Petroleum Exploration: Discouragement About the Atlantic Outer Continental Shelf Deepens

A gloomy scientific appraisal is apparently being borne out by current drilling

In 1978, the United States consumed more oil and gas from domestic sources than it found, thereby depleting its reserves of these vital mineral resources for the eighth consecutive year. The outer continental shelf (OCS), which includes the ocean bottom out to a depth of about 200 meters, has been considered a prime prospect in the search for new deposits of oil and gas to replenish these declining reserves. But results from the new OCS areas explored since the Arab embargo have been disappointing, with the likely quantities of recoverable oil and gas running well below the amounts initially estimated. The experience is a reminder that the estimation of undiscovered oil and gas resources before any drilling is done continues to be a very inexact process.

The Atlantic OCS, situated offshore from a region that consumes about 7 million barrels of oil a day and produces almost none of it, had been regarded by some as a particularly exciting prospect. In 1974, the U.S. Geological Survey (USGS) tentatively estimated that as much oil might be found on the Atlantic OCS as is now thought to remain undiscovered in Alaska. The amount of undiscovered gas was estimated to be equal to the amount yet to be found in West Texas. These amounts approach 50 percent of the total proved oil reserves of the United States and 30 percent of proved natural gas reserves.

In fact, things have not worked out that well. Even the more modest estimates made since 1974 may turn out to have been far too high. The worst news is that 13 out of 15 wells in the Baltimore Canyon Trough, the best prospect in the Atlantic OCS, have been dry, and the two finds were gas, not oil. The prospects for economically producible fields in the Baltimore Canyon area, and even the Atlantic OCS, are "dismal" or "very grim," according to some experts.

Although no one is about to write off the Baltimore Canyon area, much less the entire Atlantic OCS, geologic data accumulated over the last 10 years have been increasingly discouraging. Dwindling expectations as the amount of information has increased have been typical of petroleum exploration in many new OCS areas in recent years. In spite of highly sophisticated scientific tools, it is still very much a gambler's game.

Until drilling in the Baltimore Canyon began in 1976, the U.S. Atlantic OCS was a frontier, unexplored by deep drilling, but exploration geologists already had investigated some broadly comparable areas outside the United States. The results were not encouraging.

The earliest drilling in a possibly comparable area was, unlikely as it may seem, off the northwest coast of Africa. The geologic connection between the two areas goes back about 180 million years to the breakup of Pangaea, the supercontinent that included all the land area in the world. As is happening now in the Red Sea and the Great Rift Valley of East Africa, molten material from the earth's mantle welled up, the continental crust split, and the two new continents began to drift apart as new ocean crust formed between them.

During this rifting process, a chain of freshwater lakes and swamps probably formed first, then a long, narrow seaway, and finally the open Atlantic. Continental shelf formed as the broken, hot edges of the continents slid off the new spreading center and began to cool. Being cooler and thus more dense, the shelf slowly sank and began to accumulate sediments washed down from the adjacent continent.

Such thick deposits of sediment on the continental shelves can provide the necessary conditions for the eventual creation of an oil or gas field. The first condition is that at some point organic matter, the source of oil and gas, was buried along with the sediment. The organic matter can come from the remains of microscopic phytoplankton in lakes, restricted seaways, or the ocean. It can also be washed down from the land.

When American oil companies drilled on the continental shelf off northwest Africa, they did not find significant oil or gas deposits, in part at least because not enough organic matter had accumulated to form good source rocks in the first place. Some explorationists with an interest in the North American Atlantic OCS took this as a discouraging sign because of the two coasts' common origin in the breakup of Pangaea.

Closer to the U.S. shelf, more extensive but similarly discouraging exploration has taken place on the Canadian section of the Atlantic OCS in the Scotian Basin. All of the areas of interest off the Atlantic coast (the Scotian Basin off Nova Scotia, the Georges Bank Basin, the Baltimore Canyon Trough, and the Southeast Georgia Embayment) are areas of particularly thick sedimentary rock that formed because the earth's crust beneath them sank more than the surrounding crust. One thing that makes each basin unique is the way that the layers of sediment, which are initially laid down in more or less horizontal beds, have been altered or distorted. These altered rock strata, when porous enough, can provide a place to accumulate the oil and gas generated from the buried organic matter. Such reservoirs are another prerequisite for the creation of oil or gas fields.

