PS Seismic Attribute Analysis of a Mississipian Chat, Osage County, Northeast Oklahoma*

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Abstract

Chert is a microcrystalline or cryptocrystalline sedimentary rock material composed of silicon dioxide (SiO_2). Chert occurs as nodules, concretionary masses and as layered deposits. Chert is an unconventional reservoir rock that has been developed successfully in west Texas, Oklahoma, California and Canada (Rogers and Longman, 2001). The deposition of chert reservoirs commonly occur in close stratigraphic proximity to carbonate rocks, although chert reservoir origin, characterization, and distribution may be quite different from adjacent carbonate rocks. Cherts which show high porosity and low resistivity are sometimes called Chat. The Mississippian tripolitic chat is currently an exploration and development objective throughout southern Kansas and northern Oklahoma, including our survey area in Osage County.

Analysis of Mississippi Chat core from a well within our study area shows porosity values ranging from 12% to 42%. Image (FMI) log of the Mississippi Chat shows complex internal architecture characterized by vugs, nodules, fractures and little remnant of original depositional fabric. Through core and log measurements, we are able to establish a good correlation between impedance and porosity. To this end we map seismic acoustic impedance volumes to predict additional sweet spots. The chert is also controlled by diagenetically altered fractures which we are able to seismically map using coherence and most-negative principal curvature volumes. Combining these geometric attributes with impedance estimates and well control, we generate 3D lithofacies maps with the goal of understanding the distribution of fractures and the production from the wells.

Introduction

The geology of Oklahoma, while complex, is one of the best-interpreted geological provinces (Figure 1a) in the United States because of the amount of drilling and seismic exploration that has been done in search of hydrocarbons. Great thicknesses of sedimentary rock are preserved in a series of major depositional and structural basins separated by the orogenic uplift that formed during the Pennsylvanian time.

The sedimentary basins mentioned above contain ~20,000 to ~40,000 ft of sedimentary rock, mostly Paleozoic and marine, overlaying complex Precambrian basement igneous and some low-ranking meta-sedimentary rocks (Johnson et al., 1988). In the early Paleozoic, during Cambrian and Ordovician, a tectonic event took place and three major depositional provinces formed: the Oklahoma basin, the southern Oklahoma aulocogen, and the Ouachita trough (Figure 1b).

Seismic Attribute Analysis

Different seismic attributes like RMS amplitude, fault lineaments from coherency volume, and curvature attributes like most positive and most negative have been generated on the post-stack seismic data. The two way time structural map of MC is shown in Figure 2a. The RMS amplitude calculated along a window of +-10 ms along the Mississippian Chat with the fault lineaments are shown in Figure 2b. It is observed from the figure that the top of MC is compartmentalized with the fault lineaments (see the encircled areas). Wells 2 and 3 fall in one compartment on the western side of the field whereas Well 1 falls in another compartment. Figures 2c and 2d show the most negative and most positive curvatures respectively along the Mississippian Chat.

Post Stack Acoustic Impedance Inversion

Model based acoustic impedance inversion has been generated on the post-stack data. The petrophysical data from five wells in the field have been used. Petrophysical logs of Well 1 are shown in Figure 3a. High values of porosity (up to 30%), low resistivity, low density and Vp are observed from the logs of Well 1. The petrophysical properties of the MC can be easily distinguishable from that of the carbonates above and below it. Well 1 has sonic Vp and Vs logs, Gardner's reverse equation has been used to generate the Vp and synthetic seismograms from density logs for all the rest of the four wells. A combined wavelet of constant phase (Figure 3b) has been extracted from all the five wells and used to remove the wavelet effect from the seismic volume to get the reflectivity series of the subsurface.

A model is created by using five horizons and the entire seismic volume is inverted to get the impedance volume which shows the layer properties of the subsurface. Figure 4a shows the seismic wiggles of a seismic line superimposed on the acoustic impedance response that is passing through Well 1. The impedance values of MC are very low, indicative of good lithofacies with hydrocarbon saturation. A cross plot is drawn between the impedance log and neutron porosity of Well 1 (Figure 4b); the MC has low impedance with high porosity as compared to the rest of the formations encountered in the well. An impedance slice 10 ms below the MC has been extracted and shown in Figure 4c with the fault lineaments. The distribution of lithofacies are different from one compartment to another compartment. The dark colors, like blue and magenta, are indicative of poor facies with low hydrocarbon saturation, while the light colors, like green and yellow, are indicative of good lithofacies with hydrocarbon saturation and the production of these wells infer the same. The three wells are producing at different rates and the porosity distribution is also not uniform in the MC.

