Scan to know paper details and author's profile

Seismic Time-Depth Conversion for Reservoir Depth Determination and Digital Well Log Interpretation of Fluids in an X-Field of the Niger Delta, Southern Nigeria

Ogini Arthur A & Airen Osariere J.

University of Benin

ABSTRACT

Seismic time-depth conversion for reservoir depth determination and digital well log interpretation of associated fluids was carried out in an X-field of the Niger delta with a view to establishing time-depth functions, in the vicinity of control wells, that could be used to estimate the reservoir depths and thickness of a pay zone (Horizon M10) elsewhere in the field prior to drilling. A combination of check-shot data and time picks on seismic section was used to generate time-depth functions from which depths to the top and bottom of the reservoir in the vicinity of two wells were established. An integrated multi parameter well log analysis was used to interpret the reservoir fluids within the selected horizon. Results showed that the top of Horizon M10 in the vicinity of well-7 was 5230 ft while its bottom was estimated to be 5327 ft with thickness; 97 ft. Around Well-4, the horizon was calculated to be 5108 ft at the top and 5194 ft at the bottom, its thickness was found to be 86 ft. Comparison with wire-line log depth recordings in the reference Wells showed that depth estimates from the seismic time-depth conversion fell well within the reservoir limits even though the reservoir thickness seem to be slightly underestimated. It was concluded that the seismic time-depth conversion for this X-field has an acceptable limit of accuracy and hence reliable for application elsewhere in the X-field. The fluid interpretation of the reservoir was found to be gas sands around well-7 and oil sands in the vicinity of well-4.

Keywords: seismic time-depth conversion, digital well log interpretation of reservoir fluids.

Classification: For Code: 020399p

Language: English

London Journals Press

LJP Copyright ID: 92564
Print ISSN: 2631-8490
Online ISSN: 2631-8504

London Journal of Research in Science: Natural and Formal

Volume 21 | Issue 6 | Compilation 1.0

Seismic Time-Depth Conversion for Reservoir Depth Determination and Digital Well-Log Interpretation of Fluids in an X-Field of the Niger Delta, Southern Nigeria

Ogini Arthur [A] & Airen Osariere J.

ABSTRACT

Seismic time-depth conversion for reservoir depth determination and digital well log interpretation of associated fluids was carried out in an X-field of the Niger delta with a view to establishing time-depth functions, in the vicinity of control wells, that could be used to estimate the reservoir depths and thickness of a pay zone (Horizon M10) elsewhere in the field prior to drilling. A combination of check-shot data and time picks on seismic section was used to generate time-depth functions from which depths to the top and bottom of the reservoir in the vicinity of two wells were established. An integrated multi parameter well log analysis was used to interpret the reservoir fluids within the selected horizon. Results showed that the top of Horizon M10 in the vicinity of well-7 was 5230 ft while its bottom was estimated to be 5327 ft with thickness; 97 ft. Around Well-4, the horizon was calculated to be 5108 ft at the top and 5194 ft at the bottom, its thickness was found to be 86 ft. Comparison with wire-line log depth recordings in the reference Wells showed that depth estimates from the seismic time-depth conversion fell well within the reservoir limits even though the reservoir thickness seem to be slightly underestimated. It was concluded that the seismic time-depth conversion for this X-field has an acceptable limit of accuracy and hence reliable for application elsewhere in the X-field. The fluid interpretation of the reservoir was found to be gas-sands around well-7 and oil-sands in the vicinity of well-4.

Keywords: seismic time-depth conversion, digital well-log interpretation of reservoir fluids.

Author 1: Department of Physics, University of Benin, Benin City, Edo State Nigeria.
Author 2: Department of Physics, University of Benin, Benin City, Edo State Nigeria.

