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SEISMIC ATTRIBUTES AND WELL LOG ANALYSIS OF " HABI" FIELD, NIGER DELTA, NIGERIA.

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Abstract:

The quest for optimum method of hydrocarbon production has been an issue which many oil and gas companies are interested in. Alvarado and Manrique (2010) have stated that the effort of industries to increase production by the use of large capital investments to enhance oil recovery sometimes prove futile. One of the major ways of resolving this issue is through hydrocarbon reservoir properties modeling. This study has been carefully and thoroughly carried out in aspects focusing mainly on reservoir modeling of "HABI" field, Niger Delta using an integrated Seismic approach and well log analysis.

(I) INTRODUCTION

In exploration geophysics, subsurface structures and properties of interest include: the reservoir architecture, porosity, fluid Saturation, lithology and permeability. In the procedure for subsurface property modeling, it is usual that geophysicists first provide spatial distribution of seismic attributes from observed seismic record.

Seismic attributes can be used for both quantitative and qualitative purposes. Quantitative uses include prediction of physical properties such as porosity or lithology (Leiphart and Hart, 2001; Sagan and Hart, 2006). Qualitative uses include detection of stratigraphic and structural features. Then from the derived seismic attributes, we can evaluate and estimate subsurface properties of interest using physical theories, statistical methods and geological model, along with well-log data.

(II) OBJECTIVES OF THE STUDY

The objectives of this study include, but not limited to the: Determination of the seismic attributes of the HABI Field ,Identification and definition of potential reservoirs and key hydrocarbon horizons useful for field development

STUDY AREA

The "HABI" oil and gas field is situated within the western margin of the Niger-Delta. The Niger-Delta is situated in the Gulf of Guinea

GEOLOGY OF THE NIGER DELTA BASIN

The Stratigraphy of the Niger Delta The stratigraphy of the Niger Delta clastic wedge has been documented during oil exploration and production; most stratigraphic schemes remain proprietary to the major oil companies operating concessions in the Niger Delta basin. The composite Tertiary sequence of the Niger Delta consists, in ascending order, of the Akata, Agbada and Benin Formation. They are composed ofestimated 28,000ft (8,535m) of section at the approximate depocenter in the central part of the delta (Avbovbo, 1978).

There is decrease in age basin ward, reflecting the overall regression of depositional environments within the Niger Delta clastic wedge. Stratigraphic equivalent units to these three formations are exposed in eastern Nigeria (Figs. 6a, 6b and Table 1). The formations reflect a gross coarsening-upward progradationalclastic wedge (Short and Stauble, 1967), deposited in marine, deltaic, and fluvial environments (Weber and Daukoru, 1975; Weber, 1986).

The stratigraphic distribution of these rocks is poorly understood because of the lack of drilling information and outcrops (Avbovbo, 1978 The Akata Formation represents the prodeltafacies of Eastward prograding Tertiary delta (deposited in the front of the advancing delta). It occurs at the base of the delta , and is of marine origin. A type section ofthe Akata Formation was defined in Akata-1 well, 80km east of Port Harcourt (Short and Stauble, 1967). A total depth of 11,121 feet (3,389.68m) was reached in the Akata-1 well without encountering the base of this formation. The top of the formation is defined by the deepest occurrence of deltaic sandstone beds (7,180ft in Akata well). The formation is estimated to be 18,000ft (about 6000m) thick in the central part of the clastic wedge (Doust and Omatsola, 1989)

(III) METHODOLOGY (MATERIALS AND METHOD)

i. Four composite well Logs (ASCII): these includes Gamma ray (GR), resistivity (RES) and density (RHOB), Seismic volume ,Check-shot survey data (ASCII), which was used to generate the Time-Depth conversion curve.

SEISMIC DATA IMPORT

The seismic volume is imported into a user defined folder in SEG-Y format. It is cropped and then realized. From the crop-realized volume, inline, crossline are inserted. After loading into memory, time slice is also inserted.

