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GEOCHEMICAL EVALUATION OF CRUDE OILS IN THE LLANOS ORIENTALES BASIN

Evaluación geoquímica de crudos en la cuenca llanos orientales

Julián Camilo Moyano Montaña

Universidad Pedagógica y Tecnológica de Colombia, Escuela de Ingeniería geológica, Colombia.
Email: julian.moyano01@uptc.edu.co

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Abstract

The area of the present study is located in the Llanos Orientales basin, in which the main objective was a geochemical evaluation of crude oil in the geological and production provinces: Piedemonte, Arauca, Casanare and Meta-Vichada based on related information about bulk parameters, gas chromatography and biomarkers. The data for each of the provinces were analyzed and reorganized according to the geological formation corresponding to the reservoir rock indicated for each crude oil sample, from which 576 crude oil samples were obtained with the information that allowed relating some petroleum compounds and defining the depositional environments of the source rock facies of crude oil, identify biodegradation processes and mixtures of crude oils. In the same way, maps were made where the crudes were classified according to their quality. It was established that the best quality crudes belong to the Piedemonte sector in the Mirador Formation. On the other hand, the sector where the crudes show lower quality corresponds to Meta-Vichada in the San Fernando Formation. This analysis was carried out for the four provinces, obtaining key information for future exploratory campaigns in the Llanos Orientales basin, taking into account that it is the richest basin in hydrocarbons in Colombia.

Key words: *biodegradation, biomarkers, bulk parameters, chromatography, crude oil mix, reservoir rock, source rock.*

Resumen

El área del presente estudio se localiza en la cuenca de los Llanos Orientales, en la cual se realizó como objetivo principal una evaluación geoquímica de crudos en las provincias geológicas y de producción: Piedemonte, Arauca, Casanare y Meta-Vichada a partir de información relacionada con parámetros bulk, cromatografía de gases y biomarcadores. Se analizaron los datos por cada una de las provincias y se reorganizaron de acuerdo con la formación geológica correspondiente a la roca reservorio indicada para cada muestra de crudo de donde resultaron 576 muestras de crudos con la información que permitió relacionar algunos compuestos del petróleo y definir los ambientes de depósito de las facies de las rocas generadoras de los crudos, identificar procesos de biodegradación y mezclas de crudos. De igual manera, se realizaron mapas donde se clasificaron los crudos de acuerdo a su calidad. Se logró establecer que los crudos de mejor calidad pertenecen al sector Piedemonte en la Formación Mirador. Por otra parte, el sector donde los crudos muestran menor calidad corresponde a Meta-Vichada en la Formación San Fernando. Este análisis se realizó para las cuatro provincias obteniendo información clave para futuras campañas exploratorias en la cuenca Llanos Orientales, teniendo en cuenta que es la cuenca más rica en hidrocarburos de Colombia.

Palabras clave: *biodegradación, biomarcadores, cromatografía, mezcla de crudos, parámetros bulk, roca generadora, roca reservorio.*

1. INTRODUCTION

Th The sedimentary basin known as Llanos Orientales is the largest in Colombia, with an area of 225,706 km², in this basin are located approximately 358 oil fields of which 89 are productive. It covers the departments of Casanare, Meta, Arauca, and Vichada [1]. Oil production in the basin is distributed as follows: Meta contributes 71.5%, Casanare 19.1% and Arauca 7.8%. In terms of the quality of the crude extracted, heavy crudes account for 68.6% of total production, while normal and light crudes correspond to 12.8% and 5.6%, respectively [2].

In this basin there is a great variety of crudes in terms of their basic properties (bulk parameters such as API gravity and sulfur, vanadium and nickel content). These variations in crudes may be a consequence of complex petroleum systems and are associated with different generating intervals, biodegradation processes and hydrocarbon mixing [3].

Considering that this basin is the most important in Colombia in terms of discovered resources (37,000 Mmbpe / OOIP) [4], it is necessary to understand the temporal, stratigraphic and geographic distribution of these processes with the purpose of obtaining conclusions that contribute to the visualization of additional exploratory opportunities. Petroleum geochemistry is a powerful tool that can effectively contribute to the understanding of hydrocarbon generation, migration, loading and preservation processes.

This work is developed using geochemical information published by the ANH in 2011 and covers the geological and production provinces recognized in the Llanos basin: Piedemonte, Arauca, Casanare and Meta-Vichada. Information from approximately 631 crude samples and geological and petroleum geology information published in different regional and local studies that talk about depositional environments of source rock facies and the relationship with the reservoir rock is used [5-6].

The geochemical information used includes bulk parameters (API gravity, sulfur, vanadium, and nickel content), gas chromatography, liquid chromatography and biomarkers [7].

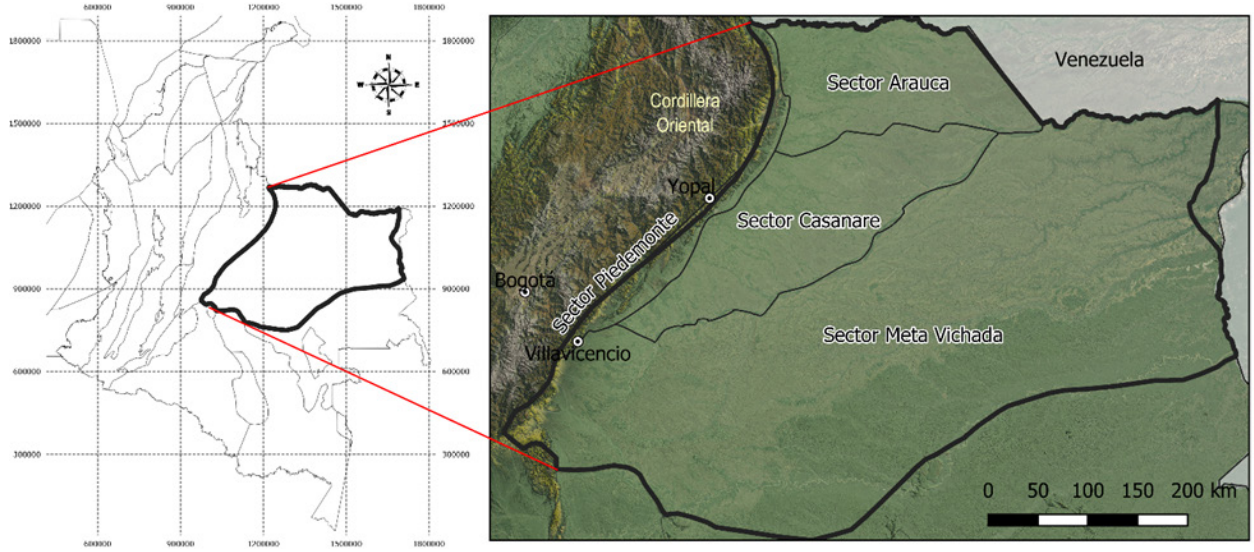

Figure 1. Location map of the Eastern Plains Basin and its sectors. **Source:** author, 2023.

