Feature Article

Hydrocarbon Evaluation of Multinational Sedimentary Basins in the Red Sea and Gulf of Aden: Research Center to Continue Regional Cooperation

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Abstract

Successful exploration for oil and gas in the frontier basins of the developing world is mutually beneficial for the oil industry and the economies of the countries involved. This type of exploration, however, has proved difficult when the basin to be explored underlies two or more countries. To determine more exactly what these difficulties are, the World Bank undertook a market survey of the international petroleum industry. The survey results indicate that in order to be successful, promotional efforts (scientific advertising) should include the entire frontier basin, rather than one geographic part of it. As a result, the World Bank chose the Red Sea/Gulf of Aden Basin as a prototype of regional basin promotion for reasons of both geology and economic development.

Detailed interviews were subsequently undertaken with the eight (now seven) governments involved, as well as members of the oil industry who were most likely to be interested in exploration within this basin. A detailed work plan was developed, with funding from several donor agencies. Specialized analytical investigations were conducted in the areas of source-rock geochemistry, paleontology, sedimentology, and heat-flow studies.

Data were provided by the seven governments rather than the companies that originally acquired the data, as a means of avoiding confidentiality problems. The presence of the World Bank as an intermediary between the governments and the oil companies provided the required clarity and transparency of process. At the completion of the project, the participating governments were sufficiently pleased with the results that they requested preserving the process through conversion of the project's Cairo Work Station into a regional research center.

The project database and results remain in Cairo, in the care of the Egyptian government, which has agreed to provide the physical facilities for the research center. An American public organization and a private one are interested in continuing the work and providing the required personnel, equipment, and internal facilities; however, the funding issues have not been resolved.

Introduction

The World Bank (hereafter, the Bank) has been directly involved in the hydrocarbon assessment of frontier basins of the developing world for more than 16 years. The primary purpose of this involvement is to improve the economic development of these countries through increasing the rate at which their hydrocarbon endowment is utilized.

The discovery and production of a developing country's oil and gas potential requires the expenditure of enormous sums of money over a sustained period of time. Engagement of a high degree of technical expertise that is not commonly available to these countries is also required. Moreover, the provision of these exploration efforts is clearly beyond the capabilities and mandate of any economic development institution. The international oil industry—which contains these attributes in abundance—must therefore be engaged in these development efforts. In order to be effective in creating this engagement, the outputs of the Bank's assessment efforts must closely match the data interpretation requirements of the oil industry.

An early retrospective study of the initial promotional projects undertaken by the Bank demonstrates that although they were successful in an institutional sense, these projects left much room for improvement when viewed on a cost/benefit basis (Figure 1). In order to increase the effectiveness of its promotional efforts, the Bank conducted a large-scale market survey of the petroleum industry, from which two points became clear:

1. Most of the developing countries contain portions of several potentially petroliferous sedimentary basins rather than the entirety of one basin. This is particularly true in Africa, where most of the Bank's promotional efforts were concentrated.
2. Oil companies explore sedimentary basins rather than countries; they are driven more by geology than by geography.

Project Objectives

The Red Sea and Gulf of Aden Regional Hydrocarbon Assessment Study grew out of the Bank's market survey. This project was developed in 1986 in response to the collapse of oil prices that year, which had a severe negative impact on the foreign exchange reserves of the nonproducing developing countries. The survey results strongly suggest that a multinational basin exploration promotion would be a more effective vehicle for the engagement of the international oil industry than a similar series of country-specific promotions involving the same basin. If this engagement were successful, it would most likely be an effective vehicle for the advancement of the economic objectives of the countries involved.