After the seismic volume is imported into the software, cropping and realization is carried out, so as to reduce the processing time due to the data and to chop away part that is not needed for work, leaving behind only the area of interest.

A 3D window is opened and a new interpretation window to view and also start fault mapping. The faults were mapped on the crosslines and the continuity viewed on the inlines.

SYNTHETIC SEISMOGRAM

The fundamental input in the synthetic process is a sonic log, a density log and check shot; and acoustic impedance log is produced, which was convolved with a wavelet to give the synthetic seismogram.

Synthetic seismogram showing a good fit enables us to confidently identify seismic reflections which are reservoir or falls in our zone of interest. 3D Seeded auto tracking was used in picking horizon for this research work.

GENERATION OF TIME AND DEPTH STRUCTURE MAP

These grids were transformed into points of value, and then the computer contours it to best fit with consistent contour spacing specified. Since the horizons are in time domain, we can only generate a time structure map, in order to generate depth structure map, the horizons in time have to be transformed to depth domain using a velocity model. The process is carried out using the check shot data for each of the wells.

SEISMIC ATTRIBUTES

The seismic data were processed using Landmark's *SeisWorks* from which the X-line and In-line sections were produced. Complex trace method was adopted in the analysis of the 3D-seismic sections, and this was done manually. Various seismic reflection events which image the sedimentary facies and structures were identified and discriminated on basis of reflection continuity, reflection amplitude, geometric relationships between reflectors and the overall form. Reflection types were further distinguished by variations in reflection strength and continuity, geometric relations between overlying and underlying layers and gross form or shape (e.g. irregular, folded or faulted). Table shows the interpretation scheme used.

Table 1: Summary of seismic facies attributes characterized by parallel and divergent reflection configurations. (*Modified from Veil et al, 1977).*

Properties of seismic facies attributes	**Depositional environment / setting: Delta front / delta plain**
Lithofacies and composition	Shallow marine delta front sandstone-shale grading upward into sub-aerial delta plain shale, coal and sandstone channels
Geometry and structure	Sheet-like wedge shaped or tabular on shelf; prismatic to lenticular, basinward of adjacent shelf edge with growth faults and roll-over anticlines; relatively stable, uniform subsidence of shelf
Lateral relationships	Landward gradation into alluvial systems and basinward into prodelta / slope facies
Nature of upper / lower boundaries	Normally concordant at top but may rarely onlap or baselap; upper surface may be eroded by submarine canyons; basal surface generally toplap by prodelta slope and clinoforms on shelf.
Amplitude	High in delta front and marine transgressive facies; low-moderate in most delta plains and prodelta where there is good lateral continuity with delta front.
Continuity	High in delta front and marine transgressive facies; low-moderate in remainder of delta plain and prodelta where in continuity with delta front
Frequency	Variable; broader in delta front; marine transgressive facies; moderately low in other delta plain and prodelta where in continuity with delta front.

(IV) RESULTS AND DISCUSSION

Among other objectives, the 3-D structural interpretation of the seismic data was carried out to give an overview of the reservoir-trapping configuration in "HABI" field. As one of the major objective of the work, the depth structure maps were mapped for closures or structures that possess efficient trapping system suitable for hydrocarbon accumulation, development and production. These are necessary for projecting the horizons into areas where well control may not exist. The results generated from this research work, were presented in the forms:

Seismic Section of the mapped faults and horizons., Seismic structural Maps (Time and Depth)., Seismic Attribute map, Seismic-to-well tie.,

FAULT MODEL

Fault modelling is the process of generating a faulted 3D grid and inserting the horizons, zones and layers into it, as seen the faults penetrated the two mapped horizons. The process takes 3 steps:

Fault Modelling - The purpose of this step was to define the shape of each of the faults that should be modeled. This was done by generating "Key Pillars".

