Pitfalls in seismic processing: part 1 groundroll sourced acquisition footprint

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Summary

Whether it is in reference to the limitations of interpretation or associated with seismic processing, usage of the phrase acquisition footprint is never in a positive context. Footprint contaminates both time structure map and impedance inversion. Although common, footprint is often poorly understood. Footprint is more common in older, lower fold surveys. Part of this mystery is due to the division of labor in most exploratory companies. Processing is usually conducted by specialists in a service company, while attribute analysis is conducted by interpreters (often geologists) in an oil company. Often, younger interpreters have never processed 3D seismic data, while younger processors have never analyzed attributes. As a part of a reprocessing effort for quantitative interpretation analysis, Cahoj (2015) encountered severe footprint masking his shallow exploration target. We attempt to modify his processing workflow to ameliorate the footprint lead to an effort to understand its cause, at least for this survey. Upon completion of seismic processing we are left with a stacked version of our synthetic data in which we can compute seismic attributes. We show that the subsequent attribute interpretation is greatly affected by footprint caused by residual groundroll. Lastly, we show an attribute interpretation corresponding to real 3D seismic dataset and conclude that many artifacts seen in the dataset, often labeled under the broad category of acquisition footprint, are actually residual groundroll not properly removed during the processing flow. Because out of plane groundroll can have hyperbolic moveout common noise removal techniques, such as F-K filtering, that operate under the assumption of modeling noise with different linear moveouts, fail.

Introduction

Acquisition footprint refers to the imprint of acquisition geometry seen on seismic amplitude timeslices and horizons. Acquisition footprint can obstruct not only classical seismic interpretation but also affect interpretation based on seismic attributes (Marfurt and Alves 2015, Marfurt et al., 1998). Seismic attributes, especially coherence and curvature, often exacerbate the effect of footprint making their utility diminish (Marfurt and Alves 2015; Verma et al., 2014).

With footprint being such a common problem its occurrence and formation are often poorly understood (Chopra and Larsen, 2000). Although many methodologies have been developed to remove linear coherent noise and acquisition footprint (Cvetkovic et al., 2008 and Marfurt et al., 1998), little has been done in the way of illustrating its occurrence via modeling. Hill et al. (1999) investigated acquisition footprint is caused by inaccurately picked NMO velocity. Although groundroll is one of the prime causes of acquisition footprint, the footprint pattern caused by the presence of groundroll has not been modeled and documented.

One of the main causes of seismic acquisition footprint is sparse spatial sampling. It is particularly challenging to remove aliased groundroll. Because of this the residual groundroll's occurrence on the stacked seismic data can be strong enough to influence the interpretation. We study a low fold legacy seismic survey of North Central Texas and observed acquisition footprint with the North-South lineaments (Figure 1a) aligned with the receiver lines. We investigate what can cause such footprint to be present in our dataset; in this paper we present the findings.

Motivation

We observed north–south acquisition footprint present on the curvature attribute shown in Figure 1a. The presence of this acquisition footprint hindered our attribute assisted interpretation. Because of this we had an incentive to understand its origin. We hypothesis that this acquisition footprint could have three potential sources:

1) Inadequate removal of groundroll,
2) NMO far offset stretch, and
3) Improper velocity analysis

In this paper we decide to investigate the effect of inadequately removed groundroll. In Part 2 (Cahoj et al., 2015) of this abstract we will try to understand the effect of NMO stretching and incorrect velocity analysis on our seismic interpretation. Equipped with an actual seismic dataset with acquisition footprint, we are able to construct a synthetic analogue.

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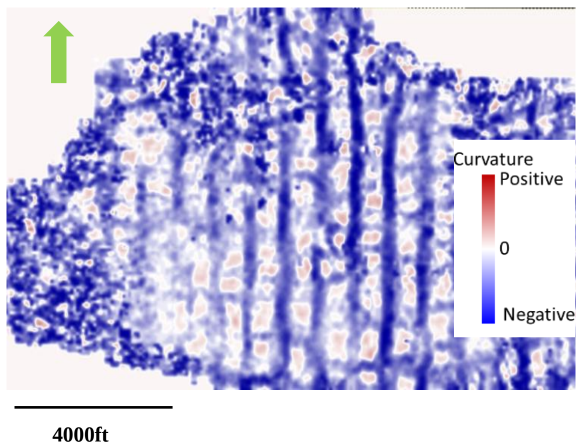

Figure 1. (a) Timeslice at t=0.41s through most negative curvature volume from real seismic dataset. The North-South lineaments are aligned with the receiver lines. These artifacts contaminate attribute volumes.

