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Internal multiple prediction on Hussar synthetics

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Summary

The inverse scattering series internal multiple prediction algorithm is often called upon due to its unique ability to predict internal multiples with no subsurface information and without compromising the primaries. This technology does not require velocity information from the subsurface or any advance knowledge of the multiple generators, and it predicts first-order internal multiples that are generated by all possible generators below the free surface. In this paper, we employ the 1.5D internal multiple prediction algorithm on synthetics from the CREWES Hussar dataset. The synthetics are acquired by blocking the well 12-27 with different depth steps. We find that it can successfully predict internal multiples generated by the relatively thin layers of the Hussar geology (provided the interval between two primaries is larger than the optimal ϵ value). By extending the synthetic in offset, we see that certain prediction artifacts can be tied to land apertures.

Introduction

Internal multiple prediction and attenuation has historically mostly been limited to marine environments, especially in deep water. The characteristics of land seismic data (i.e. noise, statics, and coupling) are major obstacles for the application of internal multiple elimination (Luo et al., 2011). The layer/boundary approach introduced by Verschuur and Berkhout (2001) has been tested in such environments by Luo et al. (2007) and Kelamis et al. (2008) with some success. However, for the application of this method, advance knowledge of the main multiple generators is required. On land, most of the internal multiples are generated by a series of complex, thin layers encountered in the near surface (Kelamis et al., 2006). Therefore, this type of method is not always suitable, as it requires the definition of many “phantom” layers. Luo et al. (2011) report significant improvements in tests of the inverse scattering series approach (Weglein et al., 1997; 2003); recently Hernandez and Innanen (2014) have demonstrated that clear predictions based on the latter theory and approach are even possible on poststack land datasets.

The purpose of this paper is to examine the ability of 1.5D internal multiple prediction in a specific land application. We carry out an experiment on a synthetic land dataset using the sonic log synthetics acquired by CREWES near Hussar, Alberta. Prestack data are analyzed with the 1.5D version of the algorithm, in particular with an eye for the success with which the multiples reverberating in the relatively thin-layering of even the blocked log model can be predicted, and for the influence of realistic offsets on the generation of far-offset artifacts in the prediction (Pan and Innanen, 2014).

Hussar synthetics

In September 2011, CREWES collaborated with Husky Energy, Geokinetics, and INOVA to carry out a seismic experiment. This was in order to collect a dataset to test the inversion methods and study the low frequency content of seismic data near Hussar, Alberta (Margrave et al., 2012). The line was 4.5km which crossed 3 wells 12-27, 14-27 and 14-35, see Figure 1 (Lloyd, 2013). All wells have P-wave sonics, density and gamma ray logs, while well 12-27 has an extra S-wave sonic. In this test, we only use the P-wave sonic of well 12-27, the depth of log in which extend from 200m to about 1600m. In Figure 2a, we displayed v_p log only, in order to analyze and model the arrival times of the events for the seismic data.

The well data illustrated in Figure 2a are used to develop a blocked v_p profile, using blocklogs.m from the CREWES toolbox to carry this out. The algorithm eliminates all shoulder effects so that the log curves are resolved into zones of constant value, separated by horizontal boundaries. The geology becomes more 'bed-like' in appearance. Also, a gradient overburden is attached that extends from the surface to the local averages of values found at the top of the log. In this case, we chose P-wave velocity to be 2563m/s to fill in a linear gradient overburden from the first logged depth to the surface. We illustrate the original log in black and the blocked log in red (Figure 2b), along with the blocked log alone (Figure 2c). The depth step of the log being blocked is 100m. As we can see, some details have been ignored because of the size of the depth step. We will test a smaller depth step for thin layers in later section.

