Data Report: Prestack Waveform Inversion at GC 955: Trials and sensitivity of PWI to high-resolution seismic data[1]

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1. Abstract

Understanding the spatial extent and variability of hydrate deposits has important implications for potential economic production, climate change, and assessing natural hazards risks. Seismic reflection techniques are capable of determining the extent of gas hydrate deposits and can shed light on hydrate concentrations and properties. Using high resolution prestack time migrated seismic data collected during a 2013 US Geological Survey expedition and prestack waveform inversion (PWI) techniques, we produce highly resolved velocity models and compare them to co-located well logs. Coupling our PWI results with velocity-porosity relationships and nearby well control, we compare hydrate properties at site 955 in the Green Canyon and site 313 at Walker Ridge.

2. Introduction

We performed prestack waveform inversion of the reprocessed and prestack time migrated high-resolution seismic data collected at GC955. The goal of this work was to determine the utility of the high-resolution data for detailed velocity inversion in two major ways: (1) to investigate lateral changes as they relate to bottom simulating reflectors (BSRs), and (2) to determine if there is evidence for free

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gas inclusion in the hydrate stability zone (HSZ). Initial results were promising and showed variability along the BSR and velocity reduction above the bottom of the hydrate stability zone, but data corruption was discovered in these initial results. We ultimately conclude that these high-resolution data were acquired without the required offset to accurately invert for seismic velocity and thus cannot make conclusions related to our target scientific questions.

3. Methods and Materials

The data were collected by the USGS aboard the R/V Pelican on April 18 to May 3, 2013 on cruise P-13-LA. The seismic system was comprised of a 105/105 cubic inch, generator-injector airgun source and recorded on a 450-meter 72-channel hydrophone streamer. These seismic data were processed using Landmark and Paradigm software through prestack time migration including velocity picking and tomography to prepare the data and starting velocity models for seismic inversion. For the inversion work, we focused on line GC225a for its quality and the presence of geologic features relevant to our study.

Results from the imaging show some clear features as interpreted in Figure 1. First, free gas below the hydrate stability zone is bright and well contained, a result we could leverage to investigate lateral changes along a BSR. Second, fractures and potential chimney structures are present indicating these data may be ideal for investigating high concentrations of gas in the hydrate stability zone, including free gas possibilities.

4. Results

4.1 Results – Trial 1

We chose 7 sites to perform detailed prestack waveform velocity analyses as a first-pass at our scientific objectives (Figure 2a). These results were encouraging (Figure 2b) and showed high correlation between the real data and the synthetics generated by the inversion process (Figure 3). We then compared the borehole measurements taken at site GC-955H to the seismic data at the same location (Figure 4). Inversion results show a velocity slow down within the hydrate layer and an inverse relationship between the velocity measurement anomalies when comparing the borehole and seismic inversion measurements. These results suggested the inclusion of free gas in the hydrate stability zone.

To determine the sensitivity of these data, we ran inversion trials with various other starting models. We tried 4 models: the prestack time migrated velocity (including gas in the HSZ), a model with the HSZ informed by the borehole measurements (no free gas in the HSZ), the downhole sonic velocity model, and a linear velocity-depth model. In table 1 we show the results of these tests. We revisited the data and found data corruption in all but the original data file; specifically, the seismic amplitudes had been clipped. We were unable to determine where and when exactly the data was corrupted.

4.2 Results – Trial 2

We began a second set of trials checking each data file as the inversions were run. We tested the same sequence of starting velocity models (plus one additional reasonable model), each representing a different Earth subsurface structure (Figure 5).

As expected, the original data and prestack time migration velocity model yielded nearly identical results to our first trials. The starting models with reasonable background velocity models, yielded similarly good correlations between the real and synthetic data (Table 2). However, trials using a simple linear velocity gradient and the sonic logs resulted in poor results and correlations. No models were able to significantly vary the background velocity trends due to the limited offset nature of the high resolution data.

5. Acknowledgements

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6. References

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7. Tables

Table 1.

Model (color)	**Inverted Correlation**
Prestack time migration (black)	85%
Reduced gas presence (magenta)	60%
Sonic velocity (blue)	72%
Linear velocity gradient (not shown)	69%

Table 1. First trials starting inversion model and correlation between real and synthetic results.

Table 2.

