[PS]Rescaled Decline Curves: A Solution for Shale Gas Assessment*

Jean-Yves Chatellier[1,2], Bob Menard[1], and Sylvestre Charles[1]

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[1]Talisman Energy Inc., Calgary, AB, Canada (jchatellier@talisman-energy.com)
[2]Tecto Sedi Integrated Inc., Calgary, AB, Canada

Abstract

The intent of this study has been to find a reliable way to predict ultimate recoveries as soon as possible after the start of production in unconventional gas wells. In order to create single decline curves that combine many wells, our approach has been to rescale the data by using the logarithm of the cumulative production instead of the traditional production parameter (Mcf or Bcf). In our graphs we refer to this parameter as the “normalized production index”. The main reason for the use of the logarithm is to better define the bottom part of a decline curve. The advantage of this rescaling is the ability to inspect with more precision the behavior of the production rate (the proxy being the log of production divided by the number of days).

The method has been first tested with data from tight sand reservoirs for which long term production is readily available and for more than 160,000 wells from the US and from Canada. The same method has then been tested for some shale gas, keeping in mind that the historic data is more limited in time, the Barnett Shale being the exception.

Many wells can thus be plotted at once using rescaled decline curves, any of these curves is typical of an inverse function (harmonic behavior) that is a simple and very reliable mathematical equation; the result of which can be easily plotted and efficiently compared. Comparison for the same formation in different basins has been achieved and has demonstrated the robustness of the method. The effect of limited data has been tested by reducing the data to a selection of time periods; the results of that test indicate the need to compare production between wells using the same length of time.

The rescaled decline curves become most useful when referenced to a normal decline curve. Shale gas rescaled decline curves have been compared to normal decline curves in two ways:

● to the production per day starting from the peak production month,

● to the normalized production per day achieved in the peak month.

Rescaled decline curves allow a quick assessment of the type of production decline that any well should experience. They could thus be used as a first pass or as a quick test to estimate the level of success of any change in completion design as well as the expected ultimate production potential.

Rescaled Decline Curves,

a Solution for Shale Gas Assessment

A new method tested

T.S.I.

Jean-Yves Chatellier [1,2] Bob Menard [1] and Sylvestre charles [1]

1 Talisman Energy Inc. Calgary
2 Tecto Sedi Integrated Inc. Calgary

Abstract

The intent of the study has been to find a reliable way to characterize the production decline and predict ultimate recovery as soon as possible after the start of production in unconventional gas wells.

The first iteration of our approach has been to rescale the data by using the logarithm of the cumulative production instead of the traditional production parameter (Mcf or Bcf). This allows to create single decline curves that combine multiple curves. We refer to this parameter in our graphs as the “normalized production index”. The advantage of this rescaling is to be able to inspect the behavior of the production rate (the proxy being the log of production divided by the number of days). Many wells can thus be plotted at once and the curve of a single well or group of wells is typical of an inverse function (harmonic behavior) that is a simple and very reliable mathematical function.

The adequacy of the inverse function for describing the decline of gas production has been tested for various formations from many basins, mainly addressing shale gas and tight sands. After testing more than 160,000 tight sand gas wells, we applied the same analysis to hundreds of wells from the Montney hybrid shale as well as to more than 11000 wells from the Barnett shale. We will show results from these three data sets; we also analyzed other unconventional units such as the Milk River and Second White Specks from Alberta.

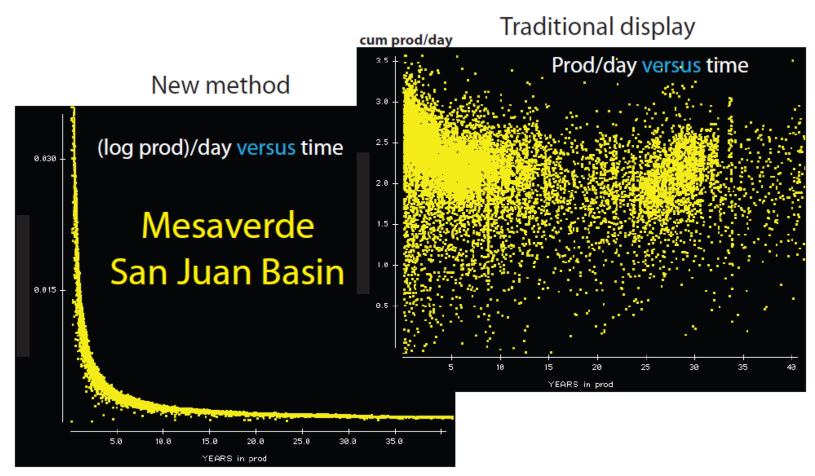
Each extracted data set is unique; thus the Tight Gas Sand data consists of final production volumes; the Montney data consits of the monthly data with producing hours but only 21 data points per well were used; finally, the Barnett shale data set has the monthly production but the precision is less than for any Canadian data set (hourly data for Montney, Milk River and Second White Specks).

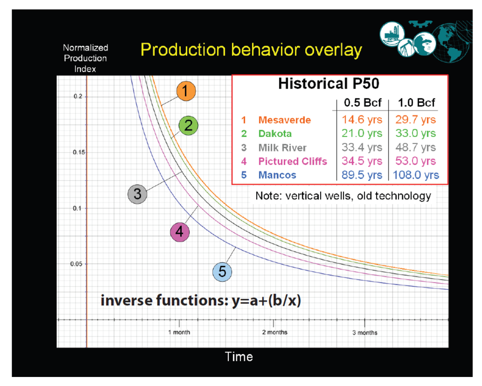
Results from our analyses confirm repeatability of the results, even from one basin to another when dealing with the same stratigraphic tight sand units. An in-depth analysis performed on hundreds of wells, representative of the Barnett shale, has demonstrated that the inverse function gives an excellent match to the decline curve when starting with the first half year production after peak production, i.e. eliminating the peak month of production and the data of the next 5 months. Comparison with normal decline curves shows a good match with the inverse function. The latter is a very stable mathematical function y=a+(b/x) and the same values are obtained with any su itable software; moreover the results are not program or operator dependent (e.g. b factor).

