[PS]Geochemical Characterization of Rocks, Fluids and Solid Bitumens from Kwanza Basin, Angola*

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Abstract

The Kwanza Basin of Angola is a South Atlantic Basin whose evolution was controlled by the Early Cretaceous rifting and later transition to a passive margin basin. This margin has been interpreted by several authors as lying over a Hyperextended Margin. In such a setting thinning of the lithosphere is not linear from undeformed to oceanic domain as in the pure shear model (Mc Kenzie, 1978) but present "hyperextended" portions where crust or mantle lithosphere has been preferentially removed (Huismans and Beaumont, 2011).

The objective of this study was to carry out the geochemical characterization of rocks, fluids and solid bitumens from the Locosso-1ST1 and Catchimanha-1 wells. 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 one oil sample was analyzed by Gas Chromatography – Mass Spectrometry (GC-MS) and Carbon Isotopes. Finally, the solid bitumens were analyzed using Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS) and Gas Chromatography-Isotope Ratio Mass Spectrometry (GC-IRMS).

Post-salt and pre-salt rocks contain mainly marine organic matter and very low quantities of terrestrial organic matter. Post-salt and pre-salt rocks in the Locosso-1ST1 Well are immature to early mature, while in the Catchimanha-1 Well, post-salt rocks are immature and pre-salt rocks are post mature (dry gas window).

Locosso-1ST1 and Catchimanha-1 gases are mainly wet and thermogenic in origin. The isotope gas composition indicates that Locosso gases are likely to be late mature oil/condensate associated gas, and Catchimanha gases probably represent a mix of condensate associated gas and dry gas. It is possible that high quantities of thermogenic Catchimanha gases were generated from secondary cracking of liquid hydrocarbons.

One oil sample from the Locosso-1ST1 Well shows classical molecular characteristics of a lacustrine oil. Minor marine inputs are possible. This oil was generated by a highly mature clay-rich source rock. Calculated Rc% of 1.20 possibly reflects the maximum thermal maturity for the Locosso oil.

The geochemical characterization of the pyro-products from solid bitumens indicates different sources for Locosso and Catchimanha solid bitumens. The differences in biomarker and isotopic signatures for the various pyro-products suggest that the solid bitumens are a mixture of lacustrine (Bucomazi Formation) and marine sourced oils. The pre-salt section in the Locosso-1ST1 Well is immature to early mature. Under these maturity conditions the formation of solid bitumens is not related to thermal cracking of oils. Locosso solid bitumen was probably generated by gas de-asphaltening or oil mixing. On the other hand, the Catchimanha solid bitumen probably was generated by thermal cracking of oils. The maturity in the pre-salt section in the Carchimanha-1 Well reached values up to 1.8-2.0 Rc (equivalent to ~190-200º C).

References Cited

Huismans, R.S., and C. Beaumont, 2011, Depth-dependent extension, two-stage breakup and cratonic underplating at rifted margins: Nature, v. 473, p. 74-78.

McKenzie, D., 1978, Some remarks on the development of sedimentary basins: Earth Planetary Science Letters, v. 40, p. 25-32.

Geochemical Characterization of Rocks, Fluids and Solid Bitumens from Kwanza Basin, Angola.

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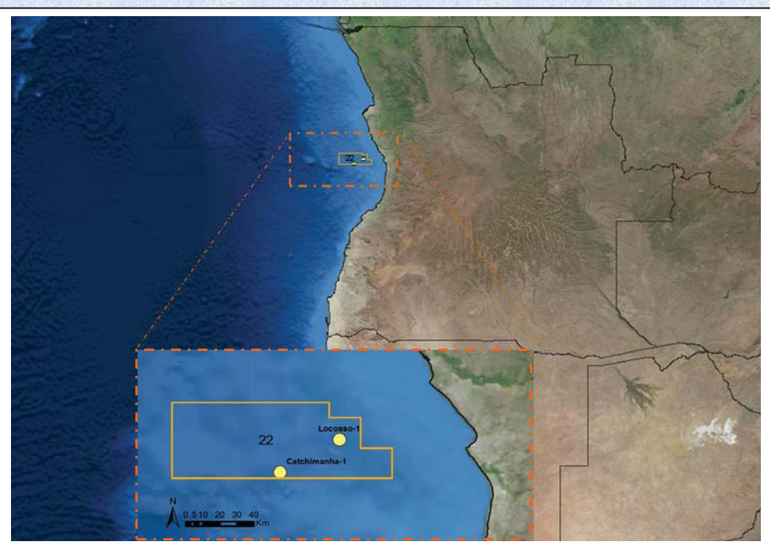
Introduction

