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Optimization of the stacking quality of seismic data in the onshore Niger Delta Basin by the implementation of refraction statics

Adizua Okechukwu Frank[1], Anakwuba Emmanuel Kenechukwu[2] and Onwuemesi Ajana Godwin[2]
[1]Department of Physics (Applied Geophysics Option), Faculty of Science, University of Port Harcourt, Rivers State, Nigeria
[2]Department of Geological Sciences, Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
okechukwu.adizua@uniport.edu.ng

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Abstract

The role of the derivation and implementation of refraction statics in the enhancement of the end result of the stacking procedure, which entails improving overall data quality and integrity, was investigated using a high resolution onshore 3D seismic data acquired from a prospect field in the Niger Delta Basin. The processing approach adopted to achieve the focal objective of the study was to obtain a brute stack for traces of a select common midpoint (CMP) from the data without any form of refraction statics applied. We subsequently derived an appropriate and complete refraction statics solution and applied it to the data and stacked for the same CMP, to mirror the same segment of the dataset which was then placed side by side with the initial brute stack and critically analyzed to enable us establish the role and impact of the derived and implemented refraction statics which has been applied to the data in terms of stacking result optimization. After the analysis of both stacks (brute stack and the stack after application of refraction statics), we observed that the stack after refraction statics was applied revealed a clearer subsurface image in the CMP display panel in terms of the structures and stratigraphy than in the brute stack. Potential reflectors were properly aligned with no incidence of mis-ties of reflectors, reflectors exhibited remarkable continuity. Jittery reflections around marked horizons were completely re-aligned to their actual positions on the CMP panel where refraction statics was applied than in the CMP display of the brute stack.

Keywords: Brute Stack, Stacking, Stacking velocity, Stacking Optimization, Common Midpoint (CMP), Refraction statics and Mis-tie of Reflectors.

Introduction

Seismic data processing facilitates better interpretation because subsurface structures and reflection geometries become more apparent or better defined when they are correctly performed. Simply put, the end target of seismic data processing is to generate a section which is representative of true primary reflections emanating from structures directly underneath the seismic sources-receivers in a surveyed area. This section to a very reliable and precise extend should provide true quantitative information about the geologic structures of the area being probed.

In seismic data processing with emphasis on optimizing seismic imaging quality, stacking and statics implementation are two key procedures which when correctly performed would grossly enhance the imaging objective. The term stacking refers to the summation of a collection of seismic traces from different records into a single trace[1]. This recorded trace provides insights that could be related with the path of the waves in the surface, which generates recorded events such as primary reflections, multiple reflections and diffractions. On the other hand, refraction statics (also known as statics correction) are sets of corrections applied to seismic data to compensate for the effects of discrepancies in elevation of sources and receivers, weathering thickness and velocity or reference to a datum[2]. A clear link, showing the impact of appropriate statics implementation on the optimization of stacking quality of seismic data has not been clearly established or demonstrated from our literature searches on the subject matter at this time. This paper therefore, seeks to provide this empirical link. We seek to establish the role statics derivation and implementation plays in improving the effectiveness of the stacking procedure in the quest to optimize seismic imaging of the prospect field being investigated. The impact of the implementation of statics correction on stacking quality optimization of seismic data is thus the focal aim for the present study.

We have successfully characterized the near-surface, using a hybrid and integrated strategy[3], to reveal the layer characteristics, in terms of seismic velocities and thicknesses of the near-surface over the prospect. Subsequently, the near-surface characterization result was deployed to derive a comprehensive refraction statics solution for the 3D seismic datasets from this prospect with the effectiveness of the derived solution being determined on several gathers from this same field[4]. The refraction statics solution that was sought and derived is now to be used to investigate the stacking quality optimization at the advanced seismic data processing stages of the same high resolution 3D seismic field dataset acquired from the prospect under investigation.

The prospect field is situated in the southern part of the Niger-Delta Basin, Nigeria and with huge hydrocarbon potential. The field covers an extensive area of over 151.3 square km., the terrain is predominantly onshore but with a network of rivers, swamps, creeks and adjoining canals. The vegetation over the prospect is mainly mangrove. The 3D seismic acquisition for the prospect was prosecuted in three (3) acquisition phases. Each acquisition phase covered approximately 13 swaths. The entire acquisition project was actualized with well over 28,000 shots. A Sercel recording instrument was deployed for the acquisition and the shooting geometry was a symmetric split spread configuration. Figure-1 is a map of the Niger Delta area showing the approximate location of the prospect (the black star). The inset side figure (bounded by arrows) gives an insight about the geometry and optimally high and uniform fold of the acquired 3D seismic field dataset.

The Niger Delta Basin consists of three main tertiary stratigraphic units overlain by Quaternary deposits[5]. These three subsurface stratigraphic units are the Benin, Agbada and Akata Formations. The Akata Formation comprises mainly of marine shale and sand beds. Its composition consists of primarily dark-grey sandy, silty-shale with plant remains towards the top of the Formation. It is over 1200m thick and thought to be the main hydrocarbon kitchen (hydrocarbon source rock) of the Niger Delta Basin[6]. The overlying Agbada Formation is a sequence of alternating sandstones and shales. It consists of an upper predominantly sandy section with minor shale intercalations and a lower shale unit which is thicker than the upper sandy section. The thickness is over 3000m. The Benin Formation is made up of predominantly massive, highly porous freshwater-bearing sandstone, with local inter-bed of shales. Quaternary deposits made up of top soil, red laterite, clay, fine sand, medium sand and coarse sand constitute alluvium of the Benin Formation. The thickness is variable but exceeds 1800m.

The Niger Delta basin is one of the most hydrocarbon-rich provinces in the world. Exploration and exploitation of the hydrocarbon resource have been ongoing in the region to as far back as 1956, when oil was first discovered at Oloibiri in present day Bayelsa State, Nigeria. This basin is an excellent petroleum province, ranked by the United States Geological Survey World Energy Assessment (U.S – GSWEA) as the twelfth richest in petroleum resources, with 2.2% of the world's discovered oil and 1.4% of the world's discovered gas[7]. By virtue of the size and volume of petroleum accumulation in the Niger Delta basin, various exploration strategies have evolved in the past few decades to recover the enormous oil and gas deposits locked therein.

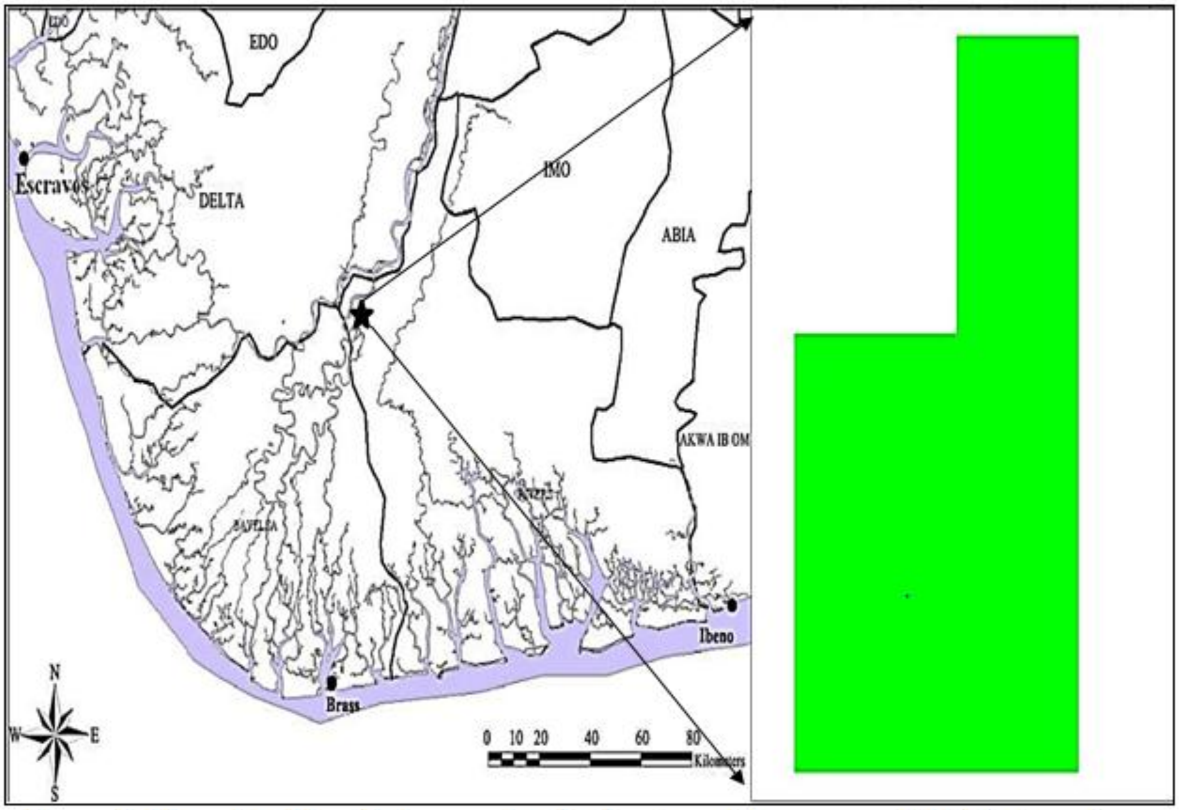


Figure-1: Map of the Niger Delta area showing location of the prospect field. The inset figure bounded by arrows gives insight to the geometry and highly uniform fold of the 3D seismic field dataset.

