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THE APPLICATION OF EDGE DETECTION TECHNIQUES TO MODEL AND 3D FIELD DATA USING SEISMIC SEMBLANCE AND CEPSTRAL DECOMPOSITION

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ABSTRACT: *Faults are critical to the accumulation of hydrocarbon and manifest themselves asabrupt, gradual or gentle changes of seismic amplitude. However reliable hydrocarbon entrapment in the presence of numerous subtlesub-parallel faults and their identification with computer–based algorithm is a major challenge.Fault detection technologies have proven to be important tools for seismic interpretation. Traditionally, edge detection techniques such as coherency algorithms, derivative methods, semblance,etcin time domain are employed in evaluating faulted hydrocarbon prospects by examining trace to trace similarity in data. These are inherently noisy. In frequency domain,spectral decomposition, requiring the use of a time window e.g. Fourier transform (FT),Hilbert transform(HT),Maximum entropy(ME),etc are used to unmask subtle events. However, these have high sensitivity to noise, weak frequency resolution arising from applied windows, and computational truncation, and are therefore unreliable. This has led to the need for improved techniques. We present the results of the application of amplitude-derived Semblance and Cepstral decomposition to model and 3D field data from the Niger Delta. The Semblance measures localized similarity while the Cepstrum is the Fourier transform of the log of the spectrum of the data and transforms the data from frequency to Quefrency domain. The attributes provide new improved information on the seal risk of hydrocarbon prospect. Our algorithm is based on fast Fourier transform convolution techniques. It was developed from basics and outside oil-industry interpretational platforms using standard processing routine such as Matlab,Gnuplot, Surfer. The results of the algorithm, when implemented on both oil-industry IHS Kingdom Advanced and general platforms were comparable and convincing. The Cepstral decomposition of the thin bed reservoir revealed subtle sub-parallel faults and provided an enhanced level of evaluating the seal risk on prospect. This will facilitate improved reservoir production and performance.*

KEYWORDS: Fourier transform,Maximum Entropy,Cepstrum,Semblance, Homomorphic,Depobelt

INTRODUCTION

Hydrocarbon prospects that are faulted have special risks because faults can cause leakage from hydrocarbon accumulations or provide lateral seal. Data interpretations usually end after identifying the fault plane in the wrong belief that the fault plane itself creates a lateral seal. However an important element of entrapment is the presence of numerous subtle sub-parallel faults. The identification of the faults in the absence of clear break of horizon or diffraction particularly with a computer-based algorithm is a major challenge. (Downey, 1990)

In this study, we present the results of the application of amplitude-derived semblance and cepstral decomposition to model and 3D field data from the Niger Delta. The cepstrum is the Fourier transform of the natural logarithm of the Fourier transform of the data and transforms the data from the frequency

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to quefrency domain, while the semblance measures localized trace similarity. Cepstral domain analysis separates source and transmission path effects and provides new improved information on the seal risk of hydrocarbon prospect by revealing the presence of multiple sub-parallel faults capable of increasing the probability of up-dip lateral seal for hydrocarbon traps. This is to guide prospect evaluation in fault –trapped prospect.

Geologic Setting

The source of our data is the Niger Delta region of which the 'X' –basin is a part is a prolific hydrocarbon province formed during three depositional cycles from middle cretaceous to recent in Nigeria. The recent Niger Delta has the continental, transitional and marine environments comprising braided streams, meander-belt systems, floodplain basins, barrier bars, fire sand, silt and clay. Most of the hydrocarbons are in the sandstones of the Agbada formation, mostly trapped in roll over Anticline, fronting growth faults (Figure 1). The shales create lateral and top seals (Short and Stauble1967). The reservoirs of this formation are typically channels and barrier sandstone bodies and values of porosity and permeability are generally high (up to 40% and 1-2 Darcys respectively).