The Red Sea and Gulf of Aden were chosen as the prototype for this redirected promotional effort. This basin is shared by seven (originally eight, before the reunification of Yemen) developing countries. This choice was based on four important elements:

1. The basin has a unified tectonic origin that is clearly defined throughout its length as a result of its formation through the rifting and ultimate separation of the Arabian plate from Africa.
2. The northwest extension, into the Gulf of Suez, has been intensively explored with prolific results during the past 30 years, and is an effective model for exploration of the main portion of the basin.
3. The common occurrence of oil seeps, shows, subeconomic discoveries, and gas blowouts in the basin suggests that exploration techniques developed in the Gulf of Suez would be equally productive here.
4. Four of the countries that share the basin had already gone through country-specific exploration promotion efforts, with varying degrees of success.

The primary objective of the regional project was to involve the petroleum industry in the exploration effort; the secondary objective was to prepare the petroleum sector of the participating governments to deal more effectively with the expected increase in exploration interest.

Thirty-four oil companies and consulting institutions were interviewed in depth as the project's first step. The purpose of the interviews was to ensure that the project design was relevant to the industry's requirements; in past promotions, the Bank had done too much of some things and not enough of others. The Bank selected companies that had

previously explored the basin or had the technical and financial resources to do so. The consulting companies interviewed had previously served as governmental advisors, which provided them insight into exploration issues not common to the general petroleum industry.

Perceptions. A broad consensus emerged from the interviews that the concept of a multinational basin study was of strong exploration interest. Within this consensus, however, were four major areas of concern common to nearly all the companies interviewed:

1. Data availability: Within the basin were eight independent and scattered data sets. These were typically poorly archived; hard to locate, access, and study; and generally difficult to reproduce. The reduction of eight data sets to a common data set would involve considerable work before a basin-wide evaluation could be undertaken.

2. Technical and economic risk assessment: The basin was commonly perceived to be geothermally hot and gas prone. There was little economic interest in further exploration for gas, which had no apparent commercial value because of the lack of a market.

3. Political risk assessment: The governments within the basinal area hold a wide diversity of political views. Their resulting differing reactions to industrial inquiries regarding petroleum exploration and related matters had proven difficult for companies.

4. Corporate reorganization: Most companies had undergone a high turnover rate of experienced exploration personnel following the 1986 fall in oil prices. Many knowledgeable technical staff had been made redundant or given early retirement. Other companies had disappeared through merger or purchase by larger companies. The result was an overwhelming loss of effective corporate memory. This memory loss was compounded by the removal of files for areas not under active exploration to cheaper offsite data-storage repositories. The existence of these "dead files" in many cases was unknown to the remaining exploration staff.

The overall effect was an extraordinary industry-wide diminution in access to its frontier exploration database and senior knowledgeable staff. The predictable result was a severe reduction of corporate exploration efforts in areas that were not under current study (e.g., the frontier basins of the world). The companies were generally left without means to compensate for this double loss. As a result of the industry's few remaining available resources, it was unlikely that there would be any serious efforts in the midterm to broaden exploration into the frontier basins.

Project Strategy

In response to these findings, the Bank developed a tripartite project strategy involving the collection, integration, and common archiving of a basin-wide data set. Work was focused on technical analyses of the data and evaluation in areas indicated by the industrial interviews as of particular interest.

With respect to the nature and maturation of basin source-rock geochemistry, the Institut FranVais du Pétrole oversaw the source-rock geochemical work by its industrial subsidiary (BEICIP) utilizing the Rock-Eval technique. This approach focused on the nature of the source rock, its richness, and its degree of maturation.

To maintain internal consistency of data interpretation across the major facies changes along the length of the basin, Robertson Research (now Simon Petroleum Technology) studied the biozonation and chronostratigraphy of the basin. This provided a time/rock stratigraphic framework within which the geochemical results could be placed in a consistent and geologically meaningful fashion. This framework was augmented by a series of sedimentological studies designed to determine the facies relationships between the source and reservoir rocks and heat-flow and maturation studies. The seismic, geochemical, and sedimentological results were integrated into an overall basin subsidence model.

