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Effects of Source, Receiver and Offset Parameters in 3D Seismic Data Quality in Niger Delta

By

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Abstract
Data acquisition in 3D seismic is influenced by various elements. They may range from lithological features, terrain or environmental conditions to acquisition design parameters, instrumentation, and data collection style. This paper considers the design parameters used for orthogonal geometry seismic acquisition and how they influence the quality of data obtained from surveys carried out using the 3D technique in the Niger Delta region of Nigeria. This study presents an investigation done on six 3D seismic acquisition design data used for land seismic explorations in the Niger Delta. The design parameters investigated were divided into three main categories. These categories were then independently compared with the nominal fold obtained in each acquisition data studied. The categories are source parameters (parameters related to the source or shot events), the receiver parameters (parameters related to the receivers), and the offset parameters i.e. maximum offset, minimum offset, and largest minimum offset. Regression analyses were carried out to adequately compare the nominal fold and the investigated parameters. Furthermore, mathematical expressions showing the relationships between these parameters and the nominal fold were obtained from the generated regressions. The source point interval, receiver point interval and the minimum offset were observed to show no direct relationship with the nominal fold. The source line interval, the receiver line interval and the number of receiver lines showed a linear relationship with the nominal fold. Furthermore, a polynomial trend line was observed to exist between the number of source lines, the total source line length, total receivers, the receiver line length, the maximum offset and the largest minimum offset (LMO).

Keywords: Nominal fold, inline fold, cross line fold, source, detector, source array, detector array.

Introduction

The seismic method, to an acceptable degree of precision, provides answers to questions of position, magnitude and depth of subterranean materials,[1] just like every other method of geophysical investigation. However, the seismic method is, to an extent, limited due to data quality challenges, as data lose value when recorded alongside irrelevant or unusable signals. This accounts for a percentage of poor imaging quality experienced by seismic explorationists in the oil and gas industry[2].

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[1] Vermeer, G. J. O, (2008). *Alternative strategies for tackling scattered noise*: 78th Annual International Meeting, Society of Exploration Geophysicist, Extended Abstract, 95 – 99.

[2] Cordsen, A., D. C. Lawton, 1996, *Designing 3-component 3-D seismic surveys*: 66th Annual International Meeting, Society of Exploration Geophysicists, Expanded Abstracts, 81–83.

The starting point of any seismic survey, most times considered the most critical, is the design stage. Seismic acquisition fields are designed to enhance production of recordable signals of known characteristics[3]. Adequate field design is therefore key for a successful seismic campaign; for no amount of work done in the processing centres can compensate for a poorly designed survey.

Over the years, adjustments have been implemented on various elements of seismic acquisition and processing techniques for the sake of noise mitigation and control[4]. This study presents a unique data quality improvement technique, through adequate calculation and design of source – detector parameters.

It is important to note at this point that various noise mitigation and control techniques are currently available, and some have proved fairly effective and enjoy constant usage in noise reduction procedures in the oil and gas industry[5], this paper is limited to data quality improvement at the design phase of 3D seismic through improvement of the magnitude of nominal fold per survey. Increment of the nominal fold where possible is plausible as it leads to better suppression of recorded noise[6], better resolution and removal of migration artefacts[7].

Source parameters as used in this study are; source point interval, source line length, source line interval and total number of sources. The receiver parameters as used in this study are include; receiver point interval, receiver line length, receiver line interval and total number of receivers. The offset parameters as used in this study include; the maximum offset, minimum offset and the largest minimum offset (LMO).

Methodology

The nominal fold represents a sensitive parameter in 3D seismic; if the nominal fold is doubled, a 41% increment is observed in the S/N ratio, in other words, doubling the S/N ration require quadrupling the fold, assuming the fold is distributed in a random Gaussian fashion[8].

Design data of six 3D land seismic surveys carried out in the Niger delta was examined in this study. From the design data, the calculated nominal fold ranged from 48 – 150 folds. However, analyzed data showed a constant charge size of 2kg (0.4kg x 5 holes) per shot point, shot in pattern holes of 3.5m deep. MS_4 geophone groups separated by 50m were employed for all surveys. The shot point interval was also observed to have a 50m separation. Varying shot and receiver line

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[3] Cordsen, A., D. C. Lawton, 1996, *Designing 3-component 3-D seismic surveys*: 66th Annual International Meeting, Society of Exploration Geophysicists, Expanded Abstracts, 81–83.