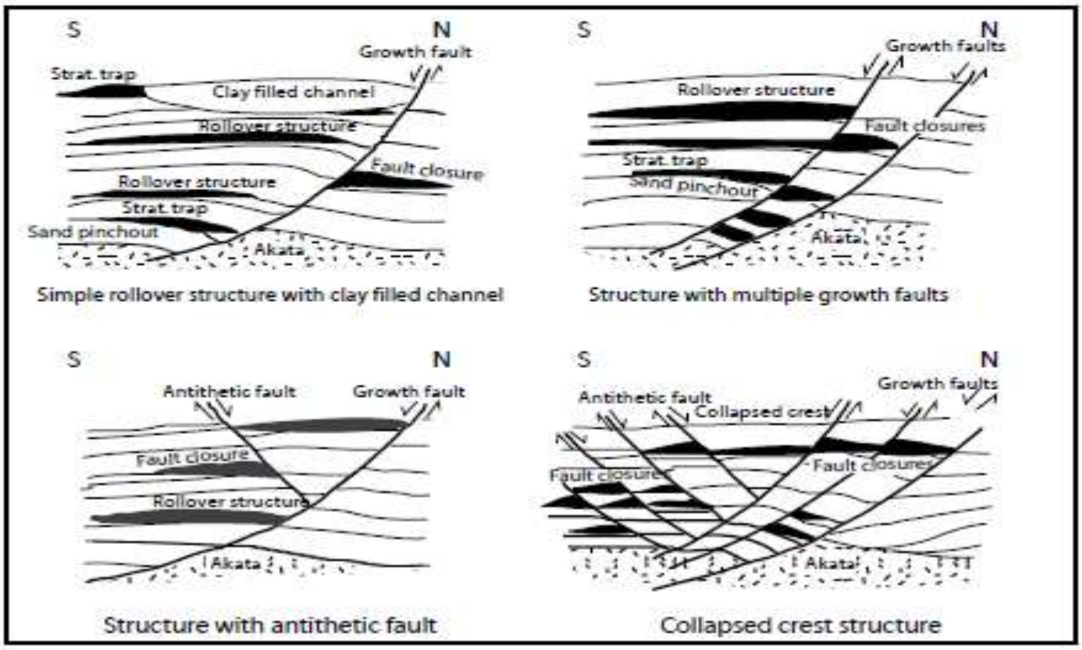

Figure1: Examples of Niger Delta Oil Field Structures and AssociatedTrapTypes.
Modified from Doust and Omatsola(1990) and Stacher(1995).

Basics

Semblance

This edge detection attribute is a more meaningful quantity than the coherence attributes (E_t),whichmeasures edges over a narrow window. According to Tanner et al. (1979), semblance (S_t) denotes the ratio of the total energy of the stack, within a gate of length Δt, to the sum of the energy of the component traces within the same time gate. Using the terminology above, we can write semblance as

$$S_t = \frac{\sum_{t=t}^{t+\Delta t}(\sum_i x_{ti})^2}{\sum_{t=t}^{t+\Delta t}\sum_i (x_{ti}^2)} \qquad (1)$$

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The semblance attribute will not only tend to be large when a coherent event is present but the magnitude of the semblance will also be sensitive to the amplitude of the event. Thus strong events usually exhibit large semblance and weak events will exhibit moderate values of semblance while incoherent data will have very low semblance. (Taner et al., 2009, Ofuyah et al, 2014).

Cepstral Transform (CT)

Cepstral decomposition extends the widely used process of spectral decomposition. It measures bed thickness even when the bed itself cannot be interpreted (Hall, 2006). Spectral decomposition maps are typically interpreted qualitatively using geomorphologic pattern recognition or semi quantitatively, to infer relative thickness variability Spectral decomposition is rigorous when analyzing subtle stratigraphic plays and fractured reservoirs.