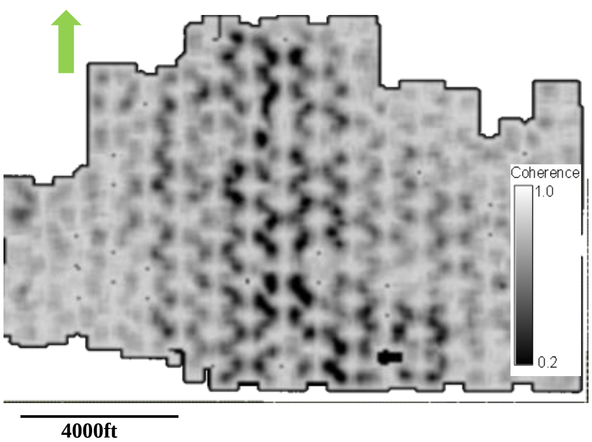

Figure 1. (b)Timeslice at t=0.41s through coherence volume from real seismic dataset. The North-South lineaments are aligned with the receiver lines. These artifacts are weaker at depth but overprint the objective at t=1.0s.

Methodology

Seismic modeling

The objective of this model is to see the effect of residual groundroll on stacked seismic data after processing and its relation with reflectors.

To do so we created a simple 3D flat layer seismic model with four layers. The acquisition geometry is shown in Figure 2, with 6 receiver lines and 9 shot lines. Each receiver line contains 60 receiver groups totaling 360 geophones, and each shot line contains 18 sources totaling 162 shots. The model has a strong presence of broad bandwidth (0-50Hz) dispersive groundroll. We generated two separate models, one for groundroll using an elastic modeling approach with only the weathering layers and a second model with four layers using an acoustic modeling approach. We added these two models to simulate the final 3D acquisition geometry for our study.

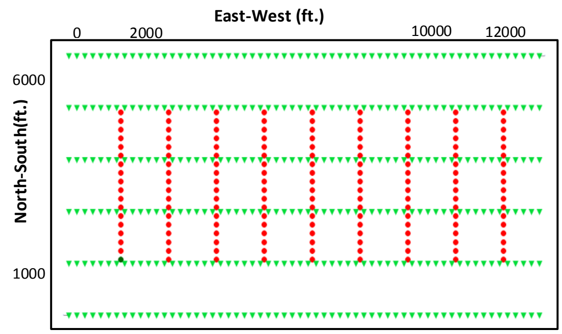

Figure 2. The synthetic model's geometry. Sources are in red and receivers are in green. The geometry is perfectly rectilinear which is not the case with actual seismic data due to surface obstructions.

Seismic processing

The seismic processing can be broken into 7 steps.

1) Importing the synthetic seismic data
2) Defining the geometry
3) Sorting the data by absolute offset
4) Identifying the noise corridor with a mute and finding its respective linear moveout velocity
5) Model the noise in the F-K domain
6) Inverse linear moveout and subtraction
7) NMO correction and stacking the synthetic data

Figure 3a shows a common shot the synthetic sorted by absolute offset. It is easy to identify the lower velocity groundroll crosscutting and overbearing the reflectors. Figure 3b shows the groundroll modeled by a standard F-K noise filtering procedure and Figure 3c shows the results after the modeled groundroll is subtracted from the input model. In this figure we see that most of the high amplitude groundroll has been removed and the reflectors, once overprinted, are now visible. Upon completion of groundroll removal the synthetic data were NMO corrected and stacked (Figure 4a).

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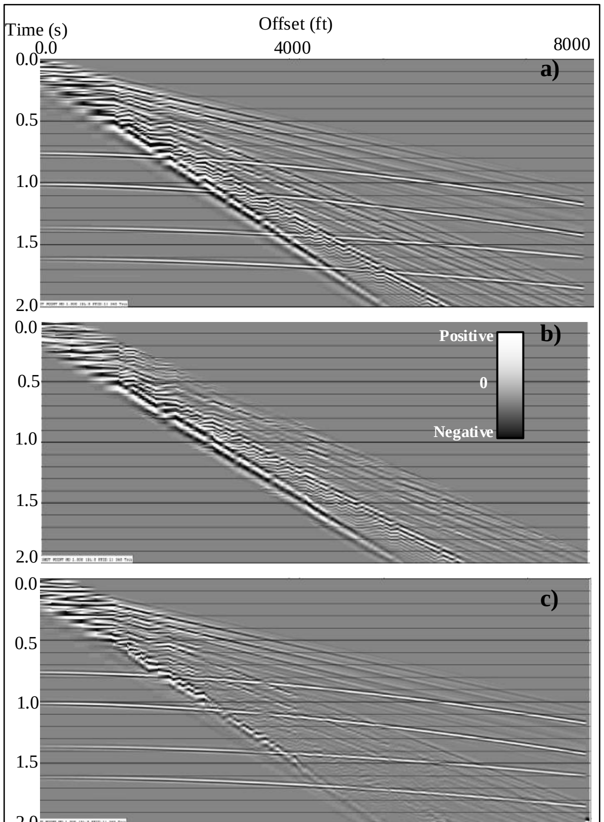

Figure 3. Shot vs absolute offset sorted (a) modeled seismic data with four reflectors and groundroll with a large bandwidth (0-50Hz). b) F-K modeled groundroll to be removed from the modeled seismic data (a). (c) Result of subtracting F-K modeled groundroll (b) from modeled seismic (a). Notice large amounts and high amplitude groundroll is removed, but residual remains.

