[PS]Enhancing Seismic Data Resolution with Multi-Attribute Analysis Using Both Well Log Data and Seismic Data – A Case Study*

K. John R. Fernando[1]

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Abstract

The available well locations for a 3D survey area are often irregularly spaced and may even be few in number. 3D seismic data has to be relied on to generate a 3D volume of various log properties such as P-wave velocity, density, or porosity between well locations. Well log curves have very fine sampling in the vertical direction and hence good resolution, but lithologic properties are desired spatially for reservoir characterization and prospect generation. Seismic data possess lower resolution but good spatial sampling and so can be used for the purpose. Therefore, the ability to improve the seismic resolution through multi-attribute analysis followed by neural network-type processes and thereby improve the details of the derived log property is a definite advantage in terms of determining new drilling locations in a 3D survey area. The target logs are porosity logs, which are commonly available at the well locations, and these logs can be used to correlate with various seismic attributes at each well location on a sample-by-sample basis. The correlation process derives relationships between the target log data, in this case porosity logs and seismic attributes and is referred to as the "training" stage. A subset of the available target logs are used in the training process and the relationships that are derived during the training stage of the process are used in the "application" stage of the process to predict the log property of porosity throughout the 3D survey area. The Blackfoot field is a glauconitic compound-incised valley system comprised of three cycles of incision with the upper and lower incised valleys being the main reservoirs. Twelve wells within the area of 3D seismic data will be used in this project. A comparison of the porosity log curves from the multi-attribute transform and the Probabilistic Neural Network (PNN) with the actual log data will illustrates the ability of the PNN workflow to enhance the seismic resolution in terms of the lithologic property i.e. porosity. Various displays such as contour maps, data slices in time, as well as along horizons, coherence, and colour enhanced decomposition slices will be used to illustrate the channel fill system as derived from the multi-attribute analysis and probabilistic neural network application.

References Cited

Dufour, J., J. Squires, W.N. Goodway, and A. Edmunds, 2002, Case History: Integrated geological and geophysical interpretation case study, and Lame rock parameter extractions using AVO analysis on the Blackfoot 3C-3D seismic data, Southern Alberta, Canada: Geophysics, v. 67/1, p. 27-37.

Hampson, D., J. Schuelke, and J. Quirein, 2001, Use of multi-attribute transforms to predict log properties from seismic data: Geophysics, v. 66/1, p. 220-236.

Jackson, P.C., 1984, Paleogeography of the Lower Cretaceous Mannville Group of Western Canada: in J.A. Masters (ed.), Elmworth - case study of a deep basin gas field, AAPG Memoir 38, p. 49-77.

Sharma, R.K., and S. Chopra, 2015, Determination of lithology and brittleness of rocks with a new attribute: The Leading Edge, v. 34/5, p. 936-941.

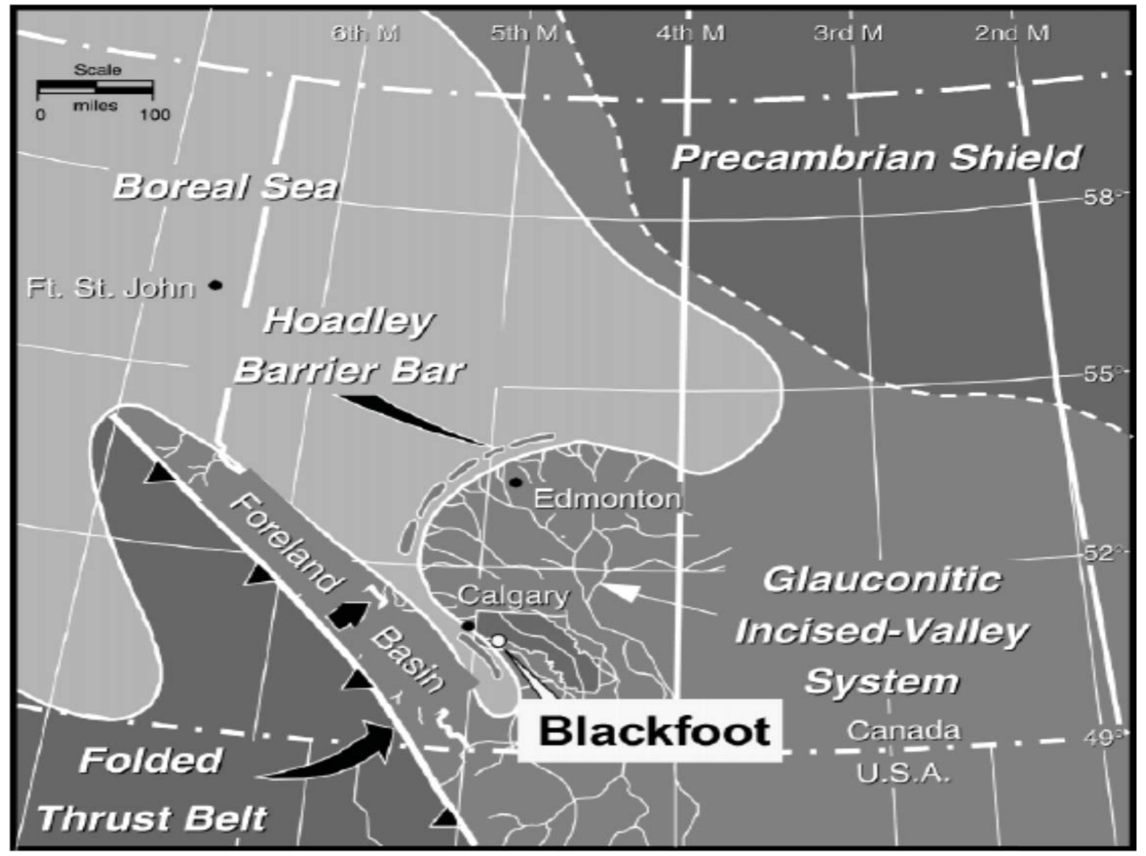
Enhancing Seismic Data Resolution with Multi-attribute Analysis using both Well Log Data and Seismic Data – a Case Study

K. John R. Fernando - SAIT Polytechnic*

Geological Background

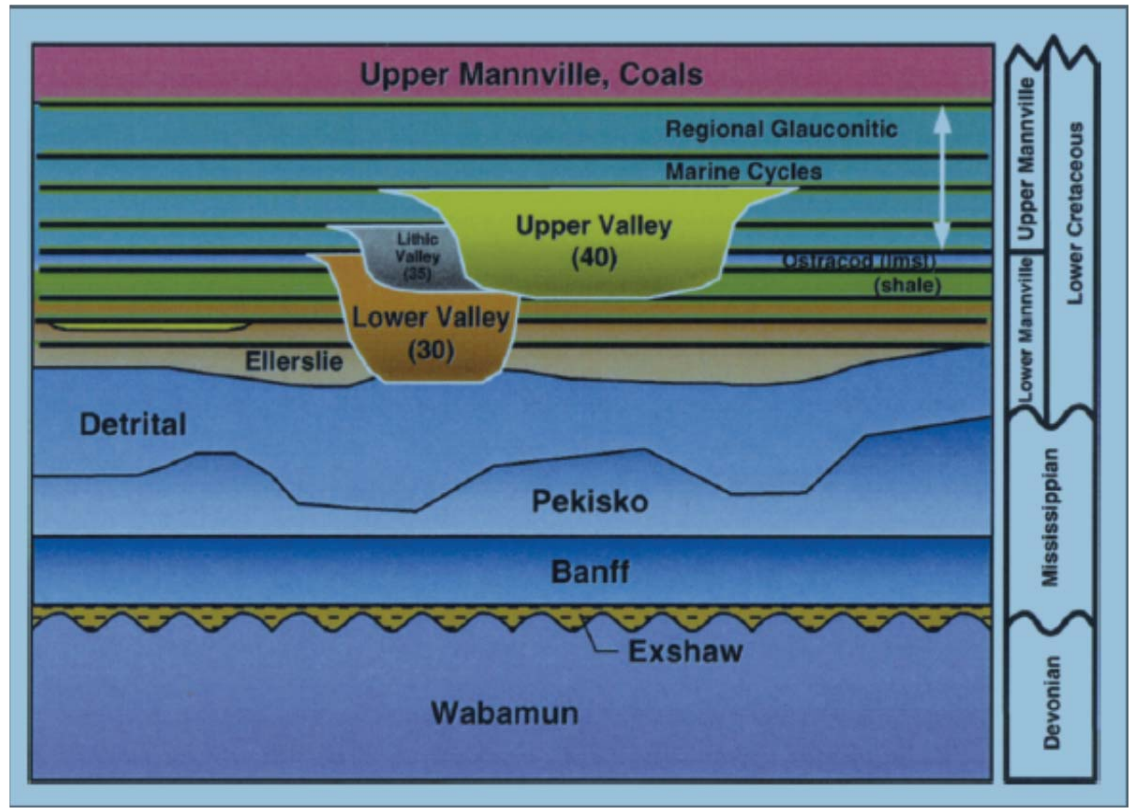
The Blackfoot field, is a Glauconitic compound-incised valley system comprised of three cycles of incision with the upper and lower incised valleys being the main reservoirs. 12 wells within the area of 3D seismic data were used in this project.