Method tested

on

Tight sands

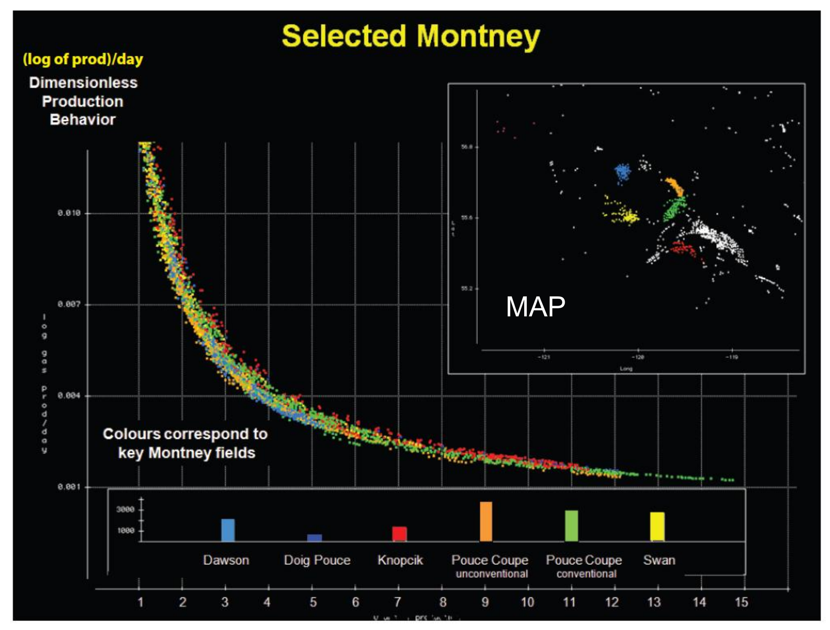




Method applied

on

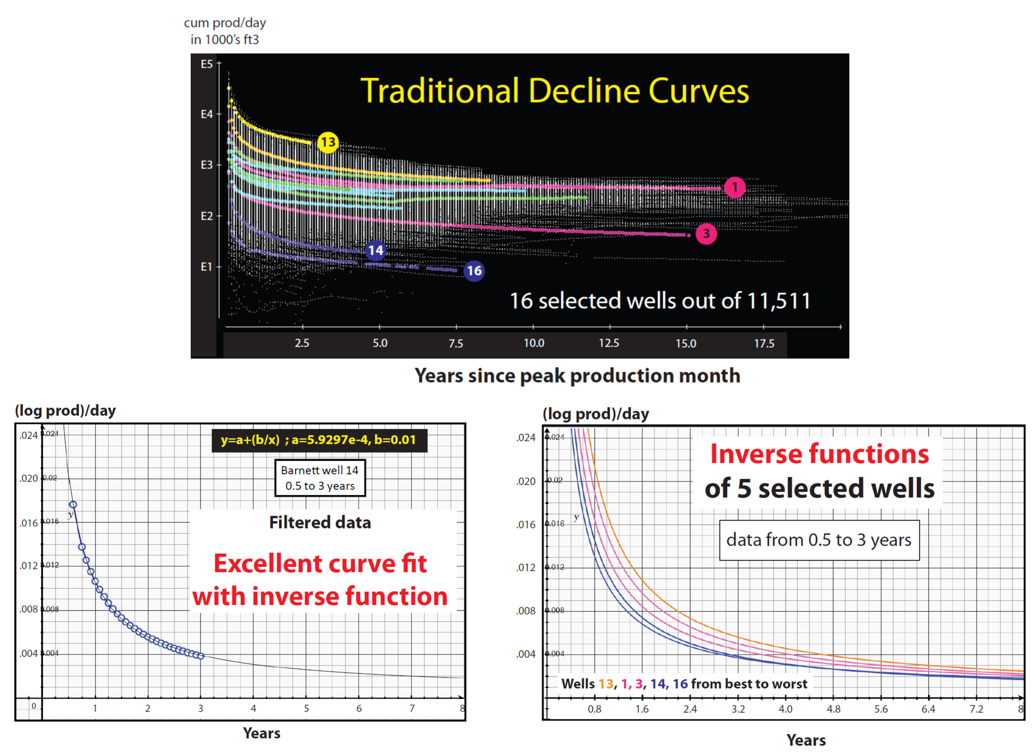
Montney Shale



Method verified

on

Barnett Shale

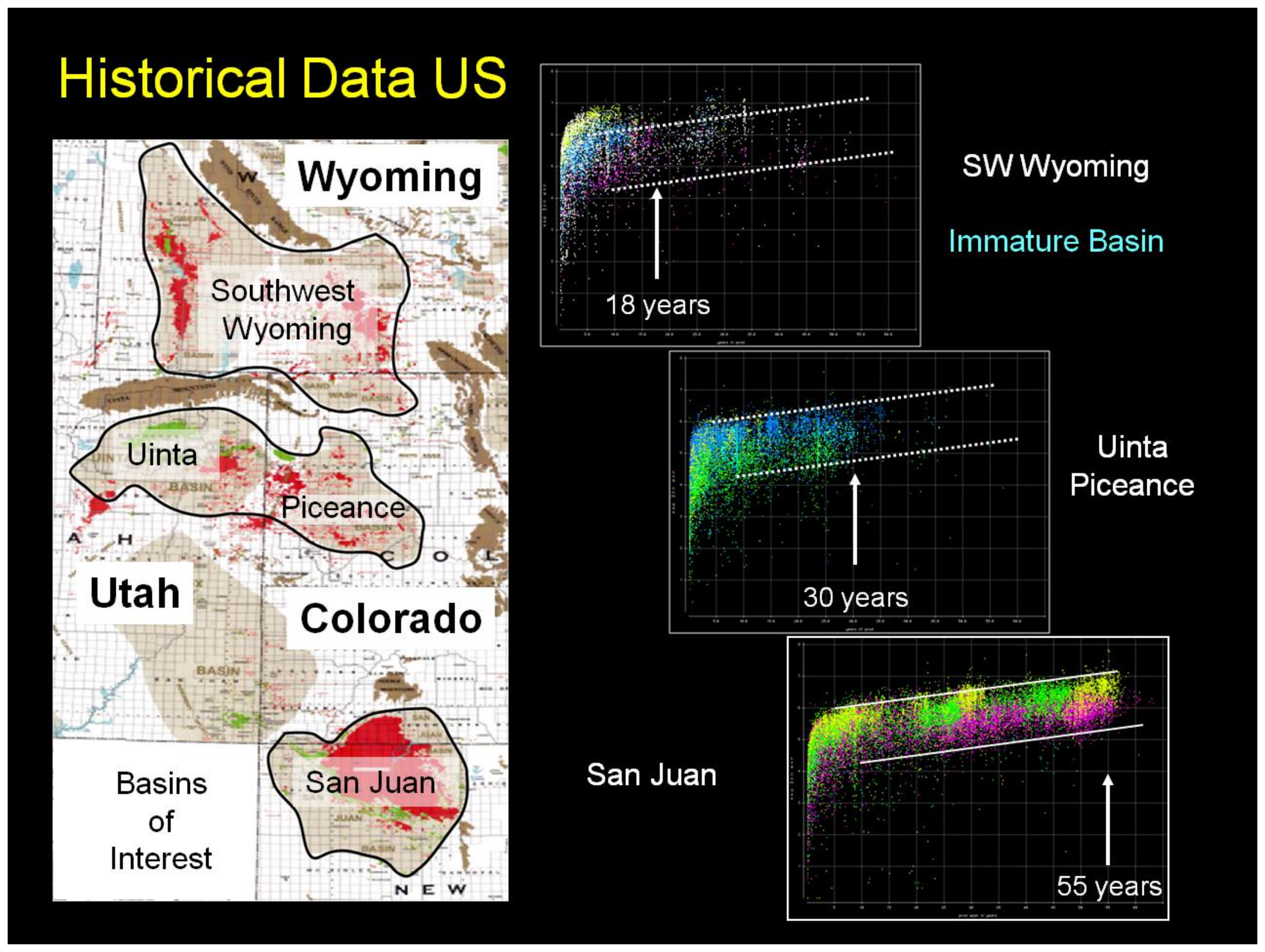


Traditional Production Profiles (tight sands)

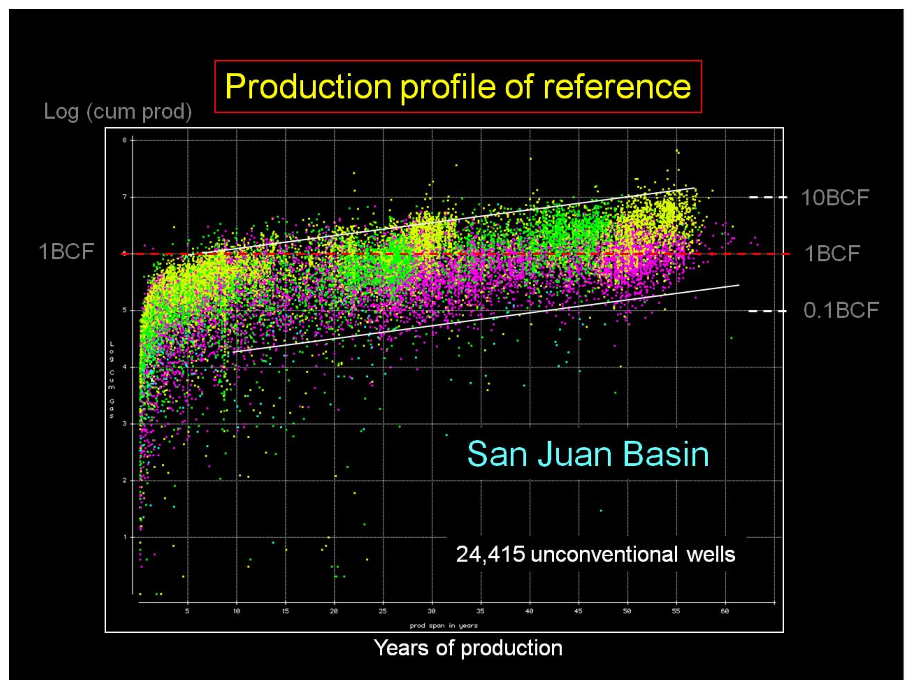
Tight sands | Multi Basin Study | Repeatability | Cum Production Data

