3-D Surface Seismic Attribute and Prestack Impedance Inversion Characterization of the Red Fork Formation, Oklahoma, USA*

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Abstract

While the Red Fork Formation has been extensively explored and is productive, there still remains a significant number of undiscovered resources. The parts of this play in Kansas and Colorado show low thermal maturity levels, have poorer reservoir quality and overall fewer sands than the parts of the play in Oklahoma and Texas and are therefore not projected to have as much resource potential. Historical data on major discoveries, individual well completions, and thermal maturity are used extensively in assessing this play. The main objective of this project is to apply simultaneous prestack impedance inversion and 3-D seismic attributes to discriminate lithologies and relate them to the defined incised valley-fill channel stages of the Red Fork Formation in Oklahoma.

We use simultaneous prestack seismic impedance inversion calibrated to well-log data to differentiate between porous and non-porous sand and shale channels in the Red Fork Formation in the Anadarko Basin. Such differentiation can then be used to define a workflow that can be applied to unexplored areas. We did not focus on predicting fluid content because the rocks are so well-consolidated that fluid prediction will be very difficult to achieve.

3-D seismic attributes, such as edge-sensitive most positive and most negative curvature, coherence and Sobel filter similarity, combined with facies-sensitive spectral decomposition, are used to highlight features not readily apparent on the seismic amplitude data. This method is employed in order to be able to improve the lithology discrimination analysis and characterize the incised valley-fill channels in the Red Fork Formation based on the channel sinuosity. Previous models by Clement (1991) and Peyton et al. (1998) show a total of five stages, while we are able to add a sixth stage to their model.

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3-D surface seismic attribute and prestack impedance inversion characterization of the Red Fork Formation, Oklahoma USA

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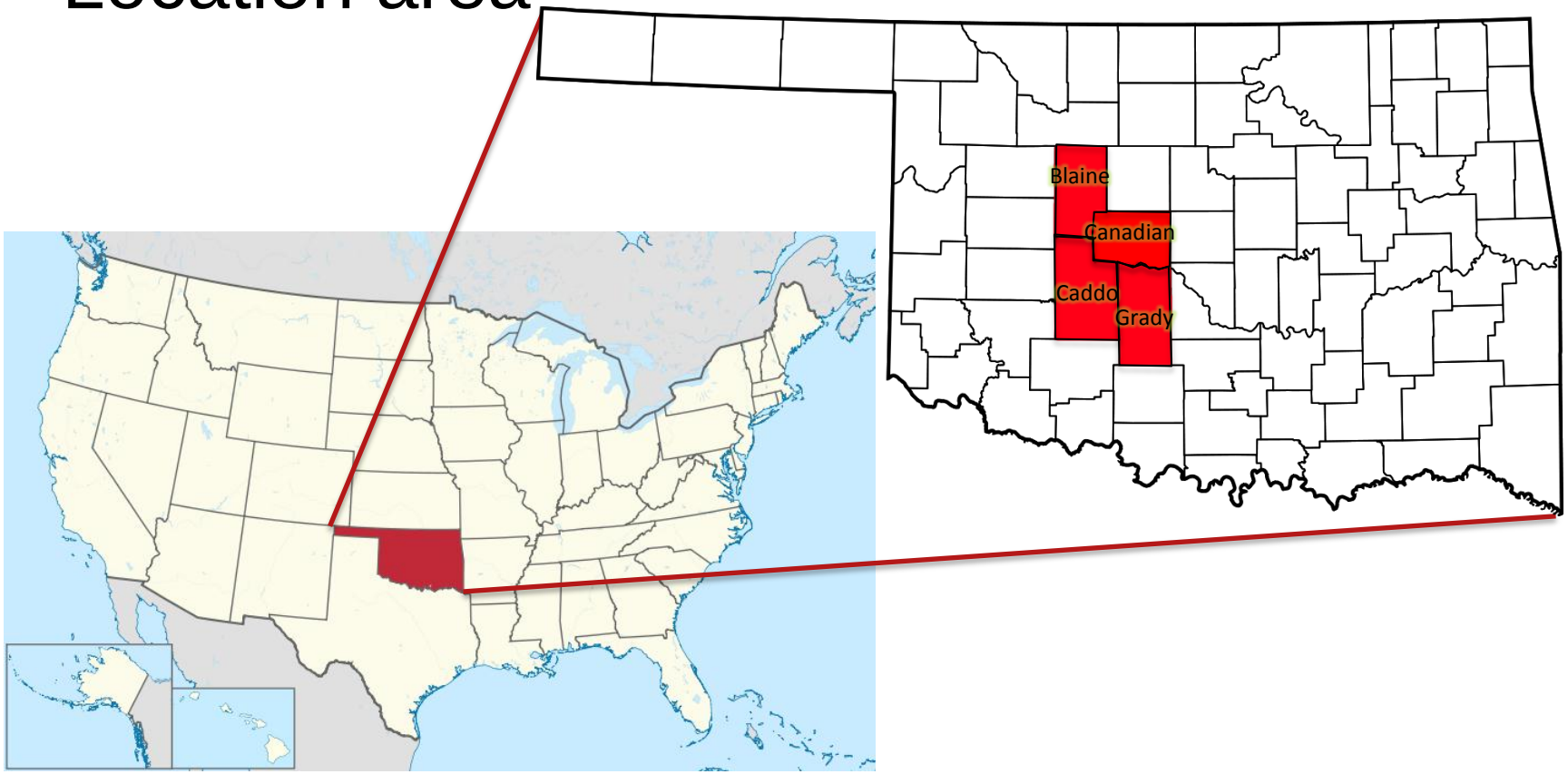
Agenda

- Introduction and Objectives
- Geological background
- Seismic attribute evaluation
- Petrophysical analysis
- Seismic inversion
- Geological interpretation
- Conclusions

Introduction

- Location area

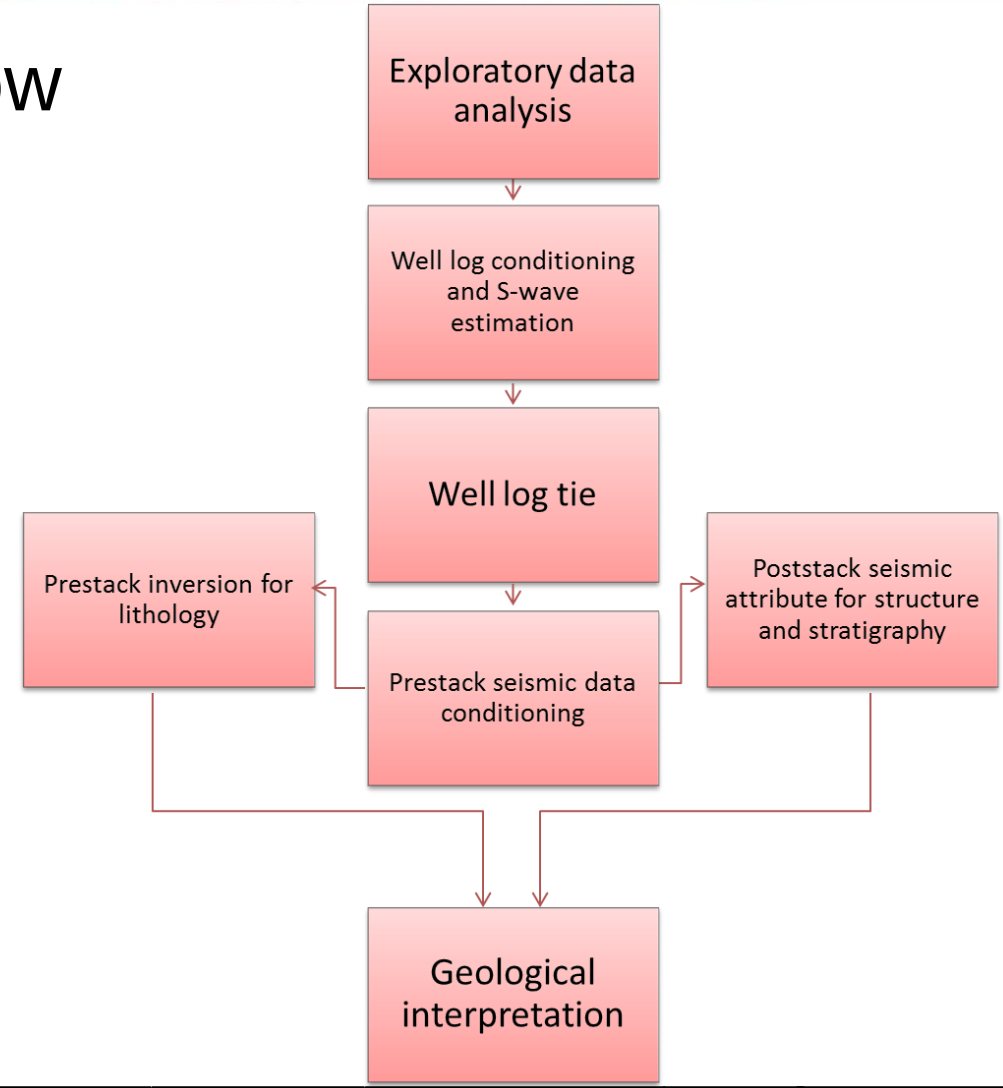


Introduction

- Observation and hypothesis
  - Red Fork Formation is well explored and productive, but there still remains a significant number of undiscovered resources.
  - We hypothesize that petrophysically-calibrated AVO, prestack seismic impedance inversion and seismic attribute analysis can differentiate between porous and non-porous sand and shale channels in the Red Fork Formation in the Anadarko Basin. Such differentiation can then be used to define a workflow that can be used in unexplored areas.

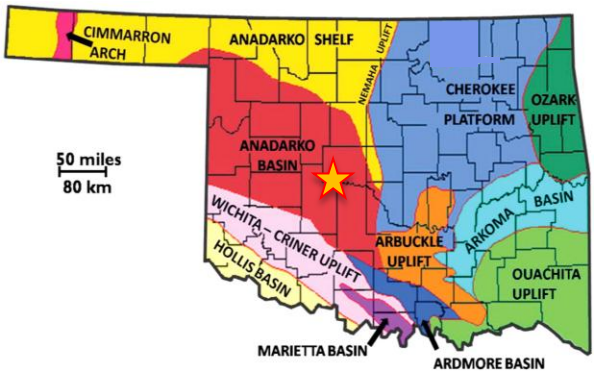
Introduction

- Workflow

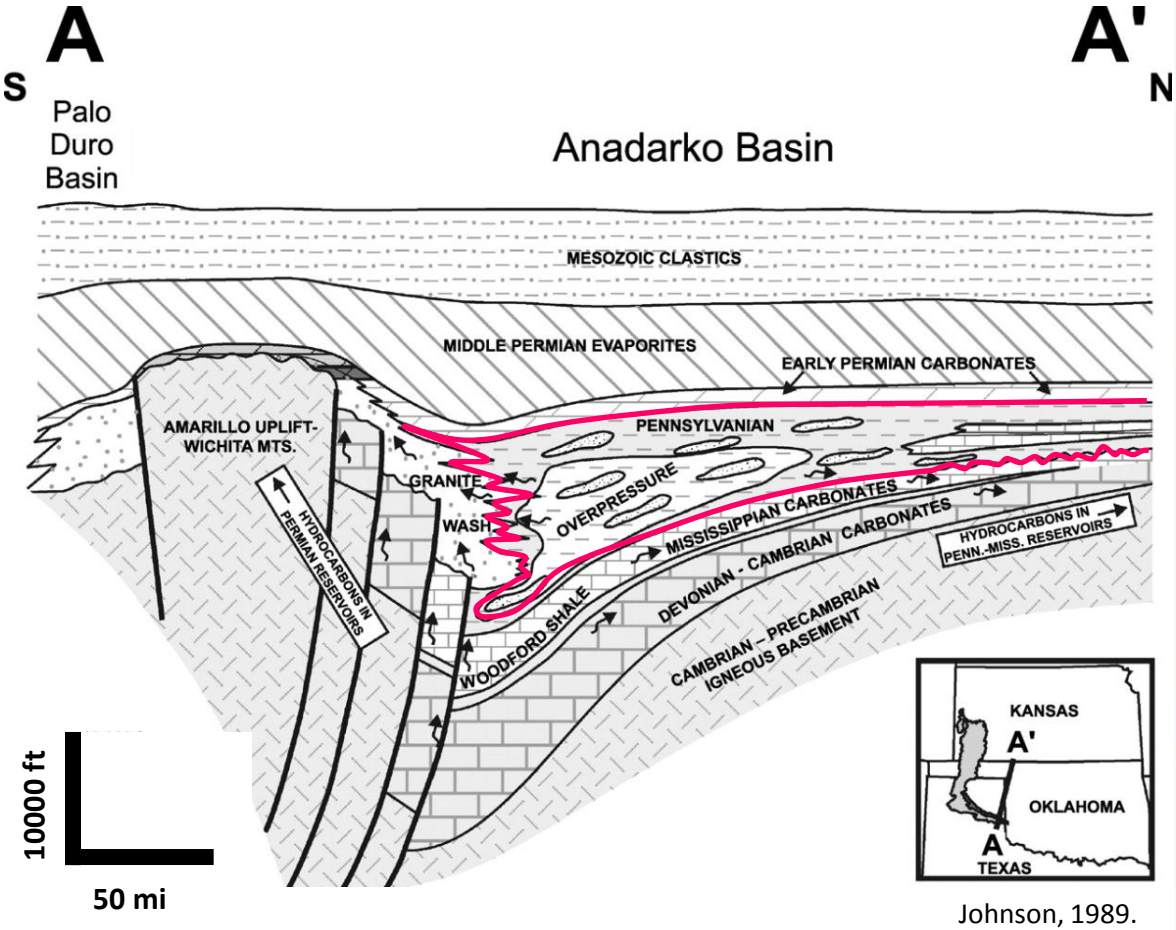


Geologic Background

- The Red Fork Fm. in the Anadarko Basin.



Northcutt and Campbell, 1988



Johnson, 1989.

Geologic Background

- Red Fork petroleum system elements:
  - Trap: Stratigraphic.
  - Reservoir: Red Fork sands.
  - Porosity: 12-15%.
  - Permeability: 0.1 mD, varies along the reservoir.
  - Source rock: Middle and Upper Pennsylvanian black shales (TOC: 0-18%).

Geologic Background

- Columnar section

SYSTEM	SERIES	GROUP	UNIT	
PENNSYLVANIAN	VIRGINIAN	Shawnee/ Cisco	TopekaLs	
			Pawhuska Ls	
			Hoover Ss	
			Elgin Sd	
			Oread Ls	
			Heebner Sh	
			Endicott Ss	
		Douglas/Cisco	Lovell Ls	
			Haskell Ls	
			Tonkawa Ss	
	MISSOURIAN	Lansing/ Hoxbar	Avant Ls	
			Cottage Grove Ss	
		Kansas City/ Hoxbar	Dewey Ls	
			Hogshooter Ls	
			Layton Ss	
			Checkerboard Ls	✱
			Cleveland Ss	
	DESMOINESIAN	Marmaton	Big Lime	
			Oswego Ls	✱
		Cherokee	Cherokee Marker	
			Prue Ss	
			Verdigris Ls	✱
			Skinner Ss	
			Pink Ls	
			Red Fork Ss	✱
			Inola Ls	
			Mona	
	ATOKAN	Atoka	Novi	✱
			13 Finger Ls	
	MORROWAN	Morrow	Morrow	✱
			Primrose	
	SPRINGERAN	Springer	Cunningham	
			Britt	
			Boatwright	
MISSISSIPPIAN	CHESTERIAN	Chester	Chester Ls	✱
		Manning	Manning Ls	
	MERAMECIAN	Meramec	Meramec Chat	✱
			Meramec Ls	
	OSAGEAN	Osage	Osage Ls	
	KINDERHOOKIAN	Kinderhook	Kinderhook Sh	
	CHATTANOOGIAN		Woodford Sh	✱
			Misener Ss	
SIL./DEV.	ULSTERIAN	Hunton	Hunton Group	✱
	NIAGARAN			
	ALEXANDRIAN			

