

# **PS Optimizing Subsurface Predictions with Limited Capital Investment\***

**Peter Bauman<sup>1</sup>, Chris Barton<sup>2</sup>, and Torr Haglund<sup>3</sup>**

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## **Abstract**

In both highly developed and exploratory hydrocarbon producing regions the predictability of reservoir properties is limited by the quality and amount of available data. During the latest industry downturn, we have been challenged with ‘do more with less capital’ and subsequently less subsurface information, while maintaining, and in some cases, improving probability of success. However, if a systematic approach to interpretation of the available data is employed, a maximization of return on investment and confident decision making is obtained. Here we present an example of the Highvale Oil pool located in Central Alberta, Canada, which produces light oil from dolomitized carbonates of the Mississippian Banff Formation and we employ a systematic approach to the integration of outcrop data, a pre-existing 3D seismic survey, and petrophysical log data in order to gain a clear definition of the subsurface. This approach includes outcrop analysis, the creation of 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, fill in data gaps, to increase the fold and create the common depth point gathers more suited to pre-stack time migration (PSTM). With nominal costs and time associated with data quality improvements and interpretations of the existing data, the resultant work provides a clear image of the Highvale Oil Pool Mississippian surface. This approach to subsurface prediction and planning leads to savings, including necessary data integration, interpretation time, confidence in the subsurface model and ultimately optimizing drilling locations.

# Optimizing Subsurface Predictions with Limited Capital Investment

## Geology

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*Peter Bauman P. Geo, Chris Barton P. Geo, Torr Haglund P. Geoph, Alex Horner G.I.T.*

### Location and Geologic Setting

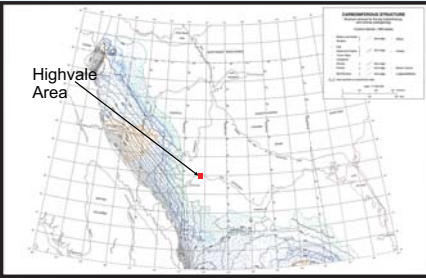
#### Summary

In both highly developed and exploratory hydrocarbon producing regions the predictability of reservoir properties is limited by the quality and amount of available data. During the latest industry down turn, we have been challenged with 'do more with less capital' and subsequently less subsurface information, while maintaining and in some cases improving probability of success. However, if a systematic approach to interpretation of the available data is employed, a maximization of return on investment and confident decision making is obtained.

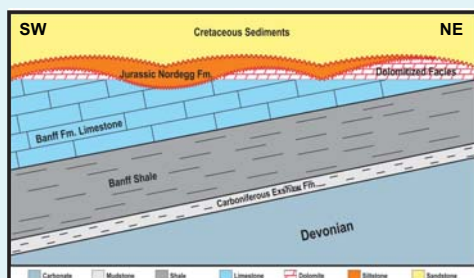
Here we present an example of the Highvale Oil pool located in Central Alberta, Canada, which produces light oil from dolomitized carbonates of the Mississippian Banff Formation and we employ a systematic approach to the integration of outcrop data, a pre-existing 3D seismic survey and petrophysical log data in order to gain a clear definition of the subsurface. This approach includes outcrop analysis, the creation of 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, fill in data gaps, to increase the fold and create the common depth point gathers more suited to pre-stack time migration (PSTM).

With nominal costs and time associated with data quality improvements and interpretations of the existing data, the resultant work provides a clear image of the Highvale Oil Pool Mississippian surface. This approach to subsurface prediction and planning leads to savings including, necessary data integration, interpretation time, confidence in the subsurface model and ultimately optimizing drilling locations.

#### Carboniferous Regional Structure of Western Canada



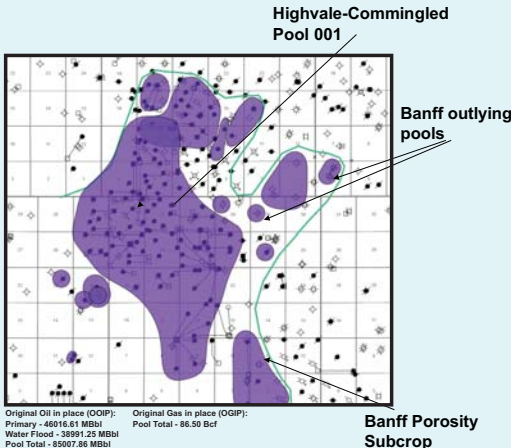
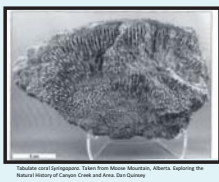
#### Highvale Area Reservoir Schematic Model



