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Research Article

INTEGRATED STATIC RESERVOIR MODELING: A CASE STUDY OF THE "ALPHA" FIELD

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ABSTRACT

The Alpha Field in which exploration efforts began with the drilling of a wild cat well is located in the Niger Delta Basin of Nigeria. Data available for this study are from biostratigraphy, well logs,checkshot survey and seismic survey of the field.These data types were integrated with the aim of building a full earth model of the field for reservoir simulation and well planning. The goal of the modeling excersise was to stochastically simulate the spatial distribution and connectivity of the sedimentary facies in particular.Hydrocarbon volumes in place and reserves estimates were also made. A geostatistical study was carried out on the Alpha Field using 3 D software. Modelling showed that values obtained from well logs of the lone well are relatively representative of the properties of the entire field. Analysis of the depositional environment using high resolution biostratigraphy and well los signatures shows that the sands were deposited in disributary channels and barsbwhich are known to form prolific reservoirs. From Stock Tank oil initially in place (STOIIP) estimates ranging from 90-75 MMSTB for the three reservoirs, as well as a gas initially in place (GIIP) value of 50 MMSCF, it was concluded that the Alpha Fielf represent an economically viable hydrocarbon accumulation and the drilling of more oil wells for appraisal and accurate delineation of the reservoirs recommended.

INTRODUCTION

The concept of reservoir modeling developed from the need for greater certainty in the exploration and exploitation of hydrocarbon in the oil industry. Apart from the increasing difficulty in locating hydrocarbon accumulations, there is the need to maximize existing discoveries and recover as much as possible from the reservoirs to meet growing global energy needs and profit investors maximally while reducing losses. Since the global oil crises of the eighties, crude oil prices have fluctuated erratically, forcing oil companies to focus their efforts on the accurate estimation of the economics of their projects and reducing risks to as low as is reasonably possible.

A model is a copy of something usually small than the original (Encarta dictionary). Geologic models are built to gain visual insight into the architectural elements within the reservoir. The reservoir within which hydrocarbon occurs, is a rock which is porous (possessing pore spaces) between its grain within which hydrocarbon is sorted) and permeable (possessing connected pore spaces which permit the transmission of fluids from the pores of the rock). Reservoirs are complex structures. This could be attributed to the depths at which they occur, and the pressures to which they are subjected as a result of their depth of burial and overburden. It could also be attributed to their architectural elements or compartments based on their structural and stratigraphic features (Slatt R. M., 2006). Architectural elements and components of a reservoir are the main factors that control the volume of hydrocarbon that can be stored in it as well as its behavior during production slat R. M. (2006) said, defining architectural elements of the reservoir on the basis of:

A detailed study of a reservoir would involve an in-depth analysis of these aspects of its structure. The process of defining a reservoir in this manner is described as reservoir characterization.

Objectives of the Study: The objectives of the study are: To produce an earth model of the 'Alpha' field

METHODOLOGY

(A) DATA ACQUISITION:

The 'AIpha' field project occurs in the Niger Delta basin of Nigeria, where petroleum production has been in progress since 1956 when the first discovery was made at Oloibiri, Bayelsa state. Thus, regional geologic data is available and also data from offset wells, as well as structure tour maps of the study area.

The following data requirements were identified for this study:

(a) 3D seismic data in SegY format: 3D seismic data of the field was acquired and the data obtained from it processed.

(b) Well data (deviation data, header info and reservoir tops & bases): well data simply defines information on the wells that enables us to position them on the earth's surface in terms of coordinates.

- Gamma Ray Log, Resistivity Log , Density Log, Bulk Compensated Sonic Log , Biostratigraphic zonation data.

(B) DATA ANALYSIS:

Analysis of data for this project began with the loading of data into the seismic to simulation software. First data loaded was the well data. Well header, Well logs, Well deviation.

(a) Wireline Log Analysis: Wireline logs are records of reservoir properties obtained with the use of special logging tools, in which drilling of specific depths of the hole has been completed. Wireline logging tools are run in after drill strings have been pulled out of the hole. A graphic representation of the variations in parameter as a function of depth or time called a log is produced. Wire line logs provide measurements of both the natural and induced parameters of reservoirs.

