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# The oils and source rocks of the Patuca, Niobe and Mosquitia Basins, Honduras

**Chris Matchette-Downes and Huw Williams**

CaribX (UK) Limited, Cedar House, Marlow, SL7 1DQ, England

www.caribx.com

**Abstract**

Analysis of recently collected oils combined with a review of the source rocks in the western Caribbean area support both a regional Tertiary, and Cretaceous source and provide some information as to the origin of the Caribbean.

Offshore eastern Honduras comprises of a terrane (Chortis) that has been interpreted to have been introduced into the Caribbean from the Pacific margin as part of an active transtensional margin separating the Caribbean and North American plates. There are two distinct structural domains in the Honduran offshore area: (1) an approximately 120-km-wide area called the Honduran Borderlands which lies immediately south of the Cayman Trough. The area is characterized by narrow rift basins controlled by basement-involving normal faults sub parallel to the margin, and a significant degree of transtensional and some transpressional tectonic movement. This can clearly be seen in Figure 1. We examined two basins within this domain; the Miocene Patuca basin and the associated younger Niobe basin to the North. (2) The Nicaraguan Rise, which is characterized by small-displacement normal faulting and sag-type basins. The Mosquitia basin on the southern flank and basins to the east in Jamaica are here described in terms of their source and reservoir rocks and migrant oils.

The migrant oils and source rocks can support the western incursion but more plausibly an in-situ origin for at least part of the western Caribbean.

## Introduction

The Upper Nicaraguan Rise is an area which has historically experienced limited hydrocarbon exploration. As a consequence, there is limited data concerning the petroleum character and potential within this vast region stretching from Jamaica in the east to Honduras in the west (Figure 1).

In 2009 CaribX commenced exploration activities in the area for the first time since the hiatus of exploration which had been in place since 1980. At the same time Petroleum GeoServices separately undertook a 2D seismic data acquisition programme. Offshore eastern Honduras however remains lightly explored with only 31 exploration wells drilled to date in both the offshore and onshore. The most significant well drilled in the area is the Main Cape #1 well (Figure 1), drilled at the tail end of a rising structure within the Mosquitia basin in 1973 by UNOCAL (now Chevron), in which oil was recovered at the surface from 3 separate Drill Stem Tests and from the mud pits. In addition to the well penetrations there is approximately 19,600 line-kilometres of 2D seismic, most of which has been acquired within the last decade.

In 2013 BG Group were awarded the Main Cape block, and, during a 4-year exploration program, acquired a long-offset seismic data set along with 35,000 km$^2$ of Full Tensor Gravity (FTG) and magnetics data, high resolution multi-beam bathymetry, an extensive seabed coring programme, 36 fully calibrated seafloor heat flow measurements, and the geochemical analysis (GC, GCMS) of seabed core extracts and an onshore seep. The result of this exploration programme was the identification and mapping of several leads and prospects across the Patuca, Niobe and Mosquitia basins (Figure 1).

CaribX first visited Honduras in 2009, during which they studied the potential and placed their initial bid for the Main Cape block. In 2017 the Main Cape block was assigned to CaribX, since then significant work has been conducted to build on the initial exploration programme. The recent exploration effort has allowed the further understanding of the three basins in the study area (Figure 1): the Niobe (Miocene and younger), the Patuca (mainly Eocene to Miocene) and the Mosquitia (Upper Cretaceous to Palaeogene). Additionally, the likely source for the hydrocarbons found within the seabed cores, shows in the wells, and in the seeps onshore has been extensively researched.

CaribX's most recent research, and the objectives of the studies are here presented and provide an attempt to define the likely Petroleum System or Systems within this region, away from the calibration points by recourse to biomarker and isotope assemblages from the analysis of oil samples from each end of the Upper Nicaraguan Rise.

The geochemical data presented can also be used to help determine the origin of the Caribbean.

The analysis of oil shows, seeps and source samples collected from Jamaica and Honduras are compared with CaribX's regional oils data base. The results are presented within the geological framework established from seismic and potential fields data evaluated by the authors and other specialist researchers in this part of the western Caribbean.

**Geologic Setting**

The geology of offshore Honduras is poorly constrained due to the the limited well and seismic coverage, and further complicated by the "basin and horst" geometry that characterizes the Upper Nicaraguan Rise (Figure 1). The Nicaraguan Rise is thought to be the result of a Late Cretaceous collision of the Great Arc of the Caribbean with continental crust of the eastern Chortis Block, followed by a left-lateral displacement of the NW Caribbean Plate (Pindell & Kennan 2001; Mann et al. 2006; Pindell et al. 2006). Oils data provide an alternative possibility. The Nicaraguan Rise is thought to be underpinned by Jurassic sediments, however the deepest wells only reach Apto-Albian aged sediments. Much of the upper Cretaceous and lower Tertiary has been removed, but the degree of removal varies across the Nicaragua Rise relating to this basin and horst geology.

The study area is comprised of the eastern part of Chortis which broadly occupies the northern flank of the Nicaraguan Rise. The area is demarcated by the Cayman Trench and the Swan Fault system to the north, and runs towards western Jamaica (Figure 1). It is approximately defined by a line from the Coco River mouth along the Honduran and Nicaraguan maritime boundary. Within this study area CaribX have focused on three disinct basins, the Patuca, Mosquitia and Niobe basins (Figure 2). Each basin possesses distinct characteristics related to their age and proximity to the the Cayman Trench and the Montague-Polochic-Swan Islands Fault System (Figure 3).

The Patuca basin is dominated by faulted and karstified mid-Miocene platform and reef-forming carbonates. The older Mosquitia basin to the south is largely composed of platform carbonate of Eocene age with some episodic clastic input from the paleo Coco River. To the north of the Patuca basin, the geology youngs towards the Cayman Trench. The Niobe basin, the least explored part of the Honduran Borderlands, is thought to be of upper Miocene to Pliocene age. There are no well penetrations or outcrop control, however it can be seen that the carbonate character of the Patuca basin does not extend into the Niobe basin.

The geologic and depositional history of the three basins is presented here:

***The Patuca Basin***

The Patuca basin is one of a series of elongate rift basins which run sub-parallel to the Cayman trough (Figure 1), and has been controlled by basement-involved normal faults striking sub- parallel to the trend of the Montague-Polochic-Swan Islands Fault System (Cavajal-Arenas et al 2015). The basin's proximity to the Cayman Trough has had a significant influence on the complex basin architecture. The Cayman Trough, an approximately 100 km-wide and 1100 km-long submarine depression, formed and developed as a pull-apart basin generated by the reorientation of the Caribbean Plate from NE to east during the Eocene – Recent (Mann et al. 1995). The proximity of the Patuca basin to the belt of transtension along the southern edge of the Cayman Trough has resulted in a complex series of compression, transpression and deformation (Dewey et al. 1998) during the Cainozoic.