A tectonic framework was concurrently established by the University of Hamburg Institute of Geophysics to serve as a backdrop for viewing the complex sedimentary response study. This framework comprises academically derived crustal refraction and deep-reflection surveys, magnetic and gravity data,

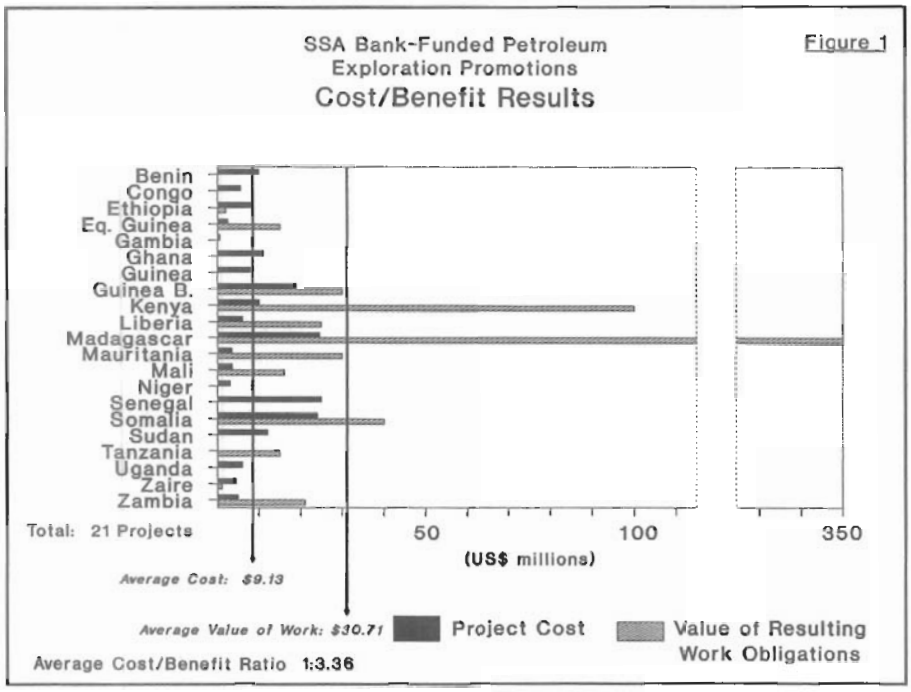

Figure 1.

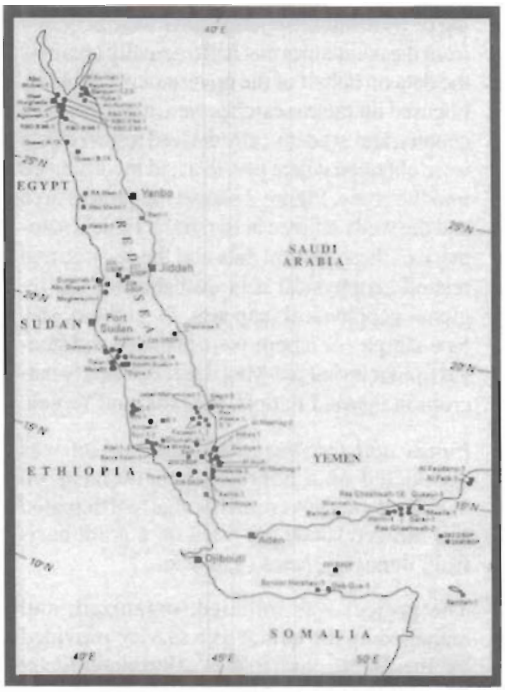

Figure 2. Geography of the Red Sea area, and well locations.

and their interpreted results merged with the project's industry data and the analytical results from the five Deep Sea Drilling Project core holes along the basin axis.

Project Inputs

Data Sources and Data Set. The industry data were provided by each of the seven governments from its public domain files. This was the single most important organizational function of the project because it involved the countries' technical personnel directly in the process of conducting the project. It allowed the required transparency of process to be clearly seen by both the governments and the oil companies. This freed the project from the issues inherent with industrial confidentiality requirements. Without the organization and supervision of the neutral supranational agency of the Bank, it is unlikely that the governments would have agreed to an across-the-board release of their national databases. Only data from relinquished areas within the project were utilized. Table 1 lists the governmental agencies that served as data sources.

