

The Impact of Quantitative Seismic Amplitude Interpretation on the Success of Galaxy-02 Well Drilling

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ABSTRACT

Seismic amplitude anomalies that clearly conform to structure are usually part of reliable hydrocarbon indicators in the Niger Delta. In some instances, subtle amplitudes anomalies can be indicative of hydrocarbon presence, and a detailed analysis of the amplitude anomalies can reveal the fluid type and contact information embedded in the seismic data. This is the case of the C9400 and F9000 stacked reservoirs in the Galaxy field. At these levels, we had uncertainties in the fluid type and contacts warranting the application of quantitative seismic amplitudes interpretation techniques to de-risk them. An appraisal program to resolve the uncertainty in fluid type and contacts at the C4000 and F9000 was developed as part of the Field Development Planning for the Galaxy field. Due to the non-availability of pressure data and fluid samples to deterministically infer the fluid type and contacts at these levels, quantitative seismic amplitudes analysis techniques were deployed for use to infer the fluid types and contacts pre-drill. With a reservoir model, typical hydrocarbon indications can be highlighted, a possible prediction technique chosen and calibrated to subsurface physical property changes. Well data and knowledge of subsurface properties are thus essential. A rock physics model was generated based on Galaxy-01 well. The gas, oil and brine responses were modelled using known fluids and reservoir properties. The rock physics model at the C9400 sands show that gas-on-oil-on-brine situation might be recognisable on seismic however, for the F9000 very subtle differentiation could be made between the oil and gas responses as the properties of the two fluid phases are similar but differ from brine. Using seismic gathers analysis, clear AVO responses were established for the C94000. Cross plot analysis of up dip down dip amplitudes for F9000 differentiated hydrocarbon and brine and gave a subtle indication of a possible oil rim. Upon drilling, the Quantitative Interpretation fluid phase prognosis and predicted hydrocarbon water contacts at both C4000 and F9000 were found by the appraisal well as predicted pre-drill.

Keywords: Rock Physics, Cross plots, AVO, Geohazards, Amplitude anomalies, Fluid Phase Prognosis

INTRODUCTION

The Galaxy field is located Northeast of Port Harcourt in one of SPDC's Oil Mining Leases in the Niger Delta. It is a partially appraised field. Galaxy lies within the greater Rami structure comprising a simple rollover structure elongated in the East-West direction.

The Galaxy field is a multi-stacked reservoirs discovery with fluid contacts uncertainties at the F9000 and C9400 reservoirs.

The field was discovered in 1971 by exploration well Galaxy-01. The field has good potentials for substantial

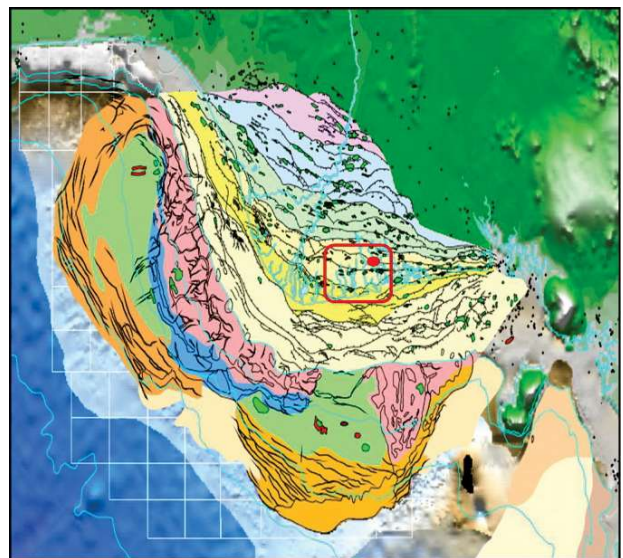


Figure 1: Location map of Galaxy field.

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hydrocarbon recoveries. It has 2 well drilled to date with plans for 5 appraisal/development wells.

