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Mud Gas and Carbon Isotope Profiles in Well M, Offshore Guinea Bissau

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Abstract.

The mudgas profile was delineated for well M, gas samples were obtained using a gas extractor which is a stand alone modular system. AStation for acquisition, resolution and peak integration was employed.The maturity of the mudgas for this study ranges from –40‰ to –55‰, corresponding to 3200m to 3000m. Gases above 3000m are immature.Isotopic reversal observed at 2300m is attributed to marine regression. Diffusive migration was delineated as themigratory pattern with mixing tendencies of biogenic and thermogenic gases. The methane profile showed isotopic rollover at about 2200m, isotopic reversals were also observed at the same depth. The potential for biodegradation is higher at 2500m and shallower depths.

Keywords: Mudgas, biogenic, thermogenic wet gas, isotopic rollover, isotopic reversals, reservoir

1. Introduction.

Mud gas are gases that are produced during drilling, these gases are monitored for vital signals pertaining to the geological characteristics of reservoirs and their sealing systems, formation maturity and potential tectonic events that may results in the evolution of gases that may be isotopically heavier than the normal abundant isotopes.Hydrocarbon gases are generally generated by cracking of oil generated by labile kerogen at 150ºC–180ºC or by refractory kerogen at higher than 180ºC[2],[7]. However, carbon isotopic composition may differ depending on prevailing isotopic composition and circumstance during the deposition of their source matrix.The isotopic composition varies between –20‰ to –30‰ for gases sourced from refractory kerogen and –30‰ to –45‰ for gases from oil to gas cracking. This implies that isotopic composition is heavier (more positive)for lower temperature processes or fractionation [2],[7],[14]. In contemporary times, the concept of isotope reversals (rollovers) has been invoked to portray certain fundamental processes in the generation of gas from labile organic matter and from cracking of oil to gas [3],[4],[5]. Isotopic rollover occurs when isotope values show a change in trend from the initial pathway,while isotopic reversals are inferred when there are inflexions that indicate an initialchange in trend, it could be with reference to geological data (well depth) or isotopic and compositional ratios. The observation of isotopic rollover has been applied as a tool for implying generation of gaseous hydrocarbon from oil.While other observations had been used to infergeological,structural porosity, fractures and faults and low integrity seals /caprocks [7],[8],[10].

2. Geology and Location of Study Site

The geology of the study site is reflected on the lithological and stratigraphic description of the formation that consist the wellbore of Well M [17],[18]. The most shallow formation is the tertiary sediments, which overlays the Senonian–Maastrichtian sandstones. This in–turn overlays the Cenomanian–Turonian Shales. Underlying is the Albian clastic rocks which overlays the Aptian Shale, this is underlain by the Neocomian– Jurassic Carbonates and finally the Triassic anhydrite, sandstone and cobbled clastics.

Well M is located within the offshore Guinea Bissau, which was formed during the opening of the Central Atlantic at the separation of North America from North West Africa in the Permian –Triassic. The Guinea Bissaubasin is one of the basins in the North West Africa among the North West African Atlantic basins. Regionally, the depositions are of Late Jurassic to Holocene in age. The basal unit was deposited during the rifting and is coarse sandstone, overlying is fine sandstone and evaporites, then the series after the rift were thick carbonate formation ranging from the Middle to Upper Jurassic, the unit continued to the Aptian and Albian particularly in the Central offshore area. At the Cenomanian, thick marine shale was deposited with intercalations of marginal marine sandstones. The Turonian presented widespread deposition of black bituminous shale during marine transgression, while the Senonian showed a major marine regression leading to the extensive deposition of sandstones [16],[17],18]

The regional morphology is characterized by gravitational features characterized by high density currents/turbidity currents. Well M is a deepwater exploration well located Offshore, Guinea Bissau(figure 2). Guinea Bissauis part of the MSGBC (Mauritania, Senegal, The Gambia, Guinea Bissau and Guinea Conakry) hydrocarbon basin, where there has been proven hydrocarbon successes.