The governments retained the rights to their data, including the newly obtained analytical results, but not to the conclusions derived from the results. Technical task forces formed from each of the governmental agencies accompanied their data sets in a sequential fashion to the central work station, which was established in Cairo. There, the basic data were integrated and the study results fitted into a consolidated map set, which was put into a report format and provided to each respective government.

Where governmental data sources were missing or were unusable, duplicates were acquired from the companies that had originally obtained the data on behalf of the government (Table 1). Focused literature searches were made for each country, and academically derived research data were obtained where possible and incorporated into the study. Figure 2 shows the project area and the wells utilized in the study. Table 2 summarizes these control data and the seismic and related geophysical data available for the regional geophysical map sets. In addition, surface samples or reports were obtained and studied from relevant pre-Miocene sedimentary outcrops in Egypt, Ethiopia, Somalia, and Yemen.

Funds and Organization. The project was conducted on a nonreimbursable basis on behalf of the governments that participated and utilized funds provided on a grant basis from donor agencies (Table 3).

The project was initiated, organized, and managed by the author as a service provided by the Bank, and it was administered by Project Technical Manager Dr. A. Hakim Sikander at the Cairo Work Station. Dr. Ziad R. Beydoun of the American University of Beirut served as Project Scientific Director to ensure scientific integrity and coherence. Specialized consultant and exploration staff from British Petroleum provided external supervision and industrial quality control as well as specialized support services; British Gas provided technical support.

The Cairo Work Station was provided through the auspices of the Egyptian government as official host and was housed in the Egyptian Geological and Mining Authority building under the direction of the Project Technical Manager, assisted by a geophysical and a geological supervisor, technical consultants, and technical and administrative support staff.

Project Outputs

Country-specific Outputs. Each government received a proprietary report on the petroleum geology and geophysical evaluation of its portion of the basin as an output of its national task force's stay at the Cairo Work Station. The report was inventoried onto a PC-compatible diskette, and an instruction manual was provided with each national diskette package. The task forces were trained in using and subsequently updating the reports. A regional bibliography was compiled and provided to each task force, whose members were also trained in the interpretation and integration of their data set into the regional database in a manner relevant to the needs of the petroleum industry. BEICIP and Robertson Research (Simon Petroleum Technology) also provided full reports, including analytical results of all work that they had conducted on samples provided to the project.

Regional Report Outputs. As part of the country-specific report submitted to each government, a section describing the regional geological and geophysical setting of the entire basin was included. This served as a common backdrop against which each country may view its own geologic setting and petroleum potential in context.

The Cairo Work Station provided a basin-wide structural evolution study on four common map horizons and the intervening three isopach intervals and a regional study of the tectonic evolution, sedimentary response, and habitat of petroleum for the basin. Robertson Research provided a study of the paleoenvironment, diagenesis, thermal maturation, and petroleum potential of the entire basin in a time-slice format; a regional paleoenvironmental and stratigraphic overview; integration of the sedimentary sequence; and a proposal for a regional nomenclature system for the basin.

All reports produced by the project are in a technical format common to major oil company exploration departments. The project's objective is that industry will use this product directly, rather than as an input to in-house studies. These reports and the data from which they were drawn are the property of each of the participating governments. Each government has its own policy regarding viewing, study, and possible purchase by interested parties. Inquiries may be made to the relevant governmental agencies listed in Table 1 regarding terms and conditions for access and/or purchase.

Public Dissemination of the Results. The mechanism of peer-reviewed publication was selected to achieve the objective of widespread dissemination of the project conclusions to the exploration management of the international petroleum industry. Oral and poster presentations have also been made at selected scientific congresses and other petroleum-related conferences in North America, Europe, Africa, and the Middle East.

