Comparative analysis between Common Reflection Surface (CRS) and NMO/DMO stack techniques from the structural point of view.

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Abstract

In the early 80's Peter Hubral succeeded in establishing the foundations of an alternative stack technique, it was based on the expansion of the Taylor's equation, allowing it to enter the three way kinematic parameters of search (Emergent angle β, the bends of the wave fronts RNIP and RN). Data derived from these parameters are taken and the final stack generates a field of improved velocity for each sample. The main feature of the technique is that Common Reflection Surface (CRS) stack allows increasing the signal / noise ratio due to the fact that the number of traces is superior. A seismic line from the Caribbean offshore of Colombia was processed using CRS in addition to conventional NMO/DMO, with the aim of comparing the stacking sections from the interpretive point of view. As a result, several important imaging aspects arose, such as better lateral continuity of reflectors and improved quality of the structural image at depth.

Introduction

The new projections petroleum industry, in Colombia, have focused on exploring areas outside Coast and in improving the seismic information obtained in these areas.

The CRS method is a technique which results are stacked images apparently of good quality. This technique automatically determines its stacking parameters through measurements of values of consistency in the pre-stack data. CRS employs more traces for the simulation of every trace of the zero-offset section, which provides an improvement in the signal / noise ratio and, in turn, more suitable for the structural geometries in the subsurface (especially for areas with complex geometries) compared with the conventional process NMO / DMO or Kirchhoff´s PSTM (Hubral, P., et al, 1999). In this research we want to apply the CRS stacking technique in marine seismic data 2D, acquired in a sedimentary basin located in offshore, NW in Colombia.

Theory

The CRS stack technique describes a transformation of reflection data (pre-stacked) 2D in a zero offset simulated stack section. The transformation employing the technique is based on derived data from the CRS special stacking operator and not a model of macro-velocity as it is employed by the conventional technique (NMO / DMO).

The two hypothetical experiments provide wave fronts of the wave's type called Eigen waves by Hubral, P., 1983. Those are shown in Figures 1 and 2 for a model of three homogeneous layers. We consider a NIP point on the second interface associated with a ray of normal incidence emerging in the Xo location on the surface.

To review the concepts behind the Eigen waves, see Figure 1, Eigen waves are obtained by placing a point source in NIP, it generates one wave that starts as a point on the reflector, and goes directly upward, it is known as NIP wave. An experiment of exploitation reflector generates the second wave, which is directed upward, but at the starting point it takes the form of the reflector curve at NIP, this wave is called N wave, see this in figure 2. In a neighborhood of Xo both wave fronts approaching circles with the radius of RNIP curvature of the NIP wave, and the radius of curvature of the normal wave RN (Mann, J., et al, 2000).

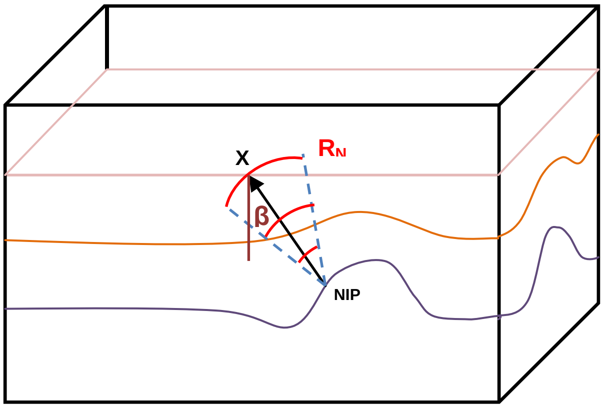


Figure1. Hypothetical experiment which generates the NIP wave, produced from a point source located at NIP. The wave fronts are described in red, the normal incident ray (black).

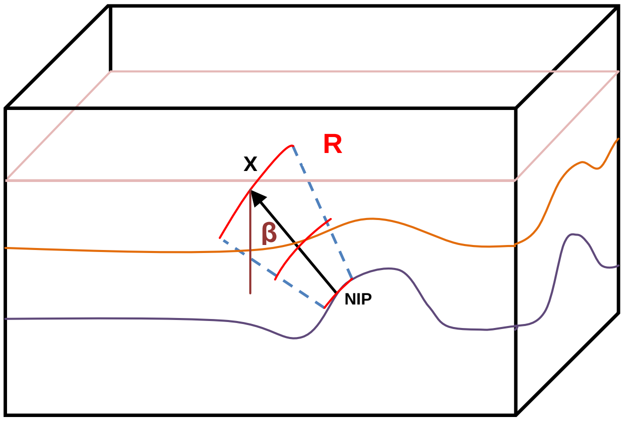


Figure 2. Hypothetical experiment which generates the normal wave, produced by the experiment of explode reflector. The wave fronts are described in red, the normal incident ray (light black).