OBJECTIVES

The objectives of this paper include the following: To show how some quantitative interpretation methods were used in resolving hydrocarbon type and contact dilemma thereby securing energy, sustaining growth and affordability.

This paper will also outline some simple and affordable technology deployed in derisking a well to achieve development objective while drilling safely.

BUSINESS CHALLENGE

Safety is a deeply held value and a generally upheld vision for ensuring that no leaks occur, and no harm is caused to people or the environment in every drilling operation. Bearing this in mind, various quantitative interpretation techniques were deployed to evaluate this multimillion dollar well (Galaxy-02) with specificity to the two reservoirs (C9400 and F9000) of interest which have some high impact uncertainties. These include:

1. Fluid contact uncertainty in the C9400 reservoir
2. Fluid type and contact uncertainty in the F9000 reservoir and
3. Potential Presence of geohazards especially at the top-hole section
4. Ascertaining suitability of the planned well trajectory in optimally meeting the target reservoirs.

DATA AND METHODOLOGY

In carrying out this study key data input include Galaxy field 3D Reflectivity seismic and velocity data, quadrature and relative impedance data, offset well data (well logs, check shots, daily drilling reports), horizon interpretations, planned well trajectory, casing depths and field geotechnical information.

The following methods were followed in carrying out this study:

1. Carry out geohazards assessment.
2. Carry out pre-drill health check.
3. Amplitude extraction and analysis.
4. Integration of predrill and drilling outcome.

REFLECTIVITY SEISMIC DATA

In carrying out the geohazards assessment, the conventional reflectivity seismic data was used as the base seismic volume.

In seismic reflection, the layers or bands observed in a seismic section are termed reflections. These reflections in the seismic data result due to contrasts in the seismic impedance (density * seismic velocity) across a geologic boundary. For a seismic wave intersecting a layer or

boundary at normal incidence, the ratio of the reflected-to-incident amplitude is the acoustic impedance (R), which defines the strength or amplitude of the seismic reflection.

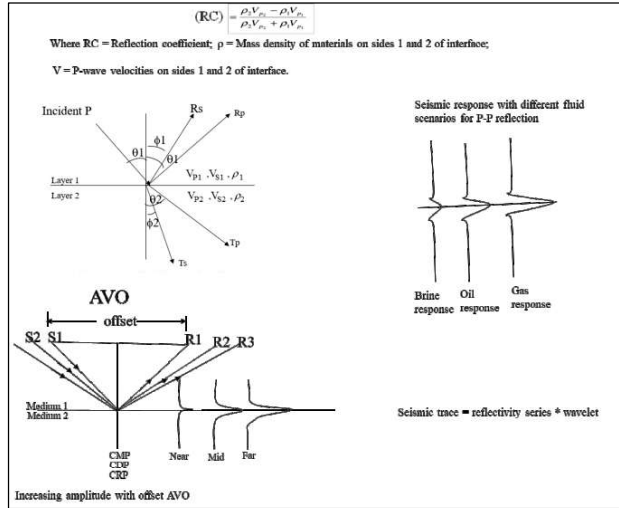


Figure 2: Reflectivity seismic traces computational relationships.

QUADRATURE SEISMIC DATA

According to Zhao et al, (2021), the 90° phase conversion of the reflectivity seismic data intends to give the meaning of the seismic reflection event representing the stratum interface to the lithologic strata by means of phase shift. The seismic data is therefore converted into 90° phase to make the seismic event axis face the stratum. Quadrature data preserves the high frequency spectrum in the seismic data hence preferred for use in shallow gas analysis (Figure 3).