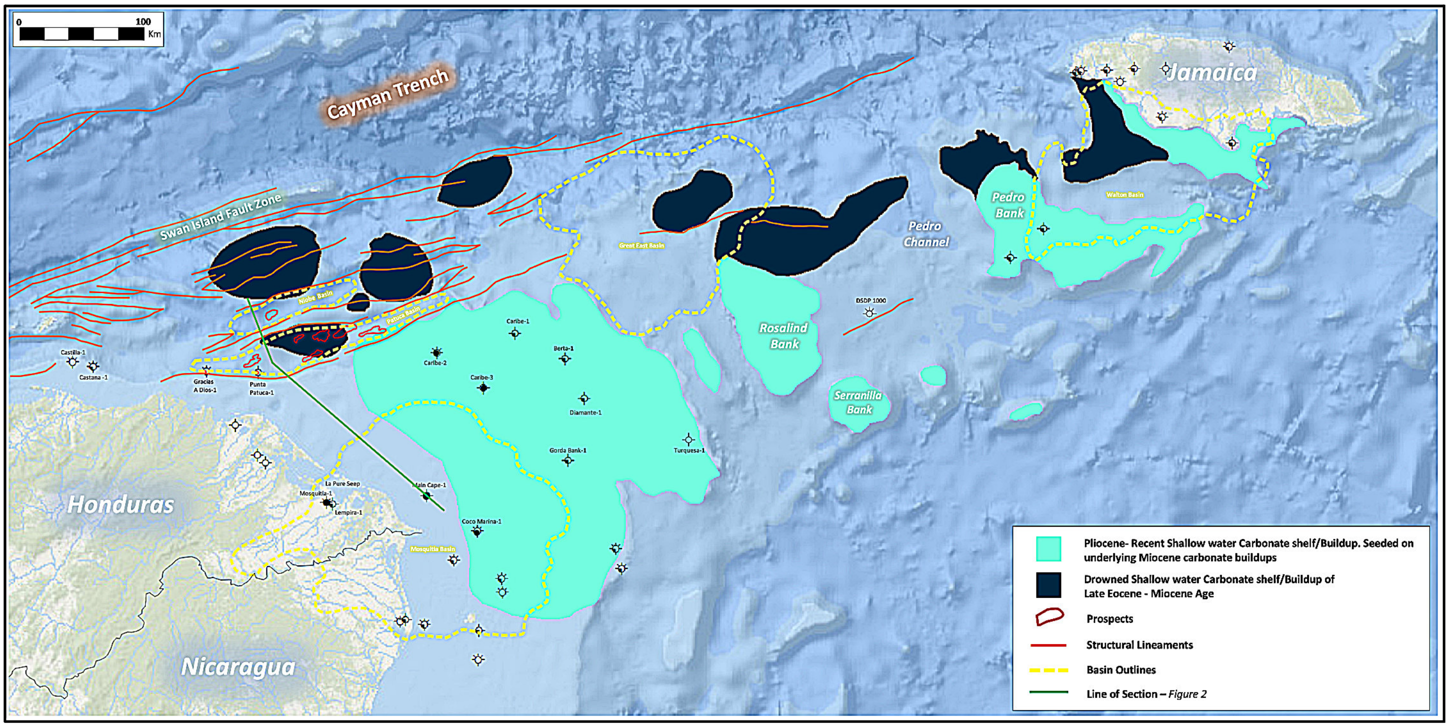


*Figure 1. Study area, (Ref CaribX data base, Esri, Garmin, GEBCO, NOAA NGDC). NB the elongate character of the basins along the northern flank of the Nicaraguan Rise*

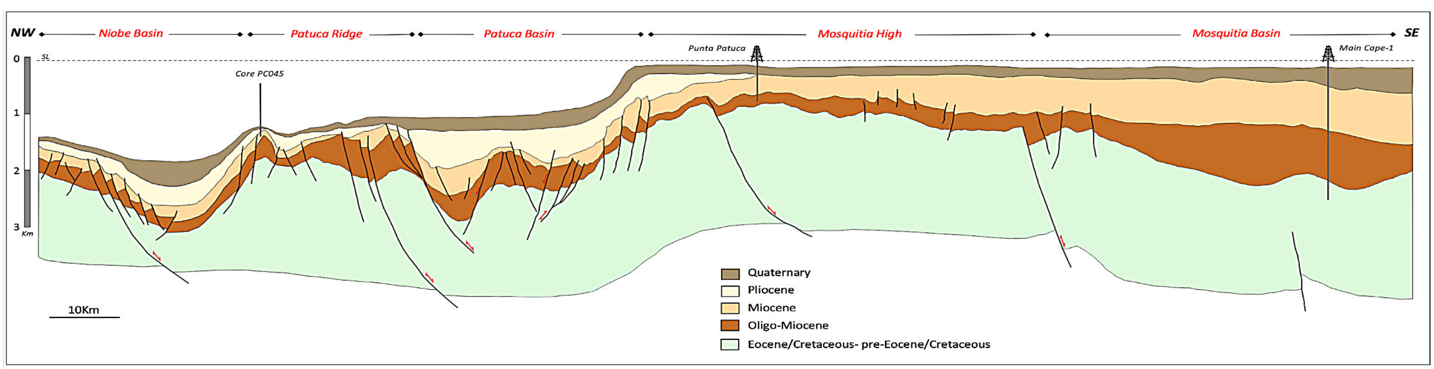


Figure 2. Regional cross section Niobe-Patuca-Mosquitia basins. Location of line indicated on Figure 1

By Late Eocene a significant counter-clockwise rotation of the Chortis Block occurred during the development of the Montague-Polochic-Swan Island strike-slip fault system (Emmet and Mann, 2010), and the resultant initiation of the Cayman trough spreading centre. This rotation and spreading adjacent to the Patuca basin resulted in a compression of the basin and an uplift and deformation of the Cretaceous-Eocene strata. Such deformation resulted in the development of an axial high within the basin, and by Early Oligocene water depths along the high were suitable for the initiation of carbonate deposition (Figure 4B). Initial deposition in the shallow waters was dominated by shallow carbonate platform facies, similar to those seen in the White Limestone Group of Jamaica (Mitchell, 2004; 2013) which is dominantly composed of Nummulites and Foraminifera.

A continued eastwards transport of the Chortis-Siuna Block along the curved Montague and Swan Islands Fault System during the late Oligocene to Early Miocene resulted in additional counter-clockwise rotation of the block, which in turn resulted in a switch to a more Transpressional regime in the Patuca basin. This switch in basin process resulted in a tilting and submergence of the deposited carbonate platform. This deepening of relative sea level in the Patuca basin resulted in a switch in type of carbonate deposition, to a more 'keep-up' style of deposition. The Miocene biota likely inhibited the development of a rigid reef framework, with the deposition of low-relief, mounded, lenticular geometries more likely (Figure 4c). A major lateral movement along the Cayman Trough occurred during the Late Miocene resulting in a brief return to a compressional setting within the Patuca basin. A consequence of this compression was a rapid uplift, exposure and erosion of the thick carbonate succession which had been deposited in the basin (Figure 4A). Such emergence and erosion is readily identifiable on seismic data through the basin with the top carbonate horizon marked by a hummocky relief and truncated reflectors indicative of a karstified surface (Figure 5A).

The large-scale counter-clockwise rotation of the Chortis Block had ended by the conclusion of the Miocene, with the Caribbean Plate changing its overall movement direction from north-eastwards to eastwards (Mann et al. 1995). A resultant southward tilting and deepening of the Nicaraguan Rise rapidly submerged the previously exposed sequences, with the Patuca basin entering a phase of relaxation and accelerated subsidence. Basinal deposition became dominant in the Pliocene to Recent (Figure 4E).

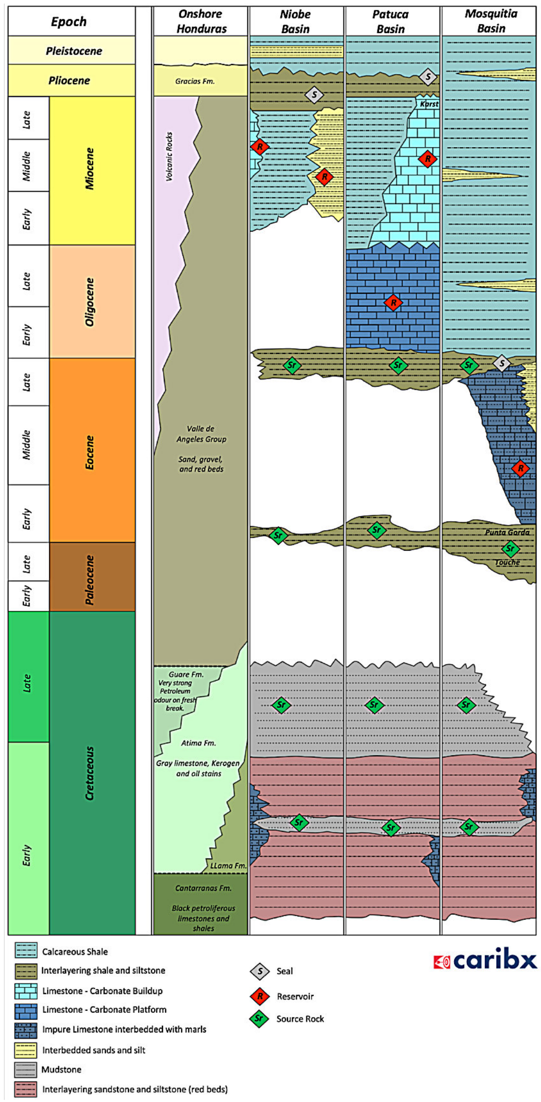


Figure 3. Onshore Honduras, Niobe, Patuca and Mosquitia Basin geology.

***The Mosquitia Basin***

The Mosquitia High and Mosquitia Basin form part of the broad carbonate shelf of the Nicaragua Rise. The Mosquitia basin is very different to the transtensional elongate basins to the North of the Nicaraguan Rise, such as the Patuca and Niobe basins. The Mosquitia basin formed during the Cretaceous as a diffuse, rounded relaxation/sag basin (Figure 2), with minimal fault control. The quality of the seismic data in the Mosquitia basin is generally quite poor (Figure 5B), however, there are wells within the basin which provide an indication of the stratigraphy. The most notable well is the Main Cape #1 well, which flowed oil to surface from Middle Eocene carbonates. These carbonates were deposited in a carbonate platform environment, however, the block and trough environment of the

Nicaraguan rise was not well established in the Middle Eocene. As a result of this, open-marine, clean-platform carbonates were only established towards the latter part of the Eocene and into the Oligo-Miocene. Therefore, the first carbonates deposited on the recently established blocks tended to be impure limestones and marlstones, with both clastic input and intermittent purer limestone development.