Dissecting the Data

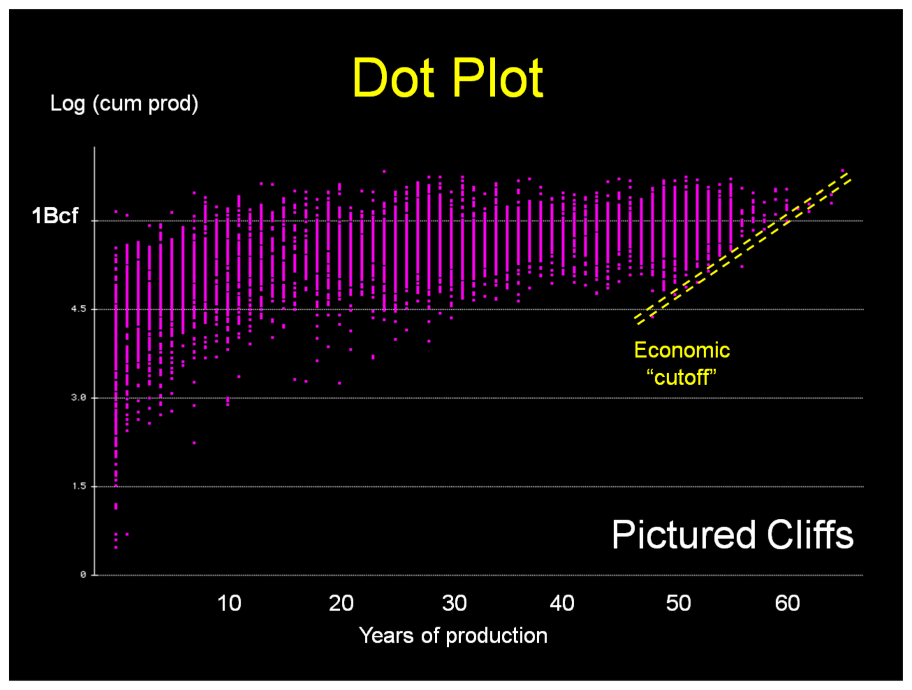
Production profiles

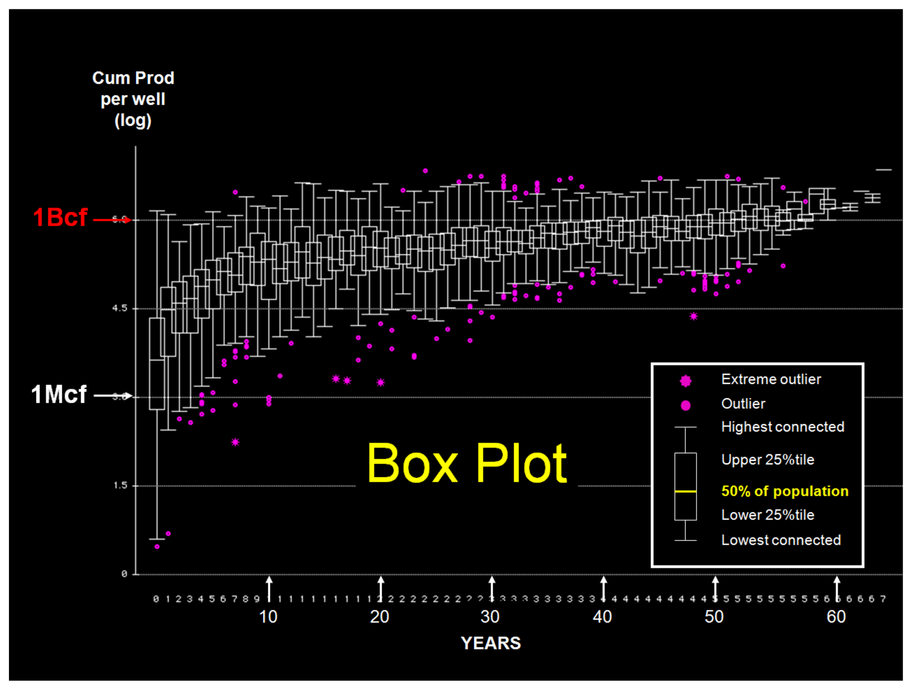


One data point per well: cum production



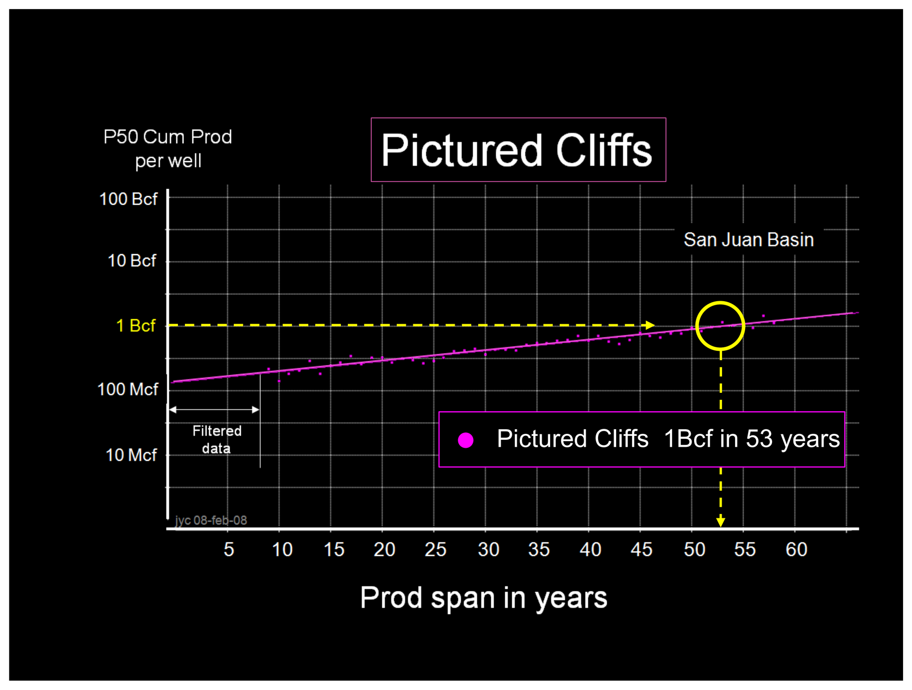
San Juan Basin

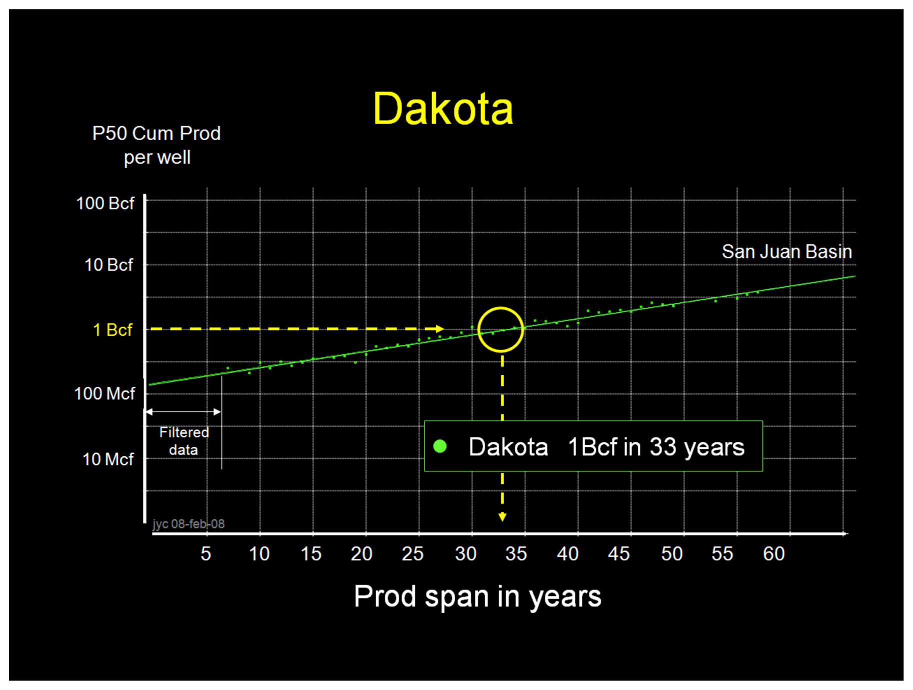


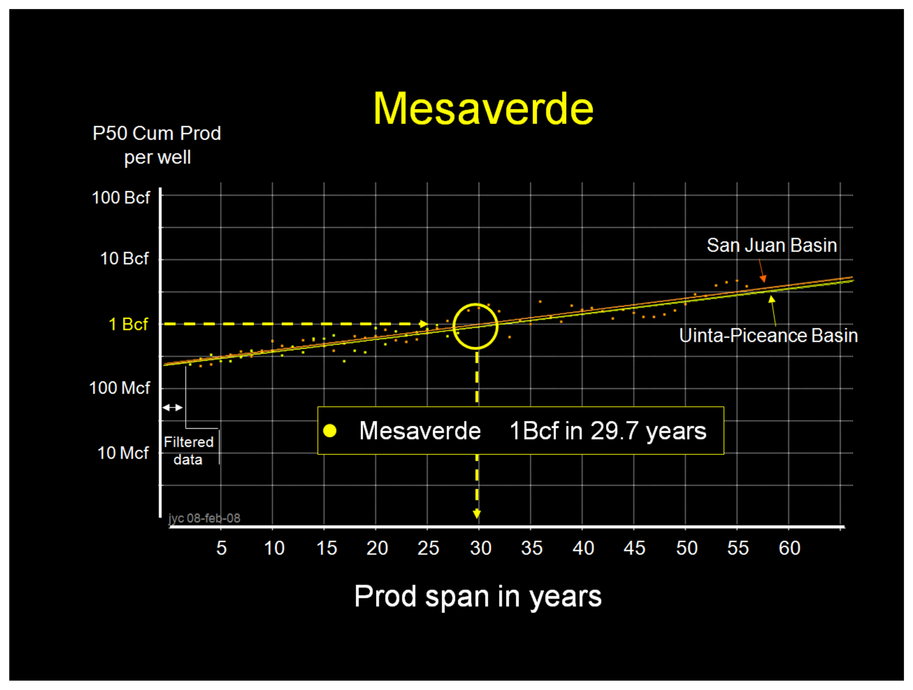


Essential Statistical Values

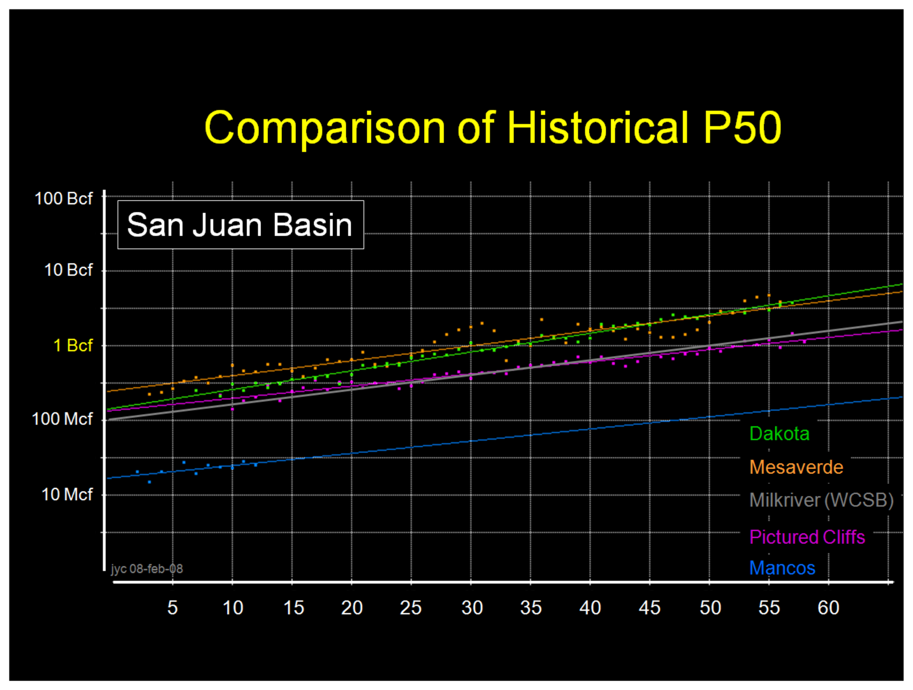
Trends using P50







The P50 is always slightly optimistic as wells that stop producing early are not taken into the statistical analysis of later years

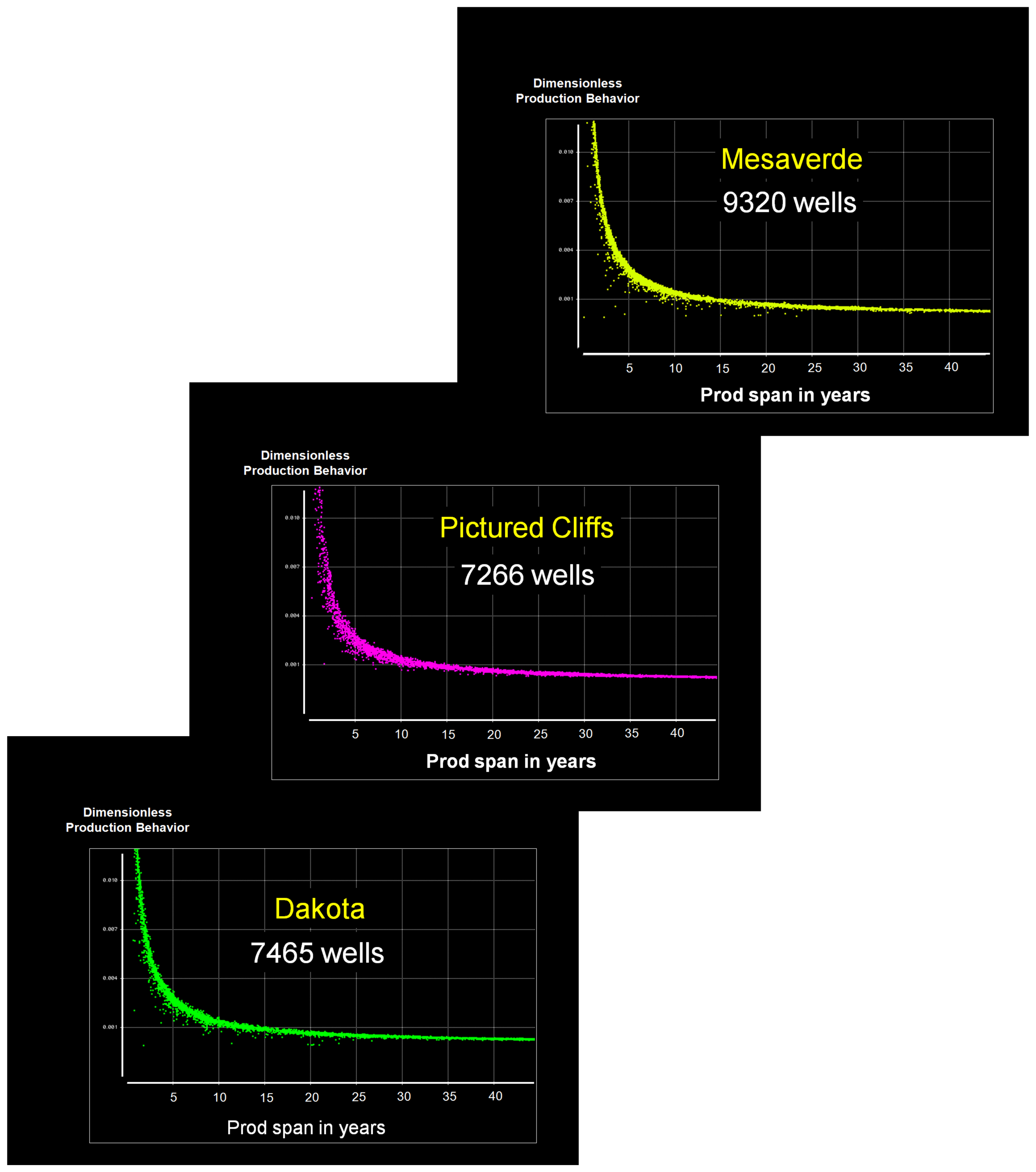


The P50 trends do however give a good view of the productivity of a formation against others

Rescaled Decline Curves (tight sands)

