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Ataga oil Field: Modelling Hydrocarbon Generation and Biodegradation Risk

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Abstract:

The hydrocarbon generation was modelled for the Akata formation in the Ataga Oil field area. S_2 and TOC data were obtained from well logs, while other essential geological input data were derived from literature. PetroMod version 12 was used for a 1D model to achieve the objectives of predicting maturity, timing of generation, evaluate risk of in-reservoir process such as biodegradation. The model unravel that early hydrocarbon generation at the interformational shale within the Ataga oil field area commenced at 3km, which corresponds to top of the Akata formation at 0.54%R_o in the Late Miocene, the critical moment which depict the generation-migration-accumulation of petroleum within the petroleum system was observed at the Pleistocene. The biodegradation risk which is about 50% at the surface reduces to zero % at about 2.1km and lower, where reservoirs were observed. This infers that the generated and accumulated hydrocarbon is preserved and do not stand the possibility of biodegradation.

Keywords **—Critical Moment, Event Chart, Generation, Modelling, Niger Delta, Timing.**

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I. INTRODUCTION

Hydrocarbon generation modelling is an aspect of Petroleum System Modelling (PSM) [7]. It views maturation of sedimentary basin which may be confined to formations, potential for generation of hydrocarbons and the timing of hydrocarbon generation which on a wider horizon pictures the possibility for hydrocarbon accumulations and preservation of accumulations. Petroleum system modelling corroborates information from stratigraphy, geophysics and petroleum geochemistry in an integrated manner for maturity predictions and generation interpretations [7], [10]. Varieties of modelling spans across 1D, which is mostly used for maturity and generation studies, 2D which is most used for accessing lateral variations of maturity of source rocks and 3D which permits spatial analysis of migration and changes in accumulations over time [7]. Some aspect that could be observed in petroleum system modelling, include burial history which takes into account rate of sedimentation, also identify and quantify duration and magnitude of uplift, erosions and non-depositional times [7]

The thermal history deals with the variation of temperature through time, which depends on heat flow. Maturation history unravels maturation of source rock and generation through time and timing of peak generation, by measuring the kerogen kinetic parameters, which describes the rate of conversions of different kerogens to hydrocarbons [6].

The Niger Delta basin comprises two major source rocks, the Akata and Agbada source rocks. The Niger Delta petroleum system has been named as the Akata-Agbada tertiary petroleum system [12], however, other petroleum systems has been defined, such as the Lower Cretaceous petroleum system and the Upper Cretaceous petroleum system. However, the depobelt concept does not portray the Niger Delta as a single petroleum system. Its postulates that the Niger Delta was deposited in a series of mega sequences with considerable lithological differences. Each mega sequence has been formed within a geological interval of 5Ma and has been 30km to 60km wide in addition; each mega sequence has an independent sedimentation history, compaction history, deformation history, thermal maturation of source rock history and petroleum system history [12].The fact that independent mega sequences constitute the Niger Delta Basin, may also be postulated that there may be variations of petroleum system on the premise that each mega sequence has its own sedimentation, deformation and petroleum history [12].

The tectonic framework that resulted in the inception of the Niger Delta Basin is based on Cretaceous fracture zone which are in the form of trenches and ridges, the Continental margin in the region of Nigeria were divided into basins from the boundary faults of the Cretaceous Benue–Abakaliki trough which resulted in the failed arm of the rift triple junction [12]. Rifting commenced in the late Jurassic and diminished in the Late Cretaceous [12]. Gravity tectonic became the driver for shale mobility resulting in internal deformation as a result of deposition of poorly compacted overpressure clay due to ineffective de-watering mechanism, upon which high density sand were deposited. Slope instability resulted in basin ward progradation of the delta front.

The hypothesis on which this study rest is that where there are individual mega-sequences with different petroleum system, the modelled details of hydrocarbon generation may bear some significant differences over the various depobelts of the Niger Delta Basin.

II. MATERIALS AND METHODS

Data in the form of well logs, well header and well deviations were obtained. Method adopted include the use of Techlog version 2015 to model TOC and S_2 using the well logs and invariably HI (hydrogen index) was calculated. S_2 measures the amount of thermally generated hydrocarbons, in mg/g of rock that are yet to be expelled. According to [7] S_2 is believed to be more realistic than TOC because the latter includes "dead carbon" that cannot generate hydrocarbon.

The 1D package of PetroMod version 2012 was employed in generating depth plots, time plots and burial histories. Geological data consisting formation data, deposition, formation erosion, age of deposition and facies were obtained from literature, well completion reports and well information folios.