The method is implemented through the expansion of Taylor equation (equation 1), which is derived from the theory of paraxial ray (Schleider et al., 1993; Tygel et al., 1997) as follows:

$$(1): t^2(Xm, h) = \left[\left(to + \frac{2Sen\beta}{Vo}\right) \times (Xm - Xo)\right]^2 + \frac{2toCos^2\beta}{Vo} \times \left[\frac{(Xm - Xo)^2}{R_N} + \frac{h^2}{R_{NIP}}\right]$$

The average distance between source and receiver is denoted with h, while Xm denotes the midpoint between source and receiver. The method requires a known parameter, the velocity of the near surface, Vo. The stacked trace is at the position (to, Xo).

The CRS operator is an approach that gives good results for small displacements. However, the implementation of the CRS stacking technique needs to fixe the limits on the displacement from midpoint (Xm - Xo), and the average distance between source-receptor (h), but these conditions are provided by the user. To these limits are known as openings (Gamboa, J., 2003).

CRS Stack

CRS is done through the analysis of consistency stack operator; the following is a brief description of the stages used by the technical CRS, according to the guidelines of Mann, J. 2001.

The first step proposed by Jäger, R., et al (2001) was the automatic stacking by Common Mid Point (CMP), which left the optimization problem of the 3 parameters highly costs-demanded, in terms of the computer usage, therefore they decided to search them in separate steps; stating that the input parameters are restricted to specific seismic gathers.

The search begins taking into account the settlement by CMP (Xm = X = 0, it means Δx = 0). The technique is based on the CRS hyperbolic approximation of the equation (2), which is reduced to the equation (3),

$$(2): t^2(\Delta x, h) = \left(to + \frac{2Sen\beta}{Vo}\Delta x\right)^2 + \frac{2toCos^2\beta}{Vo}\left(\frac{\Delta x^2}{R_N} + \frac{h^2}{R_{NIP}}\right)$$

$$(3): t^2_{CMP}(h) = to^2 + \frac{2toh^2Cos^2\beta}{VoR_{NIP}}$$

The technique uses internally **q** parameter explained in the equation (4), this term is related to the stacking velocity as follows (5),

$$(4): q = \frac{Cos^2\beta}{R_{NIP}}$$

$$(5): V^2_{NMO} = \frac{2Vo}{toq}$$

This **q** parameter is used to get the most value for coherency along the stacking hyperbola. The **q** values to be tested are determined indirectly, considering that **q** is a function of **q** = f(V^2_{NMO}). So, the parameters are organized this way (6),

$$(6): V^2_{NMO} = \frac{2VoR_{NIP}}{toCos^2\beta}$$

Its becomes in the normal moveout (NMO) equation (7),

$$(7): t^2_{CMP}(h): to^2 + \frac{4h^2}{V^2_{NMO}}$$

The second step consists in the pursuit of Zero Offset section through the plane-wave equation; at this stage it will be determine the initial values of the emerging angle β.

The next step involves finding hyperbolic events in the zero offset (ZO) section, including the 2nd order terms of the stack operator; note that in this step those terms are not zero. So, knowing β, 2nd order terms can be considered. In Zero Offset section, hyperbolic approximation (8) with all terms is,

$$(8): t^2_{HYP}(\Delta x) = \left(to + \frac{2Sen\beta}{Vo}\Delta x\right)^2 + \left(\frac{2toCos^2\beta}{VoR_N}\Delta x^2\right)$$

At this point parameter R_N can be computed.