The Kwanza Basin of Angola is a South Atlantic Basin whose evolution was controlled by the Early Cretaceous rifting and later transition to a passive margin basin.

This margin has been interpreted by several authors as lying over a Hyperextended Margin. In such setting thinning of the lithosphere is not linear from underformed to oceanic domain like in the pure shear model (Mc Kenzie, 1978) but present "hyperextended" portions where crust or mantle lithosphere has been preferentially removed (Huismans & Beaumont, 2011).



Objectives

The objective of this study was to carry out the geochemical characterization of rocks, fluids and solid bitumens from wells Locosso-1ST1 and Catchimanha-1. 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 one oil sample was analyzed by Gas Chromatography – Mass Spectrometry (GC-MS) and Carbon Isotopes. Finally, the solid bitumens were analyzed using Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS) and Gas Chromatography-Isotope Ratio Mass Spectrometry (GC-IRMS).

Rocks Locosso-1ST1

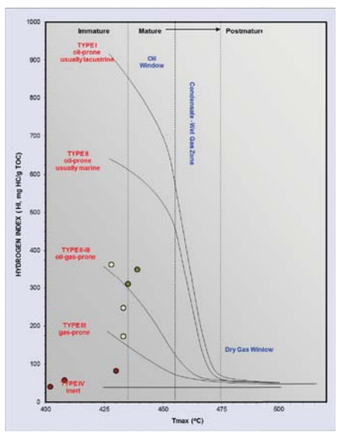


Figure 1

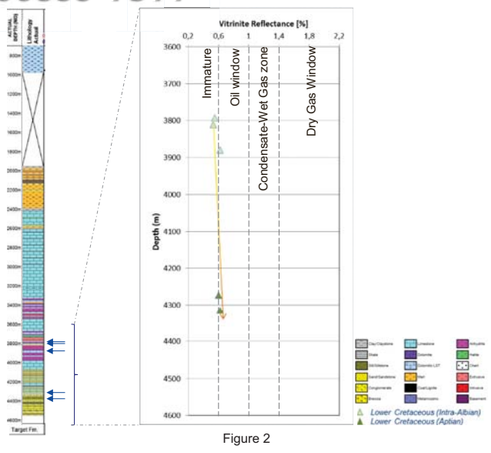


Figure 2

Intra-Albian and Aptian rocks are immature to early mature. Detailed Tmax values points to a very slightly increase on thermal maturity with depth (Aptian materials seem slightly more mature than Albian rocks). It can be stablished that Intra-Albian and Aptian rock samples contain a mix of Kerogen Types II-III, related to marine organic matter with inputs of terrestrial organic matter. (HI versus Tmax diagram on the left). Intra-Albian and Aptian rocks in Well Locosso-1ST1 are immature to early mature (figure on the right. Vitrinite Reflectance (Ro%) versus depth).

