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Research Article

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Thermogenic Wet Gas in Immature Caprock Sections: Hydrocarbon Migration or In situ Generation

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Abstract Headspace gas data consist theC1 to C4 compositional distribution of hydrocarbon in drilled cuttings that are sampled and stored in tins or isogas jars or sample bags. The gas is present in the matrix of the cuttings which have migrated out. Analytical results indicate that samples from formations which are relatively immature bear very mature thermogenic wet gas while some formations show the presence of immature gas. The concept of in situ generation of hydrocarbons (earlier generation of hydrocarbon at vitrinite reflectance ≤ 0.4%) seems to compromise the understanding of the mechanism behind the presence of thermogenic gas in immature caprock sections. The thermogenic gas profile for most wells show consist trend upto the reservoir–caprock interface, this indicates migration from the reservoir not in situ generation since the caprock sections are immature.

Keywords Thermogenic Wet Gas, Hydrocarbon Migration, In situ Generation

Introduction

Gas geochemistry, an aspect of Petroleum Geosciences is evolving, various concepts has been used to evaluate potential source rock for shale gas while in conventional petroleum exploration similar concepts have been used to determine productive formation for liquid hydrocarbons. In contemporary times, great concern on preservation of accumulation has raised views on prospect analysis and the suitability of prospects for bidding invariably presences an inquest on the need for certainties on caprock integrity of petroleum reservoirs in the context of derisking exploration.

Prior to the present times, headspace gas data had been used to identify by pass pays, serve as indicators of petroleum accumulations, evaluate maturity and productive capacity of corresponding formations, evaluate the maturity and source of gas accumulations.

The integration of studies in bid to achieve high degree of accuracy in prospect evaluations, has resulted in the use of direct hydrocarbon indicators (DHIs) such as oil stains, oil shows and seeps. Current trends in caprock studiesentails the use of gas clouds on seismic cross sections.

The advancement in gas geochemistry has witnessed the application of concepts on headspace gas to expound the efficiency of petroleum caprocks whose major role is to foster accumulation and preservation. This enables extricating potential mechanism behind the occurrence of mature thermogenic gas in immature caprock–reservoir interface, whether it is better explained by migration or generation. In this study, thermogenic wet gas is observed in immature caprock section, could this be explained by migration or in situ generation of thermogenic wet gas? this on a wider horizon will unravel the mode of occurrence of migrant hydrocarbons relative to indigenously generated hydrocarbons in caprock rock sections overlying the reservoirs.

The headspace gas may consist biogenic gas, thermogenic gas or a mixture of both biogenic and thermogenic gases depending on geological/diagenetic processes within the formation. Biogenic gas is mostly dry gas with about 97% methane in its composition and mostly source from immature organic matter at shallow depth such as lignites. Thermogenic gas is mostly source from deeply buried matured organic matter and consist of both dry and wet gases, thermogenic *wet* gas consist not less than 5% wet gas i.e. ethane, propane, butane and at times pentane, while thermogenic *dry* gas consist mainly methane form post mature organic matter in metagenic stage of evolution [1].

Materials and Method

Samples are headspace gas which is obtained from drill cuttings that had been sampled and preserved from the shale shaker during drilling. The gas at the headspace of the canned cuttings or isogas jars is analyzed and the distribution of the hydrocarbon components per depth range is derived from GC– FID data.

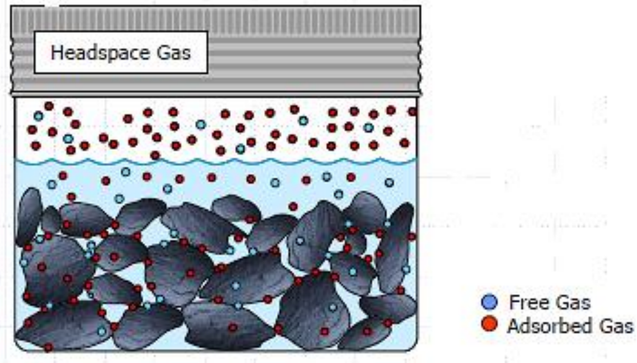


Figure 1: An illustration showing headspace gas migrating out of the drill cuttings into the headspace above the canned cuttings [2]

The headspace gas has been preferentially used in this study, this preference is based on the fact that compare to other gases i.e. interstitial (occluded), because headspace gas migrates out of the sediments withoutthe application of undue force [3]. The headspace gas shows significant anomaly from the background gas compared to the occluded gas [3-5]. In addition, it produces the most significant regional anomalies and that in surface geochemical context, it serves as a possible secondary petroleum indicator [3].

