

CENTRAL ATLANTIC OIL STUDY

**PETROLEUM GEOCHEMISTRY
OF CRUDE OILS FROM CENTRAL
ATLANTIC BASINS**

GEOMARK

A PROPOSAL

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INTRODUCTION

The Central Atlantic (Northeast Brazil to Canada and Ghana to Morocco) is characterized by an exceptional diversity of source rocks. They reflect the varied tectonic history of this segment of the Atlantic and they contribute to a rich variety of plays and play opportunities. Ages range from the Ordovician to the younger Tertiary. Source settings include anoxic deep marine, deltas, lakes and sabkha environments. The Cretaceous marine sources tend to be regional in their development, especially in Africa and South America. The resulting oils carry distinctive biomarker signatures that can be readily used to portray the setting, maturity and increasingly the age of the source horizon. Plays and play opportunities primarily involve deepwater sand fans, carbonate banks and shallow marine to deltaic sands.

To assist in exploration efforts in the Central Atlantic GeoMark Research has conducted an oil study of the region. The objective of this study was to explain and detail, within a plate tectonic and Petroleum Systems framework, the diversity of source rocks and to present a coherent picture of the resulting plays and their areal extent. The focus is on the deepwater where the greatest range of source rocks and basin floor sands are present. These areas, since they host the thickest wedges of sediment, also provide the best settings for the maturation of the Atlantic margin source units. Though there are few deepwater wells, there are a number of DSDP coreholes, many of which penetrated oil-prone source rocks. Reservoirs were also encountered. The Amazon Cone is the most obvious example of the region's deepwater potential, but large areas of the Northwest Africa margin are also now known to be prospective. An example is the tight grouping of recently awarded blocks offshore from Agadir in Morocco. Here the objectives are Cretaceous and Tertiary basin floor sands. The traps are salt related. The active source rocks remain to be fully defined. Ghana, the Ivory Coast, Mauritania, Senegal, Surinam and Guyana are also the sites of recent acreage awards. Most of these awards are associated with deepwater objectives.

Much of the Central Atlantic region is underexplored and large areas remain to be adequately examined. An example is the Maranhão to Pará region of offshore Brazil. This area extends over more than 500 kilometers, but there are no active licenses outside the confines of the deepwater Amazon Cone (one block is being offered in the 2nd round). Interestingly, no analogues have been found in Brazil for the increasingly important Albian source and reservoir play of the Ivory Coast and Ghana conjugate margin.

A second example of under exploration is the east coast of the USA where many structures in the deepwater remain to be tested. Deep targets also remain to be tested. Both limestone and sandstone reservoirs are developed. Because of the apparent paucity

of oil-prone, regionally mature source rocks, particular attention will be given to the maturity and provenance of the oil samples from this region.

The April 1999 discovery of a new gas play at Panuke in offshore Nova Scotia provides an excellent example of the future potential of the Central Atlantic. This twin discovery is especially important as the area was regarded as relatively mature and the Jurassic carbonate bank hosting the play is a regional feature. Regions with a similar geology remain to be adequately tested along both margins of the Atlantic. Dana's first well in western Ghana is a further example of the region's emerging potential. The well, completed in February 2000, is expected to result in Ghana's first commercial field.

Several of the source units are believed to be localized, while the more regional sources, such as the Cenomanian and Turonian, exhibit wide variations in maturity. The proposed study, by systematically detailing the source succession and its maturity based on oil geochemistry, will provide a unique tool for risking this still largely frontier region. The provision of oils from both margins is seen as a particularly effective way, when combined with the palaeogeography, of contributing new understanding.

TECHNICAL PROGRAM

GeoMark has assembled a collection of sixty-nine (69) crude oil samples from basins along both sides of the Atlantic. The samples are shown in Figure 1, and listed in the Appendix at the back of this proposal. Each of these samples was analyzed using the analytical program discussed later in this proposal, and integrated with local geology to assess petroleum potential. Although we did not analyze source rocks for this study, we feel that analysis of available oil samples is the best way to evaluate this region at this time.

Specifically, attempted to determine the following:

- Determine the number of distinct oil families represented along both margins of the Central Atlantic and predict depositional environments of corresponding source rocks.
- Estimate the ages of these various oil families.
- Determine if any oil family correlates across the Atlantic.
- Determine the thermal maturity range of each of the oil families.

