Effect Of Linear Versus Curved Wavelet Paths In Seismic Oil Exploration Over Kukawa Axis, Borno State, Nigeria

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ABSTRACT

An investigation into the error effect of the assumption of straight line paths for seismic waves instead of the ideal curved wave path is undertaken. The study entailed a comparison of the actual depths calculated by the use of straight line paths with those computed with curved paths which are both determined by the reflection time of a wave from surface to the target bed as well as the velocity of propagation. The strategy adopted in this study was based on the results of an earlier research which made the comparison to be rather between the height (h) obtained by actual measurements and (h') obtained by the assumption of a straight line path. Results obtained show that the use of straight lines instead of curved paths introduced an average percentage error of 0.07 which is not significant in terms of the precision of seismic exploration results obtained between 1976 – 1996 in Kukawa, Borno state, Nigeria.

KEY WORDS: seismic, reflection, exploration, prospecting

1. INTRODUCTION

In contemporary times, oil prospecting has been graced with several methodologies ranging from the use of crude heuristic approaches to the most recent advanced technologies like 3-D seismic reflection, water or steam injection, remote sensing, the most recent e-field Airborne Electromagnetic Technologies (EMT) in oil exploration pioneered by Barringer [2], etc. Most of these methodologies for finding oil/gas deposits in the subsurface rely on the injection of a ray of pulses to the ground in one way or the other either from the surface of the earth , under the water, or aboard an aeroplane. In particular, the seismic reflection technique uses the assumption that the sent ray/train of pulses or wavelet follow a straight line course/path as against the reality of a curved path which is more reasonable and practical due to the nature of the materials that constitute the earth surface. According to Enikanselu [3], there is generally a weathered surface layer on the land which is otherwise called a "low velocity layer (LVL)" with seismic velocity much lower than normal. This layer, according to Enikanselu[3] is characteristically composed of top sediments which are highly aerated and unconsolidated and may range from a few meters thickness to (rarely) tens of meters depending on the geologic nature/structure of the area.

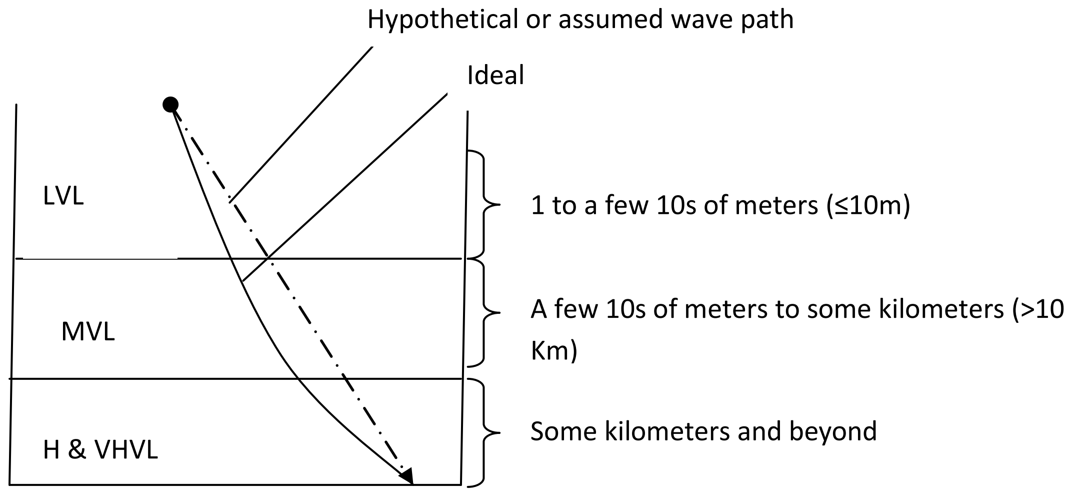

Fig.1: Layer velocity categorization

Moreover, this layer is also described as a zone of high seismic energy absorption, disproportionately high effect on seismic wave travel times, sharp bending of seismic rays into near vertical and near curved wavelets due to the high impedance contrast at the base of the layer [3],[1],[4]. It has also been shown that velocity increases with depth [1], such that the path taken by a penetrating wave must be curved due to differences in velocity between the earth sediments. See the velocity-depth profile in fig.1. The layers are categorized as Low Velocity Layer (LVL), Medium Velocity Layer (MVL) and High and Very High Layer (H&VHVL) [3].

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2.0 Seismic Travel Time/Velocity Models for the Experiment

Consider the sketch in fig.2 where a wave generating source produces a train of pulses at 'l' (the surface) which is at a height of 'h (m)' from the 'target' reflection sedimentary bed 'm'. The incident wave $\overline{lm}$ is received at 'n' as $\overline{mn}$ after traveling a horizontal distance of x(m) and a vertical height $\overline{om}$ of h(m). The issue is whether the use of straight (doted) paths $\overline{lm}$ and $\overline{mn}$ against the actual curved paths $\overset{\frown}{lm}$ and $\overset{\frown}{mn}$ will introduce an error, which by notable precision standards, can be regarded as statistically significant [1].