[4] Anderson, B., P. van Baaren, M. Daly, W. Grace, J. Quigley, and D. Sweeney, 2006, *Point-receiver seismic data offers new approach to managing onshore E&P development cycle*: First Break, 24, no. 2, 63–69.

[5] Vermeer, G. J. O. (2012). 3D Seismic design. 2nd ed. Tulsa, Oklahoma, USA : Green Press.

[6] Xiao, F., Yang, J., Liang, B., Zhang, M., Li, R., Li, F., Xiao, H., Lei, H., Liu Q. & Heesom, T. (2014). High-density 3D point receiver seismic acquisition and processing – a case study from the Sichuan basin, China. *First Break*, 32(12), 81-89.

[7] Cordsen, A., Galbaraith, M. & John, P. (2000). Planning 3D seismic surveys. *Society of Exploration Geophysicist*, geophysical development series 9, 14–21.

[8] Pap, A., *Notes on geophysics as applied to land seismic acquisition*: http://freeusp.net/RaceCarWebsite/TechTransfer/Reports/ConsultingNotes/AndyPap/AndyPap.html_save, accessed 29 May 2012.

lengths were used. The Sercel SN 428/XL, SN 408/UL and SN 388 recording equipments were used.
A computer aided comparative analysis was done for all 3D parameters *viz*. source, receiver and offset parameters, and Mathematical equations were generated from graphs plotted.

The field, source, receiver and offset parameters as discussed earlier, and their magnitudes are shown in Table 1.1 below.

Table 1. Field, source, receiver and offset parameters

FIELD	A	B	C	D	E	F
NORMINAL FOLD	150	66	48	54	48	48
SOURCE PARAMETERS						
SOURCE POINT INTERVAL	50	50	50	50	50	50
LINE INTERVAL	400	560	600	600	500	600
NUMBER OF LINES	67	51	28	37	62	30
TOTAL SOURCE LINE LENGTH(km)	2149.15	1263.85	571.6	684.85	350	200.05
RECEIVER PARAMETERS						
RECEIVER INTERVAL(m)	50	50	50	50	50	50
LINE SPACING(m)	200	500	600	500	400	600
NUMBER OF RECEIVER LINES	88	53	46	48	67	48
TOTAL RECEIVERS	44880	30712	13896	14658	34540	15984
RECEIVER LINE LENGTH(km)	2000	1535	692.5	730.5	1000	203.5
OFFSET PARAMETERS						
MAXIMUM OFFSET	8309	7815.5	4847.33	6836.7	5801	6752.9
LARGEST MINIMUM OFFSET	800	781	398	620	360	573
MINIMUM OFFSET	35.36	35.36	35.36	35.36	35.36	35.36

Result and Discussion

The effects of seismic acquisition sources, receivers and offsets on the nominal fold carried out in this study are illustrated below.

Effects of source parameters on nominal fold

1. *Source Point Interval* – As shown in Table 1, the source point interval, albeit its relatively great influence in lateral resolution of seismic data, was observed to have a minimal impact on the nominal fold. The source point was maintained at 50m per survey for all surveys sampled, while the nominal fold varied from 48 to 150. The source point and receiver point interval are observed to be completely dependent on the bin size. The maintained 50m observed show that the smallest stratigraphy imaged had a width of 200m.

2. *Source Line Interval* – As shown in Figure 1, a linear regression was observed to exist between the nominal fold and the source line interval. The relationship observed can be represented by the equation; $y = -0.486x + 339.7$, where y is the nominal fold and x is the source line interval. An

increment in the source line interval produces a reduction in the nominal fold, in other words, a reduction in the source line interval supports nominal fold increment. This clearly supports the Areal 3D geometric design.