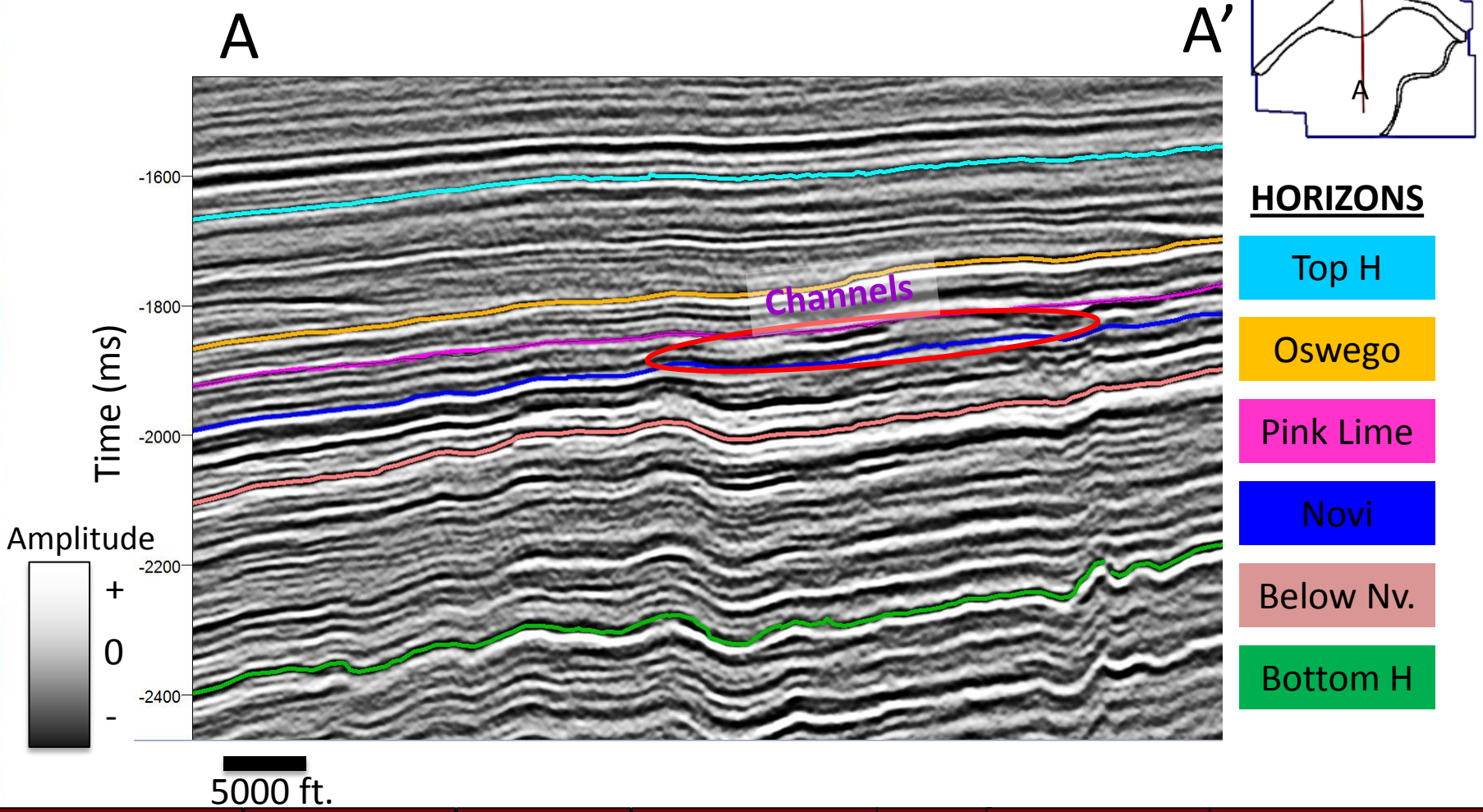
Red Fork

✱ Oil production

✱ Gas production

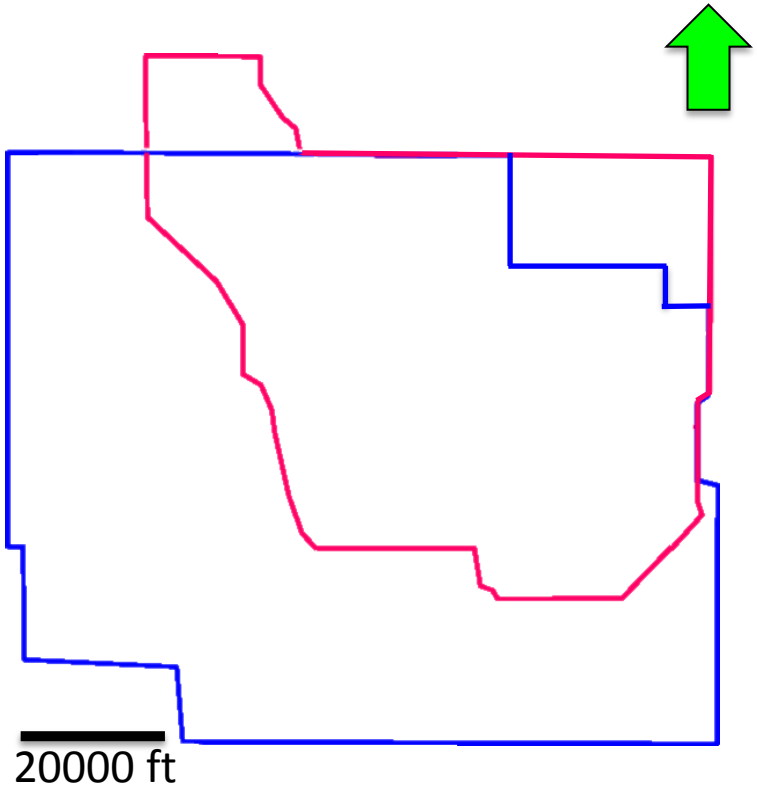
Geologic Background

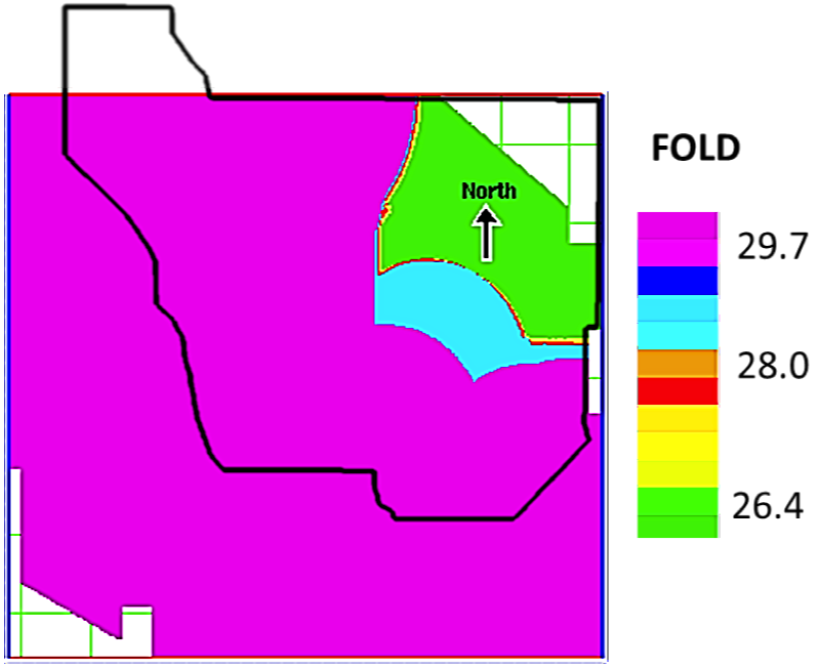
- Interpreted seismic horizons



Seismic data quality evaluation

- Seismic data available





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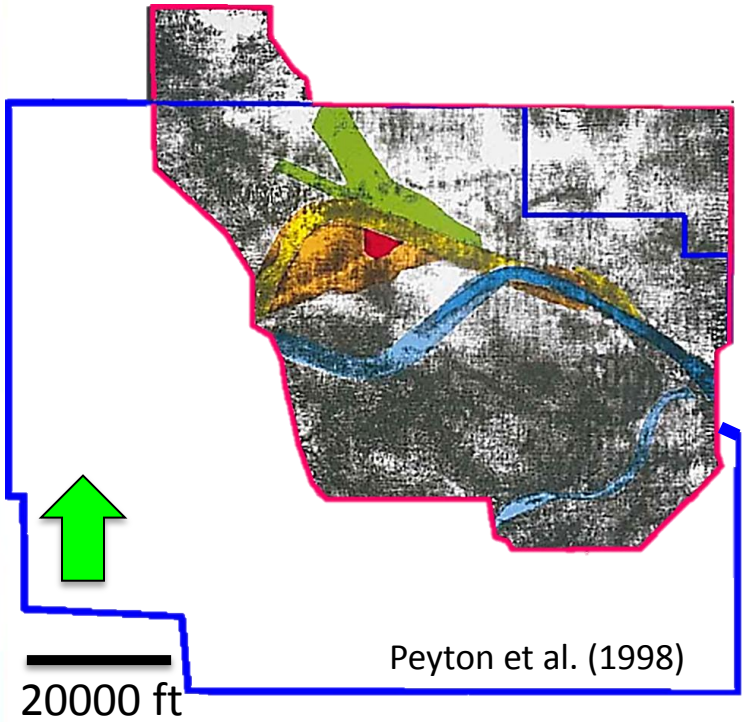
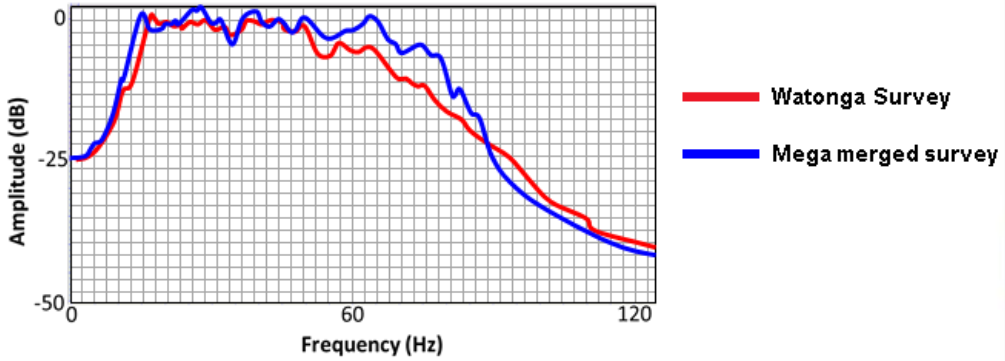
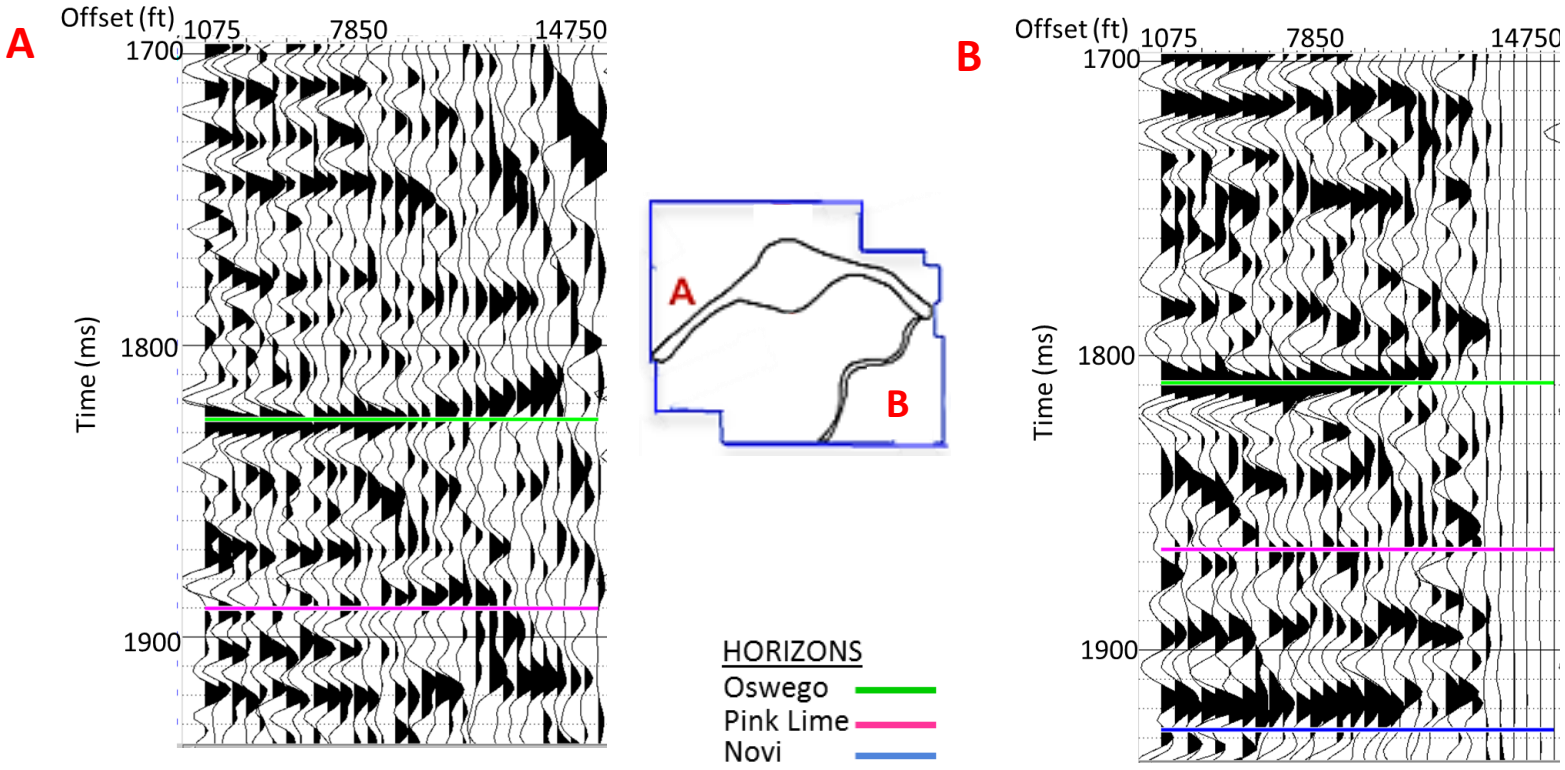


	Mega merged survey	Watonga survey
Bin size	110ft*110ft	82.5ft*82.5ft
Inline direction	N-S	W-E
Crossline direction	W-E	N-S
Total number of inlines	872	886
Total number of crosslines	721	923
Seismic area	244.6 mi^2	136 mi^2



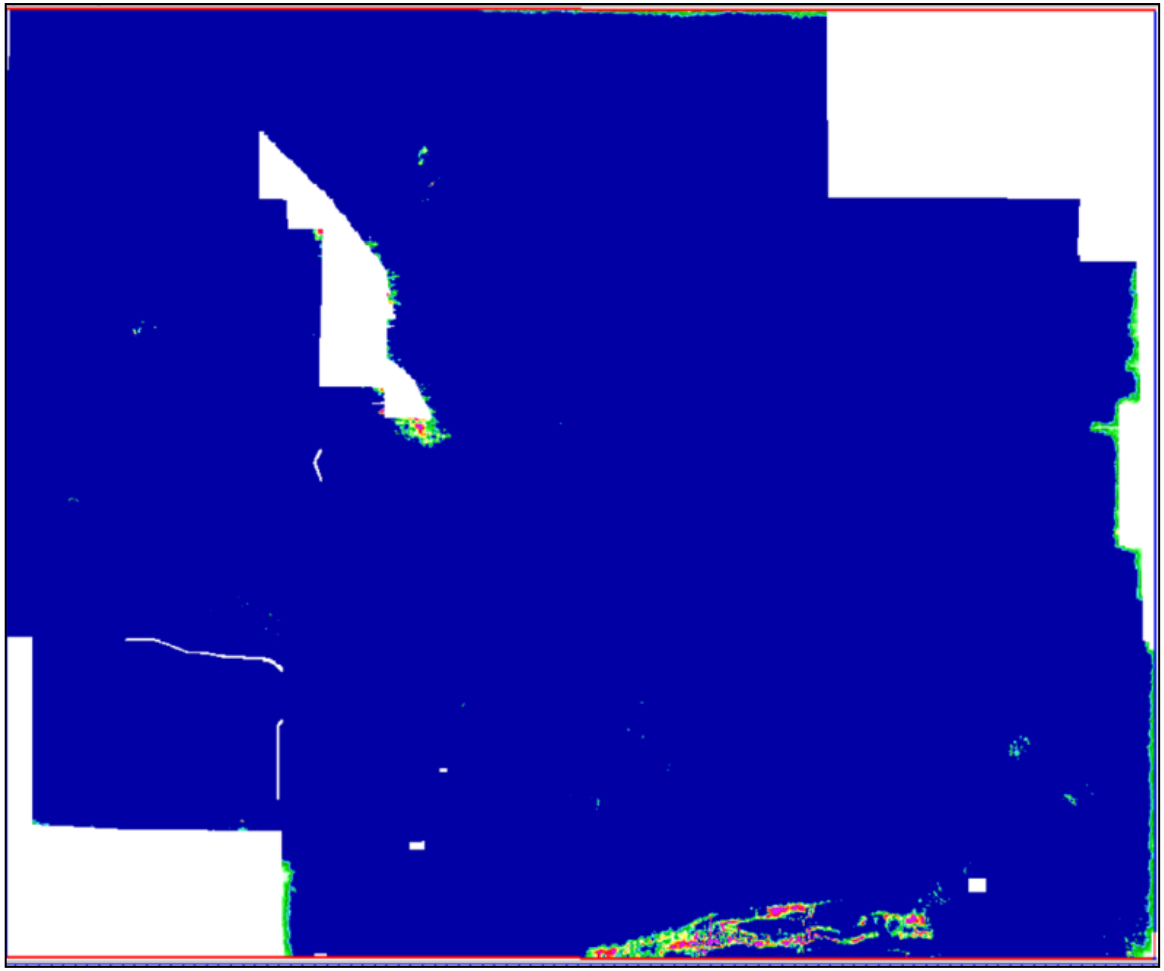
Seismic data quality evaluation

- Gathers illustrating seismic quality along the seismic survey



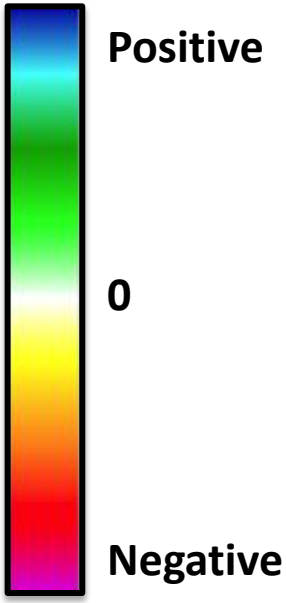
Seismic data quality evaluation

- Horizon slice along Oswego



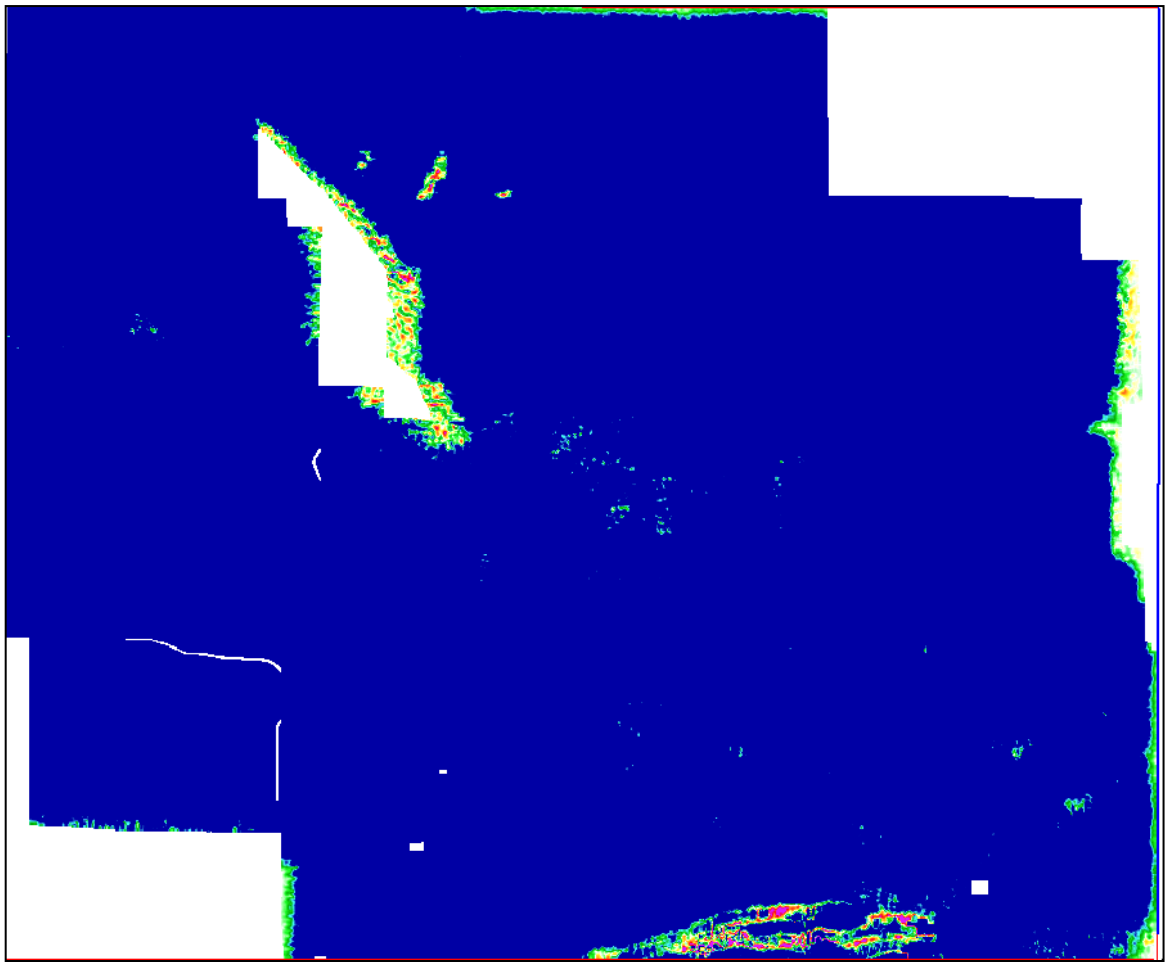
Offset range:

