Abstract
The study area is located towards the North of the Caribbean Deformation Front, specifically where the structures of Sipororo, La Yuca and Barrancas oils fields are located, near the Barinas Traditional oil Fields. From a structural point of view, the area of interest is bounded by the following structural features: Bocono Fault Northward, Arco de El Baul East, Caribbean Deformation Front to the North and Arco de Merida to the South (Figure 1).

The methodology developed was first to evaluate the geochemical characteristics of the crude oils and rocks. Then, from geological-structural model proposed in the area, was built a geochemical modeling 2D and 3D as a result of the interpretation performed on 2D (15.520 km) and 3D (1.350 km2) surveys. The results model 2D/3D suggest two possible intervals for generation and expelling potential hydrocarbons of Cretaceous age: the Quevedo and La Morita Members of Navay Formation were identified in the Northwest of the study area, which were active in the Miocene and currently at levels equivalent to maturity phase of maximum generation of liquid hydrocarbons (1.3% Ro). These hydrocarbons have migrated vectors a Northwest-Southeast direction, towards the Barinas Basin. Thus, according to the result of this model and Mass Balance the opportunities displayed on the study area, have received enough volume of oil from these Cretaceous source rocks (Miocene generation) (5035.31 MMBLS) and its lateral equivalent La Luna Formation (generation in the Eocene), directly or through remigration oil that was accumulated in the Barinas fields. Molecular parameters have allowed corroborating the crude oils Northern Barinas and traditional Barinas areas have mainly marine origin with some contribution of terrestrial organic matter and different levels of maturity and biodegradation.

Keywords: oil, generation, expulsion, migration, entrapment, geochemical, structural.

Introduction
The study area, is located towards the North of the Caribbean Deformation Front; specifically where the structures of Sipororo, La Yuca and Barrancas oils fields are located, near the Barinas Traditional oil Fields. The UTM area coordinates boundaries are: Xmax = 410000, Xmin = 335,000, Ymin = 910,000 and Ymax = 990,000. From a structural point of view, the area of interest is bounded by the following structural features: Bocono Fault Northward, Arco de El Baul East, Caribbean Deformation Front to the North and Arco de Merida to the South (Figure 1).
The development of the model presented was in this paper done mainly from the 2D/3D seismic data (seismic transects and map in depth), key wells available and the interpreted stratigraphic framework interpreted from this data. Key tops formations were identified, as well as eroded thicknesses, formation ages, lithology of each interpreted sequence and geochemical parameters of the source rock such: total organic richness, effective thickness and type of kerogen.

**Objective**
Building a 3D/2D basin model using 3D Temis and some 2D lines (2D Temis), with the purpose of determining maturity, migration, transformation ratio, generated and expelled hydrocarbon volume by the source rocks and their contribution with charge of the proposed exploration opportunities in the area, in order to integrate and update previous studies in the Barinas Basin.

**Methodology**
The methodology developed was first to evaluate the geochemical characteristics of the crude oils and rocks. Then, from geological-structural model proposed in the area, was built a geochemical modeling 2D and 3D as a result of the interpretation performed on 2D (15,520 km) and 3D (1,350 km2) surveys (figure 3,4).

**Results and Discussion**
The results were divided in two ways: The Petroleum System Elements and the Petroleum System Processes.

**Petroleum System Elements**

**Crude Oils / Source Rock**
The crude oils Northern Barinas and traditional Barinas areas have mainly marine origin (carbonate and/or shale) with some contribution of terrestrial organic matter and different levels of maturity to increase from Southwest to Northeast in the study area. The biodegradation can be interpreted in different levels, ranging from high in the seeps studied, to moderate and low, in some cases as presented of the Barinas fields (figure 5).

From previous studies, the main hydrocarbon source rock is represented by Navay Formation, which is constituted by La Morita and Quevedo Members, for Barinas Basin.

The figures 6 show the TOC variation and Ro for the Quevedo and La Morita Members, for Barinas Basin.

The general trends for both of them increase from Southeast to Northwest.
**Reservoirs**

The gobernador and Escandalosa Formations have been identified as the main reservoirs in the Barinas Traditional Field. In the Gobernador Formation sandstones of Middle Eocene age, have porosities between 9 to 18% and Escandalosa Formation between 2 and 10% in areas already drilled.

