

# STUDY REPORT

## Geochemical Study of Sedimentary Basins and Oil Seeps of the Dominican Republic

December 2023

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**INDEX**

1.	INTRODUCTION.....	4
2.	LITERATURE REVIEW .....	4
3.	SAMPLING CAMPAIGN.....	5
4.	ANALYTICAL PROGRAM .....	8
5.	METHODS AND ANALYTICAL WORKFLOW.....	9
6.	RESULTS .....	12
6.1	Sedimentology - Digital Cuttings.....	12
6.2	Inorganic geochemical characterization of rock samples.....	13
6.3	Thin section petrography.....	14
6.4	Micropaleontology.....	15
6.5	Source rock characterization – TOC and Pyrolysis.....	16
6.6	Source rock characterization – Vitrinite reflectance and Palynofacies .....	16
6.6.1	Vitrinite reflectance .....	16
6.6.2	Palynofacies .....	19
6.7	Gas-chromatographic (GC-FID) characterization of migrated and indigenous hydrocarbons (G9+) .....	20
6.8	Geochemical characterization of oil seeps .....	21
6.8.1	HRGC analysis.....	21
6.8.2	GC-MS and GC-MS/MS analysis.....	22
6.8.3	EA-IRMS analysis.....	24
6.8.4	Oil-source rock correlation .....	26
7.	CONCLUSIONS.....	29

## 1. INTRODUCTION

The present project has been completed to meet the requirement of the contract awarded by the Ministerio de Energía y Minas (MEM) to Geolog called: "Execution of a geochemical study, identifying and selecting areas of exploratory interest using geological, geochemical and geophysical criteria with a focus on hydrocarbon exploration, enabling the geochemical information of the different elements that make up the petroleum system of the Dominican terrestrial sedimentary basins, which allows to support future competitive processes of allocation of areas for the oil and gas exploration in the Dominican Republic".

In recent years, petroleum geochemistry has been characterized as a mature science, meaning that powerful and remarkably successful theories and tools were developed to characterize source rocks and to understand the origin, migration, and accumulation of petroleum. Geochemistry increases exploration efficiency by accounting for many of the variables that control the volumes of petroleum available for entrapment (charge), including source rock quality and richness, thermal maturity, and the timing of generation-migration-accumulation relative to trap formation. Moreover, geochemistry is the key to petroleum systems because it is required to establish the genetic link between petroleum and potential source rock(s) and to map the extent of the petroleum system.

The aim of the present project is to establish the potential occurrence of petroleum accumulation by means of geochemical tools applied to surface exploration. Therefore, outcrops, cuttings and oil seepages from different basins of the Dominican Republic have been sampled and subjected to several geochemical analyses to evaluate the occurrence and quality of the different elements of a petroleum system, in particular the source rock, the reservoir rock, the seal rock and the presence of hydrocarbons, either accumulated or bypassed (useful to identify migration pathways).

The present document and relative enclosed ones report the main findings of the study, which are also discussed in detail in a dedicated presentation done by Geolog Technologies (GeoTech) personnel to Dominican Republic technical and government representatives.

## 2. LITERATURE REVIEW

The literature on the Petroleum Systems of the Dominican Republic is not particularly rich; a selection of the most interesting papers published in the last twenty years has been collected in [Annex 2.0](#).

A comprehensive review of both literature and available data was edited during a collaboration between the governments of Cuba and the Dominican Republic by a group of experts (2006 – Capriles et al.).

More recently two groups of researchers of the Universidad Complutense of Madrid and of the University of Houston were very active on this subject. A Special Publication of the Geological Society of London includes their most recent studies (Davison, I., Hull, J. N. F. and Pindell, J. Eds -2021 - **The Basins, Orogens and Evolution of the Southern Gulf of Mexico and Northern Caribbean**. - Geological Society, London, Special Publications, 504, 437–478).

In short, the possible critical aspects of the petroleum systems of all the basins in the Dominican Republic have been defined as follows:

1. Sandstone reservoirs are likely to be of poor quality because Cretaceous–Cenozoic sandstone is mainly derived from the erosion of quartz-poor, clay-rich rocks of the leading edge of the Caribbean plate. Caribbean carbonate reservoirs, with a few exceptions, have not proven successful in this region (for a more comprehensive review of the sedimentology literature, refer to the relevant report in Annex 6.1).
2. Structural traps are likely to be complex and breached by pervasive, Neogene faulting.
3. Source rocks are likely to be poor to fair, deposited under dysoxic environments (Kerogen II/III to III) and confined to smaller depocenters.
4. Timing is a key issue that must be addressed and assessed in any future exploration in the basin.

Points 3 and 4, i.e., the presence and maturation of the source rock(s), are probably the most concerning in terms of hydrocarbon potential in the area.

All the authors agree on the need for a more detailed definition of the Petroleum System(s) through the acquisition of new data focused in particular on source rocks.

### **3. SAMPLING CAMPAIGN**

This chapter deals with the first phase of the study ranging from the planning to the collection of lithological samples at the level of the geological formations of interest that make up the elements of the possible petroleum systems of the different basins.

Information from the MEM Database was used, as well as stratigraphic columns, and descriptions of Bedrock, Reservoir Rock and Seal Rock highlighted in the document called "1st Licensing Round of the Dominican Republic". Regarding the geological and topographic maps, and the descriptive reports, they were provided by the National Geological Service (SGN), serving as the main background for the project.

The activities of this first stage have been divided into two phases. The first phase was planning prior to sampling, where the background of the area to be studied, geological and topographic maps, as well as the access roads to the type localities were evaluated. During this phase Geolog has digitized the outcropping geological formations of interest through the geological maps, in order to visualize the areal extent of the basins to be evaluated and to prepare a representative sampling.

The second phase consisted of detailed geological observation, collection of data and representative samples of fresh rock (not weathered) at the level of the formations of interest for the Azua, Enriquillo, Cibao, San Juan and Llanura Oriental basins.

All the geological maps were georeferenced and scaled in Google Earth to spatially place unique geographic features defined within a specific coordinate system and datum. Special reference was made to the coordinates of the map versus the satellite image, although in some cases they were

confirmed with the roads in the area, hydrography and with the most outstanding topographic features located. In addition, each of the outcropping geological formations in the various basins studied were digitized, converting the geographic information available in analog to digital formats.

All the selected samples were representative of the formations of interest and special emphasis was placed on petrographic identification, sedimentary structures, mineral reactions, with the aim of comparing rocks belonging to formations of the same age in different parts of the areas under study. Another important factor, which in some cases was difficult to achieve, was to ensure that the rock was as fresh as possible, avoiding weathered levels. They were numbered, marked, labeled and placed in plastic bags to protect them from abrasion or contamination. Regarding the samples required for the micropaleontological description, they were oriented with respect to the stratigraphic top of the evaluated sequence, taking special care to avoid cross-contamination with samples from other localities.

A total of 159 samples were taken, of which 128 correspond to outcrops distributed along the outcrop formations of interest for all the basins evaluated, additionally they were completed with 26 samples of drill cuttings. The selection of the sampling was punctual, where the quality of the outcrop and the geomorphological and/or vegetation conditions allowed it. They were taken in proportion to the outcropping area to achieve an areal cover that would allow the definition of good correlative patterns between the geological formations and basins.

The outcrop samples sampled by each basin are:

**Cuenca Azua (23 samples)** – Fm. Neiba (0), Fm Ventura (4), Fm El Número (3), Fm Jura (4), Fm. Ocoa (4), Fm. Sombrerito (4), and Fm Trinchera (4).

**Cuenca Enriquillo (22 samples)** - Fm. Neiba (6), Member Aguacate de Neiba (1) Fm Sombrerito (8), Fm. Trinchera (2), Fm. Angostura (3) and Fm. Jimaní (2).

**Cuenca Cibao (50 samples)** – Fm La Toca (4), Gr Tabera (4), Fm. Altamira (5), Fm. Cercado (10), Fm. Gurabo (14), Fm. Mao Adentro (3), and Fm Mao (10).

**Cuenca San Juan (12 samples)** – Fm. Trois Revieres (3), Fm. Ventura (3), Fm Jura (1), Fm Neiba (1), Fm. Sombrerito (2) and Fm. Trinchera (2).

**Cuenca Llanura Oriental (17 samples)** – Fm. Las Guayabas (4), Fm. Rio Chavón (4), Fm. Loma de Anglada (4), Upper Cretaceous Limestone (2), Fm. Yanigua (2), and Fm Los Haitises (1).

**Cibao East Basin (4 samples)** – Fm Las Guayabas (4).

**Drill cuttings (26 samples)** - Caño Este-1 well (8 samples – Possible Miocene, Possible Miocene – Oligocene and Possible Oligocene); Maleno Este-1 and Maleno Este-2 wells (18 samples – 5 Fm. Arroyo Blanco and 13 Fm. Trinchera).

A detailed report describing the sampling campaign is available together with the georeferenced maps and the location of the sampling is available in [Annex 3.0](#). Pictures of the outcrop samples can be found in [Annex 3.1](#).

#### 4. ANALYTICAL PROGRAM

A summary of the analyzed sampled, classified by basin and type of analysis is reported below. A detailed sample manifest with comprehensive sample description and performed analyses is enclosed to the present document as separate spreadsheet (**Annex 4.0**). The present analytical program is different from the one originally agreed. This is due to obtained experimental results, which required amendments to cope with encountered sample quality and organic abundance.