(b) Stratigraphic Modeling: Stratigraphy is the study of the temporal and spatial relationship between bodies of sedimentary rocks (Gluyas J., 2004). Stratigraphic analyses are carried out with the aim of determining the temporal sequence of sedimentary rocks in the area of investigation. The process of stratigraphic analyses in frontier exploration is in the establishment of the disposition and age of the main subdivisions of basin fill. With this knowledge the geoscientist identifies most likely locations of source, reservoir and seal rocks. From these he can develop a geochemical and structural model with which he determines source rock maturation and reservoir rock quality.

A successful paleoenvironmental interpretation requires an integration of multiple data sets — s, seismic, outcrop and cores. This integration is the best approach to the stratigraphic modeling of the subsurface geology. The following are the five methods for stratigraphic analysis:

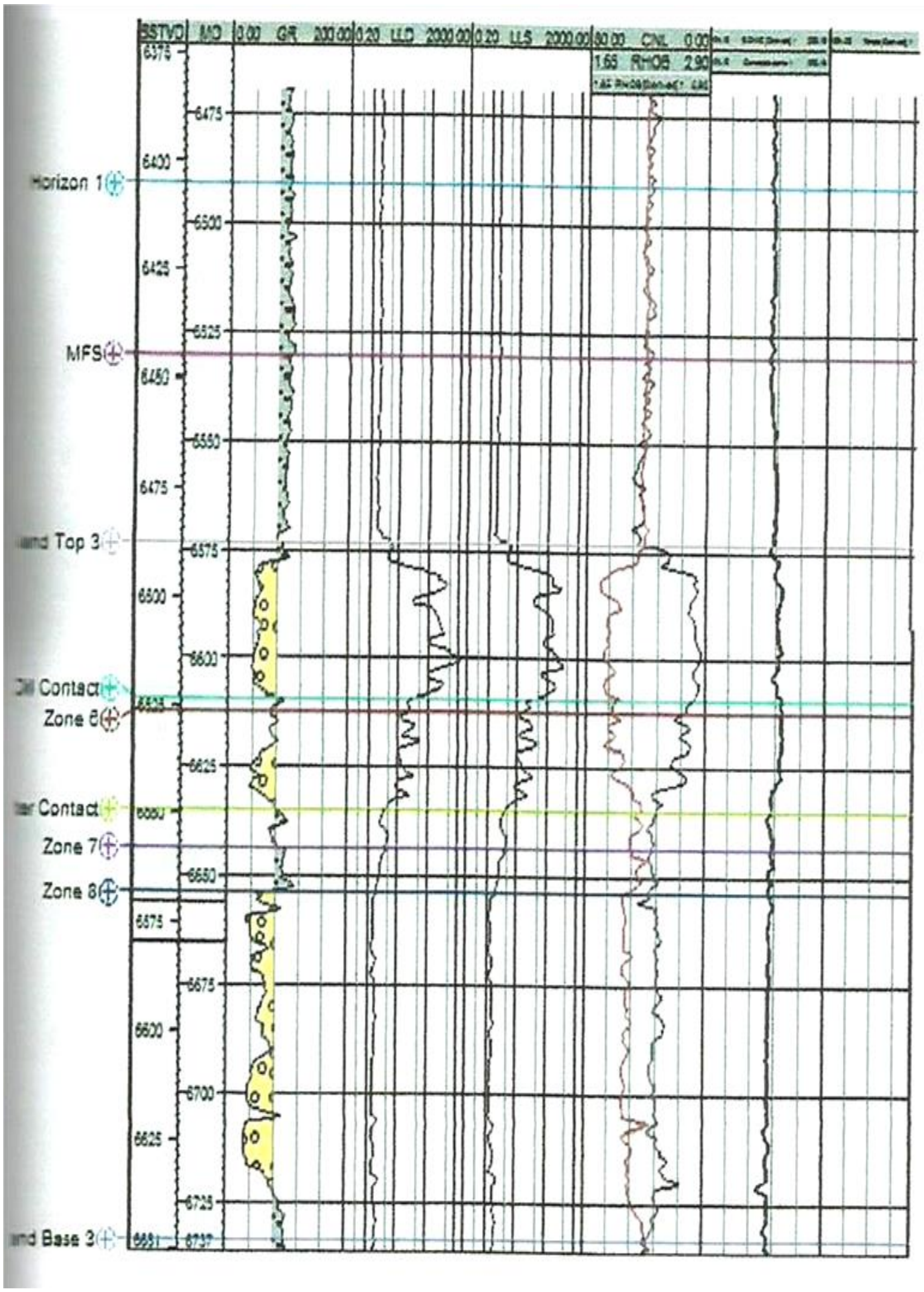

Figure 1: Fluid contact in Sand

PRESENTATION OF RESULT

Reservoir Characterization:

Several viable reservoirs have been identified from the well log, but this study concentrates on the 3 most attractive in terms of thickness of sand body and apparent fluid content.

