

**EVALUATION OF THE CRETACEOUS
PETROLEUM SYSTEMS OF NORTHERN
SOUTH AMERICA USING ADVANCED
BIOMARKER TECHNOLOGY**

**REGIONAL PETROLEUM GEOCHEMISTRY
OF CRUDE OILS FROM VENEZUELA, COLOMBIA,
ECUADOR, AND PERU**

GEOMARK
RESEARCH, INC.
HOUSTON, TEXAS

A PROSPECTUS

EXECUTIVE SUMMARY

GEOMARK RESEARCH has conducted a regional evaluation of the Cretaceous petroleum systems of Venezuela, Colombia, Ecuador, and Peru. Specifically, 124 crude oil samples were analyzed using new GC/MS/MS technology in order to evaluate and compare the corresponding source facies developed in the La Luna, Querecual, Villeta, Napo, Chonta, and other Cretaceous source facies. These 124 representative oils were carefully selected from a collection of over 500 crude samples in which routine bulk, biomarker, and carbon isotopic analyses have also been performed by GEOMARK RESEARCH (see location map Figure 1). Based on these results and our ensuing knowledge of the number, diversity, and geographic extent of various 'oil families' representing different Cretaceous systems, the results of the GC/MS/MS analyses are expected to aid in the exploration for, and exploitation of oil and gas in northern South America by providing the following:

- An assessment of the relative 'oil proneness' or generative capacity of the various Cretaceous carbonate, marl, and shale source rocks throughout the region
 - precisely measure the amount of 24-*n*-propylcholestanes (only by GC/MS/MS) and prepare regional maps contouring the relative abundance of these oil prone biomarkers
- An appraisal of the thermal maturity variation within and between different systems
 - an accurate determination of sterane maturity parameters using GC/MS/MS
- A determination of the most important geochemical controls on oil quality (source facies/maturity/migration distance/biodegradation)
 - evaluating the effect of biodegradation on steranes combined with more accurate maturity and facies determinations using GC/MS/MS
- An overall ranking of the oil and gas source potential of the region, especially the under-explored basins

Products include Data Volumes showing mass chromatograms, both hard copy and on magnetic media; a bound interpretive report with geological and geochemical integration; and interpretive full color, wall-sized maps/montages.

The cost of the study is US \$ 35,000.00 and is available immediately.

INTRODUCTION

Cretaceous source rocks have long been thought as being important in northern South America (e.g., Hedberg 1931; Zumberge 1984). From the deposition of the well known La Luna carbonates/marls of the Maracaibo and Middle Magdalena basins and reported chrono-stratigraphic equivalent source rocks of the Villeta (Upper Magdalena) Chonta (Maranon), Napo (Oriente), and Querecual (Eastern Venezuela) formations to less well established Cretaceous sources in the Llanos and Barinas basins, this was a time of prolific productivity and subsequent preservation of marine oil-prone organic matter over an expansive aerial extent. Since nearshore deposits can contain terrestrially-derived organic matter with a lesser capacity for petroleum generation, it is important to determine the quality of a source rock (i.e., 'oil proneness') by measuring the kerogen properties such as atomic H/C ratio, pyrolysis Hydrogen Index, vitrinite content, etc. However, the source rocks are frequently unavailable for analysis because they are either buried too deeply (e.g., US Gulf Coast and Beaufort Sea, McKenzie Delta) or the facies available for sampling may be different from the facies which generated oil. Organo-facies can vary enormously over the aerial extent of the source rock's deposition.

It has recently been shown that biomarker distributions in oils can be used to predict kerogen facies properties of the corresponding source rock (Dahl *et al.*, 1994; McCaffrey *et al.* 1994). Therefore, mapping certain biomarker distributions for oils related to a given petroleum system delineates those parts of a basin which are more oil-prone than others correcting for any lateral migration. Because kerogen properties are important factors in determining the ratio of gas to oil during generation, biomarker distribution maps are helpful in evaluating exploration prospects and economics.

Along with biodegradation and thermal maturity, source rock facies control oil gravities, sulfur content, and gas-oil ratios during generation. A proper assessment of source rock quality from oil analysis requires the use of GC/MS/MS. Parameters such as the relative abundance of 24-*n*-propylcholestanes and the ratio of 4- to 3- methylstigmastanes, which have been shown to be related to % oil-prone kerogen, Hydrogen Index, and H/C ratio, can only be measured effectively by GC/MS/MS methods. Analysis of steranes by GC/MS/MS provides, at the same time, improved accuracy in measurement of maturity [e.g., 20S/(20S+20R) and $\alpha\beta\beta/(\alpha\beta\beta+\alpha\alpha\alpha)$] and source (e.g., diasteranes/regular and %C₂₇, C₂₈, C₂₉, C₃₀) parameters, and the evaluation of steranes altered by biodegradation.