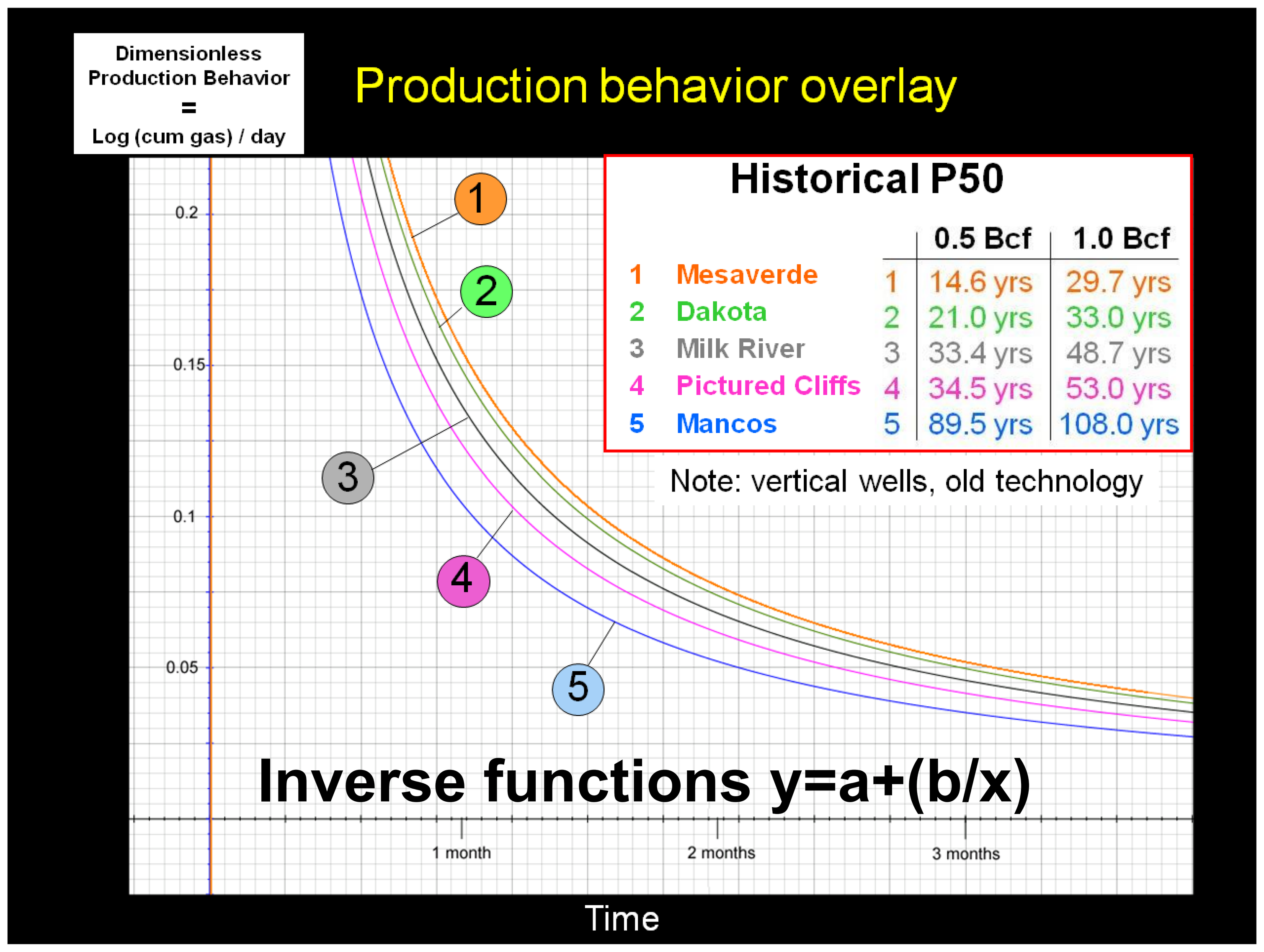
Tight Sands | Multi Basin Study | Repeatability | Simplicity

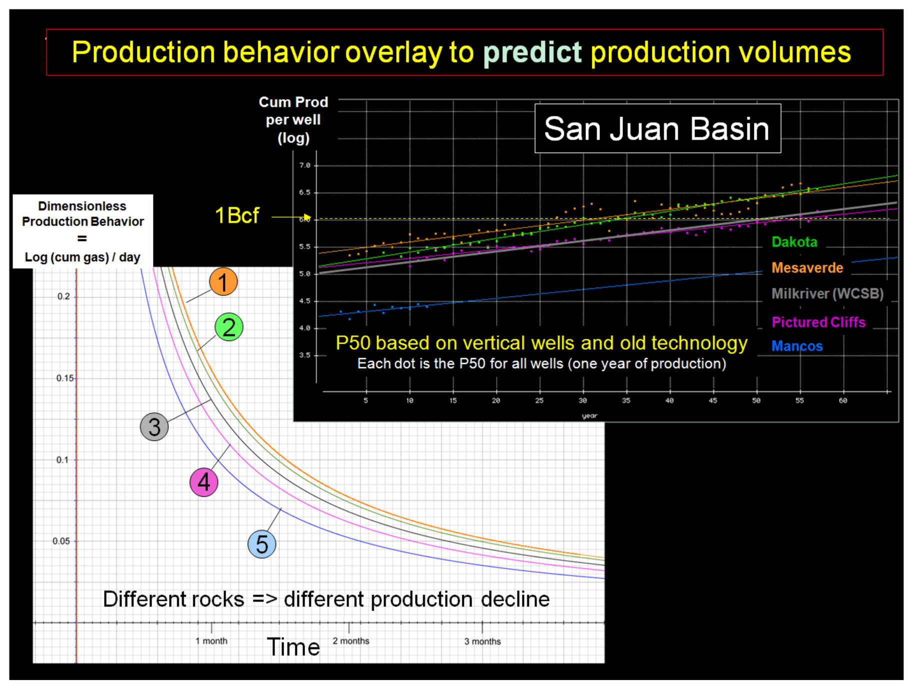
Various Formations



Inverse Functions

Log (cum prod) / day



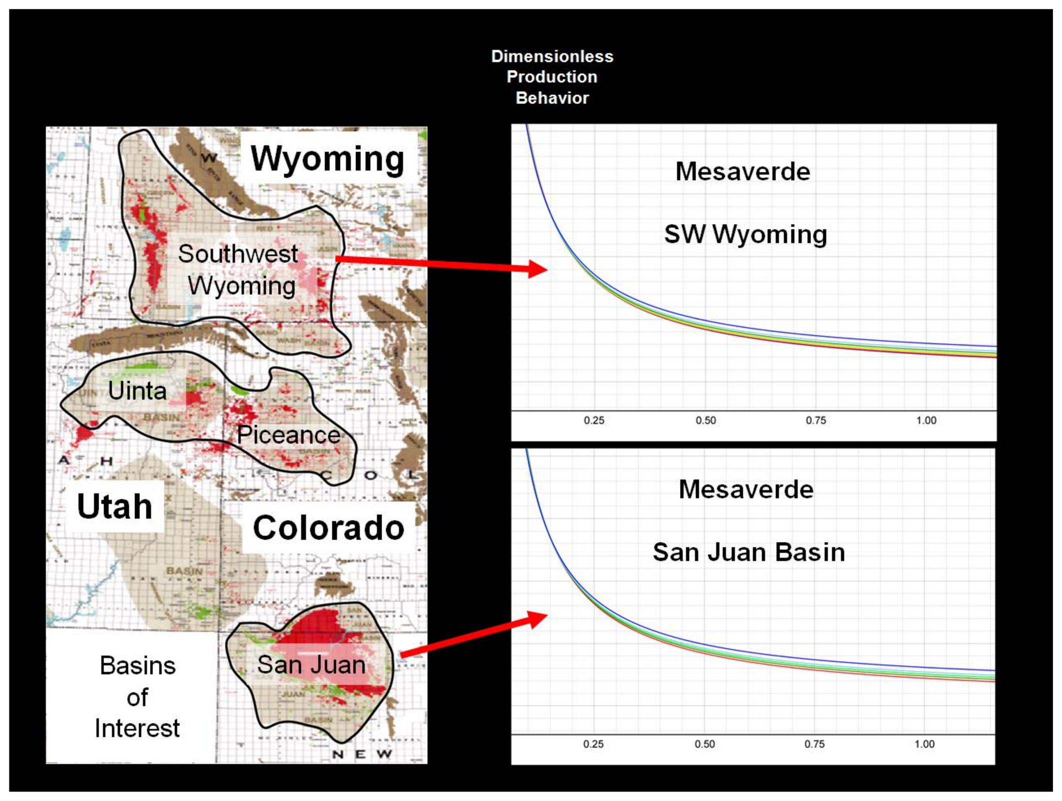


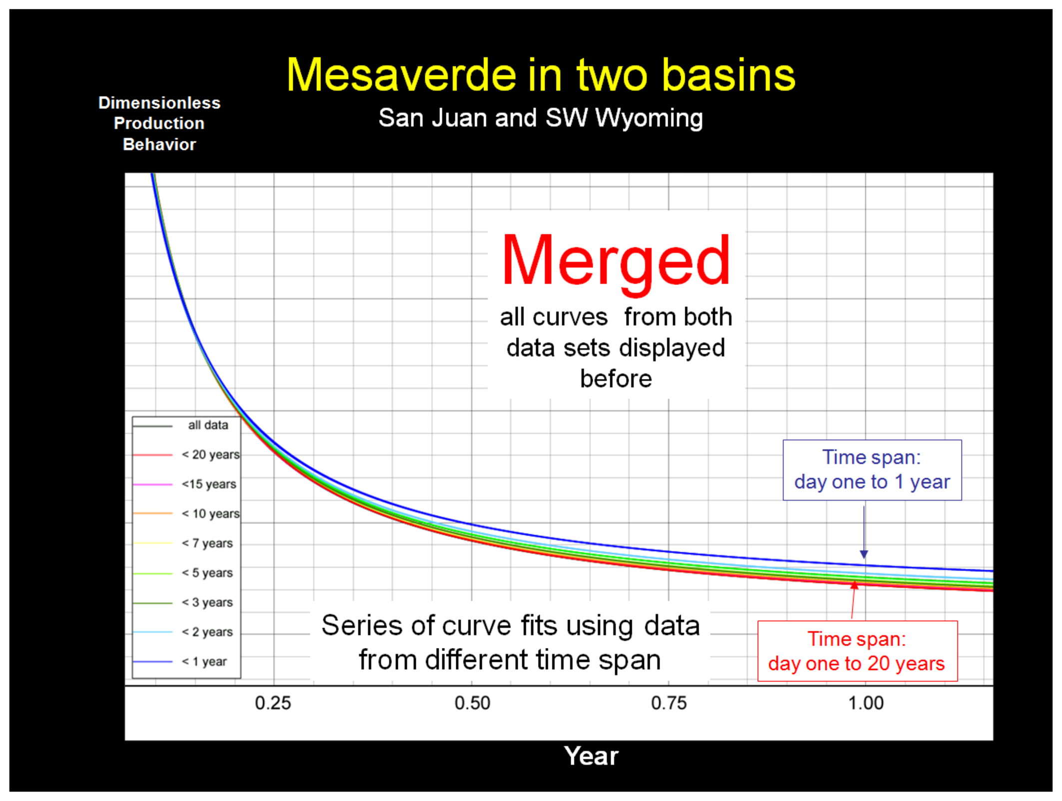
Inverse functions based “decline curves” honor the production data very well;

They allow quick comparison between wells and rock units;

They are perfectly suited for multi well studies as they allow to combine wells together