I. INTRODUCTION

The usefulness of seismic data to solve real-time hydrocarbon exploration and production problems lies in the accuracy of the seismic time-depth conversion, while the processed seismic data is visually enhanced, it is usually in time domain and interpretation on the other hand is in the distance or depth domain (Mohamad et., al 2013; Laurence and Rachel, 2005). The means to achieving dependable time-depth conversion is contained in a body of algorithm referred to as velocity analysis wherein the necessary information or data for velocity analysis could be derived from sonic logs, check shots, Vertical Seismic Profiling (VSP) and Uphole seismic surveys (Hitlerman, 1977; Boise, 1978). The significance of velocity models, which may be highly inhomogeneous in time and space, are not limited to basic processing operations like Normal Moveout (NMO) correction and migration, but also in their special application to time-depth conversion during seismic interpretation (Sheriff and Geldart, 1995; Dobrin and Carl, 1988; Kearey and Brooks, 1991). Seismic interpretation is basically the picking of two way travel times of reflection events corresponding to horizons of strong acoustic impedance on a seismic section which may later be analyzed as faults/folds, major subsurface discontinuity or lithologic contrast often displayed on time maps. To know the depths at which these time events are actually located for a cost effective drilling/exploitation of targets, an accurate time-depth conversion for the field in question is necessary (Mc Quillin et al., 1979). Once the depth at the top and bottom of any horizon of interest has been established to an acceptable level of accuracy, it is simple to determine its thickness by simple subtraction. Ogbamikhumi and Aderibigbe (2019) noted that there is a certain level of uncertainty inherent in seismic time to depth conversions in oil fields which calls for statistical analysis of the best method suitable in the Niger Delta. On that note, Sofola (2018) had identified an uncertainty of less than and over 50 ft depending on the depth of interest, using instantaneous gradient velocity function and polynomial methods respectively. This paper hopes to provide a case example of seismic time-depth conversion in an X-field of the Niger Delta using the polynomial function method, and the subsequent interpretation of associated reservoir fluids using the physical relationships between the logged parameters and the reservoir static/dynamic properties.

LOCATION OF STUDY AREA

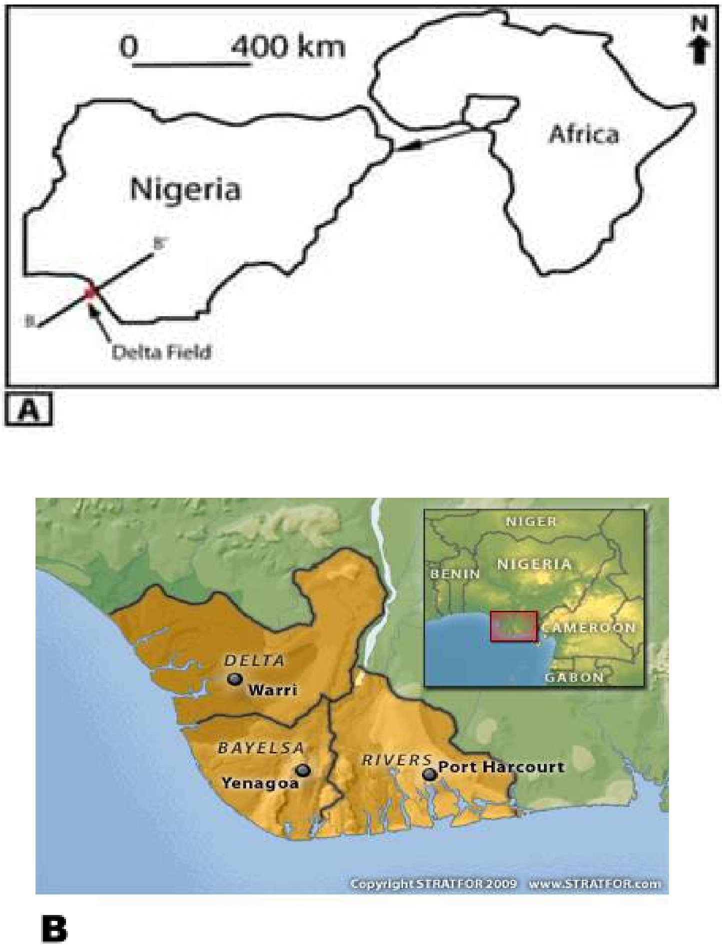

Figure 1: (a) the Niger delta in relation to Nigeria and the African continent; (b) Map of the Niger delta after (STRATFOR.com)

The Niger delta is located on the continental margin of the Gulf of Guinea in equatorial West Africa between latitudes (3° and 6°) N and longitudes (5° and 8°) E, it extends from the planes of southern Nigeria into the continental shelf of the Atlantic ocean in the south-south geopolitical region of the country. The Niger delta is Nigeria's major petroleum province hence has attracted oil exploration and exploitation activities since the discovery of commercial petroleum crude in 1956.

II. MATERIALS AND METHOD

Materials: The following materials were used: Base map showing the position of 3 wells, 3-D polarity display seismic section of an X- field in the Niger Delta oil province, point shots (T-Z) scatter data for the 3 wells and reflection time picks for the chosen horizon (M10). Well-log suites (gamma ray, density, sonic, resistivity) furnished with porosity and hydrocarbon saturation information.