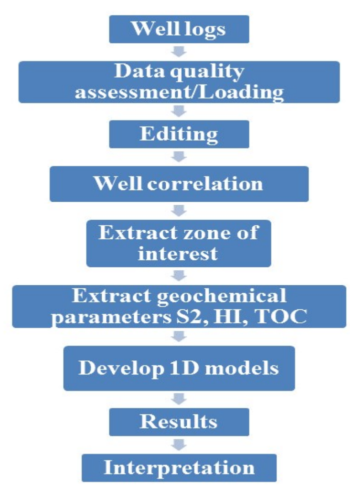


Figure 1. Adopted workflow for modelling hydrocarbon generation using well log derived data.

The input parameters include:

(a) Thickness of Deposition
(b) Depositional age in Ma (millions of years)

(c) Lithological Composition
(d) Petroleum System Elements (Source Rocks, Reservoir rocks, Seal and Overburden rock)
(e) Properties of source rocks (TOC and HI)
(f) [11] type III kerogen Kinetics
(g) Boundary Conditions:
   i. Basal Heat Flow (BHF) – lower thermal boundary
   ii. Sediment Water Interface Temperature (SWIT) – upper thermal boundary
   iii. Paleowater depth.

III. RESULTS AND DISCUSSION

The results of the modelling research are presented as (i) subsidence and burial history modelling, sedimentation rate, maturation history (vitrinite reflectance), and hydrocarbon generation.

A. Subsidence and Burial History

The burial history model is presented in figure 2. The burial history model (depth-time plot) indicates sloping inclination which infers rapid sedimentation for the Early Eocene to Late Eocene corresponding to 56Ma to 35Ma. There after sedimentation was uniform up to the Late Miocene at 10Ma, when Uplift and erosional activities resulted in another phase of rapid sedimentation to recent.

The development of a basin depends on the equilibrium between the sedimentation rate and subsidence rate. The study area is within the passive continental margin and is characterized by a regressive sequence in which the sediment supply exceeds the subsidence rate. This actually results to in-effective dewatering and consequently high-pressure sequence where the overburdened is bored by the trapped interstitial water rather than the grain to grain contact. The sedimentation rate-depth plot in figure 3, shows fluctuations in sedimentation which may have resulted due to transgressions and regressions of sea level resulting the variability in the sedimentation rate.

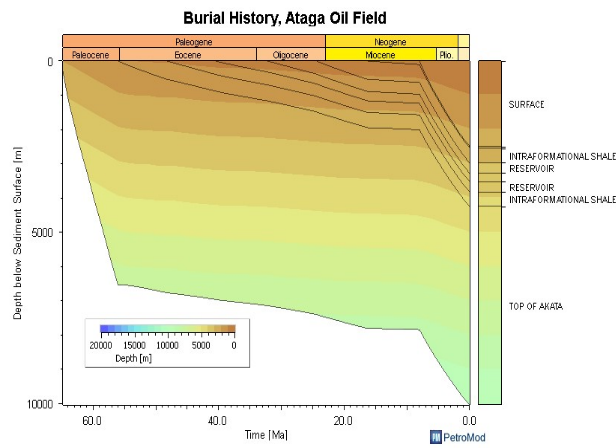


Figure 2. Burial history (Time-Depth Plot) depicting sedimentation and subsidence

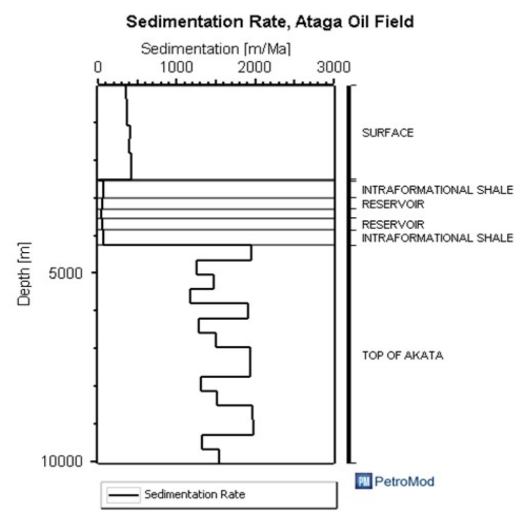


Figure 3. Depth plot depicting sedimentation rate.

B. Temperature Model.

The temperature model in figure 4, show temperature variation depth-wise, temperature ranges from 0ºC at the surface to about 100ºC below the reservoirs. At about the top of the Akata formation the temperature reaches about 130ºC, at about 3000m, the model also infer that the reservoirs are within temperature range that will not foster the existence micro-organism in the reservoir [12].

