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Basin Modeling Of Parts of the Niger Delta: Thermal Maturity Evaluation and Prediction Of Petroleum Generation.

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Abstract: *Predicting petroleum generation is a critical issue in prospect evaluation for the deeper prospects because of its economic implications. This paper focuses on predicting hydrocarbon charge in the deeper zones of the Niger Delta using integrated basin modeling methods and techniques. Burial history and stratigraphic profiles were generated for ten wells using the available well data whereas extrapolations were carried out for depths beyond total depth penetrated using data from adjacent field and estimates from the global sea level curve. The resulting model was calibrated using key petrophysical, temperature, pressure and vitrinite reflectance data until the best match was achieved. From the thermal model, the oil window is predicted to occur at a subsurface temperature of about 80-120^oC. The predicted deep Eocene source rock has maturity between 1.2-2.0R_o and likely to be in the gas window. Present day Gas window is predicted to occur at a subsurface temperature of about 121-180^oC. Main hydrocarbon charge is predicted to have occurred between 11.5-15.0Ma, followed by a second reduced charge phase at 8Ma to present day, diminishing to almost zero. Trap formation was likely after charge was generated from the source rock. This study provides good prediction on source rock maturity and likely to have hydrocarbon types charged in the deep prospect.*

Keywords*: basin, maturity, hydrocarbon, charge, source rock and prospect.*

I. Introduction

Predicting petroleum generation is a critical issue in prospect evaluation for the deeper prospects in the Niger delta petroleum province (Fig.1) because of its economic implications. An excellent way in reducing investment risk in the exploration of petroleum is to first establish that a potential structure contains hydrocarbon, next is to determine the type and volume of petroleum before penetrating the structure (*Oilfield Review* Summer 2009).

Efforts have been made to predict hydrocarbon charge in the Niger Delta by using seismic to capture structural closures and establish petroleum traps; however this method does not accurately determine the content of the trap. Penetrating a structural closure close to a viable hydrocarbon field, does not imply that the same fluid will be encountered. Successful drilling demands an approach that is capable of predicting success given the necessary data and associated uncertainties (*Oilfield Review* Summer 2009).

Simulating a basin is now a predictive technique in the exploration plans of most oil companies since it presents a continuous, critical and robust view of events that include deposition of sediment, compaction, fluid flow, heat transfer, maturation of source rock, migration, accumulation and expulsion of petroleum. Apart from giving explorers the platform to model the evolution of a basin in a definite pattern, hydrocarbon charge in the deep prospect can equally be predicted. The aim of this work is to analyze the charge history in the deep prospect within anonymous fields of the Niger Delta Petroleum Province. The objectives of this study amongst others include reconstructing the burial history of the area, model the thermal history of the area, generate the maturation history of the source rock and predict the petroleum generation in the deep prospect using basin modeling techniques.

II. Geology Of Niger Delta

The most prolific sedimentary basin within the Western African sub-region is the Niger Delta, in the gulf of Guinea. It is known to be one of the world's top twelve accumulations of recoverable petroleum; having reserves over thirty four billion barrels of crude oil and ninety three trillion cubic feet of gas (Tuttle et al., 1999). The tectonic setting of this basin has been attributed to the divergence of the African and South American Plates and creation of Southern Atlantic. It has also being proposed that a triple junction developed (Burke et al., 1971). Grant (1971) suggested RRF (ridge-ridge fault) mechanism for the initiation of this separation. Wright (1976) on the other hand, proposed an RRR (ridge-ridge-ridge) mechanism. The inactive rift of this triple structure is the Anambra/ Benue rift valley where the Oceanic crust was inactive. The rivers' depositional centers moved seawards and in consequence, the coastal plain deposits became progressively younger in that direction. The Niger Delta complex has undergone little deformation at the upper region but the subsurface had experienced major deformation by large scale synsedimentary features such as growth fault, rollover anticlines and diapers

Location of the Study Area

The study area is located in OML 18 and 24 about 40km South West of Port Harcourt, which is part of the Coastal Swamp Depobelt of the Cenozoic Niger Delta. (Fig.1). Its co-ordinates are longitudes $6^0 46^{'} - 6^0 53^{'}$E and latitudes $4^0 28^{'} - 4^0 32^{'}$N and covers a total area of about 154sqKm with a perimeter of about 50km. Ten wells were used for the research. Sediment deposition in this area started in early Miocene times.

