

Wavefield component separation and debubble on a 3D OBN dataset

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ABSTRACT

In this report we demonstrate the pre-processing steps performed on the OBN Gulf of Mexico data set provided to us by Shell in preparation for an FWI type workflow. We show the results of performing PZ-summation on the hydrophone data for up and downgoing wavefield separation, and follow with the extraction of the estimated source wavelet and creation of a shaping filter to remove the bubble and facilitate better phase matching with our synthetic data. We apply this filter to the remaining data and find we can effectively remove the bubble.

INTRODUCTION

In order to successfully perform an FWI style of inversion with our dataset, we first need to apply a standard processing flow. An important goal to keep in mind is that we ultimately want to calculate a ‘good’ residual for use in our inversion. To do this, we need to have some similarity between our synthetically modeled data and the observed data. One feature in our observed data that can be difficult to accurately recreate in our synthetic data is the bubble that follows the initial source injection. For this reason, we choose to remove it from the observed data.

This paper intends to show that a straight-forward way to simultaneously remove the bubble and increase similarity between our observed and synthetic data is to shape the observed data to the source wavelet we use in our synthetic modeling. To do this, we first perform separation of the up and downgoing components from the hydrophone data using PZ-summation. Next, we extract a representative wavelet from the observed data first-arrival, and then estimate a filter that shapes it to the synthetic data source wavelet. We then apply this filter to the entire dataset, resulting in a debubbled dataset that has a high degree of phase similarity with our synthetic data.

PZ-summation

Since the dataset was recorded on ocean bottom nodes (OBN), the first arrival in the hydrophone component contains an up-going ocean bottom reflection that nearly coincides with the downgoing direct arrival event. This means the wavelet we extract

from the first arrival event will have an ocean bottom event mixed into it. To get an accurate estimated source wavelet, we need to isolate the downgoing direct arrival. For this reason, we first need to perform PZ-summation before we do any source wavelet estimation.

PZ-summation is a technique used to separate the up and down going components of hydrophone data (figure 1) using the complimentary information found in the vertical component data (figure 2). We base our application of this processing step on the approach and assumptions used by Biondi and Levin (2014), which represents the up and downgoing data with the following equations:

$$P_{up}(f, k) = \frac{1}{2}P(f, k) + a(f)\frac{\rho}{2q(f, k)}Z(f, k), \quad (1)$$

$$P_{down}(f, k) = \frac{1}{2}P(f, k) - a(f)\frac{\rho}{2q(f, k)}Z(f, k), \quad (2)$$

where P is the designated pressure data, Z is the designated vertical data, $a(f)$ is the calibration filter, ρ is the water density, and q is the vertical slowness of the water layer defined as:

$$q(f, k) = \sqrt{c^{-2} - p^2(f, k)}. \quad (3)$$

In this case, c is the water velocity at the receiver position and p is the ray parameter.

One event in the data we can leverage is the refraction event, which by definition is an upgoing event. Furthermore, the refraction event is naturally separated in the time domain at far offsets, making it easy to isolate (see figures 3 and 4).

We can estimate a filter $\hat{a}(f)$ to apply to the windowed refraction event such that it minimizes its energy. However, the inverted $\hat{a}(f)$ contains the effect of the vertical slowness and water density. We can represent this with equation 4:

$$\hat{a}(f) = a(f)\frac{\rho}{2q(f, k)}. \quad (4)$$

However, we assume the water velocity and density are constant throughout, and that the ray parameter is constant in the window we minimize. We can then remove this effect from $\hat{a}(f)$ to get $a(f)$. We can estimate the ray parameter p in the rest of the data which allows us to reuse $a(f)$ to separate the upgoing (figure 5) and downgoing (figure 6) components using equations 1 and 2.