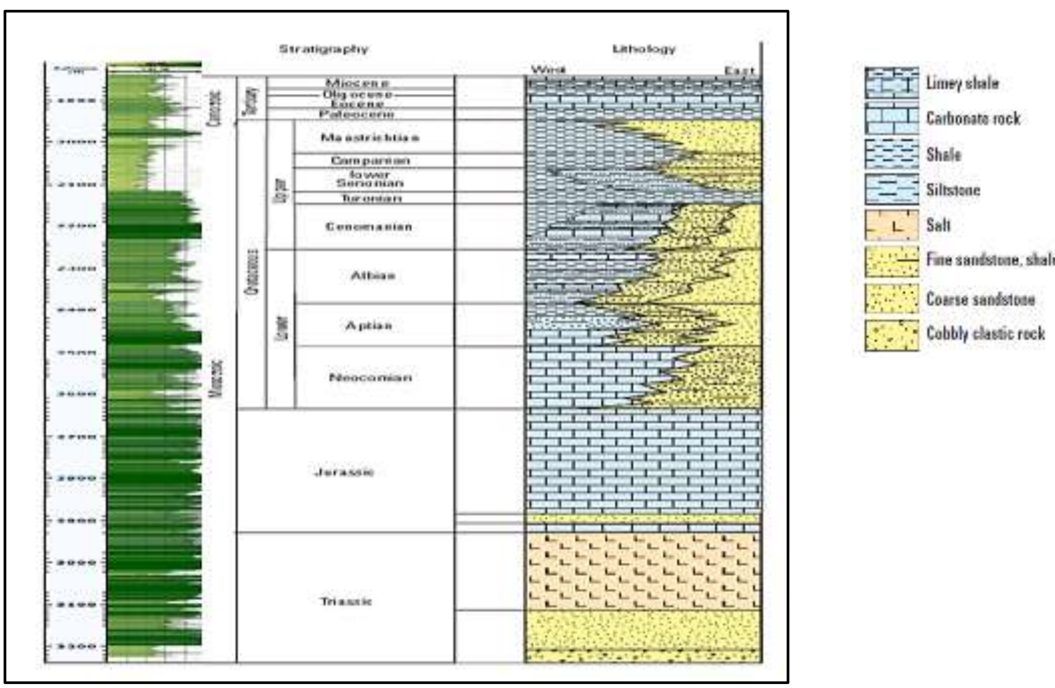

Figure 1. A corroboration of shale volume model from Well M and the regional stratigraphy of Guinea Bissau Basin