Method: Check shot (t-z) data was used to derive time-depth function which was used to convert two-way reflection times to depths. Microsoft Excel scatter and function developer was used for the associated plots. Using in-lines and cross-lines (bines and stacks), the horizon of interest was mapped across the field. The horizon of interest (M10) was carefully traced along bins and stacks followed by two-way reflection time picks at the top and bottom of the horizon and subsequently posted to their corresponding acquisition grids. Using the t-z function, two-way times at the top and bottom of the horizon were converted to depth and their thicknesses derived by subtraction.

III. CALCULATIONS

The t-z function for well-7 as determined from the graph (figure 2) was given by

$$t = 0.296489z + 14.93 \qquad (1)$$

t = two-way seismic reflection time in milliseconds (ms)

z = depth in feet (ft)

Now, horizon M10 top corresponds to 1565.714 ms on seismic two-way reflection time; the depth equivalent is got by transforming eqn. (1)

Thus

$$z = (t - 14.93)/0.296489 \qquad (2)$$

Where z = seismic depth equivalent of two-way reflection time

t = two-way seismic reflection time at horizon M10 top

Substituting for 't' in (2);

$$z = (\frac{1565.714 - 14.93)}{0.296489}$$

$$= \frac{1550.784}{0.296489}$$

$$= 5230.494 \text{ ft}$$

This is approximated to 5230 ft.

Also, horizon M10 bottom is identified at 1594.286 ms on the seismic section.

thus,

$$z = \frac{(1594.286 - 14.93)}{0.296489}$$

$$= 5326.86 \text{ ft}$$

$$= 5327 \text{ ft approx.}$$

The horizon thickness (h) is got by subtracting the top depth from the bottom depth;

$$h = 97\ ft\ .$$

Again;

The time-depth function for well-4 (figure 3) is;

$$t = 0.301096z + 7.632 \qquad (3)$$

t is the seismic reflection time at horizon M10 top

z is the depth equivalent of seismic reflection time at horizon M10 top

Thus,

$$z = (\frac{t - 7.632)}{0.301096} \qquad (4)$$

Substituting for 't' in (4) where t was picked at 1545.713 ms

$$z = \frac{(1545.713 - 7.632)}{0.301096}$$

$$z = 5108.2744$$

This is approximated to 5108 ft.

Also, horizon M10 bottom was picked at 1571.428 ms two-way seismic reflection time and by applying equation (4), the seismic bottom depth equivalent of horizon M10 is;

$$z = (1571.428 - 7.632)/0.301096$$
$$= 5193.679$$

~ 5194 ft.

The thickness h was got by subtraction;

$h = 5194 - 5108; \quad = 86$ ft approx.