In this study, headspace gas data were obtained from well completion reports sourced from the public domain of the Norwegian Petroleum Directorate. Log view plots were modelled using Schlumbergers' Techlog, while the descriptive lithologies were modelled using Zetawares' genesis version 4.8.

Results

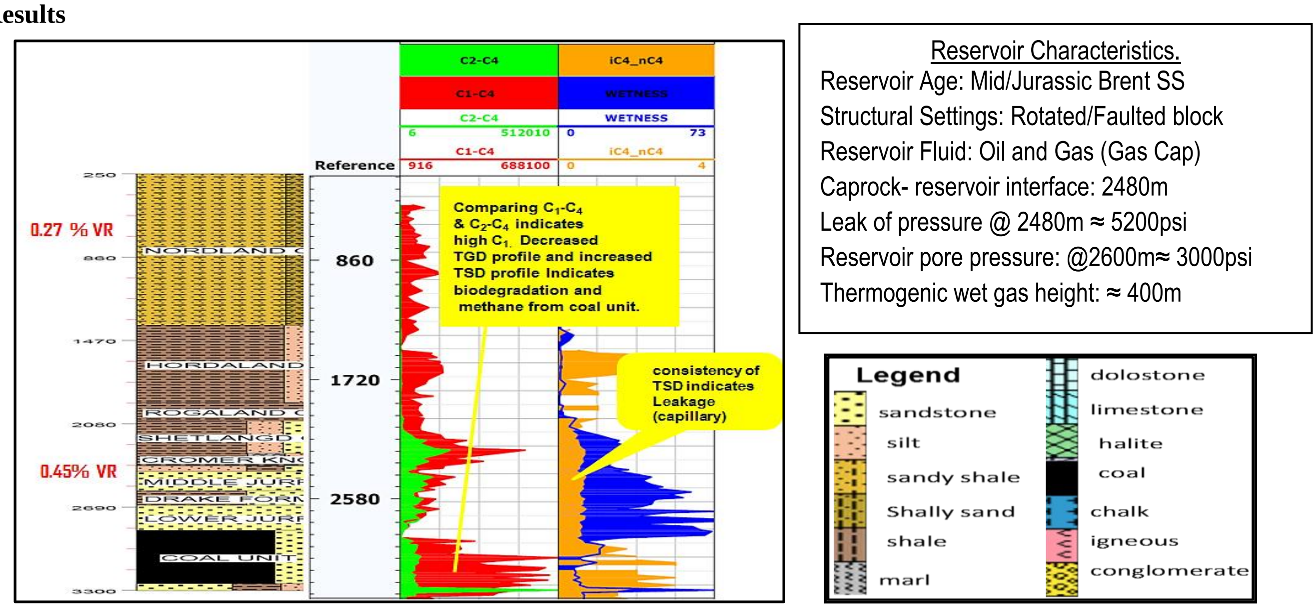
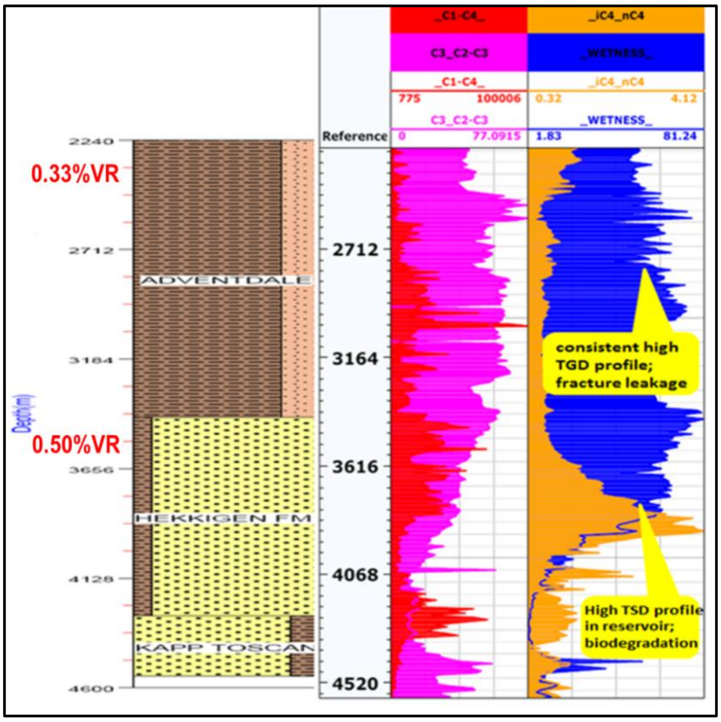