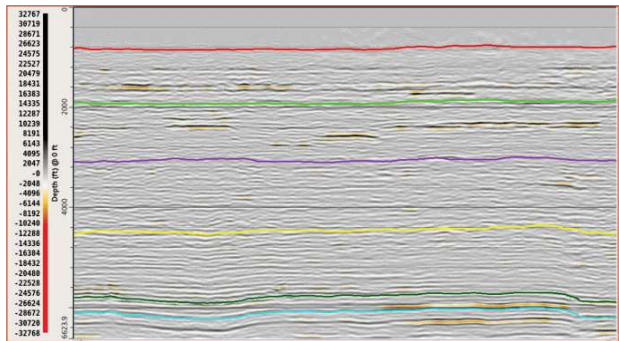


Figure 3: A section of the Quadrature data across the Galaxy field.

Geohazard assessment was carried out for the planned GALAXY-02 on quadrature data derived from the VA_21_PSDM_FULL_TI_RZP_NFLT_3D_GALAXY seismic volume (Figure 4). The data was analysed for the presence of Shallow Gas bodies. Offset well analysis was also done for neighboring wells (GALAXY-01, RAMI-01, and -016) within the field. A well summary was generated

for the planned well trajectory detailing the outcome of the geohazard assessment for each interval along the planned well trajectory (Figure 5).

Offset well analysis in the field revealed issues ranging from high torque, stuck pipe and overpull as gathered from the daily drilling reports. Review of field geotechnical

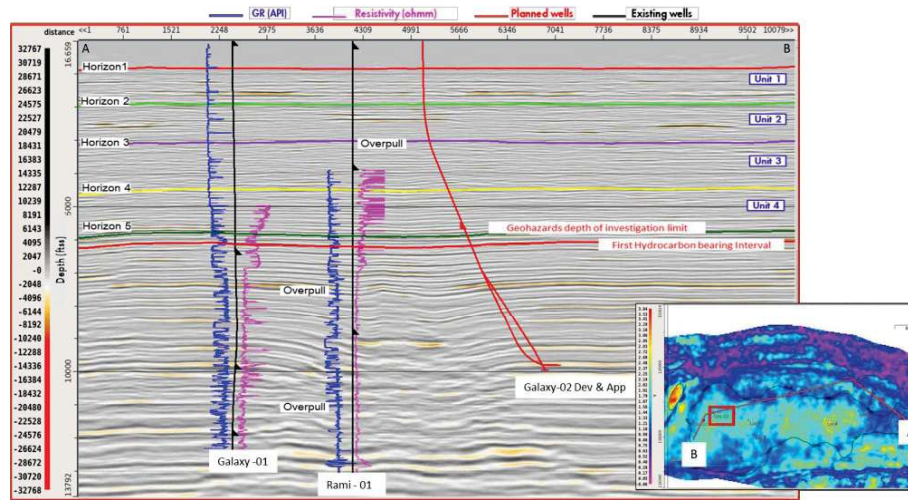


Figure 4: Offset well analysis for the Galaxy-02 development and appraisal wells.

Well Summary		Event	Unit	Depth SS (ft)	Time (TWT) (ms)	Unit Thickness (ft)	Predicted Lithology and Potential of Geohazard Occurrence	Shallow gas	Hole stability issues	
GALAXY-02 Bin 28590 28540 28490 28440 28390 28340 28290 28240 28190 Track 42465 42500 42535 42565 42600 42635 42670 42700 42735 distance 3097 2354 2511 2861 3166 3451 3736 4022 4323 4624 32787 30719 28671 26623 24575 22527 20479 18431 16383 14335 12287 10239 8191 6143 4095 2047 -0 -2048 -4096 -6144 -8192 -10240 -12288 -14336 -16384 -18432 -20480 -22528 -24576 -26624 -28672 -30720 -32768 Depth (ft)		HORIZON1	1	828	264	1087	Poor seismic image between 0-300ft. Analysis done were based on offset wells and geotechnical report. There are no records of shallow gas from the drilling report and geotechnical reports in this interval.			
		HORIZON2	2	1915	610	1085	Sands prone interval with claystones. Observed bright amplitude was traversed by Galaxy-01 offset well and there are no records of shallow gas from the drilling report in this interval. The amplitudes could be lithology related and not due to shallow gas. Some minor near surface faults/channel margins are observed around the planned well.			
		HORIZON3	3	3000	954	1499	Sands prone interval with claystones. Observed bright amplitude was traversed by offset wells and there are no records of shallow gas from the drilling report in this interval. The amplitudes could lithology related and not due to shallow gas. Some minor near surface faults/channel margins are observed around the planned well.			
		HORIZON4	4	4499	1337	1348	Sands prone interval with minimal claystones. No amplitude anomalies were observed along the planned wells trajectories in this unit			
		HORIZON5	5	5847	1581	1348	Sands prone interval with shale interccations. Faulting observed about 100m to the planned well. There are no observed hydrocarbon related amplitude around the planned well trajectory in this unit			
		Geohazards depth of investigation limit								
Seismic Volume: VA_21_PSDM_FULL_TI_RZP_NFLT_3D_GALAXY		Chance of Occurrence	Low	Moderately Low	Moderate	Moderately High	High			
Depth Conversion: Galaxy-Rami Seismic Velocity			<10%	10 - 20%	20 - 30%	30 - 40%	>40%			
CRS: Minna/Nigeria Mid Belt (26392) meter										

