[PS]Seismic Characterization of the Navajo Reservoir, Buzzards Bench, Utah*

Kimberley Haar[1,2], Robert Balch[2], and Robert Will[3]

Search and Discovery Article #51503 (2018)**
Posted July 23, 2018

*Adapted from poster presentation given at AAPG 2018 AAPG Annual Convention and Exhibition, Salt Lake City, Utah, May 20-23, 2018

[1]New Mexico Institute of Mining and Technology, Socorro, NM, United States (kimberley.haar@student.nmt.edu)
[2]Petroleum Recovery Research Center, Socorro, NM, United States
[3]Schlumberger Carbon Services, Denver, CO, United states

Abstract

The CarbonSAFE Rocky Mountain team is a task force charged with investigating the regulatory, financial, and technical feasibility of commercial-scale CO_2 capture and storage from two coal-fired power plants in the northwest region of the San Rafael Swell, Utah. The long-term objective is to develop a template of CCS implementation in the Rocky Mountain region for subsequent, seamless CCS development. The reservoir injection interval is the Navajo Sandstone which is approximately 160 m thick and is at an average depth of about 2200 m below the surface. There is potential storage for up to 100,000 metric tonnes of CO_2 per square mile. This reservoir meets the DOE's requirement on carbon storage capacity and fulfills the initiative to develop protocols for commercially sequestering carbon sourced from coal-fired power plants.

A representative geologic model is a fundamental requirement for accurate assessment of storage potential and as the framework for simulation modeling of CO_2 plume migration. Seismic data can greatly improve a geologic model by providing inter-well control on structure, stratigraphy, and reservoir petrophysical properties. While highly preferred, 3D seismic data is frequently unavailable for regional projects and early project phase characterization studies such as the CarbonSAFE Rocky Mountain Phase 1 study. Three "legacy" regional 2D seismic profiles obtained for this study were used to provide a sparse grid of structural and stratigraphic control for the sizeable regional geologic model. The age, quality, and sparsity of both seismic and well data posed challenges to interpretation tasks such as interpretation loop closure, seismic-to-well ties, and depth conversion. However, the seismic interpretation made significant contribution towards reduction of geologic uncertainty within the vast areas of otherwise unconstrained model space. This paper presents the methods used and challenges encountered during seismic interpretation and conversion to depth domain for use in the geologic and simulation models.

Selected References

Allmendinger, R.W., H. Farmer, E. Hauser, J. Sharp, D. Von Tish, J. Oliver, and S. Kaufman, 1986, Phanerozoic Tectonics of the Basin and Range - Colorado Plateau Transition from COCORP Data and Geologic Data: A Review: American Geophysical Union, Geodynamics Series Volume 14, p. 257-267.

Arabasz, W.J., and D.J. Williams, 1986, Analysis and Summary of Seismographic Data Recorded in Vicinity of Joes Valley Dam, Emery County Project, Eastern Wasatch Plateau, Utah: Technical Report to U.S. Bureau of Reclamation, Seismotectonic Section, Engineering and Research Center, Denver, Colorado.

Kassab, M.A., and A. Weller, 2015, Study of P-Wave and S-Wave Velocity in Dry and Wet Sandstones of Tushka Region, Egypt: Egyptian Journal of Petroleum, v. 24, p. 1-11.

Loope, D., and C. Rowe, 2003, Long-Lived Pluvial Episodes During Deposition of the Navajo Sandstone: Journal of Geology, v. 111, p. 223-232.

Parrish, J.T., and H.J. Falcon-Lang, 2007, Coniferous Trees Associated with Interdune Deposits in the Jurassic Navajo Sandstone Formation, Utah, USA: Paleontology, v. 50/4, p. 829-843.

Petrie, E., D. Barton, and J. Evans, 2013, Tectonic History and Distribution of Faults and Fractures in the San Rafael Swell, Utah: Impacts on Subsurface Fluid Flow: Utah Geological Association Publication 42, p. 75-90.

Shelander, D., V. Smith, H. Leetaru, R. Will, and M. Coueslan, 2014, The Evolution and Effect of the Velocity Model on Various Aspects of Surfaces Seismic Data Analysis: Energy Procedia, v. 63, p. 4374-4384.

Sorensen, T.N., 2017, Progressive Deformation in Monocline, San Rafael Swell, Utah: Master Thesis, Department of Geosciences, University of Oslo, Oslo, Norway, 79 p.

Williams, D.J., and W.J. Arabasz, 1989, Mining-Related and Tectonic Seismicity in the East Mountain Area Wasatch Plateau, Utah, USA: Pageoph, v. 129/3-4, p. 345-368.

Seismic Characterization of the Navajo Reservoir, Buzzards Bench, Utah

Kimberley Haar[1,2]
Robert Balch[2]
Robert Will[3]

[1] New Mexico Institute of Mining and Technology

[2] Petroleum Recovery Research Center

[3] Schlumberger Carbon Services

In conjunction with the PacifiCorp Power Plant:

Funding provided by:

carbonSAFE Rocky Mountain Phase 1

ABSTRACT

The CarbonSAFE Rocky Mountain team is a task force charged with investigating the regulatory, financial and technical feasibility of commercial-scale CO_2 capture and storage from two coal-fired power plants in the northwest region of the San Rafael Swell, Utah. The long term objective is to develop a template of CCS implementation in the the Rocky Mountain region for subsequent, seamless CCS development. The reservoir injection interval is the Navajo Sandstone which is approximately 160 m thick and is at an average depth of about 2200 m below the surface. There is potential storage for up to 100,000 metric tonnes of CO_2 per square mile. This reservoir meets the DOE's requirement on carbon storage capacity and fulfills the initiative to develop protocols for commercially sequestering carbon sourced from coal-fired power plants.