Basin Comparison





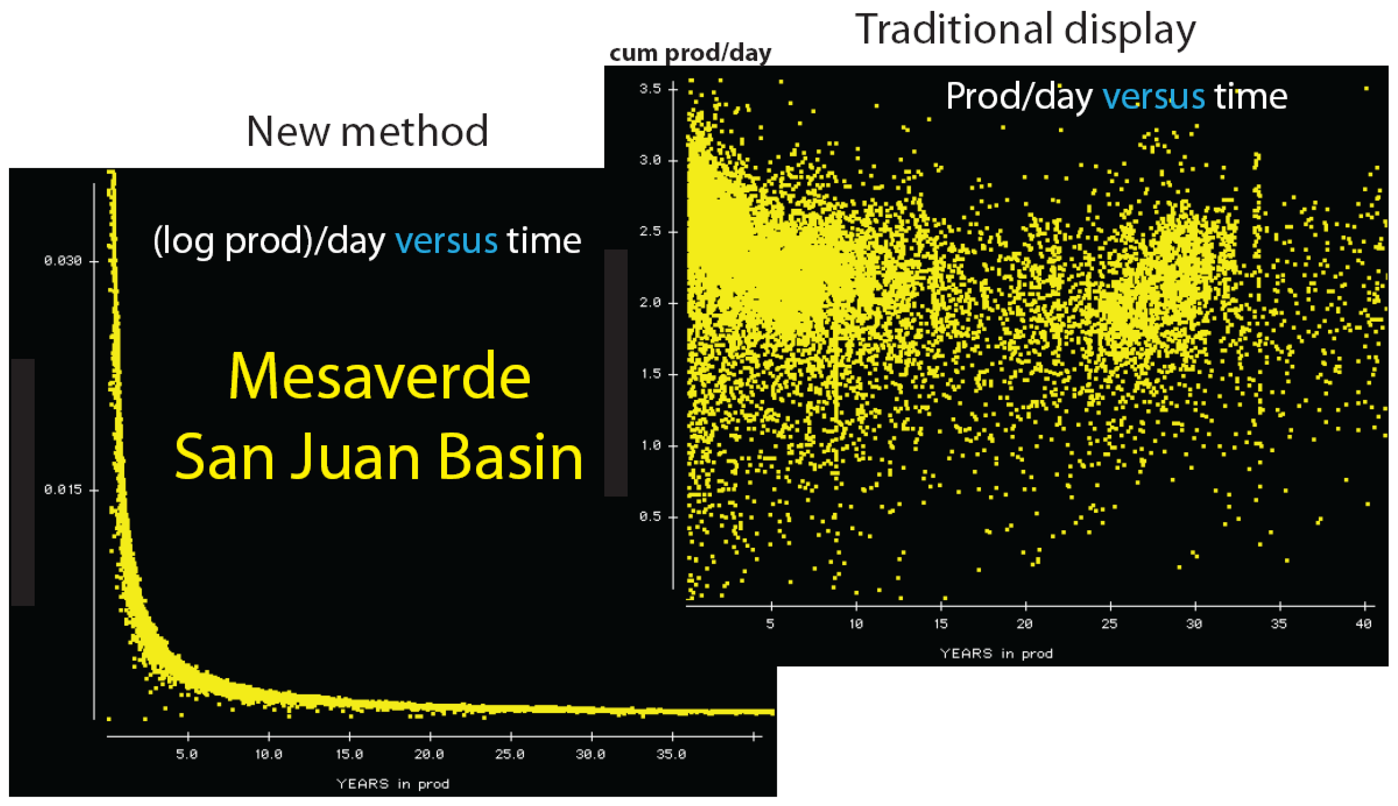
How much data is needed?

Several production data set have been created by restricting the data to a fixed number of years (20, 15, 10, 7, 5, 3, 2, 1 yrs)

The production of the Mesaverde has been separately studied for two individual basins

The results indicate that the same results are obtained for the same formation in different basins when using the same number of years of production

Conclusion



Conclusions for tight sands

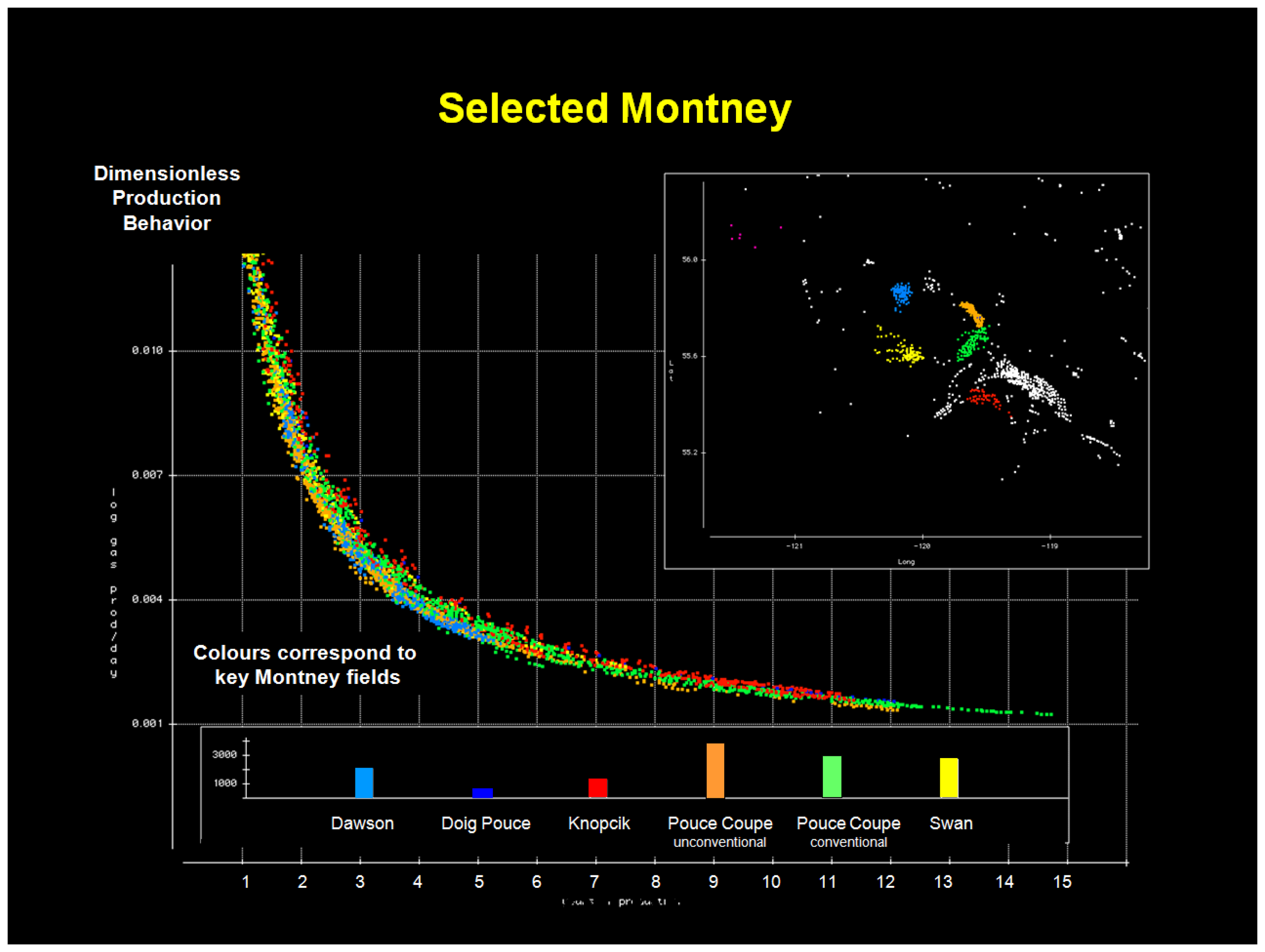
- Log (cum prod) / day is the parameter used instead of cum prod / day
- Inverse functions y=a+(b/x) characterize well production behaviors
- Very good match between cumulative production and inverse functions
- Repeatability between basins when using same production duration
- Analyses overestimate the recovery when smaller time intervals are used

Rescaled Decline Cuves (Montney shales)

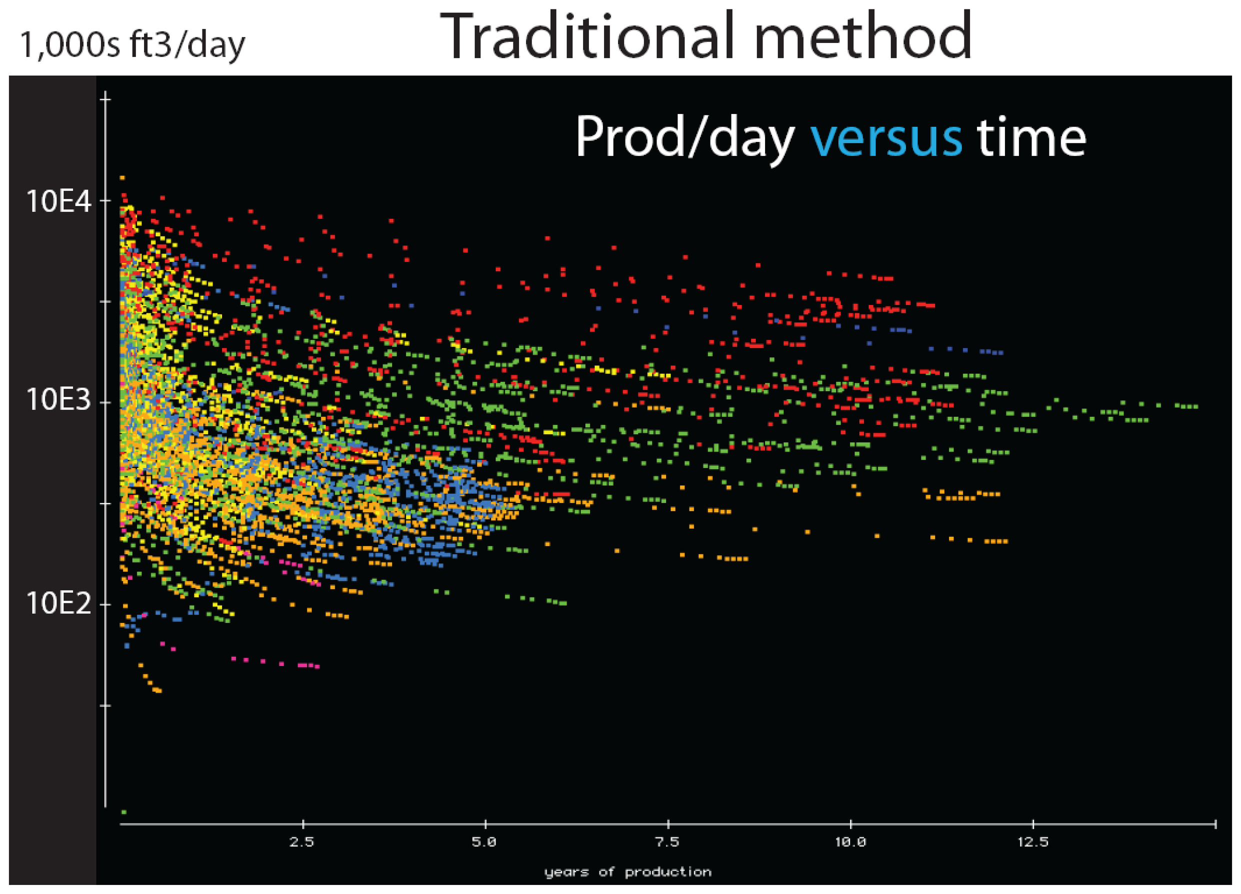
Hybrid Shale | Alberta | Non-continuous data | Hourly precision