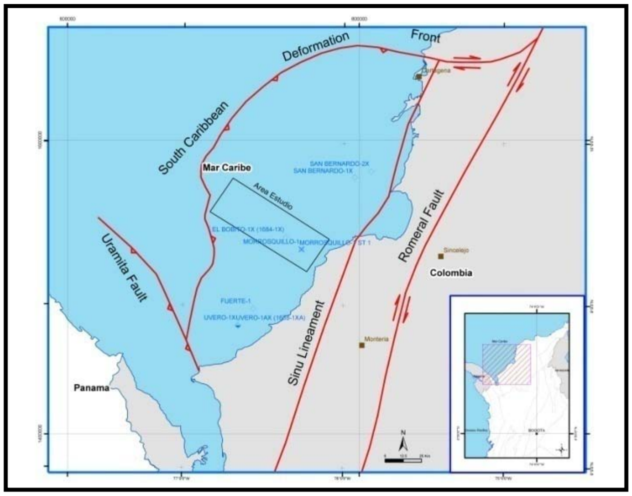
The fourth step involves computing initial CRS stacking, in the previous steps search and stacking are all confined to the specific seismic gathers and using hyperbolic lines as stacking operators. One of the biggest differences in this stack is that CRS runs on stacking surface with a complete 2D stacked based on the initial attributes, β, R_N and R_{NIP}.

Finally, the fifth step is called optimized CRS Stack, where we first estimated parameters (β, RN and RNIP) obtained in the previous step are used an optimization process, involving the three parameters simultaneously. This process essentially represents the refinement of previous searches in the process of finding the most appropriate outcome for the parameters, after refinement is obtained optimized (Gamboa, J., 2003).

Geological Setting

The study area (seismic line) is within the area known as Sinú, located NW of Colombia, in the Caribbean Sea. The area has the following characteristics: its length from north to south is approximately 240 km^2 ranging from San Juan de Urabá until Cartagena. Its western boundary coincides with the deformed belt of the Caribbean, its eastern boundary is the line of the Sinú and its southern boundary is the Uramita fault (Figure 3).

The Basin of northern Colombia is located within the Caribbean plate. The complexity of the interactions between tectonic plates Caribbean and South American, present from the Cretaceous, controlled the tectonic evolution of northwest Colombia and overlapping systems of the southern Caribbean (Toto, E., et al, 1992; Vernette, G. et al.1992). This contributed to the Caribbean basin providing it with a structural complexity of great interest to the scientific community, this work was concentrate in the study of a contraction spots entwined bounded by overthrust on a sub horizontal decollechment.



Figures 4 and 5 are the seismic images obtained with both stack techniques, we observed the following features, consecutively enumerated, because from our point of view, they are relevant for the comparative study. Figure 4 shows 9 elements, 1) Highly deformed zone. 2) Grown strata. 3) Reflection interception. 4) High dips horizons. 5) Flanks deformation. 6) Linear noise. 7 and 9) Long-time horizons (very deep) and 8) Deformation zone. Figure 5 shows 4 elements like, 1) Flanks of the thrusting horizons. 2) Wedging of the horizons. 3) Noise. 4) Long-time information. Figure 6, in this we only show one of the sections, it was interpreted, just to show the differences in the final interpretation.

Results

It is clear that with the Common Reflection Surface technique we have more information in certain areas (such as the deep zone), where the NMO/DMO technique only showed chaotic areas. Also, it was not found any anomalies in CRS sections, while sections with NMO/DMO do present anomalies that are generally call or attributed to coherent noise. It is also clear that towards the intermediate section; there were mute zones for both techniques don't allowing stating anything specific or conclusive. We also note that while the seismic sections with NMO/DMO technique keep your information with low relative low amplitude, CRS boosts them.

Conclusions

CRS stacking gives plausible image at depth (> 4 s.) which is in general not evident in NMO/DMO stacks.

The choice of CRS operator length affects the structural definition of CRS stacked images. The longer the operator, the greater the reflector continuity, both in gentle and steeply dipping events. Enhancing reflector continuity is helpful in structurally complex areas where geometry definition is challenging. However, naturally discontinuous reflectors such as pinch-outs, onlaps, and faulted subhorizontal horizons may appear as artificially continuous horizons due to an excessively long CRS operator. Therefore, a balance must be sought, so as to increase the signal-to-noise ratio while preserving the geological features on the seismic line.

With regards to the interpretation results, which were evaluated from the qualitative point of view, it is possible to estimate how much is increased the signal to noise ratio, knowing the total number of traces employee by each technique and considering that this parameter obeyed to the laws of coherency, the factor $\sqrt{N}$ gives us a quantitative idea. So, in the NMO / DMO case it is $\sqrt{60}$ and in the CRS technique is 4.24 times $\sqrt{60}$.