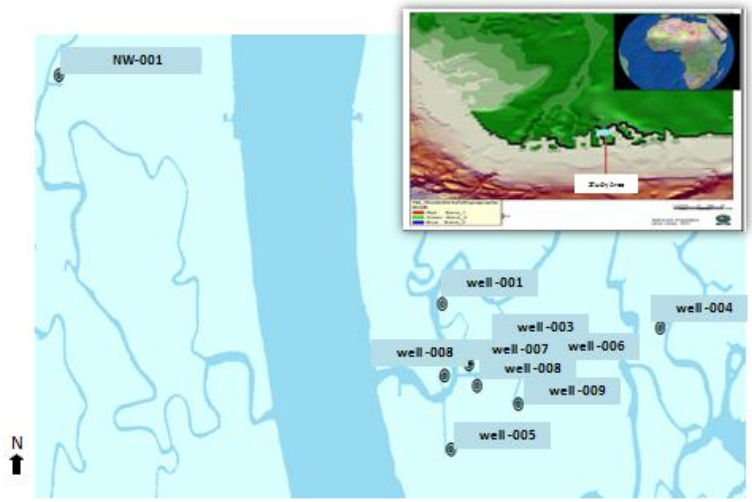

Figure 1: Map of study location (inset) and location of wells across the field.

III. Materials And Method

The materials used for this study include the following: Base map of the study area showing well locations, Log suites which include Gamma ray logs, resistivity logs, neutron density logs, and porosity logs, Biofacies data, Paleobathymetric environment of deposition, 3D seismic data, Pressure and temperature data, Vitrinite reflectance and other available geochemical data and Niger Delta Cenozoic chronostratigraphic chart.

IV. Methodology

Basin modeling workflow (fig. 2) modified after Hantschel and Kauerauf (2009), Waples et al. (1992), Welte et al. (1988) and Tissot *et al*. (1987) was used in predicting the Charge history in the study area. The three major stages involved in this model building include the basin modeling stage (burial history curve and thermal model), numerical simulation stage and calibration stage.

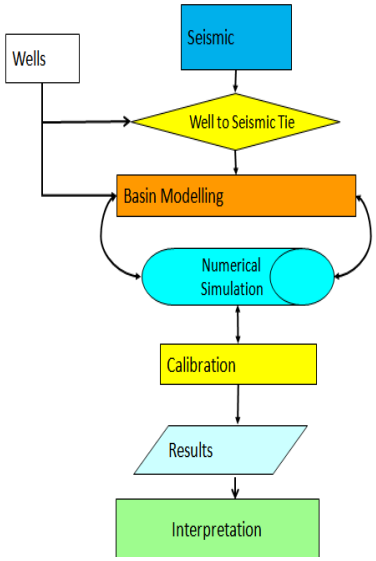

Figure 2: Basin modeling workflow chart

V. Results And Discussions

From the resulting thermal model (fig 3), bottom hole temperature and vitrinite reflectance was used to predict the hydrocarbon level. From the deepest well(well 005) the oil window (Light oil) was predicted to occur likely at depths beyond 13034.7ftss (3974m) at vitrinite reflectance of 0.8VRE and subsurface temperature of 124^{0}C at 10.6Ma and the floor of the oil window at 11.5Ma. The deep Eocene source rock is expected to be in the gas window with maturity between 1.2-2R_0 and subsurface temperature of about 121-180^{0}C at a depth of 18368ft. Maximum hydrocarbon expelled from the source rock at 11.5-15.0Ma and a later phase at 8Ma – present day with oil expelled rate at almost zero (Fig. 4). Comparing the predicted charge from the model generated with the hydrocarbon contacts in the study area (Fig 5), trap formation was likely to have occurred after maximum expulsion of main charge from the source rock. This study provides good prediction on the occurrence of pressure as well as on source rock maturity and likely hood of hydrocarbon composition to be charged in the deep prospects in the Niger Delta.