0-5,000 ft



Seismic data quality evaluation

- Horizon slice along Oswego



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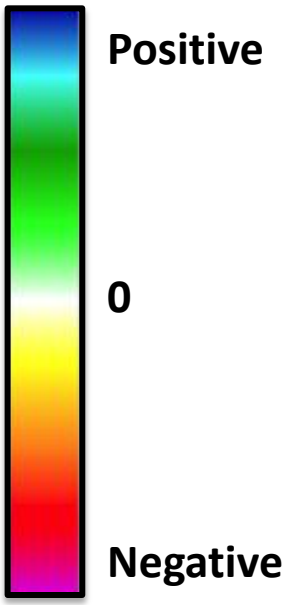
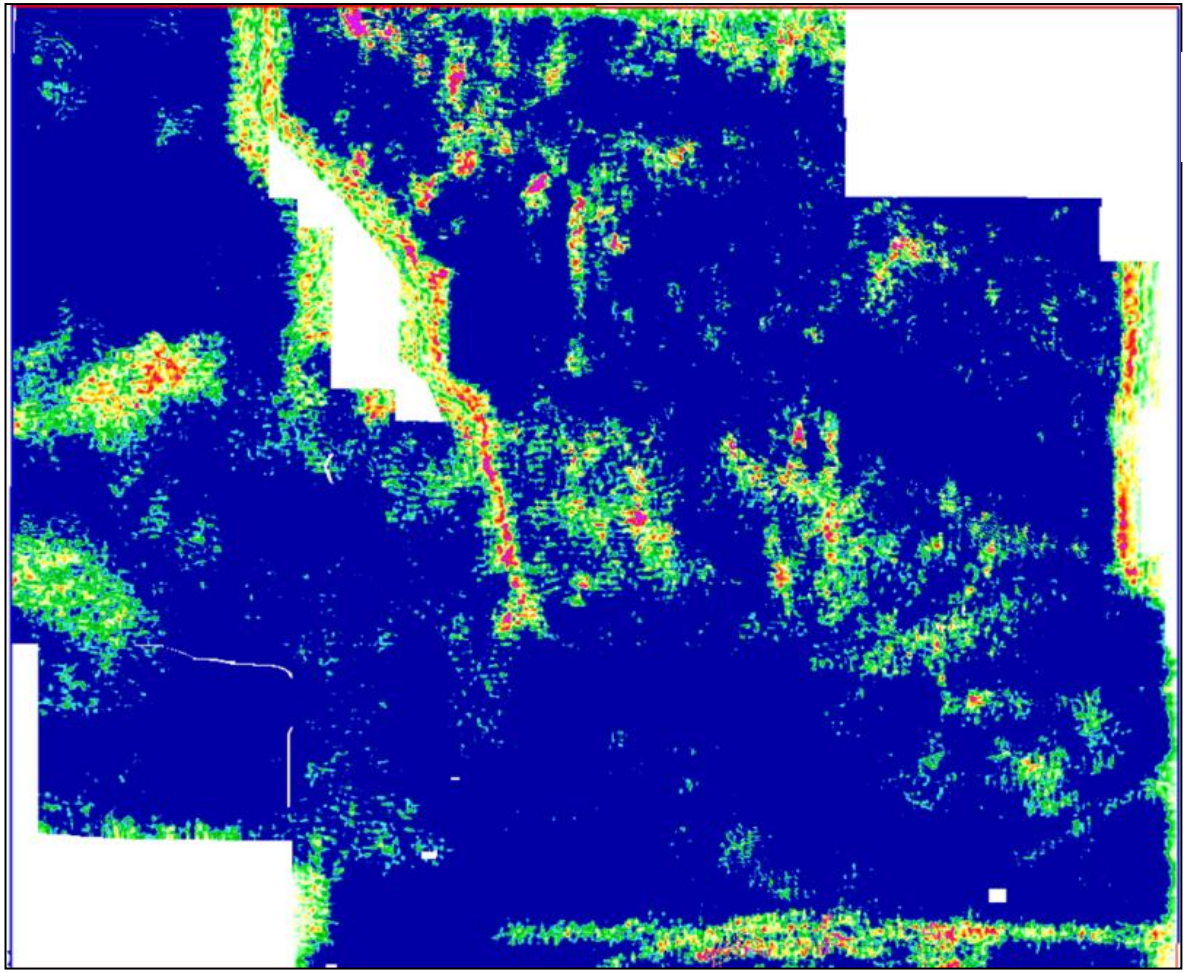


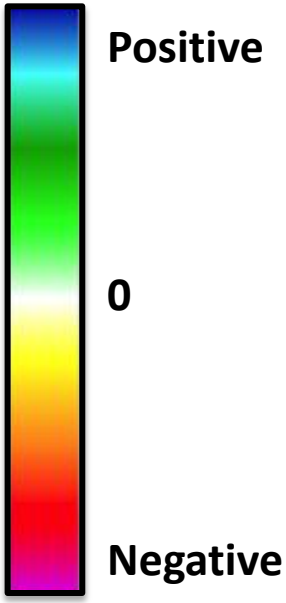
Seismic data quality evaluation

- Horizon slice along Oswego



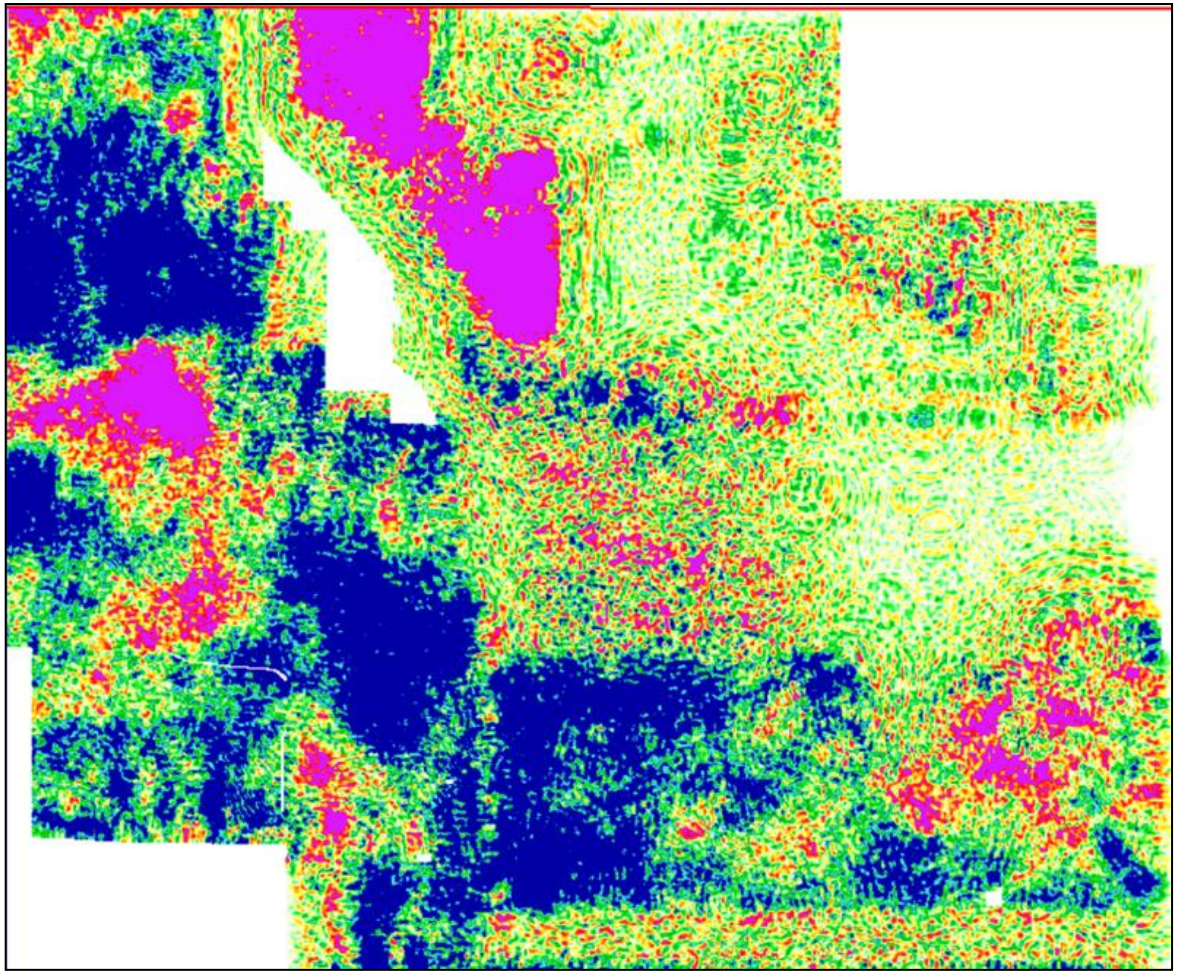
Offset range:

8,000-11,000 ft



Seismic data quality evaluation

- Horizon slice along Oswego



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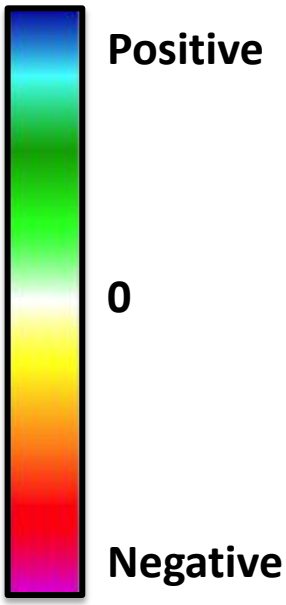
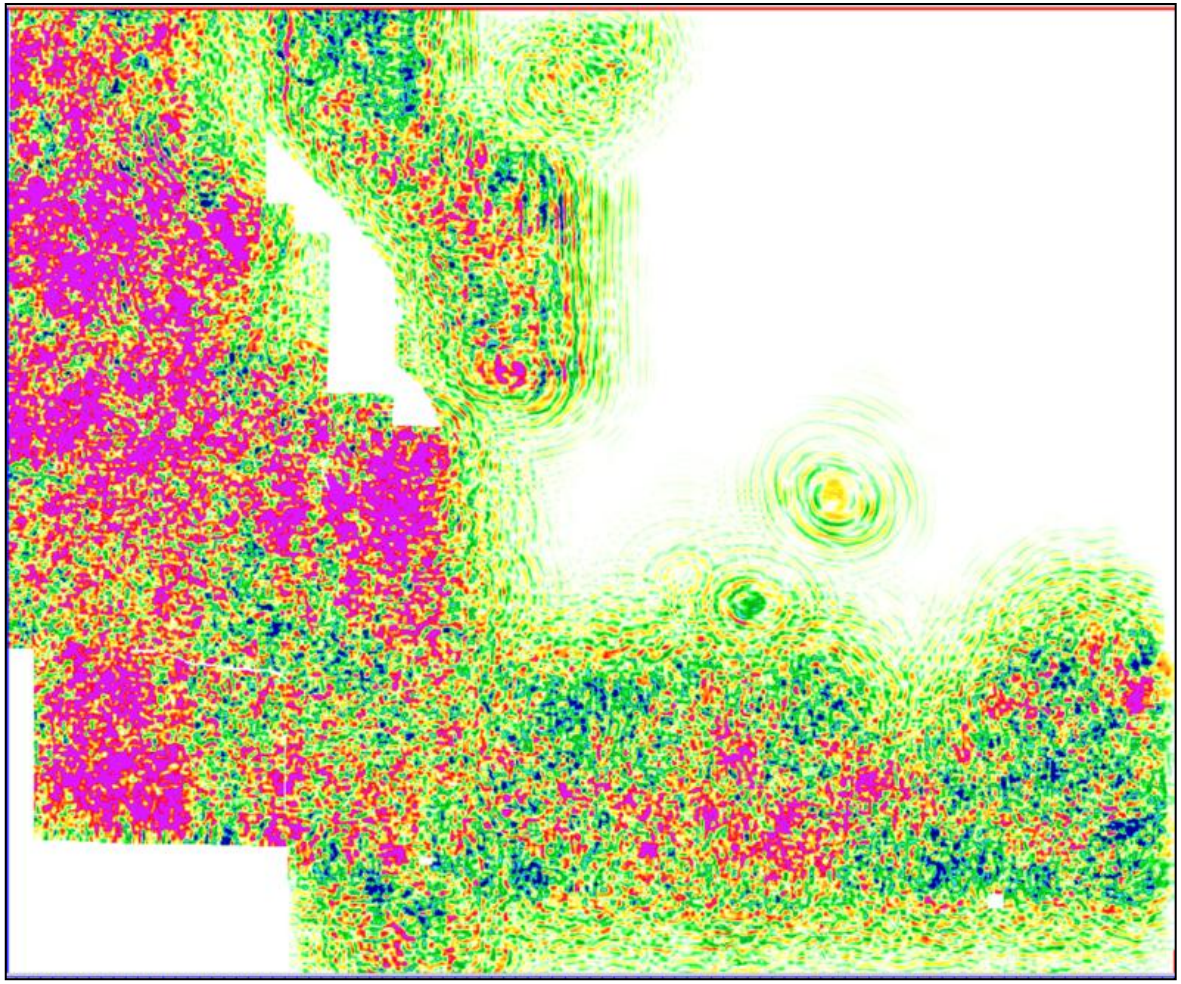
11,000-14000 ft



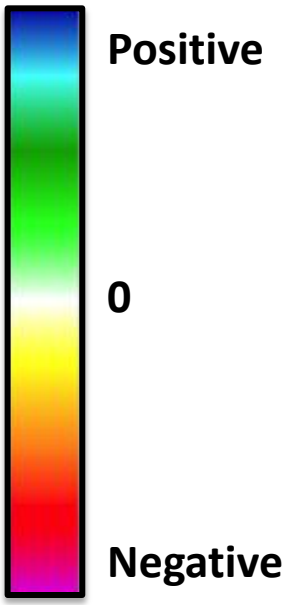
Seismic data quality evaluation

- Horizon slice along Oswego



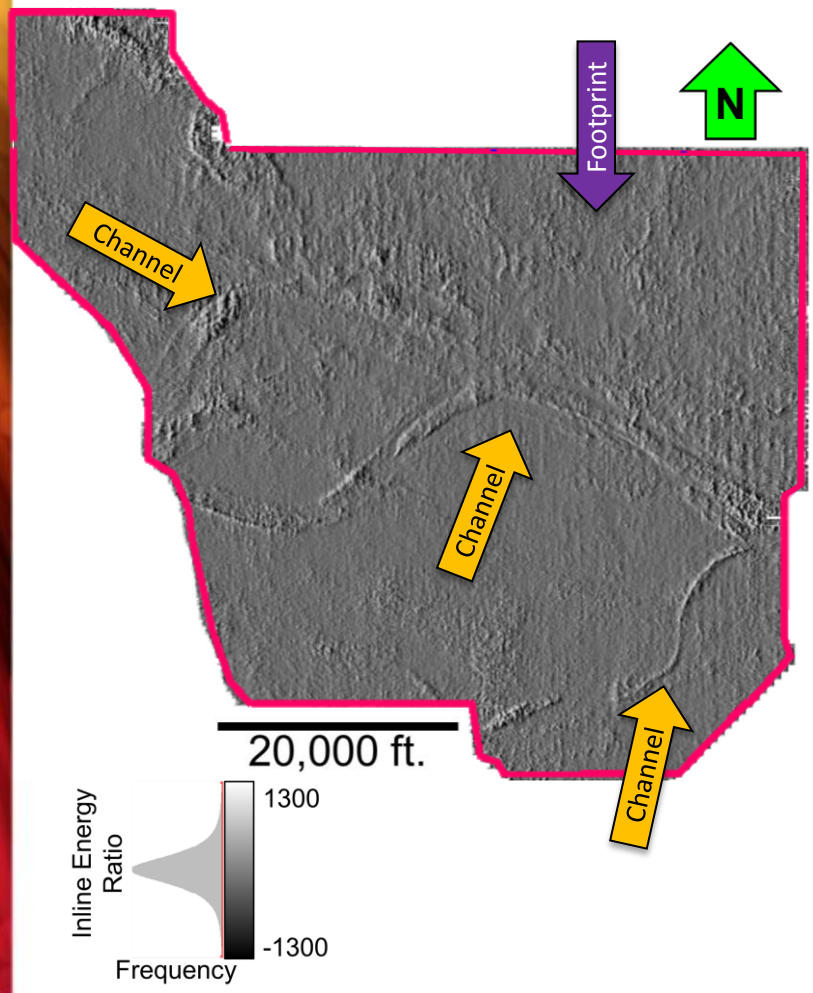
Offset range:

