Pitfalls in seismic processing: part 2 velocity analysis sourced acquisition footprint

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Summary

Seismic interpretations are often highly subjective and depend on the interpreter's understanding of the limitations of seismic acquisition and processing as well as the tectonic and depositional environment. Small errors in processing may give rise to features that look like geology. Such processing errors may include improper statics, poor velocity analysis and not adequately removing coherent noise. The result of these errors, if not mistaken as geology, is often classified under the broad category of acquisition footprint.

In this paper we use synthetic seismic data composed of four reflectors to investigate the effects of poor velocity analysis and normal moveout stretch (or migration). We compare the results from the synthetic seismic dataset to a real 3D seismic dataset. We show an attribute interpretation of both datasets and how inaccurate processing can lead to fallacious claims about the geological background.

Introduction

Processing procedures can greatly affect the reliability of conventional interpretation and the utility of seismic attribute interpretation. While seismic modeling is routinely used to calibrate and show the advantages of new processing and imaging algorithms, it is less commonly used to show pitfalls in seismic processing. Very few efforts have been made to explain acquisition footprint and processing generated noise using synthetic models. Hill et al. (1999) discussed acquisition footprint caused by inaccurately picked NMO velocity. Ha (2014) used seismic modeling in an attempt to better understand the response of a fractured granitic basement. He also used elastic modeling to identify coherent seismic noise, such as groundroll. With the insight gained from seismic modeling he was able to better identify and eliminate coherent noise during seismic processing.

Seismic attributes, especially coherence and curvature, often exacerbate the effects of inaccurate processing procedures (Verma et al. 2014; Marfurt and Alves, 2015). Because attributes are popular, particularly among less experienced interpreters, as a method to hasten interpretations this could lead to pitfalls in our geologic model (Marfurt and Alves, 2015).

One of the key factors affecting the resolution of seismic data is velocity analysis. With improper velocity analysis or inaccuracies without mutes the frequency content of the reflectors can be greatly deteriorated, and can create pseudo-geological artifacts that could lead to an incorrect interpretation. Using a small 3D seismic land dataset from North Central Texas, we investigate the origin of features in our final stack and attribute volumes after reprocessing this legacy dataset.

Motivation

We processed a small 3D land seismic dataset with a conventional workflow. Upon completion we arrived at the conclusion that the geophysical interpretation contained features that did not match the a priori geological background. With the geological background being confirmed by vast numbers of wells in the adjacent area drilled over many decades of oil and gas exploration. This led us to conclude that the cause of the incorrect interpretation was due to erroneous processing parameters. We hypothesize that these artifacts are due to any of the three factors:

1) NMO (migration) far offset stretch
2) Improper velocity analysis
3) Inadequate removal of groundroll

In this paper we investigate the effects of NMO stretching and improper velocity analysis on synthetic seismic data. In Part 1 (Verma et al., 2015) of this abstract we investigate the effect of groundroll on our seismic interpretation.

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Methodology

Seismic modeling

We created a simple 3D isotropic seismic model with four layers. The acquisition geometry is shown in Figure 1, with 6 receiver lines and 9 shot lines. Each receiver line contains 60 receivers totaling 360 geophones, and each shot line contains 18 sources totaling 162 shots.

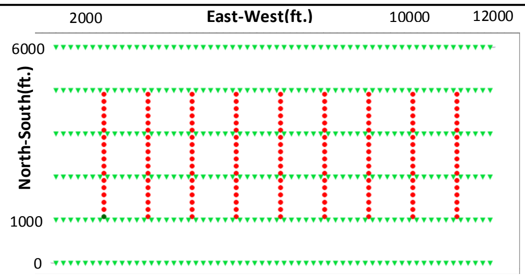

Figure 1. The acquisition geometry for the synthetic model. Sources are in red and receivers are in green. The geometry is perfectly rectilinear which is not the case with actual seismic data due to surface obstructions.

Seismic processing

The seismic processing can be broken into 5 steps:

1) Importing the synthetic seismic data
2) Defining the geometry
3) Velocity analysis
4) NMO correction
5) Stacking the synthetic data

Figure 2a shows the raw synthetic seismic data sorted in shot versus offset. The four hyperbolic reflectors in the model are clearly identifiable. Figure 2b shows the semblance panel and Figure 2c shows the respective NMO corrected gather of the picked semblances (in white). In this figure we see that the processor has picked the velocities on the semblance panel to be too fast for reflectors 2 and 4. The result is an undercorrected NMO corrected gather. Figure 2d shows a semblance panel with flower picks for reflectors 1 and 3; Figure 2e the corresponding NMO corrected gather; and Figure 2f the NMO corrected gather with a 30% stretch mute. With these inaccurately picked velocity models we NMO correct and stack the synthetic seismic model.