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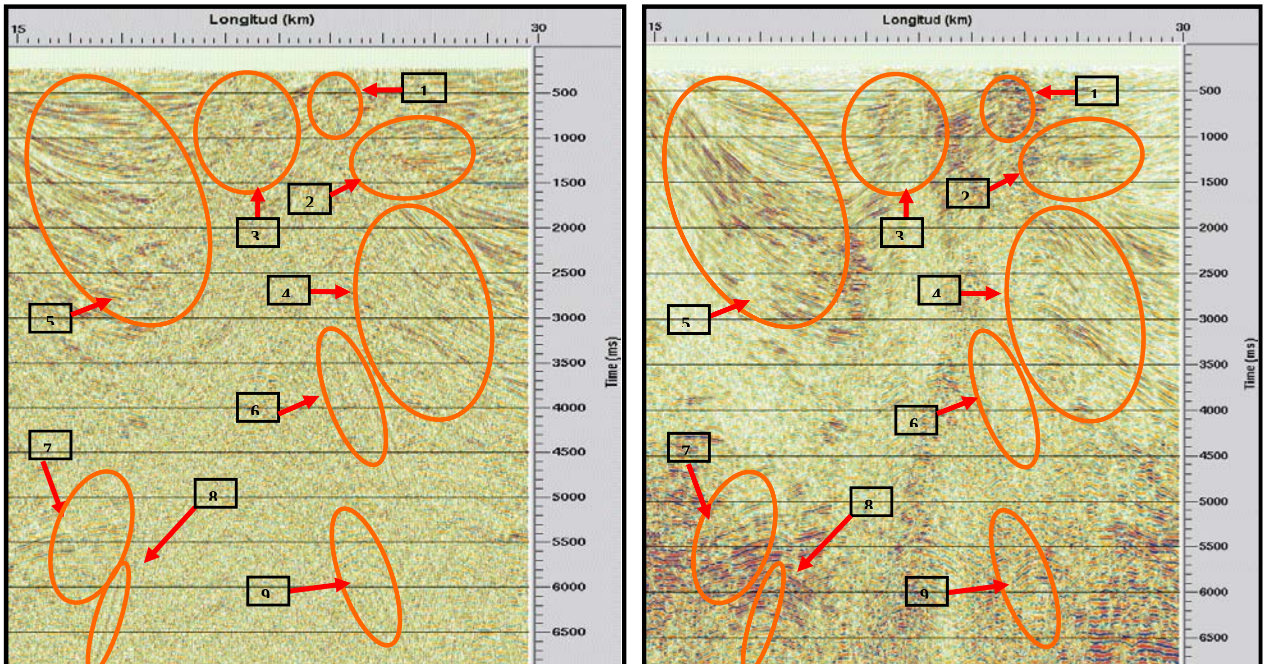

Figure 4. Sector I of the seismic line. The left image is NMO/DMO technique and right image is CRS technique.