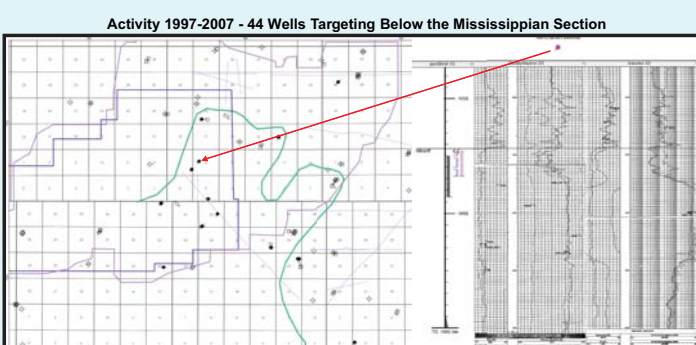
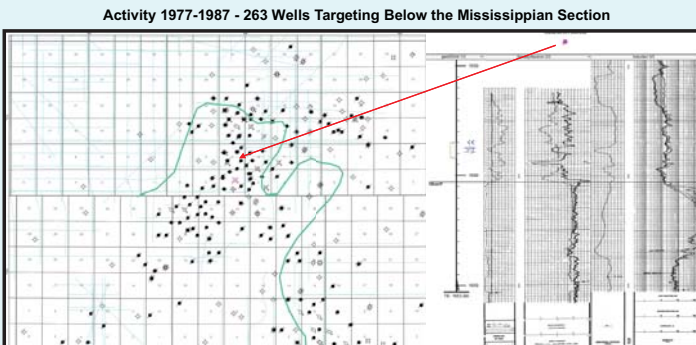
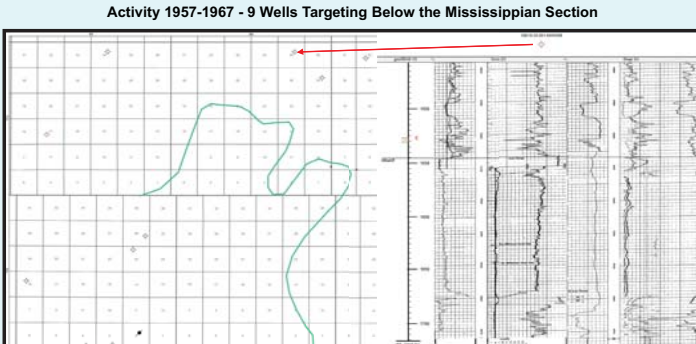
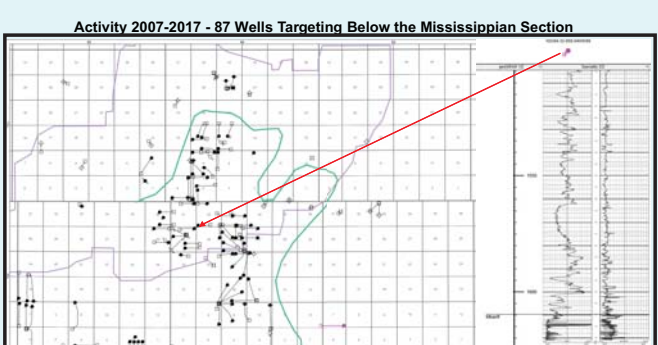
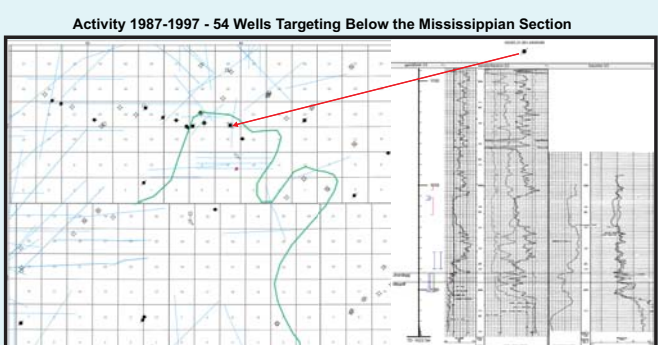
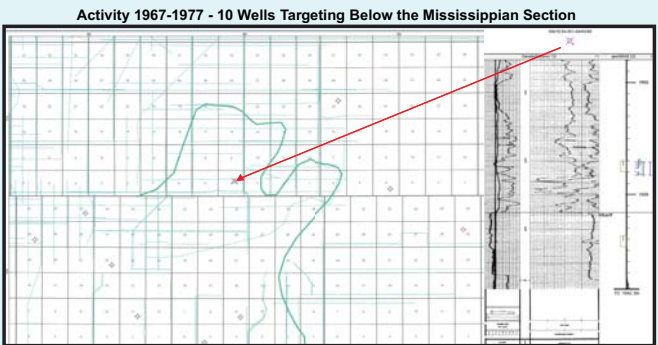
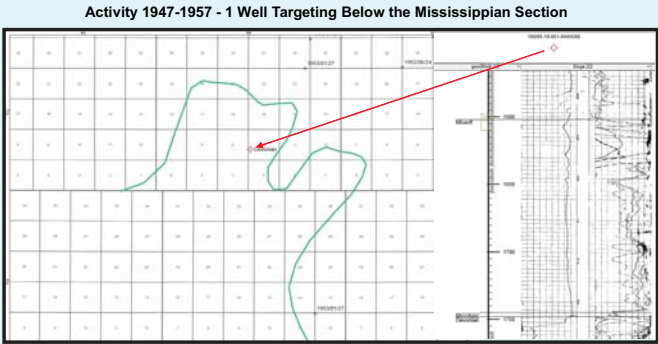
#### Mississippian Stratigraphy of Alberta

HIGHLAND AREA		STAGE	UNIT	CENTRAL SOUTHERN ROCKY MTS. ALTA., B.C.	SUBSURFACE SOUTHERN ALBERTA	WILLISTON BASIN
TOURNAMENTIAN		CARBONIFEROUS	1	Banff Limestone	Banff Limestone	Scallion Mbr.
			2	Banff Sandstone	Banff Sandstone	Lodgepole (part)
			3	lower Banff Shale	lower Banff Shale	upper Bakken
			4	Exshaw Silt	Exshaw Silt	middle Bakken
DEVONIAN	FAIRMONT		5	Exshaw Shale	Exshaw Shale	lower Bakken
			6	upper Cretaceous	Big Valley	Big Valley
			7	lower Cretaceous	upper Stettler	Torquay / Three Forks
8	Morro	lower Stettler				

#### Out Crop Analysis



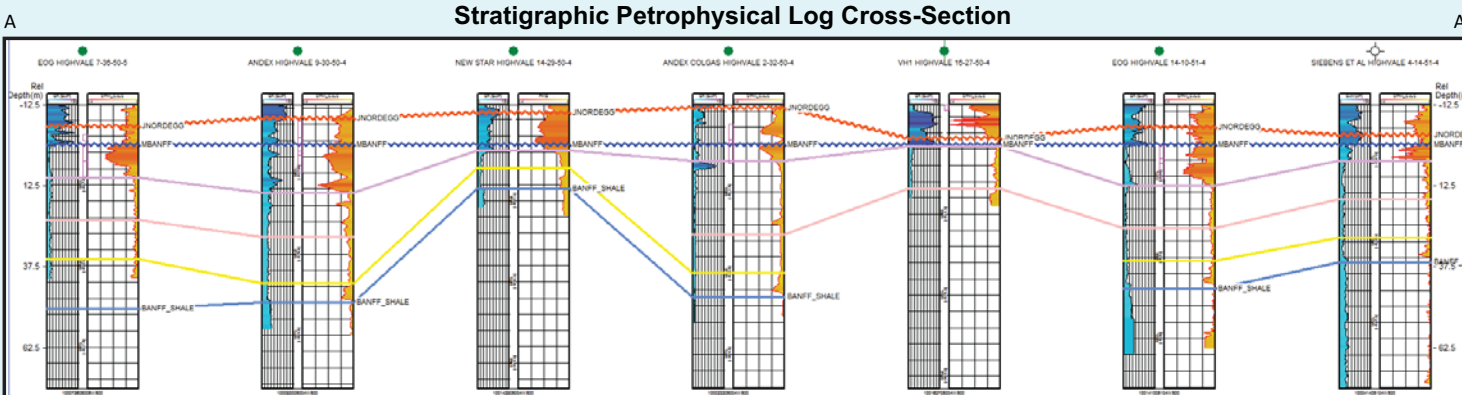
### History and Development of the Highvale Area