The Cepstrum can be defined as the Fourier transform of the log of the spectrum. Given a noise free trace in time (t) domain as x (t) obtained by convolution of a wavelet and reflectivity series r and assuming X (f), W (f) and R (f) are their frequency domain equivalents, then ,Since the Fourier transform is a linear operation, the Cepstrum is

F [ln (mod X)] = F [ln(mod W) + F[ln (mod R)]   (2)

The Cestrum is useful because it separates source and filter and can be applied to detect local periodicity. There is a complex cepstrum (Oppenheim, 1965) and a real Cepstrum.. The complex Cepstrum method used here is employed to recover signals generated by a convolution process and is called Homomorphic deconvolution (Oppenheim and Schafer, 1968).

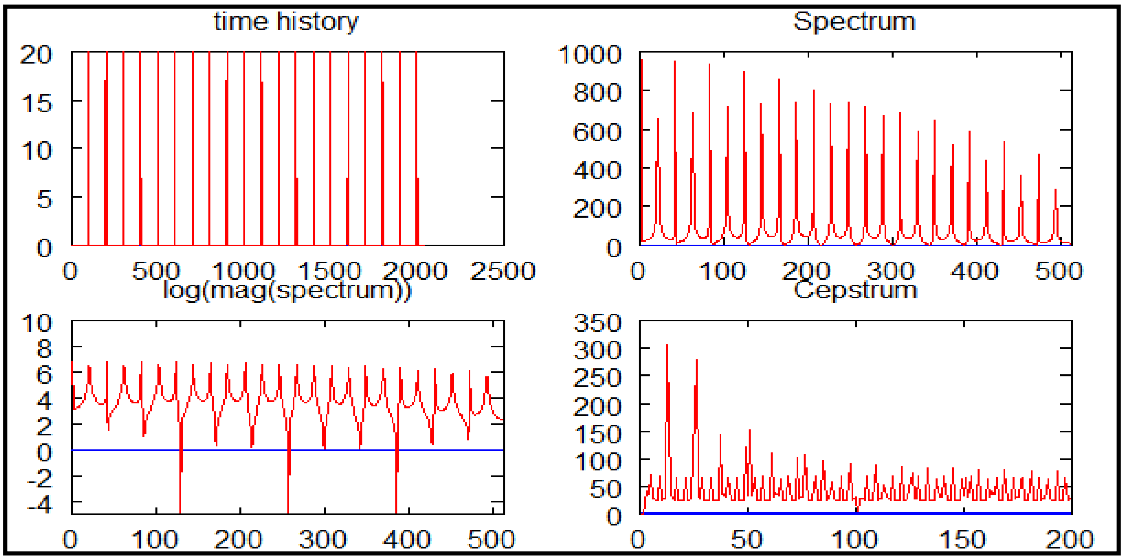

Figure 2: Cepstrum and Spectrum compared with original data and log of magnitude of its spectrum (Source: Wikipedia Free Encyclopedia,2017,*https://en.wikipedia.org/wiki/Cepstrum*)

METHOD

The method adopted is fast Fourier transform convolution techniques. The algorithm was tested by computing the semblance attribute of a three-layer geologic model of a fault using a 40Hz Ricker wavelet for simulation. The faulty bed in the model is a low impedance medium embedded in a high

