# [PS]Geochemical Characterization of Rocks and Fluids from Liberia and Sierra Leone Offshore*

**R. Tocco[1], Porti S. Martínez[1], J. Franques[2], and A. Franco[1]**

Search and Discovery Article #11203 (2019)**
Posted March 11, 2019

*Adapted from poster presentation given at 2018 AAPG Europe Regional Conference, Lisbon, Portugal, May 2-3, 2018
 DOI:10.1306/11203Tocco2019

[1]Repsol Exploration, Madrid, Spain (rtoccop@repsol.com)
[2]Repsol Exploration America, Houston, Texas, United States

## Abstract

The study area is a portion of the South Atlantic passive margin, implying a complex thermal history (rifting), located at the oceanic-continental transition. A rapid sedimentation with important lithological contrasts and important water depth variations through time are characteristics of this margin. Volcanic intrusions and sub-aerial activity are known to have occurred during the basin evolution.

Sierra Leone and Liberia basins are limited by the Sublima and Liberia plateaus. The Sublima Plateau is the result of the intersection of the Sierra Leone TF and the African continental margin. The Liberia Plateau is a basement high formed at the intersection of the North Atlantic and South Atlantic transform systems with the continental margin.

The objective of this study was to carry out the geochemical characterization of rocks, and fluids (oil and gas samples) from the wells Montserrado-1 (Liberia) and Jupiter-1, Mercury-1, Mercury-2, Venus-1B wells (Sierra Leone). The geochemical evaluation of rock samples included Total Organic Carbon (TOC), Pyrolysis Rock-Eval, Visual Kerogen Analysis, Vitrinite Reflectance (Ro%), Thermal Alteration Index (TAI), and Pyrolysis-GC. Gas samples were analyzed by Gas Chromatography and Isotopic Analysis, and oils/organic extracts were analyzed by Gas Chromatography (GC) and Gas Chromatography–Mass Spectrometry (GC-MS).

Campanian and Coniacian to Albian units show the best petroleum potential based on organic matter richness (TOC). Turonian to Albian source rock quality (Type II Kerogen, marine) increases toward the northwestern part of the studied area (in Venus-1 and Jupiter-1 wells). Maturity of Cenomanian to Albian rocks increases towards the northwest. These sequences present a maturity that ranges between the peak oil generation to late mature.

Thermogenic gas was identified in the deeper part of the Venus-1B Well (4050-5630 m), at 4590-4850 m in the Mercury-1 Well, below ~440 0m in the Mercury-2 Well, and below ~5000 m in the Jupiter-1 Well. Important thermogenic contributions in the total hydrocarbon gas from

the middle-deeper part of the Montserrado-1 Well were observed (from ~3800 m). The thermogenic component is mainly oil-condensate associated gas.

Different biomarker ratios support oil-oil correlations for Mercury-1 oils, indicating one genetically related petroleum system. The source rock that generated these oils is characterized by high marine organic matter contributions. Analyzed organic extracts at 4564 m and 4568 m in the Mercury-2 Well show mixed organic matter with significant mature terrestrial organic matter input. Mercury oils are associated with a mature shaly source rock (marine shale), probably of Late Cretaceous age.

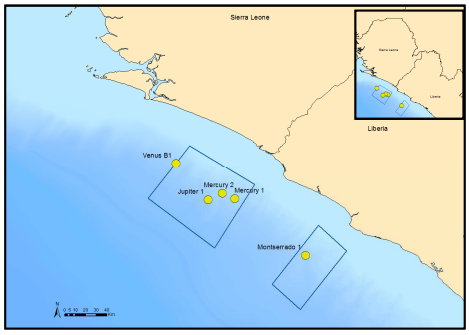
# Geochemical Characterization of Rocks and Fluids from Liberia and Sierra Leone Offshore.

Tocco R.[(1)], Martínez Portí S.[(1)], Franques J.[(2)] and Franco A.[(1)]

[1]Repsol Exploration, Madrid, Spain; [2]Repsol Exploration, Houston, USA

## Introduction

The study area is a portion of the South Atlantic passive margin, implying a complex thermal history (rifting), located at the oceanic-continental transition. A rapid sedimentation with important lithological contrasts and important water depth variations through time are characteristics of this margin. Volcanic intrusions and sub-aerial activity are known to have occurred during the basin evolution. Sierra Leone and Liberia basins are limited by the Sublima and Liberia plateaus. The Sublima plateau is the result of the intersection of the Sierra Leone TF and the African continental margin. The Liberia plateau is a basement high forming at the intersection of the North Atlantic and South Atlantic transform systems with the continental margin.