To obtain the travel time t as well as the two – way travel velocity (TWTV) that explains this phenomenon ,[1][5] modeled the actual travel time for curved path as

$$t = \frac{1}{k} Cosh^{-1}\left[1 + \frac{k^2\left\{\left(\frac{x}{2}\right)^2 + h^2\right\}}{2v_0(v_0 + kh)}\right] \qquad \ldots\ldots\ldots \qquad 1.0$$

Where k is the angle factor given by

$$k = \sqrt{\frac{v_1 - v_0}{v_1 + v_0}} \qquad \ldots\ldots\ldots \qquad 2.0$$

, v_0 = velocity of the layer $\overline{om}$, v_1 = velocity of the 2nd layer.

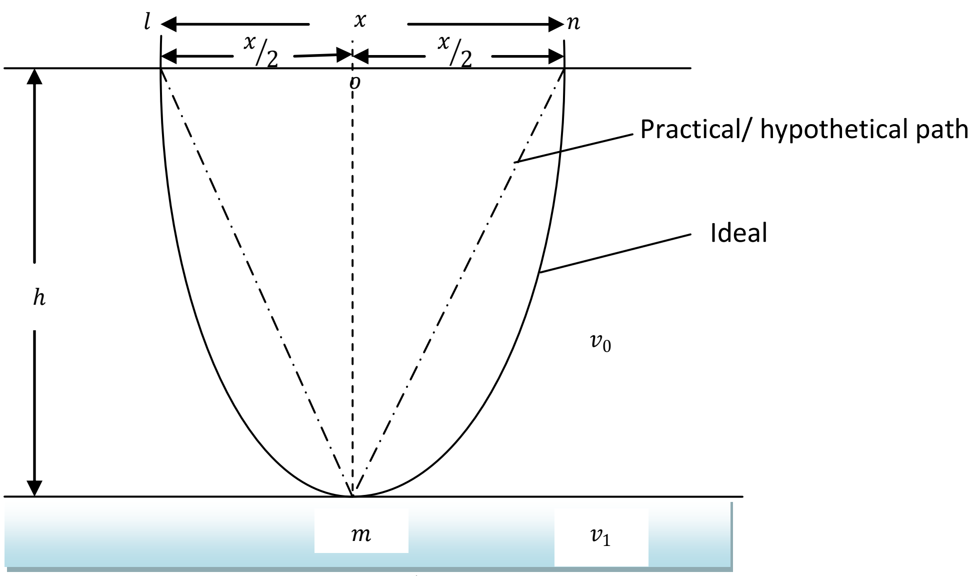

Fig 2: Ideal curved wavelet paths against the practical straight line path assumption

However, the fiduciary (F_t) or vertical time corresponding with the actual time results obtained from well shooting would correspond to the time for the path $\overline{om}$ and is obtained from equation (1) when x/2 =0; i.e

$$F_t = \left(t_{\frac{x}{2}} = t_0\right) = \frac{1}{k} Cosh^{-1}\left[1 + \frac{k^2h^2}{2v_0(v_0 + kh)}\right] \quad \ldots\ldots\ldots \quad 3.0$$

Or

$$t_0 = \frac{1}{k} Cosh^{-1}\left[1 + \frac{k^2h^2}{2v_0(v_0 + kh)}\right] \quad \ldots\ldots\ldots \quad 4.0$$

But the average vertical velocity of the wave from shot point to depth h, also called the two way travel velocity (TWTV) is given by

$$\vec{v} = 2\frac{h}{t_0} \quad \ldots\ldots\ldots \quad 5.0$$

, derived from the travel time t from the surface to the top of bed m and back [6]. Moreover, [1] has shown that the comparison is actually between the actual depth 'h' measured and the hypothetical height, h′, computed using the formulae

$$h' = {}^1/_2\sqrt{\vec{v}^2t^2 - x^2} \quad \ldots\ldots\ldots \quad 6.0$$

Which is the one-way distance calculated between the point m (at an average velocity $\vec{v}$ and time t) and the point 'o' on the 'x' distance axis [1].

In principle, therefore, the absolute error due to the depth computed from eqn. 5.0 and the actual measured depth 'h' from the field gives a measure of the precision in assuming a straight line propagation instead of the ideal curved path for computational convenience [5],[1],[6].

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3.0 KUKAWA DESERTS AND OIL EXPLORATION ACTIVITIES TO DATE

Exploration activities were said to have started in the Chad Basin in 1976 and continued till 1996 without remarkable success[3],[7],[8]. During this period, 23 test wells were drilled with an acquisition of 33,000 square km of 2-D seismic data, processed and interpreted [9]. Of all these wells, only two wells recorded non-commercial gas discoveries, viz. Wadi – 1 and Kinasar – 1 [9],[7],[8]. This exploration was later suspended in 2000 for alleged lack of commercial discoveries, amid growing suspicion and concerns/allegations that the oil giants were not serious, but rather drilled half of the depths of each of the wells and suspended the wells because they had their eyes gazing constantly at their oil acreages in the productive Niger Delta region [8],[7].