Power of Inverse Function

Inverse Functions

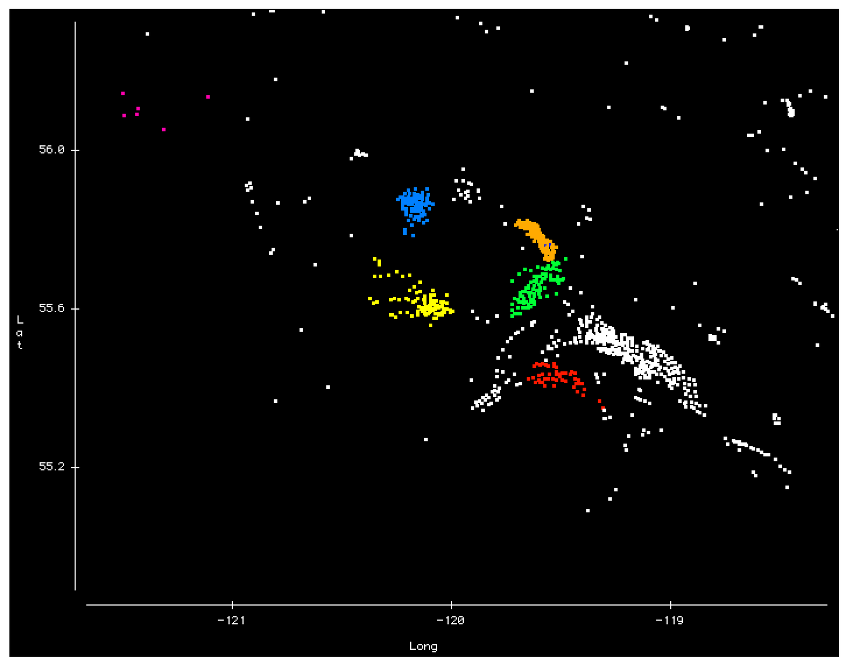


Log (cum prod) / day



Cum prod / day

Map



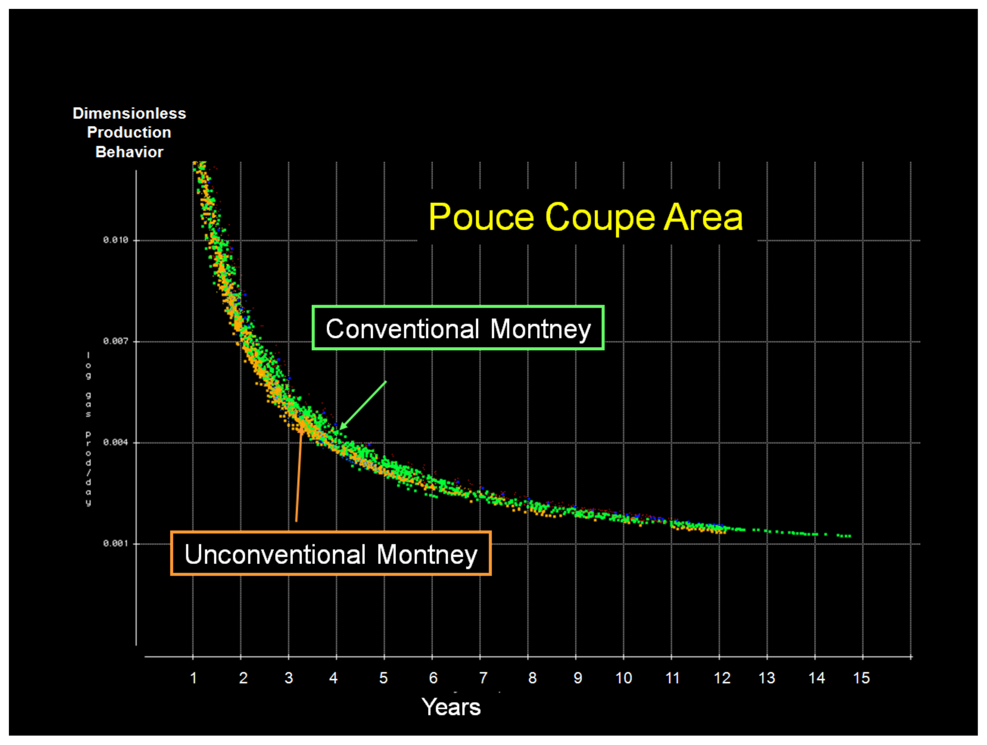
Hundreds of wells

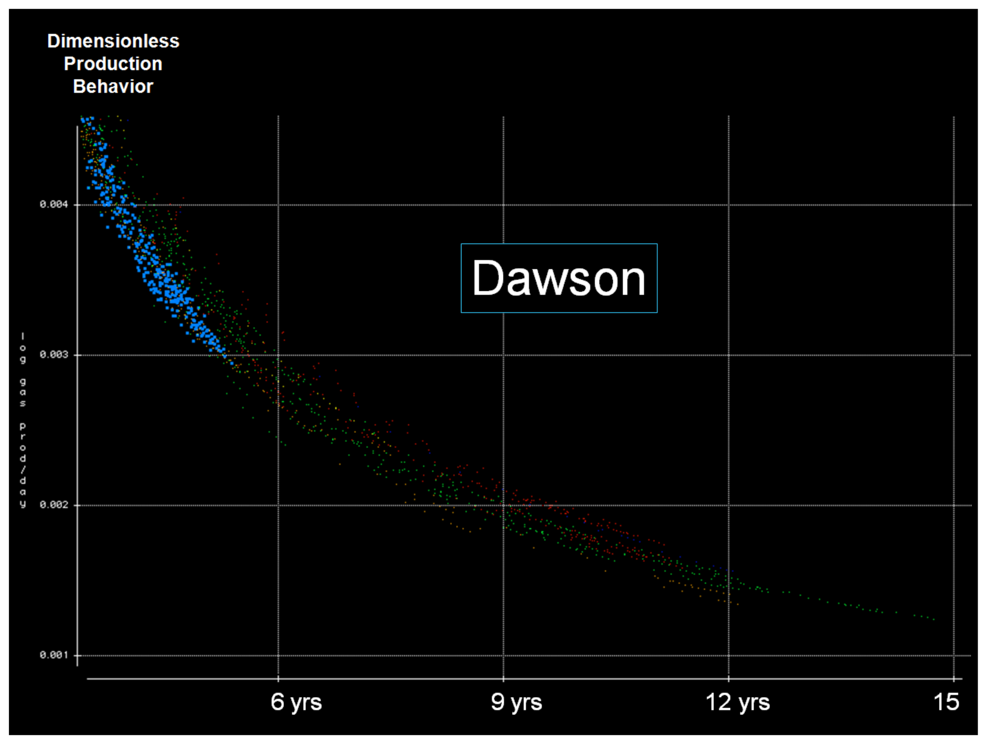
21 data points per well

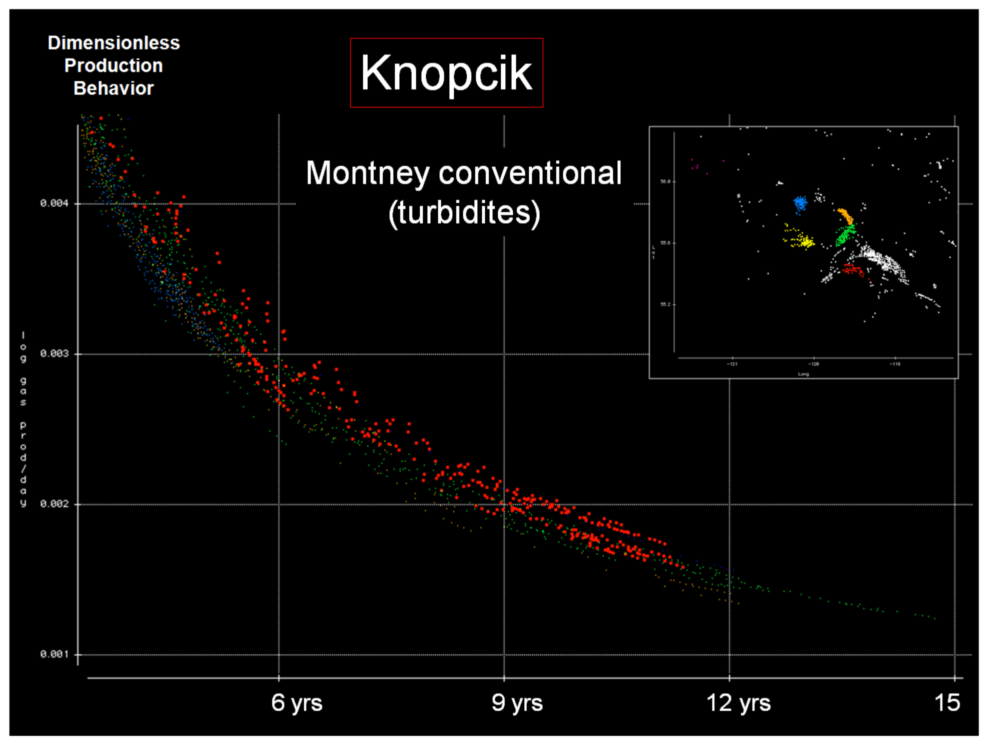
Different colors indicate different areas