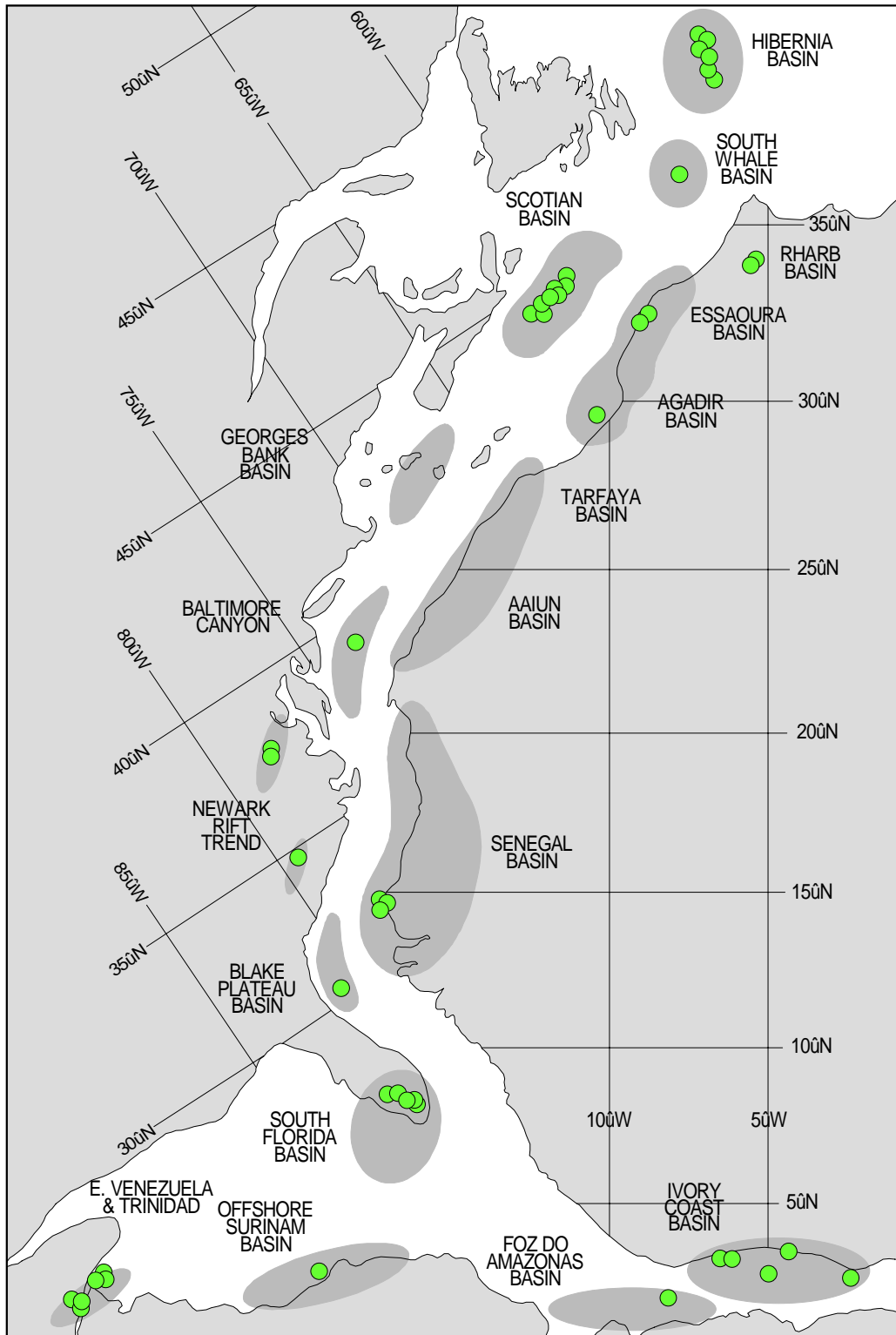


Figure 1. Location of Crude Oil Samples Selected for Analysis.

METHODOLOGY AND EXPLORATION APPLICATIONS

In areas such as the Central Atlantic where minimal exploration has occurred, a regional oil study is an excellent way of identifying, evaluating and comparing the various petroleum systems that exist in the region. A regional oil study approach is particularly useful in regions where little source rock work has been attempted.

The regional petroleum systems within the study area will be evaluated by first determining the number of effective source units within a region by establishing the number of compositionally distinct oil families using multivariate statistical techniques. The source facies of each oil family will then be deduced from the oil geochemistry (e.g., Zumberge, 1987). Conclusions will be reached regarding source lithology, anoxicity, salinity, organic input (marine, non-marine or marginal marine) and thermal maturity using a variety of parameters based on molecular and bulk composition. In many cases it may be possible to bracket the age of the source from the oil data.