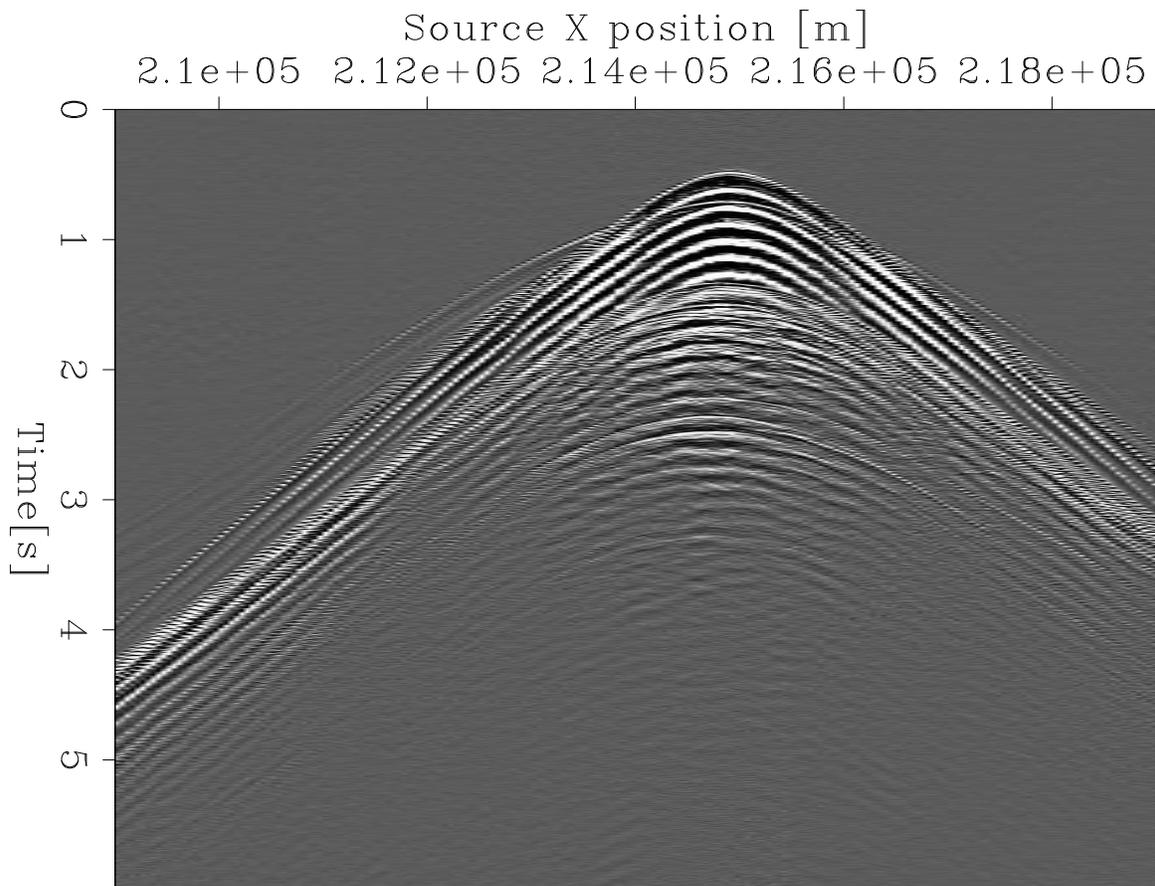


Figure 1: 2D line receiver gather example from designated and bandpassed hydrophone data. [CR]

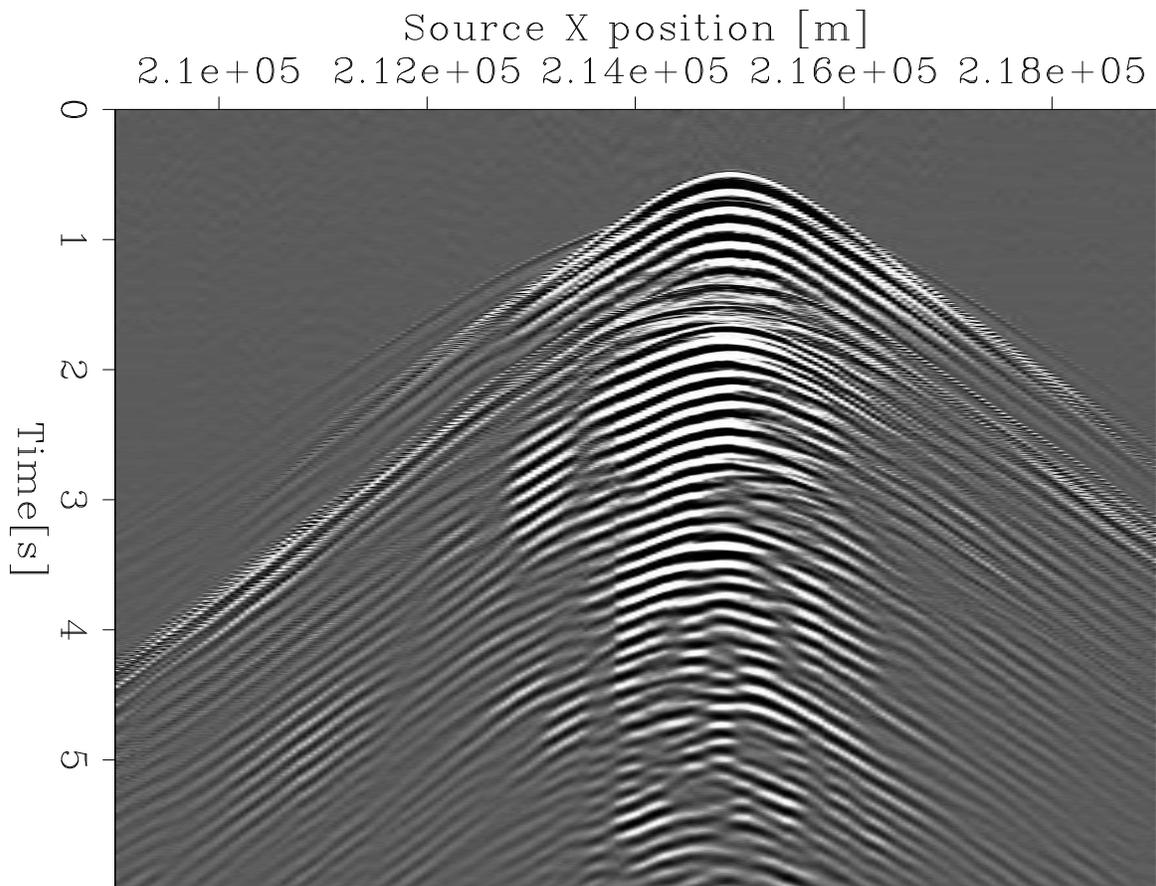


Figure 2: 2D line receiver gather example from designated and bandpassed geophone data. [CR]



Figure 3: Hydrophone data window (isolating the refraction events) used for estimating PZ-summation filter. [CR]