Figure 5: Well summary for the Galaxy-02 well.

SUMMARY OF GEOHAZARDSASSESSMENT

Observations from quadrature 3D seismic data and semblance data show that there are no obvious migration paths for hydrocarbons from deep to shallow intervals visible on the seismic data. The observed amplitude anomalous bodies around the planned well trajectory in Units 1 & 2 are likely not due to hydrocarbons as they were traversed by offset wells without any records of shallow gas or other geohazards.

report did not reveal any geohazards issues in the near surface.

Based on the geohazards assessment carried out for this well; the chance of occurrence of encountering shallow gas for all the units as shown in the well summary is rated low. However, the rating at Unit 1 & 2 for other drilling issues is moderately low as the well may be traversing some minor faults.

PRE-DRILL HEALTH CHECK

Well trajectories, logs and generated synthetics seismograms were overlain on a section of the reflectivity and relative impedance section to evaluate Suitability of the planned well trajectory in optimally meeting the target reservoirs.

The Galaxy-02 is expected to meet the C9000 reservoir at about 2040ms (9785ftss). The sand body is correlate-able across Galaxy to Rami fields on both the Reflectivity and Relative Impedance volumes.

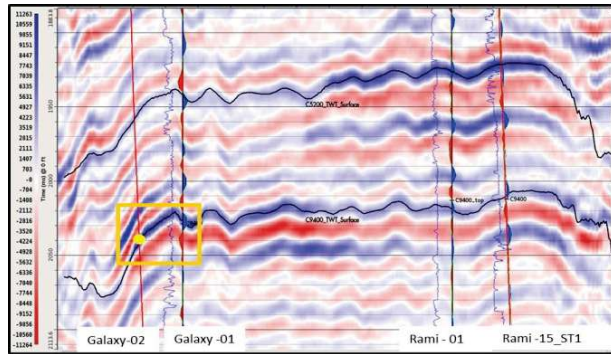


Figure 6: A section of reflectivity Seismic showing Galaxy-02 planned well, Gal-01, Rami-01 & 15_ST1.

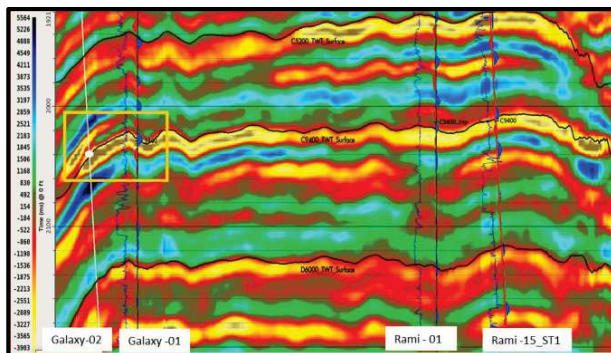


Figure 7: A section of relative impedance seismic showing Galaxy-02 planned well, Gal-01, Rami-01 & 15_ST1.