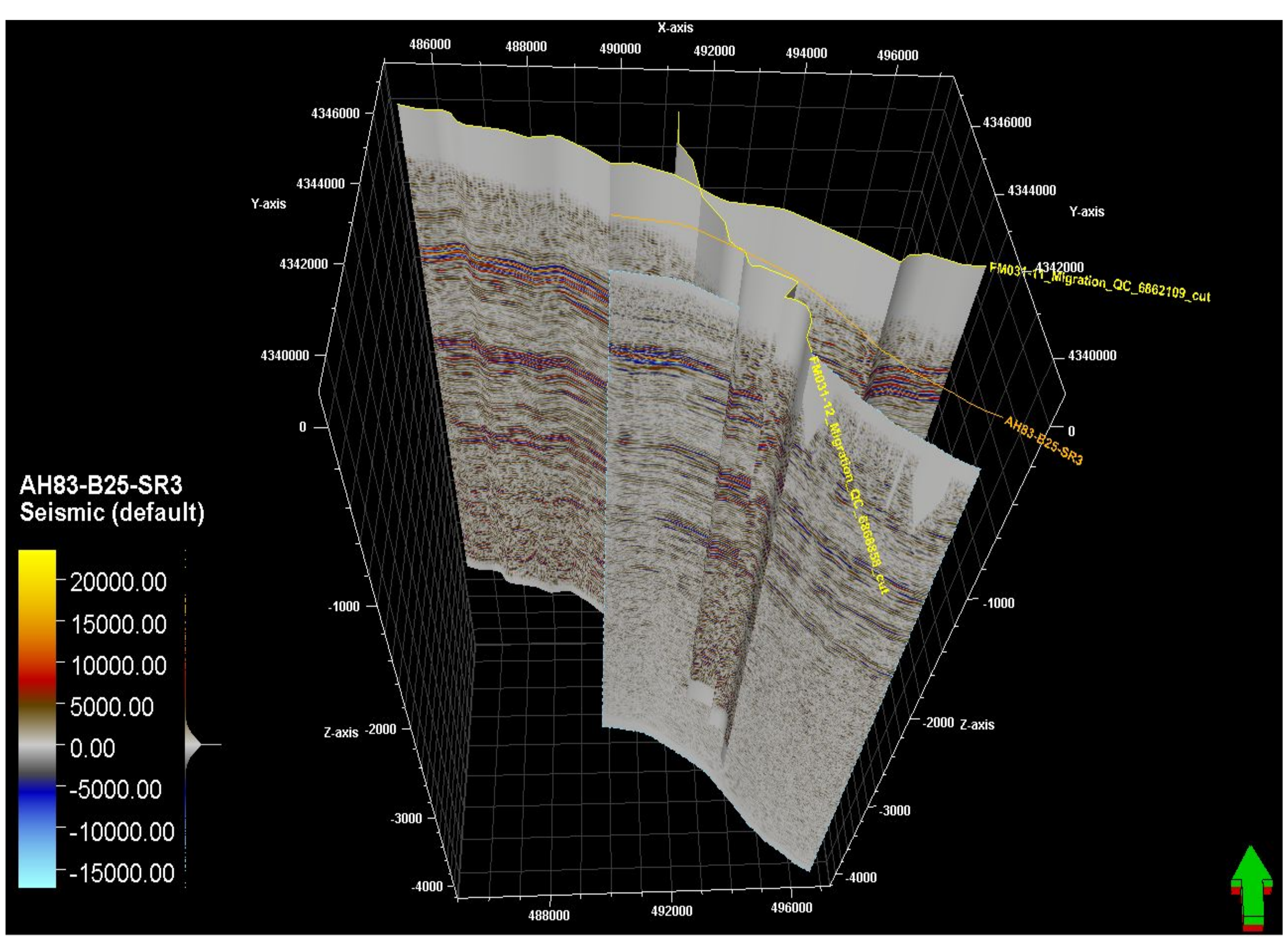
A successful carbon storage project requires a comprehensive geologic model for CO_2 migration simulations. A geologic model can be greatly enhanced with 2D seismic data because it provides an expansive, planar snapshot of geologic structures. With multiple orthogonal seismic profiles, formation surfaces and geologic features can be modeled laterally with less uncertainty. Reducing uncertainty therefore reduces project risk by strengthening migration simulations in the geologic model. The seismic interpretation was challenged with poor resolution legacy data and sparse, adjunct well logs.