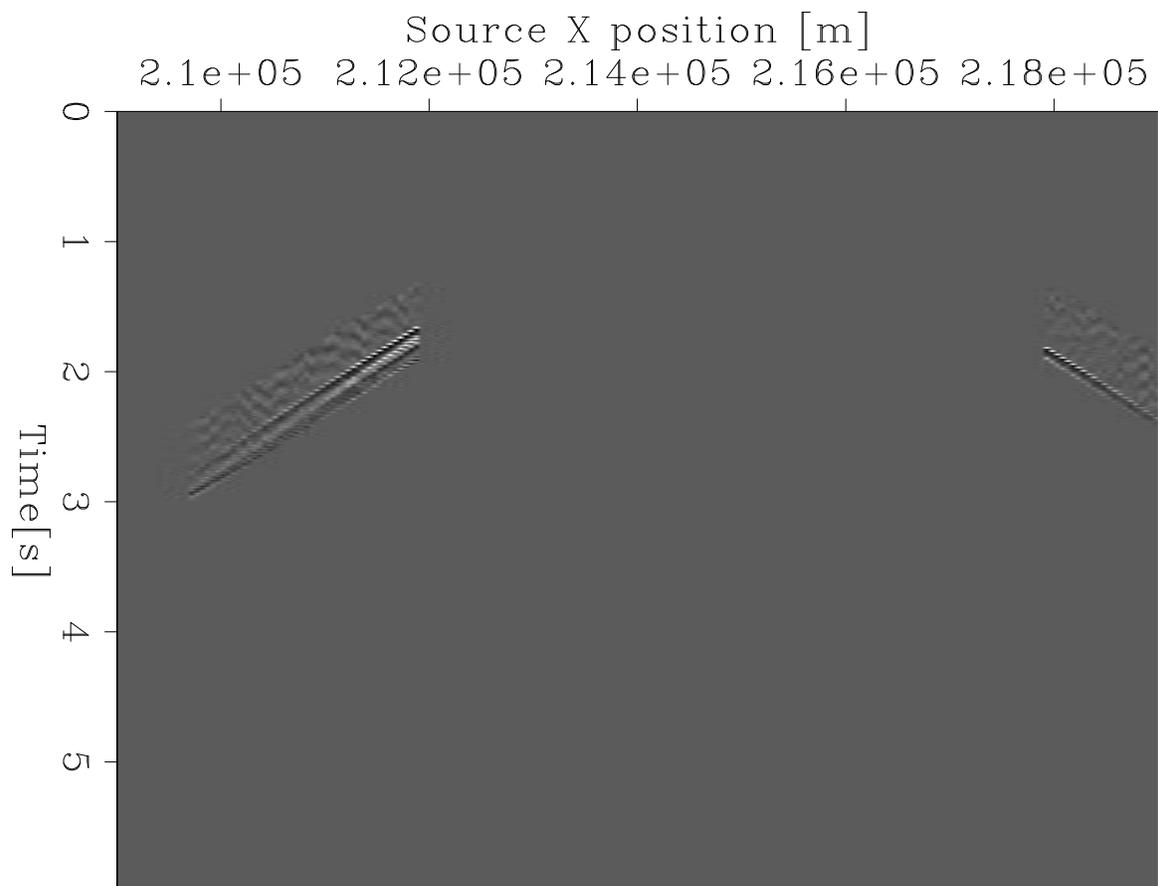


Figure 4: Geophone data window (isolating the refraction events) used for estimating PZ-summation filter. [CR]

