Processing converted-wave data in the τ-p domain: rotation toward the source and moveout correction

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Abstract

The asymmetry of the converted-wave raypath is one of the main sources of complexity in the processing of multicomponent data. Such asymmetry is controlled by Snell's law, which also states that in an isotropic and flat layered medium the ray-parameter value p is preserved, even for converted-wave modes. In this study we propose that processing converted-wave data in the ray-parameter domain offers a more suitable framework for dealing with this type of waves. Here, we address the problem of rotations toward the source in 2D media with dipping reflectors, converted-wave velocity analysis, and NMO corrections. Results show that reversing the polarity of the traces to correct for the orientation of the horizontal components around the zero ray-parameter condition provides consistent polarities along all the events. Also, using an elliptical approximation to the PS-moveout in τ-p domain provides an alternative tool for velocity analysis and converted-wave moveout correction. Its implementation is very similar to conventional processing in the x-t domain. However, results show that in the τ-p domain, the information in shallow events can be fully exploited. The ability of shallow events to reach wider reflection angles, and therefore larger ray-parameter values, makes them a good target for τ-p domain processing We noticed that the polarity reversals present in the converted-wave events are a source of numerical artifacts. A new τ-p transformation algorithm, able to account for these polarity reversals and to avoid introduction of these artifacts, is required to provide cleaner data for further processing.

Rotation into the source-receiver plane

In an isotropic geological model, with flat and homogeneous layers, PS-mode conversion present radial symmetry around the source. This means that, to solve the conflicting polarities of the data recorded on the inline component of a 2D-3C survey, we just need to reverse the polarity of the traces recorded in one end of the spread. However, in a geological model with dipping reflectors PS-mode conversion is not symmetrical and the polarity change is shifted away from the zero offset location. This shifting will depend on the magnitude of the dip. Therefore, in a multiple layers model with different dips polarity reversals are expected to change their location with time. To illustrate this idea synthetic converted-wave source gathers were simulated using ray-tracing. Results performing the polarity correction in x-t and τ-p domains are shown in figures 2 to 4.

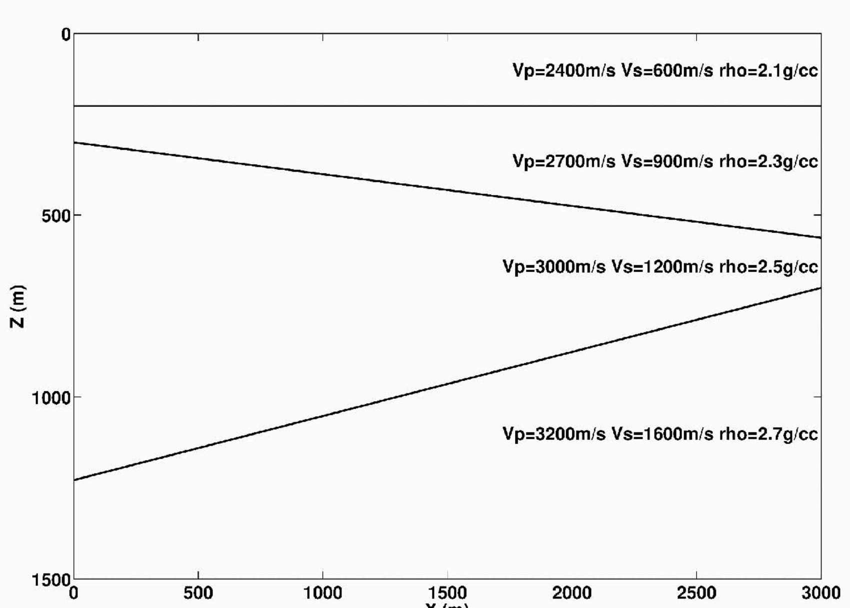

FIG. 1. Velocity model used to compute synthetic converted-wave traces via ray-tracing. The second and third reflectors present a dip of 5° and 10° respectively.