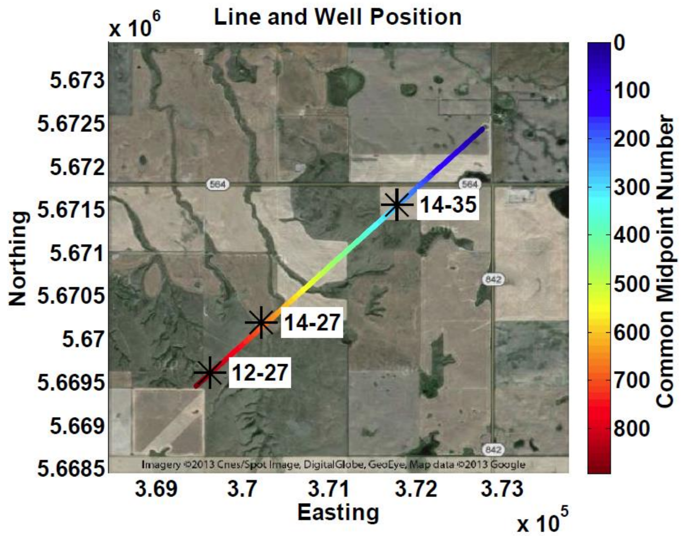

Figure 1: The 4.5km Hussar seismic line is shown along with the locations of 3 wells (from Lloyd, 2013).

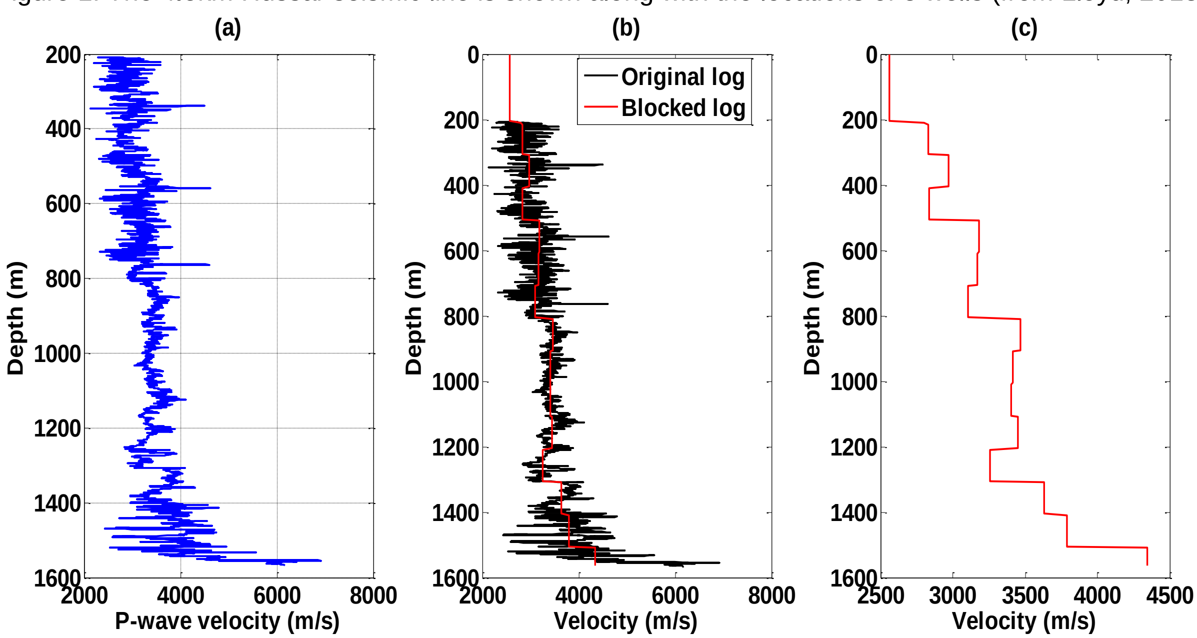

Figure 2: (a) Well 12-27 P-wave sonic log; (b) shows the original log in black and the blocked log in red; (c) shows only the blocked log. The depth step of the log being blocked is 100m.

