Post-Stack Seismic Attribute Analysis and Impedance Inversion for Characterization of the Mississippian Reservoir, South-Central Kansas

George Tsaflias, Lynn Watney, Ayrat Sirazhiev

SUBSURFACE APPLICATION: Seismic characterization of Mississippian carbonate reservoirs. Assessment of post-stack seismic analysis methods for prediction of carbonate reservoir heterogeneous properties.
STATUS: Project completed and not yet published
TIMING: Significant results to be reported – Results currently available to membership
FUNDING: Partial from United States Department of Energy

Purpose
Mississippian chert reservoirs are important hydrocarbon resources in North America. These reservoirs are highly heterogeneous, typically below seismic resolution and, therefore, challenging to characterize using seismic data (e.g. Mazzullo et al., 2009; Montgomery et al., 1998; Rogers and Longman, 2001; Watney et al., 2001). In this study we conducted a seismic attribute analysis of the Mississippian chert reservoir at the Wellington Field, south-central Kansas using well-log and 3D (PSTM) seismic data. The microporous cherty dolomite reservoir exhibits a characteristic vertical gradational porosity reduction and associated increase in acoustic velocity, known as a ramp-transition velocity function. The primary objective of this study was to investigate possible relationships of the reservoir thickness and porosity with post-stack seismic attributes, including inverted acoustic impedance.

Project Description
We examined the seismic response of a ramp-transition velocity function in order to predict the thickness of the Mississippian chert reservoir. The Mississippian top is characterized by a vertical gradational porosity decrease and a corresponding ramp velocity increase that results in a gradational impedance increase (Figure 1). We employed seismic wedge modeling using both synthetic and original sonic logs to aid the interpretation and investigate the resolution limits of the seismic data. A characteristic amplitude decrease, wavelength increase (frequency decrease) and 90-degree phase change are observed at the top of the Mississippian as reservoir thickness increases. Seismic amplitude is shown to predict reliably reservoir thickness in the range of 5-25 m when a well-defined porosity reduction is present (Figure 2).

Post-stack model-based inversion of the seismic data was used to derive the acoustic impedance model of the subsurface. The resolution of the model-based inversion was evaluated for the case of the gradational impedance increase within the Mississippian reservoir interval using synthetic wedge models. Multilinear regression analysis is used to transform the inverted acoustic impedance to porosity distribution within the Mississippian reservoir (Figure 2). The reliability of the predicted porosity model is tested by cross-validation during the multilinear regression analysis.

Results of this research could benefit the characterization of similar chert as well as clastic and carbonate reservoirs characterized by downward porosity reduction. In
addition to predicting the reservoir porosity and thickness, the seismic response of a ramp-transitional velocity function related to downward porosity reduction might be useful in understanding depositional and diagenetic histories of such reservoirs.

**Key Findings**

- A gradational porosity decrease at the top of the Mississippian reservoir corresponds to a gradational P-wave velocity increase
- A gradational or “ramp” velocity function results in the integral of the seismic wavelet with lower amplitude, lower frequency content and waveform phase change
- The characteristic seismic amplitude response of the top of the Mississippian is used to predict reservoir thickness when true thickness is $1/16\lambda - 5/16\lambda$ (5–25 m)
- Post-stack model-based acoustic impedance inversion provides reliable porosity predictions for reservoir thickness range of $1/8\lambda - 7/16\lambda$ (10–35 m)

**Deliverables**

i) Seismic attribute analysis methods of gradational (ramp) velocity profiles such as the Mississippian Chert at Wellington Field.

ii) Calibration of seismic amplitude and acoustic impedance inversion to reservoir thickness and porosity distribution respectively.

iii) Mississippian reservoir thickness map over the extent of the 3D seismic data.

iv) Acoustic impedance volume and derived reservoir porosity distribution at Wellington field.

**References**


Figure 1. Generalized stratigraphic section of central Kansas (from Nissen et al. (2009), originally from Cansler (2000)); impedance log and synthetic seismogram at well #15-191-22591.

Seismic Attribute Analysis: Predicting Mississippian Chert Reservoir Properties

Amplitude envelope vs. porosity gradient
R=0.89; RMS prediction error=0.12%/m

Predicted reservoir thickness (5-25 m range)

Predicted reservoir porosity (10-35 m range)*

*Porosity estimates are valid only within the Mississippian reservoir

Figure 2. (top left) Relationship of porosity gradient to seismic amplitude. (right) Reservoir thickness inferred from seismic amplitude. (lower left) Porosity prediction from inverted acoustic impedance with overlain original formation porosity log at well #15-191-22591.