# Source to Reservoir Correlation and Hydrocarbon Compositions of Oil Sand Deposits in Dahomey Basin, Nigeria*

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## Abstract

Oil sands, also known as tar sands, are classified as unconventional hydrocarbon plays and are being exploited to augment global energy needs. Nigeria has the largest conventional oil industry in Africa but is also endowed with marked oil sand deposits. These are found within the Afowo Formation in the Eastern Dahomey Basin. The deposits occur across an area of approximately 120 by 6 km, and the reserves are estimated at about 30-40 billion barrels. Over the last decades, the Nigerian government and oil companies have focused on the exploitation of conventional hydrocarbon reserves with very limited attention to the vast oil sand resources. The current push and paradigm shift to diversify the economy and to increase petroleum reserves and create jobs makes the exploitation of oil sands an ideal target of high national interest. In this study, results from some of these oil sands are presented. Outcrop samples of the source rock, oil sand and bitumen seepage from a location (J4) in the state of Ogun, South Western Nigeria have been evaluated for organic matter maturity and hydrocarbon compositions. Pyrolysis results for the source rock indicate that total organic carbon (TOC) ranges from 5.95 weight % to 18.46 weight % with organic maturation temperature (Tmax) within the range of 417°C to 426°C. A complementary Gas Chromatography (GC) analysis of the free hydrocarbons present within the source rocks illustrates that both light and heavy hydrocarbon components are present. In contrast, oil sand and bitumen hydrocarbon analyses show that mostly heavy hydrocarbon end are present with hydrocarbon chains C6-C12 missing, consistent with biodegraded oils. Such a hypothesis is supported by the high oxygen index of the source rock (oxidation effect). This study demonstrates that these oil sands represent viable exploration targets for the

petroleum industry. With vast oil sand deposits in the Dahomey Basin, the exploration and exploitation of this resource will open new frontiers to complement Nigeria’s hydrocarbon production from conventional plays.

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# Outline

- Objectives
- Introduction
- Source Rock Evaluation
- Hydrocarbon Compositions
- Conclusions

# Objectives

## *Paradigm Shift and needs to diversify the economy*

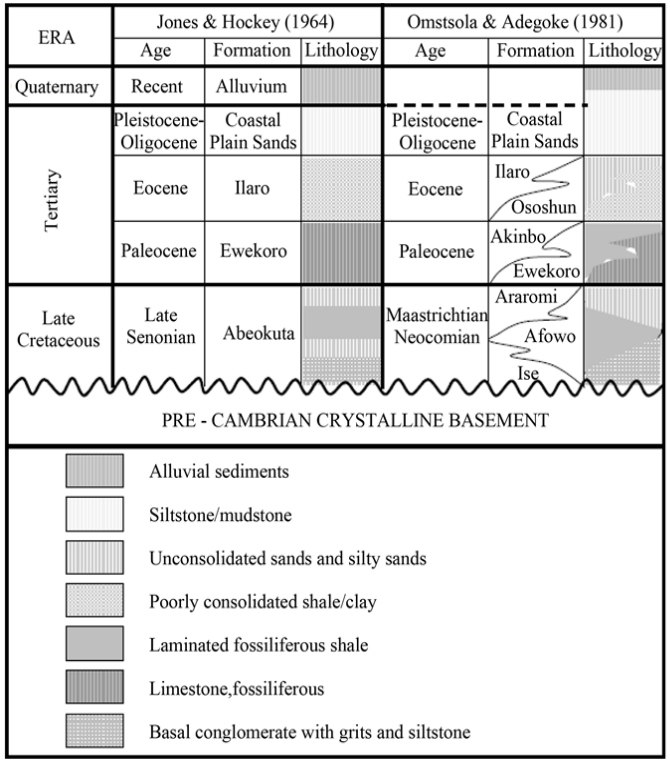
- Evaluate the source rock
- Appraise the hydrocarbon compositions of the source rock
- Determine the hydrocarbon compositions of oil sands and bitumen
- Establish genetic relationship