The concept of stacking and refraction statics and their expected outcomes

Stacking is one of the most crucial seismic data processing step[8]. The concept of "stacking" in seismic data processing is often times encountered in different stages of the processing workflow. For instance, it is encountered in summation of traces in velocity semblance, constant velocity scans – CVS, common midpoint stack, dynamic stack during velocity analysis and the summation of diffraction hyperbola in some kinds of migration algorithms[9-12]. In the seismic data processing perspective of our present investigation, we are considering the common midpoint (CMP) stacking, which is the summation of Normal Move-out (NMO) corrected traces across a CMP gather into a single trace (an ideal trace of some sought) whose signal to noise ratio (SNR) is expected to be higher than those of the individual traces within the gather.

The CMP stacking technique as it is known today was an offshoot of Mayne's idea of common reflection point horizontal stacking[13]. During the past close to six decades now, the techniques name has evolved from Mayne's original idea of common reflection point horizontal stacking to common-reflection point, common-bounce point, common-datum point, common-reference point, roll-along, common-depth point to the now generally accepted common-midpoint (CMP) stacking. A very incisive and thorough discussion of the CMP stacking technique, its principles, assumptions, violations, the chronicle of its evolution and a peep into the future of what is to be expected from this technique is well documented in Rashed, M.[12]. Kumar, L. and Sinha, D.P. have categorized the stacking procedure into sub-groups based on the type of input gathers to the stacking procedure as – i. Summing/ Mixing/Vertical stacking, ii. Common Midpoint (CMP) stacking, iii. Common Reflection Point (CRP) stacking, iv. Common Reflection Surface (CRS) stacking

The important extract from their research exposition was that currently, stacking has moved beyond CMP to CRS in a bid to improving continuity, resolution and imaging quality of the stacked section. The CRS stacking technique is a highly technology driven imaging process which uses larger stacking surfaces rather than relying on a single CMP stack location as in the conventional stacking procedure. A detailed description of this CRS technique, its parameters and applicability can be found in[15-18]. We are basing our stacking procedure on common midpoint (CMP) basis due to the constraints/limitations of our imaging hardware.

Refraction statics on the other hand, are sets of corrections applied to seismic data, to compensate for the effects of variations in elevation, weathering thickness and velocity or reference to a datum[2]. The expected outcome for applying these sets of corrections is to ascertain as precisely as possible the reflection arrival times which would have been observed if all seismic data acquisition measurements were made on a choice reference datum which is usually considered to be a flat (or close to flat) plane with no weathering or low velocity materials present[19]. The near-surface heterogeneities is an important mix which needs to be taken into cognizance and adequately modeled before mid/advance processing steps can be implemented to remedy their undesirable effects as they are capable of inducing static anomalies on the imaged seismic section. This is often times, a difficult and challenging step in the processing workflow[20-22]. However, if successfully implemented would effectively place source(s) and receiver(s) at a common datum plane, thereby ensuring that reflection events on intersecting lines appear at the same time, eliminating the undesirable occurrence of mis-tie of reflection events[20]. The reflection events also are expected to align better and assume a near-hyperbolic appearance on shot gathers as traces would have been adjusted back to their appropriate position/timings[4].

A comprehensive refraction statics correction should be an accurately calculated mix of field statics, refraction statics and residual statics (1st and 2nd residual statics)[4]. These individual component of statics correction have been extensively discussed and their applicability fully demonstrated[2,4,19,22,23-36]. However, a clear link or relationship showing the impact of statics implementation on the optimization of stacking quality of seismic data has not been clearly defined. This paper therefore, seeks to provide this connection.

Data Presentation, Field Data Characteristics and the Processing Strategy/Workflow

The seismic shot records deployed for the study (Figure 2) was an unprocessed 3D seismic data in SEG-D format acquired from the prospect field, in the onshore part of the southern part of the Niger delta basin. The dataset was extensively large, occupying a memory space of over 28GB on hard disk. Accompanying geometry (SPS) (Source – Receiver) relation information files for the prospect was equally utilized at certain stages in the processing workflow. Up-hole data gathered from an up-hole survey in the prospect were equally leveraged upon to yield a better near-surface velocity model of the prospect. Several geophysical software's (some custom and others like *PROMAX*^{TM} and *VISTA*^{TM}) were used in a very robust and high–end PC workstation for the entire processing tasks performed in the course of the study.

The seismic field data acquired from this prospect field as expected had several receiver and source lines. A very significant portion of the dataset (about 13 swaths) was used out of the full spread of over 30 swaths which were acquired in up to three acquisition phases. For illustration purposes of the subject of present discuss, inline 79 will be predominately mirrored (imaged so to speak) to demonstrate and actualize the focal objectives of the study. The entire in-line and cross-line configuration over the entire prospect field is shown in Figure-3, while our deployed processing strategy is summarized with the workflow presented in Figure-4.

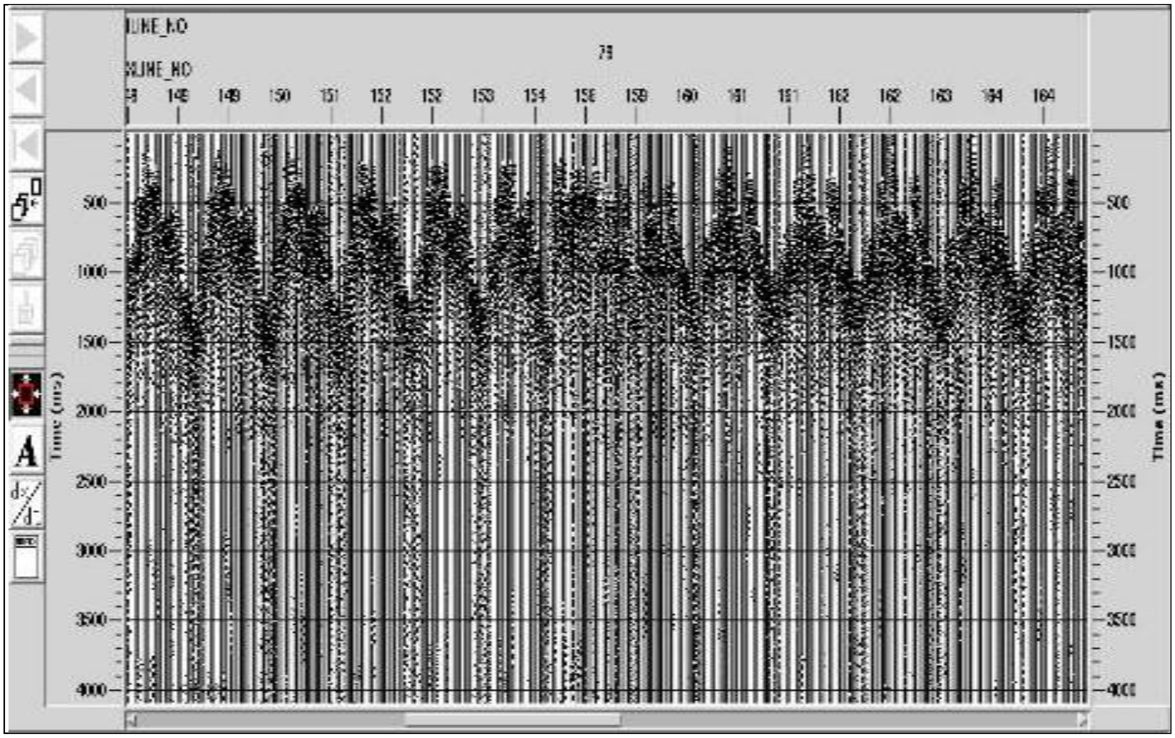
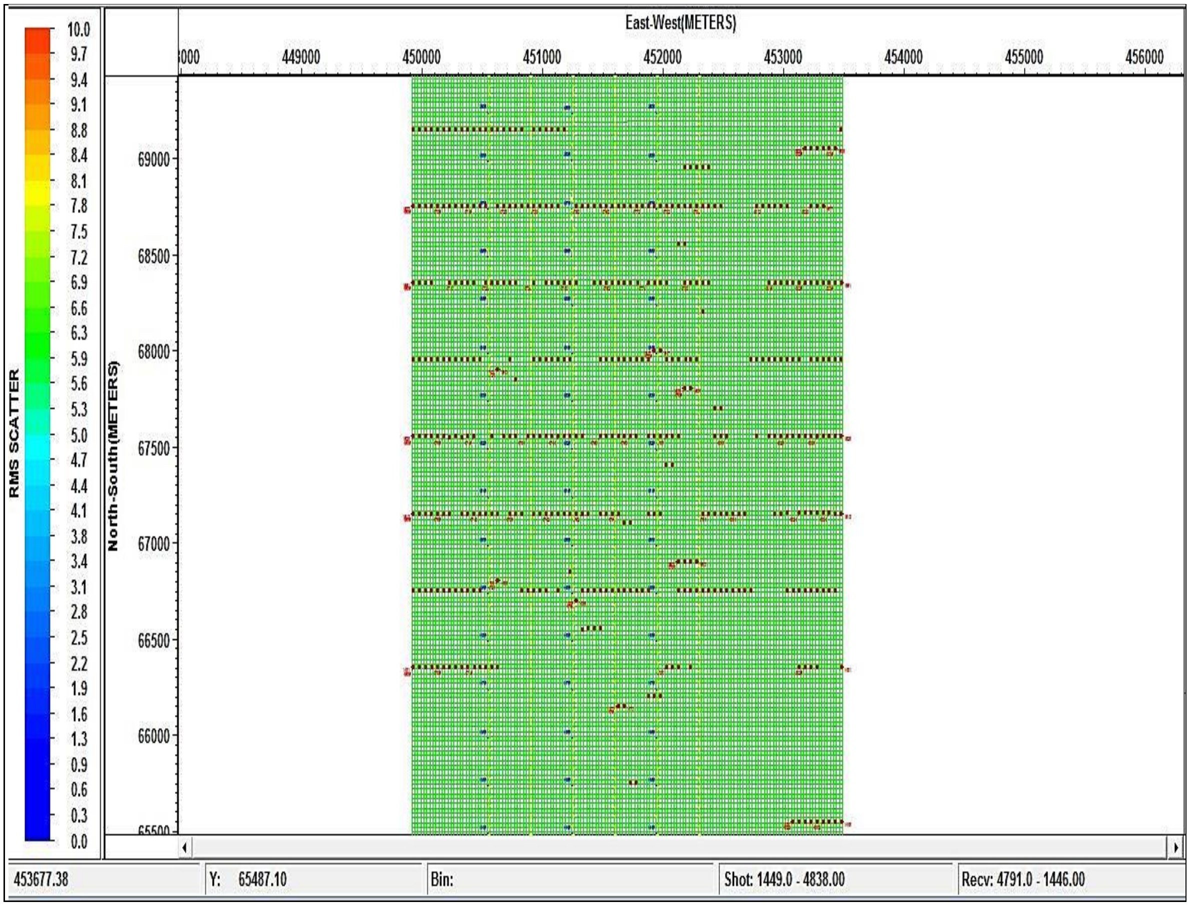