INTRODUCTION

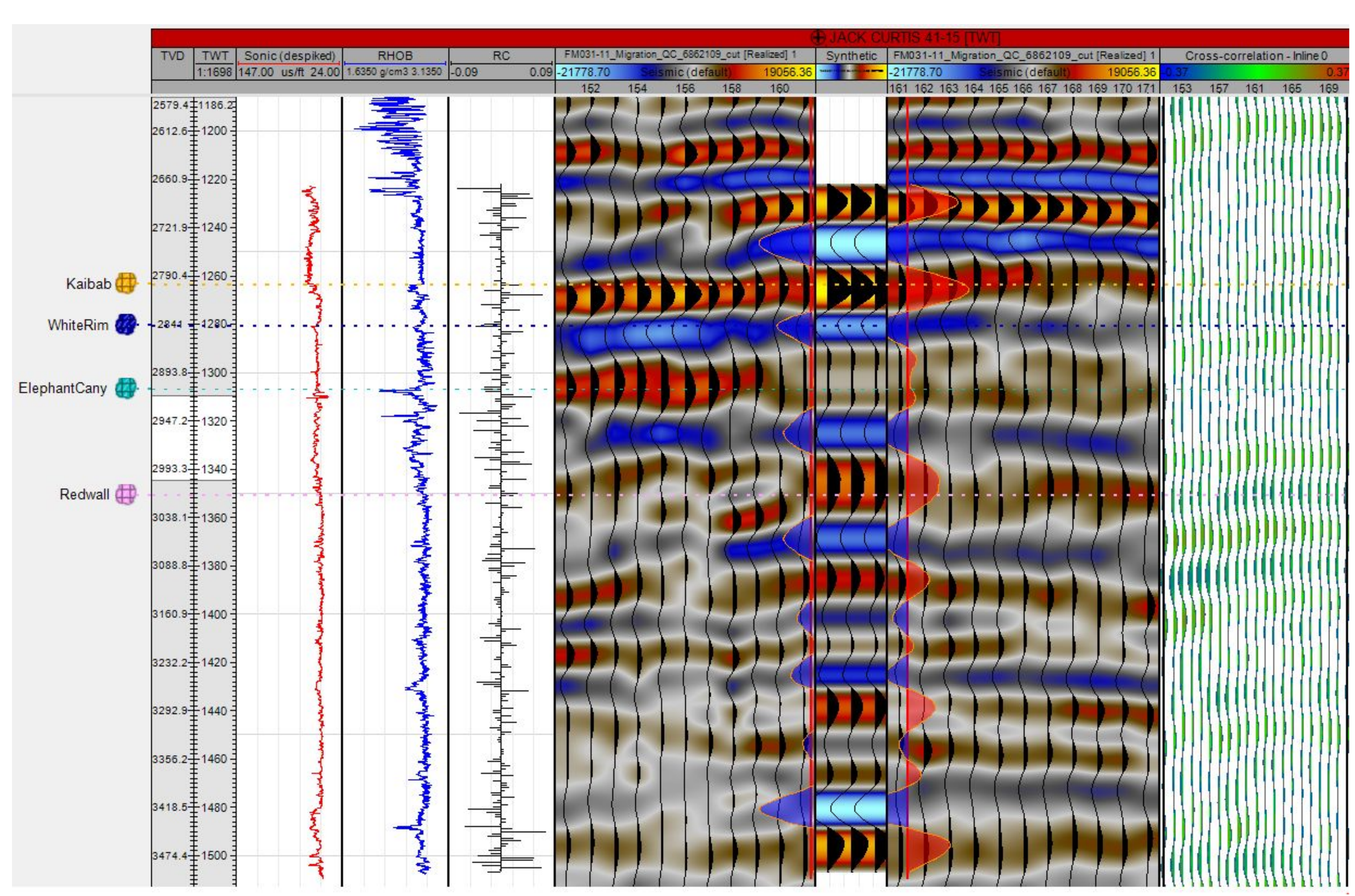
The potential sequestration site is located in the northwestern region of the San Rafael Swell, south central Utah. Two coal fired power plants in the area will provide CO_2 from the effluent gases; up to 14 million tons/year of CO_2 is estimated to be captured and stored. The data set includes 1200 wells with well top data, 72 of which have logs. The intended reservoir will be the Navajo dune formation. This rock body is most well known for the spectacular cliffs it creates in Zion national park, however, in the San Rafael Swell it sits 2100 m below the surface. The caprock is the sabkha deposit known as the Carmel formation.

Three legacy seismic lines were interpreted with aid of one well. The well is located 103 m north of the FM031-11 line and only had sonic and density data for 829 m in the Moenkopi through Red Wall formations which are 549 m below the formation of interest: the aeolian Navajo formation. Density difference between the bottom of the Carmel and top of the Navajo is typically about -0.2 g/cm^3 and sonic difference ranges between 0 and 20 μs/m. Such a small acoustic impedance between the reservoir and caprock is expected at this depth between water-saturated sands and shales.