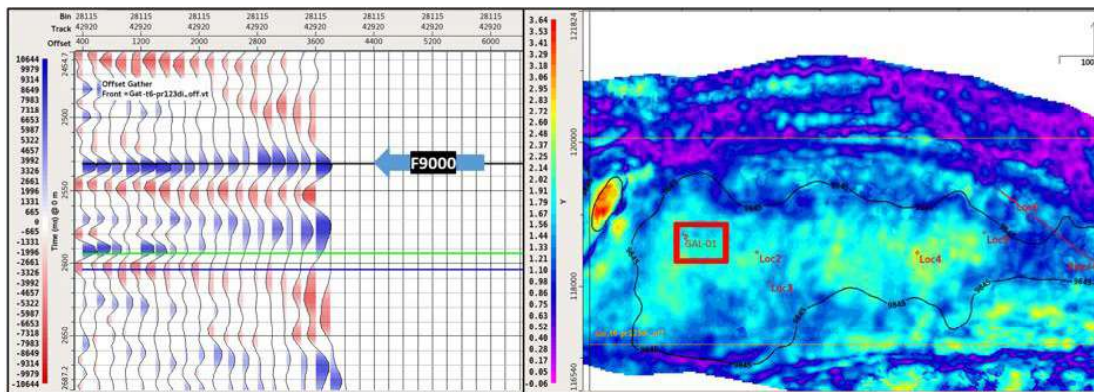


Figure 8: The F9000 at location showed class 2/3 AvO, with amplitudes rising with offsets (good gradient).

AMPLITUDE EXTRACTION AND ANALYSIS

AVO response cannot be easily visualized with respect to changes in rock properties, lithology, porosity, fluid type, and fluid saturation utilizing available techniques modeling and cross plotting the measured AVO response (Castagna and Swan, 1997), and classification of various AVO responses (Rutherford and Williams, 1989) remain an integral part of amplitude analysis.

AvO gradient analysis was carried out on the F9000 based on various locations to further help derisk amplitudes seen at this level.

C94000 AMPLITUDE EXTRACTION AND ANALYSIS

Quantitative Interpretation based Amplitude Versus Depth analysis on seismic data was carried out. A polygon was created, amplitudes extracted and interpreted. A two-hydrocarbon fluid phase was predicted with contacts placed at: GWC at 7515 +/- 15fts.

Quantitative interpretation-based amplitude versus depth analysis on seismic data was carried out. A polygon was created, amplitudes extracted and interpreted. A two-hydrocarbon fluid phase was predicted with contacts were placed at: GOC at 9791fts and OWC at 9854ftss (Figure 10).

These predictions were reviewed by an integrated team concluded that F9000 oil and gas column contact predictions should be incorporated into the volume computations.

Post Drill Results

- Preliminary interpretation of Galaxy-2 indicates a GWC of 7501 ftss logged in the C9400. While predicted was 7515 +/-15ft
- Contact and fluid type is confirmed from pressure data.
- This eliminates the fluid contact uncertainty in the C9400 reservoir.