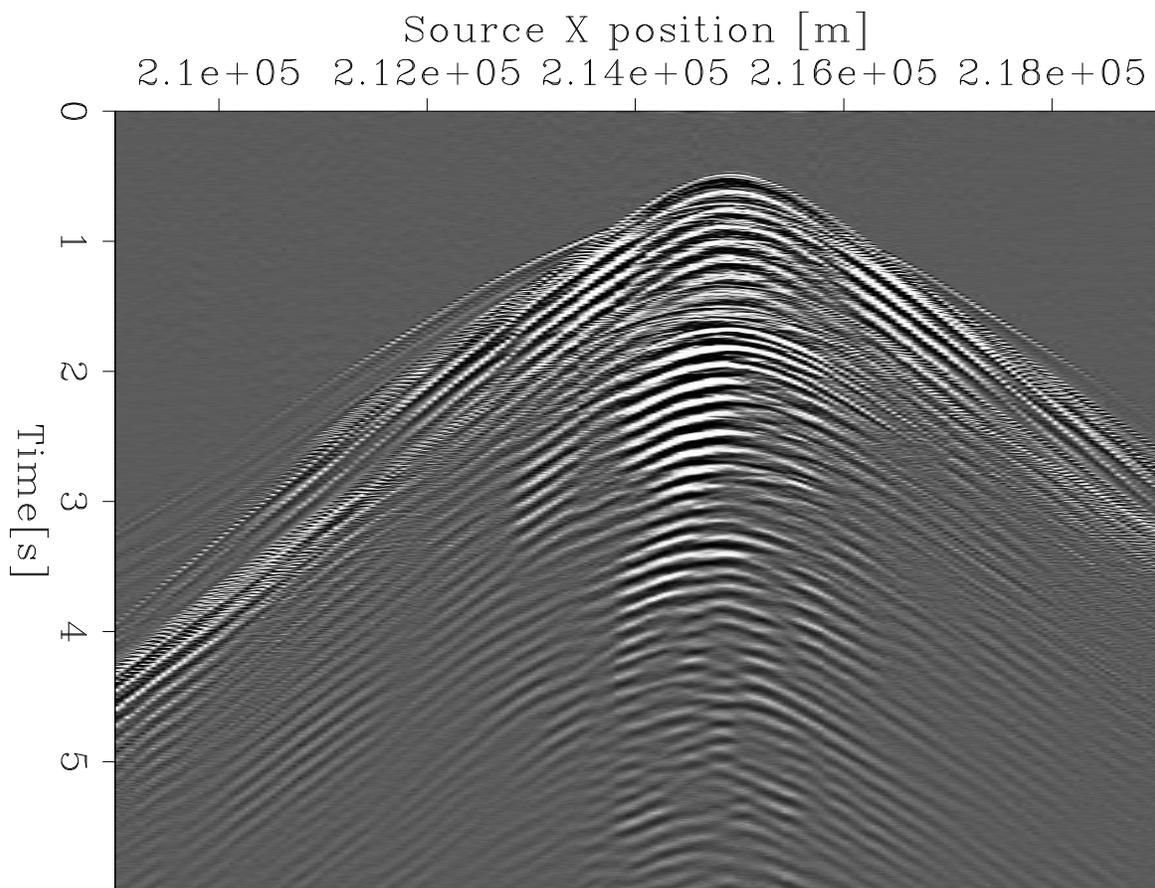


Figure 5: Upgoing component output from PZ-summation. [CR]

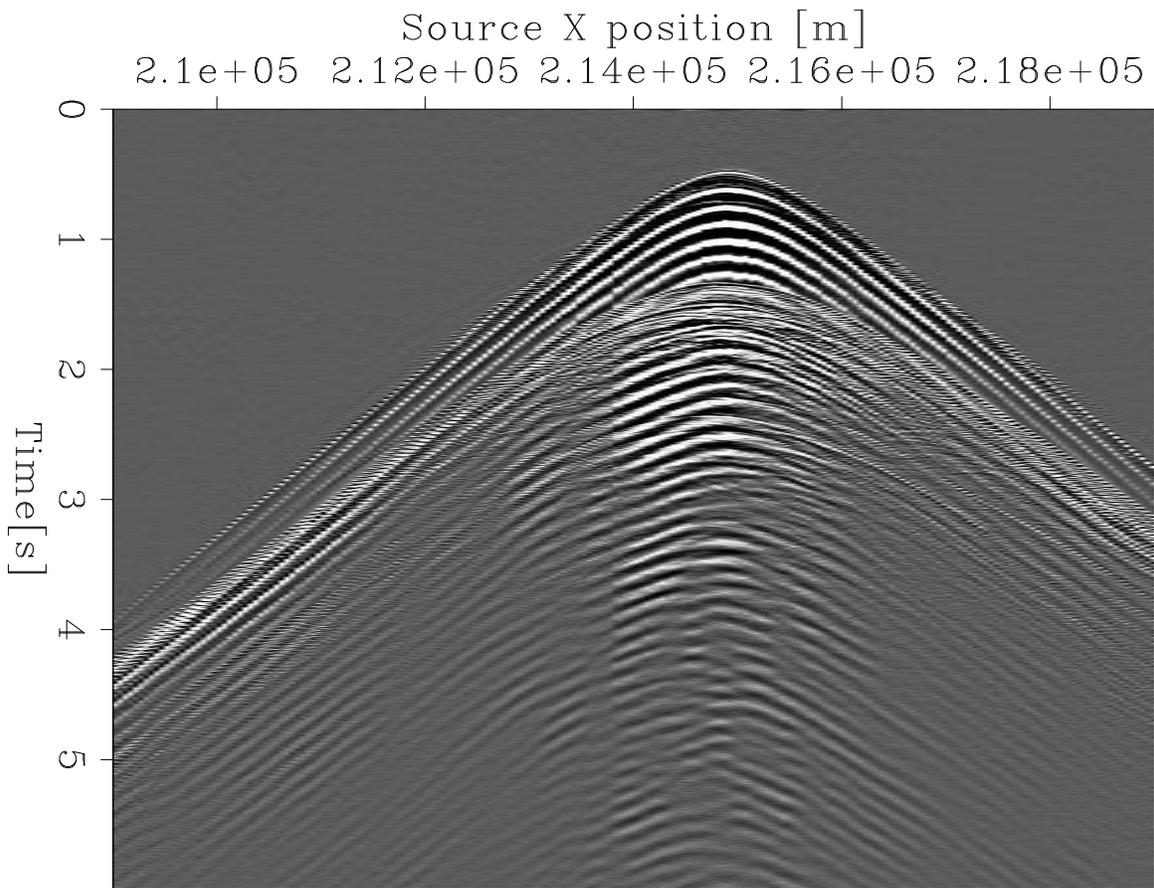


Figure 6: Downgoing component output from PZ-summation. [CR]

Debubble and wavelet shaping

Picking the data wavelet

Once we have the downgoing component of the hydrophone data separated, we can estimate a source wavelet from a near-offset subset of it (figure 7). First, we perform hyperbolic moveout (HMO) for each node gather to align the first arrival event across all offsets (figure 8). We can then stack across all offsets to find a single wavelet representative of that node gather (figure 10). To increase our averaging further, we can stack across all node gathers (figure 11). To do this however, we need to align the first arrival event in each node gather to a common time position ($t_0 = 0$ for example). This means shifting based on the relative depth of each of the nodes respectively. We perform this shifting and stacking across nodes to find a final wavelet representative of the average of the sources actually used. In this wavelet we notice the bubble signature as periodic, fading pulses.