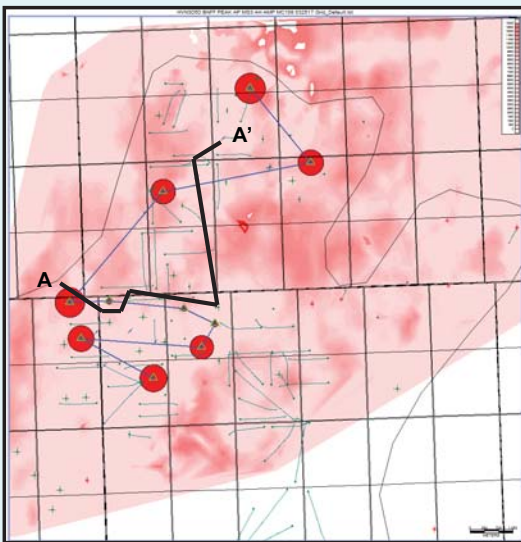
#### Total Activity 1947-2017 - 468 Wells Targeting Below the Mississippian Section



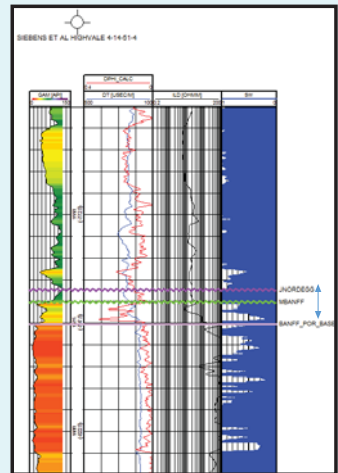
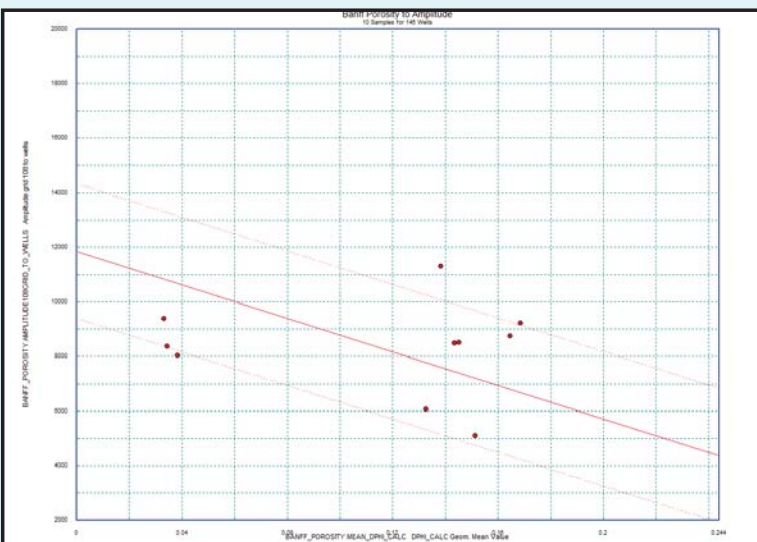
### Interpretation and Integration with Re-Processed Seismic



#### Banff Formation Average Porosity versus Top Banff Formation Amplitude



#### Banff Formation Porosity to Banff Formation Amplitude Crossplot



### Acknowledgements



# Optimizing Subsurface Predictions with Limited Capital Investment Geophysics

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## Introduction

The following poster shows an overview of the geophysical development of the Banff Reservoir in the Highvale area of Central Alberta. Highlighting improvements in processing and interpretation the poster shows how you can add resource value with limited capital investment.

## 3D vs 5D Interpolation Processing

5D Interpolation regularizes Pre-stack 3D seismic data in 5 dimensions. The 5 dimensions involved are time, Common midpoint X (CMPX), Common midpoint Y (CMPY), azimuth, and offset. Time refers to trace sample time and is regularly sampled at acquisition, so there is no need to regularize. CMPX and CMPY are the common mid points between the shot and the receiver in the X and Y directions respectively. Azimuth is the bearing of the shot to receiver vector. Offset is the absolute distance from shot to receiver.

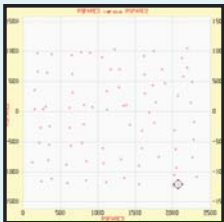
The end product of this program is a set of regularized CDP gathers. Each output gather has the same number of traces. Each trace in each output gather has a CMPX and CMPY equal to that of the output CMP bin center coordinate that it belongs to. Within each azimuth bin, in each output gather, there are traces with offsets incrementing in an orderly fashion.

There are many benefits of regularized data such as:

1. Regularized data will help prestack migration with cancellation
2. Regularized data will tend to remove acquisition imprints
3. Since only the dominant spectral events are being extracted for the output, many forms of noise are left behind

CDP fold distribution before 5D

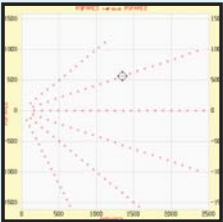
This gather is actually pretty good, in that it is randomly distributed. Normally with 3D data, you have very few near offsets and a large number of far offsets. However, this will not migrate as well as the regularized data. Horizontal axis is CMPX direction offset in meters. Vertical axis is CMPY offset in meters.