Legacy Seismic with Tieing Well



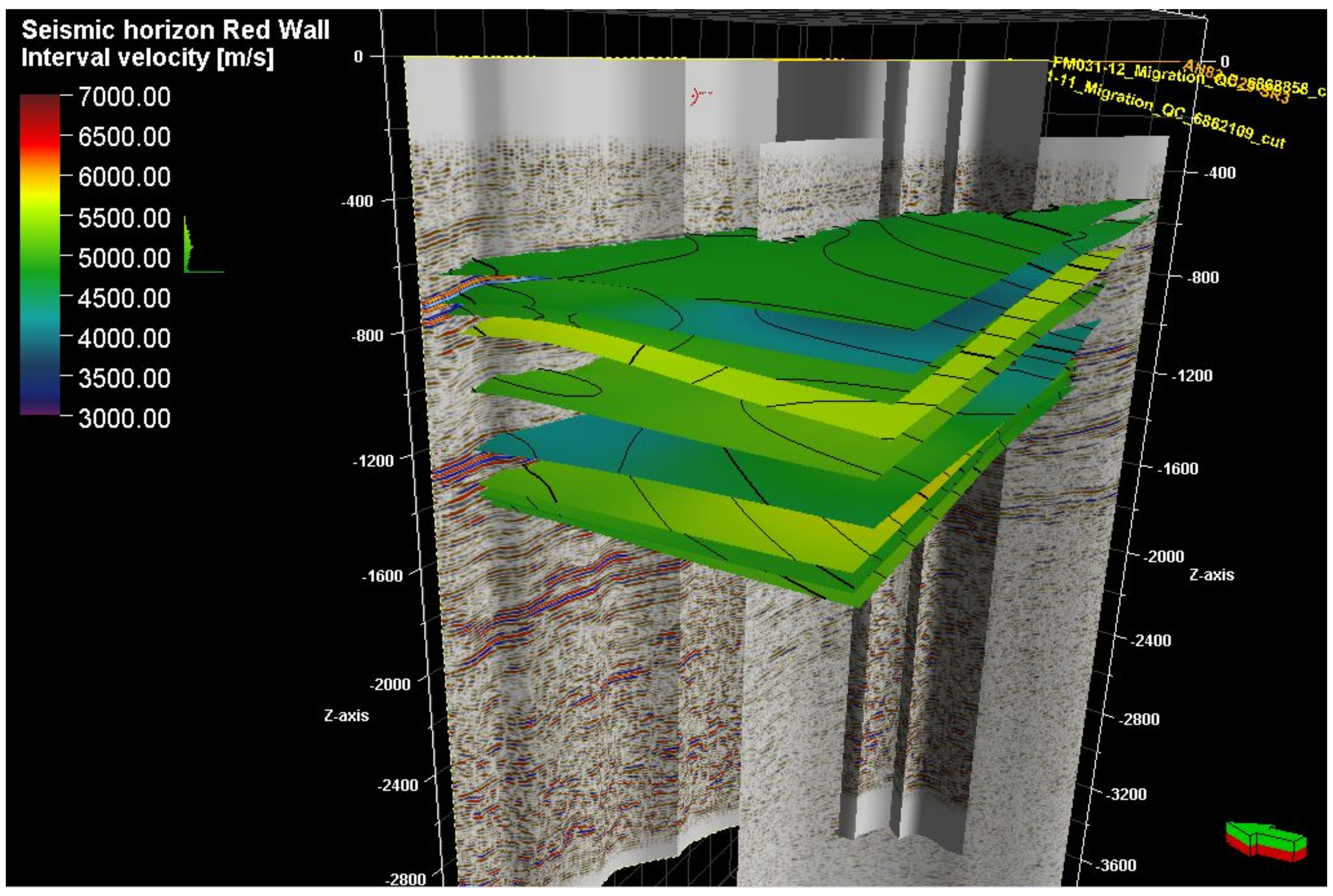
Seismic Well Tie



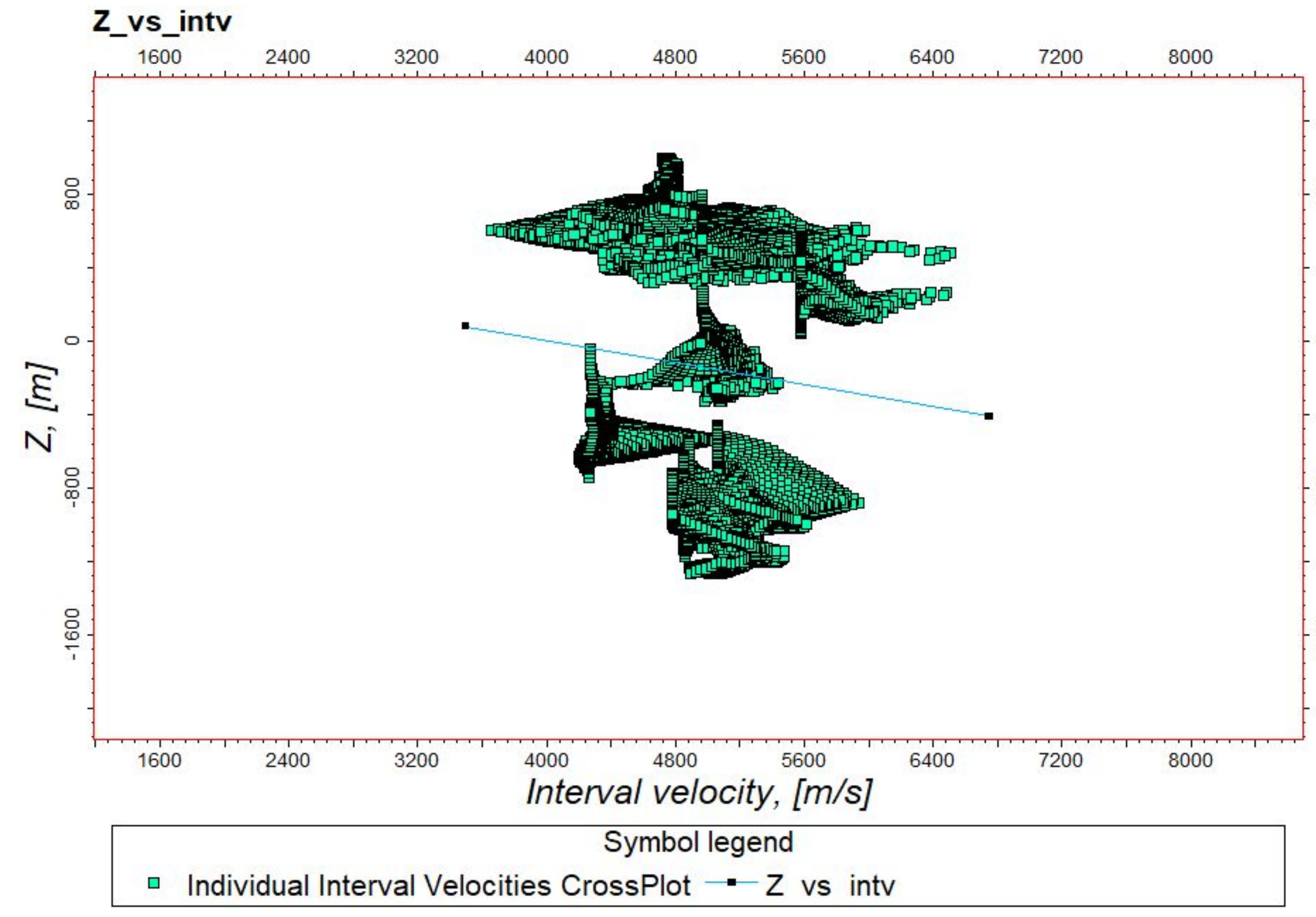
The seismic well tie was performed with an extracted wavelet from three wiggle traces on either side of the trace that intersected the strike line to the well and was calculated for the interval that had sonic and density data. The wavelet had a peak frequency of 35 Hz. The power spectrum was removed at high frequencies because it is unlikely that such frequencies would be attenuated at this depth in the subsurface. The cross-correlation between the synthetic and seismic ranged between 5% and 18%. Because no check shot data was available, the time-depth relationship was developed by taking a weighted sum of the interval velocities with respect to depth. Lack of coherence between amplitudes of the synthetic and seismic is potentially due to the automatic gain control applied to the post-stack migration data upon initial processing.

SEISMIC-WELL TIE VELOCITY MODEL

Velocity Model



Depth vs. Interval Velocity



The Seismic-Well Tie velocity model was created from seismic horizons interpreted with the aid of well tops in the tieing well. The surfaces were then corrected with well tops throughout the data domain. The velocity value used to create the model was estimated from the well TDR and was set to constant. Therefore, for each zone, a constant, single velocity value was used. Even though this is unlikely realistic of the subsurface, with such sparse data this method reduces the amount of 'invented' features in the model.