Results to Date

The results of the project represent a significant advance in knowledge regarding the tectonic development, sedimentary response, and petroleum potential of the Red Sea and Gulf of Aden basin. A major accomplishment has been to accumulate the existing data in one place, normalized to a common standard and fitted together into an overall view of the basin and its origins. On this foundation much productive future industrial and scientific work still remains to be done.

The project conclusively demonstrates that, when shielded from outside political considerations, close, meaningful technical cooperation between neighboring nations can be effectively developed. Friendships, a sense of shared purpose, mutual respect, and cooperation have developed among the ministerial representatives who attended the project's five management meetings.

A strong consensus has developed among the participating governments that the benefits obtained from the project should not be lost through dismemberment of the project infrastructure and integrated data set. The governmental representatives have recognized that, as an integrated whole, the value of the data set is significantly greater than the sum of its component parts; a resource of great practical value to the region has been created. Consequently, these governments have decided to retain the Cairo Work Station and see it converted into a permanent regional research center.

The research center would continue to be used by the participating governments as well as by the petroleum industry and scientific community as a base for continued work. It has been recognized that the truly meaningful regional work has barely started. A regional center would also serve as an industrial training center, a place where regional petroleum

Table 1. Participating government agencies and industrial data sources

	Government Agencies	Industrial Sources
Egypt	Egyptian General Petroleum Corporation (EGPC)	AGIP
Sudan	Geological Research Authority of Sudan (GRAS)	Amoco/IPL
Ethiopia	Petroleum Exploration Promotion Project; Ministry of Minerals & Energy	British Gas
Djibouti	Ministry of Industrial Development	British Petroleum
Somalia	Directorate of Hydrocarbons, Ministry of Minerals and Water Resources	Geco
Republic of Yemen	Yemen Oil and Mineral Resources Corporation (YOMINCO); Ministry of Oil and Mineral Resources	Geodata Index International
Kingdom of Saudi Arabia	Ministry of Minerals & Petroleum (Dhahran)	Harms and Brady
		Institute of Geophysics (University of Hamburg)
		Mobil
		Royal Dutch Shell
		Sun
		Western Geophysical

Table 2. Control data

Biostratigraphy and Source-rock Geochemistry

		Wells analyzed/reviewed	
	Total wells available	Biostratigraphic control	Geochemical control
Egypt	13	11	10
Sudan	12	11	11
Ethiopia	8	8	5
Yemen (Red Sea)	10	8	8
Saudi Arabia	10	4	2
Yemen (Gulf of Aden)	11	7	7
Somalia (Gulf of Aden)	2	2	2
Deep Sea Drilling Project	5	5	0
Total	71	56	45

Seismic Data (km)

	Shot	Utilized
Egypt	21,518	4,350
Sudan	27,790	4,965
Ethiopia	29,626	6,603
Djibouti	123	123
Somalia	7,369	4,510
Yemen	23,773	9,651
Total	110,199	30,202 (27.4%)

Table 3. Project funds sources

United Nations Development Programs	Bureau of Arab States
Canada	Petro-Canada International Assistance Corporation
United Kingdom	Overseas Development Administration
France	Ministry of Foreign Affairs, Directorate of Development and Scientific, Technical Cooperation and Education

conferences may be held and where ministries could meet informally to discuss issues of importance and mutual interest. National technical staff would have access to their neighbors' data to reduce issues of uncertainty in discussions. Oil companies and universities with appropriate authorization would be able to access and study these data in a workshop environment. The government of Egypt has agreed to continue providing work space for the research center and, until such time as it comes into being, is serving as curator of the data sets and report archives.

