Channel and fracture indicators from narrow-band decomposition at Dickman field, Kansas

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Summary

In our ongoing effort to relate seismic attributes to geologic features at Dickman, we have generated a series of narrow-band attribute volumes from migrated data. Unlike traditional time-frequency methods (Chakraborty and Okaya, 1994) that seek a trade-off of time and frequency resolution, we have chosen to use a pure frequency isolation algorithm. In fact, the method we use is traditional Fourier bandpass filtering with a very narrow response centered on the frequency of interest.

Introduction

Our study area is the Dickman field in Ness County, Kansas, a type locality for geology that will be encountered for CO2 sequestration projects from northern Oklahoma across the U.S. mid-continent. Since its discovery in 1962, the Dickman Field has produced about 1.7 million barrels of oil from porous Mississippian carbonates and basal Pennsylvanian sandstone that locally develops on a regional Miss-Penn unconformity surface. The Dickman field includes a small structural closure at about 4400 ft drilling depth. Project data includes 3.3 square miles of 3D seismic data, 142 wells, with log, some core, and oil/water production data available. Only two wells penetrate the deep saline aquifer. Geological and seismic data are being integrated to create a geological property model and a flow simulation grid.

The goal of this research is to identify workflows that develop 3D seismic technologies to assess the structural integrity and heterogeneity of subsurface reservoirs with potential for CO2 sequestration. The specific objective is to apply advanced seismic attributes to aide in quantifying reservoir properties and lateral continuity of CO2 sequestration targets.

Method

The initial narrow band (NB) data was created using SeismicUnix (SU). Specifically, the sufilter program was driven by a shell script that implemented the following steps:

```
User sets fmin and fmax
for fmin to fmax by 1 Hz{
     read segy and convert to SU format
     set params to isolate one frequency
     apply sufilter
     extract time slice
     create pdf figure
}
```

This allowed quick narrow band data scanning for features of interest in time slice or vertical view. Once a particular narrow band was selected for further analysis, sufilter was applied to the original data and the entire NB attribute volume was output to segy format and imported to SMT for further analysis.

While multiple-frequency scanning is not currently implemented in SMT, narrow band data of the type described here can be calculated using:

Tools>Trace_Pak...>Process_Multiple_Traces...>Trapezoid Filter

This process done in SMT produced associated NB volumes that were subjected, along with the narrow band SU volumes, to further analysis.

In the vertical view, the narrow band results are not very enlightening. It is tempting to conclude the new data has no time information content, but in fact, there is time localization in the amplitude modulation of each trace although it seems to have little value in the vertical view. Analyzing the spectrally decomposed volumes in time slice view reveals structural and stratigraphic features not seen in the full bandwidth data.

6 Hz Results

The Miss/Penn unconformity is represented in the data set at roughly 848 ms. Producing a time slice through the 3D volume at this time exposes a prominent incised channel. Figure 1 is a full bandwidth time slice of this channel. There are no obvious extensions of the channel, and aside from a slight amplitude change to the SW, we see no evidence of overbank or secondary channel features. Note that there are no clear trends in this broadband time slice aligned with the yellow dashed lines. Furthermore, the channel does not approach the tip of the yellow arrow.

This SU method described earlier was used to create NB 6 Hz and 41 Hz data volumes (Figures 2 and 3).

The SU NB 6 Hz time slice (Figure 2), shows clear alignment with the dashed yellow lines from Figure 1. A natural question is possible alignment of these features with acquisition geometry (Figure 4). Data lineations aligned NW-SE could be related to source lines and north-south features related to receiver lines. But NE-SW lineations seen in Figure 2 have no relation to acquisition geometry. These features possibly indicate fracture orientations as described using curvature by Nissen et al. (2004,2006).

Further investigation of these trends used an SMT trapezoidal filter centered on 5 Hz (Figure 5a). However, the NE-SW trend is less prominent in this result, perhaps due to leakage of frequencies outside the desired narrow band (Figure 5c). Application of the 5 Hz isolation filter in SU does not exhibit this leakage, as shown in Figure

6b (SU segy imported and displayed in SMT to minimize display differences with Figure 5a). The difference in ability of the SU and SMT filters to isolate low frequencies is evident from the NB vertical sections (Figures 5b and 6b).

These are not esoteric differences. It is important to know that any filter program correctly implemented will show these low frequency features. We find this SMT frequency leakage effect is present, but has less effect in the analysis of higher frequencies.

41 Hz Results

A trapezoid filter in SMT was used to create data centered on 41 Hz (Figure 7). Two SMT trapezoidal filters were tested. The first used corner frequencies of 39/40/42/43 Hz. We term this filter A. The second filter (B) has 40.8/40.9/41.1/41.2 Hz. Each filter was used to create an attribute volume. Visual inspection of time slices from SMT filters A and B showed no discernable difference, nor did they show any clear difference from filter A implemented in SU (Figure 3).