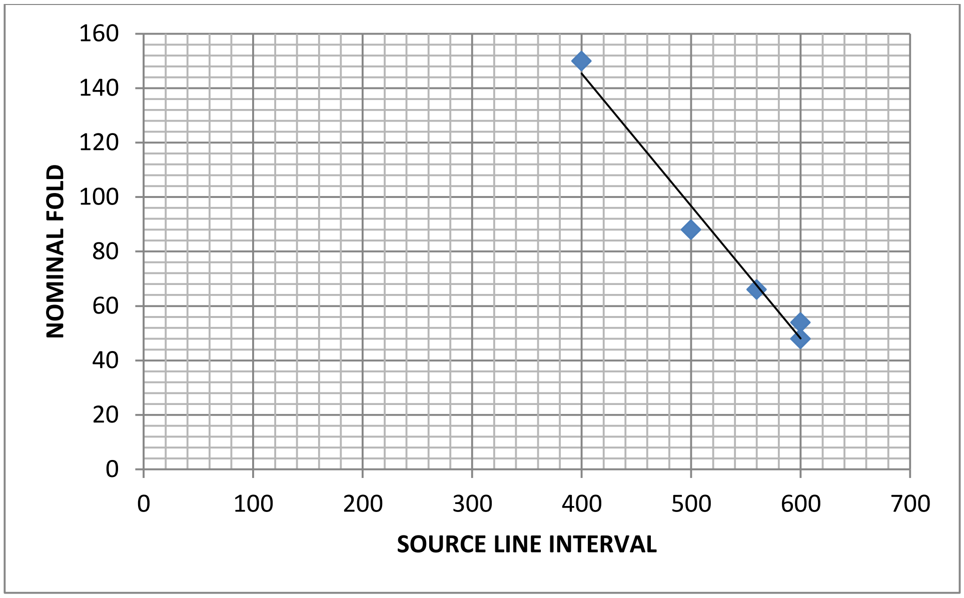

Figure 1: Nominal fold vs. Source Line Interval

3. *Number of source lines* – A polynomial regression with equation $y = 0.103x^2 - 7.689x + 186.9$, where y is the nominal fold and x is the number of source lines, was observed to exist between then nominal fold and the number of source lines. This is shown in Figure 2 below.

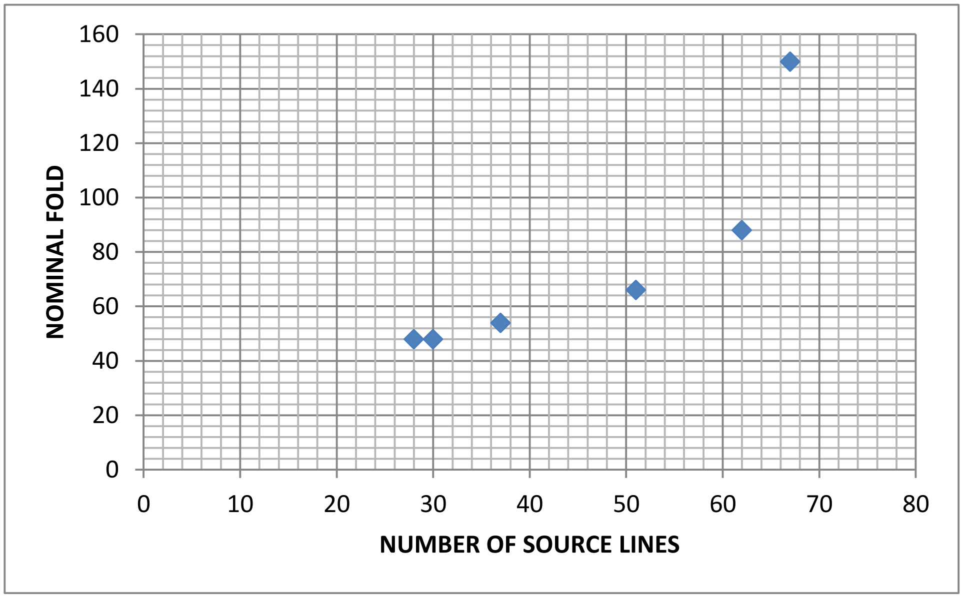

Figure 2: Nominal fold vs. Number of source lines

4. *Total Source Line Length* – A polynomial regression trend was observed to exist between the total source line length and the nominal fold. As noticed in figure 3, an increment in the source line instigates a sharp rise in the nominal fold. The relationship can be reduced to the mathematical equation; $y = 4E\text{-}05x^2 - 0.063x + 76.73$