CDP Fold Distribution Before 5D Process

CDP fold distribution after 5D

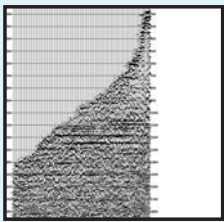
Data is very regularly distributed in azimuth and offset. Horizontal axis is CMPX direction offset in meters. Vertical axis is CMPY offset in meters. This 5D was run using 8 azimuths. However, as you can see from the diagram only 6 azimuths appear. This is a result of these 2 azimuth banks (0, 180) being too far away from the original data in terms of azimuth. They exceeded the inclusion zone and were automatically excluded. The program checks the proximity to the original data in terms of CMPX, CMPY, azimuth and offset so that over extrapolation or interpolation does not occur.



CDP Fold Distribution After 5D Process

CDP Gather before 5D

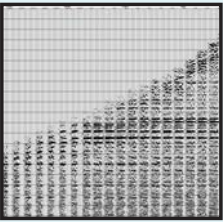
Data is very noisy. CDP gather fold is 81.



CDP Gather Before 5D Process

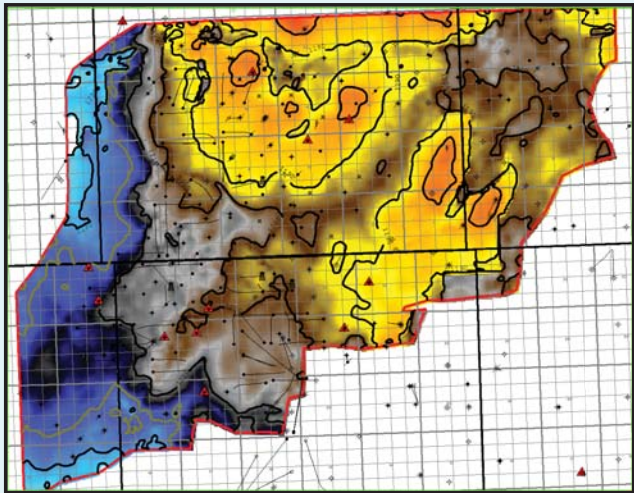
CDP Gather after 5D

CDP gather is less noisy and has a higher fold of 121 than the data without 5D interpolation. The Highvale 3D is well shot, and the 5D results in a 50% increase in fold, and a resulting SNR improvement on the stack. In irregular acquired 30%, or sparsely acquired 3D's the fold improvement would be significantly more.

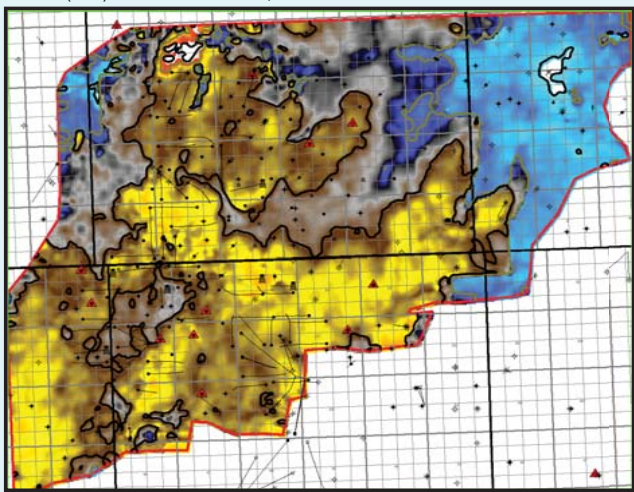


CDP Gather After 5D Process

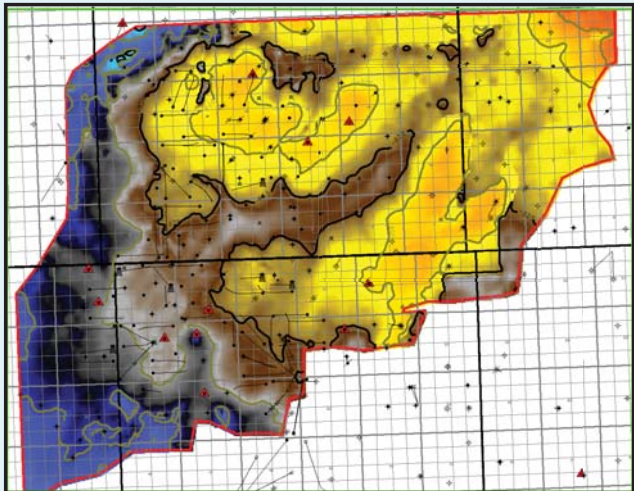
## Interpretation of the 3D - 2012 to 2016



Paleozoic (Banff) Time Structure. Scale 1:40,000. CI = 10 ms.

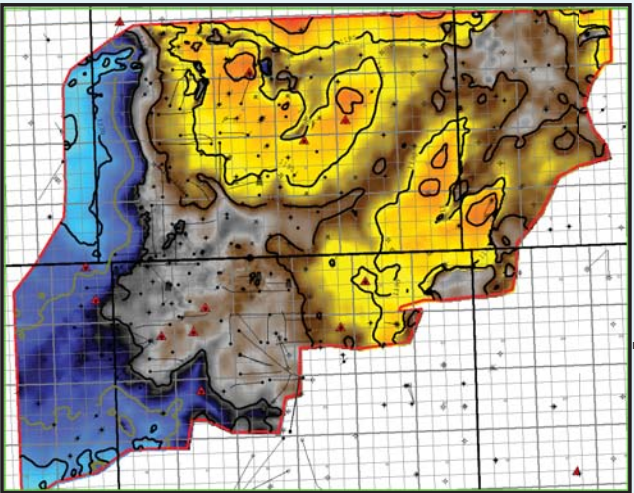


Paleozoic (Banff) to Devonian (Wabamun) Isochron. Scale 1:40,000. CI = 10 ms.

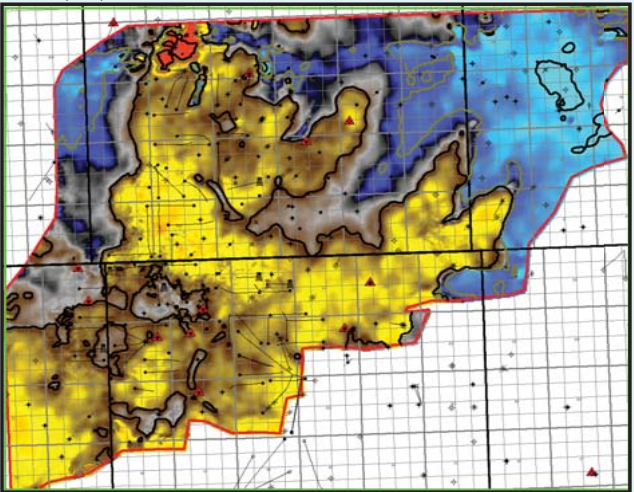


Paleozoic (Banff) Depth Structure. Scale 1:40,000. CI = 25 m.