Rocks Catchimanha-1

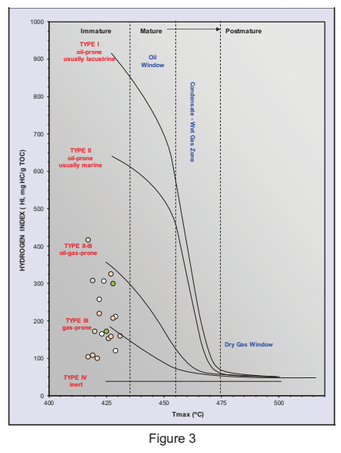


Figure 3

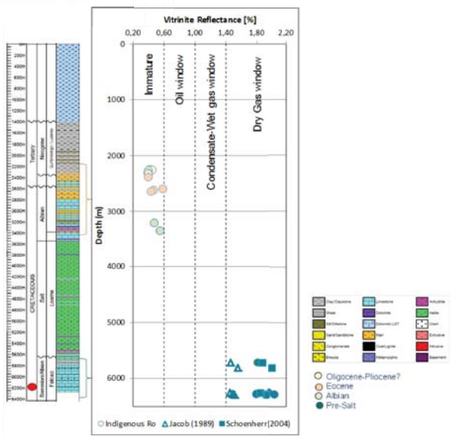


Figure 4

According to plotted data in Figures 3 and 4, post-salt rocks from Well Catchimanha-1 are immature Type II-III kerogen, while pre-salt rocks are post mature (dry gas window). Visual kerogen analysis of pre-salt rocks shows pyrobitumen as the dominant component. Pyrobitumen is non-fluorescent, granular and interconnected. The residual organic matter type is mainly associated to non–fluorescent Amorphous Organic Matter (15-45%).

Fluids Locosso-1ST1

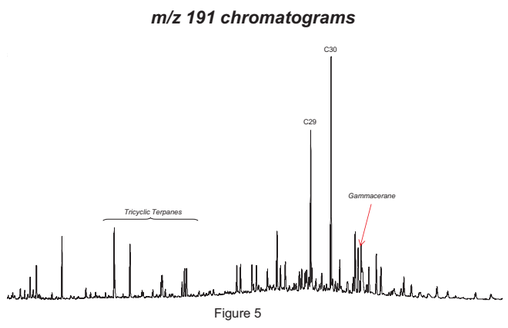


Figure 5

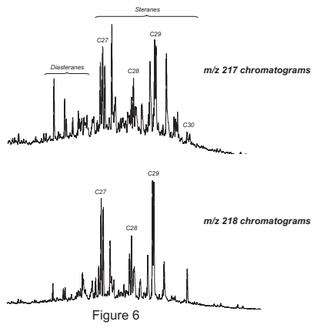


Figure 6

Figure 5. m/z191 of one reservoir liquid showing classical molecular characteristics of a lacustrine oil (high gammacerane, presence of low extend hopanes, abundance of tricyclics and C26/C25 tricyclics > 1).

Figure 6. C27-C28-C29 sterane distribution reflects characteristics of a lacustrine oil. Nevertheless, presence of small quantities of C30 steranes indicates marine source rock input. Relative high concentration of diasteranes indicates fluid derived from a clay-rich source rock.

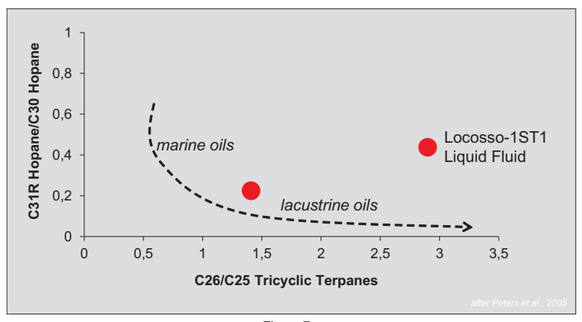
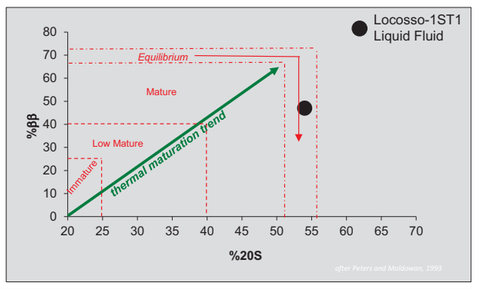


