of Geophysics joined to conduct surveys of the Gorda Ridge, which is entirely within the EEZ (fig. 16). It has a slower spreading rate than the Juan de Fuca Ridge, and thus has greater topography and more sediment in its axial zone. One sample of sulfide was reported to have been accidentally dredged there several years ago, but the exact locality was not reported. A survey was concluded that yielded excellent, continuous coverage by Sea MARC II side-scan sonar images of the Gorda Ridge and Blanco Fracture Zone (fig. 16). The sonar digital data have not yet been processed, but an example of the onboard display as the survey was being done is shown in figure 17. The sonar image is 10 kilometers wide, and shows the axial rift with escarpments along normal faults inside the rift. The rift also includes a small, fresh-looking volcano (fig. 17). Throughout the survey area, the Gorda Ridge is dramatic, an underwater mountain range cleft in two, with halves of split volcanoes on each side of the axial rift. Detailed bathymetry and sonar images that NOAA obtained on an earlier cruise allowed us to identify prime targets for possible hydrothermal activity. No vents were found, but dredged samples were covered with anomalous amounts of manganese, and a clay alteration product, nontronite, was present. These are good signs that hydrothermal vents were nearby. We will be making photographic surveys and sampling further when we have analyzed and integrated all the data obtained last summer.

Even newer than polymetallic sulfides to be recognized as potential resources are the cobalt-rich manganese crusts of the central Pacific sea floor. Such crusts have been known for a long time, but it was not until 1982 that their resource aspects became apparent. A USGS scientist on a German cruise in the Line Islands southeast of Hawaii, noted a consistent occurrence of about 1 percent cobalt in the samples being obtained. It is believed from preliminary USGS observations that these crusts range from 2 to 9 centimeters in thickness, that they occur on seamounts far from sources of blanketing sediment in a depth window 1,000 to 2,600 meters below the ocean surface, and that cobalt may be richer with decreasing depth inside that window. Other than these observations, we really know very little. We are now gathering and analyzing crust samples from archives of many oceanographic institutions, and we will be cooperating with the Bureau of Mines in this effort.

Right now, our research ship S. P. Lee is on a pole-to-pole scientific cruise, called Operation Deep Sweep (fig. 18). While this symposium is convening, the crew will be surveying island slopes and seamounts of the proper depths for the cobalt-rich crusts in EEZ waters around the Hawaiian Islands. The cruise is designed to obtain side-scan sonar images to show detailed topography of the seamounts, underwater photography for high-resolution views of the surfaces and possible crust

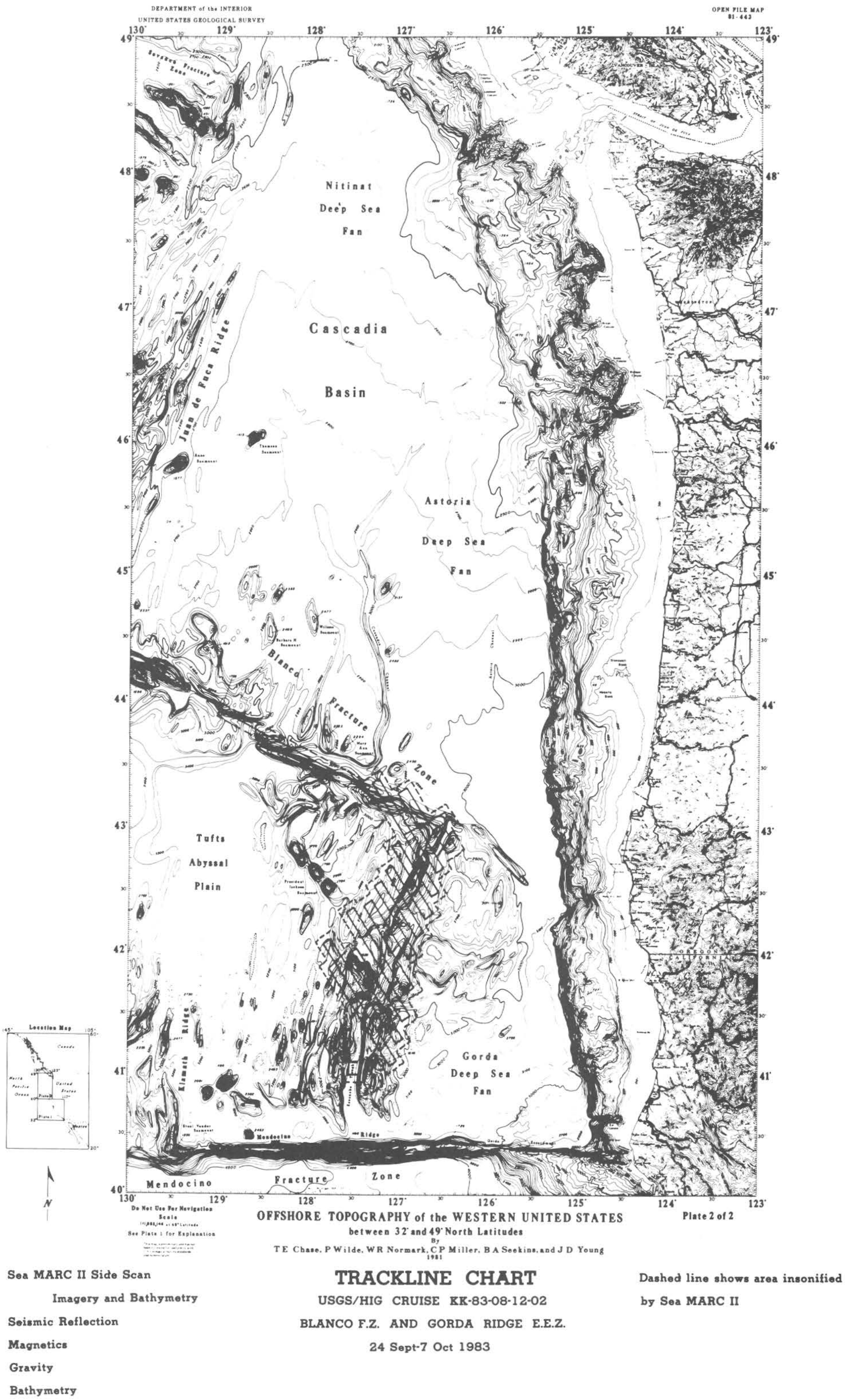


Figure 16. Ship tracklines along which Sea MARC II data were collected in the vicinity of the Gorda Ridge.

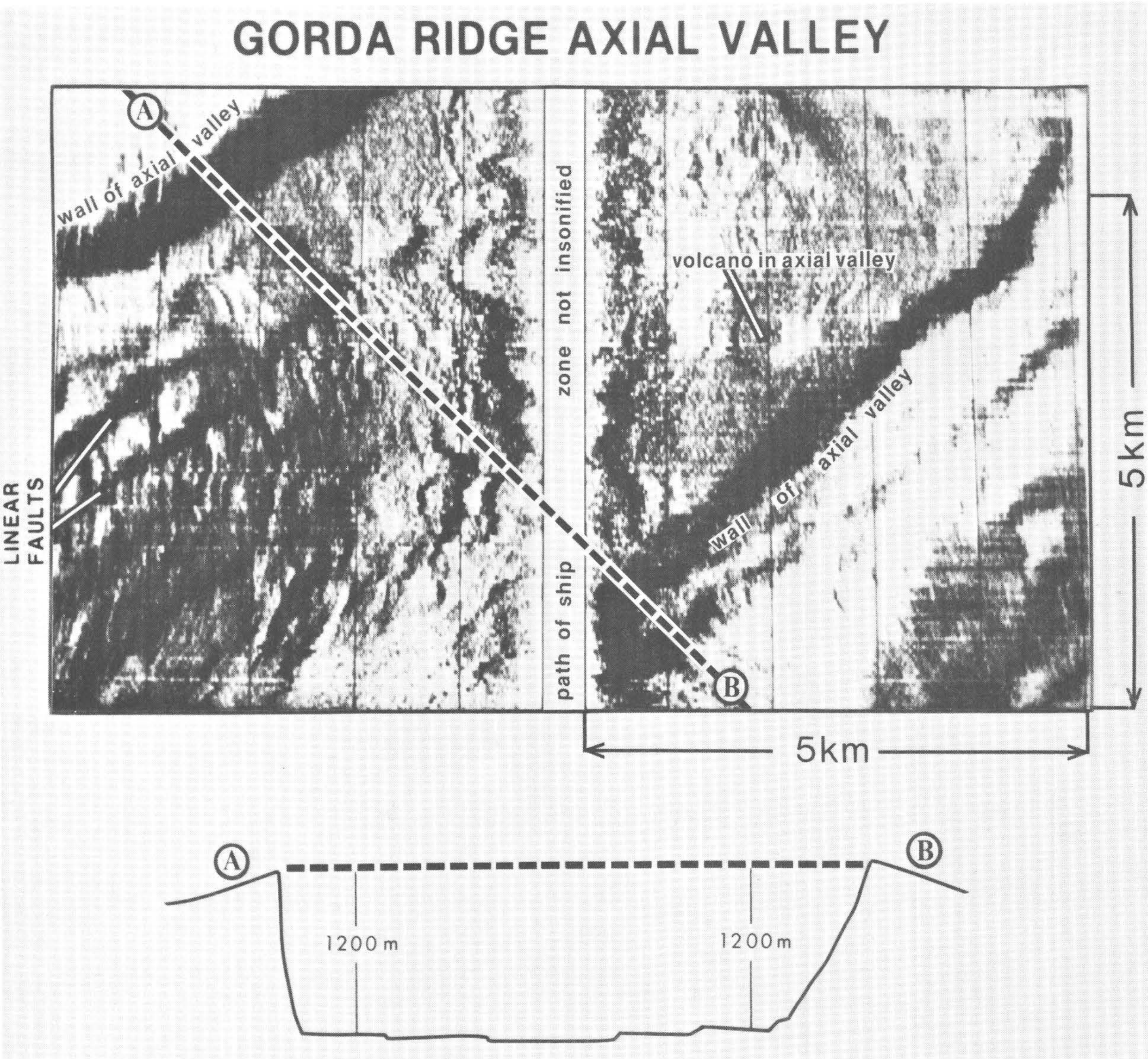


Figure 17. Photograph of Sea MARC II sidescan sonograph of the axial valley of the Gorda Ridge. Total width of sonograph is 10 km. Valley walls are located at upper left and lower right of photograph. A volcano is present within the axial valley.

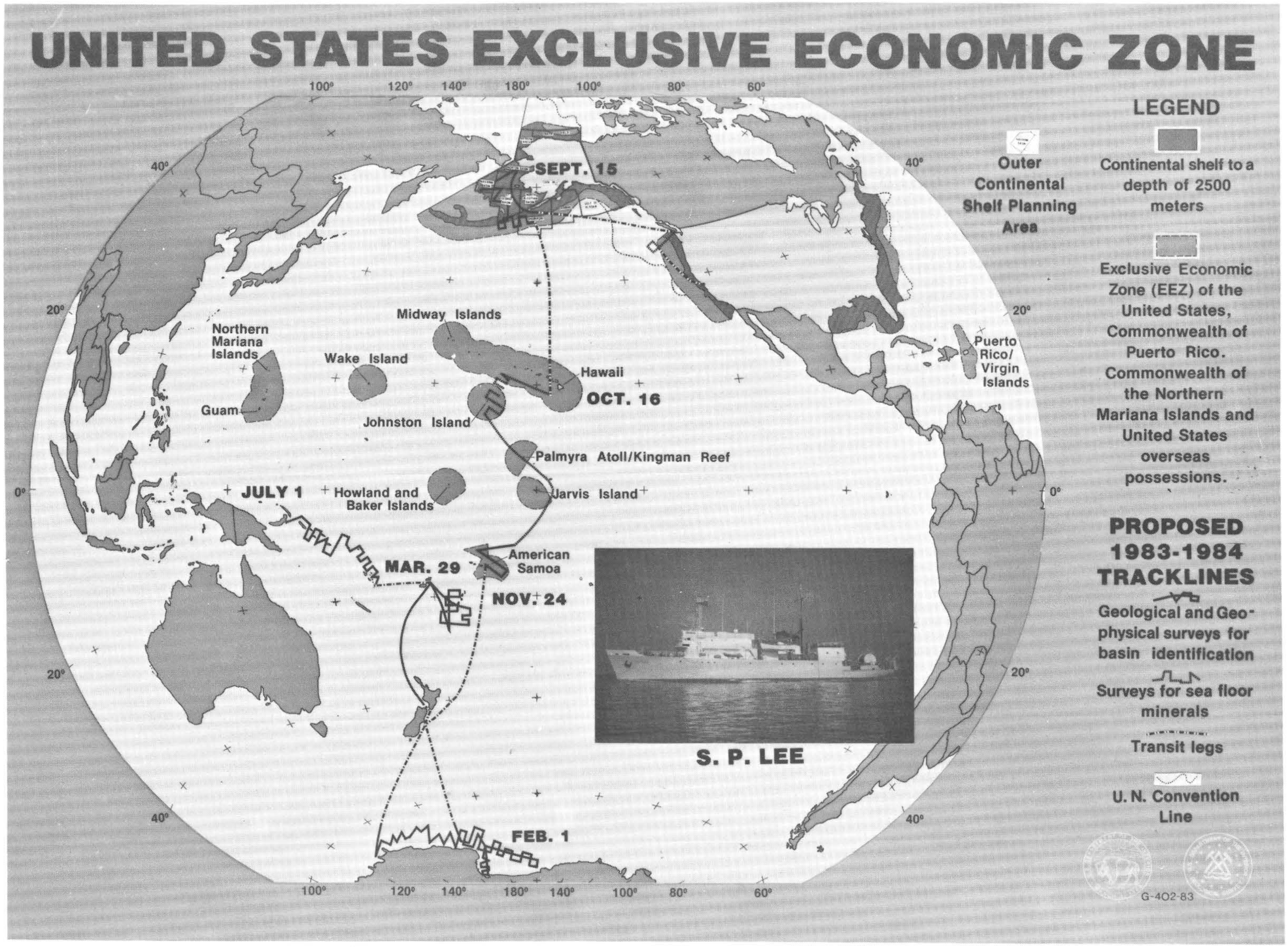


Figure 18. Ship trackline of the S. P. Lee on a pole-to-pole cruise called Operation Deep Sweep.

deposits, and samples of crusts gathered in a systematic fashion in order to permit studies of lateral and vertical variations in occurrence and composition of crusts and perhaps even a very rough estimate of resources for selected localities.

After the Hawaiian Islands survey, similar work is planned off American Samoa. From there the Lee will head south for seismic surveys of the Ross Sea-Wilkes Land margin of Antarctica (fig. 19). These waters are not in the EEZ, but they can be expected to become important to America sometime in the future. In the meantime, there is excellent science to do there, which will increase our understanding of passive continental margins, such as our own Atlantic margin. The track lines for this survey in Ross Sea-Wilkes Land area are shown in figure 19.

After the Antarctic work, the Lee will then conduct a series of surveys sponsored by the U.S. Agency for International Development, Australia, and New Zealand to investigate the potential for hydrocarbon and mineral resources of several South Pacific island nations. Again, the framework knowledge gained in an area of modern plate subduction and island arcs will be directly applicable to understanding U.S. areas like the Aleutian and Marianas arcs and fossil examples of arcs now part of the North American plate. We think, for example, that the kind of heat that forms sulfide deposits in spreading centers ought to be available to drive similar processes in volcanic arcs, back-arc basins, and undersea volcanoes. Indeed, we already know that many analogous onshore sulfide deposits did form in back-arc settings. The Lee cruise will offer a chance to obtain data in such areas. On the way back home to Redwood City, the ship will survey areas of the Marshall Islands and the Hawaiian Islands for possible cobalt-rich crusts on the sea floor.

However, that is not all the mineral potential of the EEZ. There are placer deposits of heavy minerals and sand and gravel (fig. 20), although the distribution of heavy-mineral placers is too poorly known to establish true economic potential. For example, recent USGS work suggests that significant amounts of heavy minerals are present in the top meter of sediment underlying a broad area of shallow water off the Virginia coast. It is not clear yet if these deposits are economic or whether they could be extracted in an environmentally safe way, but the resource potential seems to be very large. Our scientists are actively conducting research on sand and gravel deposits and current movements off the North Slope of Alaska, where gravel may be needed for artificial islands for drilling. We also are studying sand and gravel in Long Island Sound and at various places along the California coast. Phosphorite and manganese deposits seaward of the Carolinas are also being evaluated (fig. 20).

These are but a few highlights. We have many other projects that continue to develop knowledge of the geologic framework and processes, which include the plate tectonics and resources of the Caribbean, the use of an instrumented sled to study movement of sand in the surf

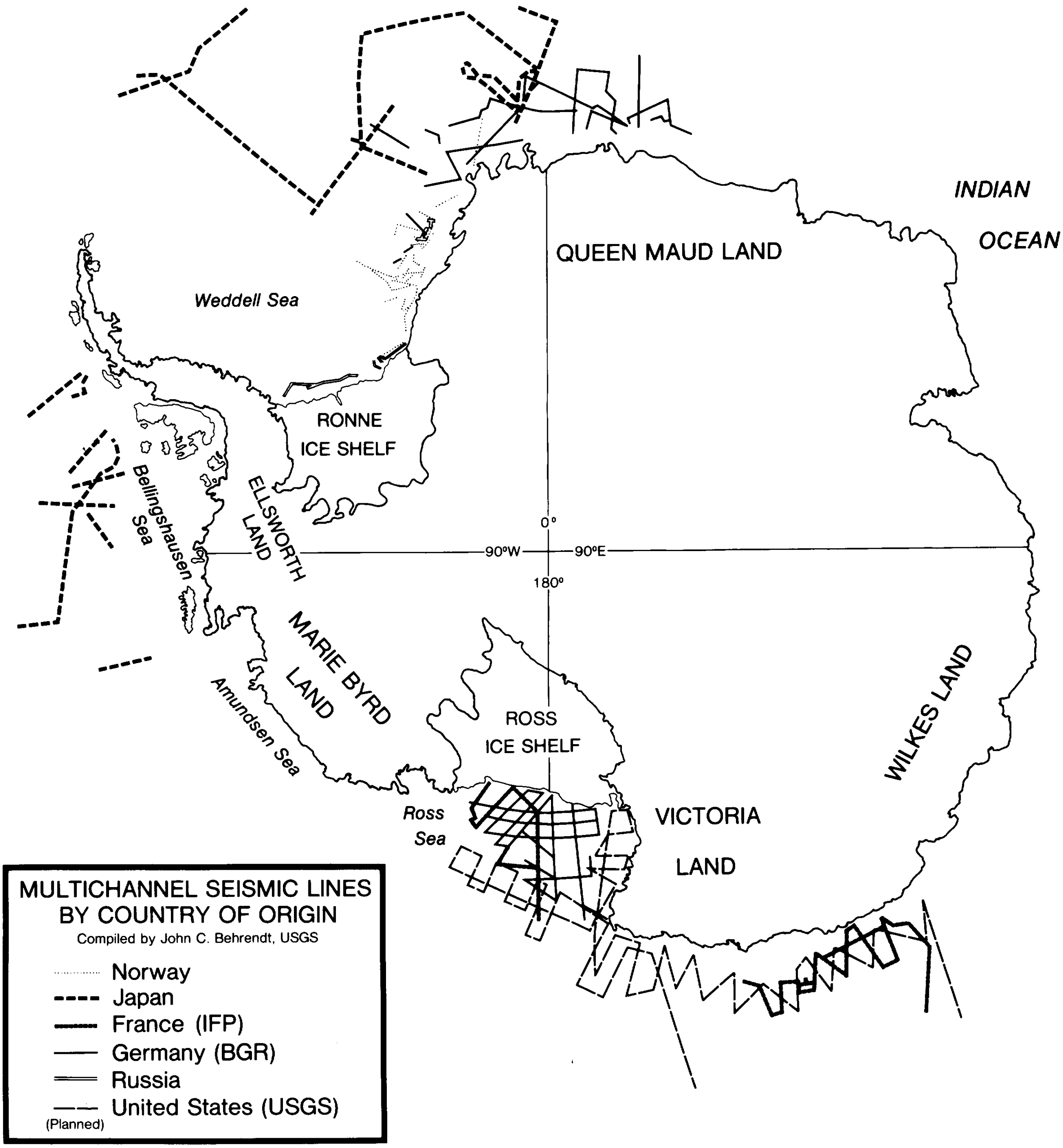


Figure 19. Ship tracklines of seismic relfection profiling survey to be conducted by the S. P. Lee in the Antarctic.

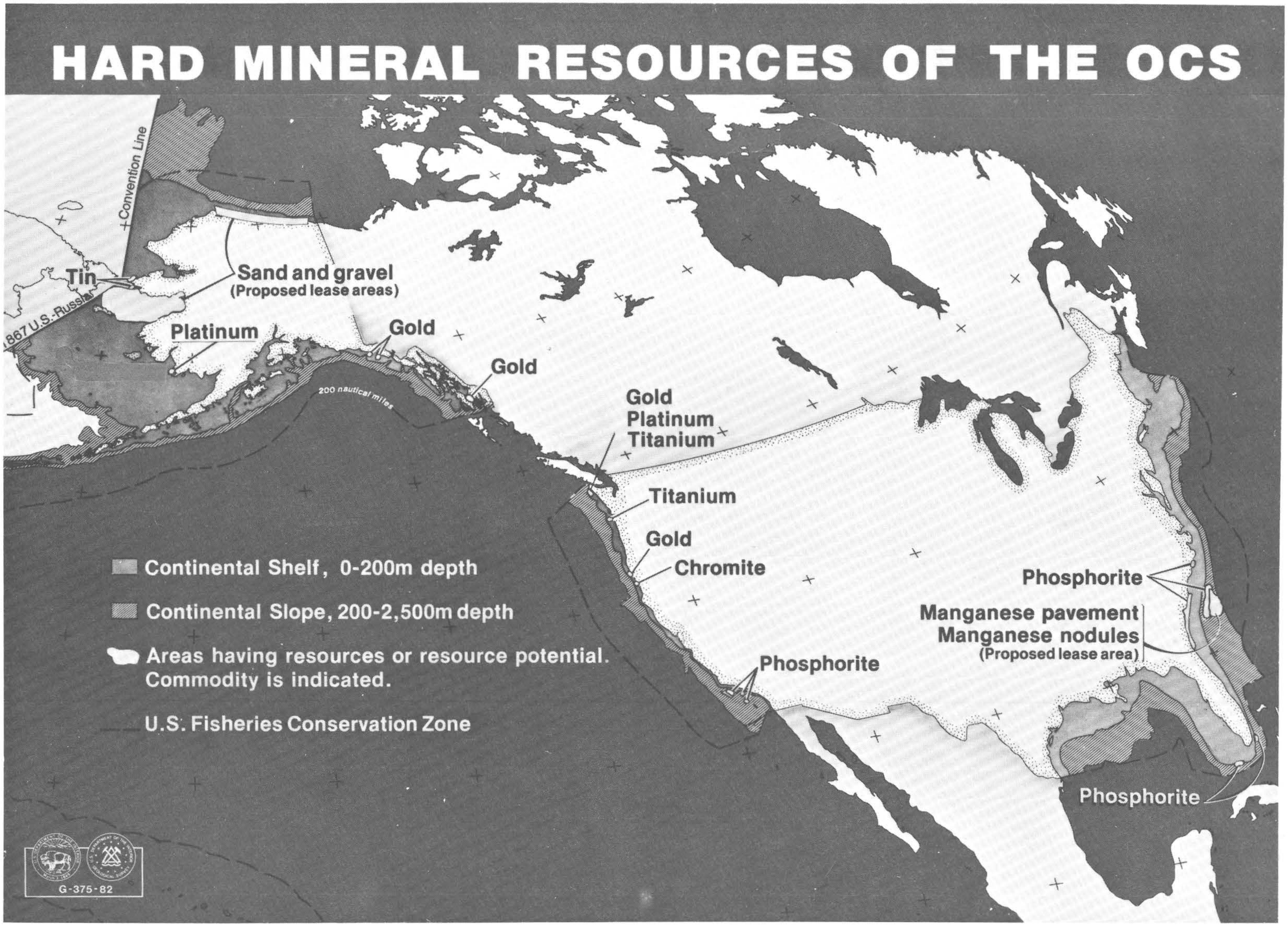


Figure 20. Hard mineral resources contained within the U.S. EEZ include manganese, phosphorite, gold, platinum, and titanium. Many of these mineral deposits are found in sand and gravel deposits on the Continental Shelf.

zone, and a series of studies of bottom currents and sediment movement to gauge the potential for pollutant dispersal around offshore drilling sites.

These are some of the things we are doing. Now, I will focus on what we plan to do, especially in the EEZ. Much of what I have described, of course, is already in the EEZ. In order to sharpen the focus, to make an orderly progression of our activities, and to assure that our scientific investigations provide advance information and good support for present and future industry concerns about the Nation's resources, we have settled on a variety of related studies in specific corridors. These corridors have been chosen to present diverse geologic settings and research targets that are representative of the broad reaches of the continental margins (fig. 21). Over a period of time we will try to add additional corridor studies on our margins and in key areas of the Pacific EEZ.

Our specific plans include extending the seismic lines seaward across the EEZ, as well as conducting joint studies with the Advanced Ocean Drilling Program in order to get much-needed detail both on deep-water sedimentary accumulations such as deep-sea fans, and on the slope and rise of each margin. We are increasing efforts to obtain data in Arctic waters. Other studies focus on gas hydrates as possible hazards or resources. We are undertaking shallow drilling near shore to obtain information to help in understanding sedimentation processes, sea-level changes, and paleoclimate, as well as to improve the interpretation of seismic data. We are even beginning to consider how a continental-margin deep drilling project might be fostered, for in no other way can we truly understand the evolution of our plate margins.

Besides these activities within and adjacent to the identified corridors, there are two other major efforts. One is small-scale reconnaissance side-scan sonar imaging to acquire relatively coarse resolution image-mosaic base maps of very large areas. This fiscal year we will contract a GLORIA survey of the conterminous U.S. Pacific margin. After digital massage, the mosaic base will be very similar to the Landsat image mosaic for the onshore United States. The other major effort is to compile our historic and incoming information in an organized, useful format. We have established a marine map series, a system of folios with the individual maps making up an area folio which will be issued as soon as they are ready. The first maps will begin to appear in a few months, at scales ranging from 1:1,000,000 to 1:250,000, depending on the density of our data and the scale of the features to be shown. Much of our information is already published and available in a variety of formats and places. Collating the existing data in the new map series, plus adding new information during the process, should result in folios completed in the first go-round for the U.S. margins over the next 5 years.

The EEZ is enormous, but our fleet, and our scientists working with academia on UNOLS vessels, are organized to deal with the problem.

The USGS marine program is covering framework, process, and resource aspects of geology in the Arctic and offshore Alaska, the Pacific margin and the vast Pacific Basin, the Gulf of Mexico, the Caribbean, and the Atlantic. We work now, and will continue to work with Government, academic, and industry colleagues. We want especially to be aware of industry's needs for basic information as we design or fine-tune our programs in coming years. This symposium is intended to bring us all together to obtain a grand design and to foster partnership or cooperation. There is so much to do--it's an exciting venture.

EXCLUSIVE ECONOMIC ZONE

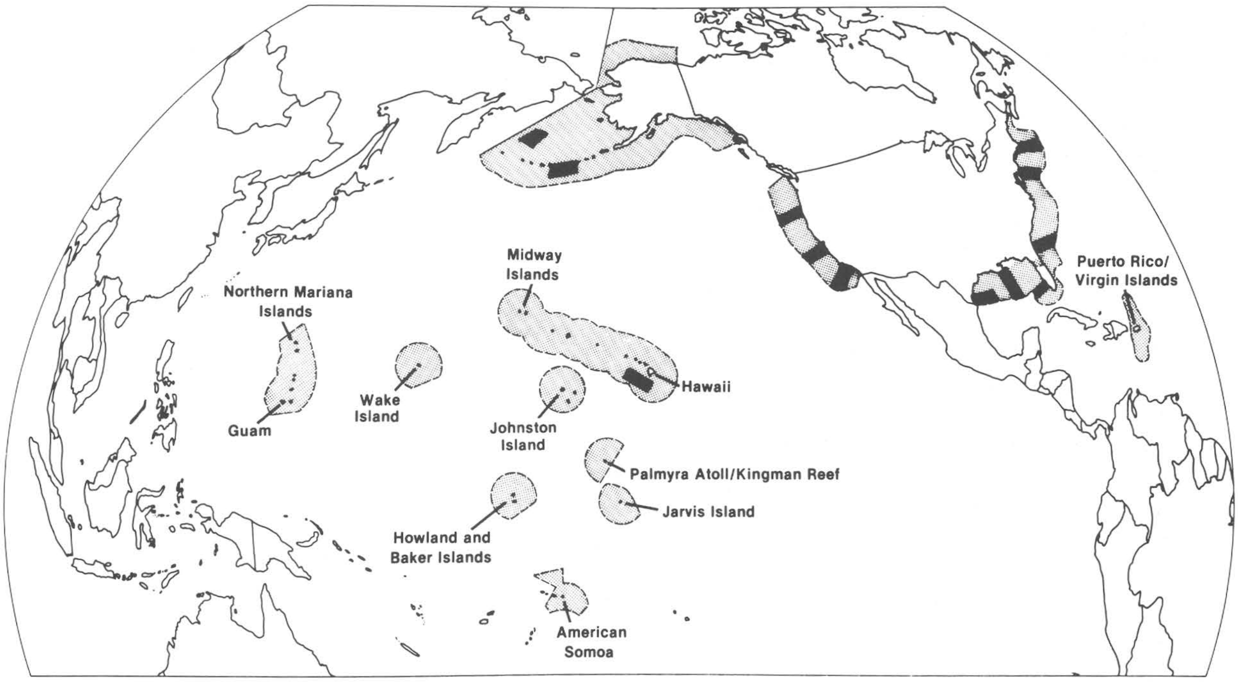


Figure 21. A series of corridors representative of diverse geologic settings have been designated within the EEZ for study.

Chapter 7

LEASING AND MANAGEMENT OF RESOURCES IN THE EEZ

by

David C. Russell
Minerals Management Service

Some of you heard portions of the confirmation hearing for the new Secretary of the Interior. I think you'll find Judge Clark to be a very reserved and intelligent man. He served on the bench in California for some years in the Supreme Court there. My exposure to him over the last several weeks, in a number of hours of meetings with him has been that he's a good listener and he'll take a careful, cold look at the programs in the department, including, perhaps, the one you're looking at today. He will judge a number of them to be sound and proceed with those. In some cases he may make modifications; in some cases he may change the program entirely. We have no indication precisely where he's going to go; Judge Clark is his own man.

So I think any presumption about where the department will be a year from now is probably premature, except in one area. And that is offshore leasing. He has committed himself to maintaining the 5-year schedule of lease offerings. He has stated his opposition to leasing moratoria, such as those attached as riders on appropriations bills. He stated the importance of offshore oil and gas leasing to American energy independence, so I think we will see a continuation of that program.

It would be unfortunate if our review of current and proposed activities in this segment of the symposium failed to provide a rationale for many of the steps we have taken in carrying out the Republic's most aggressive leasing program. It's a simple case of "why" being more important than "who, what, where, and when." It is especially important at a time when many observers say that America's energy programs are a thing of the past, of little real relevance to our societal decisions and resource development.

Until very recently, the United States was in the enviable position of being able to meet virtually all minerals and energy needs with indigenous domestic resources. At the end of World War II, for example, the United States was the world's largest producer and exporter of petroleum. The Texas Railroad Commission, which had the power to prorate oil output from wells in Texas, had more to say about world oil supplies and prices than did Aramco or OPEC. Most of you are too familiar with postwar events to sit through another counting of policy missteps that led America inexorably toward the energy shocks of the 1970's. Suffice it to say that America's propensity for using oil trailed behind our ability to produce it. As a consequence, we imported oil in ever-increasing amounts to fill the ever-expanding gap between domestic consumption and production. By 1973 we were so dependent on foreign oil that our historic ability to set world oil production and prices had been reversed. We were on the receiving end. Other countries determined world supply and prices, and it was our turn to like it or lump it. The rest is history, of course. But if we've learned nothing else in the 1970's we should have realized that being dependent on other countries for basic resources was something to be avoided at all costs.

Had I appeared here January 1, 1970, and told you that the price of oil on the world market would be over $40 per barrel by the end of the decade, you wouldn't have believed me. Yet in the 1970's we did witness $40 per barrel oil and periodic shortages. Had I appeared before you 10 years later on January 1, 1980, and told you that 1983 would see falling prices and a worldwide oil glut, you wouldn't have believed me again. How much stock would you place in my prediction of world oil and metal prices and supplies 10 years from now?

The fact is that world oil commodities and commodity prices and supplies reflect random and unpredictable events such as wars, coups, and assassinations as frequently as they reflect the relationship between supply and demand. The importance of this is that the United States has no means for protecting its citizens from such events, except by insulating them from dependence on other nations. This is true for oil and it's true for the cornucopia of lesser known minerals that are needed in the world's largest and most sophisticated economy. As the agency most intimately connected with the production of oil and other important minerals offshore, we at the Minerals Management Service are highly sensitive to the role that the EEZ might play in restoring America's energy and mineral self-reliance. Much of the experience the United States has had with oil is directly transferable as we begin thinking about the importance of the EEZ in meeting national needs for critical and strategic minerals.

Of all the lessons of the 1970's, the one with the clearest bottom line is, "dependeth not on other nations for energy or critical and strategic minerals, for yes, verily and foresooth, their interests are not thine interests. And the temptation to squeezeth is great." Seriously, we don't think that the reasons for offshore development are broadly understood by the public even though most of us in this particular room understand them. The public at large is unaware of our mineral dependence, and uninformed of its long-range implications. In our urge to tell everyone what to do, let's not forget to tell them why. Because if we don't, the end lies in potentially disastrous limitations on our offshore oil and gas leasing program. Written into the fiscal year 1984 Appropriations Bill last month is a tragic example of what can happen when the "why" for a particular program isn't understood.

It should come as no surprise that the Minerals Management Service is centered on the idea that our offshore wells should be developed as rapidly as realistic economics and sound environmental policies permit. Towards this end, this organization which we call the MMS has taken several initiatives. Last year we asserted jurisdiction for the Department of the Interior for leasing polymetallic sulfides in the Juan de Fuca and Gorda Ridge areas, offshore from Oregon and Washington. We accomplished this through some rather advanced cowboy diplomacy techniques from the Joan Rivers School of Tact. Some of you may have heard about the "Russell Disputed Zone" up near the Canadian Border.

The Minerals Management Service has also established within its offices a new Office of International Progams and Critical Strategic Minerals. It's headed by long-time initiator of new minerals programs in Government, Reid Stone. Reid will coordinate the existing programs and direct the national program for management of critical and strategic minerals in the EEZ. In addition to setting up this office, and asserting jurisdiction, we have moved forward with a sand and gravel lease offering in support of oil and gas development in the Arctic. We assume that the sand and gravel in and of itself has no value. We'll assign no royalty basis for this lease offering. It is our intent to offer enough lease tracts to satisfy all the demand and not to extract a monopoly rent from the sand and gravel lease offering.

The Minerals Management Service is also preparing to offer for lease the Gorda Ridge area off northern California and Oregon next fall. Polymetallic sulfides are the resource here. The draft EIS will be out in about 3 weeks, I understand. Samples brought back from a recent USGS/MMS expedition showed strong indications that the Gorda Ridge area contains minerals of economic interest. This is all pursuant to a program approved in January 1982 by Secretary Watt, which said that we will respond on a case-by-case basis to industry interests for offshore hard-rock minerals.

In addition, we have plans for periodic lease offerings of offshore hard-rock minerals to include other than Arctic sand and gravel: phosphorite, off the Atlantic and Pacific Coast; placer minerals, including gold off Alaska; and cobalt-bearing manganese crusts from seamounts off Hawaii. We're developing lease terms and conditions which are tailored to the unique circumstances for each of these hard-rock minerals through the environmental regime which is located in the area. Therefore, there will not be rules that will be promulgated to set up a huge bureaucracy around this program; rather we'll tailor lease stipulations and exploration standards to meet the commodity and level of technology. I'll refer you to a fuller discussion of lease terms and conditions in the panel III discussion today with Reid Stone, Bob Beauchamp, Mike Cruickshank, and Jack Rigg, our experts in the Minerals Management Service on hard-rock leasing. I think you'll get an idea of where we are in detail with these polymetallic sulfide offerings and the sand and gravel offering.

In closing, I would note that NOAA and the USGS have at times vied for dollars and research projects in the EEZ and particularly for mineral commodities. The Minerals Management Service isn't in the business of pure research. We've left that to our sister agencies, particularly the USGS. And we will rely on them for the research upon which to base our lease offerings.

Bob Ballard said he believes in a free-marketplace program. Well, we certainly do, too. We try to run the Minerals Management Service as a business even though it's a regulatory agency, and the free-marketplace concept is particularly relevant. We'll put together a lease offering, understanding that it's an infant technology. There's not a large amount of data presently. We'll try to act as the party that makes the opportunity available for the private sector or for the academic sector, or for our sister agencies, the USGS and NOAA, to go in under exploration permits to extract some of this resource and to find out whether it's ecomomic to produce and market in the United States or abroad.

One other program element that I think is particularly important here, even though we are being rather aggressive and assertive in everything from jurisdiction to lease offering times, is that we are doing so only by working closely with the states. Bob Bailey from Oregon and I have talked about this program, and he's talked with our specialists about the polymetallic lease offering scheduled for next fall. He's concerned that the state be very involved, just as we are. For this reason, we've worked with Gordon Duffy from California on this hard-rock mineral lease offering. And I can announce to you today that because of Governor Deukmejian's request yesterday, we will add another public hearing in Eureka on the draft Environmental Impact Statement. It will be out in about a month. We're working closely with the states, and I hope that the relationship we've had in the past will continue.

Chapter 8

THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION'S ROLE IN THE EEZ

by

Ned A. Ostenso
National Oceanic and Atmospheric Adminsitration

I am pleased to be here to represent the Administrator of NOAA Dr. John V. Byrne who was committed to a Whaling Commission meeting in Japan. First, John and I have some things in common other than our association with NOAA; and that is before we became bureaucrats, we were both working geologists. Second, we have had a long, and I must say fond, association with the U.S. Geological Survey. In fact, on reflecting on this late last night, it occurred to me that the first paper I ever published was in the USGS Professional Paper series. It was work on the Jarvin glacier in the Alaskan range that I did with Bill Holmes. Those are fond memories, indeed.

Finally, John and I are both opposed to speechmaking, and if he were here, he wouldn't speak to you. He would talk to you. As I am here as his representative, I would like to replicate that style to the best of my ability. My prepared document starts out with many really nice examples of how NOAA and USGS have worked together in the past and plan to continue to work together in the future. We have both formal and informal mechanisms of cooperation. But I don't really think you're interested in hearing about that. Just believe me that it is true and will continue to be true to the best of our abilities.

Rather, I'd like to focus on the title of this symposium, the Exclusive Economic Zone, and some of my puzzlement with the whole thing. First of all, I will admit it is a zone by legislative definition with real boundary lines. However, the exclusive part puzzles me a little bit, because I'm just not sure what exclusive means nowadays. Clearly, there is a role for many players in this adventurous new concept that was proclaimed by our President less than a year ago. There is a role for research, and there is a role for development. There is a role for conservation. And in selected areas, there is even a role for preservation and we do have a sanctuary program expressly for that purpose. There is a role for government. There is a role for academia. There is a role for industry of all types in this zone. So I do not see where it is all that exclusive.

I guess conceptually it is exclusive to the United States. But it seems to me that with the growing interconnecting economic links in the world, it is very difficult to even speak in terms of national exclusivity. For instance, I am not sure we have a national automotive industry anymore. I feel pretty strongly about buying America when I can. The last time I bought a car, I went to great pains to buy a U.S. built model. It was a Chevrolet. When I got it home and looked under the hood, nearly everything I saw had "made in Canada" stamped on it. This is but one example (and you can think of many others) of commercial interdependence. Thus the whole business of "exclusive" is a bit of a mystery to me. I am not trying to be critical but rather to emphasize the complexity of user and judgmental claims that will be placed on this "exclusive" zone.

So then, we get to the final remaining word and that is economic. To me that is the bottom line. That is what this is all about and what we ought to be focusing our attention on. How can we make this enormous new piece of real estate that has been accrued to the United States contribute to the wealth and well-being of America and the world at large?

In this context, let me discuss NOAA's role to the Nation and NOAA's role relative to other agencies, to academia, and to industry. I think our responsibilities are threefold. One is in the prosecution of fundamental research to understand what is there and, if you will, how it works. You can then extrapolate from limited pieces of information because you understand the underlying processes. NOAA does have a clear mandate to do ocean research. We do it in two ways. We have an in-house capability for doing research through our laboratories, and we have an external program, substantially through academia. The division of our resources between in-house research versus extramural research is a subject for continuing debate. In basic research, the split is basically 50-50. When you throw in development, then clearly more of our resources go into intramural R&D.

Our oceanographic research program cuts across NOAA involving nearly all of our organizational elements, including the Weather Service. Because oceanography is the application of numerous disciplines (from physics to biology) to understand processes in a unique medium, we must avail ourselves of all the intellectual tools that are needed to do the job. Accordingly, we do have a marine geology and geophysics program. It is not as big as we would like, but I think it is reasonably good. It is substantially augmented by university efforts supported by us in addition to the USGS, NSF, and other Federal agencies.

To the extent that our research uncovers resources of potential economic value, so much the better. This is what we hoped for, although it is not the sole purpose of the research. In the research on polymetallic sulfides, one can argue its potential value all the way from one extreme to another. Some say that its value as a mineable resource is going to be nil, because we are developing such powerful insights into ore-forming processes that we will more intelligently search on land where recovery can be more economically exploited. So our ocean research may be a surrogate value, if you will. On the other extreme, some people say in fact you cannot talk about mining of polymetallic sulfides; you more properly have to think about harvesting them. They are formed at a rate so great that they are, in fact, a renewable resource.

Anyway, the story that I would like to tell you is that one of our contributions to making the EEZ "economic" is pursuing fundamental research that will lead us down unpredictable paths. For instance, although polymetallic research is now one of the most exciting things going, history is likely to prove that substantially greater value is derived from other activities such as the possibility of exotic new drugs and chemicals from the sea and a new view of the ocean's assimilative capacity for waste disposal of various types and in various forms. The greatest value from spreading centers may turn out to be as a source of energy, an issue that has hardly been scratched. We must pursue all avenues of research to fully realize the potential value of our new EEZ.

The second contribution NOAA has to make towards developing our EEZ is that we do have a substantial capacity to work at sea, and we work at sea for many purposes: for mapping and charting, for research, for fisheries-stock assessment, for ocean-quality assessment, etc. We have the technologies and equipment to work over, on, and under the oceans as well as to monitor it remotely.

A responsibility of government is to provide some essential service for economic development. As but one example, no development can proceed without a map or a chart. If you're talking about land development in New York City, mining in Montana, or trying to open crab fisheries off the coast of Alaska, you need a basic map or chart. This is an interest and a capability that we share in common with the USGS. Although we are usually preoccupied with mapping our own areas of responsibilities, as needs or opportunities occur, we join together. We are now producing joint charts to show both the terrestrial and submarine topography and geology to the best of our knowledge.

One of the tools we do have is a ship equipped with multibeam mapping capability. We have the SEABEAM system on the Surveyor, and we are in active discussions with USGS to make that capability available for joint use. For those of you who are not familiar with the SEABEAM system, it is a multichannel computer rectifying system that, instead of measuring a line, actually produces a swath of topographic data, that are corrected for slant distance and contoured producing a strip of chart along the ship's course whose width is approximately 0.8 times water depth. We have fond hopes of acquiring electronics for a second system that will go on another one of our Class I ships, for which the hull is already configured with the required transducer arrays. We also have hopes of getting a satellite global positioning system to go with this capability which reduces the processing time and effort by literally an order of magnitude. The issue is resources. And the issue we and USGS have in common is that we have an abundance of opportunity and a superabundance of enthusiasm, and more than adequate skills. We are resource limited, though, and must make difficult priority decisions.

NOAA also has another unique ability called Bathymetric Sonar Survey System, which we lovingly refer to as BS cubed. That is a system similar to the SEABEAM, but designed for very shallow-water work: 100 meters or so in depth. This system is unique and was painfully developed through research, acquisition, and getting into application, and we must view it as a national capability. These systems assist us in producing the essential maps and charts on which we can base economic development.

Another responsibility we have is for archiving data and information that has been acquired largely at public expense. We have a number of data centers that archive and make available both geophysical and oceanographic data. This activity is also part of the Federal Government's responsibility to provide an essential foundation for economic development, which is the second aspect of NOAA's role.

Third, the increased human activity involved in the development of our EEZ is going to require additional services of all types. Although there is a legitimate debate about the degree to which these services should be provided by the private sector or by government, to the extent that we do have identified responsibilities, we are going to do the best job we can. To that purpose, John Byrne has put an enormous amount of his time and effort into aggregating these services into "a one-door-to-knock-on" Ocean Service Center accessible to any audience who needs them. In fact, just 2 weeks ago, we formally launched the first of our Ocean Service Centers in Seattle. You can come to this one location and get the full panoply of services that NOAA is paid by the taxpayer to provide the public. We hope, if this works out, to have more of these Ocean Service Centers strategically located around the country.

In summary, I think our responsibility is, first, to work with our research colleagues in providing a foundation of understanding. Second, we must work with those other elements of government that have the responsibility of providing the necessary foundation for developing a unique economy. And third, we need to recognize that the development of the EEZ is going to require additional services. We are trying to organize ourselves to do a much better job in these areas.

Chapter 9

RESEARCH CONTRIBUTION OF THE NATIONAL SCIENCE FOUNDATION IN THE EEZ

by

Grant M. Gross
National Science Foundation

It's a delight to be here, I've worked with many people at the USGS over many years. And it's a pleasure to see my old friends again.

Dr. Knapp unfortunately could not be with us today. He had originally planned to speak, but a congressional hearing was scheduled on super computers yesterday and today; therefore, I'm standing in his place.

The National Science Foundation has quite a distinctly different objective from the other agencies whose representatives will be speaking to you today. As Bob Ballard very accurately described, NSF is a free market for ideas, and a highly competitive one at that. NSF receives about 25,000 proposals a year. Less than half of the proposals received can be supported. The second point that I would make is that NSF itself does not conduct or carry out research. The research which we support is carried out by academic institutions. Third, NSF-supported institutions have some unique research capabilities. We are making those available to other groups, such as the mission agencies who have spoken today. We are delighted to serve in that role.

The Division of Ocean Sciences is the principal supporter of university-based ocean research of interest to this group. We, through the Foundation, provide nearly half of all the R&D money going from the Federal Government into ocean research. We provide about 70 percent of the monies for basic research going to the universities. So, our role is large and through time it has been increasing.

Now I'd like to tell you about some of the activities supported by the National Science Foundation. We have several directorates, with something like 30 research supporting divisions, of which mine is one. The Ocean Sciences Division is the largest research supporting division within the Foundation. The FY 1984 budget is approximately $1.3 billion. Through my division we spend roughly $115 million on ocean research; NSF spends about $120 million per year. We have a variety of research programs, but I will speak of only a few examples.

Before going further, I should make one other point. Unlike the other agencies represented here today, NSF does not plan research. Thus, I cannot at this time tell you precisely what the NSF ocean research program will be. It depends on the proposals we receive and the resources available. When I write our annual report at the end of the year, I can tell you what we did. This free market approach has been exceedingly successful. We continue to show the world how to stimulate the intellectual resources of the Nation's universities.

I'm going to talk about one of our newest programs; many of you probably do not know about it. We have a program, less than 2 years old, in the Engineering Directorate, on minerals and primary materials processing. This program--on the order of $1/2 million per year--supports research on the physical and chemical processes in the minerals industry and the various activities involved in taking an ore and turning it into a commercial commodity.

Most of the research that is put through our division is done from ships, operating throughout the world oceans. A typical activity involves one of our newer research vessels--a complicated buoy device for measuring the atmosphere and the near-surface atmosphere. Hanging below it are several current meters to measure water movements in the near-surface ocean. Since this symposium is focused on coastal ocean regions, I should point out that several years ago, NSF recognized the emerging importance of coastal areas and built two new research vessels. One of them is the R.V. Cape Florida from the University of Miami, the other is the R.V. Cape Hatteras from the Duke University-University of North Carolina complex in North Carolina. This is one example of our efforts to make sure that U.S. scientists have the best possible equipment to do work in the coastal areas.

Let me now turn to another facility used by U.S. scientists, the submersible ALVIN. She was built originally in 1964 by the Office of Naval Research for engineering purposes; since 1973 ALVIN has been jointly supported by NSF, ONR, and NOAA. And as Dallas Peck has already told you, this working arrangement is also used to make ALVIN available to other agencies such as the USGS. From a marine geologist's perspective, ALVIN is somewhat like a jeep used to look at the deep-ocean bottom. Perhaps a better analogy might be an elevator. ALVIN simply doesn't have much capability to move around on the ocean bottom so it has to be handled and positioned very carefully before diving. ALVIN accommodates two scientists and one pilot. One thing that has made ALVIN so successful is the instruments and techniques developed by scientists, like Bob Ballard at WHOI. His camera systems are widely used in our activities.

ALVIN has very distinct limitations. One of these is that she is limited to depths less than 12,000 feet. Less than half of the ocean bottom is accessible to ALVIN. Much of our work has been confined to mid-ocean ridges, simply because they are shallow enough so that we can get to them. We hope, at some point, to have a deeper diving capability. We look with envy upon the French, who are building one at present, and the Japanese, who also have plans for one. We are neither building nor do we have plans for this facility. But we still have hope.

Work on the mid-ocean ridges is a successful example of the scientific payoff resulting from research projects supported by the Foundation. This symposium and workshop is focused on one of the more spectacular contributions: the exciting discoveries of hydrothermal vents and associated mineral deposits. You have all seen the very famous picture of the initial discovery of the "black smokers," a discovery that truly changed the way we look at the processes of sulfide ore formation. These vents are basically oases of life in an otherwise barren environment on the ocean bottom--oases because of the abundance of food there. This finding is especially important because the food comes not from photosynthesis, as does most of the food which we depend on, but from chemical synthesis of the food materials using reduced sulphur and metal compounds discharged by the vents. This discovery has truly changed our view of possible life forms. We are just beginning to see the impact of such studies on our understanding of life processes in the ocean and perhaps of possible life on other planets.

Another significant study was on sediment-covered areas in the Gulf of California. There the hydrothermal venting occurs beneath a thick pile of sediment. Organic matter deposited in the sediment is actually broken down by the heat and the "cracked" products of that heating are carried out to the sediment surface; this is basically an oil refinery on the ocean bottom. The sediment surface has a yellowish tint caused by a bacterial mat, depending on the chemical synthesis. Individual bacterial cells are 100 to 150 microns in diameter, easily visible to the naked eye. One thing that has captured the attention of many individuals, companies, and agencies is the possibility of the production of minerals from the hydrothermal vents and from the adjacent deposits.

These are only a few examples of the activity that we support. In our division we initiate about 600 new projects each year, based on the proposals that we receive. Some of them investigate the processes that we will be discussing today. Others investigate processes which, I suspect, in the future will be equally exciting and important.

Let me now turn to our deep-ocean drilling projects. The Glomar Challenger just finished her last leg and came into Mobile, Alabama, on the 8th of November 1983. We are now demobilizing the ship and storing equipment for use in the next phase of drilling. On the same day the Challenger came into port, bids were received at the Texas A&M Research Foundation for the lease of a new drilling vessel.

Ocean drilling has involved many scientists, some of them are in this room: some from the USGS, some from the Smithsonian, and many from foreign countries. We have had international participation in drilling since the mid-1970's, and we anticipate having continued, perhaps even increased, international participation in the new drilling program. We are now talking with Britain, France, Germany, and Japan about their continuing participation. And we have signed Canada as a candidate member, the first stage toward full membership. We have other possible participants in the wings. We're very optimistic about the continuing international participation in ocean drilling.

The first product of ocean drilling was cores of ocean sediments and igneous rocks. The cores provided the first direct confirmation of plate tectonic theory by dating the basement. These showed that the oceanic crust was older and older as one moved away from the mid-ocean ridge. In the late 1960's, this was an important bit of evidence confirming plate tectonic theory. Such important--and often surprising--results continue to come from the drilling program. For example, salt recovered from cores showed the rather surprising desiccation of the Mediterranean, about 6 million years ago, when sea level stood lower than it does at the present. The Mediterranean actually dried up, and there were huge waterfalls from the Atlantic into this desert.

Now we have gone even further, we've begun to use the hole for science as well. Logging techniques, adopted from the oil industry, permit scientists to look at the hole and measure the properties of the rocks so we can understand the oceanic crust. Unfortunately, drilling can penetrate only part of the crust. We have penetrated about a kilometer in igneous rock and something like 1 1/2 kilometers in sediments. So with an ocean crust averaging 5- to 7-kilometers thick, we've got a long way to go. Another recent development has been the use of the hole to implant a seismometer in the ocean bottom. By putting a seismometer into the hole, the noise level was greatly reduced. We have two deployments, both successful.

New drilling techniques must be developed to permit drilling into the bare, recently formed rocks of the mid-ocean ridges. Present drilling technology requires that there be a sediment cover to spud into to begin drilling. Thus, it has not been possible to drill into new crustal rocks where hydrothermal circulation and ore formation are taking place. This is a high priority for the new ocean drilling program. In a few years, I hope to be able to report on the findings of such activities.

There is another interesting problem for ocean drilling. Up to now, it has not been possible to drill the thick sediment deposits near continents. The reason is that we cannot be sure we will not find oil. With the Challenger, we did not have the capability of controlling such production. This requires emplacing a riser--a large diameter pipe--through which one not only drills, but also is able to control possible oil and gas flows. The technology exists, but it requires a ship larger than Challenger. The new drilling vessel will be able to handle a 6,000-foot riser. By the end of the 1980's, we hope to be able to drill with a riser near the ocean-continent boundaries.

I will close with just a glimpse of what I think the future holds for ocean studies. The satellite, SEASAT, in 1978 was able to map ocean surface elevations with the precision of tens of centimeters using altimeter data. The map of the sea surface reflects the sea-floor topography. The sea-surface elevations and depressions are caused by seamounts, trenches, and other bottom features. Now for the first time it is possible to map the ocean bottom by using satellite information. In many areas we lack data to check the map--in the South Pacific, for example. We have great hopes for such new innovative approaches. Studying the ocean crust on a global scale will provide us with information about behavior of the ocean crust. In turn, such studies will also give us new insights for mineral exploration on the continental margins.

In conclusion, let me say that NSF does not have a research program that is focused specifically on the continental margins or on the U.S. Exclusive Economic Zone. Yet, I stand here today very confident about the future contributions of such research efforts. I may not be able to tell you what we're going to be doing tomorrow, or next year, or the year after. But if I come back 5 or 10 years from now, the basic scientific understanding resulting from these activities will have given us the same sort of eye-opening, even revolutionary results that we have gained in the last 5 to 20 years. And I'm quite sure that the findings will provide information that is extremely useful to us in exploiting the economic capabilities and characteristic of deposits in our Exclusive Economic Zone.

Chapter 10

ACADEMIC COMMUNITY ACTIVITIES IN RESEARCH, RESOURCE ASSESSMENT AND TECHNOLOGY DEVELOPMENT

by

John E. Flipse
Texas A&M University

It's a pleasure to be here. And, if I convey any connotation of negativism, it's only bred by my long experience. The problems attendant on the development of the marine hard-mineral resources are still with us. The miserable metal markets are still here. Would you believe, the price of copper is the same today as it was when marine mineral development became a research project at Newport News Shipbuilding in 1966? The price is the same, in spite of the appreciably increased cost of energy and the high energy content in a pound of copper.

A second problem is the Outer Continental Shelf Lands Act, deemed applicable to marine hard minerals by the Department of Interior. We're going to have a workshop this afternoon where we will talk about the regulatory accommodations that are possible under that act. It is, perhaps, much more logical from a pragmatic approach to live with that act, rather than seek a generic act through new legislation that would be more amenable to hard-mineral development on the Continental Shelf. That is a political decision. But there are basic problems with the act, including: how can the Minerals Management Service do its job in determining the "fair value" of the resource, and then negotiate a lease if, in fact, they know as little as today's state of knowledge?

There is a strong pressure to do this "on my watch," to use a seafaring term. I think that's one of the reasons for the expected early solicitation of bids for EEZ hard minerals. It's fine to say that the resource is of no value, and if you'll stick with that when it comes time to negotiate for its exploitation, I think there will be a significant increase of interest in the sale. However, a change of executive department managements portend against keeping that promise.

Another problem that should be mentioned is the discipline that is imposed on us by using computer "payout" models. Some 6 years ago I decided that if I couldn't <u>do</u> ocean mining, I could <u>teach</u> it. I migrated to that rather pragmatic area of the world known as Texas where I was able to obtain support from our Federal establishment in the economic evaluation of deep-ocean mining of manganese nodules. Much of the methodology developed is readily adapted to the evaluation of polymetallic sulfide development.

When you set up a mathematical model to determine return on investment, especially on a discounted cash-flow basis, you run into the realities of development project promotion. There are two serious problems. One is you have to have a number (value) in every "slot" in the algorithm or the program doesn't run. That brings on the second problem. No one has a very high level of confidence in what some of these numbers should be. I'm not talking just about the price of copper, as our last model needed $1.25 per pound of copper to get the ROI out of the cellar. As mentioned earlier, that is an unrealistic price today. The point is that the very discipline that's imposed on you by the math model makes you extremely vulnerable to the "nay sayers" on the board of directors because there is no way you can substantiate your carefully prepared, and sometimes optimistic, estimates. Therefore, the model and the computer give your analysis a feeling of accuracy which is easily challenged by anyone who would like to turn off the project. The more complete the model, the easier it is to discredit.

Another problem that we have to face has been discussed at length by other speakers. Marine hard minerals on the Continental Shelf, if they in fact exist, are distributed over a tremendous area. The time and cost to survey all of this area is beyond our ability to estimate. We have not scratched the surface. I would also like to remind our hosts that they have surveyed only a small percentage of the terrestrial public lands.

Some hints about the nature of the resource are being developed through the superb geology that is being done by the scientific community. But they are the broadest kinds of hints, such as extension of land deposits such as the phosphates off Cape Fear, North Carolina. But these hints are severly limited. The "smokers" are probably the worst kind of a hint you could have as they indicate fast-spreading centers. Are the fast-spreading centers the right place to look? Sure, they are the easy place to look, but the Canadian Maritime deposits suggest that the "smokers" are the wrong place to look and that the margins or slow-spreading centers may be the site of minable deposits. On the basis of the cost per sample, as taken by the submersible Alvin, we are a long way from the capability of economically evaluating any deposit. Economic deposits are going to be much harder to find and much harder to evaluate.

We also have a fundamental problem, which I call the "Short-War Mentality." If the next war is to be over in a few days, why worry about manufacturing or transportation, much less critical materials? I remember raising some $30 million, when dollars were pretty hard to come by, for ocean-mining development by using the strategic/critical metals argument. But, here is a report dated August 1983, "Strategic and Critical Non-fuel Minerals, Problems and Alternatives," a Congress Budget Office study, where the words "marine minerals" do not appear in print. Marine mineral resources were not even dismissed! And yet we were assured when we came to this symposium that the national awareness of strategic minerals needs was driving the current program. You may believe it if you so desire.

The "Short-War Mentality" is encouraged by some real problems such as budget deficits and cheap and plentiful foreign sources of many of these strategic minerals. We're "out of our minds" to mine them in the ocean if they cost us several times the current market price and we can buy them from somebody else.

The foregoing comments are my introductory remarks. My assigned topic is academic community activities in research, resource assessment, and technology development. The only marine hard-minerals research being done today is being done by the oceanographic institutions. Many excellent papers were presented at OCEANS '83 in San Francisco last September. The marine geologists did a superb job, and the sessions were very well attended. We were all a little disappointed yesterday that Bob Ballard did not show us his superb marine photographs of the "smokers" and the unique marine life that exists in the hot sulfide environment. This research should be left to the oceanographic institutions, and I fully support Bob's argument that it needs more funding.

The advanced ocean-drilling program received accurate coverage today. I can only emphasize several remarks which are of real importance to ocean mining in the EEZ. "Spudding-in" on rock, an important problem in scientific deep drilling, is essential to EEZ mining. Similarly, the downhole tools and techniques developed for the drilling program are germane to our work. Yesterday the drilling program was dismissed as not relevant to EEZ mining, but today's discussions should indicate its potential for technology transfer. I would like to point out that if you are planning to use these drilling techniques to verify a commercial EEZ hard-mineral deposit, you may find that the cost of exploration exceeds the value of any deposit yet reported.

A really serious matter surfaced at the OCEANS '83 meeting but was not investigated. The time it takes to play the "proposal game," even where expert service is available, seriously detracts from the quantity and quality of research that the good PIs can do in a year. I suggest then that we go for "bigger bites"--multi-year programs with more dollars.

The subject of hard-mineral resource assessment in the EEZ is extremely difficult. We hope to learn more about it in the symposium. I recommend we do not hunt for "smokers" and that we do not randomly drill to try to define the deposits. We have to focus our search program. We have to identify the areas of high probability, and there is no question that geology is an important first factor here. But we also have to develop a better means of determining the horizon between the host rock and the polymetallic sulfide deposits because the ones that are worth developing may be under several hundred feet of sediment. A most important requirement, in my opinion, is that we develop a "third dimension" capability. There is a great need for further science support in this area.

We also have to define and provide some rationale and workable criteria to determine the mineability of marine hard minerals in the EEZ. Although briefly discussed previously, we do not know how much work has to be done to justify further exploration, deposit definition, and then commitment of major capital to build PMS ocean mining and ore-processing equipment. If we do not develop and gain acceptance of an evaluation criteria, industry and the banks will use typical land criteria. We are not likely to even come close to meeting those criteria, as we cannot measure the distance between drill holes to the same accuracy, and so forth.

I believe that technology development is industry's role. And by industry I'm talking about "metal company" investors. Do not be misled by the propaganda of purveyors of high technology and industrial research. The real investors are the investors who need feed stock, material to run their plants and meet their market requirements. The industry role is to use the available data and the Government counterpart to that, of course, is to supply these data. The industry will do the engineering research and development, as one of our speakers said so well yesterday, if there is a <u>real</u> return on investment and if there is a strong supportive environment, fully justified, on the part of the Government.

Unfortunately, technology development, as we have learned in the manganese nodule business, takes more than a few years and a few million dollars. It is more likely to take a few decades, perhaps, with attendant costs. The Government's role includes monitoring the safety of seagoing personnel and protecting the marine environment. It may also be necessary for the Government to "grandfather" the investment of the "pioneers." I don't mean that as a "grab bag" but that if the deposits are economic, the pioneer has an opportunity to proceed to win his return on investment.

My last admonition is that the U.S. critical material stockpile be just that--a stockpile--and not a means for Government control of the metal markets. Remember my "Short-War Mentality" remarks? Well, the stockpile will handle the short war. In fact, if we're really right about a short, short war, we won't even get to the stockpile. So the stockpile is not really a stimulus, but it could be misused and therefore become a very negative factor in EEZ hard-mineral mining.

Let me conclude by suggesting that the workshop, and the subsequent dialogue, must use the best brains in this business, and I think most of them are here. We must decide what information is needed to determine the economic feasibility of each stage of commercial development. We must decide if we have the tools and techniques to do the job of getting these data to plug into the evaluation model to get the answer.

I appreciate the opportunity to talk to you today and to raise the questions which the next generation must answer before the EEZ marine hard minerals are developed on a commercial basis.

Chapter 11

SYMPOSIUM PERSPECTIVES

by

William P. Pendley
Department of Interior

I returned last night from Metairie, Louisiana. Our Minerals Management Service office in New Orleans is having its fourth annual information transfer with the private sector. About 400 people met for 3 days, sessions going back-to-back, consecutively, on information relating to oil and gas development on the Outer Continental Shelf. What was interesting about this meeting was that it wasn't just the private sector--the oil and gas industry; it was academia, state and local government people, people frankly eager to come in and present papers relating to oil and gas development in the Outer Continental Shelf, especially in the Gulf of Mexico. I think that's symbolic of the fine level of communication we have established in the oil and gas field, and the kind of communication that we hope to establish with this symposium.

Frankly, we are gratified by the show of support indicated by the number of people who have given their most precious asset, which is their own time, to be here with us for the last 3 days.

The first day, we had about 250 people here in the auditorium. We had about 217 registered. About 203 stayed and participated actively in the workshop panels. I think that's a real credit to all of you--your dedication and your desire, and frankly, the level of interest in this important area.

Who are we? About 58 percent of us are government employees, from state, local, or Federal Government, including people from the executive branch, and from the legislative branch, and representatives from foreign governments. This is an even more diverse group than the 58 percent government figure might suggest. Twenty-five percent of us are from the private sector--from industry. Seventeen percent of us are from academic institutions. I think that's an exciting mix, and I think that's indicative of exactly where we want to be going; we want a diverse group working together.

How would we characterize what we've been doing? I think one word would sum up what we are doing today, and yesterday, and the day before, what we hope to be doing in the years and the decades ahead, and that's communication. How easy it is for us to lose touch, to lose touch with our families, to lose touch with our friends, to lose touch with our co-workers, just because we stop talking, because we stop communicating. How many times have we felt we were on the outs with someone simply because we hadn't picked up the phone, we hadn't heard from them, we hadn't shared information, we hadn't just simply sat down over coffee and talked. How easy it is to become paranoid, to become nervous about your own position, about your relationship, if you don't have good communication.

Frankly, that happens all the time. It happens in our own personal lives. I think it happens in our professional lives. It happens in government. It happens in the Department of Interior. We need to increase the lines of communication. We need to sit down together and talk about where we're going and what we would like to achieve; what our goals are; how we can work together to achieve them. I think it's critical that this understanding be developed among academia, the private sector, and the government.

Several months ago, I was on a trip, picked up one of the airline magazines, and read an interview with Don Rumsfeld, who is now the President's envoy to the Middle East. Rumsfeld was asked, as a private sector representative, what he thought was the biggest problem in the Government. He replied that the biggest problem he saw was the fact that this Government, unlike other governments around the world, was at loggerheads with the private sector. As he looked around the governments in the other parts of the world, governments knew that the survival of the government, survival of the state, survival of a nation, is based upon a good working relationship between the government and the private sector. He said, "In America, we've lost track of that."

I would hope, from a partisan standpoint, that this administration is coming in with a slightly different attitude about the need for the Government and the private sector to work together with the academic institutions and with the American public to make America great again. I think that that's what we are about now; that, as a government, we can join with our friends in the private sector to do that.

We need to plan ahead, and government sometimes is the worst planner in the world, especially those of us in what we like to call "policy positions." We're awash in a blizzard of paperwork, and the snow blindness that results from that makes it sometimes impossible for us to lift our heads from the paperwork, look out onto the horizon, and see where we want to be in a couple of years. We sometimes have problems looking beyond the next budget cycle. While that looks like long-range planning to us when we talk about fiscal year 1985, you, in the academic community and especially you, in the private sector, are decades ahead of us in terms of planning: Where will we be getting minerals in the year 2000? Where will the investment dollar go in the 21st century? And we're looking at 1985. So you have to help us, guide us, give us the opportunity to work with you to understand your concerns, thoughts, dreams, plans, and hopes for America so that we can lift our eyes from the paperwork and look at the horizon.

To go back to the first day, we were talking about the Exclusive Economic Zone and we were talking about what started it all. A simple memorandum from the Secretary of a minor department, the Department of Interior, to other Cabinet officials saying; "Let's develop a national oceans policy and let's have an exclusive economic zone as a part of the national oceans policy." Less than 7 months later, the President of the United States, by a proclamation, declared an Exclusive Economic Zone. When you've been inside Government and seen how slowly we move, and how careful and restrained is our pace, I think you have to marvel at how quickly a fundamental change involving major new action took place.