However, following the federal government's directive in 2002, a consortium of 10 consultants was engaged to carry out integrated studies utilizing all the generated data. Today, exploration effort in the region is geared at the acquisition of three thousand, five hundred and fifty (3550) square kilometers of high resolution seismic data in 2-years and the data are to be processed with state of the art equipment. Currently, it is also true that the Federal Government, through the IDSL (Integrated Data Services Limited), a subsidiary of the NNPC, has entered into a partnership with Bureau for Geophysical prospecting (BGP), a Chinese company, and more than 380 square kilometers of seismic data has been acquired, already. The present arrangement uses one of the latest 3-D technologies, the GPS 1200 (which works with satellite) to take coordinates of the prospective oil blocks. Also, vibrator equipment which produces 6000 pressure seconds per inch (PSI) are also utilized to create input energy(waves) which propagate straight to the ground to create seismic waves that travel to the deep (100s of meters) and send information (reflected signals) to the surface for analyses. This study is based on a random selection of 6 prospective oil blocks within the prospective Kukawa oil field within the neighborhoods of Wadi-1 and Kinasar-1, which are currently being re-examined. These measurements of height (h) and distances 'x' from the detectors were obtained from the site with the aid of the site engineers and the permission of the caretaker Chairman of Kukawa Local Government Council, Mala Mustafa Kukawa, in November, 2010.

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This study has as its key objective, the estimation of the percentage error associated with the assumption of a linear (straight) path for the seismic waves as against the ideal curved path so as to know if this could have a significant effect in the discovery of oil in the Kukawa Basins, a subset of the Nigerian Chad Basins.

4.0 DETERMINATION OF PERCENTAGE ERROR DUE TO THE USE OF STRAIGHT LINE PATHS IN DEPTH ESTIMATION

Measurements were taken from six different prospective oil blocks within the kukawa axis of the chad basin in Borno State. Results obtained and plotted with an angular factor of K=0.5 sec^{-1} and a vertical velocity of v_0 = 1828.80m/sec are displayed below.

Table 1: Determination of percentage error for the experiment

S/N	h(m)	x(m)	$\frac{x}{2}$ (m)	t(sec)	t_0 (sec)	$\vec{v}$ (m/s)	h'(m)	$\lvert h - h' \rvert$(m)	% Error
1	1524.00	914.40	447.20	0.727	0.6966	4375.54	1523.38	0.62	0.04
2		1219.20	609.60	0.750	0.6966	4375.54	1523.42	0.58	0.04
3		1524.00	762.00	0.778	0.6966	4375.54	1521.99	2.01	0.13
4	2133.60	914.40	447.20	0.940	0.9191	4642.80	2133.68	0.08	0.00
5		1219.20	609.60	0.955	0.9191	4642.80	2131.48	2.12	0.10
6		1524.00	762.00	0.975	0.9191	4642.80	2131.24	2.36	0.11
7	2743.20	914.40	447.20	1.134	1.1192	4902.07	2741.61	1.59	0.06
8		1219.20	609.60	1.146	1.1192	4902.07	2741.94	1.26	0.05
9		1524.00	762.00	1.161	1.1192	4902.07	2741.73	1.47	0.05
10	3352.8	914.40	447.20	1.312	1.3010	5154.19	3350.09	2.71	0.08
11		1219.20	609.60	1.322	1.3010	5154.19	3351.94	0.86	0.03
12		1524.00	762.00	1.333	1.3010	5154.19	3349.69	3.11	0.09
13	3962.40	914.40	447.20	1.477	1.4680	5398.37	3960.39	3.57	0.09
14		1219.20	609.60	1.484	1.4680	5398.37	3958.93	3.47	0.09
15		1524.00	762.00	1.494	1.4680	5398.37	3959.93	2.47	0.06
16	4572.00	914.40	447.20	1.630	1.6220	5637.49	4571.75	0.25	0.01
17		1219.20	609.60	1.635	1.6220	5637.49	4568.15	3.85	0.08
18		1524.00	762.00	1.643	1.6220	5637.49	4568.08	3.92	0.09
Totals									1.20

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$$The\ average\ \%\ error\ = \frac{Total\ \%\ Error}{No\ of\ cases} = \frac{1.20}{18} = 0.0667 \cong 0.07$$

5.0 Conclusion

The study is aimed at investigating the effect of the assumption of a linear (straight) line path for seismic waves used for prospecting for crude oil in the Kukawa axis of the Chad basin as against the actual/ideal curved paths for seismic waves. The results show that of the six random sample points chosen, the average percentage error due to this assumption is 0.07% which is quite insignificant. This implies, then, that the assumption has nothing to do with the so far fruitless toil for commercial crude oil in the Kukawa axis of the Chad basin, Nigeria.

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