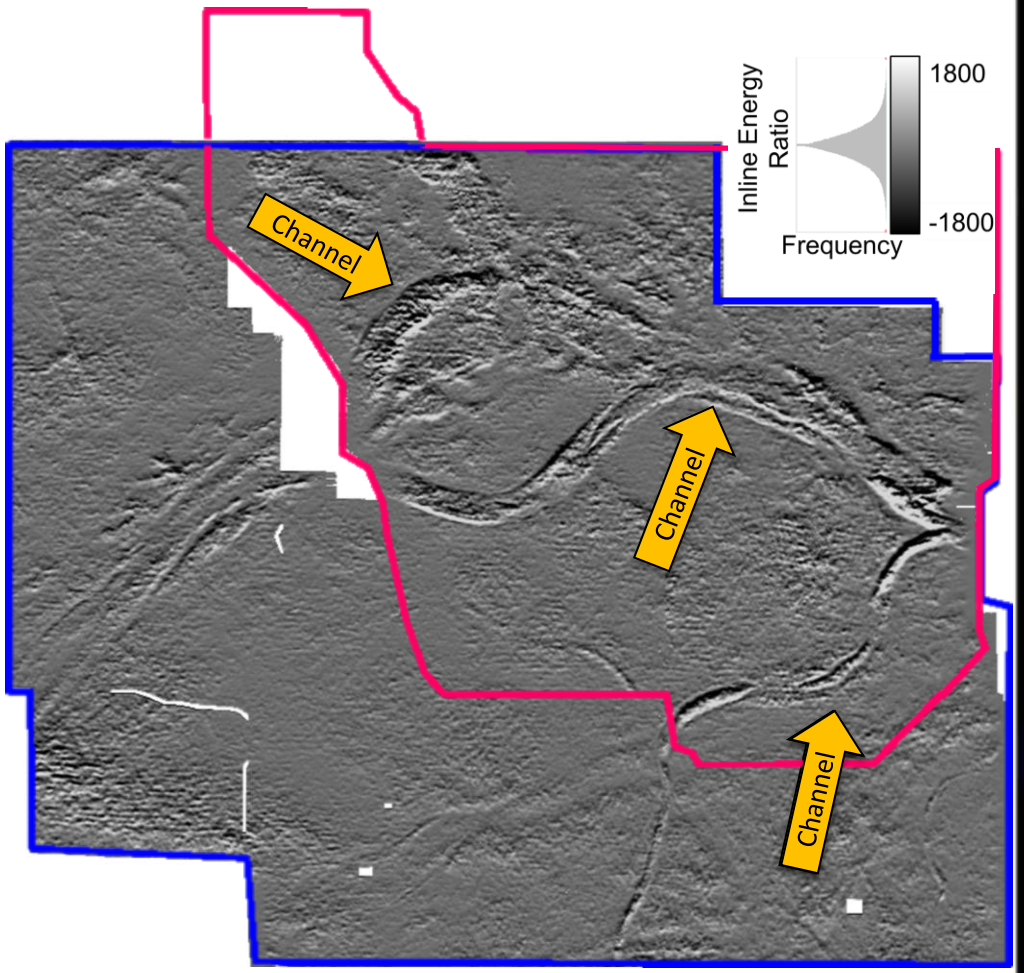
14,000-17,100 ft



Attribute evaluation of merged and reprocessed legacy seismic surveys

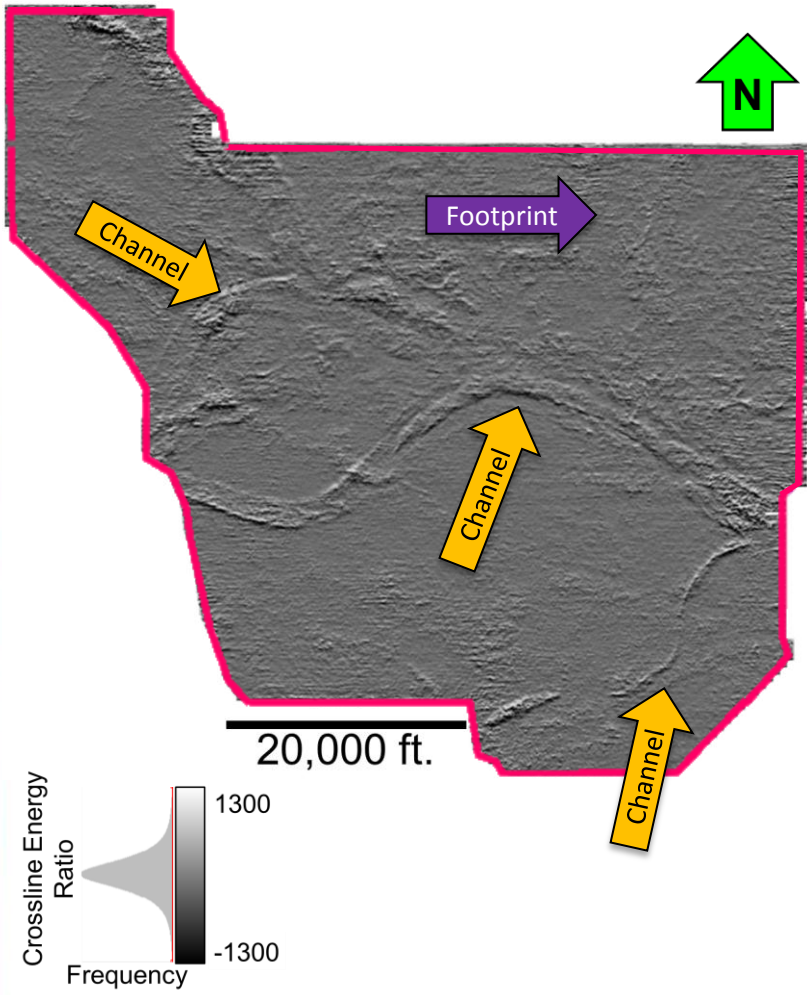
Inline coherent energy component

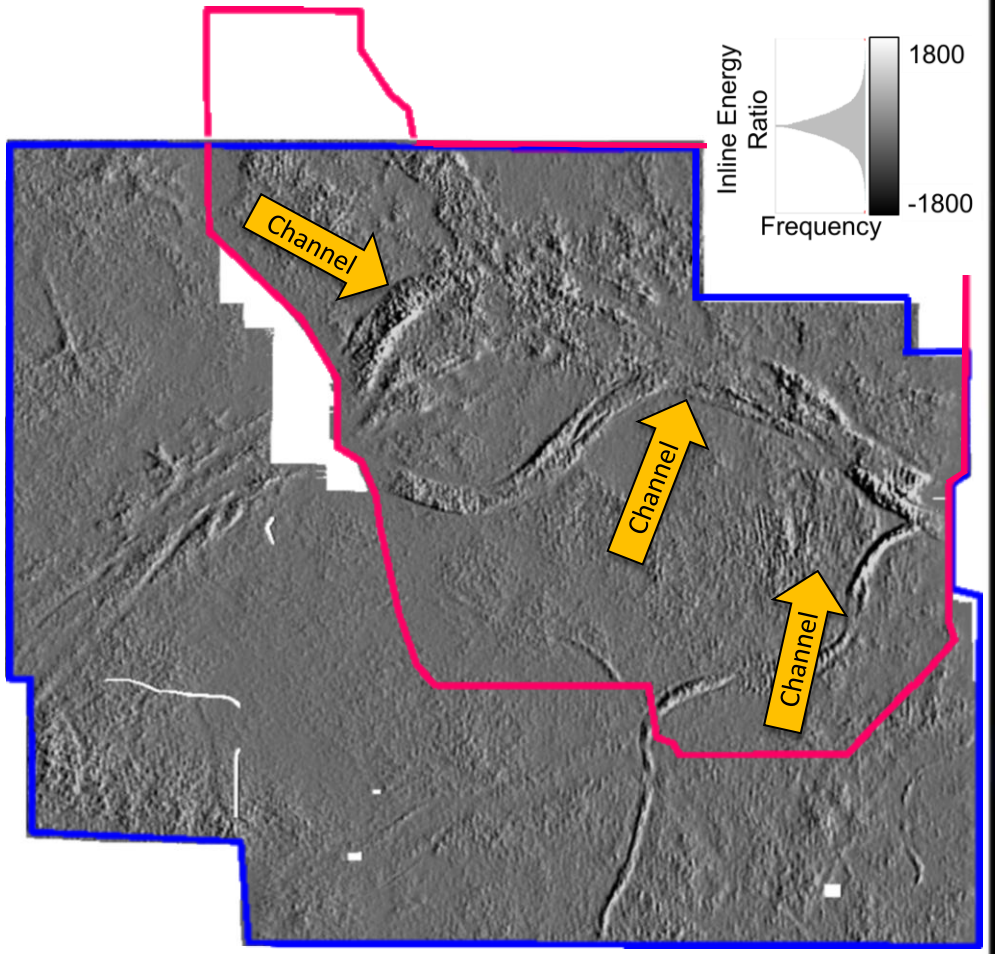




Attribute evaluation of merged and reprocessed legacy seismic surveys

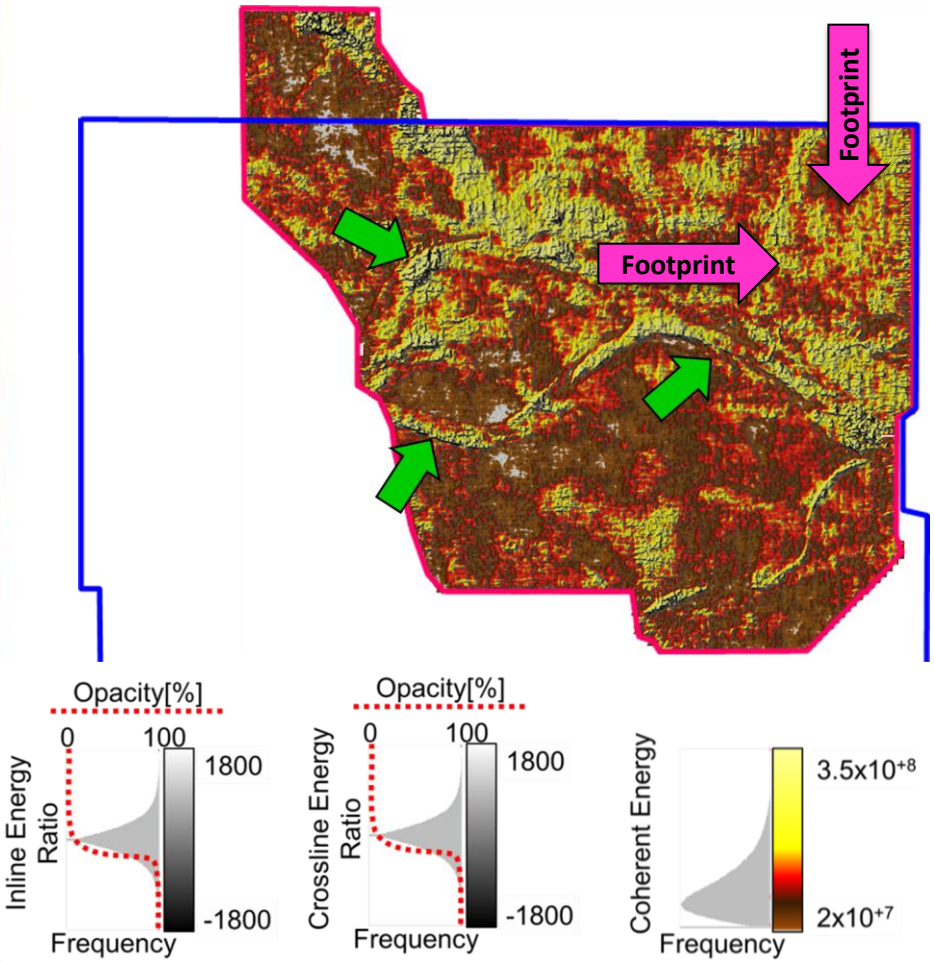
Crossline coherent energy component

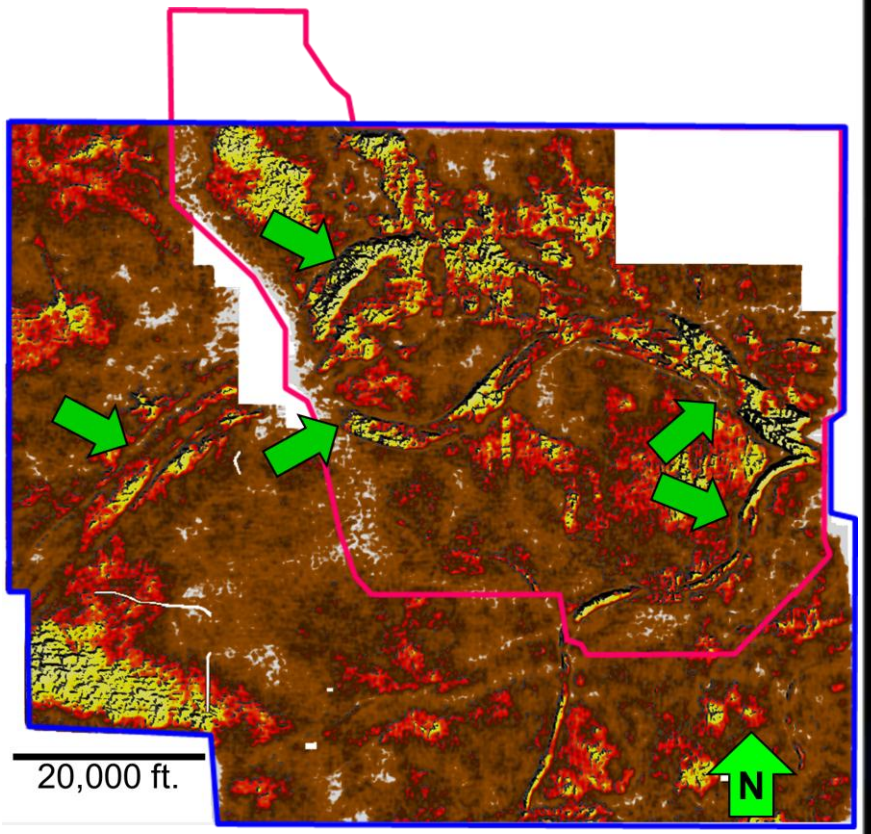




Attribute evaluation of merged and reprocessed legacy seismic surveys

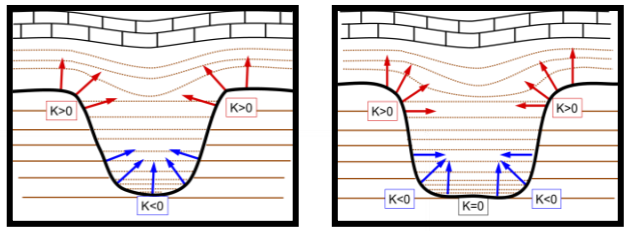
- Inline/Crossline energy-weighted coherent amplitude co-rendered with Coherent energy