Figure-2: Display of raw shots from in-line 79 in FFID and channel number order.



453677.38 | Y: 65487.10 | Bin: | Shot: 1449.0 - 4838.00 | Recv: 4791.0 - 1446.00

Figure-3: Inline and cross-line configuration over the surveyed area.

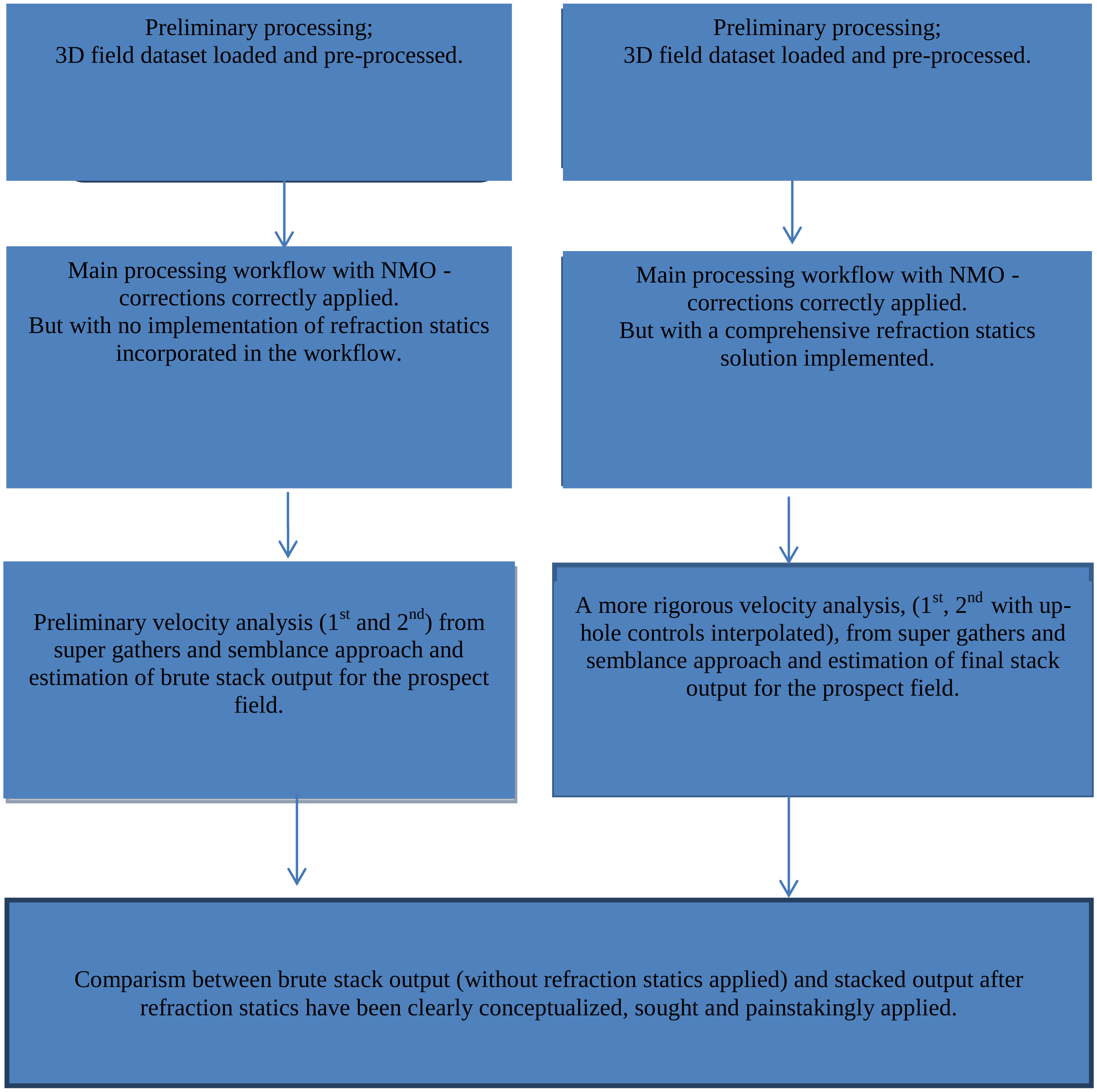


Figure-4: Summary of processing strategy adopted in actualizing the focal objectives of the study.

Results and Discussion

The near-surface model that was previously generated in[3], was carefully deployed as input parameter together with certain seismic field header information to derive a comprehensive refraction statics solution, which was a special blend of field statics, refraction statics and 1st and 2nd residual statics correction and applied to several shot gathers from the prospect to demonstrate and determine the effectiveness of the sought and derived refraction statics solution in Adizua, O.F.[4]. Details of first break picking would be minimally highlighted here, as they have been thoroughly discussed in Adizua, O.F. et al[3]. It was achieved with a neural network first break picker module on *PROMAX*™ and was subjected to adequate QC to obtain smooth picks. This first break picks gives important clues to time shifts due to spatial variation of elevation of source(s) and receiver(s) and refractor's dip as would be shown in the quantitative field (source and receiver statics) time shifts of Tables-1 and 2.

The statics values presented above show appreciable static shifts for the seismic traces for each source and receiver location at defined Source Index Number (SIN) locations and receiver stations respectively. These quantitative values are now modeled into receiver statics plots (Figure-5) and source statics plots (Figure-6) to butress at a quick glance the contribution of the source and receiver components of the field statics that was sought and applied.

Table-1: Quantitative values of the source statics components of the field statics solution before statics implementation and after statics have been derived and applied.

Before		After	
Source Index Number	Source-Statics (ms)	Source Index Number	Source-Statics (ms)
22	38	22.1	31
24	34	24.4	29
41	29	40.6	23
118	32	117.8	32
139	32	139.4	30
159	34	159.5	28
320	11	320	15
374	23	374.1	23
390	17	390.3	18
433	15	432.7	11
472	13	472.1	11
515	15	514.6	7
594	5	594.1	6
626	13	625.7	2
679	4	679	1

Table-2: Quantitative values of the receiver statics components of the field statics solution before statics implementation and after statics have been derived and applied.

