PSImplications of Seismic Attribute Computations from Depth-Migrated Data*

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Search and Discovery Article #41980 (2017)**
Posted January 23, 2017

*Adapted from poster presentation given at AAPG/SEG 2016 International Conference and Exhibition, Cancun, Mexico, September 6-9, 2016

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Abstract

Prestack depth migration (PSDM) is a highly popular imaging process because it enhances seismic images of structurally complex subsurface, by handling both vertical and lateral velocity variations. Thus, in principle, seismic attributes extracted from depth-migrated data are more reliable than those from time-migrated data. However, there are significant conceptual differences in the way seismic attributes are calculated from depth-migrated data. For instance, vertical sampling is no longer in milliseconds but in meters. Attribute calculations are no longer in frequency (cycles/s) but in wavenumber (cycles/m). Using constant windows to compute such attributes is no longer valid due to the wavelet stretching produced by the rapid velocity changes accounted for during PSDM.

A common solution to circumvent these issues is to convert depth-migrated data to time and only then compute seismic attributes, which is valid if seismic attributes are used for qualitative interpretation but not for quantitative interpretation. In this work, we discuss the computational implications of extracting seismic attributes from depth-migrated data and to what extent the interpreter can rely on seismic attributes calculated directly from PSDM data. To illustrate the implications for attribute extraction we present examples of time- and depth migrated synthetic and field data. Not surprisingly, frequency-based attributes are the most affected ones and corrections for steeply dipping interfaces need to be implemented. We believe geoscientists can benefit from this discussion given the increasing availability of depth-migrated data.

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Implications of Seismic Attribute Computations from Depth-Migrated Data

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Abstract

Prestack depth migration (PSDM) is a highly popular imaging process because handles both vertical and lateral velocity variations. In principle, seismic attributes extracted from depth-migrated data are more reliable than those from prestack time-migration data (PSTM). There are differences in the way seismic attributes are calculated from depth-migrated data. For instance, vertical sampling is no longer in milliseconds, but in meters. Attribute calculations are no longer in frequency (cycles/s), but in wavenumber (cycles/m). Using constant windows to compute such attributes is no longer valid due to the wavelet stretching produced by the rapid velocity changes accounted for during PSDM.

A common solution to circumvent these issues is to convert depth-migrated data to time and then compute seismic attributes, which is valid if seismic attributes are used for qualitative interpretation, but not for quantitative interpretation. We discuss the computational implications of extracting seismic attributes from depth-migrated data and to what extent the interpreter can rely on seismic attributes calculated directly from PSDM data. We believe geoscientists and practioners can benefit from this discussion given the increasing availability of depth-migrated data.

Motivation

- Transition from time-domain to depth-domain seismic imaging in the Mexican oil industry.
- Standard Computation Workflow

  PSDM to Time ➤ Attribute Computations ➤ Back to Depth

- Can we benefit from higher-resolution PSDM images by computing seismic attributes with traditional time-domain procedures?
- Does it really make a difference to convert depth-migrated data to time to extract seismic attributes?
- Are attributes extracted from data in depth domain more reliable and, if so, why?
- Interested in poor, but smart practitioner approach using open source computational tools.