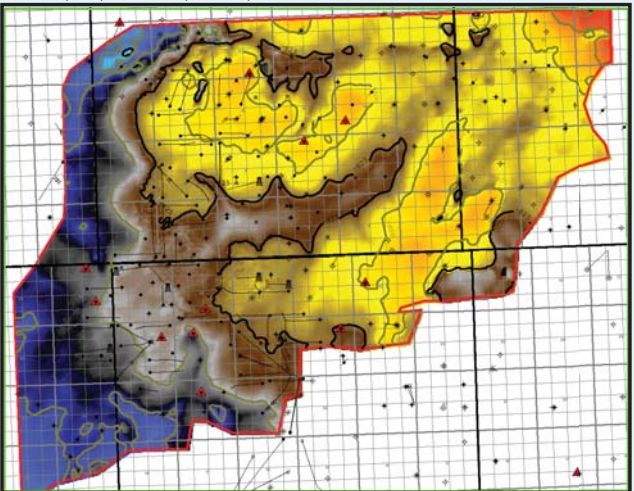
## Interpretation of the 3D with 5D Interpolation - 2017



Paleozoic (Banff) Time Structure. Scale 1:40,000. CI = 10 ms.

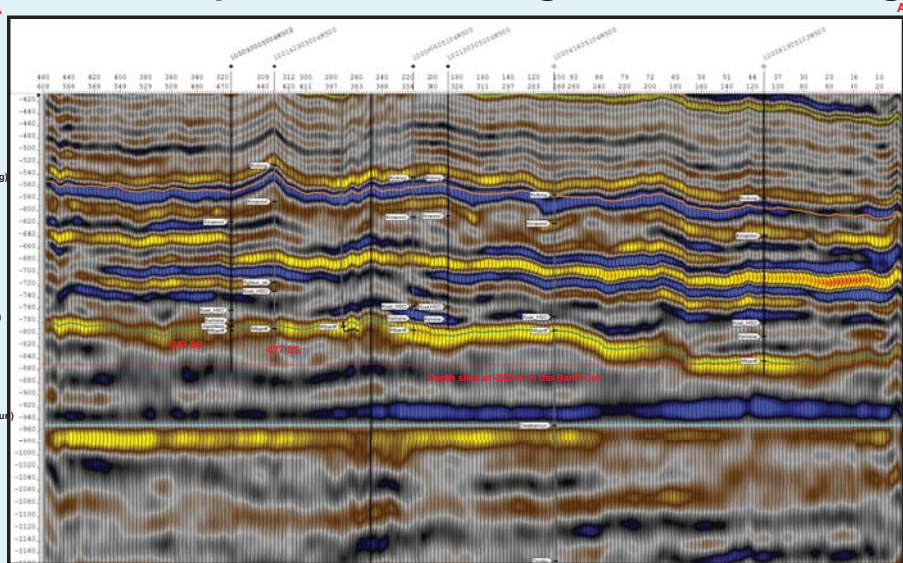


Paleozoic (Banff) to Devonian (Wabamun) Isochron Scale 1:40,000. CI = 10 ms

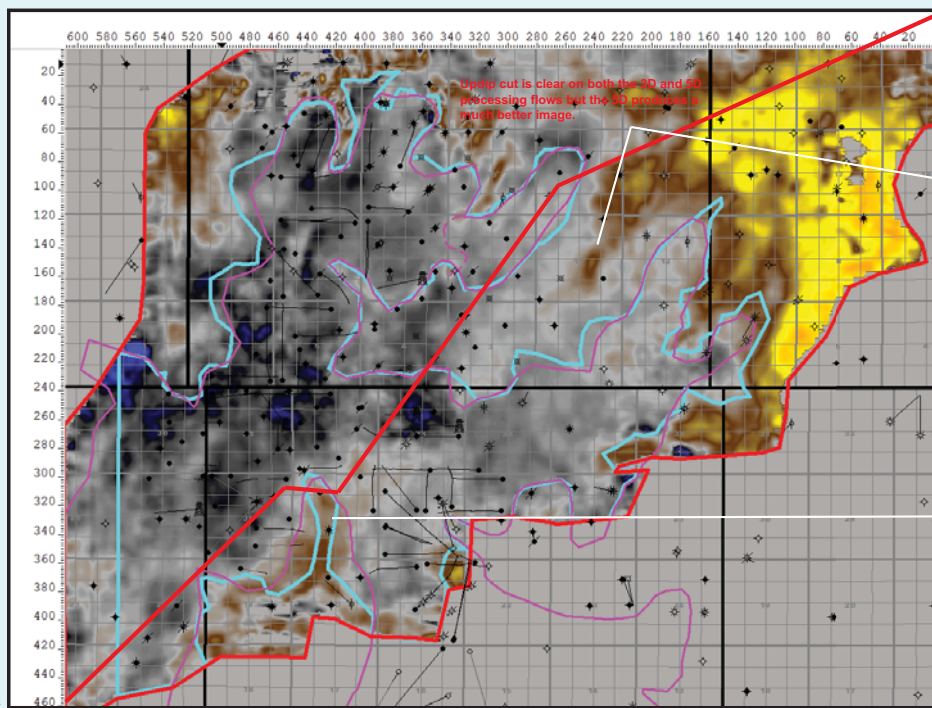


Paleozoic (Banff) Depth Structure. Scale 1:40,000. CI = 25 m.