We are an action-oriented administration and this is an action-oriented department. We're not going to be dotting the I's and crossing the T's of the Law of the Sea Treaty. We're not going to be preoccupied with the esoterica of the meaning of the Exclusive Economic Zone. It's here; it exists; it's real; it's part of America. That new frontier for us must be explored. It's just waiting for us to move into it. We're going to make it happen. That's our style.

As I read Judge Clark's transcripts and as I listened to him speak, I hear his commitment to the concept of an Exclusive Economic Zone. I think it's one of his proudest accomplishments in his tenure as National Security Adviser to the President. I know he'll want to flesh out that work by making it a reality. We need your help in doing all these things What do we learn from listening to you? We've learned Government's going to have to get organized. We're going to have to focus our efforts on minimizing agency conflicts.

I'm delighted with the fact that the Congress has given to the Geological Survey a new program in marine geology that places an emphasis on the EEZ. We will be working hand-in-glove with NOAA to ensure that we're not duplicating each other's work. We're going to work with our friends, the Canadians, as we have over the past summer.

We need to disseminate information more widely. We need to let you see what we've got. If we can do it under the law or statute, then we shall do that. We need to know what you have, to the extent that you can share it with us so that we won't duplicate your fine work. There's precious little money around in the U.S. today without duplicating each other's work. We need to conserve and be careful with our dollars, and by communicating one with another, I think we can do that.

We've got to be creative. We've got to maximize our research investment through new approaches. I'm delighted to see the representation of the academic community here today and over the period of this conference, sharing with us your ways of doing things. After all, we're only public officials. We're just scientists and lawyers trying to do our job. We need your guidance and we need your help.

I think we're on the right track. This kind of communicative effort is very, very important. I'm sensitive to the frustration that many of you feel: Well, it's just another symposium, another paper shuffle, another report to set on the shelf or pass across the desk and review and summarize. I hope not. I hope we've made a fundamental change. I hope we've indicated that we're for real. We're going to take this information; we're going to use it; we're going to feed it back to you. We're going to ask you to feed it back to us and help us guide our efforts. So, what next, you say? Maybe we should do this again soon. Maybe we should break down into smaller groups on a more frequent basis.

But, more than anything else, you've met us and we've met you. We now know each other. We're going to keep up the communication. We're going to step up the cooperation. We've learned a lot in 3 days. You know there is a reality out there and you're part of the reality. You're spending the dollars. You're fighting for the dollars in the corporate board rooms, and before the presidents of the universities and the boards of trustees, going for that grant dollar or going for that investment. We need to be more sensitive to that. I like the definition Paul Harvey gives of Washington: A small piece of land on the banks of the Potomac surrounded on all sides by reality. We're very sensitive to that. We talk too much to ourselves and not enough to you. We hope that this will allow us to talk to you and you to us, and for us to fashion our realities in your world and not just in the political world that lies only between Capitol Hill and the White House.

We're excited about the future. It's a tremendous future out there. We're going to a place that no one's ever been before. Three years ago, 4 years ago, nobody knew what a polymetallic sulfide on the ocean floor was. Today, we're talking about going down and mining it. We've explored 25 kilometers out of 50,000 kilometers of rift zones in the world. And we've discovered minerals. How much more will be find? How much more is there out there? Who knows? We're optimistic. We're excited about the future and the potential.

I think this conference is a new beginning to an exciting future. I think it is worth every ounce of time and dedication that was required to accomplish it.

I want to thank you all very much. I look forward to hearing of the results of the panel discussions. We're going to come back together again. We've opened the lines of communication. Let's keep talking.

PART B. PANEL REPORTS AND RECOMMENDATIONS ON STATE OF KNOWLEDGE AND UNDERSTANDING OF THE MINERAL RESOURCES IN THE EEZ

Panel IA

GEOLOGIC STUDIES RELATED TO OIL AND GAS DEVELOPMENT IN THE EEZ

Panel Chairmen:
Kim D. Klitgord, U.S. Geological Survey
Joel S. Watkins, Gulf Oil Company

INTRODUCTION

The offshore regions of the United States within the EEZ encompass diverse marine environments with geologic-tectonic settings that contain a variety of known and potential petroleum-exploration targets. Division of the offshore region into four major areas -- East Coast Atlantic, Gulf of Mexico, West Coast Pacific, and Alaska -- simplifies discussions although several distinct geologic settings require consideration in each area. With the exception of the Gulf of Mexico Continental Shelf west of Florida and the Santa Barbara Channel, the U.S. offshore is a frontier area with respect to petroleum development. We shall briefly outline the general geologic/tectonic setting of the four regions and then examine research directions which need to be followed for the assessment of the resource potential and the geohazards associated with resource development.

EAST COAST ATLANTIC MARGIN

Regional Geologic Setting

The U.S. Atlantic continental margin is underlain by four major sedimentary basins -- Georges Bank basin, Baltimore Canyon trough, Carolina trough, and Blake Plateau basin (Folger and others, 1979) (fig. EC-1) (Figures relating to east coast are designated EC). These basins lie beneath the Continental Shelf and Slope and contain sedimentary rock between 10 and 15 km thick. Each of the basins (fig. EC-2) is delineated by a basement hinge zone (block-faulted zone) along its landward flank and a buried paleoshelf edge on its seaward flank that is a transition further offshore to a thick section (as much as 8 km) of Continental Rise deposits.

Evolution of the Atlantic margin began in the Late Triassic when rifting formed a series of grabens between North America and Africa. Upper Triassic and Lower Jurassic nonmarine clastic sediments and volcanic material accumulated in these grabens. Separation of the two continents in the Early Jurassic (or perhaps as late as Middle Jurassic, 175 m.y.B.P.) and the formation of oceanic crust between them initiated development of the marginal rift basins and the Atlantic ocean basin.

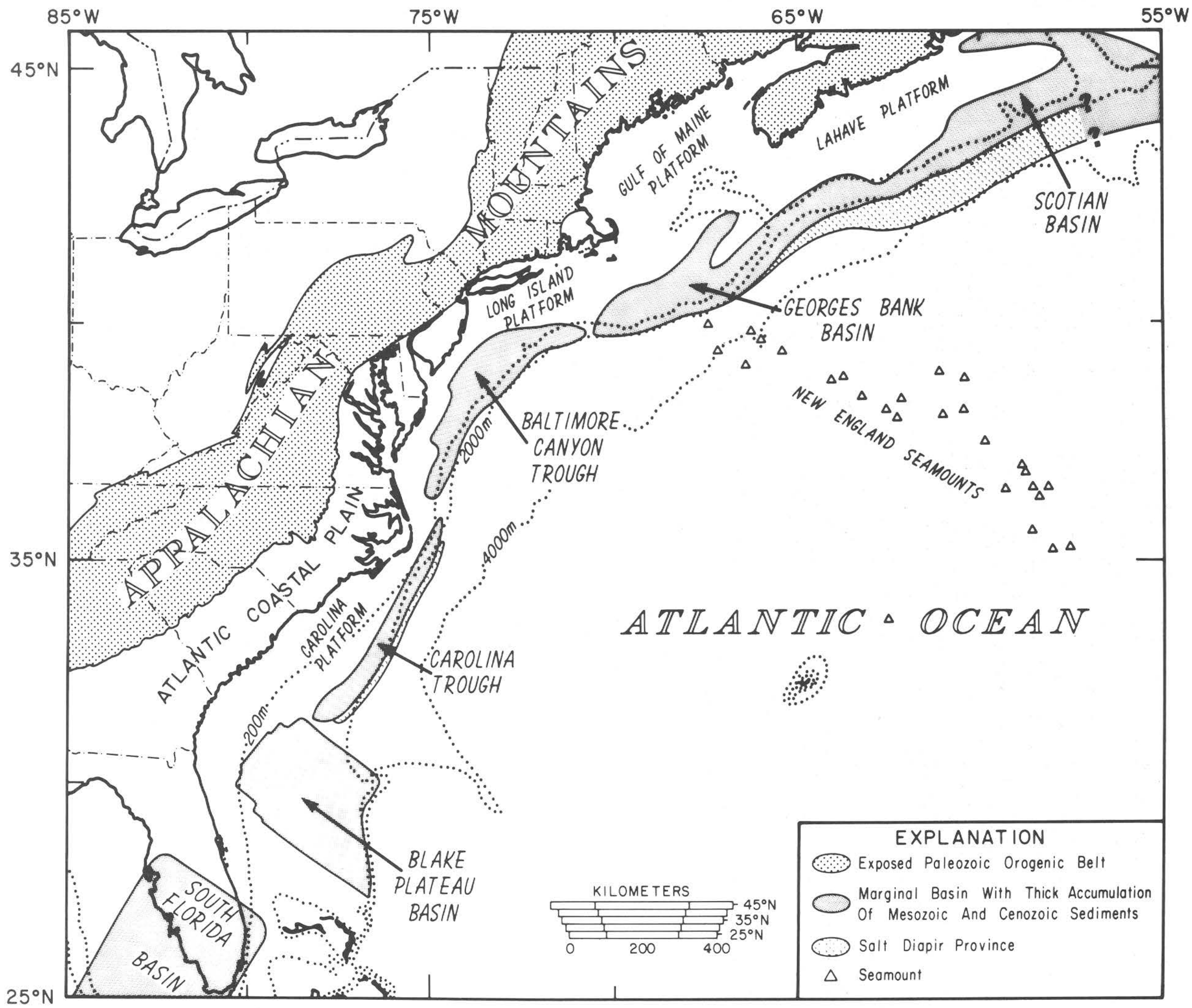


Figure EC-1. Distribution of major Mesozoic sedimentary marginal basins and adjacent shallow basement platforms on the North American Atlantic continental margin.

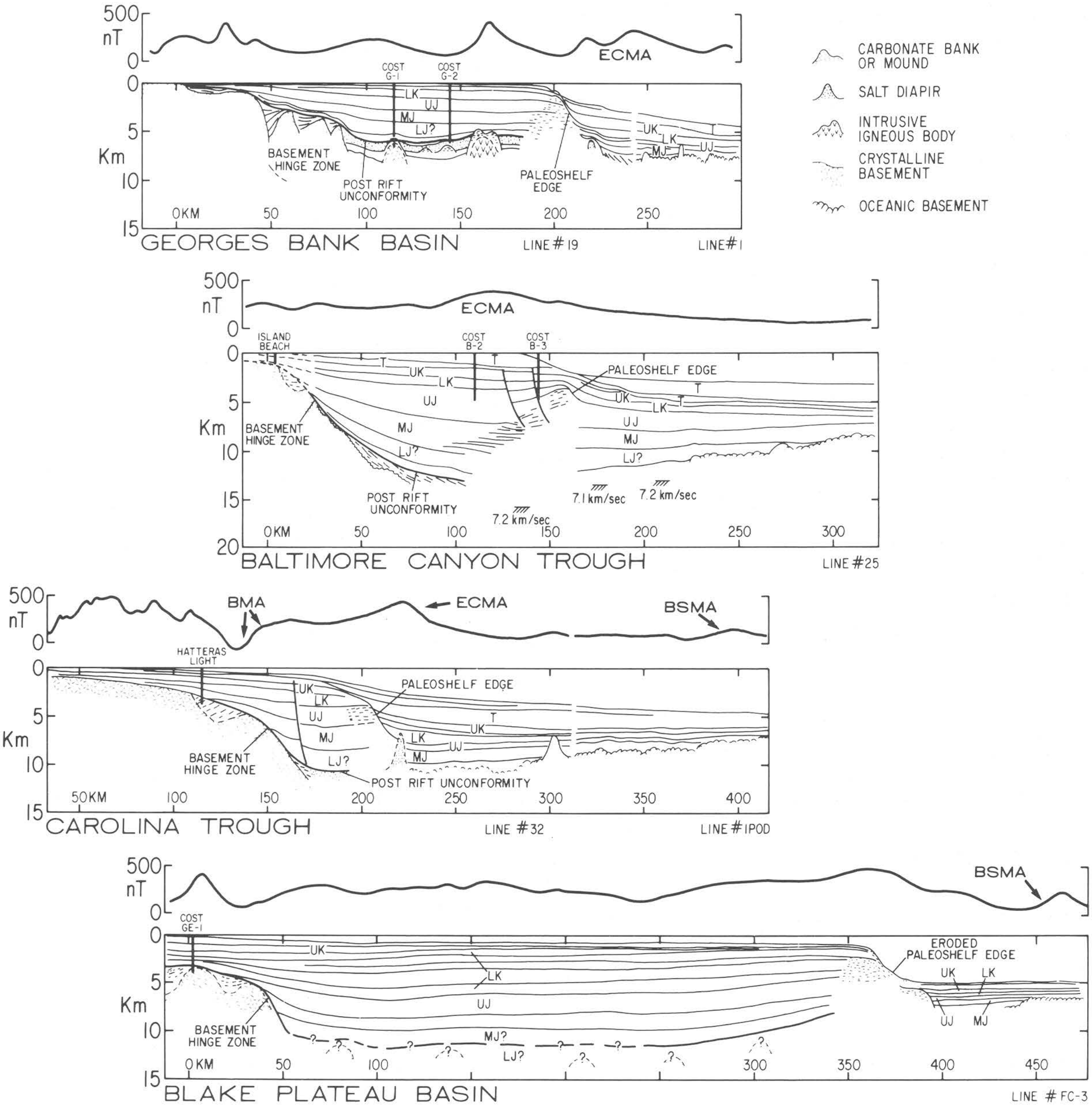


Figure EC-2. Cross sections of four main basins on U.S. Atlantic margin with magnetic anomaly profile across the top of section. COST G-1, G-2, B-2, B-3, and GE-1 wells, Island Beach well, and Hatteras Light well projected onto line of section. ECMA = East Coast Magnetic Anomaly; BSMA = Blake Spur Magnetic Anomaly; BMA = Brunswick Magnetic Anomaly.

Restricted water circulation, in the narrow ocean basin at this time, resulted in the formation of anhydrite and salt deposits over the synrift clastic deposits in the subsiding marginal basins. Salt has been found in Baltimore Canyon trough and Georges Bank basin, and linear chains of salt diapirs are located just seaward of Georges Bank basin and Carolina trough paleoshelf edges (fig. EC-1). By Middle Jurassic, a carbonate bank developed along the shelf edge. An open ocean environment prevailed by the end of the Middle Jurassic; clastic sedimentary rock nearshore merged seaward into carbonate sedimentary rock; a bank or reef at the shelf edge restricted sediment influx to the Continental Rise. Buildup of the carbonate-bank shelf edge complex continued into the Late Jurassic and Early Cretaceous, as clastic sediment accumulated behind it on a slowly subsiding Shelf. Deposition of fore-reef carbonate debris mixed with pelagic carbonates prevailed on the Continental Rise. Fluctuations in sea level and terrigenous sediment supply during this period produced variations in depositional patterns on both the Shelf and Rise. Clastic deposition finally overwhelmed the carbonate bank by the middle of the Early Cretaceous, causing a flood of clastic material to the Continental Rise and deep sea. Continental Rise deposits had changed to carbonaceous claystone and shale by Late Barremian time with siliciclastic deposition dominating throughout the rest of the Cretaceous and Tertiary. Transgressive and regressive periods, in response to variations in margin subsidence, sea-level fluctuations, and deep-sea circulation shifted depocenters back and forth across the margin and produced a complex depositional-erosional pattern on the Continental Shelf, Slope, and Rise.

Initial studies of the margin have included a USGS - oil industry cooperative high-resolution aeromagnetic survey (Klitgord and Behrendt, 1977, 1979), gravity surveys (e.g., Grow and others, 1979), acquisition of a coarse regional grid of multichannel seismic-reflection profiles (fig. EC-3) by USGS supplemented by profiles gathered by academic institutions, and detailed grids of multichannel seismic data acquired by the oil industry over potential prospects. Numerous single-channel seismic profiles also have been acquired over the Continental Rise and deep sea by various academic institutions (e.g., Lamont-Doherty Geological Observatory (LDGO), University of Texas (UTMSI) and Woods Hole Oceanographic Institution (WHOI)) and government agencies. High-resolution seismic surveys for environmental geologic hazards studies have been acquired by USGS, MMS, BLM, NOAA, academic institutions (e.g., LDGO and WHOI), and the oil industry.

Sampling programs on the margin have included surficial dredging and grab sampling, shallow drill holes, deep drill holes, and submersible dives. The surficial sampling program was undertaken as part of a USGS-WHOI cooperative in the 1960's, with additional subsequent sampling by various government agencies and academic institutions. Shallow drilling programs on the margin included the oil industry Atlantic Slope Project (ASP), the USGS Atlantic Margin Coring Project (AMCOR) and the National Science Foundation (NSF) funded Deep Sea Drilling Project (DSDP) of the academic institutions. Deep drilling on the margin commenced with the

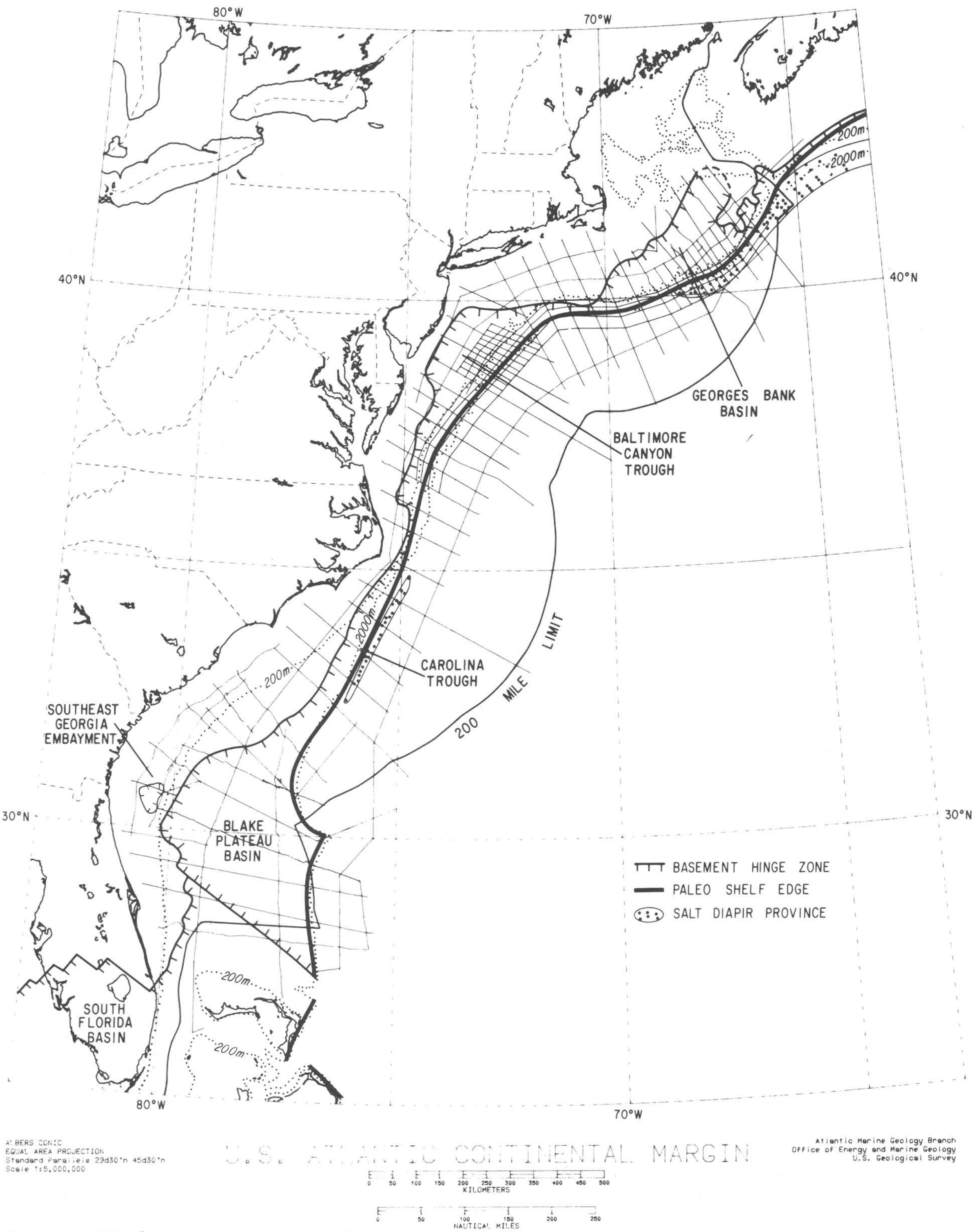


Figure EC-3. Multichannel seismic reflection profile grid acquired by USGS and from a USGS-BGR (German Geological Survey) cooperative on the U.S. Atlantic margin. Major boundaries of the marginal basin are indicated.

oil industry Continental Offshore Stratigraphic Test (COST) well B-2 in December 1975, and there are now 5 COST wells and 43 exploratory wells (fig. EC-4).

Leasing began in August 1976 with OCS sale #40 in the Baltimore Canyon trough and there now have been seven lease sales (plus 1 resale) on the Atlantic Outer Continental Shelf (OCS) (fig. EC-5) (Collignon, 1981; McCord, 1983). Primary exploration targets have been structures associated with an intrusive body (called the Great Stone Dome), rollover structures associated with growth faults, salt pillows, and other structural traps on the landward side of the paleoshelf edge in the Baltimore Canyon trough; targets in the Georges Bank basin include structures related to intrusive bodies, a bright spot in the center of the basin, and other structural traps on the landward side of the paleoshelf edge; future targets in the Carolina trough include rollover structures on a large, linear growth fault about 40 km behind the paleoshelf edge, and salt swells behind the paleoshelf edge. The leasing and drilling in the South Atlantic have been just landward of the Blake Plateau basin hinge zone in the Southeast Georgia Embayment. Targets in the Southeast Georgia Embayment were structural traps in Paleozoic and Triassic(?) units around a small graben structure. To date there have been 8 dry wells in the Georges Bank basin, 6 dry wells in the Southeast Georgia Embayment and 24 dry wells in the Baltimore Canyon trough. There have been five wells in the Baltimore Canyon trough with measured flows of gas, all just landward of the paleoshelf edge on 4 adjoining lease blocks owned by Texaco, Tenneco, and Exxon. Shell presently just completed a dry well into the paleoshelf edge in about 2,000 m of water (fig. EC-6).

Future Studies

Exploration of the Atlantic continental margin has gradually shifted from a reconnaissance phase into a more detailed study phase of research. The general geologic and tectonic structure of the Georges Bank basin, Baltimore Canyon trough, and Carolina trough have been defined, but the evolution of margin crust and sedimentary basins (e.g., thermal and subsidence history; lithologic deposition patterns) are too poorly defined to evaluate adequately regions away from areas of existing wells. Numerous potential targets for hydrocarbon production have been delineated but economical gas or oil finds have not been discovered. Studies of the Blake Plateau basin have been limited by the acoustic nature of the carbonate rocks which cover much of the plateau, yielding poor seismic-reflection records over much of the region.

Present research on the Atlantic margin has delineated one promising petroleum zone -- the carbonate-bank paleoshelf-edge complex. Other potential target zones include updip stratigraphic traps at the basement hinge zone and Late Triassic to Early Jurassic age grabens just landward of the basement hinge zone. Of more marginal interest are the deep-sea gas deposits associated with clathrates (frozen gas hydrates) just beneath parts of the sea floor seaward of the Carolina trough and Baltimore

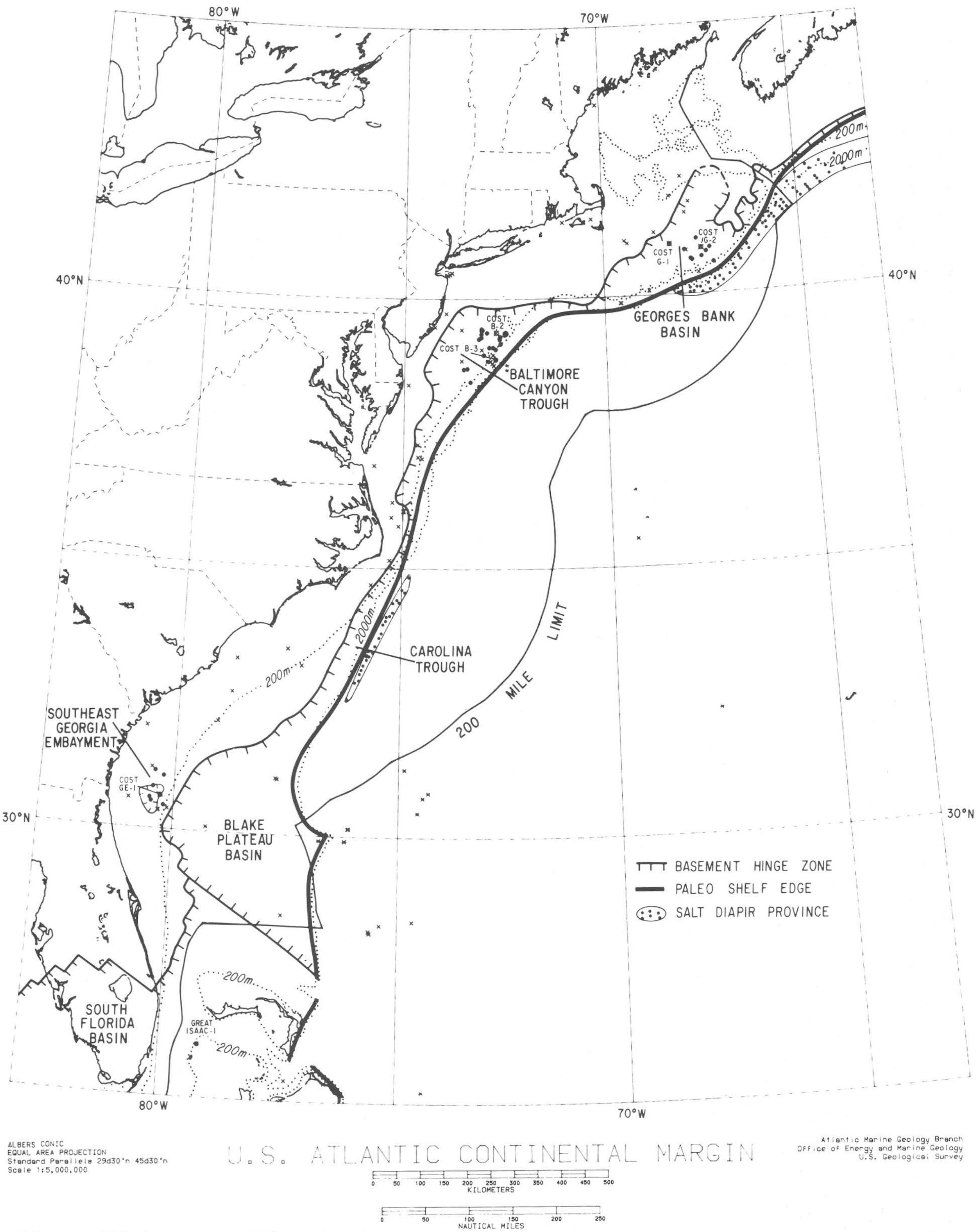
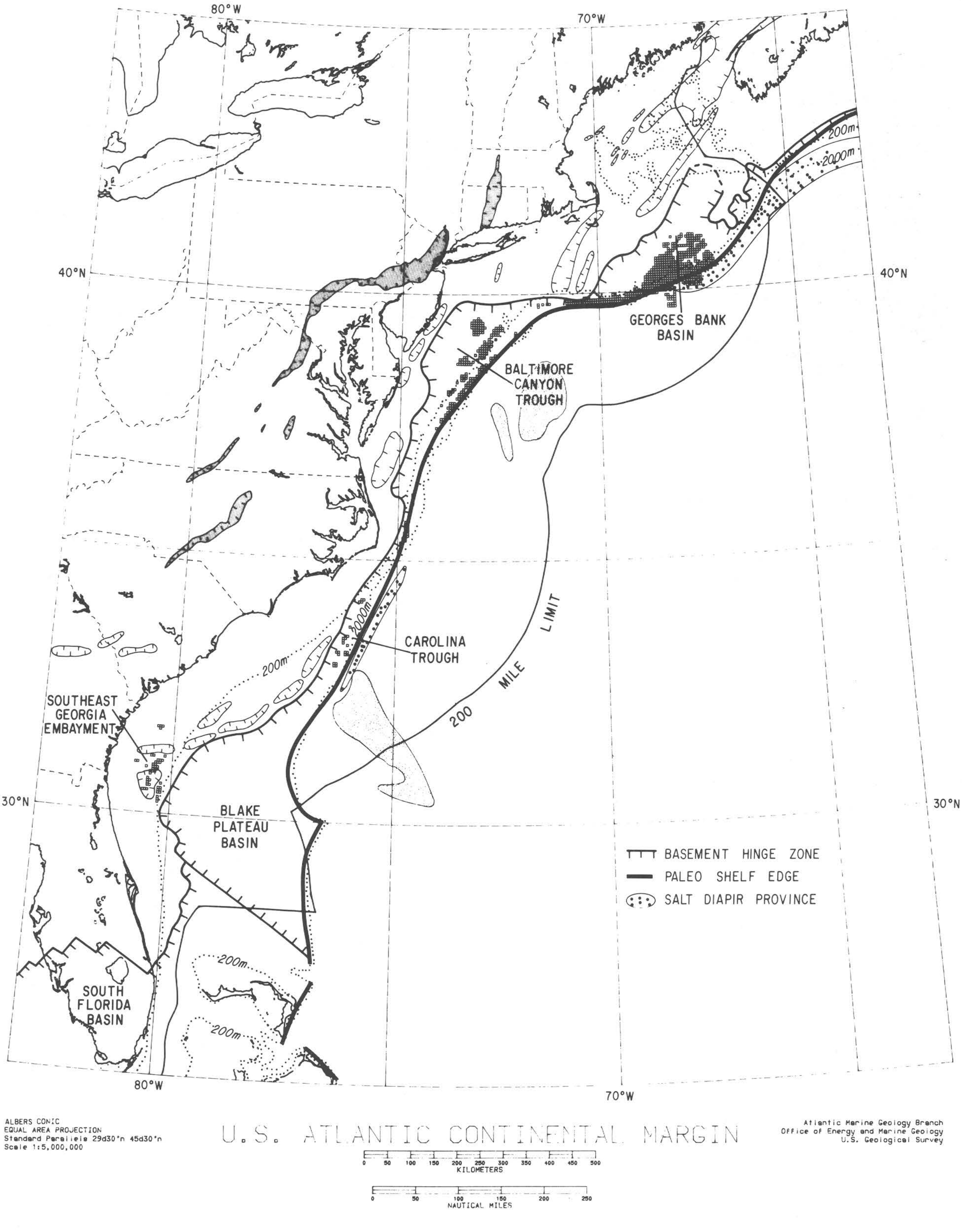


Figure EC-4. Drill hole data available on the U.S. Atlantic margin. Shown are COST wells - ⊗ ; industry exploratory wells - ⊕ ; DSDP wells - * ; ASP, AMCOR and other shallow penetration wells - X .


80°W
70°W
40°N
30°N
GEORGES BANK
BASIN
BALTIMORE
CANYON
TROUGH
CAROLINA
TROUGH
200 MILE LIMIT
200m
2000m
SOUTHEAST
GEORGIA
EMBAYMENT
BLAKE
PLATEAU
BASIN
SOUTH
FLORIDA
BASIN
BASEMENT HINGE ZONE
PALEO SHELF EDGE
SALT DIAPIR PROVINCE
ALBERS CONIC
EQUAL AREA PROJECTION
Standard Parallels 29d30'n 45d30'n
Scale 1:5,000,000
U.S. ATLANTIC CONTINENTAL MARGIN
Atlantic Marine Geology Branch
Office of Energy and Marine Geology
U.S. Geological Survey
0 50 100 150 200 250 300 350 400 450 500
KILOMETERS
0 50 100 150 200 250
NAUTICAL MILES

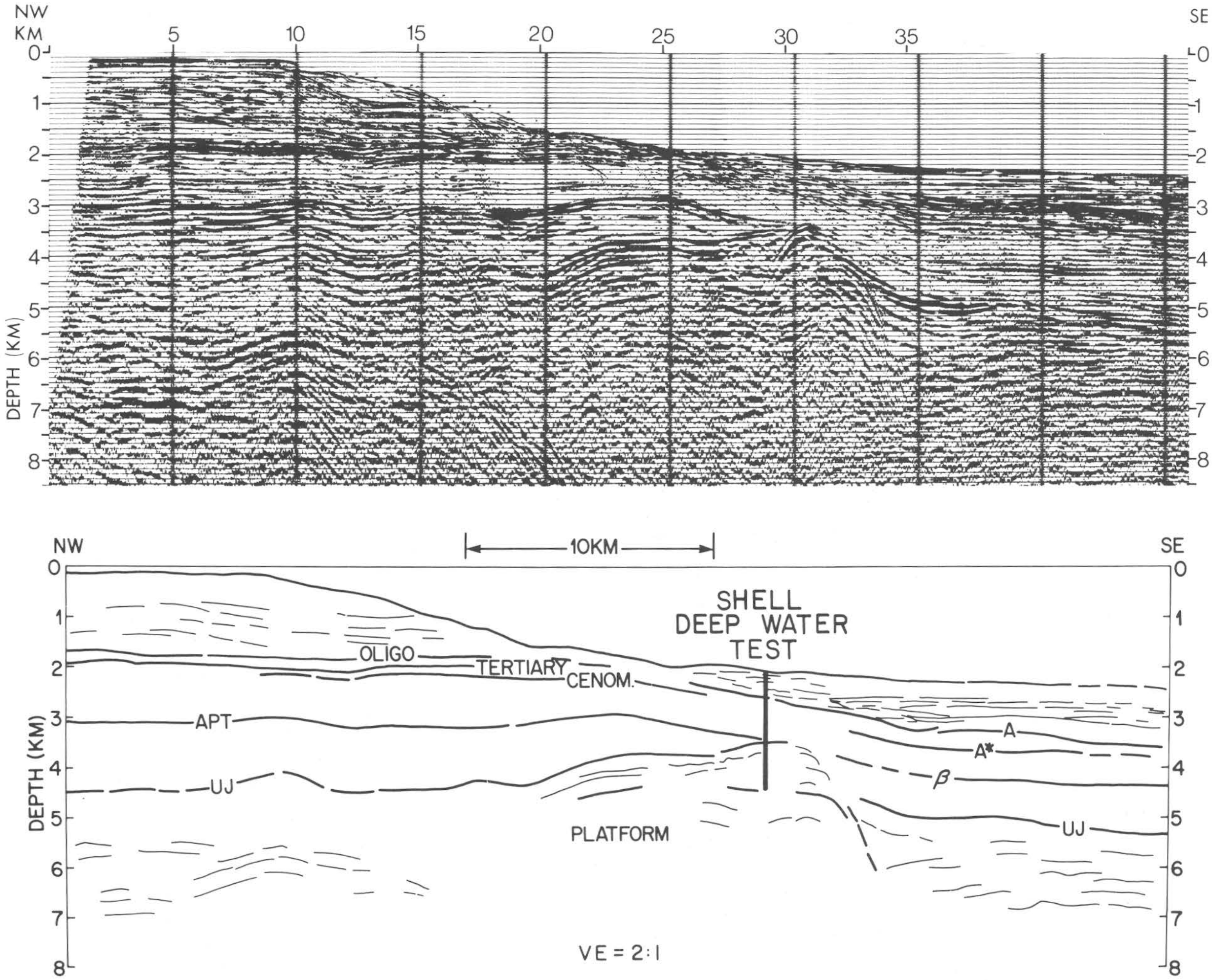


Figure EC-6. CDP seismic line 6 depth section across central Baltimore Canyon trough buried carbonate platform-paleoshelf edge. Approximate location indicated of Shell Oil Co. deep water well.

←Figure EC-5. Leasing activity on the U.S. Atlantic Margin. Lease blocks from OCS sales 40, 42, 49, 56, 59, and 76 plus proposed lease sale 52 on Georges Bank. Major Triassic-Jurassic rift grabens are indicated landward of basement hinge zone. Gas hydrate zones seaward of paleoshelf edge indicated with shading.

Canyon trough. We shall examine in more detail these four zones, starting with the most promising carbonate-bank paleoshelf-edge complex.

Carbonate-Bank Paleoshelf-Edge Complex

The complex, buried Jurassic-Cretaceous paleoshelf edge (fig. EC-7), with its associated carbonate banks, reefs, talus slopes, and deep-sea fans clearly constitutes not only an important key to the understanding of passive continental margins, but may also contain significant resources of hydrocarbons in the deep water area of the EEZ.

This suite of rocks, which is characterized in seismic data by high velocities and incoherent reflectors typical of reef masses or carbonate banks, extends almost completely around the Gulf of Mexico through the Bahamas and along the Atlantic margin at least as far the Grand Banks--a total distance of about 8,500 km. Extensive oil and gas production comes mainly from Cretaceous rocks in the trend that have been drilled both onshore and offshore Mexico. Some production has been found in the Edwards-Glen Rose trend in Texas and Louisiana, but the few exploratory holes that have penetrated this section off western Florida and eastern Canada have been dry. With the exception of the Shell well that was just completed on Lease Block 587 off the Middle Atlantic States in about 2,000 m (6,448 feet) of water, none of the 43 exploratory wells previously drilled off the Atlantic coast penetrated the reef axis or fore-reef facies. This trend thus has been mapped primarily on the basis of publicly available multichannel seismic-reflection data.

The paleoshelf-edge, carbonate-bank complex has two basic configurations: a rimmed platform or a ramp, and in places it has migrated back and forth across the margin (Schlee and Jansa, 1981). The general structure and evolution of this feature has been determined primarily from seismic-reflection data. Offshore drilling has just begun to test the hydrocarbon potential of these structures and seaward flank. It is the reef flank facies on the Mexican equivalent of this carbonate buildup that are such prolific producers in the Gulf of Mexico adjacent to Yucatan. The success there should cause us to assess more closely the characteristics of deposits flanking the paleoshelf edge--their geometry, their continuity, and their acoustic characteristics.

The Continental Rise deposits in front of the paleoshelf edge are potential deep-water targets worth further investigation. The Jurassic and Lower Cretaceous carbonate-rich strata may terminate against the carbonatebank complex or may even continue beneath the paleoshelf edge in places. Lower Cretaceous sand and shale deposits lap onto the paleoshelf edge and may even merge into units which continue over the paleoshelf edge. The Lower Cretaceous black shale deposits in the western Atlantic may serve as a source rock which has been buried sufficiently deep beneath Upper Cretaceous and Tertiary deposits on the upper Continental Rise for hydrocarbons to mature.

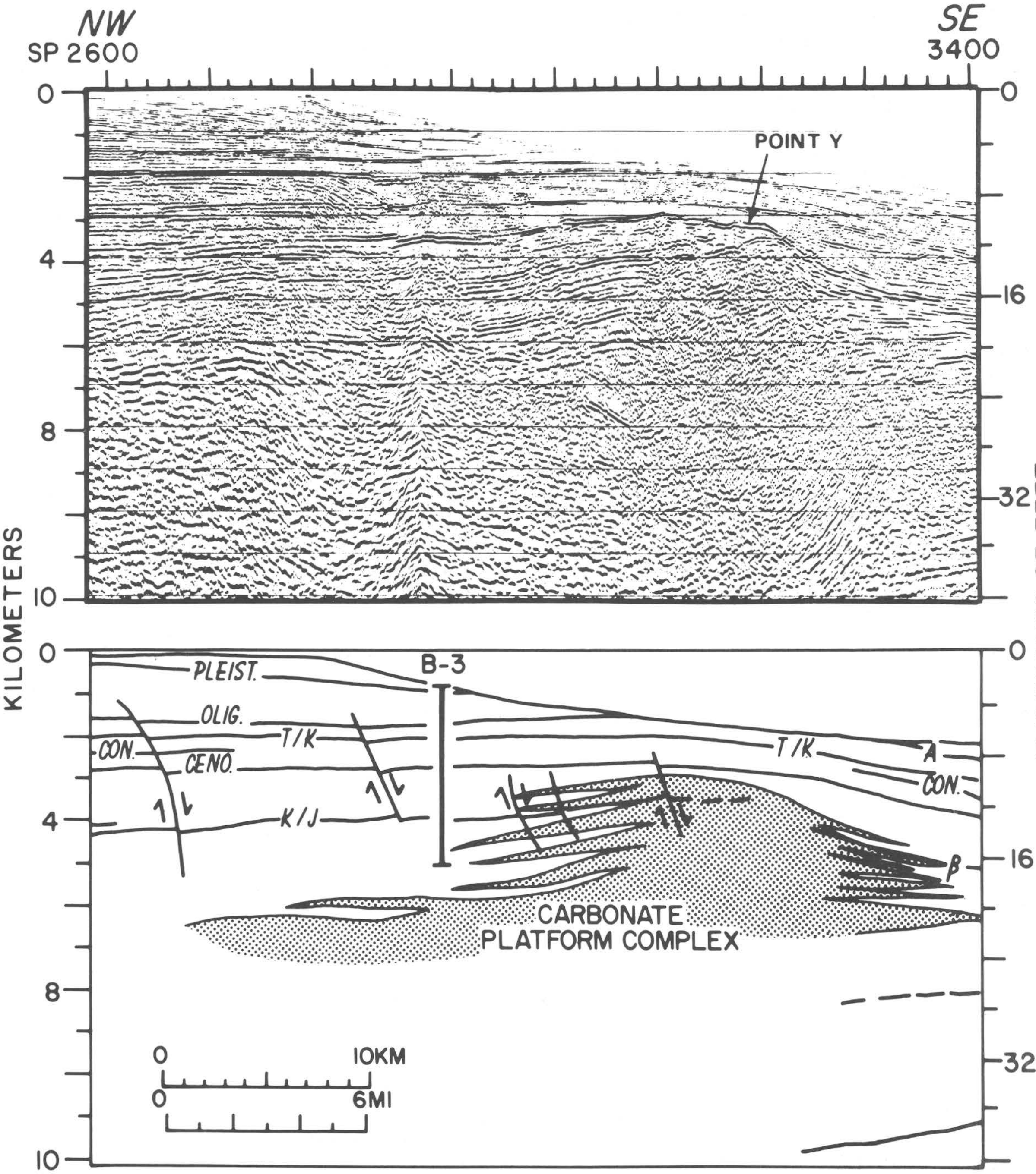


Figure EC-7. CDP seismic line 25 depth section across northern Baltimore Canyon trough in vicinity of COST B-3 well.

The discovery of an Early Cretaceous deep-sea fan 500 km east of Cape Hatteras (185 km southeast of Atlantic City) by DSDP drilling on Leg 93 last May shows that the platform front has been breached by gaps through which sand has moved into the deep sea from the shelf. Approximately 218-m-thick terrigenous sand and sandy turbidites were deposited at the site and these units should provide, in an updip direction, suitable reservoirs for oil and gas. What other types of fans and debris aprons are there in the sedimentary prism that underlies the Continental Rise remains to be seen as more holes are drilled.

Structures associated with salt diapirsm form important targets behind and in front of the paleoshelf edge. There are 26 diapirs that have penetrated the upper rise seaward of North Carolina (figs. EC-1 and EC-3) just in front of the paleoshelf edge (fig. EC-8) of the Carolina trough (Dillon and others, 1982, fig. 1). Three salt diapirs or pillows have been found just landward of the paleoshelf edge in the Baltimore Canyon trough. A series of broad salt pillows are also present seaward of the rimmed carbonate platform along eastern Georges Bank. The Georges Bank structures are the termination of a much bigger system of salt ridges, plugs and pillows--part of the "Sedimentary Ridge province" that makes up the Continental Rise off Nova Scotia.

Intersecting the New England margin at Georges Bank and traversing the Continental Rise is the New England Seamounts, a 1,200 km long chain of cone-shaped volcanic mountains that were intruded into the thick rise sedimentary prism 100 million years ago. Bear Seamount, the seamount closest to New Georges Bank, has created major disruptions in slope-rise sedimentation, provided a local heat source that may have converted organic matter to hydrocarbons, and has created a distinctive sedimentary apron around the core.

Future Studies

In summary, the seaward deep-water margin of the EEZ off the eastern United States not only poses a significant array of complex geological problems related to passive margin evolution but also constitutes a prospective frontier region for petroleum resources. Detailed studies of depositional-erosional sequences related to sea-level fluctuations and deep-water paleocirculation variations are needed to reconstruct the depositional history for the outer shelf and slope, including the role of the carbonate-bank shelf-edge complex and its relation to controlling Continental Rise deposition. Velocity studies of the shelf-edge complex are vital to define lithologic types and structural surfaces. Enhanced acoustic penetration into the carbonate-bank complex is needed to determine the deeper structures which may have controlled the shelf-edge position through time. Finally, there is a first order need for drill-hole information from the Cretaceous and Jurassic units that lie in front of the paleoshelf edge and which lap onto it. What is the effect of the salt diapirs on the upper Rise deposits of the Carolina trough and Georges Bank basin? Detailed stratigraphic studies of the upper Rise sediments pierced by these diapirs coupled with selective drilling are needed to evaluate the petroleum potential of these deep-water areas.

Basement Hinge Zone Structures

On the landward side of the marginal basins, all Mesozoic sedimentary units shallow and thin as they approach the basement hinge zone (fig. EC-2). This region is characterized by the updip pinchout or onlap of most Jurassic units and, in places, some Lower Cretaceous units. The interaction between sea-level fluctuations and basin subsidence has produced a series of transgressive onlap and regressive offlap sequences. Beneath the postrift sedimentary sequences are deformed synrift deposits in a seaward deepening series of graben structures in the Georges Bank basin (figs. EC-2 and EC-9) and northern Baltimore Canyon trough and in a seaward thickening clastic wedge behind the paleoshelf edge in the southern Baltimore Canyon trough (fig. EC-10).

The stratigraphic sequence over the basement hinge zone contains an important record of the variation in crustal subsidence rates between continental crust and a marginal rift basin. Considering the uncertainties in the early subsidence (and thermal) history of the margin, the result of insufficient Middle and Lower Jurassic chrono-stratigraphic data, correlation of the depositional-erosional sequences in this region with global sea-level fluctuation patterns is essential. These studies are essential in the construction of a better defined history for the margin.

The petroleum potential of the region is also dependent on the sedimentary facies and depositional structures associated with the material just seaward of the hinge zone. Interpolation of depositional units between onshore wells and the OCS wells may be of some use in determining the facies variations, but a broad range of sea-level and paleoenvironment fluctuations makes this fairly unreliable. High-resolution seismic facies studies such as those proposed by Vail and others (1977) of Exxon are essential for this region. Detailed velocity studies of the crustal rocks and overlying sedimentary rocks provide important input parameters to both subsidence modeling studies and lithologic inferences from seismic-reflection studies. Drill-hole sites can than be planned to obtain chronostratigraphic and lithostratigraphic information needed to test the petroleum potential in the hinge-zone region.

Triassic-Jurassic Rift Basins

The potential for economic concentrations of petroleum associated with the buried Triassic-Jurassic rift basins beneath the outer Coastal Plain and Continental Shelf (fig. EC-5) is virtually unevaluated. A combination of factors make these areas particularly attractive targets for exploration. Rift lakes are traps for autochthonous organic matter and are often colonized by algae and other potential kerogen or hydrocarbon precursors; they can be anoxic at depth leading to conditions

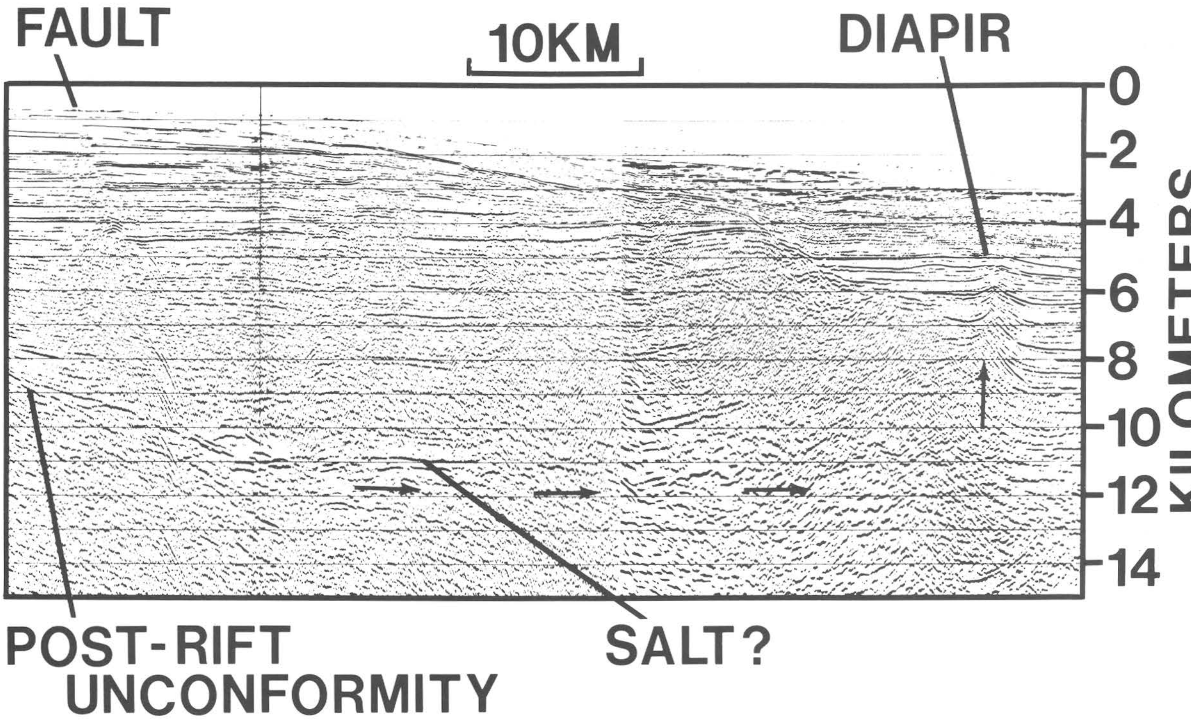


Figure EC-8. CDP seismic line 32 depth section across central Carolina trough. Arrows indicate possible salt withdrawal causing growth fault and salt diapir.

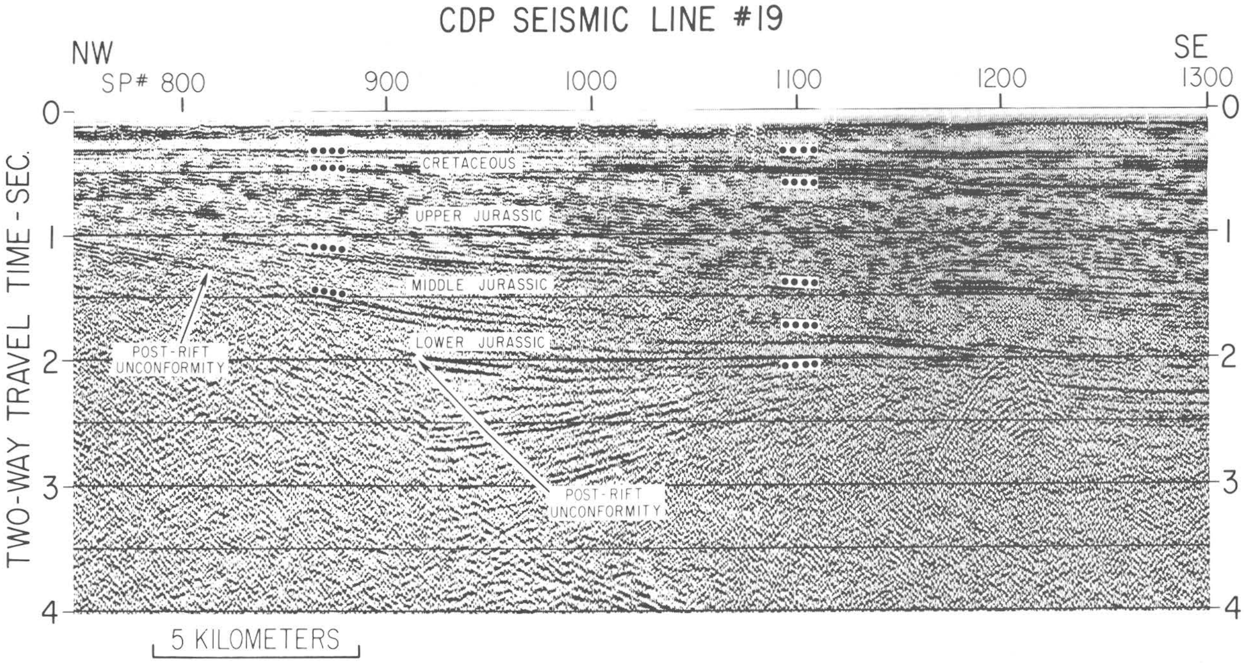


Figure EC-9. CDP seismic line 19 time section across Georges Bank basin basement hinge zone showing synrift deposits in graben beneath postrift unconformity. See figure EC-2 for depth section.

conducive for perservation of organic materials. Their thermal history includes high heat flow to promote maturation temperatures of source beds and porous and permeable reservoir rocks. Structural and/or stratigraphic traps and impermeable seal rocks are all characteristic of rifted environments. Most occur landward of the hinge zone on the platform margins, and are thus accessible to the drill.

To date, exploration for hydrocarbons in the Triassic-Jurassic rift basins has been confined to the exposed basins of the Piedmont or the shallow subsurface basins beneath the Coastal Plain. No tests have yielded commercial quantities of oil or gas from these rocks; however, there have been some interesting shows. Black shales, which when heated to temperatures above 400°C yielded shale oil in amounts up to 12.7 gallons per ton of shale, have been documented for rocks from the Deep River Triassic basin of North Carolina. Black kerogen-rich lacustrine shales have been described in the Fundy, Newark, Gettysburg, Culpepper, Taylorsville, Richmond, Farmville, and Dan River basins. Oil or gas shows have been reported in the South Georgia Rift and Deep River basin. However, no deep tests have penetrated the outer rift basins of the margin such as those of the Long Island platform or Brunswick Graben just offshore the Carolinas. It is possible that the grabens offshore New England are primarily late Paleozoic structures similar to the Narragansett and Boston basins. Exploration in the Southeast Georgia Embayment has concentrated on the rim of one of these rift grabens. The target units in this basin were Paleozoic marine sediments of the northern Florida Suwannee basin and not Triassic rocks.

Future Studies

Although the locations and depths of most of the rift basins have been outlined from magnetic depth and signature analyses and seismic-reflection profiling, only a few have been sampled by the drill. The possibility of petroleum associated with rift basins may be greater as the continental edge is approached, as the deeper basins may have had some marine history, which would be favorable for oil rather than gas generation. In fact, almost nothing is known of the depositional conditions or paleoenvironments in these deeper basins. A drilling program aimed at these shallow basins needs to be established to obtain lithostratigraphic information.

Gas Hydrates

Gas hydrates, also known as clathrates, are icelike crystalline solids, formed as a cagelike structure of water molecules, surrounding a gas molecule. The gas, in nature, can be CO_2 or H_2S, but most commonly is CH_4 or several other low molecular-weight hydrocarbons. Gas hydrates are stable above the temperature of solid water (ice) at the relatively elevated pressures present in the ocean. Within the sediment, biogenic generation of methane from organic matter can produce enough gas to create significant amounts of gas hydrate. Gas hydrate is likely to be present on the slope and rise within the upper 500 m of sediments in a layer which parallels the sea floor (fig. EC-11). Below that depth, any gas would be dissolved or present as free gas. Two major zones of gas hydrate formation are present in the western Atlantic, one offshore the Carolinas and the other offshore New Jersey (fig. EC-5).

Although it ultimately may be possible to produce gas from the sea-floor gas hydrate (Holder and others, 1983), the introduction of heat into sediment will tend to break down the hydrate, and the addition of other chemicals that act as antifreeze may present considerable technical difficulties. Gas hydrate-saturated sediments may be far more important in a role as seals for gas traps (Dillon and others, 1980). The simplest case occurs when the sea floor is formed into a dome. In such a case, the gas hydrate layer (paralleling the sea-floor topography) will also form a dome and can trap gas. Gas can be trapped where permeable beds, interlayered with impermeable beds, dip back toward the Continental Slope and are sealed at their updip ends by gas hydrate. Another type of gas hydrate-sealed trap is produced where a gas hydrate layer crosses a salt diapir. The salt diffusing from the diapir will act as antifreeze for the hydrate, and the diapir will conduct heat upward more effectively than surrounding sediments because salt has a higher heat conductivity. Both factors will inhibit gas hydrate formation above the salt diapir and produce a dome in the base of the gas hydrate layer. Such traps would probably be small and noncommercial, but such shallow gas could be a hazard to drilling if not recognized.

Geohazard Studies

Geohazard studies on the Atlantic margin have focused on two primary topics: (1) sediment transport and (2) sea-floor stability. Broad regional studies and detailed areal studies related to leasing have been conducted over the last decade by various government, industry, and academic groups (Knebel, in press).

Sediment-transport studies include characterization and measurements of long-term and transient (wind- and storm-induced) currents and their ability to transport suspended matter, such as sediment marine nutrients and pollutants along the Atlantic coast. Other sediment-transport studies have focused on (a) the definition and dynamics of a modern (presently active) area of deposition for fine-grained sediment on the shelf of southern New England; (b) the dynamics of sand-wave mobility on Georges Bank.

Sea-floor stability studies have identified areas where the sea floor, particularly on the Continental Slope, has collapsed or slid out of place, been eroded, or disturbed by shallow faulting (e.g., fig. EC-12). As expected, most possible hazards are in the vicinity of the Continental Slope, also the region of greatest petroleum potential. Mass wasting has been an important factor in sculpturing the shelf-slope upper-rise morphology but not necessarily as a continuous process. Sea-level fluctuations and sediment supply factors are important parameters

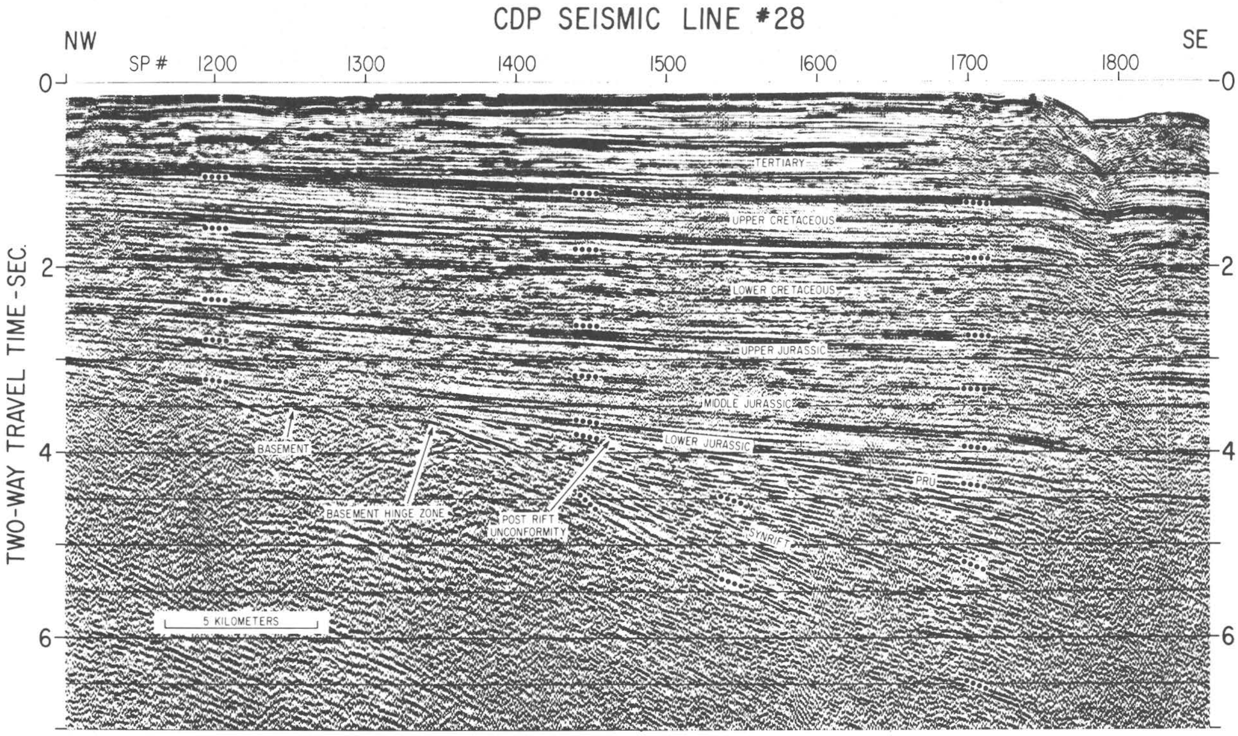


Figure EC-10. CDP seismic line 28 time section across southern Baltimore Canyon trough basement hinge zone showing thickening wedge of synrift deposits in front of hinge zone.

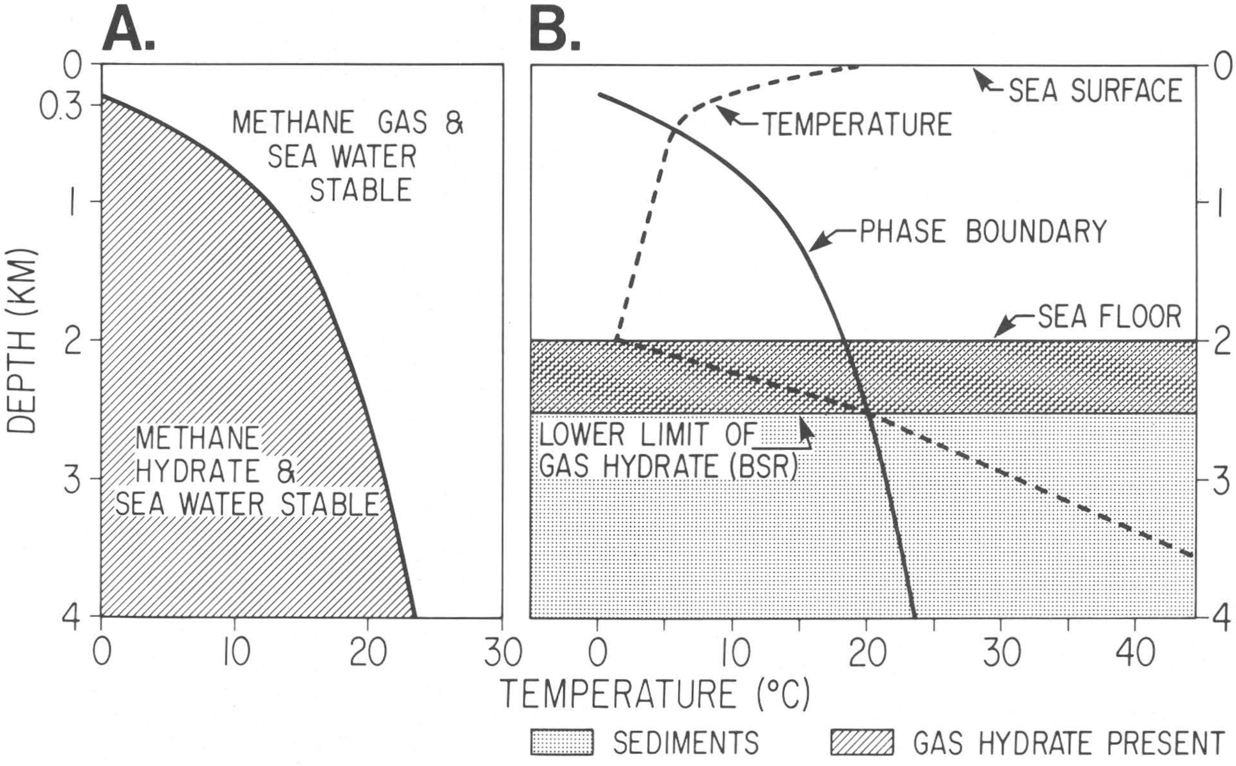


Figure EC-11. Schematic diagram showing gas hydrate stability regimes in deep-sea sedimentary units.

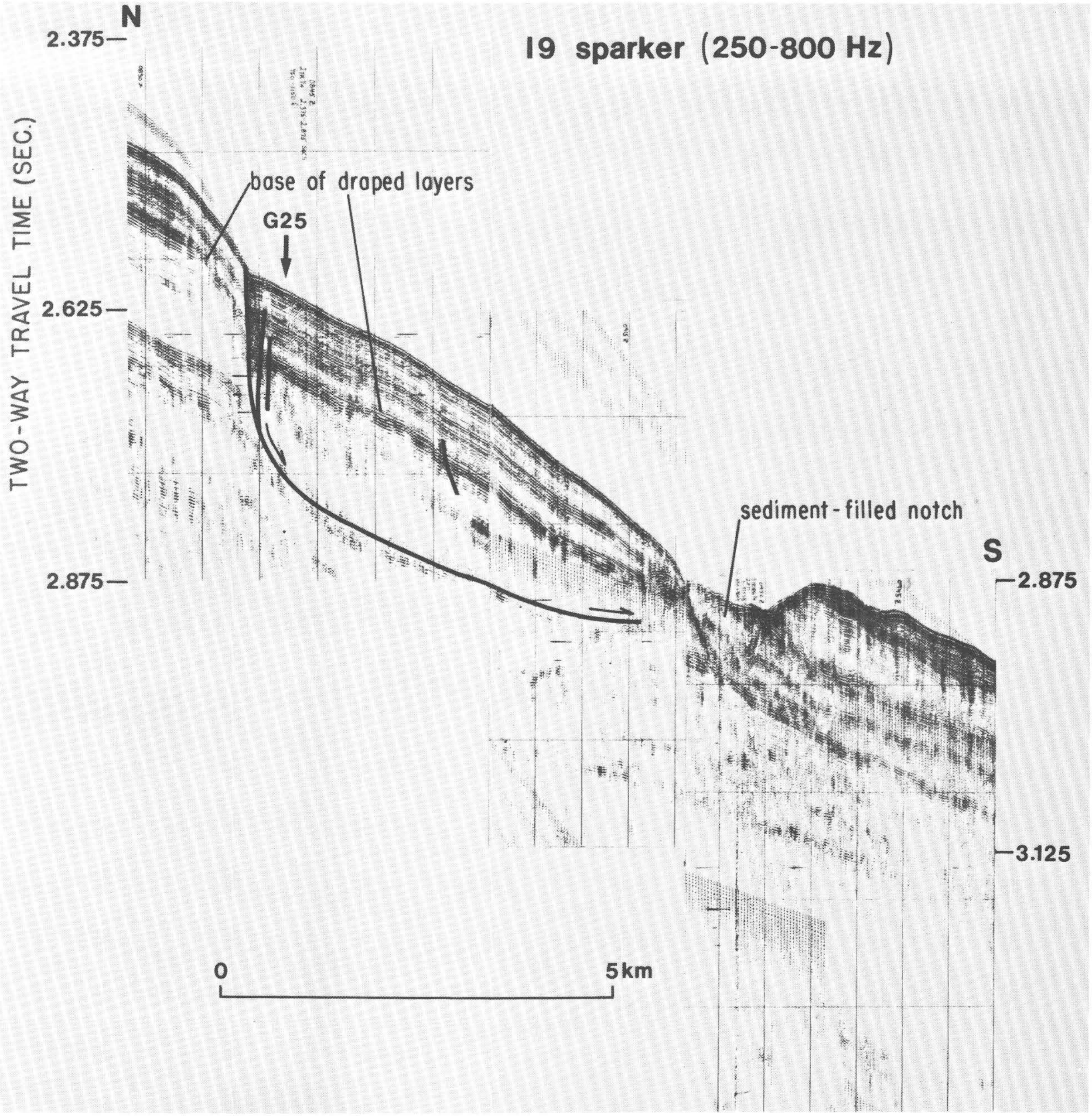


Figure EC-12. Single channel seismic reflection profile across Georges Bank Continental Slope showing block displacement along shallow listric fault. Note that the structure has been draped with younger sediment and re-activated.

in the timing of mass-wasting events. We are finally gaining an understanding of the distribution of masswasting events (e.g., slumping and turbidite flows) but the time of occurrence remains uncertain. Many of the observed slumps may have occurred during the last sea-level lowering and are not likely to happen at present sea level condition. The ability to attach timing information as well as distribution patterns to geohazards represents an important problem for future research.