*Table 4.1. Summary of inorganic characterization analyses carried out in the present campaign.*

Location	XRD	XRF	Digital cuttings	Thin sections and Petrography	Paleontology
Azua	23	23	23	6	4
Enriquillo	22	22	22	8	4
Cibao	50	50	50	7	7
San Juan	12	12	12	1	3
Llanura Oriental	17	17	17	2	4
Cibao Este	4	4	4	-	-
Rio Blanco (Cordillera Central)	5	5	5		
Cuttings (Maleno1, Maleno2, Caño Azul)	26	26	26		

*Table 4.2. Summary of organic characterization analyses carried out in the present campaign.*

Location	G9+	TOC	Pyr	Ro%	Palynofacies	GCMS	GCMSMS	HRGC	d <sup>13</sup> C
Azua	23	13	9	5	7				
Enriquillo	22	22	7	4	7	-	-	-	-
Cibao	50	50	6	5	13	-	-	-	-
San Juan	12	12	6	3	4	-	-	-	-
Llanura Oriental	17	17	5	3	4	-	-	-	-
Cibao Este	4	4	2	1	1	-	-	-	-
Rio Blanco	5	5	5	1*					6
Cuttings - (Maleno1, Maleno2, Caño Azul)	26	26	23						
Oil seepages						6	3	3	6

\*Analyzed by Raman Spectroscopy to get equivalent Ro%



## 5. METHODS AND ANALYTICAL WORKFLOW

The general analytical workflow adopted in the present study is reported in Fig. 5.1.

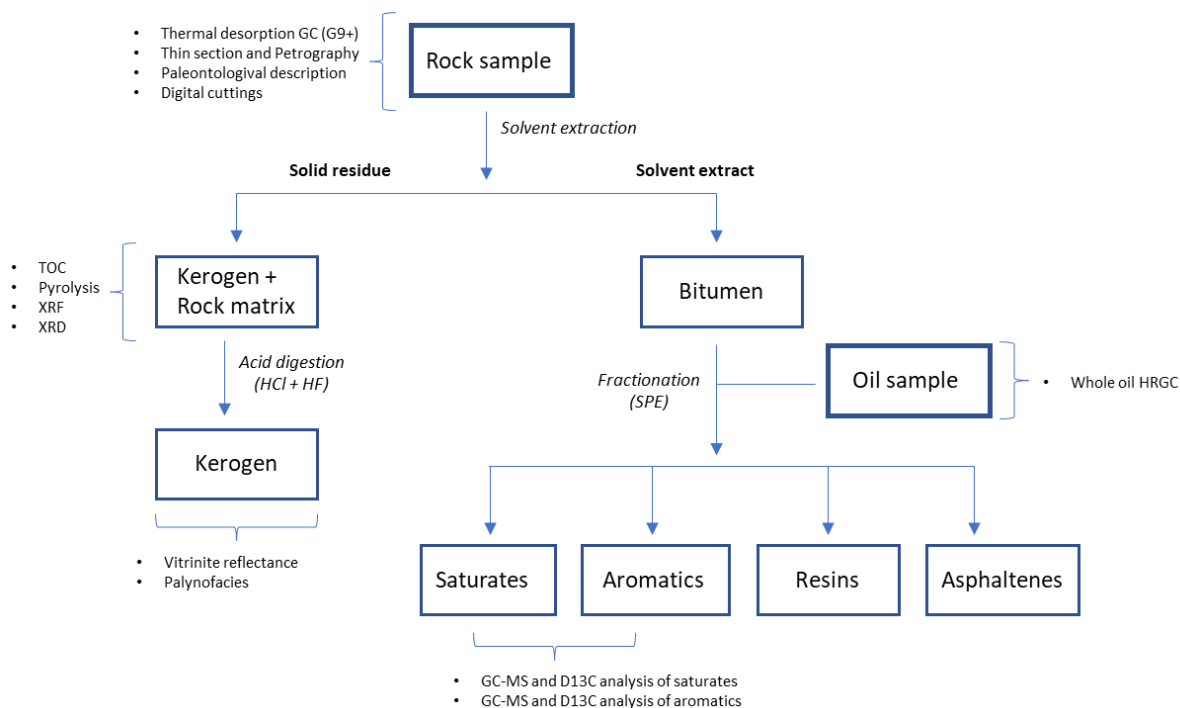


Fig. 5. 1. Analytical workflow adopted in the present campaign.

A quick description of the different analyses carried out in this study is reported below. A detailed analytical procedure is reported in the appendix enclosed with the present report.

- **TOC (Total Organic Carbon).** Total organic carbon is determined in (solvent) washed and dried rock samples using a carbon analyzer Elementar® Vario TOC Select®, which oxidizes the sample at 980 °C. Before analysis, the sample is treated with HCl to remove carbonates. Calibration and quality check are carried out using certified standards. The analysis is aimed to determine the abundance of organic matter in (potential) source rock samples, which in turn affects its capability to generate hydrocarbons.
- **Pyrolysis.** The pyrolysis is carried out using a bulk-flow pyrolysis-FID instrument (GeoPyrolysis®) similar to a RockEval instrument. Calibration and quality check are carried out using certified standards. It allows the determination of S1, S2, Tmax and allows to calculate the production potential (PP), the production index (PI) and the hydrogen index (HI). Pyrolysis experiments are used to understand the type of organic matter in a (potential) source rock, as well as its thermal maturity.
- **Thermal desorption gas Chromatography (TD-GC).** Detailed characterization of hydrocarbons thermally extracted (330°C) from rock samples using a proprietary instrument (G9+®). GC-FID characterization of C9-C35 profile, including zonation in light, medium and heavy hydrocarbons, oil maturity/biodegradation estimation through biomarkers (pr/nC17 and

ph/nC18) and UCM determination. It is used as a screening tool to select samples for further advanced analyses.

- Vitrinite reflectance (Ro%). This measurement allows to obtain information about thermal maturity of kerogen. It represents the reference methodology in industry for thermal maturity assessment. The measurements can be done either on solvent washed rock samples (polished plugs) or kerogen concentrates. The reflectance measurement is made on vitrinite/huminite (preferably telocollinite) under oil immersion oil at a wavelength of 546 nm (unpolarized light). Maceral descriptions follows the guidelines laid down by the ICCP (1963, 1971, 1975) and ISO (1994 c).
- Palynofacies description. The purpose of this analysis is to provide indications on the kerogen composition (palynofacies determination) and source rock maturity (Thermal Alteration Index). These analyses are normally integrated with other data (e.g., pyrolysis data, vitrinite reflectance). The palynological content is then analyzed by transmitted light microscopy, while TAI is measured by observing the color changes of sporomorphs (i.e., pollen and spore grains) under a transmitted light microscope.
- Gas Chromatography -Mass Spectrometry (GC-MS) analysis of the saturate and aromatic fractions. This analysis provides the detailed composition of the saturate fraction in terms of n-alkanes, isoprenoids and biomarkers, including steranes and terpanes (saturated biomarkers), as well as polycyclic aromatic components (C10-C22), including monoaromatic and triaromatic steranes. In order to separate whole extract/oil into saturate and aromatic fractions (also, removing resin and asphaltene fractions), a pre-analytical fractionation step is carried out by using solid phase extraction (SPE) silica cartridges.
- Gas Chromatography – Tandem Mass Spectrometry (GC-MSMS) analysis of saturate fraction. This analysis is carried out on saturate fraction to determine more complex petroleum biomarkers and compute relative geochemical parameters.
- High Resolution Gas Chromatography (HRGC) analysis of whole oil. The purpose of this analysis is to obtain a quantitative composition of the gasoline-range hydrocarbons for characterization and correlation of fluids. Therefore, a full resolution of all hydrocarbons in the C6-C8 range is achieved. It also provides the fingerprint of the whole "stabilized" fluid, with quantification of the n-alkanes, pristane and phytane in the C8-C40 range.
- d<sup>13</sup>C analysis via Elemental Analyser Isotope Ratio Mass Spectrometry (EA-IRMS). This analysis provides stable carbon isotope ratios of the bulk hydrocarbon composition in saturate and aromatic fractions. This analysis is accomplished by means of a continuous-flow isotope ratio mass spectrometer coupled with an Elemental Analyzer (EA-IRMS). All analyses are performed in triplicate (at least) reported in per mil vs. VPDB, with a standard deviation usually less than 0.3‰.
- XRD analysis. Crystalline mineral analysis of cuttings using X-Ray Diffraction. Provides quantification of all crystalline minerals and information on the total amount of clays. Calibration is done on more than 40 synthetic mixtures of certified reference minerals and real rock samples are used for fine-tuning of the quantification method.

- XRF analysis. Elemental analysis of cuttings using X-ray Fluorescence is carried out on powdered samples. The following elements are included into analysis and quantified: Al, As, Ba, Ca, Cl, Co, Cr, Cs, Cu, Fe, Ga, Gd, K, La, Mg, Mn, Mo, Nb, Nd, Ni, P, Pb, Rb, S, Si, Sr, Th, Ti, U, V, Zn, Zr.
- Digital Cuttings. High-Resolution Digital images, colour averages, integrated with XRF and XRD, cuttings morphology, to generate lithofacies and lithotypes using brightness and luminance.
- Petrography and thin section. Petrographic description is performed on standard 30 micron thin sections obtained from outcrop samples. Thin sections are then put under a polarized microscope to obtain qualitative and semi-quantitative information on rock's texture, structure, mineralogy, alteration, fossiliferous content, cementation, and porosity.
- Paleontological description. The study of microfossils is performed on thin sections observed under transmitted light using a stereomicroscope; this analytical technique allows to identify microfossils and their association is crucial for paleoenvironmental reconstructions and determination of depositional age.

## 6. **RESULTS**

### 6.1 **Sedimentology - Digital Cuttings**

The detailed results are available in [Annex 6.1](#).

In this section, the sedimentary features observed for the various formations, both in literature and in the present study, have been presented in more detail for the different basins.

The study is based on the integrated interpretation of the results coming from different analytical techniques including:

- Digital-Cuttings analysis (Ann. 6.1),
- petrographic analysis (Ann. 6.3),
- micropaleontological analysis (Ann. 6.4),
- palynological analysis (Ann. 6.6).

A Digital-Cuttings summary sheet for the whole basin is found in Annex 6.1, where sample locations, pictures and analytical results are presented in an integrated way to facilitate comparison.