Pillar Gridding - This was done in the Pillar Gridding process. The result of the pillar gridding process is a "Skeleton grid", defined by all the faults and all the pillars. This was not associated with any other input than the faults.

Layering - the final step was to insert the horizons into the faulted 3D grid. At this point, the 3D grid was attached to depth by associating it with inputs such as time or depth maps and/or well tops. After the horizons were inserted, the final step was to make the fine-scale layering, suitable for property modelling.

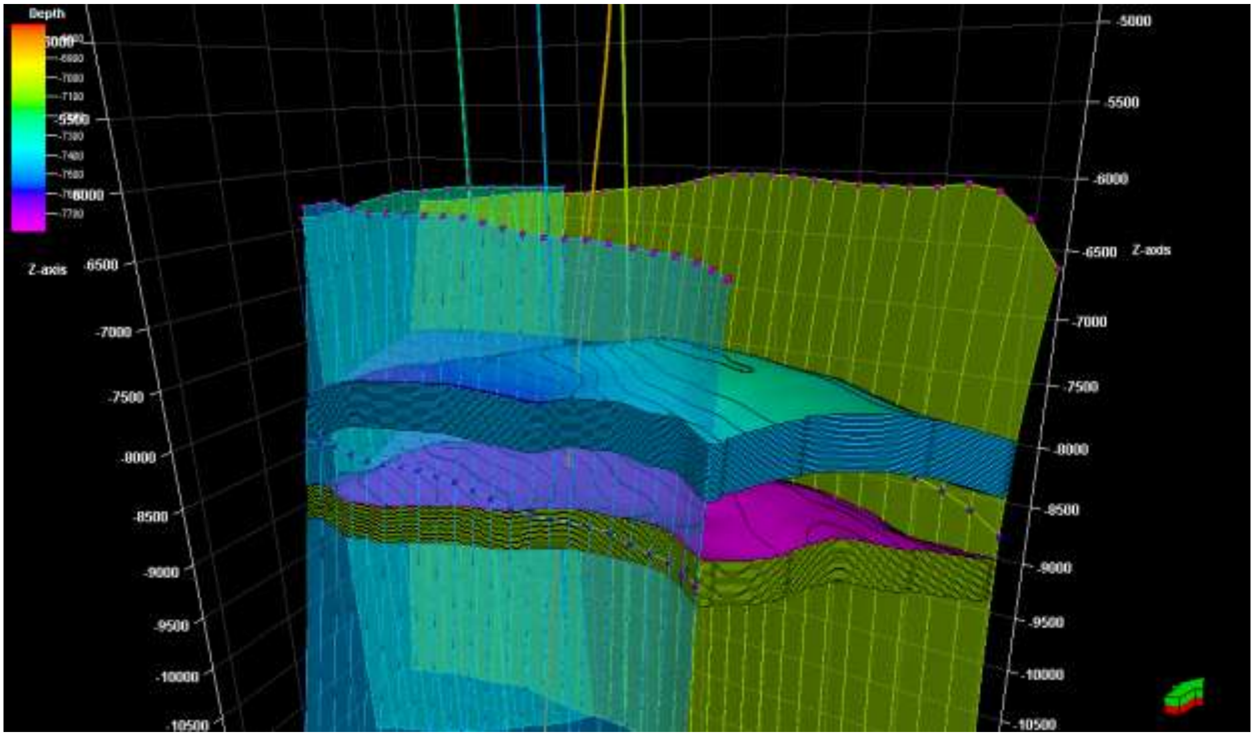

Figure:1 Reservoir Architecture showing Fault Model and reservoirs.