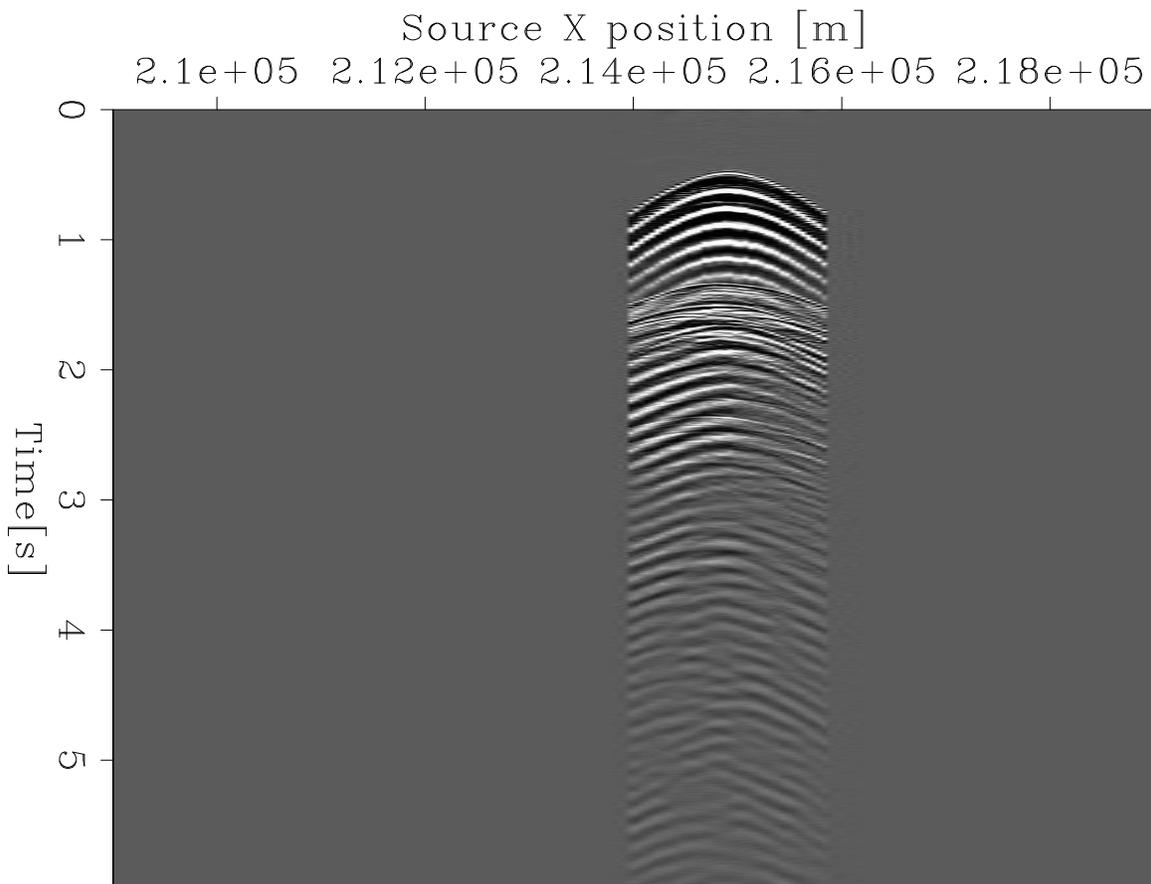


Figure 7: Near offset ($< 1000\text{m}$) subset of figure 6 chosen for estimating observed source wavelet. [CR]