Analyzing a 41 Hz volume at the 848 ms time slice, we observe a dark channel-like feature extending from the main channel to the yellow arrow of Figure 1. Figures 7 and 3 show the new channel feature is robust with respect to filtering in either SU or SMT.

We studied detailed variation between the NB results of SMT filters A and B by subtracting the resulting data volumes (Figures 8). There are, indeed, slight differences between the outputs from the two SMT filters. Both volumes show the same result, but with opposite amplitudes due to changing the subtraction order. The difference plots show energy in horizontal bands representing acquisition footprint (receiver orientation), a large fault in the NW corner, a bright karst (sinkhole) feature near the center, and a network of curved lineations of unknown origin. In an absolute sense, the maximum amplitude difference is on the order of 10% in the mentioned features, otherwise less that 2%.

Future Work

We plan to refine the use of filters to better isolate single frequencies. To validate the fracture and channel indicators in NB data, we will compare well log data in and out of the features looking for structural, lithologic, rock property, or stratigraphic changes that may account for the observed features. With 142 wells in the Dickman data set, this is a rare opportunity to calibrate seismic attributes against dense well control in mature oil fields in the U. S. midcontinent.

Once formation tops and sequences have been established, the logs can then be utilized to build a geologic cross section of the area. This will allow structural and stratigraphic interpretation. Once this has been completed, it will be possible to tie this information to the seismic volume. The seismic volume itself will also be interpreted to determine if there are any visible signs of the channel extension.

Characterization of the possible fractures will proceed two fold. First, analyzing resistivity logs (i.e. deep, medium and shallow) that are available in the region of interest will confirm the existence of such fractures. Second, by considering the associated anisotropic effects, if the fractures in these carbonate units are assumed vertical, then the fractured zone can be represented by an anisotropic layer (HTI). From here velocity and amplitude variations with azimuth will be determined to quantify the anisotropic effects from these fracture orientations.

Conclusions

We have done narrow band decomposition of 3D seismic data at the Dickman field using traditional band pass filters. Low frequency results (6 Hz) viewed in time slice reveal linear features not seen in the original broadband data and possibly indicating fractured carbonate structural grain. Mid-frequency decomposition (41 Hz) indicates meander channel features without a broadband expression. Both potential fracture and channel features are being investigated using dense well control to confirm geological reality.

Acknowledgements

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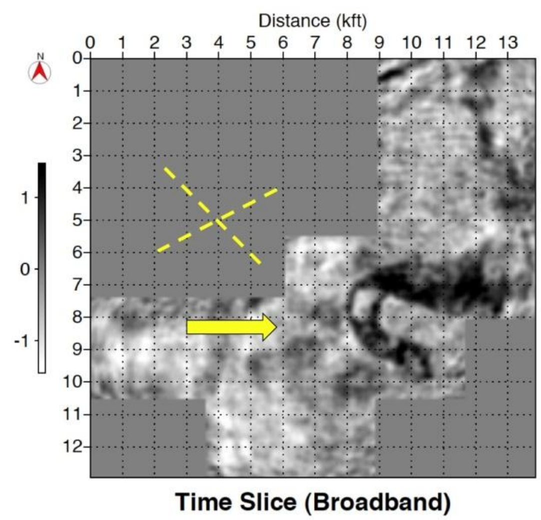

Figure 1. Broadband time slice at 848 ms, approximately coincident with the Miss/Penn unconformity. Features observed in narrow band data (Fig. 2 and 3), but not on the broadband data, are indicated in yellow.

