8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-328

An Analytical Approach to Noise Attenuation: A case Study from Interior Sub Basin, Gabon

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Summary

Seismic data processing is aimed at increasing the signal to noise ratio to produce an interpretable image of the subsurface. Raw shot gathers are generally contaminated by the presence of coherent and incoherent noise that masks the primary reflection events of interest for faithful and confident reconstruction of the subsurface. The buzzword is therefore to enhance the signal to noise ratio with approaches and methodologies that do not hurt the basic character of the seismic dataset. Various generic and conventional processing workflows in use do not assure in producing good image of the subsurface in presence of rough topography, near surface and subsurface velocity variations & complex geology among others, which happen to be the characteristic of the area under study. Therefore, selection of optimal set of processing parameters and judicious use of various noise removal schemes assumes primary significance for arriving at geologically conformable output sections.

A case study from interior Sub Basin, Gabon is presented in this paper. The study delves in the methodology employed for removal of spatially varying ground roll masking the signal, selection of optimal deconvolution scheme for enhancement of temporal resolution, robust static solutions, estimation of velocity filed, choice of migration algorithm followed by discussion on the resulting stack and migrated section.

Out of the various algorithms available for noise attenuation and deconvolution it was observed that Surface wave noise attenuation followed by surface consistent deconvolution and spectral balancing of the dataset resulted in clean gathers for subsequent processing. The objective of processing was realized as the subsurface image could be mapped with confidence and the results were found to be conformable with the geology of the area.

Study Area & Regional Geology

The study area, 'SHAKTI' (FT2000), is geographically situated in northeastern part of oil rich country Gabon and is a part of the less explored interior sub basin. Block 'SHAKTI' of approximately an area of 3760 sq. km is logistically difficult due to undulated terrain covered with thick equatorial forests, undergrowth, river/lake/swamps and non-availability of approach roads (Figure 1). The Block 'SHAKTI' (FT2000) is located adjacent to the main continental basement margin within the Interior Sub-basin. This basin is essentially an asymmetric graben along the axis of which is a major westward dipping longitudinal fault known as Axial fault (Figure 2).

The main structures in the Interior Sub Basin are Lambarene Horst, and the Axial Fault. The Sub-basin consists of a narrow, north northwest – south southeast trending asymmetric rift basin that formed in the early Cretaceous . It is proximately 120 km long and 60 km

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wide, bound to the east by Precambrian basement, and to the south west by the Precambrian Lambarene Horst, and is filled with up to 3000 meters of Cretaceous sediment. The basin is shallowest to the east and thickens towards the Lambarene Horst in the west. Source rocks have been identified in the Bokoue & Bikoume formations and in the Bifoun Formation from several wells in the FT2000 block. Good quality reservoir sands have been found in the M'Vone, N'Dombo/Kekele, Fourou-Plage and Gamba formations within the Interior Sub-basin. The Ezanga evaporites form a seal for the Gamba reservoirs in the western part of the basin (e.g. Remboue field). Elsewhere in the basin the seal above this reservoir is likely to be poor. The Fourou-Plage will be sealed by the surrounding Lobe shale. The Deeper N'Dombo/Kekele reservoirs will be sealed by the Kango Bokoue and Bikoume shales (the main source intervals in the block).