Attribute interpretation

We computed a suite of seismic attributes using a commercial software package on both the modeled synthetic seismic data and the actual seismic data. Such attributes included dip and azimuth, energy ratio similarity and curvature. With these attributes we were able to determine footprint's response from improperly removed groundroll. Using the modeled seismic data we were able to make an analogue to actual seismic data to compare groundroll's response and effect on interpretation.

Results

Figure 4a shows the inline of the stacked synthetic seismic data. The undulations in the shallow section are the responses of constructively and destructively interfering groundroll not properly removed by F-K filtering. Figure 4b shows the corresponding inline through the actual seismic data. It is evident that similar undulations exist in the shallow section of the real seismic data.

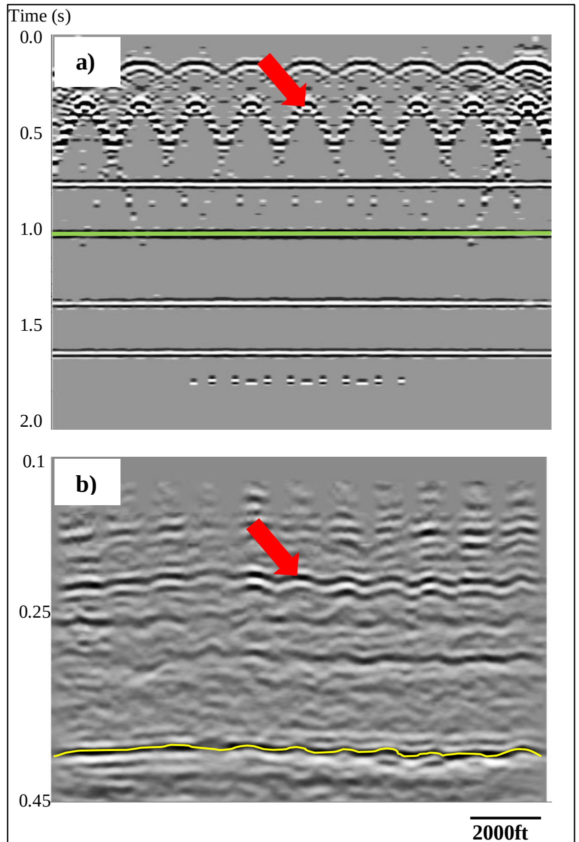

Figure 4. (a) Inline through the synthetic seismic data. (green horizon is displayed in Figure 6a) (b) Inline of real seismic data (yellow horizon is displayed in Figure 6b) . Notice the undulation anomalies caused by inadequately removed groundroll in Figure 6a and similar undulation features can be seen in Figure 6b most likely caused by groundroll.

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Figure 5a is a timeslice at t=1.320s through the most negative curvature response of the stacked synthetic seismic data. We find that the response of curvature, an attribute commonly used to map folds, flexures and deformation about faults, is greatly contaminated by the inadequately removed groundroll. Figure 1a shows the corresponding timeslice at t=0.410s through the most negative curvature of the real seismic data; containing a similar footprint expression.

Figure 6a shows a horizon tracked through the 2nd layer in the synthetic dataset. Because the layers were modeled to be horizontal we expect a uniform surface at a constant depth. However, we can see rectilinear features, particularly strong in the East-West direction. These features can also be seen in Figure 6b, the real seismic data.