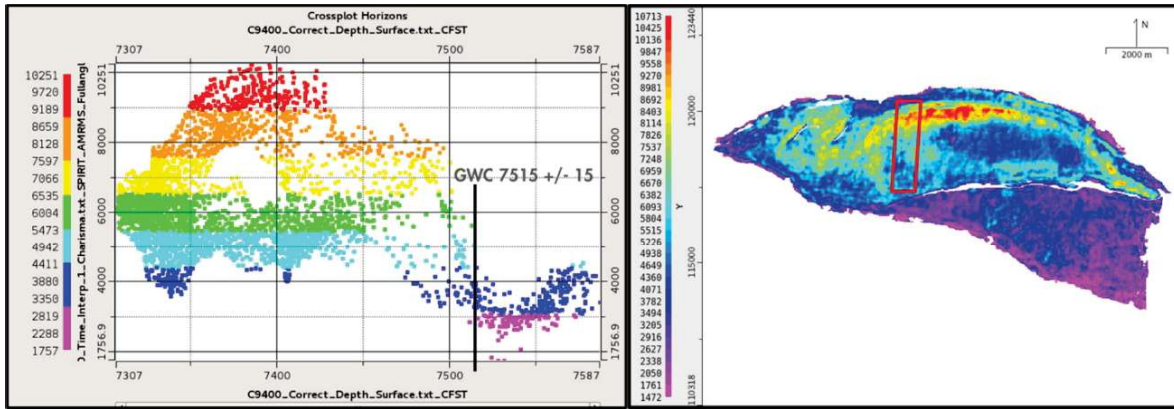


Figure 9: C9400 Amplitude extraction and analysis

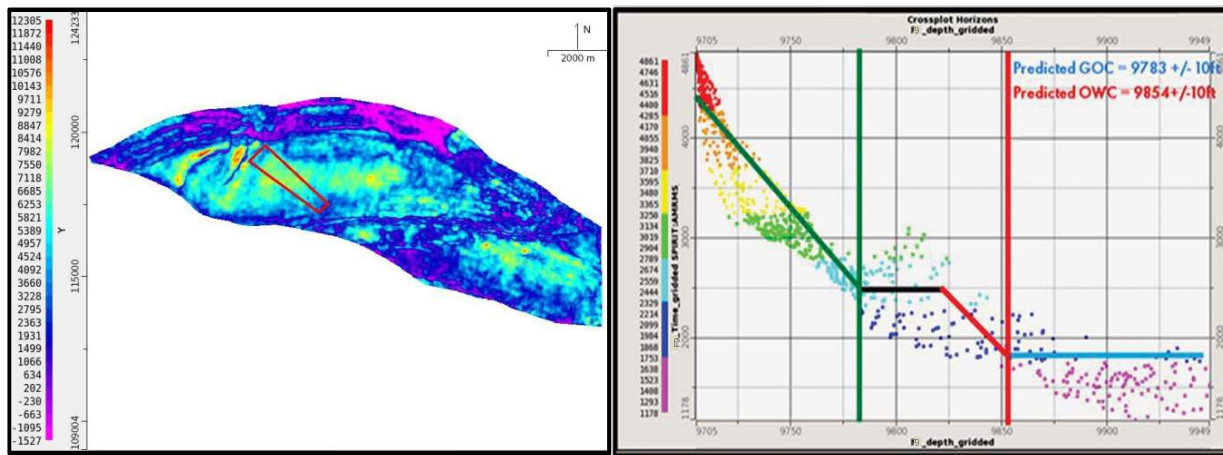


Figure 10: F9000 Amplitude extraction and analysis.