Figure 7



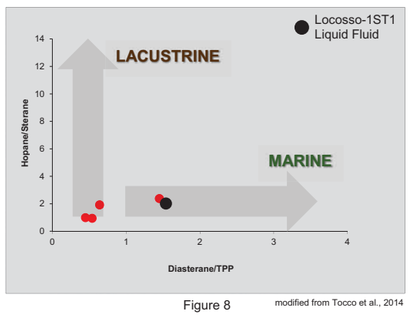


Figure 8 modified from Tocco et al., 2014

Locosso-1ST1 reservoir liquid is an oil with molecular characteristics that denote lacustrine organic matter contributions. The C26/C25 triciclyc terpanes ratio value (>1) is a classical molecular characteristic of a lacustrine oil. (Figure 7). On the other hand, the plot of the Figure 8 indicates that Locosso-1ST1 reservoir liquid is a mixed oil with lacustrine-marine organic matter contributions. This fluid presents similar molecular characteristics of some Campos oils of Brasil.

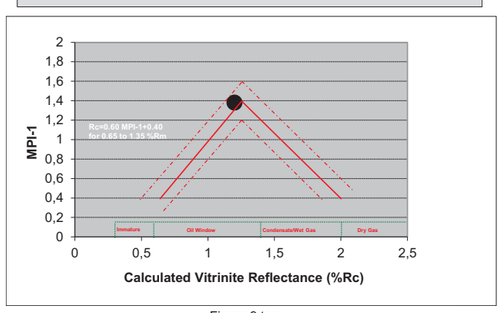


Figure 9 top
Figure 10 bottom

The oil was generated by a mature-highly mature source rock.

Gases Catchimanha-1

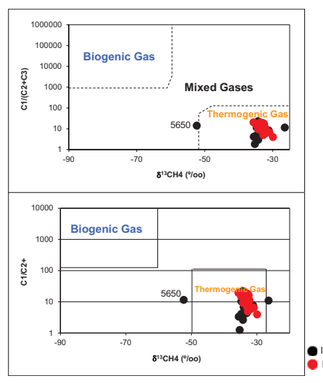


Figure 11

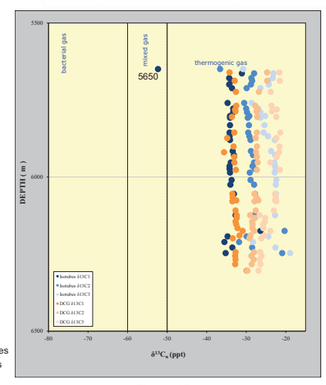


Figure 12

Gas chromatography and carbon isotope analyses show that Catchimanha-1 gases are wholly thermogenic in origin (Figure 11 and 12) .

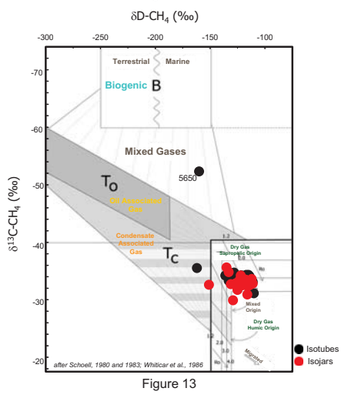


Figure 13

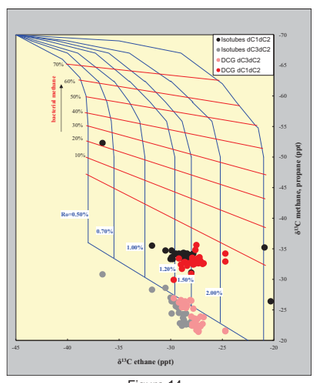


Figure 14

Carbon and Hydrogen isotopes of the total hydrocarbon gases from Well Catchimanha-1 shows mainly dry gases (Figure 13).

Tornado Plot (Figure 14) indicates that the thermogenic component of the total hydrocarbon gas associated to Catchimanha-1 gas samples has an equivalent Vitrinite Reflectance value varying in general between 1,1 – 1,8%.