Overall reservoir development in the studied samples seems to be low and mostly confined to carbonate lithologies. The observed sandstone samples, even when coarse grained, appear to be consistently characterized by common clay-rich matrix and localized fracture-filling calcite, which prevented the preservation of any noticeable open porosity.

In the Enriquillo Basin, the mid-ramp bioclastic carbonates of the Neiba Superior and at the base of the Sombrerito Fm. appear to have some possible reservoir development, within minor intraparticle, mouldic and vuggy porosity. The clastic Trinchera Fm. does not show any reservoir development.

In the San Juan Basin, the analysed carbonate facies of the Neiba and Sombrerito formations appear to be mostly tight, due to non-porous matrix and/or calcite cementation. No noticeable reservoir development in the Trinchera Fm.

In the Azua Basin, the Sombrerito bioclastic wacke-packstones show poor to fair reservoir development, associated with minor intraparticle, mouldic and vuggy pores. Minor interparticle porosity appears to be present at the sandstones at the base of the Trinchera Formation.

The Cibao Basin hosts the largest amount of good reservoir rocks, observed in reef-related carbonates of the Altamira, Cercado, Gurabo and Mao (Adentro Mb.) formations. These lithofacies are generally characterized by large bioclastic fragments and associated large inter and intraparticle pores, moulds and vugs. The localized presence of tighter interbeds and the locally isolated nature of some of these large pores in a possibly tight micritic matrix may result in lower reservoir quality than initially expected for these formations.

In the Llanura Oriental, very good reservoir quality is hosted in the reefal facies of the Yanigua and Los Haitises formations, thanks to the presence of large inter and intraparticle pores, moulds and vugs. Locally, the presence of a large network of open burrows may exponentially increase the connectivity of these common large pores.

The dominance of carbonate-hosted reservoir development in the observed samples from the various basins of the Dominican Republic suggests that lateral reservoir distribution may be relatively limited, depending on the lateral extent of the reefs and/or high-energy mid-ramp environments recorded in the various formations. While good reservoir hosted within turbiditic formations can be traced for long distances, good reservoir hosted in shallow carbonate platform facies may have a patchier distribution, which is harder to predict. This must be kept in mind when planning to explore these potential reservoirs.

## 6.2 Inorganic Geochemical Characterization of Rock Samples

A detailed picture of geological formations and their chemical and mineralogical composition is crucial to identify and evaluate the role of every geological formation, which is needed for a reliable petroleum system assessment.

Inorganic geochemical characterization of both outcrop and cuttings samples is performed by coupling the elemental composition and the bulk mineralogy of each sample obtained respectively using X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) analytical techniques.

Cutting samples are initially washed with water to remove any mud contamination that could invalidate the analytical results, while outcrop samples do not need any washing passage.

A representative portion of every sample is then milled using a planetary ball mill and the obtained sample powder is analyzed first with Malvern-Panalytical Epsilon 1 XRF and then with ThermoFisher Equinox 100 XRD

The detailed results are available in [Annex 6.2](#) and they're divided by basins and wells into different excel files. Every file contains the following sheets:

- XRF\_Ox\_age labelled: shows elemental composition of main elements in percentage and of trace elements in ppm for every sample. Samples are ordered by age from the younger to the older. Main elements' values are expressed in oxides except Sulphur because is usually accumulated in sediments under anoxic condition in a reducing environment. In addition to elemental composition there is also shown a computed parameter, Chemical Gamma Ray (CGR), that is calculated using U, Th and K values, as well as some ratios that can be used as proxies for rocks characterization; these ratios are grouped into thematic fields and can be used as indicators of particular geological related events or processes that were prevalent during geological history as sand/clay ratio, sediment provenance, paleo-redox conditions, carbonate diagenesis and fracturation intensity.
- XRF\_Ox: same as XRF\_Ox\_age labelled but the samples are not ordered by age.
- XRF\_el: main elements percentages are expressed in elements rather than oxides.

- XRD data age labelled: contains mineralogical composition in percentages for every sample ordered by geological age. Minerals are grouped with color-coding into Carbonates, Silicates, Accessories, Evaporitic, Clays & Micas mineral super-groups.
- XRD data: same as XRD\_ data age labelled but the samples are not ordered by age.
- Plots (only readable on cuttings samples): The mineralogical composition of cuttings samples, as well as the mineral's super-groups are plotted in two horizontal logs to help the visualization of mineralogical changes.

### 6.3 Thin Section Petrography

The results of the study are summarized in Table 6.3.1. The pictures of the thin sections and the detailed petrographic interpretation are available in [Annex 6.3](#).

*Table 6.3.1. Summary of the thin section petrography results*

Sample code	Basin	Geological Formation	Lithology	Classification	Depositional environment	Porosity
1P	Azua	Ocoa	Siliciclastic	Terrigenous mudstone	Turbidite	No visible porosity
6P	Azua	Sombrerito	Carbonate	Packstone	Carbonate ramp	Primary < 5-10% ; Secondary 5-10%
9P	Azua	Jura	Siliciclastic	Lithic Wake	Turbidite	No visible porosity
12P	Azua	El Número	Carbonate	Wakestone	Pelagic	No visible porosity
13P	Azua	El Número	Siliciclastic	Siltstone	Turbidite	No visible porosity
18P	Azua	Trinchera	Carbonate	Mudstone / Wakestone	Pelagic	No visible porosity
19P	Azua	Trinchera	Siliciclastic	Sandstone/ Lithic arenite	Turbidite	No visible porosity
21P	Azua	Ventura	Carbonate	Wakestone	Pelagic environment	No visible porosity
24P	Enriquillo	Neiba sup.	Carbonate	Packstone	Reef/ carbonate shoal	Primary 2-5% ; Secondary 1%
25P	Enriquillo	Sombrerito	Carbonate	Packstone	Pelagic	Primary 10%
28P	Enriquillo	Aguacate Neiba	Carbonate	Mudstone	Pelagic	Primary 2-5%
30P	Enriquillo	Sombrerito	Carbonate	Mudstone	Hemipelagic	Primary 1%
32P	Enriquillo	Trinchera	Siliciclastic	Lithic Arenite	Turbidite	No visible porosity
34P	Enriquillo	Jimaní Inferior	Carbonate	Breccia/ Rudstone	Carbonate ramp	No visible porosity
38P	Enriquillo	Neiba Inferior	Carbonate	Wakestone	Pelagic	No visible porosity
41P	Enriquillo	Angostura	Carbonate	Mudstone	Pelagic / hemipelagic	No visible porosity
55P	Cibao	Cercado	Siliciclastic	Arenite	Turbidite	No visible porosity
65P	Cibao	Gurabo	Carbonate	Mudstone / Wakestone	Hemipelagic	No visible porosity
69P	Cibao	Mao Adentro	Carbonate	Packstone	Reef/carbonate shoal	Primary 2-5% ; Secondary 3%
80P	Cibao	Altamira	Siliciclastic	Lithic arenite/ Mudstone	Turbidite	No visible porosity
84P	Cibao	La Toca	Siliciclastic	Arenite	Turbidite	No visible porosity

89P	Cibao	Mao	Carbonate Siliciclastic	Terrigenous Mudstone	Hemipelagic	Secondary 2%
95P	Cibao	Grupo Tavera	Siliciclastic	Arenite	Turbidite	No visible porosity
102P	San Juan	Trois Revieres	Siliciclastic	Lithic Arenite	Turbidite	No visible porosity
109P	Llanura Oriental	Rio Chavon	Carbonate	Packstone/ Mudstone	Pelagic	Primary 5%
113P	Llanura Oriental	Loma de Anglada	Carbonate Siliciclastic	Terrigenous Mudstone	Turbidite	No visible porosity
125P	Cibao Este	Las Guayabas	Siliciclastic	Arenite	Turbidite	No visible porosity

#### 6.4 Micropaleontology

This chapter includes the results of the micropaleontological study carried out in 22 samples collected in the different areas of Hispaniola (4 samples in the Azua Basin, 7 in the Cibao Basin, 4 in the Enriquillo Basin, 4 in the Llanura Oriental Basin and 3 in the San Juan Basin). These samples have been dated, to the extent possible, based on their contained in microfossils by Dr. M<sup>a</sup> Luisa Canales Fernández, micropaleontologist and Professor of the Department of Geodynamics, Stratigraphy and Paleontology of the Faculty of Geological Sciences of the Complutense University of Madrid (Spain).

The final reports are available in [Annex 6.4](#)

The samples were collected during the sampling campaign run by Geolog and then sent to the Complutense University for the thin section preparation and the following micropaleontology study.

The thin sections for the study of these samples have been made in the laboratories of the Department of Geodynamics, Stratigraphy and Paleontology of the Faculty of Geological Sciences of the Complutense University, following a classic methodology, although some of the samples have required an additional consolidation treatment using Epoxy resins, due to their poor consistency.

The study of the thin sections was carried out with a Wild M8 microscope, equipped with x10 eyepieces and a x50 zoom (Fig. 3a). The photographs were taken using a Dino-Lite 2.0 device previously attached to the microscope eyepieces.

The determination of the microfossils identified in each of the samples has been carried out using the specialized bibliography in each of the groups.

The following information is provided for each of the samples studied:

- Previous data provided by GEOLOG, which in turn used the background information provided by the MEM and the SGN of the Dominican Republic.
- Description de visu and/or with a hand-held magnifying glass or binocular magnifying glass of the sample received, made prior to its sending to the laboratory for the preparation of the thin sections.
- Description of the thin sections obtained.
- Description of the microfauna contained in the sample.
- Determination of the age of the sample, when allowed by the microfauna.