# Introduction
## *Why Oil Sand?*

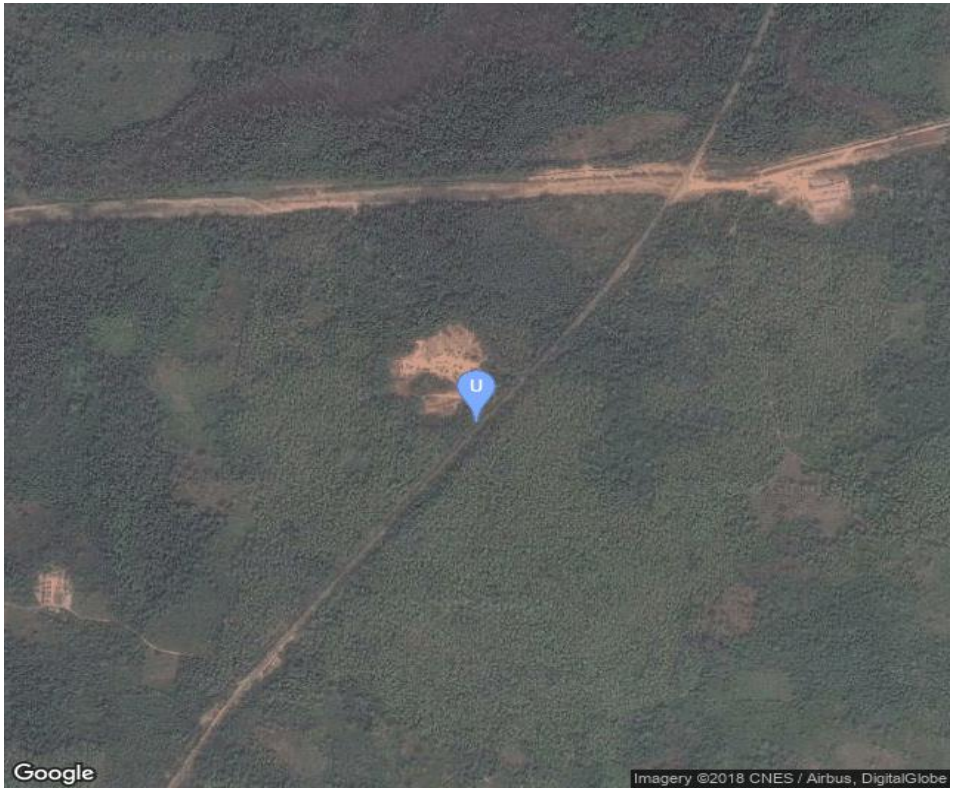
- World resources of bitumen and heavy oil are more than conventional crude oil reserves
- Vast nature of the reserves, global energy needs and technological innovations have resulted in profitable extractions
- In addition to conventional oil reserves, Nigeria has marked oil sand deposits. These are found in Eastern Dahomey Basin.
- Exploitation of the Oil Sand is an ideal target of high national interest

# Contextual Information

- The oil sand deposits of Nigeria are found in the Afowo Formation, in the Eastern Dahomey Basin.
- The Formation is composed of Sandstones, Shales, and Claystone
- The sandy facies is oil bearing while the shales and claystone are organic rich
- Outcrop samples of shales, oil sands and bitumen were collected, prepared and analyzed to evaluate organic matter maturity and hydrocarbon compositions




Generalized Stratigraphy of the Eastern Dahomey Basin (Jones et. al., 1964 and Omatsola et. al. 1981)




Google Map showing the Outcrop location. The outcrop is located within a Forestry Reserve (J4).