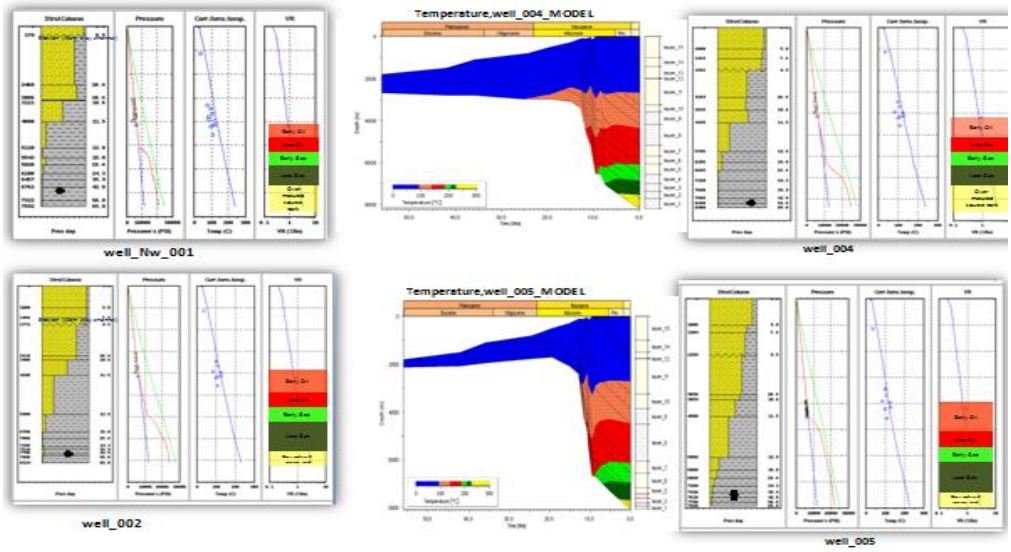

Figure.3: Thermal model showing the predicted charge.