Conclusions

The petrophysical properties of Mississippian Chat is different from other lithofacies in the study area. The RMS and impedance maps along the Mississippian Chat indicate non-uniform distribution of the facies, and that the reservoir is compartmentalized leading to a difference in distribution of reservoir properties like porosity and permeability. The production rates from different wells drilled in different compartments also support that the reservoir is compartmentalized.

Acknowledgements

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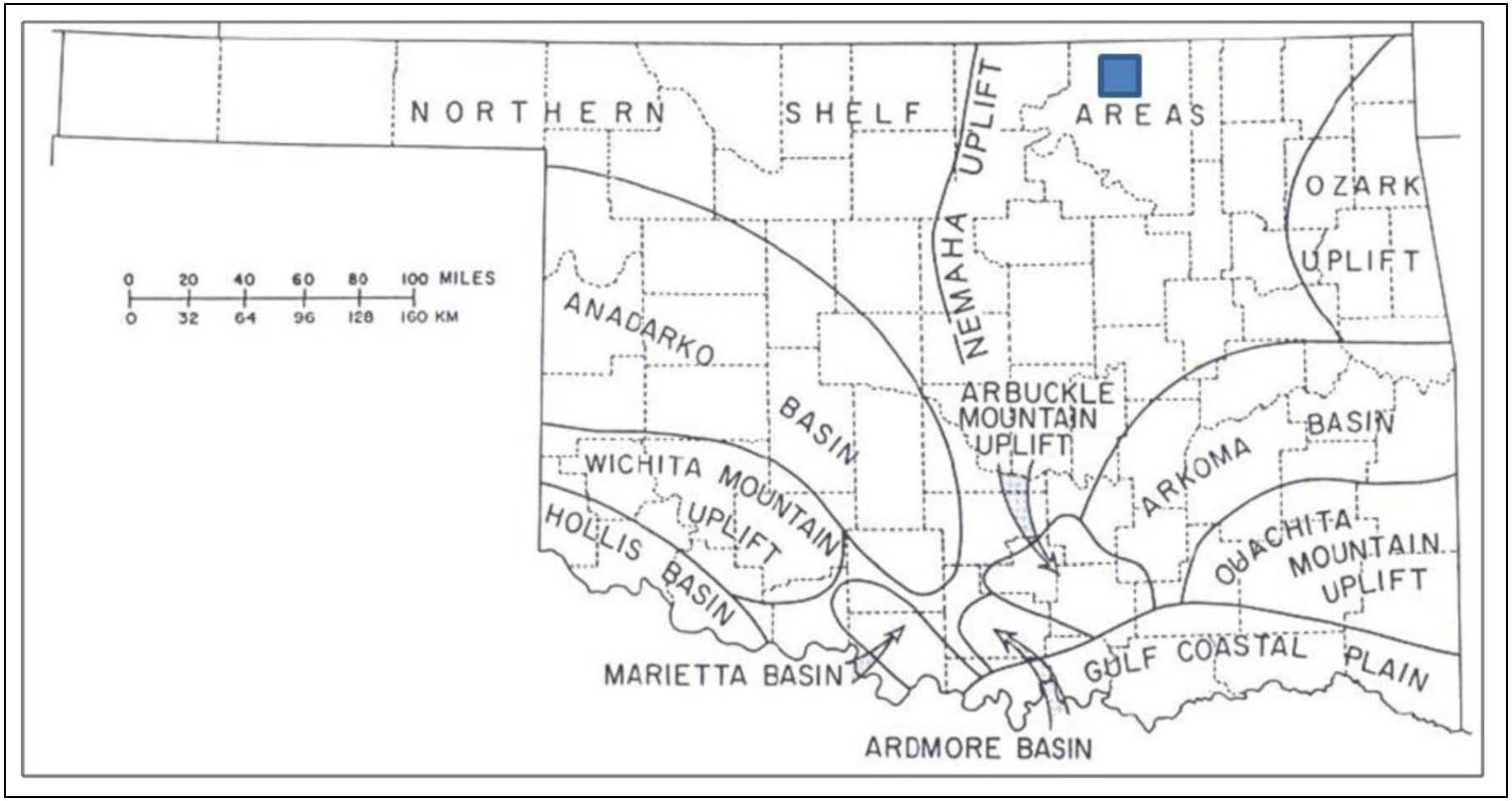