The Depth vs. Interval Velocity graph shows an overall relationship between the interval velocities and depth but not a relationship with velocity and individual formations. The yellow box in the p-wave velocity model by Arabasz and Williams shows the region that the depth was compared to the interval velocity in our model. On comparable scales, the relationship has a similar slope. This improves the credibility of our model but does not make it exclusively correct. Interval velocity of the Navajo ranges between 4350 and 5450 m/s with a peak of velocities between 5100 and 5150 m/s.

P-wave velocity model by Williams and Arabasz (1989)

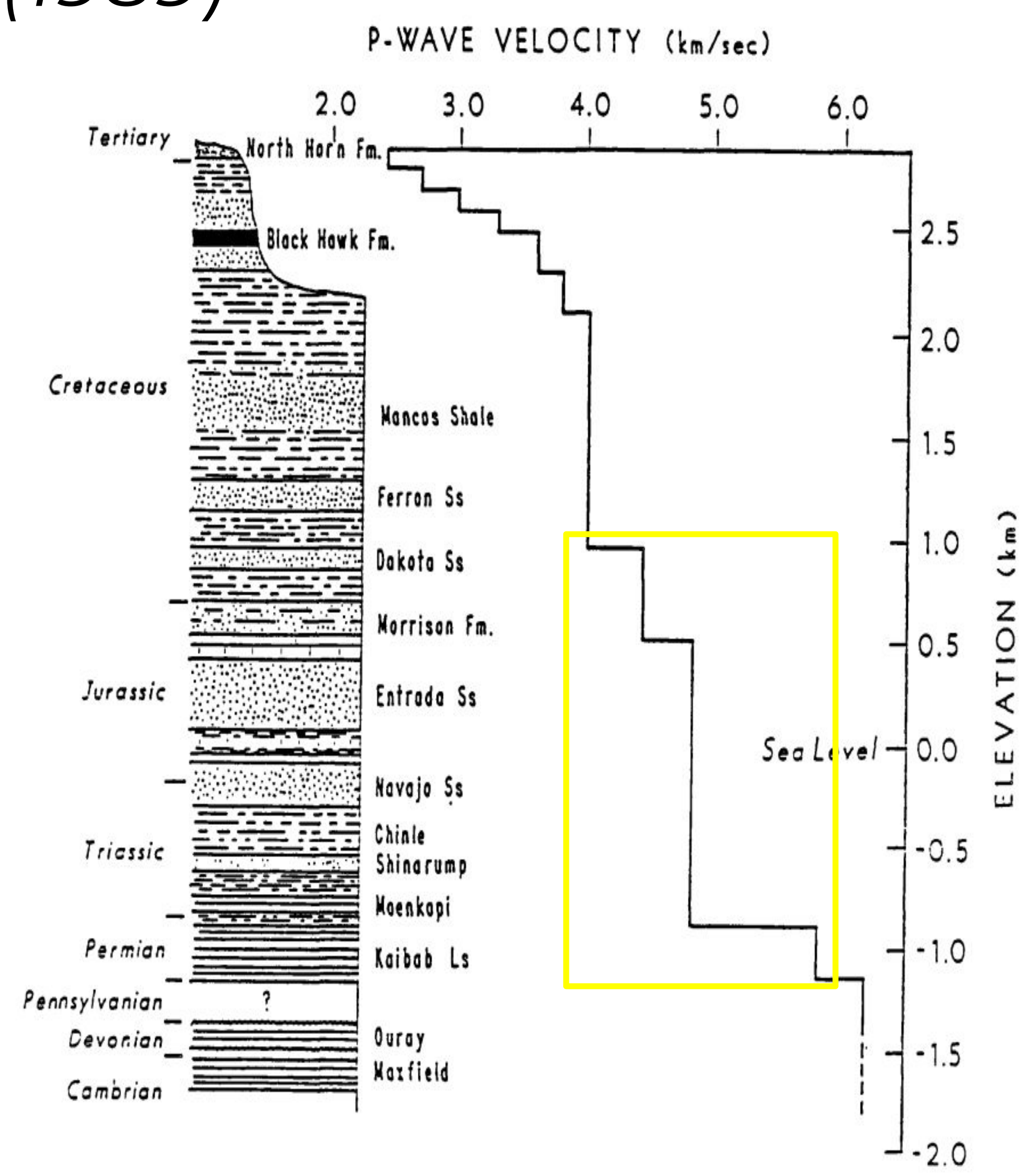
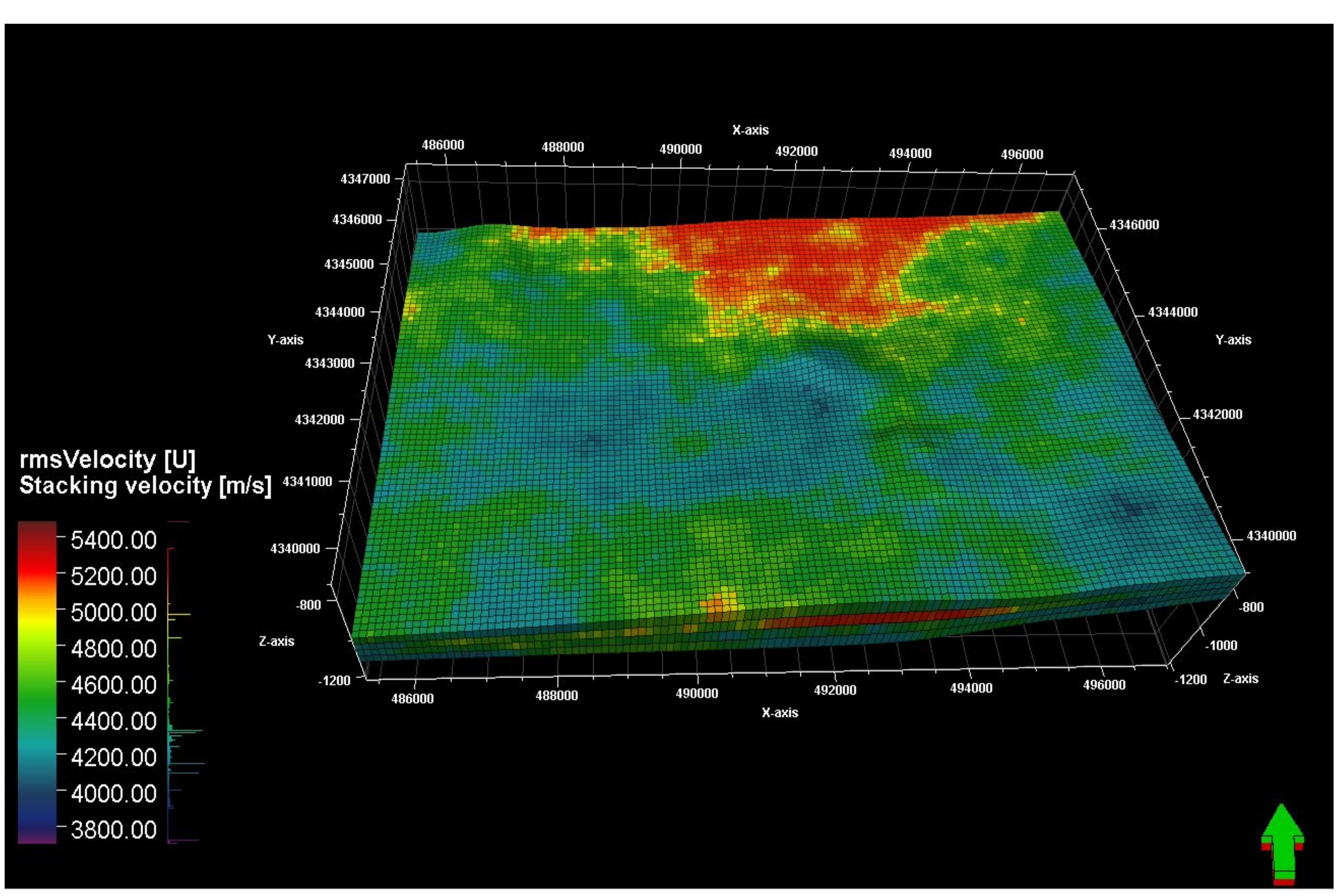