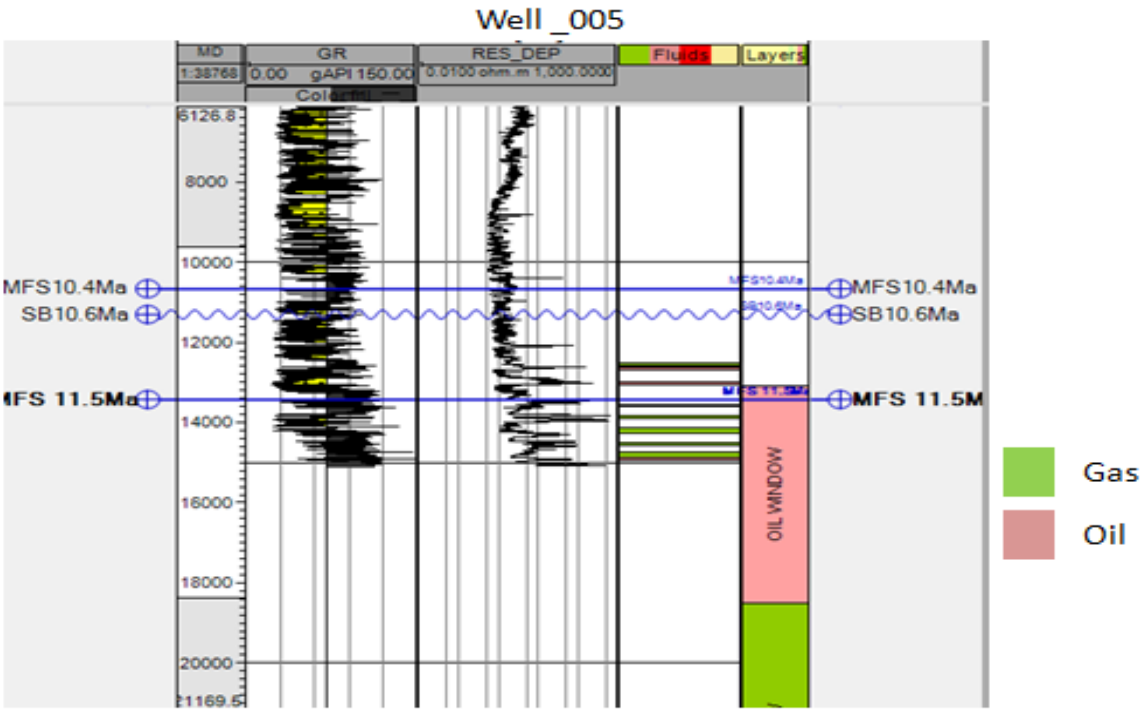

Figure.4: Well 005 showing the comparison of the hydrocarbon contacts in the field to the predicted charge(layers).