Future Studies

A primary topic for geohazard studies along the margin is the adequate characterization of the geology and morphology of the slope and upper rise in order to: (1) outline the geologic history of processes that formed the sea floor; (2) identify presently active processes; (3) predict or estimate the likelihood of major disruptive events or accelerations toward instability; (4) acquire measurements of slope stability; (5) understand how slopes fail. These studies should include:

- Accurate and comprehensive bathymetric coverage through use of SEABEAM swath surveying.

- Midrange sidescan sonar surveys to adequately interpret patterns of deformation and their relations to regional geology and bathymetry.

- Selected high-resolution seismic profiling in areas where extensive mass wasting has occurred (particularly west of 71°W).

- Drilling and coring of the uppermost 500 m of section of the Continental Slope to characterize geologic and geotechnical properties of sediments and investigate internal deformation, perhaps caused by trapped gas.

- ALVIN/ANGUS surveys to obtain critical observations and samples for age dating and structural analysis.

- Current measurements in canyons and on open slope: is erosion really a factor? Is sediment leaving the shelf and loading the slope/rise?

Inner Shelf Studies

The other most dynamic part of the EEZ is the inner shelf. We should focus on the following topics for which information is presently sparse.

- Estuarine studies to determine in what ways or under what conditions inland-derived or coastal sediments/pollutants can be dispersed to the open sea.

- Seashore-erosion studies to determine rates and directions of coastline change, particularly along barrier islands; its influence on bay sedimentation, relationship to coastal subsidence, sediment transport, storm frequency, and weather patterns; determination of long-term trends.

GULF OF MEXICO MARGIN

Regional Geologic Setting

The Gulf of Mexico is a relatively small ocean basin (1.5 million km^2) almost completely surrounded by landmasses with a variety of continental margin geologic settings. These variations are summarized by the generalized structural provinces (fig. GM-1) and generalized sedimentary provinces (fig. GM-2) of Martin (1982) (Figures relating to Gulf of Mexico are designated GM). The distribution of salt, carbonate, and clastic deposition during the Mesozoic and Cenozoic is a dominant factor in the development of petroleum potential around the Gulf of Mexico. The following discussion of the Gulf of Mexico basin is extracted from Martin (1982) with minor modifications.

Evolution of the Gulf of Mexico began with Late Triassic-Early Jurassic rifting and the deposition of nonmarine red beds of the Eagle Mills Formation around the rim of the Gulf. A second parallel rift system beneath the present Texas-Louisiana shelf (fig. GM-3) has been postulated by Jackson and Seni (1983) and others. Breakup of North America from Africa and South America, with the initiation of rapid plate separation and sea-floor spreading, occurred in Middle Jurassic (~175 m.y.B.P.). The influx of Pacific or Tethyan waters with restricted marine circulation led to the accumulation of Callovian to Oxfordian age Louann evaporites around the rim of the Gulf (East Texas, North Louisiana, and Mississippi salt-dome basins) and Challenger evaporites near the center of the early Gulf basin (Gulf Coast Salt Dome basin) (figs. GM-3 and GM-4) (Watkins and others, 1978). Subsequent sea-floor spreading and salt flowage in response to sediment loading produced the present distribution of salt around the Gulf (fig. GM-5).

Following the last major cycle of evaporite deposition early in Late Jurassic time, the Gulf of Mexico region was flooded by open seas. Depositional environments quickly changed from evaporitic and continental to shallow and, perhaps locally, deep marine. Terrigenous sands and muds initially were deposited across the basin, and eventually they were overlain by predominantly carbonate accumulations as subsidence slowed and the supply of terrigenous clastic material waned. A carbonate depositional regime prevailed into the Early Cretaceous, during which time, broad carbonate banks composed of limestones, dolomites, and interbedded anhydrites were constructed around the periphery of the basin (figs. GM-2, GM-4, and GM-5). The seaward edges of these shallow banks were sites of reef building and detrital carbonate accumulations, and eventually the formation of thick, steeply fronted carbonate platforms that grade abruptly seaward into a relatively thin sequence

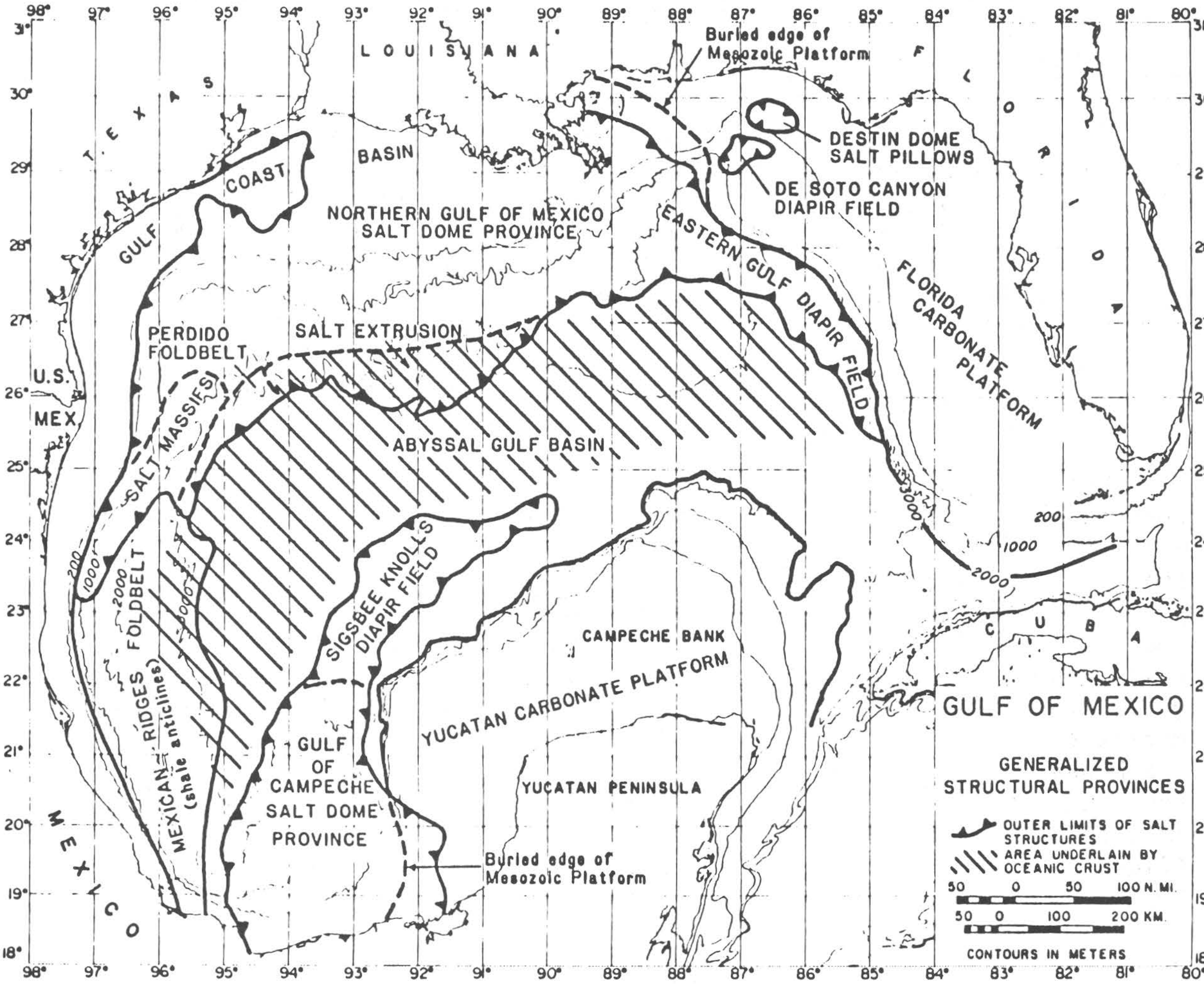


Figure GM-1. Map of Gulf of Mexico region showing generalized structural provinces, distribution of diapiric salt structures, and extent of oceanic crust. From Martin (1982, fig. I-1) and Buffler and others (1980).

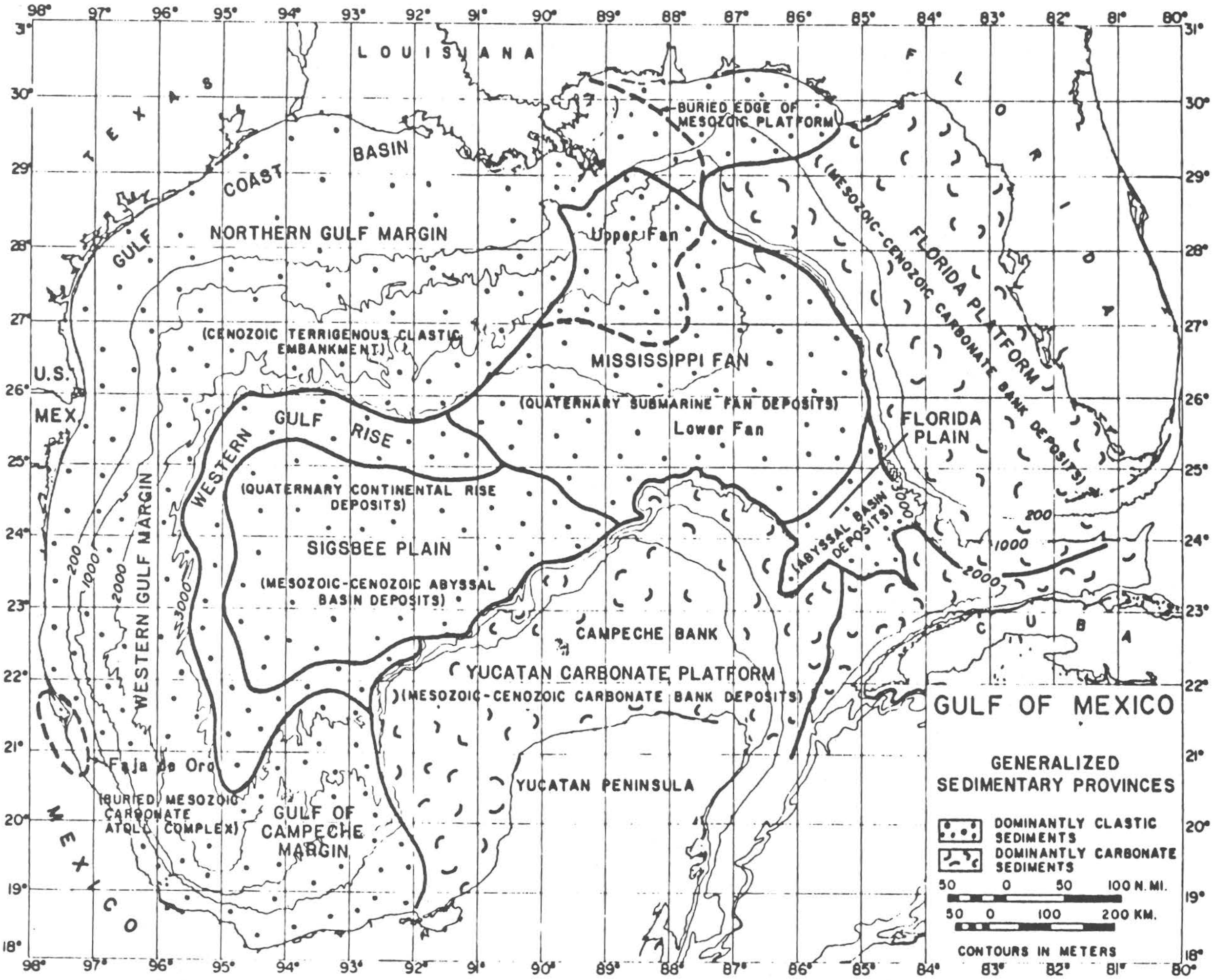
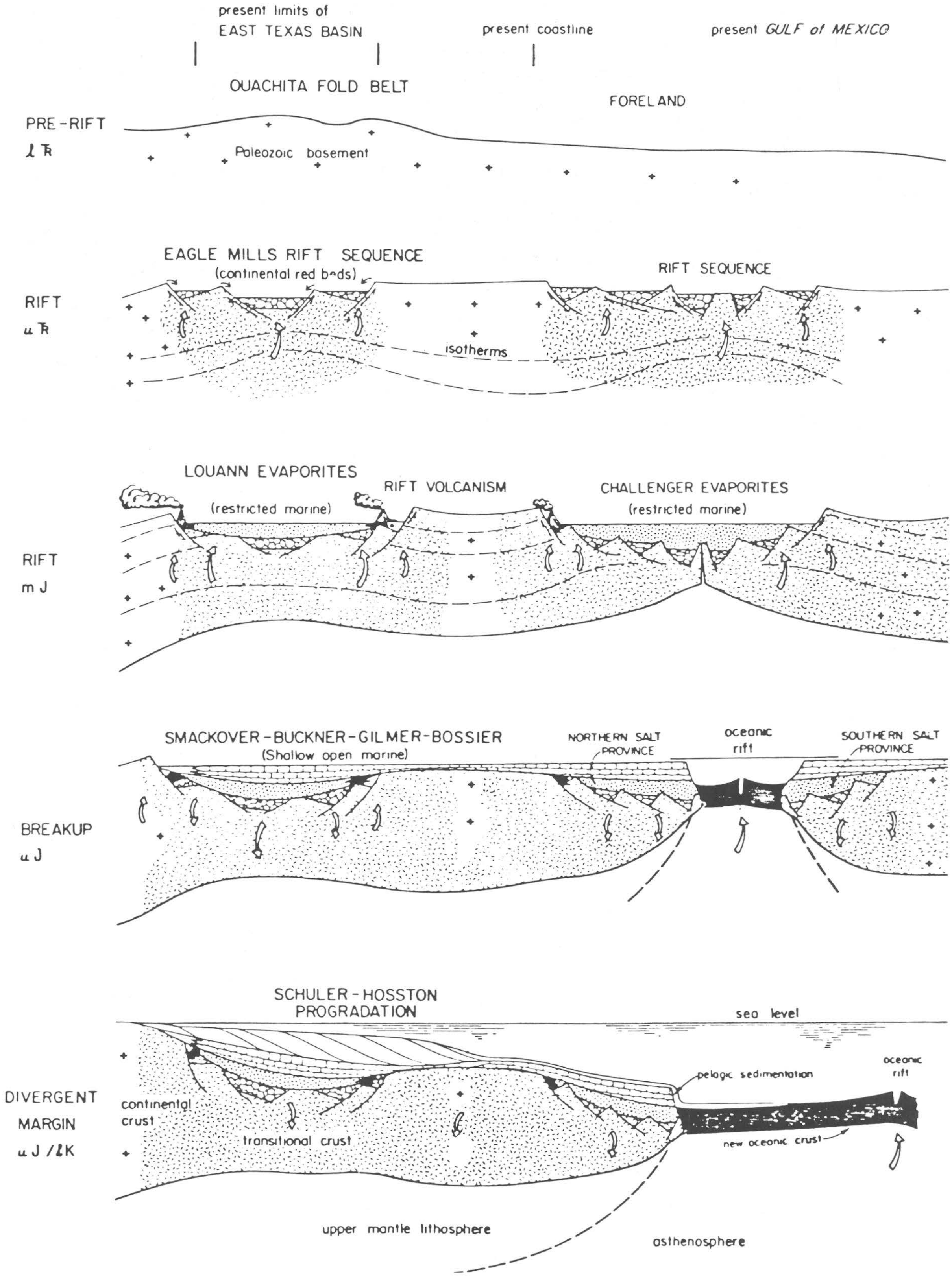


Figure GM-2. Map of Gulf of Mexico region showing generalized sedimentary provinces. From Martin (1982, fig. I-3).

Figure GM-3. Schematic northwest-southeast cross sections showing evolutionary stages in formation of East Texas basin and adjoining Gulf of Mexico (not to scale). Intervening area lies just south of present Sabine Arch. Arrows indicate thermally induced isostatic movement of crust. From Jackson and Seni (1983, fig. 2). →


present limits of
EAST TEXAS BASIN
present coastline
present GULF of MEXICO
OUACHITA FOLD BELT
FORELAND
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l Tr
Paleozoic basement
EAGLE MILLS RIFT SEQUENCE
(continental red beds)
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RIFT
m J
SMACKOVER-BUCKNER-GILMER-BOSSIER
(Shallow open marine)
NORTHERN SALT PROVINCE
oceanic rift
SOUTHERN SALT PROVINCE
BREAKUP
u J
SCHULER-HOSSTON
PROGRADATION
sea level
pelagic sedimentation
oceanic rift
DIVERGENT
MARGIN
u J / l K
continental crust
transitional crust
new oceanic crust
upper mantle lithosphere
asthenosphere

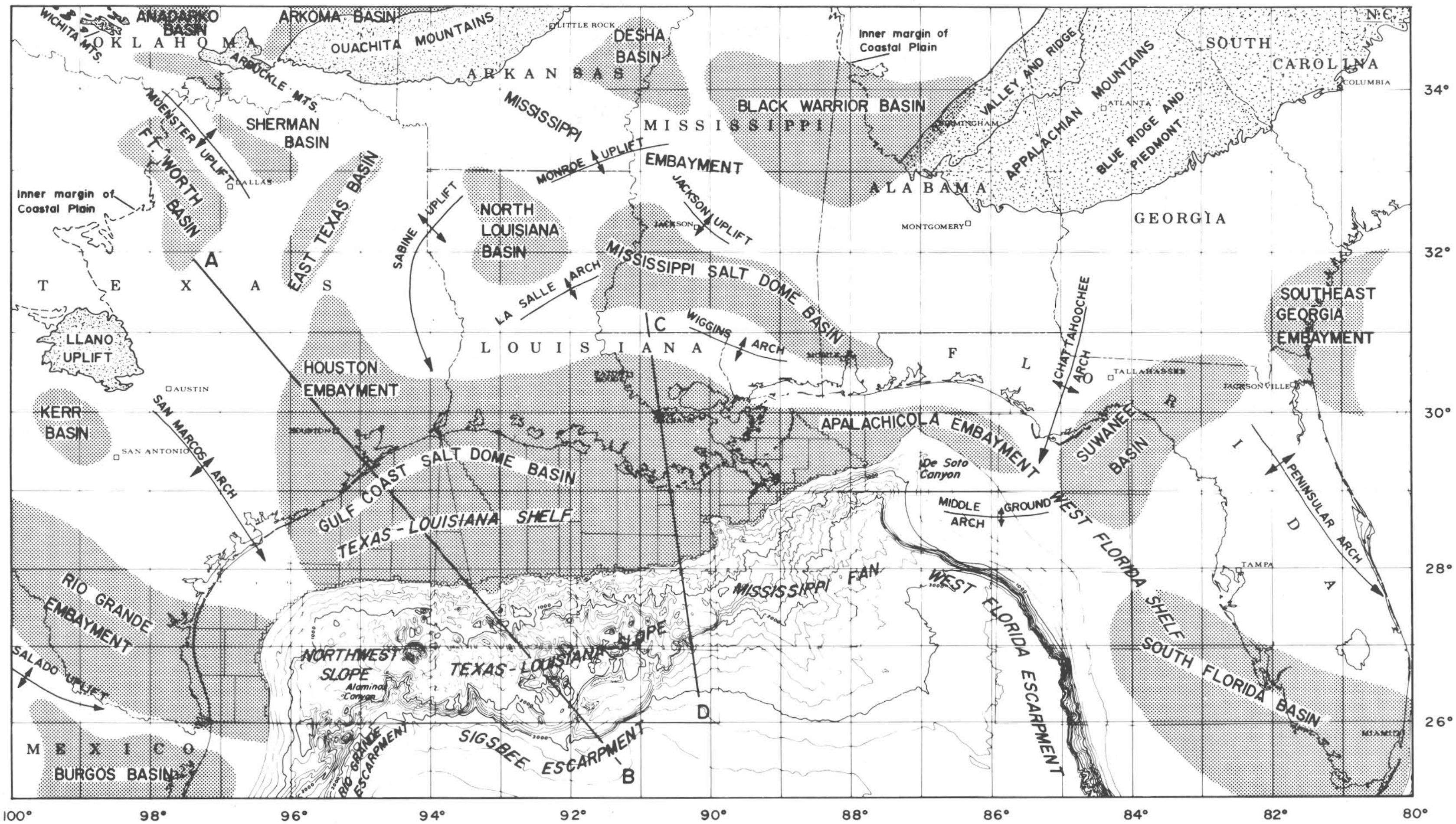


Figure GM-4. Physiographic and geologic provinces and subsea topography of northern Gulf of Mexico. Contour interval, 200 m; scale approximately 1 cm = 120 km. From Martin (1982, fig. I-5).

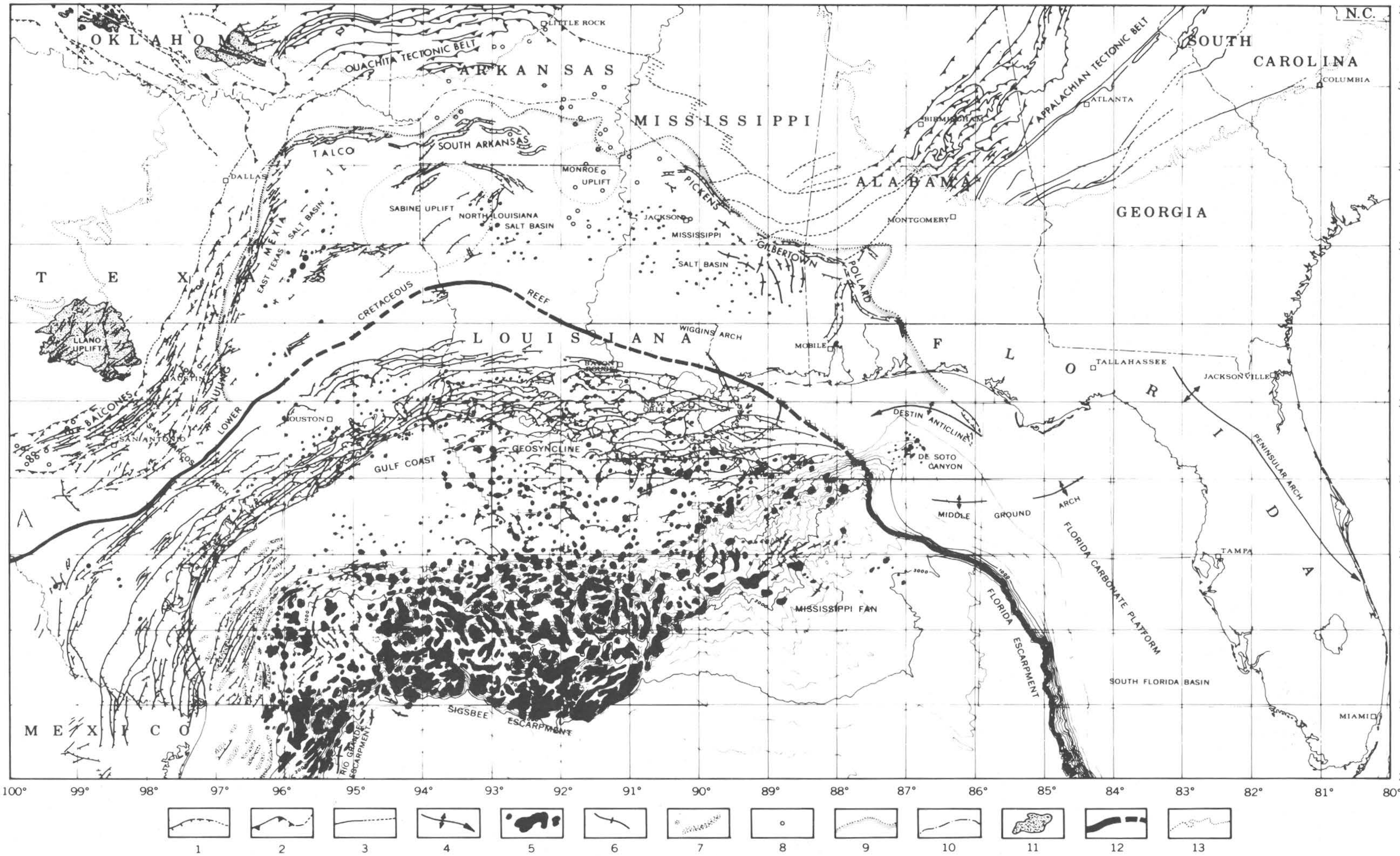


Figure GM-5. Tectonic map of northern Gulf of Mexico region. Explanation of patterns and symbols (1) normal fault, (2) reverse fault, (3) fault of undetermined movement, (4) broad anticline or arch of regional extent, (5) salt diapirs and massifs, (6) salt anticlines and pillows, (7) shale domes and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

of time-equivalent deep-water strata. The present-day Florida and Campeche Escarpments in the eastern and southern Gulf are exposed edges of these Early Cretaceous platforms.

In mid-Cretaceous time, a rise in sea level affected the carbonate depositional environment throughout the Gulf region. As the Late Cretaceous seas expanded over the region, shallow-water carbonate environments transgressed landward from the outer margins of the banks. An increase in land-derived sediment supply and load-induced subsidence in the Gulf region quickly overwhelmed the carbonate environments in the northern and western regions of the basin (fig. GM-2). Carbonate depostion persisted, however, on the Florida and Yucatan platforms in the eastern and southern Gulf.

General uplift of the North American continent during the Laramide Orogeny (latest Cretaceous and early Tertiary times) produced voluminous amounts of clastic sediment that were delivered to the northern, western, and southern Gulf regions throughout the Tertiary period. Large volumes of land-derived sands and muds were deposited in successively younger wedges of offlapping strata as the basin subsided relatively rapidly and the primary depocenter shifted seaward (fig. GM-6). Sedimentation rates during the Tertiary and Quaternary exceeded the general rate of subsidence, causing the margins to be prograded as much as 384 km (240 mi) from the edges of Cretaceous carbonate banks around the northern and western rim of the basin to the present position of the Continental Slopes off Texas, Louisiana, and eastern Mexico. The resulting seaward migration of mega-facies from intercoastal, shelf, and slope environments of deposition is shown schematically in figures GM-7 and GM-8. The landward facies consists primarily of continental, lagoonal, and deltaic sediments, predominantly sandstones, which were deposited near the shore and are referred to as the "massive sands" or "deltaic plains complex." The middle facies consists of alternating sandstones and shales deposited in the neritic and upper bathyal environments, while mud was deposited in the outer neritic, bathyal, and possibly abyssal environments and dominates the "deep water" or seaward facies.

Almost without interruption, the voluminous infilling of the Gulf basin during Tertiary time was followed by Quaternary sediment influx of similar proportions. As Pleistocene continental glaciation waxed and waned, the resulting sea-level fluctuations caused numerous transgressions and regressions which continued the shift of older deposits seaward. Pleistocene sediments accumulated mainly along the outer shelf and upper slope regions of the northern margin, and on the Continental Slope and deep basin floor in the east-central Gulf where the topography expresses the apronlike shape of the Mississippi Fan (fig. GM-2).

Cumulative sediment thickness of Tertiary-Quaternary clastic material possibly amounts to more than 15 km (50,000 ft) in the region of the Continental Shelf off Louisiana and Texas, herein referred to as the "Gulf Coast basin."

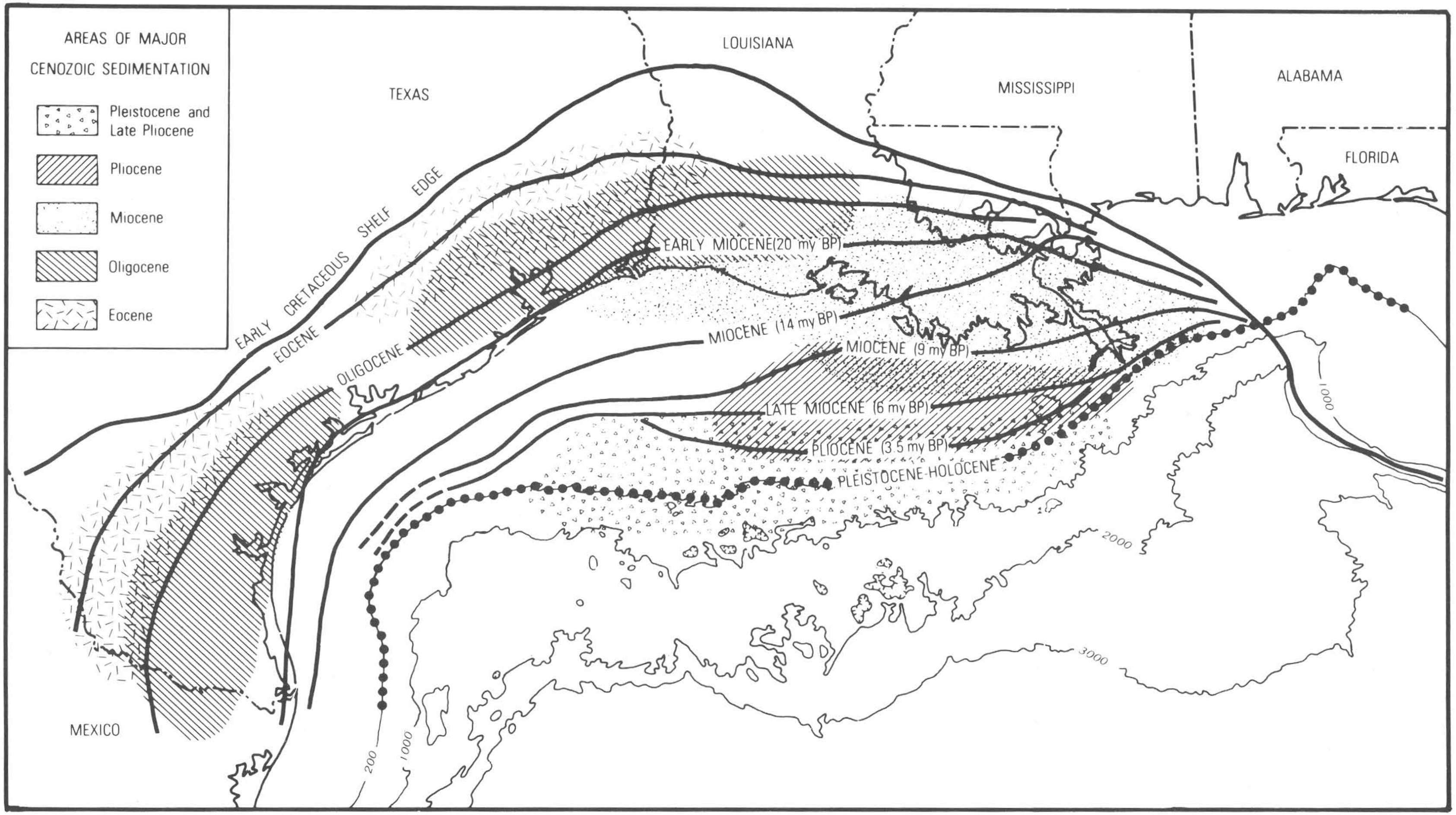


Figure GM-6. Sketch map showing paleoshelf edges in Gulf Coast basin and distribution of major Tertiary depocenters. From Martin (1982, fig. I-9).

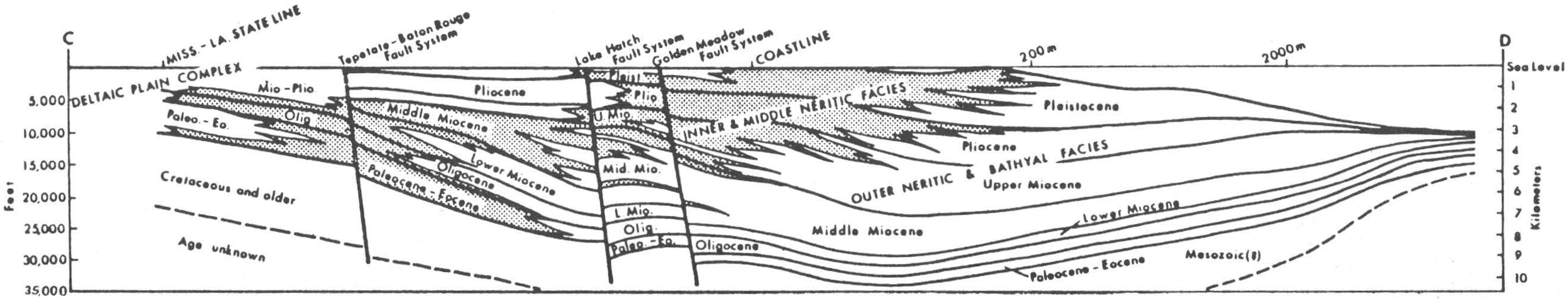


Figure GM-7. Diagrammatic cross section of Gulf Coast Basin showing migration of megafacies through time. Salt domes removed for simplicity. General location of section shown on figure GM-5. From Martin (1982, fig. I-7).

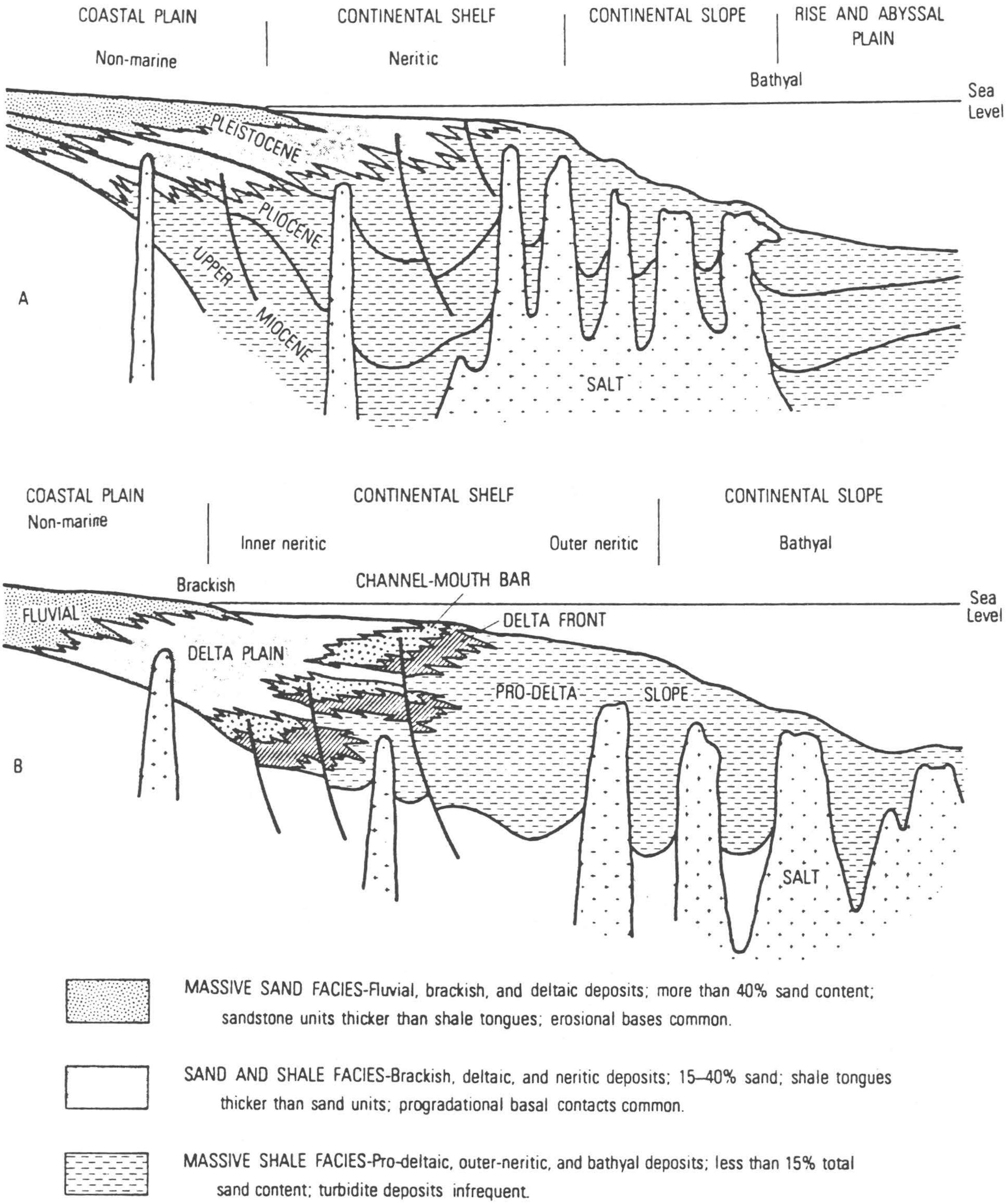


Figure GM-8. Diagrammatic cross sections showing lithofacies relations in Quaternary and Tertiary sediments of Gulf Coast basin: A - gross depositional model for Cenozoic sediments depicting net regression of continental-deltaic (massive shale) megafacies through Cenozoic time; B - depositional model for Pleistocene sediments in Texas-Louisiana Shelf region. From Martin (1982, fig. I-8).

In contrast to the infilling by voluminous clastic deposition on the northern and western margins of the basin during Cenozoic time, only small amounts of clastic debris reached the platform regions of the eastern and southern Gulf (West Florida Shelf and Yucatan platform). Consequently, the carbonate environments that had prevailed on these banks during the Mesozoic, for the most part, persisted throughout Tertiary and Quaternary times. Land-derived clasic sediments from source areas north and northwest of the Florida platform were deposited as minor components of Tertiary carbonate environments as far south as the middle shelf.

Structural Framework

Large basin development in the Gulf of Mexico was confined to a series of Mesozoic basins, separated by Paleozoic basement highs, around the rim of the Gulf with a series of late Mesozoic and Cenozoic embayments linking them to the Gulf Coast basin (figs. GM-4 and GM-9). Late Triassic-Early Jurassic rifting probably provided the structural control for the East Texas, North Louisiana, and Mississippi basins and the Apalachicola, Tampa, and South Florida basins beneath the West Florida shelf. The onshore basins and offshore Louisiana and Texas were the sites of massive Jurassic salt deposition and developed into salt-dome basins. In contrast, the offshore basins under the West Florida shelf accumulated more anhydrite than salt; the Apalachicola basin, with the Destin Dome salt pillows and DeSoto Canyon diapir field (fig. GM-1), is a transition zone between the salt and anhydrite depocenters. Primary structural control in the Gulf rim basins comes from the underlying crystalline basement and salt diapirism.

The continental margins and deep-ocean basin regions of the Gulf of Mexico, in spite of much subsidence, are relatively stable areas in which tectonism caused by sediment loading and gravity has played a major role in contemporaneous and post-depositional deformation. Mesozoic and Cenozoic strata in the Gulf basin have been deformed principally by uplift, folding, and faulting associated with plastic flowage of Jurassic salt deposits and masses of underconsolidated Tertiary shale. The Gulf Coast basin contains many small depocenters which developed in response to Cenozoic progradation and local structural formation by salt and shale diapirism, (figs. GM-10, GM-11, and GM-12). Principal structural features in the Gulf Coast basin are salt domes, regional "growth" faults and masses of mobilized undercompacted shale (fig. GM-5) that have resulted from the presence of an underlying Jurassic salt basin and the depositional and lithological characteristics of the Cenozoic sedimentary wedge that gradually advanced gulfward across it. These structural features are contained within the young sedimentary prism and are little related to deep-seated tectonic forces or crystalline basement structure.

Cenozoic strata in the northern and western margins of the Gulf are offset by a complex network of normal growth faults (fig. GM-5) that formed in response to depositional loading and attendant plastic flowage

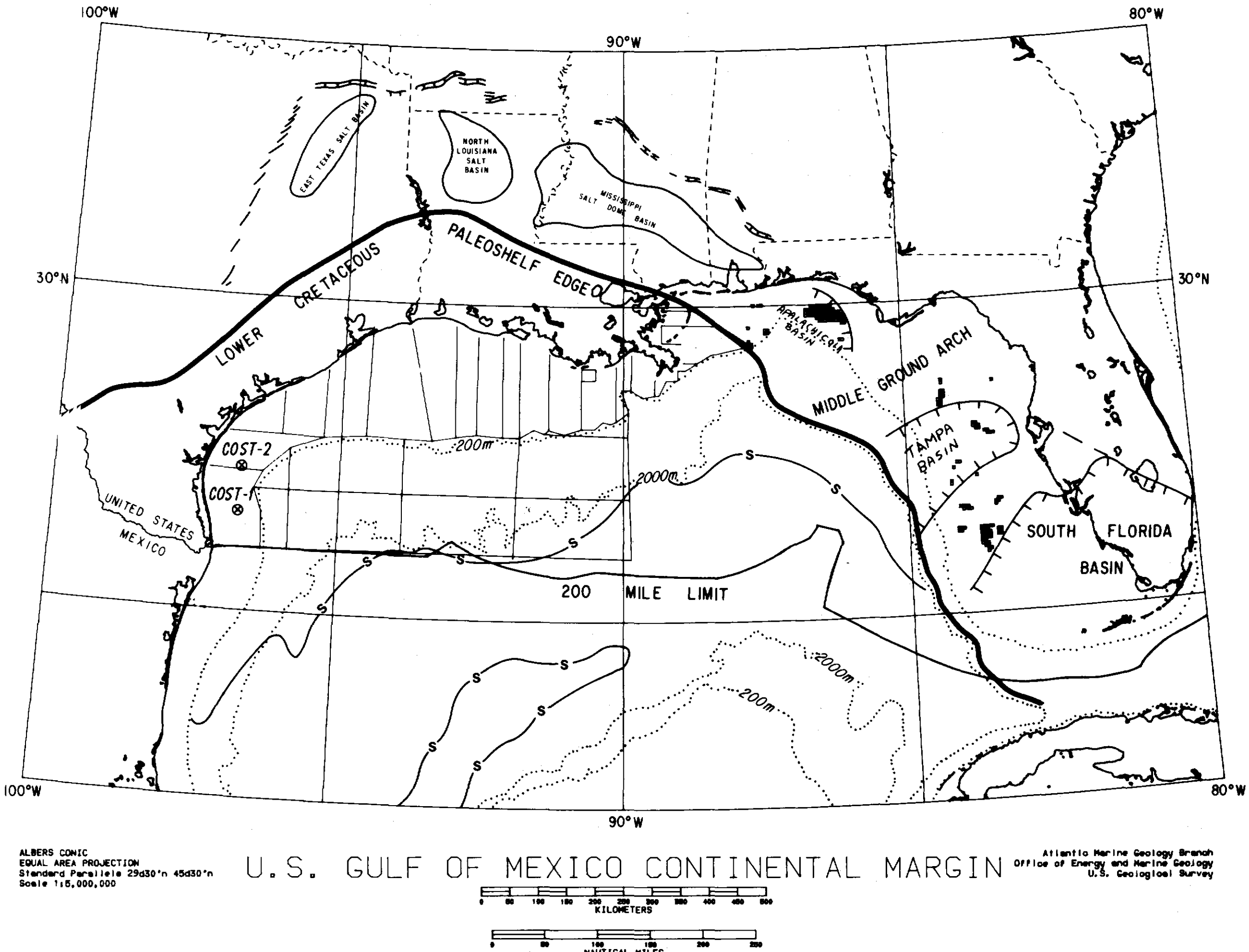


Figure GM-9. General structural map of the Gulf of Mexico showing basins around the rim of the Gulf, Lower Cretaceous paleoshelf edge, salt front (s) in the deep Gulf, leasing activity in eastern Gulf, and OCS areas in central and western Gulf of Mexico.

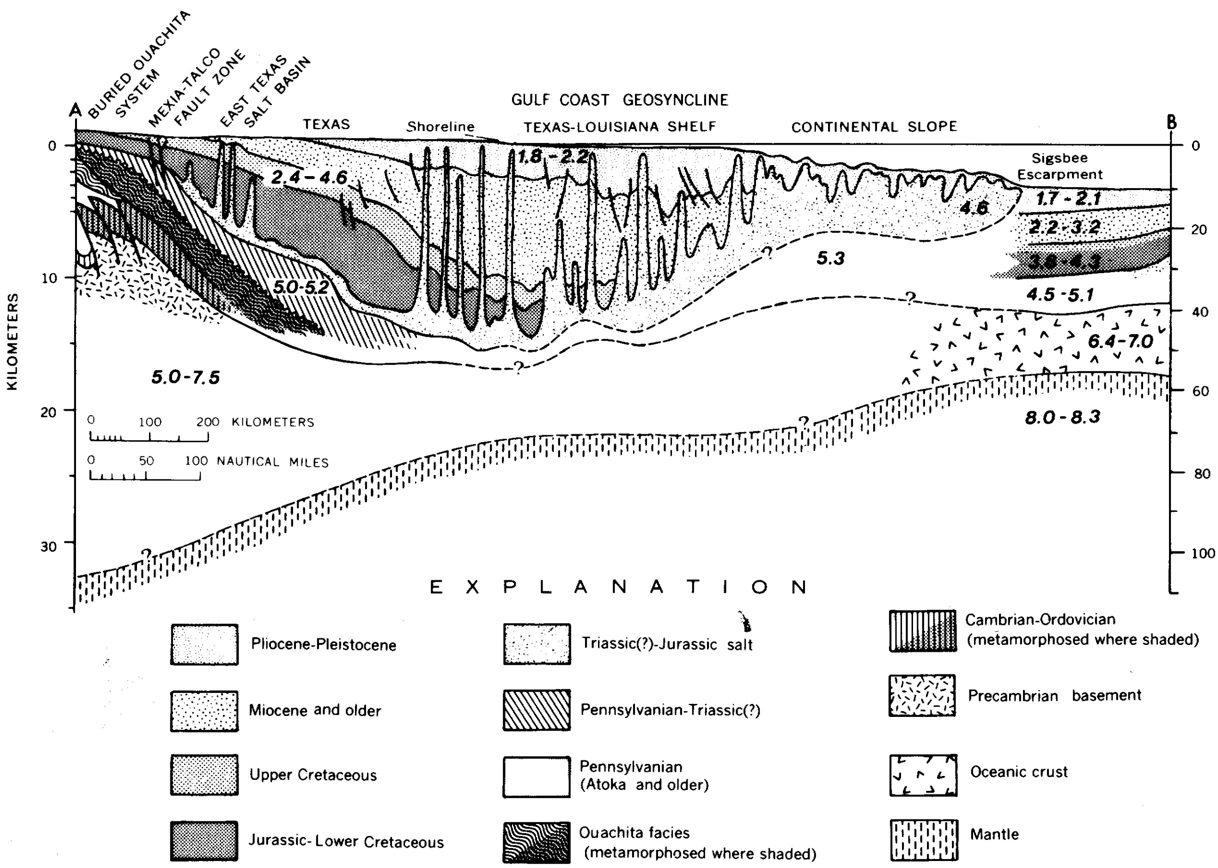


Figure GM-10. Generalized cross section of northern Gulf of Mexico continental margin. Seismic velocities in km/sec and shown in heavy numerals; Location of section shown on figure GM-4. From Martin (1982, fig. I-4).

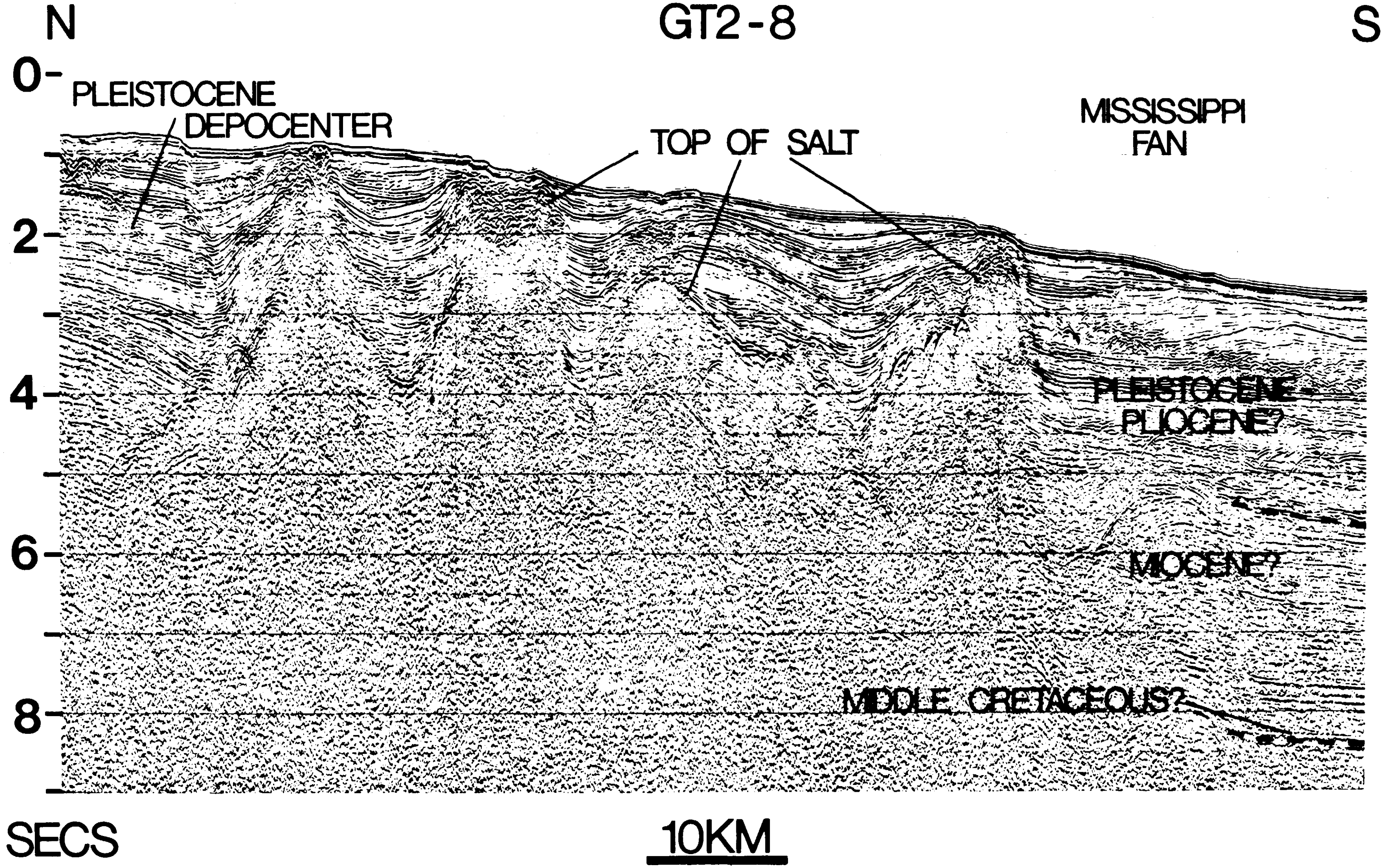


Figure GM-11. Multichannel seismic-reflection profile acquired by University of Texas (UTMSI) across eastern end of Gulf Coast basin salt diapir field near 90°W.

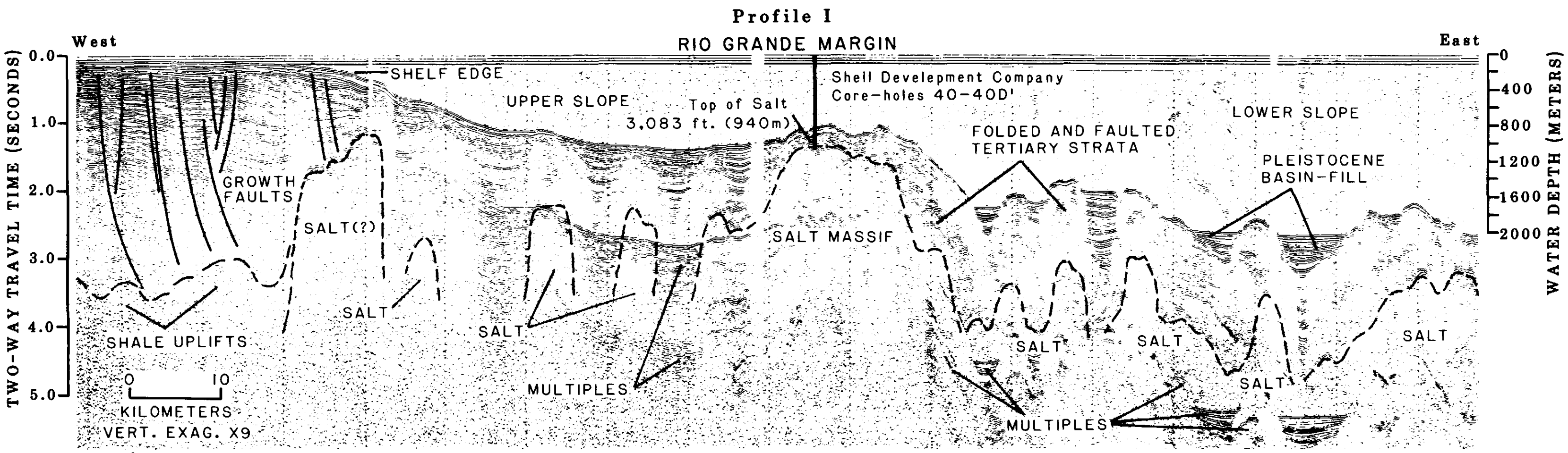


Figure GM-12. Single-channel sparker profile across Continental Shelf and Slope east of the Rio Grande showing variation of structural deformation in Tertiary and Quaternary strata from movement of undercompacted shale and diapiric intrusion by narrow salt plugs and broad salt massifs. From Martin (1982, fig. I-17).

of underlying materials along successive shelf edges (fig. GM-6) during Tertiary and Quaternary times. Sedimentary loading of thick deposits of Jurassic salt in the northern and western margin caused the formation of extensive fields of salt diapirs, which have pierced many thousands of feet of overlying strata (figs. GM-5, GM-8, and GM-10). Large regions of the northern Gulf margin have also been complexly deformed by load-induced flowage of water-saturated, undercompacted shales of Tertiary and Quaternary age. Similarly, loading of water-saturated muds that were rapidly deposited and buried in the western margin from Louisiana-Texas to the Bay of Campeche caused plastic flowage that buckled over-lying strata to form a complex and extensive system of linear anticlines and synclines (figs. GM-1 and GM-12).

Mesozoic and Cenozoic strata in the deep-basin regions of the Western Gulf Rise, Sigsbee Plain, and lower Mississippi Fan have been deformed as a result of regional crustal warping and adjustments owing to differential sedimentation and compaction; the stratigraphic sequence mainly is affected by faults and by broad wrinkles having a few tens to hundreds of feet or more of relief (fig. GM-13).

Petroleum Exploration on the Gulf of Mexico Margin

There is active production of gas and oil from many thousands of wells on the Texas-Louisiana shelf into primarily Miocene and younger units of the Gulf Coast basin (Havran and others, 1982). Although most leasing has been on the Texas-Louisiana shelf (Figure GM-14), leasing and exploratory drilling are moving into deeper water (200 m to 2,000 m, fig. GM-9) with numerous deep water leases sold in recent OCS sales 72 and 74. Activity in the eastern Gulf has focused primarily on the Destin Dome anticline (just south of the Florida panhandle), around the edges of the Tampa basin and on the northwest side of the South Florida basin (figs. GM-9 and GM-14).

Future petroleum prospects in the Gulf include deeper units in already producing areas, Pleistocene sands on the upper slope, and Cretaceous-Jurassic units on the West Florida shelf and deep-water areas. Deep Lower and Middle Miocene sands should have significant potential on the Texas and Louisiana shelfs and possibly Pliocene sands on the Texas middle shelf. The Jurassic Norphlet and Smackover carbonate units around Mobile Bay should continue offshore onto the West Florida shelf, as should the productive Upper Cretaceous Sunniland Formation in southern Florida.

Future Studies

There is an urgent need for mapping and evaluating Cenozoic and Mesozoic sedimentary structures and crystalline basement on the Gulf of Mexico continental margin, with emphasis on studies of lithofacies and depositional environments. Industry quality seismic-reflection data (of 96 channels or more) are needed on a regional basis to map and evaluate Cenozoic and pre-Tertiary units. This should be carried

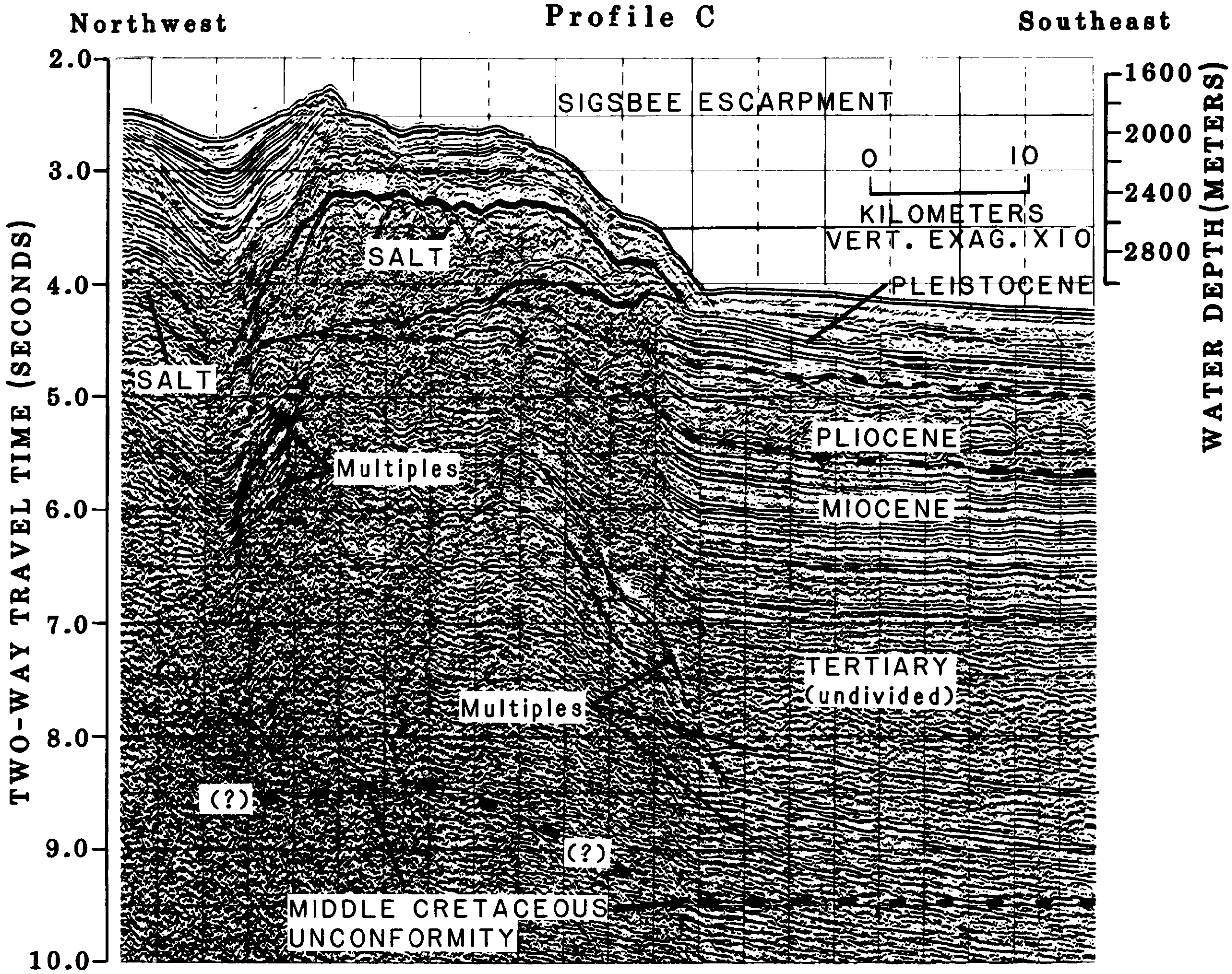


Figure GM-13. Multifold seismic reflection profile across Sigsbee Escarpment showing wedge-shaped mass of salt extruded seaward over beds of Miocene age and younger. Salt mass became detached from main salt body upslope as a result of flowage away from sediment loads exerted by rapid accumulations of large volumes of sediments upslope. From Martin (1982, fig. I-15).

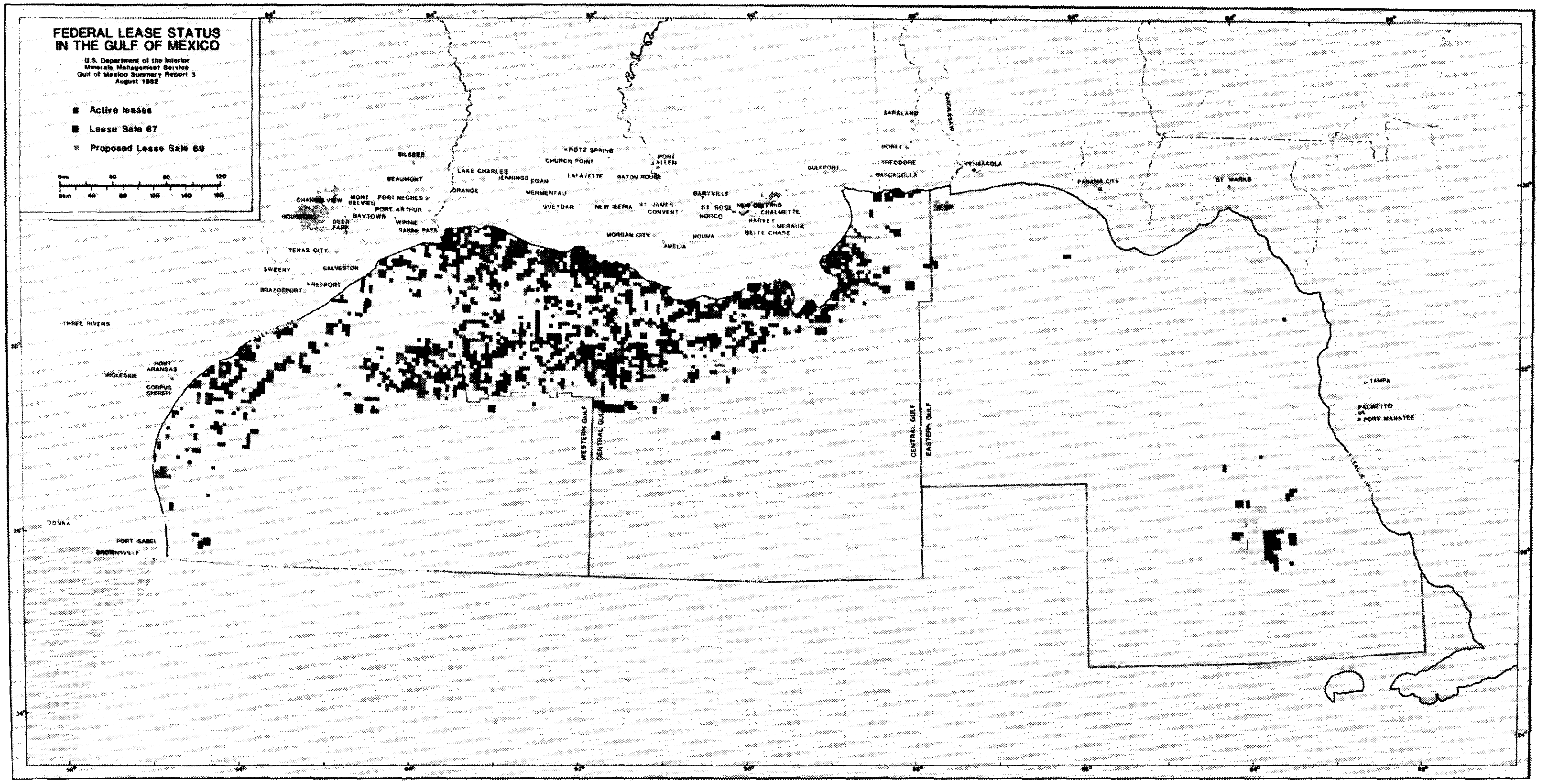


Figure GM-14. Federal lease status in the Gulf of Mexico. From Havran and others (1982, Plate 1).

out in conjunction with regional transect programs across the margin and should include a number of drill holes to provide litho-stratigraphic control where exploration drilling is not presently in progress. Existing publicly available multichannel data in the Gulf is reasonably summarized in fig. GM-15. Also, salt and shale structures mask older units of the Gulf Coast basin, while seismic reflection profiling yields rather poor results on much of the West Florida shelf. The problem of limited seismic penetration in much of the Gulf needs to be remedied with more sophisticated studies such as two-ship expanding spread profiles and constant offset profiles (COP) (Stoffa and Buhl, 1979) to obtain improved velocity with depth structure and for mapping deep structural surfaces. Aeromagnetic surveys on the U.S. Atlantic margin (Klitgord and Behrendt, 1979) and other regions of thick sediment accumulation have provided important basement depth and structure information, in the absence of adequate seismic-reflection profile data. A considerable number of industry proprietary aeromagnetic surveys exist in the Gulf of Mexico; there should be a publicly available aeromagnetic survey of the Gulf margin.

WEST COAST PACIFIC MARGIN

Regional Geologic Setting

The U.S. Pacific continental margin is an active margin involving collision and shear-zone tectonics. The following abstract of the Neogene basin formation is from Blake and others (1978).

> More than 90% of the known petroleum accumulations west of the San Andreas fault in California are in strata deposited in areally restricted Neogene basins that formed during a major tectonic reorganization of western California. These deep, localized Neogene basins replaced broad, regionally persistent Paleogene depositional aprons, although some of the Neogene basins in northern and central California had Paleogene precursors. The evolution of each of the Neogene basins is complex, and aspects of the kinematics of each are unique; nonetheless, all can be considered products of an overall right-lateral shear system associated with a sliding margin between the Pacific and North American lithospheric plates.
>
> The sliding margin developed in western California about 29 m.y. ago, when the Pacific plate contacted North America after subduction of the intervening Farallon plate. The initial position of the common boundary between the Pacific and North American plates was along the continental margin. Right-lateral slip between the Pacific and North American plates gradually shifted eastward to right-lateral slip faults, such as the San Andreas, located farther inland. The shift seems to be documented by geologic-tectonic relations in the southern California area. About 300 km of right-lateral slip has occurred along the San Andreas fault during the past 10 to 15 m.y., and at

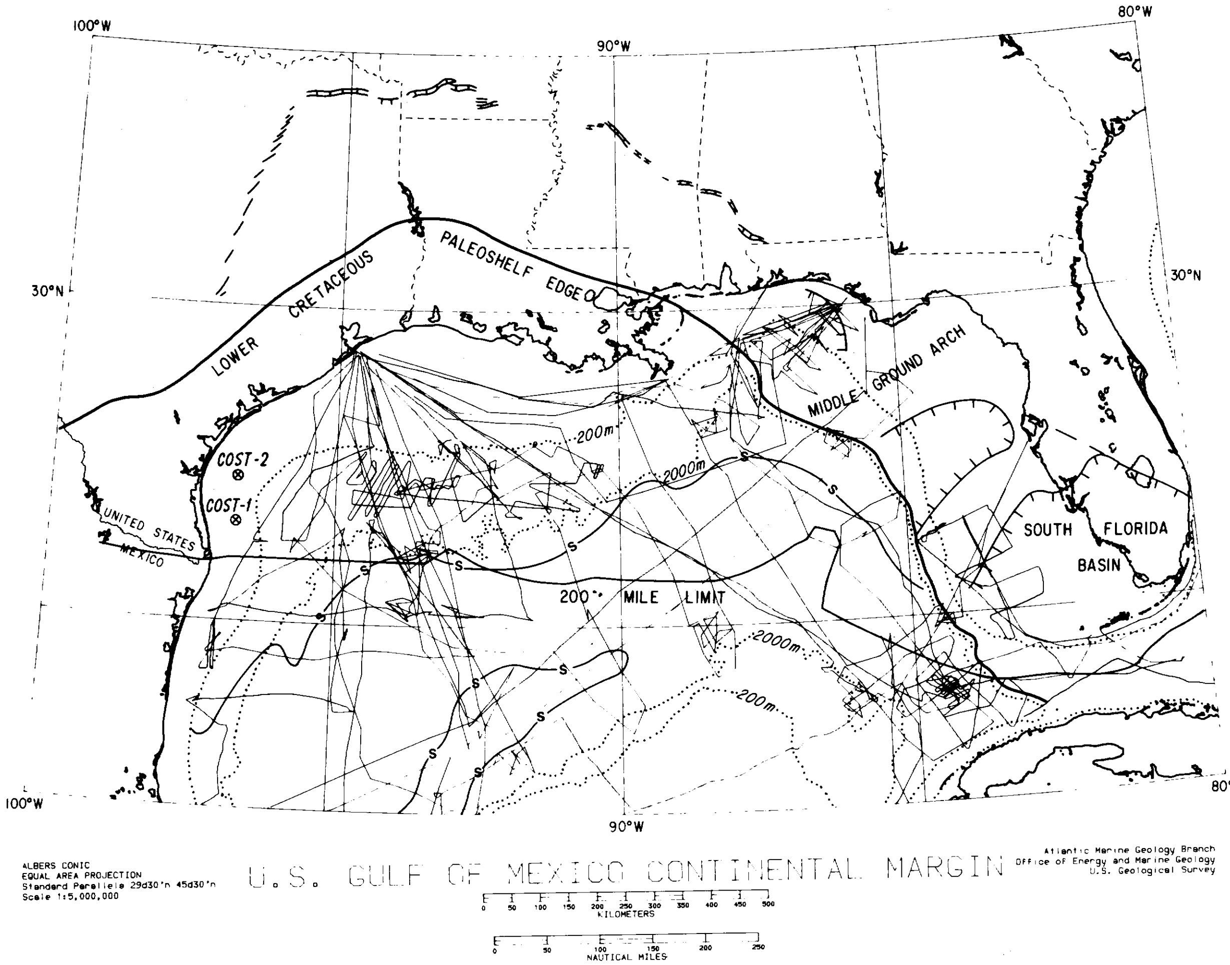


Figure GM-15. Location of University of Texas (UTMSI) multichannel seismic-reflection profiles in the Gulf of Mexico. Transit lines have not been removed.

least several hundred additional kilometers along associated right-slip faults of the San Andreas system.