Seismic Data and Velocity Models

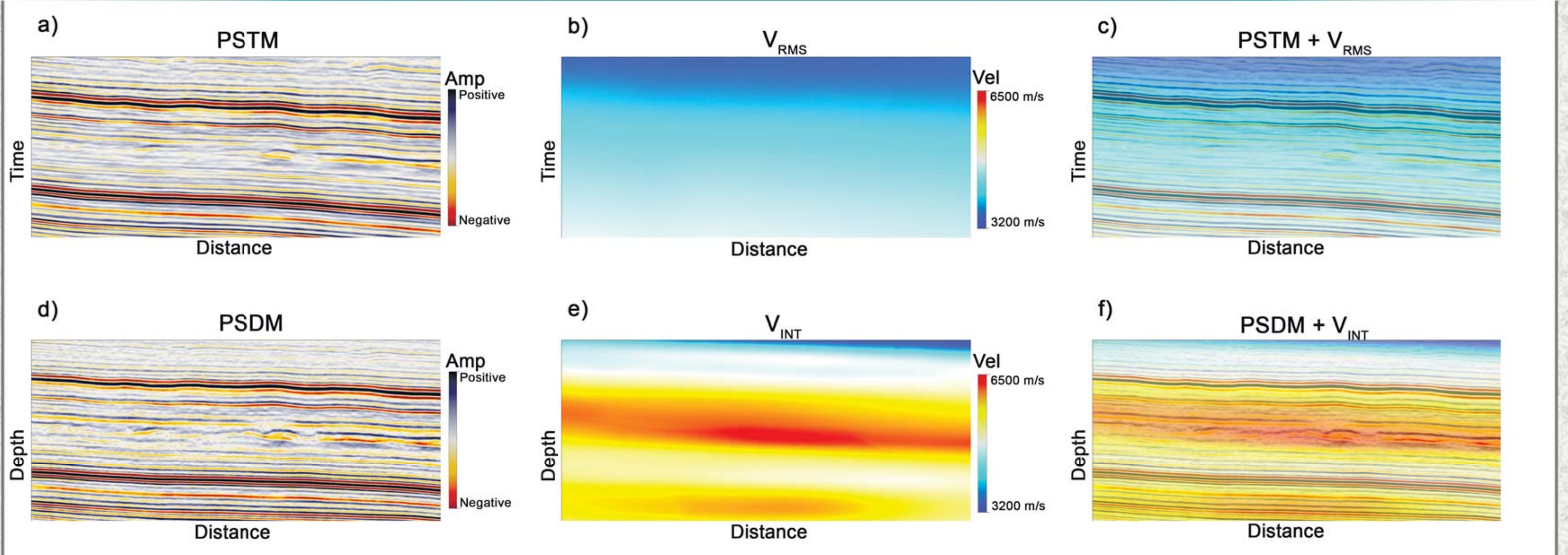

Figure 1. Vertical sections of (a) time-migrated seismic data, (b) RMS velocity model, and (c) seismic data corendered with the velocity model. Vertical sections of (d) depth-migrated seismic data, (e) interval velocity model, and (f) seismic data corendered with the velocity model. Note the lateral velocity variation accounted for depth migration. Seismic amplitudes are normalized for camparison.

PSDM vs PSTM Quick Comparison

Strengths and Weaknesses

	PSDM	PSTM
Vertical Resolution	✔	✔✔
Horizontal Resolution	✔✔	✔
Vertical Velocity Variation	✔	✔
Lateral Velocity Variation	✔	—
Wavelet Stretch	✔✔	✔
Data Driven	✔	✔✔
Model Driven	✔✔	✔

Table 1. Quick comparison of strengths and weaknesses between PSDM and PSTM seismic data.

Attribute Computations

We compute dip magnitude, similarity and structural curvature using (i) PSDM data, (ii) PSDM data converted to time (and converted to depth again for comparison), and (iii) PSTM data. We used OpendTect for simple depth-to-time conversion, and vice versa, using the velocity model.

Reflector dip and azimuth are calculated by an explicit dip scan to find the reflector with higher coherence. Using multiple window analysis, we estimate dip and azimuth of adjacent traces to discriminate lateral and vertical discontinuities along the reflector.

Similarity is a volumetric calculation of semblance, which estimates coherence between adjacent traces, within an analysis window, along structural dip.

To calculate structural curvature we need inline and crossline derivates of apparent dip components, obtained previously.

A key parameter is window size, which may be greatly affected by the wavelet stretch data suffered from depth migration. The appropriate way to determine window size is 5 samples for dip and 10 samples for similarity.