2. LOCATION OF STUDY AREA

The Llanos Orientales basin is located east of the Eastern Cordillera of Colombia, comprising the departments of Casanare, Arauca, Meta and Vichada. It is located approximately 123 km east of the city of Bogotá D.C. According to [4] and ECOPETROL-ICP (1991), it is a flat topographic depression, southwest- northeast oriented, with altitudes ranging from 50 to 500 meters above sea level, said basin developed on the western flank of the Guyana Shield. It covers an area of 225,706 km² and its tectonic evolution has been extensively studied in several studies [8-12].

Also, within this basin are the recognized geological and production provinces: piedmont, Arauca, Casanare and Meta (see Figure 1). The area in question has well-defined morphological limits. To the north, it is bordered by the Venezuelan political frontier; to the east, by the Guyana shield; to the south, by the La Macarena Mountain range, the Vaupés arc, and Precambrian metamorphic rocks; and to the west by the Cordillera Oriental fault system [13].

3. THEORETICAL BACKGROUND

3.1 Regional geological framework - Stratigraphy

The stratigraphy of the Llanos Orientales basin is described in Figure 2 and begins with the deposition in the crystalline basement of detrital Paleozoic sediments [14], overlain in discordant contact by Cretaceous rocks. The latter correspond to the Une, Gachetá and Guadalupe formations.

Une Formation: In the Casanare sector, the Formation Une is also called Ubaque Formation and Lower Sands Formation (Lower Sandstones) according to [4][15].

Gachetá Formation: In the study area it is present in the Casanare sector. Likewise, the Chipaque Formation is a stratigraphic equivalent of the Gachetá Formation [16].

Guadalupe Formation: In the study area it is present as reservoir rock in the Arauca, Casanare and Meta-Vichada sectors.

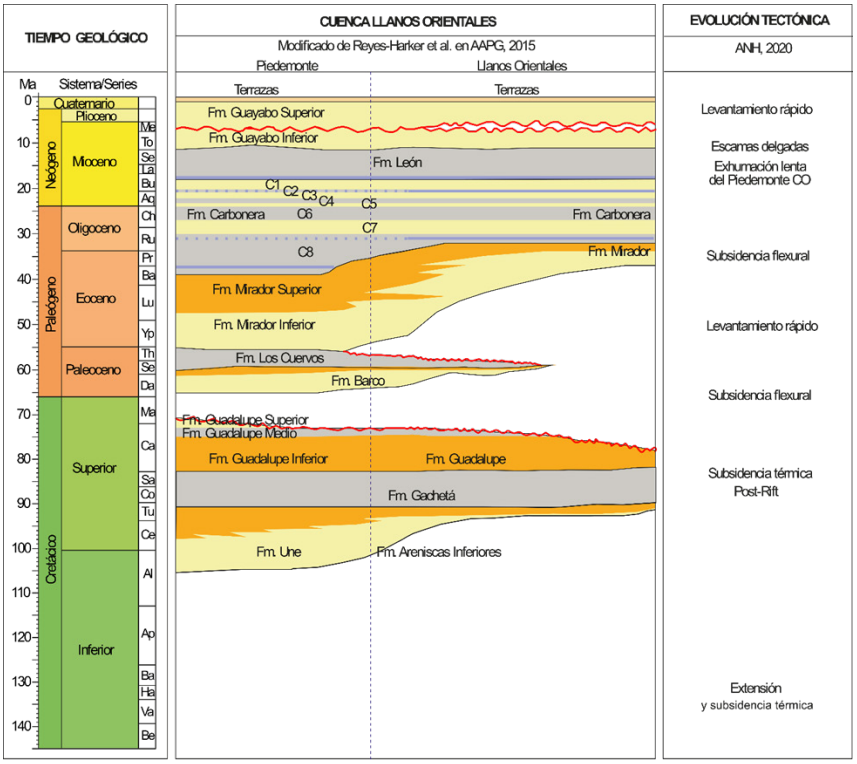

Figure 2. Stratigraphic column of the Llanos Orientales basin. **Source:** kuenka ,2023.

In the Cenozoic, from the Paleocene to the Quaternary, the following formations were deposited:

Barco and Los Cuervos Formations: these formations are associated with depositional environments of sandy fluvial facies and an increase of coastal plain. Their age ranges from Early Paleocene to Late Paleocene. In the study area, the Barco Formation is a reservoir rock in the Casanare sector.

Mirador Formation: This formation is present in the four sectors and constitutes the most important reservoir in the basin. Operationally in the Castilla area it is called the San Fernando Formation [17].

Carbonera Formation: It is a sedimentary sequence composed of clayey, silty rocks and sandstones, with occasional coal levels [18]. It was deposited during the late Eocene and early Miocene, in environments ranging from transitional marine to continental. This formation is divided into 8 operational units (C1 to C8), where the even levels are transgressive and act as regional seals, while the odd ones are sandy and hydrocarbon-producing from C7 to C3 [19]. The Carbonera Formation is distributed in the Arauca, Casanare and Meta-Vichada sectors, where it is used as reservoir rock.

Leon and Guayabo Formations: The León Formation represents the maximum invasion of Tertiary seas and is composed almost exclusively of clays [19], ending with the deposition of thick molasse-like layers of the Pliocene-Quaternary Guayabo Formation deposited in a marine environment towards the base and marine to continental fluvial at the top [14].

3.2 Geochemistry of crude oil

Petroleum is a complex chemical substance which constitutes a non-renewable natural resource. In addition to API gravity, sulfur, vanadium and nickel content, there are other compounds that make it up, which contain molecules known as biomarkers. In the hydrocarbon sector, basic geochemical analysis, also known as bulk analysis, is fundamental to determine the characteristics of crude oil.