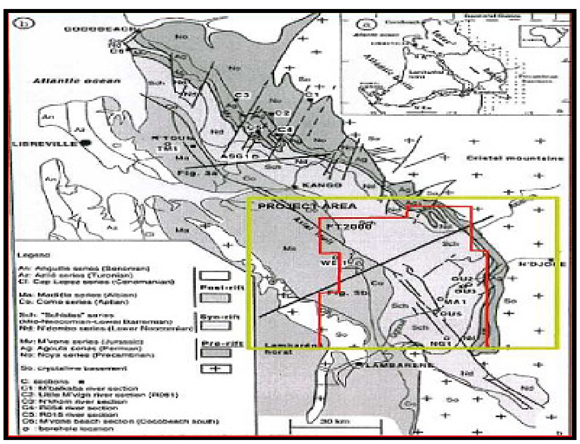

Figure 1: Location of the study area

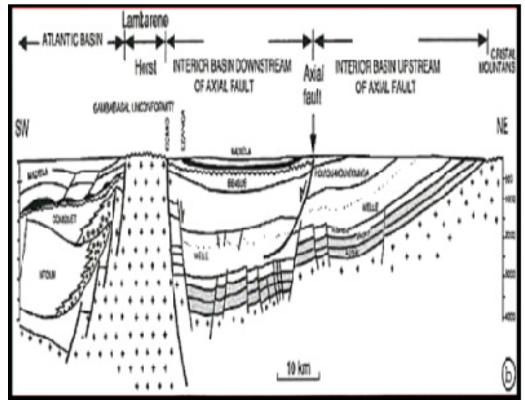

Figure 2: Gelogical Cross Section

Seismic Data Acquisition

The 2D seismic lines acquired in the block 'SHAKTI' (FT2000) are shown in the seismic coverage map in the Figure 3. The 2D seismic data acquired with 80 fold is characterized by spatially varying strong coherent (Ground roll and linear noise of dispersive nature) and random noise masking the signal. Receiver array has been used to minimize the linear noise. The challenging surface conditions and complex subsurface geology and the presence of shallow high velocity (laterally varying) layer masks the energy penetration, resulting in poor S/N ratio. The reflection events are shallow in time and buried by strong coherent noise.

The test line, in this study taken for seismic data processing is a strike line acquired in SW-NE direction.

Acquisition Parameters:

Recording Instrument	408 UL
Geometry	Symmetric Split spread
No of active channels	320
Source	Explosive
Source Interval	40 m
Receiver Interval	20 m
Foldage	80
Near offset	10
Sampling Interval	2 ms
Anti-alias filter	200 HZ
Charge Size	2.5 kg
Charge Depth	10 m
Shot pattern	single hole

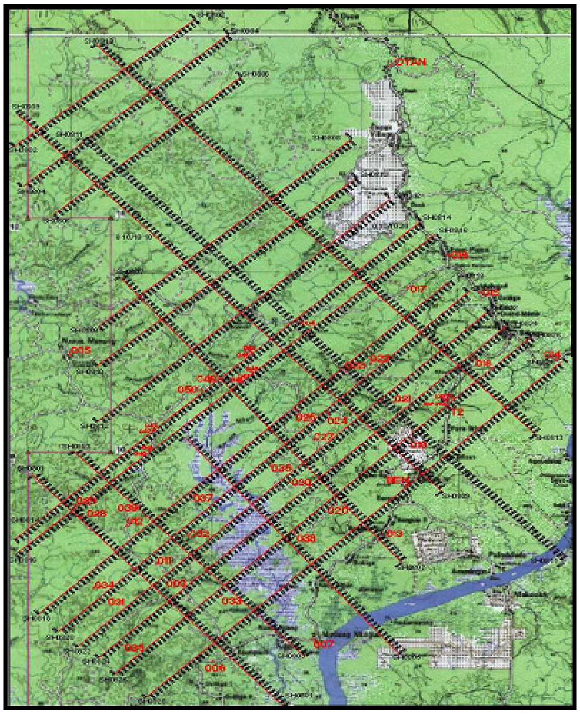

Figure 3: Seismic Base map of block SHAKTI

Seismic Data Processing

Since the raw shot gathers in the area under study were contaminated with spatially varying source generated noise, the first initiative was to arrange shot records exhibiting nearly similar characteristics under different subsets/group in terms of their spatial location. These groups were then analyzed for key characteristics viz, amplitude, amplitude spectrum, frequency, velocity etc. to arrive at the noise suppression schemes that addresses them in the best possible manner. It was observed that random noise could be controlled effectively utilizing a generic suppression scheme however, the coherent noise varying with space required different parameters for the groups. Therefore, Surface wave noise attenuation with different parameters was applied on the groups to eliminate the undesired events.

The shot gathers on the far end (south west) part of the line exhibited very poor energy penetration, it was inferred from geological information that it was primarily due to the exposure of the basement on the surface. The onset of energy (First breaks) is found to varying along the profile for shot gathers suggesting the changes in the near surface lithology, variability of the weathering layer thickness and rapid variation in elevation along the profile. Statics, solutions therefore need to be computed and applied with caution to have robust solution that depicts the real near-surface and subsurface features. Field statics and refraction statics were tested on the line and refraction statics were found to be giving better results.

Different processing tests on raw shot records and comparison of their results suggested that the best way to suppress ground roll and other coherent noises is to apply surface wave noise attenuation, surface consistent Deconvolution and spectral balancing on trace by trace basis. In surface consistent Deconvolution out of all four components (source, receiver, offset and earth's impulse response) only shot and receivers portions were used to design the Deconvolution operator and they were found to be giving good results.

The following key processing steps improved the data significantly:

1. The general statics problem encountered in this area is due to rapid variation in elevation of source and receivers along the profile, variable thickness and velocity of the weathered layer. To compensate for these variations, field statics were computed using the weathering velocity gathered from uphole & LVL data plus shot depth. On the other hand statics solution was also estimated from refraction statics method. The near surface velocity model with refraction statics was calibrated with the solution from uphole & LVL data and it was finally observed that refraction statics is giving better statics solution than field statics.