## 6.5 Source Rock Characterization – TOC and Pyrolysis

Much of modern petroleum geochemistry depends upon accurate assessment of the hydrocarbon-source capabilities of sedimentary rocks. The first step always consists of total organic content (TOC) determinations, which are expressed as TOC values in weight percent of the dry rock. TOC represents a screening tool, due to its low cost-high turnaround. Rocks containing less than 0.5% TOC are considered to have negligible hydrocarbon-source potential. The amount of hydrocarbons generated in such rocks is so small that expulsion simply cannot occur. Furthermore, the kerogen in such lean rocks is almost always highly oxidized and thus of low source potential. Rocks containing between 0.5% and 1.0% TOC are marginal. They will not function as highly effective source rocks, but they may expel small quantities of hydrocarbons and thus should not be discounted completely. Rocks containing more than 1% TOC often have substantial source potential. However, TOC alone is not sufficient to assess source potential, since many rocks with high TOC values still contain kerogen that is woody or highly oxidized (poor hydrocarbon source quality). Therefore, subsequently to TOC screening, pyrolysis measurements, vitrinite reflectance and palynofacies description are carried out on selected samples to assess organic matter quality and thermal maturity. These analyses, due to higher costs and lower turnaround, are generally done on a more limited number of samples, selected based on TOC results.

The detailed results of TOC and Pyrolysis are available in [Annex 6.5](#).

No samples with TOC>0.5 have been found in the outcrop rocks and in the well cuttings selected in the study, apart from one single sample with TOC 0.7 in Las Guayabas Fm of the Llanura Oriental Basin and one sample of the Rio Blanco Fm. (Tireo Gp.) in the Cordillera Central with a very good value of 3.5%.

This last sample has been further evaluated as a potential candidate source rock for the oil accumulation in the Azua Basin.

## 6.6 Source Rock Characterization – Vitrinite Reflectance and Palynofacies

Optical Microscopy analyses have been carried out in both transmitted and reflected light, with the aim of having information respectively on the organic assemblage (palynofacies) and of thermal maturity (vitrinite reflectance).

### 6.6.1 - Vitrinite Reflectance

Regarding the thermal maturity, it can be seen in Table 6.6.2 that most of the samples was found to contain enough fragments of the huminite-vitrinite group derived from terrestrial material (woody tissues of vascular plants) to make possible a reliable measurement. A detailed report with a description of all the results is available in [Annex 6.6.1](#).

In general, the Vitrinite Reflectance (Ro%) value is related to the stage of hydrocarbon generation as described in Fig.6.6.1. Depending on kerogen type, source rock is immature at vitrinite reflectance



values of 0-0.7% in the white zone of the diagram. The oil window starts at 0.5-0.7% (yellow zone), condensate or wet gas begins to generate at 1.1-1.3% (green zone) and dry gas at 2.0% (grey zone), respectively. The peak of oil generation is indicated by a broken line.

Using this interpretative framework, most of the samples analyzed in this study can be defined as immature to early mature. Few samples fall around the oil generation peak.

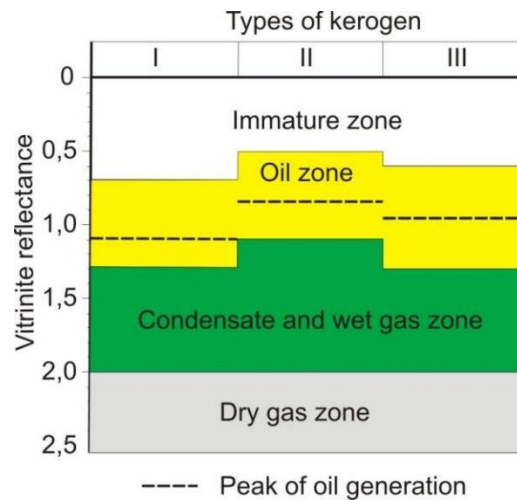


Fig 6.6.1: general diagram of kerogen maturity by vitrinite reflectance (Tissot and Welte, 1978)

Tab.6.6.2: summary of the Vitrinite Reflectance results

Sample Code	Basin	Formation	Geological Age (Based on SGN Maps)	Ro%	Standard Deviation	Nr Indigenous fragments	Nr Total measured fragments	Ro% Reworked Population	Nr reworked fragments
P1	Azua	Ocoa	Upper Eocene	<b>0.72</b>	0.06	23	30		
P13	Azua	El Número	Upper Eocene	<b>0.45</b>	0.04	7	41	0.741	34
P18	Azua	Trinchera	Upper Miocene	<b>0.67</b>	0.07	17	17		
P9	Azua	Jura	Lower to Mid Eocene	<b>n.d.</b>	n.d.	absent	absent		
P14	Azua	Jura	Lower to Mid Eocene	<b>n.d.</b>	n.d.	absent	absent		
P79	Cibao	Altamira	Oligo - Miocene	<b>0.33</b>	0.06	29	38		
P84	Cibao	La Toca	Upper Eocene – Miocene	<b>0.32</b>	0.06	34	34		
P53	Cibao	Gr Tavera	Oligocene	<b>0.59</b>	0.06	14	32		
P94	Cibao	Gr Tavera	Oligocene	<b>0.52</b>	0.06	21	23		
P95	Cibao	Gr Tavera	Oligocene	<b>0.46</b>	0.07	15	18		
P127	Cibao Este	Las Guayabas	Upper Cretaceous (Coniacian)	<b>n.d.</b>	n.d.	absent	absent		
P25	Enriquillo	Sombrerito	Oligocene - Miocene	<b>0.54</b>	0.05	12	21		
P30	Enriquillo	Sombrerito	Oligocene - Miocene	<b>0.32</b>	0.06	31	36		
P41	Enriquillo	Angostura	Lower Pliocene	<b>n.d.</b>	n.d.	absent	absent		
P28	Enriquillo	Mbro. Aguacate de Neiba	Mid Eocene - Upper Eocene	<b>n.d.</b>	n.d.	absent	absent		
P99	San Juan	Ventura	Lower Eocene	<b>0.68</b>	0.05	26	38		
P102	San Juan	Trois Revieres	Upper Cretaceous	<b>n.d.</b>	n.d.	absent	absent		
P107	San Juan	Jura	Lower to Mid Eocene	<b>0.57</b>	0.06	17	21		
P110	Ll.Oriental	Loma de Anglada	Upper Cretaceous (Maastrichtian)	<b>0.73</b>	0.06	22	43		
P112	Ll.Oriental	Rio Chavon	Upper Cretaceous (Santonian-Campanian)	<b>0.69</b>	0.05	9	24		
P117	Ll.Oriental	Las Guayabas	Upper Cretaceous (Coniacian)	<b>0.75</b>	0.06	18	21		

### 6.6.2 Palynofacies

The palynological preparations were made at the Sedimentary Organic Matter Lab of the Department of Physics and Geology, University of Perugia (Italy). Samples were processed using the standard techniques for palynological analysis (Green, 2001; Wood et al., 2002). The palynological content was analyzed by transmitted light microscopy. The detailed results are available in **Annex 6.6.2**, while a summary of the results is shown in Tab 6.6.3.

*Tab.6.6.3: summary of the Palynofacies analysis. Mp: Marine palynomorphs - Cu: Cutinite - Fh: Fungal hyphae - EOP: Equidimensional Oxidised Phytoclasts (Inertinite) - ATP: Amorphous Translucent Phytoclasts (Vitrinite) - TP: Translucent Partially (Vitrinite) - UP: Unstructured Phytoclasts (Vitrinite) - Sp: Sporomorphs - AOM: Amorphous Organic Matter - Py: Pyrite.*

Sample Code	Basin	Formation	Geological Age (Based on SGN Maps)	MP (%)	Cu (%)	Fh (%)	EOP (%)	ATP-TP-UP (%)	SP (%)	AOM (%)	Py (%)
1P	Azua	Ocoa	Upper Eocene								
6P	Azua	Sombrerito	Oligocene-Miocene				28	5		65	2
9P	Azua	Jura	Lower to Mid Eocene				13	30	3	50	4
13P	Azua	El Número	Upper Eocene								
18P	Azua	Trinchera	Upper Miocene				42	34	12	10	2
20P	Azua	Trinchera	Upper Miocene	6	2		30	54	7		1
21P	Azua	Ventura	Lower Eocene				28	38		30	4
24P	Enriquillo	Neiba Sup.	Upper Eocene - Oligocene	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ
25P	Enriquillo	Sombrerito	Oligocene - Miocene	3			26	53	2	9	7
28P	Enriquillo	Aguacate de Neiba	Mid Eocene - Upper Eocene				30	12	5	48	5
30P	Enriquillo	Sombrerito	Oligocene - Miocene	5		10	16	20	3	27	19
34P	Enriquillo	Jimani	Upper Pliocene - Pleistocene			10	11	27		40	12
38P	Enriquillo	Neiba Inf.	Lower Eocene				70	7			23
41P	Enriquillo	Angostura	Lower Pliocene			5	23	41	6	12	13
48P	Cibao	Gurabo	Lower Pliocene								
53P	Cibao	Gr Tavera	Oligocene				55	10		11	24
65P	Cibao	Gurabo	Lower Pliocene				46	31			23
69P	Cibao	Mao-Adentro	Mid - Upper Pliocene				17			78	5
71P	Cibao	Gurabo	Lower Pliocene								
79P	Cibao	Altamira	Oligo - Miocene				50	9	2	29	10
80P	Cibao	Altamira	Oligo - Miocene				24	40	4	29	3
84P	Cibao	La Toca	Upper Eocene - Miocene			3	27	48	4	11	7
85P	Cibao	La Toca	Upper Eocene - Miocene	5		4	27	45	6	9	4
86P	Cibao	La Toca	Upper Eocene - Miocene				24	57		9	10
87P	Cibao	Mao	Upper Pliocene								
94P	Cibao	Gr Tavera	Oligocene				57	29	3		11
95P	Cibao	Gr Tavera	Oligocene				52	9		29	10
99P	San Juan	Ventura	Lower Eocene				39			51	10
102P	San Juan	Trois Revieres	Upper Cretaceous								
106P	San Juan	Trinchera	Upper Miocene								
107P	San Juan	Jura	Lower to Mid Eocene								
110P	Llanura Oriental	Loma de Anglada	Upper Cretaceous (Maastrichtian)								
112P	Llanura Oriental	Rio Chavon	Upper Cretaceous (Santonian-Campanian)								
117P	Llanura Oriental	Las Guayabas	Upper Cretaceous (Coniacian)								
121P	Llanura Oriental	Calizas KS	Upper Cretacic (Coniacian)								
127P	Cibao Este	Las Guayabas	Upper Cretaceous (Coniacian)								

### 6.7 Gas-Chromatographic (GC-FID) Characterization of Migrated and Indigenous Hydrocarbons (G9+)

All the 154 outcrop samples have been screened for free hydrocarbon (indigenous and migrated) presence. Free hydrocarbon (HC) analysis is useful for correlation purposes, to assess oil accumulation presence and to identify migration pathways. Considering the high number of samples to analyze, a fast-screening tool has been deployed, which is a proprietary Geolog technology called G9+. This consists of thermal extraction-GC analysis of HC directly from rock samples (without need of pre-analytical solvent extraction) carried out using fast chromatography means. Therefore, very high turnaround can be achieved, allowing fast screening of many samples and subsequent selection for further, more detailed analysis (e.g. GC-MS). Results from G9+ screening, however, did not yield free HC in any of the analyzed samples (a typical example of the results of the analysis is shown in Fig.6.7.1 - all the chromatograms are available in [Annex 6.7.](#)).