Model (color)	**Inverted Correlation**
Prestack time migration (black)	86%
Sonic-corrected bottom of HSZ (red)	85%
Reduced gas presence (magenta)	87%
Sonic velocity (blue)	70%
Linear velocity gradient (not shown)	74%

Table 2. Starting velocity models and inverted results.

8. Figures

Figure 1.

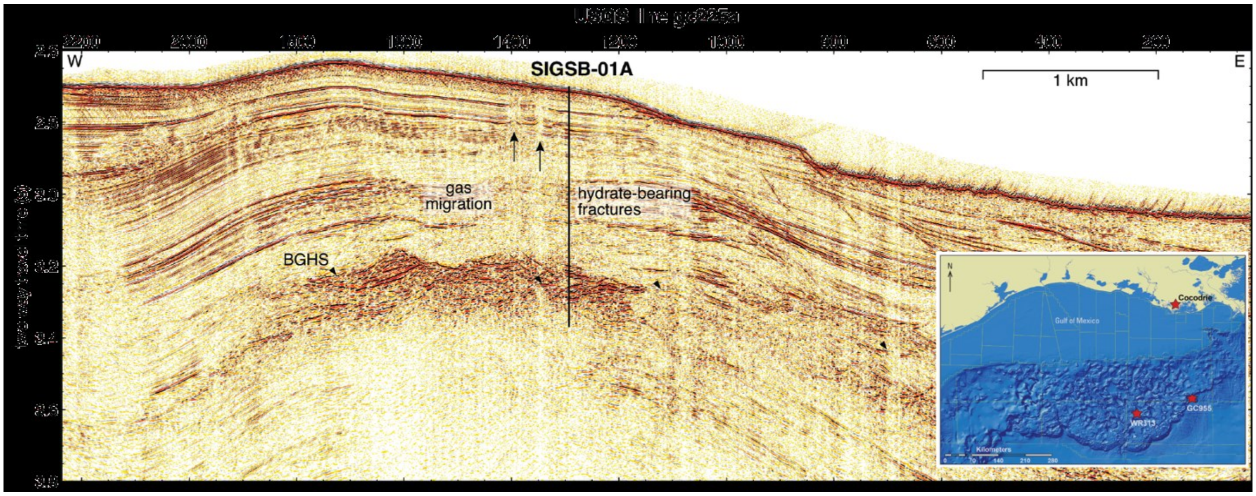

Figure 1. Seismic image of line GC225A with interpretation. Inset map shows location of GC955 and WR313 in relation to expedition port at Cocodrie, LA (From cruise report, Haines et al., 2014).

Figure 2.