## Seismic Depth Section of Original 3D Processing

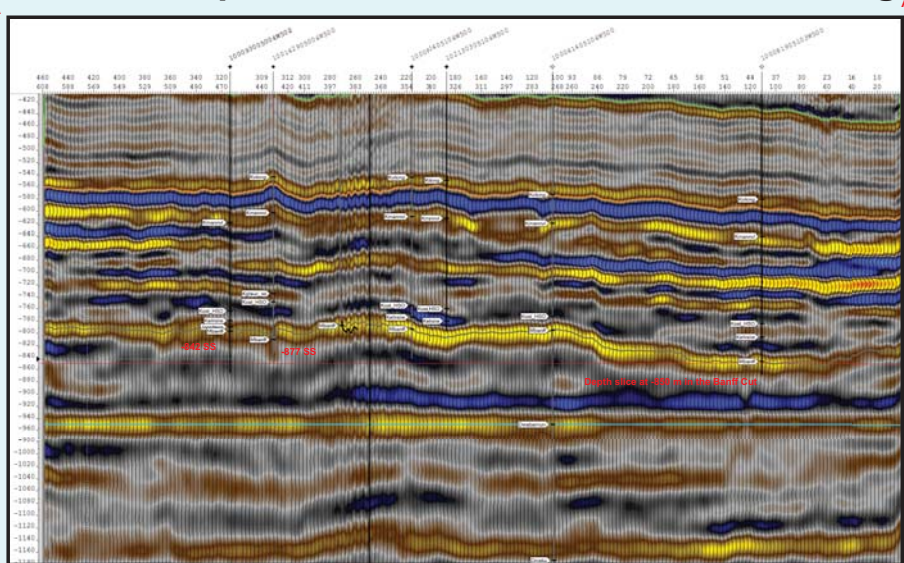


Flattened on Wabamun at -950 ms

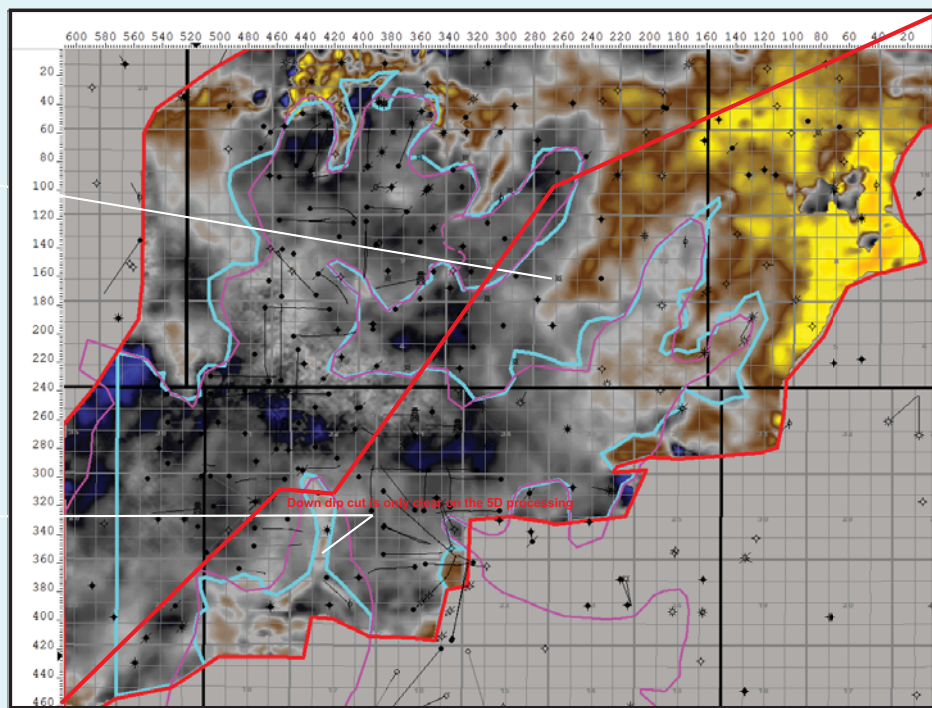


Seismic Depth Slice of 3D Processing Flow at -850 m in Paleozoic (Banff) Cut, Flattened on Wabamun at -950 ms

## Seismic Depth Section of 3D with 5D Processing



Flattened on Wabamun at -950 m



Seismic Depth Slice of 5D Interpolation Processing Flow at -850 m in Paleozoic (Banff) Cut, Flattened on Wabamun at -950 m