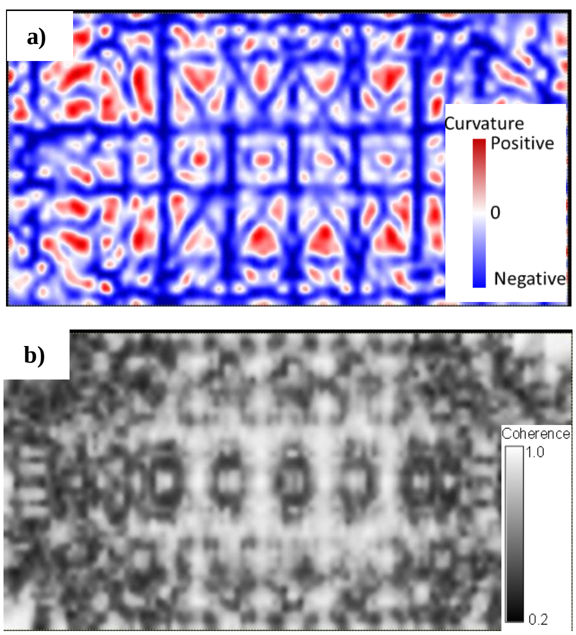

Figure 5. (a) Timeslice at t=1.320s through most negative curvature of the synthetic seismic data. Notice the undulation anomalies caused by inadequately removed groundroll. (b) Coherence at t=1.320s of the synthetic seismic data. Similar undulation features can be seen causing lateral discontinuity in the reflectors.

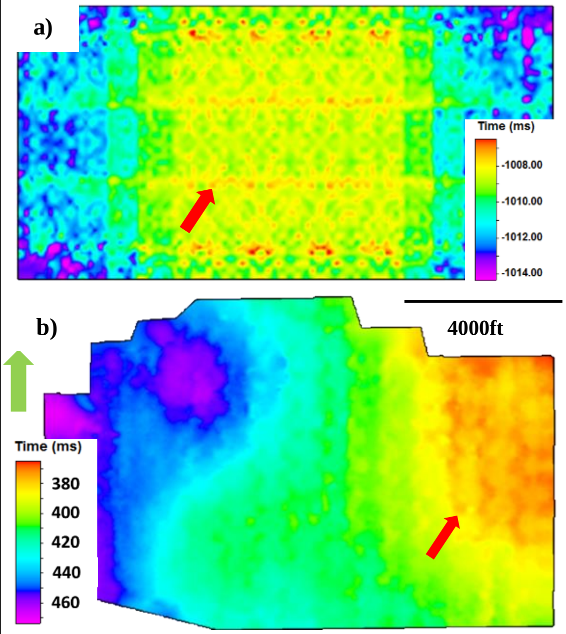

Figure 6. Horizons tracked through (a) synthetic data, displayed on Figure 4a as green horizon. (b) real seismic data, displayed on Figure 4a as yellow horizon. The linear striations (red arrows) are due to residual groundroll overprinting P-wave reflections.

Conclusions

Our analysis indicates that the undulations caused by residual groundroll will be present on the seismic, having strongest amplitude near the surface and attenuating with depth.

We conclude that inadequately removing groundroll can result in erroneous and more difficult interpretations. Furthermore, seismic attributes, often used by less experienced interpreters to accelerate there interpretations, are not immune to acquisition footprint caused by groundroll. In many cases, seismic attributes exacerbate the effects of this noise.

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EDITED REFERENCES

Note: This reference list is a copyedited version of the reference list submitted by the author. Reference lists for the 2015 SEG Technical Program Expanded Abstracts have been copyedited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

REFERENCES

Cahoj, M. P., and K. J. Marfurt, 2015, Reprocessing 3D seismic data for prestack attribute interpretation, Fort Worth Basin, Jean, Texas: Presented at the Midcontinent Section Meeting, AAPG, Poster Presentation.

Chopra, S., and G. Larsen, 2000, Acquisition footprint — Its detection and removal: CSEG Recorder, **25**, no. 8, 16–20.

Cvetkovic, M., N. Pralica, S. Falconer, K. J. Marfurt, and S. Chávez-Pérez, 2008, Comparison of some algorithms for acquisition footprint suppression and their effect on attribute analysis: 78th Annual International Meeting, SEG, Expanded Abstracts, 2637–2641.

Hill, S., M. Shultz, and J. Brewer, 1999, Acquisition footprint and fold-of-stack plots: The Leading Edge, **18**, 686–695, http://dx.doi.org/10.1190/1.1438358.

Marfurt, K. J., and T. M. Alves, 2015, Pitfalls and limitations in seismic attribute interpretation of tectonic features: Interpretation, **3**, no. 1, SB5–SB15, http://dx.doi.org/10.1190/INT-2014-0122.1.

Marfurt, K. J., R. M. Scheet, J. A. Sharp, and M. G. Harper, 1998, Suppression of the acquisition footprint for seismic sequence attribute mapping: Geophysics, **63**, 1024–1035, http://dx.doi.org/10.1190/1.1444380.

Verma, S., S. Guo, and K. J. Marfurt, 2014, Prestack suppression of high frequency ground roll using a 3D multiwindow KL filter: Application to a legacy Mississippi Lime survey: 84th Annual International Meeting, SEG, Expanded Abstracts, 4274–4278.

DOI http://dx.doi.org/10.1190/segam2015-5932350.1