

VENEZUELA OIL STUDY

**REGIONAL PETROLEUM GEOCHEMISTRY
OF CRUDE OILS FROM THE MATURIN, GUARICO,
BARINAS, FALCON AND MARACAIBO BASINS**

GEOMARK
RESEARCH, INC.

PROSPECTUS

EXECUTIVE SUMMARY

GEO-MARK RESEARCH has performed a regional assessment of all the Venezuela basins by geochemically analyzing a large suite of 187 crude oils (Appendix A).

Each of the oils have been characterized by a detailed analytical program which includes quantitative biomarker analysis of terpanes and steranes and determination of stable carbon isotope composition of both saturate and aromatic hydrocarbon fractions. With this information, as well as bulk compositional data, we accomplished the following:

- Determined the number of genetically distinct oil families in each producing region, including both Tertiary (terrestrial) and Cretaceous (marine)-derived oils.
- In Eastern Venezuela, we quantified the degree of mixing in each reservoir between end member Cretaceous and Tertiary-sourced oils.
- Mapped the stratigraphic and geographic distribution of the oil families and degree of mixing, and distinguished basins/areas with single oil families (single sources) from those with multiple oil families (multiple sources). Compared families among basins.
- Utilized geochemical characteristics of the oil families to deduce their source depositional facies, thermal maturity level, and degree of preservation.
- Determined the most likely source unit(s) in each basin by comparing the distribution of oil families and their inferred source facies with regional stratigraphy, burial history, and available source rock data.
- Estimated migrational directions by comparing oil family and mixing distributions with the location of known depocenters.
- Utilized the geographic, stratigraphic, and structural distribution of source rocks and genetically related oils to identify, mapped, and ranked the petroleum systems in each basin and in the country as a whole.
- Determined the effects of long- and short-range migration on oil composition in resultant field sizes or numbers.
- Evaluated the effects of secondary oil alterations etc. on oil composition, producibility and economic value.

All of the analytical data generated from the oils have been issued together with a preliminary interpretive report. The final interpretive report includes full color, wall-size maps showing the distribution of oil families and associated petroleum systems.

The cost of the study is US \$37,500.

INTRODUCTION

Venezuela's basins contain the world's largest oil accumulation known, the Orinoco Heavy-Oil Belt with as much as 1.2 trillion barrels oil in place. At the same time, a large number of major and smaller fields in Venezuela maintains a high production rate of light-and medium oil; large oil reserves exist as well as massive and presently under-utilized gas reserves. Finally, a huge potential of yet undiscovered hydrocarbons is expected to occur in several parts of the country.

This wealth in producible oil and gas is based on a fortunate combination of several geological factors, such as the:

- existence of thick rich source beds in all present structural basins at a depth that has allowed sufficient thermal maturation;
- existence of thick reservoir and seal units and of sufficiently developed structural trap features;
- formation of partly long hydrocarbon migration pathways at times of maximum oil generation;
- preservation of large oil quantities along basin flanks, although secondary alterations of such oils have occurred.

These petroleum-geologically critical parameters are the result of quite a variable geological history, including different major geological settings and resultant processes:

- a Mesozoic continental margin between the southern South American Continental Craton (Guyana Shield) and the Caribbean Sea and Atlantic Ocean;
- marine influences from the north and east existed at times of terrestrial sedimentation from the southern craton interior, and
- a late Cretaceous to Recent complex orogen (Andean) along the north flank of this continent.

Data from prior Paleozoic and Triassic/Jurassic events are less well known; a passive continental margin followed by orogenic events in Late Paleozoic time, and major intra-continental rifting from ?Permian to Early Cretaceous time are generally assumed.

Today several major basinal areas exist (see Figure 1); in the onshore they are, from west to east:

- Maracaibo Basin
- Barinas/Apure Basin
- Falcon Basin,
- Eastern Venezuela Basin with its Maturin and Guarico Subbasins.

Of these basins the Barinas/Apure Basin extends to the south into the Llanos Basin of East Colombia; the East Venezuela Basin extends to the east across on-and offshore Trinidad with its individual subbasins. In both the Barinas/Apure and Guarico Subbasins local depocenters lie near or partly underneath the adjacent Andean Mountain structures and thrust sheets; they

may be important oil-generating depocenters. The Bouguer Gravity Map of Venezuela quite clearly defines regional structural units, such as the main basinal (subsided) and orogenic mountain (uplifted) areas.