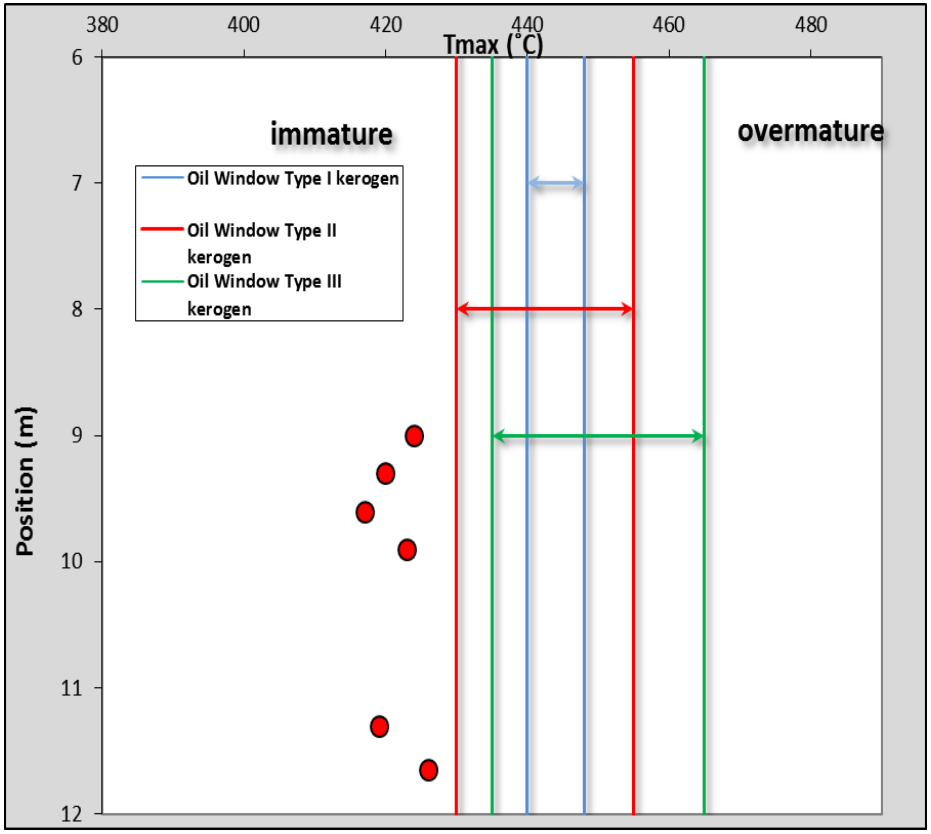
# Source Rock Evaluation

- Shale Samples were collected at varying depth intervals
- Samples were air dried, grinded using a mortar and pestle.
- Samples were prepared to avoid contamination and then evaluated using pyrolysis (HAWK*) and Gas Chromatography (TD-GC)

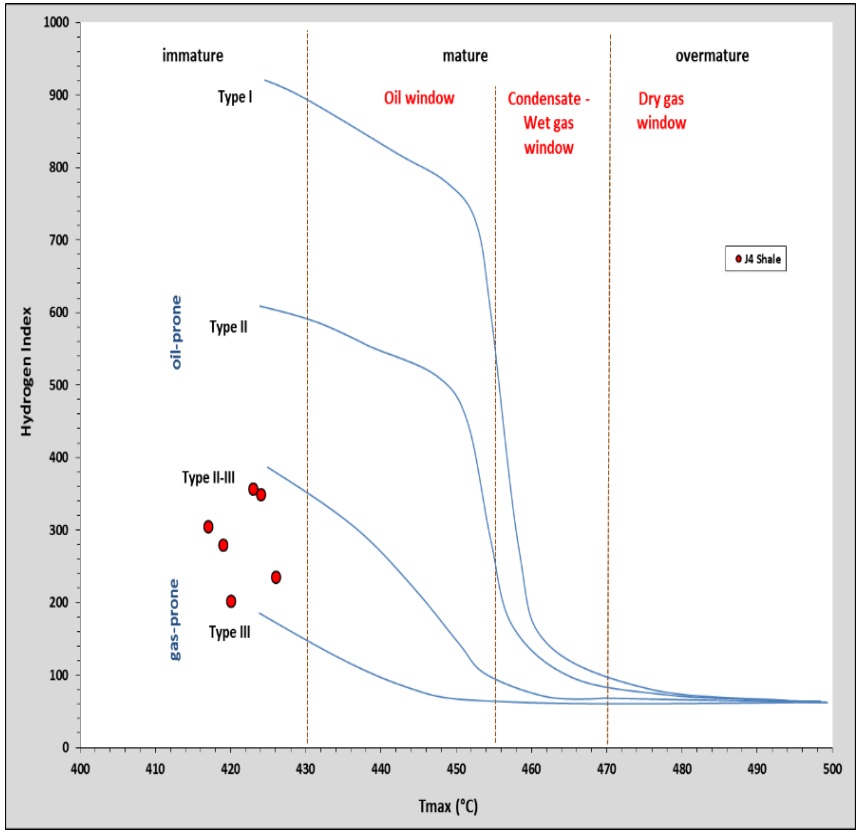
# HAWK* Summary Data showing Pyrolysis Results for Afowo Shales

