High Resolution Interpretation in the Llanos Basin, Colombia

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Summary:

A case study is presented where the need to increase the resolution was paramount to the ability to interpret thin beds and their lateral terminations and small faulting. The purpose of this paper is to demonstrate how the application of a novel bandwidth extension technique (Smith et.al. *First Break* volume 26, June 2008) based on the continuous wavelet transform and the theory of harmonics made this possible. The higher resolution seismic data generated is of much higher quality and fidelity allowing for a better and more reliable interpretation.

Introduction:

The continental-shallow marine Eocene sandstones of the Mirador formation are the main reservoirs in the area, the marine Cretaceous sandstones of Guadalupe and Une formations are considered secondary targets. Thin bedding of the marine Cretaceous sequence laterally shows progressive pinching out onlaping toward the East of the basin, at the top of the sequence truncations are identified underlying the unconformity.

The interpretation challenges are many and the need for higher bandwidth and increase resolution were the primary motivation to try this enhancing technique. BE was chosen techniques due to its versatility and robustness and many successful applications on field data. The technique is well documented in Smith et al 2008 so we will simply state the basic assumptions and salient features.

Geological Setting:

The area is located in the foreland of the Llanos basin, along the southern extension of the Santiago-Trompillos, Rancho Hermoso-Palo Blanco and Guarimena prolific oil production trends.

The Llanos basin is a foreland sub-Andean basin located in Colombia between the Cordillera Oriental and the Guyana Precambrian shield. The sedimentary record in the Llanos basin is composed of Cretaceous and Tertiary rocks, unconformably lying over an economic basement, consisting of Palaeozoic and igneous/metamorphic rocks.

Source rocks

Several source rocks (TOC>1%) have been reported in the Llanos basin. The main source rock is the Gacheta formation (Upper Cretaceous), a lateral time equivalent to the widespread organic-rich facies of La Luna formation. In addition, Cretaceous carbonate facies of the Fomeque formation (Lower Cretaceous) and Paleocene organic-rich facies of the Cuervos Fm may have also contributed to the hydrocarbon generation in the basin.

The potential source rocks are immature in most part of the foreland, however in the deep area at the western edge of the basin the Gacheta and Fomeque formations may reach high maturity levels %Ro>0.7.

Migration and Timing

Based on a regional geochemical modelling (Mora, 2005), there are several oil generation episodes in the basin. Oil generation and expulsion from the Gacheta Formation took place from Oligocene to Pliocene.

Trap

The main structural style in the foreland portion of the Llanos basin is related to normal faulting. Most of the hydrocarbon accumulation in this part of the basin is related to up-to-the basin normal faulting. Traps associated with down-to the basin faulting have not been found to be oil bearing. Small throw faults (20-50 ft) are enough to provide lateral seal. This small fault displacement are quite difficult to identify on 2D seismic in the same way potential stratigraphic traps like onlapings, truncations, pinch outs, wedging and lateral facies changes. The use of 3D seismic and high resolution images have been proven essential for a successful exploration in the area.

Reservoir

The Eocene sandstones of the Mirador formation are the main target in the area. These were deposited in a continental to shallow marine environment and have a wide areal distribution in the area. In the Cuatro area, the average gross thickness for the Mirador formation is about 50-65 ft.

Net pay ranges from 20-35 ft while the average porosity values are good ranging from 16 to 25%.

Secondary reservoirs consist of marine Cretaceous sandstones of Guadalupe and Une formations. The Guadalupe formation has a gross thickness upward of 100 ft and with porosity values ranging from 15 to 22%.

Seal

The seal for the Mirador formation is provided by regional shales of Carbonera (C-8 member). The Cretaceous shales of the Gacheta formation provide the seal for the Une reservoir. Shally facies of the Guadalupe act as the seal for the sandstones.

At least five structures can be identified as a potential leads in the western area. The closures are associated with the footwalls of up-to-the basin faults. Los Trompillos and El Palmar accumulations are related with the leads mapped in the area, because they belong to the same structural trend.