2. Surface consistent deconvolution followed by spectral balancing is one of the most effective and essential key in improving the data quality in the present study. Surface consistent deconvolution significantly improved the section by suppressing ground roll, broadening signal band width and also aided in good velocity picks due to improved semblance on gathers.

3. Velocity analysis was carried out iteratively at a very close interval of 200m because of rapid lateral velocity variation and velocities were picked very precisely to get an accurate stacking velocity field.

4. Channel consistent residual static correction further resolved the statics error caused by rapid variation in near surface lateral velocity & thickness and improved the continuity of reflectors.

5. Dip move out gave more accurate stacking velocities correcting for lateral dip variations and coherent noise attenuation; this improved the velocity estimates which enhanced the lateral resolution.

6. Pre stack time migration using the DMO velocities in the previous step improved the imaging of subsurface and increased the continuity of reflectors by collapsing the Fresnel zones to a true reflection point especially in the shallower part of the stack section.

Results and Discussions

The raw shot gathers is contaminated with source generated noises (e.g. direct, refracted, surface and air waves) and spatially varying strong coherent noise (ground roll & linear noise dispersive in nature) that hinder the signal (Figure 4).

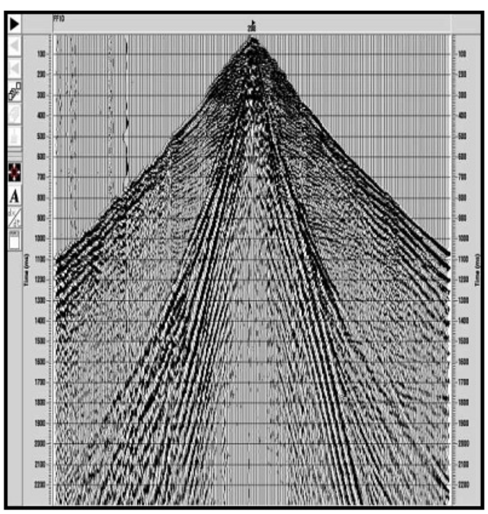

Figure 4: Raw Shot Gather

The efficacy of Surface wave noise attenuation and SC Deconvolution in attenuating the noise on trace by trace basis illustrated in fig.5. The figure clearly indicates that surface wave noise attenuation and SC Decon has suppressed the ground roll effectively, enhanced the signal and shows significant amplitude balancing.

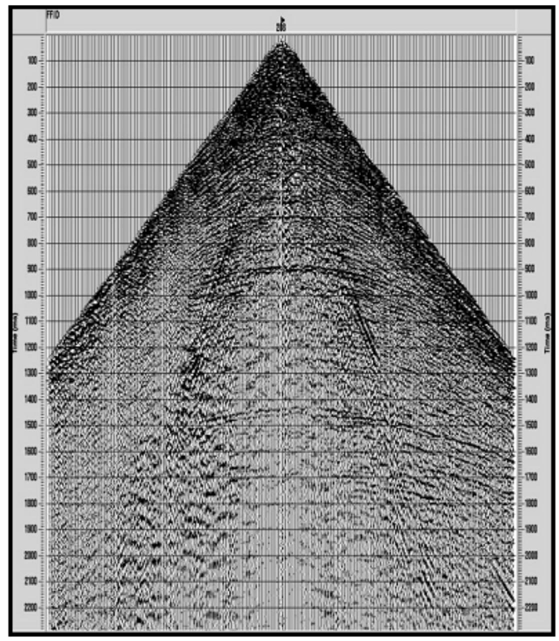

Figure 5: Shot Gather after noise removal

The efficiency of preprocess is also clearly evident on the velocity semblance panels. Figure 6 shows the velocity semblance without SWNA, SC decon & Spectral balancing, whereas Figure 7 illustrates the same with all the processes applied. Improvement in velocity analysis is clearly evident on the later.