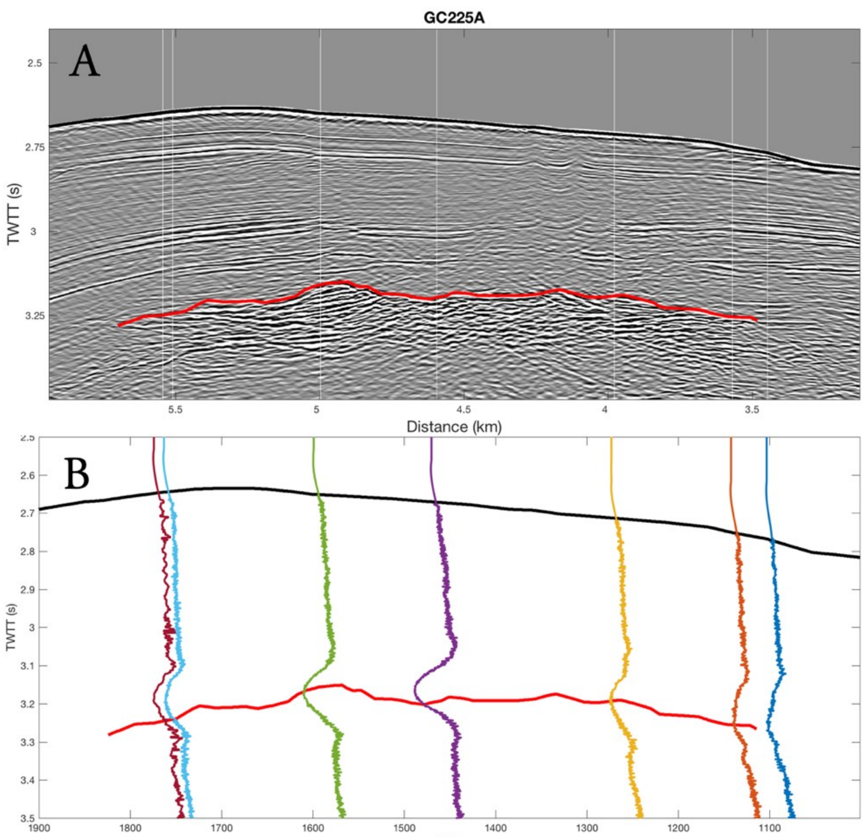

Figure 2. (A) Reprocessed prestack time migration showing the 7 inversion analysis points (white vertical lines) and the top of the gas reservoir (red). (B) Seafloor and reservoir top (black and red) with inverted velocity results overlaid.

Figure 3.

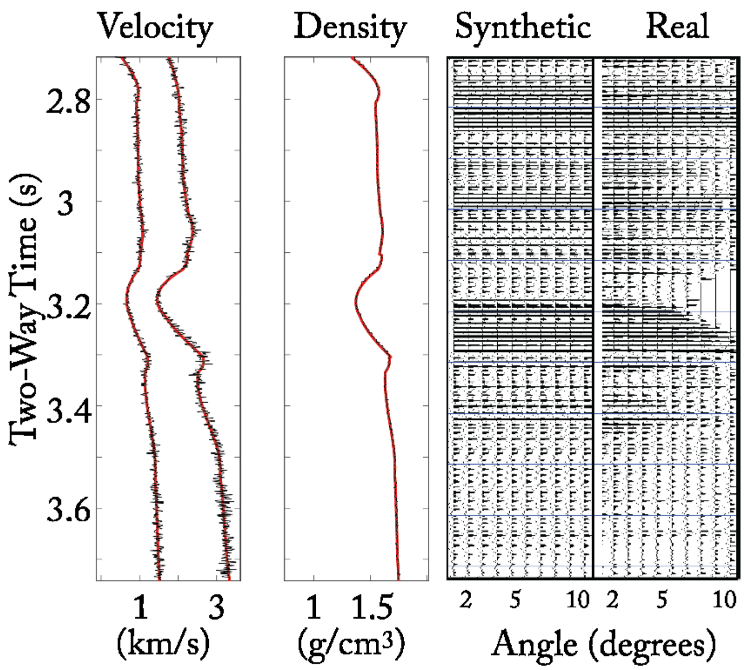

Figure 3. Inverted velocity result from gather 1273 (orange in Fig. 2) which is co-located with well GC955-H.

Figure 4.