The Neogene basins in southern California began to develop during the interval in which the boundary between the Pacific and North American plates shifted from the continental edge to the San Andreas fault, apparently because the step-by-step switch to different surfaces of weakness caused local extension and compression within a broad zone of right-lateral shear. A major phase of basin formation appears to have been synchronous with a change in azimuth of relative shear between the Pacific and North American plates to a more westerly direction, resulting in extensional strain. This change in motion initiated basin development in offshore central and northern California and affected the ongoing development of basins as a result of right-lateral slip along the San Andreas and related faults in other parts of California.

Offshore sediment accumulation, in addition to slow pelagic sedimentation, occurs in these narrow marginal basins and four large deep sea fans developing on the Continental Rise. We shall first discuss the narrow shelf basins and then briefly examine the deep-sea fans.

California, Oregon and Washington Continental Margin

Regional Geologic Setting

U.S. Geological Survey investigations have made possible a broad regional understanding of the geologic and stratigraphic framework of the western U.S. continental margin. Most of the study has been concentrated on the Continental Shelves, the area of shallow young Tertiary sedimentary basins (fig. WC-1) (Figures related to the west coast are designated WC). Industry has concentrated its efforts in this same area. The structure is known primarily from single-channel acoustic reflection records and a limited number of multichannel records (fig. WC-2). Stratigraphy is known from exploratory wells drilled in the early 1960's, several more recent COST wells, sea-floor sampling and by extension, from onshore mapping.

At the south, the northwest-trending network of structural and physiographic ridges and basins of the California borderland record a history of major accretionary events (fig. WC-3). All but the outermost set of ridges and basins are bounded on the north by the east-west trending Santa Barbara basin, a structural enigma whose boundaries are not certainly known, whose basement rocks have been sampled only by proprietary drilling offshore and whose northern margin may presently be undergoing subduction beneath the east-west trending Transverse Ranges. This region contains the petroliferous Santa Barbara Channel basins and the Santa Maria basin where the most recent discoveries have been from the Miocene Monterey Formation.

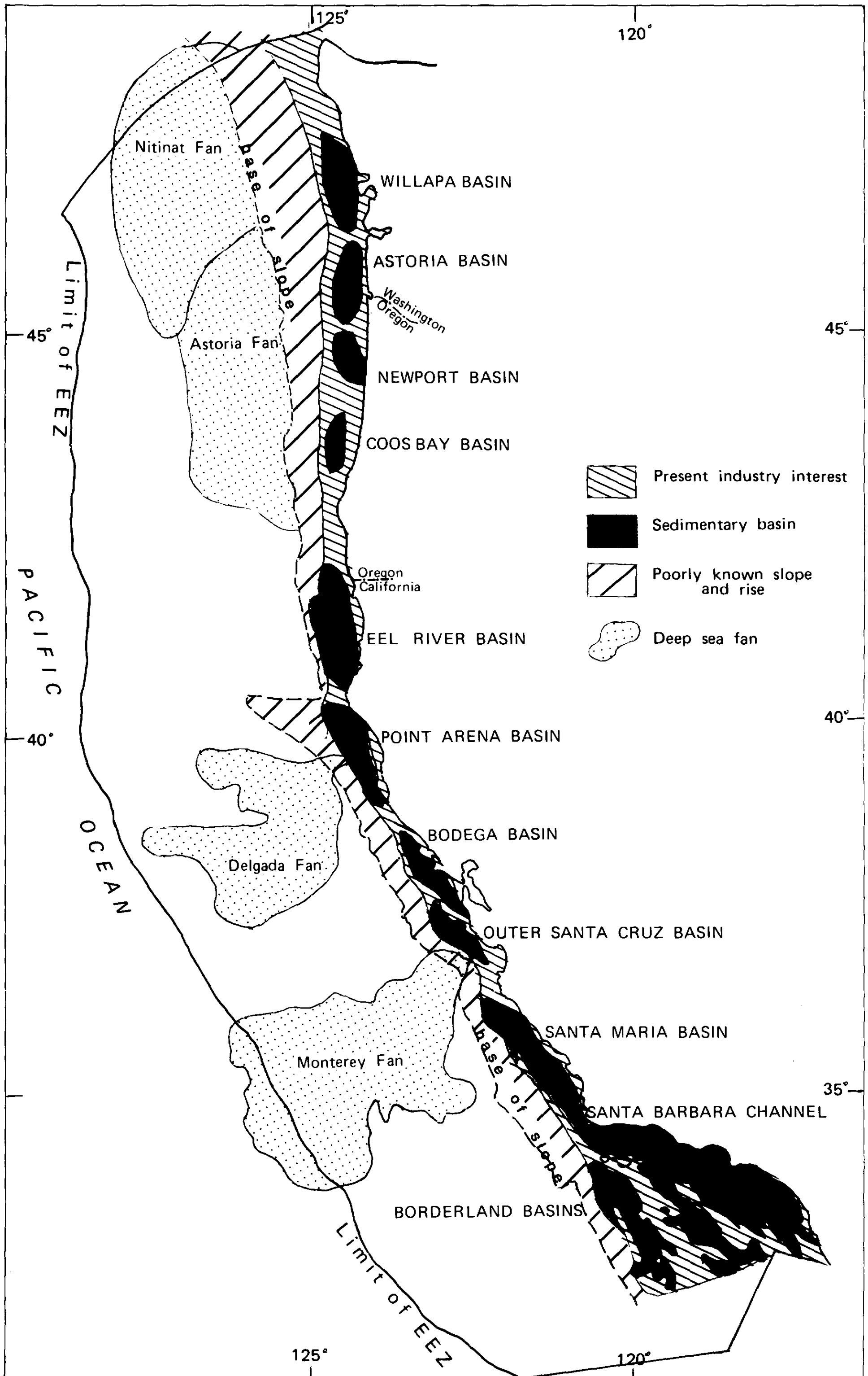

125°
120°
45°
40°
35°
Nitinat Fan
Astoria Fan
Delgada Fan
Monterey Fan
base of slope
Limit of EEZ
PACIFIC
OCEAN
WILLAPA BASIN
ASTORIA BASIN
Washington
Oregon
NEWPORT BASIN
COOS BAY BASIN
Oregon
California
EEL RIVER BASIN
POINT ARENA BASIN
BODEGA BASIN
OUTER SANTA CRUZ BASIN
SANTA MARIA BASIN
SANTA BARBARA CHANNEL
BORDERLAND BASINS
Present industry interest
Sedimentary basin
Poorly known slope and rise
Deep sea fan

Figure WC-1.

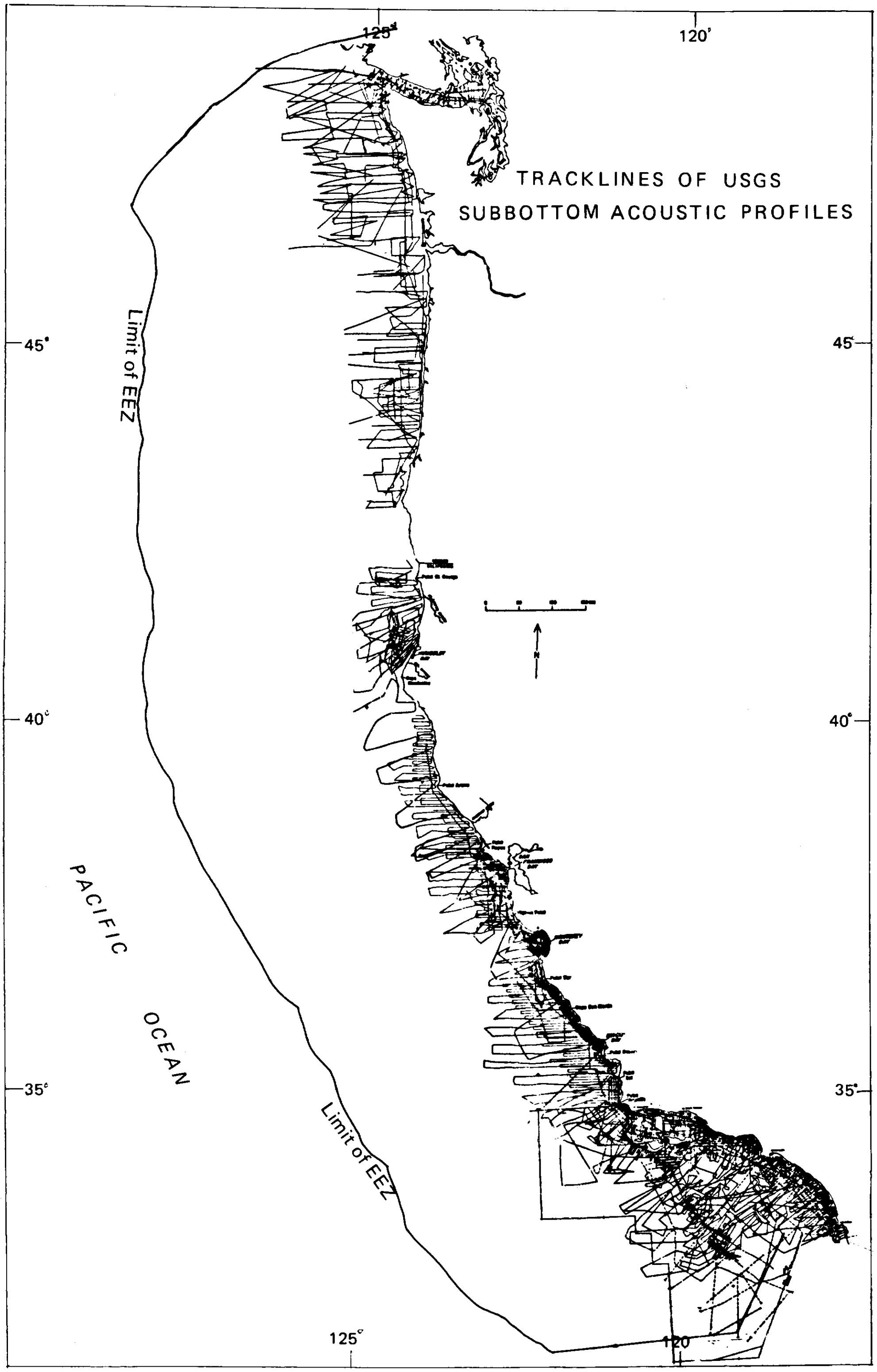

125°
120°
TRACKLINES OF USGS
SUBBOTTOM ACOUSTIC PROFILES
Limit of EEZ
45°
45°
40°
40°
PACIFIC
OCEAN
35°
35°
Limit of EEZ
125°
120

Figure WC-2.

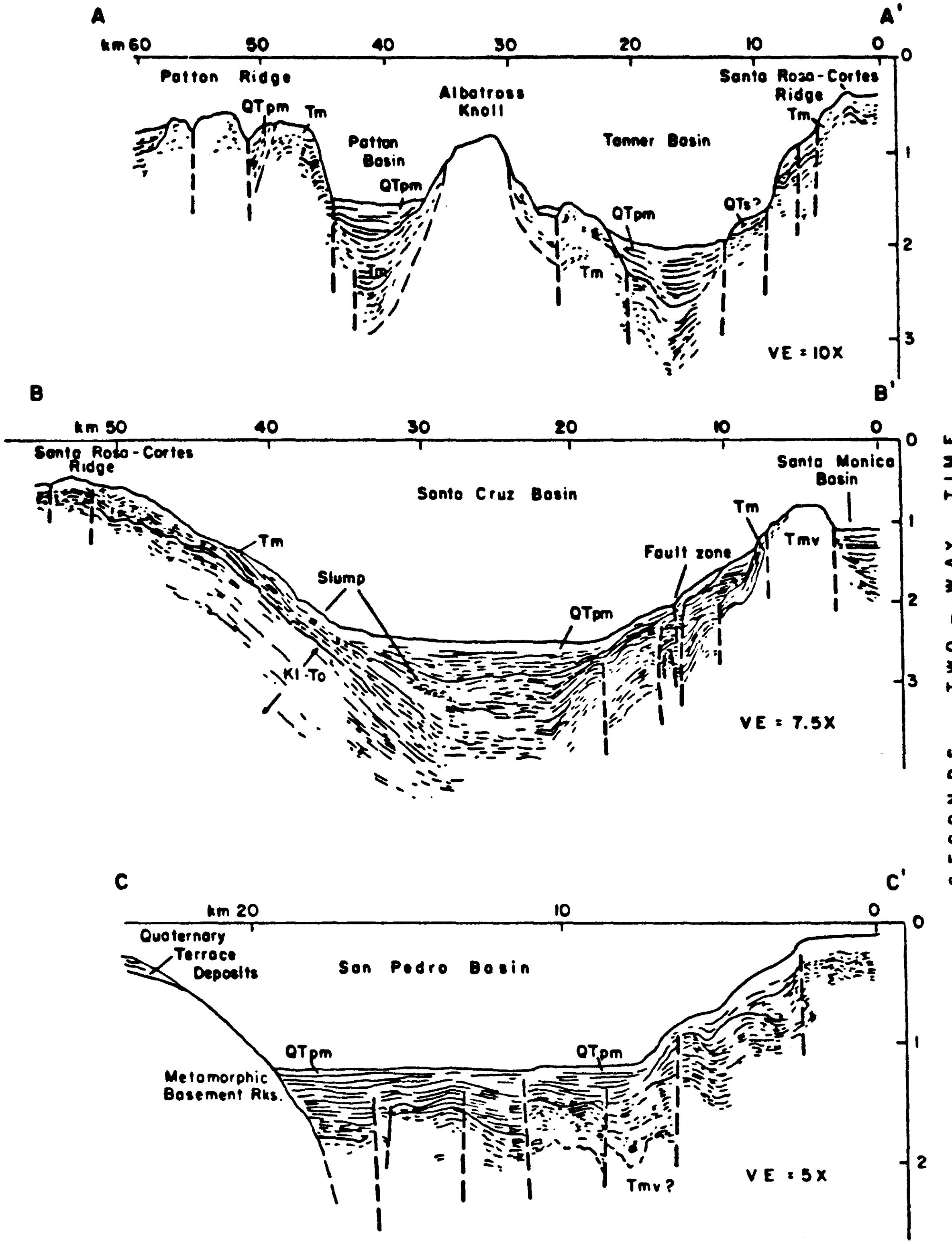


Figure WC-3. Interpretations of single-channel reflection records across the southern California borderland.

Northward from the borderland, the Continental Shelf and Slope off central and northern California narrows and the shelf supports shallow young Tertiary basins that are generally bounded on the east by major faults with large vertical separation, and on the west by structural highs (fig. WC-4). Santa Maria Basin is the southernmost of these basins and is the site of active oil-industry exploration drilling, also aimed at the prolific Miocene Monterey Formation. Basement rocks beneath the narrow shelf and slope are former crustal slivers that were accreted to the continent; some composed of marine metasediments of a Jurassic to early Tertiary(?) subduction complex, some of Cretaceous magmatic rocks, and possibly others of unknown origin. Structures within the basement rocks and the shallow Tertiary basin record both the compression and wrench faulting associated with oblique subduction that largely ceased with the final subduction of the Farallon Plate, and right-lateral shear that has accompanied the ensuing transform fault motion between the North American and Pacific Plates.

Coastal transform faulting ends at the Mendocino triple junction on the northern California shelf. North of the triple junction along the coasts of northern California, Oregon, and Washington, the effects of modern oblique subduction of the Gorda and Juan de Fuca oceanic plates is superimposed upon rocks and structures that record earlier episodes of early and mid-Tertiary subduction and intervening periods of transform faulting and extension. Compression from plate convergence has produced low-angle imbricate thrusts and, as in central and northern California, young Tertiary basins formed on these older rocks on the shelf (fig. WC-5).

Reconnaissance scale geologic hazard studies (e.g., surface and near-surface faulting, seismic activity, shallow gas, active tectonic features, slumps, slides and areas of mobile sea floor, areas of active erosion or deposition) have been completed for most of the shelf as part of the USGS investigation of the OCS leasing program.

Future Studies

The West Coast Pacific continental margin is still a frontier region, except for the Santa Barbara Channel. Recent oil and gas discoveries in the Santa Maria basin point to the need for a better understanding of the basins to the north. Future research requirements include:

(1) More detailed knowledge of the stratigraphy and structure of the slope, rise and deep ocean basin that are now only poorly known.

(2) A general assessment of modern geologic processes and stability of the surface and near-surface deposits on the Slope and Rise.

(3) A better understanding of the rates and processes related to geologic hazards (e.g., slide triggering mechanisms, geologic controls of soil deformation properties, seismic environment and sea-floor

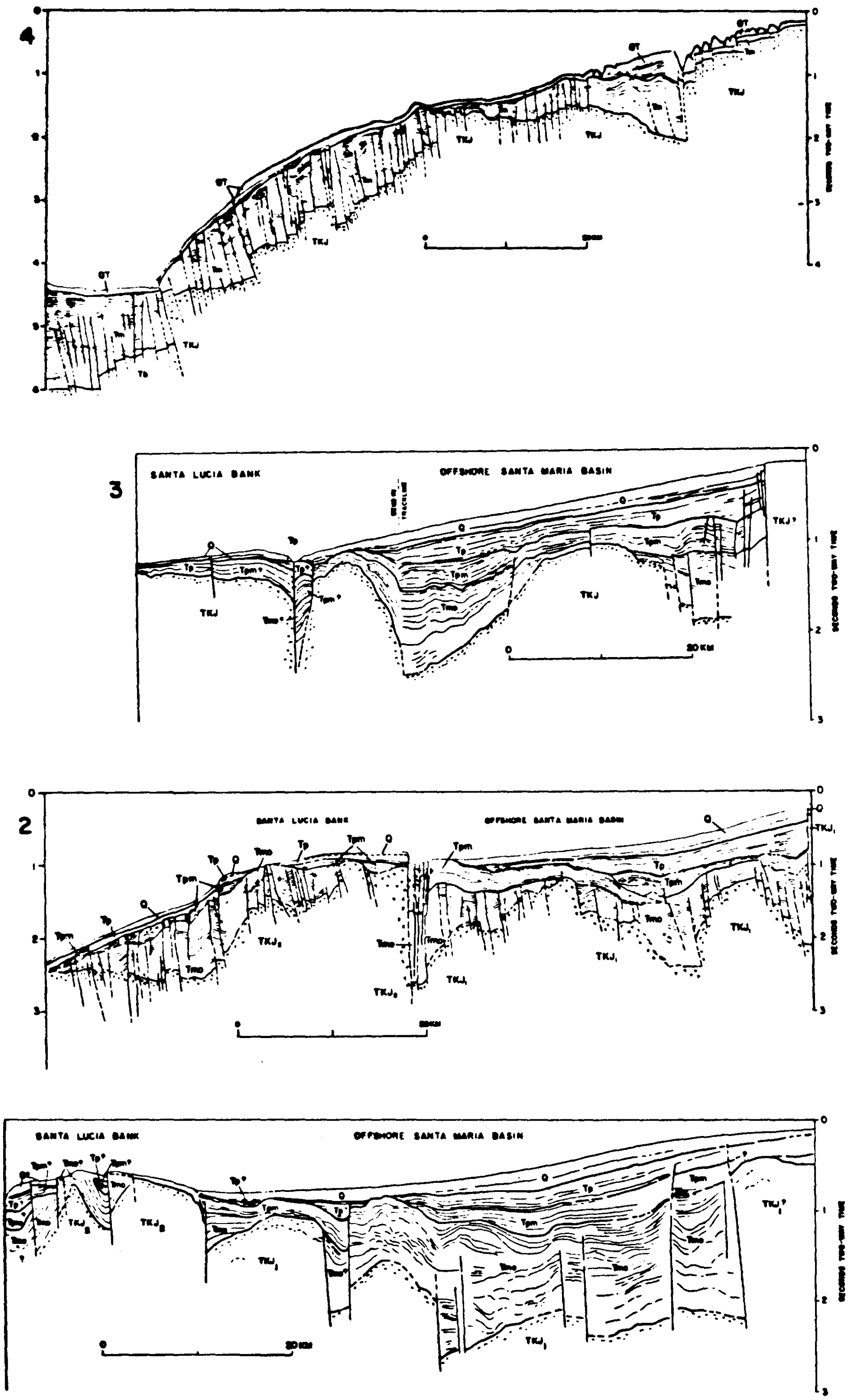


Figure WC-4. Interpretations of single-channel reflection records across Santa Maria basin. Poorly known slope basins on sections 2 and 4 lie seaward of the well-studied Santa Maria basin.

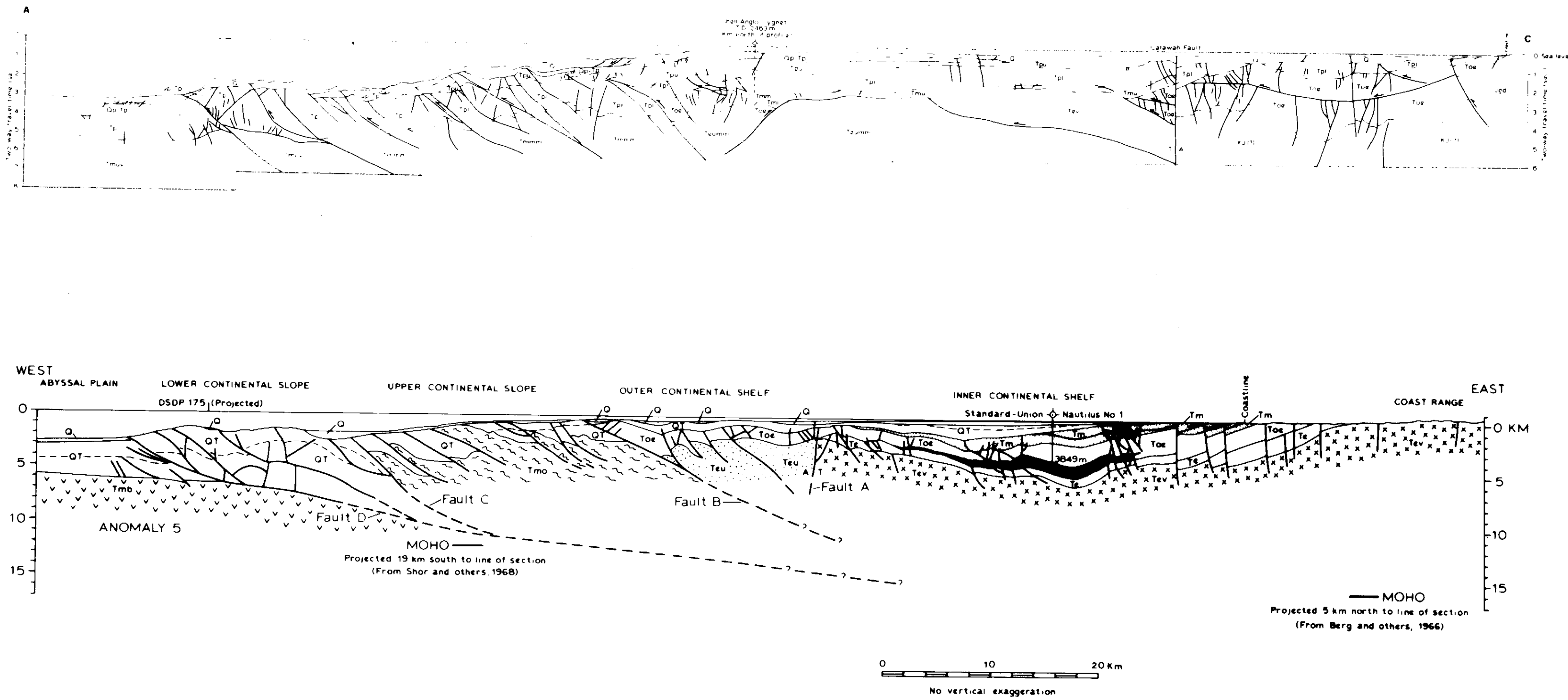


Figure WC-5. Interpretation of multichannel reflection records across northern Washington (top) and central Oregon.

seismic ground response, role of gas in sediment stability, rates and modes of sediment erosion and deposition as a function of steady state and non-steady state transport events and as a function of slope and rise physiography).

(4) Better understanding of offshore seismic activity and its bearing on coastal and offshore development.

(5) Understanding deep crustal structure and the composition and disposition of the accreted allochton basement blocks.

Critical data and information needs and priorities for data acquisition to carry out these programs are as follows:

(1) Multichannel seismic-reflection data are needed across the slope, rise, and into the deep ocean basin, and as fill-in surveys on the shelves. These data should be augmented by sea-floor sampling and shallow and deep stratigraphic test wells. Deep refraction data are needed to define deep crustal structure. Aeromagnetic data now limited to relatively small near-shore surveys should be collected over the entire Shelf, Slope, and Rise, and should extend to the offshore edge of the Tertiary sedimentary wedge that lies seaward of the toe of the Continental Slope. For estimates of resource potential, the shelf and slope surveys should include hydrocarbon analyses of rock samples and examination of near-surface gas.

(2) A rapid assessment of geologic hazards and examination for surface and near-surface geologic processes should be accomplished by a combination of long-range and mid-range sidescan sonar surveys over the entire slope and rise. These surveys should include or be augmented by multibeam bathymetry data, ideally over the entire area, and minimally in areas of special interest. Geologic hazard assessment should also include in situ and laboratory examination of soil properties from representative geologic environments to be used as a basis for generalizing soil response to natural or anthropomorphic phenomena. Sediment transport studies which bear on pollutant transfer, coastal stability, and erosion and deposition have been concentrated in the mid-shelf area, where sediment transport mechanisms and transport regimes are now moderately well understood. These studies should be extended shoreward to the nearshore coastal boundary, offshore down the slope and rise, and into the deep submarine canyons that dissect the slope and rise, and into the deep submarine canyons that dissect the shelf. This work will necessitate long-term in situ measurements that sample transitory events, and probably the development of new conceptual models.

Monterey and Delgada Deep-Sea Fans off California

Regional Geologic Setting

Preliminary studies using single-channel seismic-reflection profiles show that the Continental Rise (deep margin) off central California is dominated by 2 large deep-sea fans. Along the base of the slope and within locally filled basins under the fans, the sediment thickness reaches 2 to 3 km. Limited, short (<10 m) cores suggest that these turbidite fans contain abundant sand units. The latest Pleistocene and Holocene sediments, however, are not as rich in organic carbon as sediments in adjacent shallow shelf margin basins.

Future Studies

The initial phase of work should be to complete on-going studies of the geologic framework, facies analyses, and resource potential of this area. For these studies it is necessary to obtain: (1) multichannel seismic profiles to define the deeper basin characteristics, especially the transition from fan turbidites to slope sediments; (2) high-resolution (multibeam) bathymetry and deep-towed acoustic profiles to define surface morphology depositional processes, and modern facies relations; and (3) shallow and deep (Glomar Challenger capability) sediment cores to determine age, organic content, physical properties, and depositional facies of selected deep margin areas.

ALASKA CONTINENTAL MARGINS

Introduction

The EEZ of Alaska includes several large areas with excellent potential for oil and gas resources. These areas include passive margins (Arctic and Bering Sea margins) and a long active margin that extends from the eastern Gulf of Alaska to the western tip of the Aleutian Islands (fig. A-1) (Figures related to Alaska are designated as A). Sandwiched between the passive Bering Sea (Beringian) margin and the Aleutian Islands is the extensive Aleutian basin which, in its own right, has petroleum potential--sediment thicknesses are as great as 10 km. The Bering Sea Shelf region has large, mostly Tertiary basins, that are already of interest to industry. However, the framework beneath those basins also has economic potential. We don't even know the age and characteristics of those framework rocks. The continental framework beneath the wide Chuckchi Sea Shelf in the Arctic Ocean also is not understood.

We have arranged short summaries of the individual areas in the Alaska EEZ that are separated geographically and, in some places, geologically. Figures are included that will give the reader some understanding of the size of the basins and their acoustic characteristics.

Gulf of Alaska

Major goals of geologic studies that have been carried out in the Gulf of Alaska include investigations of petroleum potential, tectonic processes, and the tectonic and geologic history of convergent, collision, and transform margins. Regional multichannel seismic lines (line spacing of about 10 to 60 km) with associated refraction, potential

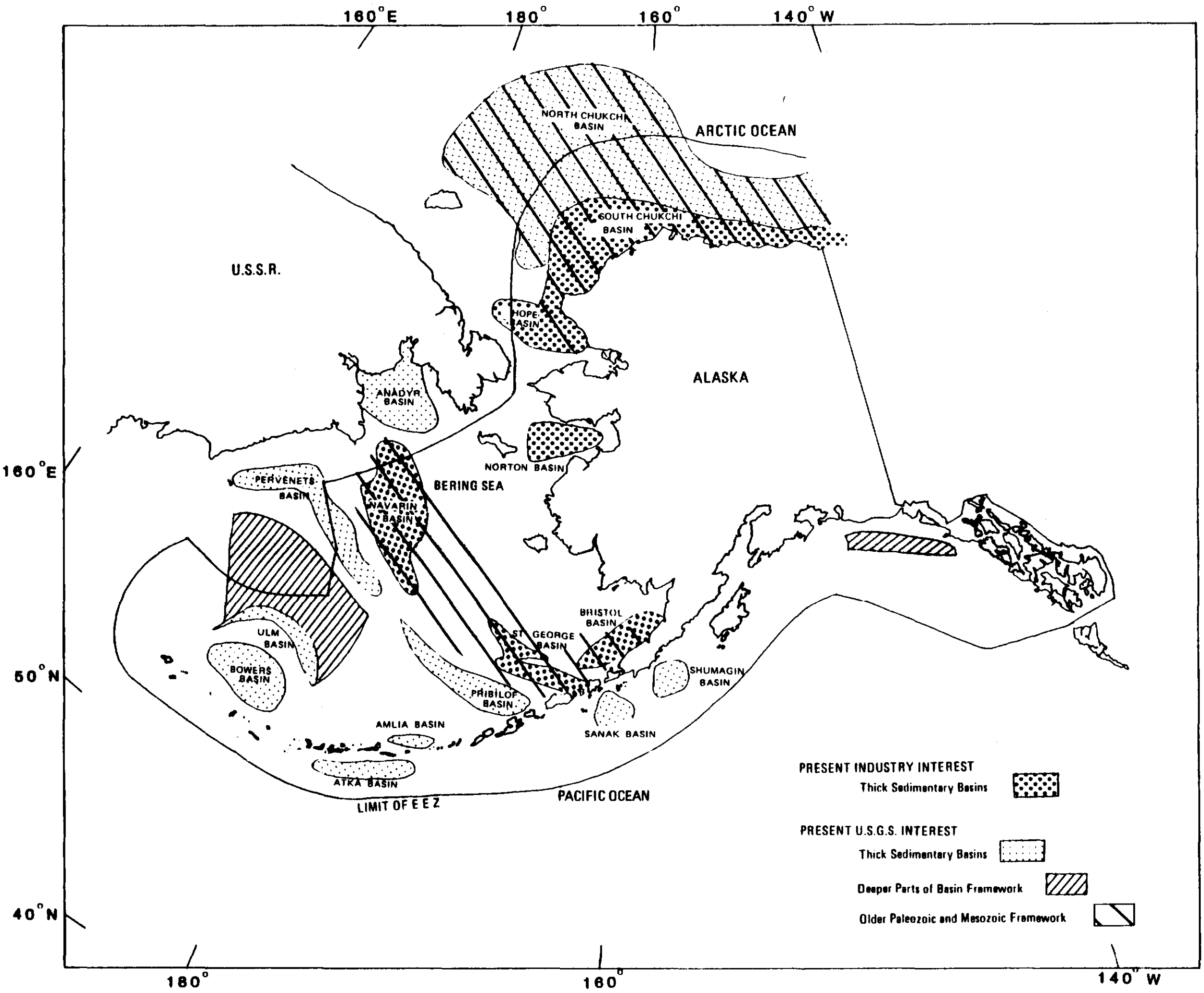


Figure A-1. Location map of major basins within the EEZ of Alaska.

field, and dredge data, have been acquired as part of these studies. With these data, the structure of much of the Shelf and parts of the Slope has been defined, and progress has been made in deciphering the tectonic and geologic history, and petroleum potential of the margins. Major conclusions include the identification of an allochthonous terrane, the Yakutat block, currently colliding with and accreting to southern Alaska; the identification of seismic events from at least 12 km deep that may indicate the presence of layered rocks deep within the margin (subducted or underplated and accreted sedimentary rocks?); the identification of long-lived transverse boundaries along the convergent margin; the delineation of some of the tectonic processes that occur at collision and subduction zones; and the sampling of rocks from the margin that indicate favorable characteristics for hydrocarbon generation and maturation.

Figure A-2, a CDP profile across the shelf just south of Kodiak Island, is included to show the characteristics of the shelf basins along the western part of the Gulf of Alaska. Figure A-3 shows tracklines of most available CDP data from the eastern Gulf of Alaska and figure A-4 is a structural contour map of the Gulf of Alaska near Icy Bay; CDP tracklines are numbered and two of them (406 and 409) are shown in figure A-5. Figure A-6 shows tracklines of CDP data from the westernmost part of the Gulf of Alaska and figure A-7 is a CDP profile (line 533) with an interpretive line drawing and magnetic gravity profiles.

Future Studies

Critical information needs in the Gulf of Alaska include acquisition of data to better delineate mineral and resource potential of the margins and adjacent deep-ocean basin. These needs include:

(1) Acquisition of data in areas of major data gaps. In particular, this includes the transform margin of southeastern Alaska and the deep-ocean basin adjacent to the margin. Seamounts may have significant mineral potential, and rock data are needed to evaluate this potential. Thick sedimentary accumulations (to 6 km) are present at the base of the slope in some areas; these basins might have hydrocarbon potential, and are incompletely defined at present.

(2) Acquisition of sample data to refine the understanding of the geologic history and resource potential of the continental margins. Especially needed are dredge data from areas where strata deeply buried beneath the shelf outcrop or are at shallow depths on the slope. Sample data are vital to define the characteristics of potentially petroliferous rocks beneath the shelf. Data from a few exploratory wells will become available in future years. However, stratigraphic drilling programs are needed to give a more complete picture of the stratigraphy, age, organic carbon content, and thermal maturity of rocks underlying the margins. Sampling programs are also needed to investigate the mineral potential of the seamount provinces of the Gulf of Alaska.

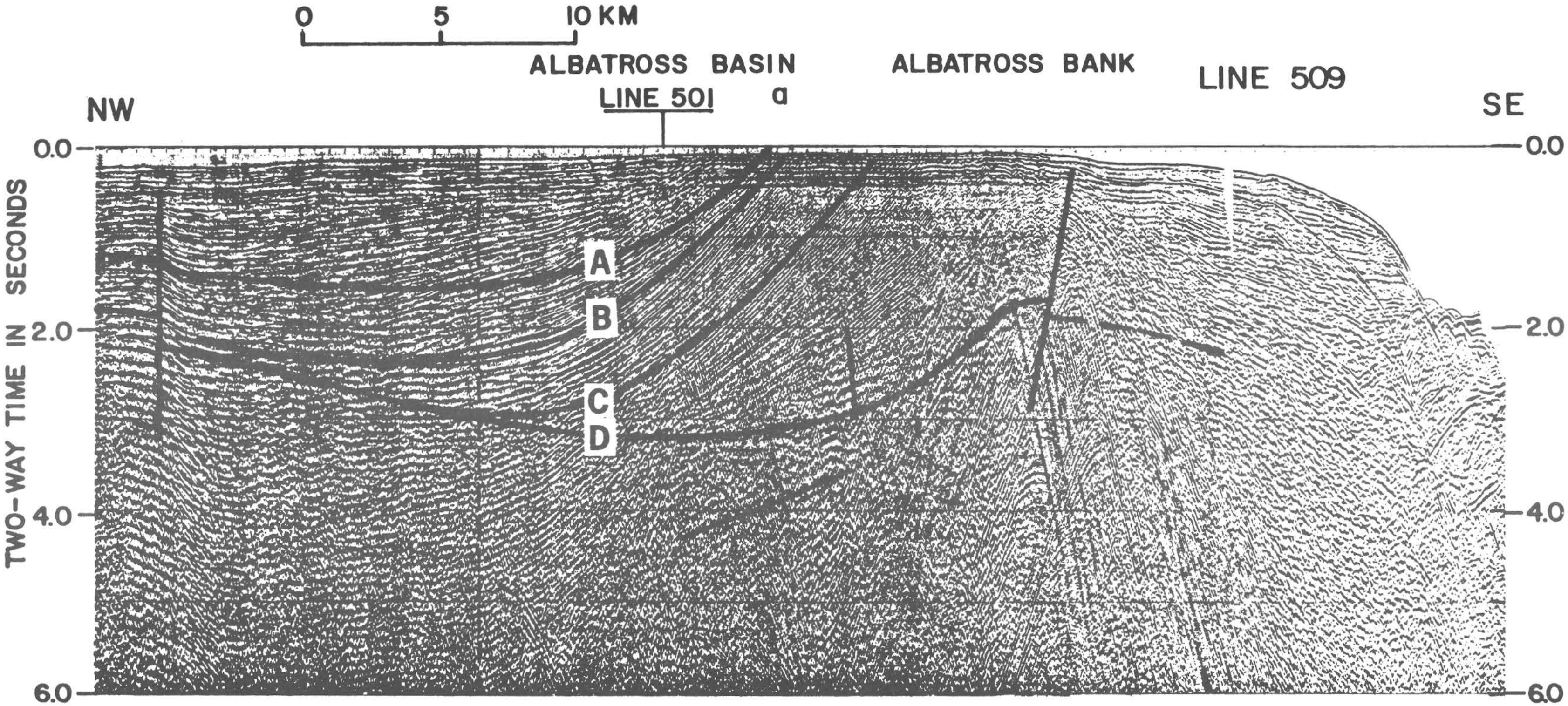


Figure A-2. CDP profile across Kodiak Shelf.

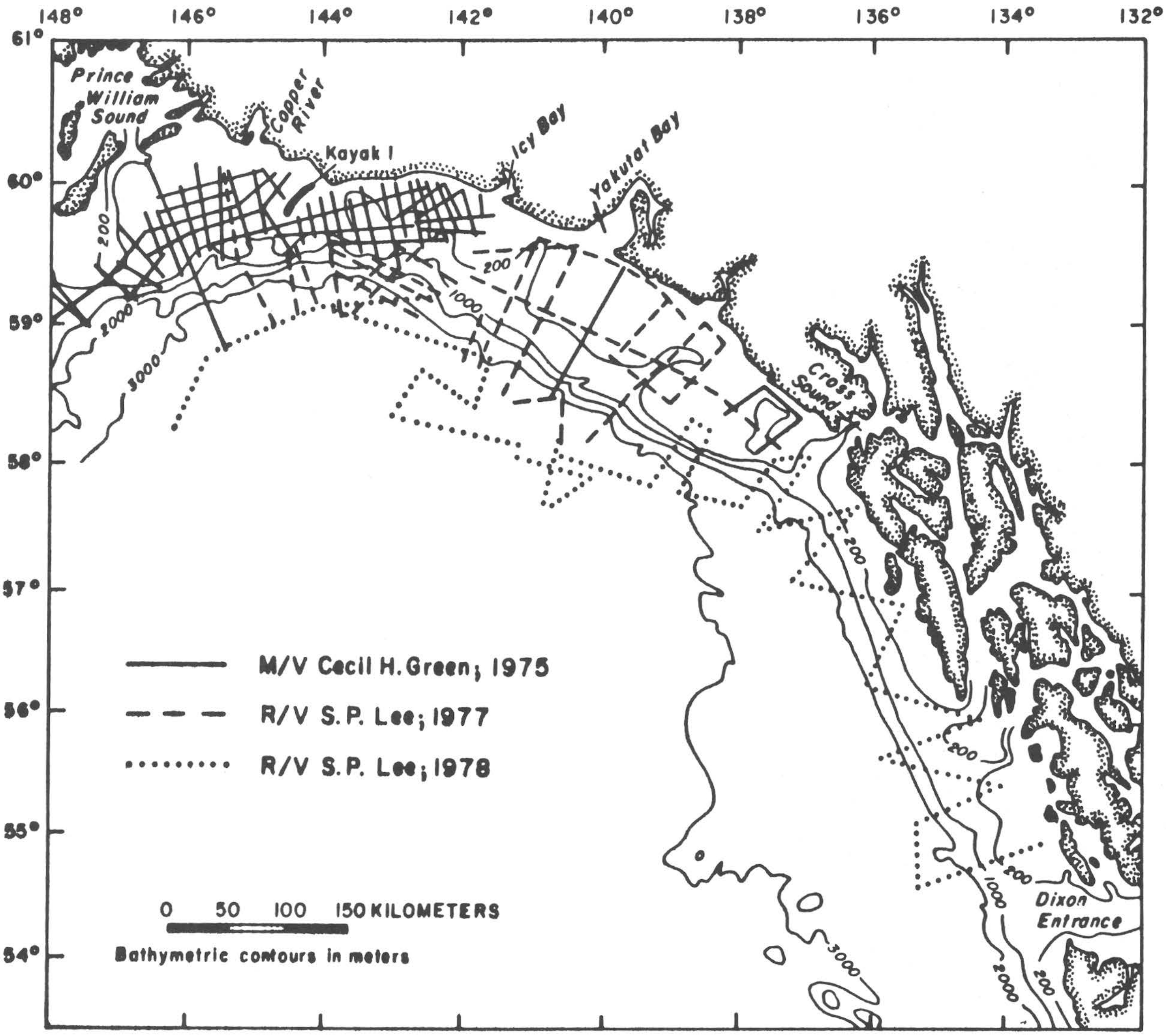


Figure A-3. Map showing CDP tracklines in eastern Gulf of Alaska.

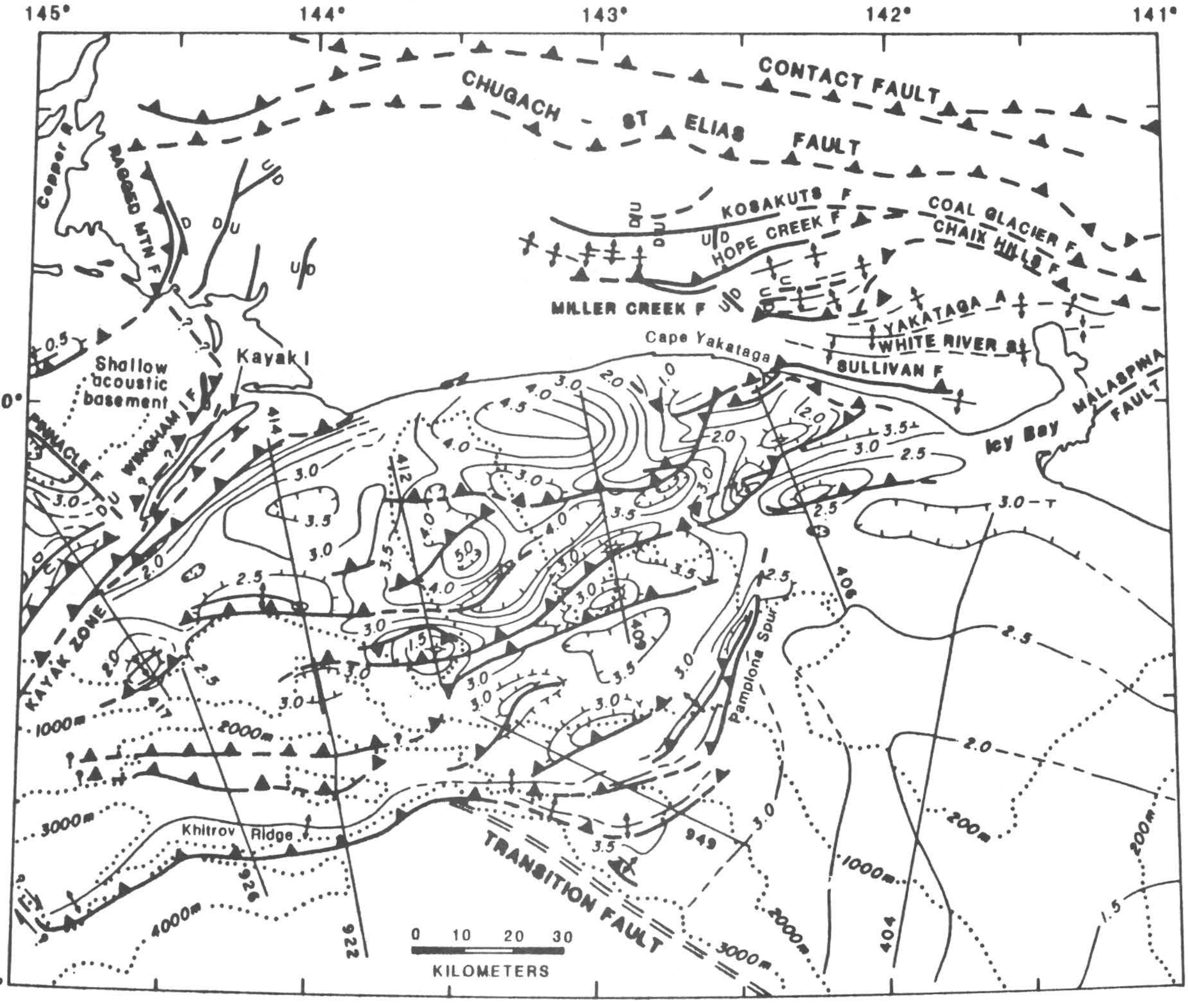


Figure A-4. Structural contour map of region near Icy Bay in the eastern Gulf of Alaska.

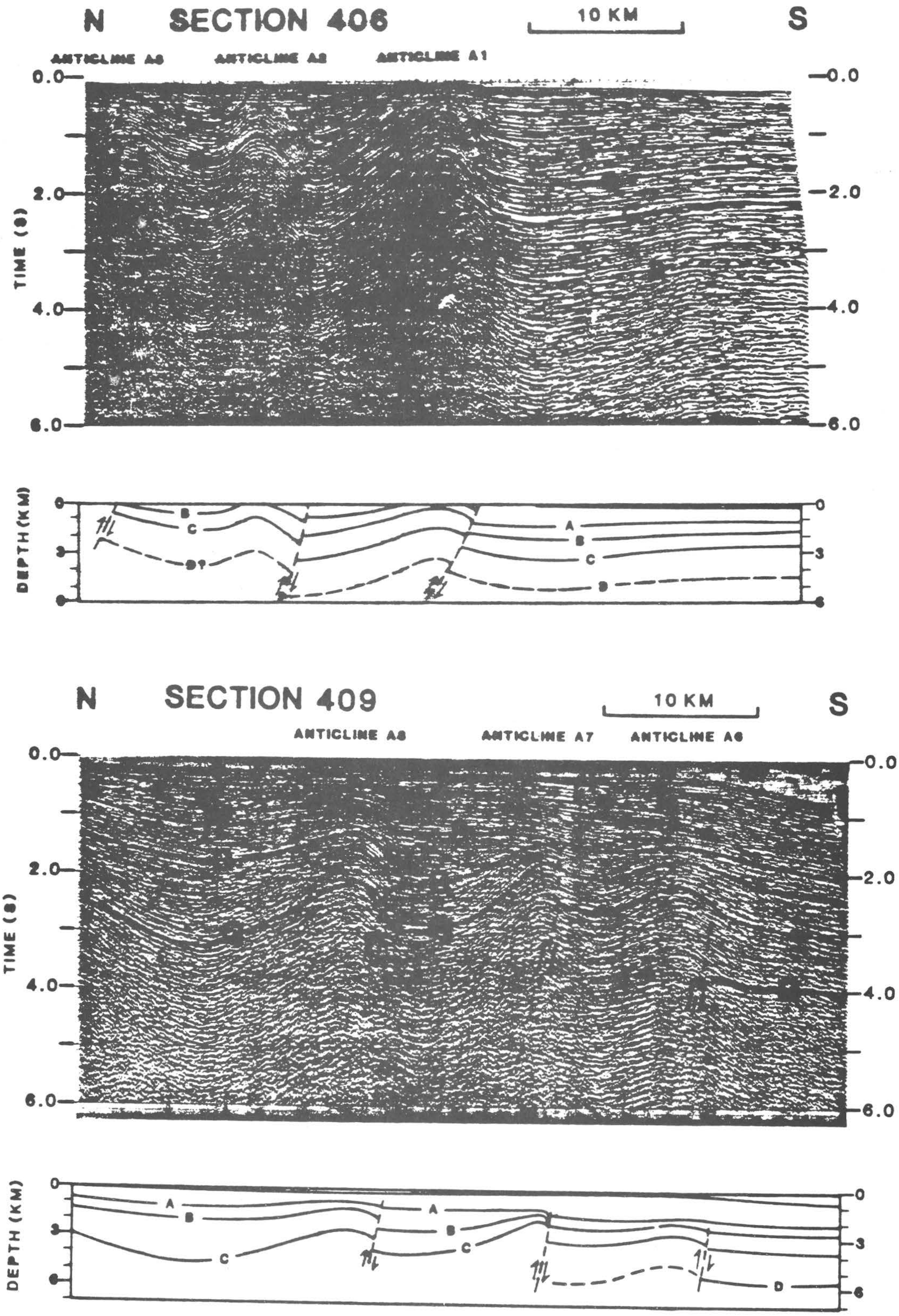


Figure A-5. CDP profiles 406 and 409 (see fig. A-4).

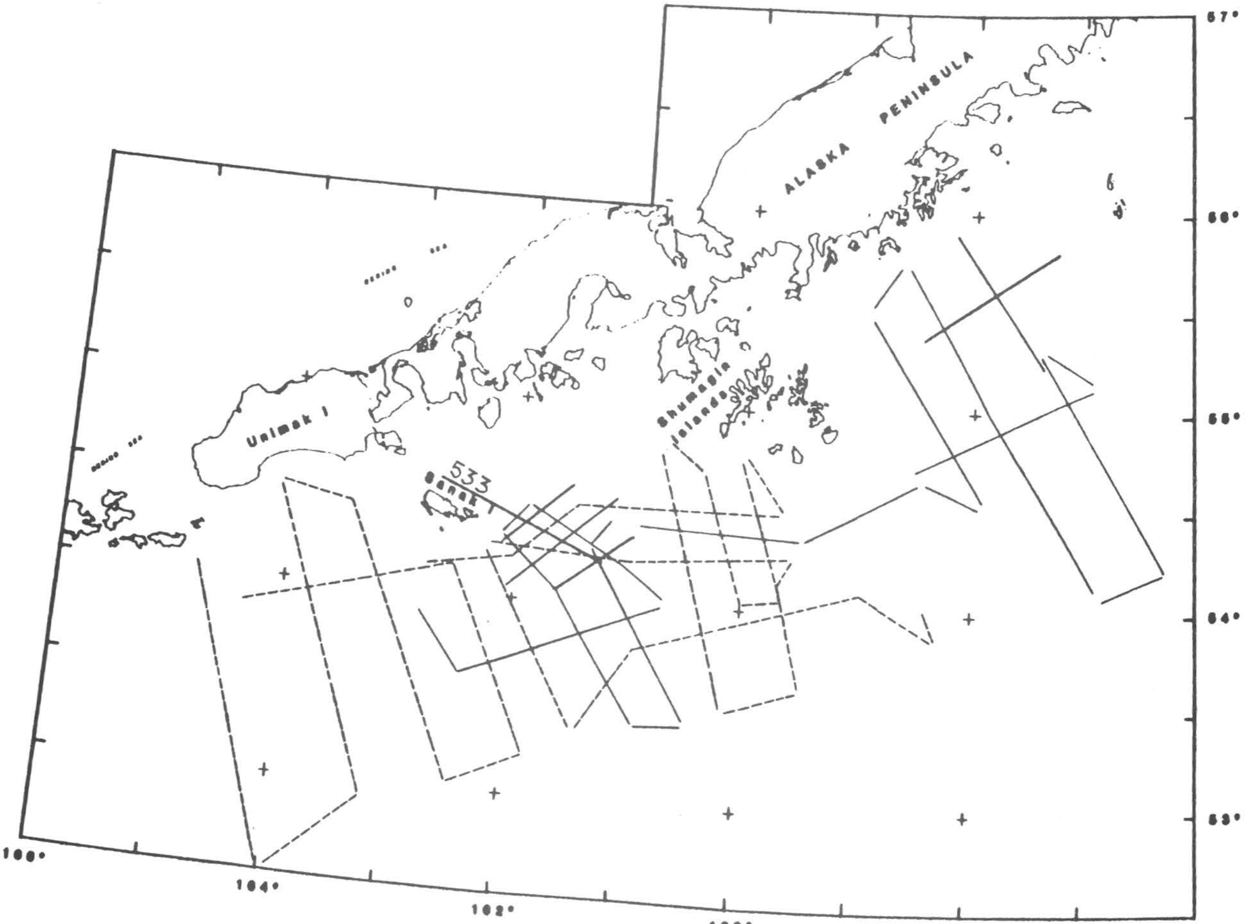


Figure A-6. CDP tracklines in western Gulf of Alaska.

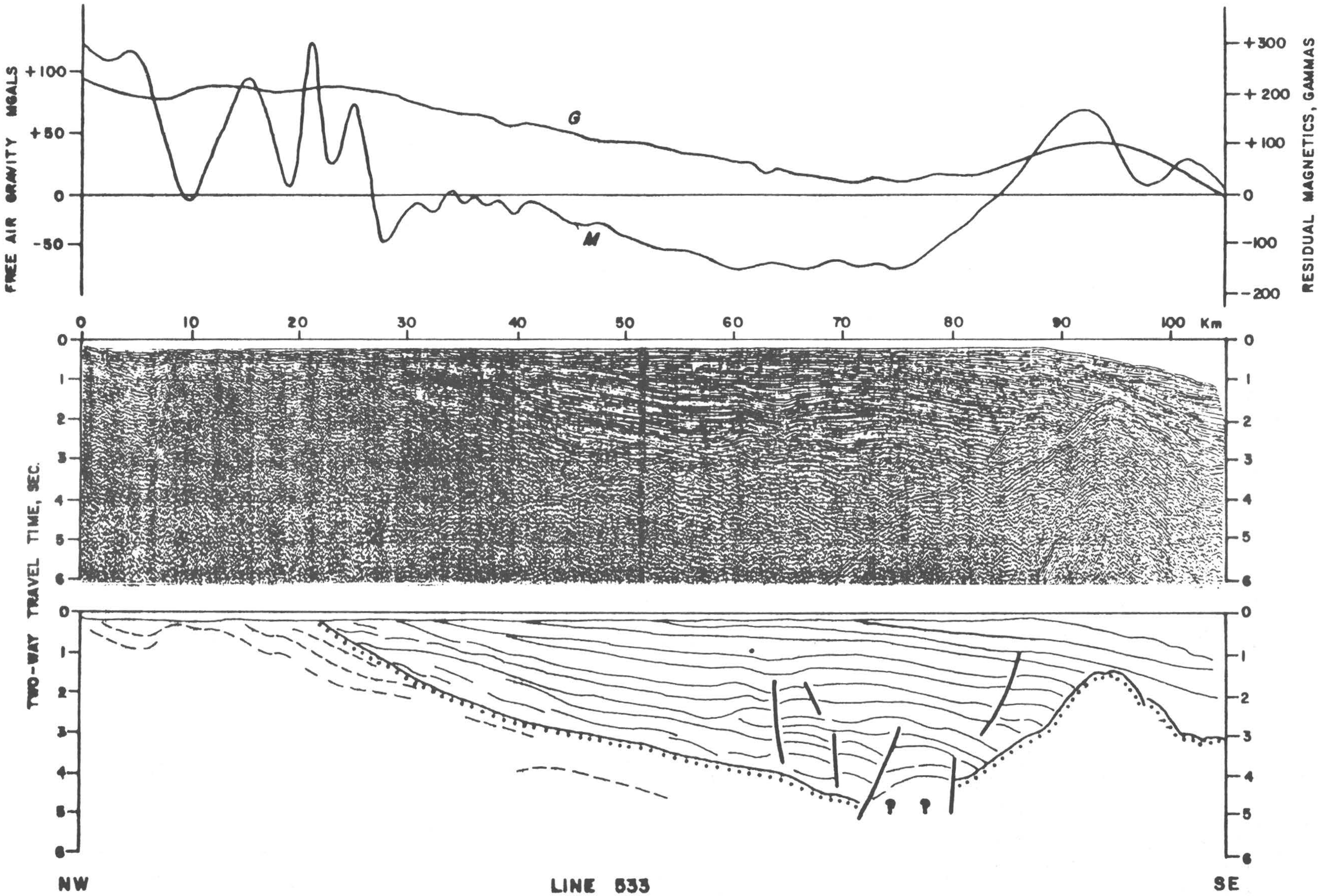


Figure A-7. CDP line 533 (see fig. A-6).

(3) Acquisition of data to better delineate the deep structure of the margin. Little is known of the pre-Miocene structure and stratigraphy of much of the margin, because multichannel seismic data provides limited acoustic penetration (about 5 to 9 km). More powerful reflection techniques and two-ship refraction and reflection experiments are needed to delineate the structure of the underlying pre-Miocene strata and basement rocks. Regional aeromagnetic surveys would provided crucial basement structural information for planning seismic line locations and for interpolating basement structures between seismic lines. Such data will lead to a better understanding of the composition and tectonic history of the crust along the transform and convergent margins and within the allochthonous Yakutat block. Such data are especially needed in the area of the Yakutat block collision and subduction, as this process may lead to maturation and migration of hydrocarbons in a manner analogous to the Rocky Mountain Overthrust Belt.

(4) Acquisition of detailed bathymetry by swath-mapping. Swath-mapping is needed over the continental margins and seamount provinces of the Gulf of Alaska for siting dredging and drilling programs. In addition, tectonic processes at convergent, transform, and collision margins are particularly suitable for study by this approach, as young structures are commonly developed within these zones. Such data can provide details of the deformation processes and the structural configuration in zones of complex structure along major faults, such as the Queen Charlotte fault, and at the Aleutian subduction zone and Yakutat block collision zone.

To fill these needs, we recommend a program of seismic-data acquisition, including two-ship work, concurrent with or closely tied to swath-mapping of the continental margin and seamount provinces. These programs should be followed by dredging programs, and finally by a drilling program in areas critical to resolving significant geologic and tectonic problems or evaluating significant resource potential. Such a program will markedly advance our understanding of the great diversity of geologic problems present in the Gulf of Alaska and will delineate the areas where deep-sea mineral and hydrocarbon potential exists.

Bering Sea Shelf (< 200 Meters)

The greatest hydrocarbon potential of the Bering Shelf is within the filled basins of the Outer Shelf: Bristol Bay, St. George, Pribilof, Zhemchug, and Navarin basins that are mostly in water depths of less than 200 meters. Prominent targets within the basins include large anticlinal and diapiric structures in the basins' fill, drape structures over basement highs, growth structures along the basins' flanks, stratigraphic traps, and targets within the bedrock beneath the basins' fill.

The accompanying figures are included to show the thickness of the sediment fill in the shelf basins. Figure A-8 is a structural contour

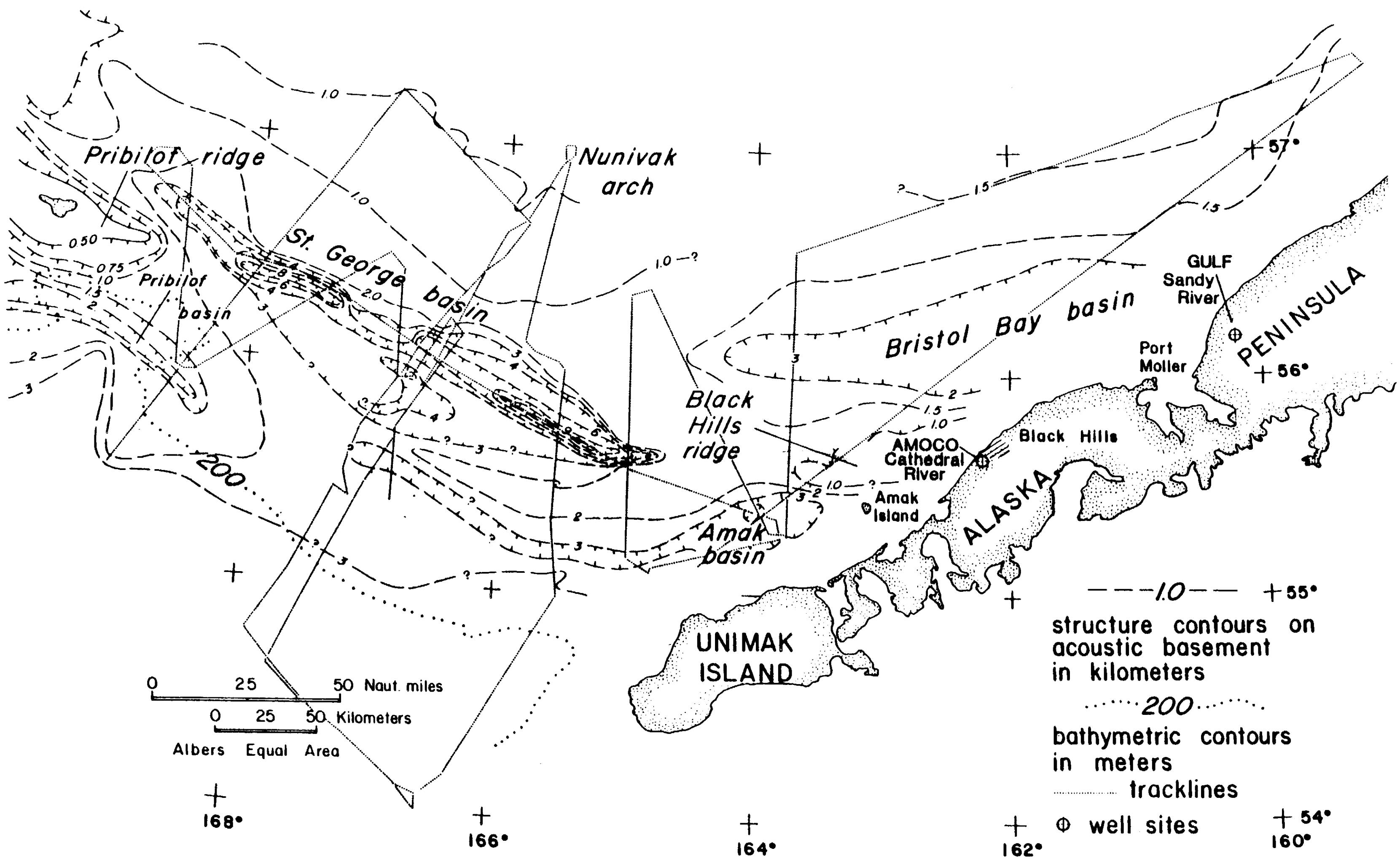


Figure A-8. Structural contour map, southern Bering Shelf.

map of the southern part of the shelf showing the thickness of sediment fill above the acoustic basment. Figures A-9, A-10, and A-11, are interpretive drawings of CDP seismic-reflection profiles across the major shelf basins.

Regional multichannel seismic-reflection coverage exists only for the outer shelf area. Magnetic and gravity coverage is lacking for the entire shelf, and very little is known about the crustal structure beneath the inner shelf. The inner shelf may be underlain by significant amounts of strategic minerals such as gold, platinum, and other valuable mineral deposits that occur onshore in Alaska.

The entire shelf area has been drilled in only six locations spread over an area equivalent in size to the states of Washington, Oregon, and California. Clearly, a regional drilling program is needed to evaluate the resource potential of the shelf.

Deep-water (> 200 meters) Basins of the Bering Sea

The greatest hydrocarbon potential of the deep-water areas of the Bering Sea is likely to reside in the thick sedimentary bodies that lie along the base of the Bering Sea margin from the Alaska Peninsula to Siberia. This area includes the named basins such as the Prevenets and "Pribilof" as well as the unnamed sediment wedges, 4-9 km thick, that extend along the entire length of the 1,300-km-long margin. Prominent targets include the large sediment fans, the diapiric and folded sediment bodies buried at the base of the margin, the normally faulted sedimentary section beneath the slope, basement structures, deep-water bright spots (VAMPS), and prograding and onlap sequences of the upper slope.

Figure A-12 shows CDP seismic-reflection profiles across the deep-water part of the Bering Sea (Aleutian basin) from north of the Pribilof Islands to Bowers Ridge (line BS765) and across the Aleutian basin, Bowers Ridge, and Bowers basin (line 44A).

Because the coverage is extremely limited in the deep-water areas, the critical need is for greater multichannel seismic-reflection, gravity, magnetic, and refraction data. Drilling must be a priority in selected areas in order to tie the geophysical data to the rocks and sediments. Additional dredging and coring of rocks and sediments along the Beringian, Aleutian Ridge, and Bowers Ridge margins also are needed. Other important data needs to include detailed bathymetric surveys by the GLORIA and SEAMARC systems.

Aleutian Ridge

The EEZ surrounding the Aleutian Island Arc contains several large basins that have the potential for generating commercial quantities of oil and gas. The basins lie in four major tectonic settings within the arc. These settings are (1) summit basins lying in relatively

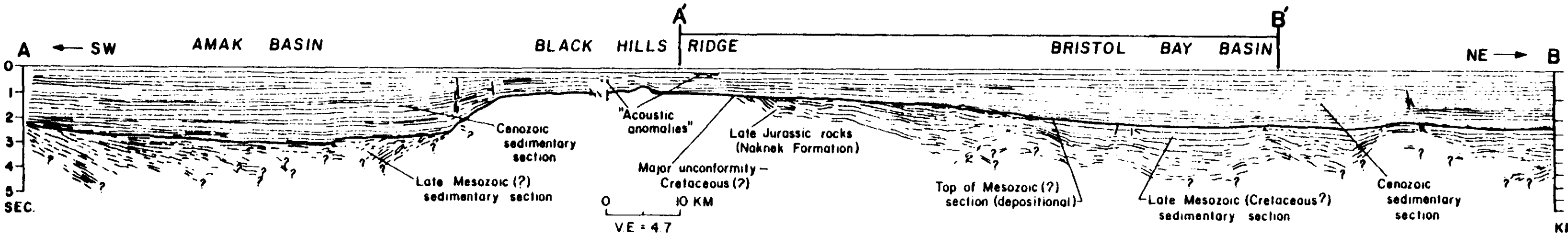


Figure A-9. Interpretive drawing of Bristol and Amak basins from CDP profile parallel to Alaska Peninsula.