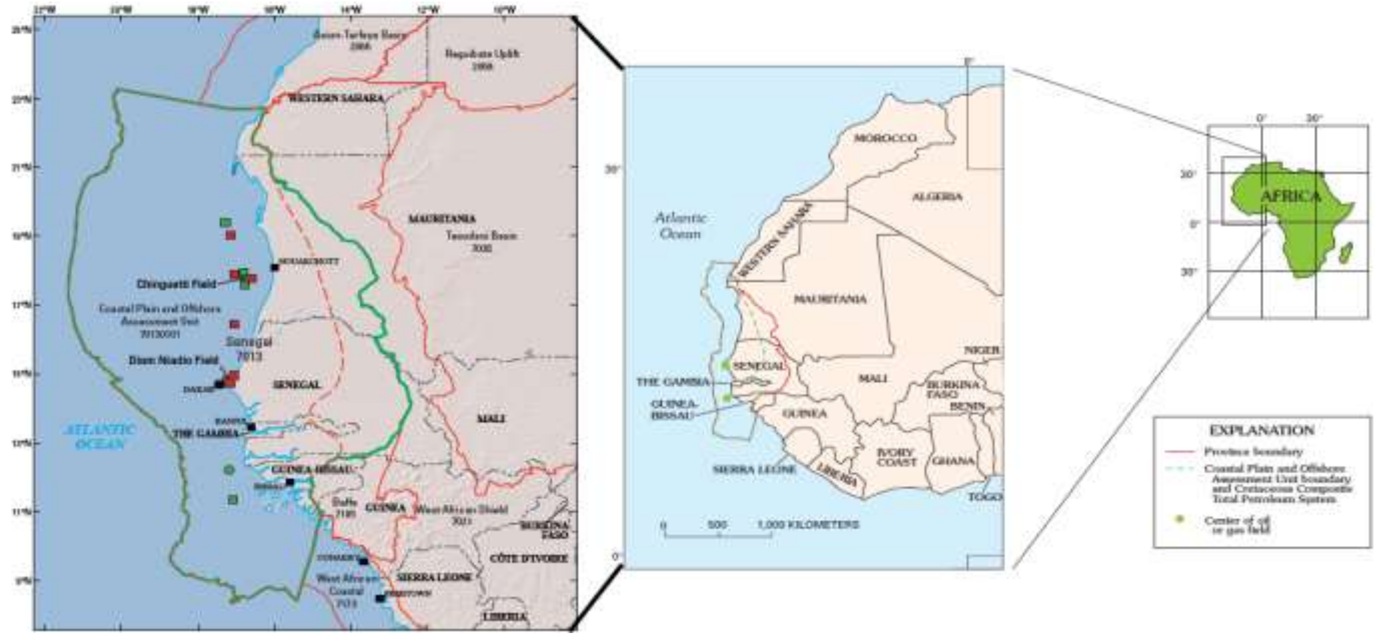

Figure 2. Approximate location of study site, Well M (green circle) Offshore Guinea Bissau.

3. Sampling and Analysis

Conventionally, gas samples are obtained via isotubes connected to gas sampling manifold, while for cuttings gas IsoJars are used.

However, in this study, gas sampling was performed using an extractor which is a stand alone modular system. A motorized mud agitator in the gas module excites and degases the mud for analysis. The extractor is connected to a C_1-C_5 Chromatograph/Total gas which performs the separation of the components and in turn connected to a station for acquisition, resolution and peak integration. The Mass Spectrometer is connected to a GC-FID the GC unit for better analysis of the gas stream components separated by the GC for peak integration.

Data obtained was processed for parametric ratios such as $C_1/(C_2+C_3)$, C_2/C_3, and C_2/C_1 and the plots were performed using Techlog version 2010.

4. Results and Discussion.

The result obtained is a large data set. Thus, results are presented as binary plots at various stages of discussion. Gas profiles has been applied in delineating reservoir structure,reservoir and diagenetic processes in the formations or on generated hydrocarbon.

A. Maturation.

Carbon isotopes profiles has been applied in delineating the maturity trend of formations that are sourcing/generating gases. The concept has been that, maturity ranges from –45‰ to –20‰ as reflected by $\delta^{13}CH_4$ value. In this study, maturity is portrayed by the gas profile in figure 3, which show that maturity ranges from –40‰ to –55‰, corresponding to 3200m to 3000m. At 2300m there is an observed change in profile which corresponds to an isotopic reversals [3],[5],