CASE STUDY AREA : BLACKFOOT 3D



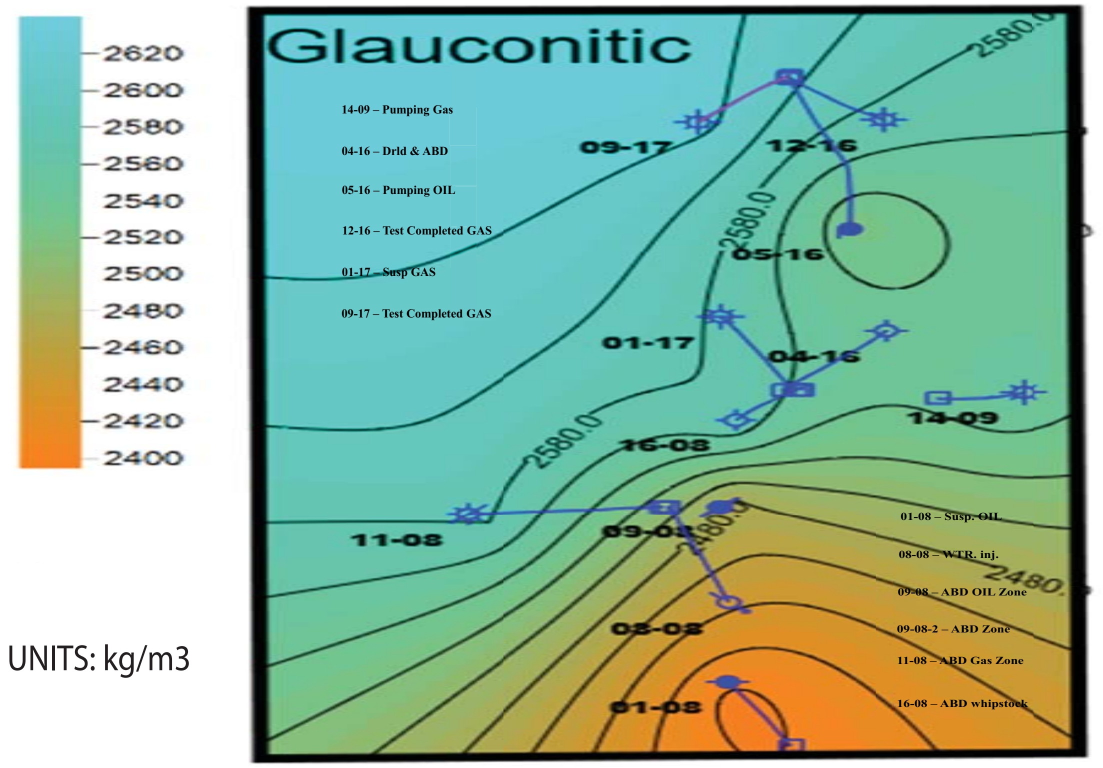
(Jackson, 1984)

SCHEMATIC STRATIGRAPHY OF THE STUDY AREA

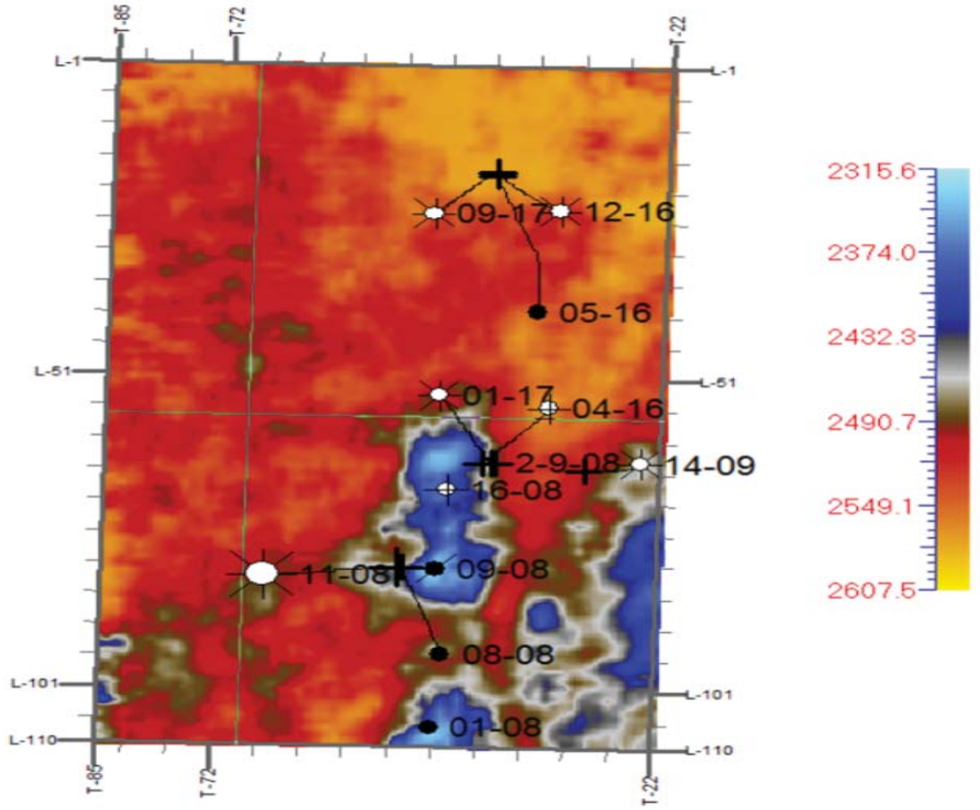


(Dufour, et al., 2002)