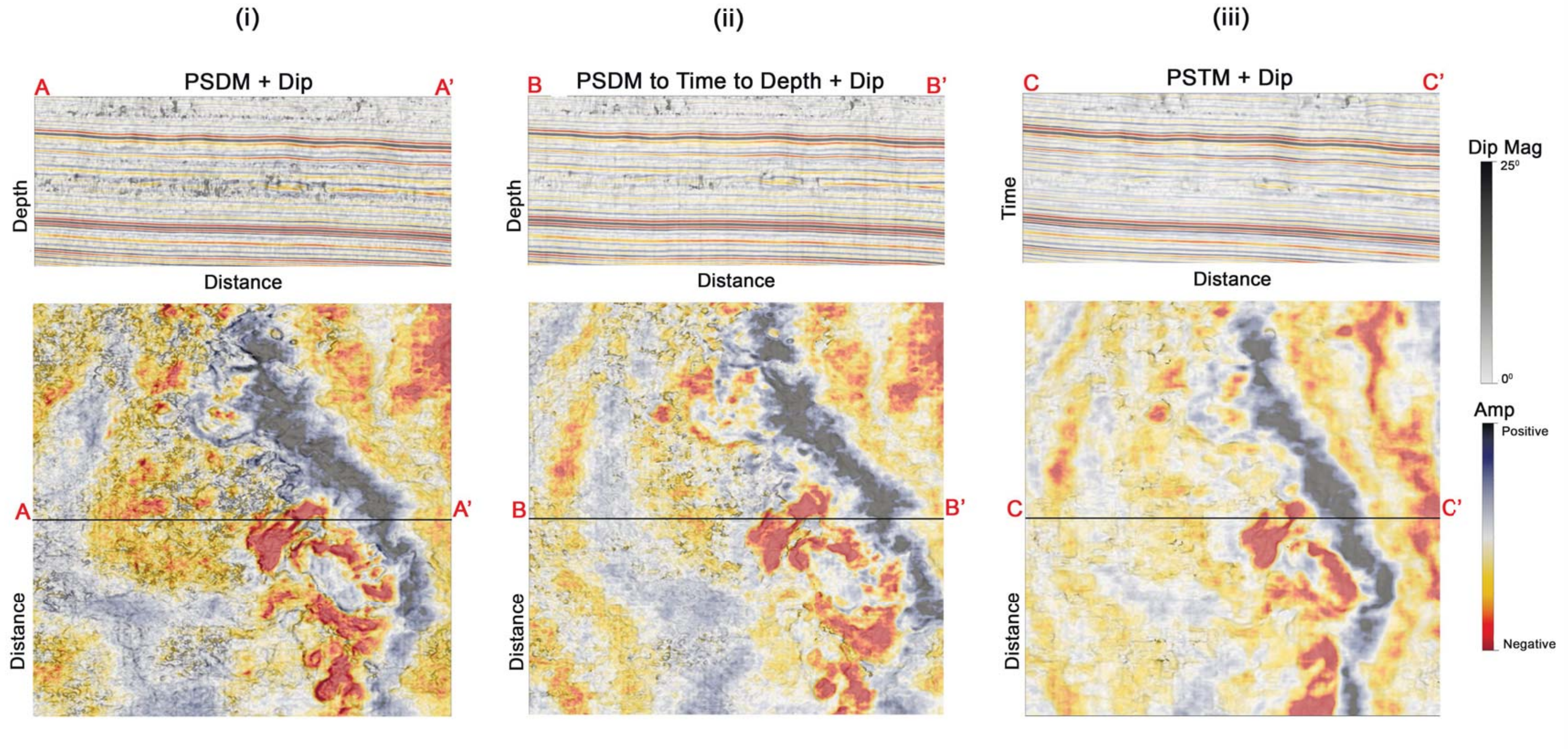

Figure 2. (A-A') Vertical and horizontal sections showing depth-migrated seismic data corendered with structural dip calculated in depth. (B-B') Vertical and horizontal sections showing depth-migrated seismic data corendered with structural dip calculated in time and converted back to depth. (C-C') Vertical and horizontal sections showing time-migrated seismic data corendered with structural dip calculated in time. Seismic amplitudes are normalized for comparison.