| Sample ID | Sample Depth (m) | Tmax °C | S0 (mg/g) | S1 (mg/g) | S2 (mg/g) | S3 (mg/g) | PC (%) | PI | S2/S3 | S1/TOC | TOC % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shale | 8.7 | ? | 0.05 | 0.18 | 0.22 | 1.38 | 0.03 | 0.45 | 0.16 | 0.22 | 0.81 |
| Shale | 9.0 | 424 | 0.03 | 2.85 | 22.98 | 1.79 | 2.14 | 0.11 | 12.84 | 0.43 | 6.57 |
| Shale | 9.3 | 420 | 0.10 | 2.58 | 27.15 | 2.96 | 2.47 | 0.09 | 9.17 | 0.19 | 13.40 |
| Shale | 9.6 | 417 | 0.08 | 10.02 | 56.33 | 3.24 | 5.51 | 0.15 | 17.39 | 0.54 | 18.46 |
| Shale | 9.9 | 423 | 0.07 | 8.21 | 50.64 | 4.56 | 4.88 | 0.14 | 11.11 | 0.58 | 14.17 |
| Shale | 11.30 | 419 | 0.02 | 2.69 | 16.71 | 3.28 | 1.61 | 0.14 | 5.09 | 0.45 | 5.95 |
| Shale | 11.65 | 426 | 0.03 | 3.05 | 31.48 | 8.08 | 2.87 | 0.09 | 3.90 | 0.23 | 13.33 |

- *It was not possible to obtain Tmax for the shale sample at 8.70m due to very lean S2 value. The results for this sample*
- *Were excluded from the analysis and interpretation.*




Organic Maturation Temperature (Tmax) Profile for Afowo Shales. The profile shows Tmax below 430 °C indicating thermal immaturity. It was not possible to obtain Tmax for the shale sample at the depth of 8.7m.




Display of Hyrogen Index (HI) versus Tmax showing organic maturity and kerogen types. The result for the sample at the depth of 8.7m was compromised. The results indicates admixtures of Type II – III kerogen and are prone to generate oil and gas at greater maturation temperature.

# Pyrolysis and Thermal Desorption Gas Chromatography (TD-GC)

| Formation | Sample Depth (m) | Outcrop Sample Type | Pyrolysis | TDGC | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | S0 + S1 (mg HCs/g rock | Paraffin %Light Condensates | %Heavy Condensates | % Naphthenes | %Aromatics | %Biomarke |
| Afowo | 8.7 | Shale | 0.23 | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 |
| Afowo | 9.0 | Shale | 2.88 | 1.69 | 89.62 | 0.96 | 2.65 | 5.07 |
| Afowo | 9.3 | Shale | 2.68 | 0.84 | 88.55 | 0.62 | 0.49 | 9.51 |
| Afowo | 9.6 | Shale | 10.1 | 4.11 | 91.61 | 0.65 | 1.63 | 2.00 |
| Afowo | 9.9 | Shale | 8.28 | 3.71 | 70.02 | 1.97 | 5.02 | 19.29 |
| Afowo | 11.3 | Shale | 2.71 | 6.11 | 86.89 | 1.63 | 2.72 | 2.65 |