DENSITY CONTOURS OF GLAUCONITIC



STRATA GRID FROM PNN DENSITY VOLUME AT RESERVOIR LEVEL



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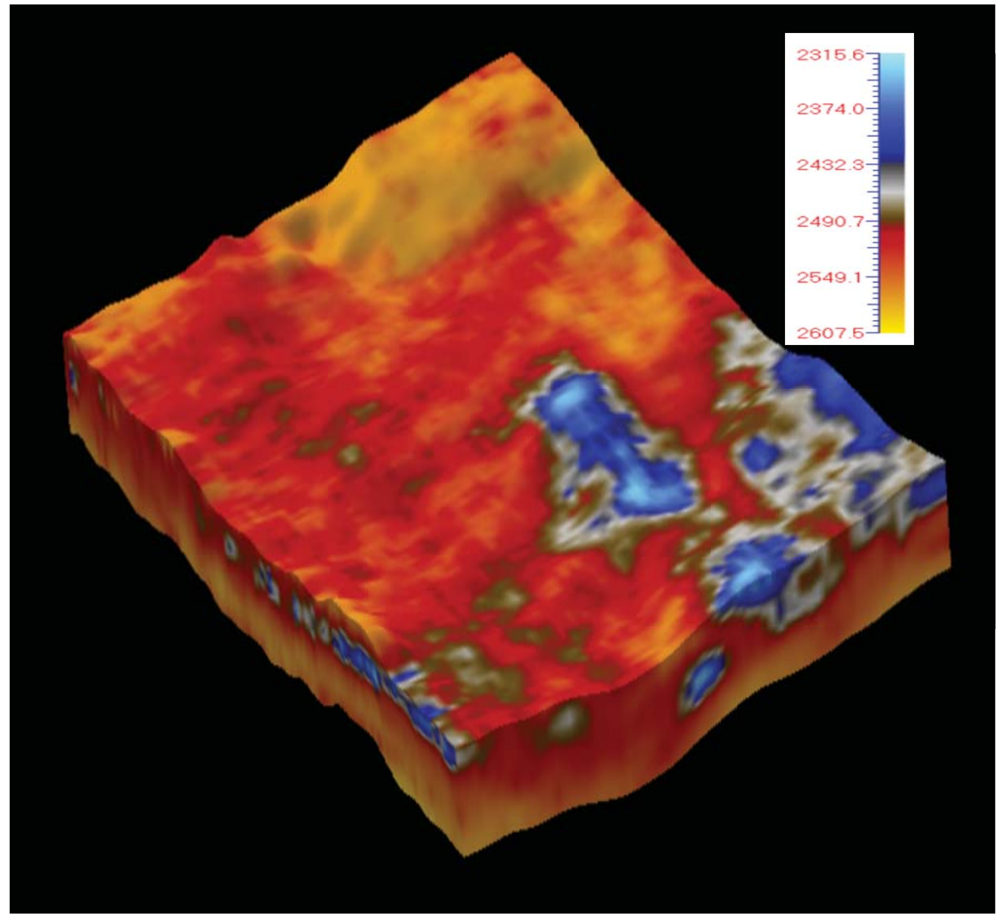
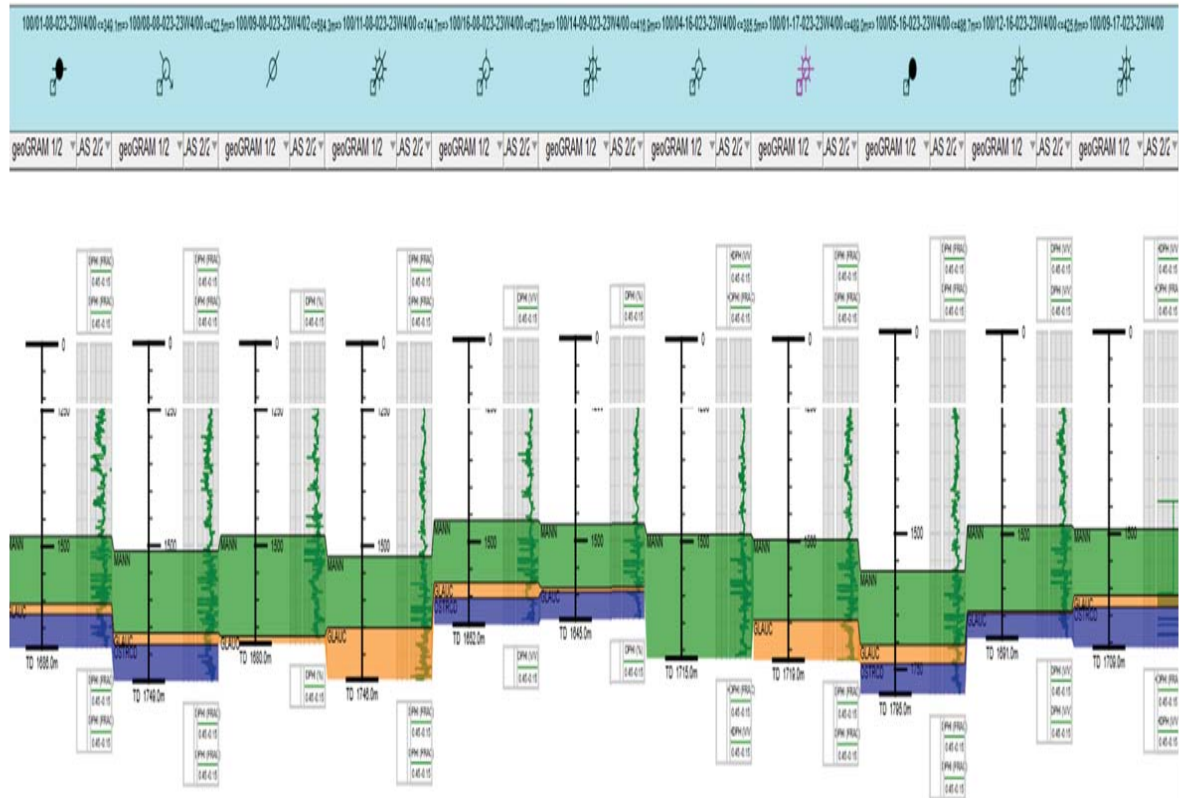
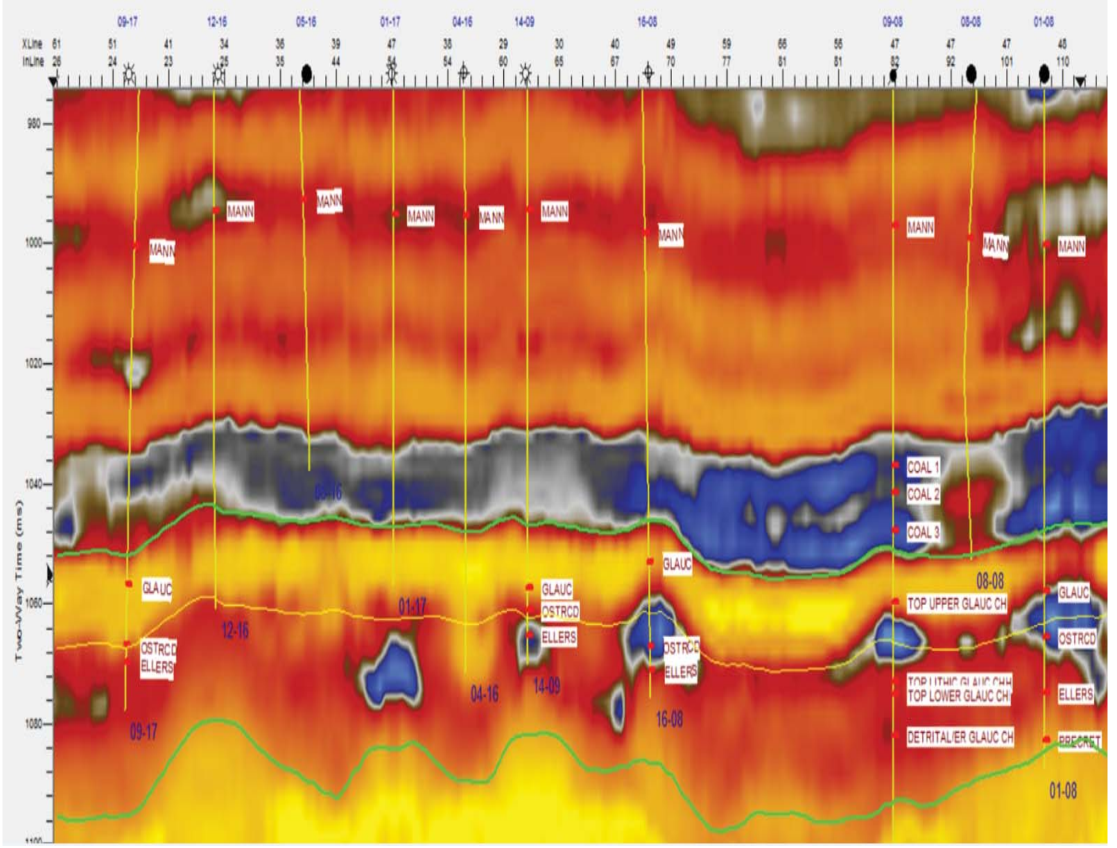