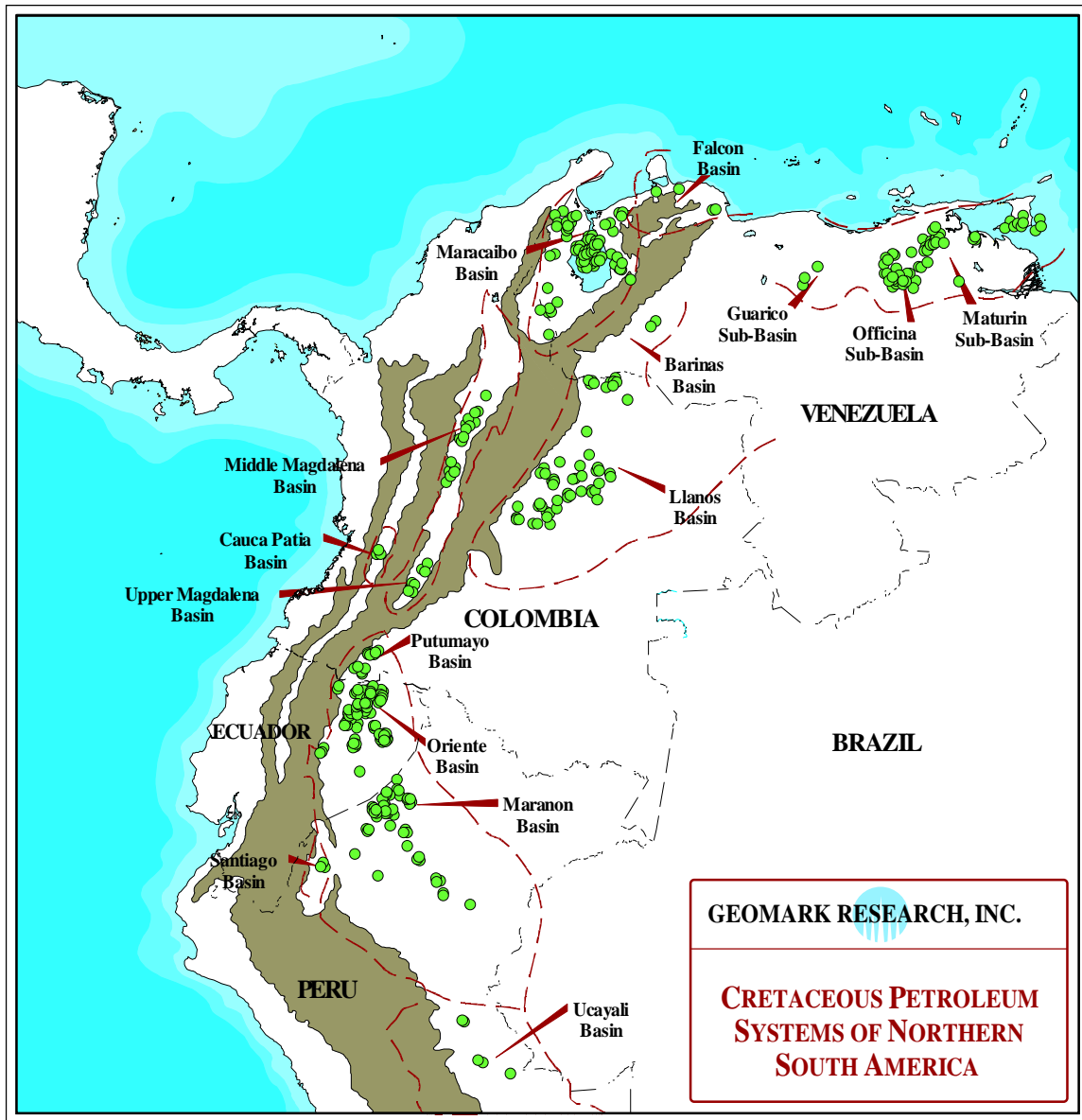


Figure 1. Location map showing distribution of samples analyzed for this study.

METHODOLOGY AND EXPLORATION APPLICATIONS

In expansive areas such as the basins of northern South America where substantial production has been established, a regional oil study is an excellent way of identifying, evaluating and comparing the various petroleum systems that have contributed to reserves. A regional oil study approach is particularly useful for comparing the remaining potential of the various basins and for predicting the distribution of particular hydrocarbon plays.

The regional petroleum systems within the study area were 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 was deduced from the oil geochemistry (e.g., Zumberge, 1987; Moldowan *et al.*, 1985). Conclusions were 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.

By analyzing representative oil samples from the identified petroleum systems using GC/MS/MS techniques (Warburton and Zumberge, 1982; Peters and Moldowan, 1993), key sterane biomarker parameters allows for the prediction of the relative oil generative capacity ('oil proneness') of the corresponding source rocks (Dahl *et al.*, 1994; McCaffrey *et al.* 1994). In addition, improved accuracy in the measurement of thermal maturity and evaluation of steranes altered by biodegradation add to the understanding of the geochemical parameters controlling oil quality (i.e., API gravity, percent sulfur, paraffin content).

ANALYTICAL PROGRAM

The following techniques have been employed on each of the 120 oil samples:

- 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/MS of branched/cyclic fraction for increased specificity of biomarker determinations

PRESENTATION OF RESULTS

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

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

- physical property data
- liquid chromatographic data
- gas chromatograms
- PC Data Base (Access™)
- stable carbon isotope data
- GC/MS mass chromatograms
- GC/MS/MS mass chromatograms.