	Reservoir one	Reservoir two	Reservoir three
Net to-Gross	77.12%	46.78%	70.64%
Effective porosity	33%	32%	32%
Permeability	3960.14md	3957.25md	3784.33md
Water saturation	15%	16%	16%
Hydrocarbon saturation	85%	84%	84%

Table 1: This results of this estimation are also available in Table 1

Property	Minimum	Maximum	Mean
Net to-Gross	0	100	72.886
Effective porosity	19%	48%	29%
Permeability	1666	7285	5619
Water saturation	11%	25%	14%

Table 2: Summary of petrophysical properties for the three reservoirs

Net-go-Gross						
Name	**Type**	**Min**	**Max**	**Mean**	**Std**	**Variance**
Property	Continuous	0	100	72.886	419663	1761.168
Well logs	Continuous	0	100	39.5416	48.899	2391.154

Table 3: Property modeling results

Property	Continuous	0.1072	0.2496	0.1844	0.0319	0.001
Well logs	Continuous	0.1026	0.2997	0.1842	0.0383	0.0015

Table 4: Water saturation

Property	Continuous	1666	7285	3018	1089	1185132
Well logs	Continuous	1192	7926	3047	1381	1906768

Table 5: Permeability

Property	Continuous	0.19	0.48	03	0.07	0
Well logs	Continuous	0.15	0.51	0.28	0.08	0.01

Table 6: Effective porosity

	Reservoir 1	**Reservoir 2**	**Reservoir 3**
S.T.O.I.I.P (MMSTB)	80	75	90
F.G.I.I.P (MMSCF)	N/A	N/A	50
Recoverable oil (MMSTB)	24	22.5	27
Recoverable Gas (MMSTB)	N/A	N/A	25