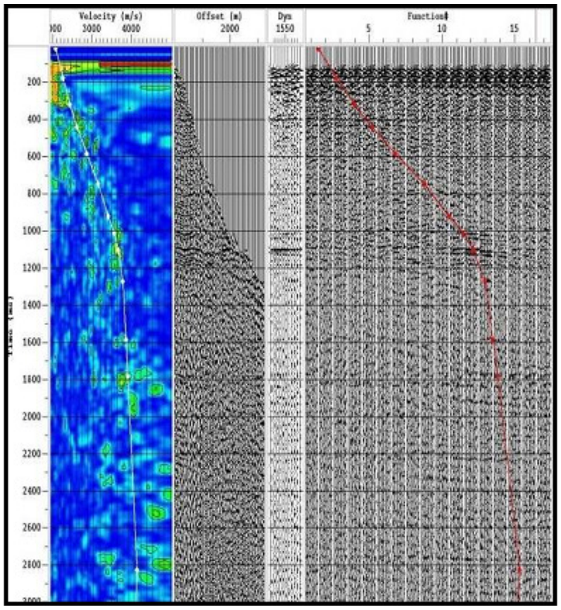

Figure 6: Velocity Analysis Panel with conventional preprocess gathers

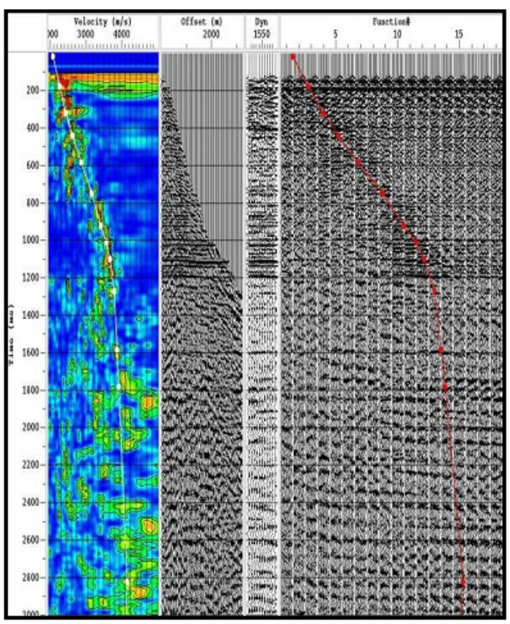

Figure 7: Velocity Analysis Panels with surface consistent deconvolution applied gathers

Stacking with this improved and accurate velocity picks brought out better continuity and resolution of events suppressing random noise. Fig 8 & 9 are a comparison between stacks obtained using conventional preprocess gathers to that obtained using surface consistent deconvolution. The application of channel consistent residual statics with iterative velocity analysis resulted in further improvement of the section in terms of overall continuity and alignments.

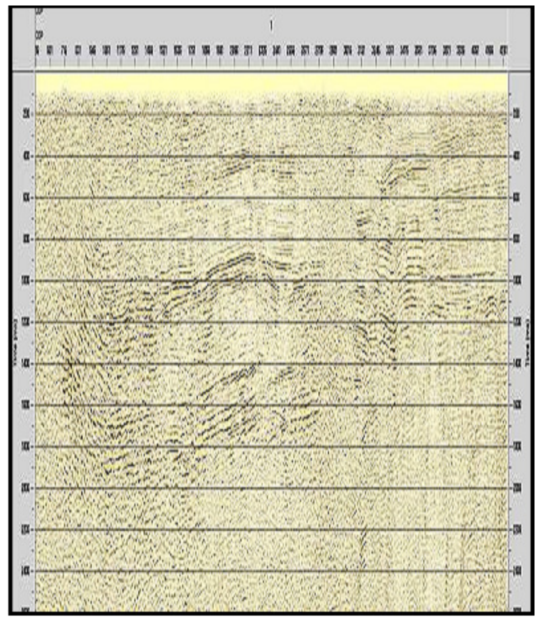

Figure 8: Stack section obtained using conventional Processing

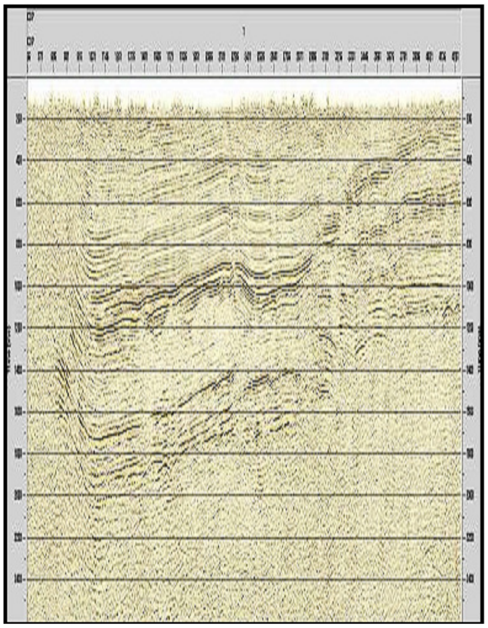

Figure 9: Stack section obtained using SC Decon

DMO applied velocity analysis panels shows significant enhancement of semblances which were otherwise difficult to pick & analyze. It is inferred that besides taking care of dip the process has additionally helped in reduction of noise as well. The semblance panels for the same are shown in Figure 10. Stacking of data post DMO analysis has resulted in resolving seismic events in areas of conflicting dips with higher fidelity and increased the overall spatial resolution of the stack section as indicated in Figure 11.

