The Multicomponent Seismic Paradigm: Conservative Principles

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Abstract

This article pretends to show the basic concept inherent to the processing of converted waves (P mode to S mode), concepts specifically related to the correction required for the location of the seismic converted wave.

A formal geometric deduction is made of the equation that governs the correction to the coordinates of common midpoint. It is solved by MatLab algorithm, considering straight ray path in an homogeneous and isotropic medium. This correction distinguishes the converted wave processing compared to conventional P-wave processing.

Introduction

Initial work on elastic wave were based on geometrical description, which prevailed until the late nineteenth century, when it was considered as the propagation of a disturbance in an elastic medium.

The development of the multicomponent sesmic processing of converted wave was established from the beginning of 1980. The theoretical basis were proposed in the nineteenth century with job's Green, Poisson and others (Achenbach, 2004).

At the mid-twenty century emerged first papers related to the S wave, until focus mode conversion of compressional wave and shear wave at the late twentieth century, reaching the pre-stack level processing, for instance, Pre-stack Time Migration, PSTM for converted waves (Fig. 1).

Behle and Dohr (1985), proposed a geometric deduction of the polynomial equation that govern the algebraic correction of the common middle point coordinates. It is applied to an homogeneous and isotropic media. This correction leads to the CDP grouping (Common Depth Point) to CCP gathering (Common Conversion Point). This gathering distinguish processing of converted wave from conventional P wave processing.

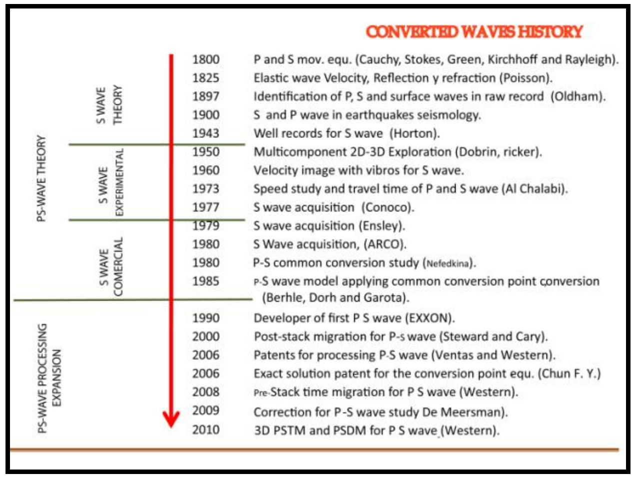

Fig. 1. *Converted wave Chronology (Adapted from Steward & Gaisser, 1999).*

With the "principle of Minimum Action", a Least Action Principle establishes that the waves propagate following path where the integrand of variations is at a minimum time and maximum energy. The reciprocity establishes that path wave (considering their reflection) would be the same if we will change the source-receiver position (receiver-source). From this we can deduce that the reflection point of a wave is located on the middle distance between source and receiver.

Empirically, it could be expressed by means of the Snell-Descartes Law; By that incident angle is equal to the reflection angle for a same wave type.

Emerging wave does not have the same velocity as the incident wave. The principle of reciprocity implies that if we change the location of the source and receiver, and considering the type of wave (P or S), the trajectory followed by an incident P wave, and emergent P wave, should be the same. Move from one to another path, for instance the path where the incident wave is S and P wave is emerging is similar to take another P and S location.

This led to think that conversion reflection point must be located between middle point and the position of the receiver (or reflector level, Fig. 2).

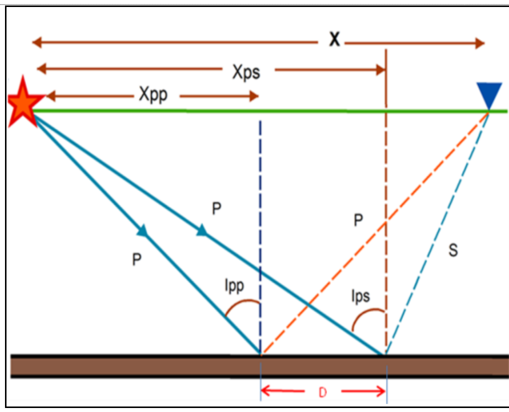

Fig. 2. *P-P ray and P-S ray tracing going to the same receiver (Modified from Tesmer & Behle, 1988).*

Note the different between of reflection points between P-S and S-P ray path, detected at the triaxial receptor (Blue triangle).

This implies the need to determine the algebraic correction to the Common Mid Point (Fig. 2), to properly locate traces (Radial component) at its true position. This corresponds to the conversion point by the equation:

$$x_p = X/2 + D. \quad (1)$$

The synthetic records can provide us with an initial interpretation of events in a P wave and S wave stacked, where the correlation can only happen if you know the geological model. We can infer that observed events in a converted-wave stack do not correspond to events observed at a P-wave stack, at least laterally i.e., there is a lateral shift in the seismic image.

One way to solve it is by pre-stack time migration in the common conversion point domain (CCP).