These analyses include the measurement of API Gravity, Sulfur Content, Vanadium Content and Nickel Content. The data obtained in this type of analysis are essential to define the type of crude oil relating its quality and the source rock environment [2]. Another relevant aspect provided by crude geochemistry is to analyze the quality of crudes, which is reflected in their physical properties together with their general composition and is the result of the interaction of different variables from which it can be stated that a good quality crude has high API gravity, low sulfur content, low content of 25-norhopane/C30 hopane and enrichment in saturates together with origin from non-marine rocks.

Lower quality crudes have low API gravity, high sulfur content, high 25-norhopane/C30 hopane content, loss of saturates, significant bacterial alteration and origin from marine (carbonate) rocks. Likewise, most crudes have low concentrations of vanadium and nickel and sulfur content lower than 1%, however, it can be associated to medium to high quality crudes, otherwise it is related to marine source rocks subjected to biodegradation processes.

Biodegradation processes affect the quality of crudes when the percentage of saturates decreases along with their API gravity and the concentration of sulfur, nickel and vanadium increases. Since 25-norhopanes are formed in states of intense biodegradation, they are an indicator of a mixture of intensely biodegraded crudes [20].

Regarding the depositional environment of the source rocks, geochemistry is a useful tool in the definition of petroleum systems. Likewise, Colombian crudes correlate with Cretaceous and Tertiary source facies deposited in marine environments that vary between deltaic marine, predominantly siliciclastic shallow marine and predominantly carbonate shelf marine.

For Cretaceous source rocks there are three main depositional environments: anoxic marine with carbonate influence (anoxic conditions, high ambient salinity and minimal input of continental-derived organic matter), siliciclastic marine, anoxic to suboxic (moderate oxygen

level, high to moderate ambient salinity and moderate input of continental-derived organic matter) and suboxic deltaic marine (relatively high oxygen level, low to moderate ambient salinity and high input of continental-derived organic matter).

For Tertiary source rocks the main depositional environment is deltaic marine. The age of crude oils in source rocks can be classified thanks to biomarkers and although the methodology is not developed, it is possible to differentiate crude oils generated from Upper Cretaceous or Tertiary rocks [20].

4. MATERIALS AND METHODS

For the execution of the project, a 6-stage methodology was established (see Figure 3), which describes each of the activities carried out to achieve the proposed objectives in the study area, which covers the recognized production sectors (Piedemonte, Arauca, Casanare and Meta-Vichada) in the Eastern Plains basin.

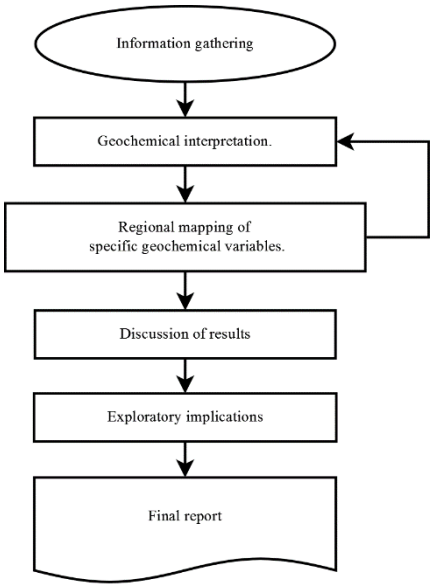

Figure 3. Diagram of the methodology used. **Source:** author, 2023.

4.1 Information gathering

This first stage consists of collecting information regarding crude geochemistry to begin to understand the relationship of bulk parameters and biomarkers, with crude quality. Likewise, this stage seeks to obtain from the database provided by the ANH, published information on geochemical data for crude samples in the Llanos Orientales basin.

Another important information obtained from this database is the shapefile of crude, fields and basins. It is also necessary to compile all the necessary information that the company has, whether it is bibliographic information, similar works that serve as a guide and information to use in the GIS.

4.2 Geochemical interpretation

The second stage consists of compiling and organizing the information in Excel files so that the data are plotted correctly for interpretation; in general, 631 data were collected, however, some of them lack information and therefore are not plotted, being necessary a reclassification. The organization is done by classifying the data by provinces or recognized production sectors, which are piedmont, Arauca, Casanare and Meta.

For each sector the wells that have information of the reservoir rock formation are extracted, likewise with the help of GIS and the shapefile previously obtained, the wells of the evaluated crudes are related with their coordinates and production field to which they belong, 576 crude data are obtained for the formation of source rock and 619 data for the quality related to API gravity. Through the accompaniment of the company, several trainings and meetings are held to prepare the interpreter and review the progress.

Seven graphs must be prepared for each sector. To understand the quality of the crude related to the type of crude, biodegradation processes and mixture, the graphs of API gravity and sulfur content; 25-norhopane/C30 hopane content and API gravity; ratio between Ni/V and sulfur content; ratio of percentage of saturates and API gravity are used. On the other hand, to interpret and find relationships with the age and depositional environment of the source rock facies in the sectors, the graphs

of pristane/phytane to oleanane/C30 hopane ratio; pristane/phytane to C35/C34 hopane ratio; gamacerane/C30 hopane and Ts/Tm ratios are used.

4.3 Regional mapping of specific geochemical variables

For the third stage it is necessary to take into account the geographic location, together with the quality and reservoir rock formation information of each well performed in the second stage. For quality, the wells were classified according to the API gravity value, having either heavy, normal or light crude in each sector. Likewise, mapping is established by geological formation of the reservoir rock of the crude sample, such data is also mapped by sectors to observe the location of each sample and thus better relate the interpretation.

4.4 Discussion of results

The fourth stage seeks to establish the reservoir rock formation(s) of better and lower quality in the basin, as well as suggesting depositional environment for the source rock facies. With the help of the mapping of the variables, the location of these formations is related to the geochemical interpretation.

4.5 Exploratory implications

The Llanos basin is of vital importance for oil production in our country. Due to its strategic location and abundance of resources, this region has become a key point for the national energy industry. The fifth stage seeks to propose the most favorable location, sector, geological formation and depositional environment to find good and lower quality crude oil.

4.6 Final report

Taking into account the density of data and the extensive interpretations for each sector, we seek to condense everything in a report that evidences the results by sector, in the same way the mapping of the data helps to improve the interpretation to propose some exploratory implications, discussion and analysis of these results.

5. RESULTS

Based on bulk parameters (API gravity, %sulfur, vanadium and nickel), liquid chromatography, gas chromatography and saturated biomarkers, a geochemical interpretation was performed to evaluate the quality of the crudes and the depositional environments of the source rock facies.