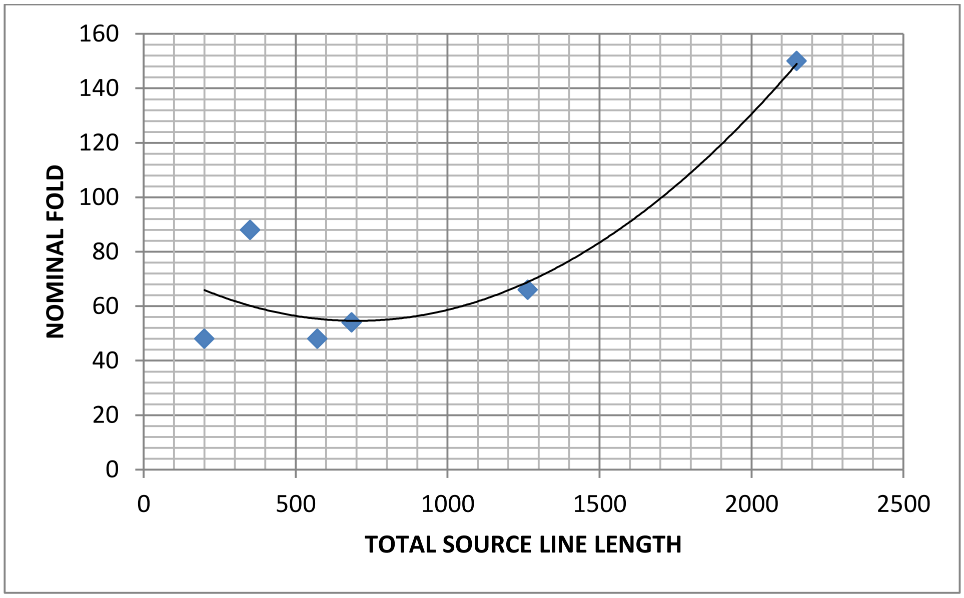

Figure 3: Nominal Fold vs. Total Source Line Length

Effects of Receiver Parameters on Nominal fold

1. *Receiver Point Interval* – Just as observed in the Source point interval, the receiver point interval is maintained at 50m per survey for all sampled surveys. This shows that the nominal fold is largely independent of the receiver point interval; same can also be said of the source point interval.

2. *Receiver Line Interval* – As observed in figure 4, the relationship between the receiver line interval and the nominal fold is linear and can be represented by the equation $y = -0.256x + 195.3$, where y is the nominal fold and x is receiver line interval. The negative slope indicates a reduction in the nominal fold with increment in the receiver line interval.

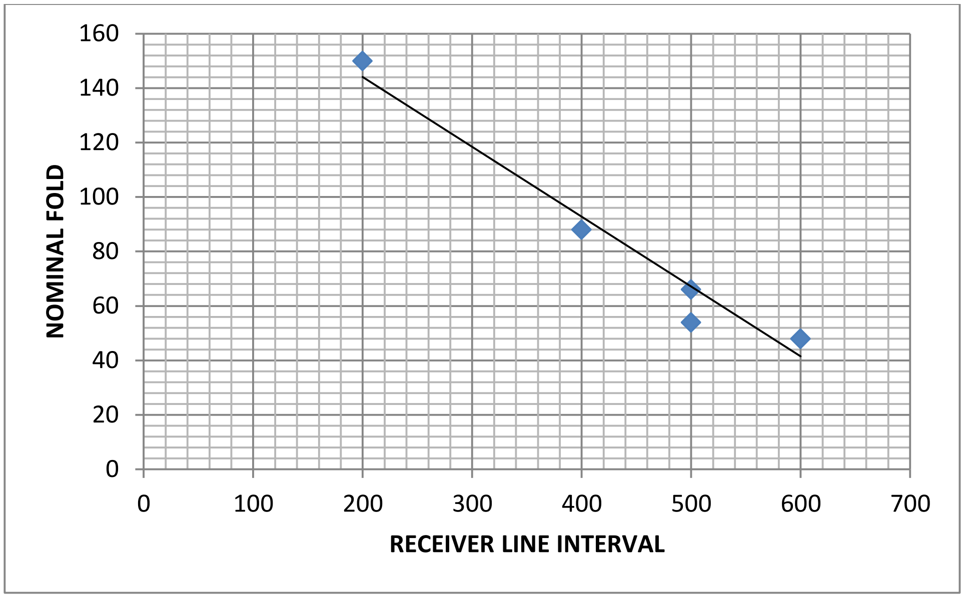

Figure 4: Nominal Fold vs. Receiver Line Interval

3. *Number of Receiver Lines* – As shown in figure 5 below, the nominal fold is observed to be greatly influenced by the number of receiver lines. A linear relationship is observed to exist between both parameters. A sharp rise is noticed in the nominal fold with rise in number of receiver lines used. Where y is the nominal fold and x is the number of receiver lines, the observed mathematical relationship is; $y = 2.382x - 63.30$