Figure 1a. Map showing major geologic provinces of Oklahoma. The study area is shown in the blue box.

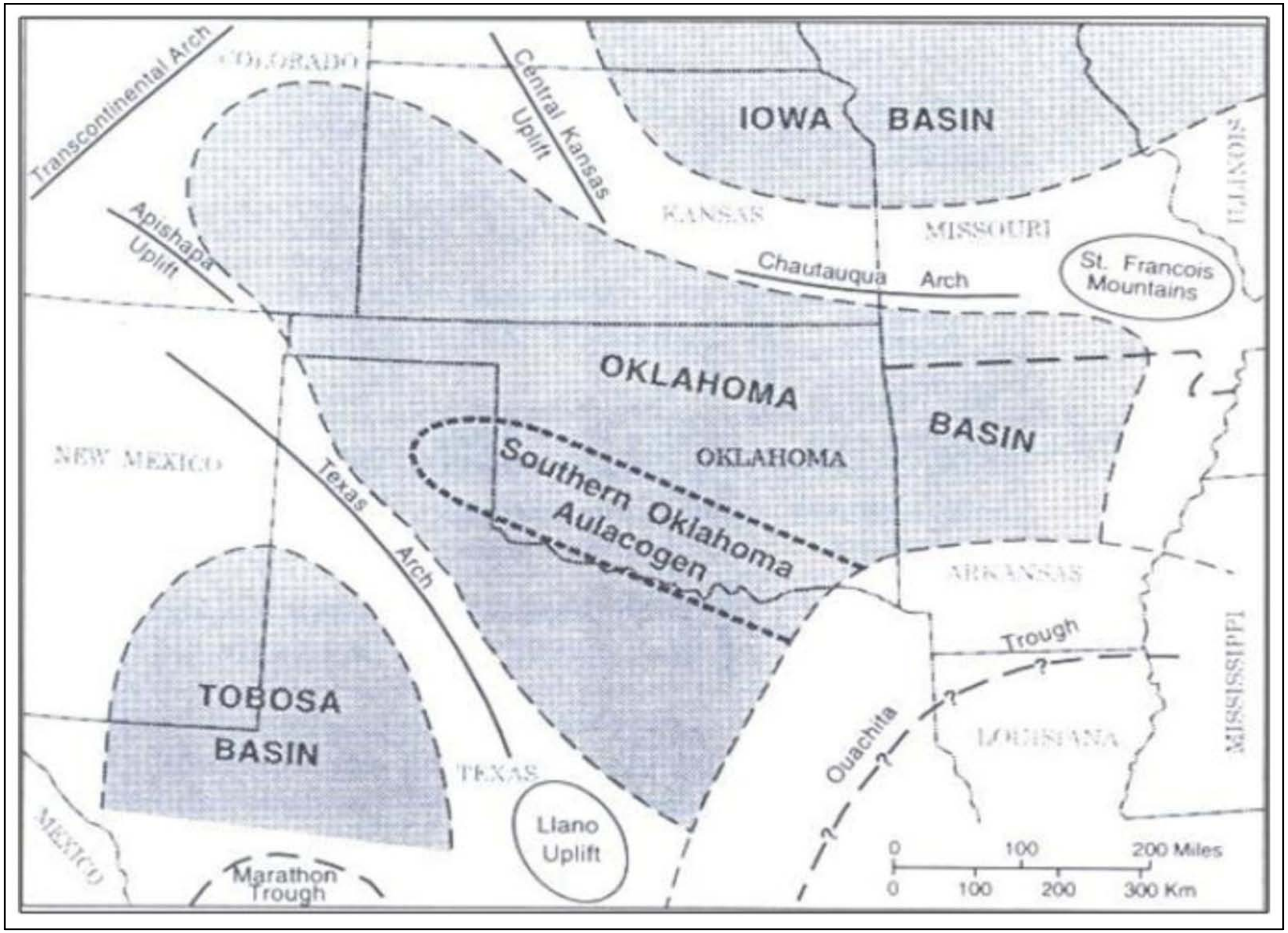

Figure 1b. Map of the southern USA showing boundary of Oklahoma Basin and other major features that existed in the early and middle Paleozoic time (Johnson, 1988).