The figures 7 show the general trend of the thickness reservoir, for the Gobernador and Escandalosa formations, the higher thickness are observed in the central part of the study area and the lower to the North.

**Seals**

The regional seal characterized by shales intervals of the Paguey Formation of Late Eocene age which is responsible of the retention of hydrocarbons in the area is represented mainly by with thicknesses varying from 1100', in the Barinas Traditional Area, to 5000' to the North, where Sipororo, La Yuca and Barrancas structures are located (Figure 8)(ANKA et al, 1998).

**Traps**

The main structure of the Barinas Basin occurred during the Middle Eocene. This period of deformation generated new inverse structures and also produced the inversion of some previous normal faults, with subsequent recovery activity during the Late Middle Miocene (The Venezuelan Andes Uplifting), generated structural styles represented by highs associated with inverse faults reactivated and Neogene age faults. There are two (2) big groups of older alignments: (1) The alignment direction (Northeast-Southwest), driven by the Boconó Fault in the Andes and (2) The economic basement heritage in the East-West direction, which left its remains well marked in the Barinas Traditional Area with a variety of structural traps that give rise to numerous opportunities identified.

**Petroleum System Processes**

To simulate the processes of maturity, generation, expulsion, migration and entrapment of oil in the North area of Barinas and Barinas traditional, Temis 2D and 3D (Beicip Franlab ®) programs were used. The following results describe the obtained products of 2D lines and 3D block to define the location of clearly source rocks, the amount of Hc generated...
(mass balance) and the direction of migration of these hydrocarbons toward the proposed structures in the area.

The figures 10, shows the 3D block and the location of the 2D lines. These NW-SE direction lines were selected to represent the structural basin evolution, which generally can be divided into 3 areas: One located to the North of the Caribbean Deformation Front, where the Sipororo, La Yuca and Barrancas structures are located. Second, located between the Deformation Front and the Caribbean Neogene Syncline foothills where Las Lomas and Guasimitos structures were located. Finally, the third structure is located to the South, in the Traditional Barinas Fields.

Figure 10. 3D block, the location of 2D lines (1 and 2) and interpreted faults in the structural model of the area, showing the deeper part of the basin to the NW (warm colors) and the shallower to the SW (cold colors) as well as the 3 stages that represent the structural evolution of the basin.

Thermal Calibration
This transect (figure 11) allowed to verify thermal calibrations by comparing the trend obtained from measured data of temperature and vitrinite reflectance of wells. So, it is possible to say according to figures 12 that the obtained calibration was successfully, since the measured data from wells and those calculated by the program are very similar.

Figure 11 Thermal Maturity variation. Yellow color indicates immature zone (0.1 to 0.6% Ro) and the green one the oil zone (% Ro 0.7a 1.3).

Figure 12 Thermal Calibration of temperature and maturity for B and A wells, showing a similar tendency between the measured data from wells and those calculated by the program.

The results model 2D/3D suggest two possible intervals for generation and expelling potential hydrocarbons of Cretaceous age: the Quevedo and La Morita Members of Navay Formation were identified in the Northwest of the study area, which were active in the Miocene and currently at levels equivalent to maturity phase of maximum generation of liquid hydrocarbons (1.3% Ro), as shown in graphics (Age My Vs% Ro) of Figures 13 and 14. In contrast, to the Southeast, is now at the beginning of the oil generation window. This is due to the Upper Eocene-Oligocene and Miocene have the biggest thickness of rocks, while thickness is smaller in the Southeast area, in the Traditional Fields of Barinas. These hydrocarbons have migrated vectors a Northwest-Southeast direction, towards the Barinas Basin.

Figure 13 Transect 2D (NW-SE), showing the thermal maturity variation and the graph showing the evolution in time (Age My Vs% Ro) for transect 1, NW-SE.

Figure 14. 3D view of maturity evolution (Quevedo Member %Ro)
According to the analysis show in the 2D sections and in the 3D block, have been identified two active source rocks in the study area: Quevedo and La Morita member. The figure 15, shown the productivity of these rocks in terms of the hydrocarbons generated. Indicating that the crude oils from Barinas Basin were generated from these two source rocks (Miocene generation) with its lateral equivalent La Luna Formation (generation in the Eocene), directly or through remigration oil that was accumulated in the Barinas fields.