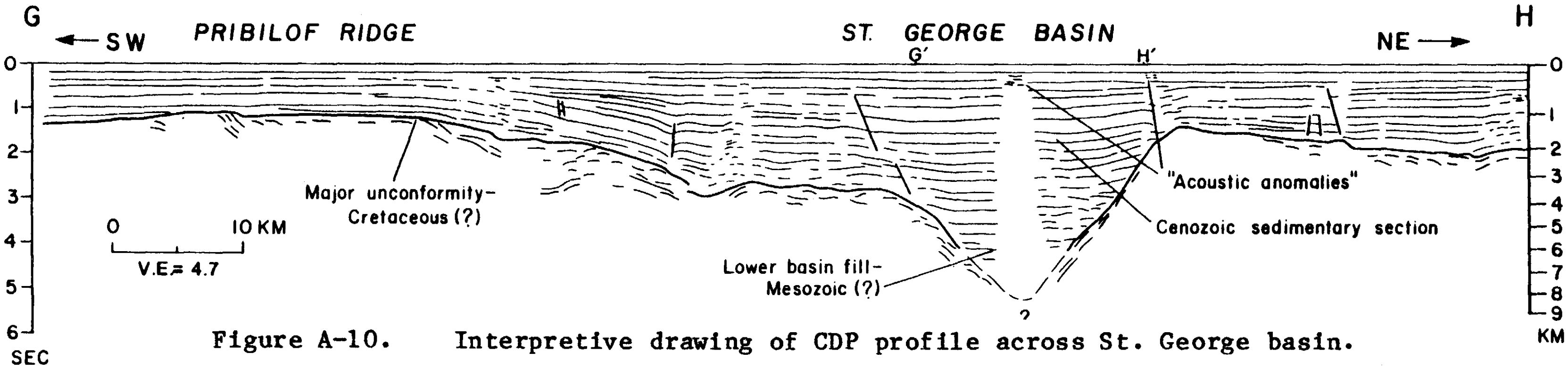


Figure A-10. Interpretive drawing of CDP profile across St. George basin.

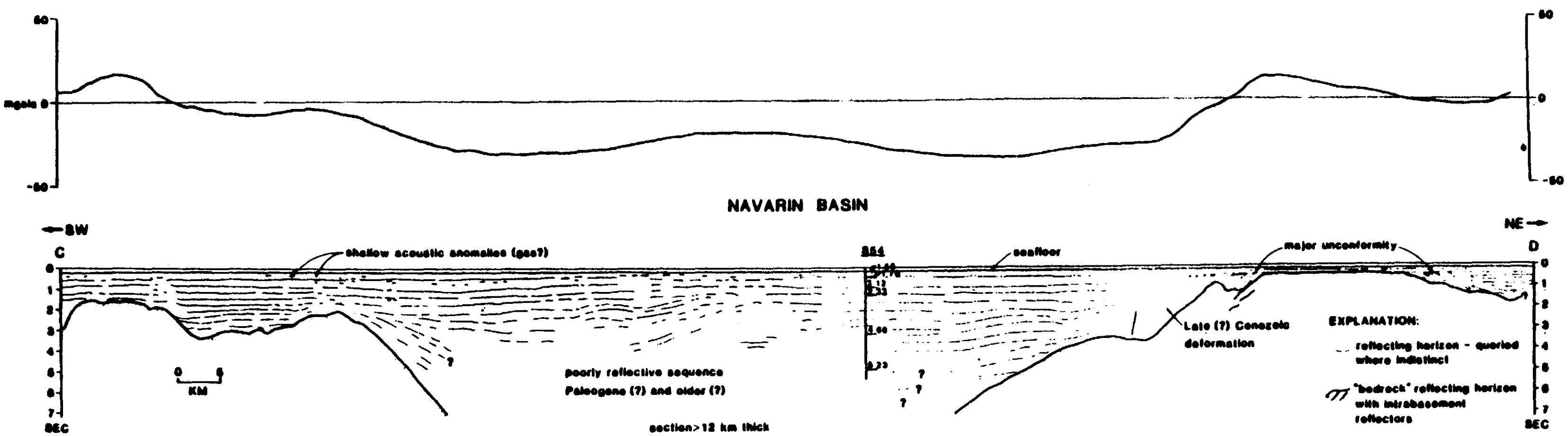


Figure A-11. Interpretive drawing of CDP profile across Navarin basin.

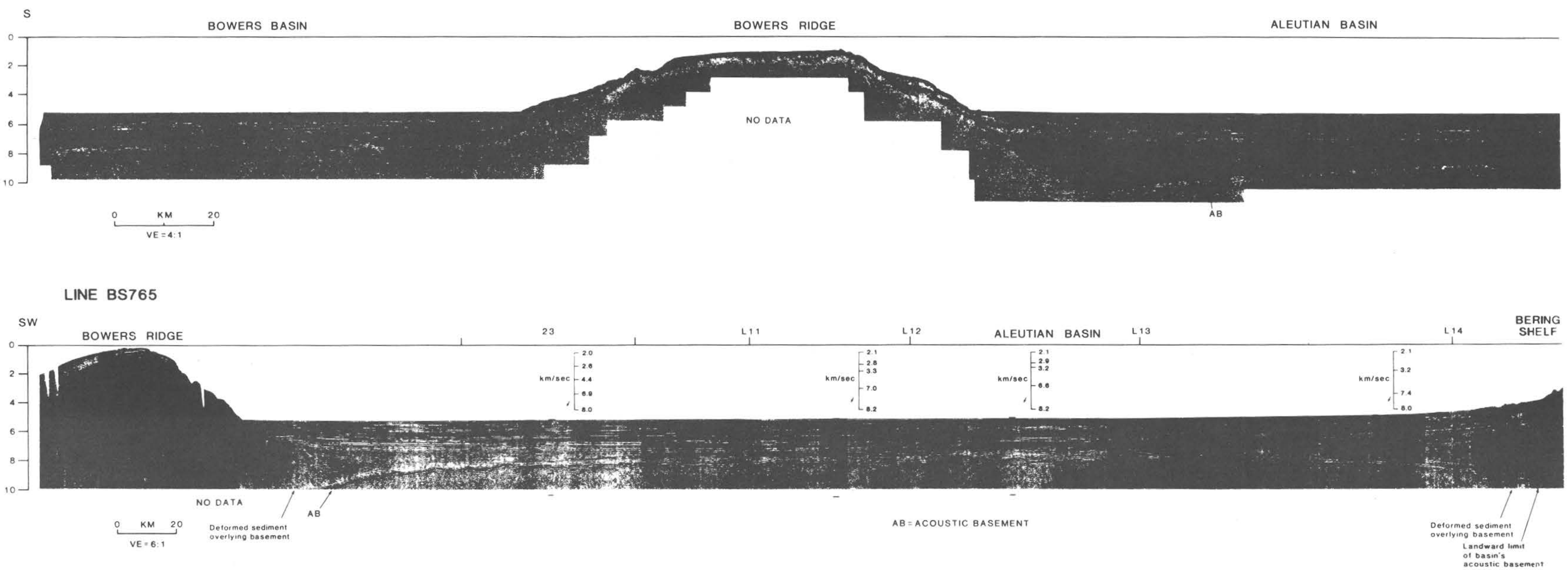


Figure A-12. CDP profiles across the deep water area of the Bering Sea.

shallow water along the crest of the arc, (2) forearc basins, lying at intermediate depths along the Pacific ocean side of the arc, (3) the trench accretionary prism lying in deep water along the seaward toe of the arc, and (4) the deep water Bowers and Aleutian basins which lie behind the arch to the north.

Many of the elements required for petroleum generation and accumulation are known to be present within or surrounding these basins. Table 1 summarizes these elements. Many of the uncertainties shown in the table are the result of the reconnaissance nature of the work completed to date. Lack of sufficient data does not allow a more quantitative approach. In particular the paucity of physical samples, all of which have been dredged fortuitously from outcrops, or cored at two shallow subsurface DSDP drill sites, does not allow a more comprehensive look at the sediment types and physical properties of rocks within the basins.

Several major factors remain to be quantified before any realistic estimate of petroleum potential for this area can be derived. Chief among these factors is the question of timing. Although many of the elements of petroleum generation are known to be present, the evolution of the basins is not known sufficiently to allow us to determine whether a proper sequence (in time and space) of generation, migration, and entrapment of petroleum resources has occurred. In addition to the question of timing, our current understanding of the distribution of rock types within the basins does not allow us to predict the thickness and areal extent of source and reservoir beds. Other elements such as heat flow, organic content, porosity and permeability, and basin geometery are quantified on the basis of regional data or they are derived from measurement on an inadequate number of samples. All of these elements must be quantified or refined before any reasonable estimate of resource potential can be made.

In order to clarify the uncertainties described above, more time is required to collect further data. The data types needed and applicability are listed in table 2. It should be noted that some of the critical data collection methods necessary to this program are not currently within our operational capability (i.e., drilling) and must be contracted.

Figure A-13 shows the CDP tracklines over the Aleutian Ridge. Most were concentrated in the Amilia sector near 172°-174° West Longitude. Figure A-14 is a line drawing, based on the CDP data, across the Aleutian Ridge in the Amlia sector; included is a sketch that shows the chronostratigraphic framework of the Aleutian Ridge. The trench and accretionary prism of the landward slope are shown in figure A-15. A line drawing (fig. A-16), based on single-channel seismic reflection profiles, shows Atka basin, a prominent forearc basin on the Aleutian Ridge. A summit basin, Amlia basin, is shown in figure A-17.

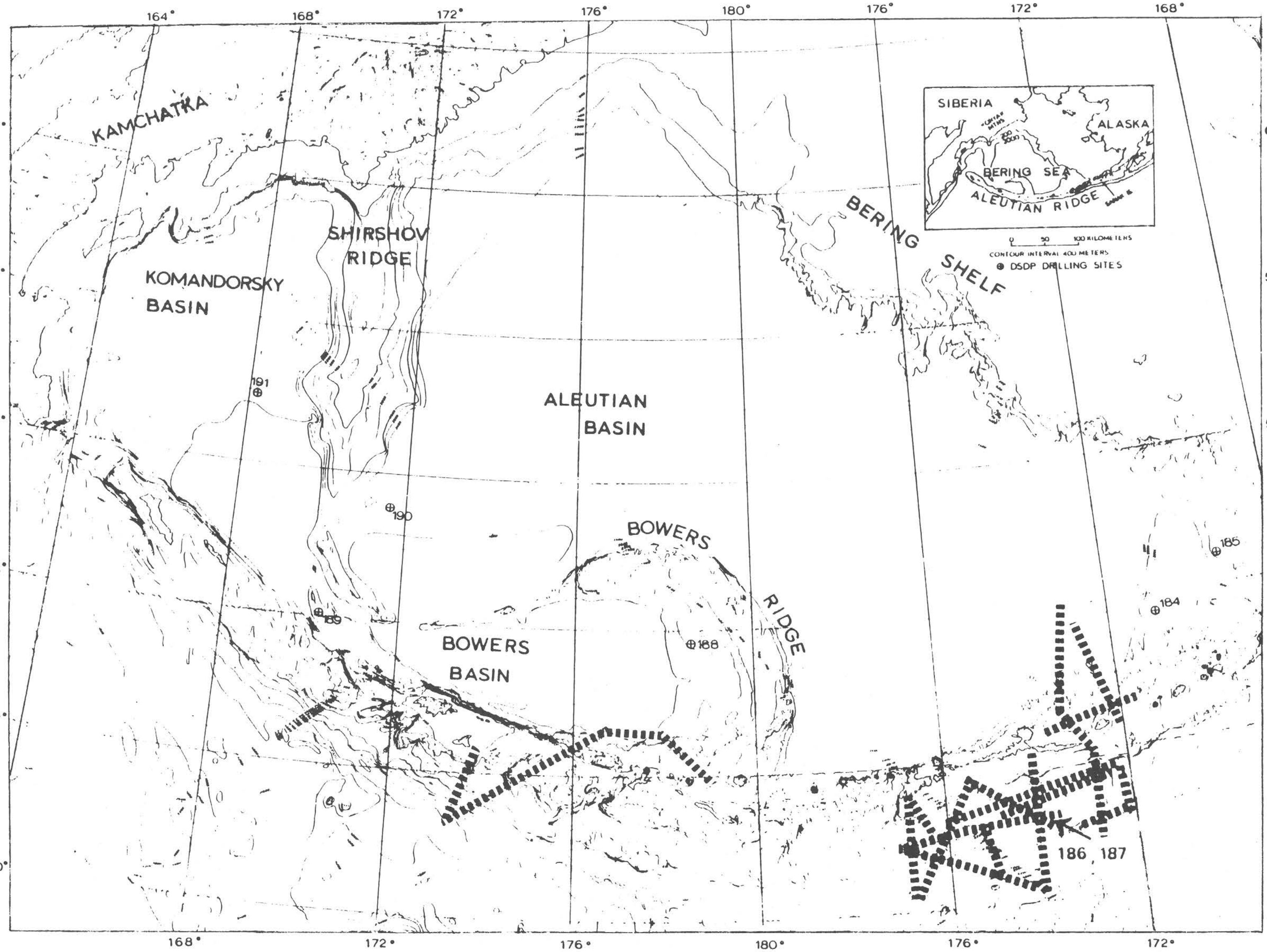


Figure A-13. Tracklines of CDP seismic-reflection profiles from the Aleutian Ridge.

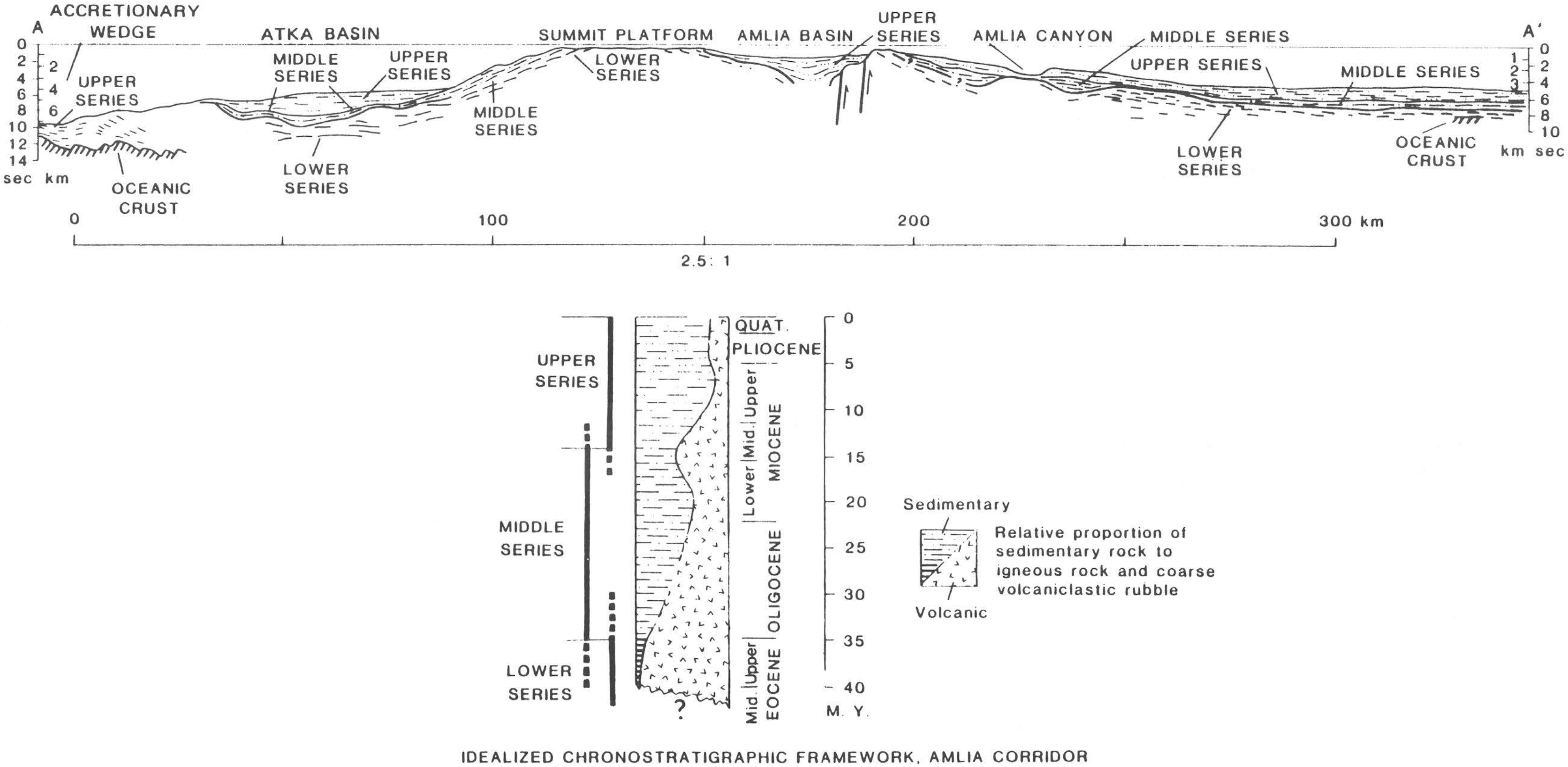


Figure A-14. Line drawing of Aleutian Ridge, south to north, showing major features and an idealized chronostratigraphic framework.

TRENCH ACCRETIONARY WEDGE

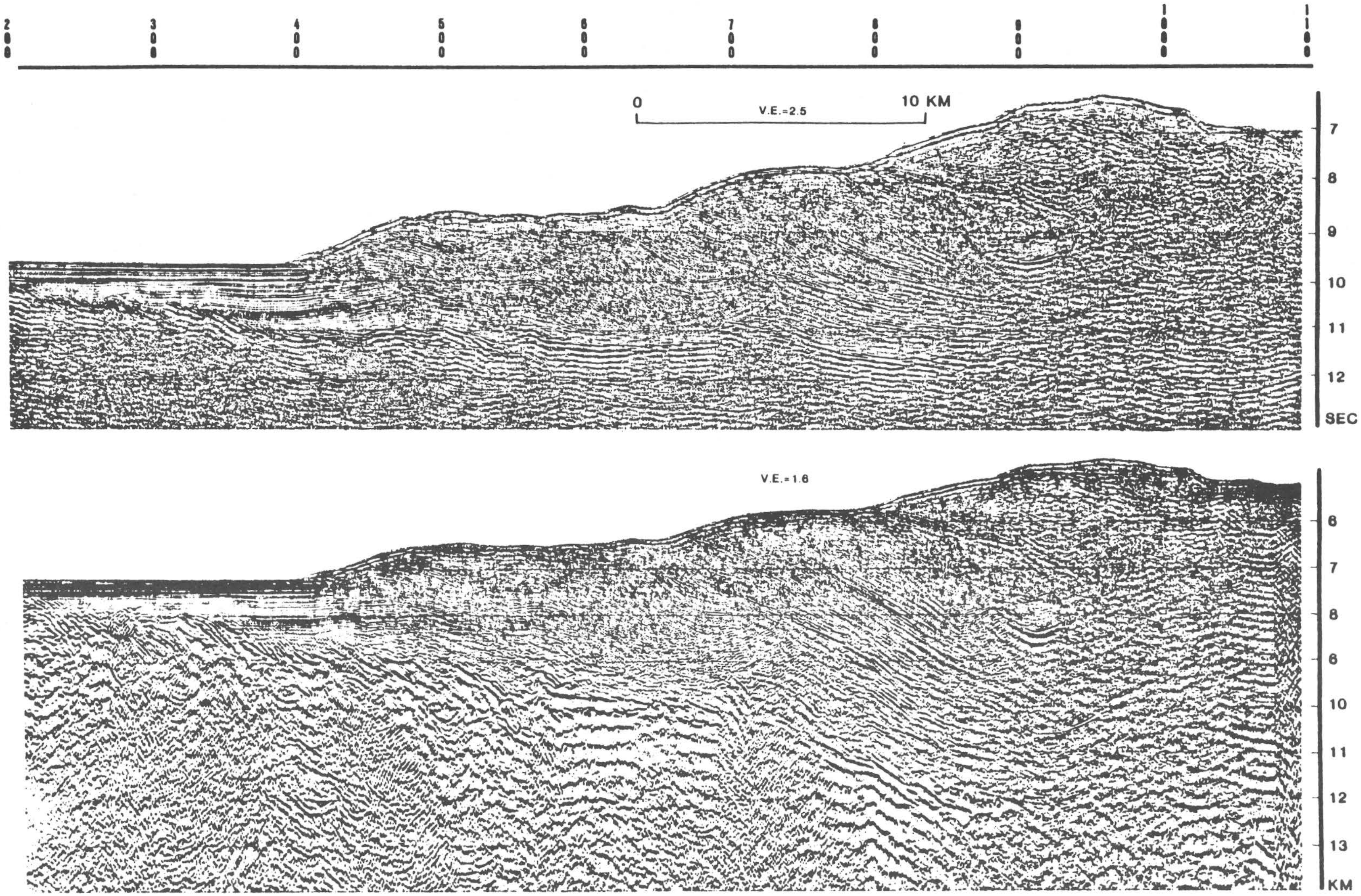


Figure A-15. CDP seismic profile across the trench and the landward slope accretionary wedge.

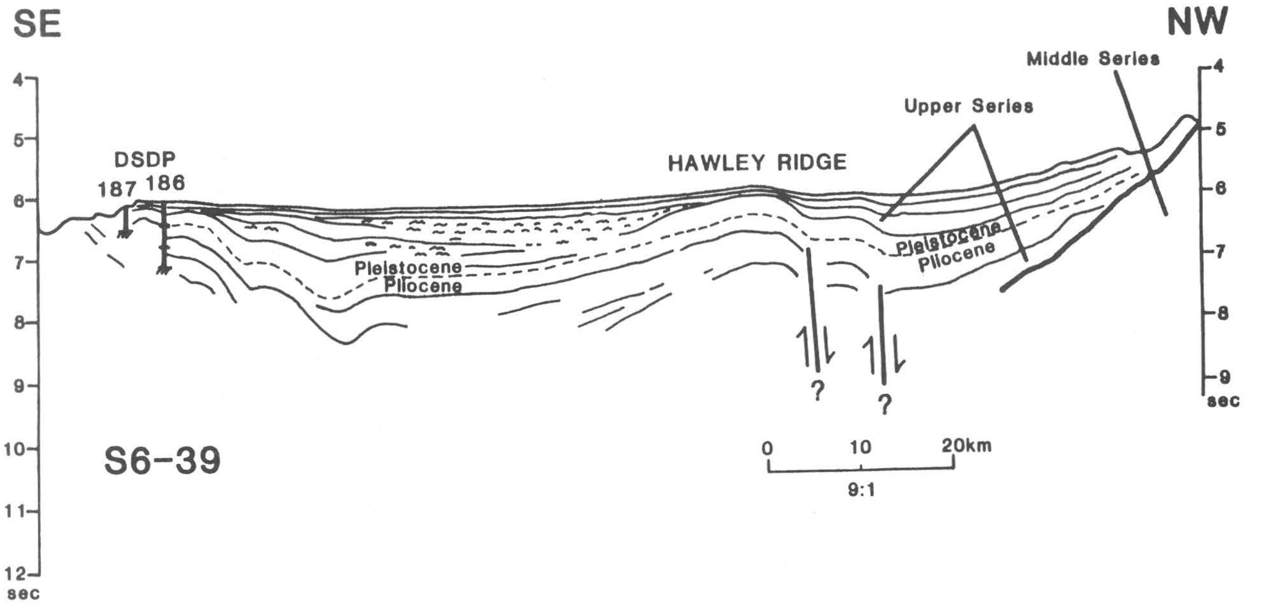


Figure A-16. Line drawing, from single channel seismic profile, across the Atka basin.

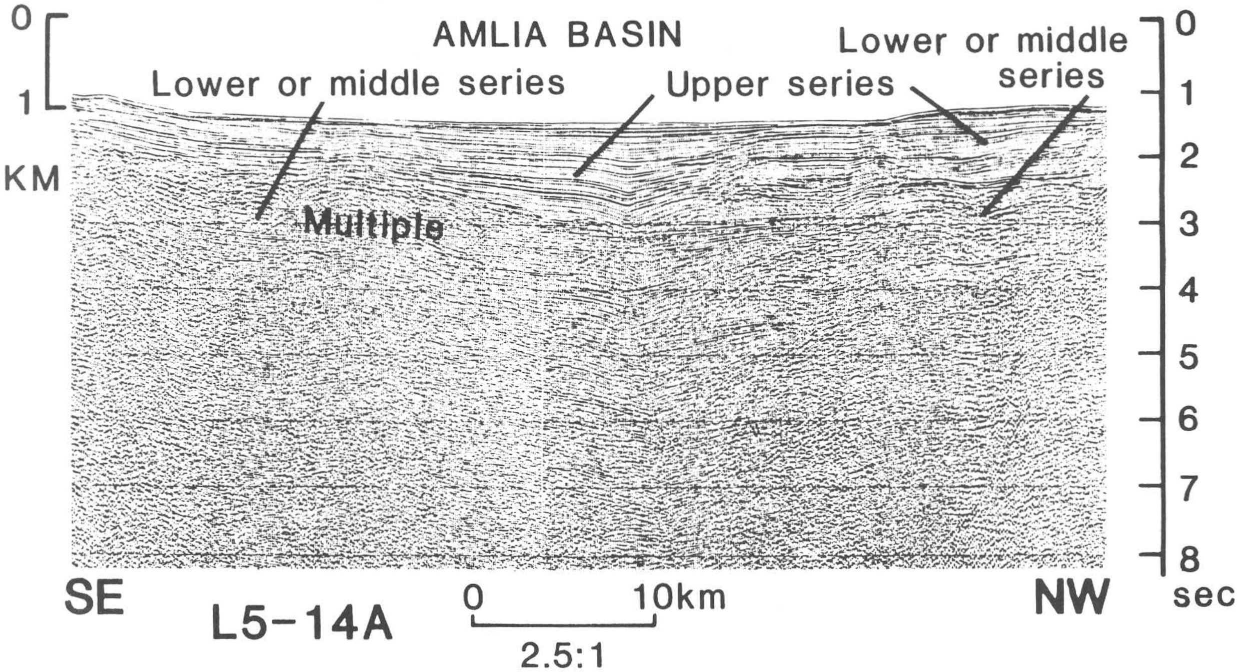


Figure A-17. CDP profile across Amlia basin, a summit basin on the Aleutian Ridge.

Table 1

SUMMIT BASINS

Sediment thickness (max)	3-4 km
Heat flow?	Adequate for maturation
Organic content	Low (more samples needed)
P/P	Low (more samples needed)
Reservoirs	Yes, volcaniclastic ss.
Structure?	Yes, faults and folds
Strat traps	Very likely

FOREARC BASINS

Sediment thickness (max)	5 km
Heat flow?	Adequate
Organic content	~ 1 percent (max)
P/P	44 percent (max) 45 Md. (max)
Reservoirs	Yes, volcaniclastic ss.
Structure?	Yes, large folds, faults
Strat traps	Likely

ACCRETIONARY PRISM

Sediment thickness (max)	6-8 km
Heat flow?	Adequate
Organic content	Unknown, believed adequate
P/P	Unknown
Reservoirs	Yes, deep water turb ss.
Structure	Yes, faults, folds
Strat traps	Likely

BACK ARC BASINS

Sediment thickness (max)	10-12 km
Heat flow	Adequate
Organic content	Unknown
P/P	Unknown, but high in areas
Reservoirs	Unknown, but many possible
Structure	Yes, folds and faults
Strat traps	Many known

Table 2

SAMPLING

Drilling
Where = in all basins and all across the arc
Purpose = define rock ages, and types, distribution, physical properties, and sed + tectonic history

Dredging
Where = along trench inner slope and forearc where critical rock sequences are known to crop out
Purpose = same as above but, because sampling is limited to outcrops, usefulness is limited

SEISMIC INVESTIGATIONS

Multichannel profiling
Where = summit basins, forearc basins, accretionary wedge, backarc basins
Purpose = increase spatial and temporal resolution of structures and sediment sequences, add to tectonic history.

Ocean-bottom seismographs (OBS)
Where = trench and forearc
Purpose = further define subduction mechanics, nature of basement rocks, and foremative history of the accretionary prism.

Swath bathymetry and long-range side-scan sonar
Where = entire arc
Purpose = help to define extent of structures, the arc's fabric or grain, modern sediment transport, current sed pattern, distribution of arc erosional debris

OTHER

Heat flow
Where = all basins
Purpose = determine thermal gradient for all basins

Two-ship refraction work
Where = all basins
Purpose = refine velocity profiles, nature of deep structures and basement rocks

Gravity and magnetics
Where = entire arc
Purpose = structural, deep crustal composition

Norton Basin

Norton basin lies beneath the northern Bering Sea, wholly within the EEZ. Seismic-reflection data from this basin are available in a 20 x 20 km grid, and lithologic and biostratigraphic data from two COST wells are now available. Future work with the well data will lead to refined concepts about the basin's geology and hydrocarbon-resource potential. The oil industry has yet to fully evaluate the present targets. In fact, the basin was thought to be about 6 km deep until October 1983, when we observed reflections from rocks as deep as

12 km below the surface. These reflections double the previously known basin depth. Therefore, it is apparent that a critical need is to trace these deep reflectors beneath the sedimentary basin and to reinterpret the geologic evolution of Norton basin.

Figure A-18 shows the USGS tracklines in the Norton basin. Figure A-19 is a structural contour map of the basin and it also shows tracklines 007 and 804 that in turn are shown in figures A-20 and A-21 respectively.

To accomplish current project goals at least three more field seasons of at least 1 month each is required. This is in addition to an essential drilling operation. Work priorities are as follows:

PRIORITY 1

Subsurface sampling, in-situ geophysical measurements via deep-water drilling techniques
Bathymetery-Gloria or Sea Marc Side Scan Surveying + Seabeam Swath Mapping
Dredging
Multichannel seismic-reflection profiling
Aeromagnetic surveying

PRIORITY 2

OBS seismic-refraction studies
Two-ship seismic-refraction and wide-angle-reflection studies

Arctic Ocean

A reconnaissance seismic reflection and gravity grid has outlined the geologic framework of most of the Beaufort Sea and much of the Chuckchi Sea shelves. Future research should extend the profiles into unsurveyed areas of the southern Canada basin and the northern part of the Chuckchi shelf. Figure A-22 shows the presently surveyed areas and those areas that require study in favorable ice years. Figures A-23 and A-24 show CP seismic-reflection profiles across the margin north of Prudhoe Bay and northeast of Point Barrow, respectively.

The critical data and information needs in the Arctic Ocean (in order of priority) are the following:

(1) A complete geophysical grid including multichannel seismic-reflection and gravity data.

(2) Stratigraphic information by dredging, coring, and drilling.

(3) Deep seismic-refraction data.

(4) Aeromagnetic data.

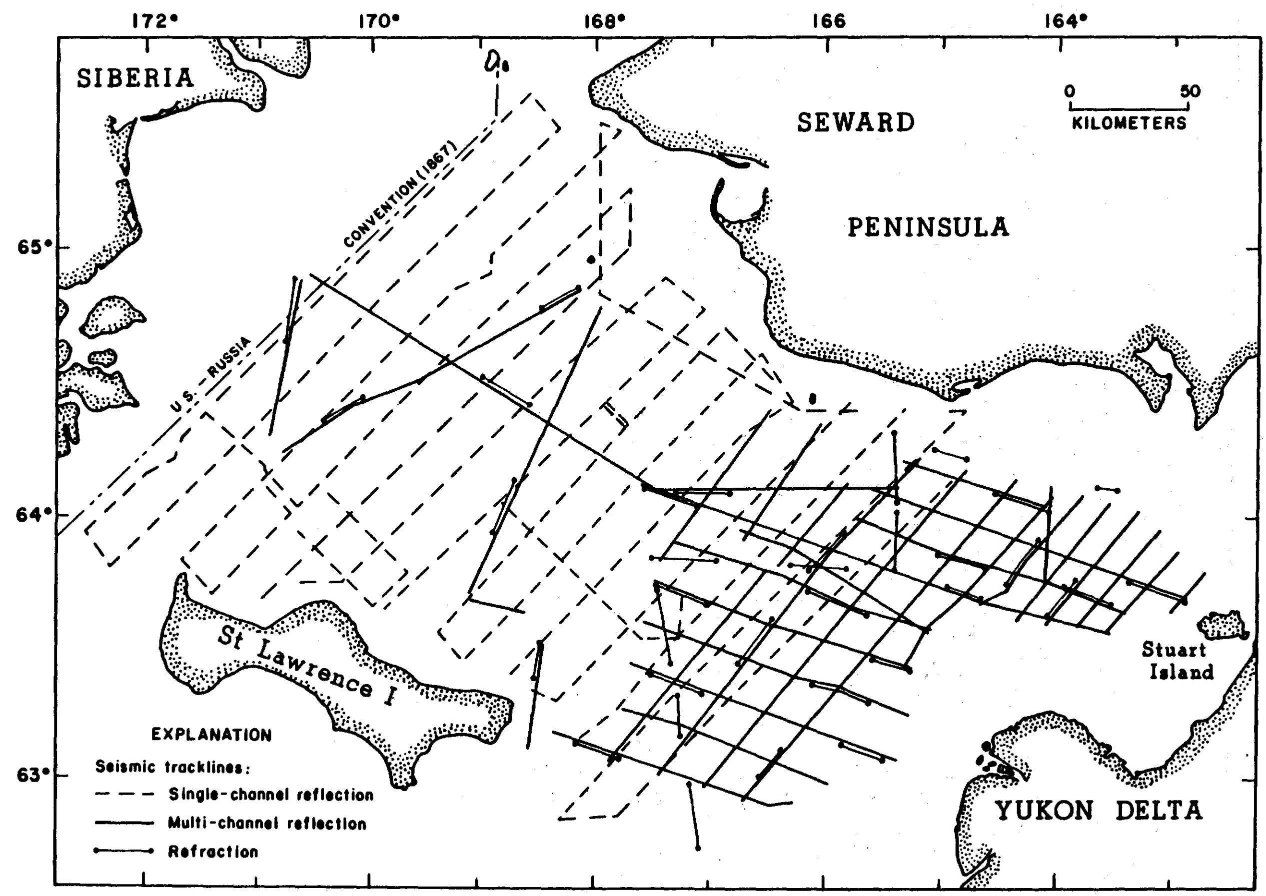


Figure A-18. U.S. Geological Survey tracklines across Norton basin.

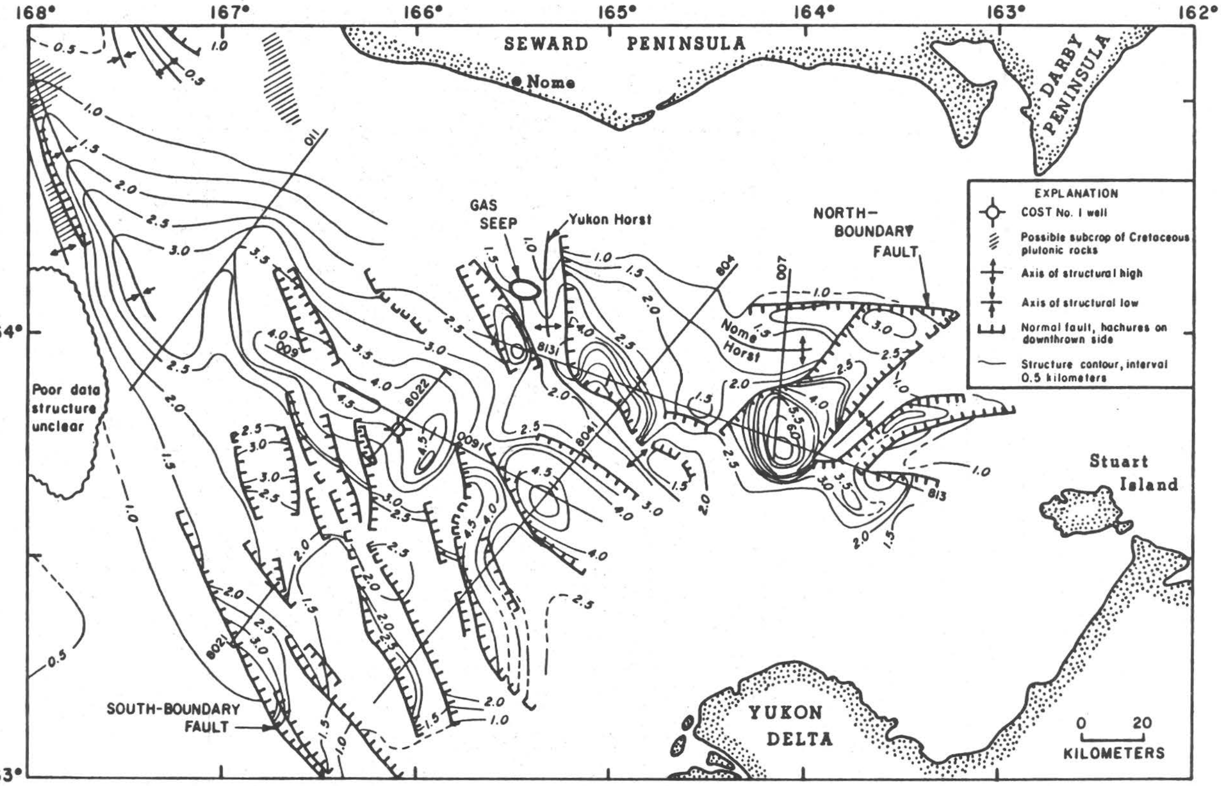


Figure A-19. Structural contour map of Norton basin Tracklines 007 and 804 are shown in figures A-20 and A-21.

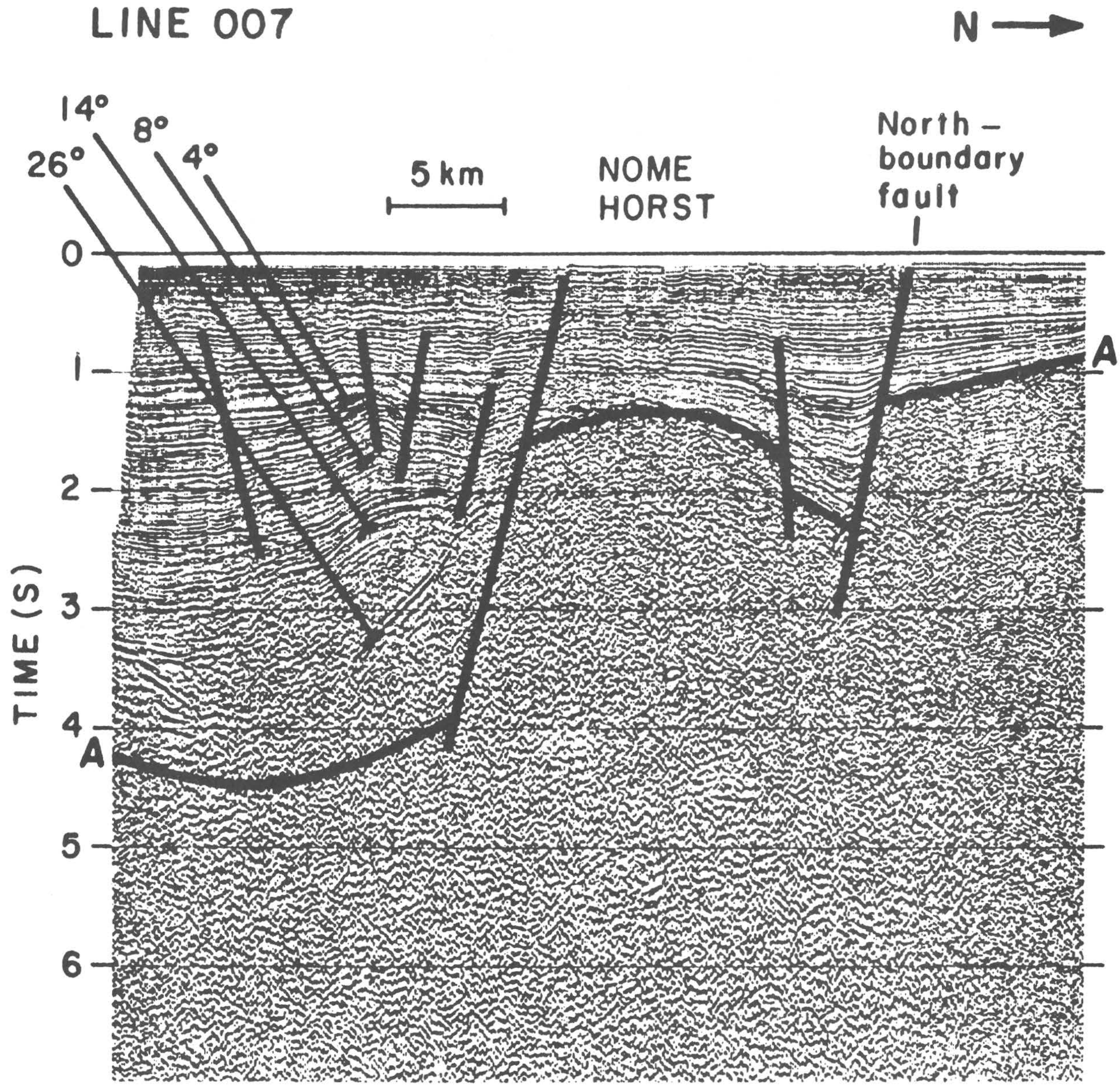


Figure A-20. CDP profile 007 across eastern Norton basin.

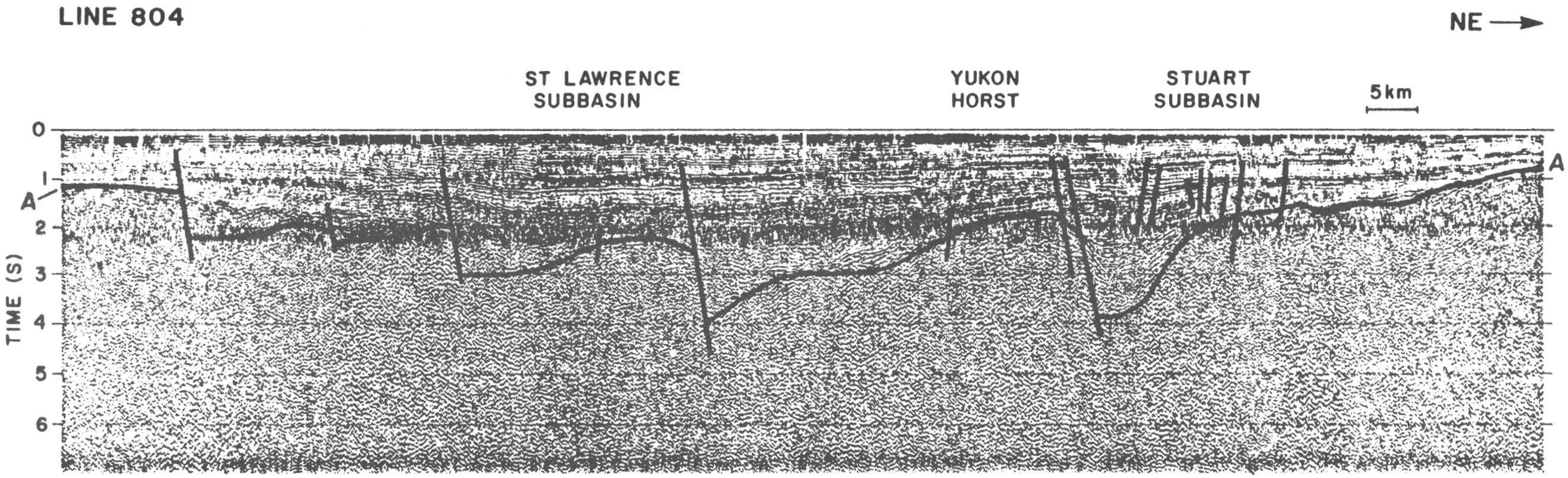


Figure A-21. CDP profile 804 across central Norton basin.

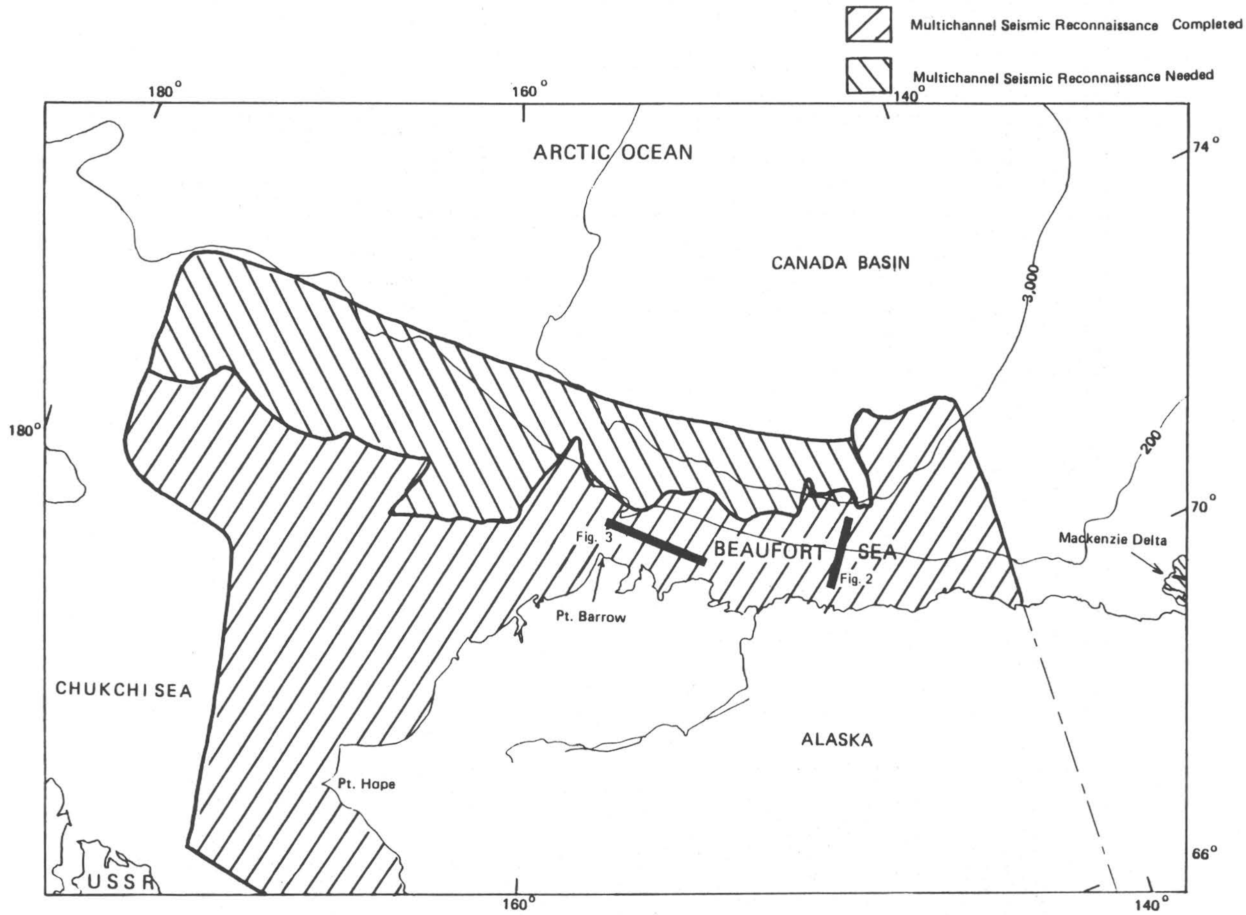


Figure A-22. Arctic 1.

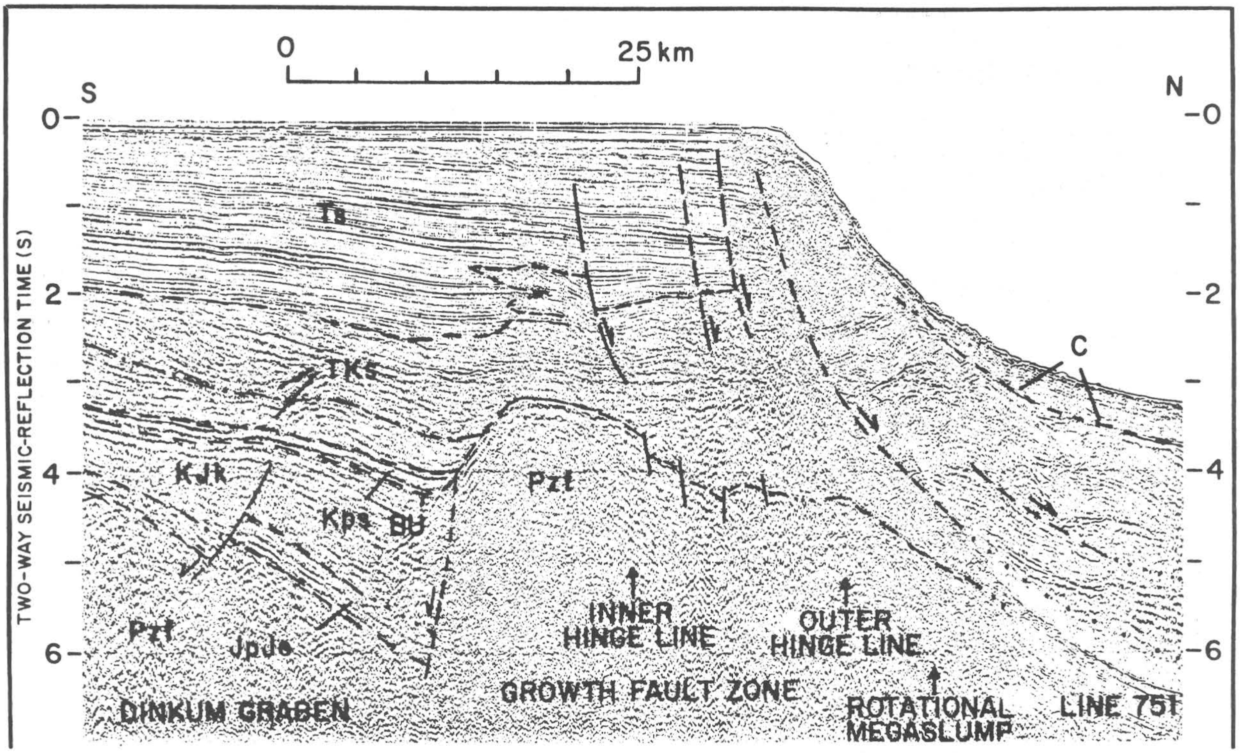


Figure A-23. CDP profile across margin north of Prudhoe Bay.

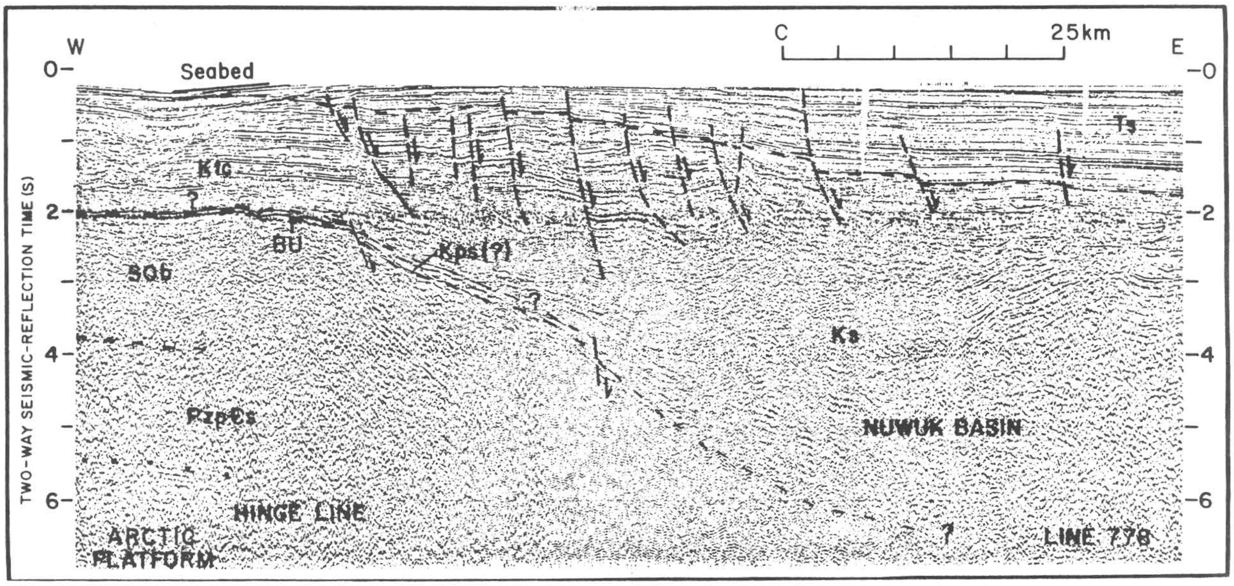


Figure A-24. CDP profile northeast of Point Barrow.

The U.S. Geological Survey should continue its role and expand the OCS responsibilities into the deeper parts of the Arctic EEZ. An effective national program can be achieved by (1) acquiring the data enumerated above, (2) making certain that laboratory space and processing equipment are available, (3) keeping all geophysical equipment in a state-of-the-art mode, and (4) providing the necessary manpower to accomplish program goals.

SUMMARY RECOMMENDATIONS

Ad hoc panel 1A met on November 16, 1983, to discuss the science-resource evaluation for oil and gas in the U.S. Exclusive Economic Zone. As a result of this meeting, the following recommendations are proposed:

1. That within 90 days the Director of the U.S. Geological Survey form a committee composed of representatives of government, industry, and academia to evaluate the feasibility of a joint program for subsurface sampling and evaluation of potential for resources in the Exclusive Economic Zone (EEZ).

2. That regional geological syntheses be undertaken by the Geological Survey and academia with collaboration of industry in principal EEZ basin. These syntheses should include, but not be restricted to:

   a. State-of-the-art seismic reflection data; for example, 2-D and/or 3-D surveying capability with 96 or more channels, 3,600 meters or more cable length, digital cable, and high-pressure and/or wide and long airgun arrays with equivalent processing technology.

   b. Tectonic and depositional environment studies.

   c. Geochemical studies.

   d. Two-ship, wide-angle reflection studies.

   e. High precision aeromagnetic and gravity surveys where required.

3. That detailed seabeam bathymetric surveys be undertaken in selected EEZ areas. We anticipate that NOAA will be the head agency acting with the advice of representatives from academia, industry, and the Geological Survey.

4. That existing sources of data be investigated before collecting additional data. These sources include industry files, geophysical contractor files, and other agency and program files such as DOD, DSDP, OMD, DMA, etc.

ACKNOWLEDGMENTS

Material for this report was provided by John Schlee, David Folger, Dennis O'Leary, Peter Popenoe, William Dillon, and Elizabeth Miller of USGS, Woods Hole; Tracy Vallier and David McCulloch of USGS, Menlo Park; and Richard Foote, MMS, Corpus Christi. John Schlee co-chaired the session with Joel Watkins on Oil and Gas Science-Resource Evaluation at the November EEZ conference.

REFERENCES

Blake, M.C., Campbell, R.H., Dibblee, T.W., Howell, D.G., Nilsen, T.H., Normark, W.R., Vedder, J.C., Silver, E.A., 1978, Neogene basin formation in relation to plate-tectonic evolution of San Andreas fault system, California: American Association of Petroleum Geologists, v. 62, no. 3., p. 344-372.

Buffler, R.T., Watkins, J.S., Worzel and Shaub, F.J., 1980, Structure and early geologic history of the deep central Gulf of Mexico, in, Pilger, R., ed., Proceedings of a Symposium on the Origin of the Gulf of Mexico: p. 3-16. Louisiana State University, Baton Rouge, March, p. 3-16.

Collignon, M.A., 1981, Atlantic Index, December 1980-June 1981. Outer Continental Shelf Oil and Gas Information Program: U.S. Geological Survey Open-File Report 81-705, 173 p.

Dillon, W.P., Grow, J.A., and Paull, C.K., 1980, Unconventional gas hydrate seals may trap gas off southeast United States: Oil and Gas Journal, v. 78, no. 1, p. 124, 126, 129-130.

Dillon, W.P., Popenoe, Peter, Grow, J.A., Klitgord, K.D., Swift, B.A., Paull, C.K., and Cashman, K.V., 1982, Growth faulting and salt diapirism; Their relationship and control in the Carolina Trough, eastern North America: American Association of Petroleum Geologists Memoir 34, p. 21-46.

Folger, D.W., Dillon, W.P., Grow, J.A., Klitgord, K.D., and Schlee, J.S., 1979, Evolution of the Atlantic continental margin of the United States, in Talwani, M., Hay, W., and Ryan, W.B.F., eds., Deep drilling results in the Atlantic Ocean; Continental margins and paleoenvironment: Maurice Ewing Series 3, American Geophysical Union, p. 87-108.

Grow, J.A., Bowin, C.O., and Hutchinson, D.R., 1979, The gravity field of the U.S. Atlantic continental margin: Tectonphysics, v. 59, no. 1-4, p. 27-52.

Havran, K.J., Wiese, J.D., Collins, K.M., and Kurz, F.N., 1982, Gulf of Mexico Summary Report 3, Outer Continental Shelf Oil and Gas Information Program, U.S. Geological Survey Open-File Report 82-242, 99p.

Holder, G.D., Angert, P.F., and Pereira, V., 1983, Implications of gas hydrates, association of gas reserves, in, Cox, J.L., ed., Natural gas hydrates: properties, occurrence, and recovery: Boston, Butterworth Pub., p. 91-114.

Jackson, M.P.A., and Seni, S.J., 1983, Geometry and evolution of salt structures in a marginal rift basin of the Gulf of Mexico, east Texas: Geology, v. 11, no. 3, p. 131-135.

Klitgord, K.D., and Behrendt, J.C., 1977, Aeromagnetic anomaly map of the U.S. Atlantic continental margin: U.S. Geological Survey Miscellaneous Field Studies Map MF-913, 2 sheets, scale 1:1,000,000.

Klitgord, K.D., and Behrendt, J.C., 1979, Basin structure of the U.S. Atlantic Margin, in Watkins, J.S., Montadert, Lucien, and Dickerson, P.W., eds., Geological and geophysical investigations of continental margins: American Association of Petroleum Geologists Memoir 29, p. 85-112.

Knebel, H.J., 1984, Sedimentary processes on the Atlantic Continental Slope of the United States: Marine Geology, in press.

Martin, Ray G., 1982, Regional geologic framework: central and western Gulf of Mexico OCS regions, in R.G. Martin, R.Q. Foote, L.E. Garrison, H.L. Berryhill, Jr., and A.S. Khan, eds., Summary report on the regional geology, petroleum potential, environmental consideration for developent, and estimates of undiscovered recoverable oil and gas resources of the United States Gulf of Mexico continental margin in the area of proposed Oil and Gas Lease Sales No. 81 and 84: U.S. Geological Survey Administrative Report, p. I-1 - I-51.

McCord, C.A., 1983, Atlantic Index, June 1981-May 1983, Outer Continental Shelf Oil and Gas Information Program: Minerals Management Service, 120p.

Schlee, J.S., and Jansa, L.F., 1981, The paleoenvironment and development of the eastern North American continental shelf: Oceanologic Acta, No. SP, p. 71-80.

Stoffa, P.L., and Buhl, Peter, 1979, Two-ship multichannel seismic experiments for deep crustal studies: Expanded spread and constant offset profiles: Journal of Geophysical Research, v. 84, no. B13, p. 7645-7660.

Vail, P.R., Mitchum, R.M., Thompson III, S., 1977, Seismic stratigraphy and global changes in sea level, part 4: Global cycles of relative changes in sea level, in Payton, C.E., ed., Seismic stratigraphy applications to hydrocarbon exploration: American Association of Petroleum Geologists Memoir 26, p. 83-97.

Watkins, J.S., Ladd, J.W., Buffler, R.T., Shaub, F.J., Houston, M.H., and Worzel, J.L., 1978, Occurrence and evolution of salt in deep Gulf of Mexico: American Association of Petroleum Geologists. Studies in Geology No. 7, p. 43-65.

Panel IB

ASSESSMENT AND SCIENTIFIC UNDERSTANDING OF HARD MINERAL RESOURCES IN THE EEZ

Panel Chairmen:
Robert D. Ballard, Woods Hole Oceanographic Institution
James L. Bischoff, U.S. Geological Survey

INTRODUCTION

The Exclusive Economic Zone (EEZ) comprises more than 3.9 billion acres of ocean bottom adjacent to the 50 States and to the territories and possessions of the United States: the Commonwealth of Puerto Rico, the proposed Commonwealth of the Northern Mariana Islands, the territories of Guam, American Samoa, Johnston Island, Jarvis Island, and the U.S. Virgin Islands. Six major resource types have been identified in the EEZ: (1) sand and gravel, (2) placers, (3) phosphorites, (4) manganese nodules, (5) cobalt crusts, and (6) massive sulfides (fig. 1).

This document examines the present knowledge concerning the distribution and occurrence of each of these resource types, summarizes the scientific understanding, and identifies areas for future scientific research which will lead to resource assessment and to the discovery of future resources. The format is to address each individual resource type in turn.

SAND AND GRAVEL

Introduction

Worldwide offshore production of sand and gravel greatly exceeds offshore production of other nonfuel minerals in both volume and value. In the United States, sand and gravel production is the largest nonfuel mineral industry in terms of volume. In 1980, nearly 1 billion tons were produced at a value of nearly $3 billion. The construction industry uses the majority for aggregate, and sizable volumes are used for land fill, manufacturing, and beach nourishment. Deposits on land presently provide nearly all the production in the U.S. However, as these deposits are depleted or no longer available owing to land-use restrictions and environmental concern, it is inevitable that deposits of sand and gravel on the seabed of continental margins will become economically competitive.

Several foreign nations, such as the United Kingdom, the Netherlands, and Japan already derive a sizable proportion of their sand and gravel needs from nearshore marine source areas. Offshore mining in England took place as early as 1897. The Dutch have removed offshore sand for shore-protection and land-reclamation engineering projects for centuries. Dredging for sand in the United States for beach nourishment began in a limited way in the early 1950's, but other commercial uses have been limited.

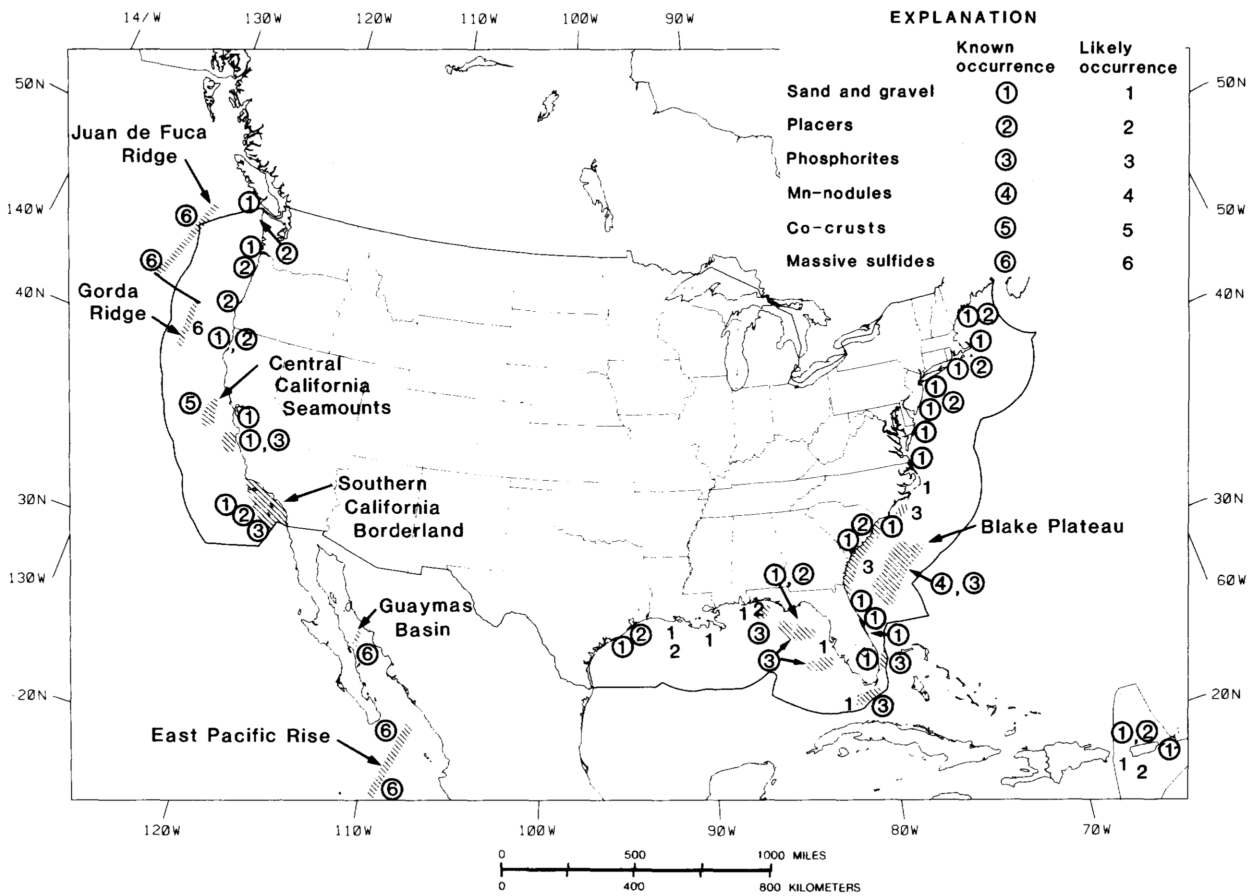
Several cities such as Boston, Chicago, New York, Los Angeles, San Diego, and San Francisco may already be experiencing periodic shortages, and unit spot prices in New York sometimes exceed $25 per short ton. Transportation cost is the main factor affecting sand and gravel price, and because transport by water is much cheaper than by truck, the use of marine sand and gravel is becoming increasingly appealing in metropolitan areas located on the coasts or having commercial port facilities.

A pressing demand for gravel presently is for construction of artificial islands off the north coast of Alaska in the Beaufort Sea to serve as oil and gas exploration and production platforms (fig. 2). Leases will be let within months and dredging and island construction is expected to begin in 1984.

Distribution and scientific understanding

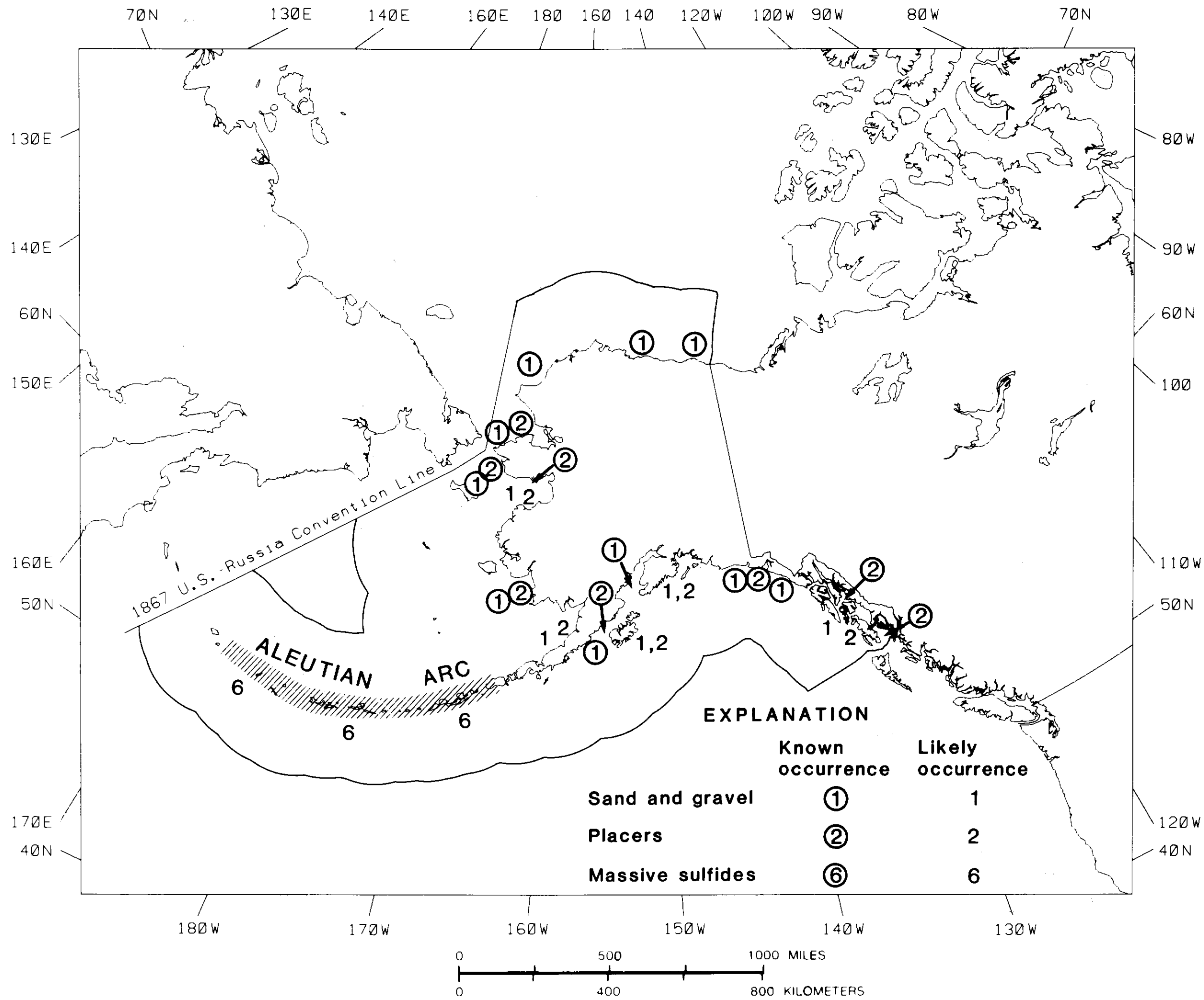
Sand and gravel resources on the U.S. Continental shelves are enormous and the best known of the primary economic minerals. The U.S. Department of the Interior OCS Mining Policy Task Force in 1979 estimated Continental Shelf resources of sand and gravel off the Atlantic and Pacific coasts of 830 and 29 billion cubic meters, respectively, resources of sand off the Gulf coast and Hawaiian coasts of 269 and 19 billion cubic meters, and "large" resources of sand and gravel off the coast of Alaska.