### *The Niobe Basin*

The Niobe basin is located north of the Patuca basin, occupies some 700 km$^2$ and is one of several elongate basins that characterise the upper Nicaraguan Rise (Figure 1). There is little seismic control and no wells, but at the time of writing there is sufficient seismic data to determine that this basin is younger than the Patuca basin and that the Miocene limestone is not present or does not feature strongly.

The late Miocene to Pleistocene section is very much thicker than in the adjacent Patuca basin with some 4 km of sediment. These successions have been interpreted to be largely clastic with some carbonate development. The basins closer proximity to both the Cayman spreading ridge and Swan Island Fault zone has resulted in the formation of significant structuration, as the transpressional stresses have created roll over, thrust and faulted block geometries (Figure 5C).

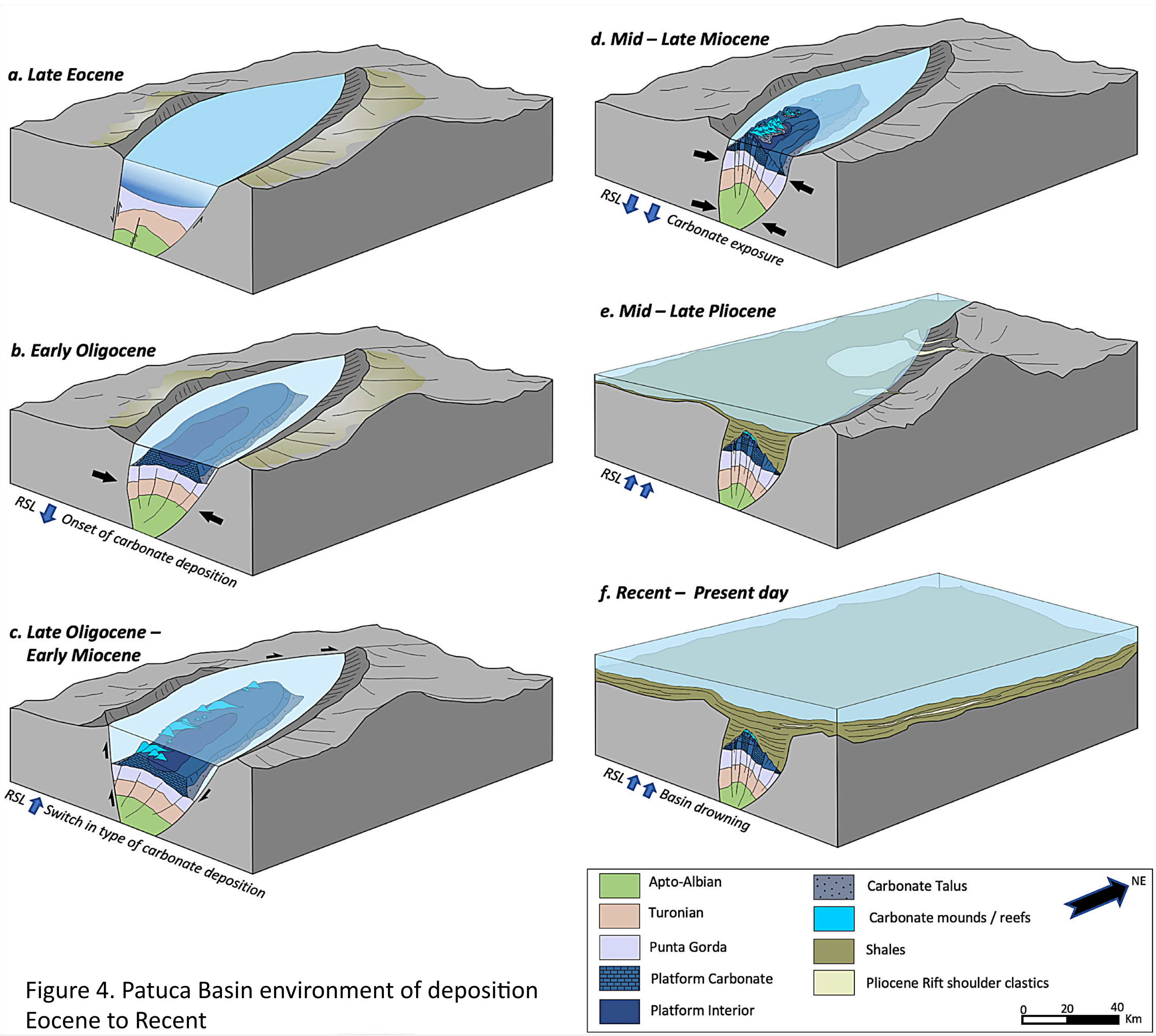


Figure 4. Patuca Basin environment of deposition Eocene to Recent

## Methodology

The Petroleum System or Systems within the AOI (Figure 1) have been defined by collection (where possible) and analysis of seeps and shows from the region. Samples have been analysed by standard geochemical techniques, including: separation into aliphatic and aromatic moieties, with further separation of the aliphatic fraction into alkane components, followed by gas chromatography (alkanes); gas chromatography-mass spectrometry (GCMS) in selected ion recording mode (SIR) (alkanes and aromatics); carbon stable isotopes (alkanes and aromatics); and, for the whole oil, measure the presence of sulphur (%), nickel (ppm), and vanadium (ppm). Biomarkers, isotopes and elemental analysis data have long been used to determine the character, maturity and the likely palaeoenvironment of the precursor source rock.

Whilst as many as four laboratories were commissioned during the period of study (2009 to 2020 the procedures are essentially the same and the ions selected for interpretative purposes were: M/z 191, 218 and 217 for the alkane components and M/z 231& 253 for the aromatic components. The analytical process is more fully described in Kenneth Peters' *The Biomarker Guide*, and in *Sampling and experimental procedures* from the Geological Society Special pub. 77. The oils data set was augmented with material from papers and summary reviews from *The Biomarker Guide*.