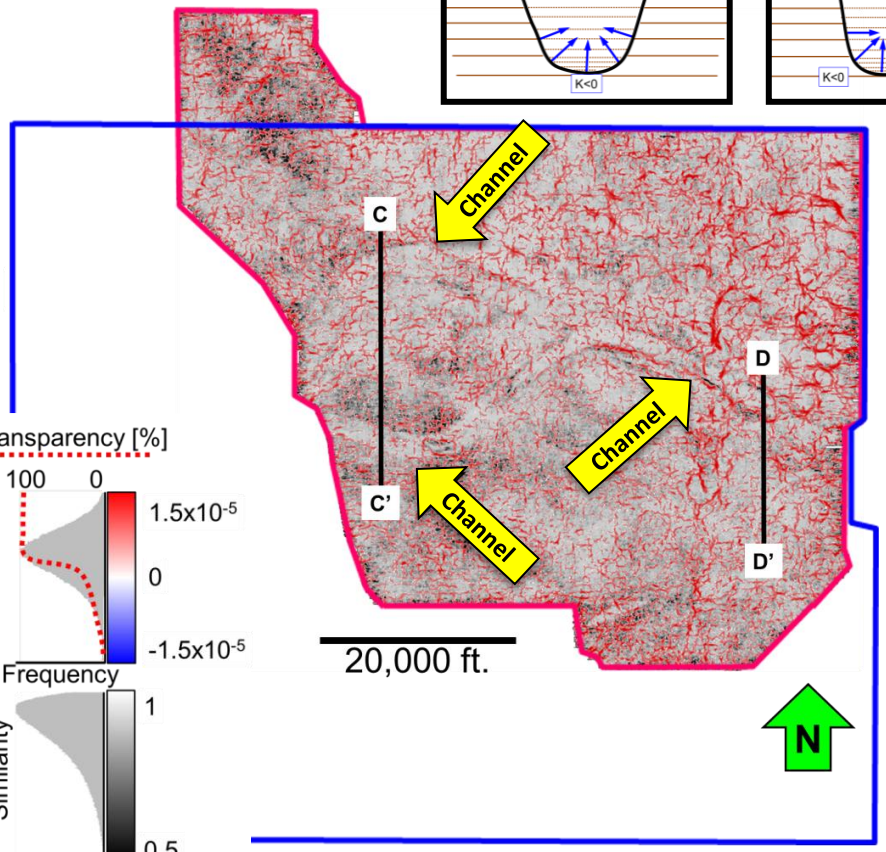


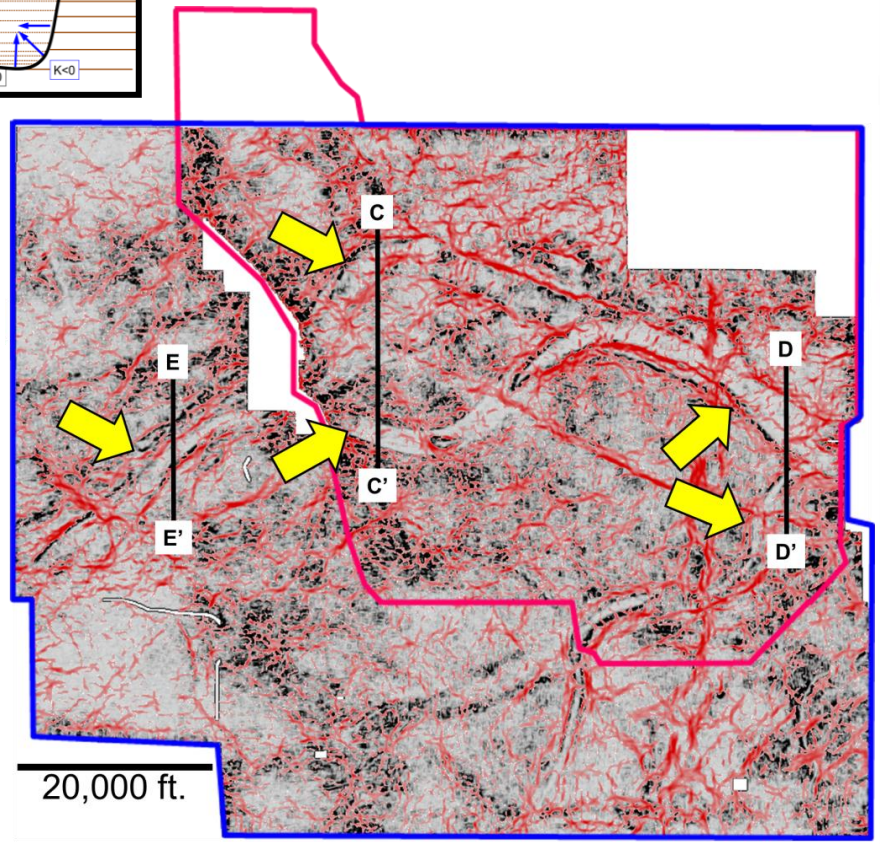


Attribute evaluation of merged and reprocessed legacy seismic surveys

- Most positive curvature co-rendered with Sobel filter similarity







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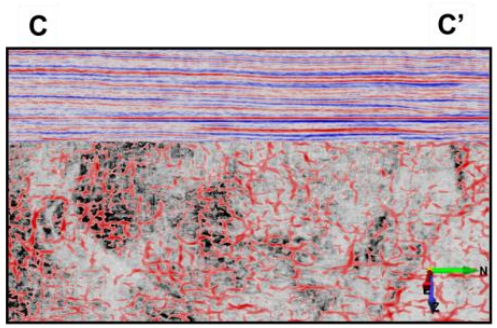
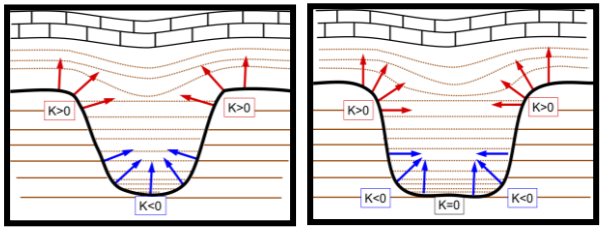
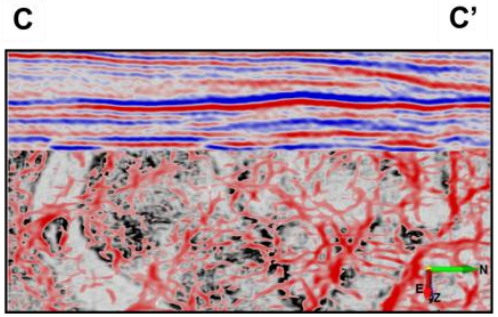
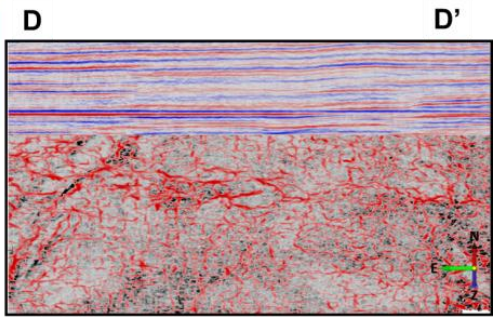
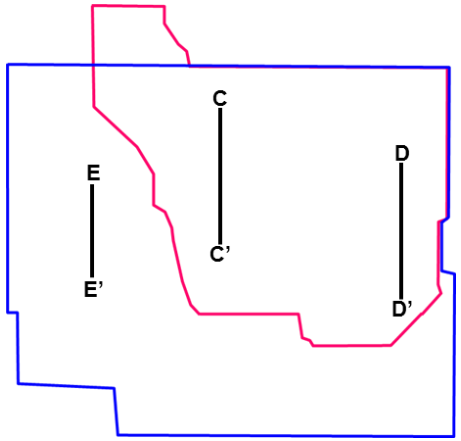
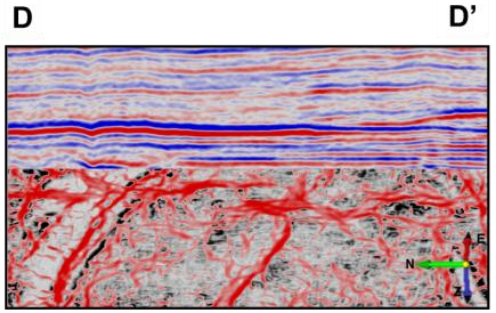


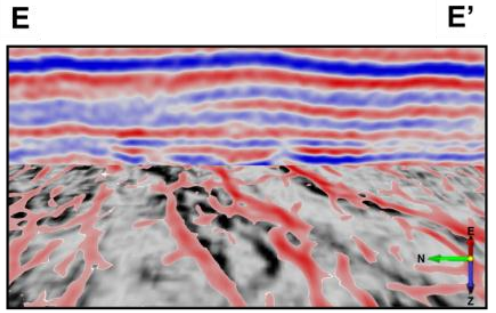


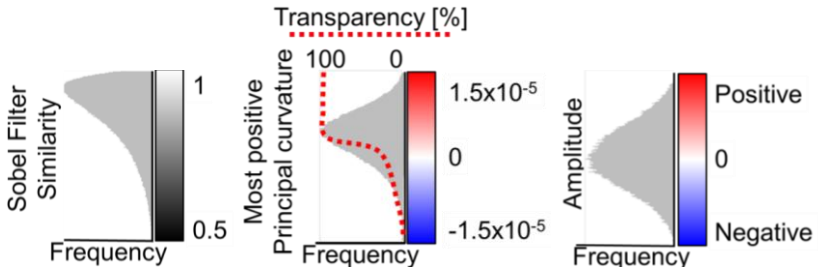






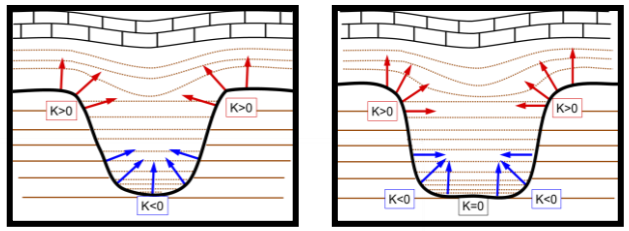


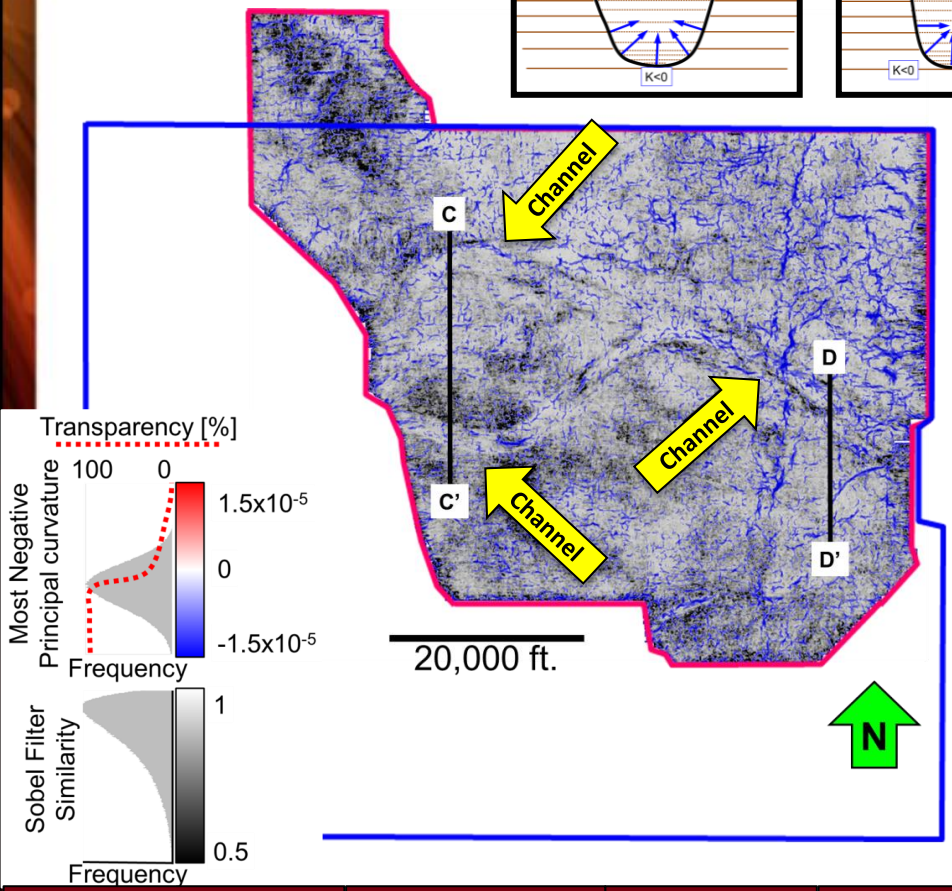


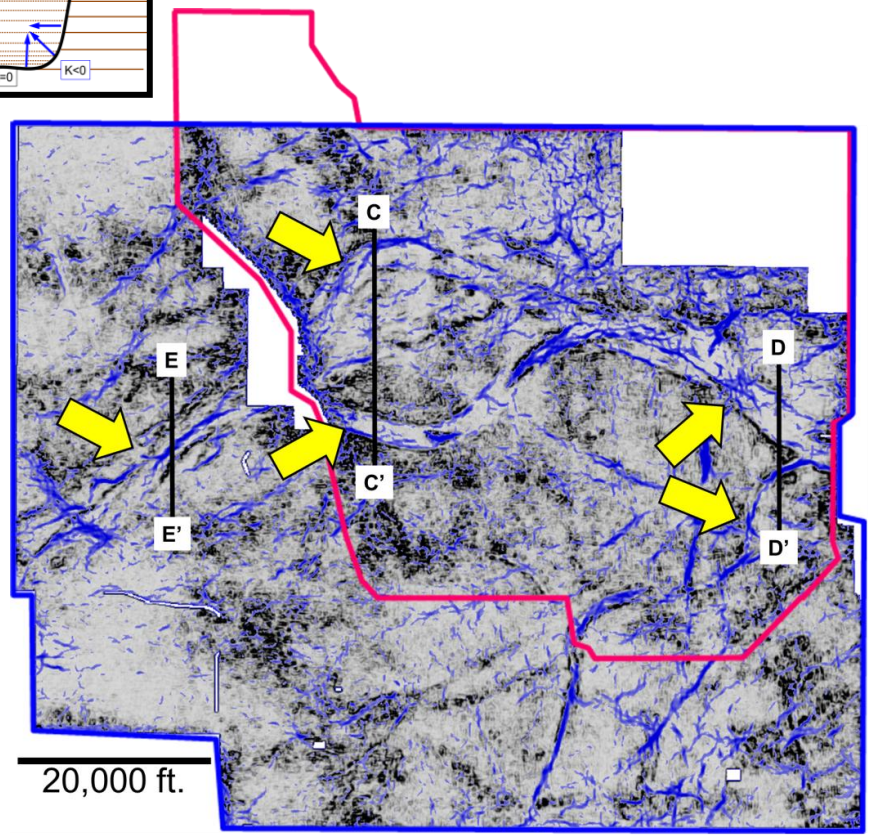


Attribute evaluation of merged and reprocessed legacy seismic surveys

- Most negative curvature co-rendered with Sobel filter similarity







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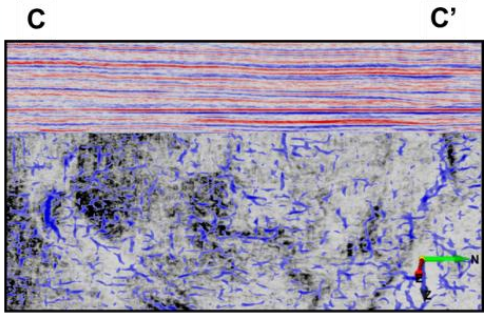
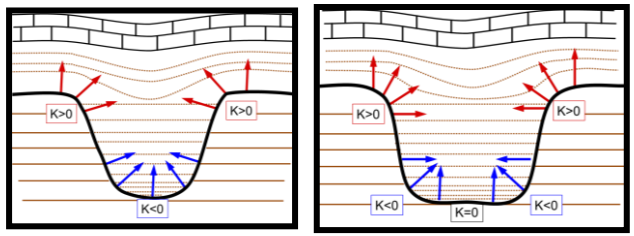
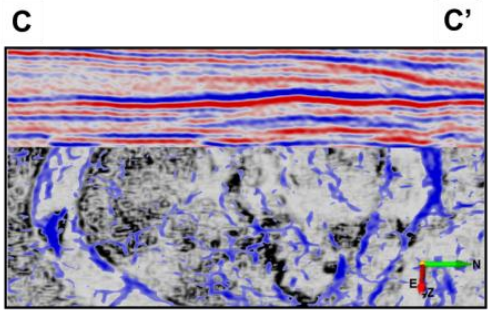
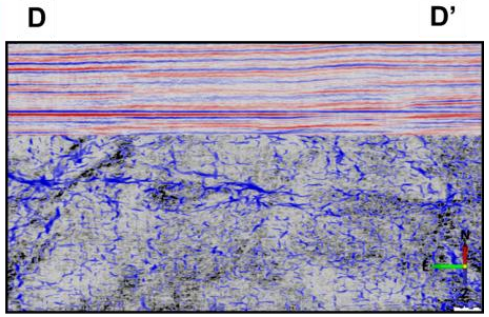
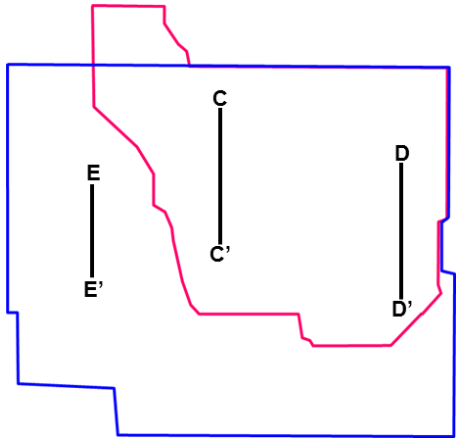
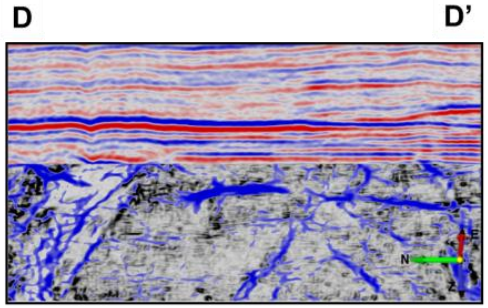


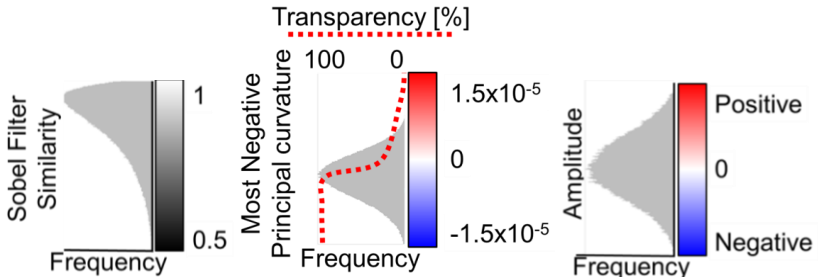


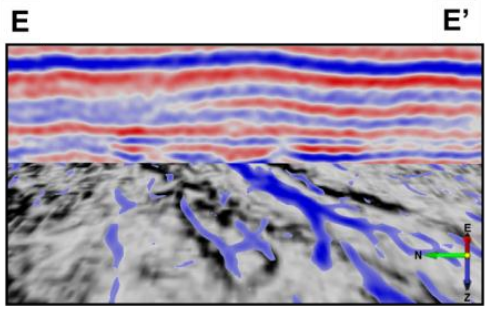






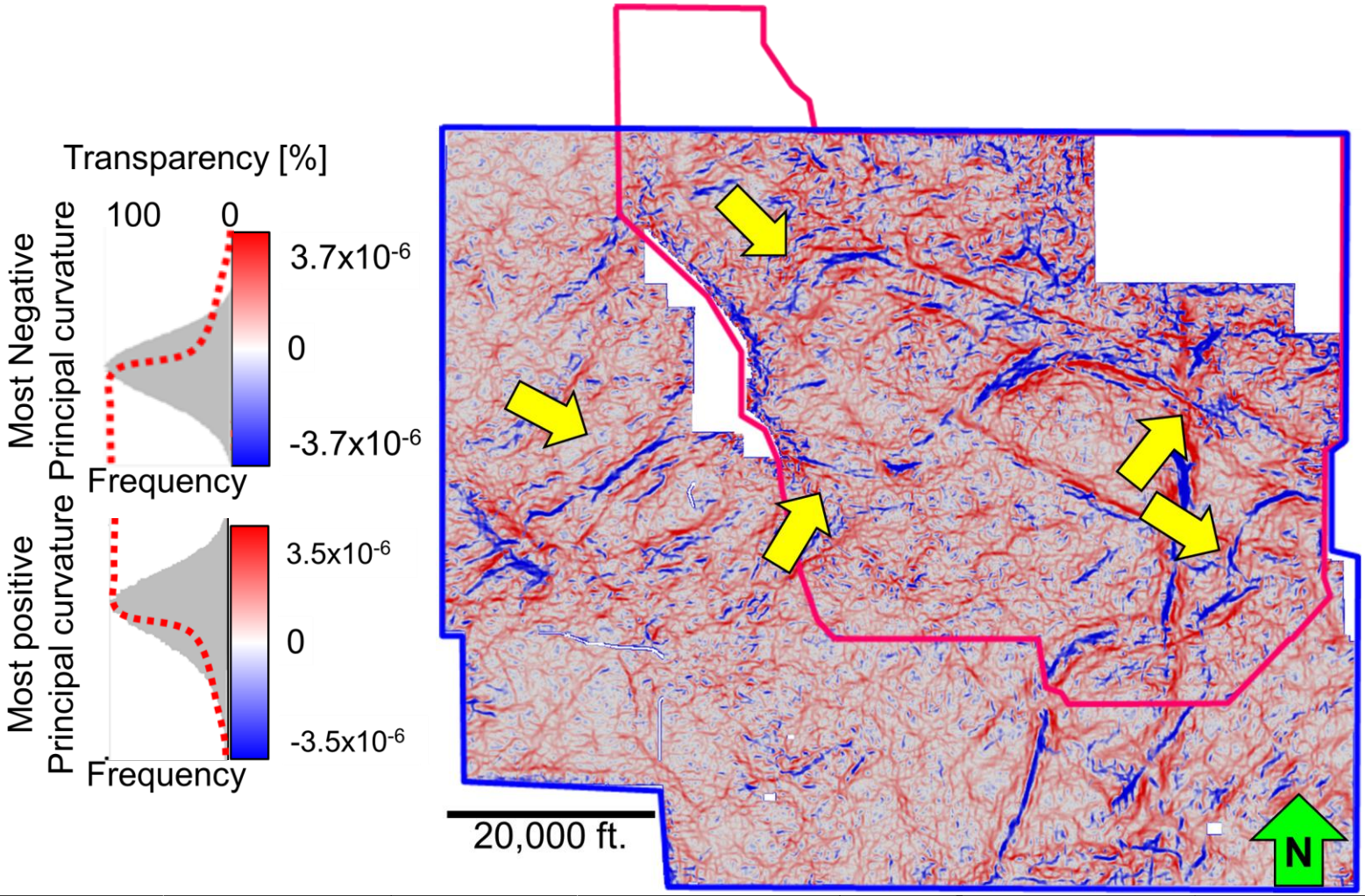






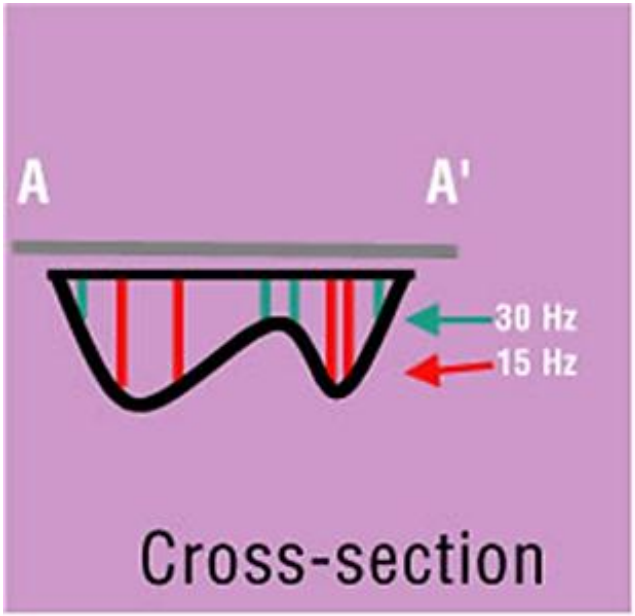
Attribute evaluation of merged and reprocessed legacy seismic surveys