The interpretation was carried out for crude oils from the Arauca, Casanare, Meta-Vichada and Piedemonte sectors of the Llanos Orientales basin.

Figure 4a corresponds to the location map of the wells with geochemical information used for this interpretation. From the graphs for the interpretation of crude geochemical data of these sectors, relevant aspects were identified, mentioned below. The mapping of duly classified and organized variables is used as a complement at the time of interpretation to better propose the exploratory implications; for this reason, for the geological formation of the reservoir rock, 576 data classified by each sector were mapped in order to relate the location of each sample with the formation being described, as shown in Figure 4b.

The API gravity mapping is used as an input to better understand the location of the samples with heavy, normal and light crudes, as shown in Figure 4c; this is convenient since this variable is the most used in the geochemical quality charts, which displays 619 crude oil sample data classified for the production sectors of the Llanos basin.

5.1 Arauca Sector

The API gravity of the crudes evaluated in the Arauca sector of the Eastern Llanos basin varies between 24.4 and 39.9 and the sulfur content between 0.10 and 0.66%. A slight tendency of increase in API gravity is observed in the crudes, going from normal to light, likewise the sulfur content and 25-norhopane/C30 hopane content have a notable decrease, which suggests a combination between intense to incipient biodegradation processes and possible mixture of crudes (see Figure 5).

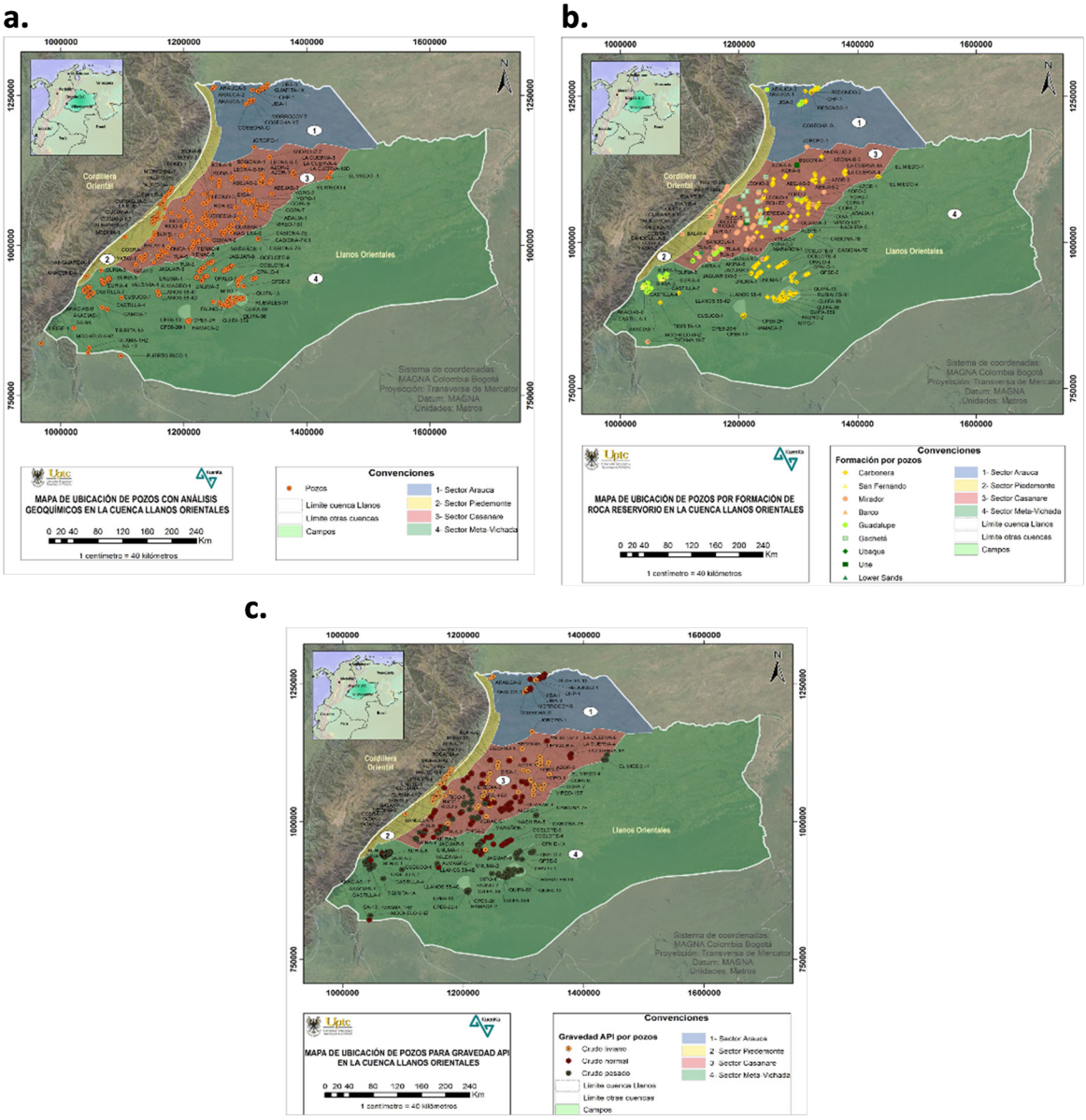

Figure 4. (a) Map of well locations with geochemical analysis (b) Map of well locations with geochemical analysis and (c) Map of well locations for API gravity. **Source:** author, 2023.

According to the pristane/phytane and C35/C34 hopane ratios, the evaluated crudes correlate with generative organic facies deposited in anoxic-suboxic to carbonate marine platform environment. According to the relationship between pristane/phytane and oleanane/C30 hopane the evaluated crudes correlate with generating organic facies deposited from shelf marine environments (siliciclastic) with variable and slight carbonate contribution to carbonate marine environment, the period to which most of the crudes in the sector belong for the Carbonera, Mirador and Guadalupe reservoir formations corresponds to Cretaceous (see Figure 6).