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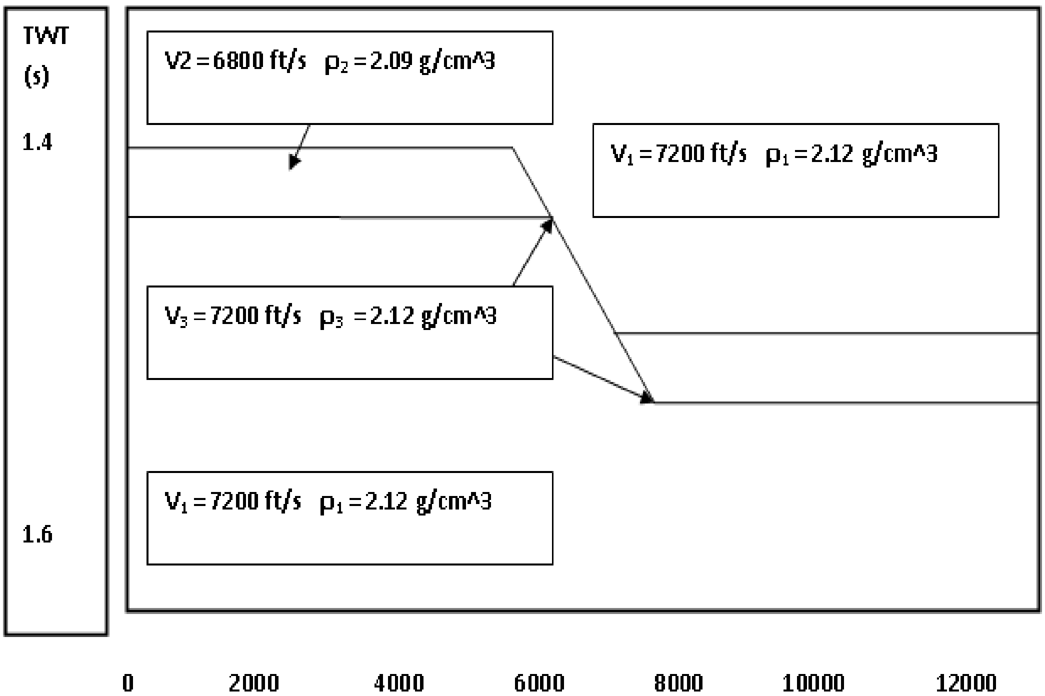
impedance medium. The geologic features were analyzed to include stratigraphic and near-vertical structural features by using a long analysis window centered on the top of the fault interval. Cepstral decomposition of the field data was computed by taking the Fourier transform of the natural logarithm of the Fourier transform of the data following the treatment by Hall, 2006.

RESULTS AND ANALYSIS

The results obtained are shown in Figures 3, 4, 5, and 6. (Figure 3) shows the computed model including its geometry and seismogram. The amplitude and phase spectra, and gamnitude and saphe cepstra are presented as Figure 4, while Figure 5 shows the semblance section using different displays.The semblance attribute will not only tend to be large when a coherent event is present but the magnitude of the semblance will also be sensitive to the amplitude of the event. Thus strong events usually exhibit large semblance and weak events will exhibit moderate values of semblance while incoherent data will have very low semblance. (Taner et al., 2009). In Figure 5, High semblance (Blue) indicates strong and coherent events, weak events exhibit moderate values (Yellow) of semblance, while incoherent data has very low (Green) semblance

Application to Model Data



Distance (ft)