Before		After	
Receiver station	Receiver-Statics (ms)	Receiver Station	Receiver-statics (ms)
118	50	118.3	35
159	36	158.6	22
181	52	180.7	52
211	25	210.9	27
235	47	235.1	40
362	22	361.9	40
430	52	430.3	39
475	21	474.6	23
533	19	532.9	20
978	35	978.8	24
1000	6	999.9	22
1016	33	1016	36
1135	30	1134.8	28
1258	22	1257.5	20
1408	26	1408.5	19

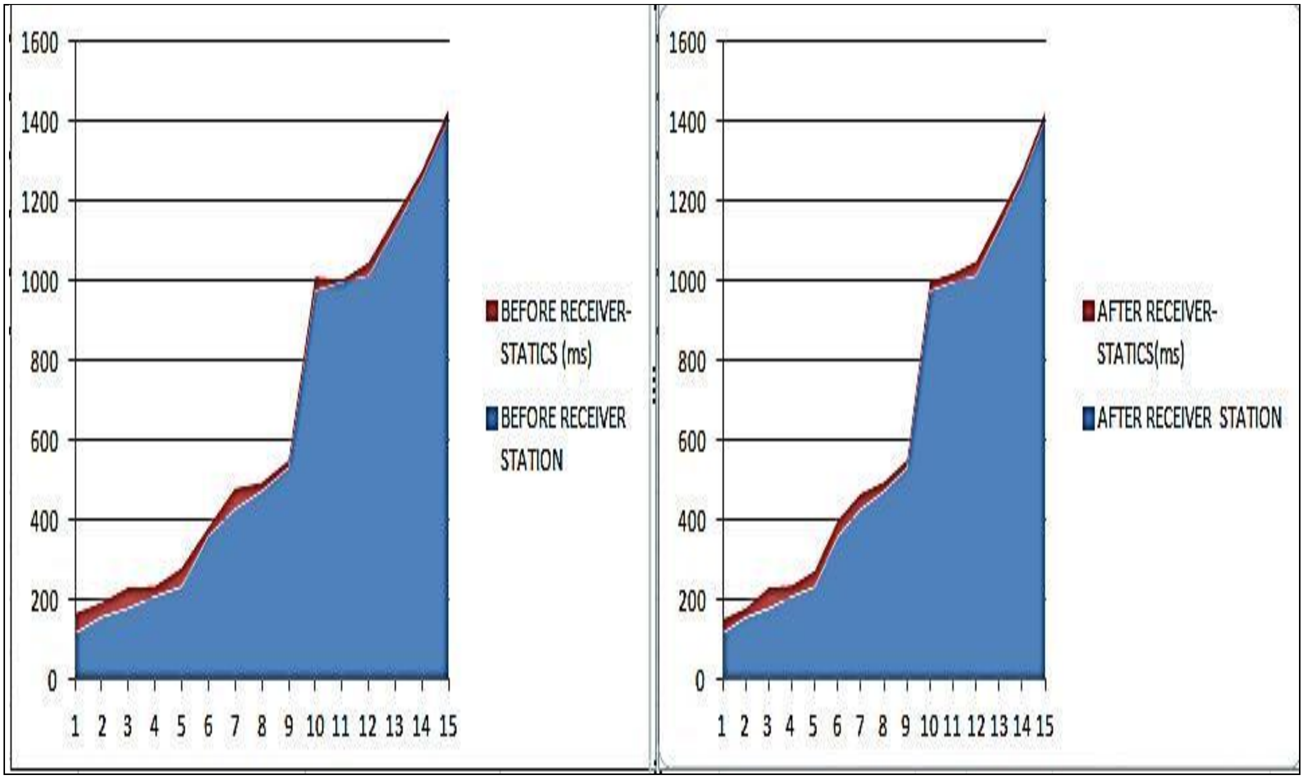


Figure-5: Receiver – statics plot of receiver statics values in (ms) versus receiver stations before and after application of the sought statics.

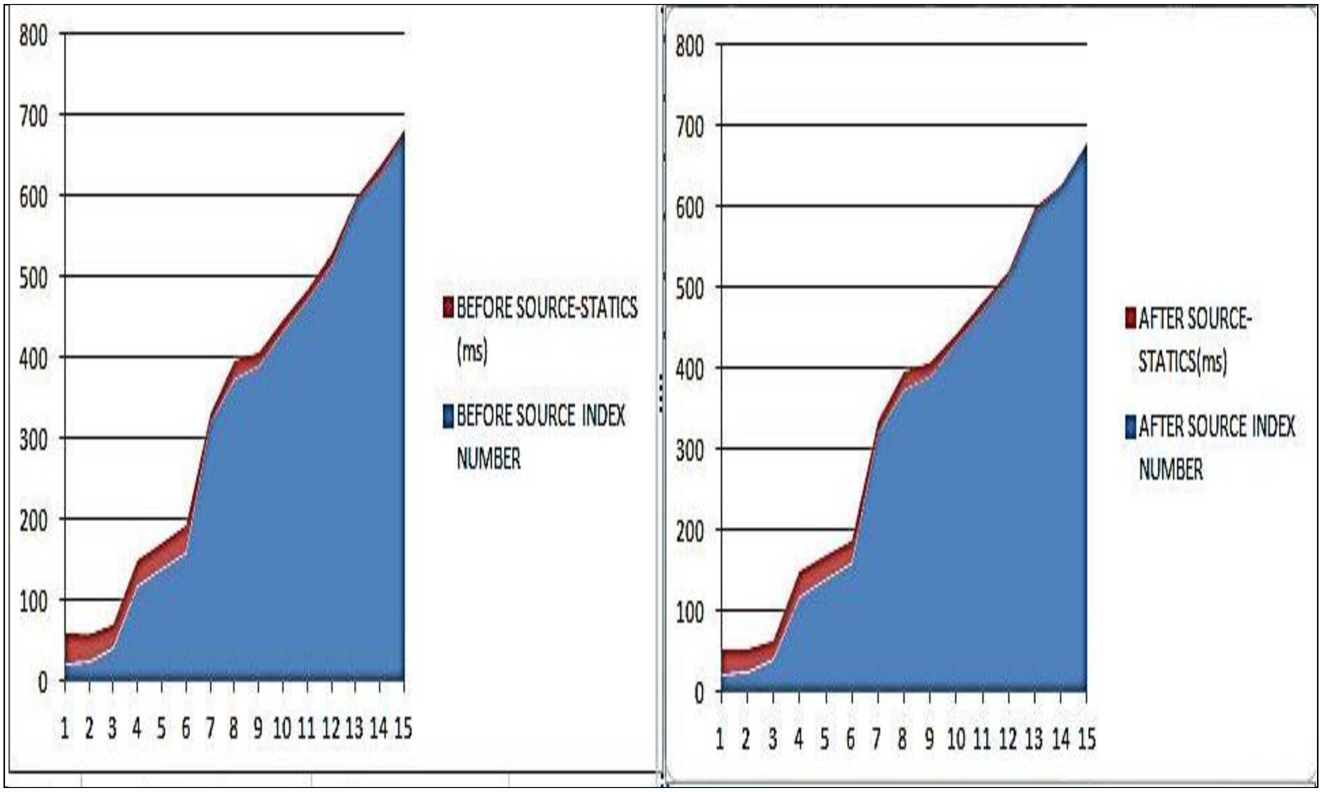


Figure-6. Source – statics plot of source statics values in (ms) versus Source Index Numbers (SIN) before and after application of the sought statics.

It is instructive to re-emphasize that the field statics derived and implemented corrected for the undulating, rugged and non-uniform topography over the prospect field or put differently, it was implemented to move source(s) and receiver(s) to a common datum. The operational domain for this component of the comprehensive statics solution was source (source statics) and receiver (receiver statics) based. Both tables earlier presented, gives quantitative statics (time shifts) values for the field statics component (source and receiver statics) derived and implemented for inline 79, showing the magnitude of statics in milliseconds (ms) at selected Source Index Number (SIN) points and receiver station locations respectively, along the chosen inline before statics application and after statics have been derived and applied. After implementing field statics, refraction statics then 1st and 2nd residual statics were derived and equally applied to the field datasets.

The principle adopted to derive refraction statics relied on supplying the first break times of all traces along each FFID (Field File Identification) into *VISTA* and *PROMAX* modules to perform refraction statics. The software modules then corrected for time in this operation and the time(s) were in sync with those in the table earlier presented. The operational domain for refraction statics is also source and receiver based. The 1st and 2nd residual statics was implemented also to cater for effects (spatial short and long wavelength) along the common depth points (CDP). Unlike the previous two statics solution which are strictly source and receiver domain operational (based), the residual statics in addition to being operational in the source and receiver domain also incorporates the CDP (common depth point) domain. This bridges potential gaps in the build up to the comprehensive statics solution which the field and refraction statics components alone may not be able to resolve.