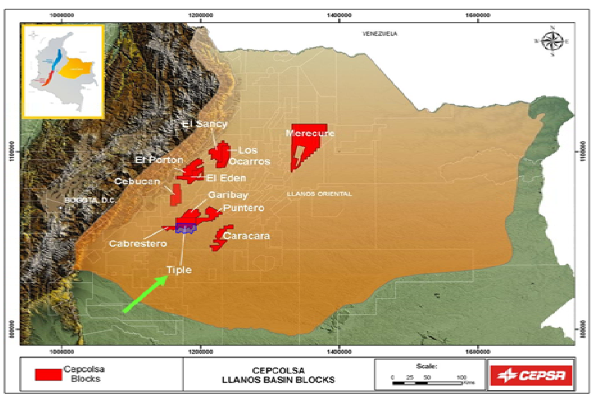

Figure 1: The data analyzed here comes from the Tiple 3D Survey in the Llanos Basin

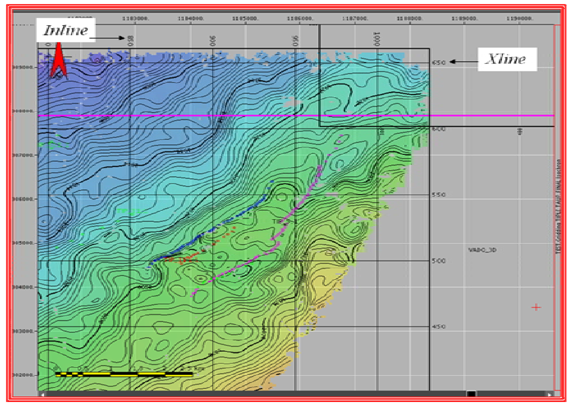

Figure 2: Detail view of the area of interest

Bandwidth Extension Technology

The method is based on modeling the high and low frequencies with the computed harmonics and sub-harmonics of the available fundamental frequencies in the signal, (Smith et.al. *first break* volume 26, June 2008).

Harmonics are integer multiples of a fundamental frequency while sub-harmonics are integer fractional multiples of a fundamental frequency. The fundamental frequencies dynamical range is defined by the data in question and it varies from case to case.

To compute this harmonics we perform a time-frequency analysis utilizing the Continuous Wavelet Transform (CWT) that defines the fundamental frequencies in time.

The CWT permits the analysis of a time-series in such a manner as to minimize the uncertainty in the time-frequency relationship. It turns out that in time-frequency analysis there is always a tradeoff between the accuracy with which we can measure the frequency of a signal and its exact time, this is known as the "uncertainty principle". The WT with its non-stationary properties provides the ideal technique for such an analysis.

At low frequencies the WT provides good frequency resolution and poor time resolution and at high frequencies good time resolution and poor frequency resolution. Octaves are closely spaced at the low end of the spectrum and less closely spaced at the high end of the spectrum.

With the CWT it is possible to analyze the signal and find the fundamental frequencies and their time relationships. From these fundamental frequencies models of harmonic and sub-harmonic frequencies can be computed and added back. These new frequencies effectively extend the bandwidth of the signal and improve the overall resolution of the seismic data.

Application of BE on the Data

After suitable preprocessing we applied the aforementioned algorithm to the data. The starting point was a poststack time migrated section with an average bandwidth of 20-70 Hz. As results of the Bandwidth Extension one can see that well over an octave was added to the spectrum both in the higher and the low end of the spectrum. Note that octaves are much smaller in the low end of the spectrum that they are in the high end. Figure 3 shows the spectrum and the remarkable extension experience.

Figure 4 and 5 show two different zones of an inline before and after the bandwidth extension. Figures 6 and 7 show the same results but for a cross-line. It is quite clear that with the new higher resolution it is now possible to resolve smaller faults, pinch outs and connected zones. The interpretation and future exploration decisions will be influenced dramatically buy the higher resolution seismic now available