Galaxy-02 Appraisal Outcome (1): C9400 Reservoir

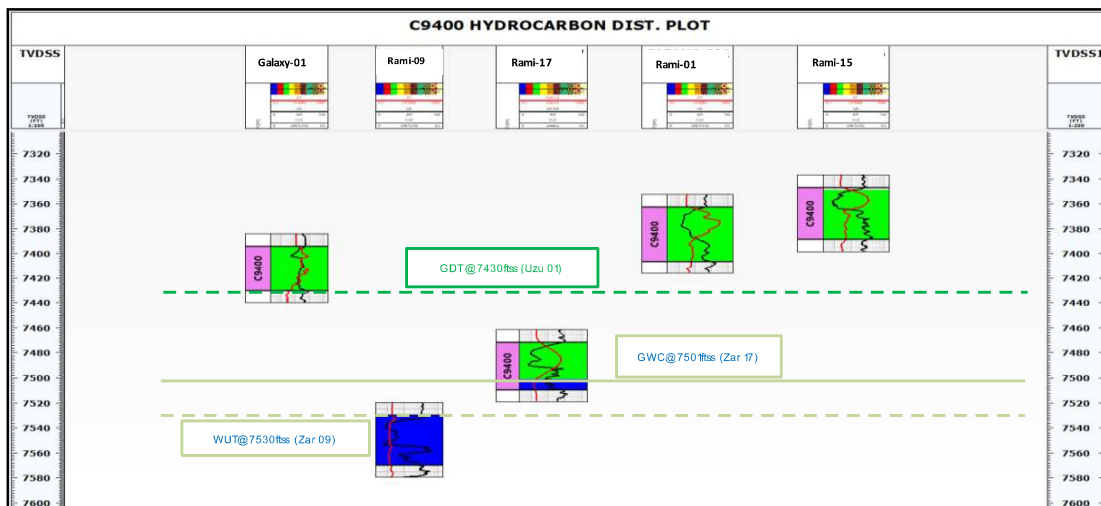


Figure 11a: C9400 hydrocarbon distribution plot.

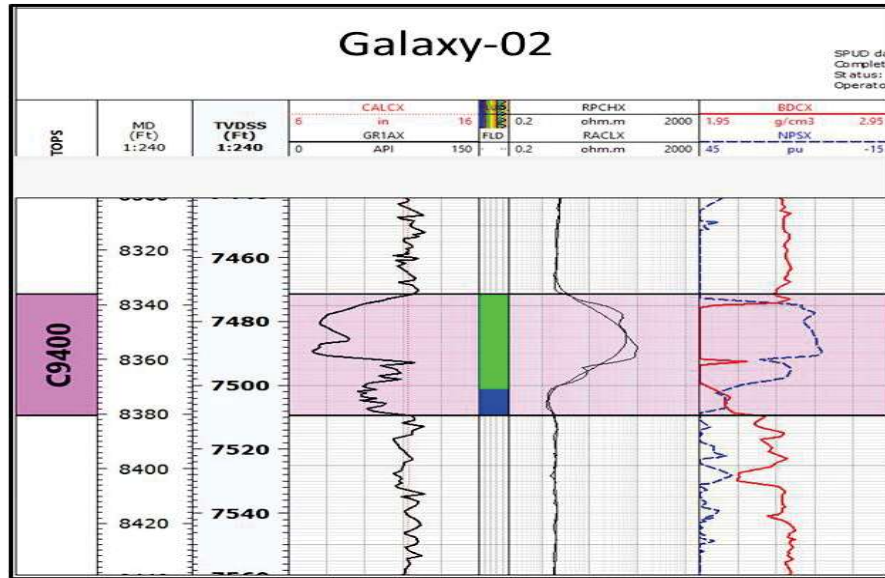


Figure 11b: C9400 hydrocarbon distribution plot.

CONCLUSION AND SUMMARY

At the C9400 reservoir, Gas on Water (GWC) was predicted predrill. The well tested the Galaxy C9400 and found Gas on Water (GWC) as predicted (with no oil rim). The prediction for the F9000 reservoir came spot on with a three-phase fluid: gas on oil on water. Based on the drilling outcome, further engagement will be carried out to secure support for the next well (Galaxy-03). Complete F9000 evaluation and propose an optimal development strategy using Galaxy-02

Galaxy-02 was originally proposed in the Galaxy Field FDP to appraise:

Appraise the F9000 reservoir to assess thickness of oil column and provide basis for an optimized oil development well into the F9000 reservoir.

Galaxy-02 was spudded and appraisal hole completed on the with the outcome as follows:

F9000 reservoir is mainly gas bearing with high CGR in compositional gradient and circa. 10ft oil rim.

C9400 reservoir, one of the largest planned developments with dedicated appraisal leg planned in Galaxy-02 was encountered in a GWC position hence resolving the fluid uncertainty at FDP/FID stage.

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