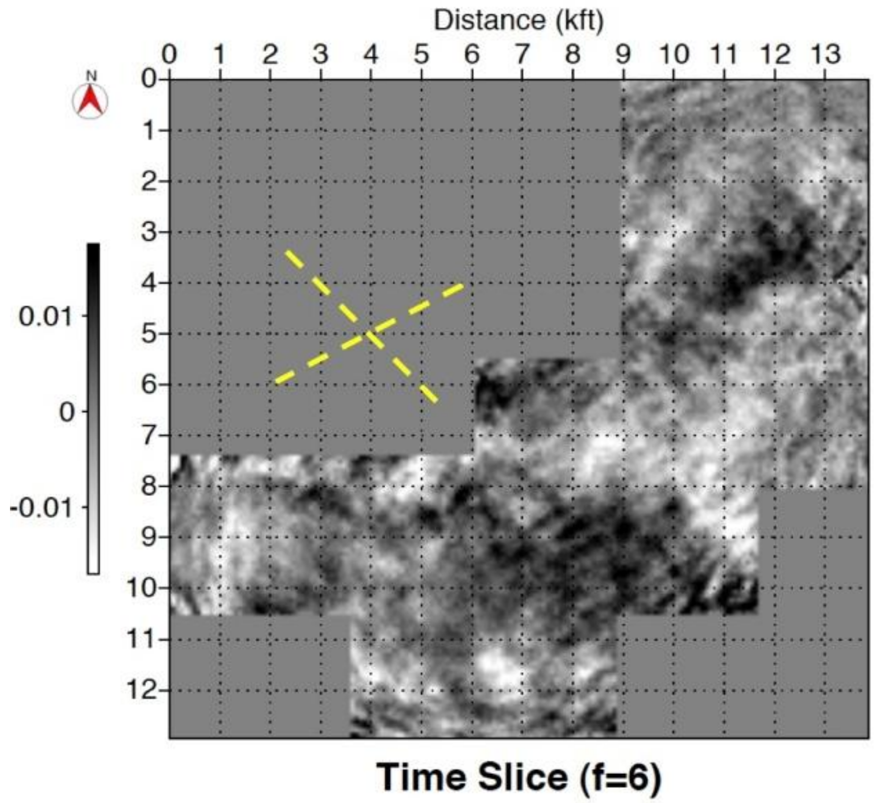

Figure 2. Seismic Unix narrow band (6 Hz) time slice at 848 ms. Yellow dash lines indicate orientation of diagonal features (perhaps related to fractures) not seen in broadband data (Fig. 1). NW-SE lineations may be related to acquisition geometry (Fig. 4), but NE-SW trending features cannot.

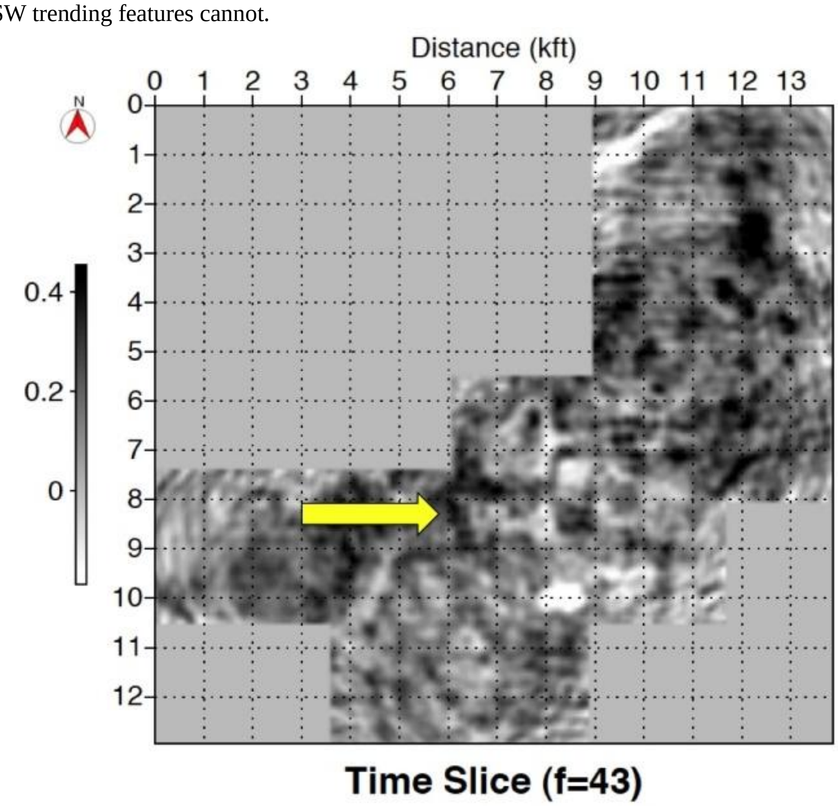

Figure 3. SU narrow band (43 Hz) time slice at 848 ms. Yellow arrow indicates possible channel feature not seen in broadband data (Fig. 1).

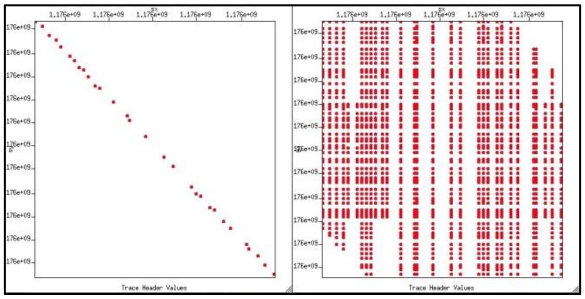

Figure 4. Shooting geometry orientation for Dickman 3D, shots (L) and receivers (R).