## Objectives

The objective of this study was to carry out the geochemical characterization of rocks, and fluids (oil and gas samples) from wells Montserrado-1 (Liberia) and Jupiter-1, Mercury-1, Mercury-2, Venus-1B (Sierra Leone). The geochemical evaluation of rock samples included Total Organic Carbon (TOC), Pyrolysis Rock-Eval, Visual Kerogen Analysis, Vitrinite Reflectance (Ro%) and Thermal Alteration Index (TAI). Gas samples were analyzed by Gas Chromatography and Isotopic Analysis, and oils/organic extracts were analyzed by Gas Chromatography (GC) and Gas Chromatography–Mass Spectrometry (GC-MS).

## Rocks: TOC and Organic Matter Type

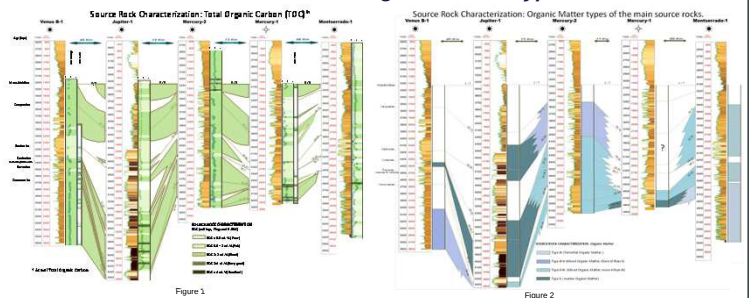



Figure 1 Figure 2

Campanian and Coniacian to Albian units show the best petroleum potential, based on organic matter richness (TOC). Effective source Rock thickness may increase towards the northwestern part of the studied area (wells Venus-1, Jupiter-1 and Mercury-2), based on TOC data (Figure 1). As Hydrogen Index (HI) is affected by maturity, the HI showed in the cross section represents the remaining mgHC/gTOC associated to the rocks. Turonian to Albian source rock quality (Type II Kerogen, marine) increases toward the northwestern part of the studied area (wells Venus-1 and Jupiter-1).

## Rocks: Thermal Maturity (Tmax and %Ro)

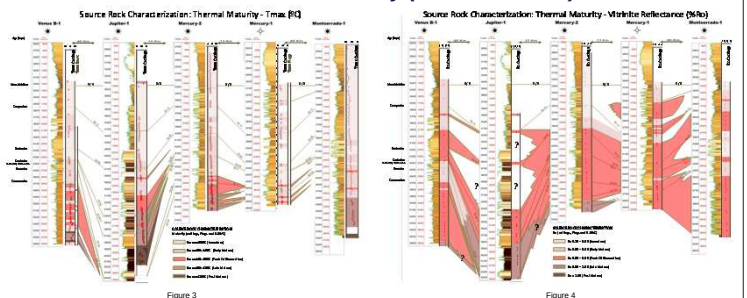



Figure 3 Figure 4

Thermal maturity of Cenomanian to Albian rocks (mainly inferred from Vitrinite Reflectance-%Ro, Figure 4) increases towards the northwestern part of the studied area (wells Venus-1 and Jupiter-1). These sequences present an equivalent maturity to Peak Oil Generation to Late Mature.