In the Scotian Basin, the most interesting potential reservoirs were salt domes. There, salt was deposited by the evaporation of seawater when the early Atlantic was only a narrow chain of isolated basins. The salt then rose up in many long fingers through more recently deposited sedimentary rocks. Above and around these fingers, the rock strata were lifted up so that oil and gas might accumulate in the resulting pockets. Particularly impermeable rock strata must overlie these reservoirs in order to trap oil or gas within them. Trapping structures are a third prerequisite for the formation of a producible field. The numerous salt domes and other potential trapping structures of the Scotian Basin attracted so much attention because they strongly reminded exploration geologists of the highly productive Gulf Coast.

When these interesting structural features became evident during geophysical

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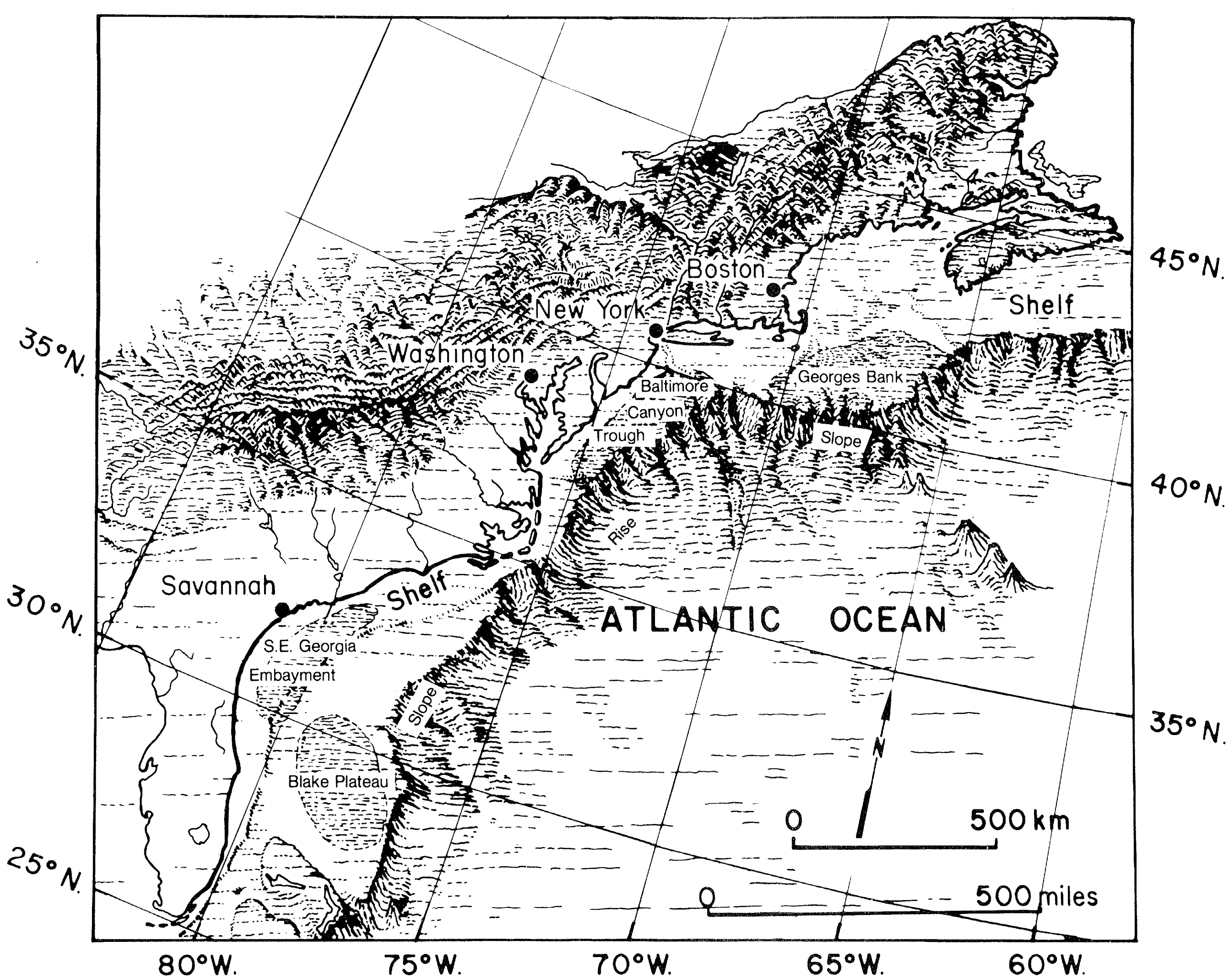
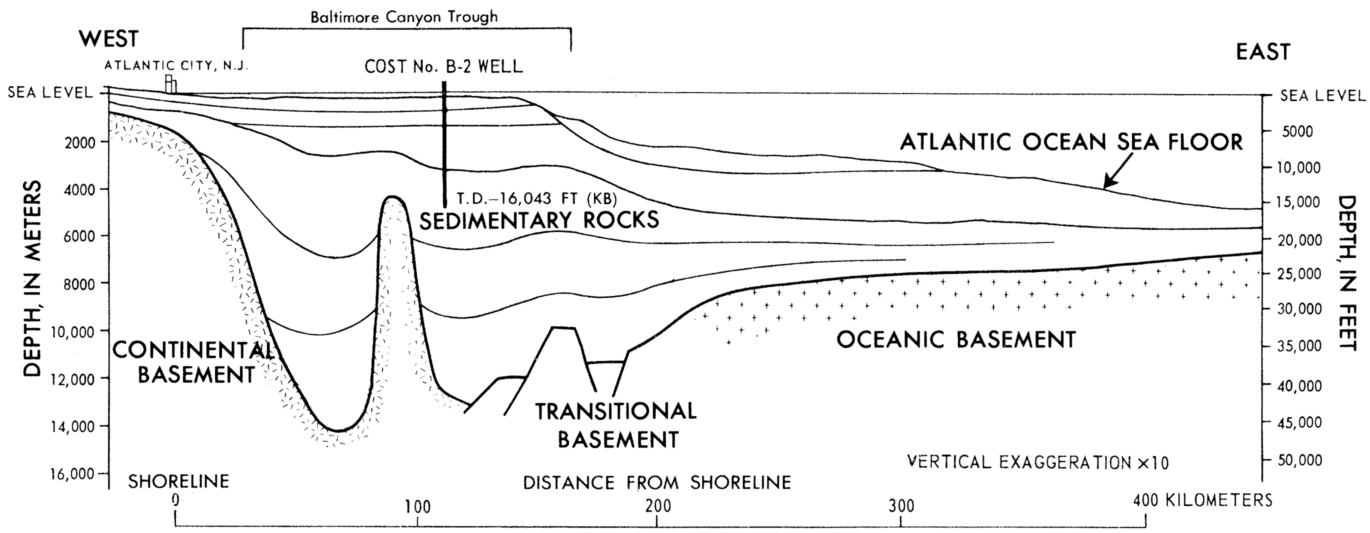
surveys of the area, before any deep drilling had been done, optimism prevailed. In 1969, the Canadian Petroleum Association estimated that 29 billion barrels of recoverable oil might be found on the whole Canadian Atlantic shelf. By 1973, 40 wells had been drilled in the Scotian Basin, some of which had traces of oil or gas or were even actual finds. But no economically producble fields had yet been found. Still, the Geological Survey of Canada estimated that there was about a 40 percent chance of finding 3.7 billion barrels of oil and 28 trillion cubic feet of gas in the Scotian Basin (6000 cubic feet of gas is equivalent in energy content to 1 barrel of oil). By 1976, the figures had been reduced to 2.1 billion barrels and 14 trillion cubic feet for the entire southern Canadian shelf, including the Scotian Basin, the Grand Banks, and the Gulf of Saint Lawrence. As of the moment, 2 to 3 trillion cubic feet of gas have been found around the Scotian Basin, but this is still not enough for production to be economical. The last well in the current round of drilling made another gas find, so more wells will be drilled to determine whether natural gas will ever be recovered from the Scotian Basin. No one expects any oil to be produced there. The Grand Banks shelf area to the northeast is proving to be more disappointing with only a single well showing a trace of oil.