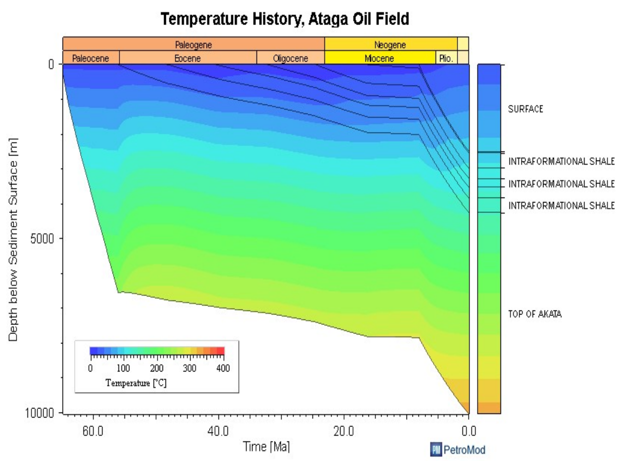
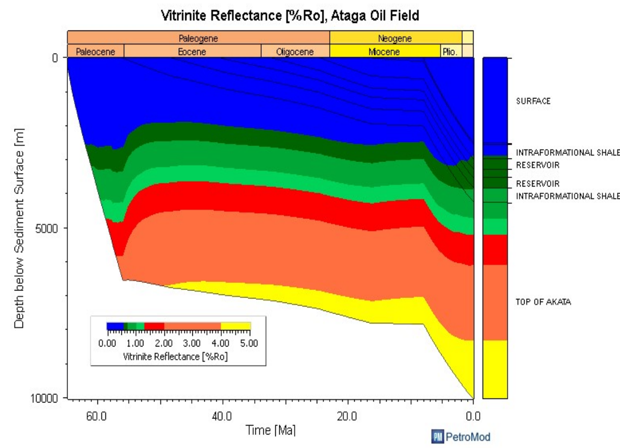


Figure 4. Burial history depicting temperature variation depth-wise.

C. Vitrinite Reflectance

Vitrinite Reflectance is a measure of the populations of randomly oriented vitrinite particles in source rock. The concept is based on the fact that reflectance depends on upon chemical composition of vitrinite phytoclast, which is made up of clusters of benzene aromatic rings linked together with chains and stacked upon one another [11]. The vitrinite reflectance model showed that vitrinite reflectance of 0.54% occurred in the Late Miocene (figure 5a). The Depth plot (Figure 5b) shows that vitrinite reflectance of 0.54% occurred at the lower intraformational shale, which corresponds to the



beginning of the top of Akata formation.

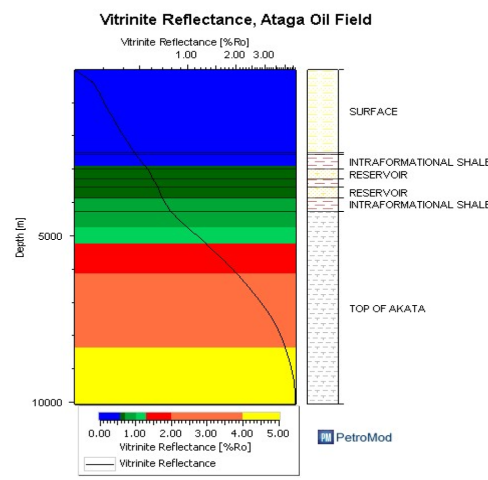


Figure 5a and 5b, Burial history depicting vitrinite reflectance and a depth plot showing vitrinite reflectance values and depth ranges.

Figures 5a and 5b indicates that hydrocarbon generation commenced at about 3000m at vitrinite reflectance of 0.54%, this observation is consistent with the model of Oben-1 well as reported by [12]. However, generation of hydrocarbon interms of the geologicaltime scale corresponds to Late Miocene into the recent. Depthwise, top of the Akata formation is in the wet gas window at 5.5km and also corresponds to the assertion by [12], which stated that the wet gas zone corresponds to vitrinite reflectance of 1.2 $\%R_o$.