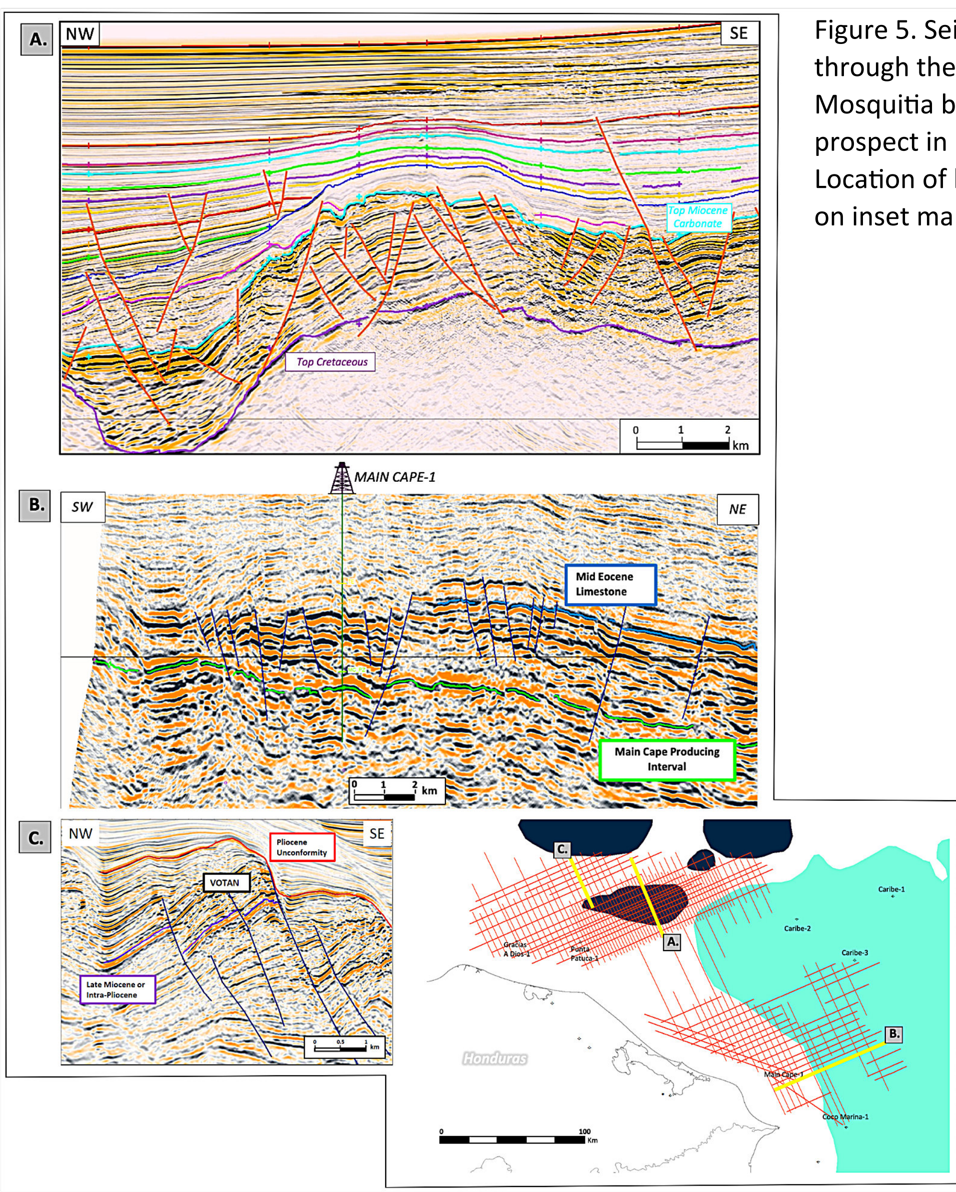


Figure 5. Seismic sections through the A); Patuca Basin, B); Mosquitia basin, C); the Votan prospect in Niobe basin. Location of lines are indicated on inset map.

Predictions regarding source rock lithology and depositional environment (largely regardless of geologic age) can be made via GEOMARK's OILS database (www.RFDbase.com), which is based on average values for global petroleum systems built through the analysis of terpane biomarkers from several thousand oils. Oils collected from the region by CaribX have been analysed for the same biomarkers and plotted against the global occurrences as described by GeoMark Research for some of the classic oils / source rock end members in the region, namely the Upper Jurassic Smackover, Lower Cretaceous Sunniland and the Turonian La Luna and Eagleford oils (Figure 6). [CaribX does not have access to the RFDbase data base.]

The above local and regional information was then used to constrain the seabed core data collected by the then BG group. BG acquired 201 seabed core samples in 2015; solvent extracted 102 sub samples for whole-oil GC analysis, and undertook 101 Headspace gas analyses. BG group also later acquired SIR GCMS data for 5 samples.

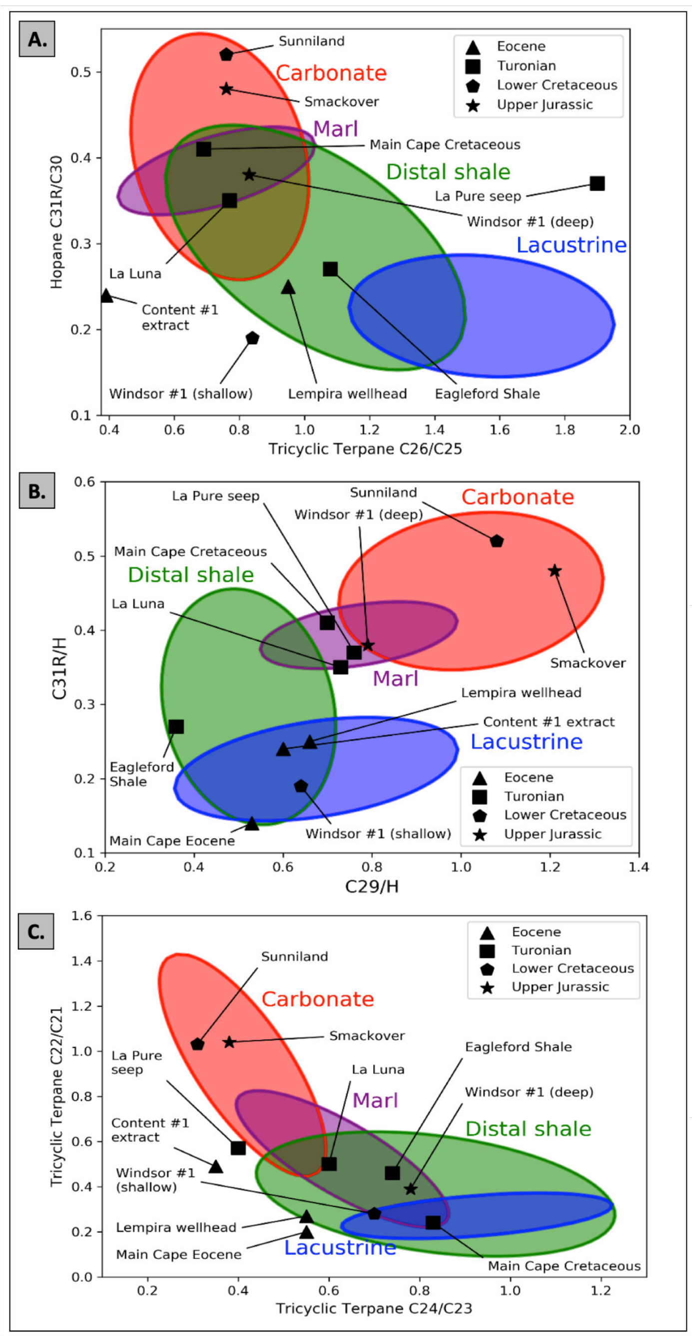


Figure 6. A); Upper Nicaraguan Rise & Western Caribbean oils compared to GeoMark Research global oils data, palaeoenvironment, and pentacyclic vs tricyclic terpane data. NB. No C26 tricylic terpanes recorded / monitored in the Main Cape Tertiary derived oil. B); Upper Nicaraguan Rise & Western Caribbean oils compared to GeoMark Research global oils data, palaeoenvironment, and pentacyclic terpanes. C); Upper Nicaraguan Rise & Western Caribbean oils compared to GeoMark Research global oils data, palaeoenvironment, and tricylics terpanes.

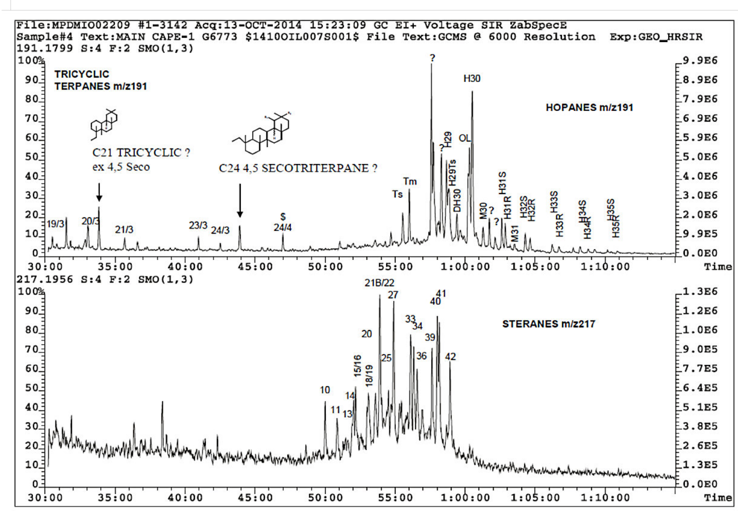


Figure 7. Main Cape oil (1), Eocene source, triterpanes M/z 191 and Steranes M/z 216 (analysis by Intertek United Kingdom, now closed)

## Discussion

### *Miocene source rocks*

Coals are recorded in the Castella #1 well on the distant flanks of the Patuca basin (Figure 1), perhaps representing paralic or limnic facies as often is found associated with lacustrine or coastal paralic settings and in part responsible for the higher plant input into the basin proper. Elsewhere log data indicates elevated TOC, but the Miocene in all penetrations is immature for oil and gas generation. The Miocene is included in this discussion as it may be mature for oil generation within the Honduran Borderland basins.

### *Eocene derived oil and source rock occurrences*

Evidence for Eocene-derived oil in the region comes from the three DST that were undertaken at the Main Cape 1 well where oil was also bought to surface. Recent analysis commissioned by BG found waxy crude (Figure 7) which was tied at the time of the drilling campaign to the Tertiary Punta Gorda formation. The Punta Gorda formation is a high-TOC carbonate-rich shale, with a significant plant debris input, deposited in a restricted marine carbonate environment. There is no reason to dispute these early observations.