PILLAR GRIDDING

The generation of the structural model was done in a process called Pillar Gridding. Pillar Gridding is the process of making the 'Skeleton Framework'. The Skeleton is a grid consisting of a top, a mid and Base skeleton grid, each attached to the top, the Mid and the Base points of the Key Pillars. The relation between the Fault Modeling process and the Pillar Gridding is an iterative process with which the user should spend some time in order to attain a grid of good quality and high cell orthogonality. The result from the Pillar Gridding is a set of pillars both along the faults but also in between faults. The grid has no layers, only a set of pillars with user given X and Y increments between them (like a pincushion). The layering was introduced when making horizons and zones. Before starting Pillar Gridding, a series of checks was performed to ensure that the fault modeling process is complete.. After the Boundary has been defined and the 2D cell geometry tuned to the point of acceptability (trends and directions was applied to help tune the 2D cell geometry), the 3D grid was constructed. The result of this construction is the Skeleton, which is a series of pillars, one for the corner of each cell. Top, middle and base skeleton grids are used to view these pillars easily in the X-Y dimensions. Under the Pillar

Geometry tab in the Pillar Gridding process window, 'Curved' for the 'Non-Faulted Pillars' was toggled off..

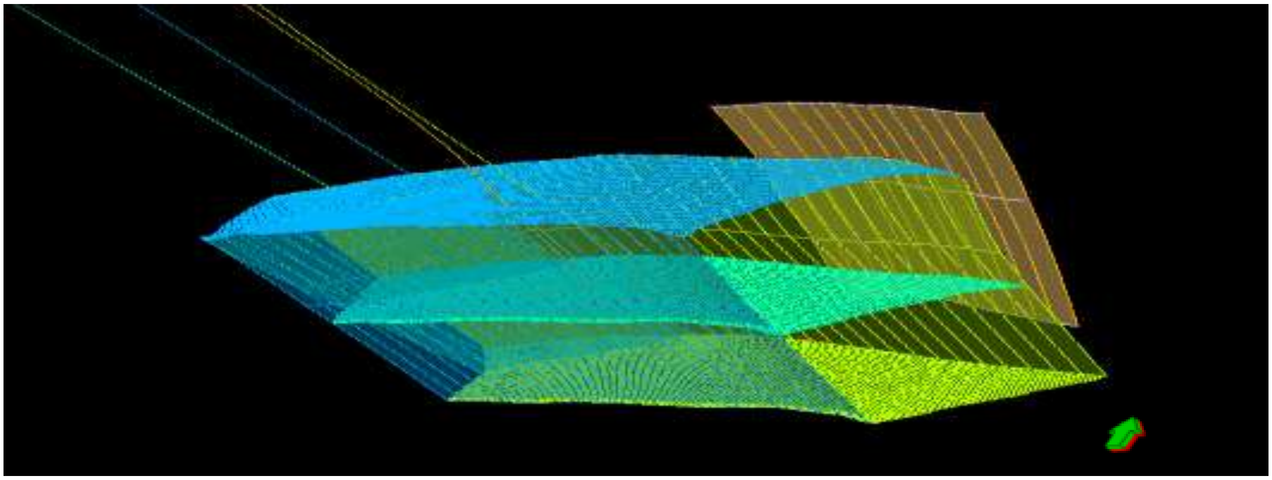

Figure 2: Pillar Gridding

ESTIMATION OF VOLUMETRIC HYDROCARBON RESERVE

The fluid contacts were delineated for the reservoirs from the neutron-density cross-plot across the reservoir from the OAK-7 well. The hydrocarbon-water contact (HWC) was at the depth of 7509ft (TVDSS).

Therefore, the reserve for hydrocarbon was estimated using the relation

$$N_f = \frac{7758 \times A \times h \times \phi \times S_h \times Rf}{B_{oil}} \qquad \text{(Asquith, 1994)}$$

Where, N_f = volumetric recoverable oil reserve in stock tank barrel (STB)

7758 = barrels per area foot A = drainage area in acres

h = reservoir thickness in ft ϕ = porosity in decimal

S_H = hydrocarbon saturation in decimal R_f = recovery factor = 0.42 (for oil)

B_{oil} =oil formation volume factor $\qquad B_{oil} = 1.05 + 0.5 \times \frac{GOR}{100}$

GOR (gas-oil ratio) = $\frac{Gas\ in\ cubic\ feet}{oil\ in\ barrels}$

N_f = 136,000,000 STB (stock tank barrels).