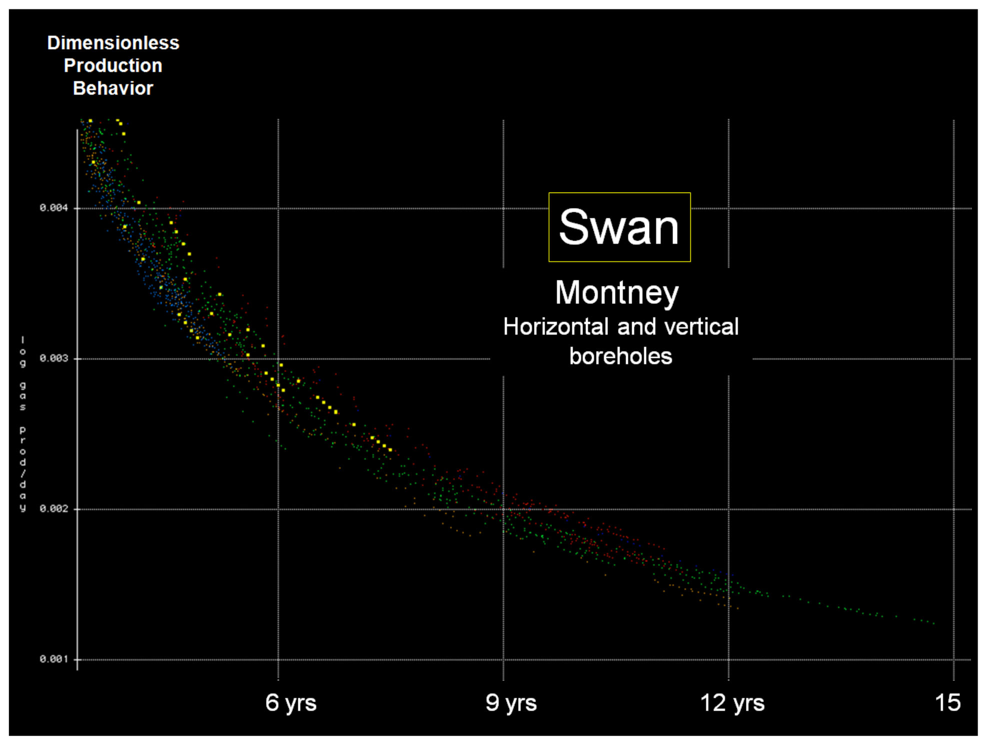
Marked Differences with Area

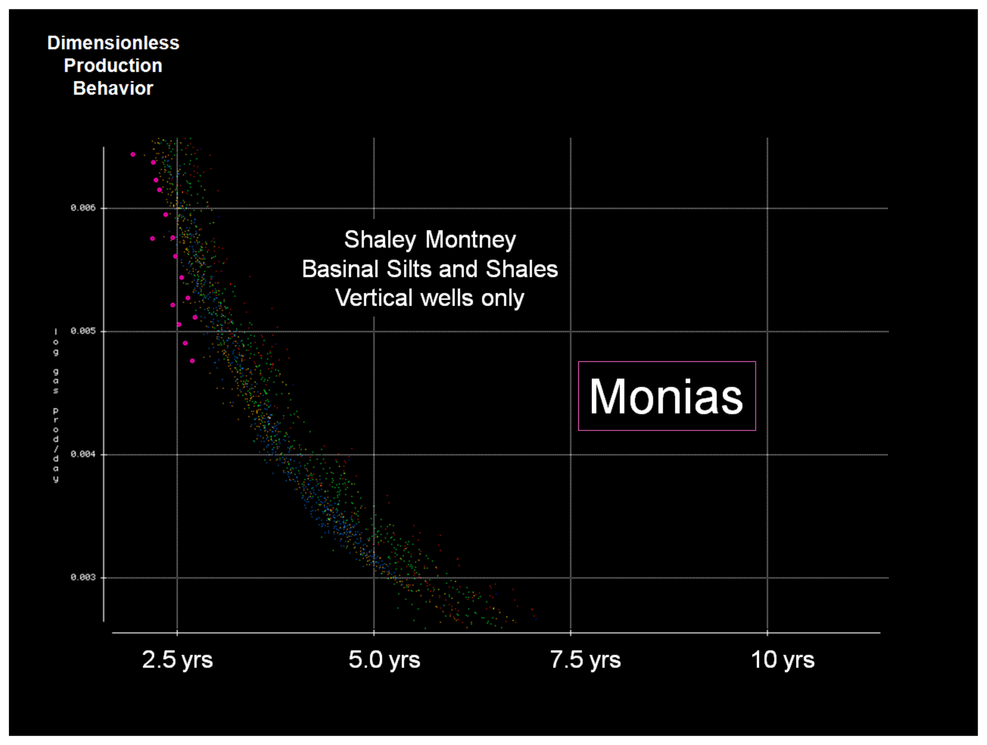
- Very large differences between various areas for the Montney Fm
- Very large differences between various Montney stratigraphic units
- 21 points are deemed sufficient to generate a reliable production profile for one well







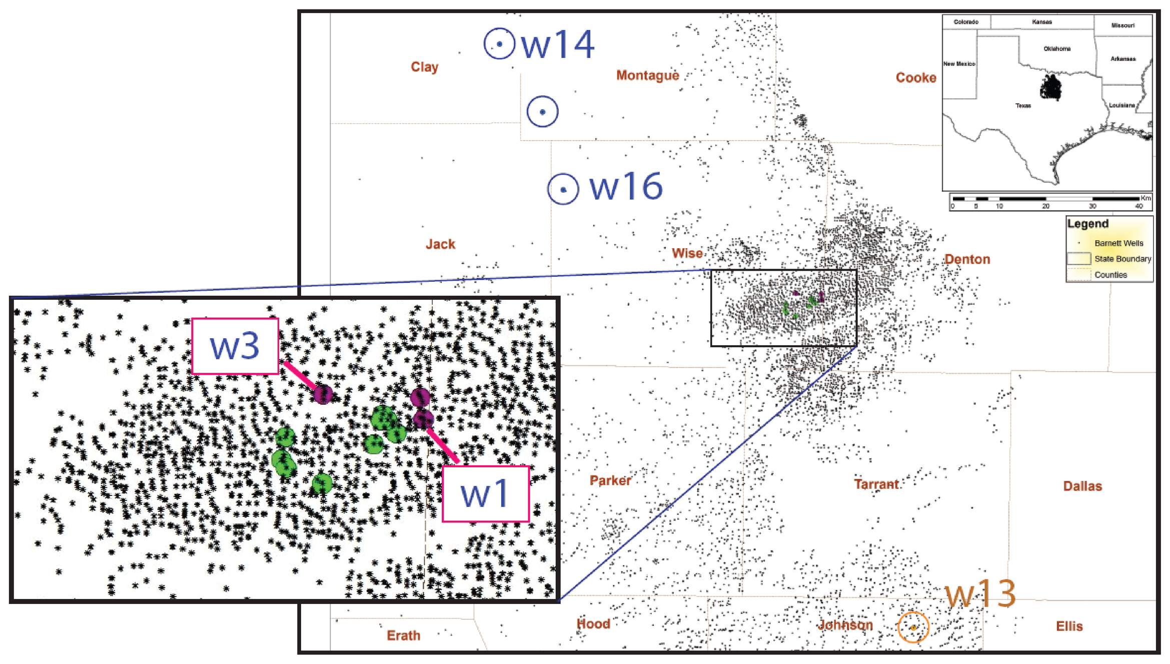


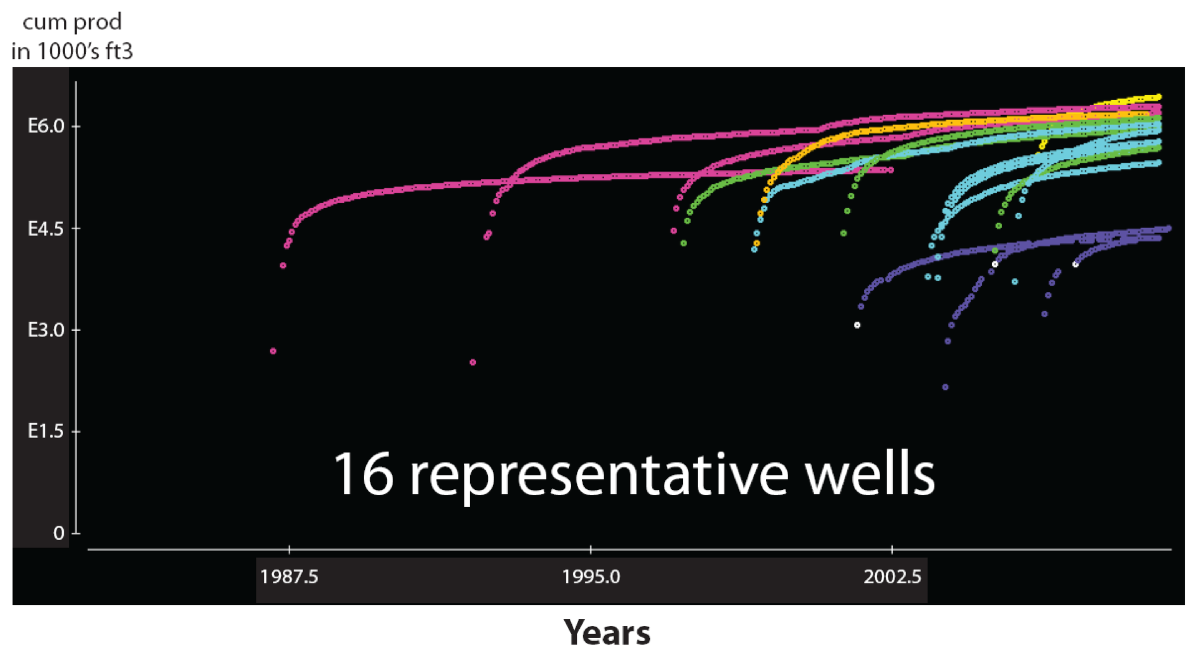


Rescaled Decline Cuves (Barnett Shale)