IV. RESULT AND DISCUSSION

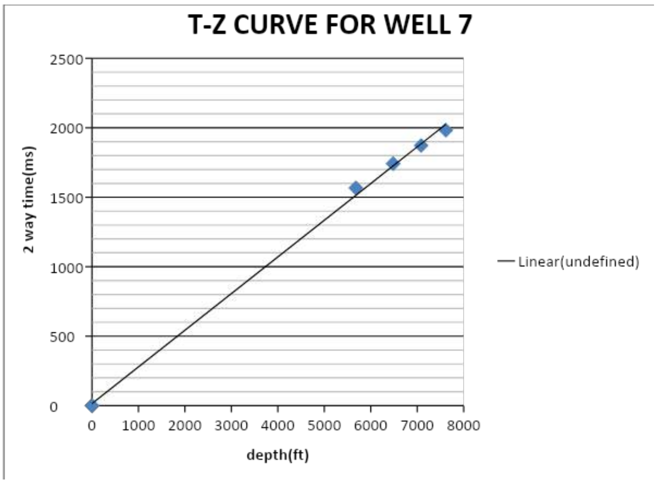

Figure 2: Time-depth graph for well-7

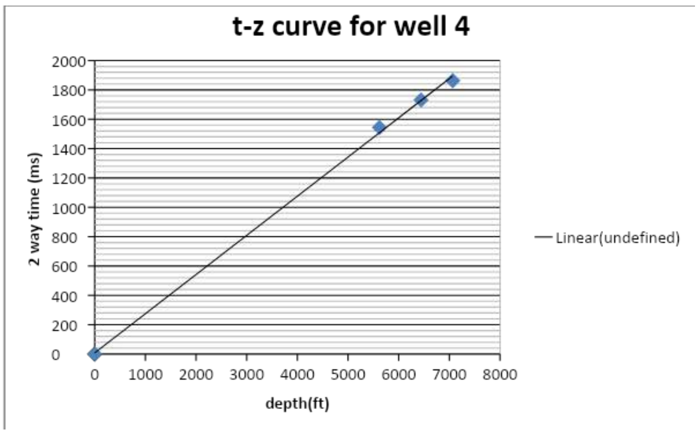

Figure 3: Time-depth graph for well-7

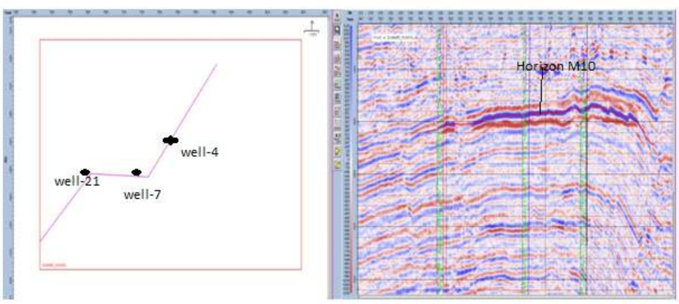

Figure 4: Map and Seismic Views of Reservoir and Wells

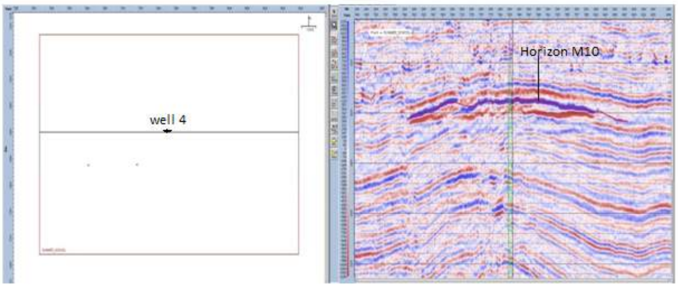

Figure 5: Map and Seismic In-line Views of Horizon M10 in the Vicinity of Well-4

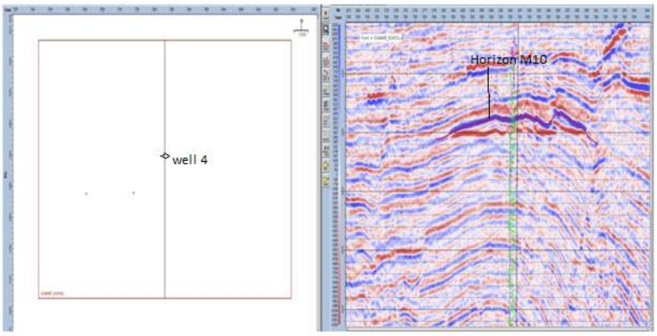

Figure 6: Map and Seismic Cross-line Views of Horizon M10 in the Vicinity of Well-4

Table 1: Seismic Time-Depth Conversion Results

Well Reference	WELL-7	WELL-4
Horizon Bottom (ft)	5327	5194
Horizon Top (ft)	5230	5108
Reservoir Thickness	97 (ft)	86 (ft)

Table 2: Digital Log Extracts of Horizon

Depth (ft)	CALP	FDC (g/cc)	RT (Ωm)	GR (API)	POR	SH	SW	REMARKS
5174.5	11.91	2.250	1.976	85.20	0.207	0.154	0.947	Shale/HC
5176.5	11.91	2.210	1.930	92.39	0.194	0.118	0.882	Shale/HC
5180.5	11.56	2.290	2.506	89.99	0.199	0.180	0.820	Shale/HC
5182	11.77	2.250	2.146	91.08	0.197	0.188	0.812	Shale/HC
5184	11.76	2.250	2.159	86.08	0.206	0.205	0.795	Shale/HC
5186.5	11.72	2.240	2.172	87.72	0.203	0.204	0.796	Shale/HC
5190	11.96	2.270	2.028	90.27	0.198	0.156	0.844	Shale/HC
5192.5	11.62	2.340	2.834	74.94	0.225	0.364	0.636	Shale/HC
5194	11.12	2.090	5.089	50.757	0.268	0.570	0.430	?
5195.5	12.28	2.090	27.280	29.262	0.307	0.807	0.193	?
5197.5	12.26	2.110	153.66	27.57	0.310	0.926	0.074	GAS