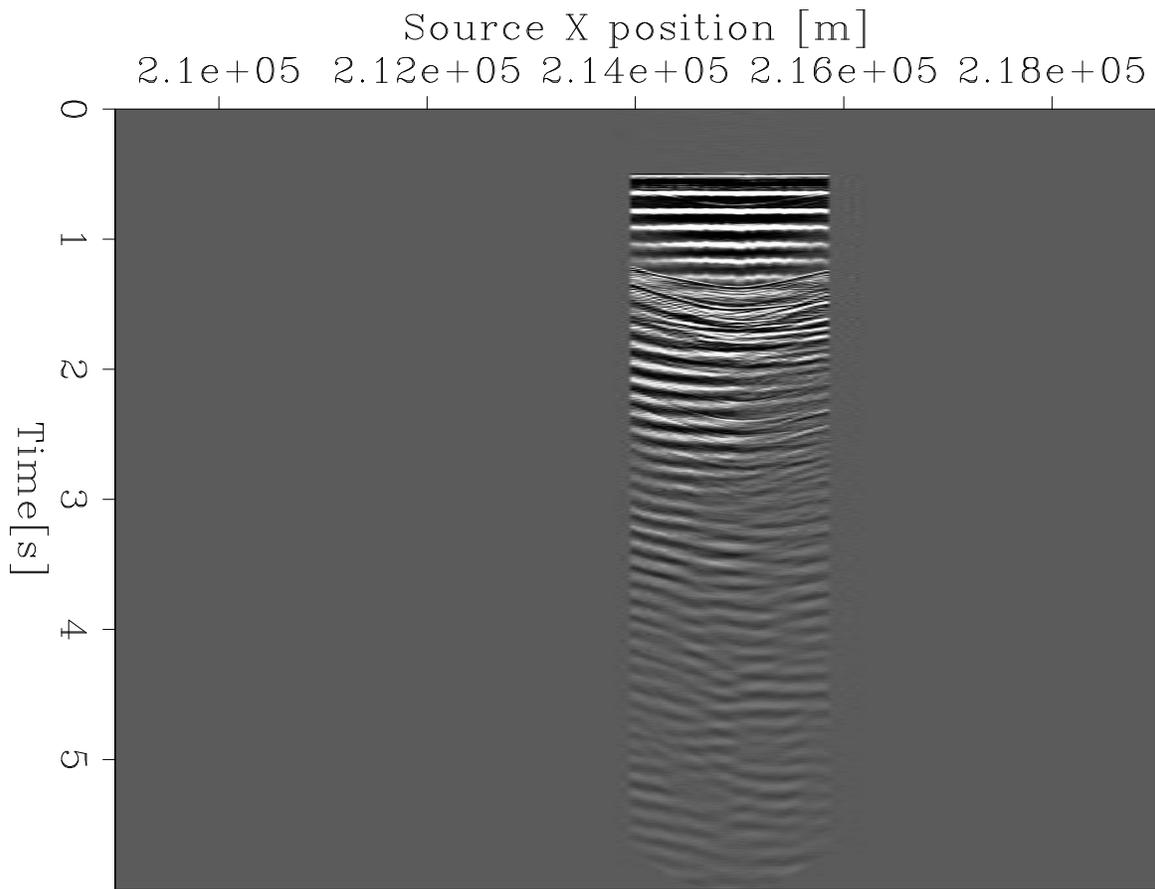


Figure 8: 1500 m/s HMO correction applied to data in figure 7. [CR]

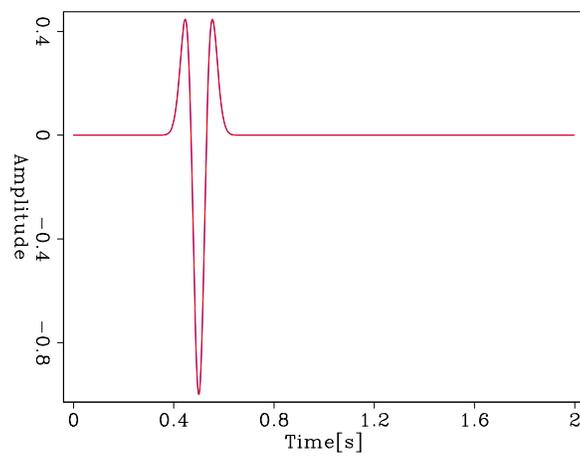


Figure 9: Wavelet used in synthetic data modeling. [CR]

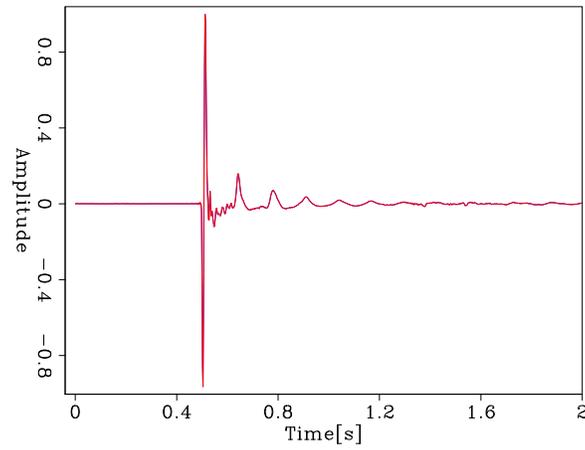


Figure 10: Wavelet produced from stacking across traces in figure 8. [CR]

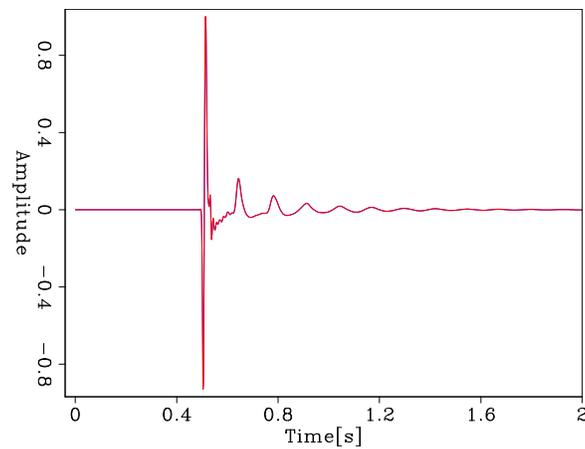


Figure 11: Observed source wavelet built from average of wavelets extracted from 381 node gathers (just as in figure 10). [CR]