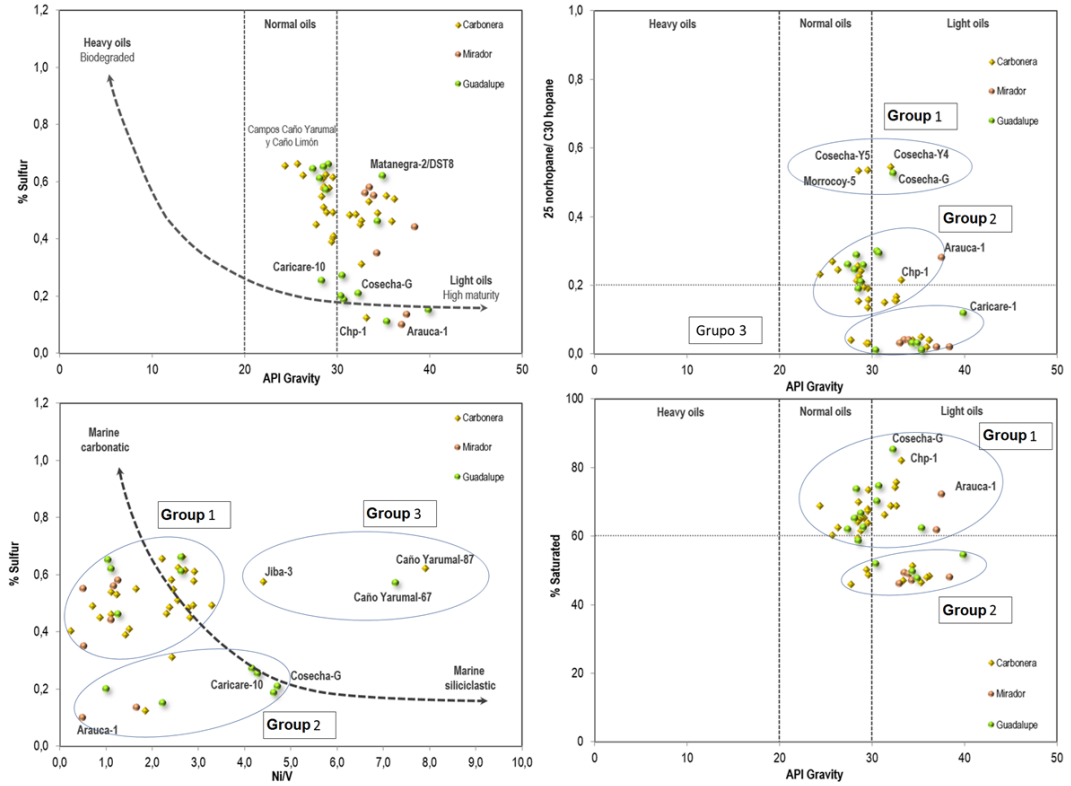

Figure 5. Quality graphs for the Arauca sector. **Source:** author, 2023.

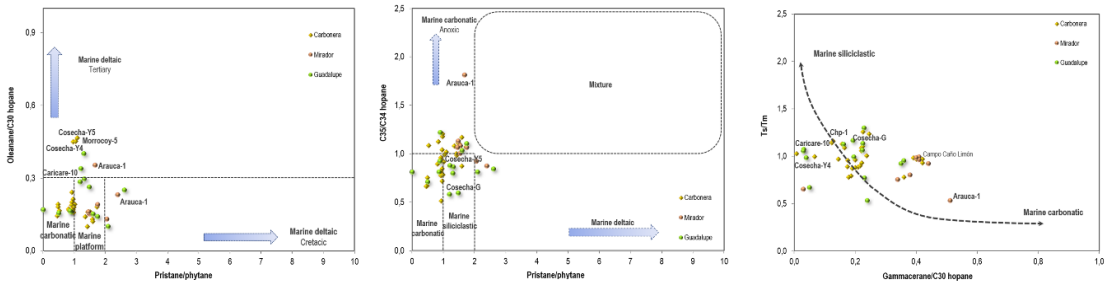

Figure 6. Depositional environment and age plots for the Arauca sector. **Source:** author, 2023.

5.2 Piedemonte Sector

The API gravity of the crudes evaluated in the Piedemonte sector of the Eastern Llanos basin varies between 25.7 and 48.4. Most of the crude data correspond to light crudes and have the best quality in the basin; likewise, the sulfur content and 25-norhopane/C30 hopane content have a notable decrease, which suggests a combination between intense to incipient biodegradation processes and crude mixture by refreshing (see Figure 7).

According to the pristane/phytane and C35/C34 hopane ratios, the evaluated crudes correlate with organic generating facies deposited from shelf marine to deltaic marine environments. According to the pristane/phytane and oleanane/C30 hopane ratios, the evaluated crude oils correlate with generating organic facies deposited from deltaic marine to shelf marine environments with low carbonate input, some from the Cretaceous and others from the Tertiary (see Figure 8).