The predicted source facies will be compared to the stratigraphy, sedimentology, and burial history of each basin to determine the most probable source units. The aerial extent and burial depth of the source units will then be combined with the geographic and stratigraphic distributions of their associated oil families and degree of mixing to determine the location of the various oil generating depocenters and the most probable migration directions.

The relative potential of the petroleum systems in each basin will be ranked by incorporating geological information on source thickness and sedimentary environment, and source potential of the various source units. The results will be evaluated in an effort to identify areas where particular petroleum systems may exist but have been overlooked or poorly tested.

ANALYTICAL PROGRAM

The following techniques have been performed on each sample and will form the analytical database of this report/project:

- API Gravity
- % Sulfur
- Nickel/Vanadium concentration
- C15+ vs. <C15
- Deasphalting
- Liquid Chromatography (%Sat %Aro %NSO)
- Capillary GC of Whole Crudes
- Stable Carbon Isotopes for both Sat and Aro Hydrocarbon Fractions
- GC/MS of branched/cyclic fraction for Terpane/Sterane Distributions (quantitative)
- GC/MS of Aromatic Hydrocarbon Fraction (qualitative)

PRESENTATION OF RESULTS

Results of the study are presented in both analytical and interpretive formats to insure all findings are accessible to explorationists and research personnel. All of the analytical data are provided in hard copy and on magnetic media.

Analytical data are presented within **Data Volumes**, and include the following:

- physical property data
- liquid chromatographic data
- gas chromatographic results
- stable carbon isotope data
- GC/MS mass chromatograms.

PARTICIPATION

The cost of the study is US \$25,500.

TIMING

The report is completed and available for delivery.

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REFERENCES

ZUMBERGE J.E. (1987) Prediction of source rock characteristics based on terpane Biomarkers in crude oils: A multivariate statistical approach. *Geochim. Cosmochim. Acta*, **51**, 1625-1637.