Then acoustic finite difference forward modeling codes in the CREWES Matlab toolbox are then used to create the data. Land data lack the well-defined free surface multiples present in marine data, but possess more complex near surface. To avoid surface multiples, we made the boundary condition to be absorbing on all four sides; surface wave effects are neglected in our current analysis. The source and receiver interval is 5m, and the record length is 1.5s with a sampling rate of 4ms. The data were generated with lowcut, lowpass, highpass and highcut frequencies of 10Hz, 20Hz, 80Hz and 100Hz respectively. As such the geology and geometry of the Hussar experiment is correctly represented but the full broadband character is not (this is to allow our numerical analysis to proceed more expediently). The algorithm requires only the upgoing field as input, so we remove the direct wave, in this case by modeling and subtracting it (in practice a direct wave mute is normally applied).

The result of our 1.5D internal multiple prediction is illustrated in Figure 3a, and compared with the original shot record (Figure 3b). The ϵ value was chosen to be 50 sample points. The result of Figure 3 is quite promising. The first internal multiple (about 0.6s), which is interfering with a primary, has been correctly predicted. Also, internal multiples from possible generators are shown below 1.1s in Figure 3a. The kinematics of the internal multiples seems to be approximately correct. The amplitudes are also as expected, with discrepancies which increase with the number of transmission interactions the event experiences (Weglein and Matson, 1998). However, artifacts become increasingly noticeable in the far offsets of the prediction record. One of the likely explanations for this is the aperture; we might inquire whether by increasing the offset we can reduce these artifacts. We simulate greater offset by increasing the source and receiver interval to be 10m, and the final result is shown in Figure 4. Compared with Figure 3, we can see significant improvement in the prediction result. There are no more artifacts in the far-offset, and the moveout pattern of each internal multiple event seems essentially correct. Thus far-offset artifacts can be effectively eliminated with acquisition changes; a significant correction of these will be possible with tapering.

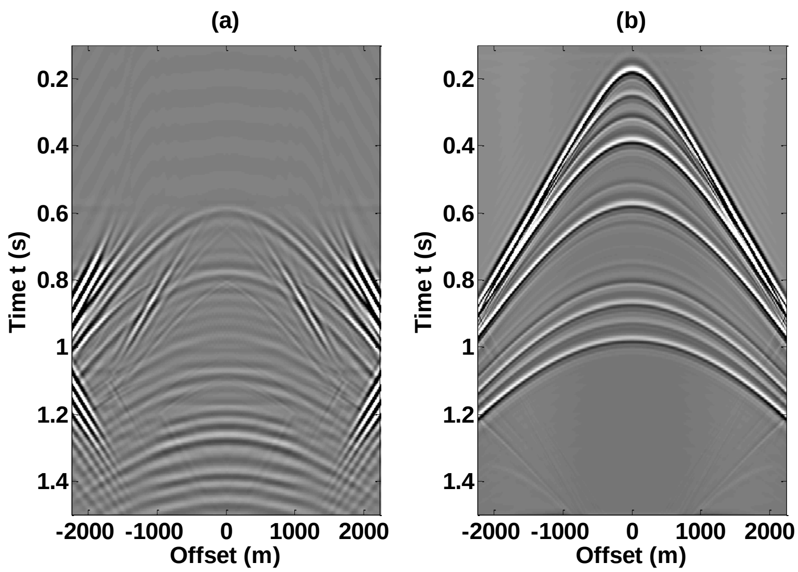

Figure 3: Comparison of prediction output with input. (a) Prediction output; (b) input data.

Next we will decrease the depth step of the log being blocked to 50m. Our goal is to study whether the internal multiple prediction algorithm can successfully predict internal multiples generated by relatively thin layers. The prediction result is shown on the left in Figure 5, while the original shot record is depicted on the right. The model is composed of a large number of thin layers, with obvious presence of internal multiples in this dataset. The performance of the 1.5D internal multiple prediction algorithm is still acceptable, especially at the zone between 0.6s and 0.8s since several internal multiples are interfering with primaries.