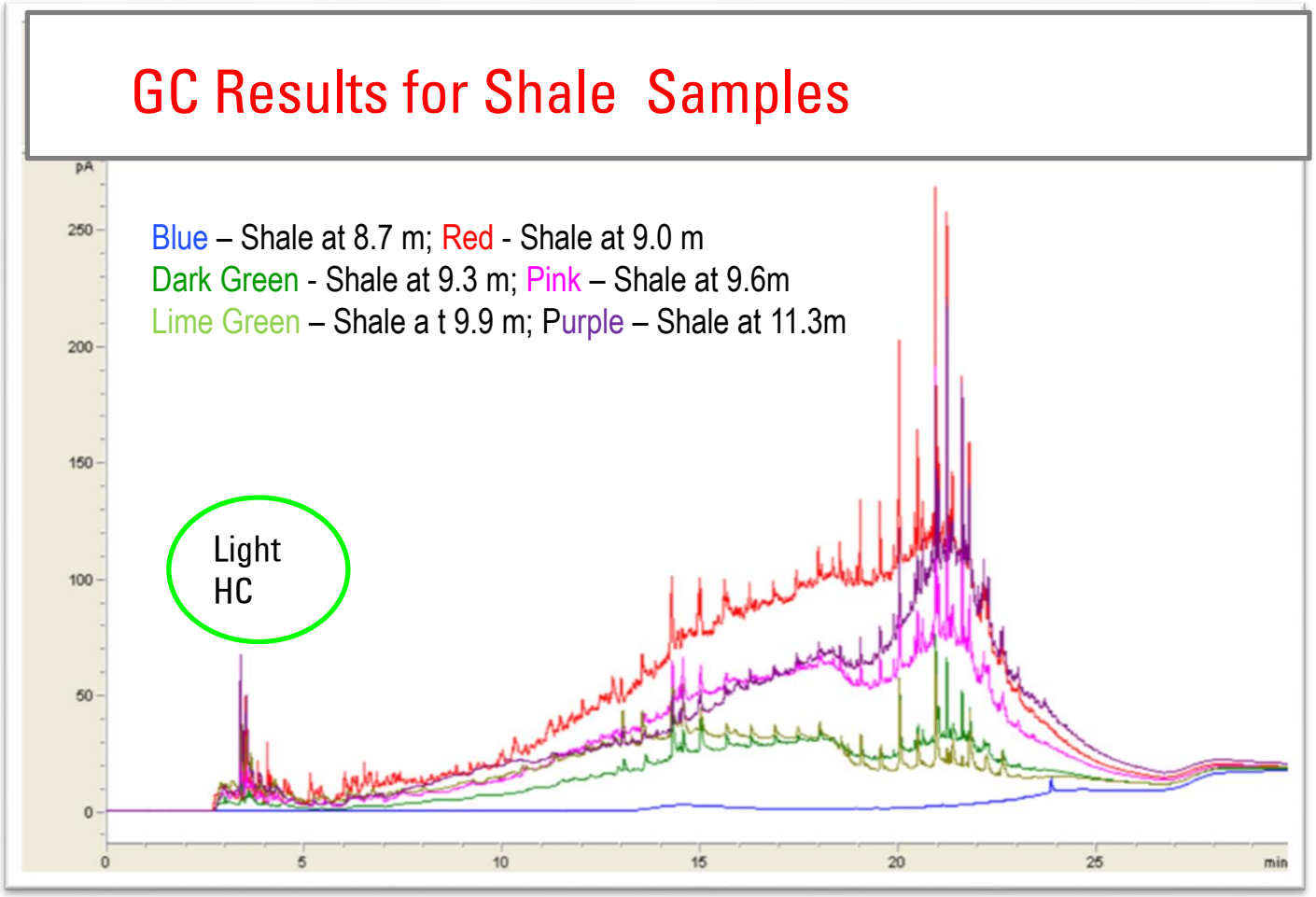
Pyrolysis and Thermal Desorption Gas Chromatography (TDGC) of Afowo shales showing free hydrocarbons and its compositions.

*No detectable hydrocarbon was observed for shale sample at the depth of 8.7m and the results for this sample are excluded from the analysis and interpretation*