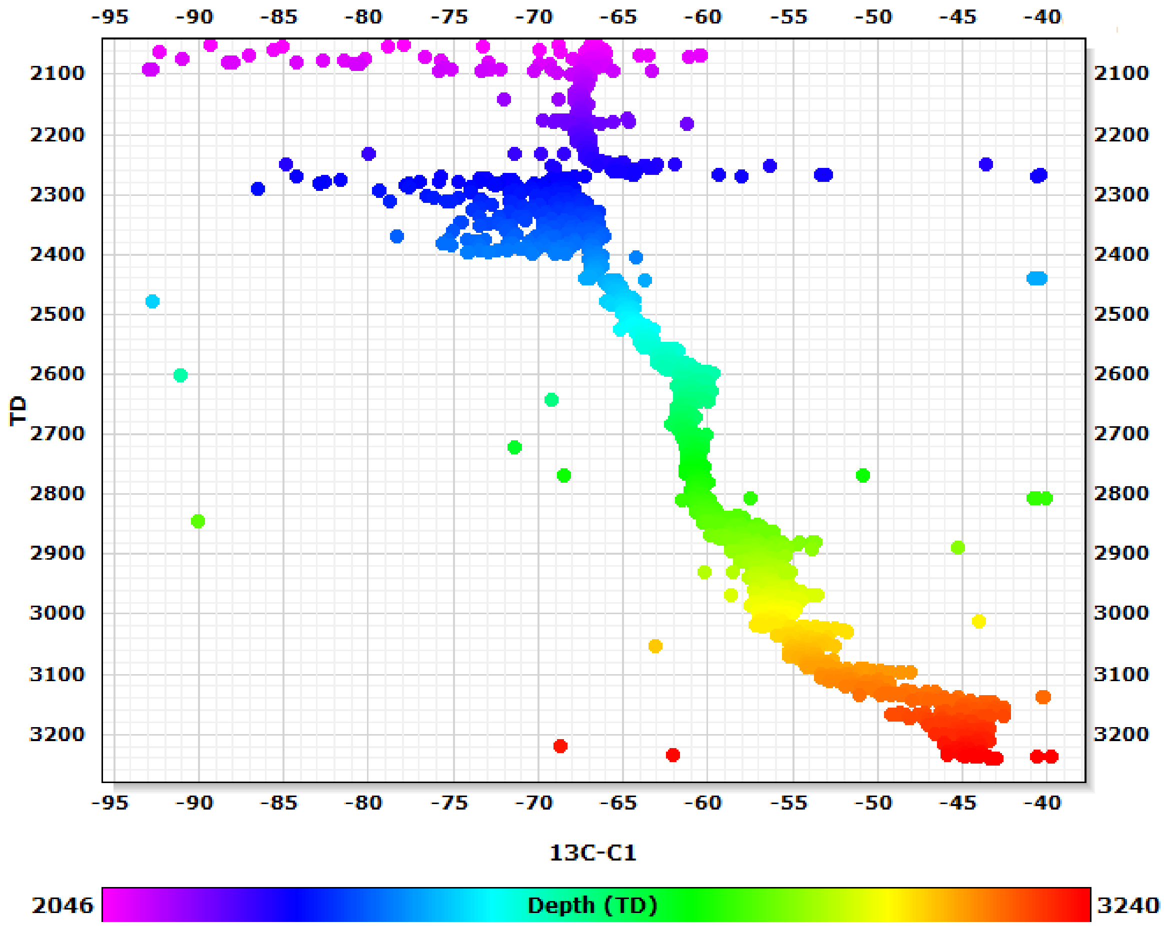

Figure 3. $\delta^{13}CH_4$ Isotopic profile showing maturity

The Isotopic reversals observed at about 2300m may correspond to the inception of the marine regression, evolving from the deposition of carbonate facies to increasing sandstone facies. The isotopic profile seemingly shows that Formations overlying 3000m are immature.

B. Methane Profile.

The methane component is normally the highest in concentration in both mud gas and cuttings gas.Figure 4, shows the profile of methane gas in the mud gas of the well. The trend is that of gradual increase in concentration from the deeper series at 3200m to 2300m where there is a sudden inflexion with rapid increase of concentration from about 2500ppm to about 20,000ppm. The inflexion indicates an isotopic rollover. The observation corresponds to the middle of marine regression resulting in the deposition of fluvio–deltaic facies [12], inaddition, the gas corresponds to the reservoir gas. The recent depositions are characteristically inferred by the $\delta^{13}C$ of methane ranging from –60‰ to –90‰