This could be due to several reasons:

- No active petroleum system.
- High maturity of the source rock samples that can result in the alteration of the liquid hydrocarbons and in the generation of gas that cannot be detected with this technique.
- Outcrop samples are not representative of the equivalent formation in the subsurface.

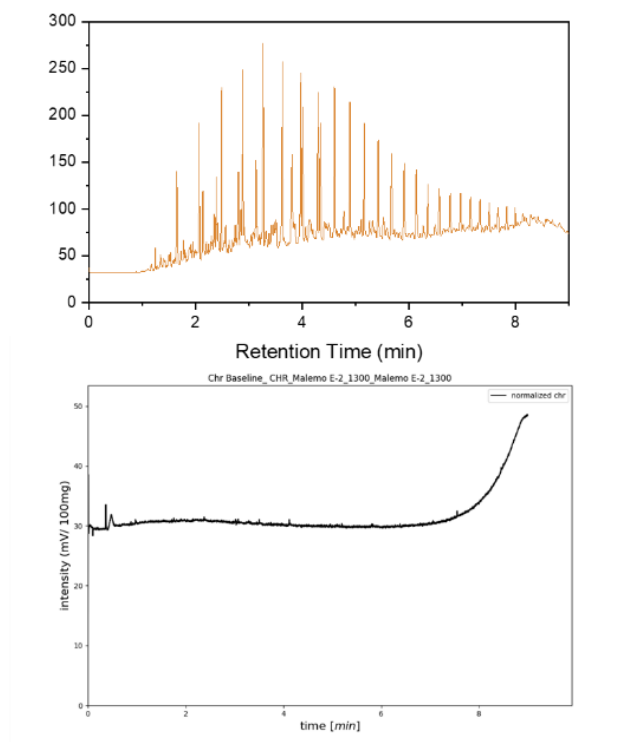


Fig 6.7.1: G9+ analysis of NSO standard oil (top) and of an example of rock samples from the present study

## 6.8 Geochemical Characterization of Oil Seeps

Since organic characterization of rock samples yielded poor results, most of the information on the active Petroleum System(s) has been retrieved from oil seep analysis. Oil seeps, namely Maleno P1, Maleno P2 and Higerito P1, were extensively characterized to carry out what is commonly called “geochemical inversion”. The Geochemical inversion approach consists of using the chemical characteristics of any encountered hydrocarbons to infer the possible character, maturity and identity of the potential source system. Geochemical inversion is most useful where pertinent source-rock information may be absent; since no data on free hydrocarbons were obtained from potential source rock extracts, the geochemical inversion represents the only way to gain information on the source rock that generated such oil seeps. Therefore, geochemical characterization consisted of HRGC-FID (whole oil High Resolution Gas Chromatography coupled with Flame Ionisation Detector), GC-MS, EA-IRMS and GC-MS/MS. Detailed chromatograms of the oil seeps are reported in a separate spreadsheet enclosed with this report.

### 6.8.1 HRGC Analysis.

Figure 6.8.1 reports the HRGC analysis of the NSO standard oil (used as reference, on top) and three oil seeps. It is clear by comparison with a standard, not altered oil, that the three seep samples suffer from biodegradation and potential sample evaporation in the lighter end. Therefore, standard geochemical models based on C7-fraction cannot be applied.

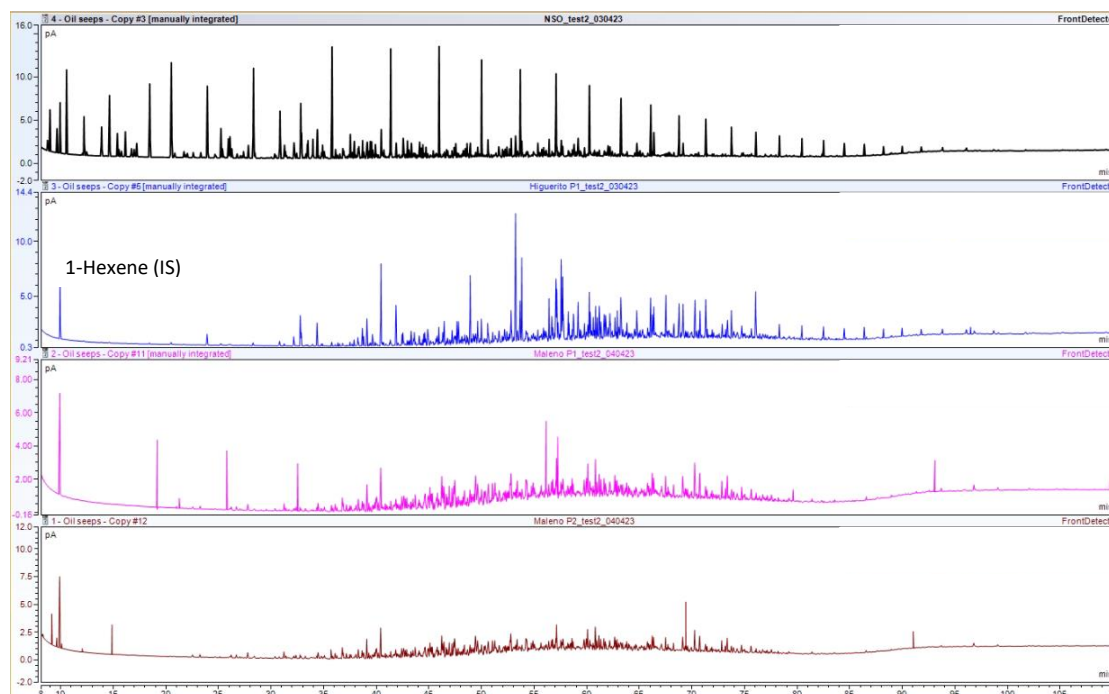


Figure 6.8.1. HRGC analysis of NSO standard oil (black), Higerito P1 (blue), Maleno P1 (pink), Maleno P2 (brown).

### 6.8.2 GC-MS AND GC-MS/MS Analysis.

The most informative characterization tool in exploration geochemistry is probably GC-MS analysis of saturate and aromatic fractions. Saturate fraction can be further characterized using GC-MS/MS to better characterize some molecular classes, such as steranes for the purpose of this study. Oil biomarkers represent a class of compounds that are indicative of the original organic material that led to kerogen and ultimately to oil formation. In other words, they can be seen as molecular fossils able to provide information on several aspects such as source rock maturity, organic facies, age, depositional environment and so on. For this reason, GC-MS biomarker analysis is probably the most useful tool to carry out geochemical inversion. **Figure 6.8.2 and 6.8.3** report triterpene and sterane profile for the three oil seep samples. For steranes an additional analysis has been run using a GC-MSMS instrument (an example is reported in **Figure 6.8.4**).

These biomarkers are discussed in this report because they are the most informative among all biomarkers. Biomarkers are very resistant to biodegradation and in the analyzed samples they are not affected by oil alteration.

The summary sheets of the three samples with the main results of the GC-MS and GC-MSMS analyses and the corresponding raw data are available in **Annex 6.8**.

Based on GC-MS data from biomarkers and aromatics, the following information on the source rock can be inferred:

- All three oils have the same origin.
- Higher maturity in Maleno-P1 and Maleno-P2 compared to Higuierito P-1 can be inferred from aromatics (saturates biomarkers do not show maturity differences).
- Oils have been generated by a carbonate rich facies of a source rock in a moderately anoxic depositional environment.
- Generation and expulsion occurred in the early to medium oil window.
- Source rock age is Upper Cretaceous or younger (high oleanane).
- Organic matter is a mix of continental and marine.