(a) Geometry of Geologic Model of a Fault

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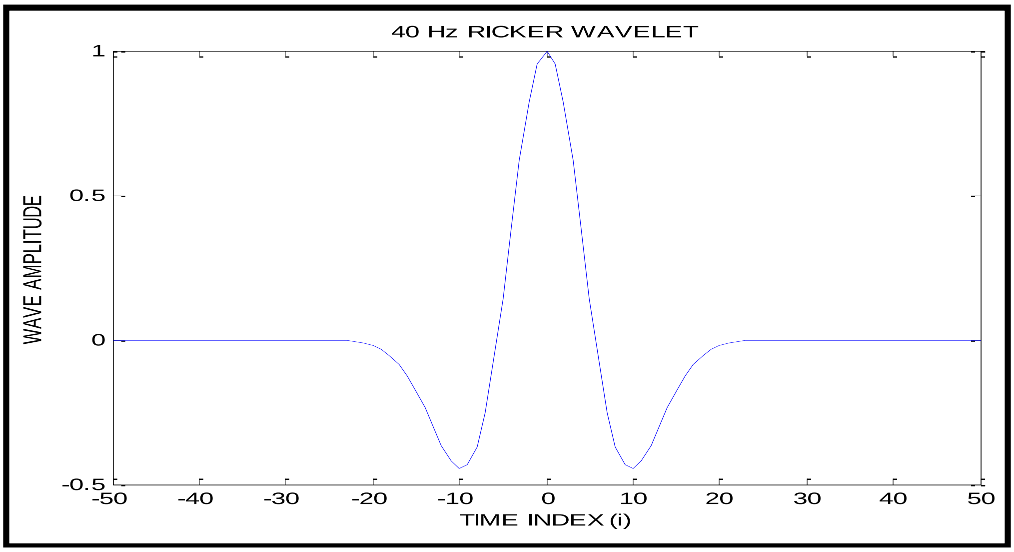
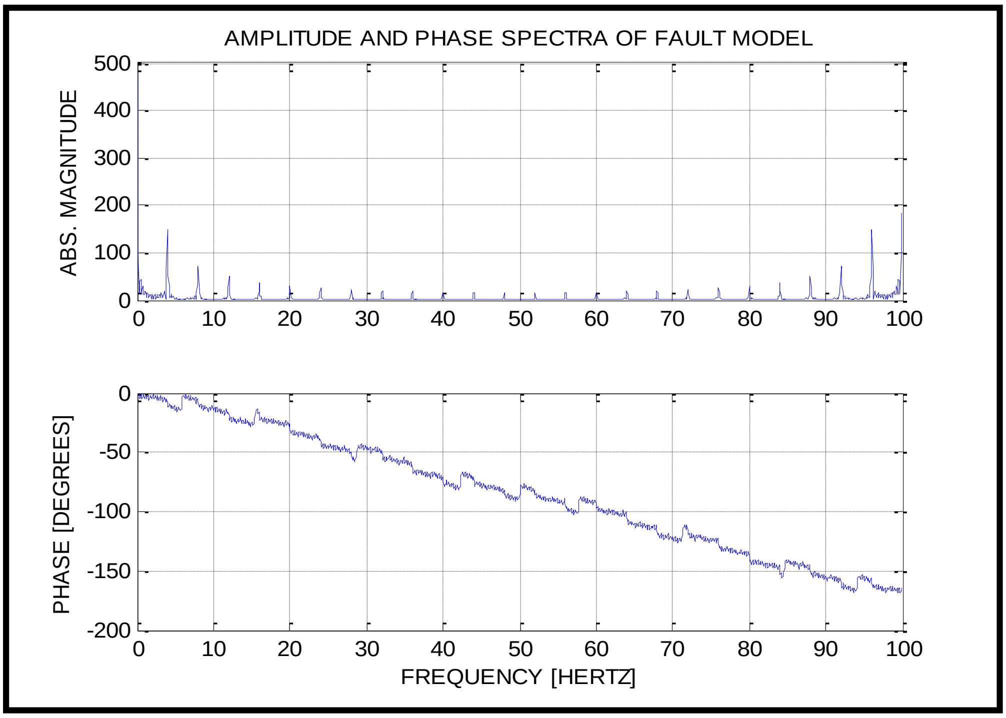


(b) 40 Hz Ricker Wavelet used for the Simulation

Figure 3: (a) Geometry of Geologic Model of a Fault (b) 40 Hz Ricker Wavelet used for the Simulation



(b) Amplitude and Phase Spectra of Model. The amplitude recovery here is not discernible**.**