Table 7: Property modeling Vis-à-vis well log results

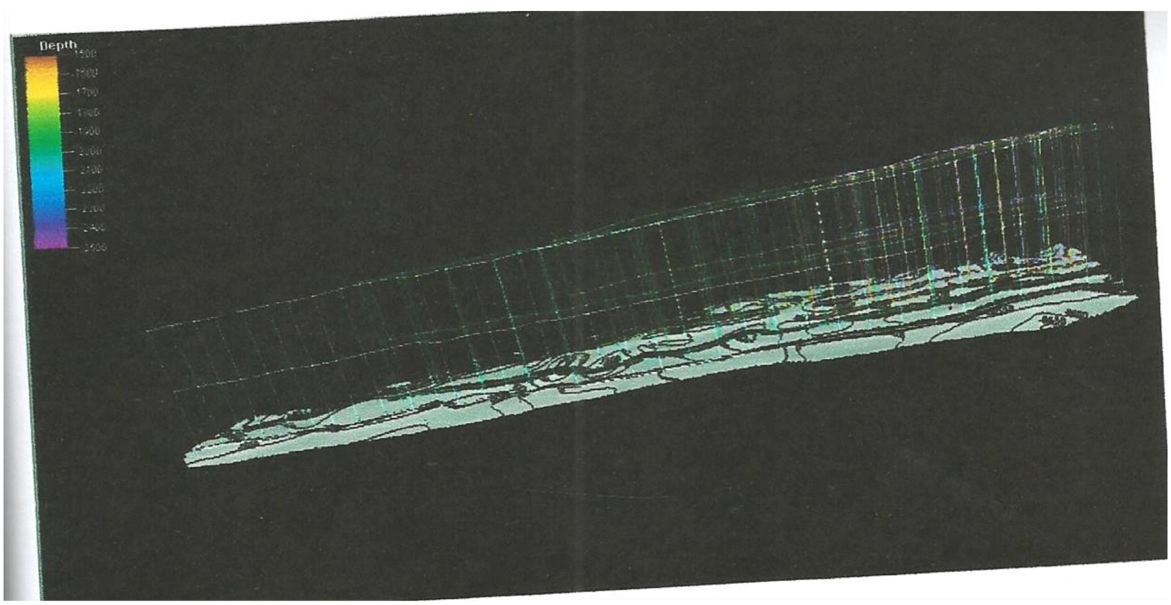

Figure 2: Fault modeling

S/N	Reservoir	Depositional environment
1	Sand 1	Distributary mouth-bar/bar sand/regressive barrier island
2	Sand 2	Channel fills
3	Sand 3	Distributary mouth-bar/channel fills

Table 8: Depositional environment

S/N	Reservoir	Total recoverable Oil (MMSTB)	Total recoverable Gas (MMSCB)	Total value of Recoverable Oil at $97/bbi	Total value of Recoverable Gas at $4.1MMBtu
1	Sand 1	24	N/A	$2,328,000,00.00	N/A
2	Sand 2	22.5	N/A	$2,182,500,00.00	N/A
3	Sand 3	27	25	$2,619,000,000.00	$100,000,000.00
4.	Total	73.5		$7,129,500,000.00	$100,000,000.00

Table 9: Volumetric estimates and Recoverable hydrocarbon volumes

RESERVOIR 1:

Biostratigraphy: From biostratigraphy, data was provided for the depths at which the fossils found in each sample were deposited.

- Based on this biostratigraphy data, the reservoir's paleobathymetry is placed between the Beach and the Middle Neritic.
- The reservoir falls within Paly zones P860/P870 and Foram zones F9700/F9800. The shale markers for this region are the Bolivina 46 and Haplophragmoides sp. Age of the sediments ranges from late Miocene (Messinian) to early Pliocene (Zanclian).

Sequence Stratigraphy: This reservoir shows a general fining upwards trend. This is indicated by sand beds becoming progressively thinner upwards and shale interbeds increasing in thickness, indicating a gradual in sea level. This stacking pattern is retrogradational and indicative of a Transgressive system Tract which forms during sea level rise when accommodation space exceeds the rate of sediment deposition.

RESERVOIR 2:

Biostratigraphy:

- Based on the biostratigraphy data, the reservoir's paleobathymetry is placed between the Beach and the Middle Neritic.

- The reservoir also falls within Paly zones P860/P870 and Foram zones F9800/F970C. The shale markers for this region are the Bolivina 46 and *Haplophragmoides* sp.
- Age of the sediments ranges from late Miocene (Messinian) to early Pliocene (Zanclian).

Sequence Stratigraphy The section also shows a general fining upwards trend, again indicative of a rise in relative sea level. Towards the top of the reservoir, the section shows shale bed thicknesses increasing while sand bed thicknesses decrease (Plate 8). The section is overlain by a Maximum Flooding Surface and underlain by a Sequence Boundary. Another flooding surface occurs above the Sequence Boundary. The stacking pattern is retrogradational and indicative of a Transgressive Systems Tract.