A synthesis and interpretation of all information is presented in a comprehensive **Final Report**. For each of the basins studies, the **Final Report** includes sections for:

- regional geology,
- differentiation of oil families/mixing by multivariate statistics,
- inferred oil/source correlations,
- oil generation and migration,
- interpretation of oil characteristics,
- regional source quality prediction.

Interpretive full color, wall-sized maps/montages have been prepared.

PARTICIPATION

The cost of the study is US \$ 35,000.00 and is available immediately.

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APPENDIX A

Samples Analyzed for this Study

Colombia		Colombia		Venezuela	
Catatumbo	Rio de Oro-15K	Putumayo	Toroyacu-1	Barinas	Silvestre
Catatumbo	Rio de Oro-44	Putumayo	Toroyacu-2	Barinas	Sinco-15
Cauca Patia	Matacea Creek	Putumayo	Toroyacu-3	Falcon	El Mene de Acosta
Foothills	Corrales-1	Upper Magdalena	Toqui-Toqui-8	Guarico	Valle-6
Foothills	Bolivar-1	Upper Magdalena	Dina-3	Guarico	Los Mercedes-454
Llanos	Cano Limon-2	Upper Magdalena	Los Mangos-1	Maracaibo	Mara-116
Llanos	Cano Limon-3	Upper Magdalena	Ortega-9	Maracaibo	La Paz-100
Llanos	Matanegra-1	Upper Magdalena	Rio Ceibas-1	Maracaibo	La Paz-94
Llanos	Cravo Sur-1	Upper Magdalena	San Francisco-8	Maracaibo	Urdaneta-45
Llanos	Arauca-2	Ecuador		Maracaibo	N. Lama-53
Llanos	Apiay-11	Oriente	Amo-2	Maracaibo	Zabandonon-1
Llanos	Cano Gandul-1	Oriente	Amo-1	Maracaibo	Bachaquero
Llanos	Cusiana-2A	Oriente	Auca-2	Maracaibo	Ceuta 76-Z-3
Llanos	Buenos Aires-1	Oriente	Auca-22	Maracaibo	Motatan-5
Llanos	Santiago-1	Oriente	Jaguar-2A	Maracaibo	Punta Benitez-183
Llanos	El Miedo-4	Oriente	Jaguar-2A	Maracaibo	Tarra-43
Llanos	Volcanera-1	Oriente	Maranacu-1	Maracaibo	Tia Juana-315
Llanos	Cupiagua-1	Oriente	Oglan-1A	Maracaibo	San Jose-2
Llanos	La Gloria-1	Oriente	Lobo-1	Maracaibo	Los Maniules-CM30
Llanos	Puerto Rico-1	Oriente	Cononaco-1	Maracaibo	Rosario-CR7
Llanos	Tocaria-1	Oriente	Limoncocha-1	Maracaibo	Lamar-400
Llanos	Uribe-1	Oriente	Limoncocha-1	Maracaibo	Lagunillas-1095
Llanos	Apiay-4	Oriente	Sacha-3	Maracaibo	Lagunillas-413
Llanos	Barquerena-1	Oriente	Sacha-3	Maracaibo	La Rosa-137
Llanos	Rubiales-1	Oriente	Shushufindi-Aguarico-1	Maracaibo	La Rosa-177
Llanos	Suria-3	Oriente	Shushufindi-31	Maracaibo	Centro LSG-16-2
Llanos	Valdivia-1	Oriente	Tetete-7	Maracaibo	Rio Zulia-10
Lower Magdalena	Boquete-2	Oriente	Tetete-4	Maturin	Cachipo-2
Middle Magdalena	La Salina-1	Oriente	Bermejo-11	Maturin	Josepin-455
Middle Magdalena	La Salina-B6M	Oriente	Payamino-8	Maturin	Moneb-1
Middle Magdalena	Payoa-17U	Peru		Maturin	Manresa-2
Middle Magdalena	Payoa-21U	Maranon	Forestal-30	Maturin	Orocual-9
Middle Magdalena	Payoa-11L	Maranon	Forestal-31	Maturin	Quinquire-449
Middle Magdalena	Payoa-20	Maranon	San Jacinto	Maturin	Quinquire-557
Middle Magdalena	Velasquez-250	Maranon	San Jacinto	Maturin	Pilon
Middle Magdalena	Teca-164	Maranon	Dorissa 1A-1-528	Maturin	Pedemales
Middle Magdalena	Cantagallo-6	Maranon	Corrientes 30-X6	Maturin	Pedemales Seep
Middle Magdalena	Buturama-3	Maranon	Bretana	Maturin	N. Oscurote-1C
Middle Magdalena	Caiman-2	Trinidad		Maturin	Nipa-11C
Middle Magdalena	Infantas-1614	S. Trinidad	Beach-300	Maturin	E. Mapiri-6T
Putumayo	Orito-1	S. Trinidad	Gaupo-M14	Maturin	N. Chimire-7T
Putumayo	Orito-1	S. Trinidad	Samaan A-4X	Maturin	Chimire-17T
				Maturin	Chimire-4T