On closer inspection, the oil also carries many of the characteristics of Tertiary lacustrine source rocks, namely: a limited pentacyclic triterpane and characteristic tricyclic triterpane distribution, and abundant oleanane (Figure 8.) A similar character is displayed in Tertiary oils from rift basins in North Sumatra (Geological Society Special Publication 77). The early fill of some of the Tertiary Upper Nicaraguan Rise basins was initially lacustrine.

Where penetrated (Coca Marina 1) the precursor source is often barely mature, this is seen in the Main Cape #1 DST samples with mortane (βα hopanes) still being present, and sterane S-to-R isomerisation not advanced, therefore an early oil window setting is envisaged for the Eocene source.

The Coca Marina #1 well (drilled in 1969) encountered some 770m of rich Middle Eocene (Punta Gorda Formation) source rock (with oil shows) (Figure 9). The same source interval is found to the south in many of the Nicaraguan wells and this interval is also believed to be the time equivalent of the Litchfield-Chapleton Formation onshore Jamaica. The Litchfield-Chapleton Formation is also a thick and robust source unit encountered in the Content #1 well (650m) (Rodrigues, 1991), and at outcrop onshore Jamaica.

Eocene source rocks have been widely reported across the Nicaragua Rise, therefore the Eocene oil occurrences in the Main Cape #1 well and onshore related to the Lempira #1 well are supported.

### *Cretaceous-derived oil and source rock occurrences*

A second, more mature oil was also recorded in the Main Cape #1 well, and additionally encountered in the onshore La Pure seep. The oil represents an earlier generative product from an older source thought to be Upper Cretaceous in age (most likely Turonian, a La Luna equivalent), and was degraded prior to a later charge resulting from a later heating event.

This second oil family possesses no oleanane, has a far more complicated triterpane distribution including elevated C35 pentakishomohopane epimers and gammacerane. It is also far more mature based on sterane and triaromatic steroidal hydrocarbon distributions. This Main Cape oil is thought to have been generated from source rocks that reached the late zone of oil generation, whilst the La Pure seep (onshore) was generated from (Upper) Cretaceous source rocks that reached peak oil window maturities. The literature surrounding the Main Cape oil types held by SERNAM[1] also includes analysis by other oil and service companies describing the older oil and the likelihood of mixing.

Until recently the Upper Cretaceous source rock penetrations have been ignored. Our work identified on Wire Line data Upper Cretaceous source rocks in the Gracias a Dios, Castana, Turquesa and Diamante wells. There are also shales recorded in Mobil's Turquesa #1 well with TOCs up to 8.5%, however there is no accompanying Rock Eval. or extract data, or indeed samples material to further characterise this marine source rock. Vitrinite reflectance (Ro%) data indicates that the Upper Cretaceous is immature at this location.

Apto-Albian source rocks are also found throughout large parts of the western Caribbean, but with the limited data available it is not possible to constrain its occurrence offshore Honduras. There are several wells to the immediate southwest of the Patuca basin with shows recorded in presumed lower Cretaceous rocks on the Mosquitia High, and it is entirely conceivable there is also Lower Cretaceous Upper Nicaraguan Rise geology (and source). The presence of a deeper Cretaceous source remains unknown, however regionally the Lower Cretaceous is a potent and ubiquitous source. If present in the Honduras offshore setting it is thought to be overly mature, though may provide some gas drive.

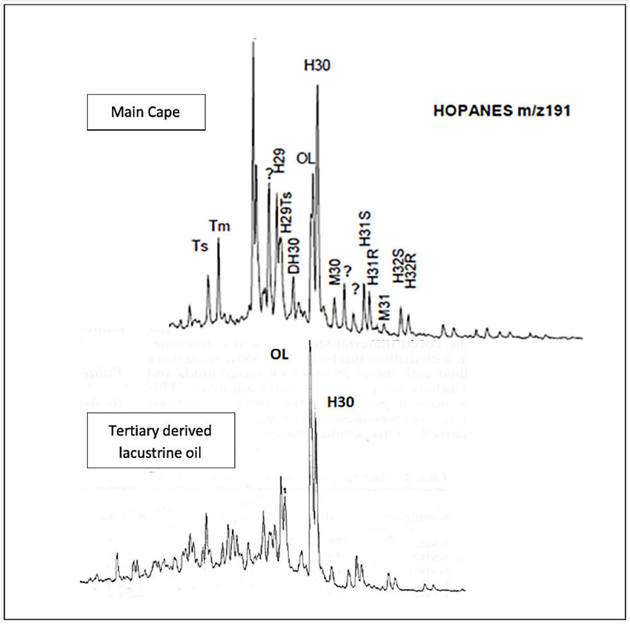


Figure 8. Main Cape oil (1) vs Tertiary lacustrine oil (Analysis by Newcastle University) compared to known lacustrine oil from similar extensional Tertiary rift basin setting (Analysis by LEMIGAS).

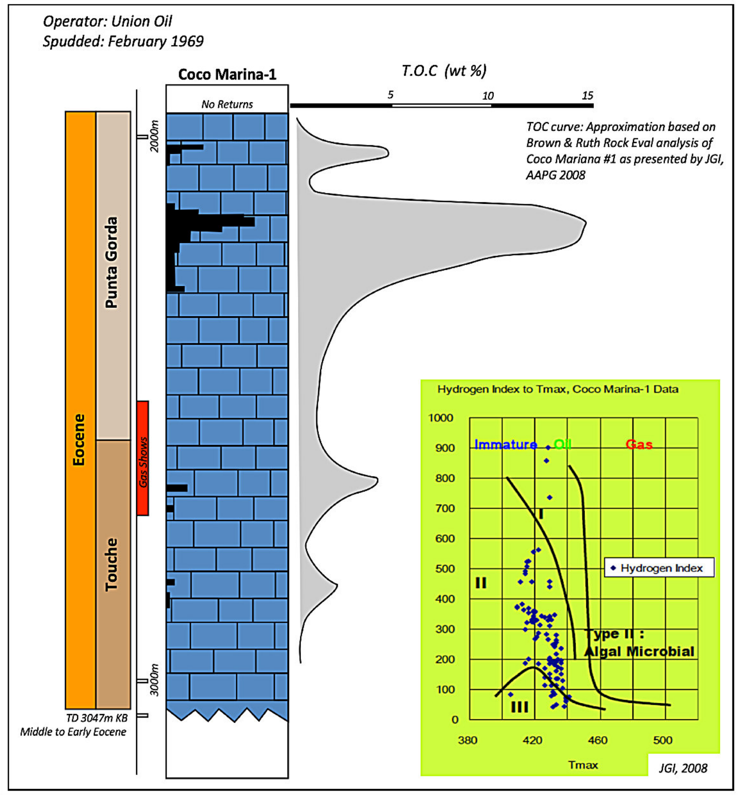


Figure 9. The Punta Gorda source succession, Coco Marina well, Mosquitia Basin, derived from Union Oil/Brown & Ruth data held by SERNAM, Honduras.

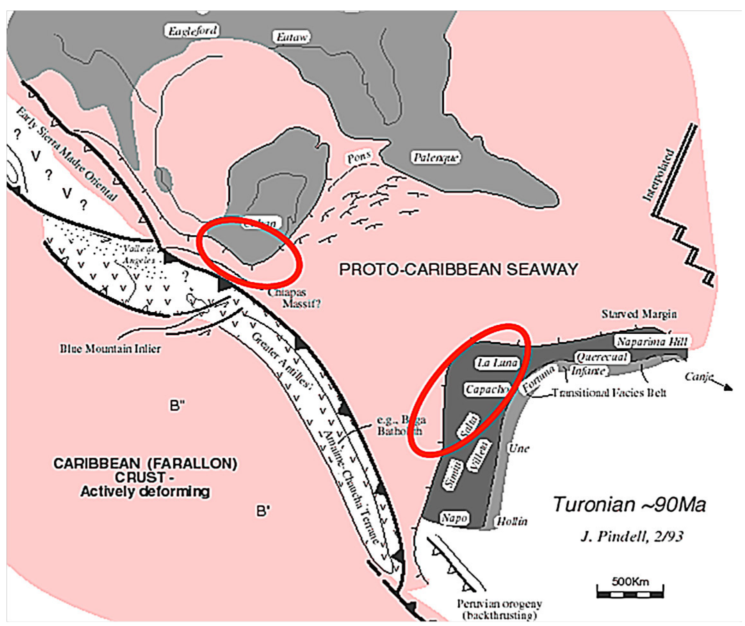


Figure 10. Northern South America block, the proto-Caribbean seaway and the Chortis block circa end Cretaceous (Pindell, 1993).