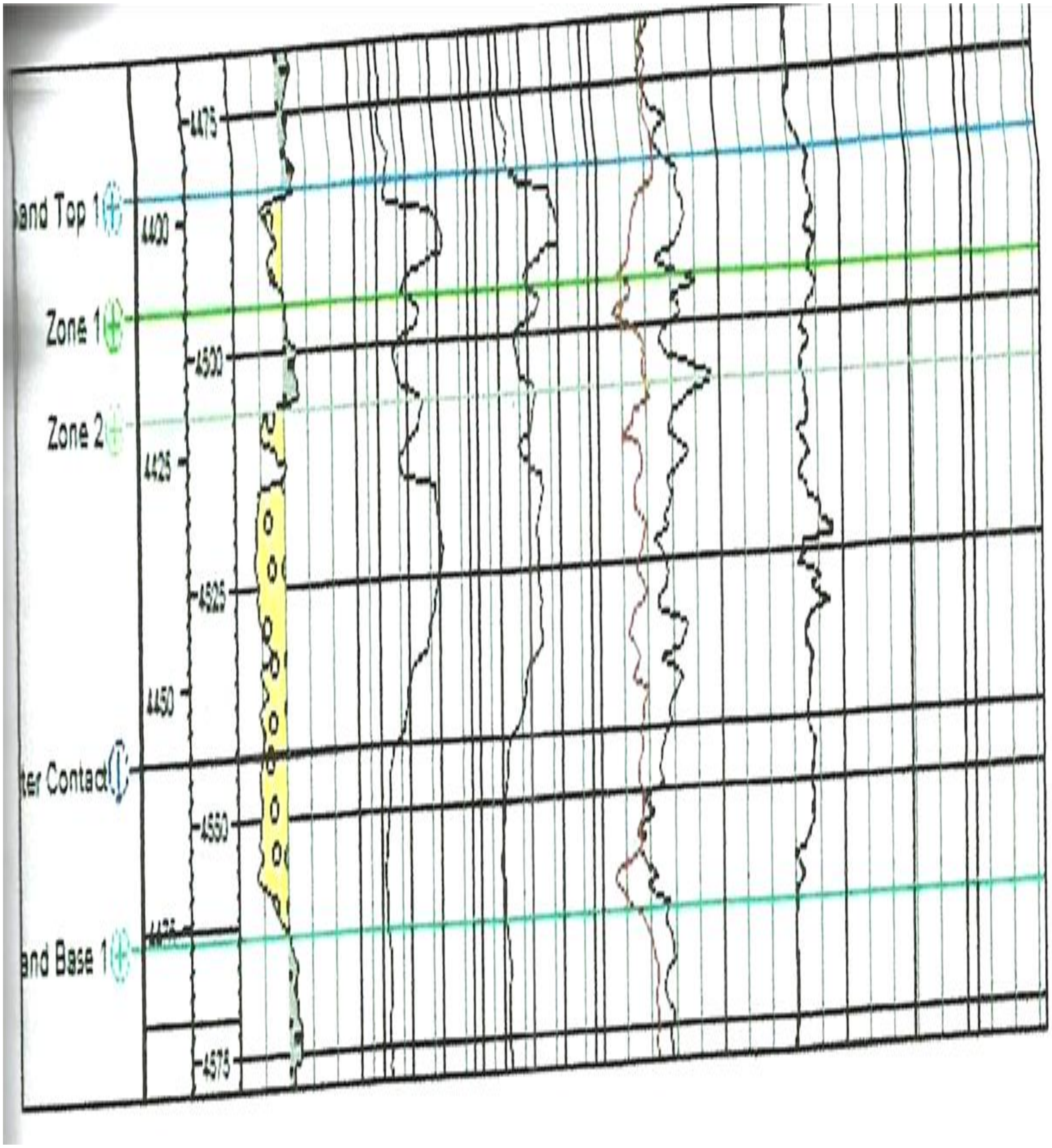

Figure 2: Well section of sand two

Depositional Environment: This was inferred from the log signature since cores are not available for this study. The log signature is serrated and blocky. From this it can be designated as a channel fill.

RESERVOIR 3

Biostratigraphy: Based on this biostratigraphy data, the reservoir's paleobathymetry is placed between the Outer Neritic-Bathyal and the Beach

The reservoir falls within Palyn zones P800 and Foram zones F9800/F9700. The shale markers for this region are the Bolivina 46 and Haplophragmoides sp. Age of the sediments ranges from late Miocene (Messinian) to early Pliocene.

