Comparative analysis of C-wave receiver static estimation in onshore data

Julián Vargas, Jorge Monsegny (DTH-EOS Exploración), William Agudelo* (Ecopetrol), Luis Montes (Universidad Nacional)

Abstract

Receiver static corrections are still a challenging problem in converted wave seismology and to overcome it several estimation techniques have been proposed, becoming effective in most of practical applications.

These methods provide a non unique solution with no clues about which one is the optimal, except a correlation with the P-wave image. In order to obtain a C-image of a 2D-3C survey acquired in the Middle Magdalena basin in Colombia, four methods for receiver statics estimation were applied, providing four different receiver statics. C-wave refraction and receiver function methods are based in the wave equation solution whereas P-source statics scaled by a 2.2 factor and the widely used hand picking on common receiver stacks methods are not.

For each method a receiver stack was obtained and compared with the P-wave receiver stack image.

Introduction

Receiver statics are the most challeging step in onshore converted wave data processing. Since the advent of 3C technology, several methods to estimate the statics on the receiver have been proposed and applied with variable results. In the same vein, studies have been conducted to determine the most desirable method to be applied in a C-wave processing sequence (Schaffer, 1991). In converted wave, the P-wave source static is assumed correct and the receiver static is estimated in the C-wave stacking step.

A first approach to estimate C-wave receiver statics is to assume that they are proportional (by a Vp/Vs factor) to P-wave receiver statics. An initial common receiver stack could be obtained following this assumption.

The refraction method is based on S-wave refractions time pickings. This method is not always practical due to the low velocity and low S/N ratio of refracted S-waves and requires hand picking of arrivals that is time consuming.

The receiver function is used to measure the delay between the arrivals of P and S wave, assuming that a converted S-wave is produced at the base of weathering. It has been used in low frequency seismological studies but recently extended to the high frequency domain. This method estimate receiver statics by deconvolution of vertical from radial components of common-receiver gathers to produce a stacked trace (van Manen et al., 2002, Langston, 1977). This approach assumes P and C waves travel along a common ray path from the conversion point.

The widely used common-receiver stack or horizon-guided method (CRM) enhances the S/N ratio providing an image which is easier to correlate with a P-wave stack, under the assumption of a common reflector.

These four methods were applied to estimate receiver statics on a 3C line acquired in the Middle Magdalena Basin (Colombia) across a region of mild topography. Due to social and environmental restrictions, the shot distribution was not regular along the line.

Method

Vertical component showed better quality information than the radial component that displayed low frequencies and low S/N ratio. The processing C-wave flow included loading the geometry, filtering, true amplitude recovering, deconvolution, apply P-source and C-receiver statics and finally stack on receiver. In 2D3C, in general is not necessary to rotate the radial components but just verify its correct orientation. A constant velocity stack analysis (CVS) in asymptotic common conversion point (ACCP) provided the Vp/Vs = 2.2 as the value that yield the best stacked image. The receiver statics were estimated using the four approaches presented before.

As result of applying each method to radial component, four common-receiver stack sections were obtained, each one with different receiver statics. The same flow applied to vertical component produced a P-wave receiver stack section (Figure 1). In all cases the source static estimated for P wave was applied. The events flattened at 1.6s in P and at nearly 2.6s in C-wave common-receiver stack, enabling the visual correlation between the two types of sections.

A first approach was to use the receiver static as 2.2 times the P receiver static (Figure 2).

After hand picking the first arrival of C wave, receiver static calculations were done by refraction method (Figure 3). A likely S-wave refraction was identified by comparing vertical and radial records and showed consistent velocities.

By the receiver function method we calculate the delay between the P arrival and the S arrival from the base of the weathering layer beneath the receiver. The common-receiver gather was top and bottom muted to isolate the target events that feds the deconvolution. Unlike marine data, usually with high S/N ratio, the receiver function stack in receiver domain of onshore data does not allow to discern clearly the delay between P and C waves. The method provided receiver statics used to create a receiver stack image (Figure 4).