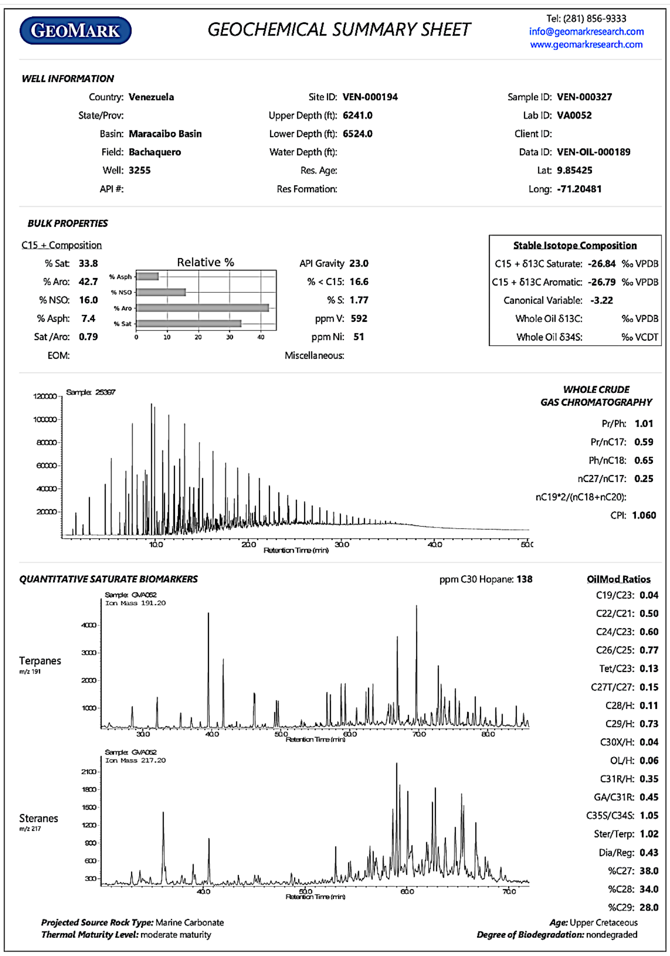


Figure 11a. Maracaibo oil data summary sheet, (GeoMark Research, biomarker guide).

There are also documented Lower and Upper Cretaceous source rock occurrences onshore throughout the region. The onshore Upper Cretaceous Guare member of the Jaitique formation is one such occurrence. The Guare member is a thin-bedded, laminated, bituminous limestone containing the occasional fossil fish which may represent a shallow lagoon, intertidal mud flat to shallow marine environment. This may have been the shallower more proximal setting to a greater La Luna type source environment, within or on the flanks of the Proto Caribbean Sea. This greater La Luna type source environment occurred at the time Chortis was moving from its coast-parallel eastern Pacific position into the proto-Caribbean region (Pindell et al, 1993).

The presence of La Luna type source rocks, as evidenced by the biomarker data on Chortis, either dates the arrival of Chortis or may suggest that the Chortis, Siena and CLIP were already in place, attached loosely to the North American Plate.

The shallow seas linked the South and North American plates and were likely closed to the East by the processing Antilles Arc, and perhaps to the west by an advancing arc which is now the Pacific Margin, thus preventing ocean circulation and thereby enhancing source rock development. On the southern side, rich source rocks (the La Luna source) developed in these shallow carbonate-rich epicontinental seas; the same is thought to have occurred on the northern periphery of this shallow sea (Figure 10 and Figure 11a & b). The alternate consideration is that the greater Chortis area was part of the North America plate.

The Upper Cretaceous oil-rich Guare member is not the source of the La Pure or Main Cape oils, with the nearest match in fact being the oil from the then opposite margin (perhaps mirror) of the proto Caribbean Sea, providing strong evidence for this greater La Luna type source environment (Figure 12). Further geochemical work is required to analyse the shows, if available, from the Cretaceous well sections and possible source rocks in other Upper Nicaraguan Rise well penetrations and onto and around Jamaica.

The geochemical data and findings suggest that Chortis has a close affinity to the North American plate, contrary to the commonly accepted position, therefore more work is required.

***Upper Nicaraguan Rise Oils compared to recent Western Caribbean oils data***

An attempt to determine the character of the precursor source rocks to the oils found on the Upper Nicaragua Rise was undertaken by examining other oils in the greater region. Stable carbon isotope ratios ($\delta^{13}C$‰) for oils and oils data collected throughout the region were compared to the Honduras oils using a conventional Sofar plot, again the bulk of the Main Cape #1 oil and the Lempira #1 well head location samples are clearly Eocene in origin, whilst the residual early oil in the Main Cape #1 well and the La Pure seep oil have Upper Cretaceous (Turonian) affinities (Figure 13).

Three Jamaican source rock types were recognized from analysis of well data (Matchette-Downes et al 2004): a mid-Eocene, an Upper Cretaceous and an Upper Jurassic source.

The mid Eocene Chapleton-Litchfield source is thought to be time-equivalent to the Punta Gorda Formation to the west. Both sources contain large quantities of terrestrially derived material, however in the east the source shales were deposited in a marine environment. Neither the Jamaican Oxfordian-derived oil (Windsor #1, figure 6) nor the Uppermost Cretaceous source character appears to the west.

Further Cretaceous derived oil found in seeps in 2019 suggests both the Lower and Upper Cretaceous contain active sources, but at the time of writing no data for these seeps has yet been made public. Re-evaluation of the Windsor #1 well data revealed two oil families, the shallower having affinities to other AOE 1 oils in the greater region (figure 6).

***Seabed core data***

The Patuca basin located in the Borderlands region (Figure 1), north of the Mosquitia High has no well penetration. However, analysis of the seabed core data in the Patuca basin (obtained by the BG group) confirms the two-oil-signature (Eocene and Cretaceous) observations discussed above (Figure 14). Both a mature light hydrocarbon and a heavy unresolved hydrocarbon are evident within the whole extract gas chromatography. The deeper Albian section may also be contributing some gas.

GCMS analysis of the data (table 1) also reveals two distinct maturity signatures. However, as there was limited sample material and few data points, the interpretation cannot be taken further. Five samples (only) were selected by BG for GCMS, but the project never completed due to the sale of the company while the analyses were in progress.

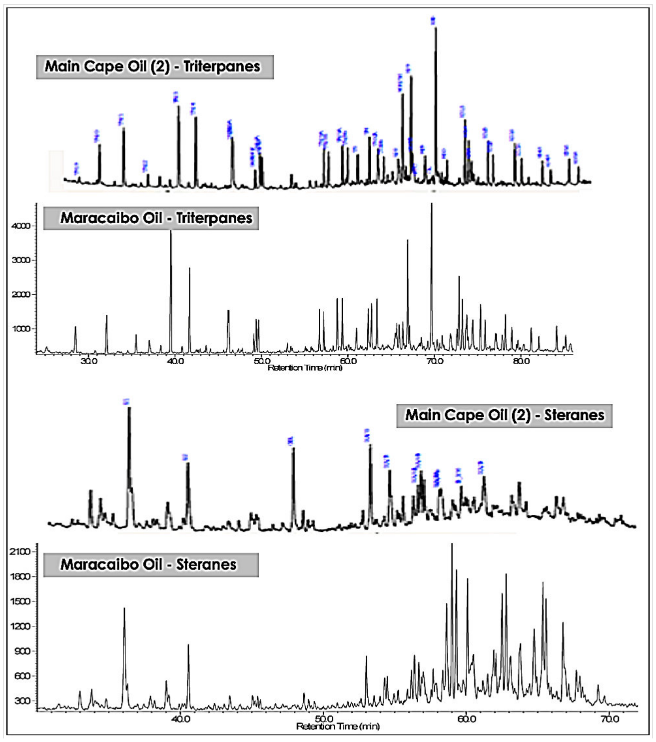


Figure 11b: Main Cape and Maracaibo oil compared. Main Cape oil (2) oil triterpanes, steranes, stable isotope ratio (δ$^{13}$C‰), elemental sulphur (S), compared to a typical Maracaibo oil.