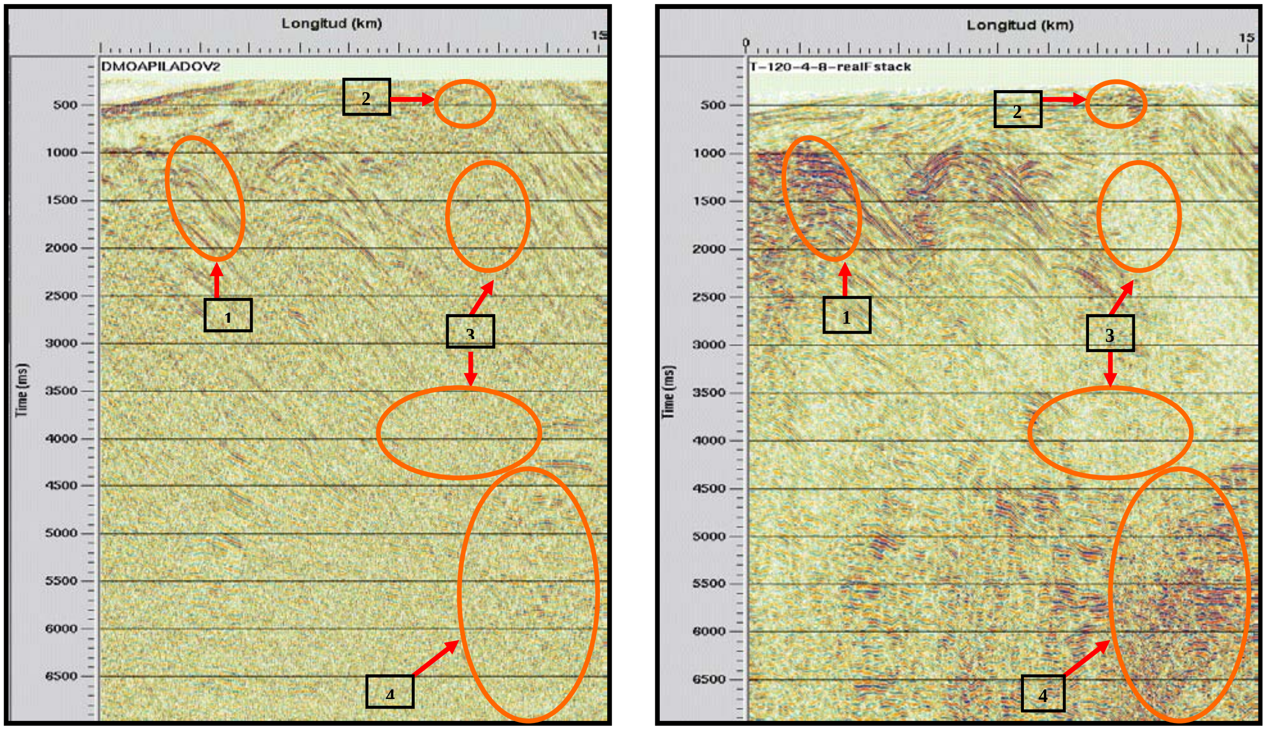

Figure 5. Sector II of the seismic line. The left image is NMO/DMO technique and right image is CRS technique.

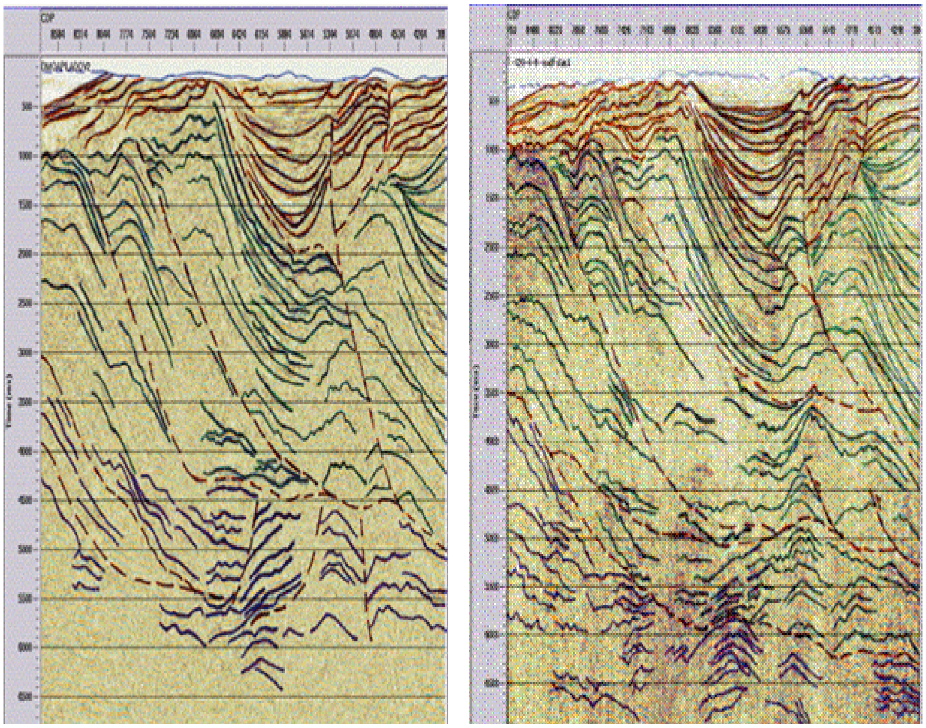

Figure 6. Stack section and interpretation. This image is the first sector of the seismic line.