D. Hydrocarbon Generation.

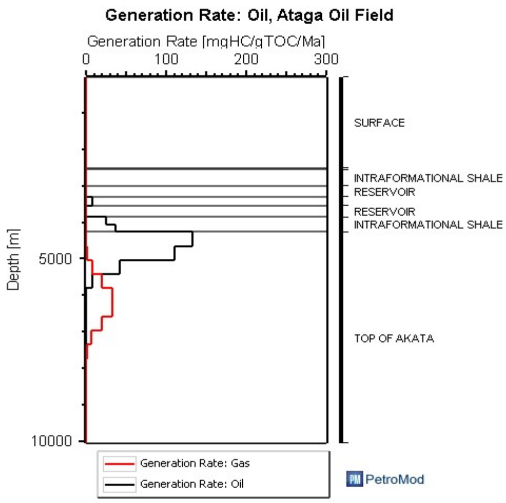


Figure 6. Profile of hydrocarbon generation for gas and oil

The hydrocarbon generation commenced in the Late Miocene (figure 5a). However, figure 5b show thatearly oil generation began at 3000m, while consistent mature generation of oil commenced at 4000m, while consistent generation of gas commenced at about 5.5km. Maximum generation of oil was at 150mg HC/gTOC/Ma (figure 6),
while maximum generation of gas was at 45mgHC/gTOC/Ma at the depth of about 6200m (figure 6).
The critical moment is the time that best explains the generation-migration-accumulation of hydrocarbon in the petroleum system. The critical moment with regards to this study is at the Pleistocene for depth range of 5050m to 5427m for a thickness of 387m of Akata formation. (figures 5a and 7). The critical moment at that time really depicts the generation, migration and accumulation of hydrocarbons [9]. However, other range of 6201m to 6587m of Akata formation was at the Eocene,

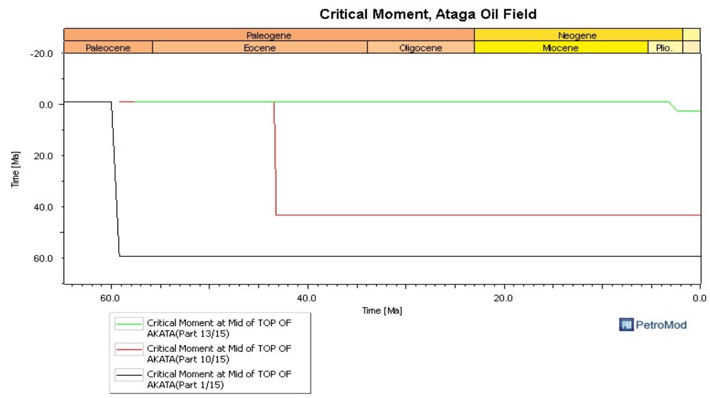


Figure 7. The critical moment at the Paleocene, Eocene and Pleistocene

while the base of Akata formation at 9677m to 10063m was at the Mid Paleocene (figure 7).
Some author has defined the critical moment to represent when the volume of accumulated petroleum is highest in the reservoir, while others define the critical moment to represent the peak of hydrocarbon generation [9], [7].

D. The Timing of Generation

The timing of generation refers to the sequential occurrence of the elements of petroleum systems [9] or whether the petroleum system occurred in the correct geological sequence and allow accumulation and preservation of generated hydrocarbon [7], [2]. This can be deduced from the petroleum system Event Chart. The petroleum system chart shows the relationship between the essential elements and the processes of the petroleum system. It can be used to compare times that the processes occurred with times that the element were emplaced [9], [7].

risk of biodegradation reduces to about 0 at about

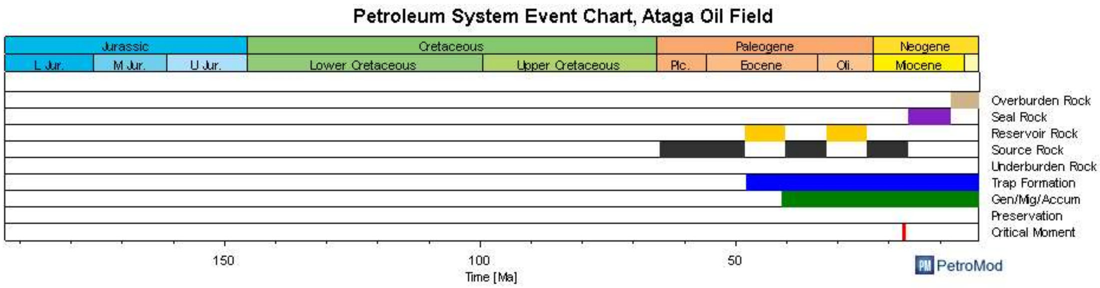


Figure 8. The Event chart of the Ataga oil field area

The event chart of the Ataga oil field area, show that the reservoir rocks was emplaced before the commencement of hydrocarbon generation. While the seal/trap was emplaced immediately before generation commenced. Migration which is averagely at the rateof 1km per 1Ma [1],[5]should have permitted adequate compaction of sealing facets before accumulation, taking into consideration the interplay between the buoyant pressure of the migrating hydrocarbon relative to the capillary pressure of the pore that comprise the matrix of seals. Hence accumulation of hydrocarbon will be successful.