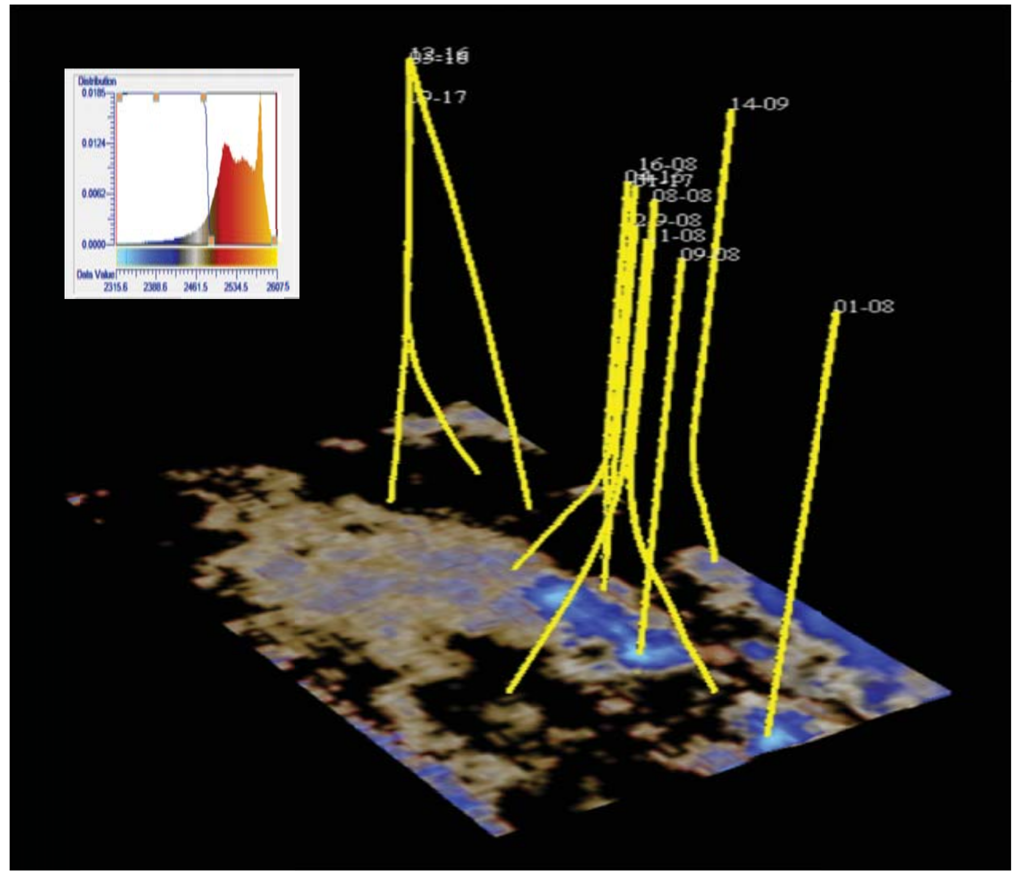
CROSS-SECTION FROM THE WELLS OF THE STUDY AREA



STRATA SLICE FROM PNN DENSITY VOLUME



STRATA-GRID FROM PNN DENSITY VOLUME WITH TRANSPARENCY AT RESERVOIR LEVEL



Data set

The Blackfoot 3C-3D data are provided by the CREWES projects at the University of Calgary and marketed through the SEG bookmart.

References

1. Dufour, J., Squires, J., Goodway, W. N., and Edmunds, A., 2002, Case History: Integrated geological and geophysical interpretation case study, and Lame rock parameter extractions using AVO analysis on the Blackfoot 3C-3D seismic data, Southern Alberta, Canada, Geophysics Vol. 67, No. 1 (January - February 2002), p. 27-37.
2. Jackson, P.C. 1984. Paleogeography of the Lower Cretaceous Mannville Group of Western Canada. *In*: Elmworth - case study of a deep basin gas field. J. A. Masters (ed.) American Association of Petroleum Geologists, memoirs 38, p. 49 - 77 "reprinted by permission of the AAPG whose permission is required for further use".

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CASE STUDY AREA : BLACKFOOT 3D

Method

From the P-wave and density log curves the P-impedance log curve is generated. The porosity log curves and P-impedance log curves from several well locations are cross-plotted and a mathematical relationship between porosity and P-impedance is derived through linear regression. Fully processed 3D migrated pre-stack CDP gather data were input to simultaneous or pre-stack inversion and P-impedance, S-impedance, and Density volumes were generated. The derived relationship between porosity and P-impedance from well data was used to transform the P-Impedance volume output from the simultaneous inversion to a porosity volume.

The porosity log data from several well locations, fully processed 3D migrated stack data, and P-impedance volume from simultaneous inversion are input to multi-linear regression analysis and a porosity volume is generated and this porosity volume is further improved through Neural Network Analysis (PNN) which accounts for non-linear relationships between the target log and the selected seismic attributes.

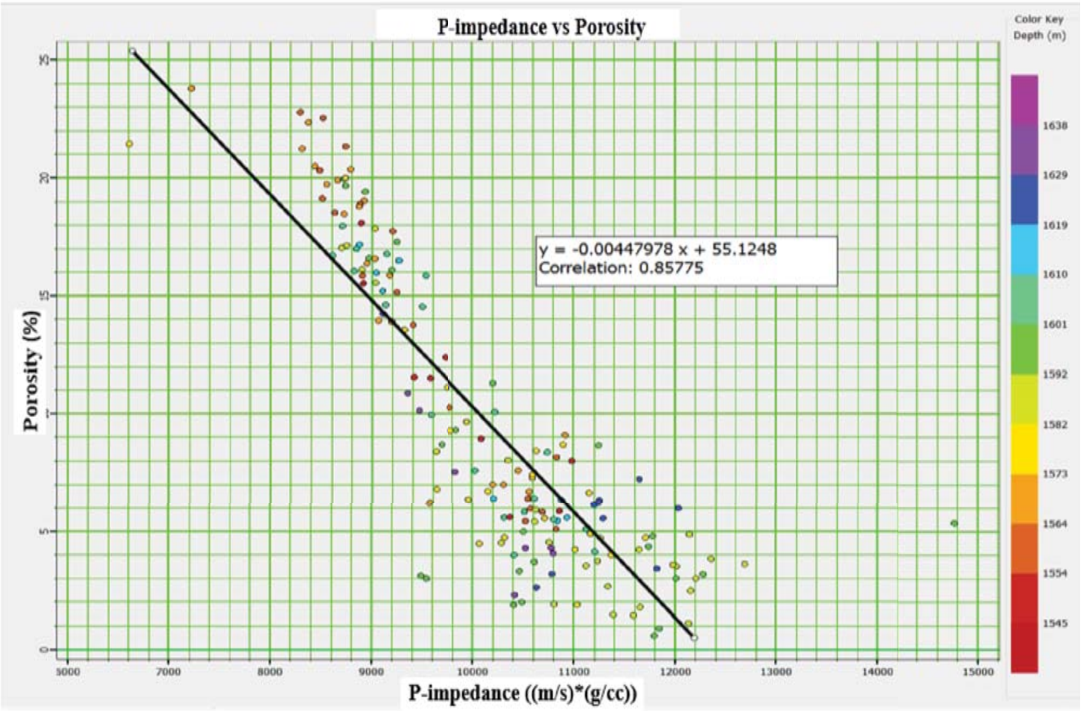
The density volume output from simultaneous inversion, in the absence of incident angles exceeding 40 degrees can be improved on by multi-linear regression and neural network analysis.

From the P-impedance and S-impedance volumes a brittleness-density (E-Rho) volume can be generated using the formula:

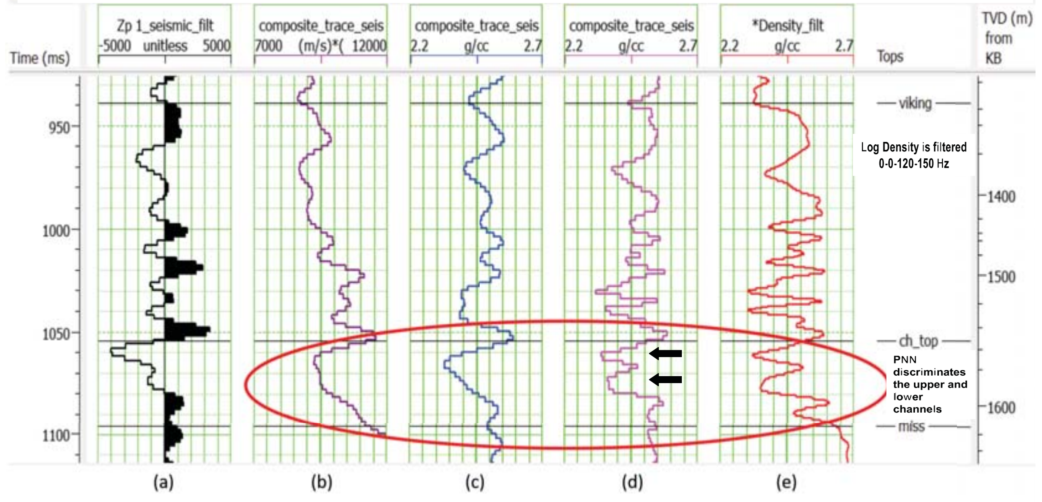
$$E\rho = I_S^2 \frac{(3I_P^2 - 4I_S^2)}{I_P^2 - I_S^2}$$

Conclusions

A Porosity volume can be generated from a P-impedance volume and a density volume can be generated from multi-attribute linear regression and neural network analysis as well as a stiffness-density volume generated from the transformation of P-impedance and S-impedance volumes output from simultaneous inversion.These three voluems of porosity, density and stiffness or brittleness can all be correlated to identify reservoir targets as well as brittle shales for fracturing operations.