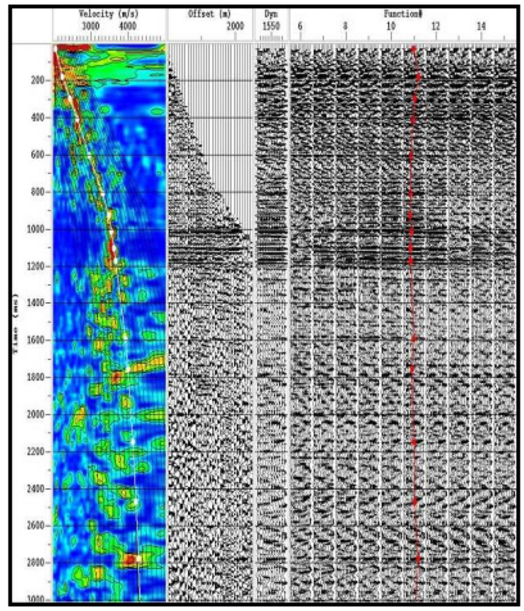

Figure 10: Velocity Analysis Panels with DMO gathers

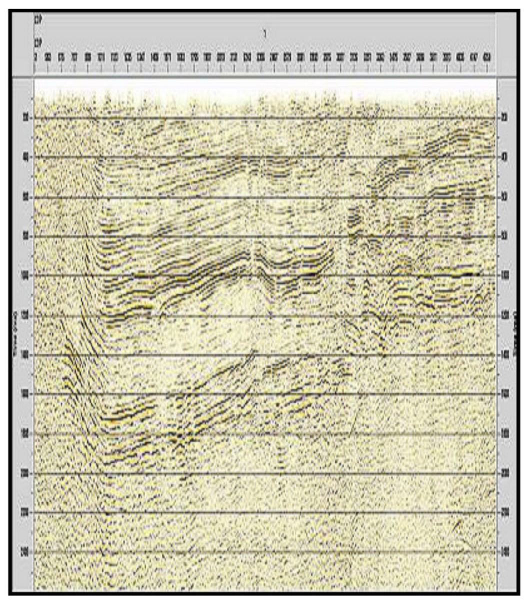

Figure 11: DMO stack section

It is further observed that PSTM stack section (Figure 12) with DMO velocity as the initial input followed by migration velocity analysis resulted in a more reliable image of the subsurface.

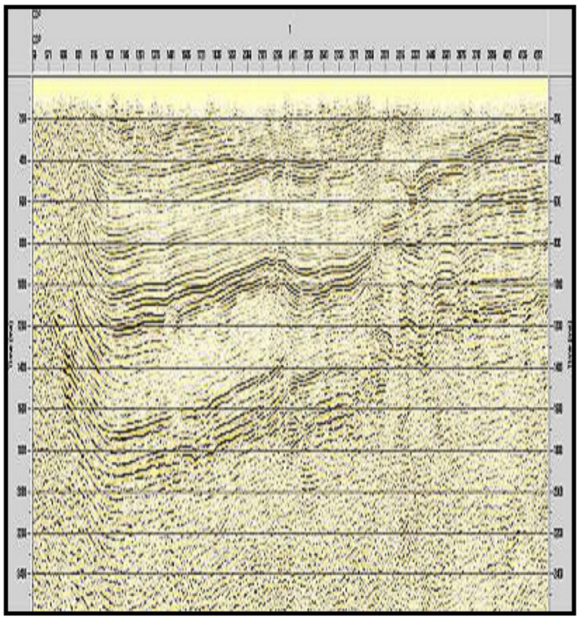

Figure 12: PSTM stack section

Conclusion

The quality of raw seismic data acquired in interior sub basin is constrained due to severe statics problem, complex subsurface geology, poor energy penetration & severe source generated noise. Despite all the above challenges, careful preconditioning of the dataset using fit for purpose workflow and processing parameters, notable among them being surface consistent deconvolution and spectral balancing, a geologically conformable image of the subsurface could be faithfully reconstructed.

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Acknowledgements

This paper appears with the kind permission of management of Oil India Limited for allowing this article to be submitted. The authors express their sincere gratitude to Shri K. K. Nath, GM (Geoservices) for giving opportunity to work on this project. Special thanks are due to colleagues for their immense support.