# Gas Chromatography

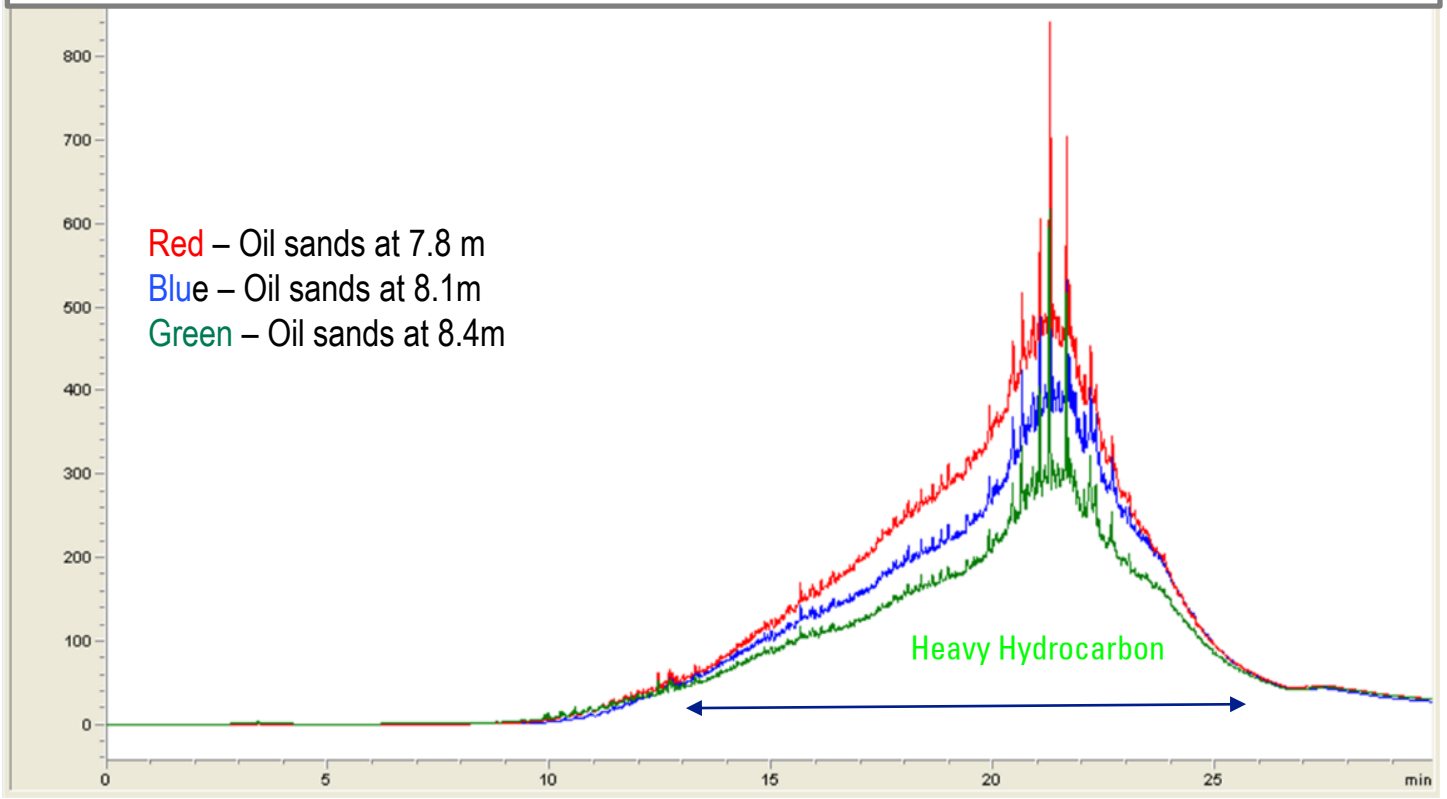
- Samples of shales, oil sand obtained at varying depth intervals were prepared and analyzed for hydrocarbon compositions
- Random samples of oil sand and seepage of bitumen were also analyzed.
- The results indicated the presence of both light and heavy hydrocarbon components in the shales.
- In contrast, only heavy components are present in the oil sands and bitumen, confirming biodegradation.