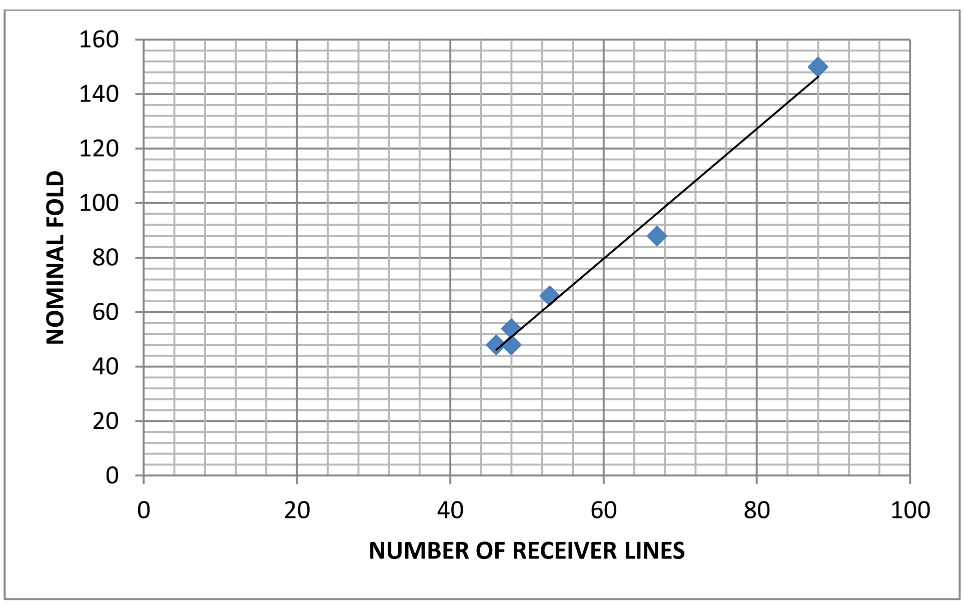

Figure 5: Nominal fold vs. Number of Receiver Lines

4. *Total Receivers* – A polynomial regression, with mathematical relationship $y = 2E\text{-}07x^2 - 0.005x + 100.8$, was observed to exist between the nominal and the total receivers as shown in Figure 6 below. Where y is the nominal fold and x is the total receivers used per sampled survey.