Figure 2.2: Generalized stratigraphic section and p-wave velocity model of the Wasatch Plateau region (from Arabasz and Williams, 1986).

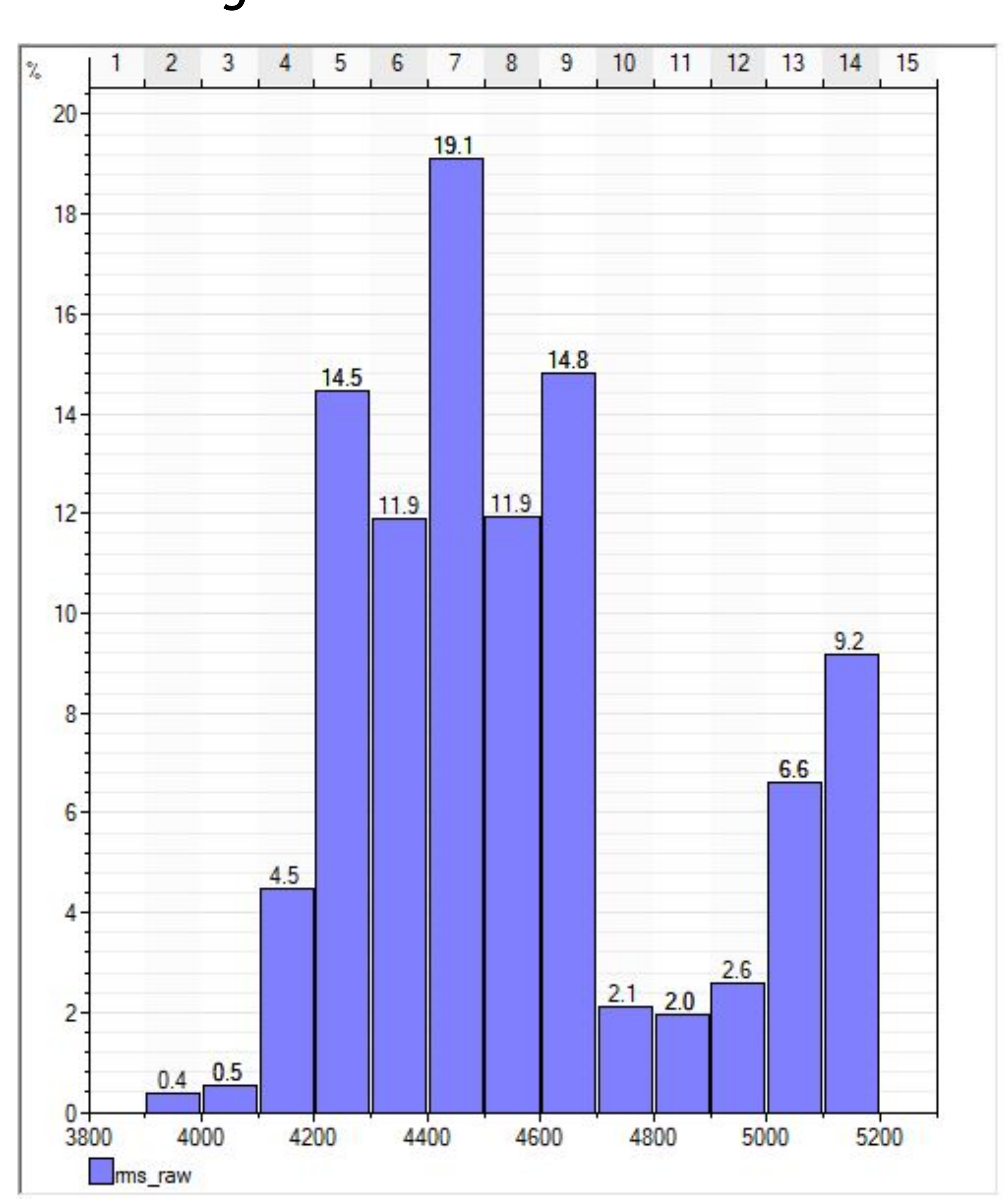
STACKING-VELOCITY VELOCITY MODEL

Stacking velocity profiles were upscaled into a time domain geocellular geologic model created from the seismic horizons interpreted with the Seismic-Well Tie process. The stacking velocities were upscaled into the model using a Gaussian Random Function Simulation and interval velocities were estimated with the Dix approximation. The minimum and maximum of the output data ranged between 3951 m/s and 5181 m/s. The data shows a bimodal distribution; 19.1% of the simulated data is between 4400 m/s and 4500 m/s.