The aforementioned preambles led to our present focal objective, which was to establish the role or impact the refraction statics plays on the optimization of the stacking quality of seismic data; the findings are hereby presented; after the demonstration of the effectiveness of the derived and applied refraction statics solution on the shot gather[4], a further step was taken by stacking the data. Stacking is basically a data compression procedure. The approach adopted was the common midpoint (CMP) stack, which sums all offsets of a CMP gather into one block trace.

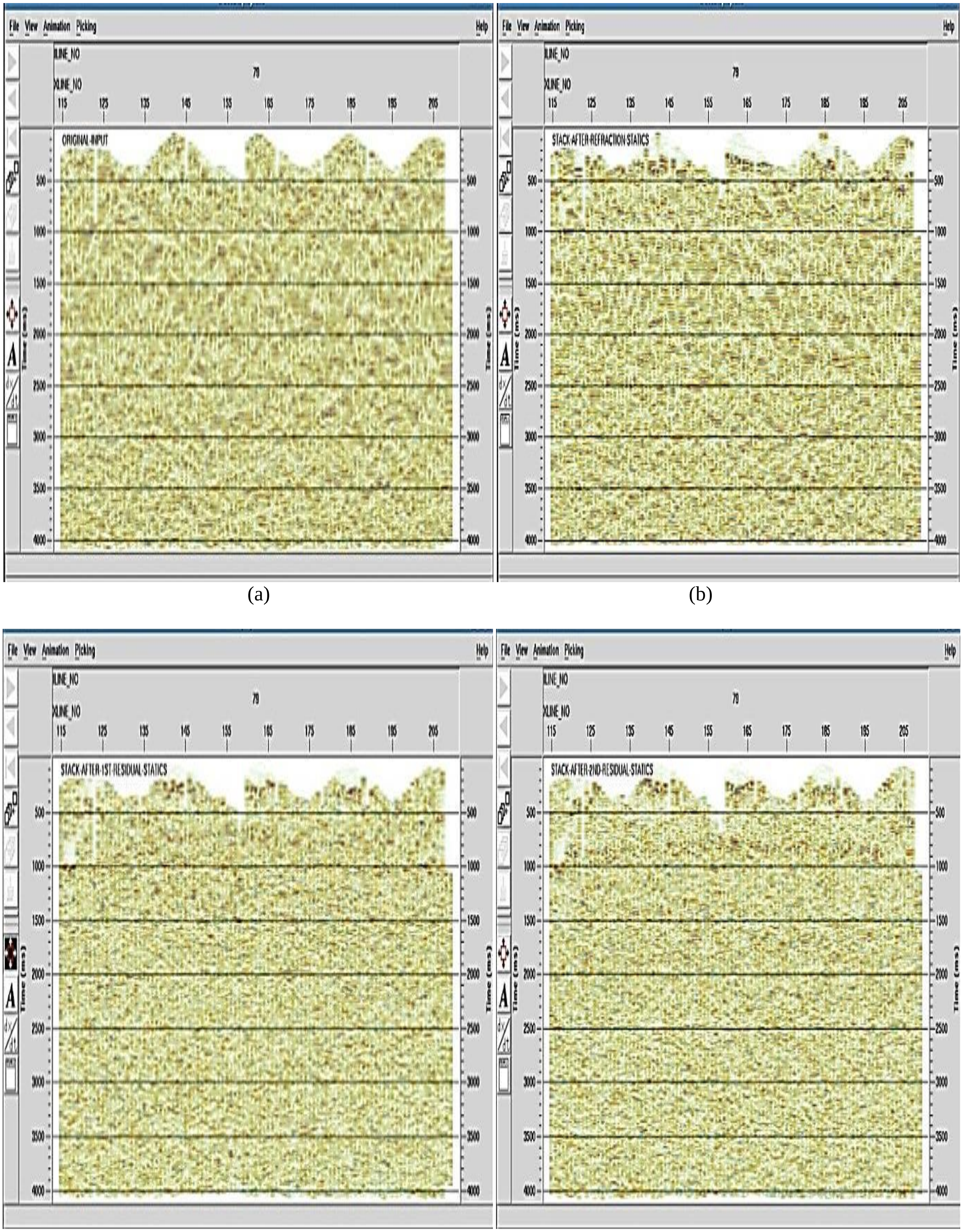
To demonstrate the effectiveness of the derived refraction statics solution, we displayed a stacked CMP in a specific in-line direction (In-line 79) without any form of refraction statics correction applied and then we applied the derived refraction statics solution to the data and stacked. After stacking, the same in-line 79 was equally extracted and displayed, to mirror the same events to see how the refraction statics solution has improved the alignment of reflection events and if the overall quality of the stacked section was sufficiently optimized. Figure 7 (a) shows a stacked section (in-line 79) without refraction statics, (b) shows the stacked section after the application of the derived refraction statics solution. The (c) part shows the stacked section after 1st residual statics and (d) the same stacked section after 2nd residual statics.

On first examination of Figure-7, the problems of refraction statics which have been resolved after the derived refraction statics solution was applied may not be easily seen by a beginner (novice) in the art of seismic data processing/ interpretation. This makes Figure-8 (a) and (b) more instructive as efforts have now been made to enlarge the already presented stacked section with annotations and markers inscribed to reveal areas were the stacked section has improved in its resolution as a result or consequence of the applied derived refraction statics solution as well as the 1st and 2nd residual statics corrections.

On a closer examination of the original input, that is, the section without refraction statics solution applied (the brute stack), spurious reflections or events at positions that were not true representation of the geology of the prospect being imaged were visibly seen. After refraction statics was applied as seen on the stack after refraction statics, events occurring at 500ms, 1500ms and 2000ms were seen to align properly and were exhibiting a better continuity.

This is a positive indication that the derived and applied refraction statics solution is the most appropriate for the prospect, and more importantly, that it has optimized the stacking quality of the seismic data being processed from the prospect. Similarly, on close examination of the section after 1st and 2nd residual statics correction (Figure-8(b)), it is equally observed that events (reflectors/refractors) are more straight or continuous and certain portions of the stacked sections with strong pseudo amplitudes (energy) were tapered to their actual amplitudes, thus improving the reliability and integrity of the dataset. This type of stacked section is the most desirable (input data type) for informed QC checks, seismic migration and detailed geological or geophysical interpretation.