The need was recognized in the 1960's to explore U.S. continental margins in order to identify potential resources of sand and gravel. Equipment such as echo sounders, high-resolution seismic-reflection profilers, side-scan sonar, grab samplers, and vibracorers are most useful in determining important characteristics of the deposits. These are the location and areal extent, sediment composition and textural properties, thickness, as well as the overall three dimensional geologic framework and geologic history and processes of formation and emplacement. Several Federal agencies, as well as State geological surveys have conducted or funded marine studies to inventory sand and gravel. The U.S. Geological Survey in cooperation with the Woods Hole Oceanographic Institution conducted a study of the northeastern continental margin from the shore to about the 2,000-m-depth contour using over 3,000 seabed grab samples (fig. 1). Results showed that much of the shelf is mantled with sand of considerable lateral continuity and gravel is present in a more discontinuous patchy distribution. Sizes of sand deposits were estimated to be 400 billion tons within the top 3 m of the seabed. Deeper sampling is needed to verify this estimate. More recently, the USGS has carried out studies offshore the U.S. Virgin



EXPLANATION
Known occurrence
Likely occurrence
Sand and gravel
Placers
Phosphorites
Mn-nodules
Co-crusts
Massive sulfides
Juan de Fuca Ridge
Gorda Ridge
Central California Seamounts
Southern California Borderland
Guaymas Basin
East Pacific Rise
Blake Plateau
0 500 1000 MILES
0 400 800 KILOMETERS

Figure 1.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150W
140W
130W
1867 U.S.-Russia Convention Line
ALEUTIAN ARC
EXPLANATION
Known occurrence
Likely occurrence
Sand and gravel
Placers
Massive sulfides
0
500
1000 MILES
0
400
800 KILOMETERS

Figure 2.

Islands and Puerto Rico and located sand resources of 42 million cubic meters and 37 million cubic meters, respectively.

From 1964 to 1981, the Corps of Engineers Coastal Engineering Research Center conducted geophysical and vibracore surveys on inner continental areas of the Atlantic, Gulf of Mexico, and southern California. The primary objectives were to access marine sand and gravel resources and describe the three-dimensional geologic framework of the shallow subbottom in shelf areas from the shore to 20 km seaward. Results of these studies document that a grand total of nearly 17 billion cubic meters of sand and gravel are present within the upper 6 m of the seafloor, and seismic data suggest that for some shelf regions thicknesses and volumes are considerably greater. The results show that sand is abundant for many regions however, it varies considerably in textural properties, and in some places is admixed with or covered by mud. Gravel is most common on glaciated shelf regions of the northeast and northwest, but south of about 40°N, gravel appears limited to a carbonate shell fraction or residual coarse sediment overlying outcrops of relict fluvial channel deposits or Coastal Plain strata. The most promising sand and gravel deposits are associated with glacial moraines and drift, outwash-sand plains, and glaciofluvial deltas. Also promising are ancestral river channels that crossed the shelf in the Quaternary period prior to the Holocene transgression, as well as the various classes of shoals (e.g., linear, cape-associated, and tidal-inlet-associated) that are present from the shoreface to the shelf edge. Most shoals seem to have originated during the Holocene transgression by littoral and nearshore hydraulic processes.

On the Pacific coast of the United States, present information indicates that promising deposits of sand and gravel occur near Grays Harbor off central Washington, within shipping distance of the Portland and Seattle metropolitan areas (fig. 1). These were formed by reworking of glacial outwash gravel. Deposits from offshore California are relatively small and fine-grained, consisting of relict beach and fluvial materials, but demand is likely to be high. One of the most promising deposits, because of its proximity to the Los Angeles and San Diego markets, lies off Imperial Beach and consists of reworked gravel on the submerged former delta of the Tijuana River.

Sand is in short supply in Hawaii, but a potential white-sand supply is located 35 km from Honolulu on Penguin Bank. This supply is located in water depths of 50-60 m and is believed to be northern of 350 million cubic yards. This calcareous sand is located on drowned Pleistocene sea-level terraces. In the Virgin Islands and Puerto Rico, where construction sands are in short supply, extensive offshore sources have been found recently that will likely dominate future production.

Scientific problems and future research

A good start has been made on identifying potential marine sand and gravel deposits, and the results to date are promising. However, most of the efforts have focused on nearshore regions where mining logically could be expected to start owing to proximity to markets and present dredge-depth limitations of 30 m. Only a small part of the total EEZ area consisting of 16 million km^2 has been evaluated for sand and gravel. Some parts of the continental margins have never been surveyed with the objective of looking at the Quaternary section where sand and gravel is most likely, while other areas of the shelf have been studied by just geophysical methods or just surface samples without control by the other. The ideal procedure is to conduct densely spaced surveys in two parts: the first to collect high resolution seismic profiles to decipher the morphology, subbottom structure, and stratigraphy, and the second to gather "ground truth" in the form of long cores. Results can yield geologic information to enable a better understanding of the framework of the margins and thus their history and evolution, and will also yield resource estimates not only for sand and gravel, but for other hard minerals as well. Heavy-mineral placer minerals commonly are are associated with sand and gravel bodies, and any cores obtained could be analyzed for both sand and gravel as well as other mineral components with a minimum of additional expense.

Suggestions for future research:

(a) An inventory should be made of all existing high-resolution geophysical and sediment data collected within the EEZ by Federal and State agencies, industry, and academic research organizations to develop an accurate assessment of the present state of knowledge regarding sand and gravel resources. For areas where gaps exist or the data are incomplete, the government should undertake reconnaissance-type geophysical and coring surveys.

(b) A series of complete, accurate and up-to-date maps of the EEZ are needed for any mineral inventory. Base maps having scales of 1:80,000 to 1:1,000,000 should include bathymetric data as well as geologic information.

(c) A better understanding of the Quaternary geologic framework of the shelves is needed. What are minimum and maximum thicknesses, sediment composition and texture? Identify shelf areas where relict sediments are present versus modern ones. Delineate the location and extent of ancestral river channels. What has the history of sea level been during the past 18,000 years, what have been the rates of rise, and where has sea level paused to allow nearshore deposits to accumulate?

(d) Better understanding of modern high-energy beaches and nearshore sand bodies and how they respond to the tides, currents, and waves that act on them as well as to rapid sea-level rise taking place recently. What factors determine whether if barrier islands will migrate progressively landward with sea-level rise as is thought for most Atlantic type barriers, or will skip by overtopping, or will drown in place and be left behind as the coast moves landward?

(e) Generally, the existing technology is sufficient to conduct such surveys; however, improvements could be made such as: (1) high-resolution medium-range sidescan sonar capable of operating at speeds of 5-10 knots, (2) navigation systems with ranges of 500 km and accuracies to ±5 m, (3) improved seismic-profile systems with penetrations to 100 m and resolution of 0.3 m, (4) coring apparatus capable of obtaining 10-m-long undisturbed cores of granular sediment in water depths to 200 m, (5) acoustic or other remote sensing equipment capable of distinguishing various sediment types from a moving survey vessel, and (6) instruments capable of yielding real-time oceanographic information about surface waves and currents throughout the water column.

PLACER DEPOSITS

Introduction

As early as 1742, Shellrock's Voyages to California told of abundant beach deposits of black minerals discovered along the west coast of America. The earliest marine placer mining efforts (those prior to 1900) were primitive, largely to recover gold and cassiterite from beach sands in South America and Southeast Asia. The first commercial mining of marine placers was conducted on the beaches of Nome, Alaska, at the turn of the century as an experiment by miners who arrived too late to acquire claims on the gold creek nearby.

Heavy-mineral requirements of the Nation, including many strategic critical minerals, exceed domestic supply. For example, in 1981 the United States imported 43 percent of the ilmenite, and nearly 100 percent of the rutile used in a variety of industrial processes where titanium or titanium dioxide is required. The primary sources of these mineral imports are Australia, South Africa, Canada, and Sierra Leone. Much of the domestic heavy-mineral mining is, or has been, associated with major deposits located onshore in the Coastal Plain of New Jersey, Georgia, and Florida.

Distribution and scientific understanding

Heavy-mineral sand of variable composition and grade on the Atlantic Shelf has been estimated to be about 1.30×10^9 m^3, which is about 0.16 percent of the estimated sand and gravel volume. This estimate may be low by a factor of five or more.

Surficial relict sand bodies, often occurring as ridges (submarine highs), are present over most of the Atlantic Shelf. They range in thickness from about 20 m to 80-140 m near the shelf edge. Some of these relict features are interpreted as ancient shore deposits that formed as the ocean transgressed the shelf at the end of the most recent glaciation. Supporting evidence for this interpretation is the presence of submerged terraces and beach ridges which are the types of features associated with interim stages of change in sea level. It has been inferred that concentrations of heavy minerals are associated with these former shoreline features.

No quantitative estimates of heavy-mineral sand on the Gulf of Mexico Continental Shelf (fig. 1) are available. Identified or indicated heavy-minerals of economic interest include many of the species found on the Atlantic Shelf, but very little mineralogic information is available.

On the Pacific Continental Shelf (fig. 1), heavy-mineral sand of various composition and grade is estimated to be about 2.06×10^9 m^3, which is about 0.77 percent of the estimated sand and gravel volume. Gold and heavy-mineral sand deposits occur rather extensively in relict beaches, buried river channels, and in reworked Pleistocene gravels. Many high-grade titanium and zircon sands have been inferred to be widespread. No definitive estimates are available for these resources in Alaskan waters, although there are some indications that heavy-mineral deposits may far exceed those of all the remaining EEZ (fig. 2).

Scientific problems and future research

Although a sizable literature exists on the nature and distribution of sediments in the EEZ, virtually nothing is known about the economic potential of heavy-mineral accumulations within these sediments. Private industry has reportedly prospected offshore for heavy minerals because of the high potential. Published data, however, are not available.

Previously published hypotheses on the occurrence of heavy-mineral placers in EEZ sediments state that there may be a correlation between terrestrial and marine locations of accumulations. Recent research directed at testing these hypotheses has shown that, at least on the Atlantic Shelf, this is not true everywhere. On the Atlantic Shelf in the areas studied, the highest concentrations of economically valuable heavy-minerals occur in offshore areas where onshore deposits contain the lowest concentrations measured, and vice versa.

Future research requirements are dominated by the need to establish qualitative and quantitative heavy-mineral data base. Construction of a high-density data base has been initiated by the USGS and involves the detailed textural, mineralogic, and chemical analysis of existing grab and vibracore samples.

The following activities are necessary to delineate the distribution and occurrence of EEZ placer deposits:

(a) Regional geologic studies. Review available literature (descriptive petrology and mineralogy) of the rocks along the coast and within the drainage area of streams entering the sea along the coast. Evidence of potential sources includes mapped, or otherwise reported mining areas, zones of mineralization, geochemical anomalies, or types of rock known or suspected to be associated with minerals or native metals of economic importance.

(b) Nautical chart studies. A surficial placer prospect is likely to be characterized by elongate geometry, modest shoaling, and "speckled" sand (a mariner's term commonly used to note abundant heavy minerals). Plan subsequent offshore surveys.

(c) Geophysical and geological surveys. Magnetic data provide initial clues for locating prospects. Seismic profiling data provide information on horizontal and vertical extent of deposit, reveal deep anomalies not found by surficial geological/geochemical tests; produce estimates of volume of potential ore-bearing sediments and overburden; suggest best sites for subsequent core sampling (the larger the sample, the more reliable the data), and provide additional information for interpreting the core data.

PHOSPHORITE

Introduction

Approximately 35 million metric tons of phosphorite are mined annually in deposits in Florida. This represents about 75 percent of the total for the United States. Most of the remaining 25 percent comes from the western phosphate field, in the area of southeast Idaho. A much smaller amount (about 1.5 million metric tons) is mined annually in Tennessee. Roughly 25 to 40 percent of this material is exported and of that used in this country, 90 to 95 percent is used as fertilizer by the agriculture industry.

The United States is the major exporter of phosphorite, and worldwide demand is clearly increasing. Present land resources may be adequate for only another 20 years. Phosphorite resources within the EEZ appear to be enormous and will become increasingly attractive as the land resources diminish.

Distribution and scientific understanding

Phosphorite deposits are known to occur within the EEZ of the United States, off both the east and west coasts. They were first discovered in 1883 on the Blake Plateau off the coasts of Florida and South Carolina (fig. 1). Since this time, phosphorite has been dredged, cored, and/or photographed at the surface of the Continental Shelf from the southern part of Florida to the shelf off North Carolina. Drilling has shown that these deposits also occur at depth beneath the shelf in Middle Tertiary rocks. Although the size of this deposit can be only roughly estimated, it represents an enormous resource of phosphorite by any standard. Approximately 2 billion metric tons of phosphorite are present on the Black Plateau alone. About half this much is also present as a pavement, in which the phosphorite is associated with ferromanganese oxides. An equal amount of phosphorite may exist off the coast of North Carolina. It is not possible to even guess at the amount of buried phosphorite, but it must surely exceed by tenfold that which is present at the surface.

Phosphorite off the coast of California was first discovered by the R.V. E.B. Scripps in 1938. The deposit has been widely recovered from the tops of submarine banks and ridges in the continental borderland, but it has also been dredged from rather steep slopes at depths as great as 3,000 meters and from the shelf to the north, near Monterey Bay (fig. 1). This deposit is considerably smaller than its eastern counterpart, representing a resource of perhaps 115 million metric tons.

Phosphorite has been recovered from several seamounts in the EEZ of the Pacific Ocean, where it is usually associated with Co-rich ferromanganese oxides. The size of these deposits is only poorly known at present.

The two Continental Shelf phosphorite deposits have several common characteristics. They are considered to be lag deposits that have been eroded from rocks of Middle Tertiary age. The phosphorite ranges in size from pellets to pavements, but most often occurs as irregular-shaped nodules. The phosphate mineral is francolite, a carbonate apatite with the approximate stoichoimetry:

$$Ca_5(PO_4,CO_3)_3F$$

The phosphorite is associated with carbonate sands, some of which may also represent a lag deposit. Middle Tertiary rocks, considered to be equivalent to the source beds of the shelf deposits, crop out on land bordering the marine environment. These rocks are dominantly limestone in Florida. In California, however, they include dolomite and highly siliceous rocks, many with high concentrations of organic carbon. These rocks also are source beds for petroleum.

Scientific problems and future research

These deposits present several problems, which need to be considered, if we are to use their distribution and associated sedimentary phases to assist with future exploration for other deposits.

What is the age of these deposits, i.e., are they derived exclusively from Tertiary rocks or is there a phosphatic component accumulating at the present time? Seismic studies allow us to ascertain the relation between the surface distribution of the phosphorite and the age and distribution of the underlying rocks. Dating of the phosphorite has given an age of greater than 800,000 years. Other phases associated with the phosphorite should also be dated, specifically glauconite. This mineral should give unequivocal dates. Bottom photography is required to more accurately determine the size of these deposits.

What are the critical associated sedimentary phases? Sedimentary phosphorite deposits always occur with carbonate rocks, but their common association with siliceous rocks has tended to attract more and, perhaps, unwarranted attention. The reason for this is understandable. Phosphorite deposits are known to be accumulating at present at only three locations, off Peru, off southwest Africa, and off the east coast of Australia. In the areas off Africa and Australia, they occur as pellets and nodules in association with siliceous muds. On the Peru Shelf, which has been investigated more intensively, the deposit is quite small. This deposit differs from those on land by its lack of association with a carbonate sediment. Thus, we need to examine the association phosphorite-$CaCO_3$-organic matter in the terrestrial equivalents of the shelf deposits. This association should also be examined on island deposits. In these the organic matter has an avian (guano) origin, rather than being fecal material of nekton and plankton, but the chemical reactions that are responsible for ultimate formation of phosphorite are surely the same as those occurring on the sea floor.

Are deposits currently forming on the sea floor that have mineral associations similar to the ancient deposits? We might look closely in areas of known carbonate deposition, where the flux of organic matter to the sea floor is somewhat high. Such environments may occur in the Caribbean.

The studies that need to be initiated are the following:

(a) Determine the age and composition of material already collected from the shelf deposits within the EEZ;

(b) Examine these areas of known occurrence by means of bottom photography and seismic-reflection profiling studies;

(c) Examine the relation between organic matter, carbonate minerals, and phosphorite and other authigenic minerals in terrestrial equivalents of the shelf deposits. Carry out similar study of island deposits which may have formed in the last few thousand years;

(d) Survey by means of bottom photography, seismic-reflection profiling, and drilling modern carbonate banks areas which may be accumulating relatively high concentrations of organic matter, or which may have done so in the recent past. Particularly important areas for these surveys are the shelf areas of North Carolina and West Florida.

MANGANESE NODULES

Introduction

Manganese nodules cover much of the deep sea floor and appear to be a rich potential resource for Ni, Cu, and possibly Co. The richest fields of nodules both in terms of grade and abundance, however, occur in international waters of the eastern equatorial Pacific between the latitudes 5° and 15°N (fig. 3). Exploitation of this resource is limited more by a lack of a favorable legal framework for leasing than by the technological problems of working on the deep sea floor. Nodules occurring within the EEZ unfortunately are not as abundant, and the terrain is more varied. Their distribution, grade, and tonnage are less well known.

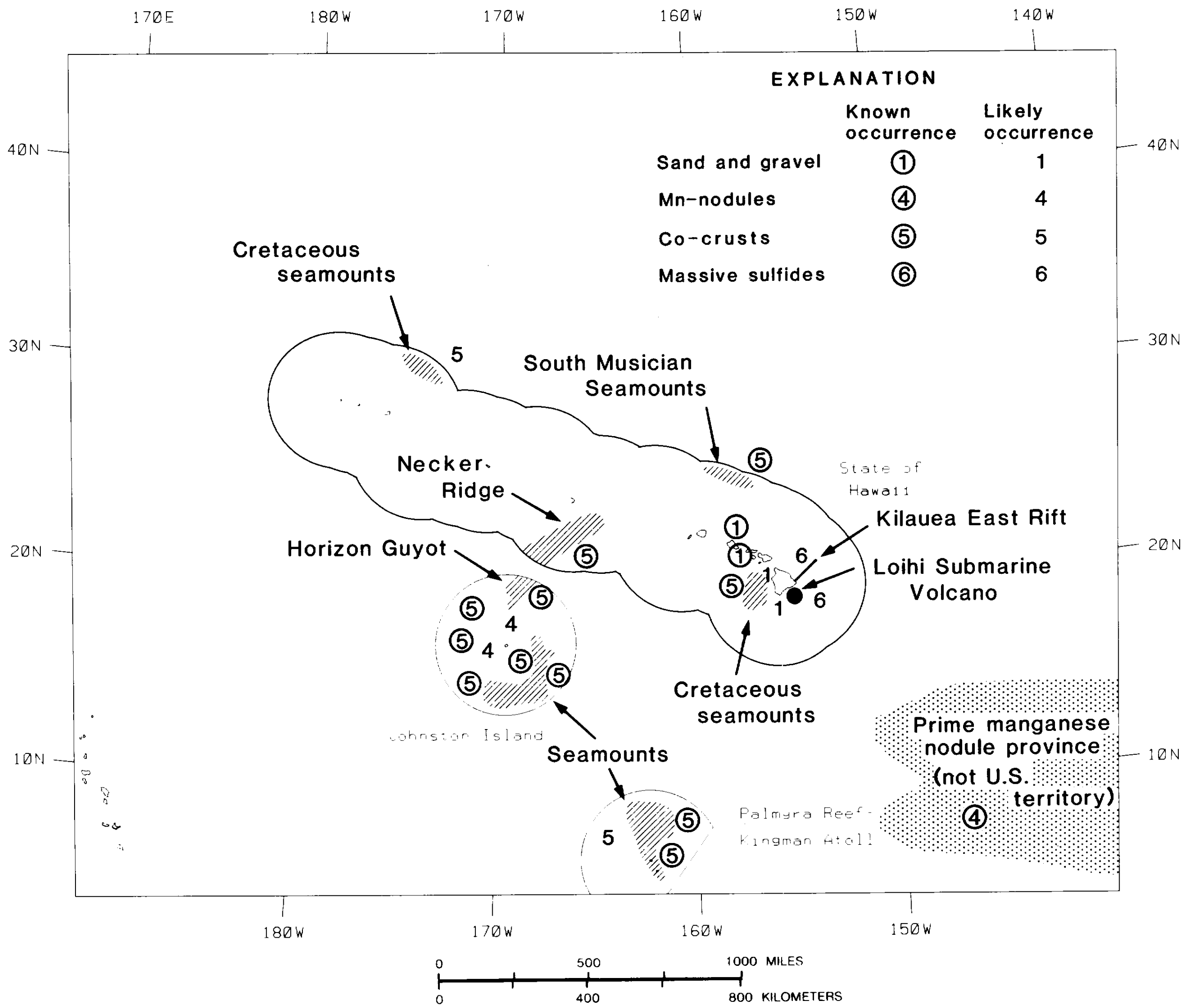
Distribution and scientific understanding

Manganese nodules have been reported within the EEZ of both the east and west coasts of continental United States, Hawaii, and Pacific Island territories (figs. 1, 3, and 4). Though not of concern in respect to the EEZ, nodules are also known in the Great Lakes. Known occurrences off the Pacific coast of conterminous United States are too irregular in abundance, composition, or some combination of these and other factors to be eligible for immediate economic consideration. Thus, for pragmatic reasons only those regions of early economic promise are included in this brief summary. The Blake Plateau off the Atlantic coast and regions near the Hawaiian Islands are the prime candidates (figs. 1 and 3). Nodules have also been observed within the 200 mile zones of Pacific Island territories.

There are many theories of nodule development and much disagreement exists among investigators. The ultimate source of metals may be from seawater or from the seafloor breakdown and oxidation of biogenic debris. As growth occurs about the nucleus, the outer surface approximates a spheroid.

The Blake Plateau (fig. 1) is a region of the Atlantic Continental Shelf off the Florida, Georgia, and South Carolina coasts. It is a wide terracelike feature submerged 500 to 1,000 meters below the sea surface. A major segment of the Blake lies within the EEZ. Much of the plateau is swept by the Gulf Stream. Bottom currents have sufficient energy to sweep the bottom clear of sediment. The middle Tertiary phosphate-enriched strata forms a corrosion and dissolution resistant substrate. Phosphatic pebbles form the nucleus of most of the nodules. Likewise it is a stratum of phosphates that forms the precipation base for pavements and slabs of manganese oxides.

Nodules were first reported in this location by Sir John Murray in 1885. More recently, investigations by Woods Hole have documented these deposits. Newport News Shipbuilding & Dry Dock Company investigations of the Blake began in the early 1960's and were continued by its successor, Deepsea Ventures, in 1969 and 1970. In July of 1970, Deepsea Ventures successfully completed the first deep-ocean nodule mining tests using a prototype airlift system. Accompaning this test were the first environmental studies of nodule mining. Blake Plateau nodule deposits in the past have been considered economically submarginal. However, the



170E
180W
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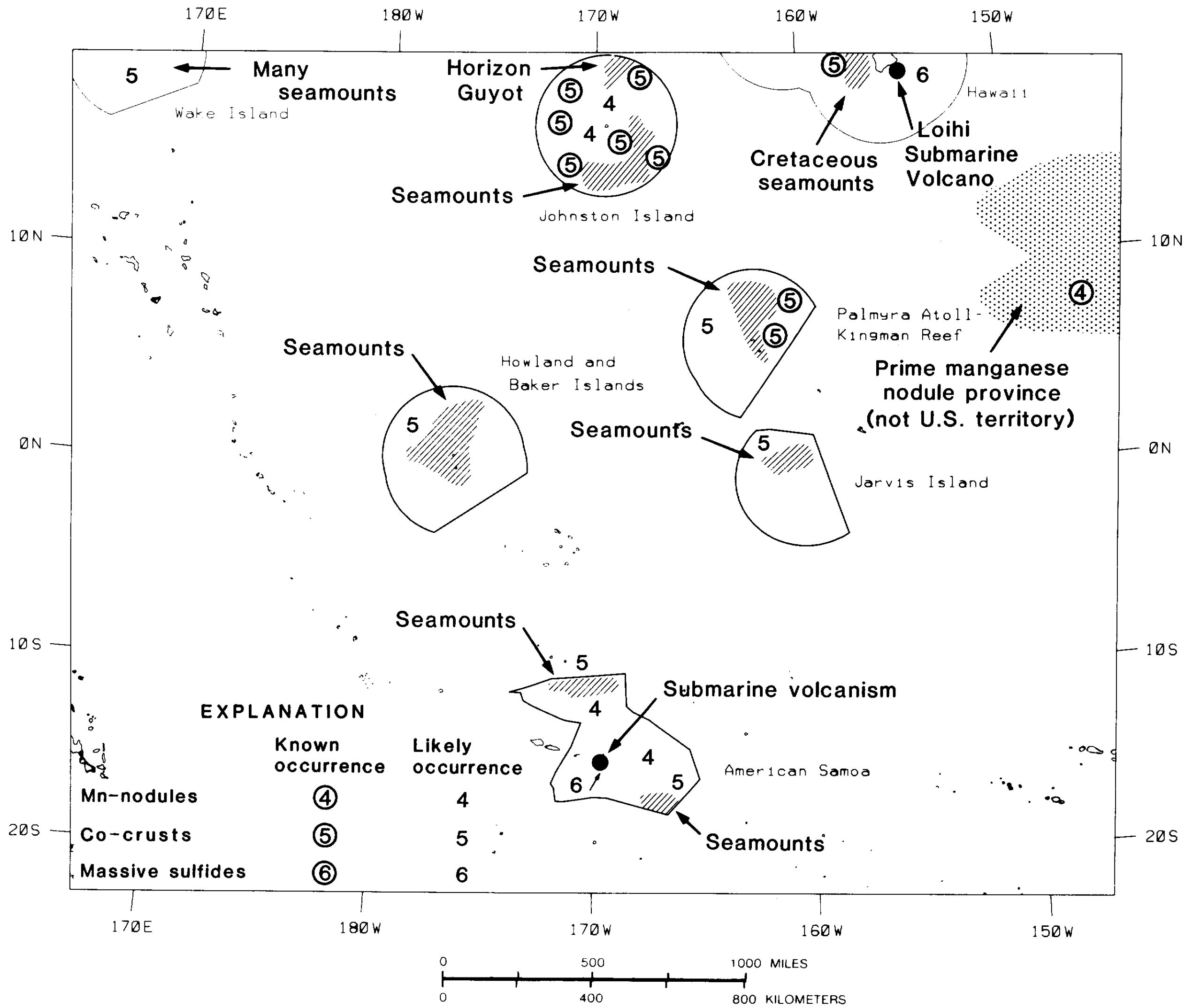
40N
30N
20N
10N
EXPLANATION
Known occurrence
Likely occurrence
Sand and gravel
Mn-nodules
Co-crusts
Massive sulfides
Cretaceous seamounts
South Musician Seamounts
State of Hawaii
Necker Ridge
Kilauea East Rift
Horizon Guyot
Loihi Submarine Volcano
Cretaceous seamounts
Johnston Island
Seamounts
Prime manganese nodule province (not U.S. territory)
Palmyra Reef-Kingman Atoll
0 500 1000 MILES
0 400 800 KILOMETERS

Figure 3.



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Many seamounts
Wake Island
Horizon Guyot
Seamounts
Johnston Island
Cretaceous seamounts
Loihi Submarine Volcano
Hawaii
6
Seamounts
Palmyra Atoll-Kingman Reef
Prime manganese nodule province (not U.S. territory)
Seamounts
Howland and Baker Islands
Seamounts
Jarvis Island
Seamounts
Submarine volcanism
American Samoa
Seamounts
EXPLANATION
Known occurrence
Likely occurrence
Mn-nodules
Co-crusts
Massive sulfides
0
500
1000 MILES
400
800 KILOMETERS

Figure 4.

recent discovery of platinum at levels 0.1 to 0.5 grams/tons have caused renewed interest in these deposits.

Manganese nodules and crusts have been recognized as authigenic sea-floor deposits in the seas surrounding the Hawaiian chain (fig. 3). Here the ferromanganese accumulations grade into slabs and crusts which come under the Co-crusts classification. The University of Hawaii initiated investigations in the Kauai Channel in the mid-1970's. The deposits here are in water depths of 1,200 to 2,400 meters and stretch almost the entire length of the channel. A region 5 to 8 miles in width has been delineated. Nodules are commonly associated with brown clay and are believed to be erosional remnants of shallower crustal zones. Throughout the EEZ of the islands, similar deposits have been sampled. In some locations crust and slab dominate.

Exploration within the 200 mile zone of the Pacific Islands (figs. 4 and 5), Wake, Northern Mariana, Palmyra, Jarvis, American Samoa, Howland, and Baker have established the presence of ferromanganese nodules, crusts and slabs. Throughout these various locations, in many places water depth and compositional characteristics resemble occurrences in proximity to the Hawaiian Islands.

Scientific gaps and future research

The EEZ offers opportunity for expansion of discovery and understanding of manganese nodule resources. It is imperative that an orderly, expedient process that permits development and utilization of these resources be generated and implemented. Formulation of programs must be designed to evoke cooperative responses of all pertinent groups -- government, academia and industry.

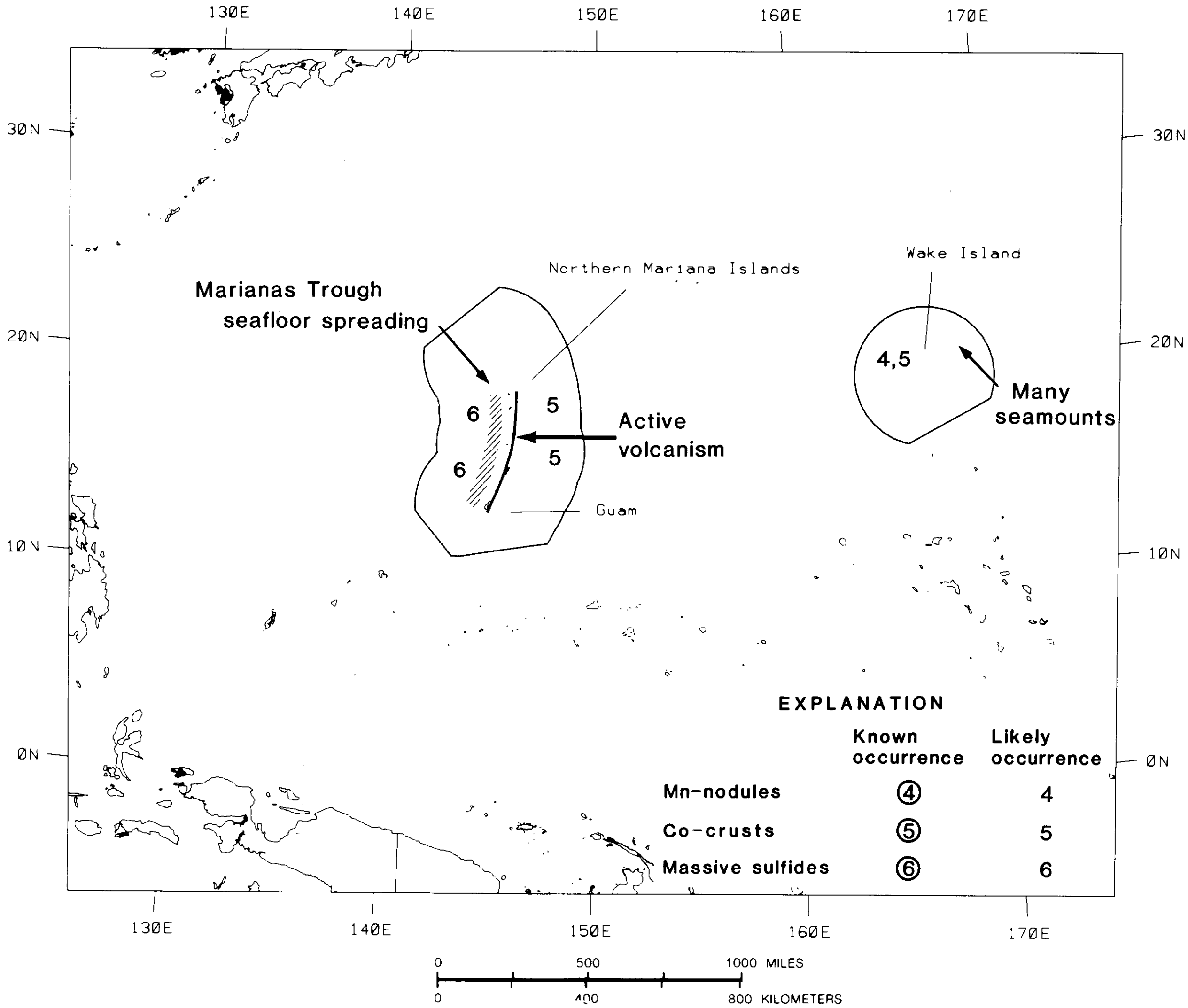
The program should include:

(a) Mapping and sampling surveys to produce bathymetric, topographic, and geologic charts, especially using mosaic-photography and multibeam and sidescan sonar;

(b) Maintenance of sample collections and data depositories;

(c) Research into uses for the low grade EEZ nodules. For example, the oxidizing compounds, including MnO_2 and other metallic oxides, and the highly porous and permeable structure of nodules are characteristics needed for a catalytic filter capable of removing pollutants from stack gases;

(d) Evaluation of the levels of platinum metals in Blake Plateau nodules and other marine mineral bodies.


130E
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Marianas Trough
seafloor spreading
Northern Mariana Islands
Wake Island
4,5
Many
seamounts
6
5
Active
volcanism
6
5
Guam
EXPLANATION
Known occurrence
Likely occurrence
Mn-nodules
④
4
Co-crusts
⑤
5
Massive sulfides
⑥
6
0
500
1000 MILES
0
400
800 KILOMETERS

Figure 5.

COBALT CRUSTS

Introduction

The recent discovery of high cobalt concentrations in ferromanganese crusts on the tops of several mid-Pacific seamounts suggests that extensive resources of cobalt may lie within the EEZ of the central Pacific.

Industrial demand for cobalt, used largely for the manufacturing of jet engines, cutting tools, and hard-facing applications, has been steadily increasing, and the United States imports more than 90 percent of its need from foreign sources (100 percent excluding recycled supplies), primarily from southern Africa.

This newly recognized resource type has considerable scientific as well as economic interest. It should be pointed out, however, that their occurrance on irregular sea-floor terrain introduces very difficult engineering problems for recovery.

Distribution and scientific understanding

Co-rich manganese oxide crusts have been found coating hard substrates on the flanks of islands and on the tops of seamounts in the equatorial Pacific (figs. 3 to 5). The crusts occur at relatively shallow depths (1,000-2,500 m), as opposed to the better known abyssal manganese nodules. The crusts are known to be present on flank areas of the Hawaiian Islands, Line Islands, Wake Island, America Samoa, Howland and Baker Islands, Guam and the northern Marianas Islands, and islands of the Trust Territories of the Pacific. Co content ranges from about 0.4 percent for the deeper crusts to 1.2 percent on seamount tops shallower than 2,500 m. The Co content is more than 2 percent in the outer 0.5-cm-thick layer of seamount crusts.

Co content of the crusts is highest at water depths of less than 2,500 m, and the most favorable areas are where the sea floor is at least 20 m.y. old (and preferably more than 80 m.y.) and mostly free from dilution by sediment accumulation. Thus, the ages and elevations of the target sea-floor areas become important considerations in planning surveys.

The importance of this resource type was recognized in 1981, and at present its distribution and genesis is little understood scientifically. Typical crust substrates are hydrothermally altered basalt, phosphorite, and hyaloclastite containing fragments of vesicular basalt. The mean crust thickness of more than 2 cm in upper slope areas may yield accessible concentrations of about 16 kg per square meter of crustal surface. Monetary values of Co, Ni, Mn, Cu, and Mo contents per square meter are significantly greater than values of comparable materials from known deep-water nodule sites. A single seamount could possibly yield between 1 and 2 billion dollars' worth of ore, including more than a 3 years' national supply of cobalt, and approximately 100 of these seamounts lie around Hawaii and the Line Islands alone.

Scientific problems and future research

No systematic sampling for Co-crusts has yet been done, and the areal extent, thickness, and composition of the crusts are still largely unknown.

Several scientific questions are immediately apparent such as:

(a) What is the source of the Co; is it derived directly from seawater, breakdown of biogenic debris, or from the crust substrate?

(b) What controls Co concentration? It seems to bear a relation to water depth and perhaps to the depth of the oxygen minimum layer.

(c) Co distribution within the crusts is not well known. Growth rate of the crusts and Co content seem to correlate inversely. This possibility needs further investigation.

(d) What is the relationship between the geologic history and age of seamounts and the occurrence of the Co-crusts? Are Co-crusts buried beneath submarine talus slopes? Does Co migrate and remobilize after burial?

If we are to answer these questions, a broad program of investigations is required. The first of these should be bathymetric and geophysical swath-mapping of seamounts in the equatorial Pacific EEZ, which should be completed before detailed sampling. Detailed sampling should then be carried out on a few selected seamounts, with several hundred samples each to answer the question of continuity of the crusts over the area. New samplers will need to be developed which can penetrate hard substrate and which can be positioned precisely on the seafloor. Traditional dredging covers too large an area during each haul and is not as useful in this regard.

After the sampling on selected seamounts, large-area bottom photographs should be taken to determine the percentage of the area that is covered by the crusts and to develop an understanding of bottom roughness to aid in engineering-feasibility studies. The large-area format is required in order to cover a significant area and to insure that the camera equipment "flys" high enough above irregularities encountered on the seamount surfaces.

Shore-based mineralogic and geochemical studies of the crusts will utilize X-ray diffraction and scanning electron microscope examination, complete analyses of the bulk crusts, and electron microprobe scans across individual crusts to assess variations in crust composition at a single dredge or core site.

A hydrocast station should be occupied in each area so that the relation between seawater chemistry and the Co content of the crusts can be evaluated. The water samples collected will be analyzed with emphasis on the Co/Mn ratio in the water and on the redox potential of the water, because Co^{2+} may be oxidized to insoluble CoO_2 which enters into solid solution with MnO_2.

MASSIVE-SULFIDE DEPOSITS

Introduction

Recently, a new type of sea-floor mineral occurrence, which may prove to be of great economic value, has been discovered in several parts of the eastern Pacific Ocean. These deposits are sea-floor massive sulfides found along sea-floor spreading centers. Several sea-floor spreading centers occur within the EEZ.

Massive-sulfide deposits are prominent features in many land-based ophiolite complexes of the world, and have provided substantial tonnages of copper, zinc, and silver in such places as Oman, Cyprus, Turkey, Italy, Canada, the Philippines, India, and the Soviet Union. Ophiolites are fragments of ancient ocean crust emplaced along continental margins during collisions between lithospheric plates.

Occurrence and scientific understanding

The suspicion that ophiolite-related massive-sulfide deposits originally formed as a result of sea-floor volcanism was confirmed by the dramatic discovery in 1979 of hydrothermal vents on the East Pacific Rise at the mouth of the Gulf of California (EPR, 21°N latitude, fig. 1). Using the manned submersible ALVIN, investigators found active hydrothermal vents with fluid temperatures exceeding 350°C. These vents were forming massive-sulfide mounds several meters high and composed of sulfides of zinc, copper, and iron and significant quantities of silver. Similar systems and deposits were discovered in 1981 at the Galapagos Rift, the Guaymas basin within the Gulf of California, the Juan de Fuca Ridge, and on the East Pacific Rise at 13°N and 20°S.

Both the Galapagos Rise and the East Pacific Rise (EPR) near 21°N are medium-rate spreading centers (total separation approximately 5 cm/yr). The presence of active hydrothermal vents at both spreading centers of a few square kilometers in extent suggests that the phenomenon may occur over much of the length of other medium-rate and faster spreading systems. Approximately 40,000 km of spreading ridges with spreading rates greater than 5 cm/yr lie within the Pacific and Indian Ocean basins.

These discoveries immediately led U.S. scientists to consider the Juan de Fuca and Gorda spreading centers off the coasts of California, Oregon, and Washington as possible targets for similar deposits within the U.S. EEZ (fig. 1). During 1981, a USGS cruise to the Juan de Fuca

Ridge recovered samples from a hydrothermal vent area just outside the EEZ boundary. The samples, which are almost identical to those discovered at the 21°N EPR, are almost pure zinc sulfide (55 percent Zn) and contain 300 parts per million silver. Such a deposit, were it found on land and in sufficient tonnage, would constitute a valuable and exploitable resource for zinc and silver. Likewise, the deposit found at the Galapagos Rift seems to be a potential copper resource, with the copper content ranging between 5 and 10 percent.

During August of 1983, fresh lavas, hydrothermal nontronite, Mn-oxides and muds were recovered by dredge on the Gorda Ridge (fig. 1). The Gorda Ridge is entirely within the EEZ and recently has been opened for leasing by the Minerals Management Service.

The process of formation of these deposits is fairly well understood. The massive-sulfide mineralization along the mid-ocean ridges are hydrothermally produced, that is, the heavy metals and sulfur are leached from rocks below sea floor by deeply circulating hot seawater and are deposited when the hot seawater is discharged on the sea floor. The actual zone of active sea floor spreading is narrow, usually only 1 or 2 kilometers in width, despite the great length of ridges. Such a geometry, and the fact that the spreading-center crests are under 2,000 meters of seawater, results in convective cooling of the spreading centers by seawater. The intense discharge of the ascending fluid is confined to a few localized and narrow channels that give rise to the isolated and rapidly discharged vents observed on the sea floor.

A dramatic reaction takes place on the sea floor where the hot (300°-400°C), acidic, metal-bearing fluid discharges into cold (2°C), oxygenated, alkaline seawater at the sea floor. Mixing produces a drastic and nearly instantaneous change in the chemical and physical conditions of the fluid, and a black plume of discharging fluid is produced. The plume consists of iron, copper, and zinc sulfide minerals that have precipated on mixing. This precipation process gives rise to chimneys and mounds of massive sulfides.

Scientific problems and future research

The foregoing implies that massive-sulfide deposits are likely to occur wherever there is submarine volcanism, or wherever a subsurface magma chamber exists. Thus, in addition to the Gorda and Juan de Fuca spreading centers currently under study, attractive targets within the EEZ for massive sulfide deposits are the active volcanic island arcs (Aleutians and Marianas) and isolated sea-floor volcanoes (many are known throughout the Pacific EEZ, including Loihi off Hawaii).

At least 30 volcanoes have been active in the Aleutian arc since 1700 (fig. 2). The segmented line of active volcanism runs a distance of 1,300 km. Farther west, along and within a graben, the presence of several seamounts suggests that active submarine volcanism is occurring today. This area has not been studied to determine the presence of hydrothermal activity. The area, however, does seem one of the more promising regions for submarine mineralization. Other promising areas along the Aleutian arc would be in submarine locations along the axes marked by the alignment of active subareal volcanoes.

The Marianas group (fig. 5) has two potential regions of active submarine volcanism where massive sulfides may be accumulating. Submarine areas along the axis of island volcanism is one region where active submarine volcanism has been reported. The other potential area is the back-arc region, the Marianas trough. The trough is an active spreading axis and should be given high priority in the search for massive-sulfide deposits. These paired, volcanically active features extend north and south for approximately 800 km, and both are entirely within the EEZ of Guam and the northern Mariana Islands. Considerable evidence indicates that hydrothermal systems similar to those at mid-ocean ridges are active in the Mariana trough, which is a backarc spreading center. Preliminary work has identified an axial graben where sea-floor spreading is now taking place.

Active volcanoes of the Mariana arc lie only a few tens of kilometers east of the back-arc spreading center in the Mariana trough. Although the tectonic framework of the arc is not well known, water depths between volcanically active islands reach 3,000 m.

The areas of opportunity and high potential are vast and will require large-scale surveys for adequate coverage. Future research should include the following:

(a) Bathymetric-swath surveys (e.g., SEABEAM) of target areas using precision navigation to provide a base map for more detailed studies.

(b) Water-column studies for identification of helium-3 and manganese anomalies. Active sea-floor vents commonly give rise to traceable quantities of ^{3}He and Mn in the overlying water columns that can be detected as far as thousands kilometers away from the vents. Research is needed on improvement of these remote-detection techniques.

(c) Detailed sea-floor photo coverage of likely target areas (e.g., ANGUS and recently developed video systems). Colored photo mosaics can clearly identify biologic vent communities and pinpoint growing massive sulfide deposits.

(d) Detailed sea-floor geophysical studies (e.g., DEEP TOW, GLORIA), including magnetic, seismic and side-scan sonar.

(e) Manned-submersible (e.g., ALVIN) studies of vent areas identified in (c) above. This allows sampling and geologic mapping of deposits to delimit grade and lateral extent.

(f) Sea-floor drilling. The best way to delimit the thickness of a deposit is by drilling. Submarine drill rigs are being developed (e.g., Bedford Institute of Oceanography, electric rock-core drill) which can be precisely positioned on the seafloor and drill to depths of 10 meters.

(g) Drilling from a drill ship - Deposits occuring beneath the sea floor can be discovered by deep drilling using a dynamic-positioned drill ship (e.g., Glomar Challenger). This approach is particularly important in the Aleutians and Marianas where large deposits may be covered by rapid sedimentation.

SUMMARY AND RECOMMENDATIONS

The review presented in this document shows that the initial discovery of most hard-mineral resources in the EEZ was made during routine scientific marine-geologic surveys aimed at understanding the framework geology and geologic processes of an offshore region. The earth-shaping processes within the EEZ boundaries are diverse, complex, and in many places still poorly understood. Nevertheless, it is essential that this history be understood if we are to adequately understand the framework and assess the resource potential of this 3.9 billion acre region. Proposed techniques for study of the individual resource types overlap, particularly in requiring large-scale sea-floor surveys and scientific drilling.

The integration of marine geological and geophysical data is an essential element in arriving at a level of understanding necessary for an assessment of the mineral resources of the EEZ. We must not only develop a fundamental understanding of the crustal history, but we must also understand the basic processes that control the parameters that influence resource distribution.

The Science Panel on Hard Minerals strongly encourages the Federal Government to establish a national program to investigate the occurrence of hard minerals within the Exclusive Economic Zone. The Panel believes that the United States should avoid being dependent on other nations for such raw materials through the delineation of hard-mineral resources within the EEZ as well as use of that data base to help in the exploration of hard-mineral deposits on land.

The Panel recognizes that the hard-mineral deposits presently known within the EEZ are marginal in value given our present data base and world metal prices. This observation, however, needs to be tempered by the following facts:

(1) In 1960 we were unaware that the mid-ocean ridge was the largest geologic feature on our planet covering 23 percent of its total surface area.

(2) By 1964 we had yet to fully embrace the concepts of plate tectonics which have subsequently revolutionized earth science.

(3) By 1979 we had yet to find the high-temperature deposition or massive sulfides on the mid-ocean ridges, let alone the more recent discoveries of similar deposits in back-arc basins and on seamounts which have also been found to have cobalt rich crusts.

Even more important is the fact that much of this new insight has come as a result of expeditions which were not seeking to find hard minerals. We openly admit our past and present ignorance and, therefore, encourage accelerated exploration. Although a variety of Government agencies are involved in carrying out investigative studies within this newly established region and should be encouraged to continue, we specifically encourage the U.S. Geological Survey, the Minerals Management Service, and the National Ocean and Atmospheric Administration to develop a coordinated national program aimed at the following objectives:

(1) The generation of topographic and geologic maps of the EEZ through the inventorying of existing data bases as well as carrying out reconnaissance surveys to further our understanding of the extent and significance of known hard minerals such as sand and gravel, placers, phosphorite, Mn-nodules, Co-crust, and massive sulfides and other hard-mineral deposits not yet discovered in the marine environment. A sense of urgency is placed on the need to generate such maps as soon as possible with emphasis upon their rapid public dissemination. Additional emphasis needs to be placed upon acquiring such maps in the most cost-effective manner possible given the 3.9 billion acres involved. For that reason, industry and academia should be given serious consideration in the production of such maps if their services are more cost-effective.

During this reconnaissance effort, attention should be given to specific geologic provinces within the EEZ in an effort to identify those hard-mineral assemblages which are associated with each particular geologic setting.

(2) The identification of areas where probability of finding such deposits is high, and the subsequent detailed investigation within those areas. Care must be taken in these studies to define the criteria to be used to evaluate the deposit. Emphasis, for example, must be placed not only on the bulk analysis of the deposits but the physical setting in which they are found, as such settings may affect subsequent exploration and ultimate exploitation.

Although the Panel stops short of making specific recommendations regarding ultimate assessments of hard minerals within the EEZ at this time given our meager data base, we encourage the Minerals Management Service to:

(1) ensure that leasing of tracks in the future will not preclude parallel scientific investigations in the same areas and,

(2) establish a legal framework similar to the framework now governing exploration in Canadian waters to guarantee the timely release of data to the public sector without injuring the companies' priority investment.

Panel IIA

OFFSHORE OIL AND GAS TECHNOLOGY ASSESSMENT

Panel Chairmen:
R. Curtis Crooke, Global Marine Development, Inc.
Lloyd G. Otteman, Shell California Production, Inc.

INTRODUCTION

The importance of the U.S. Outer Continental Shelf within the Exclusive Economic Zone and its potential for supplying a significant part of today's energy needs, and an increasingly significant part of tomorrow's needs is appreciated by all who are concerned with its development. The great unknown, however, is just how much of our future oil and gas supplies will come from the offshore areas and, from a total national viewpoint after we balance all alternatives, what is the best way to develop and use the OCS energy-resource potential. A specific subject of importance in this regard is the technology available to develop these oil and gas resources.

A panel composed of industry, government, and academia representatives reviewed the offshore oil and gas technology base presently available and being developed by the petroleum industry in its efforts to contribute to the safe, efficient, economic, and environmentally sound development of the OCS oil and gas resources. The following report presents the findings of the panel.

We will discuss, without attempting to quantify the tremendous efforts required, the status of offshore technology, particularly as it pertains to deepwater and arctic frontier areas of the OCS. We will also review briefly the present status, i.e., direction and location, of research and development activities being pursued by the U.S. petroleum industry, U.S. Government, and the governments around the North Sea.

The development of future technology will depend a great deal on the consistent and progressive application of today's technology as well as the overall assessment of the rewards and benefits to be achieved by advancing the technology. Technology is not only the acquisition and possession of scientific knowledge but, more than that, it is the application of that knowledge to solving practical problems. In this regard, we will recommend courses of action which industry, government, and academia should take to assist in providing the scientific knowledge and engineering necessary to permit the safe, orderly, economic, and environmentally sound development of our ocean resources. In particular, our primary recommendation is that government must coordinate its various programs for acquiring regional environmental data, and provide a single point of contact so that industry can access this data for input to programmatic decisions. This data should include oceanographic, meteorological, ice, and geotechnical conditions in candidate regions for development.

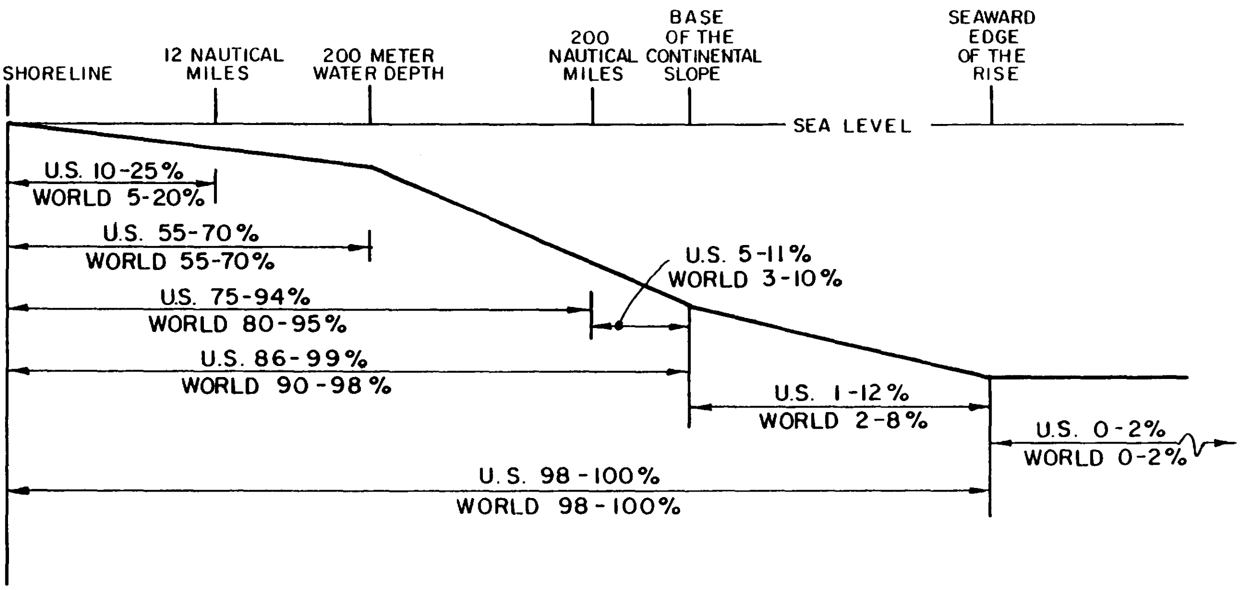
The driving force behind the technology developments of the petroleum industry has been the continuing search for oil and gas which has led the industry from onshore hills and plains into the marshlands towards the sea and, finally, into open water of the oceans throughout the world. The goal of this search has been to access and develop the potential ocean petroleum resources as has been estimated by such experts as Michel T. Halbouty(1) and the late Lewis G. Weeks. Weeks estimated that, when considering the ultimate recoverable petroleum resources beneath the sea, 59 percent of the total lies within 40 nautical miles of the shore, 68 percent beneath water shallower than 200 meters, 87 percent within 200 nautical miles offshore, and 93 percent beneath water shallower than 3,000 meters.(2)

A range of estimates of petroleum to be ultimately found and produced from under various parts of the oceans was also presented in a report by the National Petroleum Council in 1975.(3) Figure 1, in this report, shows a range of estimates which relate to the distribution of ultimate recoverable petroleum, including the already discovered resources under the oceans and semi-enclosed seas. Because of the increasing costs of exploring for hydrocarbons in deep water and arctic regions, only large and high-quality resources from these areas can be economically recovered with current technology.

EXPLORATORY DRILLING SYSTEMS

The technological challenge associated with this search has been an evolutionary process. It had its beginning around 1897 from piers along the coast of Santa Barbara, California, moved into the shallow water of Lake Maracaibo in the early 1920's and into swamps and offshore Louisiana in the Gulf of Mexico in the 1930's.

These evolutionary developments have taken place as the industry spread its activities world-wide and have created a family of mobile drilling rigs -- such as shown in figure 2 -- to drill everywhere from coastal marshlands out to 7,000 to 8,000 feet of water in the open sea. These developments were largely determined by the opportunities and economics in deepwater and arctic frontier areas. Today, there are approximately 727 of these various units (38 submersibles, 435 jack-ups, 96 drill ships and barges, and 158 semisubmersibles) in operation around the world with 145 working in U.S. waters. The worldwide rig utilization, as of October 1983, was about 75 percent and 44 new rigs are under construction.(4)



ESTIMATED DISTRIBUTION OF OFFSHORE POTENTIAL ULTIMATELY RECOVERABLE PETROLEUM

Figure 1.

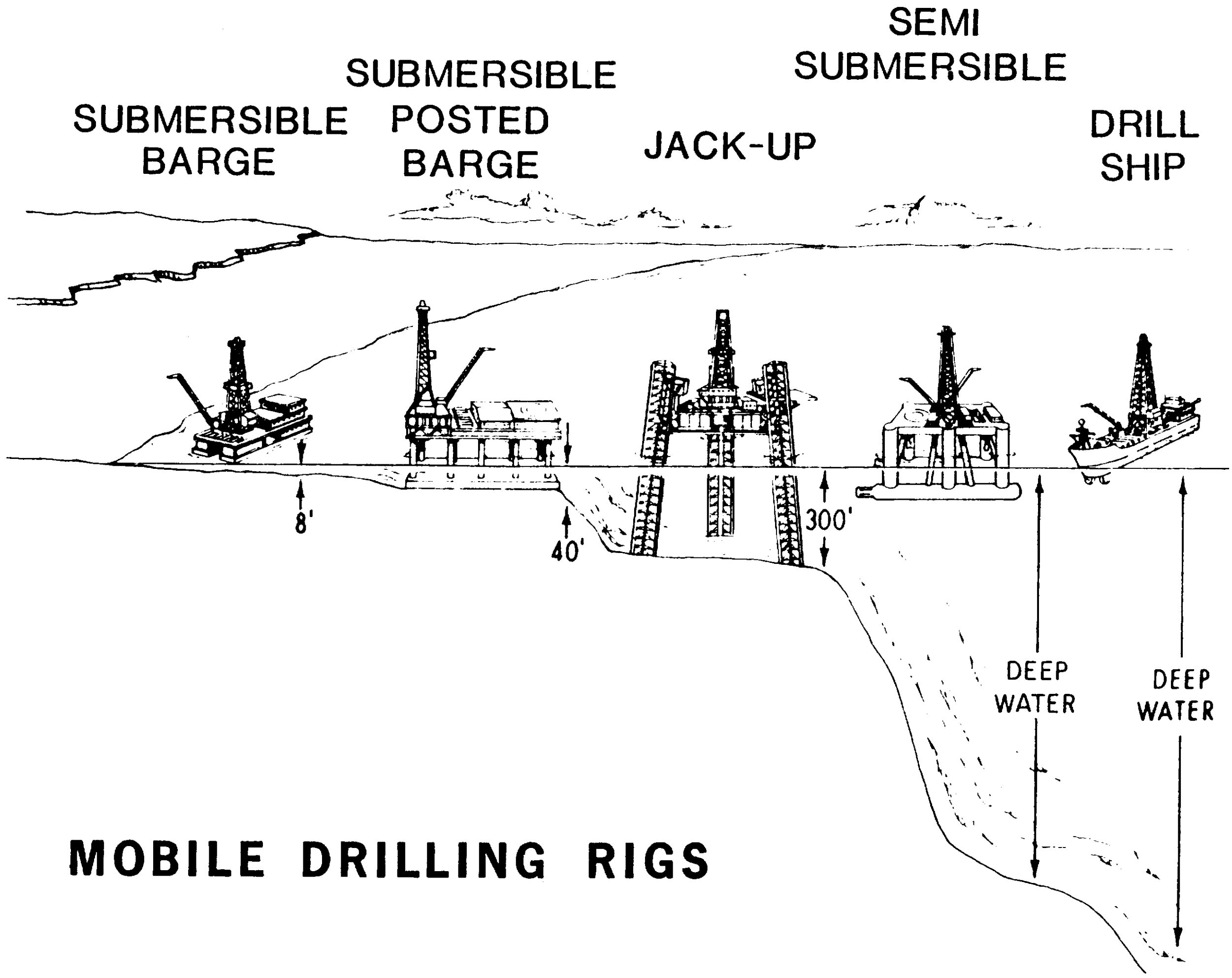

SUBMERSIBLE BARGE
SUBMERSIBLE POSTED BARGE
JACK-UP
SEMI SUBMERSIBLE
DRILL SHIP
8'
40'
300'
DEEP WATER
DEEP WATER
MOBILE DRILLING RIGS

Figure 2.

Proven drilling equipment is available today to function effectively under various environmental conditions while drilling in water depths as great as 7,500 to 8,000 feet. Figure 3 shows the drilling water depth records since 1965 and the current record of 6,448 feet. A list of the number of wells drilled in water depths greater than 2,000 feet is shown in figure 4. Also shown is a summary of drilling rigs capable of drilling in greater than 2,000 feet. Existing drilling technology should be adequate for the next decade. The four rigs with 6,000 foot water depth capability can be extended to 8,000 feet. It is believed, as shown in figure 5,(5) that the technology is currently available to permit the development of a system to drill and complete wells in as much as 10,000 feet of water by 1990, if economically justified.(6)

Industry has the capability to drill exploratory wells in deeper water, but deepwater-production-system experience has not been obtained because until recently there have been no commercial discoveries to justify installations. However, over the last several years, the petroleum industry has invested hundreds of millions of dollars in designing equipment, developing analytical tools, and performing model tests in preparation for drilling development wells and producing oil and gas in water depths to 7,500-8,000 feet and more.

OFFSHORE DEVELOPMENT SYSTEMS TECHNOLOGY

Platforms

Nearly all offshore fields have been developed with fixed-leg platforms or manmade islands. As shown in figure 6, fixed-leg platforms have evolved since 1947 to meet the needs of the U.S. deepwater locations. The size of Shell's COGNAC platform in the record water depth of 1,025 feet is approaching the economic limit for fixed-leg structures. There are now more than 1,250 major platforms in the Gulf of Mexico, plus more than 2,300 smaller well-protector structures. In addition, there are 22 platforms and 7 islands installed offshore California, 14 platforms in Cook Inlet, Alaska, and 10 exploratory gravel islands in the Alaskan Beaufort Sea.

As the petroleum industry moved into the hostile environment of the North Sea, large steel platforms were required. Also, a new type of bottomsupported structure was designed -- the concrete gravity platform with its relatively simple construction and limited installation expense. The evolution of platforms in the North Sea is shown in figure 7. The significant recent milestones have been Chevron's Ninian concrete platform -- which is the heaviest at 550,000 tons -- and British Petroleum's Magnus steel platform in 610 feet of water, a record for the North Sea.

It is expected that the fixed-leg platform will be limited to a maximum water depth of 1,200 to 1,500 feet -- primarily owing to the cost of fabrication and certain installation constraints. However, as shown in figure 8, new types of platforms such as guyed towers and

WATER DEPTH RECORDS FOR DRILLING OPERATIONS

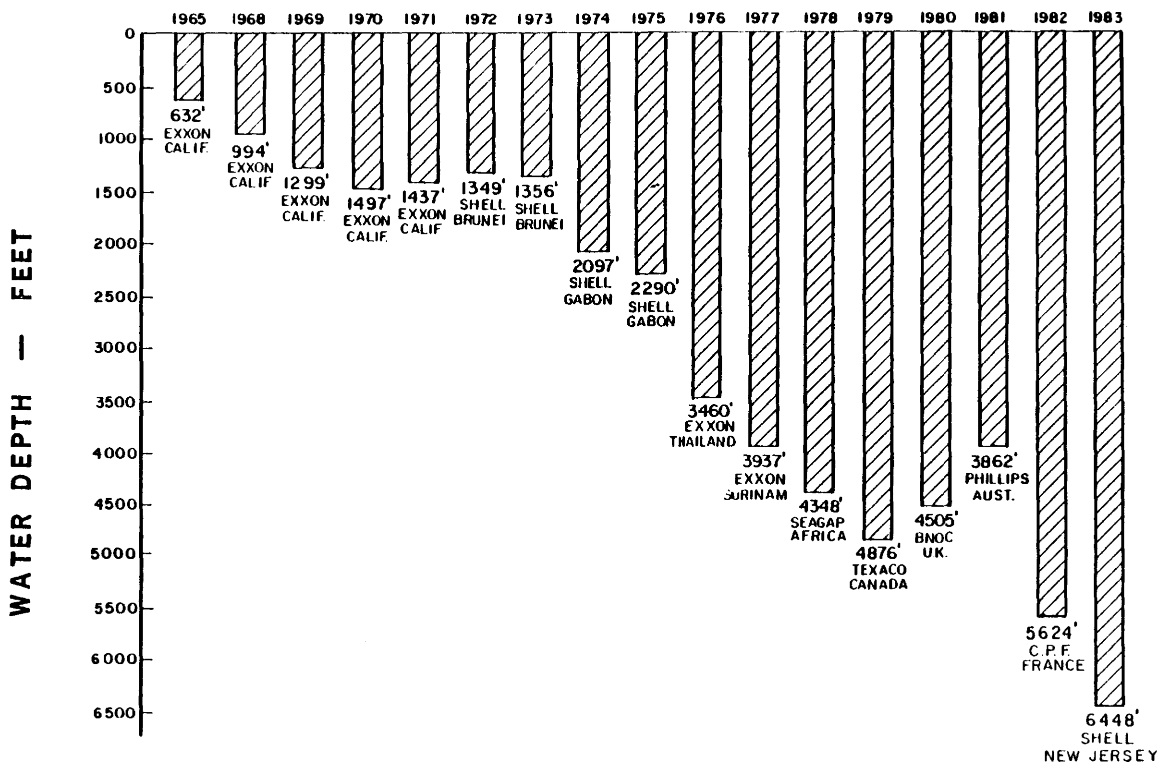


Figure 3.

INDUSTRY DRILLING EXPERIENCE IN DEEPWATER

1974-83

WATER DEPTH - FEET	WELLS DRILLED
2000 - 3000	45
3000 - 4000	23
4000 - 5000	11
5000 - 6000	1
6000 - 8000	1
TOTAL	81

WATER DEPTH-FEET	DRILLING RIGS
2000 +	33
3000 +	13
5000 +	5
6000 +	4

Figure 4.