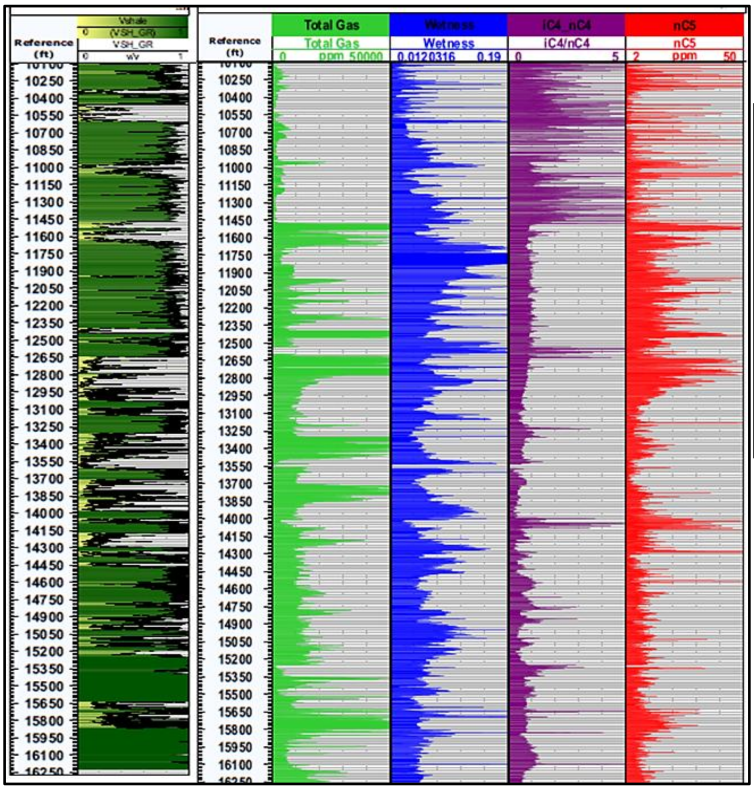
Figure 2: Log view profile of thermogenic wet gas for Asgard 6407/2-2in the North Sea

The log view plots generated from the data bear profiles generally indicating increasing hydrocarbon content into the reservoir formation. Some profiles have several spikes such as the Gbaran well 26 of the Niger delta, while others bear more of a smooth trend, mostly the North Sea wells.



Reservoir Characteristics.
Reservoir Age: Mid/Jurassic Ness, Etive (Brent Group)
Structural Settings: Rotated/Crestal
Reservoir Fluid: Oil & Gas (Gas Cap)
Caprock- reservoir interface: 1993m (Re-entry)
Litho Pressure: 6534.4psi (45.05MPs)
Reservoir pore pressure: 4667.4psi (32.18MPs)
Thermogenic wet gas height: 700m
Data Type: **Headspace gas**

Figure 3: Log view profile of thermogenic wet gas for Gullfaks 7219/8–1S in the North Sea



Reservoir Characteristics.
Reservoir Age: Oligocene/Early Miocene
Structural Settings: Rollover
Reservoir Fluid: Oil & Gas (Gas Cap)
Caprock- reservoir interface: Above 15400ft
Reservoir pore pressure:
0.7psi/ft at 15156; 0.84psi/ft at 17406ft
Thermogenic wet gas height; Uncertain, No %VR
Data Type: **Mudgas**

Figure 4: Log view profile of thermogenic wet gas for Gbaran well 26 in the Niger delta

Discussion

The vitrinite reflectance data of the formation and the corresponding log view plots for TSD (thermogenic signature–Depth) and TGD (thermogenic wet gas–Depth) of the sited cases studies from both the North Sea and the Niger delta, infers the presence of thermogenic wet gas in sections of the caprock overlaying the reservoirs. The North Sea wells show mostly immature caprock sections, while the Niger Delta Gbaran well 26 is uncertain.

Earlier studies have featured the used of thermogenic wet gas data to determine the maturity and producibility of formations. Formations for which the corresponding gas data bears the presence of wet gas/thermogenic gas were inferred to be matured and producible. This explicitly means the formation has gone into the principal zone of generation of oil and gas. However, in this study, the vitrinite reflectance data indicates that the caprock formations bearing these data are immature i.e. below the 0.5% vitrinite reflectance which is the standard for mature formations.

The concept of in–suite generation of wet gas in immature formation may raise questions as to the maturity of the end members of the caprock formations and the origin of the thermogenic gas in the caprock [3] and the mechanisms that best describes its occurrence, could it be by migration of a non–indigenous migrant gas or insitu generation? Nonetheless, the fact that kerogen starts generating at about 100 ºC during catagenesis at which point some bonds are broken and oil is generated [6], introduces some doubts as to if, hydrocarbons could actually be generated at earlier stages than stated above.