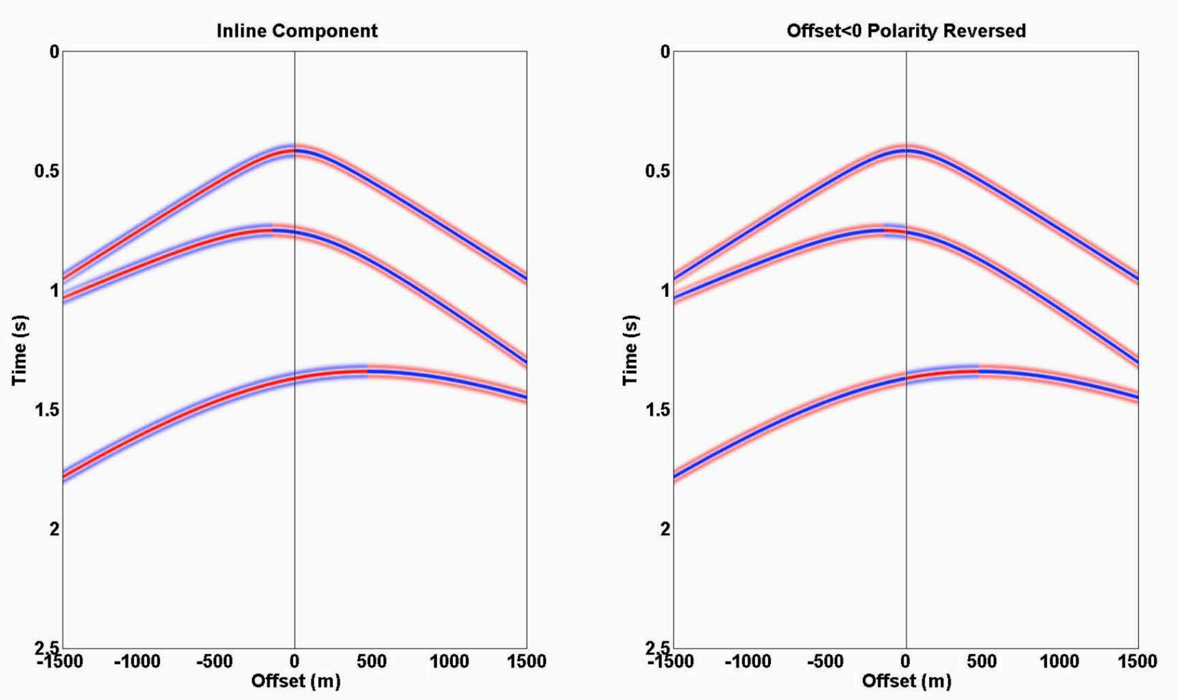

FIG. 2. (left) inline component gather for a source located in the middle of the model (x= 1500m). Notice that amplitudes have been normalized. Location of the polarity reversal characteristic of horizontal component data is shifted away of the zero offset for the dipping interfaces. (right) Result of reversing the polarity of traces recorded at negative offsets. Notice that polarities are inconsistent along the dipping events.