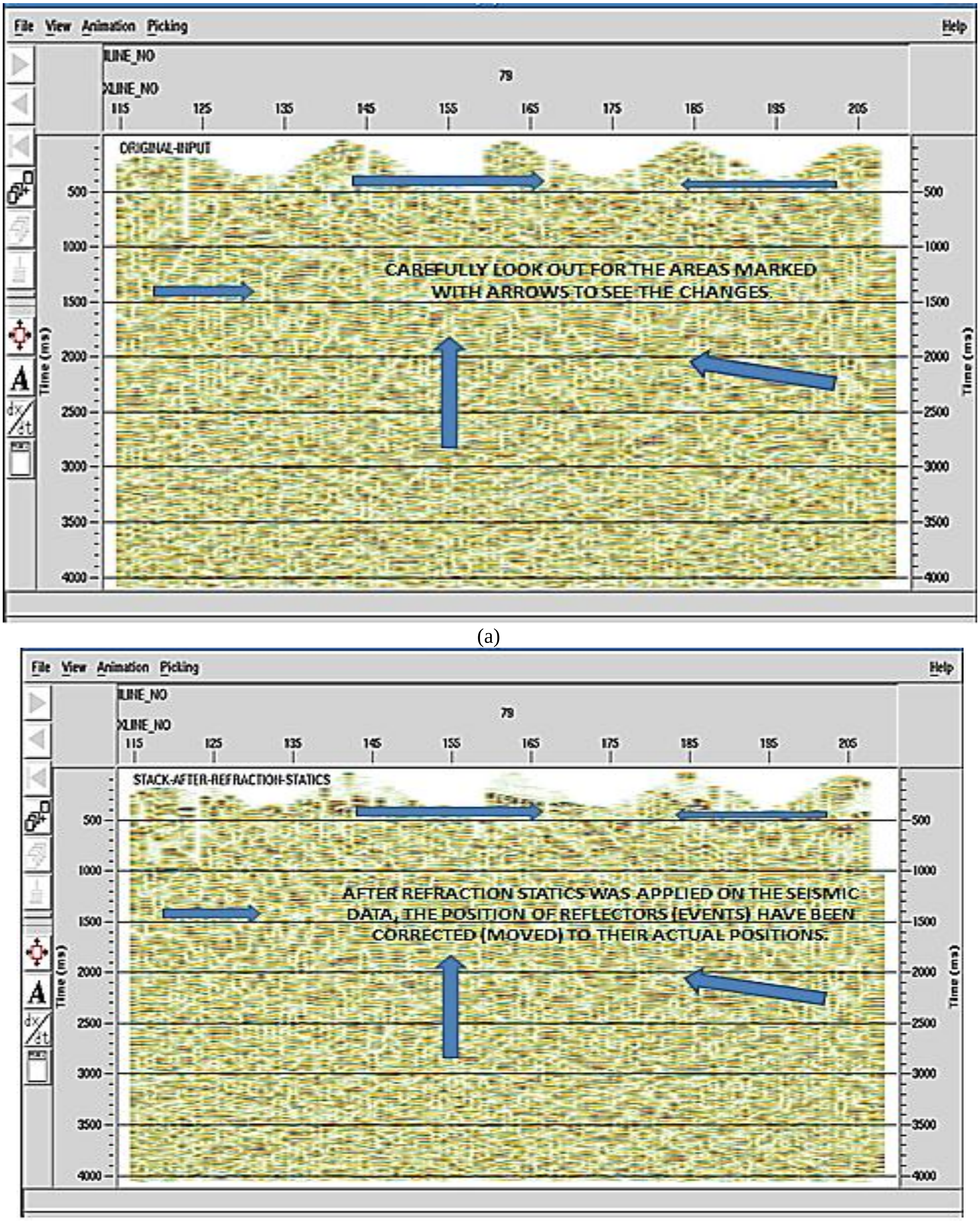
Our conviction that the derived and applied refraction statics solution has tremendously optimized the seismic data quality and integrity of the stacked section is further supported in Figure 9. in which a final step which entailed decomposition of the stacked section into time frame displays (windows) of (0 – 1.5 seconds), (1.5–3 seconds) and (3–4 seconds) was extracted and displayed for this corrections to be made more visible in support of the assertion that the derived refraction statics solution as presented in Adizua, O.F. et al[4] is the optimal solution and that it has optimized the stacking quality of seismic data from the field and thus, has fulfilled the focal objective for the present study. The (a) part of Figure-9 represents the stacked section display before (that is the brute stack) and the stacked section after refraction statics implementation at time frame (0–1.5 seconds), the (b) part is the display for time frame (1.5 – 3 seconds) while the (c) part is for time frame (3–4 seconds).



(a) (b)

(c) (d)

Figure-7: Selected slides showing (a) stacked section without refraction statics, (b) stacked section after the application of refraction statics (c), the stacked section after 1st residual statics, (d) the same stacked section after 2nd residual statics.



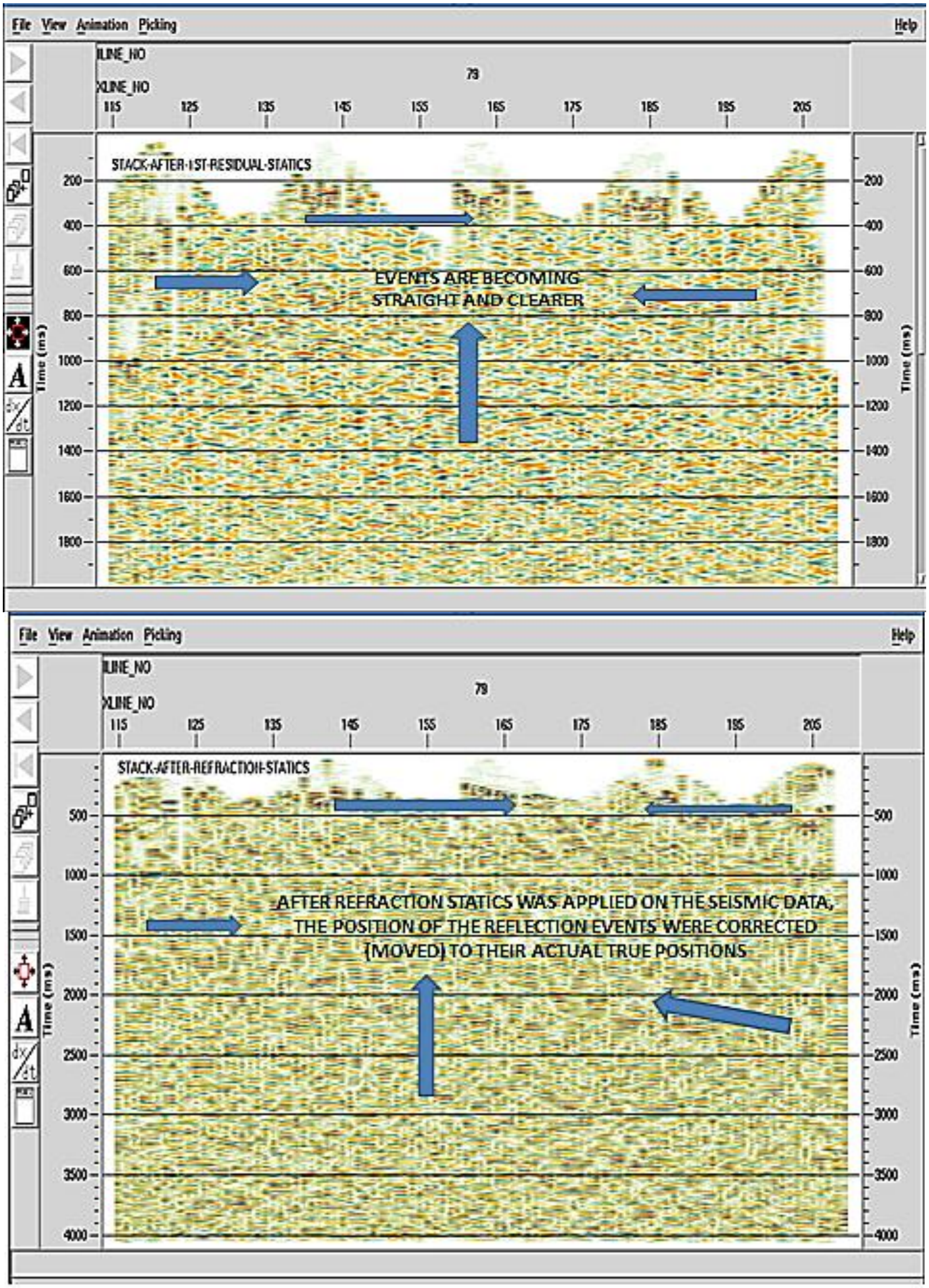
CAREFULLY LOOK OUT FOR THE AREAS MARKED WITH ARROWS TO SEE THE CHANGES.

(a)

AFTER REFRACTION STATICS WAS APPLIED ON THE SEISMIC DATA, THE POSITION OF REFLECTORS (EVENTS) HAVE BEEN CORRECTED (MOVED) TO THEIR ACTUAL POSITIONS.

(b)

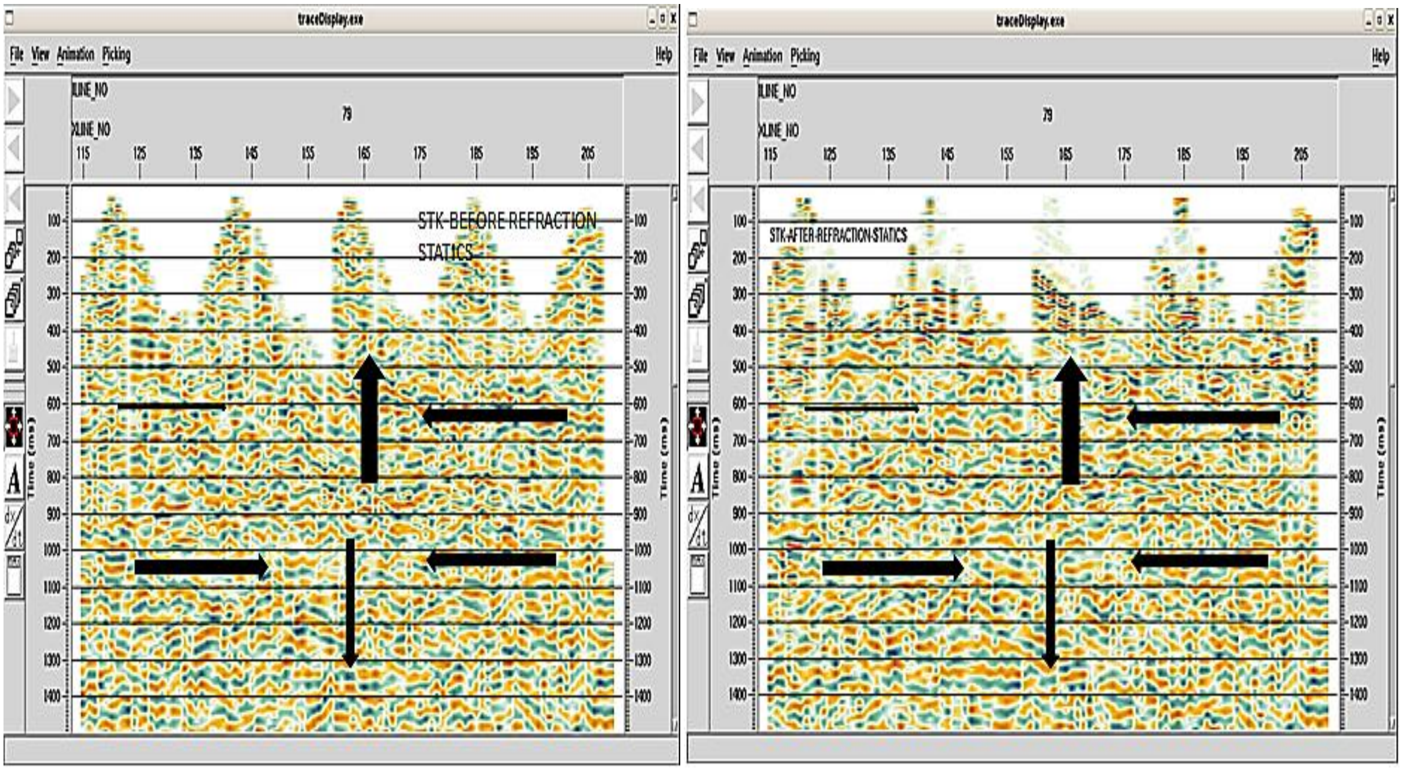
Figure-8(a): Selected slides showing with marked arrows and annotation of the resultant effect of the applied refraction statics solution on the stacked seismic section, (b) Remaining refraction statics problems are resolved with 1st and 2nd Residual Statics integrated into the refraction statics solution.