Although the science of oil and gas exploration is far from clear-cut, many oil explorationists agree that, despite encouraging predrilling data and the presence of some oil and gas, the Scotian Basin probably lacks several essential ingredients. First, predrilling surveys may have revealed many interesting potential trapping structures, but they do not hold oil or gas very well. Drilling encountered a large amount of sandstone, which is porous enough to store petroleum, but too little shale, which is needed to seal it in. In addition, those structures that do have a good sealing rock are often breached by faults so that only part of a large structure retains any oil or gas and the remainder is dry.

Another missing component in addition to intact trapping structures appears to have been sufficient heat over geologic time to convert the buried organic matter into large amounts of oil and gas. Petroleum generation is a chemical reaction. The higher the temperature, the faster the reaction. The temperature of the Scotian Basin and the entire Atlantic OCS may have been relatively low. Charlotte Keen of the Geological Survey of Canada in Dartmouth has calculated the continental margin's rate of cooling since the breakup of Pangaea and compared it with the measured cumulative effect of temperature on organic matter



A highly simplified sketch of the Atlantic continental margin and its sedimentary basins that are being explored for oil and gas. Differences in elevation have been exaggerated by a factor of 20 in order to emphasize the structure of the ocean bottom. The slope is the relatively steep drop that marks the edge of the shelf, and the rise is the gently sloping fan that grades into the flat abyssal plain. The Scotian Basin is just off the edge of the map near 45°N. The Blake Plateau Basin, another petroleum prospect, is technically on the continental slope because it lies largely below a depth of 600 meters. The area being drilled in the Baltimore Canyon is about 100 kilometers offshore of Atlantic City, New Jersey. [*Source: U.S. Department of the Interior, Geological Survey*]



Generalized cross section of the U.S. Atlantic continental shelf, slope, and rise. The vertical scale is exaggerated by a factor of 10 in order to emphasize differences in elevation. Transitional basement, unlike the more homogeneous crusts of the continent and ocean, is thought to consist of a mixture of continental fragments, rocks formed from mantle magma, and sediments. [*Source: U.S. Department of the Interior, Geological Survey*]

recovered from drill holes in the Scotian Basin. She found that the continental shelf, like much of the ocean crust, cools simply by conduction to the overlying water. This cooling was apparently too rapid to keep the temperature of the organic matter drilled so far in the range necessary for the generation of oil (about 65° to 120°C). Some researchers believe that natural gas may be produced below this temperature range. In fact, most of the finds were gas. Another factor favoring the formation of gas was the predominance of terrestrial organic matter, which usually produces gas, over marine organic matter, which usually generates oil.

A tendency toward the generation of gas rather than oil is not an encouraging sign on the OCS, where exploration and production costs are already high. The production of offshore gas requires an expensive pipeline, whereas oil can be loaded directly into moored tankers. Thus, on the OCS larger finds of gas are required for economic exploitation than elsewhere. And, as one researcher points out, natural gas does not fuel cars.

As drilling proceeded on the Canadian OCS, American exploration geologists were faced with the problem of assessing the unknown resources off their own coast before drilling began. As in the Canadian experience, the initial mood was generally optimistic. In the early 1970's, casual talk of oil potential in some circles ranged as high as 30 to 40 billion barrels of oil for the entire coast. In 1974, Vincent McKelvey, the director of the USGS at the time, released the first official estimates. He said that a tentative estimate of the potential of the U.S. Atlantic shelf was between 10 and 20 billion barrels of oil and 55 and 110 trillion cubic feet of gas.

Estimates have been decreasing ever since. The Mobil Oil Company's 1974 assessment was only 6 billion barrels of oil and 31 trillion cubic feet of gas. Only a year later, the USGS lowered its own figures to 2 to 4 billion barrels and 5 to 14 trillion cubic feet. (The lower figure in the range has a probability of 75 percent and the higher one 25 percent.)