APPENDIX A

Oil Samples Selected for Analysis

Sample ID	Lat	Long	Country	Basin	Field	Well	API
BS001	13.10	-59.50	Barbados	Northeast Caribbean	Woodbourne	Hopefield	34.0
BS002	13.12	-59.50	Barbados	Northeast Caribbean	Seep	Seep	21.0
BR001	0.81	-46.13	Brazil	Foz do Amazonas	Wildcat DST	1-PAS-9	43.2
IC010	5.08	-3.84	Cote d'Ivoire	Ivory Coast	Belier	Outpost	36.4
IC012	5.03	-4.80	Cote d'Ivoire	Ivory Coast	Lion	A-2	38.0
IC018	5.03	-4.80	Cote d'Ivoire	Ivory Coast	Lion	A3	41.2
IC023	5.01	-4.46	Cote d'Ivoire	Ivory Coast	Espoir	C1-2X; DST1A	28.7
IC040	5.03	-3.71	Cote d'Ivoire	Ivory Coast	IVCO	8; DST4	29.6
DR002	18.68	-71.10	Dominican Republic	Azua	Maleno	1	22.6
CN061	43.81	-60.73	Eastern Canada	Scotian Shelf	Panuke	PP1 I-99	46.3
CN066	43.84	-60.62	Eastern Canada	Scotian Shelf	Cohasset	CP3A P-51	42.5
CN086	43.95	-60.12	Eastern Canada	Scotian Shelf	Sable Island	2-H-58	27.4
CN087	43.95	-60.12	Eastern Canada	Scotian Shelf	Sable Island	2-H-58	35.5
CN098	44.02	-59.67	Eastern Canada	Scotian Shelf	West Venture	C-62	28.8
CN103	44.02	-59.55	Eastern Canada	Scotian Shelf	Venture	H-22	35.6
CN123	46.28	-48.26	Eastern Canada	Jeanne D'Arc	Terra Nova	E-79	35.2
CN124	46.28	-48.29	Eastern Canada	Jeanne D'Arc	Terra Nova	H-99	35.7
CN125	46.32	-48.31	Eastern Canada	Jeanne D'Arc	Hebron	I-13	16.8
CN148	46.45	-48.51	Eastern Canada	Jeanne D'Arc	Hibernia	I-46	33.3
CN149	46.45	-48.51	Eastern Canada	Jeanne D'Arc	Hibernia	I-46	31.9
CN155	46.47	-48.45	Eastern Canada	Jeanne D'Arc	Hibernia	B-08	39.7
CN164	46.51	-48.04	Eastern Canada	Jeanne D'Arc	Whiterose	N-22	28.2
CN179	44.02	-52.25	Eastern Canada	South Whale	Heron	H-73	
GA002	3.77	-59.56	Guyana	Takutu	Karanambo	1 DST7	43.4
GIL001	53.04	-12.56	Ireland	Porcupine	26	28-1; DST1	30.0
MO001	31.29	-9.50	Morocco	Essaoura	Sidi Rhalem		40.5
MO002	28.32	-13.02	Morocco	Agadir	Wildcat	MO-2	
MO003	31.45	-9.45	Morocco	Essaoura	Mescala		57.1
MO004	31.45	-9.45	Morocco	Essaoura	Mescala		57.3
MO005	34.17	-5.85	Morocco	Rharb	Zrar Inferier		31.5
PO001	39.10	-9.19	Portugal	Lusitanian	Abadia	1A	20.4
PO002	39.94	-9.03	Portugal	Lusitanian		14A-1	36.5
PO003	39.08	-9.25	Portugal	Lusitanian	Torres Veedras	4	25.5
PO004	39.10	-9.19	Portugal	Lusitanian	Abadia	#17	21.5
PO005	39.00	-9.19	Portugal	Lusitanian	Sismaria		11.2
PO007	39.00	-9.40	Portugal	Lusitanian	Moriea	1	32.8
AF113	14.75	-17.18	Senegal	Senegal	Diam Niadio	DN-4	35.7
AF114	14.82	-17.22	Senegal	Senegal	Wayambam	WY 1	58.3
AF115	14.75	-17.18	Senegal	Senegal	Diam Niadio	DN-4	40.4
AF116	14.74	-17.23	Senegal	Senegal	Kabor	Kabor-1	40.3
SP005	42.75	-3.89	Spain	Cantabrian Basin	Ayoluengo		37.5
SR001	5.87	-55.01	Suriname	Guyana	Wildcat	L1-3	23.4
TD005	10.36	-61.28	Trinidad	S. Trinidad	Tabaquite	222	26.8
TD007	10.15	-61.58	Trinidad	S. Trinidad	Forest Reserve	1179	16.9
TD010	10.19	-60.65	Trinidad	S. Trinidad	Teak	T3-30	29.1
TD011	10.18	-61.64	Trinidad	S. Trinidad	Gaupo	M-14	17.2
TD012	10.34	-60.68	Trinidad	S. Trinidad	Samaan	A-4X	34.5
TD013	10.35	-61.17	Trinidad	Nariva	Colenso	1	35.7
TD014	10.34	-61.17	Trinidad	Nariva	Colenso	3A	37.8
TD016	10.46	-61.05	Trinidad	Nariva	Cocal	1	33.7
BC001	39.33	-72.46	USA	Baltimore Canyon	Tenneco	642-2	35.8
FL001	26.23	-81.29	USA	Collier	Bear Island	Gulf Coast Realty #2-1	22.5
FL002	26.82	-81.32	USA	S. Florida	Sunniland	GCR #24	20.7
FL003	26.80	-81.30	USA	Collier	Barron Collier	1	19.7
FL004	26.50	-80.70	USA	S. Florida	Pinecrest	State #2	
FL007	27.18	-81.40	USA	S. Florida	Sunoco-Felda	33-2	25.0
GE001	30.61	-80.29	USA	Blake Plateau		GE-1	25.5
VR001	37.31	-77.71	USA	Newark Rift	Chesterfield Co.	Chesapeak E #1	42.5
VR002	37.24	-77.82	USA	Newark Rift	Chesterfield Co.	Turner #1	41.7
VR003	37.35	-77.79	USA	Newark Rift	Chesterfield Co.	Horner #1	
VR005	37.24	-77.82	USA	Newark Rift	Chesterfield Co.	Turner #1	42.4
VA002	9.08	-64.45	Venezuela	Maturin	Chimire	CHV-17T	40.9
VA003	9.08	-64.45	Venezuela	Maturin	Chimire	CHV-4T	29.4
VA014	8.92	-62.96	Venezuela	Maturin	Pilon	1	13.9
VA055	9.90	-63.12	Venezuela	Maturin	Cachipo	NO.2	31.1
VA068	9.88	-63.42	Venezuela	Maturin	Jusepin	NO.110	31.5
VA098	9.92	-63.54	Venezuela	Maturin	Manresa	MR-1	18.0
VA116	9.99	-62.26	Venezuela	Maturin	Pedernales		17.4
VA118	9.97	-63.17	Venezuela	Maturin	Quiriquire	NO. 216	24.4