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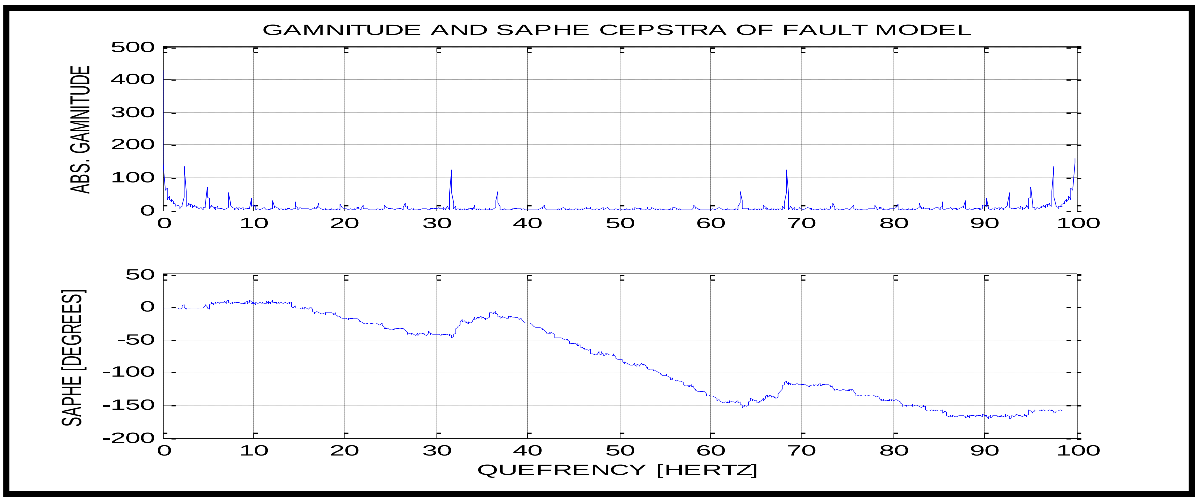
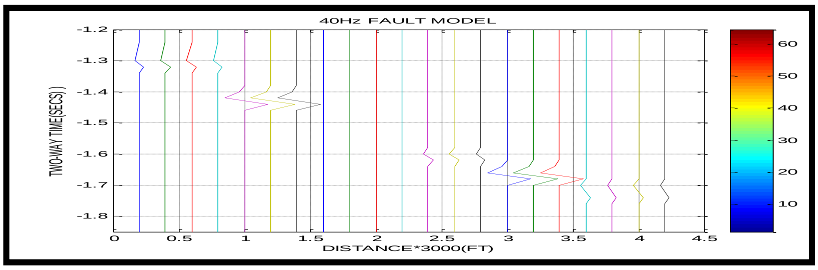
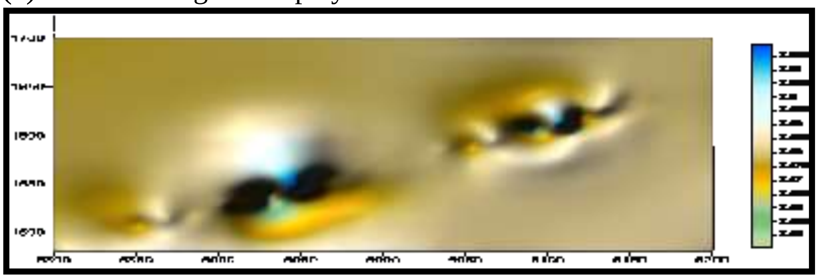


(c) Gamnitude and Saphe Cepstra of Fault Model. Note the higher amplitude recovery in the cepstral plots and compare with Figure 2.Gamnitude shows discontinuity/sequence boundaries. Saphe highlights segmentation and lithologic changes.

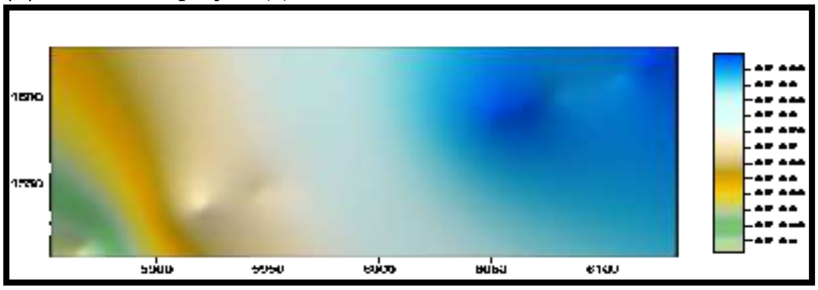
Figure 4:40 Hz Fault Model: (a) Spectral and (b) Cepstral plots



(a) Fault seismogram displayed with Matlab



(b)Surfer-8 displayof (a),



(c)Surfer-8 display of Semblance of (a)

Figure 5: (a) Fault seismogram displayed with Matlab, (b) Surfer-8 display of (a), (c) Semblance of (a) High semblance (Blue) indicates strong and coherent events. Weak events exhibit moderate values (Yellow) of semblance while incoherent data will have very low (Green) semblance.