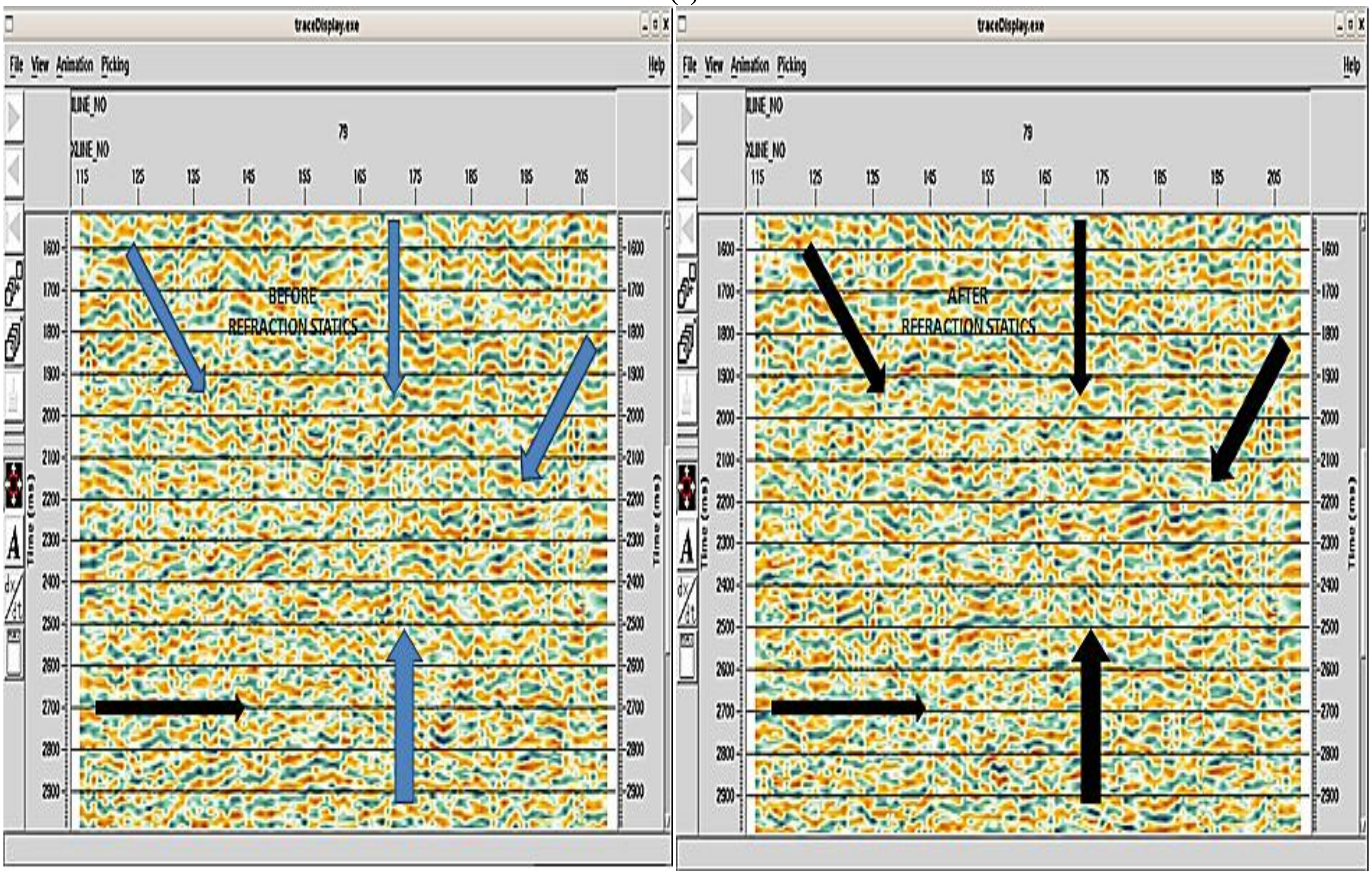
EVENTS ARE BECOMING STRAIGHT AND CLEARER

AFTER REFRACTION STATICS WAS APPLIED ON THE SEISMIC DATA, THE POSITION OF THE REFLECTION EVENTS WERE CORRECTED (MOVED) TO THEIR ACTUAL TRUE POSITIONS

Figure-8(b): Selected slides showing with marked arrows and annotation of the resultant effect of 1st and 2nd residual statics correction added to the already applied refraction statics solution on the same stacked seismic section.


traceDisplay.exe
File View Animation Picking Help
ILINE_NO
79
XLINE_NO
115 125 135 145 155 165 175 185 195 205
Time (ms)
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
STK-BEFORE REFRACTION STATICS
STK-AFTER-REFRACTION-STATICS

(a)


traceDisplay.exe
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ILINE_NO
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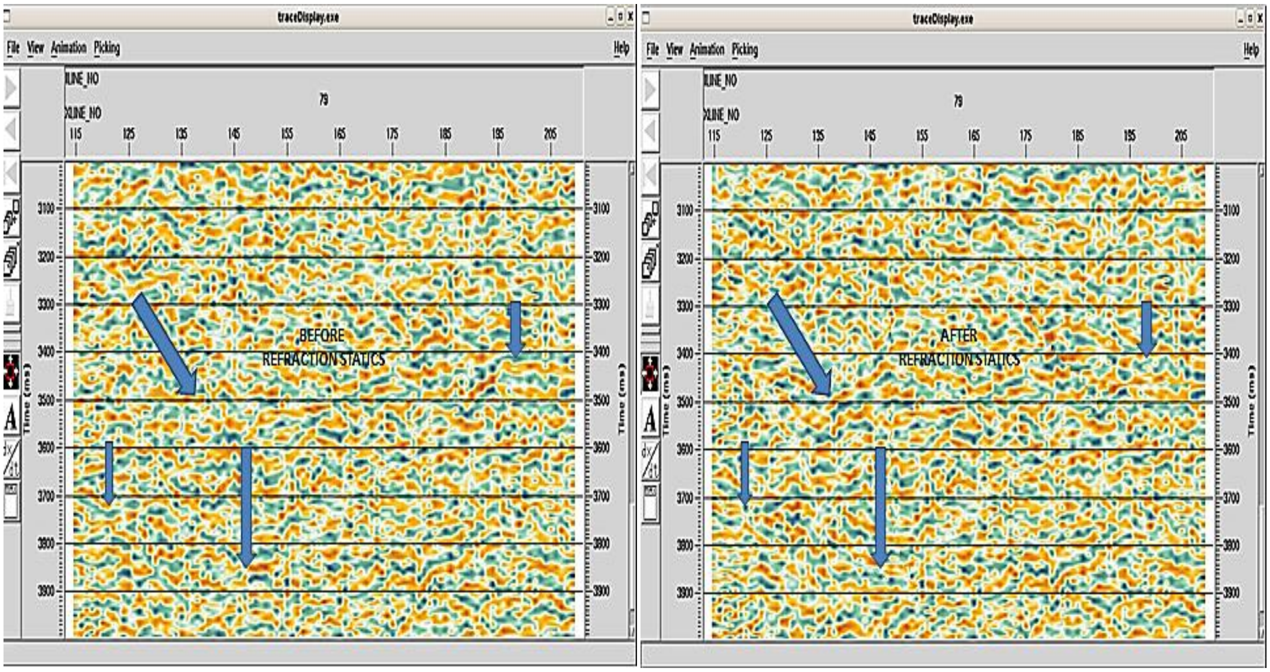
115 125 135 145 155 165 175 185 195 205
Time (ms)
1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900
BEFORE REFRACTION STATICS
AFTER REFRACTION STATICS

(b)



(c)

Figure- 9: Decomposed/Time stretched slides of stacked section before and after application of refraction statics. Time frame of 0 – 1.5 seconds is shown in (a), Time frame 1.5 – 3.0 seconds in (b) and Time frame 3 – 4 seconds in (c). The effects of refraction static are now very evident and clearly visible.