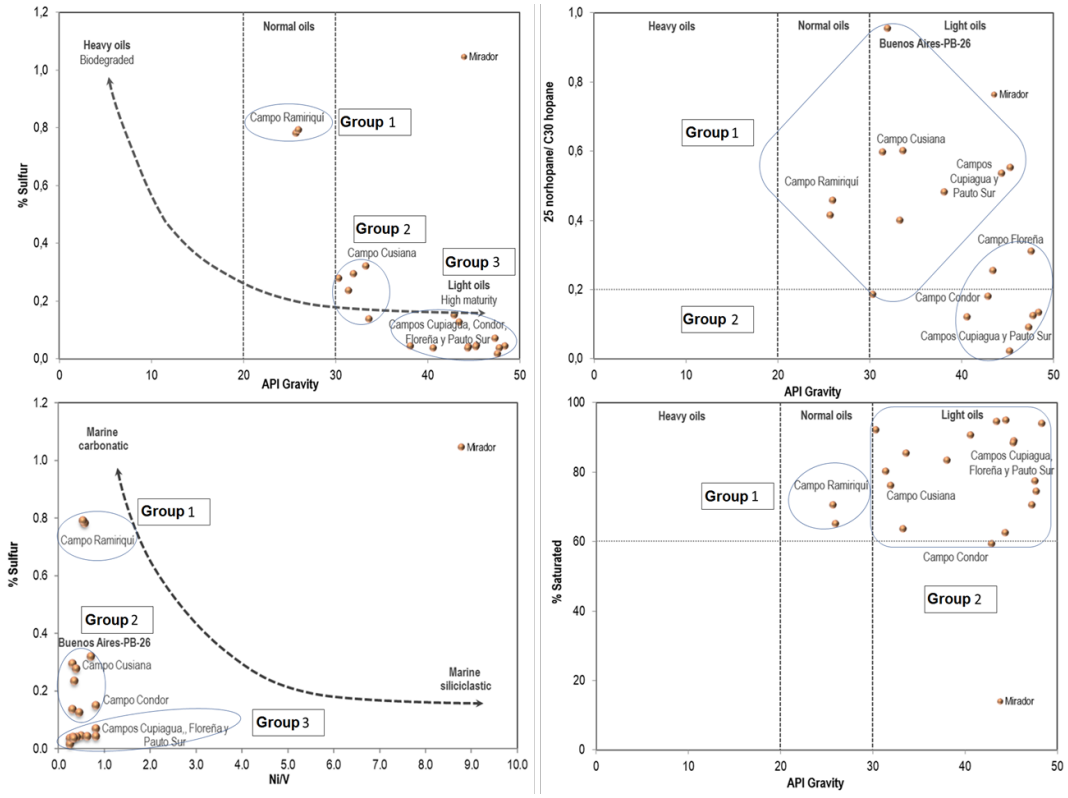

Figure 7. Quality plots for the Piedemonte sector. **Source:** author, 2023.

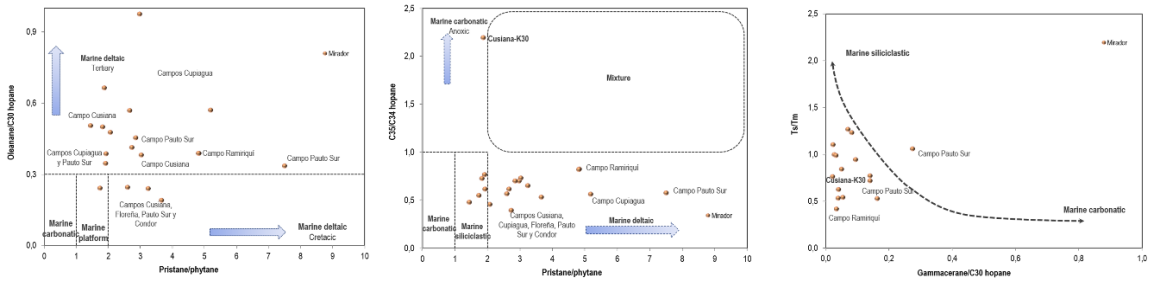

Figure 8. Depositional environment and age plots for the Piedemonte sector. **Source:** author, 2023.

5.3 Casanare Sector

The API gravity of the crudes evaluated in the Casanare sector of the Eastern Llanos basin varies between 11.0 and 42.1 and the sulfur content between 0.07 and 2.47 %. A tendency of increase in API gravity is observed in the crudes, going from heavy to light, likewise the sulfur content and the 25-norhopane/C30 hopane content have a notable decrease, finding crudes of low to very good quality, which suggests a mixture of crudes by refreshing and intense to incipient biodegradation processes (see Figure 9). According to the pristane/phytane and C35/C34 hopane ratios, the evaluated crudes correlate with generative organic facies deposited in shelf to shallow deltaic marine environments with variable carbonate input. According to the ratio between pristane/phytane and oleanane/C30 hopane the evaluated crude oils correlate with generating organic facies deposited from shelf marine and deltaic marine with variable carbonate

input, also crude oils from all reservoirs are in both Tertiary and Cretaceous zones (see Figure 10).

5.4 Meta-Vichada Sector

The API gravity of the crudes evaluated in the Meta-Vichada sector of the Eastern Llanos basin varies between 5.0 and 37.8. The crudes range from heavy to light, which have a tendency in which the sulfur content decreases while the API gravity increases, which could suggest that there is a mixture of crudes by refreshing and according to the content of 25-norhopane/C30 hopane suggests biodegradation ranging from intense to incipient (see Figure 11).

According to the pristane/phytane and C35/C34 hopane ratios, the evaluated crudes correlate with organic generating facies deposited in a siliciclastic marine platform environment with suboxic carbonate to carbonate marine environment. According to the ratio between pristane/phytane and oleanane/C30 hopane the evaluated crudes correlate with generative organic facies deposited from shelf marine and deltaic marine environments with variable carbonate input, also the crudes from all reservoirs are in both Tertiary and Cretaceous zones (see Figure 12).

6. ANALYSIS AND DISCUSSION

According to [23] the Llanos Orientales basin has a generation-accumulation efficiency (EGA) of approximately 5% and according to its geological and geochemical characteristics could reach an EGA of at least 8%, considering for this basin greater expectations and opportunities to find reserves where the risk associated to the hydrocarbon load is lower compared to the other basins in Colombia.

According to the analysis made regarding the quality of the crude, in the Arauca and Piedemonte sectors the crude is mostly light and of high quality, aligned in a northeast-southwest direction. In the Casanare sector the distribution of crudes shows that there are high, medium and low quality crudes, and a corridor of heavy crudes is observed oriented in a northeast-southwest direction from the Candelilla-Yatay field to the north in the Tilodirán and La Gloria Norte fields, and to the east of the corridor with the Rancho Hermoso and Carrizales fields; normal crudes are distributed from the eastern limit of the Piedemonte sector to the La Cuerva field and light crudes are widely shown from the La Punta, Maurita Norte, Rancho Hermoso, Barquereña and Trinidad fields, towards the east with the Dorotea, Corocora and Remache Norte fields. In addition, in the Casanare sector there is a distribution of heavy crude in the eastern end corresponding to the Caño Negro and El Miedo fields.

In the Meta-Vichada sector, the quality of crude is low and most of the crude is heavy, where the Akacias, Castilla, Chichimene, Hamaca, Suria, Quifa and Rubiales fields stand out. In general, the Eastern Llanos basin in its four sectors shows high prospectivity for crudes of all types of quality (Figure 6), the best quality crudes, light and better preserved, are shown in the north and center-west of the basin, in the sectors of Arauca, Piedemonte and central part of Casanare corresponding to the reservoirs of the Mirador, part of Carbonera and Guadalupe formations.

On the contrary, lower quality crudes with low API gravity values and more biodegraded are located in greater proportion towards the south, southwest and west of the basin, also in the Meta-Vichada sectors with reservoirs of the San Fernando formations, and part of Carbonera and Guadalupe, and Casanare in some data from the Mirador, Guadalupe and Lower Sands formations.