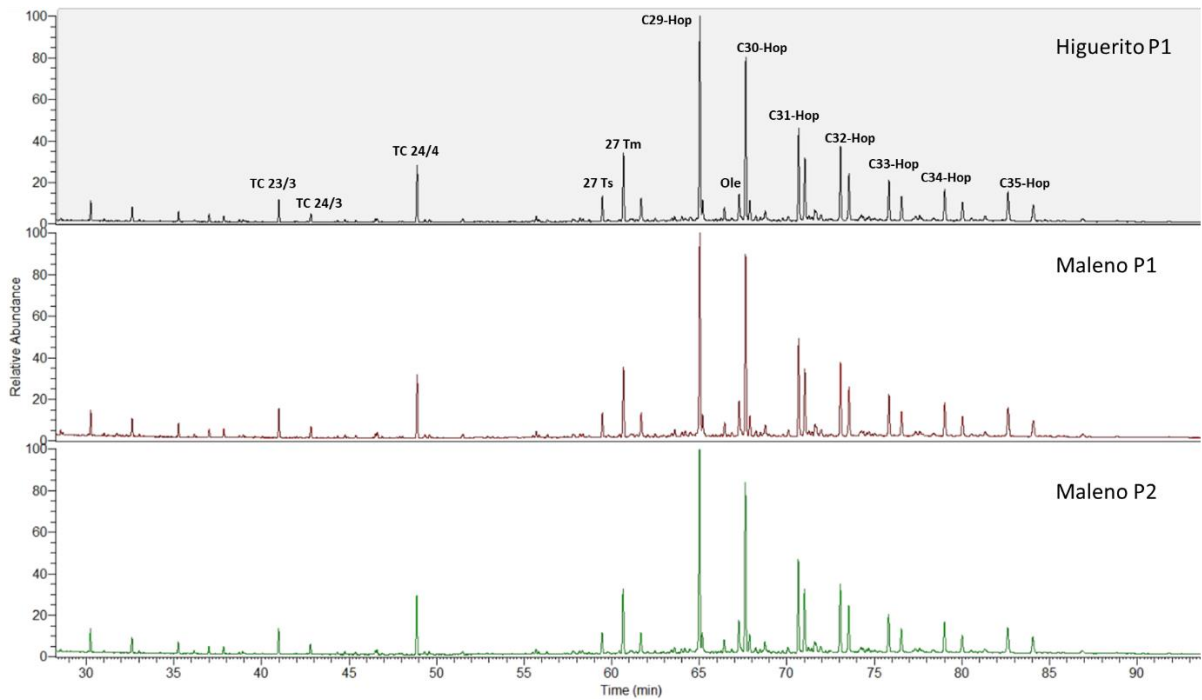


Figure 6.8.2.. GC-MS (m/z 191) triterpane analysis of Higuero P1 (black), Maleno P1 (red), Maleno P2 (green).

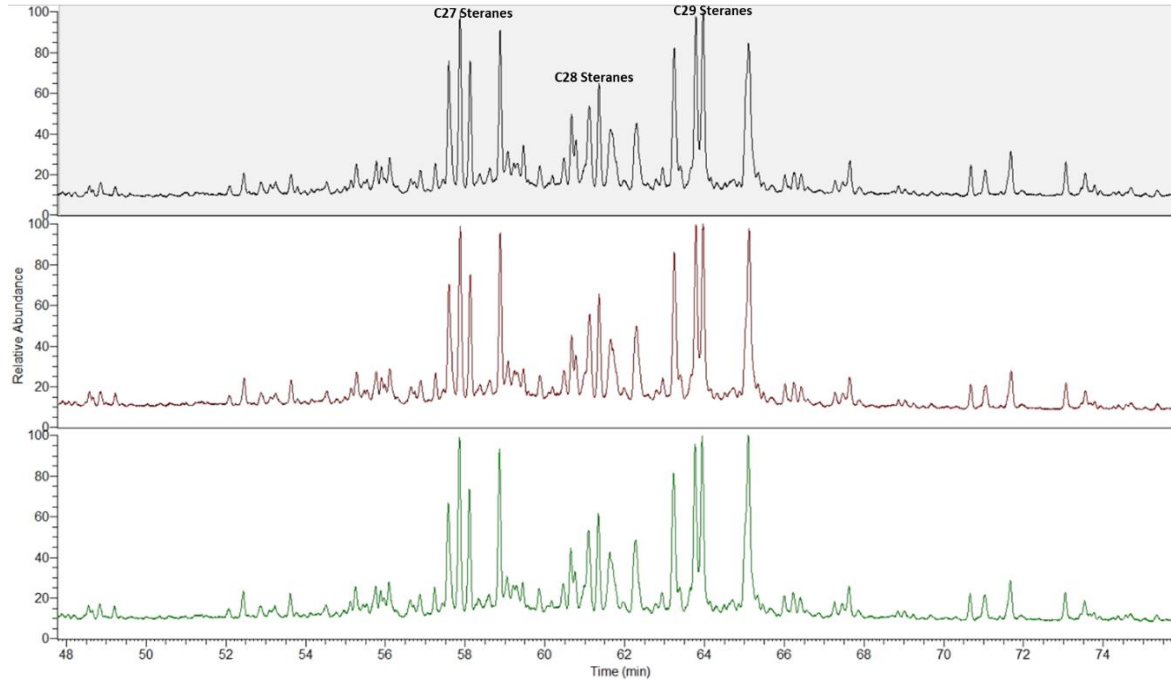


Figure 6.8.3.. GC-MS (m/z 217) sterane analysis of Higuero P1 (black), Maleno P1 (red), Maleno P2 (green).

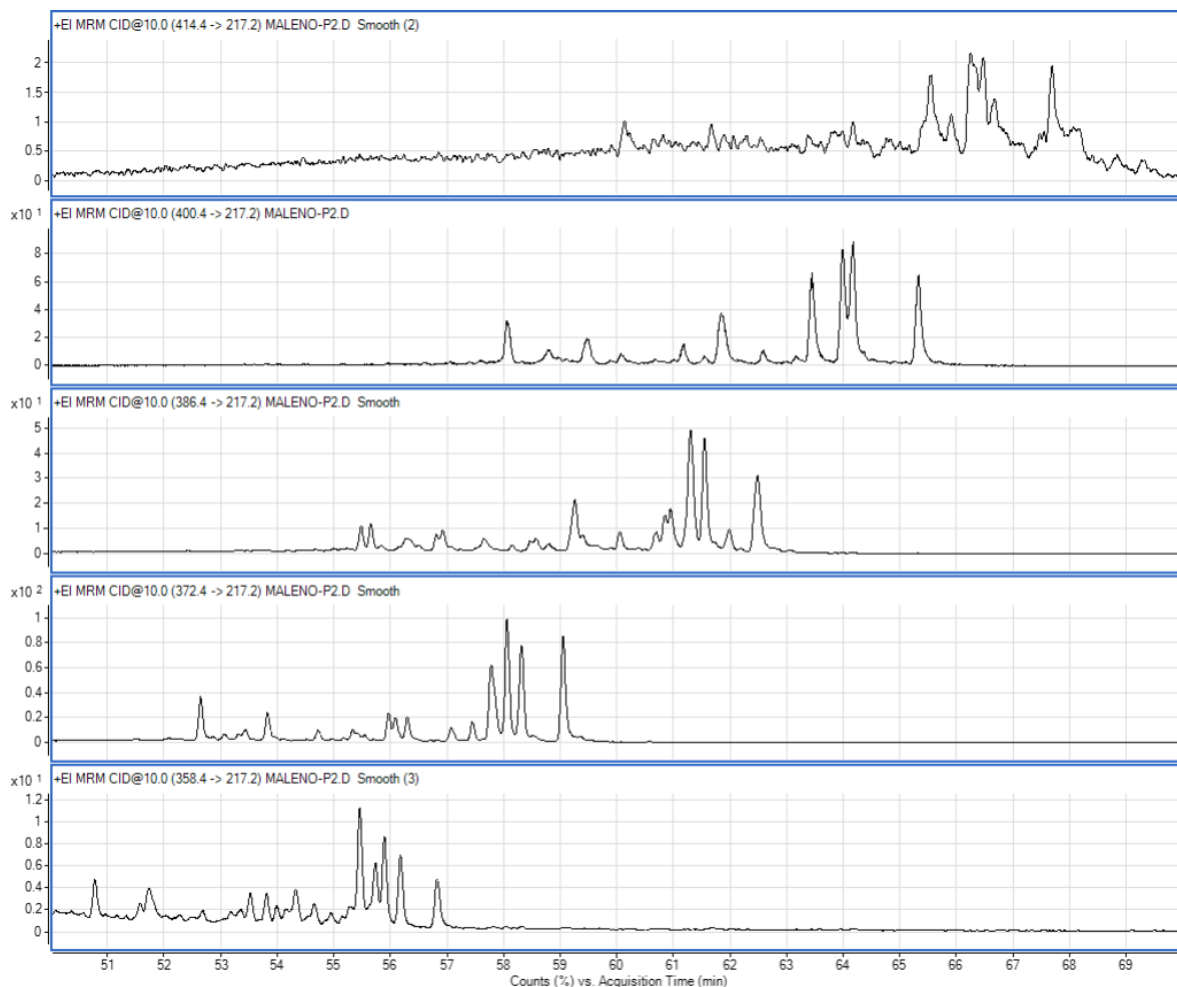


Figure 6.8.4.. GC-MSMS (MRM of  $M^+ \rightarrow m/z$  217) sterane analysis of Maleno P1: from top to bottom C30, C29, C28, C27, C26 steranes.

### 6.8.3 EA-IRMS Analysis.

The carbon isotopic analysis of saturate and aromatic fractions is extremely useful as correlation tool. Data are generally displayed on a Sofer diagram, which plots bulk carbon isotopic ratio of aromatic vs saturate fractions. The location on such diagram is generally dependent on the source age, depositional environment, organic facies and alteration. However, general rules are difficult to apply, since it often depends on the specific field. **Figure 6.8.5** shows the Sofer plot for the three analyzed oils. The most important to highlight is the very peculiar carbon isotopic composition of the analyzed oils, which is extremely uncommon as shown in a comparison with a large database of worldwide oils published by Whiticar, M.J. (Fig. 6.8.6). The effect of biodegradation on the isotopic signature can account for a shift of the  $\delta^{13}C$  values of 2-3 ‰ towards more negative values in particular for the saturate hydrocarbons, so we can expect that the original signature of the undegraded oil could be around 19-20‰ VDPB, that is in any case quite far from the most common values. This represents a big advantage for correlation purposes, since potential source rock extracts with similar isotopic values would point towards a positive correlation. A detailed report with a description of all the results and the raw data are available in **Annex 6.8**.