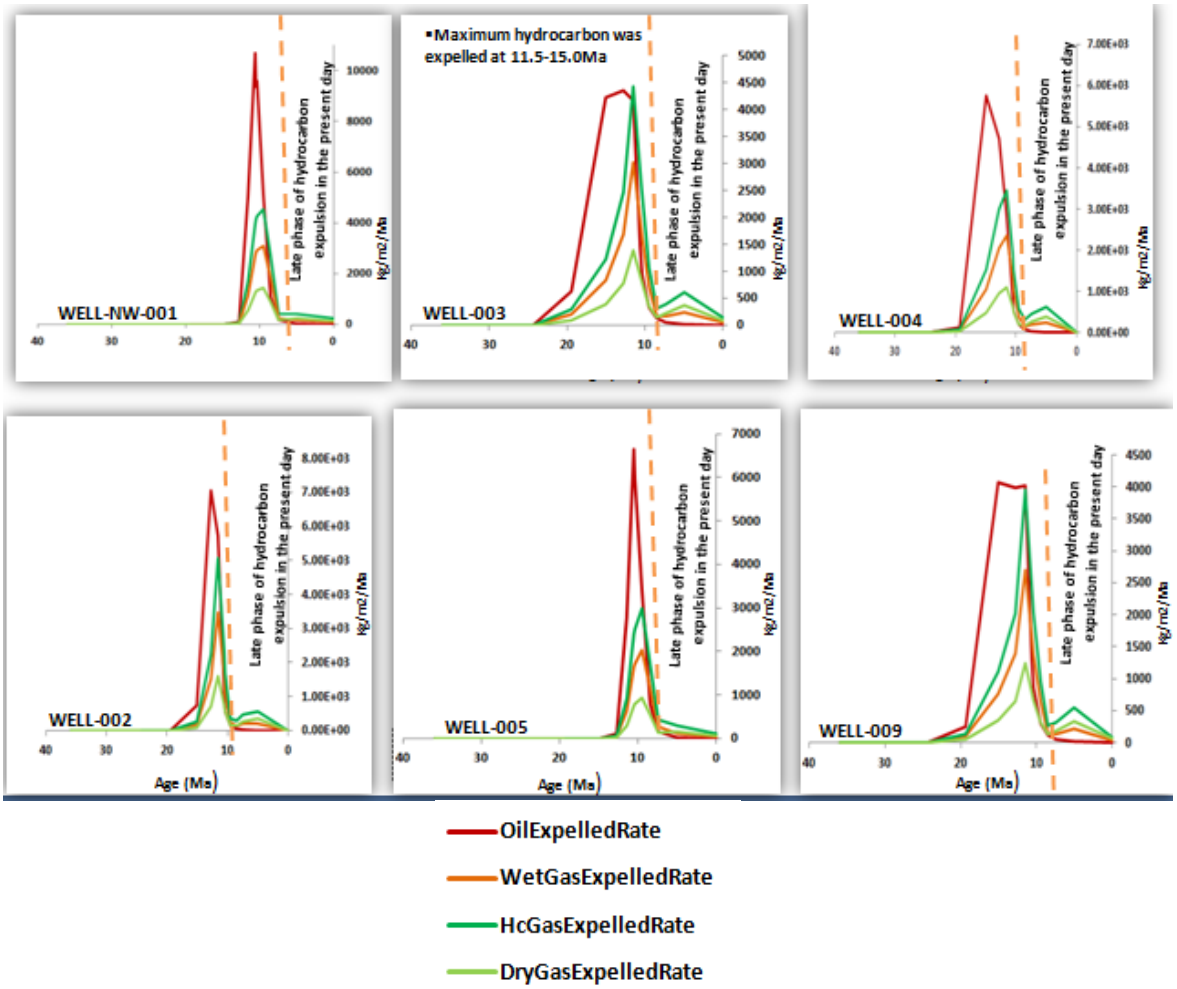

Figure 5: Main charge is predicted to have Maximum hydrocarbon expelled from the source rock at 11.5-15.0Ma and a later phase at 8Ma – present day with oil expelled rate at almost zero.

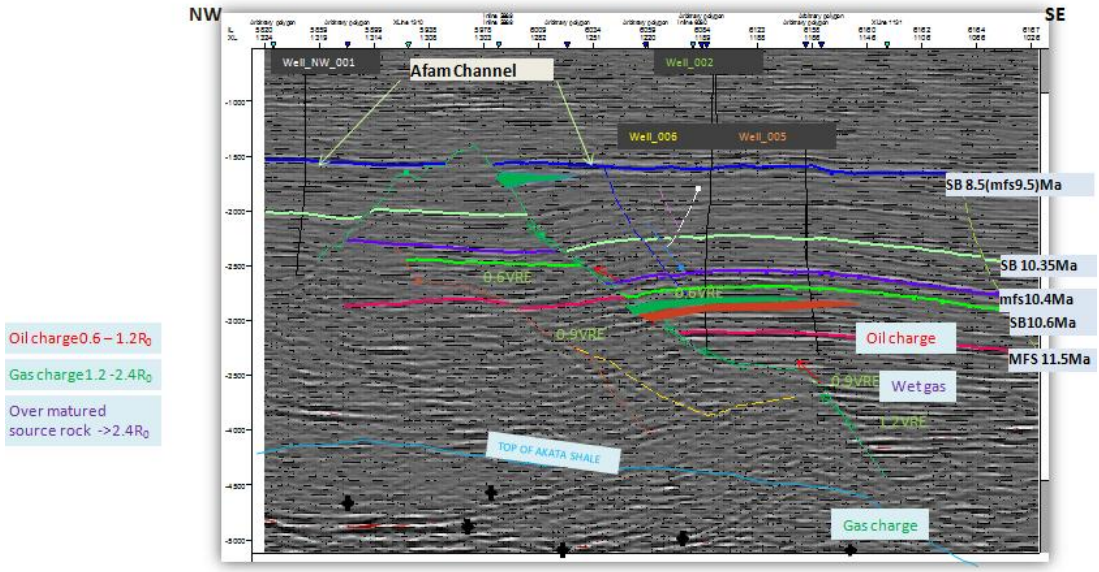

Figure 6: Diagram showing the generation, accumulation and migration of the hydrocarbon charge in the study area.

VI. Conclusion

From the study on hydrocarbon system analysis using basin modeling, the following conclusions were drawn:

- Predicted Present day oil window (Light oil) is likely to occur at 10.6Ma and the floor of the oil window at 11.5Ma
- The deep Eocene source rock has maturity between 1.2-2R_0 and likely to be in the gas window. Predicted Present day Gas window is expected to occur at about 18368ft at subsurface temperature of about 121-180^{0}C.
- Main charge is predicted to have Maximum hydrocarbon expelled from the source rock at 11.5-15.0Ma and a later phase at 8Ma – present day with oil expelled rate at almost zero.
- Trap formation was likely after maximum expulsion of main charge from the source rock.
- This study provides good prediction on source rock maturity and likelyhood of hydrocarbon composition to be charged in the deep prospects in the Niger Delta.

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