Limitations of Prestack impedance Inversion in merged seismic surveys : A study in Anadarko Basin

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1. Summary:

1. The advancement in technology has lead us to a world, where very good seismic interpretation packages are available.
2. So, the qualitative as well as quantitative seismic interpretation is not just limited to geophysicists, but also includes non-experts for e.g. newly hired geologists, geophysicist and engineer.
3. This poster shows, how two of the authors who are new geophysicist fell into the pre-stack inversion pit; but later realized their mistake, and found a way to correct it.
4. We performed prestack inversion on a reprocessed merged pre-stack seismic data. But, the inversion results had artifacts. However we later realized that it is very important to understand how the data has been merged.
5. The data was migrated to accommodate the long offsets corresponding to most recently acquired data.
6. We present here what went wrong and how we overcame this challenge.

5. Theory and Assumptions :

$$R(\theta) \approx \frac{\Delta Z_P}{2Z_P}\left(1+\tan^2\theta\right) - 8\left[\frac{Z_S}{Z_P}\right]^2 \frac{\Delta Z_S}{Z_S}\sin^2\theta$$

where
Z_P = average or background model P-impedance,
Z_S = average or background model S-impedance,
ΔZ_P and ΔZ_S = the vertical change in P- and S-impedances, and
θ = the angle of incidence

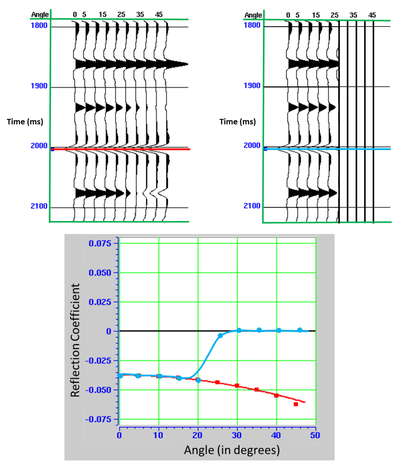

Figure 4. (a) Synthetic gather generated at a well, with angles ranging between 0°-42°. (b) Synthetic gather generated at a well, with offset range 0°-22°, and padded with zero traces from 24° - 42°. (c) Extracted amplitudes corresponding to the red and cyan

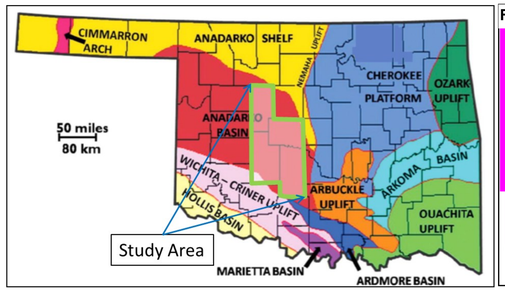

Figure 1. Location map of Anadarko basin area on map of Oklahoma, and location of study area in Anadarko basin marked by green boundary (modified from Northcutt and Campbell, 1988).

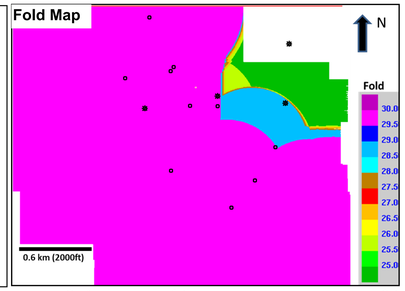

Figure 2. "Fold Map" of the reprocessed megamerged 3D seismic data volume. Superficially, this gives the impression that the data are greater than 25 fold throughout the survey. Black dots shows well locations

3. Full Data Range(2°-42°)

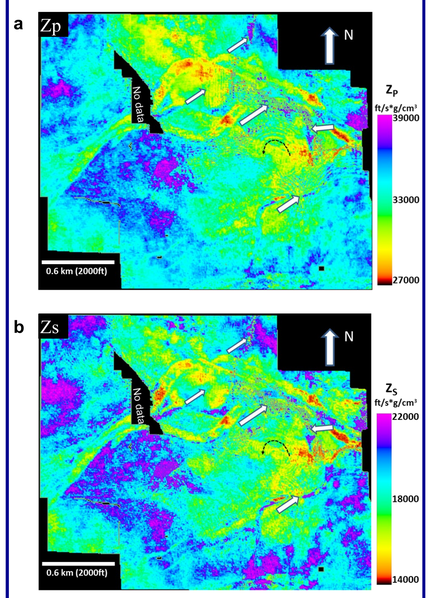

Figure 3. Phantom horizon slices 80 ms below Oswego cutting the Red Fork incised channels through (a) the P-impedance volume, Z_P, (b) the S-impedance volume, Z_S, computed from 2° -42° input migrated gathers. For both of the figures, white arrows indicate artifacts in the resulting image. Black dotted arrow indicates a circular artifact

7. Limited Data Range (2°-22°)

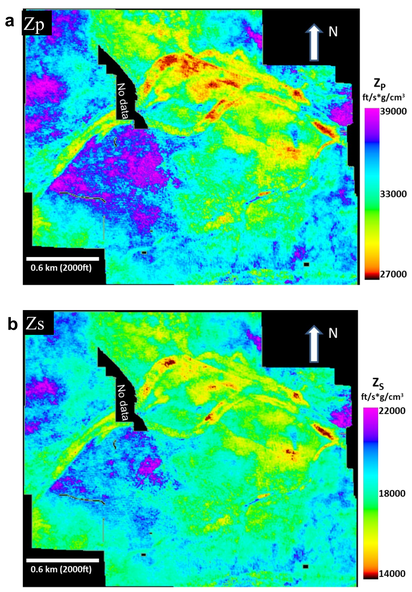

Figure 8. Phantom horizon slices 80 ms below the Oswego through (a) the P-impedance volume, Z_P, (b) the S-impedance volume, Z_S, computed from 2°-22° input migrated gathers.