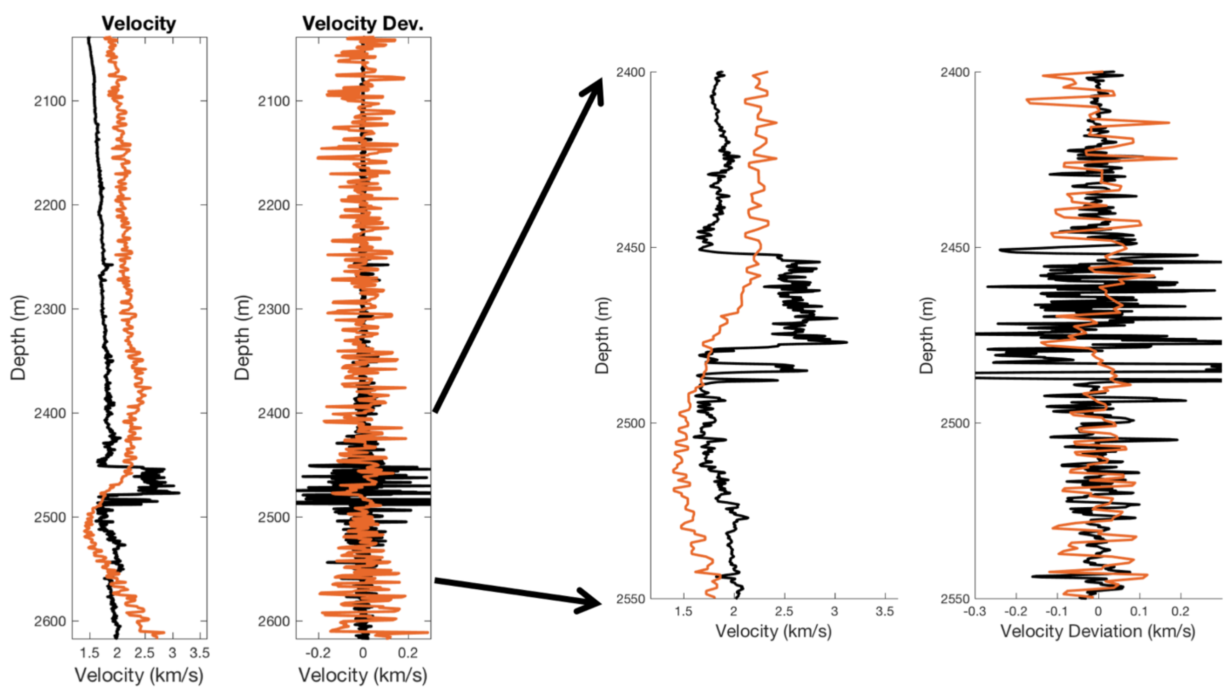

Figure 4. Inverted velocity results (orange) show with sonic velocity from GC955-H (black). Also shown are de-trended velocity deviations.

Figure 5.

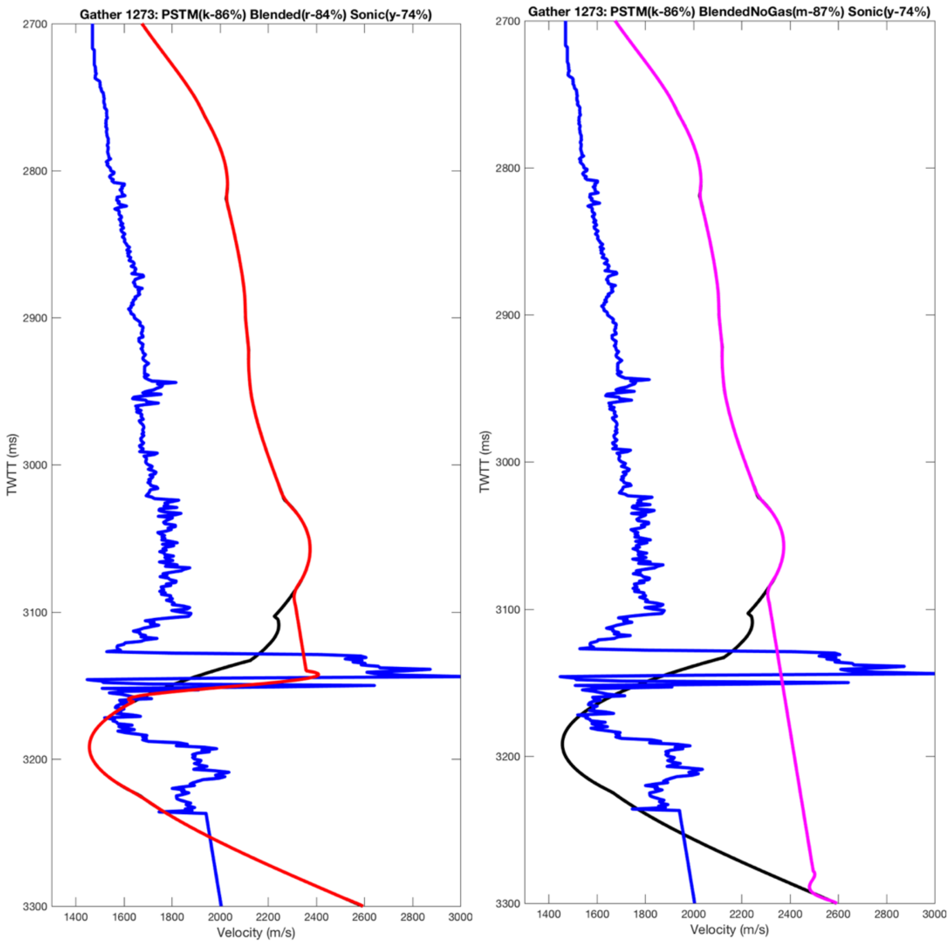

Figure 5. Starting models tested for inversion analysis. Models and colors described in text and in Table 2 below.