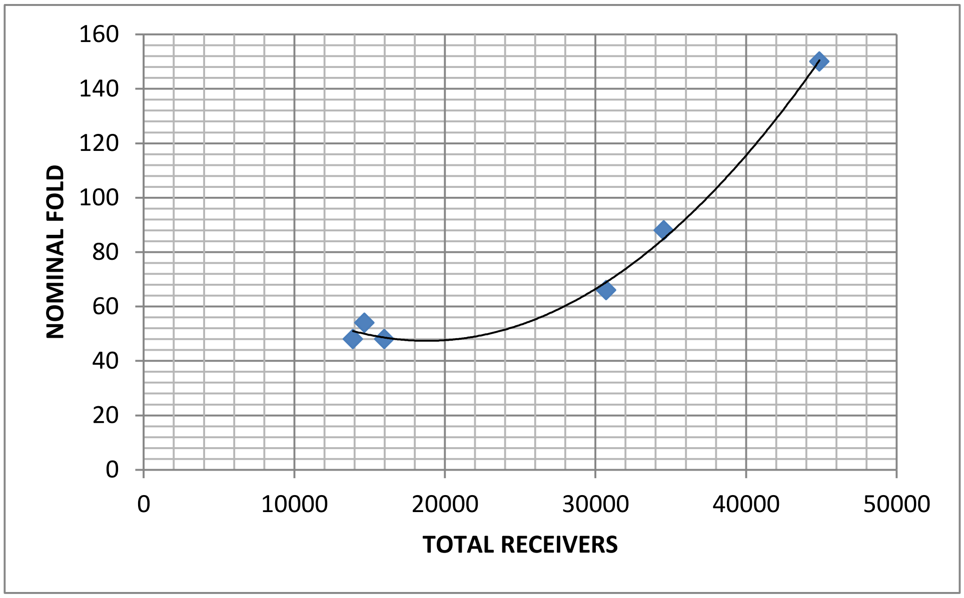

Figure 6: Nominal Fold vs. Total Receivers

5. *Receiver Line Length* – A polynomial regression trend was observed to exist between the nominal fold and receiver line length. As noticed in Figure 7 below, an increment in the receiver line length instigates a sharp rise in the nominal fold. The relationship observed to exist between the nominal fold and the receiver line length is; $y = 4E\text{-}05x^2 - 0.029x + 56.19$, where y is the nominal fold and x is the receiver line length.

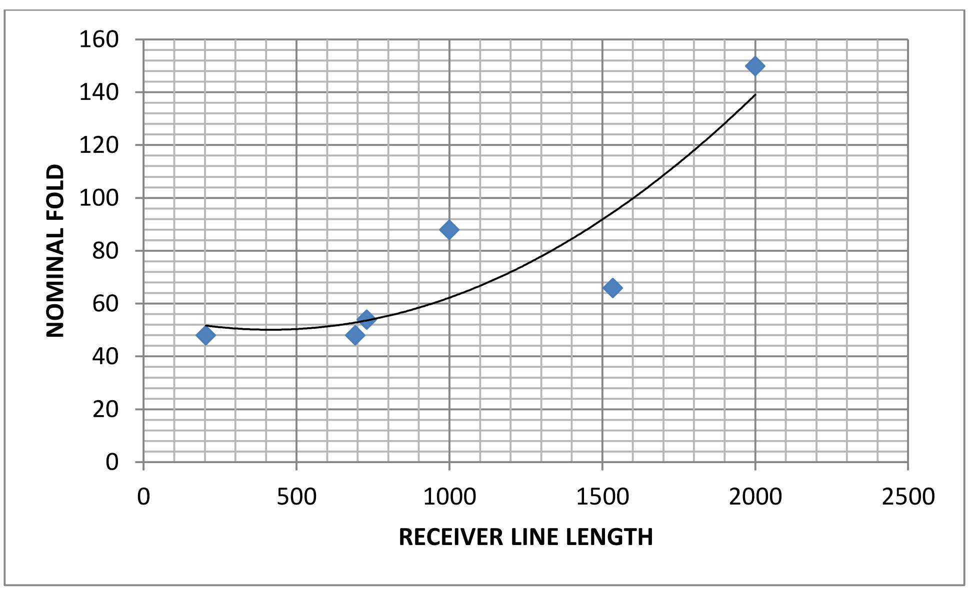

Figure 7: Nominal Fold vs. Receiver Line Length

Effects of Offset Parameters

1. *Maximum Offset* – The Maximum offset was observed to vary uniquely with the nominal fold. The relationship was observed to be polynomial, as shown in Figure 8, and can be reduced to the mathematical equation; $y = 1E\text{-}05x^2 - 0.159x + 521.2$