These results could verify the mass balance conducted in the area, in which the rocks for the Navay formation have a volume of hydrocarbons generated about 5035.31 MMBLS, a value greater than the amount of oil in place (POES) calculated for the 14 oil fields in Barinas about 4027.035 MMBLS; which is the product of the ratio between the recoverable reserves (cumulative production + remaining reserves) and the recovery factor (FR). These results are only considering the area of hydrocarbon generation located NW of the study area (figure 15).

**Figure 15.** Hydrocarbons generated (kg/m²) by the Quevedo and La Morita members of the Navay Formation, in cold colors the lowest values and warm colors the highest, at the same time histogram of the area of cumulative production Barinas Traditional, remaining reserves and POES in MMBL (Production data taken from Re-Exploration Barinas 2009 Project).

According to the estimated data obtained from the simulations, it has been determined the migration efficiency of about 80%, which is a very high value, considering the losses of hydrocarbons by primary and secondary migration. This high value is a result of the following equation: 

\[ EM(\%) = \frac{POES}{HG} \times 100 \]

where; EM: migration efficiency, POES: original oil in place and HG hydrocarbons generated, and can be explained by the low estimation of hydrocarbons generated, for this study. The hydrocarbon generation area is limited to covered the 3D model, being necessary to consider the volumes generated by the intervals corresponding to the La Luna Formation located further North in the study area, beyond the extend of the 3D model, as evidenced by the basin modeling done by the team EFAI 2009.

The basin modeling EFAI 2009 was made through a transect located West of the transect considered in this study, even when it overlaps with the covered area of the 3D model, it has the special property to extend to the North of the outcrops area of the Santo Domingo River. Simulations show the history of the basin structure and evolution of thermal maturity of source rock intervals (Figure 16). It is possible to visualize that during the Middle Eocene (46 My), the depocent of the basin was located to the Northeast of the area where the ranges of Cretaceous age of maturity reached levels equivalent of thermal generation of petroleum. This situation continued until the Middle Miocene, when subsequently, with the “Uplift of the Andes” and the inversion of the basin, the generation and maturity process was extended Southward from the basin.

**Figure 16.** Hydrocarbons of Generation areas in the Barinas Basin. (a) Generation of hydrocarbons area in Eocene-Oligocene age. (b) Generation of hydrocarbons area of Miocene age. (Taken from Schneider 2009).

**Conclusions**

- Crude oils from Northern Barinas and Traditional Barinas areas have mainly marine origin (carbonate and / or shale) with some contribution of terrestrial organic matter.
- Crude oils from the study area have different levels of maturity and biodegradation.
- Two possible intervals for generation and expelling potential hydrocarbons of Cretaceous age were identified in the Northwest area, for both the Quevedo and La Morita Members of Navay Formation.
- The maturity evolution map in terms of rate of transformation in the area, shows the existence of a possible kitchen in the Northwest area, responsible for the crude oils found in Traditional Area of Barinas.
- The two proposed source rocks in the study area correspond to Quevedo and La Morita of Navay Formation facies, according to this model (Mass...
Balance), have a good capacity of generation to provide enough volumes of oil to the structures and prospects of Barinas.

- The migration vectors have a Northwest-Southeast direction towards Barinas Basin.
- The petroleum system proposed in this study for the Barinas area, is considered an active and efficient system, due to the evidence of hydrocarbon presence during drilling and evaluation of drilled wells in the area.

**Recommendations**

- Since the migration model appears to be very sensitive to changes in porosity, permeability, capillary pressure and reservoir pressure data, it is recommended to incorporate to this study, new drilling data when it is available, in order to gradually improve approaches obtained from this study.
- To improve lithologic maps and characterization of different faults in order to have a better estimation of migration processes in the new 3D survey in the area.
- To characterize more effectively the risk of occurrence of hydrocarbon exploration prospects with the use of the basin modeling tool and subsequent calibration with the geochemical characterization of the crude oils present in the area.
- To do better estimation of the migration efficiency in the basin, in order to assess the prospectivity associated with the new proposal opportunities.

**References**


**Acknowledgments**

First let PDVSA-INTEVEP by presenting this work and to Mr. Frederic Schneider for their assistance in the same.