Diuring the horizon-guided method, a strong reflector visible at the Eocene unconformity in the CDP stacked section of P wave was handpicked, the factor 2.2 allowed calculate the position at which the reflector in C-wave common-receiver stack would appear. Using the iterative method of shifting the reflectors in a receiver stack sections (Cary et al., 1994) looking for an image correlated with the P image (Figure 1), in this case the flat reflector at 1.5s shall be visible at 2.4s in the C image. After some iterations the final receiver static was reached and the corresponding C image obtained (Figure 5)

Results and discussion

The chosen guide horizon is indicated by arrows at 1.6s in Figure 1. It appears ranging between 2.4 and 2.6 s in the C-wave common-receiver stack (Figure 2 to 6).

Figure 2 depicts the receiver static as 2.2 times the P receiver static. It was not expected that any correlation between P-wave and S-wave statics allowed an image, but surprisingly an acceptable image was obtained showing that in a certain degree there are a weak correlation between P-wave and S-wave statics, possibly due to the high water table level present in the survey zone.

Refraction method results presented in Figure 3 has a mild shift of 100 ms likely due to the velocities solution obtained with the S-wave refractions. From well descriptions a possible refractor is a conglomerate level located at 20 to 30 m depth in the area. This common-receiver stack has the lowest frequencies compared with the other three methods.

Receiver function method results are presented in Figure 4. This method required several attempts to identify the correct event in the deconvolved receiver stack image. Receiver function method provides a fast and good quality solution but it does not resolve the long period statics.

The horizon-guided method is in general of slightly lower frequencies than the receiver function but exhibits a better continuity.

The methods used to estimate receiver statics provided different solutions are compared in Figure 6. The 2.2 times P receiver static solution has most negative values whereas the receiver function method the most positive values. The solution obtained by the horizon-guided method is very close to receiver function solution (at right), and to refraction solution (at left). With the exception of 2.2 2.2 times P receiver static solution, the others methods provided statics values below ±50 ms.

Some reflector observed in C wave image do not appear in P wave image making hard to establish visual correlation between the images in order to select the best correlation.

In general, a good lateral continuity of the guide horizon is observed in all images being difficult to determine the more appropriate.

Conclusions

Four methods were used to estimate receiver statics to obtain a C-image in a 3C line in the Middle Magdalena basin.

The methods provided different statics which after applied allowed to obtain four C-wave common-receiver stack images. The images were visually correlated with a P common-receiver stack, following a ~2.6s subhorizontal reflector in C observed at 1.6s in P image.

There was not possible to establish criteria to select between refraction, receiver function or horizon-guided methods, because each one has locally good results.

The refraction method is considered the best option to estimate long-period receiver statics and provides a solution with physical meaning but is a time-consuming procedure.

The receiver function method provides a fast solution with short period but it does not resolve the long period statics.

The horizon-guided method offers a high lateral continuity in reflectors but is also a time-consuming approach.

In general all methods can provide an acceptable image and the best solution selection depends on the interpreter skills.

Acknowledgments

The authors want to thanks Ecopetrol S.A. by the financial support to the project and the permission to publish this results.

References

Schaffer, A. 1991. Converted –wave static methods comparison. CREWES Research Report 8, 3.

Langston, C.A., 1979. Structure under Mount Rainier, Washington, inferred from teleseismic body waves: *J. Geophys. Res.*, 85, 4749-4762.

Van Manen D., Robertsson J., Curtis A., Ferber R.. & Paulssen H. 2002. Shear-wave statics using receiver functions. SEG 72nd Annual Meeting. Salt Lake city.

Cary P. W. 1994. 3-D converted-wave seismic processing. CREWES Research Report, Volume 6.