As must be done in any predrilling evaluation, these estimations were made by comparing geologic characteristics of the Atlantic OCS, as determined with indirect, geophysical techniques, with those of known oil and gas fields. Such comparisons can vary considerably from worker to worker. To some, the West African and especially the Canadian drilling had been disappointing. In addition, no traces of oil or gas had been found in wells on the land flanking the Atlantic basins and no rocks containing suitable organic matter had been found in a deep well on the coast. More optimistic observers could reason that toward the edge of the shelf the sediments are much thicker, which would give higher temperatures. Drilling farther offshore would also increase the chance of encountering marine rather than terrestrial source rocks. And the potential traps, although less numerous, appeared to offer better prospects for finding intact sealed reservoirs.

The results obtained from the first deep well on the U.S. Atlantic OCS in 1976 tended to support the pessimistic viewpoint. A consortium of 31 oil companies drilled the 3400-meter Continental Offshore Stratigraphic Test well (COST B-2) in the Baltimore Canyon Trough about 50 kilometers short of the shelf edge in order to further evaluate the area before the federal government put any tracts up for bidding. Geochemical analyses indicated that, like the Scotian Basin, low temperatures had prevailed and terrestrial organic matter predominated, according to George Claypool of the USGS in Denver. Most of the organic matter in the lower part of the well, where petroleum generation would be most likely, was terrestrial and was apparently deposited when much of the shelf was exposed by low sea levels. It had not yet reached the point at which oil would be generated (that is, it is immature), but gas may have been generated, according to Claypool.

Another interpretation of the COST B-2 results, widespread in the oil industry, is that temperatures had been adequate and the blame can be placed solely on the poor quality of the organic matter; that is, its potential for generating gas and especially oil had been destroyed before it was completely buried.

One researcher took a poll of 17 of his fellow oil industry geochemists after the COST B-2 drilling and found that they were quite negative about the area or were only marginally interested. None was in any way optimistic.

In spite of these discouraging interpretations of the COST B-2 well results, oil companies paid $1.1 billion for the privilege of drilling on 101 tracts near the B-2 well. Company managers apparently bid more on the basis of how large the possible trapping structures were rather than on the basis of the odds figured by the geochemists. Among the interesting structures was the Great Stone Dome, a 40-kilometer bulge in the rock strata formed by an upward intrusion of magma about 100 million years ago. A large, saddle-shaped structure nearby also attracted a lot of attention. The thinking seemed to be that, if, contrary to the best evaluations possible, large amounts of oil and gas had been generated and trapped in these structures, then large profits might be made. Such large potential traps, it is said, must be drilled even if geochemical data are discouraging. Another factor in the bidding was the federal government. It tells the oil companies when and where they can acquire offshore federal acreage on which to drill in search of new fields. The Baltimore Canyon Trough was the frontier area selected at the time.

The $1.1 billion may have been paid for naught. Thirteen of 15 wells have been dry. The Great Stone Dome appears to be dry. The higher end of the saddle-shaped structure also appears to be dry. And the two finds, gas wells on the lower end of the saddle, have not been proved to be large enough (perhaps 1/2 to 1 trillion cubic feet) to justify commercial development. The first well drilled after the initial find, about 2.4 kilometers away, was dry. Some petroleum geologists speculate that, as was often the case in the Scotian Basin, a small fault between the two wells breached part of the trap. The second well drilled to determine the field's size was located about 3.4 kilometers from the first discovery. Gas flowed from the first layer tested, but that layer is relatively thin. Testing is continuing in other layers.

Thus, the geochemists who argued that some of the essential ingredients needed for the creation of large oil fields are absent seem to have been vindicated. The Baltimore Canyon area appears to be prone to the generation of natural gas rather than oil. Some measure of industry's discouragement over early drilling results was the meager $41 million bid on 41 additional tracts in the second sale in the area. Five oil companies have given up exploration in the Baltimore Canyon area for the time being, leaving only three to continue the drilling.

Prospects for significant gas finds in the Baltimore Canyon area may be better than those figures indicate, but actual drilling in the areas of interest will have to wait. Both Canadian and American explorationists reason that, farther offshore, the buried organic matter is more likely to be marine rather than terrestrial, greater temperatures may prevail, and more shale may be available for sealing traps. There is indeed evidence of gas generation farther offshore than the two finds. In 1976, Robert Miller and David Schultz of the USGS in Reston, Virginia, detected what now must be regarded as natural gas in a 291-meter core drilled just landward of the shelf edge southeast of the COST B-2 well. In addition, COST B-3, drilled last January in over 800 meters of water beyond the shelf edge south of B-2, encountered a trace of natural gas. The deeper waters just beyond the edge of the shelf are of particular interest to the oil companies, but the Department of the Interior withheld tracts in the area from bidding for the time being because of possible geological drilling hazards such as slumps, slides, and shallow recent faulting.