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

All basins in Venezuela contain potential oil and gas source beds. Among them Late Cretaceous marine shales and carbonates are of major importance; they are known under such stratigraphic names as La Luna Formation in the Maracaibo Basin region, or Querecual Formation and San Antonio Formation (the latter two forming the Guayuta Group) in the Maturin Subbasin. Tertiary potential source beds range from non-marine Oligo/Miocene shales and lignites to marine Oligocene and Miocene shales; here are included the Roblecito Formation, Mercure Formation, Oficina Formation, Chaguaramas Formation, Areo and Carapita Formations in Eastern Venezuela. Paleogene shales in the Maracaibo Basin region may have generated at least gas or early-matured (? heavy) oils. There are probably no source beds in the older Mesozoic rift section, nor are there yet known occurrences of Paleozoic source beds; perhaps gas generating strata of Paleozoic age may be present in some areas, for example, in the Eastern Venezuela Basin.

Subandean basins in Venezuela and elsewhere are asymmetric; they carry a gentle, wide basinal flank away from the adjacent mountain belt, and a steeper, short and partly deformed flank toward the mountain belt. Older (here mainly Cretaceous) and younger (Tertiary) potential source beds in resultant depocenters underwent different timing of maturation following individually distinct sedimentation histories and patterns. The geological history of

each potential source bed including its thermal maturation, migration, entrapment and preservation histories of oils and gases are important parameters in the understanding of present accumulations and for future exploration efforts.

Areas lying between generating depocenter lows and existing fields very likely will contain additional oil and gas reserves and, therefore, will become highly attractive for future exploration ventures. In areas that lie far away from mature source beds and outside main lateral migration pathways, however, no major reserves will likely be found. This applies equally to all the prospective and (partly) productive basins and subbasins in Venezuela.

METHODOLOGY AND EXPLORATION APPLICATIONS

In areas such as the Eastern Venezuela and Maracaibo Basins 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 various basins and for predicting the distribution of particular hydrocarbon plays.

The regional petroleum systems within the study area have been 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 have been 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. In many cases it was possible to bracket the age of the source from the oil data. Recent studies have shown that oils generated from both Tertiary source rocks containing abundant terrestrial organic matter as well as oils from middle Cretaceous marine sources are present in Eastern Venezuela (Zumberge and Brown, 1992; Audemard, 1993). In addition, many fields contain oil of mixed origin, combining various proportions of Tertiary and Cretaceous oils. Table 1 below and Figure 2 on the following page illustrate the mixing of Tertiary and Cretaceous end member oils as deduced from biomarker and bulk geochemical data.

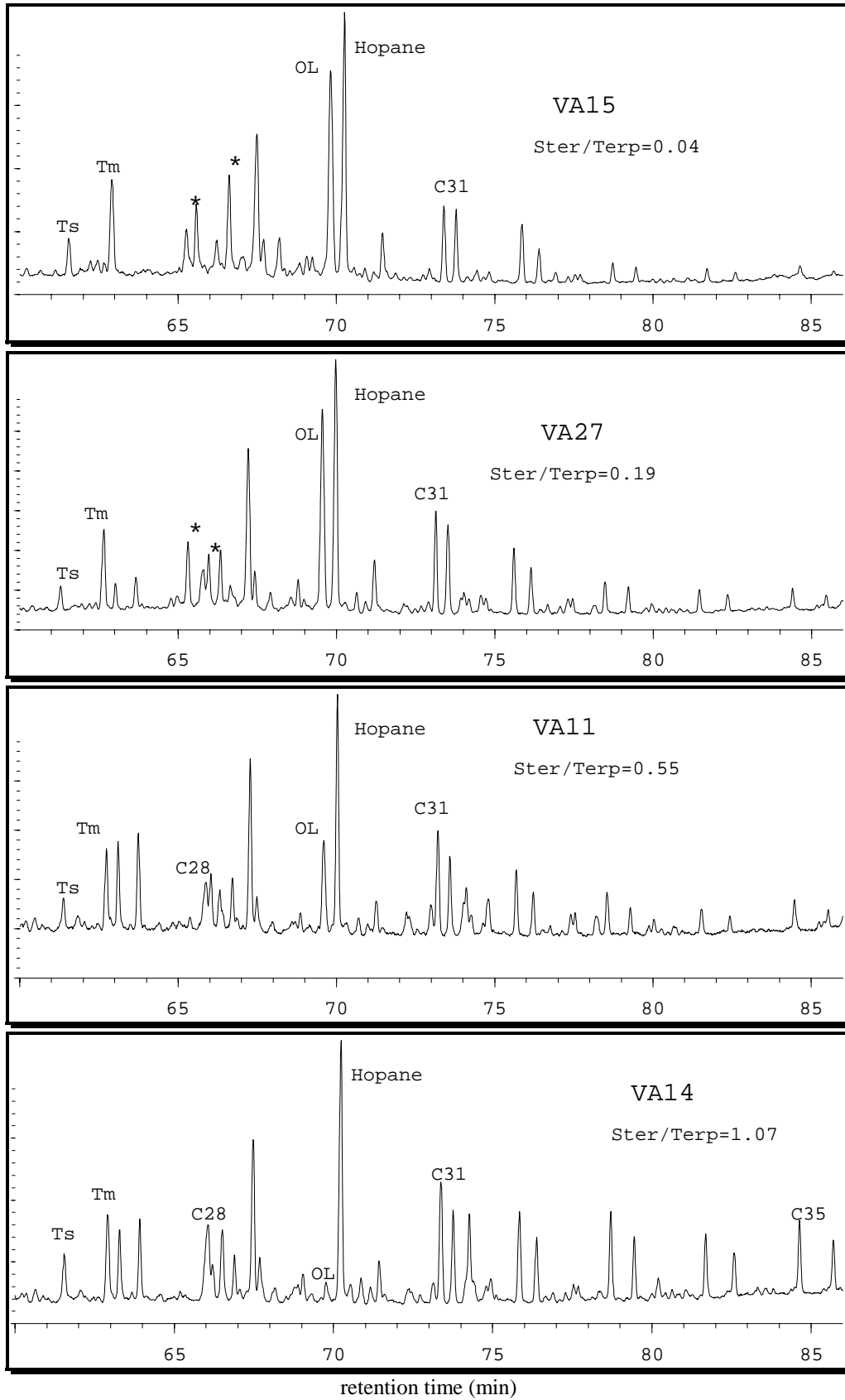
Table 1. Representative Eastern Venezuela Oils Showing Mixing of Marine (Cretaceous Querecual, etc) and Terrestrial (Tertiary Sources) Oils.