# GC Results for Shale Samples

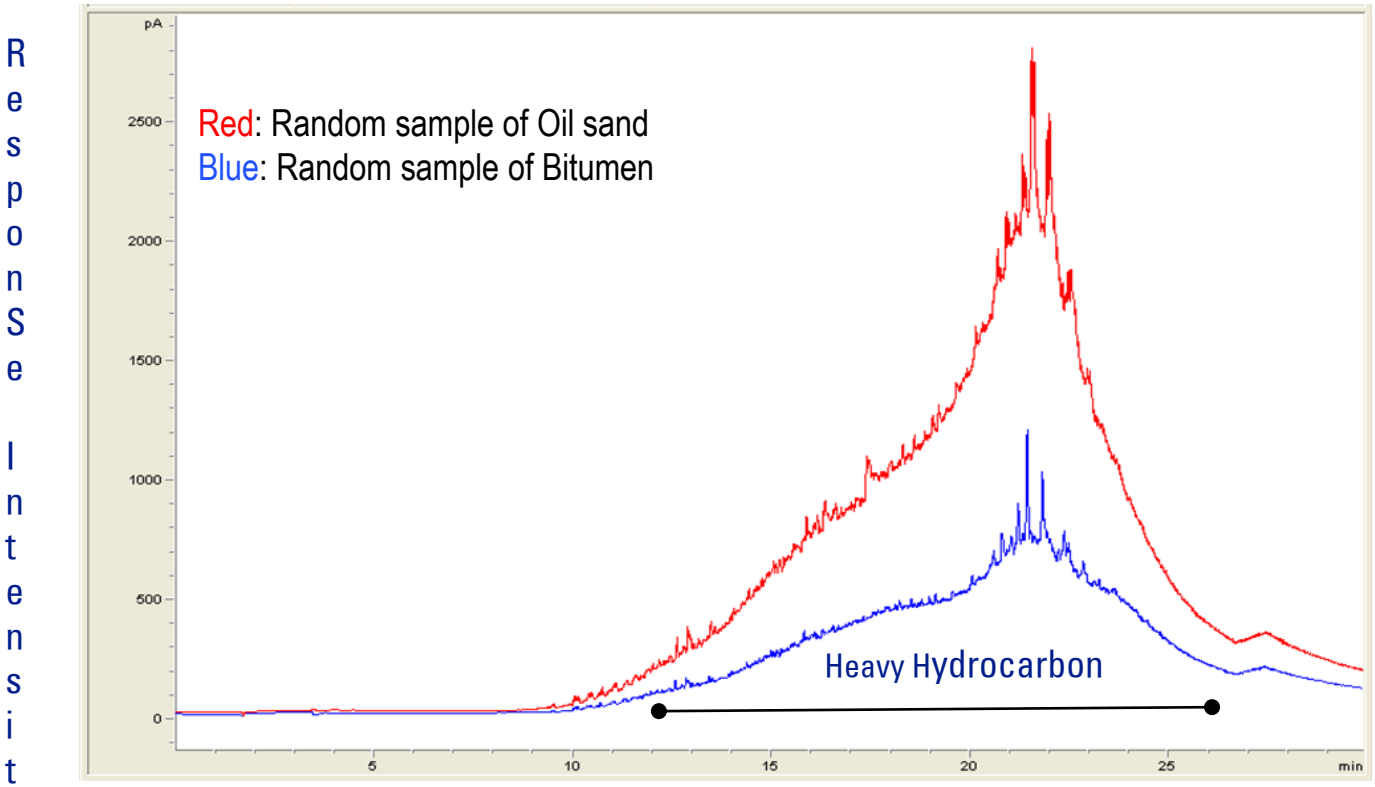



Chromatogram for shale samples showing both heavy and light condensates. No detectable hydrocarbon was observed for shale sample at the depth of 8.7m and the results for this sample are excluded from the analysis and interpretation. Response intensity peaked from about 2.5 minutes and paled out at about 25 minutes retention time, suggesting that both light and heavy condensates are present in the shales.

# GC Results for Oil Sands




Chromatogram for Oil Sands. Response Intensity is shown on the Y-axis in pico Ampere (pA) while Retention Time is shown on the X-axis in Minutes. The results shows heavy condensates in the oil sands with missing light components, consistent with biodegraded hydrocarbons. The response intensity showed no detectable hydrocarbon below 10 minutes retention time due to the absence of light condensates. The absence of n-alkanes in the chromatograms indicates that the oil sands are biodegraded




Chromatogram for random sample of oil sand and bitumen showing heavy condensates. Response Intensity is shown on the Y-axis in pico Ampere (pA) while Retention Time is shown on the X-axis in Minutes. The response intensity showed no detectable hydrocarbon below 10 minutes retention time due to the absence of light condensates. The absence of n-alkanes in the chromatograms indicates that the oil sands and bitumen are biodegraded.

# Conclusion

- Total organic carbon (TOC) and hydrocarbon yield from kerogen (S2) for the source rock indicates a viable petroleum system
- Tmax for the shales are below 430 ºC. It is probable that source rocks at deeper depths will show high maturation temperatures with potentials for oil and gas.
- Gas chromatography (GC) results for the shales indicates a dominance of heavy condensates with some light condensates. Oil sands and bitumen showed total absence of light condensates.
- The Afowo shales, oil sands and bitumen are genetically related.

- Prospects appears encouraging for deeper sources.

Many thanks for your attention