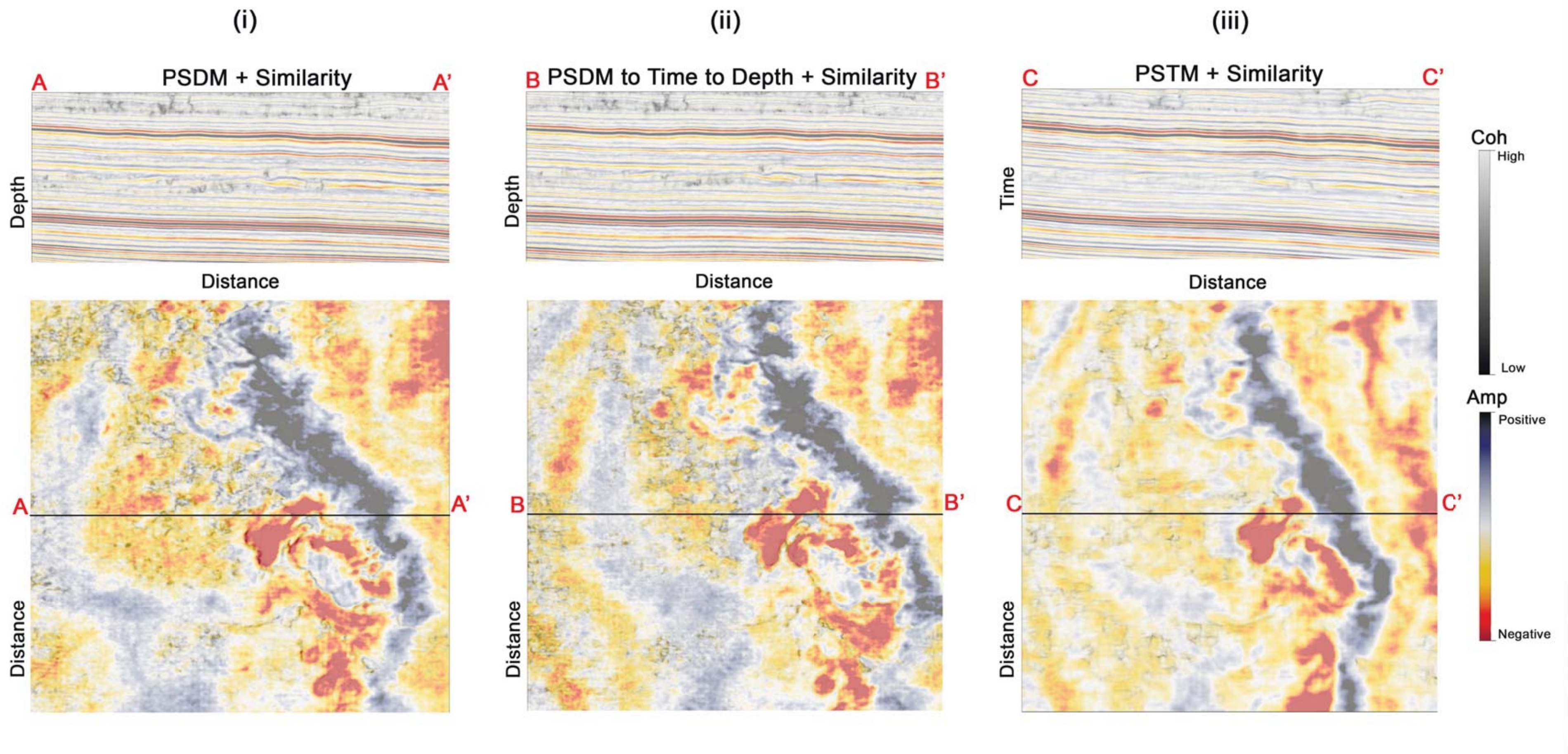

Figure 3. (A-A') Vertical and horizontal sections showing depth-migrated seismic data corendered with eigenstructure-based coherence calculated in depth. (B-B') Vertical and horizontal sections showing depth-migrated seismic data corendered with eigenstructure-based coherence calculated in time and converted back to depth. (C-C') Vertical and horizontal sections showing time-migrated seismic data corendered with eigenstructure-based coherence calculated in time. Seismic amplitudes are normalized for comparison.