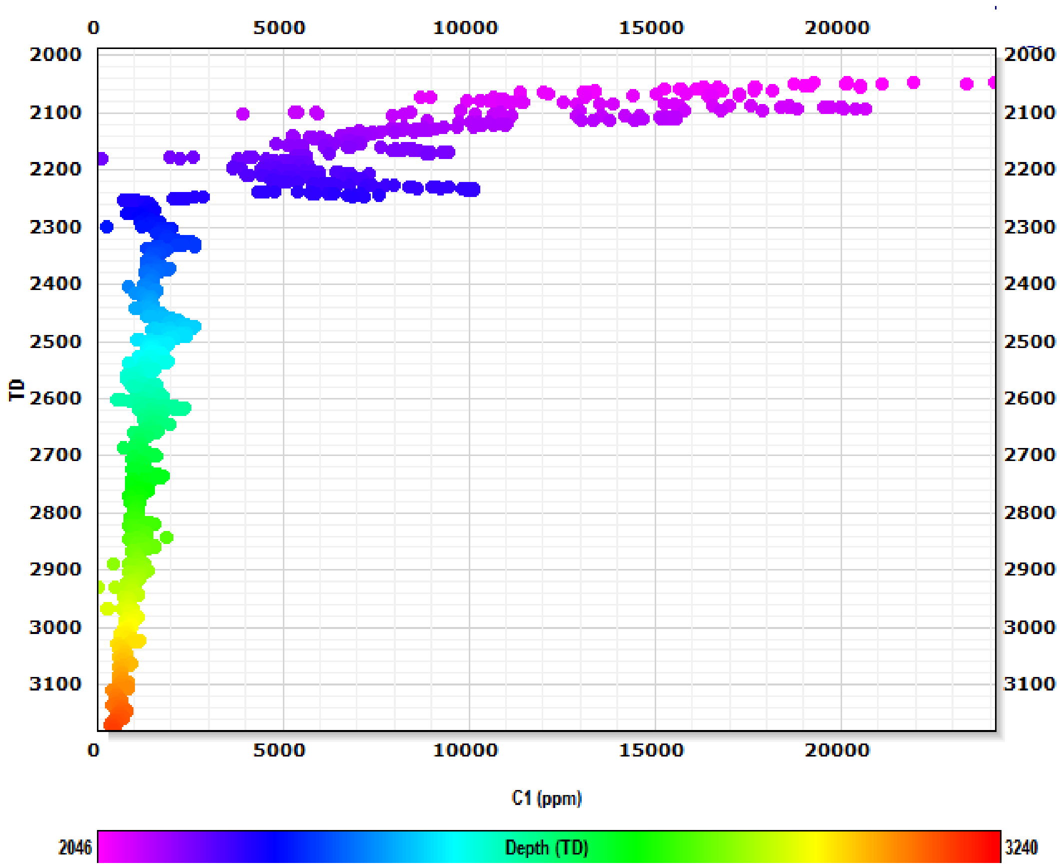

Figure 4. The profile for concentration (ppm) of C1 (methane) transverse the wellbore.

C. Migratory Pattern.

The migratory pattern of gas could be delineated using some parametric ratio on the concept of mixing diagrams as proposed by [2],[11]. The plot of $\delta^{13}C$ of methane against C_2/C_1 ratio as in figure 5 can infer a direct mixing trend from biogenic and thermogenic gas for linear profile. The curved trend tends to be interpreted as a migratory pattern that depicts some diffusive tendencies for mixing of the gases as portrayed by different axial trends. The migratory pattern is that of diffusive migration. The lighter gas with lower values of C_2/C_1 are mostly in the reservoir, while the heavier isotopic gases with higher C_2/C_1 ratios are in the deeper carbonate/shale facies. Figure 5 may also serve as an alternative for distinguishing thermogenic gases from biogenic gases. Thermogenic gases are observed towards increasing values in Y–axis while biogenic gases occur towards decreasing values in X–axis [11],[14]

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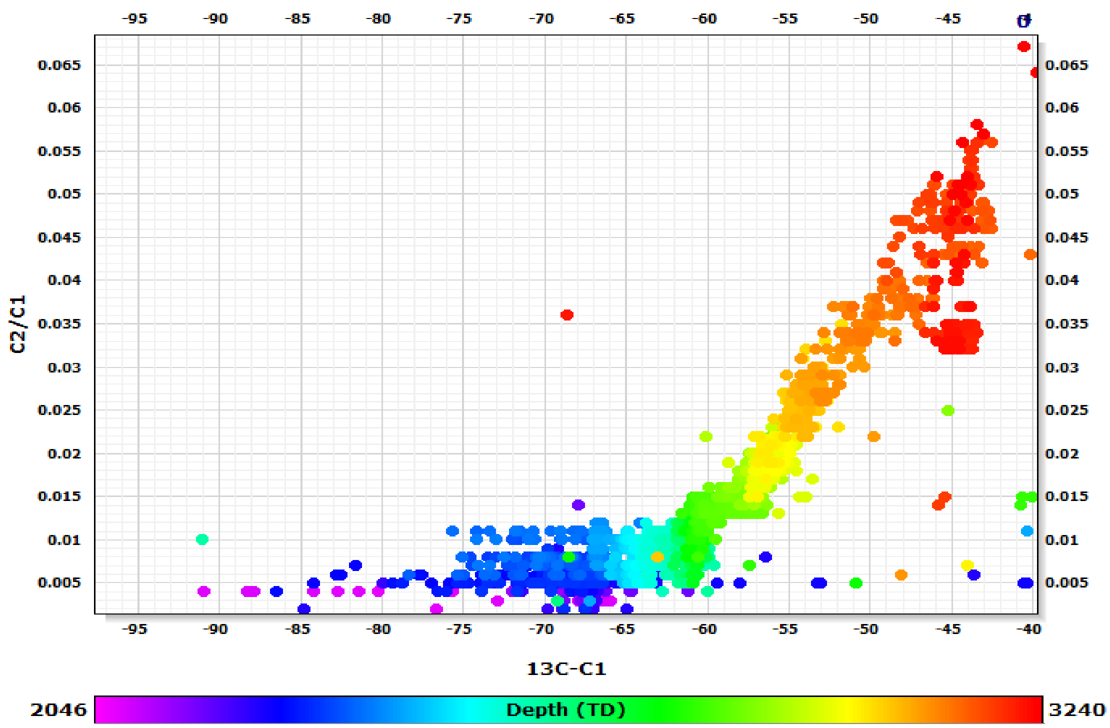