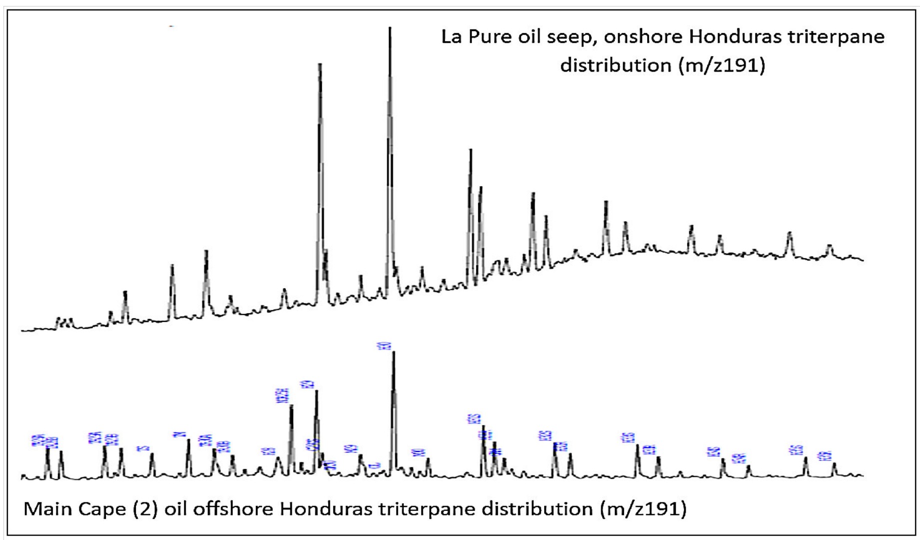


Figure 12. Main Cape Oil (2). (Analysis by GeoChemicalSolutions) and La Pure seep, onshore (analysis by Newcastle University) triterpane M/z 191 distributions compared.

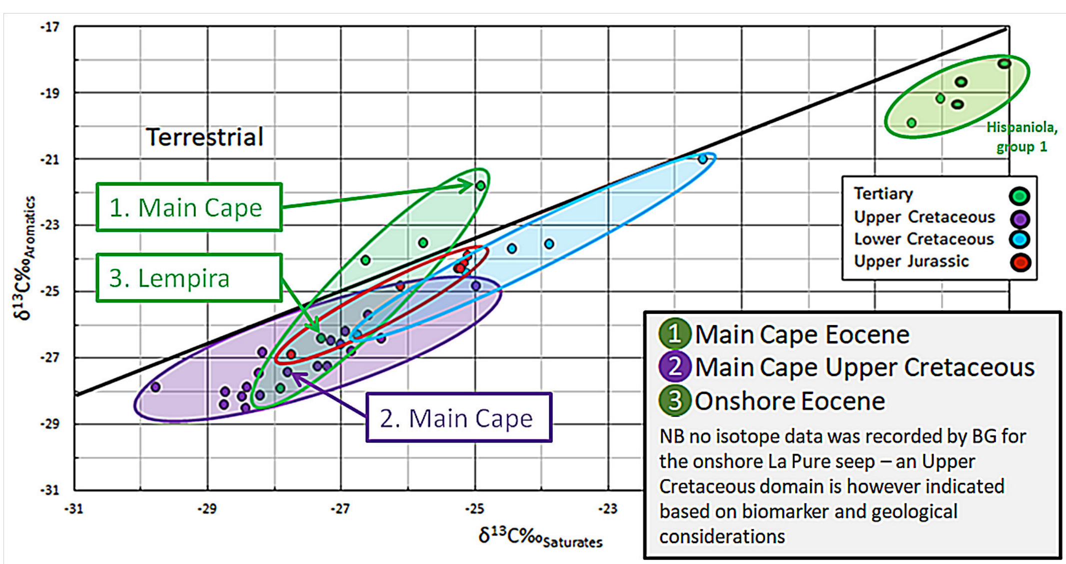


Figure 13. Caribbean Petroleum System (CaribX and MDOIL oils collection/ data bases).

1) Methyl Phenanthrenes - soluble in water so an unreliable ratio

| Location | P | 3 | 2 | 9 | 1 | 2&3 | |
|---|---|---|---|---|---|---|---|
| PC22-15 | 49061 | 2353 | 3719 | 2480 | 2070 | 11476.08 | 54794 |
| PC35-03 | 62039 | 4047 | 5942 | 4142 | 3663 | 18879.21 | 71873.3 |
| PC77-14 | 51659 | 5527 | 7883 | 4628 | 4880 | 25344.9 | 63639.08 |
| PC196-10 | 108663 | 7078 | 9199 | 5914 | 5199 | 30763.53 | 122665.4 |
| PC202-14 | 43759 | 4236 | 6823 | 3897 | 3702 | 20901.51 | 53333.74 |
| PC204-10 | 44028 | 3596 | 4445 | 2913 | 2091 | 15197.49 | 50333.04 |

2) Sterane isomerisation - measuring just background immature sterane isomerisation

| | C29AAR | C29AAS | S/S+R | |
|---|---|---|---|---|
| PC22-15 | 232.9 | 31.7 | 0.12 | immature |
| PC35-03 | 507.3 | 51 | 0.09 | immature |
| PC77-14 | 2074.3 | 286.4 | 0.12 | immature |
| PC196-10 | 20219.1 | 2554.6 | 0.11 | immature |
| PC202-14 | 2706.9 | 257 | 0.09 | immature |
| PC204-10 | 5460.6 | 1206.7 | 0.18 | immature |

3) Triaromatic steroidal hydrocarbon ratio - An indication of type of oil reaching the su
light oil condensate and black oil appear to be present

Table 1. GCMC maturity data

***Basin modelling***

The numerous lines of clear evidence for source rock presence offshore Honduras have been presented in the discussion above, however the horst and graben structure of the region and limited well coverage make it difficult to quantify their areal and vertical distribution. Early basin modelling work (Trinity™ and Genesis™) demonstrates that significant quantities of oil can be generated (Figure 15). Both the Mosquitia and the Patuca basin appear to have access to source rocks which are Tertiary and Cretaceous in age.

Very high heat flow values were recorded within the Patuca and Niobe basins (there were 12 acceptable measurements taken, 10 of which ranked good to excellent and 2 fair in terms of data quality). The values ranged from 50 to 90 $mWm^{-2}$ with the highest value being over the largest carbonate structure in the Patuca basin. These values are high but expected in this extensional setting. As a consequence of the high heat flow, the Eocene source is predicted to be in the oil window and Upper Cretaceous sources will be in the late oil window. To the south, on the Mosquitia High and within the Mosquitia basin, the limited TAI and Ro% data indicate lower thermal stress. Generation within the Patuca and Niobe basin is interpreted to be very late, starting in the Pliocene and continuing to the present day. The key reservoirs are at or above pasteurisation temperatures and are thought full to spill.

Miocene sources are yet to be examined in detail, but may be mature for oil within the Patuca and Niobe basins due to the very high and recent heat flux.

**Results**

The results of the oils, wells and core analysis all clearly indicate the presence of at least two source rock assemblages across the Nicaraguan Rise. The first is the regional Upper Cretaceous source system which is equivalent to the classic Turonian, AOE2 source rocks found on the northeast coast of the South American plate, such as the La Luna. A secondary, but potent Eocene source system developed in the sub basins across the Nicaraguan Rise.

The recognition of the presence of La Luna equivalent source rocks on the Chortis block brings into question, at the very least, the timing of the arrival of Chortis, and perhaps, more fundamentally, the fact that the Chortis, Siena the CLIP may well have always been in place with the majority of the movement occurring to the north along the Montague-Polochic-Swan Islands Fault System.

**Hydrocarbon Potential Overview**

The Patuca, Mosquitia and Niobe basins each present differing degrees of potential for hydrocarbon exploration.

**Mosquitia Basin**

The Mosquitia basin has a proven hydrocarbon system, with source likely provided by two intervals. Great thicknesses of the Eocene Punta Gorda source rock have been encountered in several wells. There is also clear evidence for an older oil which is thought to be of Upper Cretaceous age in origin.

The Main Cape-1 discovery well produced 38º API gravity oil (3 DSTs and oil in the mud pits), the DST 3 oil appears to be Eocene in origin and the DST 2 oil pre-Tertiary. The well was drilled at the toe of the Main Cape structure; however the limited and poor seismic dataset which covers the discovery prevents mapping the full extent of the closure. The sparse 2D dataset provides indications of additional leads in the Eocene carbonates both structural and stratigraphic; however a modern 3D dataset or 2D infill campaign would be required to unlock the full potential of a sparsely explored basin which has a proven hydrocarbon system.

The Miocene source interval is immature in the Mosquitia basin, but may well be mature for oil in the Patuca or Niobe basin.

**Patuca Basin**

The relatively dense 2D seismic grid present across the basin has facilitated the generation of multiple highly attractive structural prospects. The tectonically complex basin has resulted in several high relief structures within the basin main and along its margins. Analysis of the depositional history of the basin and an evaluation of key analogues would imply the Miocene carbonates which present the key exploration target in the basin, with excellent reservoir potential.