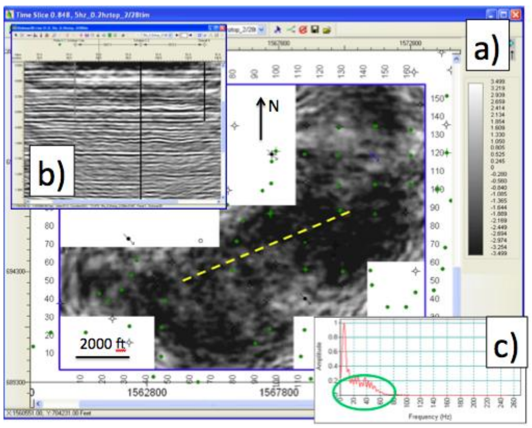

Figure 5. (a) Narrow band SMT 5 Hz time slice (848 ms). (b) Arbitrary SMT 5 Hz seismic section from trapezoid filter. (c) Frequency spectrum of SMT 5 Hz data, note significant energy above 5 Hz.

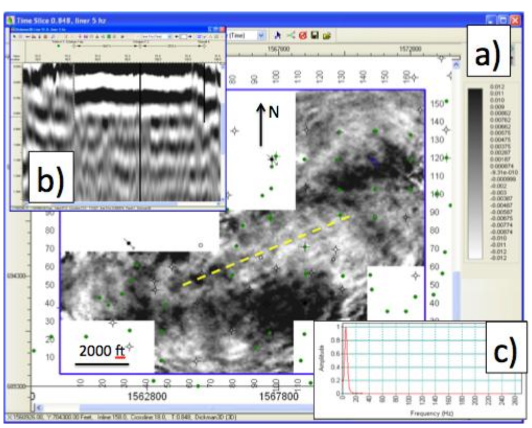

Figure 6. (a) Narrowband SU 5 Hz time slice (848 ms) displayed in SMT. (b) Arbitrary SU 5 Hz seismic section. (c) Frequency spectrum showing good localization at 5 Hz.

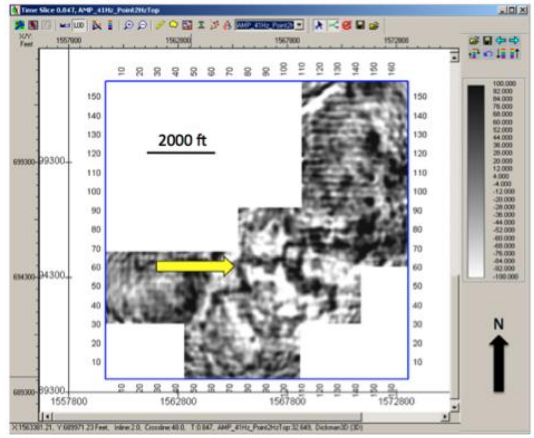

Figure 7. Narrow band time slice (847 ms) created with SMT filter B (0.2 Hz top). The yellow arrow indicates a possible channel feature.

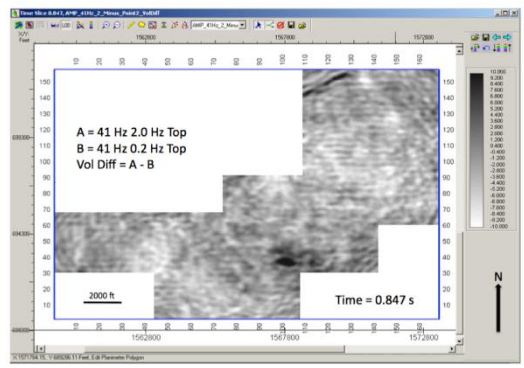

Figure 8. Time slice (847 ms) through difference volume created by subtracting SMT filter volumes.

EDITED REFERENCES

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REFERENCES

Chakrabory, A., and D. Okaya, 1994, Application of wavelet transform to seismic data: 64th Annual International Meeting, SEG, Expanded Abstracts, 725–728.

Liner, C. L., P. Geng, J. Zeng, and H. King, 2009, Toward flow simulation for CO_2 sequestration at the Dickman Oilfield, Ness Co., Kansas: 79th Annual International Meeting, SEG, Expanded Abstracts, 3359–3563.

Nissen, S. E., T. R. Carr, and K. J. Marfurt, 2006, Using new 3D seismic attributes to identify subtle fracture trends in mid-continent Mississippian carbonate reservoirs: Dickman Field, Kansas, Search and Discovery, Article #40189.

Nissen, S. E., K. J. Marfurt, and T. R. Carr, 2004, Identifying subtle fracture trends in the Mississippian saline aquifer unit using new 3D seismic attributes: Kansas Geological Survey, Open-file Report 2004-56.