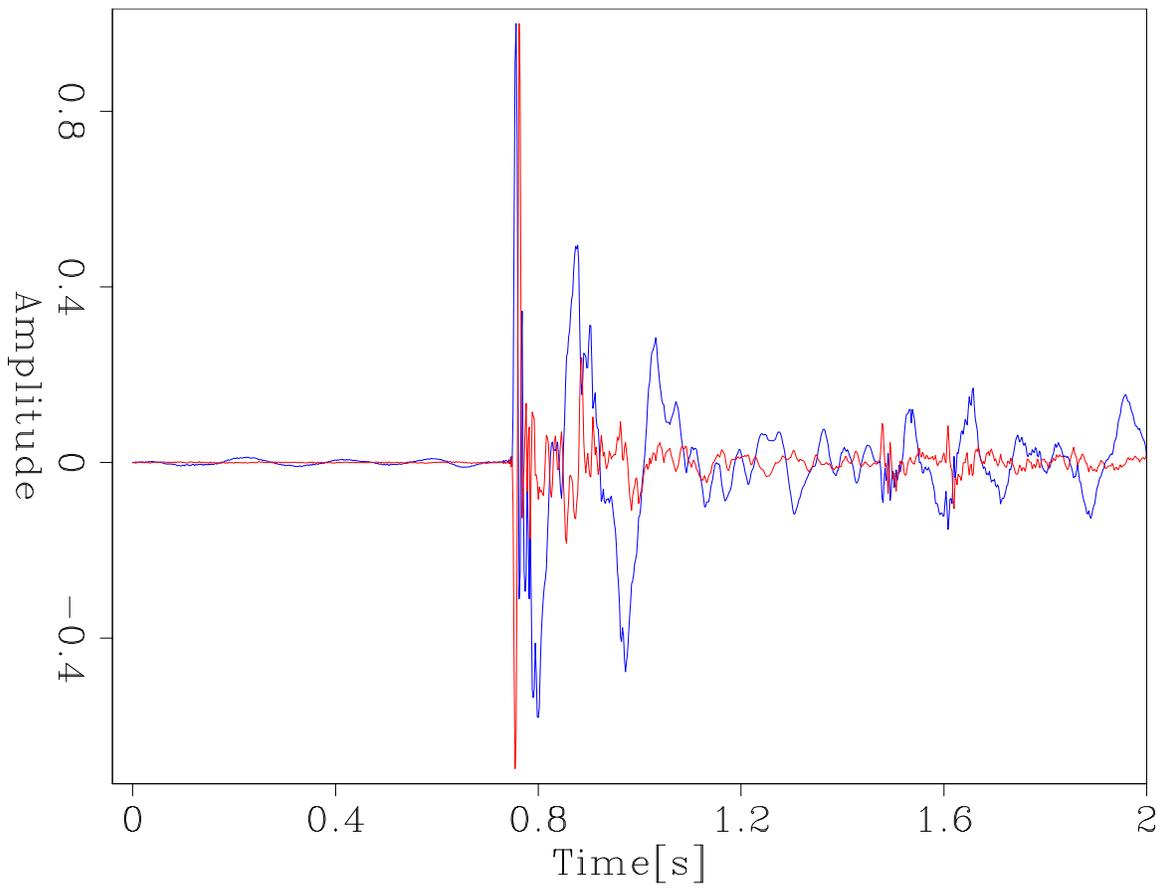


Figure 12: Example trace before (red) and after (blue) shaping filter applied. [CR]

Finding the shaping filter

In our synthetic data, we model using a simple 8[Hz] central frequency Ricker wavelet (see figure 9). When we compare against the averaged observed data wavelet (figure 11), we can see that there are some significant differences that warrant the use of a shaping filter. We estimate the filter that shapes the averaged observed data wavelet to the synthetic wavelet (see Yilmaz (1987)), and then apply to the full dataset (figures 13 and 14). When we compare figure 6 with figure 13, we can see that the bubble removal is effective, and that the frequency and phase content has become more similar to what we would expect given the lower frequency Ricker wavelet to which we match.