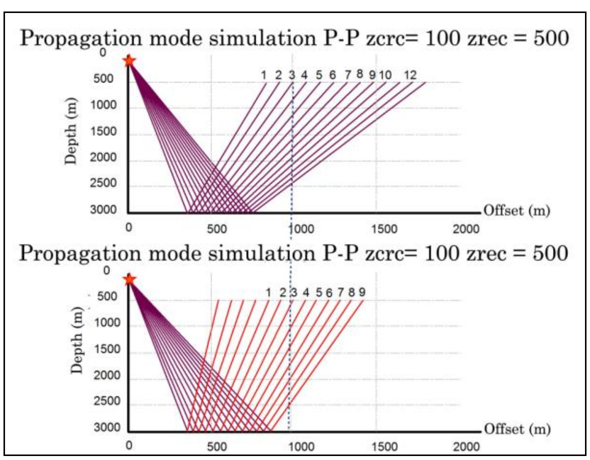

Fig. 3. *Ray tracing for P-P reflection (Upper) and P-S reflection (Lower). The relationship $V_p/V_s = 2.0$.*

Method

For understanding and interpreting the multicomponent seismic results, have been studied the cinematic behavior of the converted waves. The geological model used corresponds to an horizontal layer in an homogeneous and isotropic media (Belhe and Dohr, 1985).

We are looking which parameters were required to obtain a converted wave stack (P to S mode). An understanding of the cinematic wave and your relationship with the compressional wave was determined that location of reflection conversion point for an homogeneous layer, in the P-S mode, depend of:

1. Receiver-source Distance (Offset).
2. Reflector Depth.
3. Vp /Vs ratio.

For knowledge of exact location of the conversion point (In theory at least) for a reflection to a given depth, was necessary knowing the relation Vp /Vs like a depth function.
From the geometrical model shown in the figure 2, was establish to the common middle point (CMP), need to solve the equation 1. Using geometrical relationships were determined the D parameter. This parameter leads to one fourth-order polynomial equation, that we can solve numerically by using Matlab.

By applying this correction to each trace of the converted wave (Radial component), and then grouping in common conversion gather (CCP gather), an appropiate velocity model could be built (Fig. 4). The static elevation were calculated and then stacking by CCP, and we obtained a conversed wave stack.

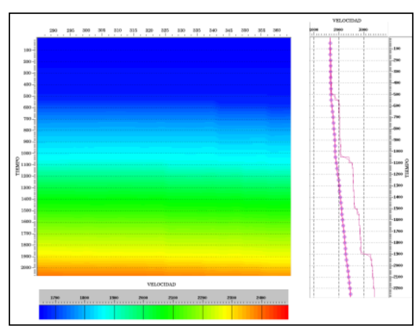

Fig. 4. *Velocity Model.*

Results

For seismic data processing were used 12 records (24 Channels), from *Blackfoot* 3C-3D survey acquired in

Alberta, Canada (1995). The seismic line R-26 was processed. From this line was processing the radial component, based on standard processing of P wave.

Then it was applied the correction according to equation 1, applying: gathering by common conversion point (Chung *et al*., 1985), stacking and finally migrating. Results are showed in figs. 5 and 6.

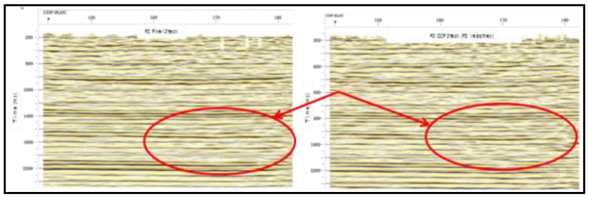

Fig. 5. Radial component stack a) CMP b) CCP. The arrows identify the best definition of events.

Fig. 5 shows the different definition of the events after had been applied the correction to the middle point. Also, can be highlight lateral coherence.

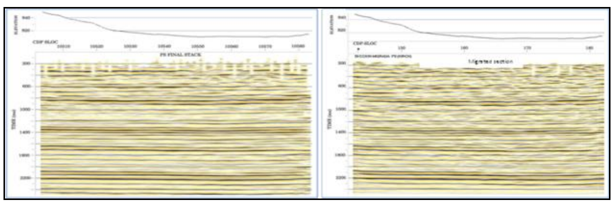

Fig. 6. *Final Sections: Final stack (Left) and CMP Migration (Right). Migrated section using velocities field of P-S converted waves.*

If the value Vp/Vs is unknown, it could be estimated using the asymptotic approximation technique. This establishes which the velocity field of the converted wave is in function of the P wave field velocity.

Exist another technique that do not use the middle point correction, it use the Common Conversion Point concept. The correction given by equation 1, in the case of dip layers require that the D parameter of the reflector surface must be included.

If we want to make a more exactly correction it is necessary that parameter D include the curvature of the ray, for the incident wave like the emergent wave.

The application in interpretation of converted wave stack is possible through two stacks in depth (P and PS waves) and the correlation of the interest events. Another way is building a P wave stack from a converted wave stack. This allow to obtain a new stack named pseudo-P.

From velocity model obtained for P component and radial component, it is possible to obtain an image that represent the Vp/Vs relation.

The focus of this work is the study of converted waves. It is necessary to mention the concepts of compressional and shear waves, and the reciprocity principle. It is the principle of conservation of energy to the seismic converted wave reflection. It also shows how Poisson's ratio as a function of the compressional and shear waves velocities. The Concepts can help us understand the relation of the correction equation with the reflection conversion point.

Conclusions

Consider processing sequence applied to the radial component, it have common conversion point, deduced from geometrical relationship and it could be resolved computationally.

The common conversion point should be applied when is concerned with radial component in multicomponent analyses.

About the receptor static, the static refraction correction does not maintain the same value like P wave.

Common conversion point location is very sensitive parameter to the offset, specially if the reflector is deeper. It shows strong dependence of the Vp/Vs rate for far offset.

Acknowledgments

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