SEISMIC ATTRIBUTES MODEL FREQUENCY ATTRIBUTE MODEL

Technically, each individual frequency or band of frequencies could be considered an attribute. The seismic data was filtered at various frequency ranges in order to show certain geological patterns that may not be obvious in the other frequency bands. There is an inverse relationship between the thickness of a rock layer and the corresponding peak frequency of its seismic reflection. That is, thinner rock layers are much more apparent at higher frequencies and thicker rock layers are much more apparent at lower frequencies. Frequency attribute has also been widely used as a direct hydrocarbon indicator based on the time-frequency seismic character of the hydrocarbon sand (Adepoju et al. 2013).

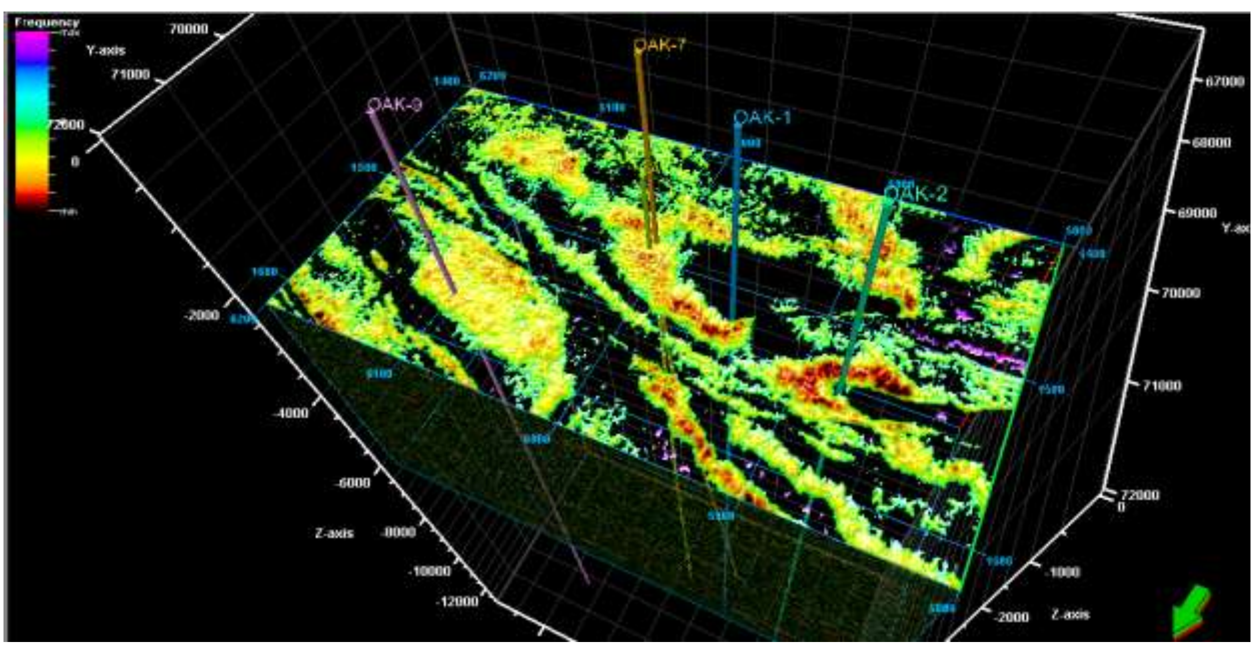

Figure 3: Frequency Attribute Model showing Sand body in Reservoir A and B.