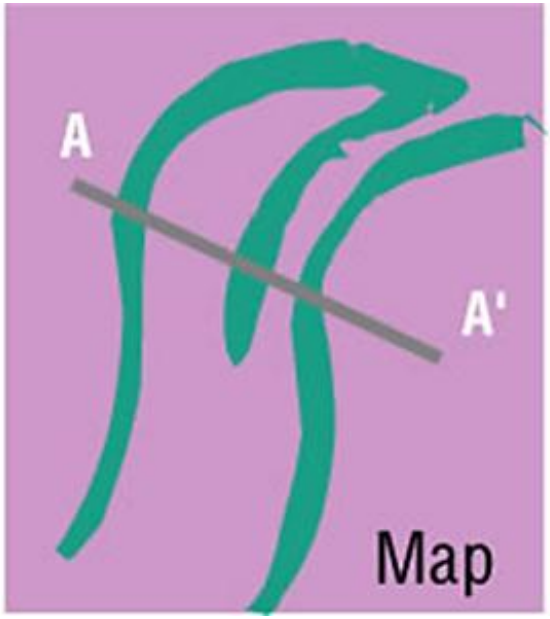
- Most negative curvature co-rendered with most positive curvature

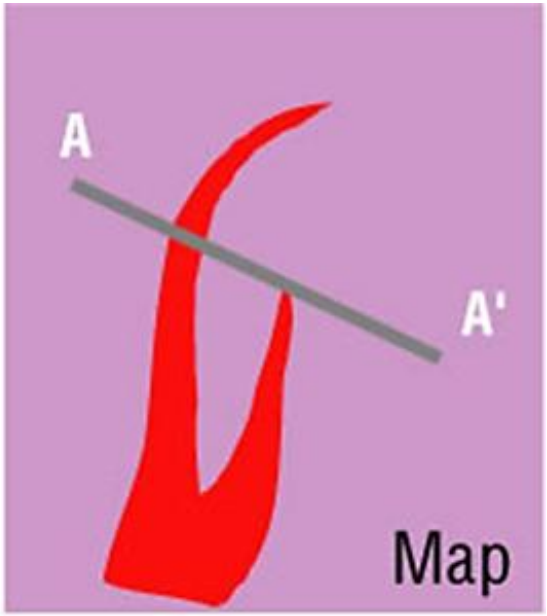


Attribute evaluation of merged and reprocessed legacy seismic surveys

- Spectral components



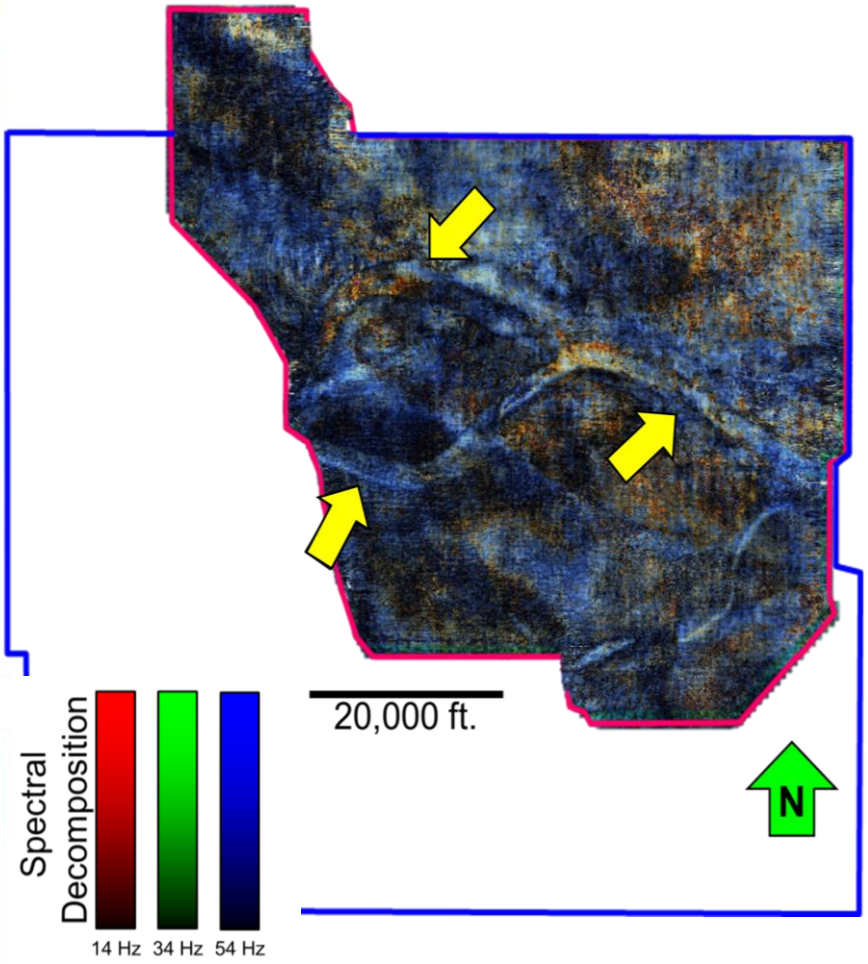


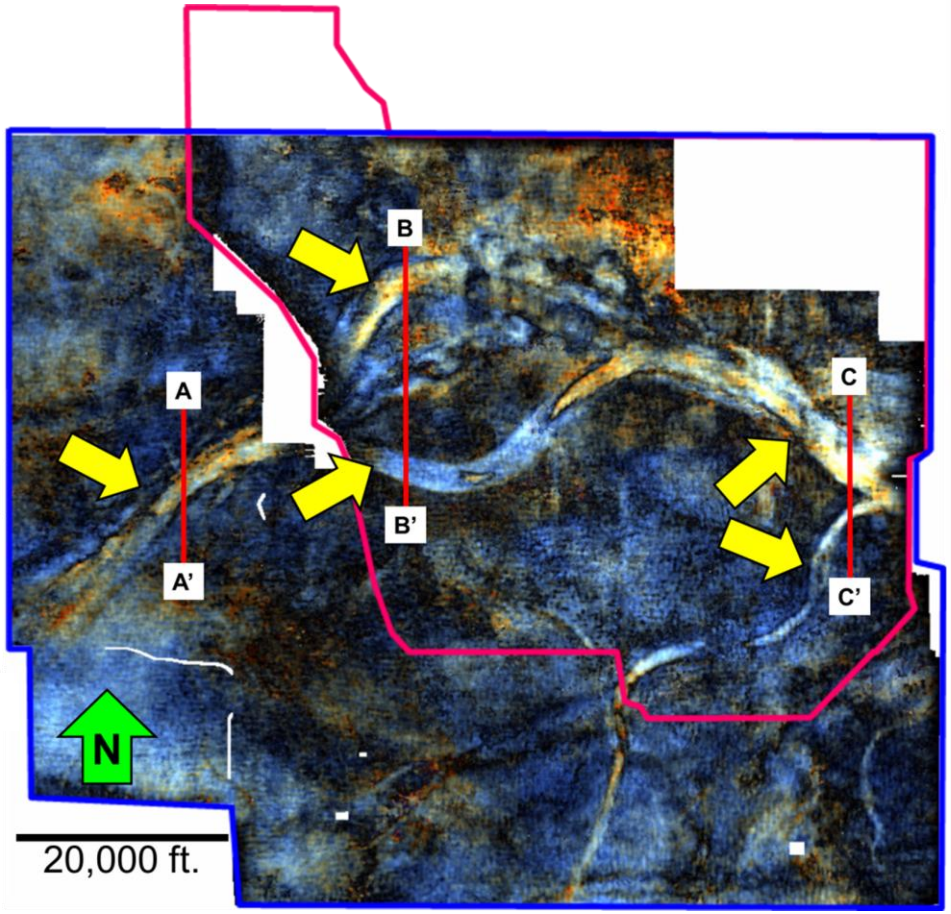


(After Laughlin et al., 2002)