## Liquid Hydrocarbons: Well Mercury-1

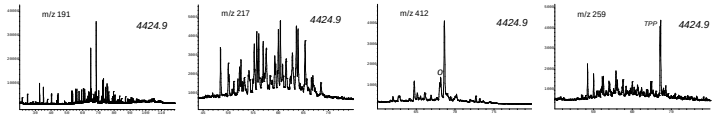



Figure 5 Figure 6

m/z 191 and m/z 217 chromatograms (Figure 5) indicate marine organic matter contributions for the source rock that generated the Mercury oils. Relative high concentration of diasteranes and low C29 nor-Hopane/C30 Hopane indicate fluids derived from clay-rich source rocks. The Mercury oils are characterised by the presence of the source and geological age specific marker oleanane (m/z 412, Figure 6). Oleanane are best preserved in deltaic rocks influenced by marine waters during early diagenesis. The oleanane/(oleanane+C30-Hop) ratio indicates probably Late Cretaceous source rock for these crude oils. Tetracyclic Polyprenoids (TPP) are highly specific for lacustrine organic matter input. Apparently, the Mercury oils have appreciable content of TPP (m/z 259, Figure 6). It is necessary to confirm the presence of TPP in these oils using GCMS/MS analysis (414->259). These results could indicate influx of freshwater algae in nearshore marine source rock settings or, input from nearshore shalow marine algae with chemistry similar to that found in lacustrine settings (Peters et al., 2005).

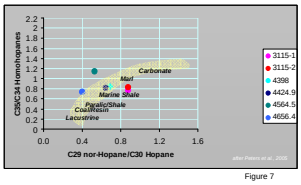



Figure 7

Shaly source rock lithology is indicated by the relatively low C29 nor-Hopane/C30 Hopane which is clearly below unity. The oils are characterized by a C35/C34 Homohopanes ratio < 1 (except oil 4564.5), which again indicates to shaly source lithology (Figure 7).

| Crude Oils | Rc from 20S/20R | Ctemp (ºC) | Rc from Ctemp |
|---|---|---|---|
| 3115-1 (API° 23.2) | 0.77 | 130 | 0.93 |
| 3115-2 (API° 23.2) | 0.78 | 134 | 0.97 |
| 4398 (API° 45.3) | 0.73 | 131 | 0.95 |
| 4424.9 (API° 33.4) | 0.77 | 128 | 0.91 |
| 4564.5 (API° 35.3) | 0.80 | 124 | 0.86 |
| 4656.4 (API° 36.2) | 0.85 | 120 | 0.82 |

Figure 8

*Ctemp (ºC): maximum temperature of hydrocarbon expulsion (Mango, 1997).*
*Rc from Ctemp: vitrinite reflectance from maximum temperature of hydrocarbon expulsion.*
*Rc from 20S/20R: vitrinite reflectance inferred from sterane distribution.*

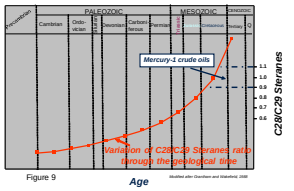


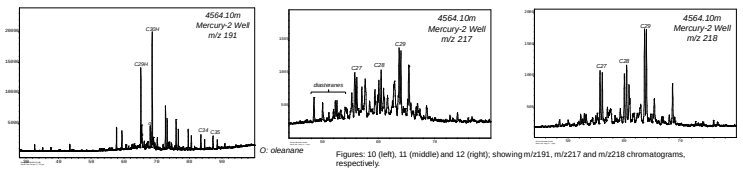

Figure 9

Mercury oils are associated to a mature shaly source rock (marine shale) probably of Late Cretaceous age .

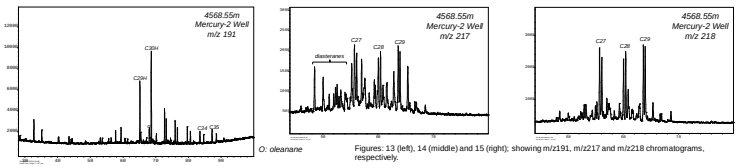
The light hydrocarbon based maturity (Rc: 0,82-0,97) is higher than the value that is based on the sterane Isomerisation (Rc: 0,73-0,85). However, expulsion temperatures over 130ºC are typical for condensates samples and the Mercury oils are originally light oils (33-36ºAPI).

It is possible that differences between light-hydrocarbon and biomarker parameters reflect mixing of light and heavy hydrocarbon components of differing thermal maturities (Peters et al., 2005). These differences could be the result of a less mature and more mature source rock have expelled hydrocarbons that observed in the Well Mercury-1. A possibility is that one source rock which is characterised by a continuously increasing maturity could have generated the Mercury oils.

## Liquid Hydrocarbons: Well Mercury-2




Figures: 10 (left), 11 (middle) and 12 (right); showing m/z191, m/z217 and m/z218 chromatograms, respectively.