"HABI" Field is a prolific field of the Niger Delta which is a deltaic region with favorable conditions for the generation, accumulation and entrapment of hydrocarbon, possessing reservoirs that fit these conditions. Hydrocarbon accumulations are present in all the major fault blocks. The field consists predominantly of hydrocarbon bearing reservoirs. Generally the accumulations are trapped in a combination of dip and footwall closures. In this light, the integration of well log correlation and 3-D seismic structural interpretation delineated a geologic structure that favors accumulation of hydrocarbon within the field of study.

Information extracted from the 3-D seismic data volume and well logs resulted in more understanding of the structure, stratigraphy and hydrocarbon potentials of the " HABI" field, Niger

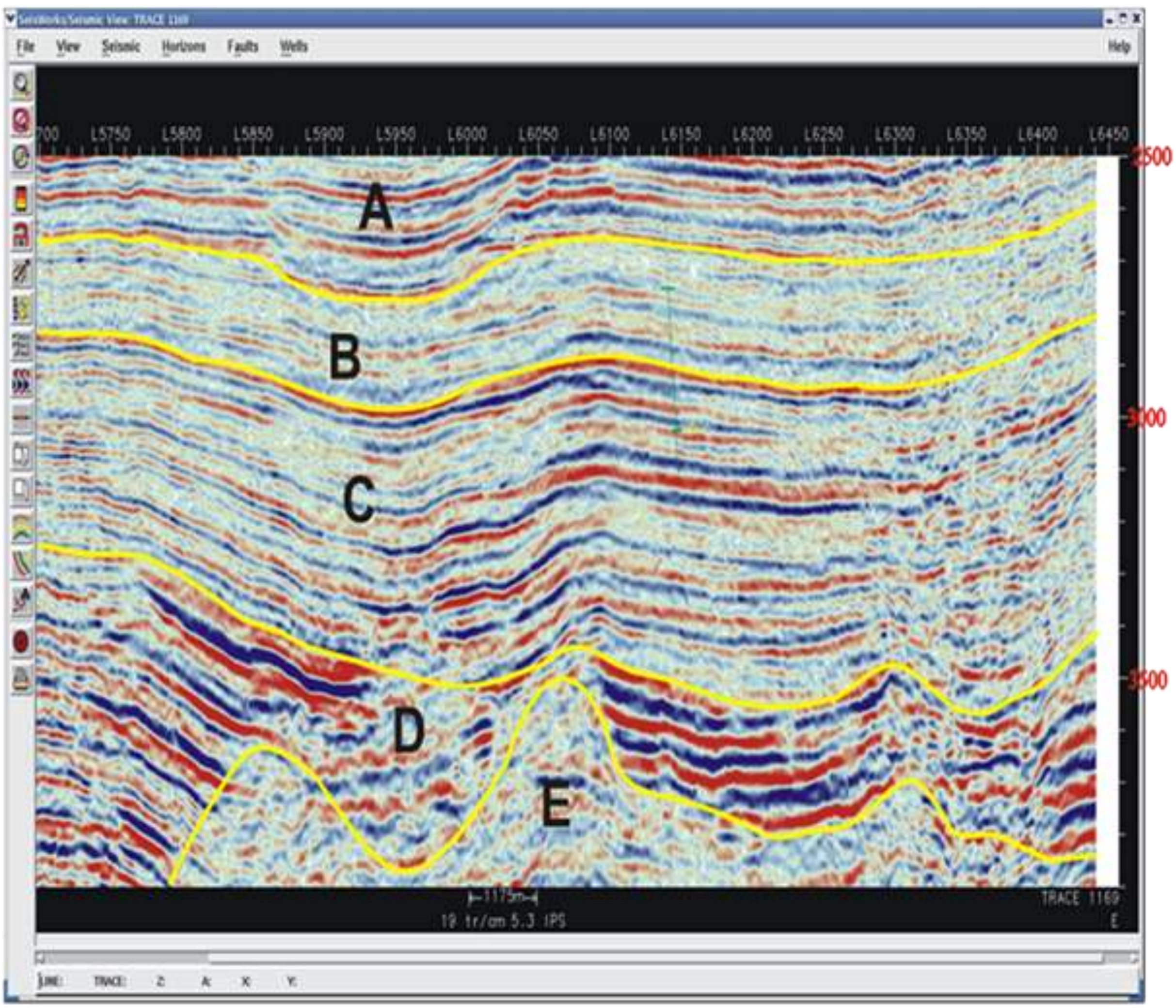

Figure 4 : Seismic reflection attributes in terms of seismic packages

Delta. The result suggests more development opportunities in the field such as the North-eastern flank of the reservoir. However the major uncertainty associated with the " HABI" field 3D interpretation is the poor resolution of the seismic data at great depth.

Table 2 : Transit time of lithologic units across HABI Field

Litho Units	WELL A				Well B			
	Depth (ft)	Δt (µs/ft)		Δt (µs/m)	Depth (ft)	Δt (µs/ft)		Δt (µs/m)
		Range	Average	Average		Range	Average	Average
Shale 1	-	140 - 105	116.17	381.14	11250 - 11400	120 - 100	108.43	355.74
Sand H	11325 - 11885	150 -110	122.00	400.26	11400 - 11962	158 - 115	124.50	408.46
Shale 2	11885 - 11975	110 -15	62.50	205.05	11962 - 12025	120 - 90	105.00	344.49
Sand I	11975 - 12300	120 - 90	105.15	344.98	12025 - 12375	145 -90	125.54	411.88
Shale 3	12300 - 12525	110 - 50	72.50	237.86	12375 - 12575	180 - 95	121.33	398.06
Sand J	12525 - 12750	125 - 90	112.78	370.01	12575 - 12810	135 -115	128.38	421.19
Shale 4	12750 - 12825	102 -70	84.00	275.59	12810 - 12875	130 -97	113.00	370.73
Sand K	12825 - 13100	140 - 84	115.82	379.99	12875 - 13175	135 - 125	130.64	428.61
Shale 5	13100 - 13400	125 - 60	91.85	301.35	13175 - 13425	135 - 90	118.18	387.73