5230.5	12.54	2.160	286.52	30.95	0.304	0.963	0.037	GAS
5240.5	14.18	2.080	105.12	31.49	0.302	0.927	0.073	GAS
5247	16.98	1.900	499.66	22.32	0.319	0.964	0.036	GAS
5260.5	15.86	1.930	980.48	26.37	0.312	0.974	0.026	GAS
5263.5	11.05	2.090	1959.6	23.29	0.318	0.983	0.017	GAS
5270	10.67	2.080	2276.8	19.37	0.324	0.986	0.014	GAS
5329.5	11.87	2.290	1.589	88.22	0.200	0.000	1.000	Shale/water

Table 3: Digital Log Extracts of Horizon M10 Well-4

DEPTH (ft)	SONIC (Δt)	CALP	G.R (API)	SH	POR	SW	BLK.D g/cc	RT (Ωm)	REMARK
5099	136	11.6	100	0.000	0.21	1.000	2.398	1.439	Shale/w
5100	130	11.0	111	0.000	0.15	1.000	2.449	1.378	Shale/w
5109.5	111	10.1	42	0.000	0.26	1.000	2.149	1.628	Shale/w
5113	119.2	9.2	38	0.658	0.24	0.342	2.132	10.56	Oil
5116.0	119.9	9.2	37	0.908	0.23	0.092	2.129	49.89	Oil
5129.5	120.8	9.2	39	0.954	0.22	0.046	2.136	93.82	Oil
5130	121.2	9.0	44	0.956	0.29	0.044	2.161	305.8	Oil
5162	120.9	9.0	42	0.905	0.26	0.095	2.152	121.5	Oil
5166.5	120.9	9.0	42	0.855	0.25	0.145	2.152	62.88	Oil
5173	124.5	9.1	44	0.922	0.23	0.078	2.161	64.80	Oil
5180	124.9	9.2	48	0.987	0.24	0.013	2.177	98.6	Oil
5190	124.4	9.2	47	0.897	0.25	0.013	2.174	90.8	Oil
5197	121.2	9.2	49	0.907	0.24	0.093	2.197	77.11	Oil
5227.5	115.7	9.2	57	0.673	0.21	0.327	2.216	9.73	H.C silt
5390	115.7	9.5	87	0.694	0.15	0.306	2.345	9.77	H.C silt

Table 4: Extract of Check Shot Data

WELL 21		WELL 7		WELL 4	
Sub data Depth(ft)	Seismic Time(ms)	Sub data Depth(ft)	Seismic Time(ms)	Sub data Depth(ft)	Seismic Time(ms)
0.0	0.0	0.0	0.0	0.0	0.0
5799.8	1613.7	5680.6	1566.9	5619.8	1544.1
6641.6	1813.3	6481.0	1741.6	6441.7	1731.1
7203.6	1931.7	7082.9	1872.4	7066.3	1863.0
7729.6	2043.9	1614.8	1982.9	-	-

IV. DISCUSSION

The digital well log interpretation was done with reference to lithologic and fluid interpretation models proposed and explained in Rider (1986), Schlumberger (1972 and 1974), Dresser Atlas (1982) and Sheriff (1995). Extracts of the interpretation parameters and their indices as applied in the present study are as shown below:

Density:

Less than 2.150 (g/cc) → Gas
Greater than 2.200 (g/cc) → Water/Shale
Greater than 2.150 (g/cc) but less than 2.200 (g/cc) → Oil

NB g/cc is read grams per centimeter cube

Resistivity:
Less than 5Ωm → Water/Shale
Greater than 5 Ωm to 100 Ωm → Oil
Greater than 100 Ωm → Gas
Gamma ray:
Greater than 60 API → Shale
Greater than 20 but less than 60 API → Sandstone (Rider, 1986; p. 57)
NB. The percentage of shale gradually increases towards and above 60 API

Table 5: Interpretation Model for Lithology/Reservoir Fluids Based on Density and Seismic velocity (Sherrif, 1995)

Lithology	Density	Velocity
shale	2.13g/cc	2287m/s
Water sand	2.08g/cc	2073m/s
Gas sand	1.98g/cc	1677m/s
Silty sand	2.11g/cc	2915m/s