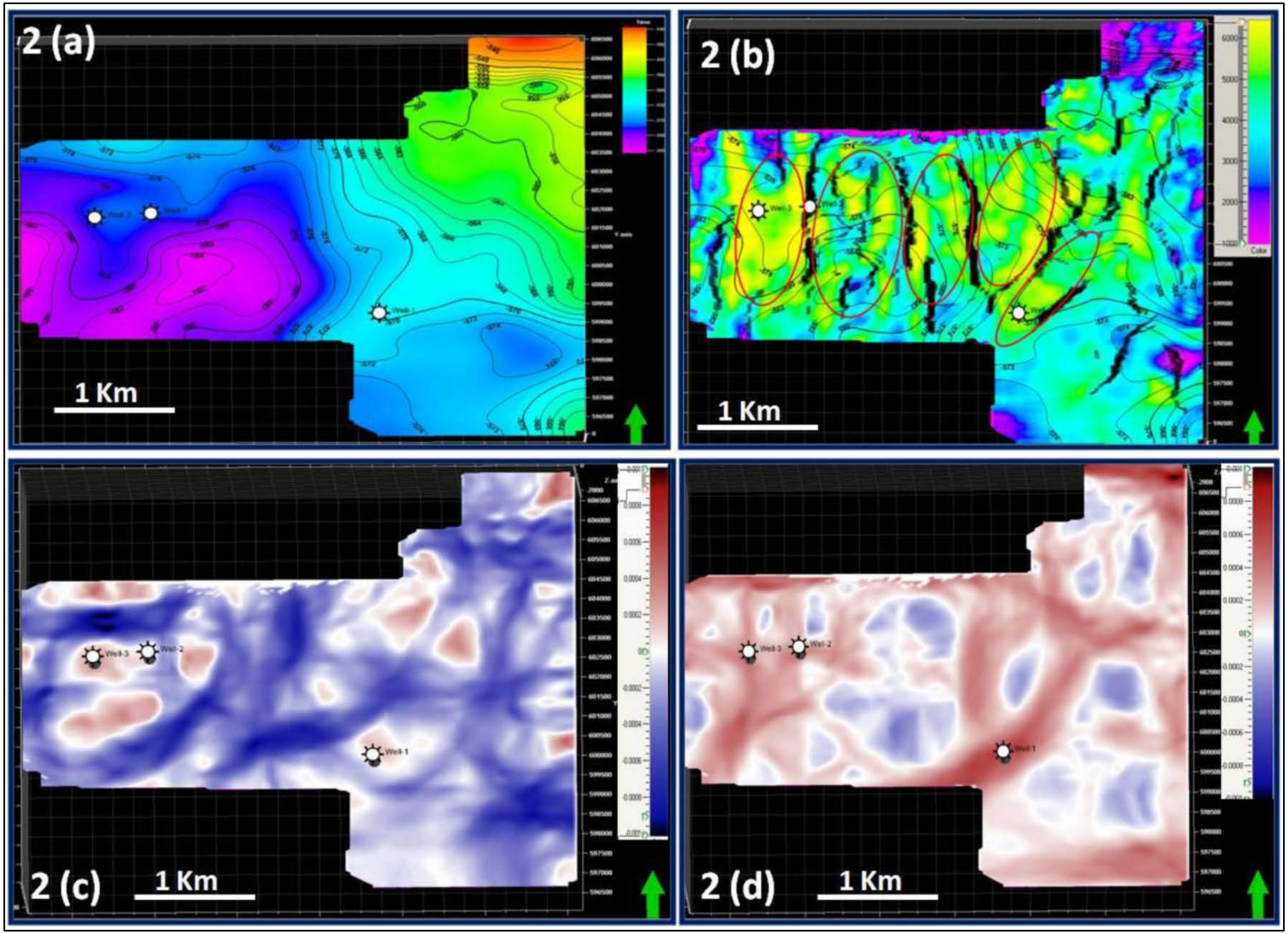

Figure 2. (a) The TWT structure map of MC, (b) The RMS amplitude map with fault lineaments from coherency volume, (c) The Most Negative curvature, and (d) The Most Positive curvature maps along the Mississippian Chat.