Conclusions

We examine the performance of the 1.5D internal multiple prediction algorithm on Hussar synthetics. The synthetics are acquired by blocking well 12-27 with different depth steps. Its effectiveness was demonstrated by the datasets, yielding promising results. The inverse scattering series technology does not require velocity information from the subsurface or any advance knowledge of the multiple generators. This method has been proven to be effective in land seismic data where close interference between primaries and internal multiples occur. Also, it can successfully predict internal multiples generated by relatively thin layers, as long as the interval between two primaries is larger than the optimal ϵ value. By extending the synthetic in offset, we see that certain prediction artifacts can be tied to land apertures.

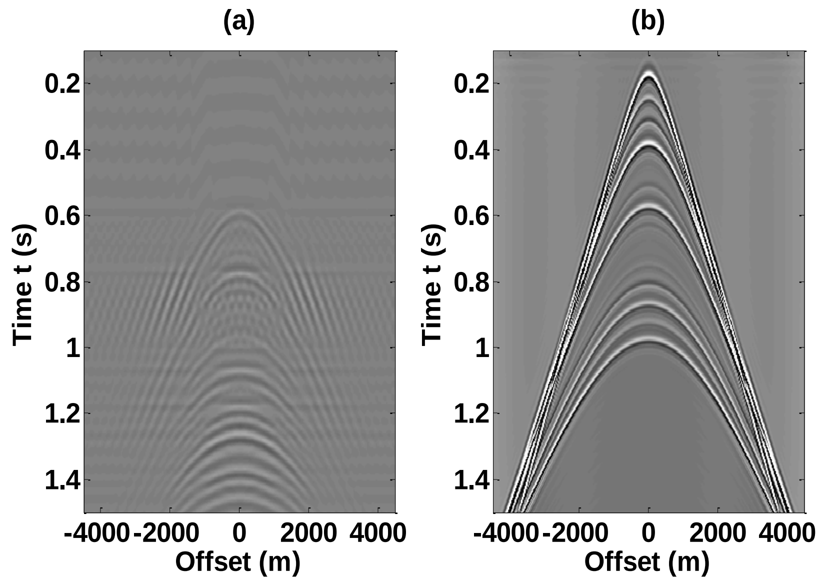

Figure 4: Comparison of prediction output with input. (a) Prediction output; (b) input data.

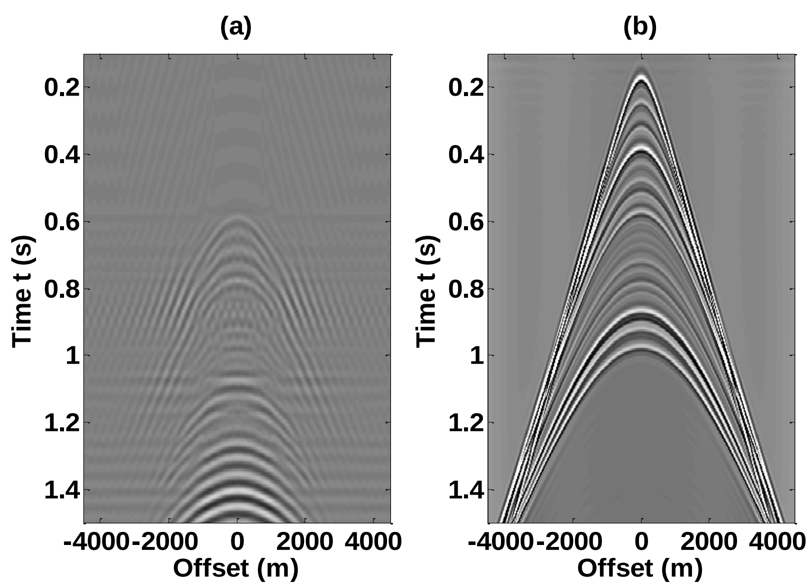

Figure 5: Comparison of prediction output with input. (a) Prediction output; (b) input data.

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