ID	SOURCE	Terpanes			Steranes			GC		Bulk		$\delta^{13}\text{C}$ CV	% Sul
		C23 /OL	ppm OL	ppm C23	Ster/ Terp	Rearr/ Norm	C27/ C29	Pr/ Ph	nC27/ nC17	ppm V	Sat/Aro HC		
VA14	Marine	20.0	55	1102	1.07	0.47	1.04	bio	bio	280	0.68	-1.6	2.0
VA11	Mix	4.80	100	480	0.55	0.66	1.23	1.78	0.74	25	1.38	-1.0	0.49
VA27	Mix	0.50	483	249	0.19	0.86	1.06	3.57	0.89	33	2.24	1.0	0.36
VA18	Mix	0.44	566	248	0.13	0.96	0.97	2.92	1.22	14	2.55	1.7	0.19
VA15	Terrestrial	0.08	788	66	0.04	>2	0.15	4.58	1.07	4	2.86	2.8	0.05

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

Figure 2. Eastern Venezuela Pentacyclic Terpanes: Examples of Tertiary Terrestrial Oil (VA15) and Cretaceous Marine Oil (VA14) with Mixed Oils (VA27 and VA11).



ANALYTICAL PROGRAM

The following techniques were employed on each of the 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)

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 is provided in hard copy and on magnetic media.

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

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

PARTICIPATION

The cost of the study is US \$37,500. The study is completed and available for immediate delivery.

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APPENDIX A
OILS SELECTED FOR ANALYSIS

Eastern Venezuela:

Maturin Sub-Basin Fields:

La Ceiba	Pilon	Chapopotal (25°-36°)
Chimire (2)	Nipa (2)	Jusepin (24°-34°)
N. Chimire	Tigre	Orocual (4)
Boca (2)	Merey	Manresa (4)
Mapiri	E. Mapiri	Acema (4)
Guico	W. Guico	Cachipo
S. Guico	Guario	San Joaquin
Dacion	Araibel	Viola
N. Cachana	Santa Fe	Tacata (4)
Mata	Esquina	
N. Oscurote	Pradera	
Oscurote	Santa Rosa	
Quiriquire (13°-34°)	Pedernales (3)	

Trinidad Fields

Barrackpore	Tabaquite	Offshore Fields
Wilson	Beach	
A. Oropuche	Forest Reserve	
Inniss	Penal	

Guarico Sub-Basin

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Maracaibo Basin

Mara (2)	Punta Bentiz (17°-24°)	Onado
La Paz (4)	Tia Juana (15°-27°)	Centro (3)
Boscan	La Rosa (5)	Motatan (2)
Urdaneta (13°-31°)	Lagunillas (20°-29°)	Mene Grand
Lama (Eocene and Cretaceous)	Bachaquero (9°-34°)	(2,000'-12,000')
Lamar (3)	San Jose	Zabalarior
Tarra (2)	Bolivar (VLA Wells; 24°-37°)	Hombre Pintado (2)
W. Tara (3)	El Mene (2)	Rosario
Los Manueles	Las Palmas	Rio Zulia
	Tibu	

Falcon Basin

Cumarebo	Miranda
Tiguaje	Mamon

Barinas/Llanos Basins

Sinco	Silvestre
Guafita	Cano Limon (2)
La Yuca	