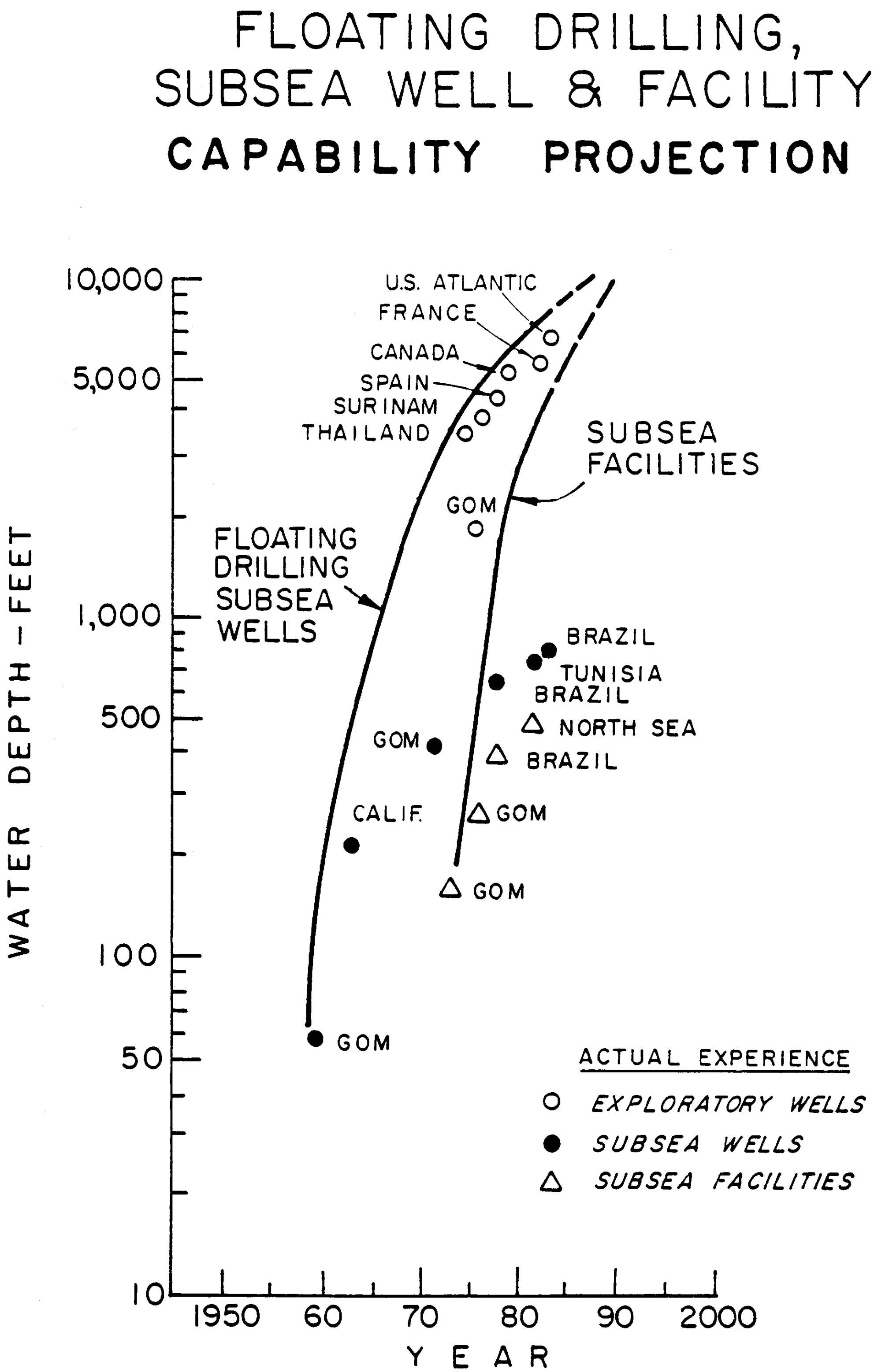
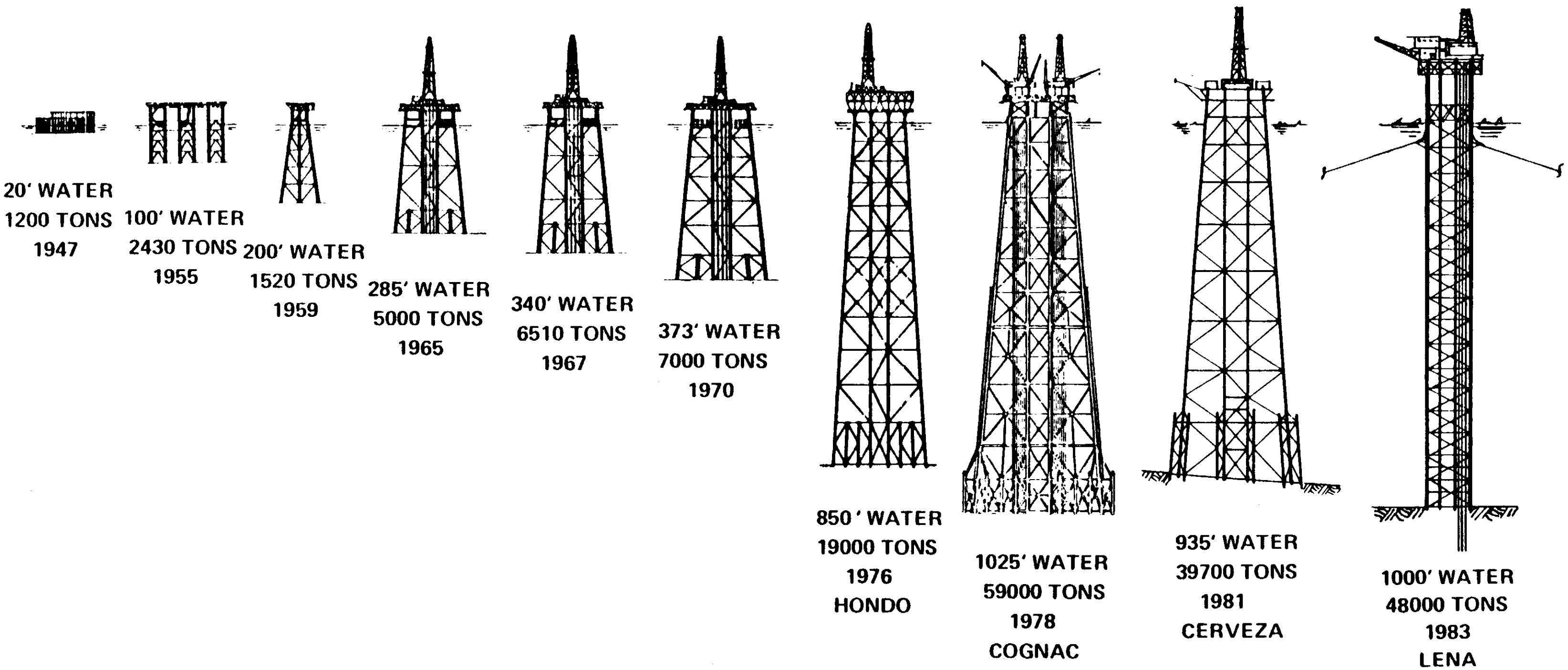
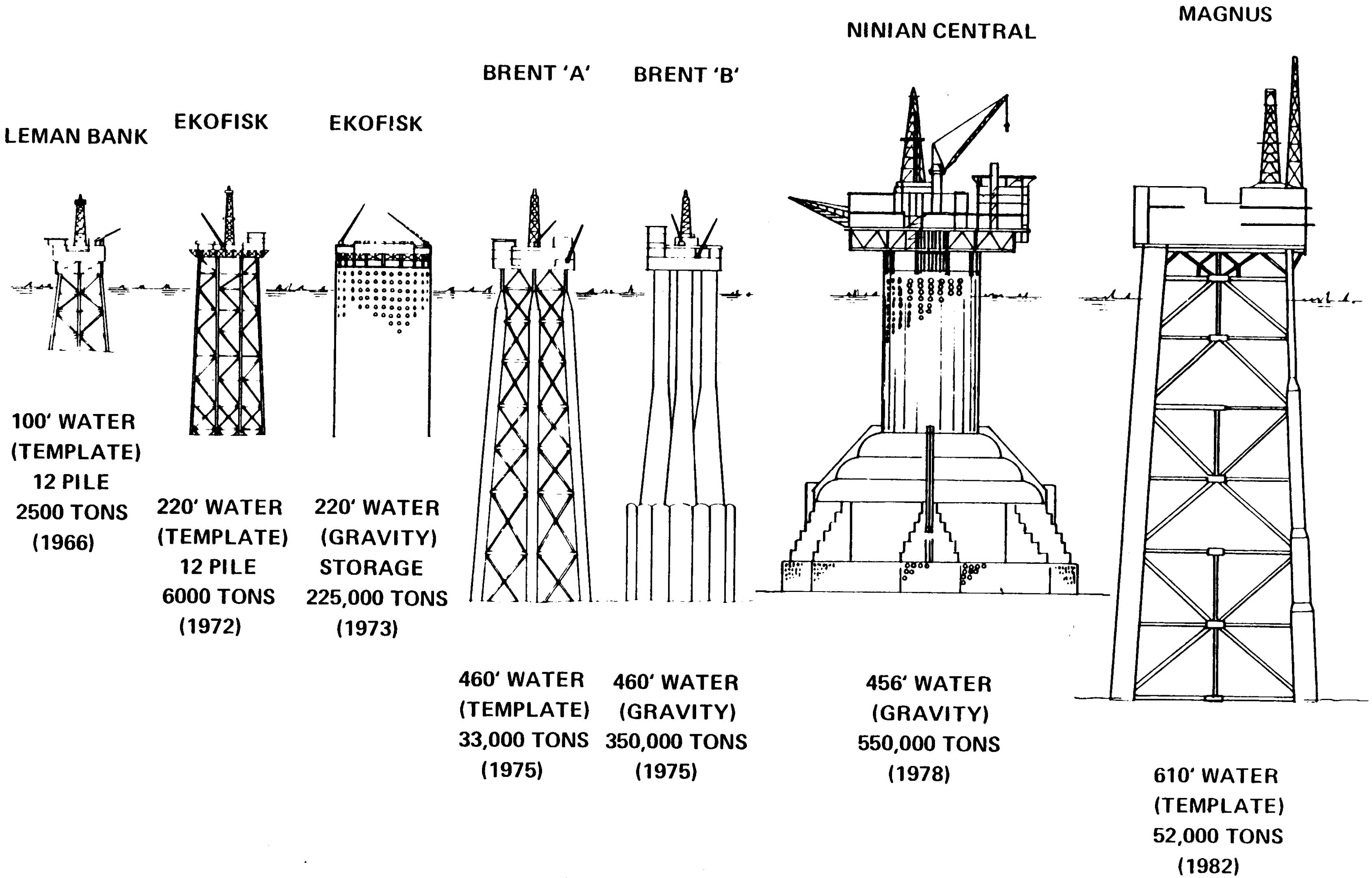

FLOATING DRILLING,
SUBSEA WELL & FACILITY
CAPABILITY PROJECTION
WATER DEPTH – FEET
10,000
5,000
1,000
500
100
50
10
1950
60
70
80
90
2000
YEAR
U.S. ATLANTIC
FRANCE
CANADA
SPAIN
SURINAM
THAILAND
GOM
SUBSEA
FACILITIES
FLOATING
DRILLING
SUBSEA
WELLS
BRAZIL
TUNISIA
BRAZIL
NORTH SEA
GOM
BRAZIL
CALIF.
GOM
GOM
GOM
ACTUAL EXPERIENCE
EXPLORATORY WELLS
SUBSEA WELLS
SUBSEA FACILITIES

Figure 5.



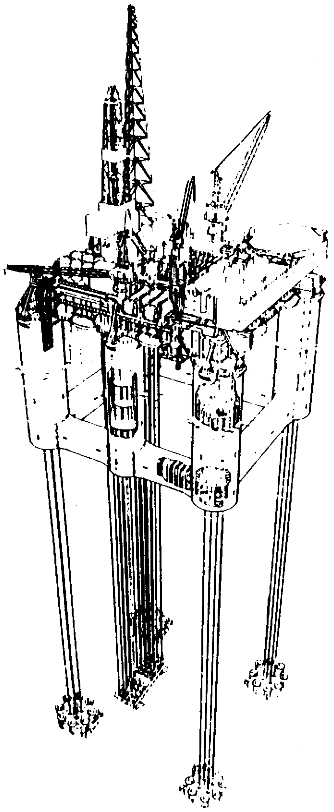
U.S. PLATFORM MILESTONES

Figure 6.

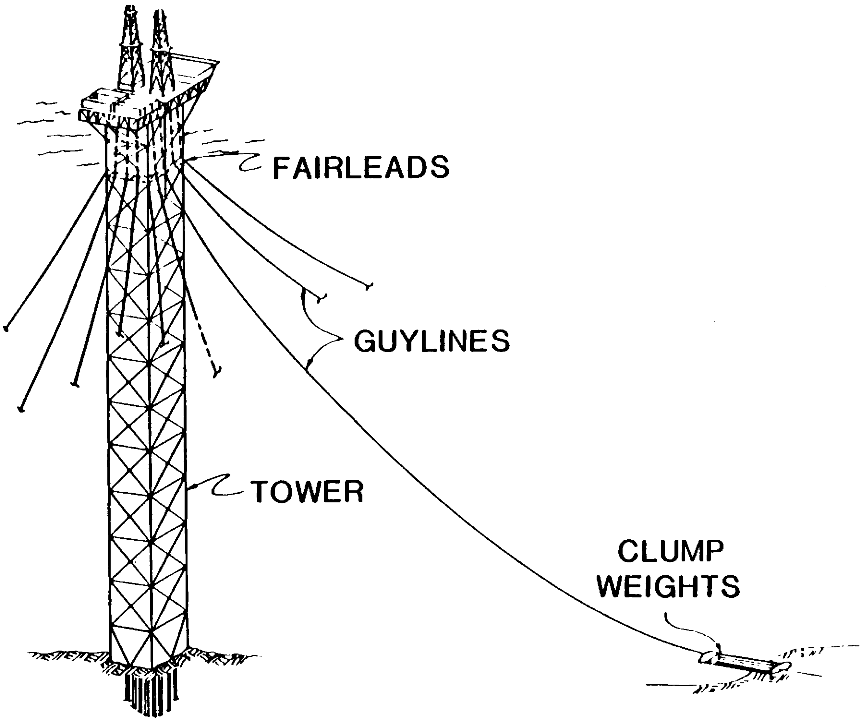


NORTH SEA PLATFORM MILESTONES

Figure 7.



HUTTON FIELD TENSION LEG PLATFORM



GUYED TOWER

Figure 8.

tension-leg platforms offer promise of extending platform capability significantly. These are known as compliant structures, which are designed to move with the forces of wind, wave, and current, rather than rigidly resist them. Exxon's guyed tower, Lena, which was recently installed in 1,000 feet of water in the Gulf of Mexico, represents one of these compliant types of platforms. This type of structure may be cost-effective in 2,000-2,500 feet of water.

The tension-leg platform being constructed by Conoco for the Hutton Field in the North Sea reflects another type of compliant structure which is applicable to deeper waters. This large floating platform, which is similar to a semisubmersible drilling rig, is connected to the sea floor by vertical tension members. This makes the cost of this type platform less sensitive to water depth. Planning by several companies is underway to determine the optimum configurations and costs for water depths where a tension-leg platform would be applicable. Although the present tension-leg platform under construction by Conoco is for use in 485 feet of water, it is believed that the basic technology is applicable for designing tension-leg platforms for working in 6,000-8,000 feet of water by 1990 and 10,000 feet of water by the year 2000.[7]

A comparison of the relative cost trends versus water depth for fixed-leg platforms guyed towers, and tension-leg platforms for the Gulf of Mexico is shown in figure 9.[8] It indicates the approximate water depth ranges for three structures and how costs of fixed-leg platforms and guyed towers increase dramatically with water depth. Similar trends would be expected in other U.S. offshore locations.

Capability of fixed-leg platform and compliant platform is summarized on figure 10.[5,9] The applicability of different platform types to various water depths is dependent on physical environmental conditions such as wave activity, currents, and ice conditions. For example, fixed structures may be uneconomic for water depths beyond 1,000 feet in the North Sea because of extreme sea states, and compliant structures may not be feasible where there are high currents. The decisions on which type of platform to select could thus depend more on environmental factors than on water depth.

Underwater completion and production systems for deep water

The other major type of deepwater production technology involves subsea systems by which the wells are drilled from a floating rig and completed on the sea floor. Production is routed to a fixed or floating platform. About 270 wells, as shown in figure 11, have been completed on the sea floor since 1960. Nearly all of them produce through flowlines to nearby platforms. Experience has been very favorable. There have been no significant pollution or unsafe incidents, even though some subsea wells have produced for over 16 years.

Subsea wells can be completed in water depths comparable to floating drilling capability. Although the present record as shown in figure 5[5]

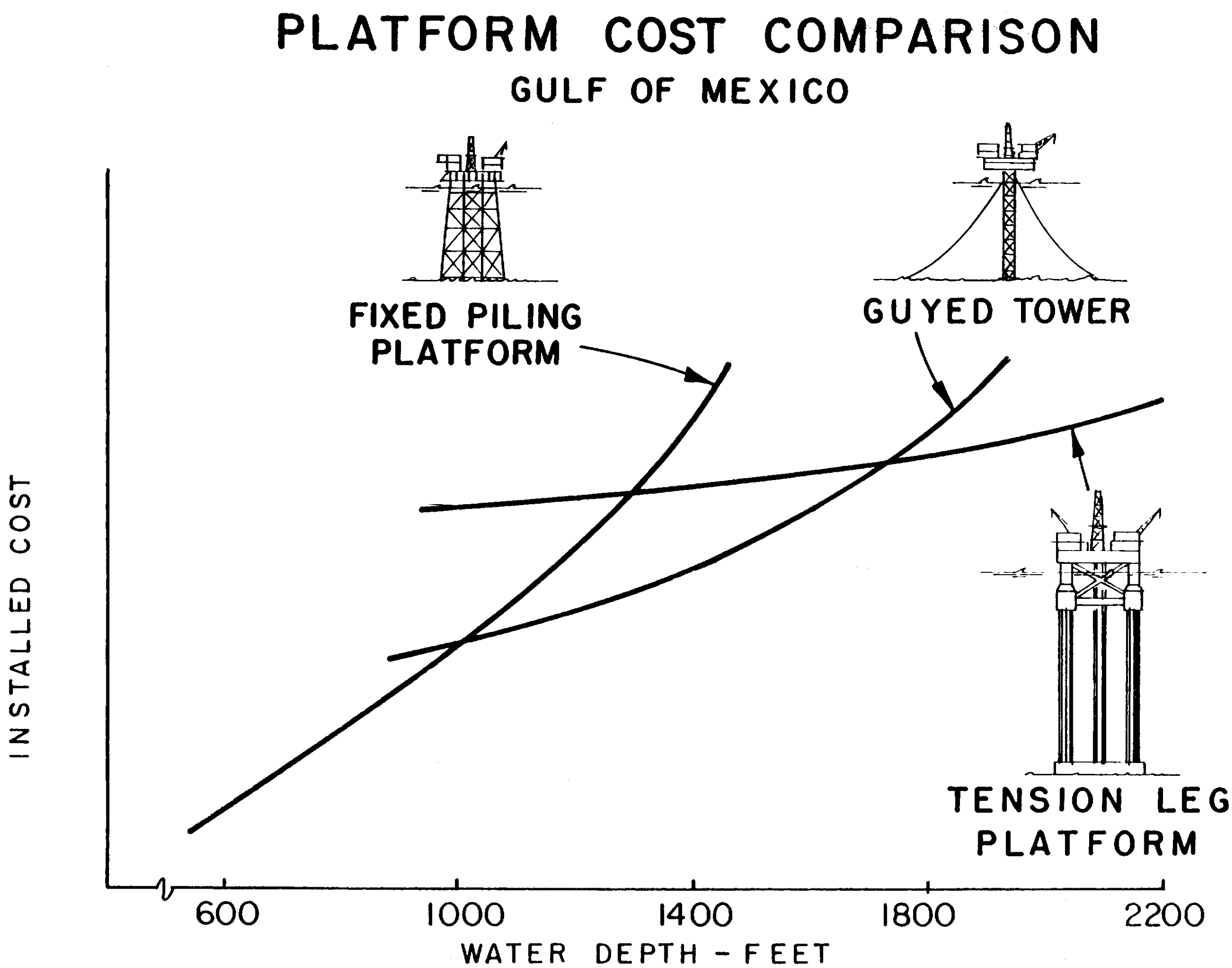

PLATFORM COST COMPARISON
GULF OF MEXICO
FIXED PILING PLATFORM
GUYED TOWER
TENSION LEG PLATFORM
INSTALLED COST
600
1000
1400
1800
2200
WATER DEPTH - FEET

Figure 9.

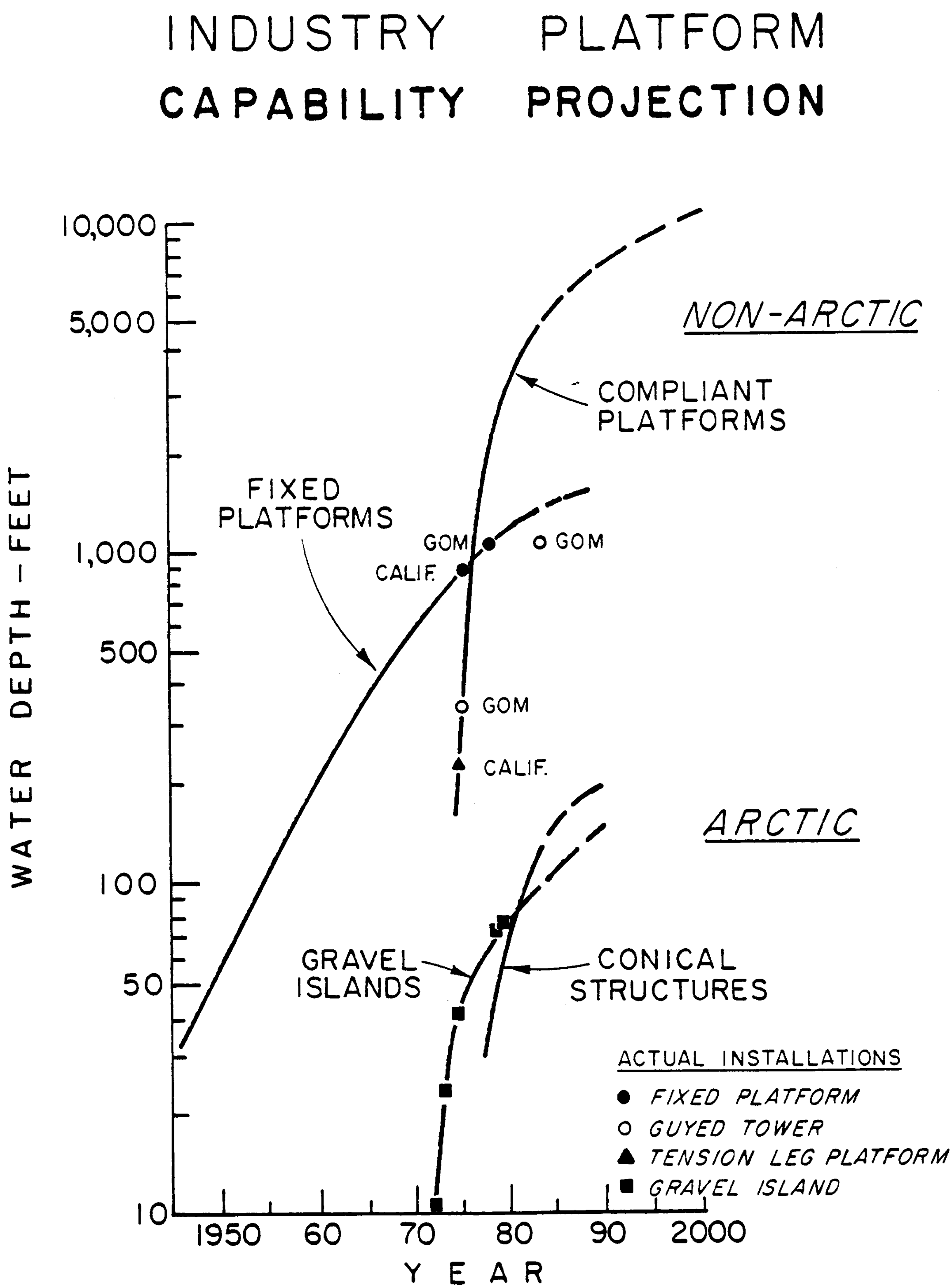

INDUSTRY PLATFORM
CAPABILITY PROJECTION
10,000
5,000
1,000
500
100
50
10
WATER DEPTH - FEET
1950
60
70
80
90
2000
YEAR
NON-ARCTIC
COMPLIANT PLATFORMS
FIXED PLATFORMS
GOM
CALIF.
GOM
GOM
CALIF.
ARCTIC
GRAVEL ISLANDS
CONICAL STRUCTURES
ACTUAL INSTALLATIONS
FIXED PLATFORM
GUYED TOWER
TENSION LEG PLATFORM
GRAVEL ISLAND

Figure 10.

INDUSTRY SUBSEA EXPERIENCE

- 270 ± SUBSEA WELLS COMPLETED
- 7 DEEPWATER MANIFOLD SYSTEMS
- 13 SUBSEA WELL/FLOATING PRODUCTION SYSTEMS

Figure 11.

is 835 feet, Chevron is currently manufacturing equipment to complete the first of two potential wells in approximately 2,500 feet of water off the coast of Spain. Subsea wells have not been completed in greater water depths, as stated earlier, because of the lack of commercial discoveries -- not lack of technology. On the basis of preliminary studies, it is believed that subsea manifolds can also be installed in water depths comparable to floating drilling. Again, lack of commercial discoveries has limited actual installations to 450 feet or less.

In recent years, several systems using subsea wells producing to floating facilities have been installed which offer potential for application in deepwater.(5,9) Figure 12 illustrates the Argyll Field system installed in 1975 in about 250 feet of water in the North Sea. Several subsea satellite wells with wet Christmas trees produce through flowlines, manifold, and riser to a semisubmersible platform. Production is then pumped through a loading system to a shuttle tanker. An additional system, which is illustrated in figure 13, makes use of a wet well and manifold system producing through an articulated riser to a tanker. Prototypes of the template and riser have been tested in 175 feet of water in the Gulf of Mexico by Exxon. One of the most advanced systems, to date, is the Tazerka Floating Production System, shown in figure 14, which was installed in November 1982 in 460 feet of water by Shell-Tunirex offshore Tunisia. Other systems being considered by the petroleum industry provide for production from subsea wells to be routed through risers to tension-leg platforms or large floating storage vessels. It is expected, as previously stated, that subsea systems will be applicable in water depths comparable to floating drilling capability.

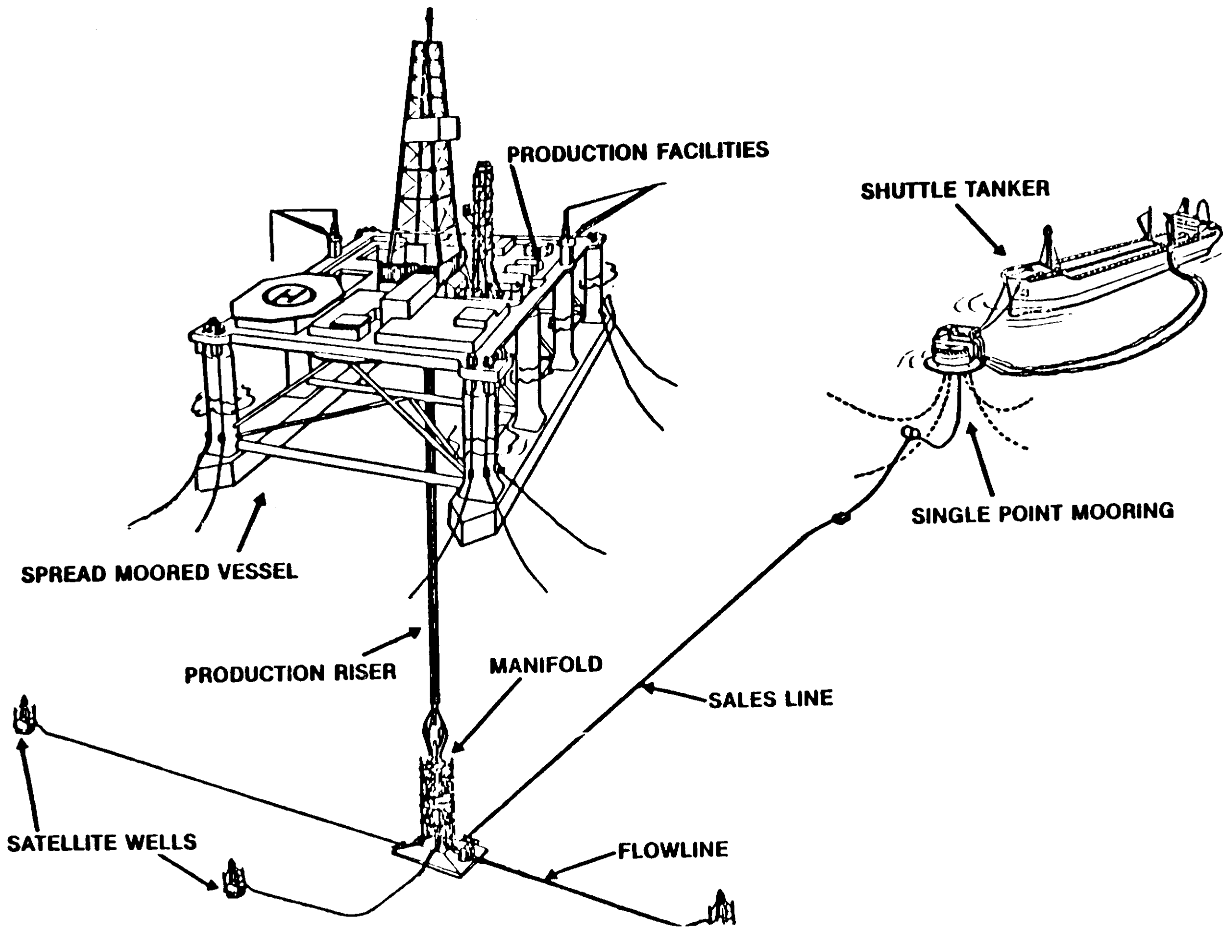
Installation of subsea well equipment and manifolds in deep water will likely be made from dynamically positioned drilling rigs. Technical problem areas to be resolved are primarily related to site-specific hardware design that will provide ease of installation, highly reliable operation, and efficient maintenance and repair.

TRANSPORTATION

Pipeline systems

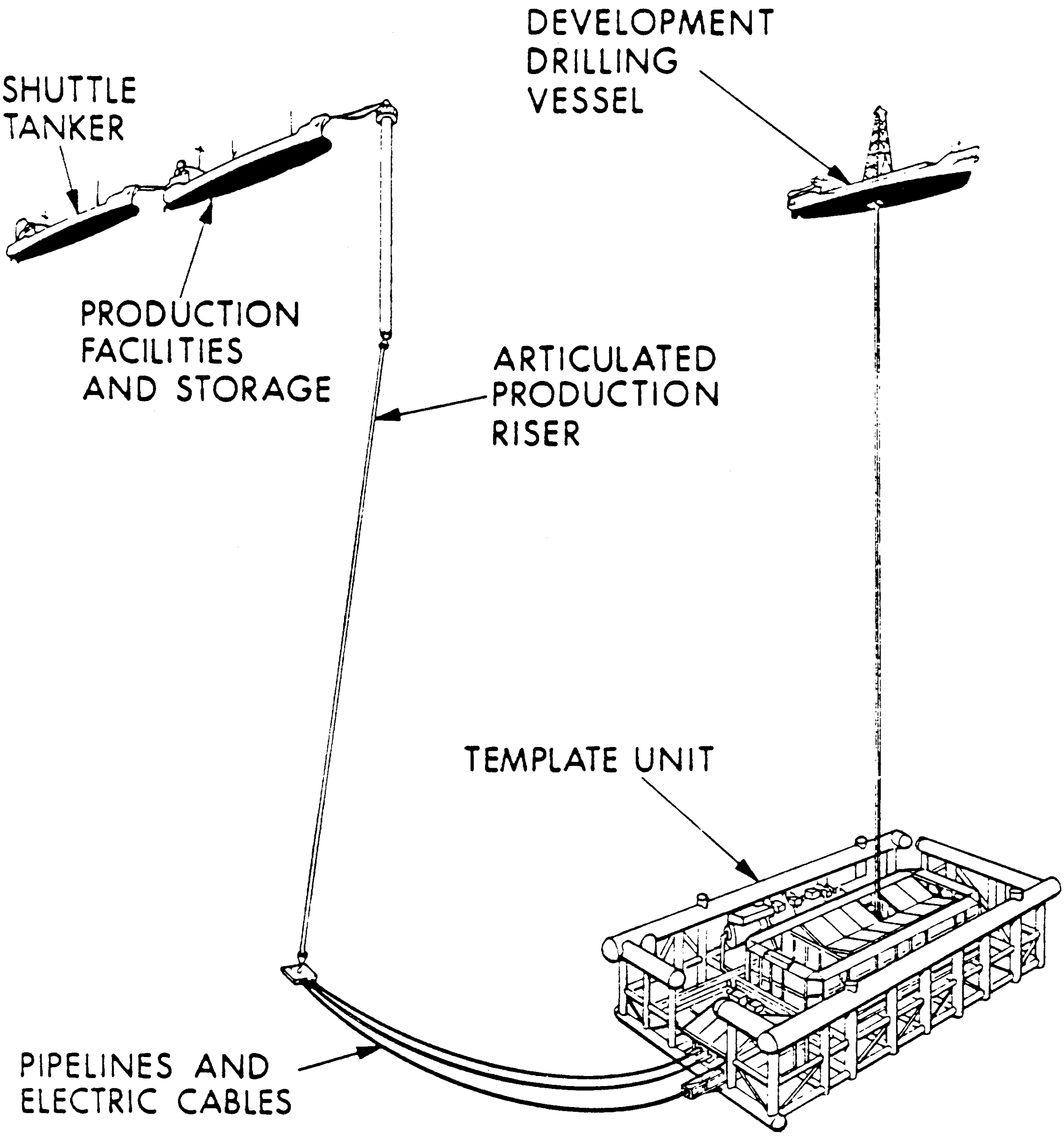
The development of offshore oil and gas resources is strongly influenced by the availability of pipeline transportation systems. Depending upon field locations and economic factors, gas production in deepwater and arctic locations will be transported by pipeline to shore or reinjected into the producing formation. Oil production will be transported by pipeline to shore or to a platform or transfer loading facility.

Deepwater pipelines can be installed by a variety of methods using different types of pipeline vessels, such as shown in figure 15, that have been developed to cope with deepwater and hostile environments. The significant milestones in deepwater pipeline-laying technology



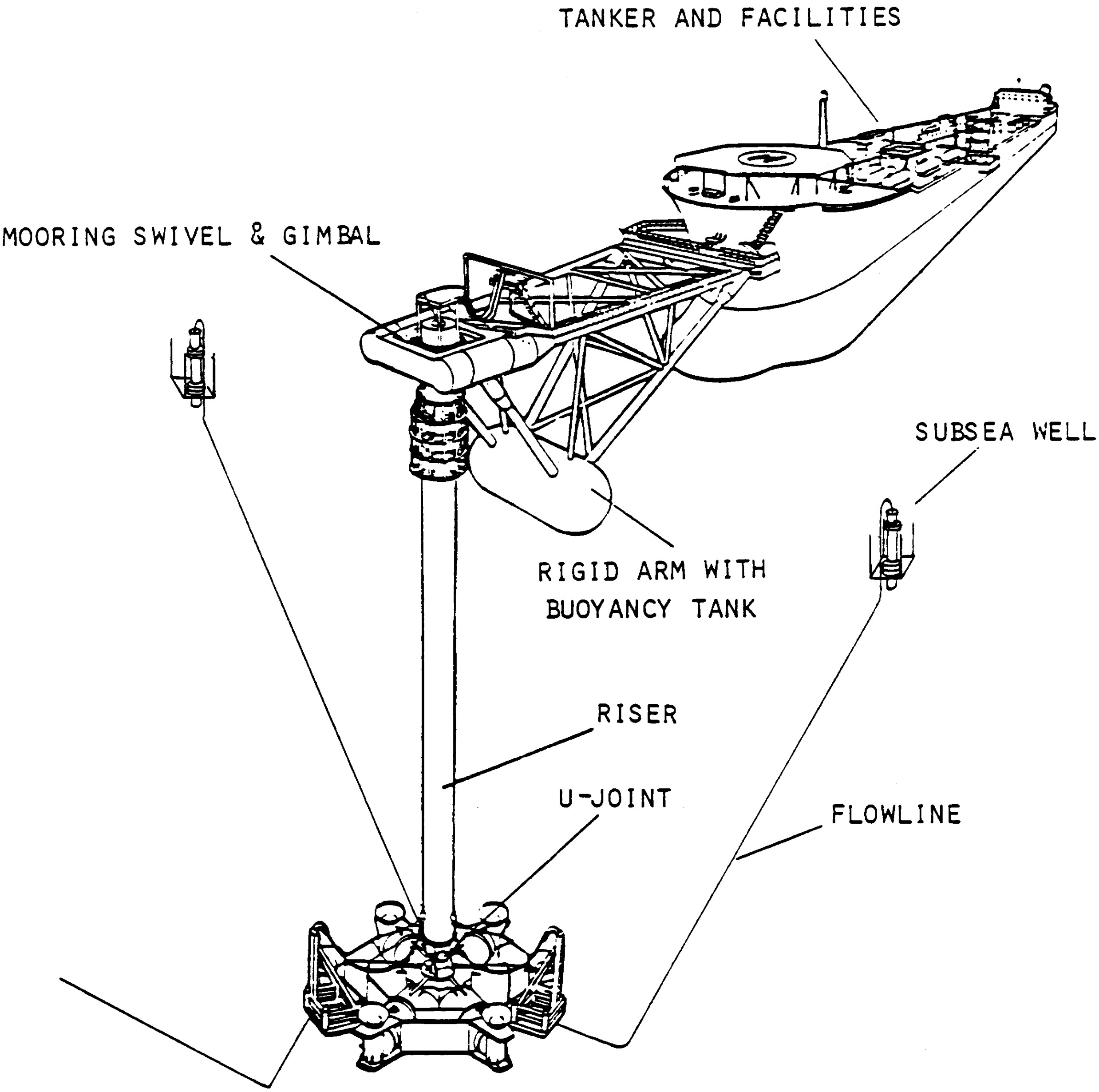
SEMISUBMERSIBLE PRODUCTION SYSTEM

Figure 12.



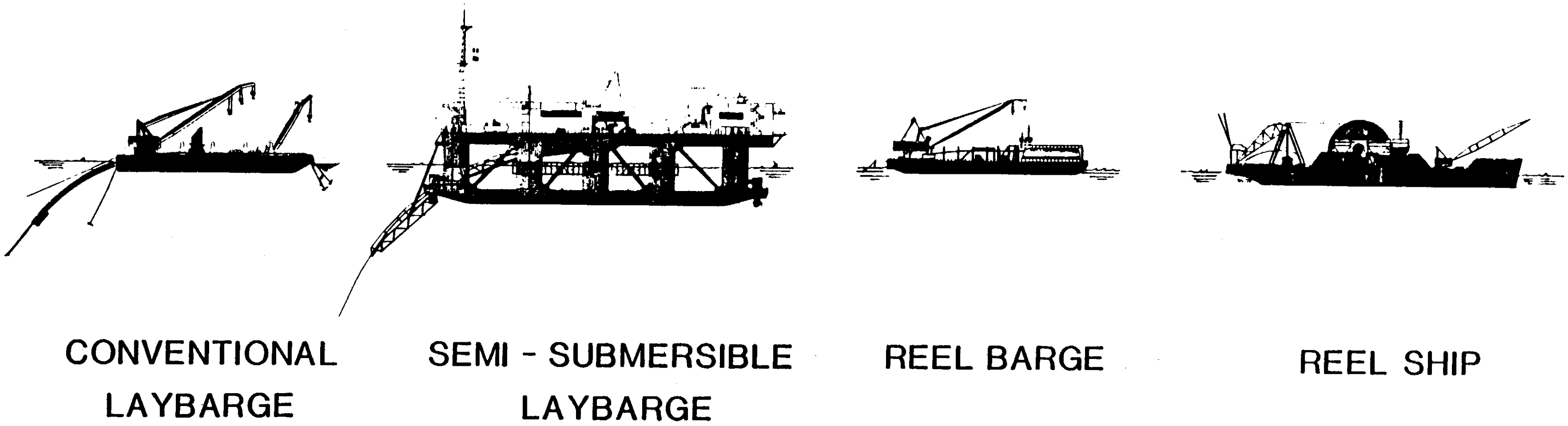
EXXON SUBMERGED PRODUCTION SYSTEM

Figure 13.



TAZERKA FLOATING PRODUCTION SYSTEM

Figure 14.



PIPELAYING VESSELS

Figure 15.

were the first specifically designed lay barge in 1958; first commercial use of a reel barge in 1962; first use of a curved stringer and tension to lay a deepwater pipeline in 1967; a 244-mile bottom tow of 7,050 feet of 36-inch pipeline in 1,260 feet of water in 1977; installation of a COGNAC 12-inch oil line at a record depth of 1,020 feet in 1979; and installation of three 20-inch gas lines by the Saipem Castro Sei semisubmersible lay barge at a record depth of 2,060 feet across the Sicilian Channel in 1980. A project has been in the planning stage by Saipem that would use a lay barge with an inclined ramp to install a pipeline in over 6,000 feet of water in the Mediterranean Sea.

The development of deepwater pipelaying technology has consistently been ahead of field application needs, as shown in figure 16[9] The industry's dedication to pipeline research in the mid-1960's stimulated the development of mathematical models to analyze suspended pipe spans, plus such needed tools as the articulated stringer, buckle arrestors, and the semisubmersible lay barge. With the previous success from the application of these research results, industry envisions no technical barriers to laying pipelines in water depths to 10,000 feet by 1990, as shown in figure 16.

Tanker systems

There are deepwater fields where pipelines to shore are not justified and tanker loading and transportation systems are required. Three systems that are presently in use that offer significant potential for deepwater fields are shown in figure 17.[5]

The world's deepest SALM (single anchor leg mooring) is installed in 530 feet of water in the Thistle Field in the North Sea. An ALP (articulated loading platform) is in service in 475 feet of water in the Statfjord Field in the North Sea. The SPAR, which also included 300,000 barrels of storage, is installed in 460 feet of water in the Brent Field in the North Sea. Water-depth limits for loading systems have not been established.

It is likely that in very deep water, pipelines to loading systems in shallow water will be the most economical method of transporting produced oil. As previously stated, gas will have to be transported by pipelines, processed offshore and/or reinjected into the formation, depending upon prevailing economics and environmental conditions.

Subsea support systems

Offshore installations will eventually be made in water depths which exceed the range where wet divers can function effectively for maintenance and inspection. This is currently about 1,500± feet although simulated dives in controlled laboratory conditions have established that divers should be able to work with relative safety and efficiency at depths greater than 2,000 feet. These deepwater operations beyond diver application will be supported by unmanned

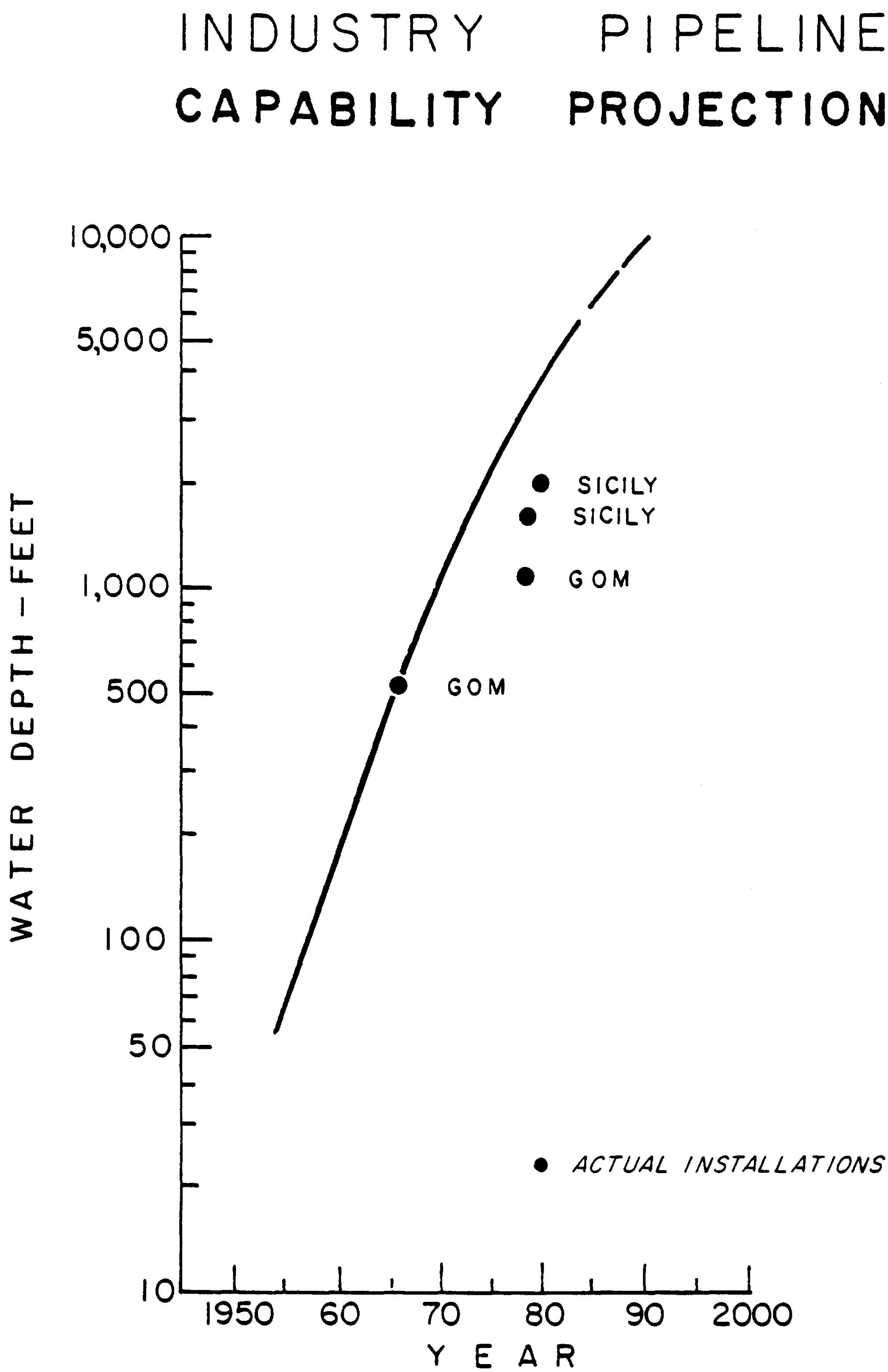
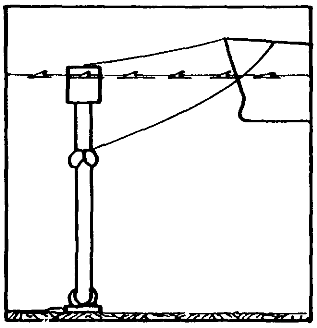
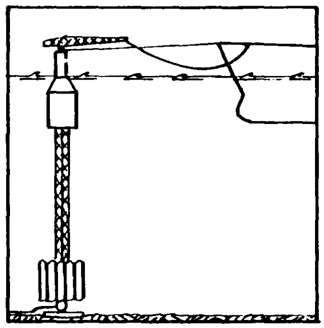

INDUSTRY PIPELINE
CAPABILITY PROJECTION
10,000
5,000
1,000
500
100
50
10
WATER DEPTH - FEET
SICILY
SICILY
GOM
GOM
ACTUAL INSTALLATIONS
1950
60
70
80
90
2000
YEAR

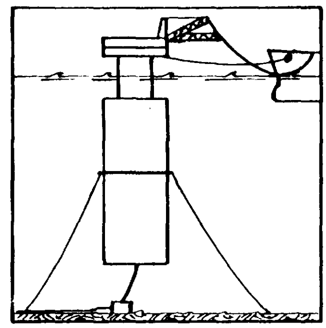
Figure 16.



SALM



ALP



SPAR

TANKER LOADING SYSTEMS

Figure 17.

remote operated vehicles or workers in dry one-atmosphere vehicles similar to those shown in figure 18[5] or by recovery of the system components to the surface.

Many of the subsea wells and manifolds installed to date have utilized variations of these support systems. Preliminary design studies, along with equipment developments and field operations, have revealed no technical barriers to the use of such systems in 10,000 feet or greater water depths.

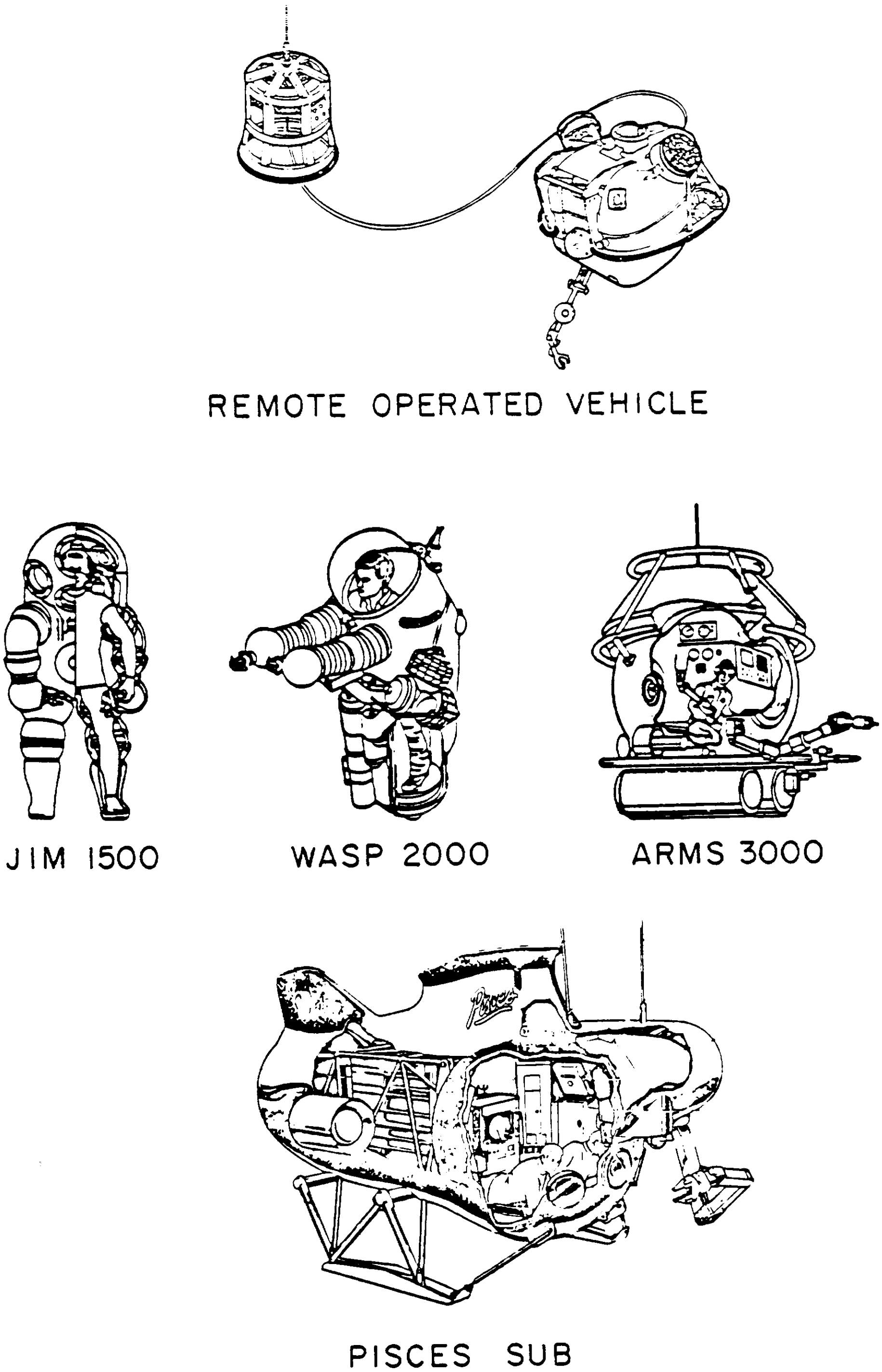
ARCTIC OFFSHORE

Perhaps the greatest challenges for the offshore petroleum industry are in exploring and developing the Alaskan Arctic offshore Continental Shelf where a significant portion of total U.S. undiscovered oil and gas is expected to exist.[10]

Industry has been actively working in the Arctic waters of Alaska and Canada for a number of years. Alaskan activity, which had its start in Cook Inlet in the 1960's, was primarily in the Beaufort Sea in the 1970's. Sand- and gravel-filled islands have been developed as safe and economical exploratory drilling platforms in the Beaufort Sea area. Twenty-eight gravel islands have been built and used for drilling in the Canadian and U.S. Beaufort Sea during the years 1973 to 1983 in water depths ranging from 4 feet to more than 60 feet. Wells have also been drilled from natural barrier islands and from a manmade ice island.

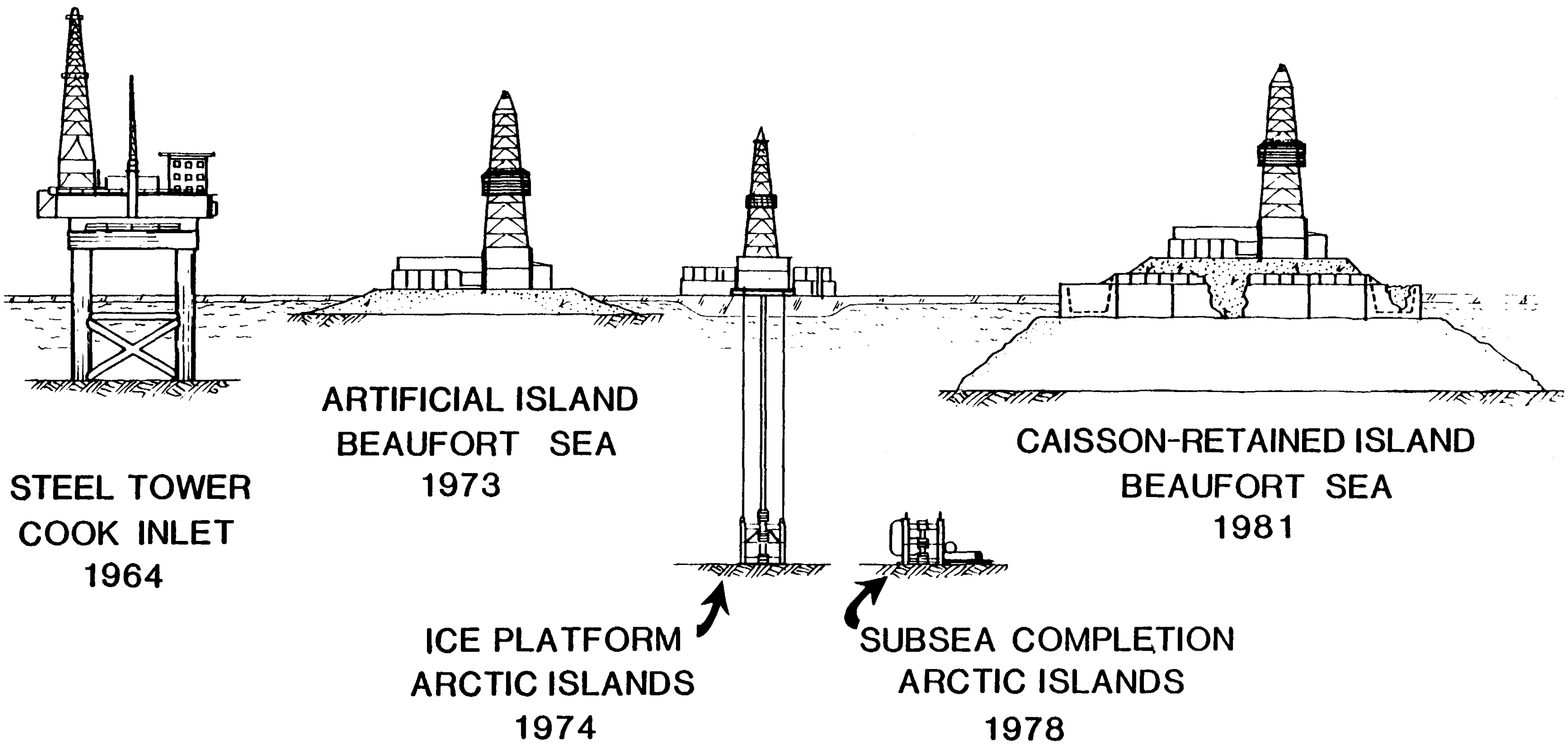
A number of milestones have occurred in exploration and production in Arctic waters, as shown in figure 19. In 1964, the first of many ice-resistant production platforms was installed in 90 feet of water in Cook Inlet, Alaska. In 1973, the first exploration well in the Canadian Beaufort Sea was drilled from an artificial island. More advances followed rapidly with the drilling of an exploratory well from a floating-ice platform in 1974 and the first arctic subsea completion in 1978, also drilled from an ice platform. A new type of artificial island -- a caison-retained island -- was installed in 1981.[11]

During the 1980's, the Arctic exploration and development activity will increase as a result of scheduled state and federal offshore sales. Figure 20 shows the major geological basins and the probable type of offshore structures that will be used for drilling and producing operations.[12] Gravel islands are expected to be economical solutions for water depths of 60 to 100 feet in the Beaufort, Chukchi, Hope, and Norton basins. Between 100 and 200 feet in these basins, ice-resistant fixed platforms, such as steel or concrete cones, will probably be used.[5,10]



SUBSEA SUPPORT SYSTEMS

Figure 18.



ARCTIC DEVELOPMENT MILESTONES

Figure 19.

ALASKAN ARCTIC BASINS & STRUCTURES

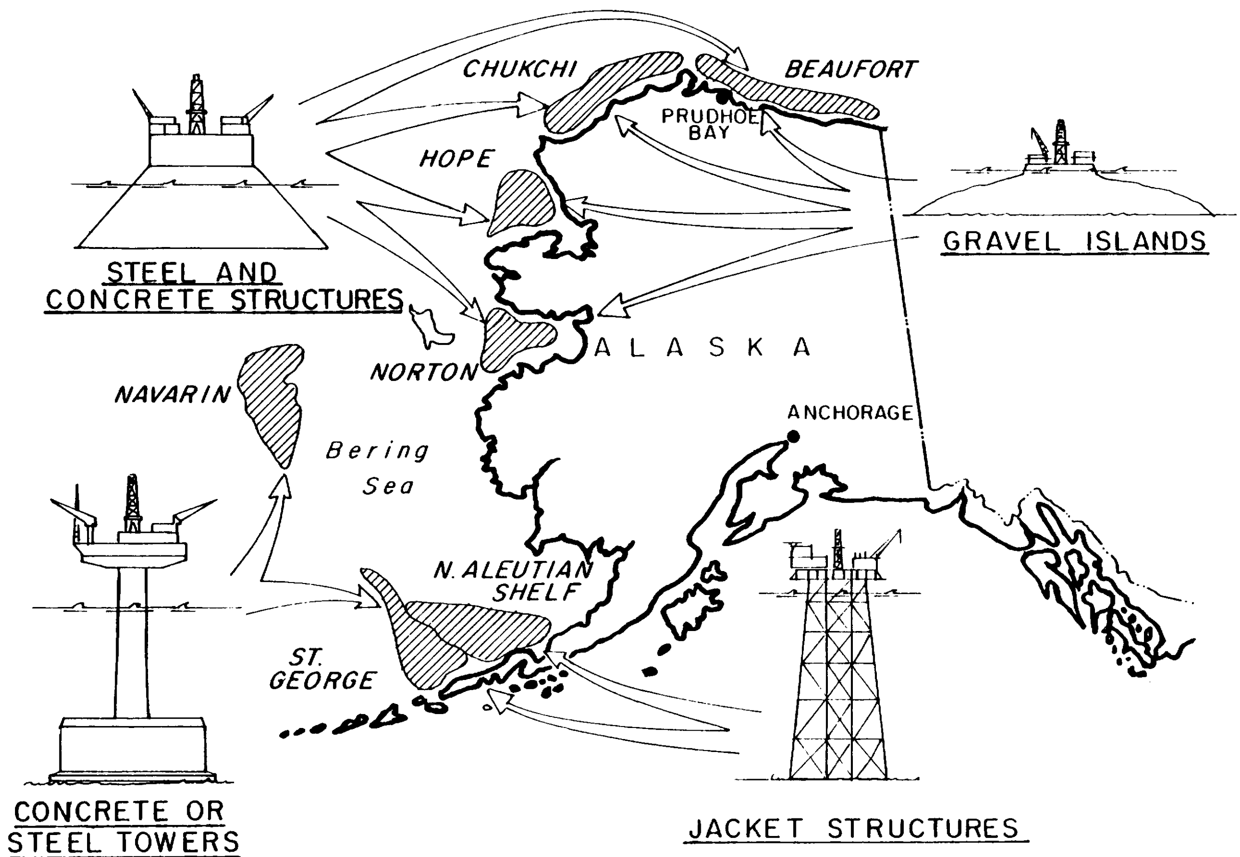


Figure 20.

In the Bering Sea, conventional jacket structures or ice-resistant concrete or steel towers may be used.[5,10] In water depths of more than 650 feet and possibly in some shallower locations, compliant structures and subsea completions, such as those discussed earlier, will be candidates.

Transportation will usually be by pipeline form the platform to shore, then to tankers or existing pipelines. An offshore pipeline depth limitation for ice-covered Arctic regions is not presently assessible and is the subject of intensive industry research and development programs. Otherwise, the pipeline systems capability discussed earlier will apply in the Arctic. Offshore storage and loading facilities may be used in deepwater and remote locations.

Arctic offshore research and development have been underway for more than a decade. Ice research has concentrated on ice strength and stressstrain behavior, ice-feature occurrence, ice movement, and ice-structure interaction. Field programs to measure oceanographic parameters in the Arctic offshore have been underway for a number of years and will continue. Work will continue in evaluating the environmental exposure (forces) and platform concepts required to extend the Arctic offshore capability shown on figure 10.[5]

OIL SPILL PROTECTION

A matter that rightly deserves parallel attention in terms of technology, if the offshore U.S. Exclusive Economic Zone petroleum potential is to be fully realized, is the environmental issue. The petroleum industry and government have continuously worked to improve operations and keep oil spills and discharges to an absolute minimum. Their efforts to this end have been successful. Data obtained and analyzed by the U.S. Minerals Management Service indicates that the frequency of major spills from platforms is about half that of a decade ago.[13] In spite of this progress, oil spills will probably occur, and government and industry must be prepared to effectively respond when they do.

Ever since the Torrey Canyon tanker spill of 1967 and the Santa Barbara oil-well blowout of 1968, there has been serious concern about major oil spills on the ocean. Recent research indicates that oil spills may not be long-term ecological disasters as once assumed;[14,15] however, there is still a need to reduce the short- and long-term impacts and aesthetic damage within limits acceptable to society and national policy.

In general, oil-spill mitigation technology has maintained pace with advances in offshore exploration and production. Containment and recovery devices are available with capacities to operate efficiently in 8- to 10-foot significant wave height.[16,17] Chemical agents, such as dispersants, are available that are less toxic and more efficient than their predecessors.[18] In some remote places, owing to extreme weather conditions or other circumstances, mechanical cleanup or use of dispersants may not be possible, and the most appropriate and effective countermeasure may be natural dispersion.

A practical limitation in offshore oil-spill mitigation is not the state-of-the-art technology, but the availability of production equipment capable of operating in that environment. To counter this problem, industry has formed oil-spill coperatives[5] in areas where oil exploration, production, and transportation take place. These substantial resources, in addition to the equipment maintained by the USCG and USN, give the Nation a capable force for response to offshore pollution incidents in the continental United States. In Arctic regions, however, spill cleanup capability has not progressed at a rate comparable to that in more temperate climates. The primary technological limitations posed by the Arctic include debris (ice pieces), high oil viscosity, reduced natural evaporation and dispersion, and impractical chemical dispersion. Oil-spill countermeasures used in temperate climates may be used in the Arctic with appropriate modifications,[19] and with a reduced degree of success. In situ burning has been demonstrated experimentally and may prove to be one of the more successful methods for cleanup in this region.

Oil-spill prevention and control has received considerable attention during the past 15 years. Millions of dollars have been expended by industry and government on environmental studies and monitoring programs, with little or no improvement in the real understanding of the ocean, its inhabitants, or the effect an activity may have on them. Therefore, it is essential that a cooperative program be continued to achieve a predictable ocean-resource technology in an efficient, cost effective, and environmentally conscientious manner.

TECHNOLOGY CAPABILITY SUMMARY

The offshore oil and gas technology and capability projections which have been briefly reviewed here have been the subject of many more detailed technical investigations, studies, and reports over the past 10-15 years by the petroleum industry,[20,21,22] the Marine Board of the National Research Council,[5,23,24,26] and various agencies of the Federal Government.[21,22,25] The technology base and capability projections, shown in figure 5, reflect that proven drilling equipment is available today to function effectively anywhere -- including ice-free Arctic regions -- of the offshore U.S. Exclusive Economic Zone in water depths to 7,500-8,000 feet, and drilling systems can be working by 1990 in 10,000 feet of water, if economically justified. Drilling in the ice-covered Arctic regions, in general, may be limited presently to 200-300 feet of water.

Underwater wells and manifolds can be installed and completed in water depths comparable to floating drilling capability.

Bottom-supported fixed-legged platforms, as shown in figure 10, can be installed economically in water depths out to 1,200-1,500 feet of water. Compliant platforms, using guyed towers, are considered capable of being installed in 2,000-2,500 feet of water and tension-leg platforms are believed applicable to working in 6,000-8,000 feet of water by 1990 and 10,000 feet of water by the year 2000.

Technology and equipment exist today to provide deep-water pipeline systems in 6,000-8,000 feet of water (ice-free Arctic regions included), and industry envisions no technical barriers to laying pipelines in water depths to 10,000 feet by 1990, as shown in figure 16. A pipeline depth limitation for ice-covered Arctic regions is not presently assessible and is the subject of intensive industry research and development programs and engineering activities.

Floating production facilities and tank-loading systems, in general, are considered to have the same depth capability as determined for tension-leg platforms. However, water-depth limits for loading systems have not been established in definitive terms since it is most probable, in very deep water, that pipelines to loading systems in shallow water will be the most economical means of transporting produced oil.

The capability exists to provide subsea support for the installation, inspection, maintenance, and repair of deepwater installations safely and efficiently in any water depth presently being considered for offshore development.

In the Arctic, proven technology and capability are available for the industry to proceed confidently with operations in water as deep as 650 feet in the southern Bering Sea and to about 200 feet or greater in the more severely ice-covered areas of the northern Bering, Chukchi, and Beaufort Seas.[10]

Oil spill protection technology has advanced to the state where most situations can be effectively handled, included the Arctic. However, further effort is presently being pursued through cooperative industry R&D programs aimed at improving clean-up techniques in broken ice areas of the Arctic.

The collective technology base exists to permit exploration of nearly all of the offshore U.S. Exclusive Economic Zone out to 10,000 feet by 1990 with the exception of some areas of the ice-covered Arctic. There are no presently recognized technology barriers which would prevent the application of this capability if economically justified. Economics, not technology, will limit the deepwater and Arctic developments, since operations in these environments will require long lead times (9-14 years), and will be extremely costly.

SUMMARY CONCLUSIONS

It should be evident from the preceding that since the early beginning of offshore drilling and production activities, the technology to provide the necessary safe and reliable systems has very adequately kept pace with this country's economic needs. Proven technology, along with trained people and equipment, have been available when needed.

Existing technology relevant to all aspects of these activities has reached a high level of competence through the interrelated efforts of research and development, engineering, and practical experience. The technology "muscle" capable of working in almost all of the offshore U.S. Exclusive Economcic Zone now stands ready to be flexed to help provide vital domestic petroleum resources to meet our Nation's energy needs. However, as is recognized, all of the engineering solutions for the site-specific application of the technology have not, at this date, been developed and will be the subject of great attention by industry over the next 15-20 years, as it demonstrates what real potential the total U.S. offshore continental margins (including the Arctic) have to offer in terms of recoverable petroleum resources.

Owing to the long lead times and significant commitments needed in terms of manpower and capital, achievement of this goal will require a closer relationship between industry and the government. The respective proper roles and strengths of each must be maximized in the development of needed environmental information, and engineering solutions and appropriate standards.

Recommended program

Regarding government-industry relationships in support of resource development, the Stratton Commission Report, "Our Nation and the Sea"[27] states that "...It will be difficult but essential to establish a reasonable dividing line between what industry should do for itself under profit motivation and what government should do to assist. In most instances, programs that benefit only a specific industry more properly should be carried out by that industry..."

The petroleum industry has clearly demonstrated its initiative to research and develop or adapt from other sources the technology uniquely required by its own business, much of which has useful application to other industries. Therefore, it should be industry's primary responsibility, with assistance from academia as appropriate, to provide any necessary extensions of present technology and develop the engineering solutions and standards that will be required for site-specific application in the fields of exploratory drilling, development drilling, producing systems, and transportation and storage systems.