In a study on light hydrocarbon gases in shallow sediments, Brekke *et al.* [3], concluded that there exists the C_{2+} petroleum like hydrocarbons (PLH) in the sediments studied, this corroborated with similar reports from other prolific areas [7] which showed that the C_{2+} PLHs did not migrate from sources or reservoir below, since there were no accumulations nor source rocks below. Brekke *et al.* [3] rather suggested that the C_{2+} PLHs were by–products generated from bacterial degradation via complex organic molecules to CO_2 or methane. Brekke *et al.* [3] also mentioned the strong likelihood that unsaturated hydrocarbon observed in the gas samples studied could have been hydrogenated to their saturated homologues by acid catalyzed reactions in the sediments; this was because the unsaturated PLHs correlate with the saturated homologues in the gas samples studied.

The studies considered consists those of both natural systems and those on pyrolysed processes which resulted in gaseous products, but immature wet gases were observed in both cases. The natural systems did not show significant evidence of generation of immature wet gas, but pyrolysis processes showed the presence of wet gas from immature sections as by–products of pyrolysis. However, the immature wet gas is not stated to be very significant and could be recognized as background gas, hence the use of a threshold value of 5% wet gas serves as a check on the influence of any background wet gas which may not be part of the migrant gas family.

The fact that insitu generation of immature wet gas does not impact on the profile of the thermogenic wet gas gives credence to the fact that thermogenic wet gas in *immature* sections of the caprock overlying reservoirs could have migrated via the caprock–reservoir interface to more shallow environments of the caprock.

Figure 2, show that the vitrinite reflectance of the formation for the wellranges from 0.27%–0.45% at the reservoir–caprock interface for Asgard well 6407/2-2, while figure 3 indicate that for Gullfaks 7219/8–1S vitrinite reflectance ranges from 0.33% to 0.50%.The vitrinite reflectance for Gbaran well 26 is not available. The vitrinite reflectance data indicates that the caprock formation for the North Sea wells are all immature for the generation of thermogenic wet gas,this suggests that the thermogenic wet gas in the formations which are immature are not indigenously generated, the gases are migrants that could have migrated from their respective reservoirs.

The Niger delta reservoirs are deltaic reservoirs, which are characterized by stacked sandstone bodies. Thus have intercalations and most cases fill–to–spill sequentially. In addition, it is observed that the trend of total hydrocarbon concentration increases as well as the thermogenic wet gas concentration profiles into the reservoir. The spikes observed indicates areas where there are built up accumulations due to low permeability facies which constraints migration, at saturation the buoyant pressure over comes the resistance of the capillary pressure and migration continuous, but where reverse is the case, accumulation occurs.

Figure 4, show that Gbaran well 26 has caprock–reservoir interface at 15,400ft, above that depth there is a continuum of total hydrocarbon, wet gas and nC_5 with a consistent profile from the reservoir through the caprock interface to the formations overlying the caprock. This infers consistent migration of hydrocarbon from the reservoir to the formations overlying the caprock.

All log views show that the percentage wetness is highest in the reservoir relative to the caprock sections. This may suggest the present of a homogenous caprock formation without any facie that serves as a potential low permeability interface. The thermogenic signature is expressed as *iC4/nC4*, high values at depth indicates biodegradation, which is characterized by loss of the normal alkanes in preference to isopreniods, however at shallow depth it represents immaturity, much lower values ($n \leq 1.0$) represents mature thermogenic wet gas.

The consistency of the thermogenic signature from the reservoir via the reservoir-caprock interface into the caprock sections indicates a steady migratory trend from the reservoir into the caprock sections. This invariably infer that the occurrence of thermogenic wet gas in the immature caprock sections of the formations,impliesmigration of thermogenic wet gas from the reservoir to the caprock sections and does not connotes that the corresponding formation is mature to generate hydrocarbon as proposed in earlier studies.

Conclusion

Gas geochemistry has been employed for delineation of the mechanism for occurrence of thermogenic wet gas in the caprock sections overlying petroleum reservoirs.

It is observed that thermogenic wet gas (nC_2–nC_4)/(nC1–nC4) and thermogenic signature (iC_4/nC_4) profiles show a consistent trend from the reservoir via the reservoir–caprock interface to shallower depths, this observation indicates migration from reservoir to more immature caprock section. The vitrinite reflectance indicate that formations corresponding to the caprock and above the caprock are immature to generate mature hydrocarbons, hence these formations are hosting migrant hydrocarbons.

Acknowledgment

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