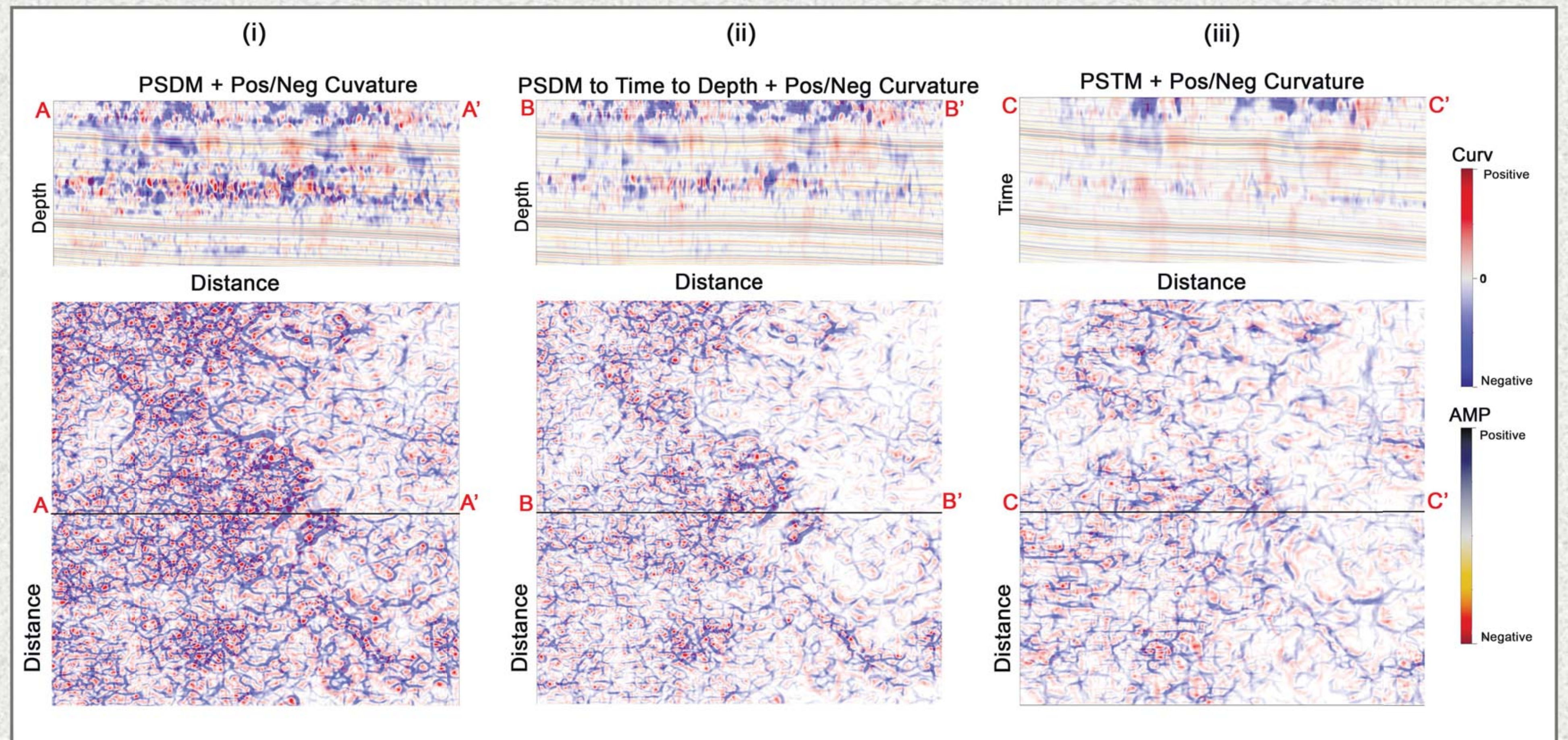

Figure 3. (A-A') Vertical and horizontal sections showing depth-migrated seismic data corendered with most possitive and most negative curvature calculated in depth. (B-B') Vertical and horizontal sections showing depth-migrated seismic data corendered with most possitive and most negative curvature calculated in time and converted back to depth. (C-C') Vertical and horizontal sections showing time-migrated seismic data corendered with most possitive and most negative curvature calculated in time. Seismic amplitudes are normalized for comparison.

Discussion

- Results suggest that attribute computations are not significantly affected by the data domain.
- We observe that the method used for depth to time conversion, and vice versa, has great influence on computations.
- If qualitative interpretation is the goal, then one can obtain reliable attribute results either from depth- or time-migrated data.*
- If quantitative interpretation is the goal, then the data domain is strongly influencing the results.*
- It is important to have access to the technical details of the software at hand, because results depend on our understanding of the techniques used.

Future Work

- Compare frequency-based attributes, such as spectral decomposition and blueing, which may be affected by data domain.
- Vary window size and use self-adaptive windows to better handle wavelet stretch shown in depth-migrated data.
- Run tests using a structurally-complex seismic data set.

Summary of Findings

- Window analysis must be appropriately designed according to data domain and sampling rate.
- We suggest that it is convenient to compute seismic attributes directly in depth, taking advantage of the superior lateral resolution.
- The ultimate purpose of seismic attribute computations indicates whether to convert to time depth-migrated data or not.

Acknowledgments

Thanks to IMP for funding, data access, usage and display. We used AASPI software for computation and OpendTect for data plotting. (*) Open communication from Paul de Groot (OpendTect).

Suggestions for Further Reading

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