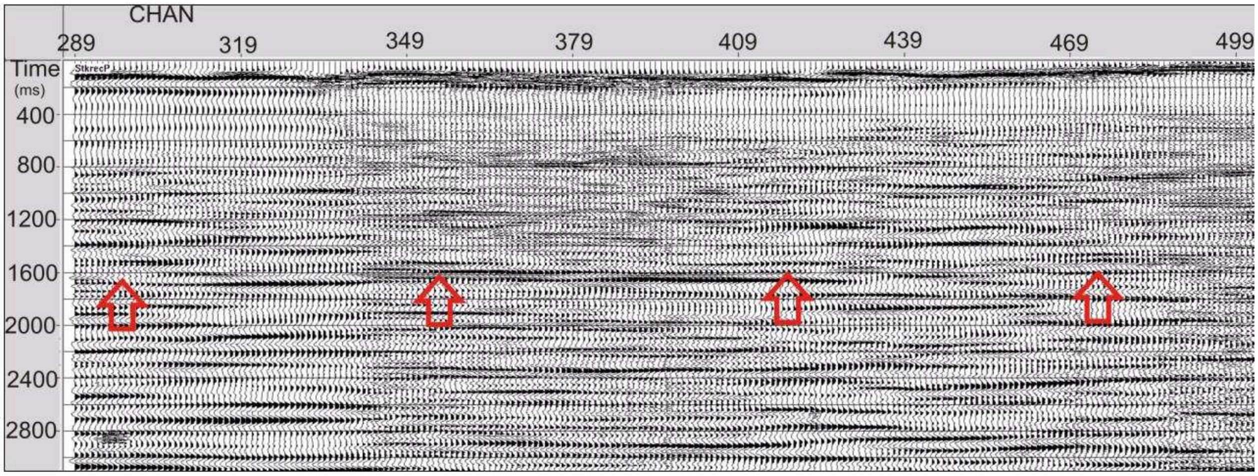

Figure 1: *P-receiver stack section, indicated by arrows the Eocene discordance flattened at 1.6 depict lack of continuity.*

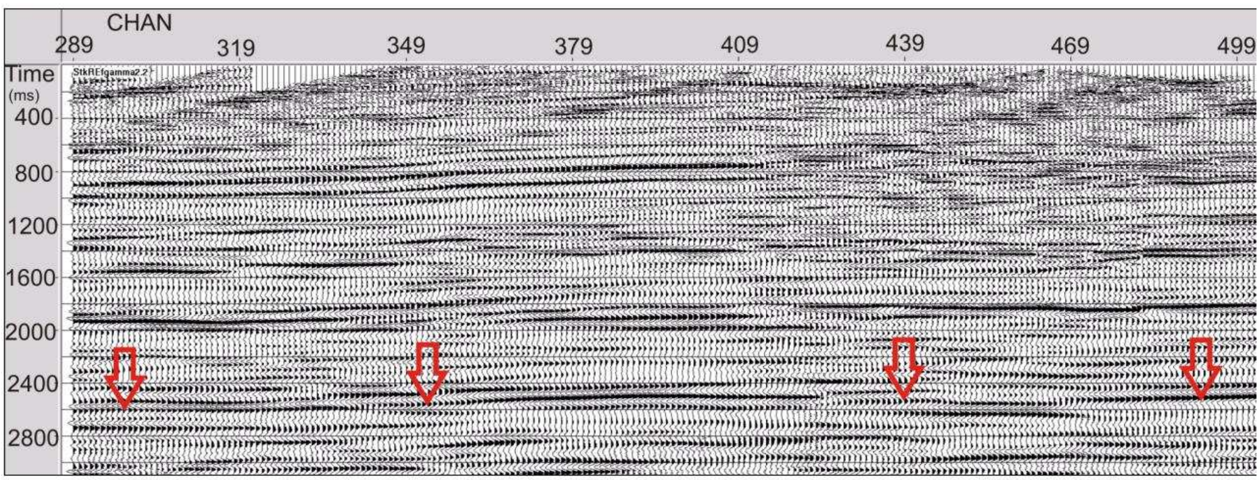

Figure 2: *C-receiver stack section with receiver statics estimated as 2.2 times the P receiver statics. The flat discordance is observed at 2.6s.*