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Application to Field Data

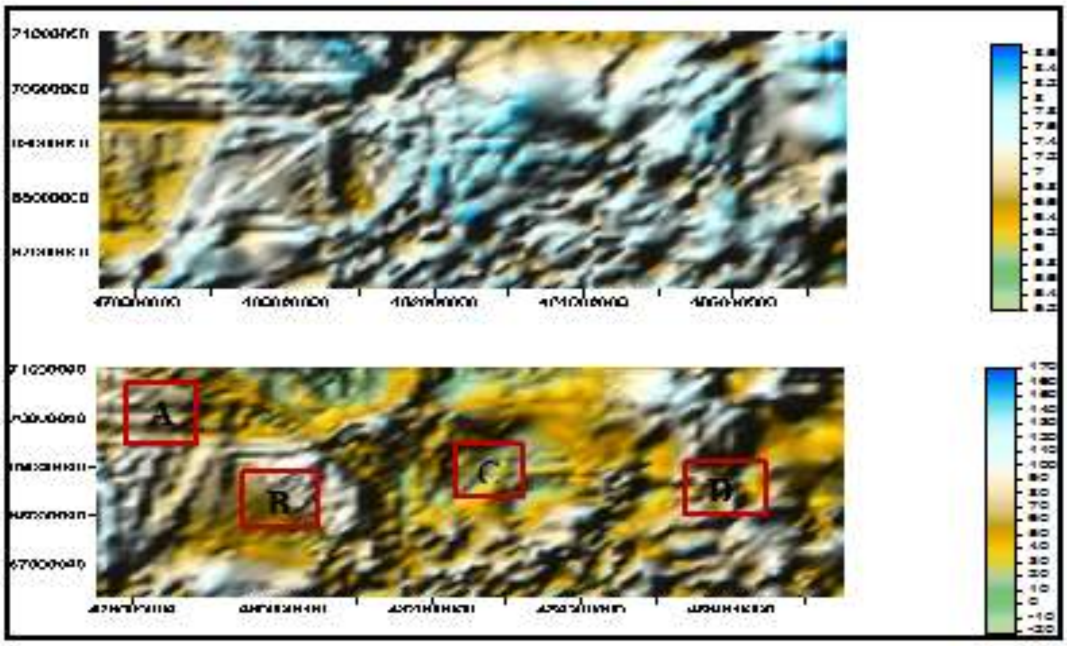

Figure 6: Top Reservoir (a) Original amplitude (top) (b) Cepstral gamnitude (bottom). The Gamnitude
shows discontinuity /segmentation and lithologic changes. Four compartments namely, A, B, C and D can be seen in (b) Gamnitude

CONCLUSIONS

Faults are critical to the accumulation of hydrocarbon and manifest themselves as abrupt, gradual or gentle changes of seismic amplitude. However an important element of entrapment is the presence of numerous subtle sub-parallel faults and their identification with computer –based algorithm has been a major challenge. In frequency domain, spectral decomposition, requiring the use of a time window to unmask subtle events have high sensitivity to noise, weak frequency resolution arising from applied windows, and are therefore unreliable. Knowledge of the presence and identification of subtle faults has led to the need for improved techniques. Our main conclusion is that Cepstral decomposition of the thin bed reservoir revealed subtle sub-parallel faults and provided an enhanced level of evaluating the seal risk on prospect. This will facilitate improved reservoir production and performance. The key inputs are the concepts and practices of seismic stratigraphy and principles of spectral and cepstral decomposition, a clear knowledge of signal analysis and properly migrated seismic data

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