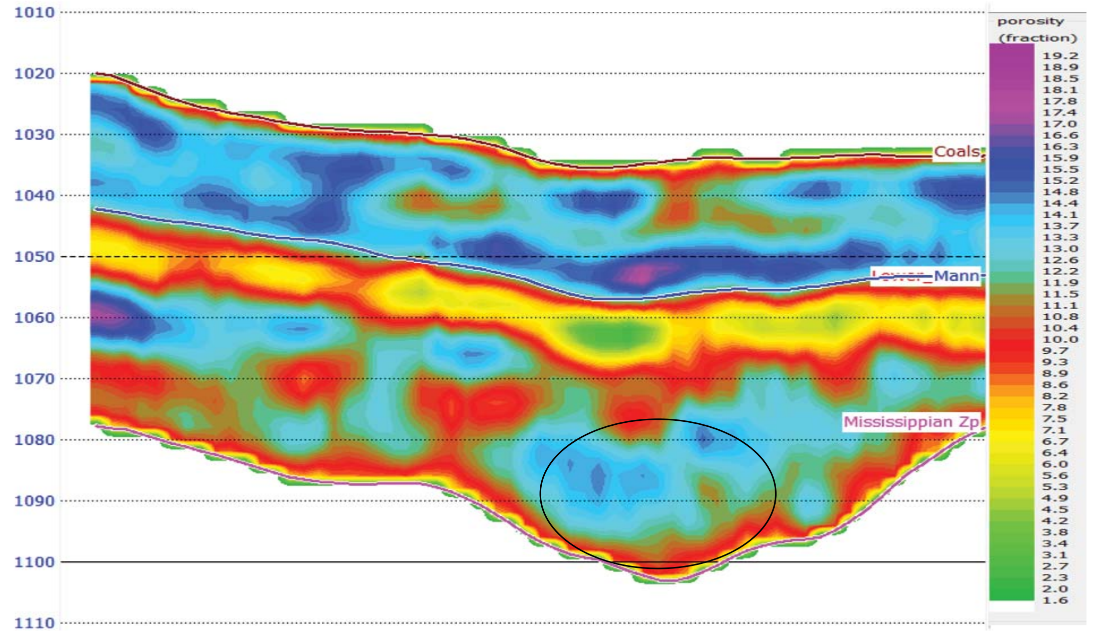


Density output volume comparisons with Log data

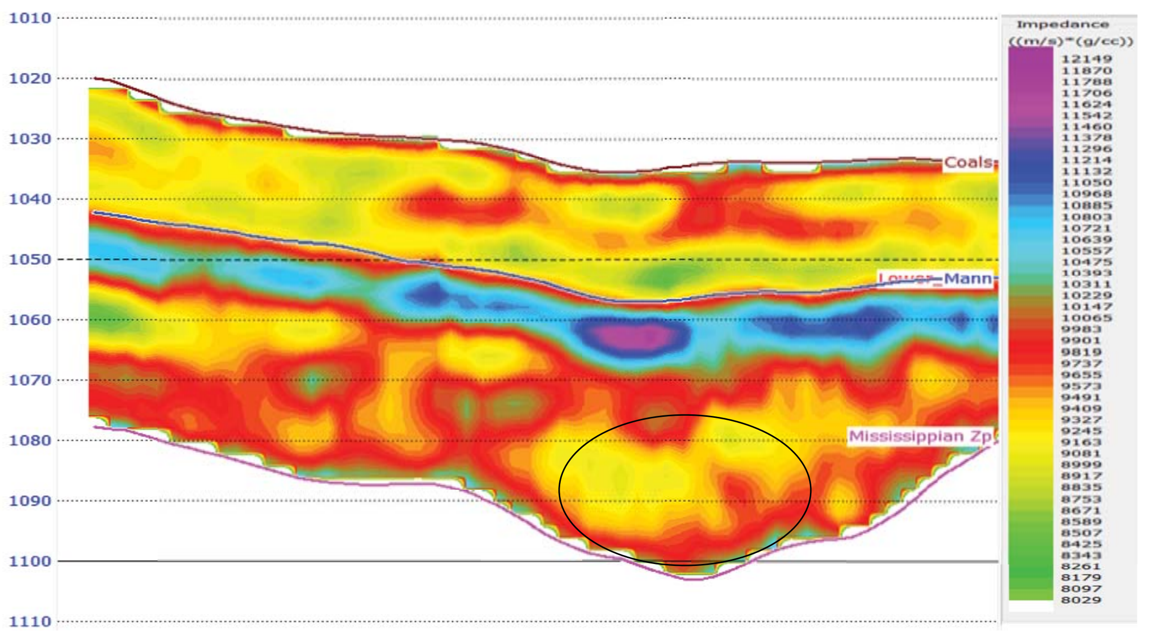


(a) Stack seismic trace, (b) Seismic Impedance trace from pre-stack inversion, (c) Density data derived from Multi-attribute transform, (d) Density data derived from Probabilistic Neural Network, and (e) Filtered Density log