The government's responsibility has been identified with key recommendations in many previous reports on this related subject.[21,22,23,24,25,26,27] With assistance from academia, appropriate Government agencies should be conducting investigations to obtain basic environmental data that could be provided by unique government laboratories, satellites, data collection and processing facilities and technical personnel. Of particular importance to the EEZ development are data such as ice coverage, formation, and movement of ice, wind, wave and swell, internal wave structure and origin, mesoscale circulations, long-term deep-current profile, and foundation strength. Programs to acquire this data should be planned with industry input for application to platforms, pipelines, and other offshore installations. These data are needed by all who operate in the offshore U.S. Exclusive Economic Zone. The government-industry environmental data requirements and interactions were thoroughly reviewed in a 1980 report by the Marine Board and are shown in figure 21.[28]

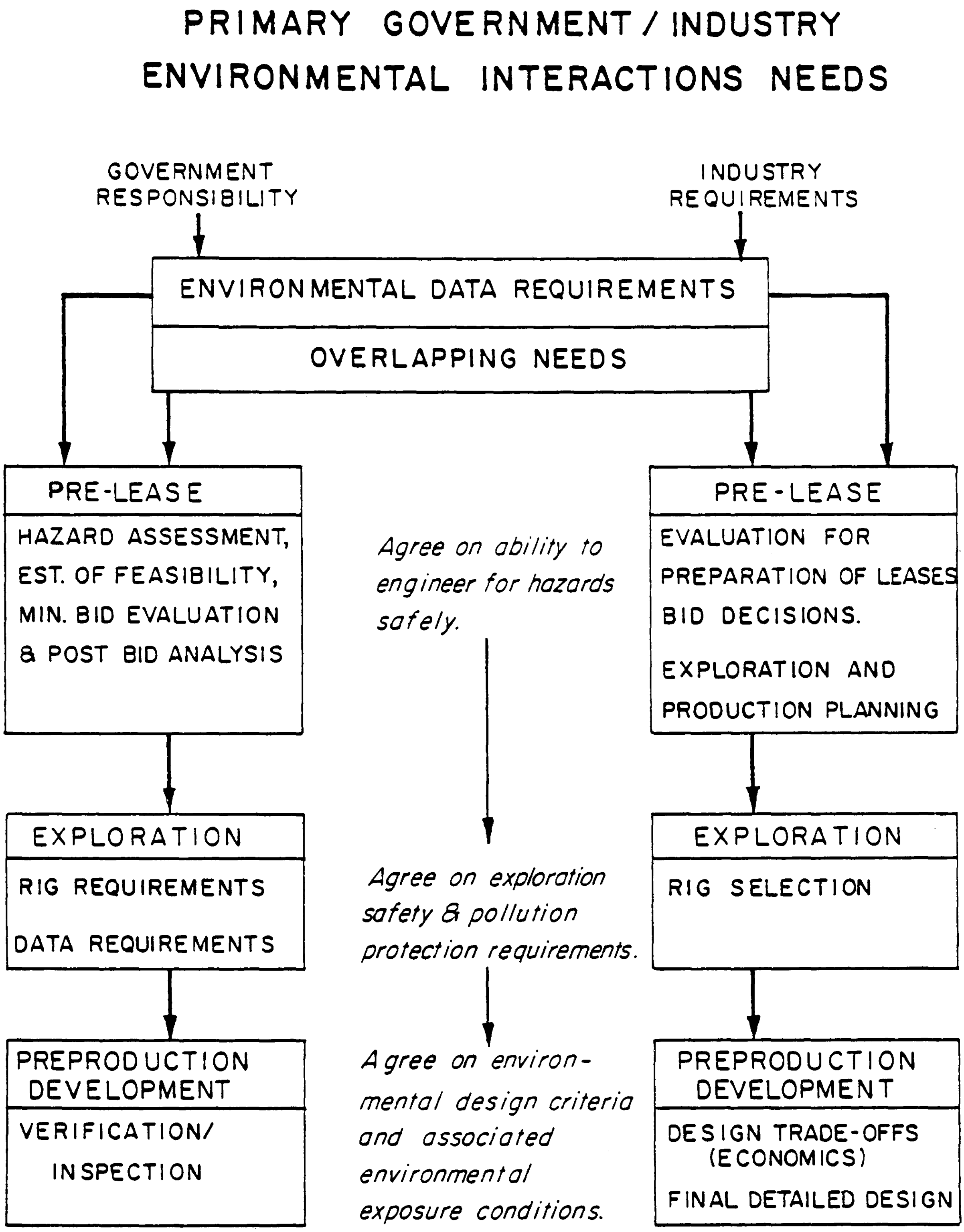
The continuing common need by government and industry for better quantitative characterizations of the offshore environmental phenomena, which must be accommodated in developing the oceans resources, dictates the requirements for base-line oceanographic and meteorological data along with Arctic data, especially in new frontier areas. Development of these data should be appropriately shared in the most cost-effective way.

The need to ensure a responsible and optimum information exchange in these subject areas between government, industry, and academia will require the establishment of focal points in government and industry with adequate levels of technical expertise as previously recommended.[23,24,25,27,28] This will enable essential long-range planning and cost-effective programs to be carried out using the Nation's resources (e.g., remote sensing satellites, and unique government laboratories and facilities) in the most optimum manner.

Commitment to long-range planning by an established and dedicated government focal point that will have long-term predictability will be essential to the development of a successful, cost-effective cooperative effort with industry in this area of technical information development and exchange.

Academia's specific contribution will be determined when the program elements to be evaluated by industry and government have been defined.

In order to implement the programs and effect the cooperation recommended in this and previous reports, certain widely recognized barriers must be removed and new mechanisms provided to facilitate the efficient and expeditious acquisition of basic environmental data and sharing of a common technological data base. One barrier is the fragmentation of government efforts and responsibilities through a variety



PRIMARY GOVERNMENT / INDUSTRY
ENVIRONMENTAL INTERACTIONS NEEDS
GOVERNMENT RESPONSIBILITY
INDUSTRY REQUIREMENTS
ENVIRONMENTAL DATA REQUIREMENTS
OVERLAPPING NEEDS
PRE-LEASE
HAZARD ASSESSMENT, EST. OF FEASIBILITY, MIN. BID EVALUATION & POST BID ANALYSIS
Agree on ability to engineer for hazards safely.
PRE-LEASE
EVALUATION FOR PREPARATION OF LEASES BID DECISIONS.
EXPLORATION AND PRODUCTION PLANNING
EXPLORATION
RIG REQUIREMENTS
DATA REQUIREMENTS
Agree on exploration safety & pollution protection requirements.
EXPLORATION
RIG SELECTION
PREPRODUCTION DEVELOPMENT
VERIFICATION/ INSPECTION
Agree on environmental design criteria and associated environmental exposure conditions.
PREPRODUCTION DEVELOPMENT
DESIGN TRADE-OFFS (ECONOMICS)
FINAL DETAILED DESIGN

Figure 21.

of competing agencies and organizations. This barrier can be greatly reduced by developing, through an appropriate interagency mechanism, common technological policies and strategies in cooperation with industry. The acquisition and sharing of appropriate data require establishment of a data base and an agreement on programs to fill in the critical gaps. This necessitates the wide sharing of information among government agencies and academia on a regular and assured basis.

Establishment of a single government focal point to represent our national interests is admittedly a formidable task. Options for focusing and coordinating the present programs of EPA, NOAA, USN, USCG, Corps of Engineers, USGS, etc., might include: (a) appointment of an interagency task, (b) designation of a lead agency, or (c) selection of a contractor-operated organization under a multiyear contract funded jointly by the participating agencies and controlled by an interagency steering group.

Industry is prepared to provide a corresponding focus. An appropriate industry focal point could be the American Petroleum Institute (API), whose Divison of Production has the expertise, experience, and stature to perform such an important function.

We believe that these recommendations, if adopted, will help the United States to develop the EEZ in the most efficient and effective manner while also maintaining its worldwide leadership in offshore technology.

REFERENCES

(1) "Petroleum Still Leader in the Energy Race," Michel T. Halbouty, Offshore magazine, June 20, 1981, p. 49-52.

(2) "International Report on Ocean Developments," by V. E. McKelvey, Ocean Industry, April 1974, p. 208-213.

(3) "Ocean Petroleum Resources," Report of the National Petroleum Council, March 1975.

(4) "Where Offshore Drilling is Taking Place," Ocean Industry, October 1983, p. 63-64.

(5) "Outer Continental Shelf Frontier Technology," Proceedings of a Symposium, Marine Board-National Research Council, National Academy of Sciences, December 6, 1979.

(6) "Deepwater Drilling Technology," Testimony at Public Hearing - Proposed North Atlantic OCS Oil and Gas Lease Sale No. 82, Carl L. Wickizer, World Trade Center, New York. July 29, 1983.

(7) "Deepwater Exploration Vital to Future," Offshore magazine, June 5, 1983, p. 31-44.

(8) "Technical Prologue - "Deepwater Development and Drilling Production-Testimony at Public Hearing - North Atlantic OCES Oil and Gas Lease Sale 52," R. L. Geer, Boston, Massachusetts, November 19, 1981.

(9) "Technology for Exploration and Development of Ocean Frontiers," The Conference on the Future of Gas and Oil from the Sea, University of Delaware, June 1981.

(10) "U.S. Arctic Oil and Gas" National Petroleum Council, Decmeber 1981.

(11) "Engineering Challenges for Offshore Exploration and Production in the '80's," Keynote Address - BOSS '82 - Third International Conference on the Behavior of Offshore Structures, R. L. Geer, Boston, Massachusetts, August 2, 1982.

(12) "Offshore Oil and Gas Operations - Assessment of the '70's and Forecase for the '80's," Keynote Address - 1981 Offshore Technology Conference, C. L. Blackburn, Houston, Texas, May 4, 1981.

(13) "A Reexamination of Occurrence Rates for Accidental Oil Spills on the U.S. Outer Continental Shelf," K. J. Lanfear and D. E. Amstutz, Proc. 1983 Oil Spill Conference, p. 355-359.

(14) "The Fate of Amoco Cadiz Oil," E. R. Gundlach, P. D. Boehm, M. Marchand, R. M. Atlas, D. M. Ward, and D. A. Wolfe, Science 221, July 8, 1983, p. 122-129.

(15) "A Natural Resource Damage Assessment Study: The Ixtoc 1 Blowout," P. D. Boehm, D. L. Fiest, I. Kaplan, P. Mankiewicz, and G. S. Lewbel, Proc. 1983 Oil Spill Conference, p. 507-515.

See also, "Informe de los Trabejos Ralizados para el Control del Pozo Ixtoc 1, El Combate del Derrame de Petroleo y Determinacion de sus Effectos Sobre el Ambiente Marine" published by Instituto Mexicano del Petroleo, 1980, p. 242.

(16) "National Strike Force Reponse Ixtoc 1 Blowout - Bay of Campeche," J. L. O'Brien, Proc. 1981 Oil Spill Conference, p. 125-130.

(17) "SOCK Skimmer - Performance and Field Tests," J. P. Fraser and L. M. C. Clark, Proc. 1982 Offshore Technology Conference, p. 471-479.

(18) "Effectiveness, Behavior, and Toxicity of Dispersants," D. MacKay and P. F. Wells, Proc. 1983 Oil Spill Conference, p. 65-71.

(19) "ABSORB: A Three Year Update in Arctic Oil Spill Response," S. O. Hillman and R. V. Shafer, Proc. 1983 Oil Spill Conference, p. 219-226.

(20) "Offshore Drilling and Production Technology - Where Do We Stand and Where Are We Heading," API Paper No. 362-C, Third Annual Meeting, API, by R. L. Geer, April 9-11, 1973.

(21) "The Ocean's Energy and Mineral Resources" Panel Discussion on "The Scientific and Technological Problems of Major Concern and Recommended Courses for their Solution" - The Oceans and National Economic Development Conference, Seattle, Washington, by R. L. Geer, July 17, 1973.

(22) Report on the Relationship between the Offshore Petroleum Industries and the U.S. Government by the Petroleum Panel of the Ocean Science and Technology Advisory Committee of the National Security Industrial Association, March 1974.

(23) "National Needs, Current Capabilities and Engineering Research Requirements - Offshore Petroleum Industry" - Report for Committee on Seafloor Engineering, Marine Board-National Research Council, by R. L. Geer, June 1975.

(24) "Seafloor Engineering - National Needs and Research Requirements" Marine Board, National Research Council, National Academy of Sciences, 1976.

(25) National Planning Conference on the Commercial Development of the Ocean-Sponsored by the U.S. Maritime Administration, National Oceanic and Atmospheric Administration, the Department of the Interior and the Energy Research and Development Administration, Washington, D.C., and Airlie, Virginia, June 9-12, 1976.

(26) "Understanding the Arctic Seafloor for Engineering Purposes" - Marine Board - National Research Council, National Academy of Sciences, 1981.

(27) "Our Nation and the Sea - A Plan for National Action" Report of the Commission on Marine Science, Engineering and Resources, January 1969.

(28) "Environmental Exposure and Design Criteria for Offshore Oil and Gas Structures" - Marine Board, National Research Council - National Academy of Sciences, May 1980.

Panel IIB

ENGINEERING-TECHNOLOGY ASSESSMENT, HARD MINERALS

Panel Chairmen:
Donald G. Kesterke, Bureau of Mines
Conrad G. Welling, Ocean Minerals Company

SUMMARY

The Exclusive Economic Zone (EEZ), declared in March 1983 by President Reagan as a part of the Nation's Ocean Policy, lies adjacent to the 50 States and to the territories and possessions of the United States: the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands, the territories of Guam, American Samoa, and the U.S. Virgin Islands, and Johnston Island, Jarvis Island, and the U.S. Virgin Islands. The zone represents a potential resource of strategic and critical minerals such as cobalt, zinc, copper, and silver, and possibly other minerals vital to the Nation's economy.

This report addresses some of the technological issues associated with mining and processing of seabed minerals, and recommends a sequence of events that must take place in order to assess the commercialization potential of this resource. A Federal/industry role for the initial phases of a national program for developing the mineral resources of the EEZ is also suggested.

INTRODUCTION

Five major categories of hard marine mineral deposits occur on the Continental Shelf generally within the Exclusive Economic Zone (EEZ) of the United States. They are (1) polymetallic sulfides ("polysulfides") off the California-Oregon coast; (2) the manganese nodules on the Blake Plateau east of Florida and the manganese sea-floor crusts around the Hawaiian Archipelago and the Blake Plateau; (3) phosphorites off the east coast from the Carolinas to Florida and off the southernmost California coast to Baja; (4) placers of various heavy metals (such as gold) off the Alaska coast; and (5) sand and gravel deposits. All of the these deposits have long-term, economic potential to meet domestic needs for critical and strategic minerals.

The physical conditions in which the deposits occur are quite variable. The polysulfides lie in 7,000 to 9,000 ft of water along major fracture zones in the crust associated with volcanic activity. Exploration to date suggests that they are irregularly interspersed with volcanic rocks and manganese oxides in small, isolated bodies ("smokers") up to large, massive bodies tens of meters thick and hundreds of meters across. The major sulfides are those of copper and zinc; silver and other metals occur in minor amounts. The nodules are scattered about the sea floor at, or nearly at, the surface in 3,000 to 5,000 ft of water. They range from mere specks to baseball size and consist mostly of manganese oxides with a little cobalt and even less copper, nickel, and other metals. The phosphorites occur as thin crusts and micronodules in sediments, in waters up to several hundred feet deep off the east coast, and to 1,000 ft or more off the west coast. Placers occur from the shoreline out into several hundred feet of water and consist of heavy minerals interspersed with sediments. The manganese crusts occur as a thin layer up to several inches thick (average is several centimeters) lying on the sea floor in several thousand feet of water, and containing very small amounts of Cu, Ni, Co, etc., in addition to the manganese oxides.

The presence of many critical and strategic metals in mineral deposits of the Exclusive Economic Zone offers the United States a potential alternative to countering unpredictable supplies and reducing the impact of supply disruption on the Nation's national security. For this reason, it is necessary to develop contingency plans for mining EEZ deposits and to emphasize research on the deposits occurring at water depths where the operational ability of present mining technology is exceeded or where operational capability is poorly known at best.

The following table compares a partial list of critical metals with the various physical types of mineral deposits of the EEZ in which they can occur:

<u>Crusts, Nodules</u>

Cobalt
Manganese
Nickel
Copper

<u>Placers</u>

Columbium
Tantalum
Chromium
Platinum

<u>Mounds, Ledges</u>

Copper
Zinc

<u>Assessment of the present status of research and development activities.</u> Among those active in R&D on hydrothermal deposits are:

- Academic institutions and private organizations such as:

  Harvard University
  Lamont-Doherty Geological Observatory
  Massachusetts Institute of Technology
  Oregon State University
  Scripps Institute of Oceanography
  State University of New York
  Stanford University
  University of Texas, Austin
  University of California
  University of Oregon
  University of Washington
  Woods Hole Oceanographic Institution

- Government agencies, including

  a. Department of the Interior

     - Geological Survey
     - Bureau of Mines

  b. National Science Foundation

  c. National Oceanographic and Atmospheric Administration

A brief chronology of events related to hydrothermal metal deposits includes:

- 1974 marks the beginning of recent research on hydrothermal metal deposits by the National Science Foundation, Office of Naval Research, and National Oceanic and Atmospheric Administration.

- In 1978, the French-American-Mexican expedition, CYAMEX, sampled ore-grade deposits of zinc, copper, and iron sulfide in the East Pacific Rise deposits that contained as much as 30 percent zinc and six percent copper.

- In 1980, the USGS and the University of Washington, Seattle, did exploratory work on the Juan de Fuca Ridge.

- In 1981, NOAA returned from the Galapagos Ridge with several hundred pounds of polymetallic sulfides; the Bureau of Mines became involved through characterization work on the samples.

- USGS and the University of Washington cruise on the southern Juan de Fuca Ridge dredged sulfide samples from 7,000 feet depth which showed that the massive sulfide is more than 50 percent lead with significant amounts of silver, cadmium, and copper.

- In 1983, the USGS made two small samples from the southern Juan de Fuca Ridge available to the Bureau of Mines for metallurgical investigations. The samples were subjected to chlorine-oxygen leaching tests which showed that hydrometallurgical processing of the zinc-rich seafloor deposits is feasible. The extraction of zinc was more than 99 percent, and the recovery of silver was more than 97 percent.

IDENTIFICATION OF PRESENT TECHNOLOGICAL LIMITATIONS AND MAJOR TECHNOLOGICAL OBSTACLES TO OVERCOME

Mining Research

Little or no technology exists for mining mineral deposits in the waters of 100 to 10,000 ft that occur in the EEZ, and adaptability of existing systems for dredging or deep sea nodule mining to EEZ deposits is virtually unknown. However, component technology does exist, and it is possible, with a limited degree of certainty and by making assumptions about the physical character of a hypothetical ore body, to engineer mining and materials-handling systems which can mine and transport ore to the surface for further processing.

Manganese Nodules

The manganese nodules on the Blake Plateau east of Florida and Georgia have nickel and copper values considerably below those nodules in Pacific Ocean deposits, but the Blake nodules occur at much shallower depths than the Pacific nodules and also contain greater cobalt values. The Blake Plateau nodules resource has been estimated at 250 million tons, submarginal in value, and potentially suitable for catalyst applications with relatively little processing required.

Composition of Blake Plateau ferromanganese nodules
concentration in percent

Mn	Ca	Fe	Si	Ni	Co	Cu	Mo
17	13	11	1.7	0.6	0.3	0.1	0.03

No technology has ever been tested for commercial harvesting of nodules in waters several thousand feet deep as on the Blake Plateau. However, one industrial company has harvested the nodules in small but significant amounts (tens of tons) with a prototype, reduced-scale ocean mining system for sampling/characterization purposes. The harvesting process involved a collector that raked in the nodules while being dragged along and then transferred them into an air/water pipe lift system. Although the system operated reasonably successfully, its reliability for adaptation to commercial mining is unknown. For R&D purposes, other system options could be conceptualized which might become successful and possibly reliable under commercial conditions. These would involve adaptation of dredging technology to the deeper waters through use of cutter and/or suction heads. Another adaptation might involve dragnet systems.

Seafloor Crusts

For seafloor crusts no technology exists to raise crusty and blocky fragments in commercial quantities through water columns of 100 to 10,000 ft associated with the EEZ. Elaborate dredging methods exist for water less than 100 ft deep, and a proven flexible pipeline lift system exists for raising deep-sea nodules from 10,000 and 20,000 ft of water. Other schemes for raising the nodules have been conceptualized (continuous line buckets, remotely controlled submersibles), but the two-phase lift (air, water) appears to lead over all the schemes. All these technologies must be reviewed and parts adapted to conceptualized, innovative system options. Options should consider segmented and/or flexible pipelines, bucket, cage or net systems, and remotely controlled versions of these devices. Consideration must also be given to the water-column depth, as waters less than 1,000 ft deep may require different lift designs than waters 1,000 to 5,000 ft deep or those over 5,000 ft, for example.

Placer Deposits

Placers of various heavy metals off the Alaska coast occur from the shoreline out into several hundred feet of water. Some commercial technology has been developed and/or is in practice to raise dredged sediments in waters less than 100 ft deep under commercial conditions, and some limited prototype technology exists for testing purposes only in waters 3,000 to 15,000 ft in depth. No technology has been developed to raise placer sediments in waters over 100 ft deep. Alternatives might include segmented, flexible pipe lift systems, bucket-line lifts, or controlled submersibles to raise the collected materials through the water column to a mining vessel and/or barge. Another adaptation might involve dragnet systems coupled with these lift system options. Consideration of these options is applicable to both nodule deposits and submarine placers located on the sea floor. For buried submarine placers, however, some adaptation of borehole mining technology could be conceptualized to fluidize and pump the placer sediment into a lift system for transport to the surface.

Extractive Metallurgy Research

Polymetallic Sulfides

Massive-sulfide sea-floor materials sampled to date are similar to conventional sulfide deposits found on land. While research conducted specifically to recover metals from these sulfides has been very limited, metallurgical practice is expected to follow state-of-the-art procedures and unit processes. Characterization of the minerals as part of the exploration process will give indications of the extent to which current practice will have to be modified.

Calcareous Nodules

From process development studies on calcareous Blake Plateau nodules in 1971, it was concluded that low-tenor nodules cannot be economically leached with acid under present economic conditions because of the high content of acid-consuming calcite. Laboratory-scale tests proved that a strong, carbonated, ammoniacal solution will dissolve the valuable metal constituents of reductively roasted nodules. Extraction of 90 percent or more of the nickel, cobalt, and copper showed the technique to be attractive for recovery of these metals. However, several serious technical problems will have to be solved to develop a practical leach process. For example, considerable difficulty was encountered in minimizing dissolution of unwanted iron and simultaneously achieving a high extraction of manganese. Furthermore, recovering the valuable metals from the complex solution involved a series of complicated and costly unit operations. If the manganese in the nodules is ignored, the nickel, cobalt, and copper in reduced nodules are readily and selectively dissolved using relatively weak carbonated ammonia solution. Most of the ammonia and carbon dioxide used for leaching is recoverable for recycling.

Co-Crusts

Sea-floor crusts around the Hawaiian Archipelago and the Blake Plateau are potential domestic sources of cobalt, manganese, and nickel. The crusts occur at relatively shallow depths (3,000 to 8,000 ft) on the flanks of seamounts. An estimate based on very limited knowledge has indicated that the crusts are as thick as 9 cm and appear to average 2 cm. Crusts are known to be present also on the peripheral areas of Wake Island, American Samoa, Howland and Baker Islands, Guam, and northern Marianas Islands, and islands of the Trust Territory of the Pacific Ocean. The cobalt content of the crusts is 30 lbs per ton which is much higher than the deep ocean nodules (4 lbs per ton).

Composition of manganese crustal materials
lbs per ton of material*

	Abyssal Nodules	Seamount Crust
Ni	26 lbs	8.2 lbs
Cu	20	1.2
Mn	500	306
Co	4.4	30
Mo	1	1
Fe	134	256
Pb	1 lbs	5.2 lbs

*Data from Cronan (1977) and McKelvey and others (1979)

Only limited exploration work has been conducted and only for selected occurrences has systematic sampling for manganese crusts been done. Further work in the U.S. EEZ is required to confirm the composition of manganese crusts and to estimate tonnage. These potential ores are of unknown character with respect to their amenability to metallurgical processing.

Phosphorites

Phosphorites off the east coast from the Carolinas to Florida and off the southernmost California coast to Baja constitute a large resource estimated to exceed 3 billion tons (2,000 million tons on the Blake Plateau and 1,300 million tons off Georgia and South Carolina).

In 1979, the U.S. Department of the Interior reported on a funded study of the offshore Georgia-South Carolina phosphate occurrence to determine the feasibility of phosphate extraction, environmental considerations, and economic viability. A 30-mile-square block was located offshore Georgia in a mean water depth of about 42 feet. On the basis of analysis of limited data and assumptions of ore grade and continuity, it was concluded that the block could contain 150 million tons of product which would be sufficient to support a major operation of 3.5 million TPY for more than 40 years. The study, which included a conceptual mining and beneficiation plan, concluded that offshore phosphate rock has great potential for the future. The study examined the benefits of beneficiation of the ore at sea, using ore washing to remove clays and any low-grade oversize material. The concentrated values then would be transported by barge to shore for flotation and further processing. Tailings sand and any clays from onshore processing would be placed in the mined-out area. Recommendations and conclusions of the study were that a long-range resource definition and environmental assessment program is indicated; that basic knowledge of the mineral resource necessary for proper economic evaluation is not developed; and that reserves must be thoroughly evaluated from a metallurgical and engineering standpoint.

The Blake Plateau phosphorites lie off the southeastern coast of the United States between Cape Hatteras and the Bahama Islands. Water depths range from 250 to 1,000 meters. The present estimate of 2 billion metric tons of phosphorite nodules may be compared with about 18 billion tons of apatite for the Florida land pebble district, and 65 million tons of phosphate nodules in the offshore southern California region. Limited laboratory tests reported in 1980 have shown that the offshore Blake Plateau phosphate beds are difficult to beneficiate and free from carbonate and other impurities, and are currently noncompetitive with land supplies. Recommendations for further engineering-technology assessment would require a sampling program conducted together with extractive metallurgical research.

RECOMMENDATIONS OF APPROPRIATE PROGRAM ROLES, A SCHEDULE OF ACTIONS, AND RESOURCE REQUIREMENTS TO IMPLEMENT AN EFFECTIVE NATIONAL PROGRAM

The resource potential of the ocean floor is not known, and marine sulfide and other mineral deposits cannot be considered reserves (ore) until extensive resource definition and equipment and process development indicate that they can be mined and treated at a profit. As such, resource characterization is the area of most pressing need, and to meet this need will require broad reconnaissance tools that define the physical and chemical characteristics of ocean-floor deposits.

A general listing of the sequence of events which must take place before reasonably accurate projections can be made about the commercial potential of ocean minerals is as follows:

1. Resource definition, including locations of inactive sulfide deposits that may be covered by sediment. This should include effort to:

- Assess the state-of-the-art of methods for resource definition and characterization.
- Identify specific areas of weakness. For example, coring tools are not available that can provide 3-dimensional characteristics of the deposits.
- Design, build, test, and refine prototype tools necessary to define the resource potential.
- Conduct a phased study of the ocean floor:
  - broad areas reconnaissance followed by a detailed study of promising sites that includes characterization work designed to lower the uncertainty level associated with mining and materials handling.

The above steps would be best accomplished as a two-phase effort consisting of:

- A near-term phase involving a program to develop new tools while at the same time continuing on-going work using existing tools. (e.g., Seabeam and Sea MARC systems) This phase should require 3 to 5 years.
- A long-term phase which will make use of new tools, and which will require at least 5 and possibly 10 years.

2. Concurrent with (1), conduct studies aimed at chemical and mineralogical characterization of core or grab samples, plus small-scale metallurgical testing of various methods for metal recovery.

Specifically, efforts are needed to characterize the mineralogical metallurgical properties of cobalt-manganese oxide crusts and polymetallic sulfides, and to test techniques to separate and recover the critical and strategic mineral values from both sources, including beneficiation, hydrometallurgical, pyrometallurgical, and other appropriate methods for recovery and processing operations. When larger, more representative samples of these deposits become available, additional studies would be needed to optimize the process variables and provide information useful in assessing the possible commercial exploitation of the resource.

3. Sequential to (1) and (2), design, test, and evaluate prototype mining systems, with the secondary objective of gathering tonnage quantities of raw material for metallurgical evaluation.

It is suggested that a twofold approach is needed to close technological gaps that are anticipated in future commercial mining of the various marine mineral deposits in the EEZ. Therefore, the deposits are treated as two distinct physical classes, consolidated and unconsolidated, because different mining technologies will be required for each class. Consolidated deposits include crusts, ledges, mounds, and vent areas; whereas unconsolidated deposits include nodules and placers.

Consolidated Deposits

° Innovative studies are needed to determine how existing fragmentation technologies can be adapted to different physical conditions in the EEZ, and how these or parts thereof can be combined with new ideas for breaking up the deposits (crust, ledges, mounds, etc.) efficiently. In examining the breaking forces involved, consideration should be given to towed versus self-propelled devices and impactors versus cutters or rippers, particularly in terms of their control and maneuverability. Consideration also should be given to the adaptabilty of existing explosives and techniques or their modifications, to rubblization of the deposits.

° Efforts are needed to develop collection systems that are compatible with fragments from the broken-up deposits. Consideration should be given to towed versus self-propelled devices and comparisons among bucket scoops, rakes, scoops with gathering arms and suction devices, particularly in terms of their control and maneuverability.

° Efforts are needed to develop lift systems that are compatible with collection systems options, such as remotely controlled containers, pipelines or continuous line buckets.

° Research concepts on fragmentation and collection and lifting systems into candidate seabed mining systems need to be integrated for evaluation of their response to closing technological gaps, and lab-scale mock-up tests should be conducted to evaluate the systems.

Unconsolidated Deposits

° Innovative studies are needed to develop deep water dredging systems and adapt existing dredging technologies, or parts thereof, to mining nodules and placers. Review of existing technologies for mining deep-sea nodules is essential to these studies. The studies should include concepts for extending and controlling dredge heads and adapting borehole mining techniques to water depths of 100 to at least several thousand feet. Consideration also should be given to rakes, drag nets, and bucket scoops, particularly in terms of their control and maneuverability.

° Efforts are needed to develop lift systems that are compatible with collection system options, such as segemented, flexible pipes, or continuous bucket lines.

° Candidate systems need to be studied and evaluated for anaysis of technological gaps, and laboratory scale mock-up tests should be conducted to evaluate concepts and close technological gaps.

4. Upon availability of raw material mentioned in (3), conduct large-scale chemical/metallurgical testing of the promising processing technology(ies).

Include:

° Efforts to determine optimum process conditions for recovering mineral constitutents in onshore pilot-plant operations and experimental investigations on techniques for partial concentration at sea, emphasizing reduction of transport costs, mineral recovery and waste management.

Government/Industry Involvement

It is recommended that an appropriate role for the government would be to provide the funds needed to assess the state-of-the-art and to support all basic research required as a precursor to developing the prototype tools. Depending on national need factors, the design and proof-of-concept testing of the tools, and the detailed survey of the ocean floor would be funded solely by the government, or co-funded by industry.

Upon completion of the survey, a go/no-go decision can be reached, and government involvement in terms of direct financial support would cease. If the survey indicates that the resource potential is promising, it would be up to industry to proceed with efforts to build the mining and materials-handling equipment.

Implementation of the Program

As a first step, it is recommended that immediate measures be taken to form a small task force to lay out a detailed plan of action. It is further recommended that the USGS take the lead, and that the members include representatives from industry, academia, as well as other government agencies.

REFERENCES CITED

Cronan, D.S., 1977, Deep-sea nodules, distribution and geochemistry, in Glasby, G.P., ed., Marine manganese deposits: Amsterdam, Elsevier, p. 11-44.

McKelvey, V.E., Wright, N.A., and Rowland, R.W., 1979, Manganese nodule resources in the northeastern equatorial Pacific, in Bischoff, J.L., and Piper, D.Z., eds., Marine geology and oceanography of the Pacific manganese nodule province: New York, Plenum, p. 747-762.

Panel IIIA

PANEL ON MANAGEMENT OF OIL AND GAS RESOURCES

Panel Chairmen:
Charles J. Mankin, Oklahoma Geological Survey
John B. Rigg, Minerals Management Service

Panel IIIA was concerned with the examination of the issues relating to the leasing and management of oil and gas resources in the Exclusive Economic Zone. This panel of 21 members was composed of 9 industrial representatives, 8 Federal agency representatives, 3 from academia, and 1 from the news media.

The panel accepted as a working premise that the OCS Lands Act was generally applicable and appropriate for the leasing and management of oil and gas in the Exclusive Economic Zone. It should be noted that the terrain that is included in the OCS Lands Act includes all of the Exclusive Economic Zone, and may extend in some places beyond the boundaries of the EEZ. Therefore all leasing and management activities for oil and gas in the Exclusive Economic Zone are believed to be covered under the OCS Lands Act and related legislation.

The panel recognized the need for considering 10 issues with respect to exploration and development of oil and gas in the Exclusive Economic Zone. These issues are concerned primarily with the frontier areas as opposed to those regions that have undergone extensive exploration and development. The panel doubts that any of these issues will require new legislation, but some clarification and/or modification of existing laws and regulations may be necessary. The issues are concerned primarily with clarification and/or new definition under the rules and regulations promulgated under the OCS Lands Act and related OCS legislation. These 10 issues are described as follows, in no particular order of priority.

1. Leasing. Four items are recognized that need special consideration within the issue of leasing. It should be noted that each item cannot be considered in isolation but must be viewed as a part of the overall leasing issue. For example, if a change is made in one item, it may well have a consequence of one or more of the other items contained within the general category of leasing.

The panel first reviewed the mechanism by which leases are made available. Alternatives to the present bonus-bidding procedure were reviewed, including work commitments, royalty bidding, and a modified lottery approach. After the panel examined each of the alternatives, their consensus, with one exception, was that bonus bidding was still the most effective way to make lands available for oil and gas exploration and development. There was a recognition that in frontier areas, the minimum bid may need to be reviewed because of the large economic risks associated with exploration and development in some of those hostile environments. In the same light, it was recommended that the royalty rate be reviewed for frontier areas, with some consideration being given to defer royalty payments at the front end in order to enhance the economic advantage of exploration and development in high-risk areas.

The panel also recommends a reexamination of the size of lease tracts. The present size of 5,760 acres seems to be an arbitrary number that may have had some significance in the early development of the nearshore, shallow-water environments. Because exploration now extends into deeper waters and into more hostile environments, a review of tract size seems to be appropriate. The panel does not offer a specific recommendation with respect to tract size, but many of the panel members believed that an expansion of several times the present size would be justified for frontier areas.

The final item considered by the panel under the general issue of leasing was that of the primary term of the lease. The panel felt, at least for frontier areas, that the primary term of the lease needs to be reviewed. The recent proposal to use 10 years as a primary term was considered to be a better approach than continuation of the 5-year primary term as currently established in OCS regulations. In some areas, it may be necessary to extend the primary term even beyond the period of 10 years because of the need to develop certain technologies, especially in very deep waters or areas of extreme ice conditions.

2. Consistency. The second issue considered by the panel was that of achieving consistency with the states potentially affected by OCS leasing. It was recognized that delays in achieving agreements with such states have resulted in delays in implementing parts of the current OCS leasing program. If such delays are extended into the frontier areas of the Exclusive Economic Zone, substantial social and economic costs may be incurred. The panel therefore urges the Minerals Management Service to continue active consultation with the states in order to minimize any delays that might occur from this activity.

3. Confidentiality of Data. It was the panel's view that confidentiality of data should be maintained and, in frontier areas, there may even be a need to extend the period of time during which data may be considered proprietary. It is recognized that this recommendation is counter to some of the concerns that individuals have expressed with respect to research activities in the OCS. But, recognizing the enormous financial commitment industry must make if it is to develop resources in the Exclusive Economic Zone, especially in frontier areas, we feel that companies must be given some competitive advantage with respect to the data they collect in their exploration activities.

4. Resource Assessment. The panel feels that the Federal Government should continue to perform regional framework geological studies in order to continue to improve our knowledge of the marine environment. The panel also believes that the responsibility that has been assigned to the Minerals Management Service for resource assessment in the Exclusive Economic Zone should be continued. It was recognized that both framework geological studies and resource assessments are important Federal responsibilities, especially in the frontier areas of the Exclusive Economic Zone.

5. Leasing Schedule. The panel discussed the 5-year leasing schedule for oil and gas exploration and development in the Exclusive Economic Zone. The panel believes that maintaining the proposed leasing schedule is extremely important in order to ensure development of the oil and gas resources. Such a schedule provides an opportunity for all parties concerned to plan for leasing and development activities on a regular, anticipated basis.

6. Congressional Intervention. The panel discussed the concern about disruptions that have occurred in the planned leasing schedule because of congressional intervention. Continuing efforts should be made to communicate with the Congress concerning the adverse consequence of ad hoc leasing prohibition. It is the panel's view that when a plan has been developed and approved for lease schedules, congressional intervention results in delays and inefficiencies in the leasing program.

7. Area-Wide Leasing. The panel believes that the present program of area-wide leasing provides for greater efficiencies and results in a more orderly development of the oil and gas resources than that achieved by the former procedure of designated lease tracts. It permits companies with different exploration strategies to test their hypotheses without undue constraints. Given a mix of exploration strategies from several companies, it should result in optimizing the development of the oil and gas resources in any sedimentary basin.

8. Regulatory Reform. The panel commends the Department of the Interior for its efforts to date in attempts to streamline OCS regulations. The industrial representatives on the panel noted several improvements in those regulations that have lead to a reduction in redundancy and improved efficiencies. The panel urges the Minerals Management Service to continue to pursue vigorously their efforts toward further regulatory reform.

9. Baseline Environmental Studies. The panel believes that the regional baseline environmental studies that have been conducted in the past in the OCS have been responsible for a substantial development of oil and gas at a minimum risk to the environment. Because of the success of this program, the panel believes it is necessary to continue to conduct regional baseline environmental studies in the Exclusive Economic Zone with special attention devoted to the frontier areas.

10. Best Available and Safest Technology. The 10th and last issue considered by the panel was that pertaining to the regulatory philosophy of requiring the best available and safest technology for drilling and completing wells in the Exclusive Economic Zone. The panel believes this regulatory philosophy has served well in the development of oil and gas in the OCS to date and therefore should be continued in the future in the further development of the Exclusive Economic Zone. Because exploration in frontier areas will require substantial technological development, the need for flexibility in applying such technology to the drilling and completion of wells is essential. This regulatory philosophy of requiring the best available and safest technology provides that flexibility while requiring that such technology meet those philosophical criteria.

Summary. The panel believes the 10 issues addressed in this report are essential to the successful exploration and development in the frontier areas of the Exclusive Economic Zone. As stated earlier, the panel believes that each issue can be addressed under existing legislation, and with only minor changes in existing regulations. Undoubtedly, as exploration proceeds in the frontier areas of the Exclusive Economic Zone, additional issues will be identified. Because of the encompassing nature of the OCS legislation, the panel is confident that those issues can be addressed as well in a similar manner.

Panel IIIB

CRITICAL AND STRATEGIC MINERALS LEGAL AND LEASING FRAMEWORK

Panel Chairmen:
Michael J. Cruickshank, Minerals Management Service
David P. Stang, David P. Stang, P.C.

A. ASSESSMENT OF THE PRESENT STATUS OF THE (1) LEGAL AND (2) LEASING FRAMEWORK FOR U.S. MARINE MINERALS RESOURCES.

1. Legal Basis for Leasing

The EEZ proclamation established the sovereign rights and jurisdiction of the United States for the purpose of exploring and exploiting, conserving and managing the natural resources of the seabed and subsoil to a distance of 200 nautical miles from the baselines from which the territorial sea is measured. The EEZ applies to the seabed off the U.S. coastal States, U.S. overseas possessions and territories, the Commonwealth of Puerto Rico, and the Commonwealth of the Northern Mariana Islands.

The Outer Continental Shelf Lands Act (OCSLA), Sec. 8(k), authorizes the Secretary of the Interior to grant leases of any mineral other than oil, gas, and sulphur in any area of the Outer Continental Shelf. In this act, the term "Outer Continental Shelf" means all submerged lands outside of States' waters which are subject to United States jurisdiction and control. Pursuant to well-recognized international law and the EEZ Proclamation, the United States possesses extensive sovereign rights and jurisdiction to grant rights related to mineral-resource development out to 200 miles.

The Department of the Interior has indicated that the OCSLA is applicable to the entire mineral-resource area of the EEZ.

2. Leasing - Present Planning Effort For Encouraging Mineral Development Within the EEZ

The leasing framework being developed at the present time for minerals other than oil and gas and sulphur on the OCS is based on several needs, including:

- Enhancement of access to domestic sources of certain critical and strategic minerals.

- Stimulation of the development of a marine mining industry within the United States.

- Provision of an equitable economic return to all affected parties.

- Maintenance of the environmental integrity of affected areas.

- Development of a sustained and credible expertise in the management of offshore marine-mineral-resource development with full participation of the academic, commercial, and public sectors.

Congress has foreseen these needs with the passage of implementing legislation including the OCS Lands Act (1953) amended 1978, which authorizes mineral leasing; the National Materials and Minerals Policy, Research and Development Act of 1980 which charges the Administration, among other things, to promote and encourage private enterprise in the development of economically sound and stable domestic materials industries; and the Deep Seabed Hard Mineral Resources Act of 1980 which encouraged development of manganese nodules. Minerals management has traditionally been one of the functions of the Department of the Interior, and is so prescribed in the Outer Continental Shelf Lands Act, which authorized the Secretary of the Interior under Section 8(k), "to grant to the qualified persons offering the highest cash bonuses on a basis of competitive bidding leases of any mineral other than oil, gas and sulphur in any area of the Outer Continental Shelf not then under lease for such mineral upon such royalty, rental, and other terms and conditions as the Secretary may prescribe at the time of offering the area for lease."

A number of studies have been made over the years in which leasing frameworks were discussed ("Study of OCS Lands of the U.S.," Public Land Law Review Commission, 1968; "Our Nation and the Sea," Report of the Commission on Marine Sciences, Engineering and Resources, 1969; "Mining in the OCS and in the Deep Ocean," National Academy of Sciences 1975; "OCS Mining Phase II Policy Task Force Report," Department of the Interior 1979; "Marine Polymetallic Sulfides Workshop Proceedings," NOAA, 1983; and "Marine Minerals: An Alternative Minerals Supply," NACOA 1983). These studies identified an issue related to the requirement of the OCSLA for competitive bidding which was necessary to establish rights to a deposit and with it the protection of proprietory data acquired through exploration investments. It was reiterated that precedents set in the Oil and Gas Leasing Program should <u>not</u> be imposed on developing a leasing program for other minerals. Major needs expressed include low up-front costs, areas sufficiently large to allow reasonable prospects for discovery in unexplored areas or for establishment of adequate logical mining units in areas where deposits were known, assurance of tenure following discovery, and flexibility in lease terms to meet the wide variety of deposit types and environments likely to be encountered.

The Secretary of the Interior, in 1982, initiated a program to offer leases on a case-by-case basis in response to industry or national needs. A basic precept of the program is to encourage exploration by placing emphasis on market reliance and downstream contingency payments based on production, rather than front-end bonuses which maximize immediate receipt of Federal revenues.

The initial lease offering proposed for metalliferous sulfides in the Gorda Ridge area off California and Oregon will provide useful experience for future leasing frameworks. Proposed lease terms and conditions specific to the Gorda Ridge offering will be published for public comment after completion of the environmental impact statement. The basic concepts being considered for this offering include areas of sufficient size and configuration for exploration; up-front costs conducive to investment; exploration and development terms to accommodate technical, environmental, and market contingencies; options for relinquishment of exploration areas on transfer from the exploration phase to development or mining phases following discovery; and the acquisition of Federal revenues based upon the success of the operation. Some form of crediting for work done could be utilized to encourage diligence prior to production. It is anticipated that 20 or more years might elapse between the lease offering and the first commercial production.

Each potential hard-mineral resource area within the EEZ will involve separate consideration, including aspects related to resource base, environment, technology, geomorphology, mineral needs, protection of multiple uses, and safety. Accordingly, lease terms and conditions are expected to be individually tailored for each offering.

B. PROBLEM AREAS ASSOCIATED WITH PRESENT PROGRAMS FOR EXPLORATION AND DEVELOPMENT OF DOMESTIC MARINE MINERALS WITHIN AND BEYOND THE EEZ

I. Leasing Regime for EEZ Hard Minerals

(A) Method of allocation of rights to explore and produce hard minerals

1. competitive bidding (OCSLA model)

2. non-competitive bidding
   first in time
   first in right (DSHMRA Model)

3. patenting (or other models)

Note: Discussion at I(F) of costs of rights

(B) Qualification of operators

1. financial responsibility

2. technological capability

3. U.S. citizenship requirement?

4. other?

(C) Size of area conveyed to holder for exploration/production rights

1. larger area for exploration (relinquishment requirement?)

2. same area for both exploration/production

3. limitation on total exploration/production area per company (antitrust considerations)

(D) Duration of exploration/production rights

A function of

1. demand for minerals

2. technology

3. economic efficiency

(E) Diligence requirements

1. linkage of diligence to incentives, i.e., operator is rewarded by investing predetermined amount capitol in exploration, and accordingly awarded (a) extended exploration/production period,(b) tax and/or (c) other incentives

(F) Costs of property rights/Federal revenues, and method of payment

1. bonus bid

a. up-front payment

b. payment spread over time

c. credit for diligence

2. rentals

3. royalties

4. combination, including incentive package of delayed payments, credit for diligence, extended lease terms

5. tax incentives

II. Delineation of Boundaries

(A) Seaward limit of lands subject to OCSLA

(B) Insular margins

(C) International boundaries

1. Canada (4)

2. USSR (1)

3. Mexico (2)

4. Cuba (1)

5. Bahamas (1)

6. U.S. territories or possessions

7. Trust territories of the Pacific

(D) Baseline from which boundary of territorial sea is measured

(E) Territorial sea

(F) Contiguous zone

III. Applicable Law

(A) International law

1. 1958 Geneva Convention on the Continental Shelf

2. Law of the Sea Treaty (?)

3. Customary international law

4. Other treaty obligations, safety at sea, pollution, etc.

(B) U.S. Federal Law

1. Submerged Lands Act

2. Outer Continental Shelf Lands Act

3. Deep Seabed Hard Mineral Resources Act

4. Marine Sanctuaries Act

5. Fisheries Conservation Management Act

6. Marine Mammals Protection Act

7. Endangered Species Act

8. Coastal Zone Management Act

9. National Environmental Policy Act

10. Clean Water Act

11. Clean Air Act

12. Other environmental laws

Note: See II

(C) Quality of Rights Acquired

1. within OCS

2. beyond OCS but within EEZ (?)

3. beyond OCS/beyond EEZ

4. exclusivity

(D) Grantor of Rights

1. DOI

2. NOAA

3. environmental permitting agencies, i.e., EPA

(E) Impediments or constraints on exercize of rights by property holder (operator)

1. high seas freedom of other users, U.S. and foreign involving

a. military and civilian navigation and overflight

b. fishing

c. scientific research

d. laying of submarine cables and pipelines

e. other uses

2. treaty and statutory regulatory regime

Note: See III A and B for examples of constraints

(F) Conflict resolution

Need to establish mechanisms for resolving conflicts involving

1. competing U.S. ocean miners

2. competing U.S. civilian and military users of water column and seabed

3. State and local government authorities

4. foreign Government and their nationals

   a. Reciprocating States Agreement model

<u>IV. Timing of Lease Offerings</u>

(A) Adequacy of data base?

(B) Adequacy of exploration tools?

(C) Market demand?

(D) National security interest in stimulating development prior to play of market forces?

   1. If so, what incentives? (Note: See I (E) and (F), Defence Production Act, etc.

(E) Adequacy of legislative framework?

(F) Aggregate advantages and disadvantages of early offering versus delayed offering

SUMMARY OF PANEL DISCUSSION AND RECOMMENDATIONS

Developing a leasing program for hard minerals is complex because there are about 88 different commodities involved, each with unique factors. As an aid in developing a management program, the various commodities are grouped into suites of minerals. Five basic groups have been identified which have sufficient differences, technically and environmentally, to warrant their management along different lines. In order words, these five groups are different enough to warrant five different aproaches. And these groups are:

Construction materials, which include items such as sand and gravel; aragonite; shell sand; low-grade, large bulk materials.

Placer minerals, which are many--gold, platinum, titanium minerals, tin, and so forth. Again, large bulk commodities but smaller content of valuable minerals.

Phosphorites, which we saw yesterday and the day before, that we have large expanses of these on both the east and the west coasts in different forms.

Metalliferous oxides, which include the high cobalt manganese crusts, recently discovered on seamounts and undersea areas in our EEZ.

Metalliferous sulfides, or polymetallic sulfides, recently discovered.

In economic terms, the world oil markets have been very depressed, and as a result, the capital that has flowed into ocean-mining ventures from the oil-company parent companies has been drying up very rapidly. Worse yet, the world metal market has been severely depressed, and as a result, capital formation for such projects as ocean mining is very difficult. There is little money around to engage in extensive exploration pursuant to a lease by any company. Even if the capital were there, the present market for those metals does not look very promising. So, from a company perspective, looking at the surrounding realities, there is not very much to motivate any early action in developing polymetallic sulfides on a commercial basis.

Considering the political context, we know that this administration has an interest in balancing the budget, which means no huge spending programs other than those related to national defense. Consider also the Reagan administration free enterprise philosophy: if there's a marketplace, let the industry discover it and develop it. But, within that political context, there's also an interest in enhancing our national security by facilitating access to the Exclusive Economic Zone in which critical and strategic minerals may be located. However, the national security interest in this area is not sufficient to finance a Manhattan-type project, and the Federal resources available to developing polymetallic sulfides are very limited.

Turning now to the legal context in which all of this planning is taking place, there are many applicable laws, but two in particular:

First is the Outer Continental Shelf Lands Act, which authorizes hard-mineral leasing on the Outer Continental Shelf. Any leasing that is to be done pursuant to that act must be done on a competitive bid basis. The other act, the Deep Seabed Hard Minerals Resources Act, authorizes licensing and permitting of ocean-mining activities, basically beyond the Continental Shelf, but that licensing is restricted only to manganese nodules, not polymetallic sulfides. Neither act was really designed to encourage the development of polymetallic sulfides.

The basic conclusions to which the companies, the State government officials, and the environmentalists agree is that there is no great urgency to hold a lease sale next year for polymetallic sulfides on the Gorda Ridge.

The reason given for that from various groups participating is the total inadequacy of the data base. The fair market value of a dream is zero. This is to be distinguished from the other four groups of minerals that the Interior Department is considering leasing, such as phosphates and construction materials, including sand and gravel. That is, the lack of enthusiasm for an immediate lease sale on the Gorda Ridge was not in any way intended to apply necessarily to other minerals which may be in greater demand.

The next point raised is the lack of exploration tools. Although offshore oil and gas drilling equipment is available, the cost of using drilling rigs is prohibitive. About 1- or 2-days' use of an oil rig out there at present rates would exhaust the value of the resource you hope to recover. Other less expensive tools have to be developed.

The third reason for not moving too quickly is the lack of major economic demand. The economic incentive will have to come from the marketplace.

The issue of legislation has been raised and whether or not, because of the Outer Continental Shelf Lands Act's requirement of competitive bidding, other legislation, more favorable to ocean mining, should be enacted. Some people recommend amending the law to include preference right approaches toward polymetallic sulfides rather than competitive bidding. Others think the existing Marine Policy Commission legislation would provide a forum in which these kinds of issues could be better addressed before a lease sale. The State government people are quite concerned about adequate participation.

We considered the question of what kinds of terms and conditions and arrangements and procedures will be necessary to insure, or at least to enhance, the success of a lease sale?

The first item addressed was the terms and conditions of an economic nature that would or could induce bidders to participate, assuming no enactment of any new legislation.

The up-front bonus bids won't work if used in any way similar to the way they are used for offshore oil and gas lease sales. Under new legislation, a preference-right approach was recommended as one probable way. But if the existing Outer Continental Shelf Lands Act were to be implemented, and if there is to be a bonus bid, it was recommended that one ought to have a combination bonus bid and, instead of the fixed royalty, have a minimum work-commitment bid. That is, if the person is awarded the lease, then he must perform a minimum amount of work annually in order to keep the lease; in other words, a diligence requirement.

The payment of the bonus bid would be deferred until after discovery and start of commercial production.

To prevent speculators running out and bidding $5 for leases, the panel recommends that the leases not be assignable except through merger. A further requirement could be that if the sole purpose of the corporation was to acquire the polymetallic sulfide lease, the purchase of that company through merger would be prohibited in so far as assignability of the lease is concerned. This is to insure that leaseholders are serious and have an intent, at least, to explore and ascertain whether there are commercially recoverable minerals.

With respect to lease terms, another suggestion that was made was that the term be for 20 years or more so long as the leaseholder is exploring or producing. It was agreed also that a partial relinquishment requirement could be used under the circumstances.

Finally, with respect to the general kinds of provisions that would induce investment, to the extent that the marketplace would otherwise allow it, it was proposed that instead of a rigid regulatory structure, such as that imposed on companies seeking to mine manganese nodules, a more flexible approach be followed in which lease terms and conditions be tailored uniquely to each offering.

The companies need predictability, and they need flexibility in the leasing arrangement to induce the kind of effort that will be necessary. This is particularly true given the lack of any existing data, the lack of exploration tools, and the other factors, such as marketplace conditions, which work towards postponing a lease sale.

The second major area that was considered, other than leasing terms, was the accommodation of other interests. According to oil company spokesmen, California's exercise of its rights under the Coastal Zone Management Act has blocked development and encouraged much litigation with respect to West Coast oil and gas lease areas. The oil company people advised their brothers in the mining industry that it would be well to make peace with the Coastal Zone Management people in the state government.

There are other users off the coast as well, not only competing mining interests but fishermen and navigators, and both commercial and military navigation.

Those who were involved in the mining of manganese nodules quickly learned that there are an awful lot of other users out there who have to be accommodated, including scientific research.

One area that was addressed with respect to the conflicting or competing uses is that under the Outer Continental Shelf Lands Act, scientific research that does not interfere with the mining operations or the oil and gas drilling or producing operations is permitted under law. The issue arose of whether or not a competitor who claimed to be doing purely scientific research should be permitted on the lease area under a polymetallic sulfide regime. That is an idea that deserves more attention.

Finally, the last area we considered was that of environmental protection. It was generally agreed by industry and the environmental representatives alike that unless the environmental issues are taken into account in advance and contained in the draft environmental impact statement and in the final environmental impact statement, the probability of interruption, lawsuits, and other such problems, would be very great. Therefore, it's best to deal with the environmental issues and resolve them ahead of time rather than trying to move quickly without appropriate participation by environmentalists, other members of the public, and particularly state and local governments who may have an interest.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The objective of this symposium was to obtain guidance and input from the industrial, academic, and government communities in formulating a plan to begin structuring a national program to assess and develop the mineral resources of the U.S. Exclusive Economic Zone. Besides opening avenues of communication among the various communities, the significant contribution to result from the symposium was the series of recommendations from the workshop discussions. With these recommendations, which are summarized below, we can begin to organize and maximize our activities in the EEZ. Designation of responsibility also can be assigned for each aspect addressed in the recommendations (see table 1).

EEZ SYMPOSIUM RECOMMENDATIONS

A. OIL AND GAS

Panel 1A: Science-Resource Evaluation

Recommendation 1: That within 90 days the Director of the U.S. Geological Survey form a committee composed of representatives of government, industry, and academia to evaluate the feasibility of a joint program for subsurface and evaluation of potential for resources in the Exclusive Economic Zone (EEZ).

Recommendation 2: That regional geological syntheses be undertaken by the U.S. Geological Survey and academia with the collaboration of industry in principal EEZ basins. These syntheses should include, but not be restricted to: state-of-the-art seismic-reflection data; tectonic and depositional environmental studies; geochemical studies; two-ship, wide-angle reflection studies; and high precision aeromagnetic and gravity surveys where required.

Recommendation 3: That detailed Seabeam bathymetric surveys be undertaken in selected EEZ areas.

Recommendation 4: That existing sources of data be investigated before collecting additional data. These sources include industry files, geophysical contractor files, and other agency and program files such as DOD, DSDP, OMD, DMA, etc.

Panel 2A: Engineering-Technology Assessment

TABLE 1. EVALUATION OF EEZ SYMPOSIUM RECOMMENDATIONS

1 REC.	2 PRIOR-ITY	3 DESIGNATION OF RESPONSIBILITY								4 RESOURCES (Financial)						5 FUNDS		6 BUD-GET	7 COMP. DATE		
		DOI	USGS	MMS	BOM	NOAA	OTHER	PRIV	ACAD	USGS	MMS	BOM	NOAA	OTHER	PRIV	EXIST	NEW		ASAP	FY84	OPEN
1A1	-	-	1	3	-	3	3	2	2	-	-	-	-	-	-	-	-	-	X	-	-
1A2	-	-	1	3	-	3	-	2	2	-	-	-	-	-	-	-	-	-	-	-	X
1A3	-	-	2	3	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	X
1A4	-	-	1	3	-	-	3	2	2	-	-	-	-	-	-	-	-	-	-	-	X
2A1	-	-	1	2	-	3	3	3	2	-	-	-	-	-	-	-	-	-	-	-	X
2A2	-	-	1	2	-	1	3	2	2	-	-	-	-	-	-	-	-	-	-	-	X
2A3	-	1	2	2	-	2	3	1	-	-	-	-	-	-	-	-	-	-	-	X	-
2A4	-	1	2	2	-	2	3	1	-	-	-	-	-	-	-	-	-	-	-	X	-
2A5	-	1	2	2	-	2	2	-	-	-	-	-	-	-	-	-	-	-	X	-	-
3A1	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	X	-
3A2	-	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	X
3A3	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	X	-
3A4	-	-	1	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
3A5	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
3A6	-	1	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	X
3A7	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	X
3A8	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	X
3A9	-	-	1	2	-	2	3	3	3	-	-	-	-	-	-	-	-	-	-	-	X
3A10	-	-	-	2	-	-	-	1	3	-	-										
1B1	-	-	1	2	2	2	-	3	3	-	-	-	-	-	-	-	-	-	-	X	-
1B2	-	-	1	2	2	2	-	3	2	-	-	-	-	-	-	-	-	-	X	-	-
1B3	-	-	1	2	2	3	-	3	2	-	-	-	-	-	-	-	-	-	-	-	X
1B4	-	-	-	1	-	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	X
1B5	-	-	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	X	-	-
1B6	-	-	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	X	-	-
2B1	-	-	2	3	1	3	-	2	3	-	-	-	-	-	-	-	-	-	-	-	X
2B2	-	-	2	3	1	3	-	2	3	-	-	-	-	-	-	-	-	-	-	-	X
2B3	-	-	3	-	1	3	-	1	3	-	-	-	-	-	-	-	-	-	-	-	X
2B4	-	-	1	3	2	1	-	2	3	-	-	-	-	-	-	-	-	-	-	-	X
2B5	-	-	3	-	1	3	-	2	3	-	-	-	-	-	-	-	-	-	-	-	X
2B6	-	-	1	2	2	2	-	3	3	-	-	-	-	-	-	-	-	-	-	-	X
2B7	-	-	1	3	2	2	-	3	3	-	-	-	-	-	-	-	-	-	X	-	-
3B1	-	-	-	1	-	2	-	2	-	-	-	-	-	-	-	-	-	-	X	-	-
3B2	-	-	-	1	-	2	-	2	3	-	-	-	-	-	-	-	-	-	X	-	-
3B3	-	-	-	1	-	2	-	2	3	-	-	-	-	-	-	-	-	-	X	-	-
3B4	-	-	-	1	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	X
3B5	-	-	2	1	2	2	-	2	3	-	-	-	-	-	-	-	-	-	-	-	X

Recommendation 1: That the Federal Government's responsibility, with assistance from academia, should be in assisting with the procurement of basic environmental data that could be provided by unique government laboratories, satellites, data collection and processing facilities, and technical personnel.

Recommendation 2: That data be developed to better characterize in quantitative terms the baseline oceanographic and meteorological data along with Arctic data--especially in new frontier areas. Development of these data should be appropriately shared in the most cost-effective way.

Recommendation 3: Establish focal points in government and industry with adequate levels of technical expertise to ensure a responsible and optimum information exchange.

Recommendation 4: That government commit to long-range planning by an established and dedicated government focal point that will have long-term predictability in the development of a successful, cost-effective cooperative effort with industry in the area of technical information development and exchange.

Recommendation 5: That "widely recognized" barriers to the above recommendations be removed by correcting the fragmentation of government efforts and responsibilities through a variety of competing agencies and organizations.

Panel 3A: Legal-Leasing

Recommendation 1: Relative to leasing: (1) minimum bid should be reviewed as a mechanism by which leases might be made available for exploration and development in frontier because of the large economic risks; (2) royalty rate be reviewed for frontier areas with consideration being given under existing regulation to defer royalty payments at the front end in order to enhance the economic advantage of exploration and development in high risk areas; (3) re-examine the size of lease tracts with the view towards expanding the size of leased tracts in frontier areas; (4) review the primary term of the lease, changing it to extend beyond 10 years.

Recommendation 2: That MMS continue active consultation with the States in order to minimize any delays that might occur from this activity.

Recommendation 3: That the topic of confidential data be reviewed. In frontier areas, the confidentiality of data should be maintained and perhaps extended.

Recommendation 4: That the Federal Government continue to perform regional geological studies, to continue to improve our knowledge of the marine environment, and especially as it pertains to the EEZ.

Recommendation 5: That the 5-year leasing schedule of oil and gas activities in the EEZ be maintained.

Recommendation 6: That efforts continue to communicate with the Congress concerning the adverse consequences of ad hoc leasing prohibition.

Recommendation 7: Continue area leasing on a basin-wide basis; i.e., offer an entire sedimentary basin for leasing as opposed to returning to the prior procedure of lease tracts.

Recommendation 8: Continue to pursue vigorously the efforts toward regulatory reform.

Recommendation 9: That the Federal Government continue to do regional baseline environmental studies in the EEZ.

Recommendation 10: Insure that the application of the best available and safest technology for drilling and completing wells in the EEZ be utilized.

B. HARD MINERALS

Panel 1B: Science-Resource Evaluation

Recommendation 1: That the Federal Government establish a national program to investigate the occurrence of hard minerals within the EEZ.

Recommendation 2: That topographic and geologic maps be generated of the EEZ through inventoring of existing data bases as well as carrying out reconnaissance surveys to not only further our understanding of the extent of known hard minerals such as sand and gravel, placers, phosphorite, Mn-nodules, Co-crusts, and massive sulfides but other hard-mineral deposits not yet discovered in the marine environment. A sense of urgency is placed on the need to generate such maps as soon as possible with emphasis upon their rapid public dissemination. Industry and academia should be given serious consideration in the production of such maps if their services are more cost effective. Particular attention should be paid to identifying defficiencies in the data bases and to identifying hard-mineral assemblages which are associated with particular geologic settings.

Recommendation 3: Conduct studies to identify areas of high probability of finding mineral deposits and carry out detailed studies.

Recommendation 4: That the MMS insure the leasing of tracks in the future which will not preclude parallel scientific investigations in the same areas.

Recommendation 5: That the MMS consider establishing a legal framework similar to the framework now governing exploration in Canadian waters to insure the timely release of data to the public sectors without insuring the companies priority investment.

Recommendation 6: That MMS review ongoing deliberations which inhibit the extraction of known deposits within the EEZ such as sand/gravel and placers, and clarify the long-term legal framework within all parts of the EEZ, in particular the western Pacific, as these legal considerations and their outcome may directly affect the priority given to the investment by public and private sources in those regions.

Panel 2B: Engineering-Technology Assessment

Recommendation 1: Assess the state-of-the-art of methods for resource definition and characterization of both unconsolidated and consolidated deposits.

Recommendation 2: Identify specific areas of weakness of technology for unconsolidated and consolidated deposits (e.g., lack of coring tools for determining the 3-dimensinal characteristics of hard-mineral deposits).

Recommendation 3: Design, build, test, and refine prototype tools necessary to define the resource potential of unconsolidated and consolidated deposits.

Recommendation 4: Conduct a phased study of the ocean floor: (1) conduct a regional reconnaissance study, (2) followed by a detailed study of promising sites that includes (3) characterization work designed to lower the uncertainty level associated with mining and materials handling of unconsolidated and consolidated deposits.

Recommendation 5: Complete the program to develop new tools while at the same time continuing ongoing work using existing tools (e.g., Seabeam and Sea MARC systems) within 3 to 5 years.

Recommendation 6: That upon completion of the program to develop new tools, use the new tools to characterize sea-floor deposits in 5-10 years.

Recommendation 7: Take immediate measures to form a task force, led by the USGS but consisting of representatives from industry, academia, and government, to detail an action plan to accomplish recommendations by this panel.

Panel 3B: Legal-Leasing

Recommendation 1: That the MMS review the terms and conditions of leasing; (1) especially the possiblity of changing the upfront bonus-bid approach to a preference-right approach or modifying the bonus-bid approach; (2) that the leases not be assignable except through merger.

Recommendation 2: That lease terms be for 20 years or more as long as the lease holder is exploring or producing.

Recommendation 3: That instead of a rigid regulatory structure such as imposed on those companies seeking to mine manganese nodules, a more flexible approach be instigated in which lease terms and conditions be tailored uniquely to each offering, rather than out of a long, rigid set of regulations.

Recommendation 4: That conflicting or competing uses be identified and addressed when developing the terms and conditions of leasing.

Recommendation 5: That a process be identified by which environmental issues can be sorted out in advance through participation by all interested parties and contained in the draft and final environmental impact statements and thereby reducing the probability of interruption to the development of the resources by lawsuits, etc.

CONCLUSION

The first steps in initiating a national program have begun with this symposium. Through implementation of the symposium recommendations and future direction, a national program will evolve having been molded through the joint efforts of industry, academia, and government agencies.

APPENDIX A

Proclamation by the President: Exclusive Economic Zone of the United States

THE WHITE HOUSE
Office of the Press Secretary

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

APPENDIX B

Attendees at EEZ Symposium, U.S. Geological Survey
November 15, 16, and 17, 1983

Name	Affiliation
Scott Allen	Law of the Sea Institute Richardson School of Law University of Hawaii 2515 Dole Street Honolulu, Hawaii 96822
Stanley Alper	National Oceanic and Atmospheric Administration 6001 Executive Boulevard, Room 720 Rockville, Maryland 20852
Steve N. Anastasion (Executive Director)	National Advisory Committee on Oceans and Atmosphere Page Bldg. 1, Room 438 3300 Whitehaven Street, N.W. Washington, D.C. 20235
Henry S. Anderson	2209 Cartwright Place Reston, Virginia 22091
Lance Antrim (Project Director)	U.S. Congress Office of Technology Assessment Washington, D.C. 20510
T. S. Ary (President, Minerals Exploration Div.)	Kerr-McGee Corporation P.O. Box 25861 Oklahoma City, Oklahoma 73125
Andrew V. Bailey	Minerals Management Service 642 National Center Reston, Virginia 22092
Robert J. Bailey	Oregon OCS Coordinator Department of Land Conservation and Development 320 SW Stark Street, Room 530 Portland, Oregon 97204
Jim Baker (President)	Joint Oceanographic Institutions, Inc. 2100 Pennsylvania Avenue, N.W. Suite 316 Washington, D.C. 20037

Name	Affiliation
Robert D. Ballard (Director)	Deep Submergence Laboratory Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543
Joan Barrows (Congressional Officer for Research)	National Oceanic and Atmospheric Administration 6010 Executive Boulevard, Room 517 Rockville, Maryland 20852
Tim Bartish	Committee on Commerce, Science and Transportation U.S. Senate Washington, D.C. 20510
Rodey Batiza	Washington University Campus Box 1169 St. Louis, Missouri 63130
Frank Baxter	U.S. Geological Survey Department of the Interior 18th and C Streets, N.W., Room 7351 Washington, D.C. 20240
Robert G. Beauchamp	Minerals Management Service 643 National Center Reston, Virginia 22092
A. E. Bence	Exxon Minerals Company P.O. Box 2189 Houston, Texas 77001
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