Regarding the depositional environments of the organic facies of the source rocks, a transitional deltaic marine to siliciclastic platform marine environment is suggested for the Arauca and Piedemonte crude oil fields, with variable carbonatic contribution, mild-suboxic (see Figure 9 and 10). In the Casanare sector, a depositional environment of the organic facies of the deltaic marine to siliciclastic platform marine source rocks with variable carbonatic contribution, suboxic-anoxic for most of the reservoir samples of the Carbonera Formation (see Figure 12).

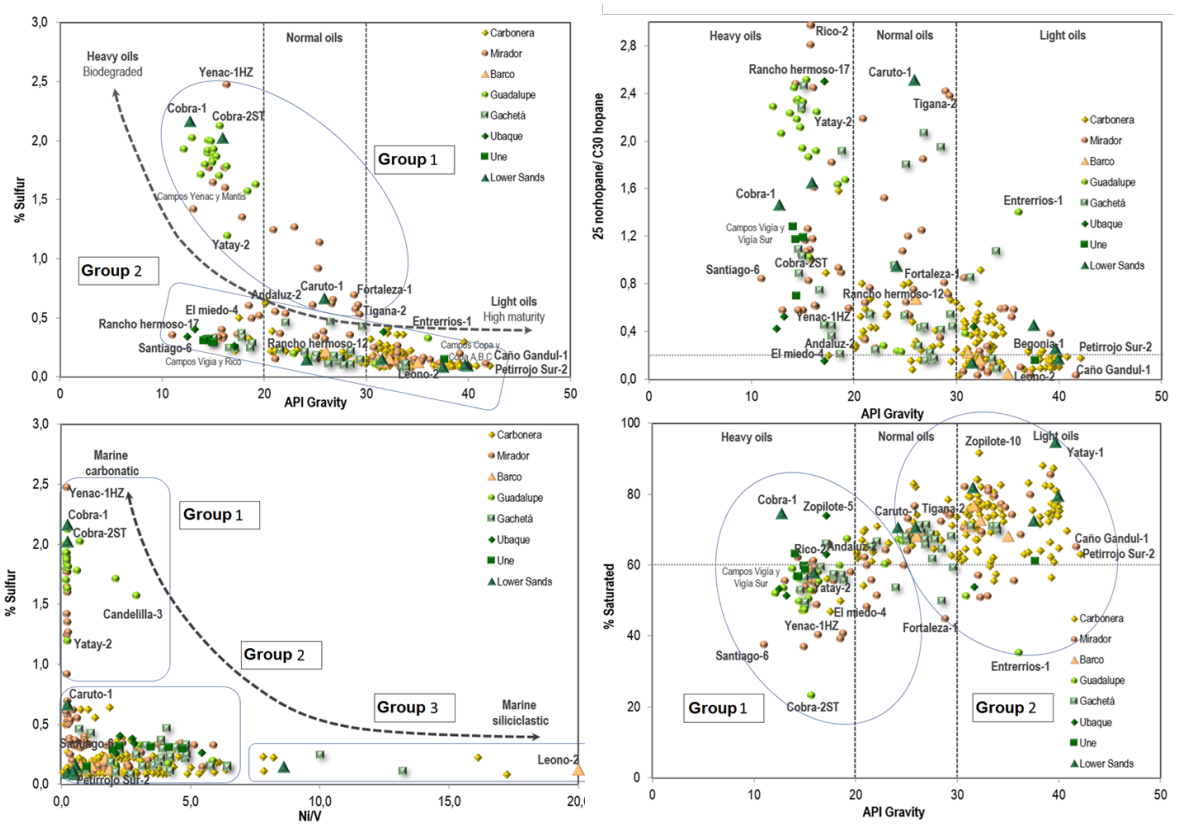

Figure 9. Quality plots for the Casanare sector. **Source:** author, 2023.

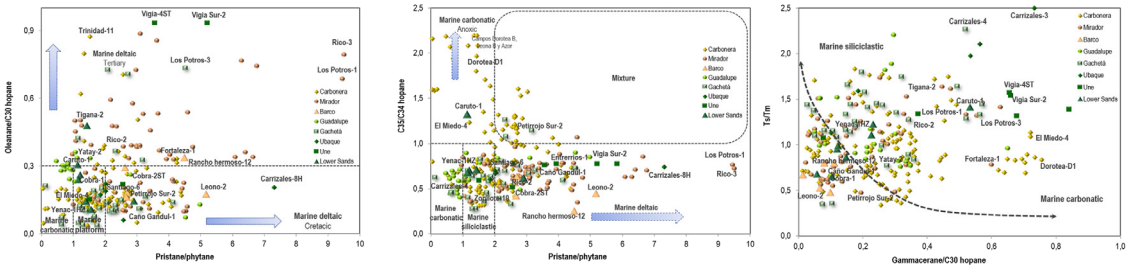

Figure 10. Depositional environment and age plots for Casanare sector. **Source:** author, 2023.

In the Meta-Vichada sector, a depositional environment of the organic facies of the siliciclastic marine platform source rocks with variable carbonatic contribution, suboxic for some of the samples from the Carbonera Formation reservoir (see Figure 14) and higher carbonatic contribution for the crude samples from the San Fernando Formation reservoir is suggested. In general, for the four sectors of the Llanos Orientales basin, the predominant depositional environment of the organic facies of the source rocks is deltaic marine to siliciclastic shelf marine with variable carbonatic contribution, suggesting crudes formed in complex organic facies environmental conditions. Regarding the age of the source rock, it shows that the crudes of each of the reservoirs are located in both the Tertiary and Cretaceous zones, which shows complexity in the basin and suggests a mixture of two crudes generated by very different stratigraphic facies.