There are no wells within the basin; however the extensive sea bed core extract data clearly displays two oil maturity signatures; therefore two oils, again the Eocene and Upper Cretaceous most likely, or some Miocene-Eocene-Upper Cretaceous combination(s).

The near basin-flanking Castilla #1 well possesses a late Miocene coaly section. Paralic or limnic basin margin facies are envisaged with increasing source potential developing within the Patuca basin in a more proximal setting.

The nearest Eocene source penetrations are found in the Mosquitia basin as previously discussed. Gracias a Dios #1 well drilled on the northern flanks of the Mosquitia High recorded WLL responses indicative of a source rock section of some 85+ m in the Upper Cretaceous, near TD. Recent biostratigraphy examination, by BG Group dates the TD section of the Gracias a Dios #1 in the Upper Cretaceous.

The extremely high heat flow (BG Group) and late generation are likely optimal for charge and charge retention, which combined with favourable migration pathways suggest significant potential for hydrocarbon retention within the large undrilled traps of the Patuca basin.

**Niobe Basin**

A full technical understanding of the Niobe basin is still in its infancy due to the scarcity of seismic across the basin and zero well control. However, initial indications on the seismic which is present are encouraging. Multiple tilted fault block geometries are clearly visible along the basin margins, and potential DHIs within the basin have been identified. Sea bed core extracts indicate the presence of hydrocarbons, and the extremely high heat flows recorded could mean that the younger section (Miocene as well as Eocene) could be mature for oil. Additional data will be required to investigate the true potential of the Niobe basin.

**Conclusions**

Oil occurrences, well penetrations and or outcrop samples at each end of the Nicaraguan Rise point to the presence of a robust, regional source rock of Lower to Mid Eocene age that is highly likely to be present in many yet to be drilled basins across the Nicaraguan Rise.

A younger Miocene source rock, only encountered in the western part of Nicaragua Rise where it is immature for oil generation, may however be mature within the younger, hotter basins that make up the Honduras Borderlands and any eastward extension of this terrain.

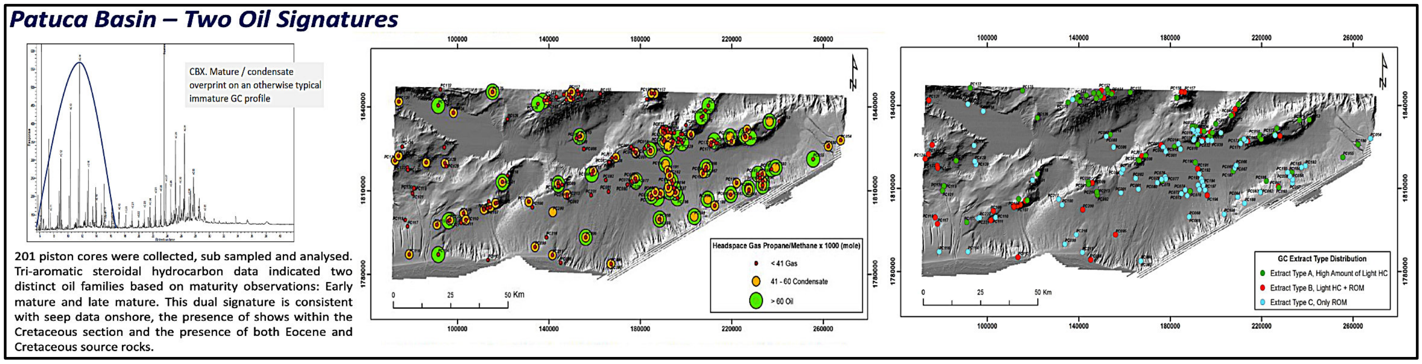


Figure 14: Two oil signatures can be seen both within the headspace gas analysis and whole extract gas chromatography

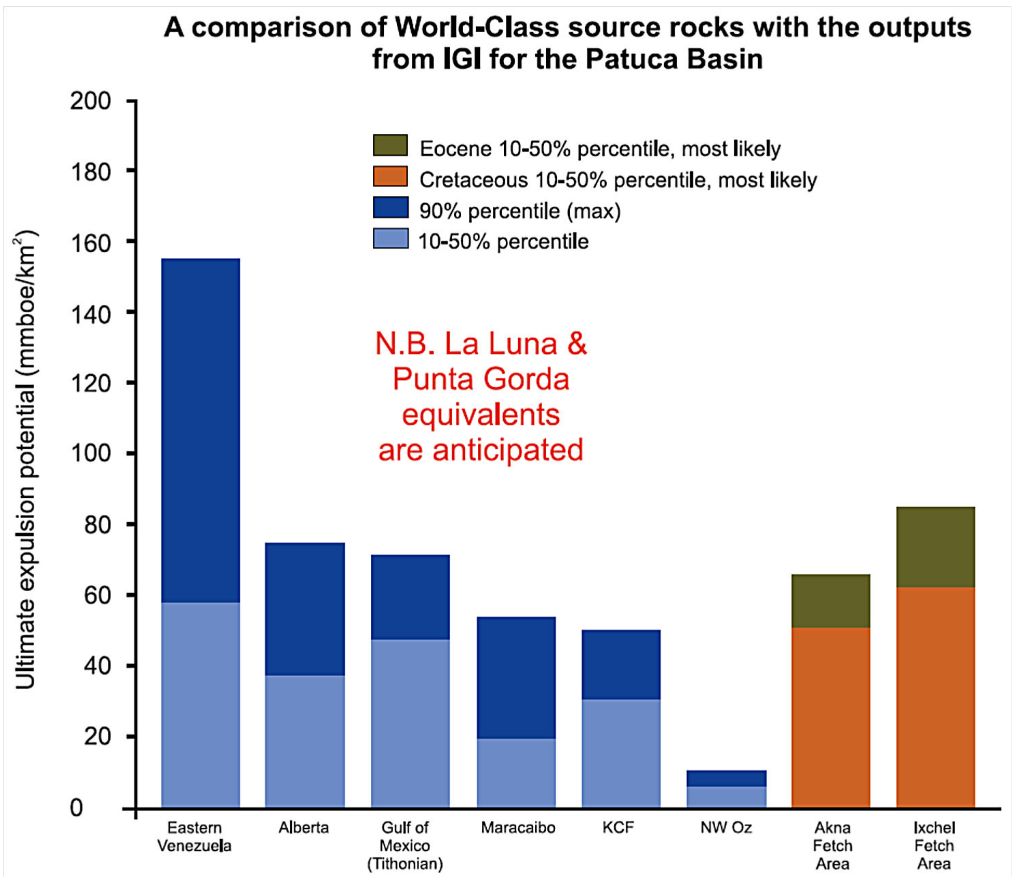


Figure 15. source summary and comparison for the Patuca Basin.

Upper Cretaceous sediments house a significant and regional source unit that is typified by the La Luna formation from the northern South American plate. This Upper Cretaceous aged source has been encountered in 3 well bores offshore Honduras and is responsible for the older Main Cape #1 oil and the La Pure oil seep onshore Honduras. Upper Cretaceous oil is reported on Jamaica, but no data is available for comparison.

Whilst Lower Cretaceous oils have been observed onshore Jamaica, (Windsor #1, shallow section) and reported elsewhere, no source rocks to date have been penetrated or recorded in outcrop. Such rocks would likely be post mature for oil or gas in Honduras.

Similarly the Upper Jurassic sourced oils from the deeper section in the Windsor #1 well are either not present offshore Honduras or are super mature and all labile material lost.

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**Profile & key information**

**Christopher John Matchette-Downes**

**2010 to present day:** Director & Consultant Petroleum Geologist CaribX Limited

- Thirty eight years global exploration experience; petroleum geology, well site geology/geochemistry, teaching, business development and project management
- Built exploration teams; secured & worked up UK, African & Caribbean projects
- Set up and promoted Jamaica's 1st and 2nd oil & gas exploration rounds
- Managing for TPDC, the promotion of the 3rd Tanzanian round
- Founder and director of MDOIL Ltd, (www.mdoil.co.uk) CaribX Ltd (www.caribx.com), Helium Resources Ltd (www.4he-resources.com)
- Helped start-up company Natural Building Technologies build its UK business
- Former Non-Executive director of Cluff Natural Resources, created its North Sea business
- Identified, confirmed, and pursued exploration opportunities for the Lower Mesozoic Western Indian Ocean oil & gas play and the Upper Nicaraguan Rise oil & gas play
- Baker Hughes (Exlog), BGS, BP, British Gas, Geochem Group, PGS and JEBCO Seismic
- CGEOL, MSc, BSc.

**Contact**
cjmd@mdoil.co.uk