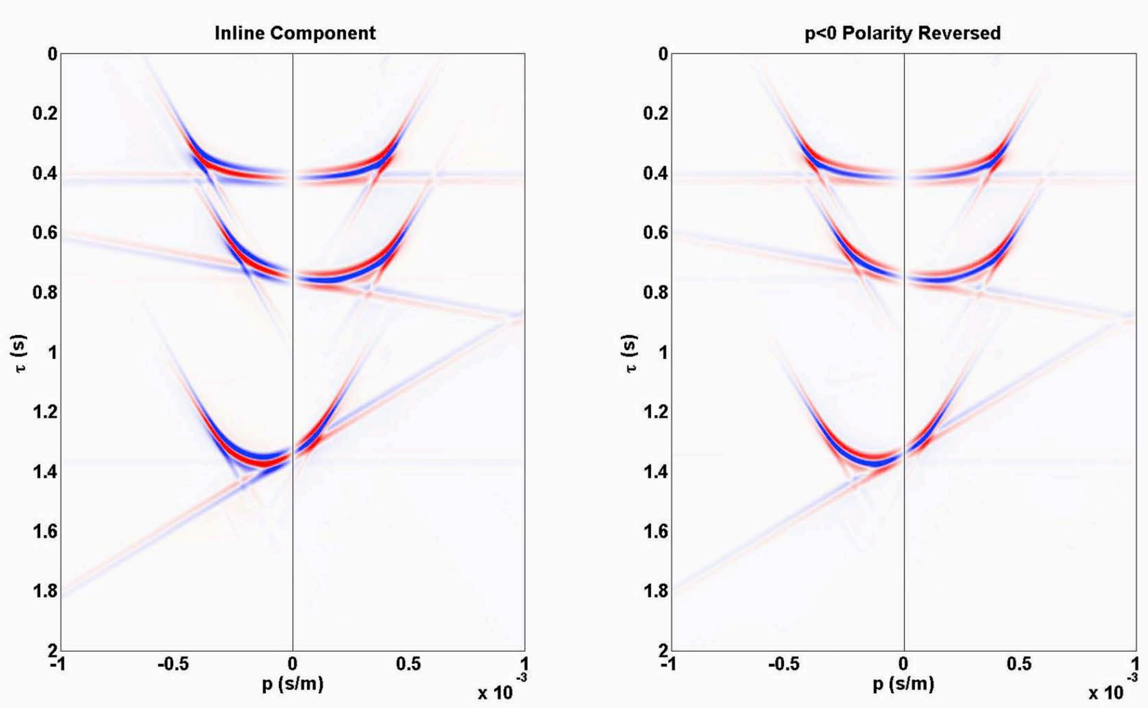

FIG. 3. (left) Source gather 1500 transformed to the τ-p domain. Notice that the polarity reversals are now aligned around the zero ray-parameter value. (right) Result of reversing the polarity of all the traces with p < 0. All the events now display a consistent polarity.

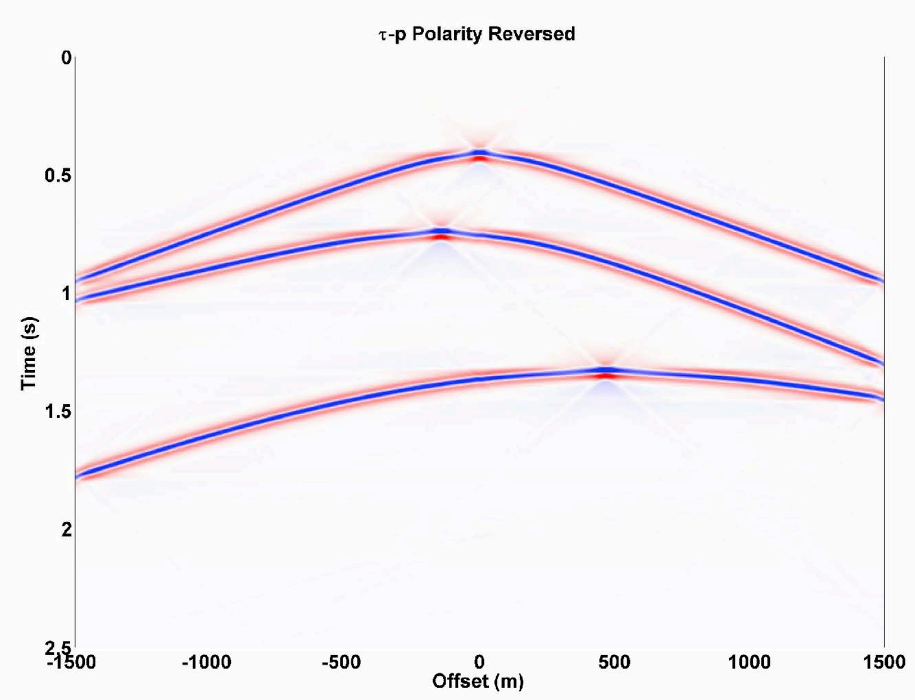

FIG. 4. Back-transformation of the τ-p polarity corrected data to x-t. The polarity of the events have been fully corrected. However, amplitudes around the location of the polarity reversal have been distorted.

NMO Correction

PS moveout hyperbolic approximation (Tessmer and Behle, 1988):

$$t_c = \sqrt{t_{c_0}^2 + \frac{x^2}{V_c^2}} \qquad (1)$$

Elliptical approximation in τ-p domain (Schultz and Claerbout, 1978):

$$\tau = \tau_{c_0}\sqrt{1-(pV_c)^2} \qquad (2)$$

Here we implemented equation 2 in the same way equation 1 is used in conventional velocity analysis and NMO correction. Figure 5 summarizes this implementation.