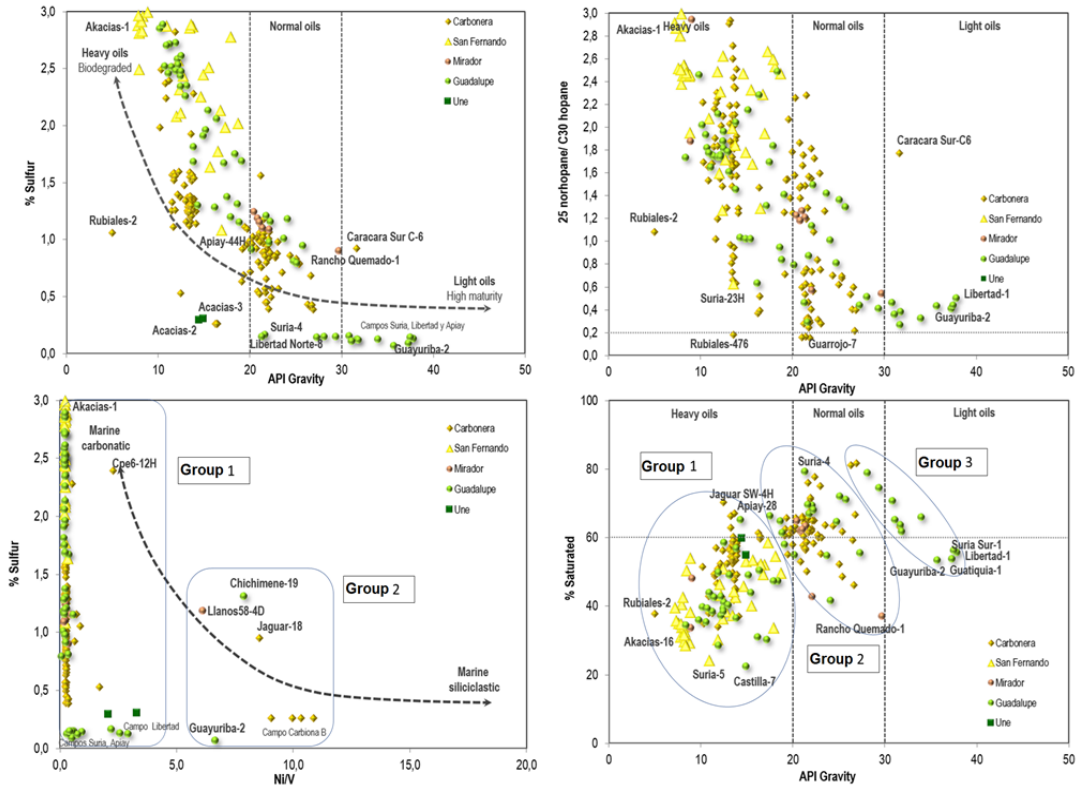

Figure 11. Quality plots for the Meta-Vichada sector. **Source:** author, 2023.

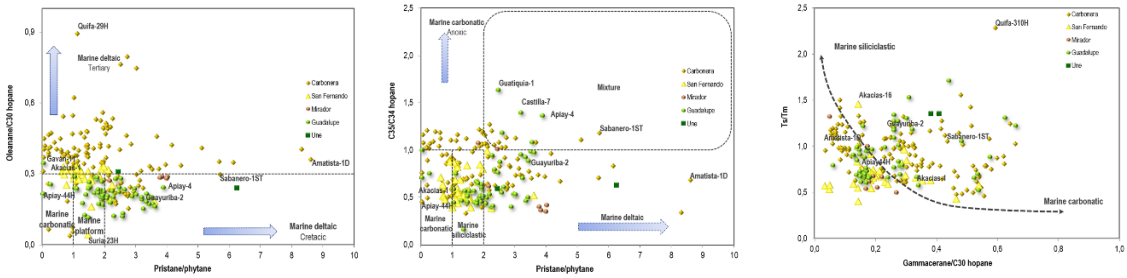

Figure 12. Depositional environment and age plots for the Meta-Vichada sector. **Source:** author, 2023.

It is necessary to complement this work with structural seismic interpretation that allows a good analysis of the reservoir formations coverage in the area, and thus link it with the geochemical interpretation performed. The above is a tool that allows a regional vision to analyze the areas in which possible prospectivity corridors can be found if combined with 1D and 3D petroleum systems modeling and even yet to find analysis, and check if the plays associated to the fields with commercial production are also present in these areas.

7. CONCLUSIONS

It was found that the best quality, light and better preserved crudes were found in the piedmont sector with the Mirador Formation as reservoir, suggesting a depositional environment of the deltaic marine to shelf marine generating facies. Lower quality crudes, with low API gravity values and more biodegraded, were found in the Meta-Vichada sector with the San

Fernando Formation reservoir, suggesting a depositional environment of predominantly carbonate shelf marine generating facies. Regarding the age of the source rock, it showed that the crudes from each of the reservoirs are located in both the Tertiary and Cretaceous zones, which evidences complexity in the basin and suggests a mixture of two crudes generated by very different stratigraphic facies.

A total of 631 crude oil sample data were compiled, classified by geological and production provinces of the Eastern Plains basin; samples with complete information on reservoir rock and API gravity were also analyzed. Finally, information on coordinates, field to which the sample belongs, crude quality and generalized name of geological formation for each reservoir rock present was added to the compiled data.

A mapping of 576 data with reservoir rock information and 619 data with crude quality information was performed for the four sectors of the Llanos Orientales basin, which has very varied quality, finding crudes ranging from heavy to light. The best quality crudes are located in the north and center-west of the basin, in the sectors of Arauca, Piedemonte and central part of Casanare corresponding to the reservoirs of the Mirador, part of Carbonera and Guadalupe formations. Lower quality crudes are located in the south, southwest and west of the basin in the Meta-Vichada sectors with reservoirs in the San Fernando, part of Carbonera and Guadalupe formations; and Casanare in some data from the Mirador, Guadalupe and Lower Sands formations.

The exploratory implications evaluated in this work can be associated with a complete geochemical modeling that includes 1D, 3D modeling and prospectivity corridor analysis that represents an input for the current exploration in the Llanos Orientales basin. It is known that several companies of the Oil and Gas industry continue making efforts and large investments in the search for resources that preserve Colombia's energy sufficiency in the energy transition process it is facing. It is also necessary to combine this type of work with other disciplines in order to have a grounded regional vision of the prospectivity in the basin.

8. FUTURE WORK

For the continuation of the interpretation it is convenient to map other variables so that the correlation with the geochemistry graphs is more accurate and thus to obtain more information of the crudes with biodegradation and blending.

The graphs used for the interpretation had to be used with predetermined values in their axes, for this reason some data, although they were plotted, do not appear, therefore, their analysis was omitted. According to the above, it would be necessary to complement the geochemical interpretation with other graphs or techniques.

Since the data obtained from crude oil comes from the public database of the ANH, it would be useful to feed this database so that crude samples appear with more information and thus perform analysis and studies of better quality.

A complementary work would be to perform an analysis of crude families for each sector, based on the geochemical interpretation, the geographic location of the data and the use of a statistical analysis software; to obtain correlation diagrams "cluster" type.

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