Prior to the completion of the project in January 1992, the University of Oklahoma entered into bilateral agreements with four of the governments to continue the scientific work through an ongoing master's program for national graduate students, who will utilize their respective data sets as the basis for their theses and dissertations. The University's Red Sea–Gulf of Aden Basin Analysis/Seismic Stratigraphy project began by bringing a replica of the Cairo Work Station data set to the United States for further research work. The University has continued the data search, and as a result, the database has been augmented with tapes for several thousand kilometers of seismic lines and more than 50 digital well logs. Both of these digital data sets have undergone extensive modern reprocessing and reinterpretation. This work, funded by the petroleum industry, continues much of the project's work in technology transfer for the participating governments. It has also proven useful to companies interested in the results of the continuing exploration-focused research efforts.

The University has subsequently entered into protocols with the Egyptian General Petroleum Corporation (EGPC) and the University of Cairo to jointly continue this work in Cairo as part of the regional research center. However, implementation of the protocols awaits adequate funding from outside sources. Once these protocols become implemented, Landmark Graphics Corporation has formally proposed providing the center a Landmark computer work station and a fully qualified technical specialist. The work station would be fully loaded with the Red Sea basinal data set and would be available to researchers and students as well as serving as a commercial demonstration of Landmark's technical capabilities.

Conclusions

The concept of regional governmental cooperation in the furtherance of exploration efforts in a common sedimentary basin has been proven valid. The marked increase in active exploration efforts within the project area since 1987, particularly in the Saudi sector, suggests that in time a number of new discoveries will occur. On a cost/benefit basis, this has proven much more effective than individual country-specific promotional programs (Figure 3).

In the interim, technical staff from ministries within the region have been trained in the access, use, and interpretation of the individual data sets. The basic data sets have been reanalyzed to a common state-of-the-art standard, and the results have been made available to each government in an industrial format for future use. These sets have been computer indexed into a common basin-wide system, and a working data set has been centrally archived in Cairo. The periodic project management meetings convened to review progress have resulted in the development of effective informal regional communication among the petroleum sectors of the participating governments.

The project, which began as an aid to economic development of the region, has thus moved well beyond its original objectives and beyond the capacity of the donor community to fund it. Future developments will depend entirely on the collective intellectual and financial efforts of the petroleum industry, the international scientific community, and the participating governments. ■

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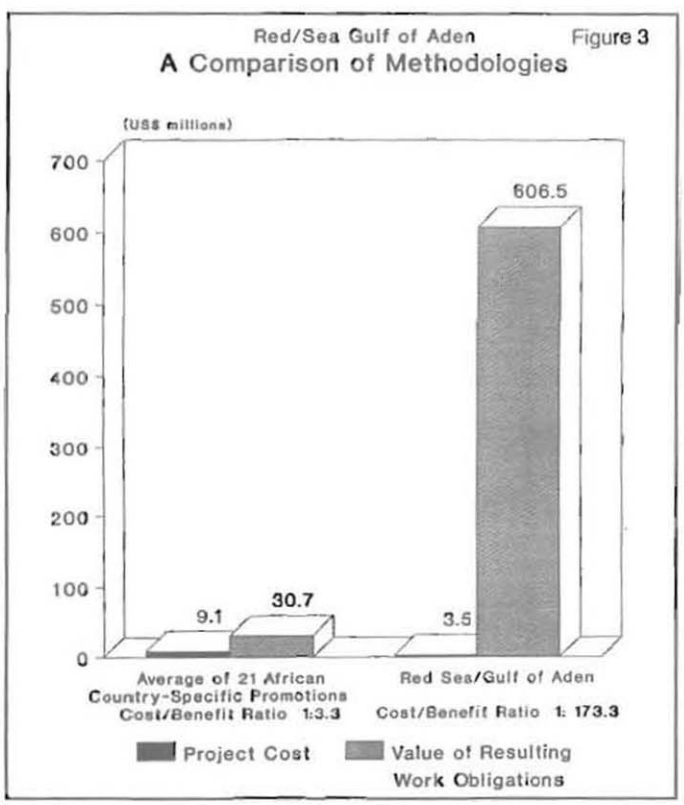

Figure 3.