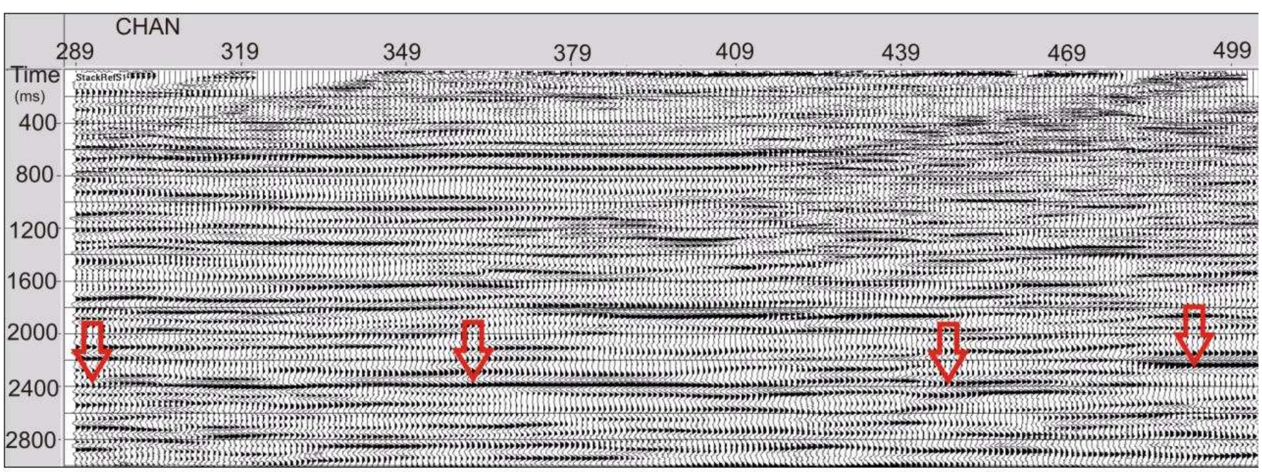

Figure 3: *C-receiver stack section , the receiver statics were provided by refraction method after picked first C-wave arrival .*

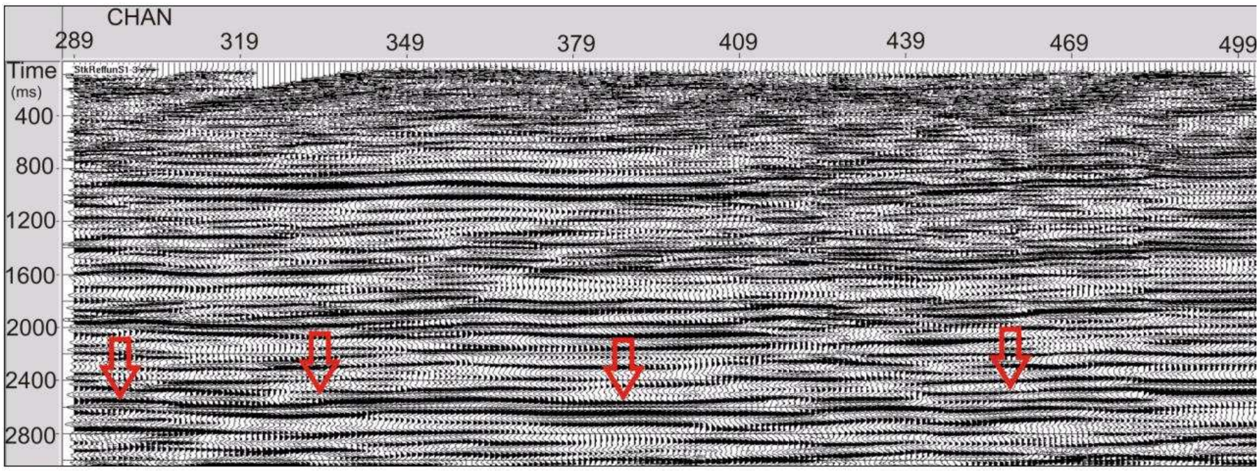

Figure 4: *C-receiver stack section with the receiver statics estimated by receiver function method.*