Figures: 13 (left), 14 (middle) and 15 (right); showing m/z191, m/z217 and m/z218 chromatograms, respectively.

The 4564.10 and 4568.55m organic extracts present mixed organic matter. Oleanane/oleanane+hopane ratios indicate a probable Late Cretaceous source rock. A shaly source rock lithology for these organic extracts is indicated by different biomarker ratios. 4564.10 organic extract show a regular sterane distribution (m/z 217, m/z 218) that reflects terrestrial material input, while some biomarker parameters indicate more marine organic matter input in the 4568.55m organic extract.

## Gases: Wells Jupiter-1 and Montserrado-1

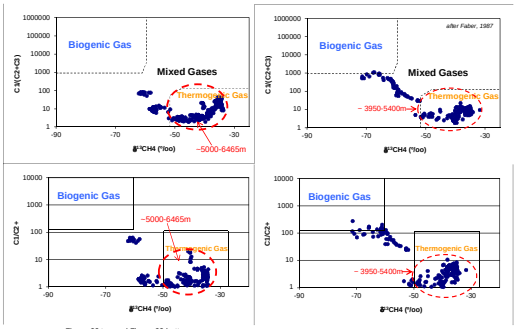



Figure 22 top and Figure 23 bottom. Well Jupiter-1.

Figure 24 top and Figure 25 bottom. Well Montserrado-1.

Thermogenic gas was identified below ~5000m in the Well Jupiter-1 (Figures 22 and 23). Important thermogenic contributions in the total hydrocarbon gas from the middle-deeper part (~3800m) of the Well Montserrado-1 were observed (Figures 24 and 25). The thermogenic component is mainly oil-condensate associated gas.

## Gases: Wells Venus-1, Mercury-1 and Mercury-2

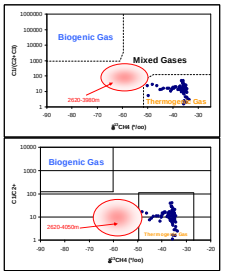



Figure 16 top and Figure 17 bottom. Well Venus-1.

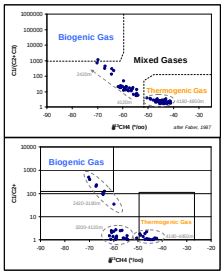



Figure 18 top and Figure 19 bottom. Well Mercury-1.

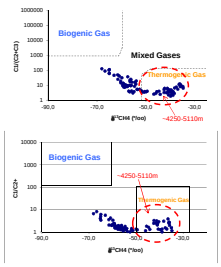



Figure 20 top and Figure 21 bottom. Well Mercury-2.

Thermogenic gas was identified in the deeper part of the Well Venus-1B (4050-5630m) (Figures 16 and 17), at 4180-4850m in the Well Mercury-1 (Figures 18 and 19), below ~4250m in the Well Mercury-2 (Figures 20 and 21).

## Conclusions

Campanian and Coniacian to Albian units show the best petroleum potential, based on organic matter richness (TOC). Effective source rock thickness may increase towards the northwestern part of the studied area (wells Venus-1, Jupiter-1 and Mercury-2 ), based on TOC data. Turonian to Albian source rock quality increases toward the northwestern part of the studied area (wells Venus-1 and Jupiter-1). Type II organic matter (marine) increases in this area. Thermal maturity of Cenomanian to Albian rocks (mainly inferred from Vitrinite Reflectance-%Ro) increases towards the northwestern (wells Venus-1 and Jupiter-1).

Different biomarker ratios support oil-oil correlations for Mercury-1 oils indicating one genetically petroleum system. The source rock that generated these oils is characterized by high marine organic matter contributions. Apparently, the Mercury-1 oils have appreciable content of TPP. Tetracyclic Polyprenoids (TPP) are highly specific for lacustrine organic matter input. For future works, it is necessary to confirm the presence of TPP in these oils using GCMS/MS analysis (414->259). Analyzed organic extracts at 4564m and 4568m in the Well Mercury-2 show mixed organic matter with significant mature terrestrial organic matter input. Mercury oils are associated to a mature shaly source rock probably of Late Cretaceous age.

Gas analyses from deeper part of all wells are thermogenic in origin.