Sequence Stratigraphy: The stacking patterns observed in this reservoir from the base upwards, show a general fining upwards trend that indicates a rise in sea level and return to deeper marine conditions. The stacking pattern is retrogradational and indicative of a Transgressive Systems Tract. This is evident in the increasing thickness of the shale beds.

Depositional Environment: From the log signatures, and stacking pattern, the reservoir shows a blocky signature on gamma ray logs. This is indicative of channel fills which could either be from tidal channels, submarine channels, or tidal sand ridges. The coarsening upward sequence that is capped by a fining upward sequence resembles the stacking patterns produced by a distributary channel incised into a delta front bar.

DISCUSSION AND CONCLUSION

The 'Alpha' field is a field which holds promise of reservoirs which will be prolific hydrocarbon producers.

Property modeling: is carried out with the aim of interpolating/extrapolating properties for the parts of the field that are unsampled such that the model realistically preserves the reservoir heterogeneity and matches the well data. From the static model produced, the results of the property modeling are presented for each reservoir in Table 1-9.

Quality Control: Having obtained values from both the well logs and the model of the entire field, a comparison of the values obtained was carried out as a form of quality control. The relative viability of the field can also be inferred from these results. It is evident that variation in petrophysical properties is not much across the areal extent of the field. The values obtained from the well log, represent the properties of the entire 'Alpha' field.

Volumetric Analysis: The calculation of the Hydrocarbon initially in Place shows that the 'Alpha' field is an economically viable field.

Reserves Estimation: The reserves were estimated by first calculating the Hydrocarbon Initially In Place (HCUP) based on the static model. The value for the recoverable hydrocarbon was calculated using the formula: Hydrocarbon in place x Recovery Factor Reserves (16) Recovery factor was pegged at 30% for oil and 50% for gas for the purpose of this calculation

Reservoir Quality: Based on the results obtained from both the well, the 'Alpha' field consists of lithofacies with high reservoir quality. The reservoir quality is optimistic. Since permeability and porosity are high, the process of hydrocarbon recovery is expected to require minimal cost.

Depositional Environment: For the three sands the depositional environment has been inferred from their well log signatures in the absence of core data. This is not absolute but can serve as a guide. The summary of these results are given in Table 8. These environments (distributary-channel and distributary mouth-bar sandstones), according to Slatt R.M. (2006), are the productive deltaic facies.

Hydrocarbon Volumes in Place and Reserves Estimates: The results of the calculation of volumes in place and reserves estimation are available in Table 9. From the figures shown there, it is clear that the field holds promise in terms of volume of hydrocarbon in place. An attempt to predict expected gross income from the reservoir was made. With an expected gross income of over seven billion dollars for oil and over a hundred million from gas, the 'Alpha' field represents a valuable field with accumulations of hydrocarbon that would be considered to be of commercial quantity.

Reservoir Continuity/Reservoir Architecture: The field is anticlinal in structure. This is obvious from the analysis of the seismic sections. Anticlines form very good traps as a result of the buoyancy of hydrocarbon relative to water when present in the sub-surface. The hydrocarbon migrates towards the crest of the anticline. The presence of shale layers overlying the reservoir sands suggests that sufficient seals/cap rocks exist.

Faults: a large number of faults were observed in this field from the seismic section (figure 2). This presents multi-dimensional implications. If the faults are sealing then they could act as reliable traps for hydrocarbon. However, they could also create compartmentalized reservoirs which are difficult and expensive to access during drilling. Faults also create challenges during drilling as a result of the high pressure associated with their presence. The fault planes could also serve as migration pathways for hydrocarbon.

The apparently continuous shale beds overlying the reservoirs, visible in seismic, might be advantageous If faulting leads to the juxtaposition of permeable beds (sand) against impermeable (shale). Otherwise, the hydrocarbon could easily be lost if the faults are not sealing. These shale beds may also lead to further compartmentalization of the reservoirs if they occur as baffles or as intercalations or as heteroliths. Horizontal wells may be needed to exploit these accumulations if this is the case.

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