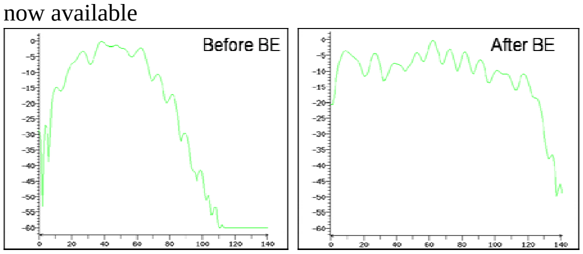

Figure 3: Spectra of pre and post processing data

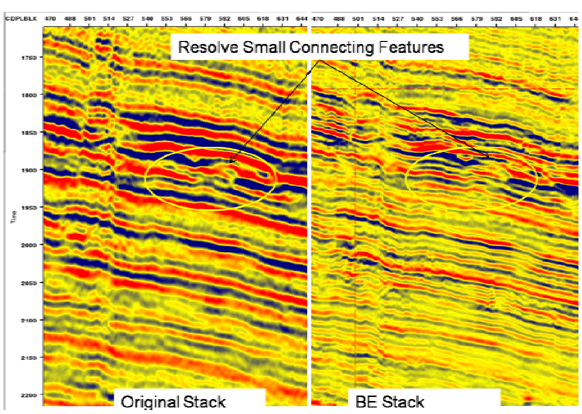

Figure 4: Shallow part of an inline section before and after BE

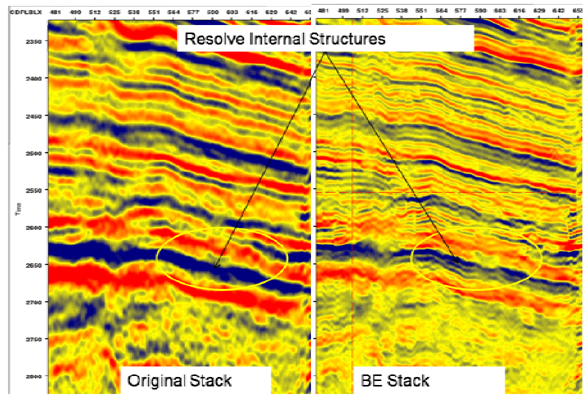

Figure 5: Deeper part of an inline section before and after BE

Conclusions

A novel Bandwidth Extension Algorithm based on the Continuous Wavelet Transform and the theory of Harmonics has been applied to a 3D survey from the Llanos basin, along the southern extension of the Santiago-Trompillos, Rancho Hermoso-Palo Blanco and Guarimena production trends in Colombia.

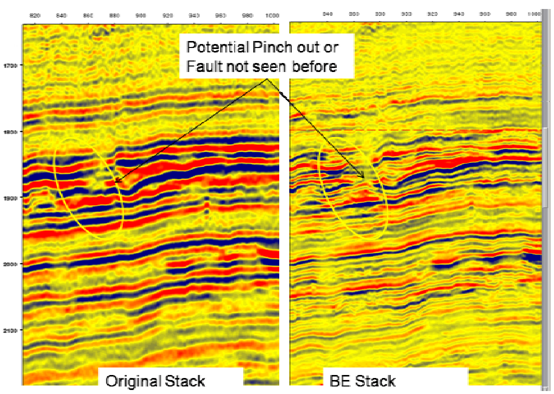

Figure 6: Shallow part of an xline section before and after BE

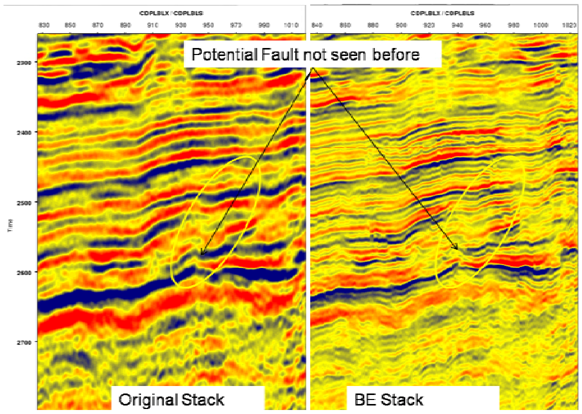

Figure 7: Deeper part of an xline section before and after BE

The complexity of the reservoir and its trapping mechanisms made it imperative to enhance the fidelity and dynamical range of the seismic in order to identify small faulting, thin beds and subtle stratigraphic features.

Several seismic sections have been presented to verify the success of the enhancement techniques both in the shallow and deeper part of the survey

Acknowledgements

We would like to thanks CEPCOLSA and Geotrace for permission to publish

References:

Michael Smith, Gary Perry, Jaime Stein, Alexandre Bertrand and Gary Y, 2008, Extending seismic bandwidth using the continuous wavelet transform, First Break volume 26, June 2008