Although there have been hopes that finds in the deeper waters of the Atlantic OCS might include significant amounts of oil, a recently announced evaluation of Deep Sea Drilling Project core analyses by Bernard Tissot of Français Petrole in Paris and Gerard Demaison of Chevron Overseas Petroleum in San Francisco suggests that potential source rocks beyond the shelf edge on the continental slope may also be more likely to produce gas than oil. Tissot and Demaison conclude that marine organic matter may have been deposited during the mid-Cretaceous period (about 100 million years ago), but the organic rich black shales of that age recovered from the western North Atlantic contain largely terrestrial material. Oxygenated bottom waters apparently allowed the destruction of the marine material while the more resistant terrestrial organic matter survived long enough to be buried. This evaluation, Demaison says, extends to the entire eastern seaboard.

Prospects of finding large amounts of oil or gas in the remaining Atlantic OCS are considered to be no better if not worse than in the Baltimore Canyon area. The COST GE-1 well, drilled in 1977 in the Southeast Georgia Embayment, penetrated hundreds of meters of rock rich in marine organic matter, but it was overlain by too little rock to be hot enough. The USGS had rated the Southeast Georgia Embayment fifteenth in oil and gas potential of the 22 U.S. OCS areas (the Baltimore Canyon Trough was rated fourth). Although details of results from the two COST wells on Georges Bank (rated eighth) have not been made public, informed sources say that the situation there is no better and perhaps worse than in the Baltimore Canyon.

The Atlantic OCS is not a large part of the U.S. undiscovered oil and gas resources. The total potential resources of the Atlantic OCS as estimated before drilling by the USGS amounted to only about 12 percent of the total estimated undiscovered resources offshore of the United States. This latter amount is only about 40 percent of the onshore potential.

But the Atlantic is not the only frontier area that has been disappointing lately. Exploration has not been exhaustive in other frontier OCS areas now being drilled, but the results so far have not been encouraging, according to Charles Masters of the USGS in Reston. These areas include southern California (rated tenth), the eastern Gulf of Alaska (rated seventh), and the eastern Gulf of Mexico (rated eleventh). Problems encountered included poor reservoir rock (not porous enough) and poor source rocks.

Even new discoveries in the OCS area considered to have the highest potential of all, the central and western Gulf of Mexico, are proving to be somewhat disappointing. According to statistics reported by *Oil and Gas Journal*, the oil industry drilled 181 exploratory wells offshore of Texas during the 15 months prior to April 1979, but 170 were dry. Ten were gas finds, and only one was an oil find. Such drilling experience, attributed in part to a scarcity of good reservoir rock, is expected to lead to a downward revision of estimated undiscovered oil and gas in the area.

The major frontier OCS areas that remain to be drilled are in the Chukchi Sea (rated second) and the Beaufort Sea (rated third). These areas also are subject to the same uncertainties of assessing unknown resources with limited data that researchers encountered in the Atlantic OCS.

Most of the new reserves added each year come from discoveries that enlarge known fields, not from discoveries in frontier areas. But, overall, Masters estimates that the rate of discovery of new reserves of oil from all kinds of domestic sources must be increased 50 percent if the United States is to avoid becoming more dependent on foreign sources. The best guesses of a few years ago on how much the Atlantic OCS might help out toward the goal of greater energy independence for the United States seem to have been too optimistic. Only future drilling will tell how good the geologists' other guesses have been.

—RICHARD A. KERR

Additional Readings

1. B. M. Miller *et al.*, *Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States* (U.S. Geological Survey Circular 725; available at no charge from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA. 22202).
2. P. A. Scholle, Ed., *Geological Studies on the COST B-2 Well, U.S. Mid-Atlantic Outer Continental Staff Area* (U.S. Geological Survey Circular 750; available at no cost from the above address).