These values were validated with the equations below:

$$\delta^{13}CCH4 = 15.4\ lnRc - 41.3$$
$$\delta^{13}CC2H6 = 22.6\ lnRc - 32.2$$
$$\delta^{13}CC3H8 = 20.9\ lnRc - 29.7$$

	δ^{13}CCH4 (Rc%)	δ^{13}CC2H6 (Rc%)	δ^{13}CC3H8 (Rc%)
Isotube Gas Samples:	~1,7	~1,2	~1,3
Isojar Gas Samples:	~1,7	~1,2	~1-3

Ethane and propane maturity for isotube and isojar gases varies between Rc~1,2-1,3%. Since the carbon isotopic difference between ethane and propane is relatively low, it appears to be assumed that the Rc~1,3% better reflects the minimum thermal maturity of the source rock that has generated Catchimanha-1 gases. The ethane and propane isotope gas composition indicates that Catchimanha-1 gases are likely to be condensate associated gas.

Methane maturity for isotube and isojar gases is Rc~1,7%. Secondary cracking of liquid hydrocarbons could generate gases with methane maturity values up to ~1,7%Rc. The methane isotope gas composition indicates that gases generated from secondary cracking of liquid hydrocarbons are likely to be dry gas. In conclusion, the Catchimanha-1 gases probably represent a mix of condensate associated gas and dry gas.

Presence of ethane, propane, butane and pentane (C2+) in Catchimanha-1 gases reflect the presence of wet gas in the well (condensate associated gas). Methane maturity values up to ~ 1,7%Rc suggest the presence of dry gas. two hypotheses can explain this: 1) A source rock that generated these gases is characterized by a continuously increasing maturity could have generated gases with methane maturity values up to ~ 1,7%Rc. 2) Secondary cracking of liquid hydrocarbons. This cracking could generate gases with methane maturity values up to ~ 1,7%Rc.

Gases Locosso-1ST1

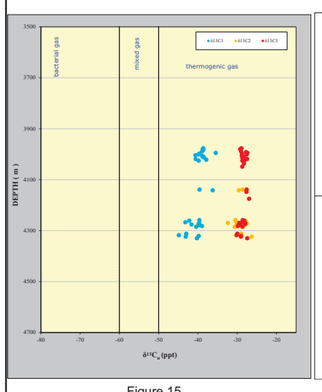


Figure 15

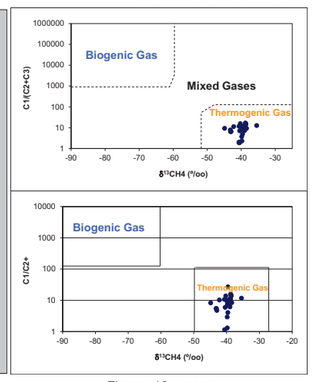


Figure 16 upper
Figure17 bottom

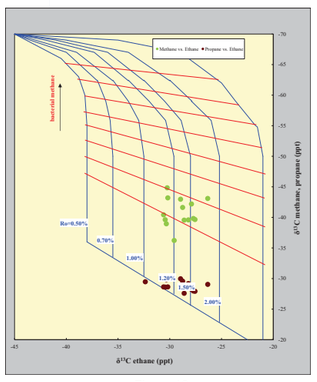


Figure 18

Gas chromatography and carbon isotope analyses (Figures 15, 16 and 17) show that gases are wholly thermogenic in origin.

Thermogenic gases have an equivalent Vitrinite Reflectance (Figure 18) ranging between 1,1 – 1,6%. Gas thermal maturity from this plot were validated with the following equations:

$$\delta^{13}CCH4 = 15.4\ lnRc - 41.3$$
$$\delta^{13}CC2H6 = 22.6\ lnRc - 32.2$$
$$\delta^{13}CC3H8 = 20.9\ lnRc - 29.7$$

CH4-C2H6-C3H8 isotopic composition of the isotubes gases reflect very well the source maturities:

	δ^{13}CCH4 (Rc%)	δ^{13}CC2H6 (Rc%)	δ^{13}CC3H8 (Rc%)
Isotube Gas Samples:	0,9-1,2	1,0-1,2	1,0-1,1

Methane, ethane and propane maturity for isotube gases change between Rc~0,9-1,2%. Since the carbon isotopic difference between methane, ethane and propane is relatively low, it appears to be assumed that the Rc~1,2% better reflects the minimum thermal maturity of the source rock that has generated the isotube gases. Isotope gas composition indicates that Locosso-1ST1 gases are likely to be late mature oil/condensate associated gas.