Figure 5. Plot of $\delta^{13}CH_4$against C_2/C_1 ratio for migratory pattern.

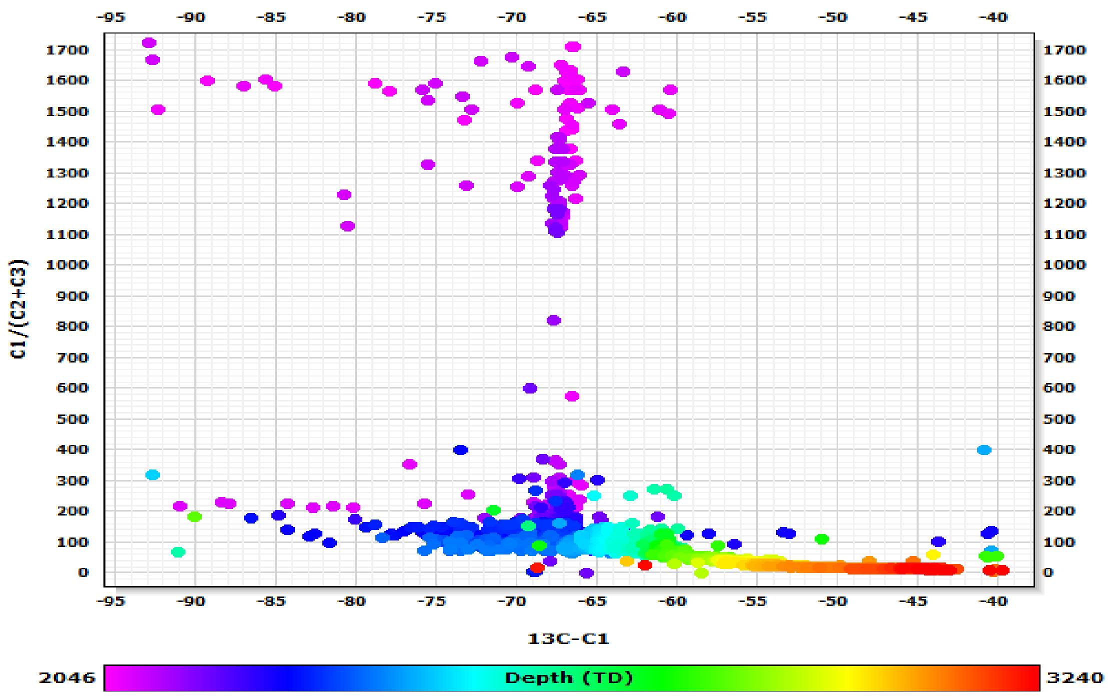

Figure 6. Plot of C1/(C2+C3) (gas wetness) against $\delta^{13}CH_4$

D. Gas Wetness Profile

Figure 6, which portrays that gas wetness profile infers the trend and quantity of thermogenic wet gas across the wellbore. Mature thermogenic wetgas occurs from 3200m to about 3000m, thermogenic wet gas will have C_1/C_2+C_3 ratio of about 1 to 100 with –50‰ as the least $\delta^{13}C$ of methane values. However, biogenic gas bears from 1,000 to 20,000 as values of C_1/C_2+C_3 ratio while lighter values than–50‰ is characteristic of biogenic gas. Gases from reservoir compartment at 2100m to 2046m seem to show some kind of isotopic reversals with isotopic values ranging from –60‰ to–90‰.In this case, the observed reversal may be attributed to their organic origin. The organic matter is mostly of terrigenous origin. The different diagenetic pathway for gas generation may have resulted to the reversals[12],[15].