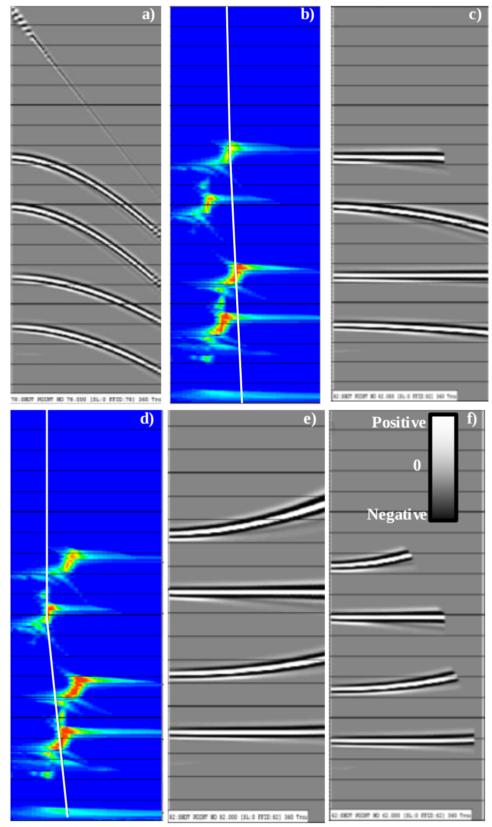

Figure 2. (a) Input seismic data with four hyperbolic reflectors. (b) and (d) are respective semblance panels for (a). (c) and (e) are NMO corrected gathers for picked semblance. (f) NMO corrected gather of (e) with 30% stretch mute.

Attribute interpretation

We computed a suite of seismic attributes from both the modeled synthetic data and the real seismic data. Such attributes included dip and azimuth, coherence and curvature. We then analyzed how improper velocity analysis and NMO stretching affect the attribute response. Using the information gained from the synthetic model we were able to use our real 3D seismic data as an analogue to better understand the influence of processing on interpretation.

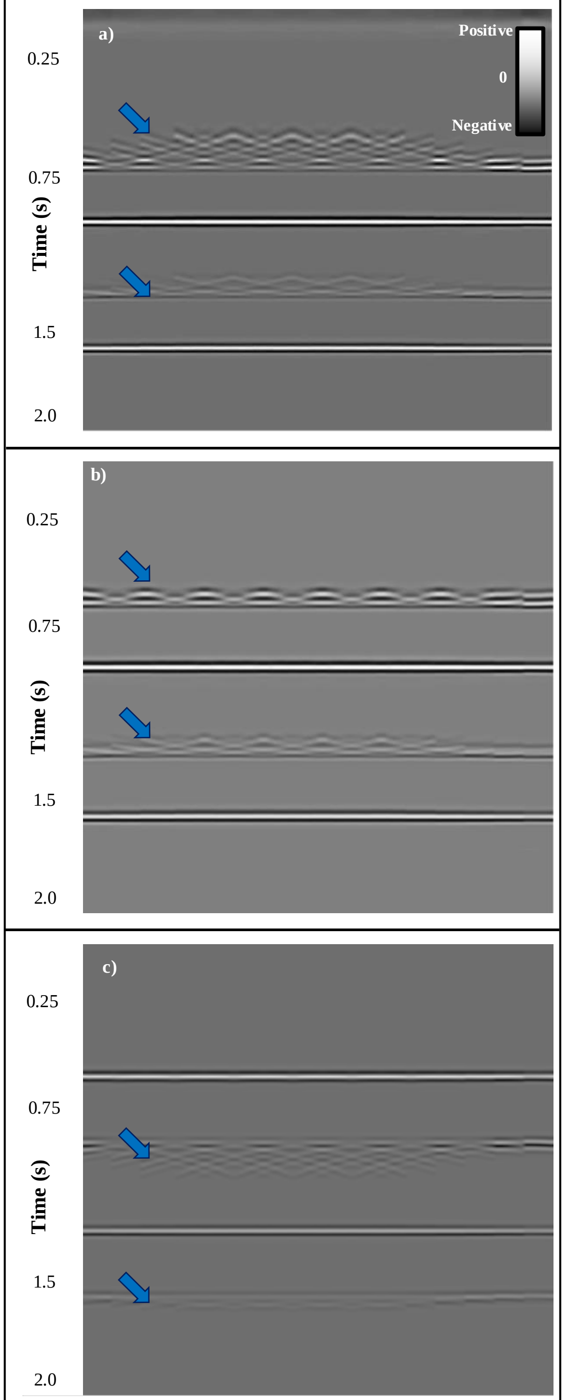

Figure 3. (a) Modeled seismic data with NMO velocity picked too slow. (b) The same data but with a 30% stretch mute. (c) Modeled seismic data with NMO velocity picked too fast.