Conclusion

We have convincingly demonstrated and established a clear link between the implementation of refraction statics and the key role it plays in the optimization of the stacking quality of seismic data, using 3D seismic field datasets acquired from a high resolution seismic acquisition program in the onshore Niger Delta Basin, Nigeria. The processing strategy adopted to achieve the focal objective of the study was to obtain a brute stack for traces of a select common midpoint (CMP) (CMP – 79) from the data without any form of refraction statics applied. Subsequently, an appropriate and complete refraction statics solution was derived and applied to the same data and stacked for the same (CMP–79), to mirror the same segment of the dataset which was then placed side by side with the initial brute stack and critically analyzed to enable the establishment of a link between the impact of the derived and implemented refraction statics which has been applied to the data in terms of stacking results optimization. After the analysis of both stacks (brute stack and the stack after application of refraction statics), it was observed that the stack after refraction statics was applied revealed a clearer subsurface image in the CMP display panel in terms of the structures and stratigraphy than in the brute stack. Potential reflectors were properly aligned with no incidence of mis-ties of reflectors and reflectors exhibited remarkable continuity. Also, jittery reflections around marked horizons were completely re-aligned to their actual positions on the CMP panel where refraction statics was applied than in the CMP display of the brute stack. These indeed show that the application of refraction statics has optimized the quality of stacking results achieved in the study.

Acknowledgements

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References

1. Xie, J., Chen, W., Zhang, D., Zu, S. and Chen, Y. (2017). Application of principal component analysis in weighted stacking of seismic data. *IEEE Geoscience and Remote Sensing Letters*, 14, 1-5.
2. Sheriff, R.E. (1991). Encyclopedic Dictionary of Exploration Geophysics. Society of Exploration Geophysicists (SEG) Publication, 323p.

3. Adizua, O.F., Anakwuba, E.K. and Onwuemesi, A.G. (2019a). A Hybrid approach to near-surface imaging and characterization for an onshore Niger Delta prospect field. *Journal of Earth Sciences and Geotechnical Engineering – JESGE*, Scienpress Limited, 9(1), 1-14.

4. Adizua, O.F., Anakwuba, E.K. and Onwuemesi, A.G. (2019b). Derivation of refraction statics solution for 3D seismic data in an onshore Niger Delta prospect field. *Journal of Geology, Geophysics and the Environment – GGE*, 45(2): 1-17.

5. Short, K.C. and Stauble, A.J. (1967). Outline of the Geology of Niger Delta. *American Association of Petroleum Geologists Bulletin*, 51: 761-779.

6. Kulke, H. (Ed.). (1995). Regional petroleum geology of the world. Part II, Africa, America, Australia and Antarctica. G. Borntraeger. Berlin, (143-172).

7. Klett, T. R., Ahlbrandt, T. S., Schmoker, J. W., & Dolton, G. L. (1997). Ranking of the world's oil and gas provinces by known petroleum volumes (No. 97-463). US Dept. of the Interior, Geological Survey, Open- File Report, (97-463).

8. Yilmaz, Ö. (1987). Seismic data processing. *Society of Exploration Geophysicists (SEG) special processing manual*, Tulsa, USA. 2027p.

9. Mohanty, P., Phadke, S. and Bhattacharya, B. (2000). Seismic resolution over coal seams: A numerical study. *Acta Geophysica*, 48: 215-222.

10. Wolf, K., Rosales, D., Guitton, A., & Claerbout, J. (2004, October). Robust Moveout Without Velocity Picking. In 2004 SEG Annual Meeting. OnePetro.

11. Kostecki, A. and Polchlopek, A. (2006). Method for Correction of the Pre-stack Migration Amplitude of converted waves. *Acta Geophysica*, 54, 113-125.

12. Rashed, M. (2014). Fifty years of Stacking. *Acta Geophysica*, 62, 505-528.

13. Mayne, W. H. (1962). Common reflection point horizontal data stacking techniques. *Geophysics*, 27(6), 927-938.

14. Kumar, L., & Sinha, D. P. (2008). From CMP to CRS: an overview of stacking techniques of seismic data. In 7th Biennial International Conference & Exposition on Petroleum Geophysics. SPG.

15. Hubral, P., Hoecht, G., & Jaeger, R. (1999). Seismic illumination. *The Leading Edge*, 18(11), 1268-1271.

16. Mann, J., Jager, R., Muller, T., Hocht, G. and Hubral, P. (1999). Common reflection surface stack – a real data example. *Journal of Applied Geophysics*, 42, 301-318

17. Jager, R., Mann, J., Hocht, G. and Hubral, P. (2001). Common Reflection Surface Stack: Image and Attributes. *GEOPHYSICS*, 2001.

18. Cox, M. (1999). Statics correction for seismic reflection surveys. *Society of Exploration Geophysicists (SEG) Publication*, Tulsa – Oklahoma, 531.

19. Marsden, D. (1993). Static corrections—A review, Part 1. *The leading edge*, 12(1), 43-49.

20. Keho, T.H. and Kelamis, P.G. (2012). Focus on Land Seismic Technology: The Near-surface Challenge. *The Leading Edge*, 31, 62-68.

21. Zhu, X.S., Gao, R., Li, Q.S., Guan, Y., Lu, Z. and Wang, H. (2014). Static corrections methods in the processing of deep reflection seismic data. *Journal of Earth Science*, 25(2), 299–308.

22. Russell, B.H. (1990). Statics correction – A tutorial; a scientific publication by Hampson-Russell software services limited in the *Recorder*. 14(3), 16-30.

23. Marsden, D. (1993b). Statics corrections – a review, part II. *The Leading Edge*, 12(2), 115-120.

24. Marsden, D. (1993c). Statics corrections – a review, part III. *The Leading Edge*, 12(3), 210-216.

25. Liu, L.S. (1998). Constrained first arrival pick up and first-break residual static correction. *OGP*, 35(5): 604-610.

26. Baker, G.S. (1999). Processing near-surface seismic reflection data. A primer: Young, R. A. Series, *Society of Exploration Geophysicists (SEG)*, Tulsa, Oklahoma, USA

27. Jing, X.L. (2003). Two steps solution methods for big residual static corrections. *OGP*, 38(1), 22-26.

28. Butler, D.K. (2005). Near-surface Geophysics. *A publication of the Society of Exploration Geophysicists (SEG)*, Tulsa, Oklahoma, USA

29. Duan, Y. Q. (2006). Residual static corrections based on refraction survey. *Oil and Gas Prospecting–OGP*, 41(2), 32-35.

30. Huang, M.Z., Feng, Z.Y. and Zhou, D.T. (2008). Directly iterated statics correction method in offset domain and its application. *Progress in Exploration Geophysics*, 31(2), 122-128.

31. Bridle, R. and Aramco, S. (2009). Delay – Time refraction methods applied to a 3D seismic block. *The Leading Edge*, 28(2), 212-215.

32. Li, P., Feng, Z. and Li, Z. (2009). Statics correction technology and applications in complex areas of western China. *The Leading Edge*, 28(2), 1384-1386

33. Luo, Y.W., Yang, J. and Duan, W.X. (2010). Comparing between several statics correction methods. *Petroleum Instruments*, 24(5): 41-43.

34. Henley, D.C. (2012). Interferometric applications in static corrections. *Geophysics*, 77(1): 1-13.

35. Ponnam, S., Navin, M., Sarvind, R., Sudhakar, M. and Dutta, N.M. (2013). Field Statics estimations: A case history from North Assam Shelf, Assam, India. *A Technical paper presented at the 10th Biennial International Conference and Exposition – SOCHI 2013*, 287-291.

36. Opara, C., Adizua, O.F. and Ebeniro, J.O. (2018). Application of static correction in the processing of 3D seismic data from onshore Niger Delta. *Universal Journal of Geoscience – UJG*, 6(1), 1-7.