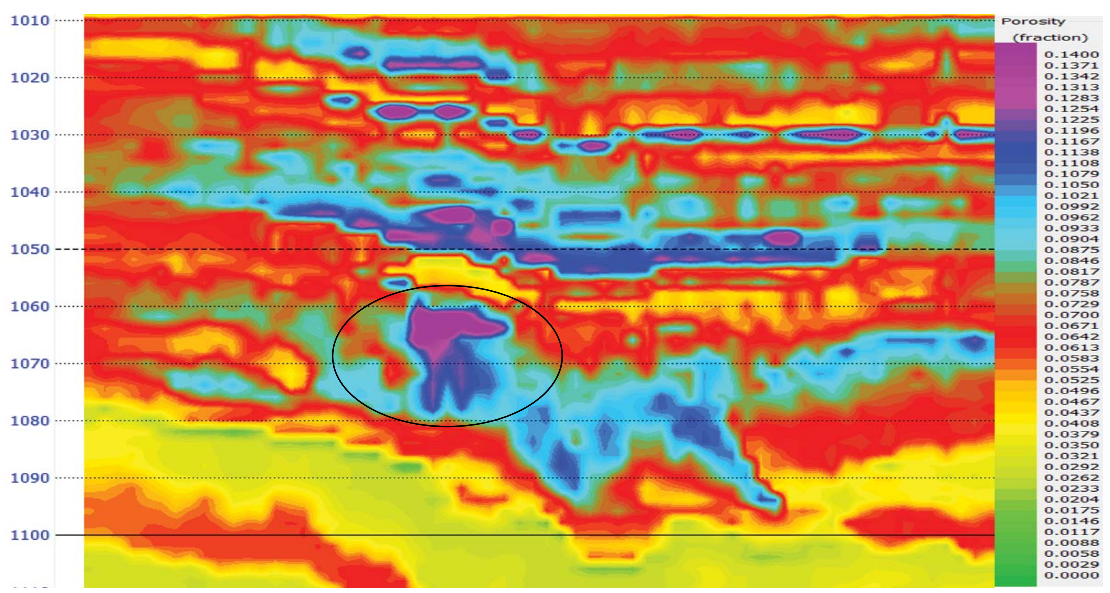
Porosity from P - Impedance



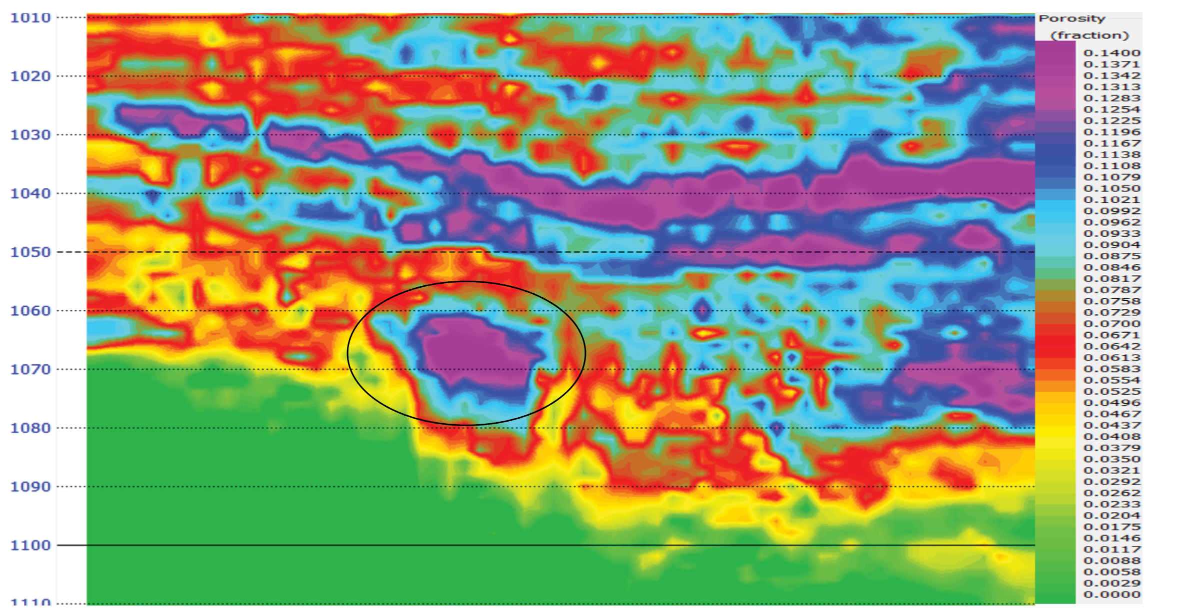
P - Impedance



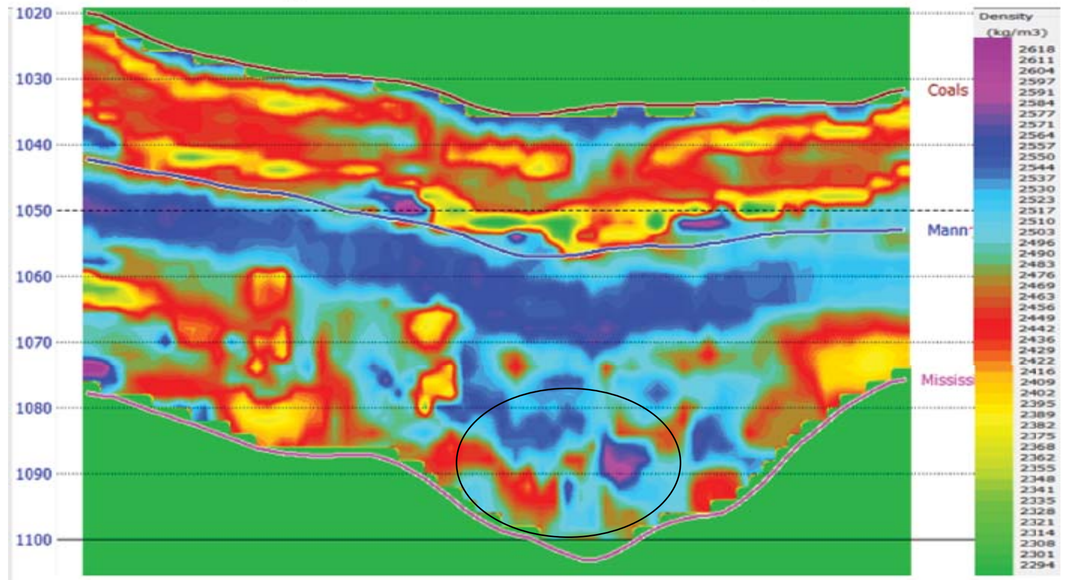
Porosity from Neural Network



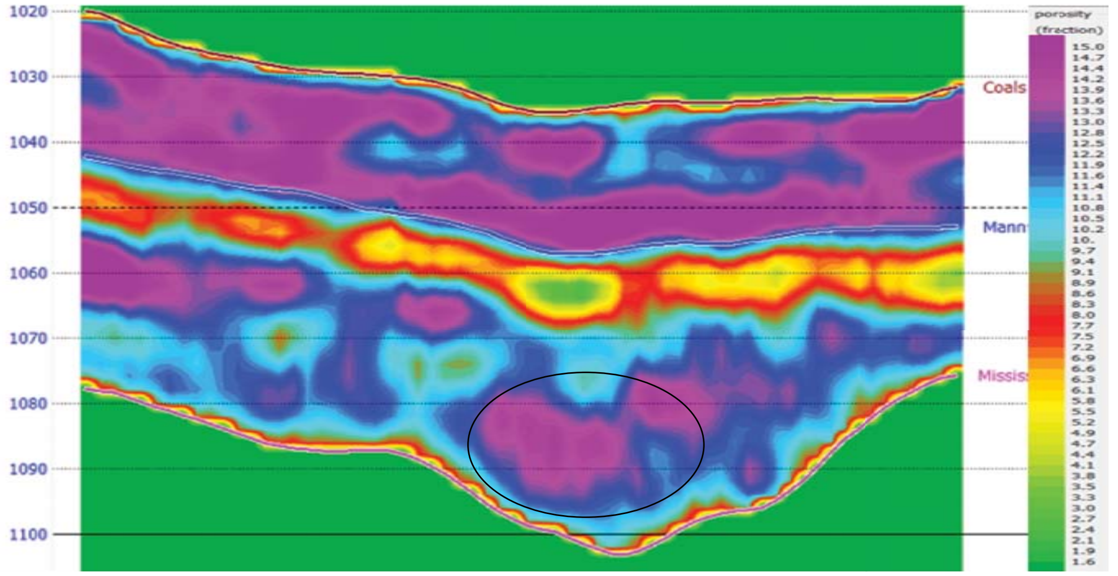
Porosity from Multi-linear Regression



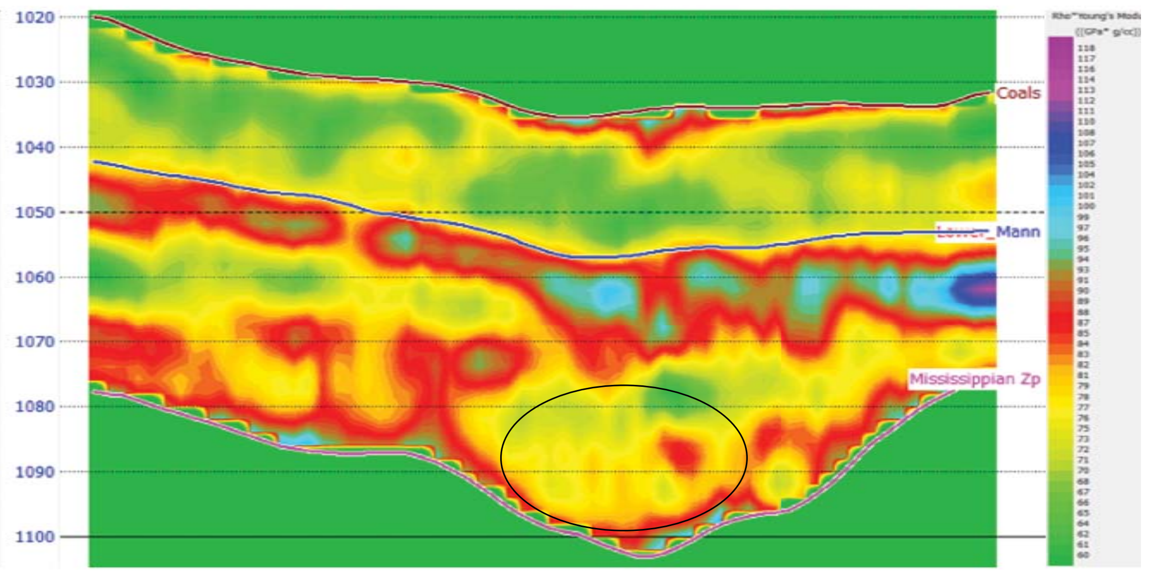
Density from Neural Network Analysis



Porosity from P - Impedance



Stiffness (E-Rho) from P – and S - Impedance



References 1. Sharma, R. K. and S. Chopra, 2015, Determination of lithology and brittleness of rocks with a new attribute, The Leading Edge, Vol. 34, No. 5, 936 - 941. 2. Hampson, D., J. Schuelke and J. Quirein, 2001, Use of multi-attribute transforms to predict log properties from seismic data, Geophysics, Vol. 66, No. 1, 220 -236.

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CASE STUDY AREA : BLACKFOOT 3D

Geophysical Background

Fully processed 3D Migrated CDP gathers are the input data to this project. From this initial data set several other data volumes were generated. They were: Angle gathers, Angle Stacks (near : 1-12 deg., 13-24 deg., and 25-36 deg.), 3D Migrated Stack, P-impedance, S-impedance, and Density.