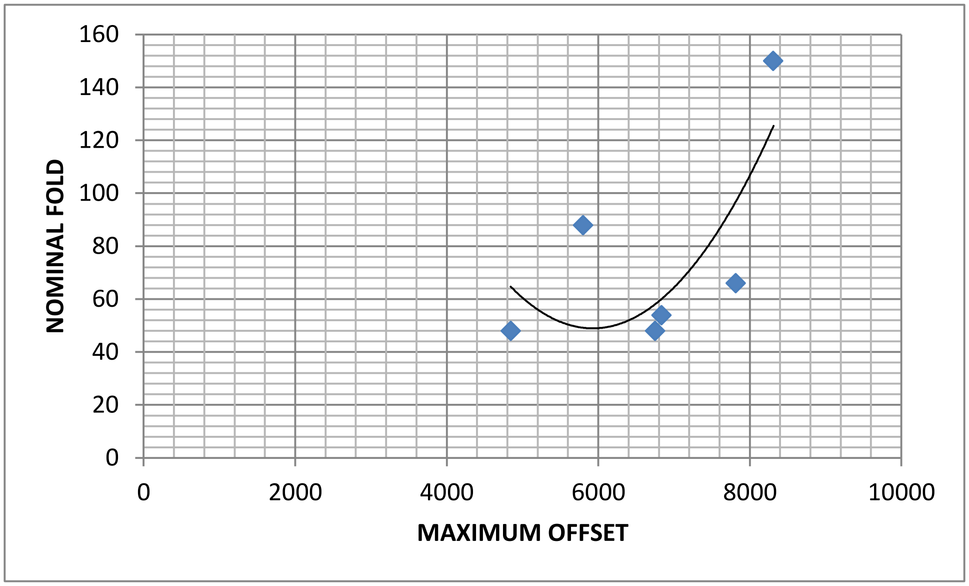

Figure 8: Nominal Fold vs. Maximum Offset

2. *Largest Minimum Offset* – As shown in Figure 8, the relationship between the nominal fold and the largest minimum offset was observed to be polynomial and can be expressed with the relationship $y = 0.001x^2 - 1.212x + 368.4$ where y is the nominal fold and x is the largest minimum offset.

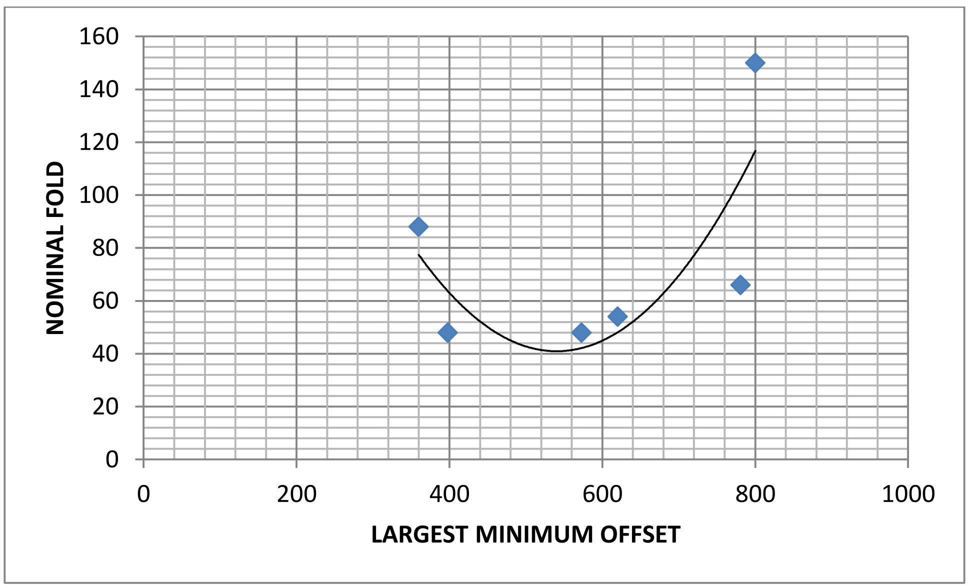

Figure 9: Nominal Fold vs. Largest Minimum Offset

3. *Minimum Offset* **–** The Minimum offset was maintained at a constant value of 35.36 for all sampled surveys while the nominal fold varied from 48 to 150. This shows that the nominal fold is independent of the minimum offset.

Conclusion

The nominal fold plays a vital role in the final outcome of 3D seismic surveys as it is a highly sensitive parameter and defines, to a large extent, the S/N ratio. Therefore, all other acquisition parameters must be tailored to maximize its value. In other words, design of 3D seismic acquisition fields in the Niger delta must be done to optimize the nominal fold coverage, as a 41% increment in signal quality can be achieved by doubling the fold value.

Based on the findings of this study, all 3D seismic acquisition parameters are relevant, but in making decisions regarding the nominal fold, the under listed parameters were observed, through the generated mathematical relationships, to greatly influence the nominal fold. These are; **line spacing** (Receiver and source line interval), **line length** (Source and receiver line length), **and total number of receivers**, the **maximum offset** and **largest minimum offsets**.

This study has provided sensitive mathematical linkages between the nominal fold for 3D seismic surveys and 3D seismic source, detector and offset parameters, through analysis of generated fit regressions. It has also pinpointed the parameters that directly control increment or decrement of the nominal fold.

In as much as other 3D seismic design parameters are equally important for a successful 3D seismic campaign, manipulation **-** using the generated mathematical relations **-** of the line intervals, line length, total receivers, and offsets at the design stage of 3D seismic explorations will aid in yielding the desired nominal fold, which will result in the improvement of the general data quality.

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