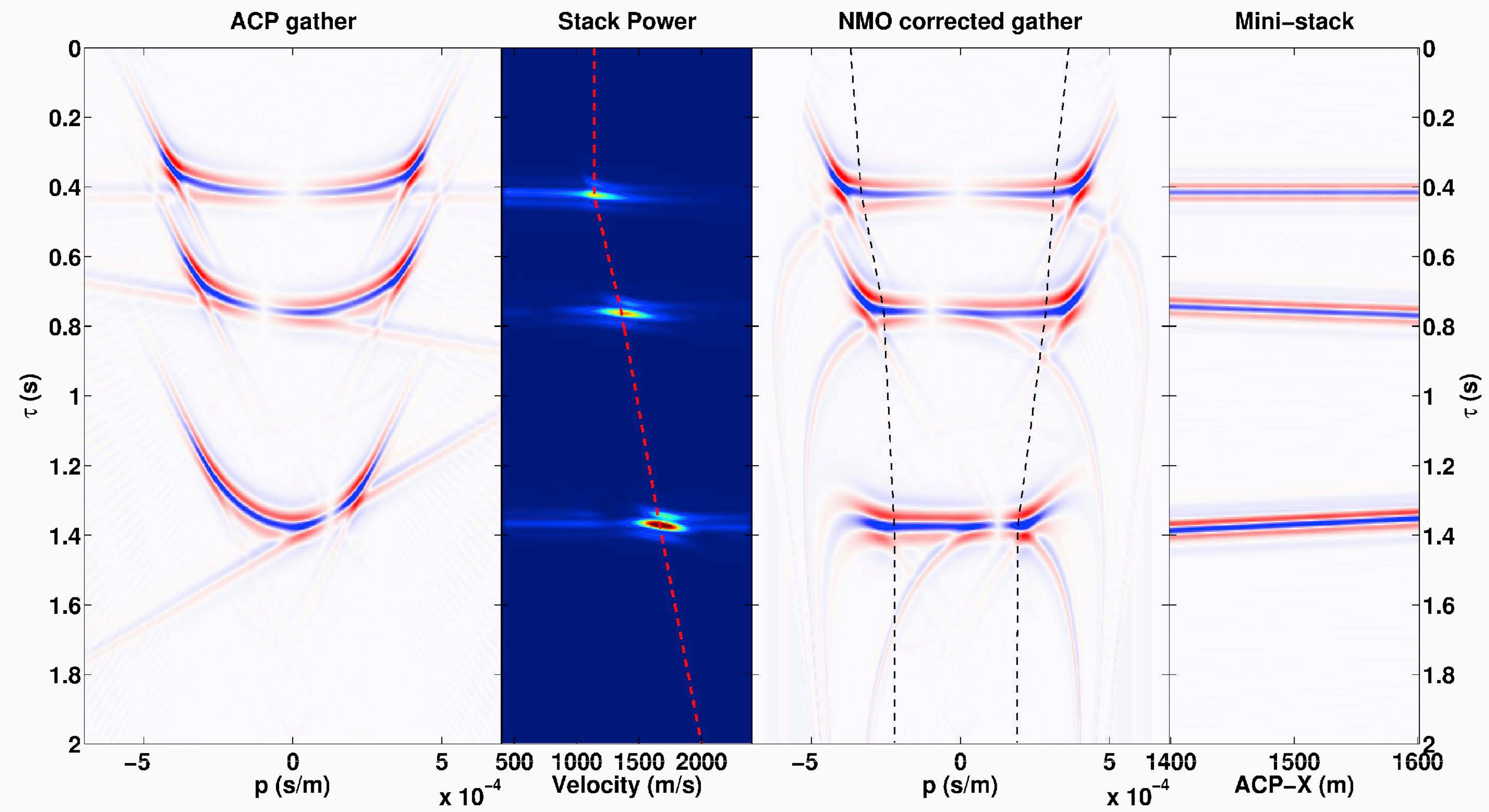

FIG. 5. Velocity analysis and NMO correction of converted-wave data in the τ-p domain. Notice that the live zone limited by the mute function (dashed lines) defined in the NMO corrected gather widens upward. Therefore, a wide range of p-traces is used to stack shallow events. This contrasts with velocity analysis and NMO corrections performed in the x-t domain where the live zone widens downward and only traces with very short offsets are used to stack shallow events.

Conclusions

This study proposes a framework to process converted-wave data in the τ-p domain. The polarity correction due to rotation of the horizontal components toward the source can be performed in τ-p. There; the imprint of the dip of the interfaces on the moveout can be accounted for. Therefore, polarity corrections around the zero ray-parameter condition instead of the zero offset conditions may lead to a more appropriate polarity correction.

Converted-wave NMO corrections can also be applied in the τ-p domain. The elliptical approximation to the τ-p moveout can be used for both velocity analysis and moveout removal. NMO-corrected gathers showed a good level of flatness that, combined with a proper polarity correction, yields an optimum stacking power. The shape of the live amplitudes zone, after muting, widens upward, enabling a wide range of p-traces to be used during the stack of shallow events. As a result, velocity analysis and NMO corrections in τ-p domain may provide a more suitable framework for processing shallow events.

Our main concern resides on the invertability of the τ-p transform. In the case of converted-waves the presence of polarity changes along the events introduces a new source of numerical artifacts. To address this problem, a new τ-p algorithm, able to handle polarity changes without introducing numerical artifacts, needs to be developed.

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