The time-depth curves for the two reference wells are shown in figures (1 and 2), while equations (1 and 3) are their respective time-depth functions. The calculated depths show that horizon M10 top, in the vicinity of well-7, occurs at 5230 ft and bottomed at 5327 ft, where its thickness was estimated at 97 ft. In well-4, the horizon top was estimated at 5108 ft and its bottom found to be 5194 ft from which the thickness was obtained as 86 ft. On the other hand, Tables (2 and 3) show extracts of digitized wire line log recordings for Wells 7 and 4 respectively, and the depth information contained in column one. The intention was to compare seismic time-depth derived estimates with the depth recordings of the real-time wire-line logs. A comparison of the two results showed that our time-depth conversions fell well within the limits of the reservoir as delineated by the wire-line logs. For instance, the wire-line log interpretation revealed the top of Horizon M10 to occur at 5174.5 ft, and the bottom at 5329.5 ft, while the seismic time-depth conversion gave 5230 ft and 5327 ft respectively. In Well-4, the wire-line recordings were; 5099 ft for the top of M10 and 5390 ft for its bottom while the time-depth conversion for this particular Well (4) were; 5108 ft for the top and 5194 ft for its bottom as earlier noted. The lithology and fluid interpretations based on combined well-log parameter analysis using templates highlighted in the beginning of this section showed that horizon M10 has a top and bottom shale seal housing the sandstone reservoir in both wells (tables 1 and 2). It could be recalled that shale is basically radioactive, accounting for why its presence has been associated with larger API values which were used to delineate the lithology. Also, a gas filled porosity exhibits higher resistivity than an oil filled porosity, the same is true for sonic velocity and the density parameters in a logging environment, even as shale tends to be denser than sandstone (Rider, 1986).

V. CONCLUSION

It could be seen that the depth estimates derived from the seismic time-depth conversions fell within the reservoir limits but not without some level of error which lead to underestimation of the reservoir thickness as observed in the bottom tie of well-4. Since the estimated depth and thicknesses are within the range of actual values as revealed by the wire-line logs, the time-depth conversion is thus to a fare approximation reliable, hence could be used in this X-field where integral and/or statistical analysis of the check shots velocity with other sources of velocity information is suggested for enhanced results and better accuracy. Aided by information on hydrocarbon saturation in the 7^{th} and 5^{th} columns of tables 2 and 3 respectively; horizon M10 in the vicinity of well-7 was interpreted to be composed majorly of gas sands while well-4 has reservoir sands with oil filled porosity.

REFERENCES

1. Boise, S. (1978). Calculation of velocity from seismic reflection amplitudes: Geophysical Prospecting, vol 26, pp. 163-174
2. Dresser, Atlas (1982), Well logging and interpretation techniques: The course for home studies, Dresser Atlas publication.
3. Dobrin, B. M., Carl, H. S. (1988). An introduction to geophysical prospecting, 4th ed. Mcgraw Hills, New York, U.S.A
4. Hitlerman, F. J. (1977). Seismic velocities, bright spots: Notes for AAPG petroleum school.
5. Kearey, P. And Brooks, M. (1991). An introduction to geophysical exploration, 2nd ed. Blackwell science London
6. Laurence, R. L. and Rachel, T. N. (2005). Fundamentals of Geophysical Interpretation; geophysical monograph series, Society of Exploration Geophysics (SEG)
7. Mc Quillin, R, Bacon, M. and Barclay, W. (1979). An Introduction to Seismic Interpretation. Graham and trotman, London.
8. Muhamad, W. P., Imam, M. G., Andry, P. and Sudarji (2013). Seismic Time-Depth Conversion and Uncertainty Analysis for Horizon Prediction in a Proposed Well-site of Sungai Gelam field: Proceedings, Indonesian Petroleum Association, 37th Annual Convention and Exhibition.
9. Ogbamikhumi, A., and Aderibigbe, O. A (20190). Velocity modelling and Depth uncertainty Analysis of Onshore Reservoirs in the Niger DeltaBasin. Journal of the Cameroon Academy of Sciences vol. 14, no.3, pp. 239-247.
10. Rider, M.H., (1986), The geological interpretation of well logs. Blackie and sons ltd., Glasgow and London.
11. Schlumberger, (1972). Log interpretation principles 1, Schlumberger publications
12. Schlumberger, (1974). Log interpretations II, Applications. Schlumberger Publications
13. Sheriff, R. E. and Geldart, L. P. (1995). Exploration Seismology. Cambridge Unive-rsity Press, London
14. Sofolabo, A. O., Dagogo, T., and Diri, J. J. (2018). Velocity Modelling using Well Data: Depth Conversion "A case Study of K-Field, Onshore Niger Delta" IOSR journal of Applied geology and Geophysics, 6(4), 18-26.