Attribute evaluation of merged and reprocessed legacy seismic surveys

- Spectral components on the Watonga survey

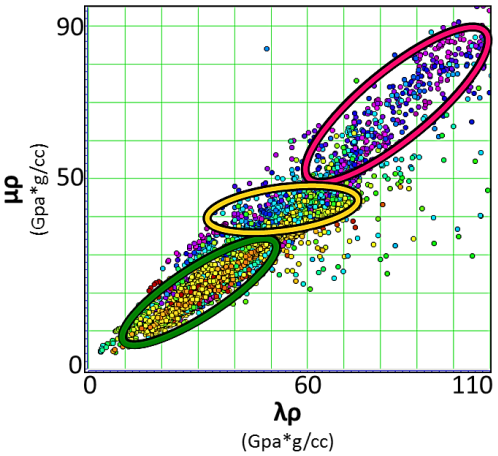




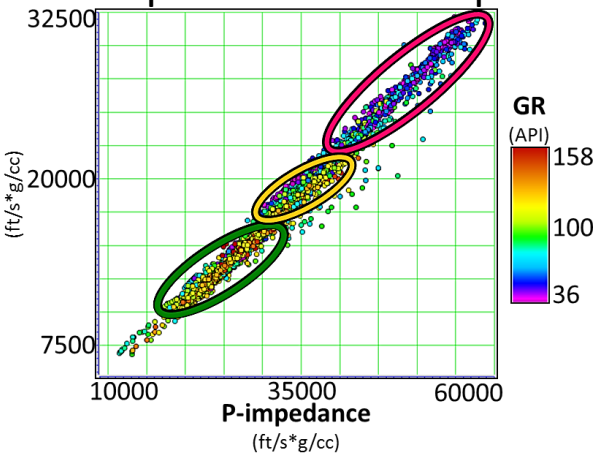
Petrophysical Analysis

- **Lithology discrimination cross-plots**

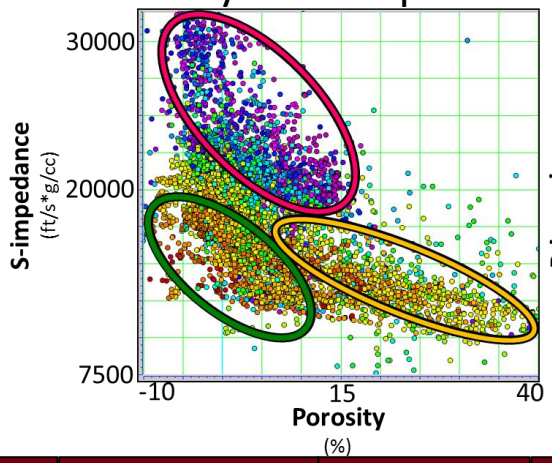
λρ vs. μρ



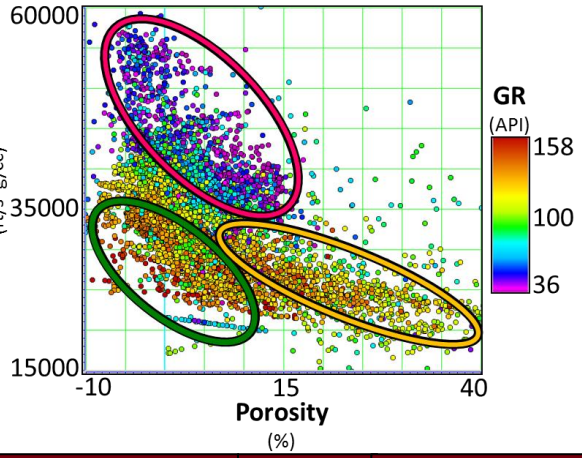
P-impedance vs. S-impedance



Porosity vs. S-impedance



Porosity vs. P-impedance



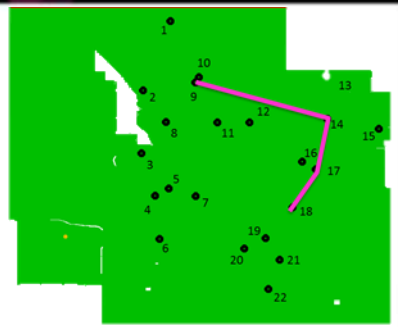
Sandstone

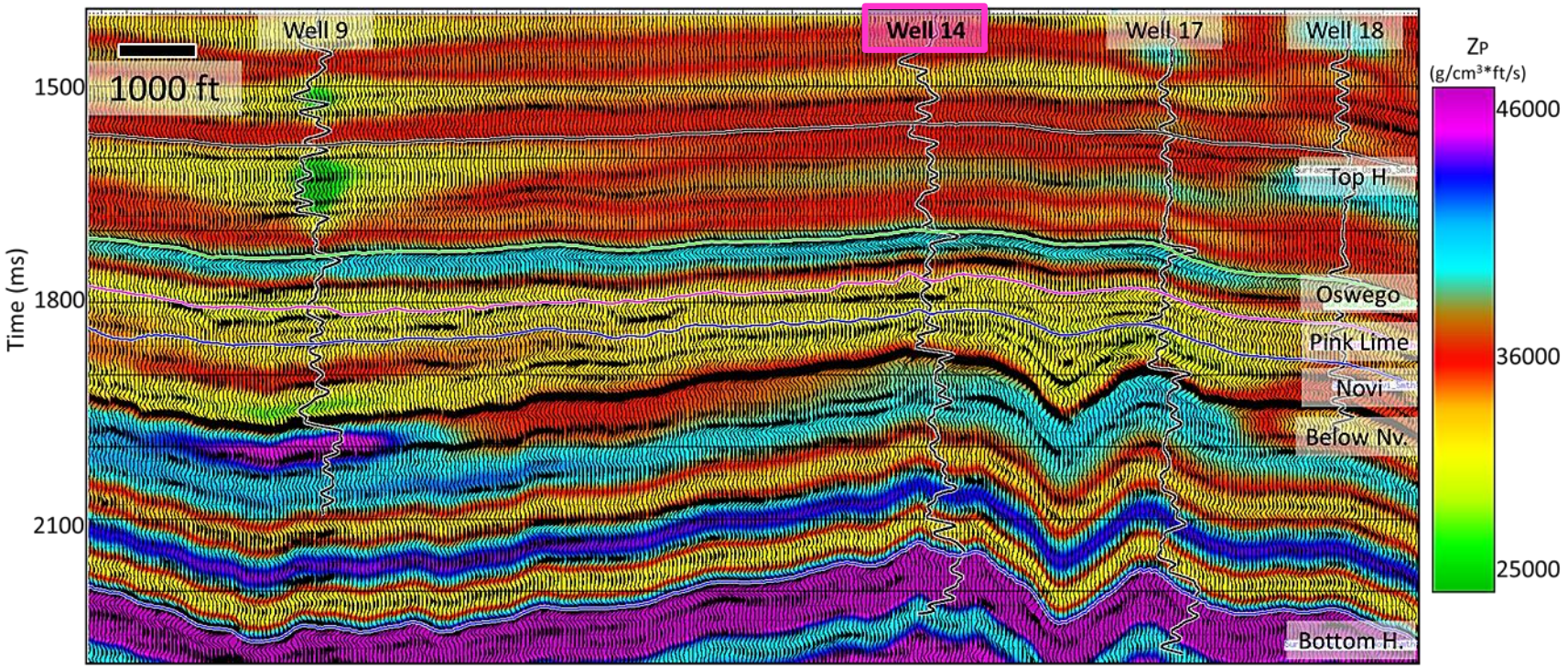
Shale

Limestone

Seismic impedance inversion

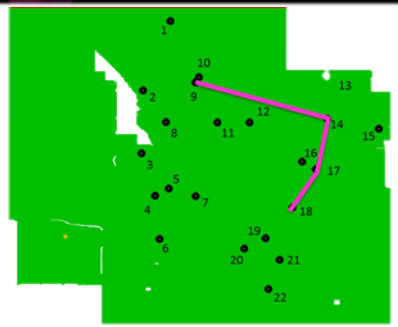
- Initial low frequency model

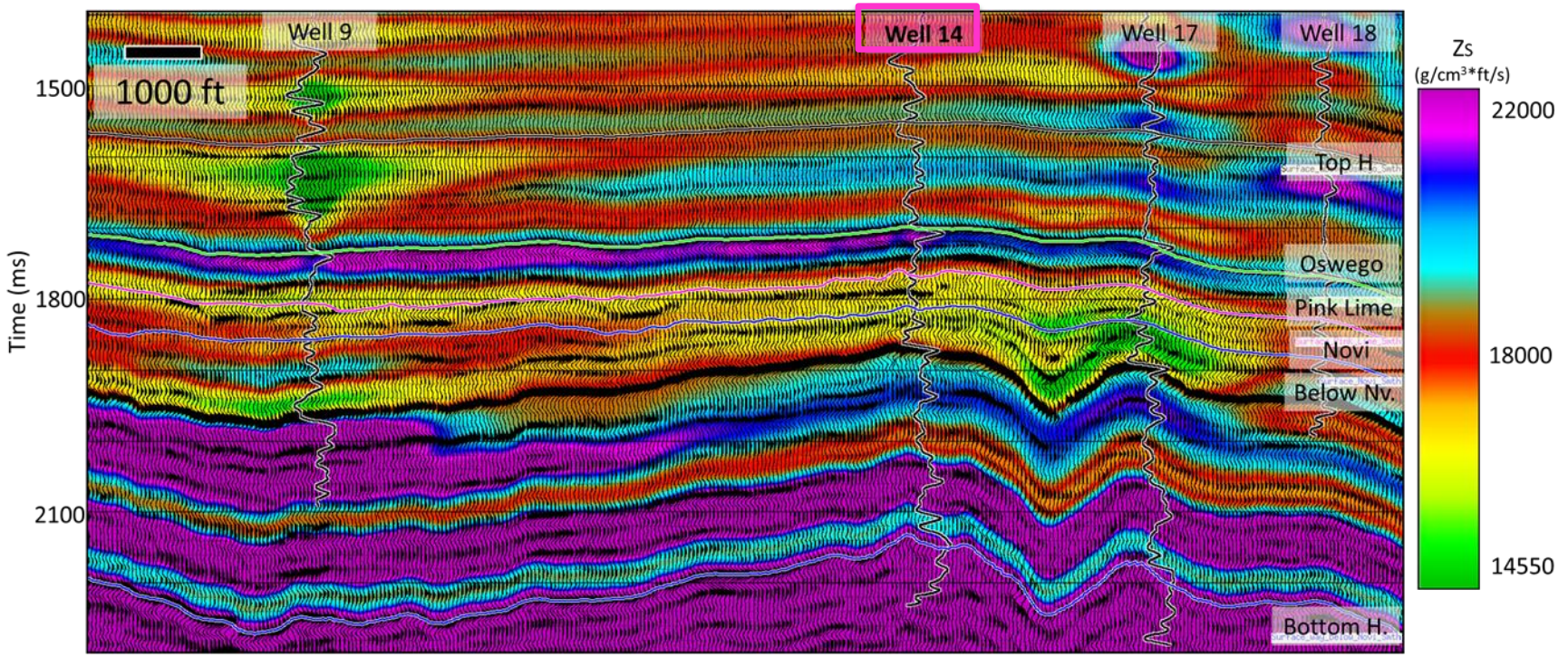




Seismic impedance inversion

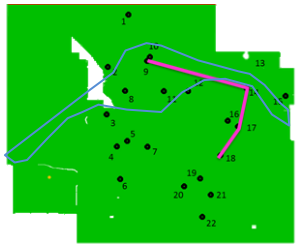
- Initial low frequency model

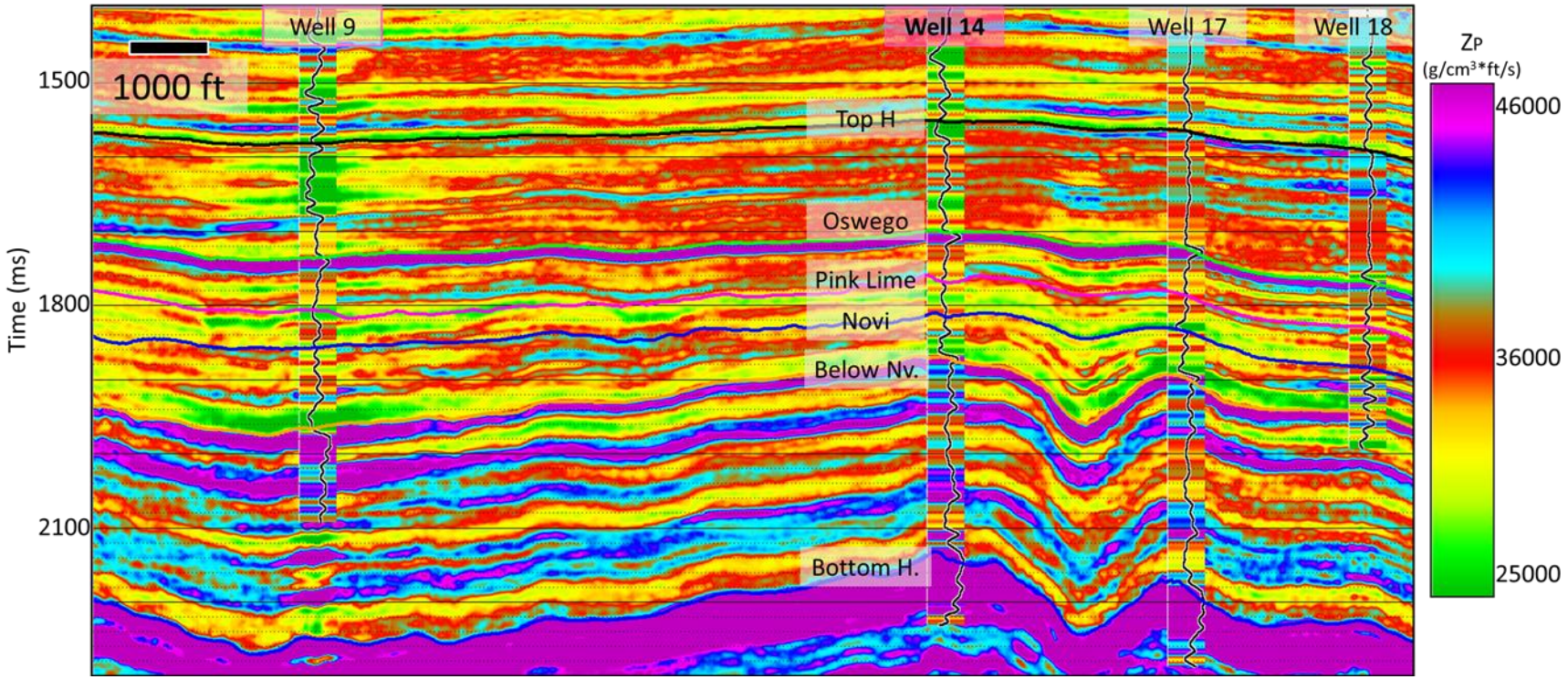




Seismic impedance inversion

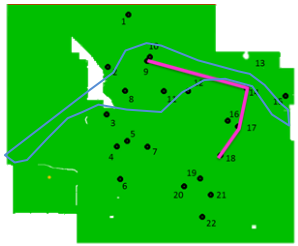
- P-impedance volume

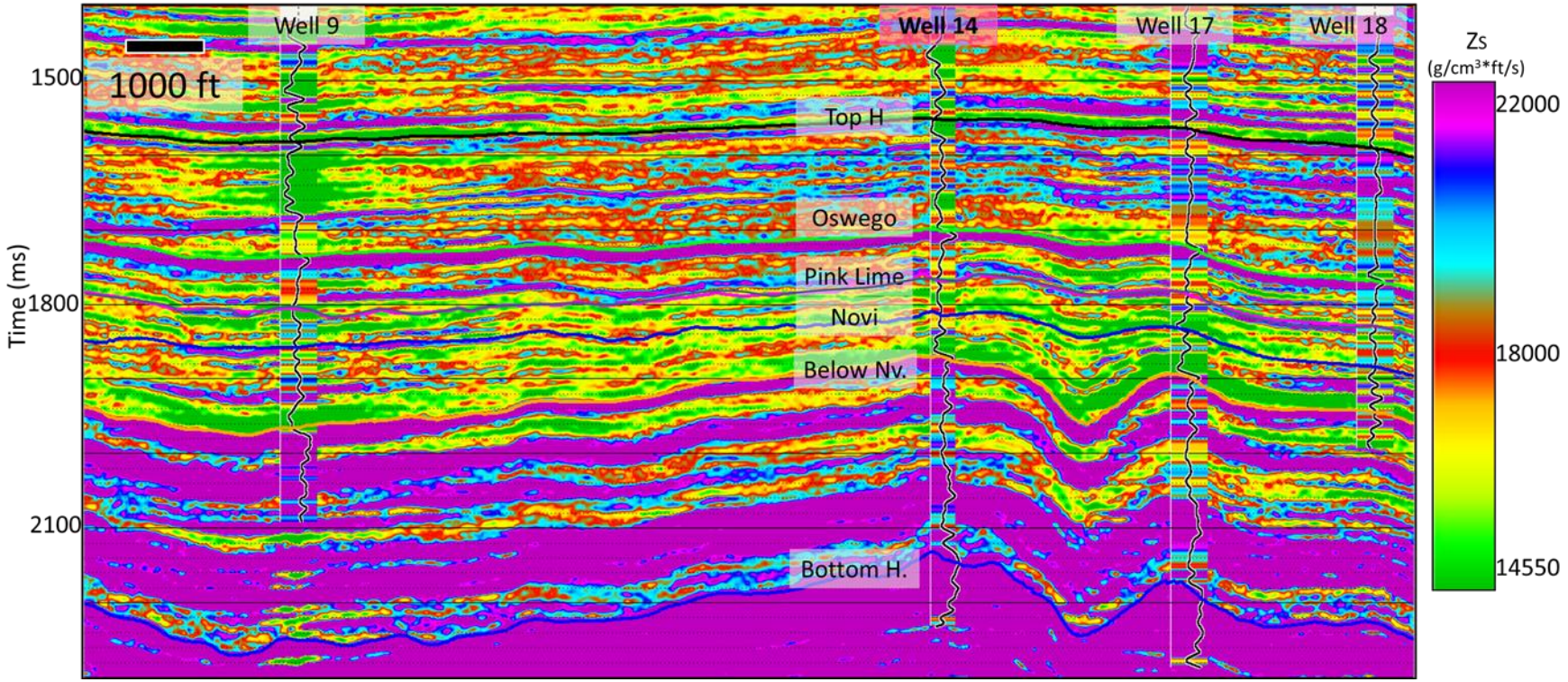




Seismic impedance inversion

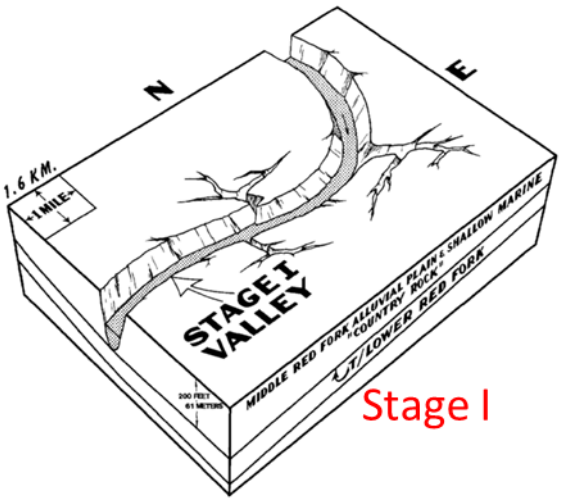
- S-impedance volume



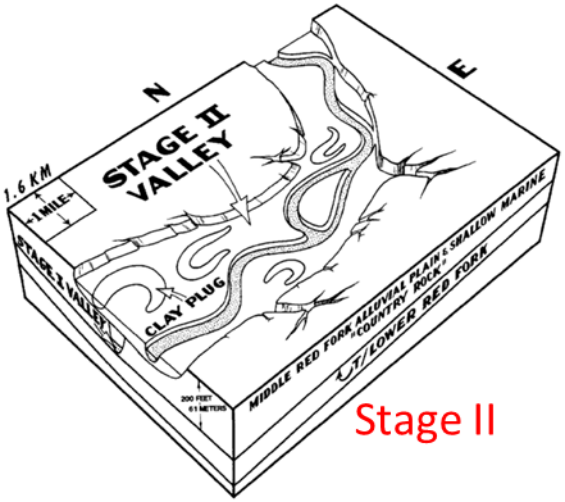


Geological Interpretation

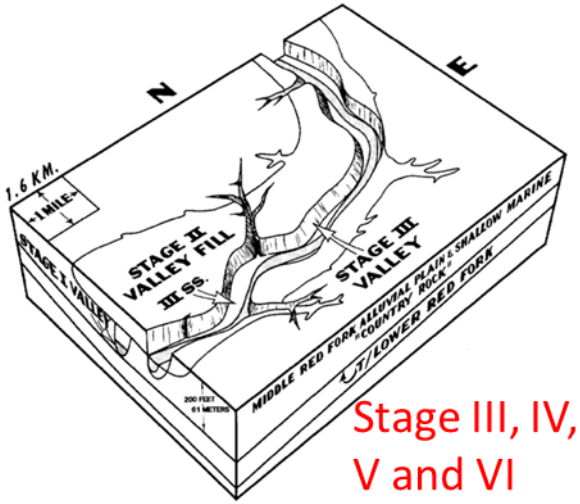
- Clement's (1991) model



Stage I



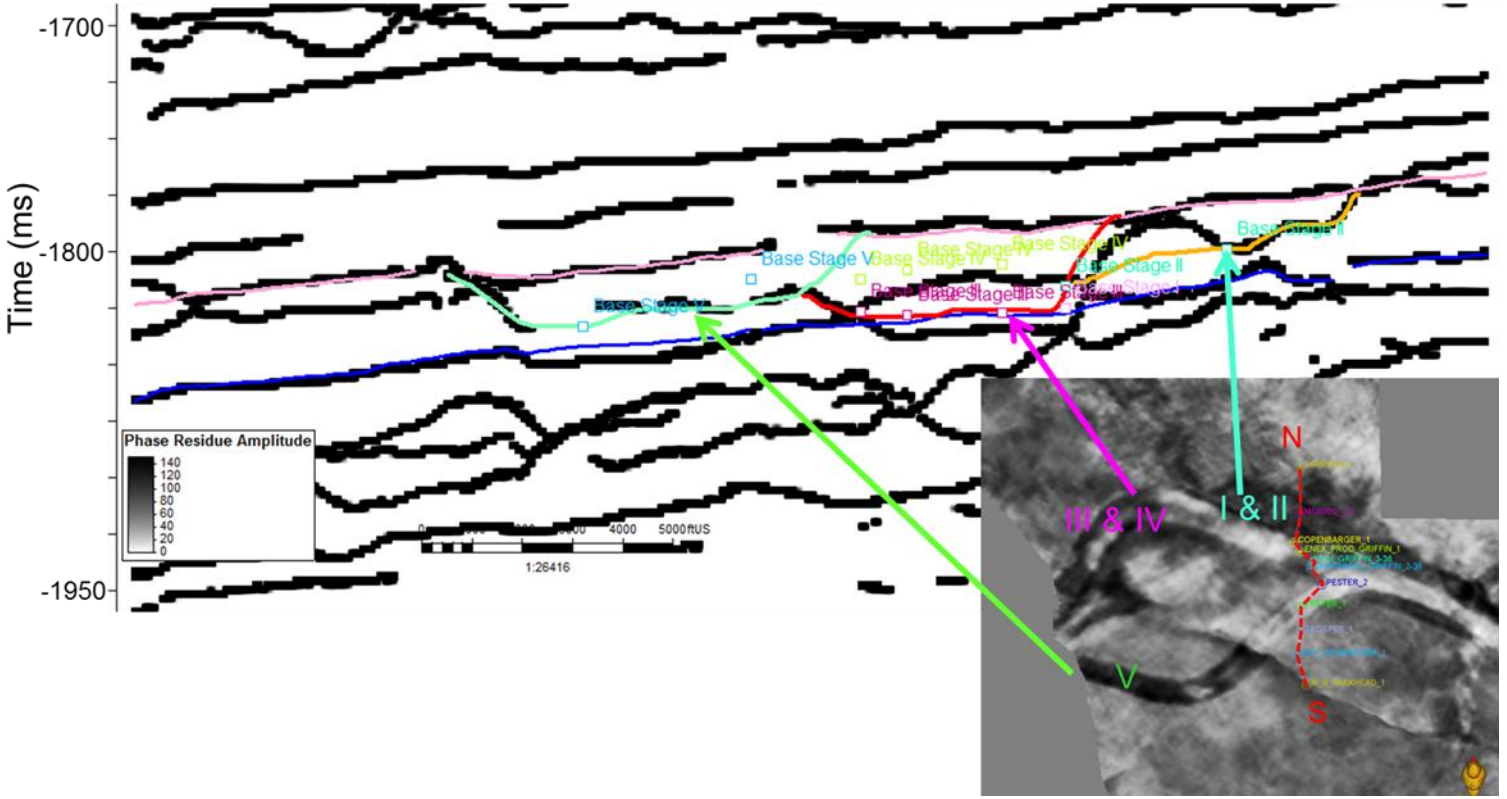
Stage II



Stage III, IV, V and VI