Py-GC-IRMS Catchimanha-1 and Locosso-1ST1

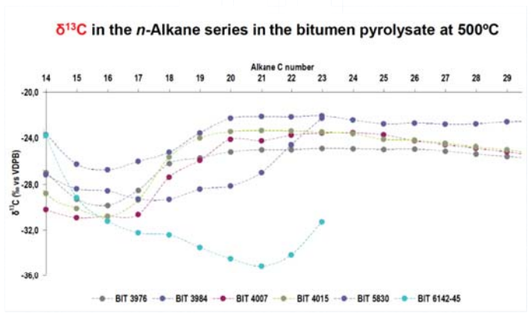


Figure 19

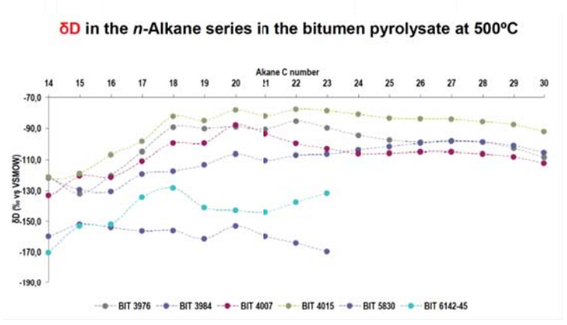


Figure 20

δ13C (Figure19) and δD (Figure 20) in the n-alkane series shows different sources for Locosso-1ST1 (3976, 3984, 4007, 4015m samples) and Catchimanha-1 solid bitumens (5830, 6142-45m samples). Small differences in δ13C and δD of n-alkane series for Locosso-1ST1 and Catchimanha-1 could represent different organofacies for the same source rock, or contributions from two source rocks.

Catchimanha-1 solid bitumens (5830 and 6142-45m samples) show hydrogen stable isotopes (δD) highly depleted (light values) for n-alkanes (C14-C23), and significantly different to the values observed for Locosso-1ST1 solid bitumen pyroproducts. The depletion could indicate that environmental conditions of original biomass production associated to Catchimanha-1 solid bitumens was in a low evaporation situation, wet environment or underwater. Heavier δD isotope composition (Locosso-1ST1 solid bitumens) are consistent with episodes of extreme evaporation.

Conclusions

Post-salt and pre-salt rocks contain mainly marine organic matter and very low quantities of terrestrial organic matter. Post-salt and pre-salt rocks in Well Locosso-1ST1are immature to early mature, while in Well Catchimanha-1, post-salt rocks are immature and pre-salt rocks are post mature (dry gas window).

Locosso-1ST1 and Catchimanha-1 gases are thermogenic in origin. Isotope gas composition indicates that Locosso-1ST1 gases are likely to be late mature oil/condensate associated gas, and Catchimanha-1 gases probably represent a mix of condensate associated gas and dry gas. It is possible that high quantities of thermogenic Catchimanha-1 gases were generated from secondary cracking of liquid hydrocarbons.

One oil sample from Well Locosso-1ST shows classical molecular characteristics of a lacustrine oil. Minor marine inputs are possible. This oil was generated by a mature-highly mature clay-rich source rock. Pyroproducts from solid bitumens indicates different sources for Locosso and Catchimanha solid bitumens. The differences in biomarker and isotopic signatures for the various pyroproducts suggest that the solid bitumens are a mixture of lacustrine (Bucomazi Formation) and marine sourced oils. The pre-salt section in the Well Locosso-1ST1 is immature to early mature. Under this maturity conditions the formation of solid bitumens is not related to thermal cracking of oils. Locosso solid bitumen was probably generated by gas deasphaltening or oil mixing. On the other hand, the Catchimanha solid bitumen probably was generated by thermal cracking of oils. The maturity in the pre-salt section in Well Carchimanha-1 reached values up to 1,8-2,0Rc (equivalent to ~190-200ºC).