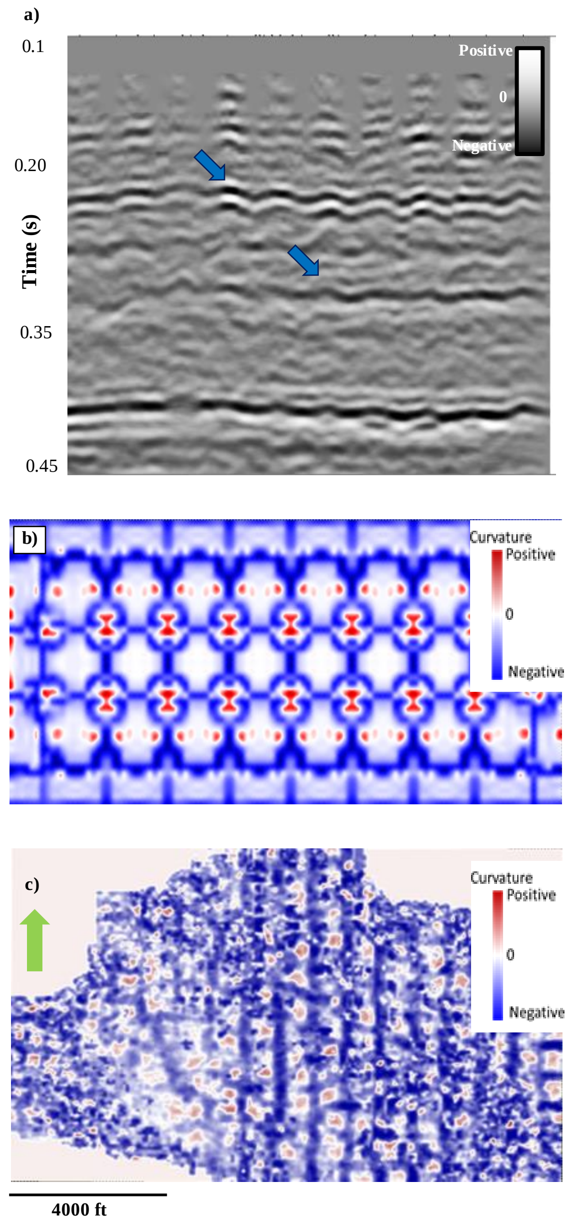

Figure 4. (a) Actual seismic data with hyperbolic artifacts that could be the effect of inaccurate velocity analysis (blue arrows). (b) Timeslice through most negative curvature of the modeled seismic data. (c) Timeslice through most negative curvature of actual 3D seismic data. Notice the discrepancy of the patterns of curvature between (b) and (c).

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Results

Figure 3a shows an inline through the processed and stacked four layer synthetic seismic dataset. Note the "corrugation" artifacts caused by the constructive and destructive interference of improperly flattened. Blue arrows indicate reflector artifacts on reflector 1 and 3. This inline is constructed from the velocity panel and NMO corrected gather shown in Figure 2d and e.

Figure 3b shows an inline through the processed and stacked four layer modeled seismic dataset. In this figure we have applied a 30% stretch mute, to mute far offset stretch. NMO and prestack time migration stretch give rise to the same phenomena. The "corrugation" artifacts caused by the constructive and destructive interference of interfaces not properly flattened during velocity analysis are smaller, however still identifiable. The blue arrows indicate artifacts on reflector 1 and reflector 3. This inline is constructed from the velocity panel and NMO corrected gather shown in Figure 2d and f.

Figure 3c shows an inline through the processed and stacked four layered modeled seismic dataset. This data underwent velocity analysis that was intentionally picked too fast. The resulting constructive and destructive interference patterns from the reflectors results in hyperbolic anomalies. The blue arrows point to the artifacts on reflector 2 and reflector 4. This inline is constructed from stacking the velocity panel and NMO corrected gather shown in Figure 2b and c.

Figure 4a shows undulatory patterns in the real data similar to those seen in our synthetic dataset. Figure 4b shows the attribute expression (most negative curvature) through a timeslice at t = 850 ms through the modeled seismic data. Compared with Figure 4c, the attribute expression of the actual seismic data at t = 365 ms, we see that although both have perturbations in their expression, they appear to have different patterns.

Although it appears that poor velocity analysis and NMO stretching can cause artifacts in the seismic data, attribute interpretation seems to show that the cause of our footprint comes from another source.

Conclusions

By constructing simple models sampled using the acquisition geometry we find that inaccurate velocity analysis and not adequate mute of NMO stretch can result in incorrect geological interpretations. While looking at an inline it appears that our real seismic dataset suffers from NMO velocities picked to be too slow. This gives rise to the undulations in the shallow sections that could be misinterpreted as shallow salt dissolution in the survey area. However, analyzing the attribute expression of both the modeled data and the real seismic data we see different patterns. This leads us toward the conclusion that velocity analysis may not be the source of our footprint. In Pitfalls in seismic processing: part 1, we analyze groundroll as a potential source of acquisition footprint. We believe that in our real 3D seismic dataset, the expression of the footprint is more aligned with that of groundroll than velocity analysis. We also deduce that footprint and noise from groundroll or velocity analysis can be deciphered by other means. From our observations groundroll's expression will start strongest at the surface and attenuate with depth. However, inaccurate velocity analysis will only display features within the interval that the velocity is mispicked. Picking a correct velocity in the vertically adjacent section will result in reflectors with no artifacts. Lastly, improper velocity analysis can create patterns that even more experienced interpreters could perceive as geology as seen in Figure 4a.

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EDITED REFERENCES

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