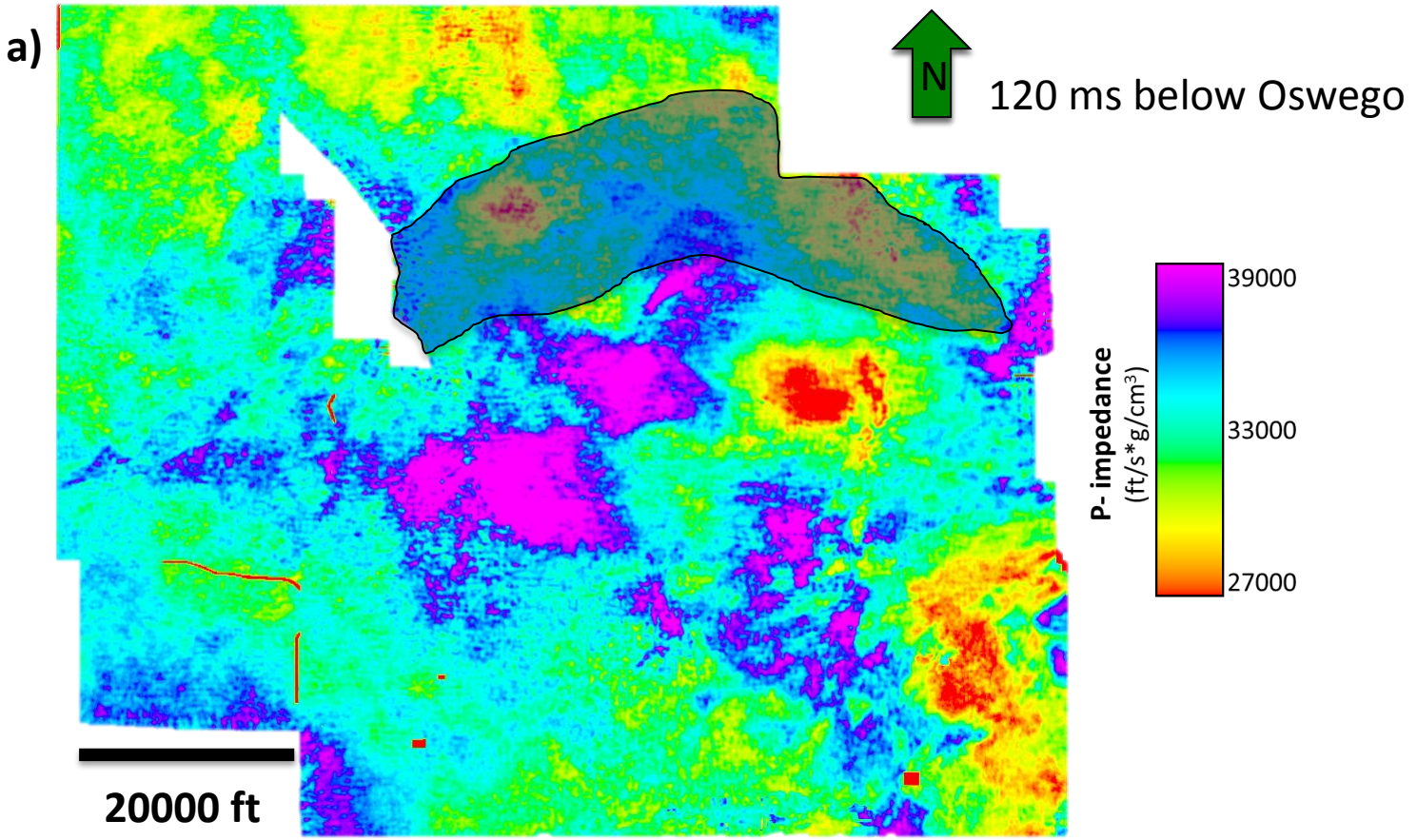
Geological Interpretation

- Davogustto et al.'s (2012) model



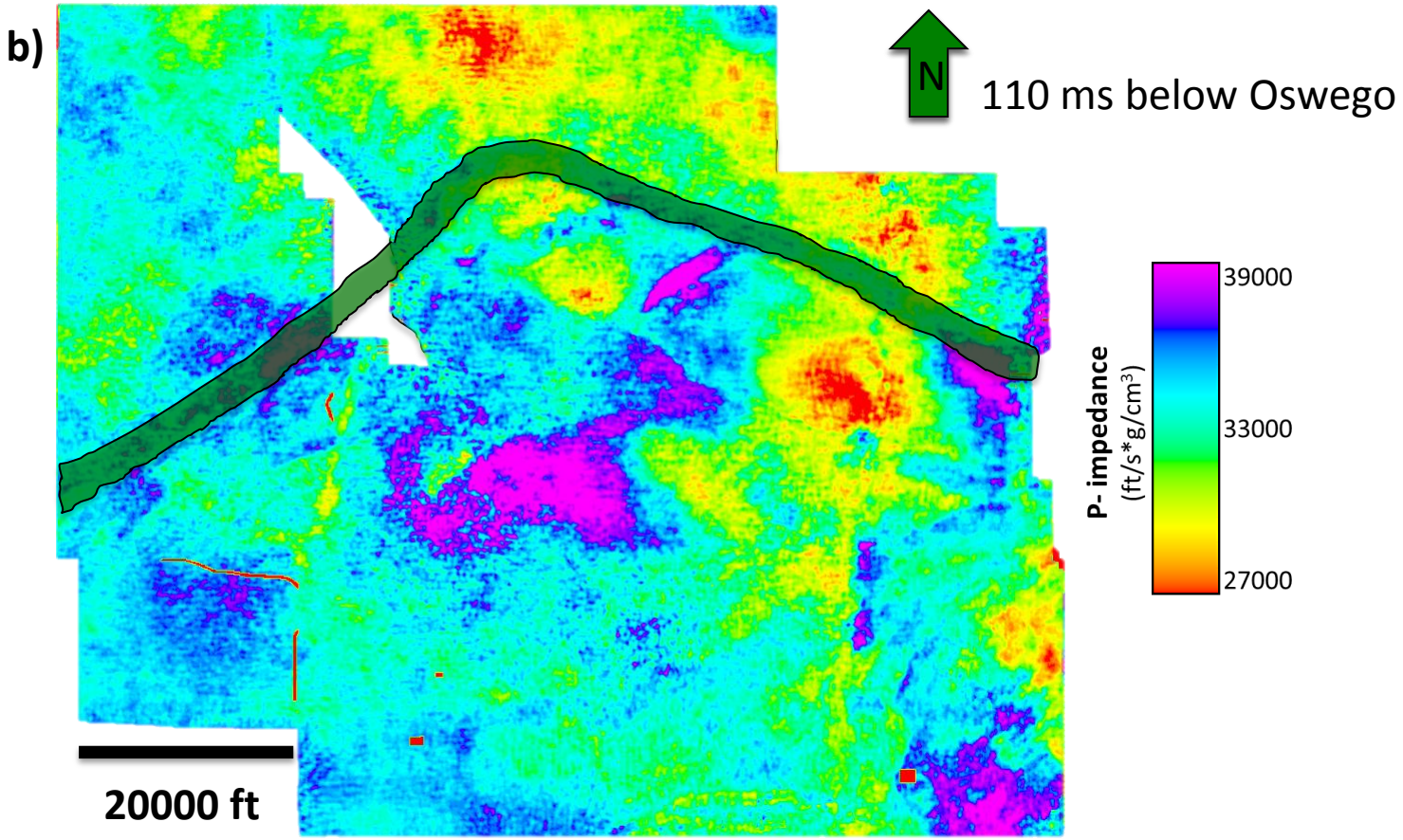
Geological Interpretation

- Stage I and II



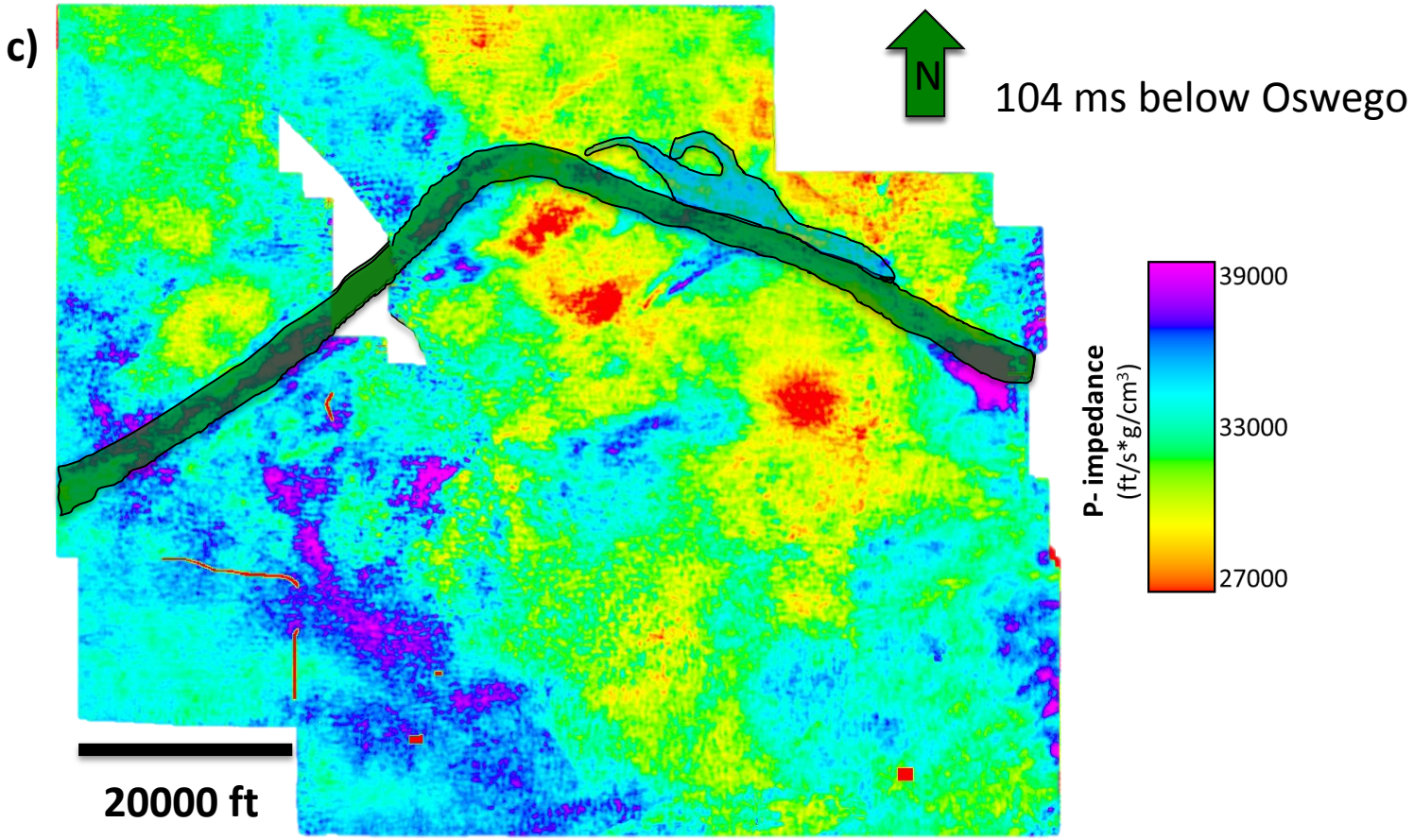
Geological Interpretation

- Stage III



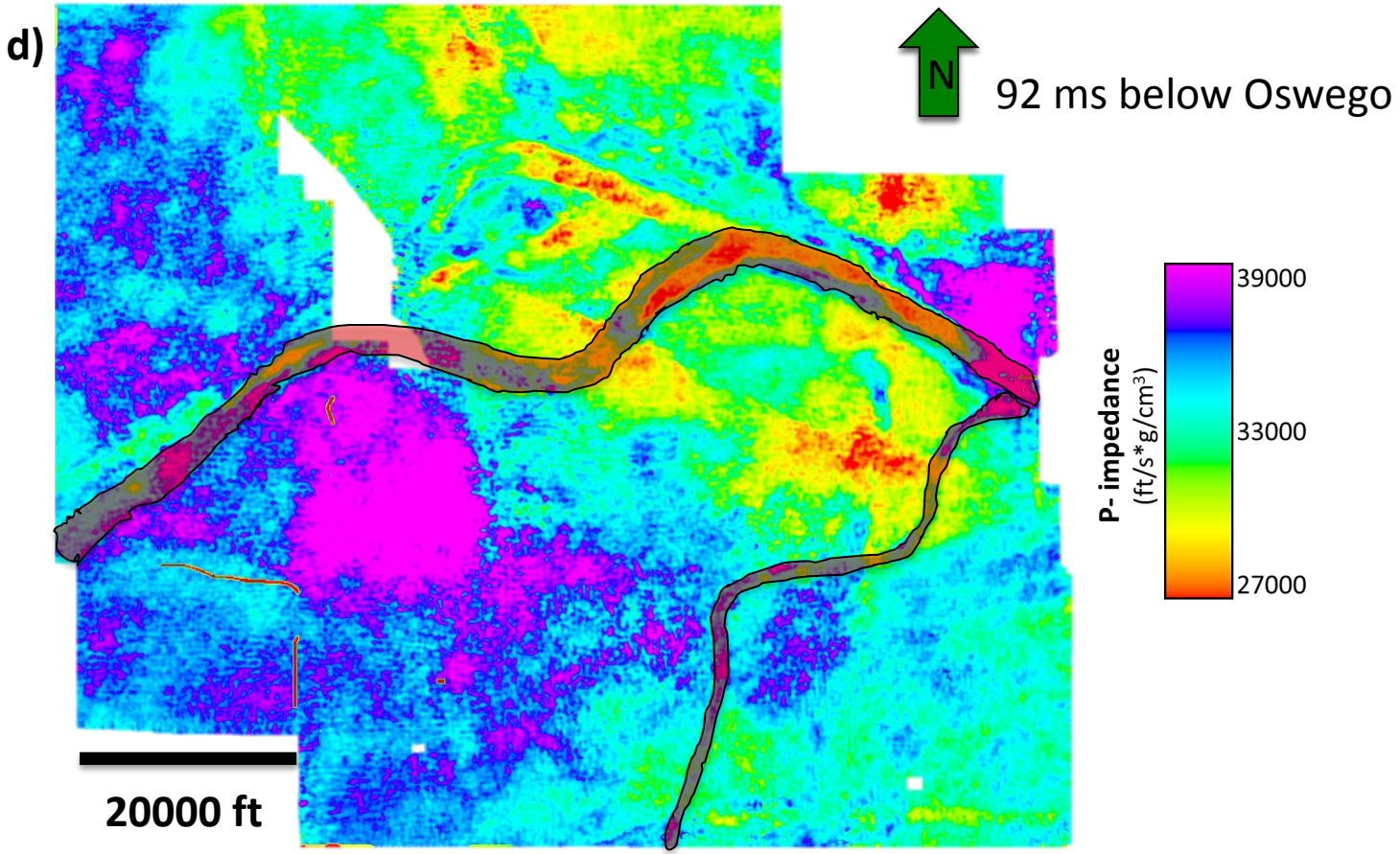
Geological Interpretation

- Stage III-IV and reactivation of stage II



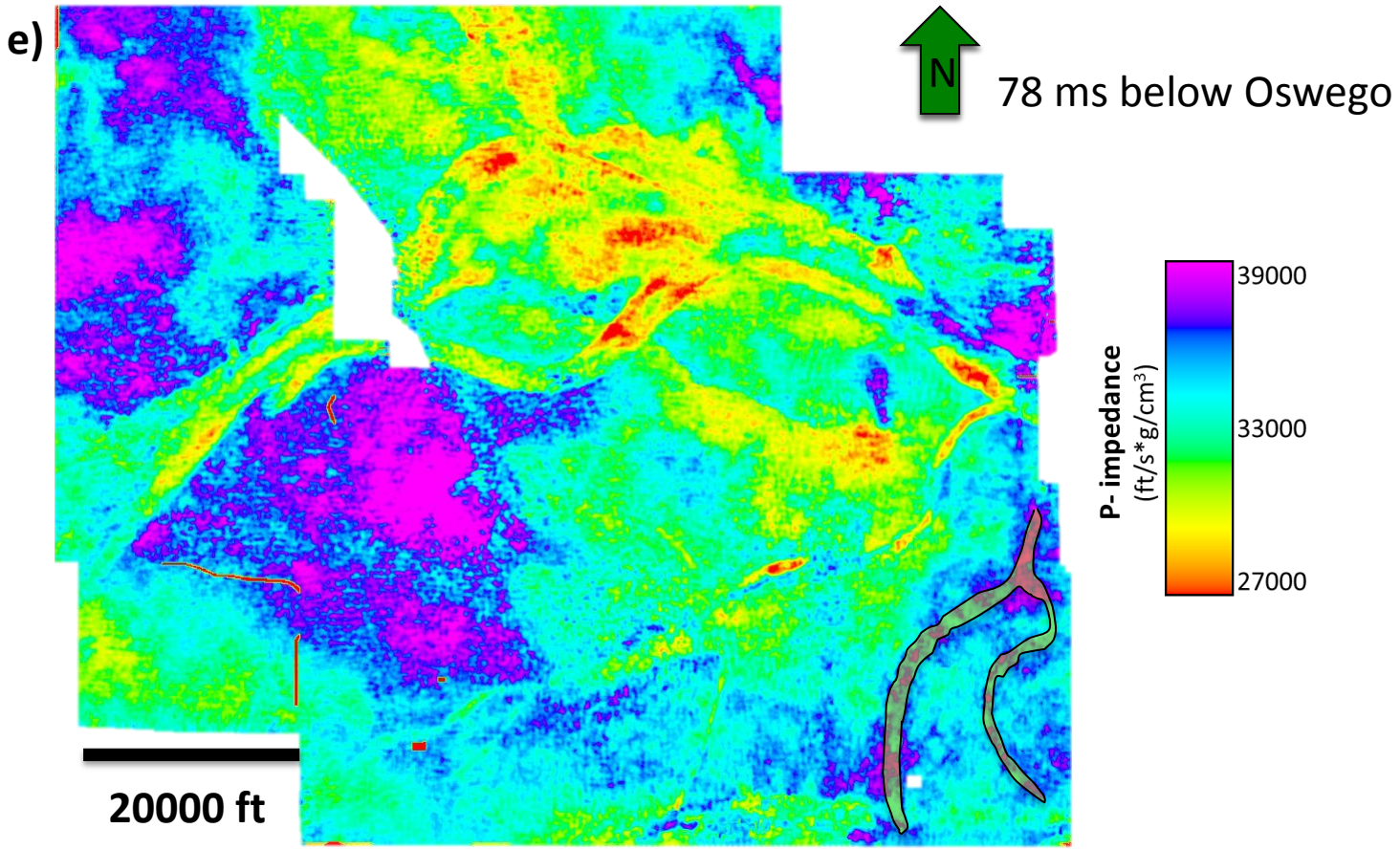
Geological Interpretation

- Stage V



Geological Interpretation

- Stage VI



Conclusions

- Low prestack impedance values correspond to **high porosity Sandstone intervals**
- High prestack impedance values correspond to **Shale or Limestone intervals**
- Seismic attributes correlate to the **Red Fork incised valley-fill channels**
- Seismic attributes are strongly affected by **acquisition parameters**
- Attention to **reprocessing** can have a significant uplift to **lateral and vertical resolution** as well as **seismic attribute** response

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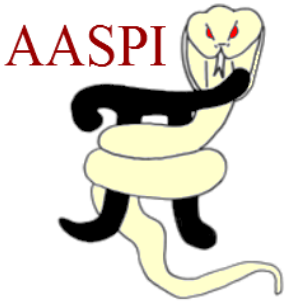
Thank you!



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noble energy

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The University of Oklahoma

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