Optimizing Subsurface Predictions in a Mississippian Carbonate Field, Central Alberta, Canada (Part 2)*

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Abstract

Previously we presented the Highvale Oil Pool, located in Central Alberta, Canada, which produces light oil from dolomitized carbonates of the Mississippian Banff Formation. We employed a systematic approach to the integration of outcrop data, a pre-existing 3D seismic survey and petrophysical log data to gain a clear definition of the subsurface. This approach includes outcrop analysis, the creation of an zone internal stratigraphic correlation within the erosional remnants of the Banff Formation, the identification of fluid contacts, estimation of saturations and porosity, mineral identification and the integration of recently developed 5D interpolation of seismic data to regularize and fill in data gaps, to increase the fold and create the common depth point gathers more suited to pre-stack time migration (PSTM).

Further to this, we have taken available data, including seismic characterization parameters such as amplitude, wavelet characterization, attribute analysis pre-stack fracture analysis and mineralogy through X-ray diffraction and X-ray fluorescence. Core calibrated petrophysical log characterization was provided by NuTech and the output parameters include, effective porosity, BVI, free water, hydrocarbon pore volume, clay volume, and permeability.

In this study, we have used multivariate analysis to quantify well performance. Well performance has been normalized by lateral length, completion type and time on production. With normalized well production, we can analyze productivity and comment on best practices concerning drilling and completions, along with key reservoir parameters and subsequent economic performance.


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This study has also shown how the integration of available data and disciplines can result in improved economic performance. The adage “you cannot engineer bad rock” is more prevalent today than ever as we move forward with more complicated plays, increased horizontal lateral length, increased hydraulic fracturing stages and drilling complexity.
Optimizing Subsurface Predictions in a Mississippian Carbonate field. Central Alberta, Canada (Part 2)

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- Mississippian Age Carbonate Reservoir in Central Alberta
- Review all the Variables that Affect the Reservoir
- Goals: Determine the Variables that most impact Production
- Predict Expected Ultimate Recovery (EUR)
Outline

- Why?
- What and Where?
- Methodology
  - Data used in Analysis
- Results
- Conclusions
Why

Integrating the Micro & Macro data into Multivariate Analysis at the Field Level

Utilize all available data variables applicable to the field/play
• Banff Formation, Carboniferous (Lower Tournaisian) Banff Formation, Rundle Group

• Argillaceous silty packstone, wackestone and mudstone, with interbeds of cherty lime packstone and wackestone with lenses of crinoidal grainstone and packestone.

• Williston Basin Bakken age equivalent
Highvale Area

Calgary

*taken from Atlas Of the Western Canadian Sedimentary Basin. Fig 14-1
• 147 Banff Formation wells (hydrocarbon produced)
• *Mature field with moderate Horizontal well development*
  • Vertical (83) and Horizontal (64)
  • Horizontal wells are open hole completed.
Reservoir Parameters:

- Average thickness: 30–50 ft (Banff Reservoir Zone)
- Average Total Thickness: 300 ft
- AVG PAY: 10–15 ft
- AVG Depth: ~5000 ft
- Average PHIE: 10 %
- AVG SW: 40%
- AVG Perm: 10–25mD
Methodology: Mineralogy & Petrophysical Workflow

Available Data

Core & Cuttings

Wireline Logs

Data Acquisition
- Portable X-ray fluorescence (pXRF)
- X-Ray Diffraction
- ICP-MS
- SEM-EDS

Data Integration
Determine linear regression association between “predictor proxies” and “response” variables

Facies Characterization
- Mineralogy
- Grain Density
- Porosity

Interpretation

Data Validation
Validation

XRD and XRF need to be complimentary in validating mineralogy

Portable XRF is cost effective and rapid

Repeated validation and sampling rate increases mineralogic resolution

VQTZ is interpreted as silica-rich clay
Measured versus Calculated Non-linear Regression prediction versus XRD

Petrophysical Analysis provided by:

NUTECH
VISIONARY RESERVOIR INTELLIGENCE
Banff Peak Amplitude-Highvale 3D
Data: Expected Ultimate Recovery

Monthly Oil Production: Vertical Wells, Time series, First Month Production Normalized

- Waterflood
- Idealized Type curve
- Individual well
- Well count
Oil Production: Horizontal Wells, Time series, First Month Production

~ 3x vertical well early production

Idealized Type curve

Individual well

Well count
Variables used in Analytics:

Response Variable:
Expected Ultimate Recovery (EUR)
  • Individual well Exponential Decline Curve Analysis

Independent Variables:
• Horizontal well Lateral Length
• Seismic Attributes:
  • Banff Peak Gradient,
  • Banff Peak Dip Diff
  • Inline & Cross Line,
  • Banff Peak Amplitude
• AVG PHIE
• AVG Permeability
• Thickness
• AVG Calcite Volume
• AVG Dolomite Volume
• AVG Clay Volume
Results - Vertical Wells

- Outlier analysis applied
- Geologically and geophysically driven selection of variables that are significant to predicted hydrocarbon bearing zones in this reservoir type, depth and area.
Results - Vertical Wells

Seismic Amplitude Significance

Porosity Significance

Analytic Significance

-Little clay in porous intervals-
Results - Horizontal Wells

Horizontal well EUR significance

- Amplitude
- Lateral Length
- Dolomite
- Porosity
- Calcite

Analytic Significance

Multiple Non-linear Regression

Predicted EUR vs. Actual EUR
Conclusions

• Calcite volume is the most significant factor in productivity in both Vertical and Horizontal wells

• When considering future field development (FFD):
  • mineralogy driving porosity is the most significant variable
  • As permeability is of lower significance, reservoir stimulation is not a driving factor in well performance.

• Horizontal wells will access more porous rock volume thereby increasing rate, but mineralogy is the key factor in porosity and hydrocarbon storage.

• Petrophysical evaluation coupled with mineralogy characterization significantly increased the robustness and validity of reservoir characterization

• Understanding geologic factors even in mature field development is Important!!!!

• Next Steps:
  • Expected Ultimate Recovery (EUR) predication outside 3D coverage area.
Thanks

XRD and XRF analysis and Software

3D Reprocessing and Analysis

Access to Highvale 3D

Seismic Interpretation and Software

Petrophysical Analysis