E. Biodegradation and Preservation of Hydrocarbon.

The preservation of hydrocarbon entails the storage of hydrocarbon without loss due to leakage or alteration due to post reservoir processes. Since the Niger Delta is not tectonically active, preservation may be evaluated based on in–reservoir alteration processes. The most frequently observed in–reservoir alteration processes are biodegradation and water washing and gas flushing, however, biodegradation is the most common, the biodegradation model in figure 9, indicate that the

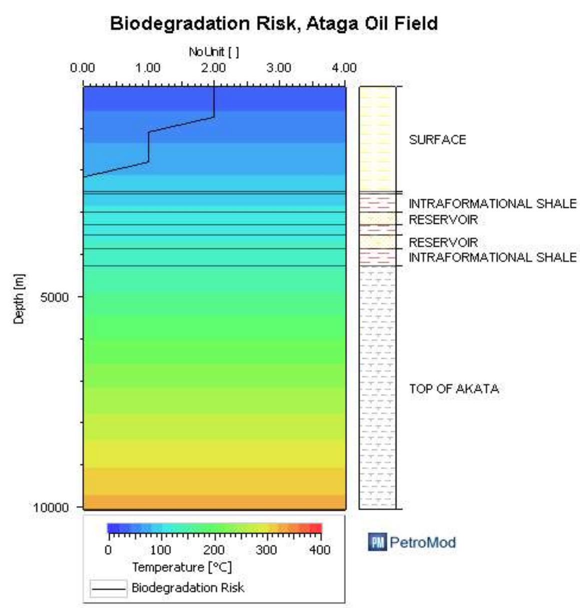


Figure 9. Depth – Temperature plot reflecting biodegradation risk

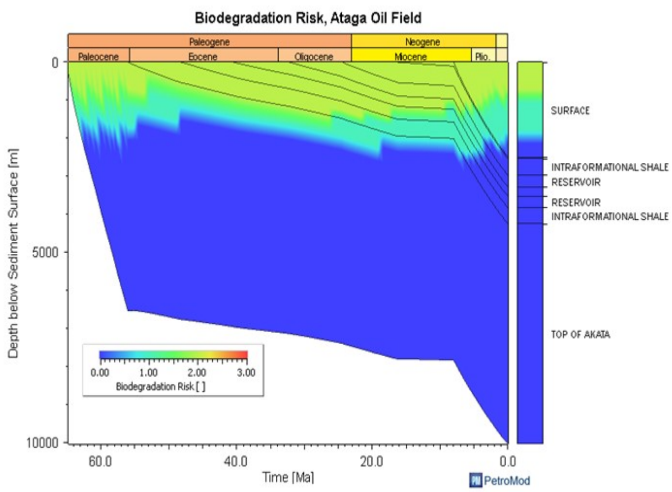


Figure 10. Burial history plot representing biodegradation risk

The corresponding temperature data indicates that the reservoirs are at temperature regimes of about 110ºC and 120ºC respectively. These temperature values are averagely above temperature regimes that are suitable for the striving of microbes that foster biodegradation in reservoirs. The corroboration of figures 5a and 10 indicates oil at (0.71Ma) 3.061km depth in the reservoir at vitrinite reflectance of 0.54%R_o for which the biodegradation risk is zero. The second reservoir is at 2.36Ma at 3.170km depth with oil corresponding to 0.58%R_o, the biodegradation risk is also zero. These models indicate that oils in the Ataga oil field reservoirs are not biodegraded by virtue of temperature regimes relative to the potential for striving of microbes that foster biodegradation.

IV. CONCLUSION.

The hydrocarbon generation and preservation were evaluated in the Ataga oil field area, TOC and S_2 data were log derived using Techlog version 2015.
Other geological inputs were obtained from literature (well completion reports). PetroMod version 2012 was employed for the modelling. Results of the modelling indicate that hydrocarbon generation at the intraformational shale commenced in the Late Miocene with vitrinite reflectance valueat 0.54%R_o. The event chart indicates that reservoirs were emplaced before hydrocarbon generation and the seals could have attain enough compaction to effectively accommodate the accumulated hydrocarbons.
The accumulated hydrocarbon is in reservoirs exist within temperature regimes that are higher than 100ºC which does not allow microbes to strive and foster biodegradation.

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