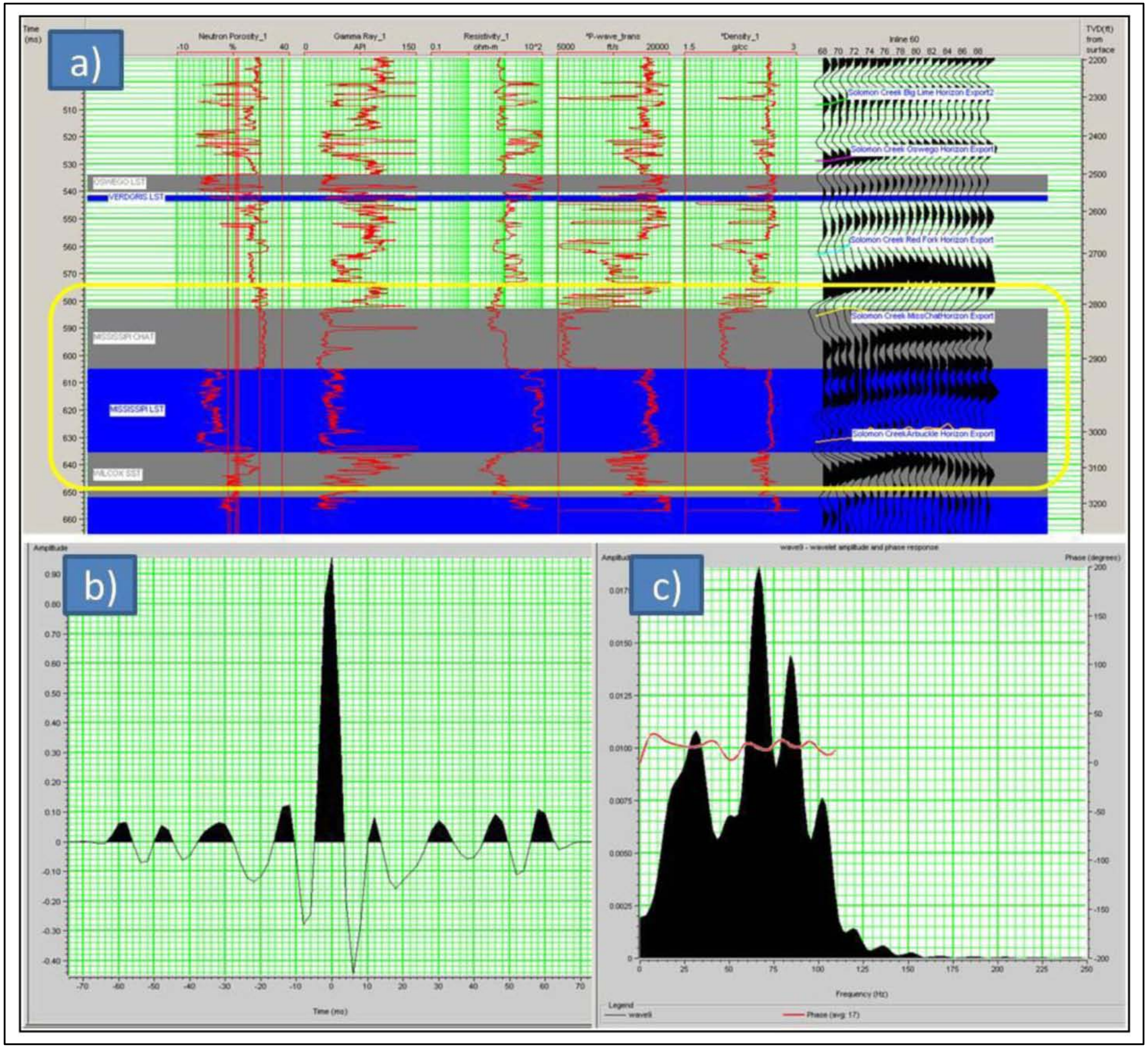

Figure 3. (a) Well logs of Well 1, (b) Amplitude spectrum, (c) Frequency spectrum of the combined wavelet.