E. Biodegradation

Biodegradation processes in gases has been monitored using the iC_4/nC_4 profile, however, the C_2/C_3 ratios has also been applied [11]. Figure 7, is a plot of C_2/C_1 against C_2/C_3. C_2/C_1ratio portrays maturity with an increasing trend on the Y–axis, while C_2/C_3 indicate biodegradation with an increasing trend on the X–axis. The plot infers that gases at more shallow depth such as 2500m and shallower,have high potential forbiodegradation, thus the potential for biodegradation reduces with increasing depth. While gases at deeper series portray more of maturity relative to biodegradation. The curved trend also showed some elements of diffusive migration [11],[14].

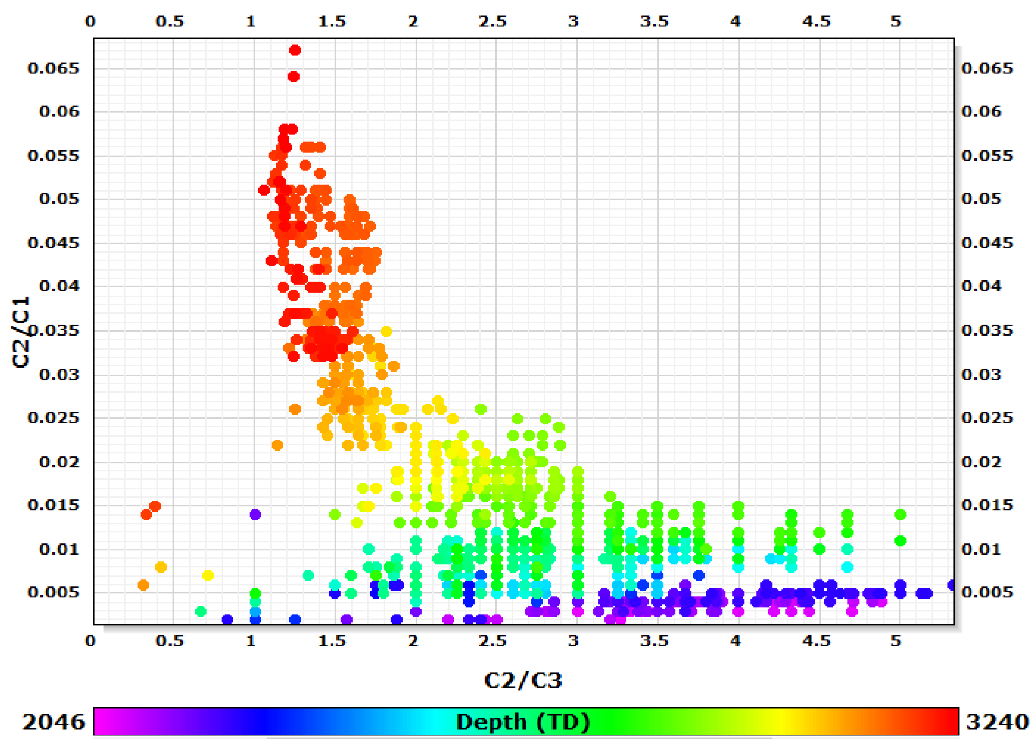

Figure 7. Plot of C_2/C_1 against C_2/C_3

5. Conclusion:

The mud gas profile showed that maturity for this study ranges from –40‰ to –55‰, corresponding to 3200m to 3000m. Gases above 3000m are immature. The isotopic reversal observed at 2300m is attributed to marine regression. The migratory pattern has been delineated to be that of diffusive migration, showing mixing tendencies of biogenic and thermogenic gases. The methane profile showed isotopic rollover at about 2200m, isotopic reversals were also observed at the same depth. Biodegradation was observed at 2500m and shallower depths.

6 Acknowledgments: The authors are thankful to the Geology Department for assistance and Geology/Mining Department of the School of Science Laboratory Technology for data processing

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