## Acknowledgements

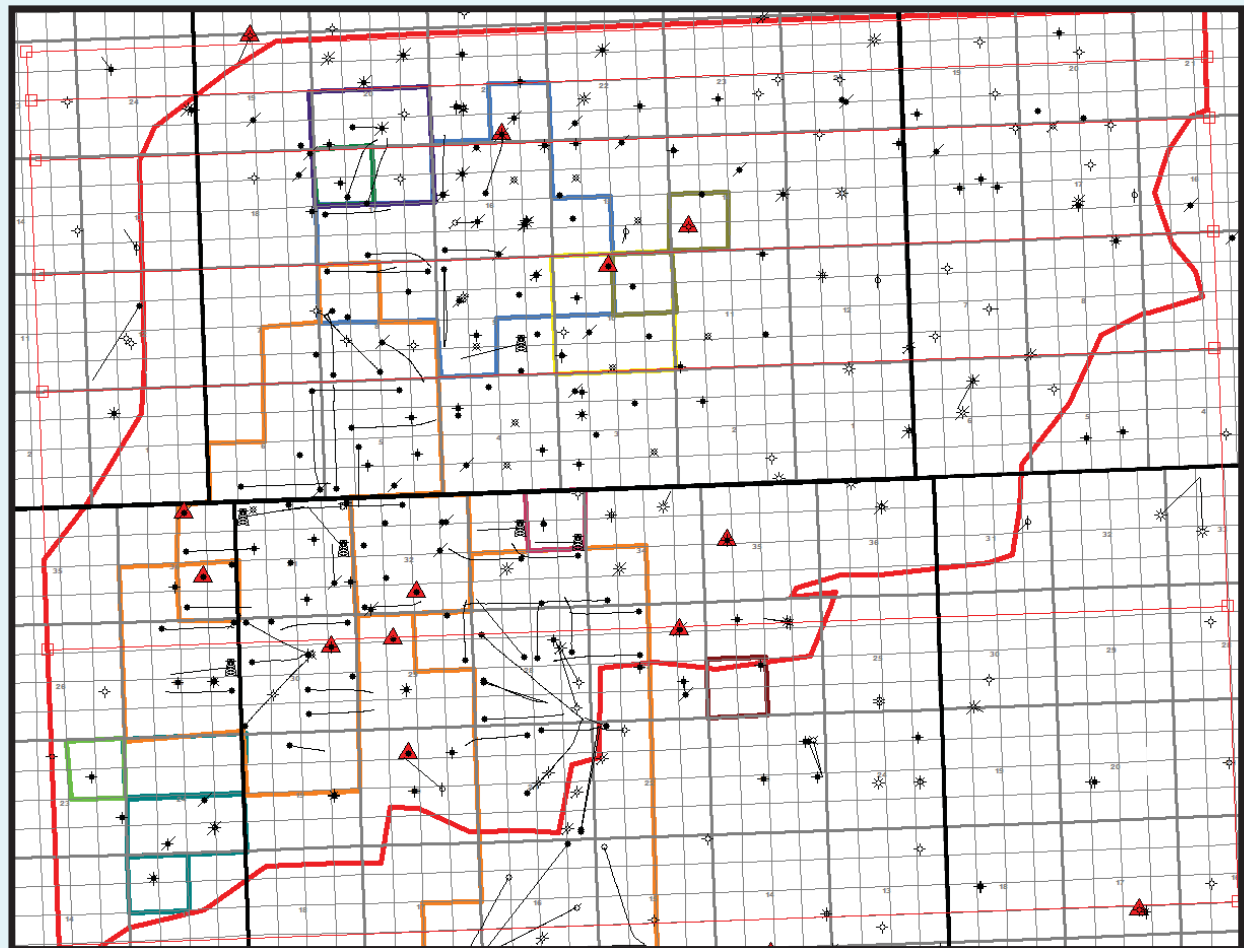


# Optimizing Subsurface Predictions with Limited Capital Investment

## Results / Optimization

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AER Pool Boundries

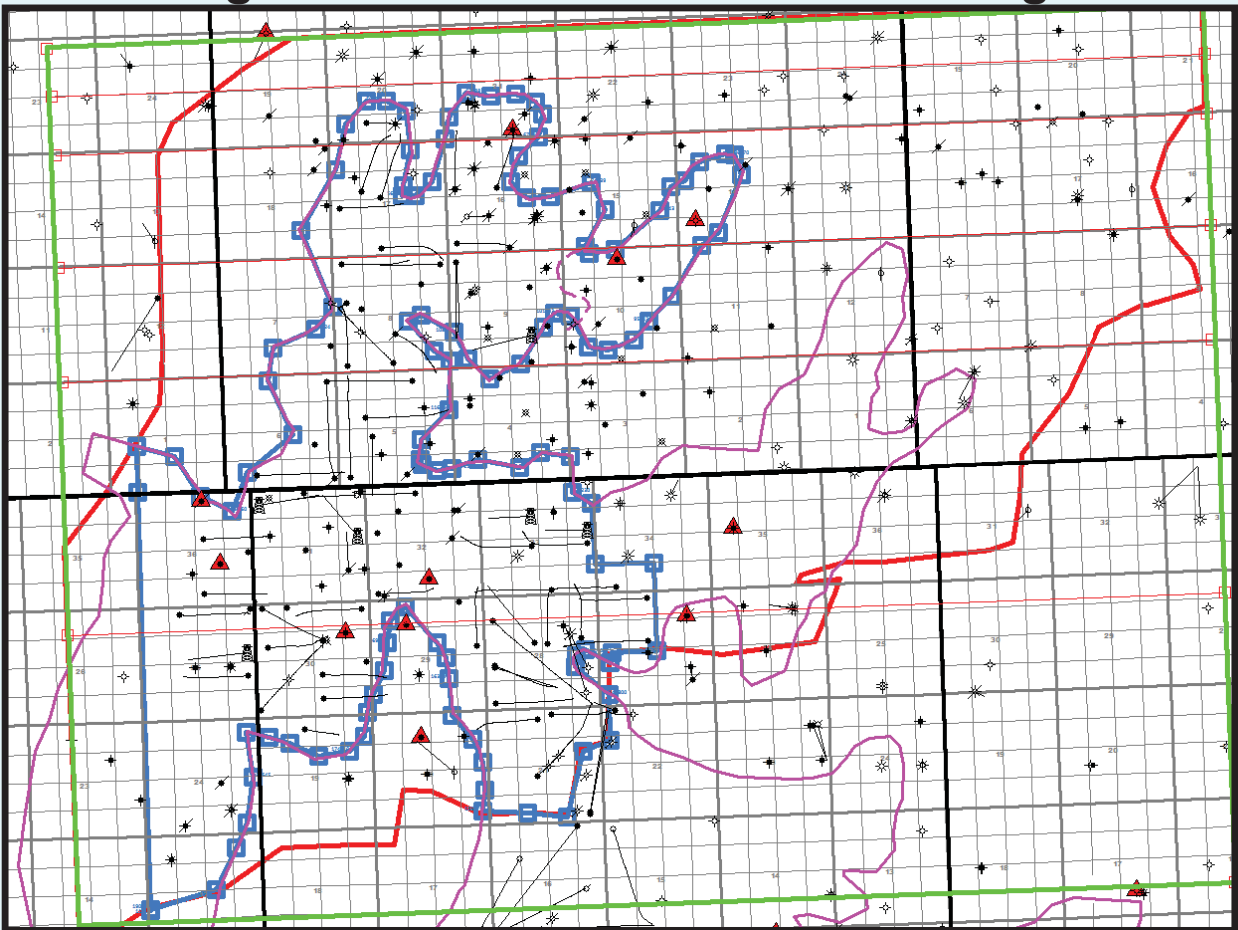


Alberta Energy Regulator (AER) recognizes 10 Banff Oils Pools within the Highvale HVN07-3D.