Data Processing of CDP Gathers

1. Deconvolution - Spiking
2. Refraction, Residual Trim Statics
3. Velocity Analysis, NMO, Mute
4. 3D Pre-Stack Migration

Data conditioning processes

1. Super gathers
2. Residual NMO/Trim statics
3. Multiple attenuation
4. 5D Interpolation

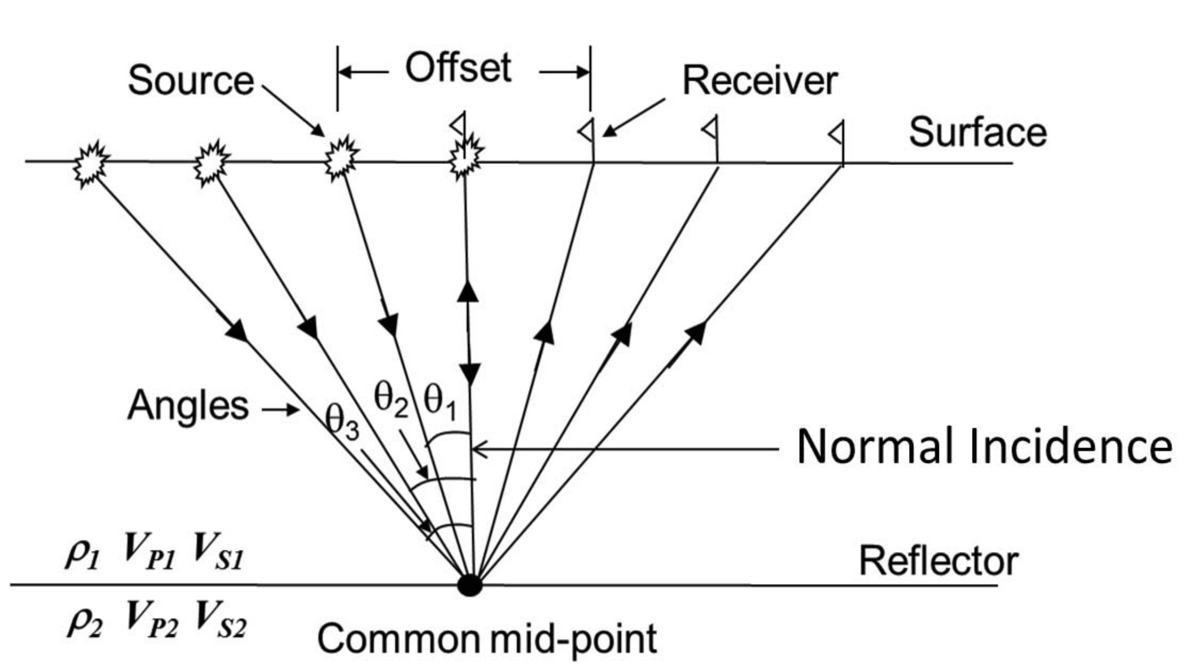
POST-STACK INVERSION

Load Well logs
(P-wave, Density)
↓
Load Seismic
(STACK DATA – fully processed)
↓
Load Horizons
↓
Extract Statistical Wavelet
↓
Correlate Well(s) to Seismic
↓
Build Initial Low Frequency Model
(Logs: P-wave & Density and Horizons)
↓
Inversion Analysis at Well Location
(Low Frequency Model, Wavelet and Stack Trace at Well)
↓
Inversion (Full Data Volume)
(Low Frequency Model, Wavelet and Stack Data)
↓
Output
(P-Impedance Volume)
↓
QC Inversion Results

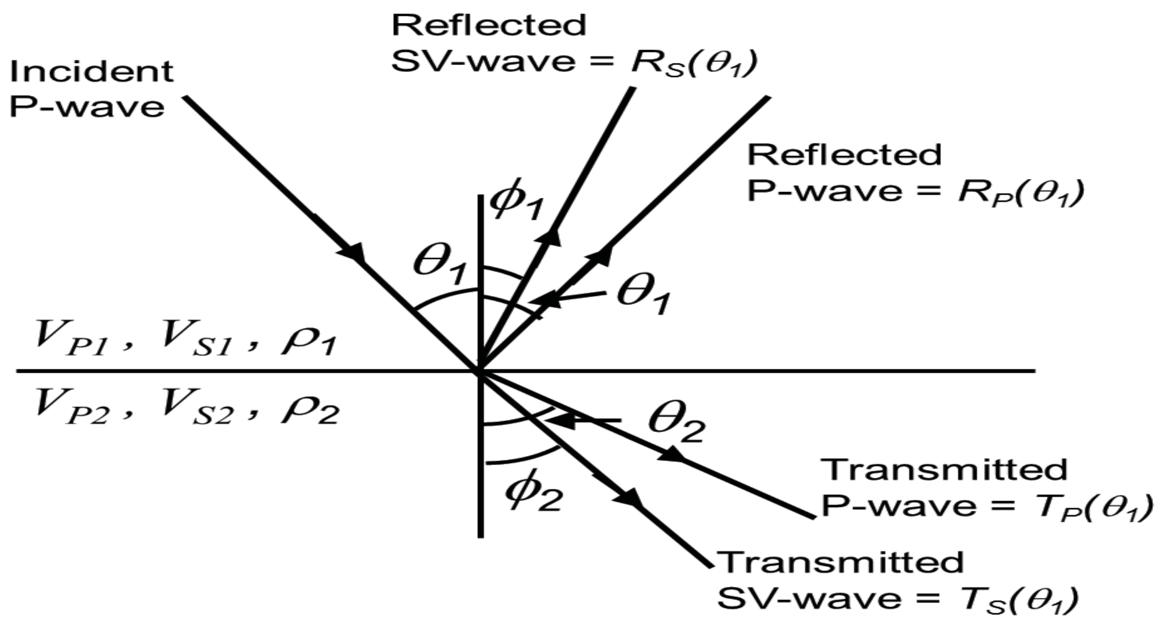
PRE-STACK INVERSION

Load Well logs
(P-wave, S-wave, Density)
↓
Load Seismic
(CDP gathers – fully processed)
↓
Load Horizons
↓
Create Angle Gathers
↓
Extract Statistical Wavelet
↓
Correlate Well(s) to Seismic
↓
Build Initial Low Frequency Model
(Logs: P-wave, S-wave & Density and Horizons)
↓
Inversion Analysis at Well Location
(Low Frequency Model, Wavelet and Angle Gather at Well)
↓
Inversion (Full Data Volume)
(Low Frequency Model, Wavelet and Angle Gather data)
↓
Output
(P-Impedance, S-Impedance and Density Volumes)
↓
QC Inversion Results

COMMON DEPTH POINT GATHER



MODE CONVERSION



$$R_P(\theta) = a\frac{\Delta V_P}{2V_P} + b\frac{\Delta V_S}{2V_S} + c\frac{\Delta\rho}{2\rho}, \text{ where:}$$

$$a = 1 + \tan^2\theta,$$

$$b = -8\left(\frac{V_S}{V_P}\right)^2 \sin^2\theta,$$

$$c = 1 - 4\left(\frac{V_S}{V_P}\right)^2 \sin^2\theta,$$

$$\rho = \frac{\rho_2 + \rho_1}{2}, \Delta\rho = \rho_2 - \rho_1,$$

$$V_P = \frac{V_{P2} + V_{P1}}{2}, \Delta V_P = V_{P2} - V_{P1},$$

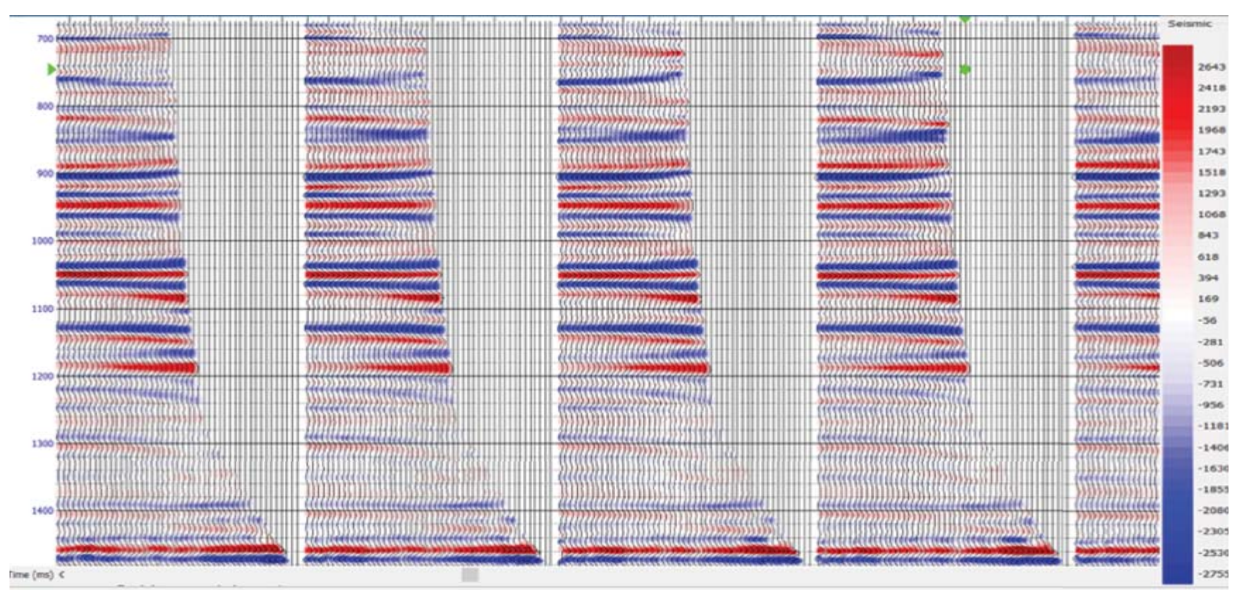
$$V_S = \frac{V_{S2} + V_{S1}}{2}, \Delta V_S = V_{S2} - V_{S1},$$