rms Stacking Velocity Model - Navajo

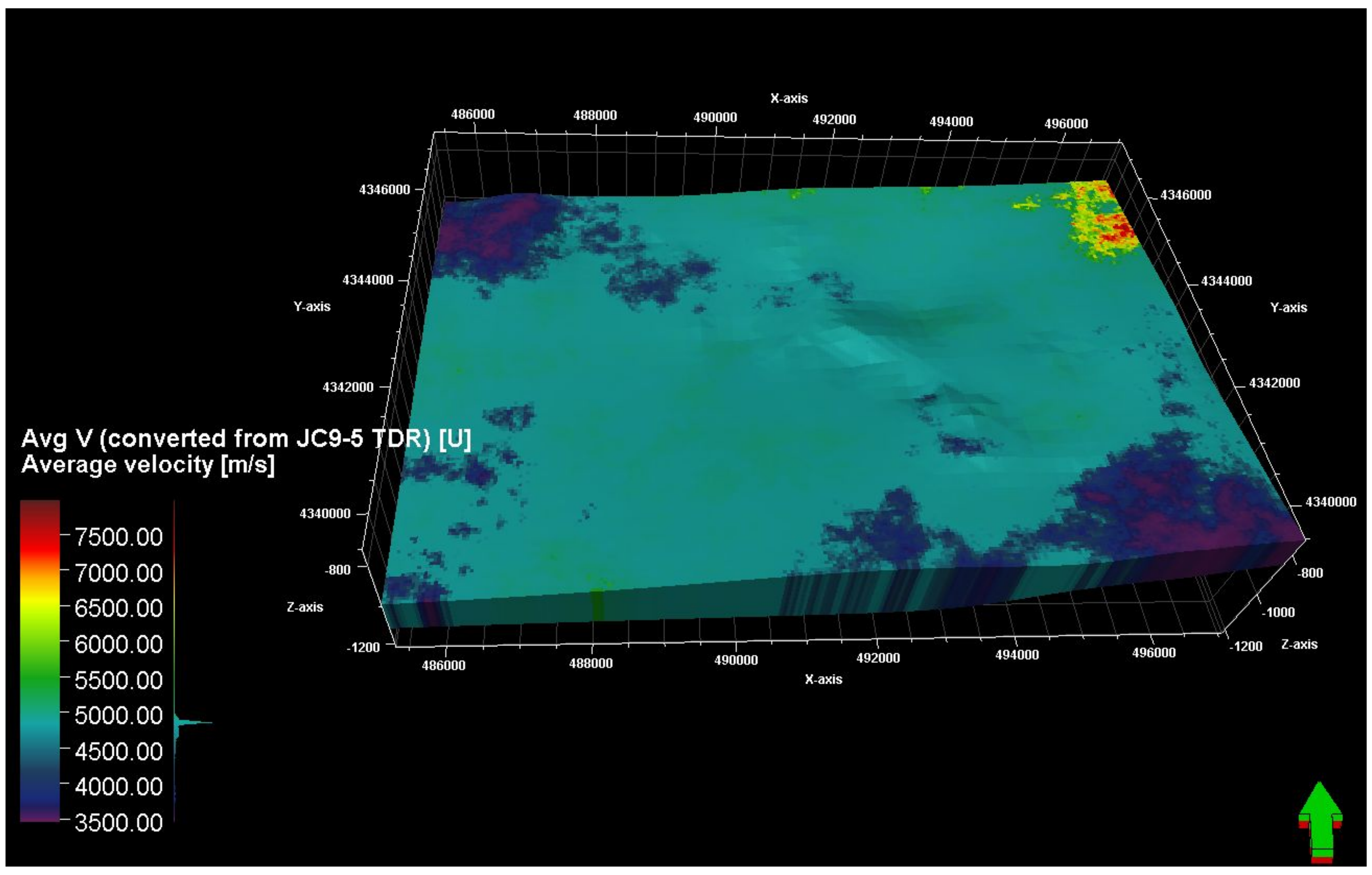


Navajo rms Velocities



COMBINED VELOCITY MODEL

Stacking and TDR Velocities Combined



The upscaled rms-velocities were used as a co-variant in co-located co-simulation of interval average velocities derived from the time-depth relationship in the Jack Curtis 41-15 well. The anisotropy range was extended to 10,000 m in order to reduce unrealistic anomalies in the velocities of the formations; this was made under the assumption that velocities change slowly with distance. The vertical range is limited to the height of the zone. The covariant was modeled using collocated co-simulation. The correlation coefficient between the primary and secondary variable was 63.5%. The average velocity from the TDR was modelled using Gaussian random function simulation. The combined velocity model ranges between 3000 and 7600 m/s.