2. Challenges :

1. Objective of the study was to do the Pre-stack seismic inversion to delineate the Red-Fork sands.
2. The fold of the merged seismic data was consistent (figure 2) and was 25 or more. The post-stack well to seismic tie gave 60-80% correlation.
3. P-impedance and S-Impedance results were not as good as we expected (figure 3).

6. QC Tools :

A. Offset Limited Amplitude Stack

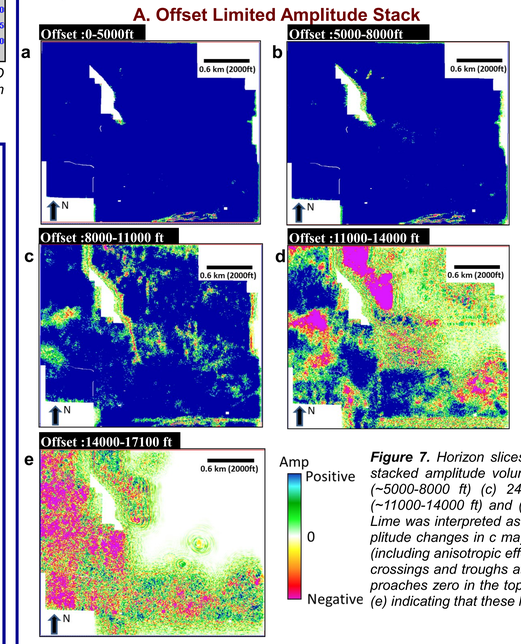

Figure 7. Horizon slices along the Oswego surface through offset-limited stacked amplitude volumes: (a) 0-1520 m (~0-5000 ft) (b) 1520-2450 m (~5000-8000 ft) (c) 2450-3350 m (~8000-11,000 ft) (d) 3350-4250 m (~11000-14000 ft) and (e) 4250-5200 m (~14000-17100 ft). The Oswego Lime was interpreted as a strong peak in the stacked seismic volume. Amplitude changes in c may be valid AVO effects. Often, inaccurate velocities (including anisotropic effects) result in misaligned gathers giving rise to zero crossings and troughs at far offsets. However, note how the amplitude approaches zero in the top right corner of the megamerged survey in (d) and (e) indicating that these large offsets were never recorded in these areas.

B. Mean Squared Error

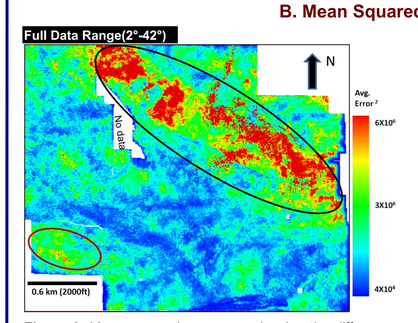

Figure 6. Mean squared error map showing the difference between the measured and modeled seismic gathers for the 2°-42° inversion. This error map was normalized with respect to number of traces.

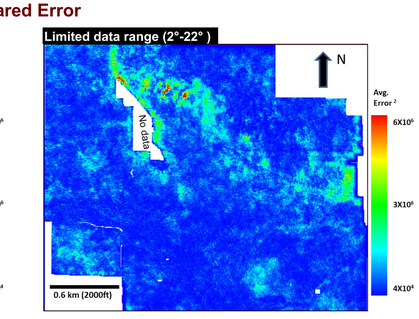

Figure 9. Mean squared error map showing the difference between the measured and modeled seismic gathers for the 2°-22° inversion. The squared error was normalized with respect to the number of traces in each gather to compare figure 6 and figure 9.

4. The Prestack Data

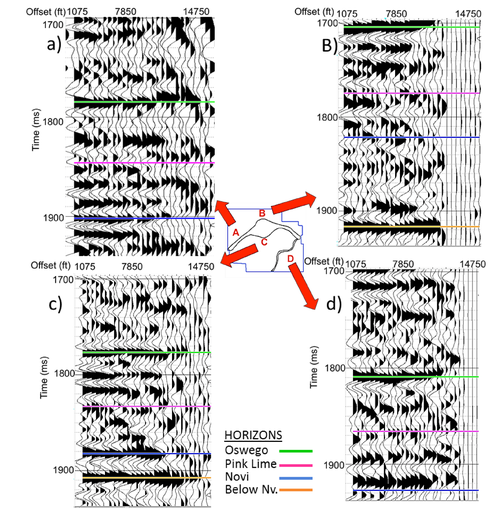

Figure 5. Representative gathers and base map indicating their locations. Note that location A and D have moderate amplitudes while B and C have low amplitudes at the farther offsets. The small residual amplitudes beyond these ranges are due to migration swings from the longer offset surveys.

8. Conclusions and Suggestions:

1. Fold of the merged re-processed data is meaningless.
2. Merged data set is to be carefully analyzed and the re-processing applied on the data should be checked.
3. For megamerge surveys where the offsets of the constituent input survey volumes are unknown, the interpreter should generate time or horizon slices through amplitude volumes for each of the offsets. Subsequent inversions should be offset limited to include only those offsets with physically reasonable amplitudes.
4. In order to avoid pitfalls, we suggest that interpreters should generate RMS error maps of the modeled-to-measured data misfit for any inversion product.

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