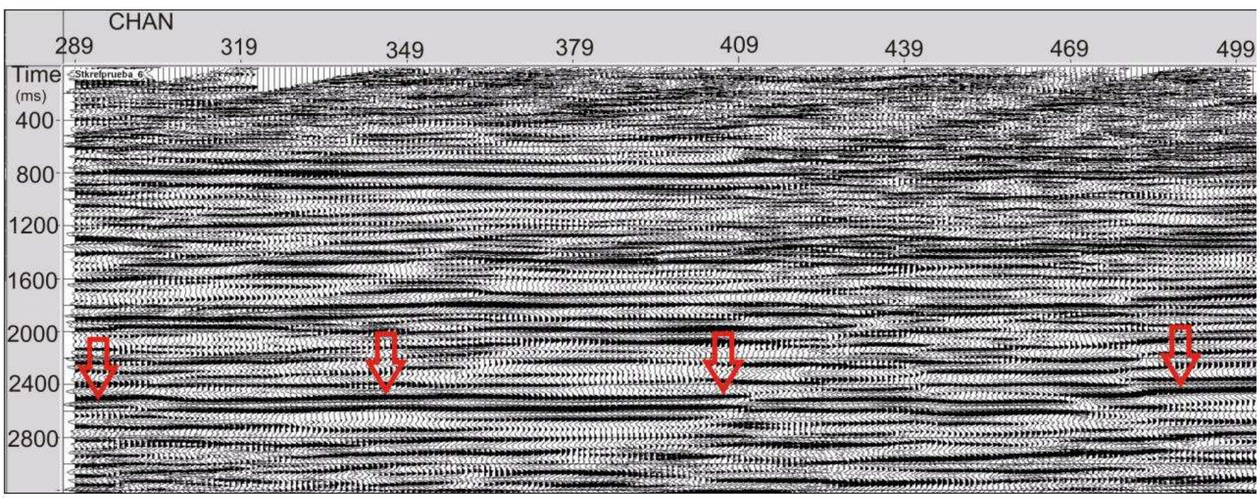

Figure 5: *C-receiver stack section, the receiver statics were obtained by flattening the Eocene discordance in receiver domain.*

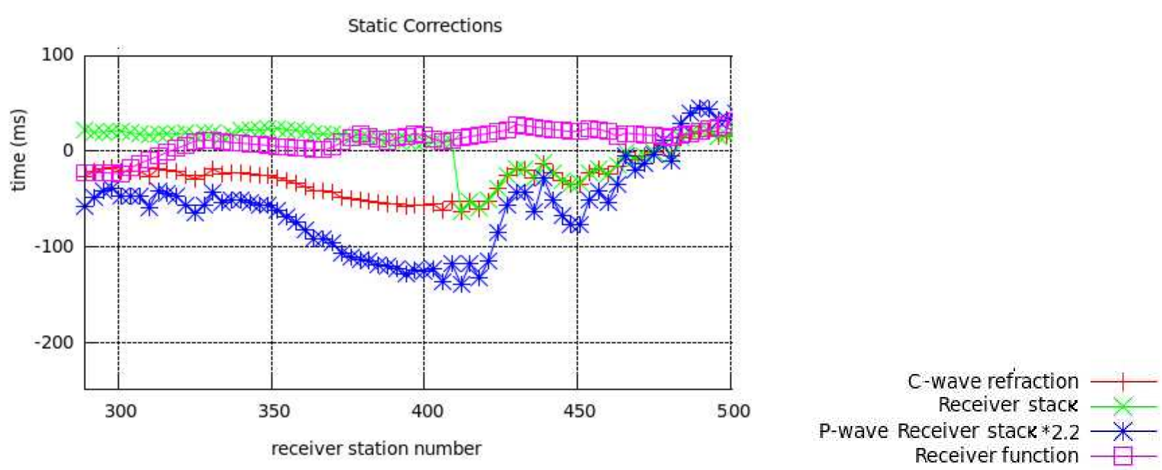

Figure 6: *Comparison between static corrections*