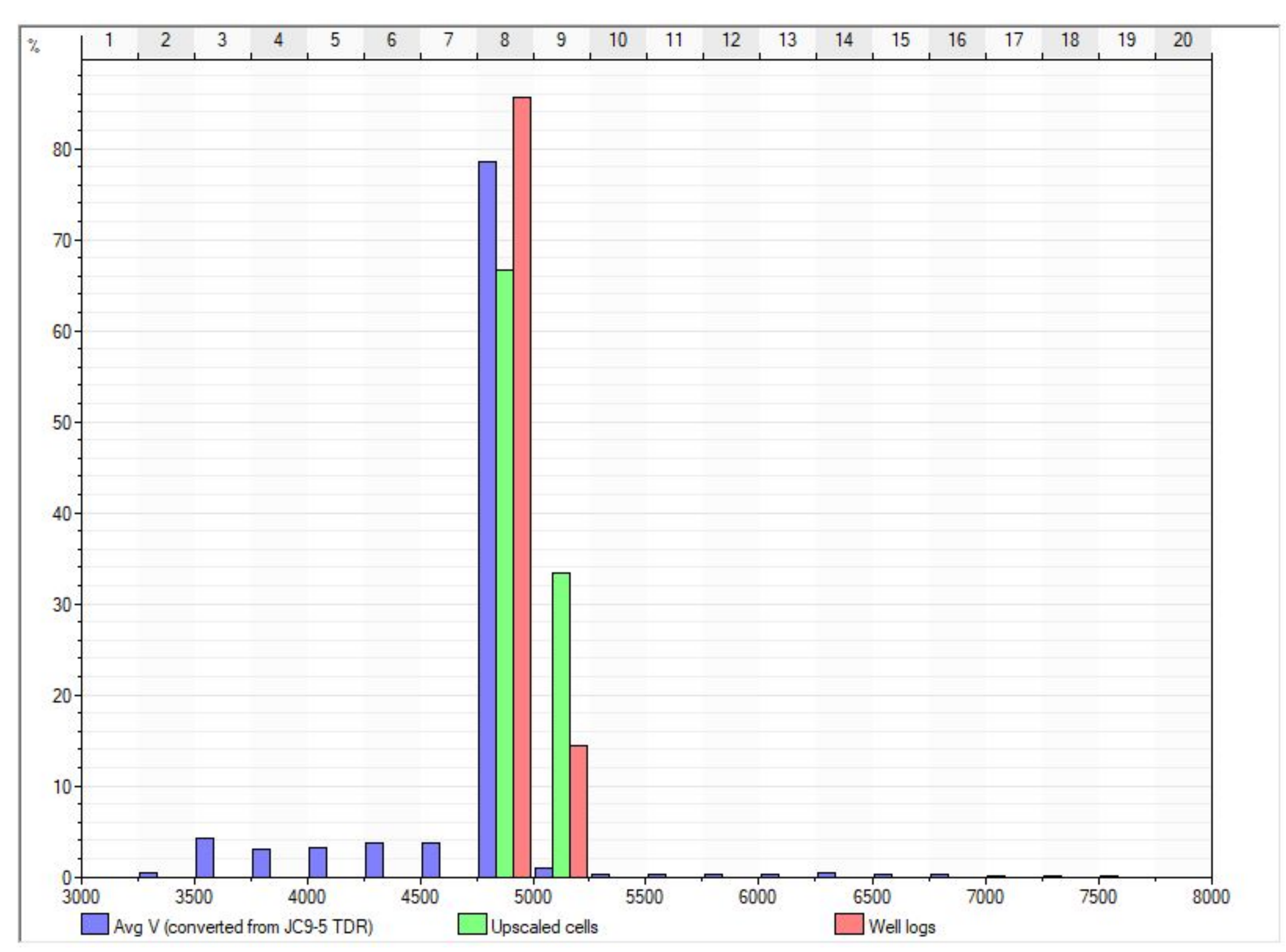
CONCLUSION

The process of upscaling data into a domain reduces the outliers in the data through averaging. This process therefore reduces statistical anomalies. However, in the case of the Navajo formation we expect to see large scale geologic anomalies caused by significant variations in density associated with interdune lake deposits. Unfortunately, the lateral velocity variations within the rms-velocity model where much larger than the expected size: 25 km^2 versus 0.65 km^2 (Parrish, 2007). This was reduced in the combined velocity model because the model honored both the average velocities from the TDR and the interval velocity from the stacking velocities.

A histogram of the combined model data for the Navajo shows that the 78% of the formation has an average velocity of 4800 m/s. These values reflect the p-wave velocity model by Arabasz and Williams (1989). However the distribution of velocities does not appear consistent with expected natural values. Further, in the event that the velocities would realize the interdune facies, one would expect to see a peak in the data honoring these higher velocity regions. Since this feature is not resolved in the histogram, there are several reservations about the model data.

This velocity model will be used to improve the time-depth relationship in the next step.

Navajo Combined Velocities



REFERENCES

1. R. W. Allmendinger, H. Farmer, E. Hauser, J. Sharp, D. Von Tish, J. Oliver, S. Kaufman. Phanerozoic Tectonics of the Basin and Range - Colorado Plateau Transition from Cocorp Data and Geologic Data: A Review. American Geophysical Union. Geodynamics Series Volumne 14, 257-267 (1986)
2. M. A. Kassab, A. Weller. Study of P-wave and S-wave velocity in dry and wet sandstones of Tushka region, Egypt. Egyptian Journal of Petroleum 24, 1-11 (2015)
3. D. Loope,, and C. Rowe, Long-lived pluvial episodes during deposition of the Navajo Sandstone, J. Geol., 111, 223–232, 2003.
4. J. T. Parrish, H. J. Falcon-Lang. Coniferous Trees Associated with Interdune Deposits in the Jurassic Navajo Sandstone Formation, Utah, USA. Paleontology, Vol 50, Part 4, 829-843 (2007)
5. E. Petrie, D. Barton, J. Evans, Tectonic History and Distribution of Faults and Fractures in the San Rafael Swell, Utah: Impacts on Subsurface Fluid Flow, Utah Geological Association Publication 42, 75-90 (2013)
6. D. Shelander, V. Smith, H. Leetaru, R. WIll, M. Coueslan. The Evolution and Effect of the Velocity Model on Various Aspects of Surfaces Seismic Data Analysis. Energy Procedia 63, 4374-4384 (2014)
7. T. N. Sorensen., 2017, Progressive deformation in monocline, San Rafael Swell, Utah. Department of Geosciences, University of Oslo, Digitale Utgivelser ved UiO
8. D. Williams, W. J. Arabasz. Mining-Related and Tectonic Seismicity in the East Mountain Area Wasatch Plateau, Utah, USA. Pageoph, Vol. 129, Number ¾ (1989)