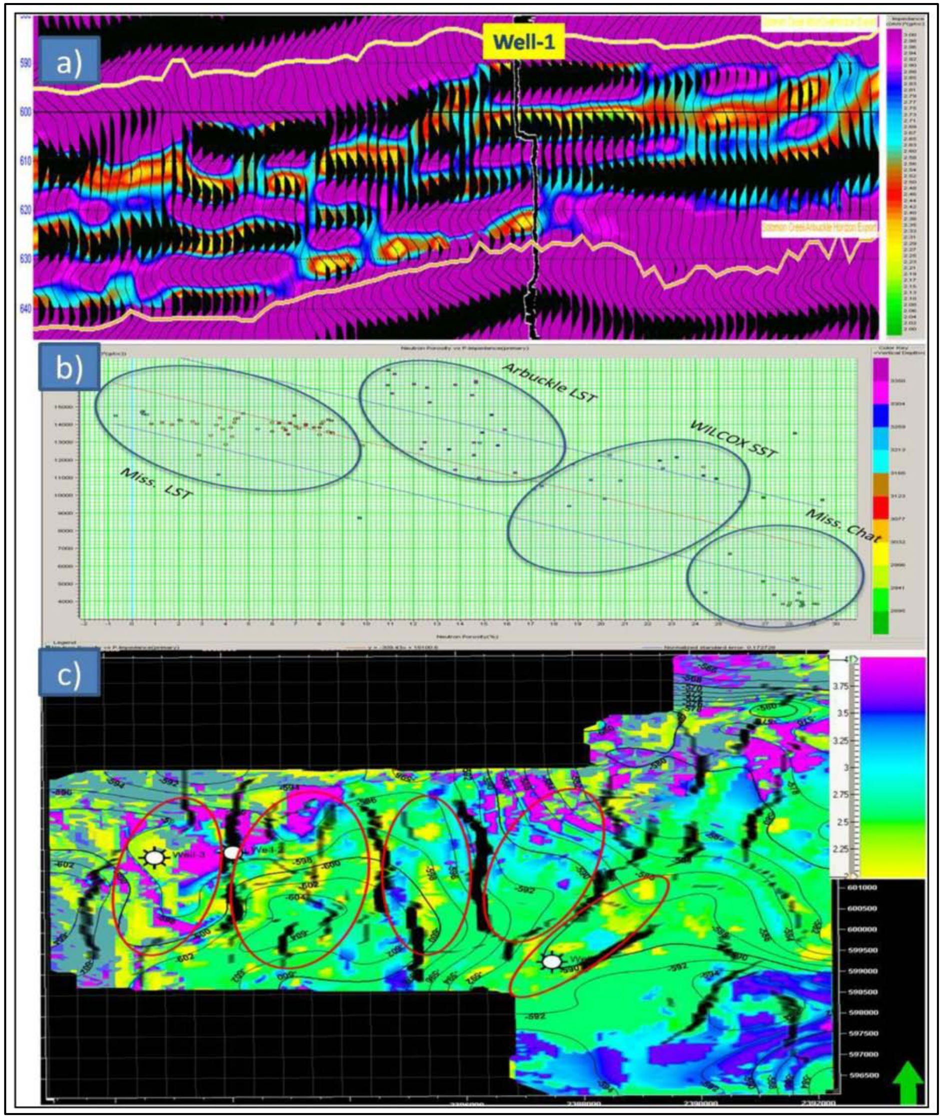

Figure 4. (a) The seismic wiggle line superimposed on impedance response along the well-1, (b) Cross plot between acoustic impedance and Neutron porosity in the well-1, (c) Impedance slice extracted 10 ms below the Miss Chat.