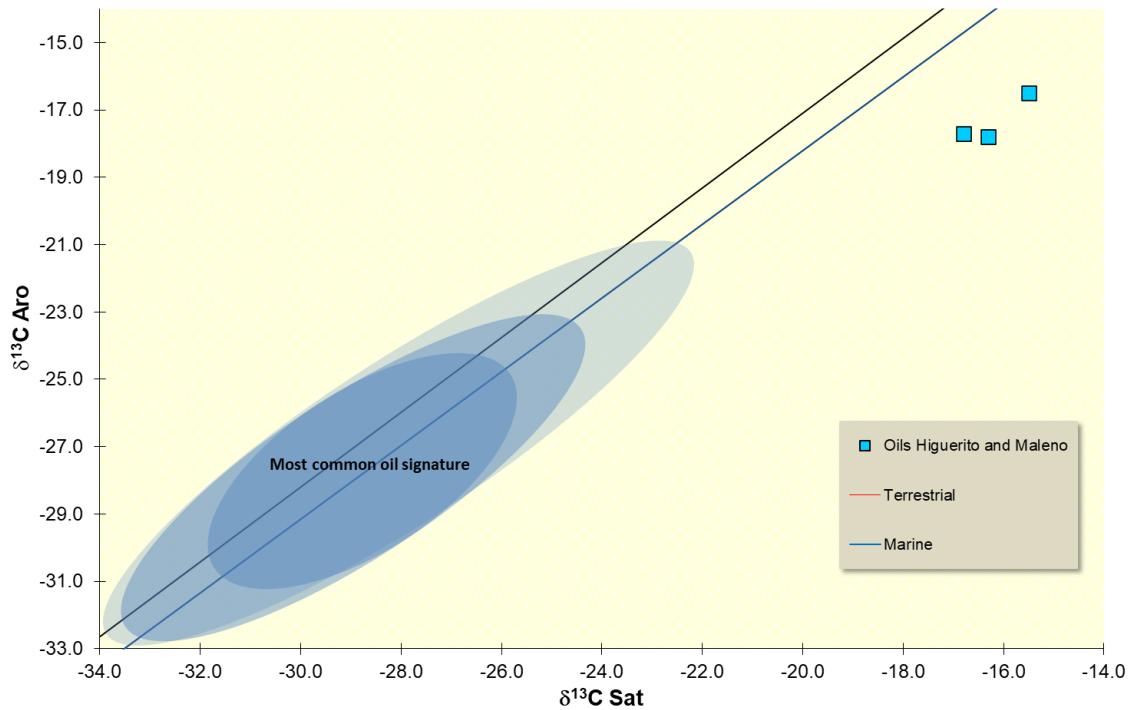


Figure 6.8.5. Sofer's plot – Isotopic signature of saturate and aromatic fractions of oil seeps

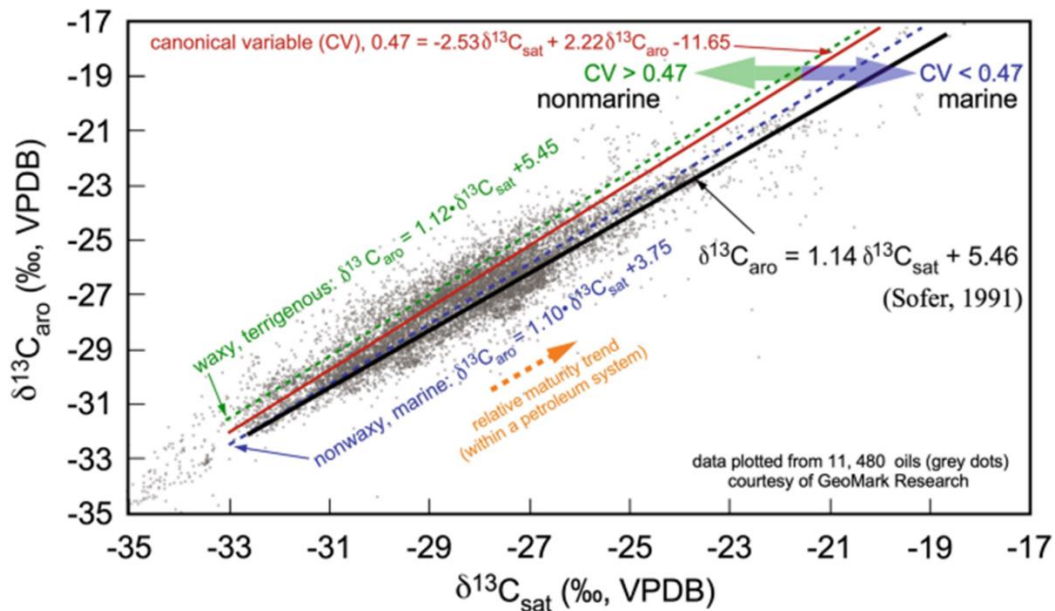


Figure 6.8.6. Database of isotopic data regarding a large worldwide dataset Whiticar, M.J. (2021). Carbon Isotopes in Petroleum Science. In: Sorkhabi, R. (eds) Encyclopedia of Petroleum Geoscience. Encyclopedia of Earth Sciences Series. Springer, Cham. [https://doi.org/10.1007/978-3-319-02330-4\\_310-1](https://doi.org/10.1007/978-3-319-02330-4_310-1)

#### 6.8.4 Oil-Source Rock Correlation

The geochemical characterization of the oil seeps is a key step to the identification of the active source rock(s) of the area.

To our knowledge up to now there are no oil-source correlation studies through geochemical tools published in the literature.

This study (see [Annex 6.8](#) for the detailed report) is the first attempt based on the results of the characterization of oils and of the sole source rock level showing a clear oil generation potential, the Rio Blanco Fm. In the Tireo Gp.

The Lower to Upper Cretaceous (Aptian to Turonian) Tireo Group (location 3 in Fig.6.9.1) outcrops at Cordillera Central. The Universidad Complutense de Madrid (J.M. Gorosabel Araus), has already sampled the sequence and has got interesting TOC values. During the Geolog field campaign, the same sequence, and in particular the Tireo Fm, was sampled again by Geolog to perform more detailed analyses.

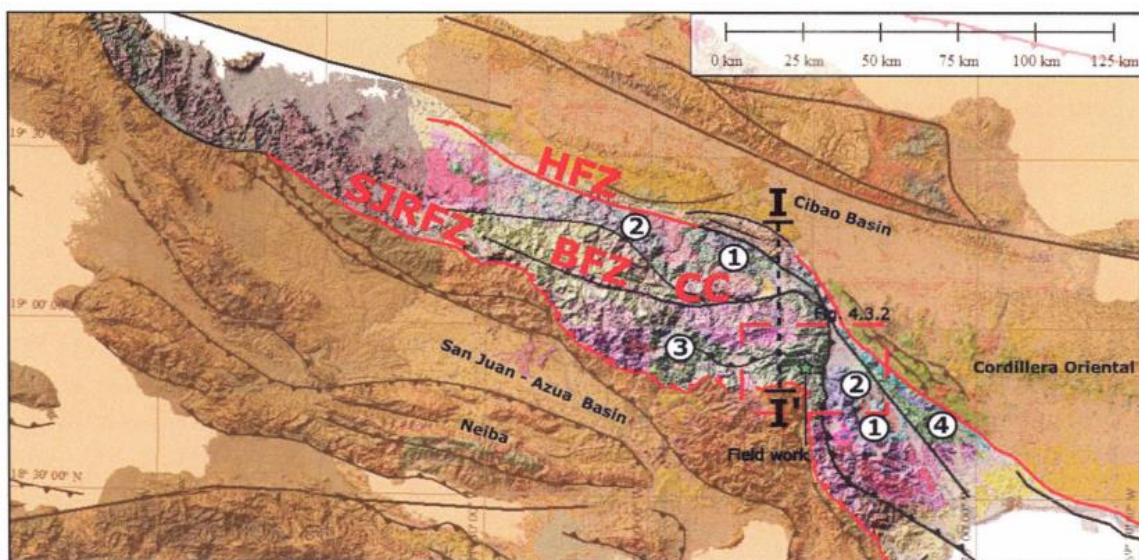


Figure 6.9.1. Location of the Tireo Gp.(3) sampled in this study

According to Gorosabel (2020) the best outcrops were located along the trace of the Blanco River, especially at the Blanco dam, where a 30 m section of sedimentary rocks was found. Nevertheless, the presence of faults could cause the repetition of the series, therefore this number should be taken cautiously. This outcrop consists of an alternation of metric layers of dark grey to black mudstones and sandstones. Shaly intervals reveal a non-calcareous composition with TOC values ranging from 0.78 to 3.6 %.

Five different rock samples from the outcrop have been collected and analysed in this study, the results of the TOC and Pyrolysis analyses are reported in Tab 6.9.1.

*Tab.6.9.1 – TOC and Pyrolysis data of the outcropping Rio Blanco Fm.*

<b>Dominican Republic - CORDILLERA CENTRAL</b>						
Formation	Sample	Sampling (composite, spot, selective)	TOC	S1	S2	Tmax
			(wt%)	(mg HC/g)	(mg HC/g)	(°C)
Rio Blanco	#1	Outcrop	3.5	0.0	0.0	
Rio Blanco	#2	Outcrop	0.4	0.0	0.0	
Rio Blanco	#3	Outcrop	0.4	0.0	0.0	391
Rio Blanco	#4	Outcrop	0.2	0.0	0.0	
Rio Blanco	#5	Outcrop	0.2	0.0	0.0	

The sample #1 shows very good TOC values, but no free hydrocarbons (S1 value of the Pyrolysis) nor residual kerogen (S2 value of the Pyrolysis). These features can be related to a very high thermal maturity of the source rock level, since this would bring to a complete depletion of the generation potential and to a cracking of all the liquid hydrocarbons to volatile gases that are lost at the surface and during the sample manipulation.

To check this hypothesis the sample with high TOC content has been studied in terms of thermal maturity. At the time of the analysis the Vitrinite reflectance lab was not able to run the sample in a short time, so we decided to use a less accurate but still very informative technique based on Raman spectroscopy. The analysis has given a spectrum typical of the beginning of anchizone, corresponding to a Vitrinite Reflectance equivalent value around 3%. This data is in good agreement with the hypothesis of an overmature condition of the source rock.