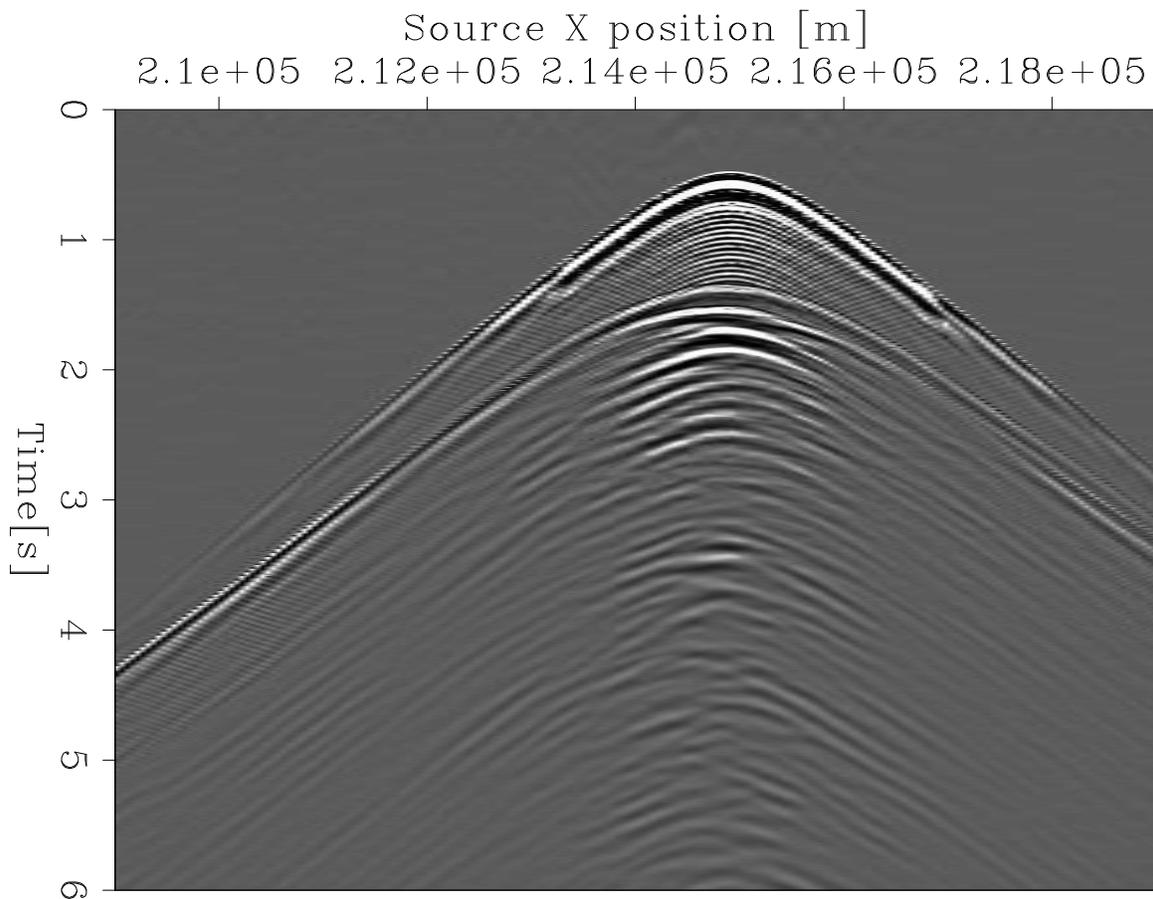


Figure 13: Downgoing hydrophone data after shaping filter applied. [CR]

CONCLUSIONS

We applied a standard processing flow to the Shell OBN dataset that began with PZ-summation to separate the upgoing and downgoing components, which are more suitable for imaging purposes than the original pressure and vertical component data.

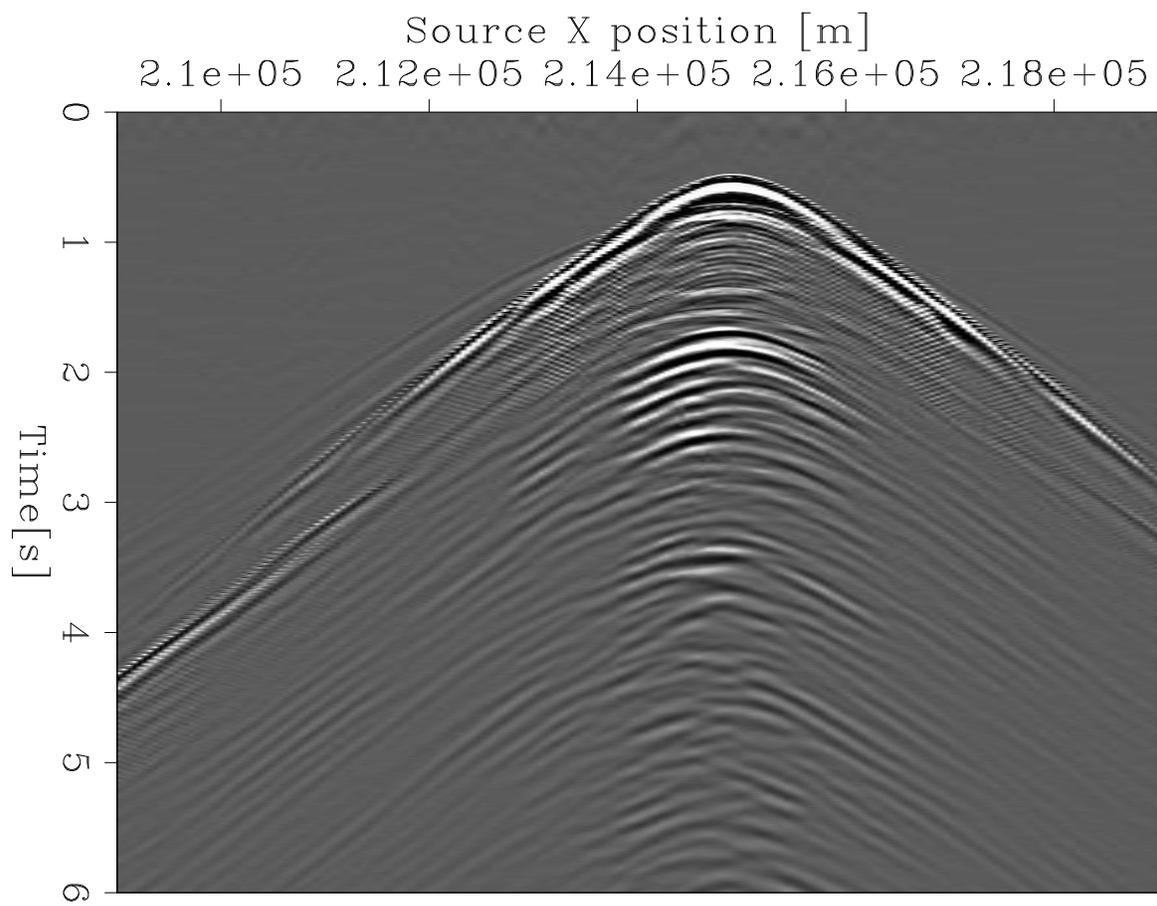


Figure 14: Upgoing hydrophone data after shaping filter applied. [CR]

A designature process was performed by reshaping the upgoing and downgoing components to a synthetic wavelet, which will be used for synthesizing data during FWI. We estimated the original wavelet by applying HMO correction, and stacking near-offset subsets of the node gathers. The reshaped data are to ultimately be tested in FWI.

ACKNOWLEDGEMENT

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REFERENCES

- Biondi, E. and S. A. Levin, 2014, Application of the up-down separation using PZ calibration filter based on critically refracted waves: SEP-Report, **155**, 119–132.
- Yilmaz, O., 1987, Seismic data processing: Society of Exploration Geophysicists.