$$\text{and } \theta = \frac{\theta_1 + \theta_2}{2}.$$

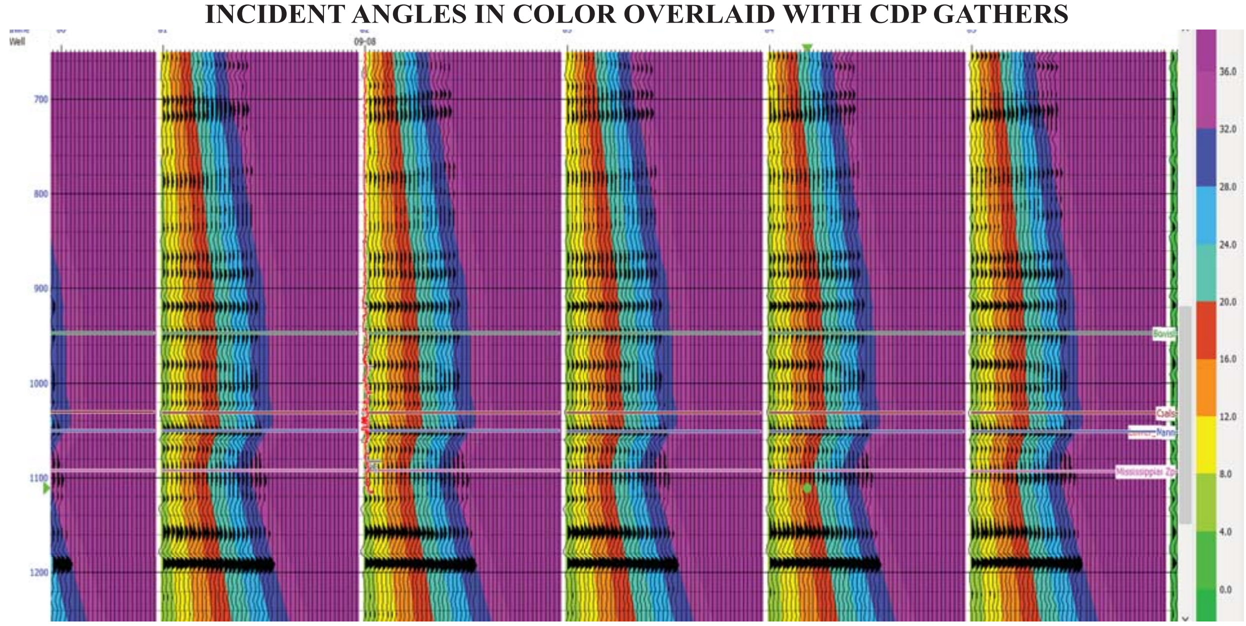
Data set

The Blackfoot 3C-3D data are provided by the CREWES projects at the University of Calgary and marketed through the SEG bookmart.

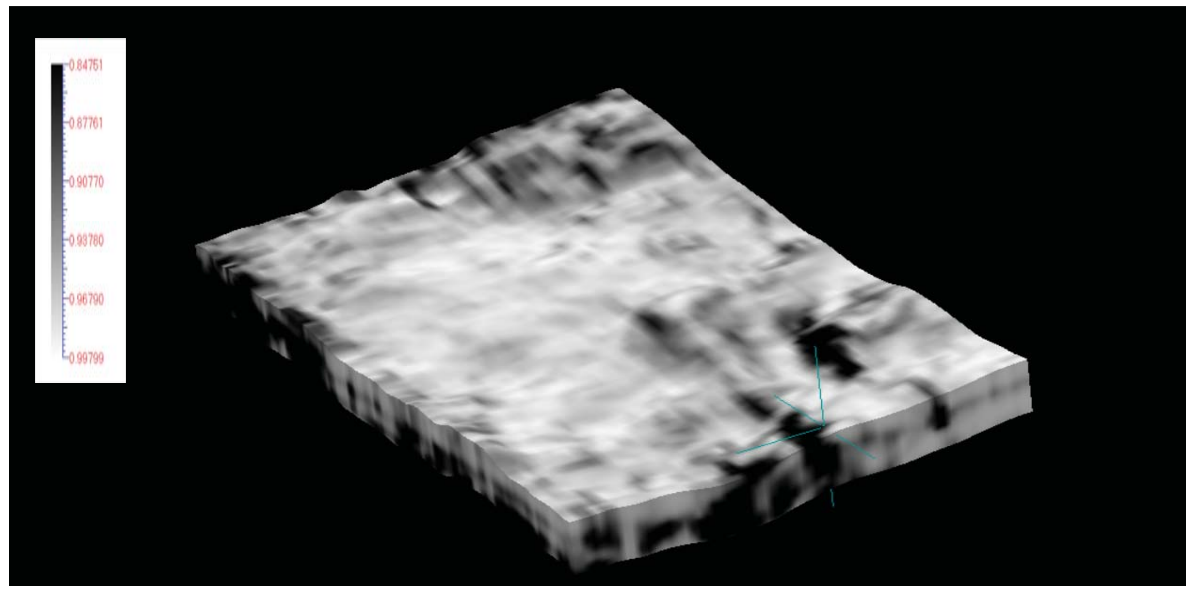
INPUT FULLY PROCESSED 3D MIGRATED CDP GATHERS



INCIDENT ANGLES IN COLOR OVERLAID WITH CDP GATHERS



SEMBLANCE COHERENCE OF MIGRATED VOLUME AT RESERVOIR LEVEL



MULTI-ATTRIBUTE ANALYSIS

Input Data Types:
There are several data types that can be input into the multi-attribute log prediction process. They are:

A) Seismic data

a) 3D Pre-Stack Migrated Stack data

b) Angle Stacks: Near (1 - 12 deg.)
Mid (13 - 24 deg.)
Far (25 - 36 deg.)

B) Attribute data

Pre-Stack inversion output volumes:

P-Impedance, S-Impedance, Density

C) Porosity Logs

WORKFLOW

3D PRE-STACK MIGRATED GATHERS
↓
PRE-STACK INVERSION
↓
MULTI-ATTRIBUTE ANALYSIS
↓
PROBABILISTIC NEURAL NETWORK

ATTRIBUTES USED

a) 1 / (inverted P-impedance)

b) Amplitude Envelope

c) Integrate

d) Cosine Instantaneous phase

e) Instantaneous Phase

f) Y-Coordinate

Acknowledgments
Graham Carter - CGG -
for his patient mentoring and suggestions throughout the project and in the use of Hampson-Russell software (EMERGE)
Mohammed Al-Ibrahim - Senior Geophysicist - Geomodeling Technology Corp.
for his assistance with generating images using Geomodeling software
Christine Carr-Bell - Customer solutions Specialist - geoLOGIC : for her assistance in the use of geoSCOUT software
Mark Egan - Senior Geophysical consultant; Satinder Chopra-Chief Geophysicist, Reservoir, Arcis Seismic Solutions, TGS; Ritesh Sharma - Geophysicist, Reservoir. Arcis Seismic Solutions, TGS; Rainer Tonn - Leading Geophysicist, DPI CAN BDN SUN, Statoil Canada; Dr. Gary Margrave, Emeritus Director, University of Calgary for their suggestions in the preparation of the poster abstract.