Government reserve numbers are as follows:

Pool	Map Color	OOIP (mmbbl)	Area (ac)	Net Pay (ft)	OOIP (BBL/ac-ft)
Banff A Pool	Blue	27.7	1463	24.61	770.65
Banff B Pool	Red	1.8	158	13.29	857.97
Banff F Pool	Green	0.29	20	26.25	567.61
Banff K Pool	Burgandy	0.03	10	6.56	494.84
Banff M Pool	Yellow	0.84	40	24.34	876.12
Banff P Pool	Olive	3.4	314	11.02	980.27
Banff S Pool	Light Green	0.65	79	12.2	677.49
Banff W Pool	Purple	2.8	237	9.84	1191.81
Banff Commingled Pool 001	Orange	85	6049	22.83	615.42
Banff Commingled Pool 002	Teal	4.6	474	15.19	640.47
Totals		127.11	8844		
Averages				16.61	767.27

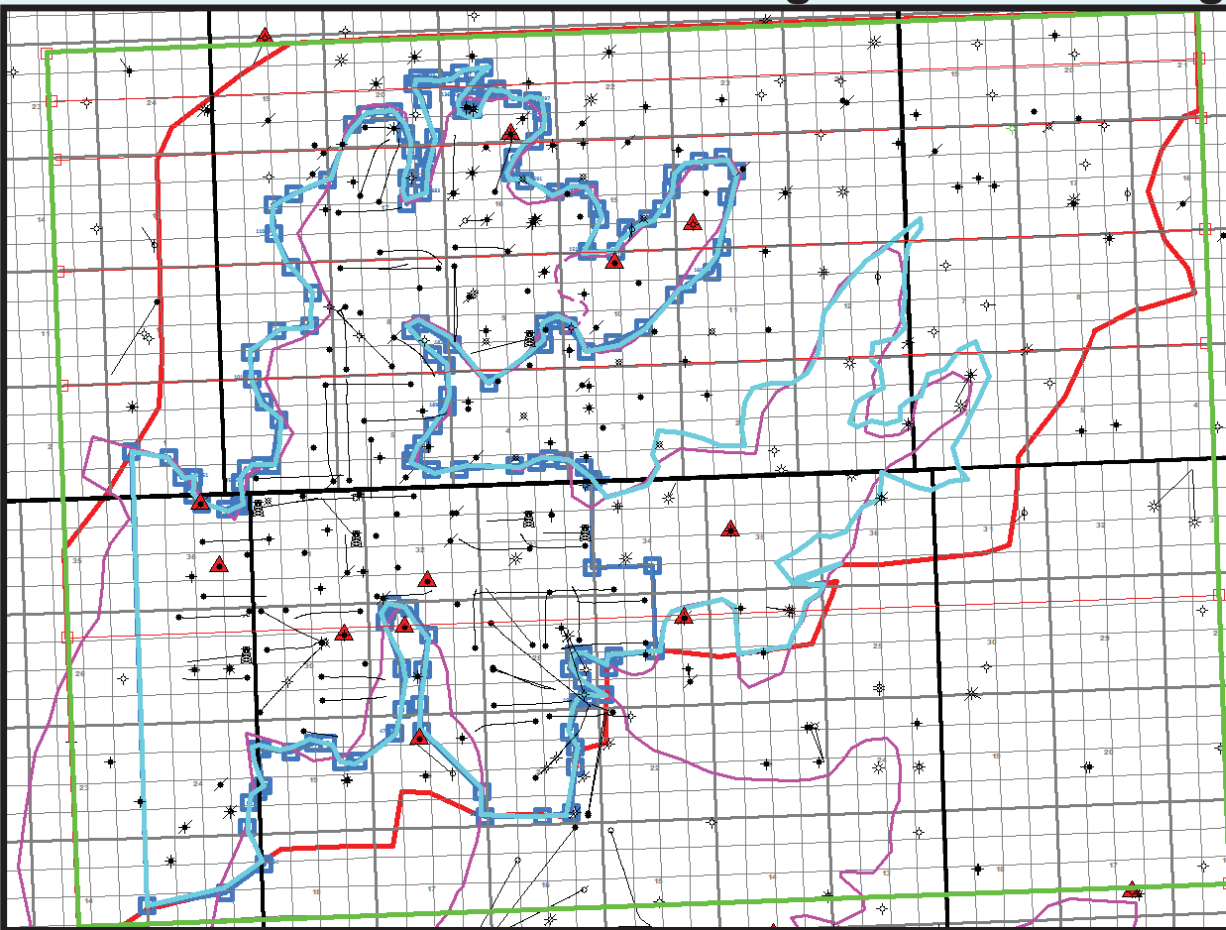
Original Banff Dolomite Reservoir Edge



Red Outline - Highvale 3D Seismic Outline  
Purple Outline - Banff Dolomite Reservoir Edge from Well Control and the HVN07 - 3D 2012  
Blue Outline - Calculated Oil Pool Area = 11,516 ac (Excludes Down Dip Wet Area and Up Dip Gas Cap)

Using the Government Pool Averages the OOIP = 11,516 ac \* 767.27 BBL/ac-ft \* 16.61 ft = 147 mmBBL  
This Resulted in a 20 mmBBL OOIP or an increase of 15.8%

New Banff Dolomite Reservoir Edge - 5D Processing



Red Outline - Highvale 3D Seismic Outline  
Purple Outline - Banff Dolomite Reservoir Edge from Well Control and the HVN07 - 3D 2012  
Light Blue - Banff Dolomite Reservoir Edge from Well Control and the HVN07 - 3D 2017  
Blue Outline - Calculated Oil Pool Area = 12,483 ac (Excludes Down Dip Wet Area and Up Dip Gas Cap)

Using the Government Pool Averages the OOIP = 12,483 ac \* 767.27 BBL/ac-ft \* 16.61 ft = 159 mmBBL  
This Resulted in a 12 mmBBL OOIP or an increase of 8.2%  
From the Original Government numbers we have an increase of 32 mmBBL OOIP or 25.2 %

Original vertical wells in the Highvale Paleozoic Banff Formation averaged a 5% Recovery Factor (RF).

The horizontal drilling program aggressively pursued in 2012 increased the recovery factor to 10%. This coupled with the waterflood has increased the recovery factor to 20%.

With the Geologic Model and the Acquisition of the Highvale HVN07-3D the OOIP increased 20 mmBBL. Taking the Geologic Model, adjusting it and starting the Horizontal Drilling Program along with running the 5D Interpolation on the HVN07-3D the OOIP increased another 12 mmBBL.

With the increase of 32 mmBBL OOIP from the government reserve numbers and the increased recovery factor of 20% we have added 6.4 mmBBL of Potential Proven (1P) reserves.

## Acknowledgements