Unfortunately, the high maturity caused a complete loss of the geochemical features like biomarkers and light hydrocarbons that could have been used as a tool for the oil-source correlation. The only geochemical feature that can still be used is the isotopic signature of the organic matter present in the rock (residual kerogen).

Since the isotopic signature of the oil seeps is quite unusual (see paragraph 6.8.3), it can be used as a good correlation tool. For this reason, the kerogen in the sample was analysed in triplicate by EA-IRMS and the results are shown in the Sofer plot (Fig.6.9.2).

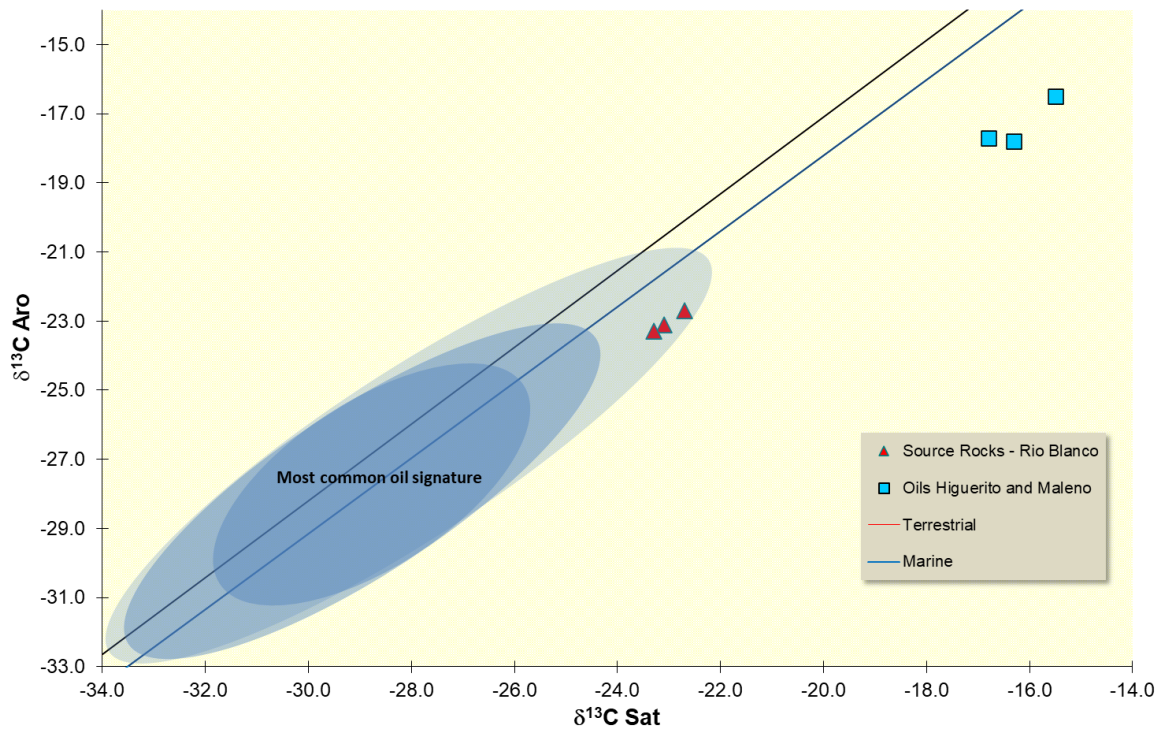


Figure 6.9.2. Sofer's plot – Isotopic signature of candidate source rock and oil seeps

Obviously, a characterization based on the analysis of a single sample of source rock is not particularly robust but, taking into account the possible alteration of the isotopic signature due to biodegradation and thermal maturity, the correlation between the Higuierito/Maleno oil and the potential Rio Blanco source rock is promising.

It's important to note that even the Rio Blanco Fm signature falls in the highly positive (heavy) area of the plot. This area is scarcely populated (not frequently measured).



## 7. CONCLUSIONS

The main outcomes of the present study are summarized as follows:

The possible critical aspects of the petroleum systems of all the basins in the Dominican Republic have been defined in literature:

1. Sandstone reservoirs are likely to be of poor quality because Cretaceous–Cenozoic sandstone is mainly derived from the erosion of quartz-poor, clay-rich rocks of the leading edge of the Caribbean plate. Caribbean carbonate reservoirs, with a few exceptions, have not proven successful in this region.
2. Source rocks are likely to be poor to fair, deposited under dysoxic environments (Kerogen II/III to III) and confined to smaller depocenters.
3. Timing is a key issue that must be addressed and assessed in any future exploration in the basin.

Points 2 and 3, i.e., the presence and maturation of the source rock(s), are probably the most concerning in terms of hydrocarbon potential in the area.

All the authors agree on the need for a more detailed definition of the Petroleum System(s) through the acquisition of new data focused in particular on source rocks.

Taking into account this need and after careful planning based on documents made available by the MEM and the National Geological Service (SGN), a new sampling campaign has been carried out.

A total of 154 rock samples were taken, (128 outcrops and 26 drill cutting samples). In addition, the main oil seeps in the Azua Basin have been sampled in different locations.

The samples have been then submitted to an analytical workflow including digital imaging, mineralogy, thin section petrography, micropaleontology, source rock evaluation, vitrinite reflectance, palynofacies description, GC-FID characterization. The oil seeps have been characterized through the main organic geochemistry tools (HRGC, GC-MS, GC-MSMS, Stable Carbon Isotopes).

Regarding the reservoir quality, overall development in the studied samples seems to be low and mostly confined to carbonate lithologies. The observed sandstone samples, even when coarse grained, appear to be consistently characterized by common clay-rich matrix and localized fracture-filling calcite, which prevented the preservation of any noticeable open porosity.

The dominance of carbonate-hosted reservoir development in the observed samples from the various basins of the Dominican Republic suggests that lateral reservoir distribution may be relatively limited, depending on the lateral extent of the reefs and/or high-energy mid-ramp environments recorded in the various formations. While good reservoirs hosted within turbiditic formations can be traced for long distances, good reservoir hosted in shallow carbonate platform facies may have a patchier

distribution, which is harder to predict. This must be kept in mind when planning to explore these potential reservoirs.

Regarding the source rock potential, no samples with TOC>0.5 have been found in the outcrop rocks selected in the study, apart from one single sample with TOC 0.7 in Las Guayabas Fm of the Llanura Oriental Basin and one sample of the Rio Blanco Fm (Tireo Gp.) in the Cordillera Central with a very good value of 3.5%. This last sample has been further evaluated as a potential candidate source rock for the oil accumulation in the Azua Basin. On the base of these results, the Cretaceous section is probably the best candidate source rock. Unfortunately, the geographic distribution and the real potential of these intervals was not characterized extensively due to the strategy adopted in the previous surface sampling campaign and also the scarcity of wells reaching these deep horizons.

Most of the samples analyzed in this study can be defined as immature to early mature. Few samples fall around the oil generation peak.

On the contrary, the Rio Blanco Fm at the sampled location is overmature.

All outcrop samples have been screened for free (indigenous and migrated) hydrocarbon presence. Results from GC-FID (G9+) screening, however, did not yield free hydrocarbons in any of the analysed samples.

This could be due to several reasons:

- Lack of active Petroleum Systems in the analysed sections.
- High maturity of the source rock samples that can result in the alteration of the liquid hydrocarbons and in the generation of gas that cannot be detected with this technique.
- Outcrop samples are not representative of the equivalent formation in the subsurface.

Since organic characterization of rock samples yielded poor results, most of the information on the active Petroleum System(s) has been retrieved from oil seep analysis. Oil seeps, collected in the area of the main oil fields Maleno and Higuerito, were extensively characterized to carry out what is commonly called “geochemical inversion”.

Based on GC-MS data from biomarkers and aromatics, the following information on the source rock can be inferred:

- All the oils in the area have the same origin.
- Generation and expulsion occurred in the early to medium oil window with a higher maturity in Maleno seeps compared to Higuerito.
- Oils have been generated by a carbonate rich facies of a source rock deposited in a moderately anoxic environment.
- Source rock age is Upper Cretaceous or younger (high oleanane).
- Organic matter is a mix of continental and marine.

The carbon isotopic analysis of saturate and aromatic fractions highlights a very positive carbon signature (around -17‰ VPDB), which is extremely uncommon as shown in a comparison with a large

database of worldwide oils published. This represents a big advantage for correlation purposes, since potential source rock extracts with similar isotopic values would point towards a positive correlation.

The geochemical characterization of the oil seeps is a key step to the identification of the active source rock(s) of the area. To our knowledge up to now there are no oil-source correlation studies through geochemical tools published in the literature, so this study is the first attempt of correlation based on the results of the characterization of oils and of the only source rock level showing a clear oil generation potential, the Rio Blanco Fm. In the Tireo Gp.

The sample showing a very good TOC value, was unfortunately found at a very high thermal maturity (Vitrinite Reflectance equivalent to around 3%). Consequently, the geochemical features like biomarkers and light hydrocarbons that could have been used as a tool for the oil-source correlation, were completely lost. The only parameter that can still be used is the isotopic signature of the organic matter in the residual kerogen.

Even the Rio Blanco Fm signature resulted to be highly positive (around -23‰ VPDB). Taking into account the possible alteration of the isotopic signature due to biodegradation and thermal maturity, the correlation between the Higuero/Maleno oil and the potential Rio Blanco source rock is for sure promising.

Obviously, a characterization based on the analysis of a single sample of source rock is not particularly robust, so the findings of this study highlight a need for a more detailed study of the Cretaceous sequences as potential source rocks.

This can be done through a new targeted sampling of the outcropping rocks, but this would result in a characterization of the facies outside the real depocenters of the source. The ideal sampling would be through the drilling of the sequences in the basins by deep wells. This could also allow a more comprehensive characterization of the burial and thermal history of the basins that is a key factor for understanding the timing of generation.