Sand L	13400 - 13525	115 -106	112.25	368.27	13425 - 13600	140 - 130	132.00	433.07
Shale 6	13525 - 13800	119 - 55	88.92	291.73	13600 - 13750	130 - 110	119.71	392.75

The structural section through the field reveals the anticlinal structure with fault that is hydrocarbon and water bearing. The high amplitude contrast on top of this anticlinal structure implies it is overlaid by shale which serves as seal or cap rock. High amplitude and strong reflection strength along the margin of the faults are indication of the smearing of the faults and sealing of the reservoirs by clays or shales, thus trapping the hydrocarbons migration within the closures. The top seals are provided by field-wide marine and continental clays/shales whereas lateral seals are provided by juxtaposition of impermeable units of shales/clays against the hydrocarbon-bearing sandstones along the fault planes (Bouvier et al, 1989). Clay or shale smears along the fault planes during faulting provided a seal to migrating gas and oil. The abundance of hydrocarbon distribution within the field could possibly be associated with lateral spill-points at the termination of discontinuous faults and seals, or lack of seals along fault planes.

The transit time varies down and across the lithologic units. The transit time of sand units are slightly higher than those of shales. While the transit time of shale ranged from 125us/ft to 15us/ft in Well A and from 180us/ft to 90us/ft at Well 05, those of sands ranged from 150us/ft to 84us/ft at Well 03 and from 158us/ft to 90us/ft at Well 05. Though variation in shale seemed to be staggered in Well B , there is generally an increase in transit time of shale units down the depth. Conversely, sands in A showed a gradual increase in transit time down the depth while those of Well 03 are staggered. Both sand and shale of Well 05 have higher transit time than those of Well 03. This implies lateral variation in the properties of the lithofacies units, probably due to changes in the depositional environment and condition.

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