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

R. Tocco¹, Porti S. Martínez¹, J. Franques², and A. Franco¹

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

Abstract

The study area is a portion of the South Atlantic passive margin, implying a complex thermal history (riifting), 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 Albion 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 Albion 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 ~4400 m 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 Montserrat-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.
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Tocco R,(1) Martinez Porti 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 mass 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 Sublina and Liberia plateaus. The Sublina plateau is the result of the intersection of the Sierra Leone T 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.

**Rocks: TOC and Organic Matter Type**

![Image](image_url)

The TOC content in the studied samples varies from 0.1 to 2.5% with a peak at 0.4%. The organic matter type is varied with low amounts of bitumen detected in some samples. The kerogen type is predominantly Type I with a minor contribution of Type II kerogen.

**Liquid Hydrocarbons: Well Mercury-1**

![Image](image_url)

The liquid hydrocarbon composition shows a predominance of aliphatic compounds, with an abundance of normal alkanes. The absence of aromatic compounds suggests a thermogenic source rock. The hydrocarbon distribution reflects the maturity of the source rock, with heavier compounds dominating at higher maturity levels.

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

![Image](image_url)

Thermal maturity of Cerro Negro to Albian rocks (mainly inferred from Vitrinite Reflectance-Ro) increases from the northwestern part of the studied area (well Venus-1 and Jupiter-1). These sequences present an equivalent maturity to Peak Oil Generation to Late Maturity.

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

![Image](image_url)

Thermogenic gas was identified in the deeper part of the Well Venus-1 (H05-H036-H038) (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**

Comparison of Continental 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 may increase towards 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 Cerro Negro in Albian rocks (mainly inferred from Vitrinite Reflectance-RA) increases towards the northwestern (wells Venus-1 and Mercury-1).

Different biomarker ratios support oil correlations for Mercury-1 oils indicating a more carbonated petroleum system. The source rocks that generated these oils is characterized by high marine organic matter contributions. Apparently, the Mercury-1 oils have appreciable content of TPH: Tetrahydrofuran Primers (TPH) are highly specific for lacustrine organic matter input. For future work, it is necessary to confirm the presence of TPH in these oils using GC/MS/MS analysis (H14-258). Analyzed organic extracts at 4540m and 4560m in the Well Mercury-2 show mixed organic matter with significant marine terrestrial organic matter. Mercury oils are associated to a marine shaly source rock. Probably Late Cretaceous age.

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