Barnett Shale | Monthly production | No hourly precision | 11,511 wells

Traditional Display Types

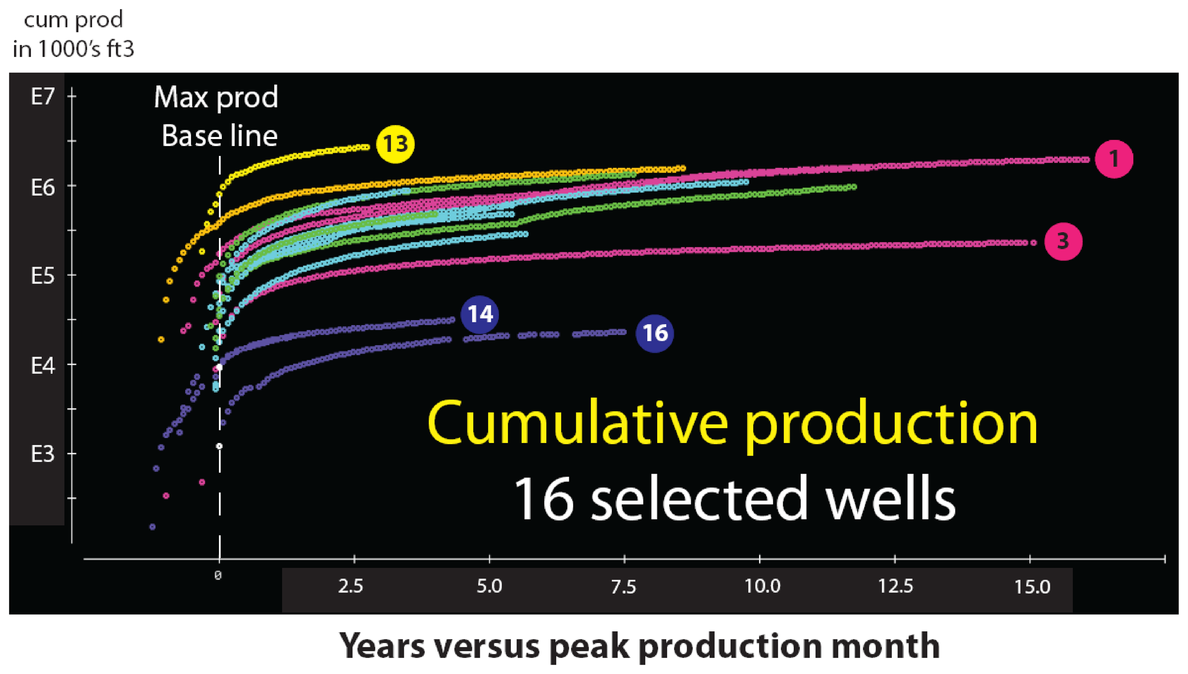


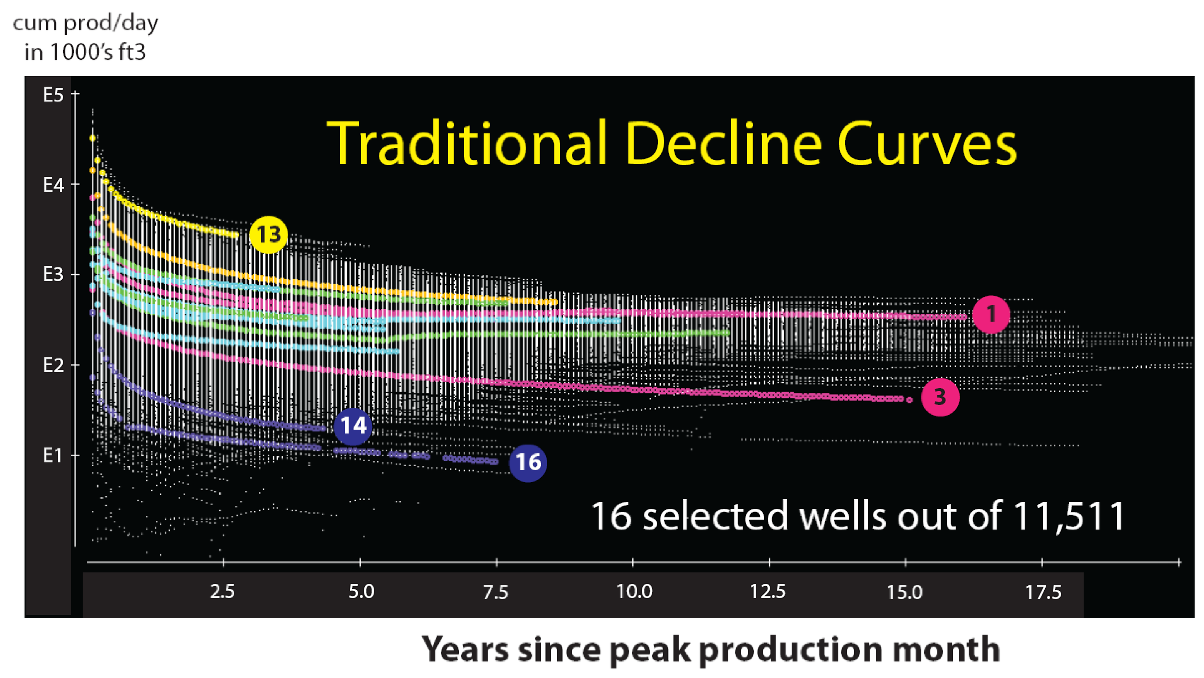


One data point
per production month

Selection of
variable type curves
for Barnett Shale

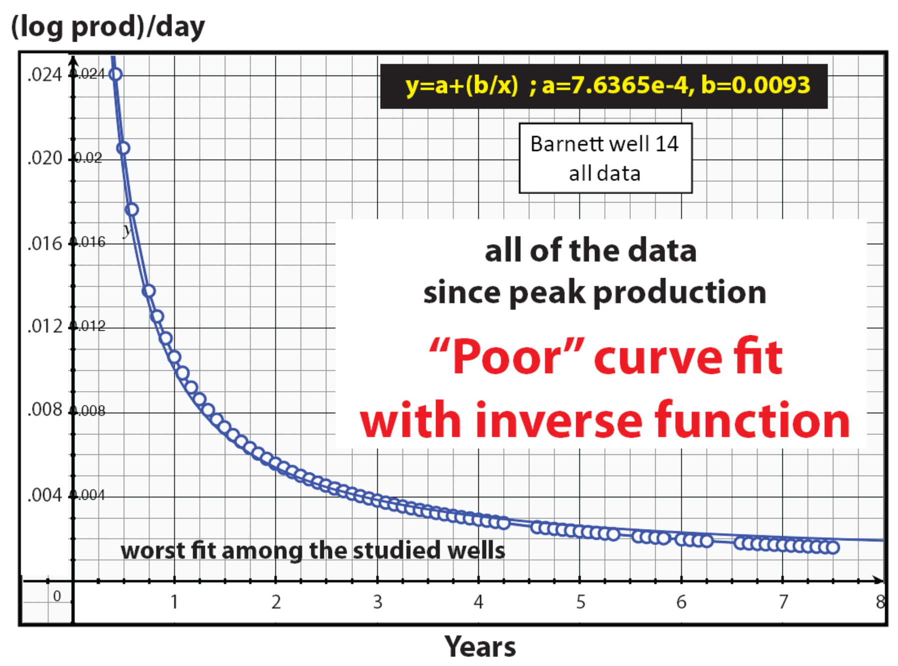
Note the variable
production time spans





Best Fit

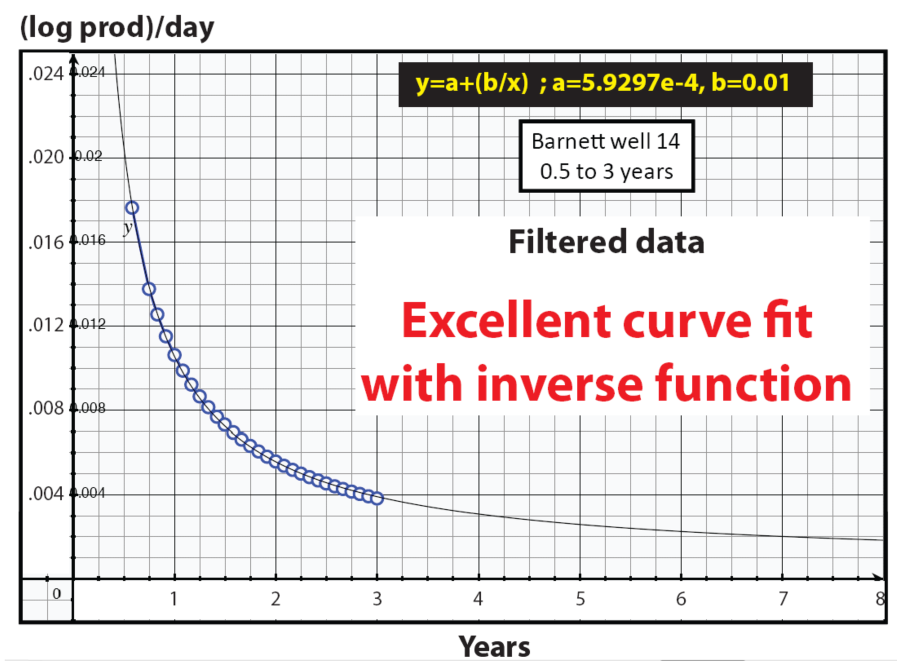
Inverse Functions



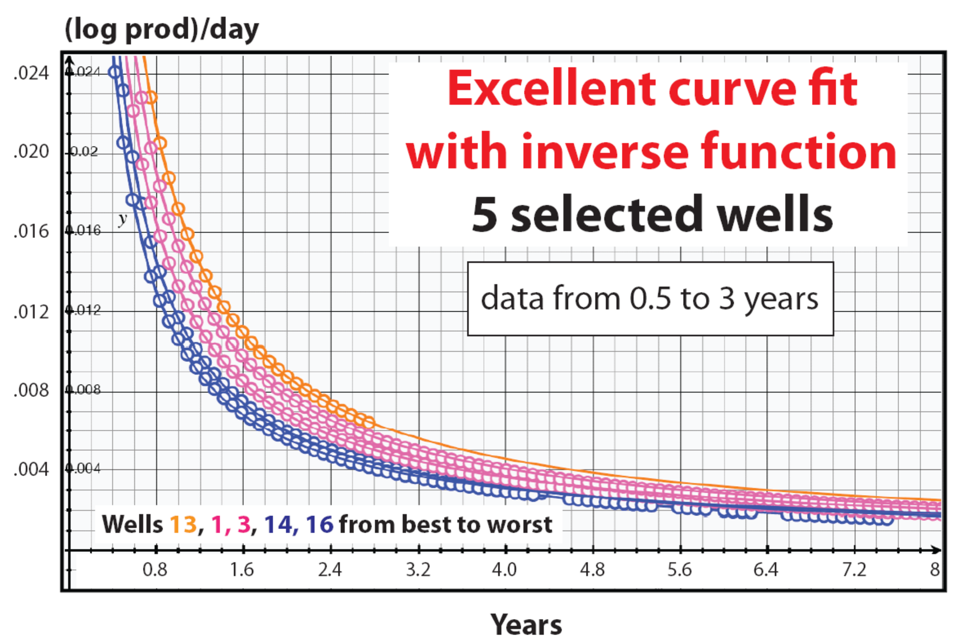
The first few months
of production can
induce poor fits

Best common fit is from
the 6th to the 36th month

Inverse Functions

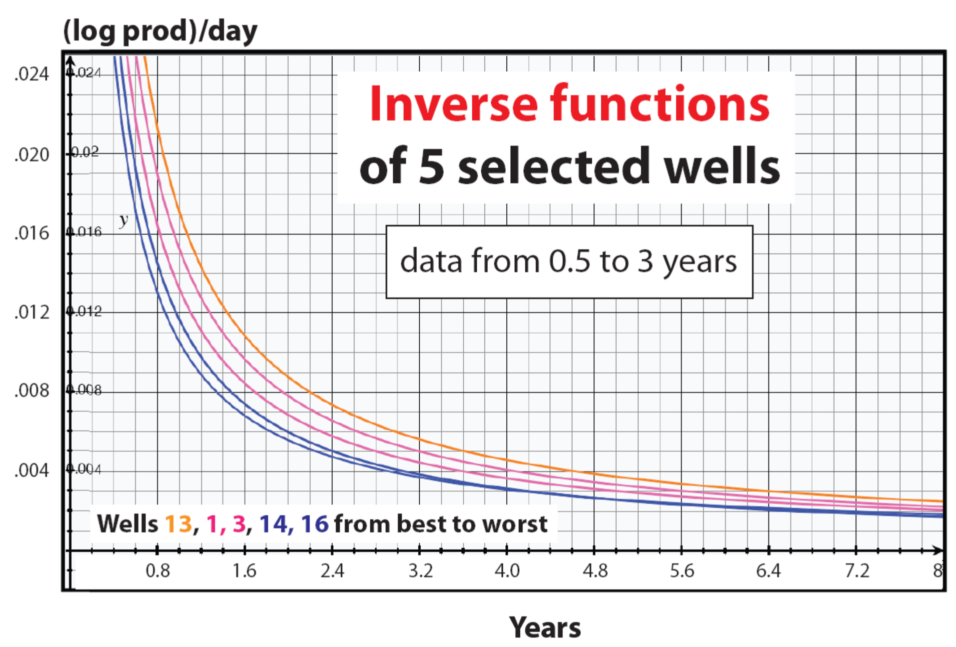


Easy Comparisons



Inverse functions
perfectly honour the data

Comparison between wells
and between areas
is very easy



Rescaled decline curves

Conclusions

Using the logarithm of the production as data input allows to better define the decline behavior of unconventional reservoirs

In all of our data sets the rescaled decline curves have constantly matched the historical data.

The main advantage of the new method is that many wells can be compared to each other in any analysis. Similar rock units in various basins have given matching curves.

The data is best matched by an inverse function, the fit is often perfect and does not require playing with the b factor of traditional curve fitting.

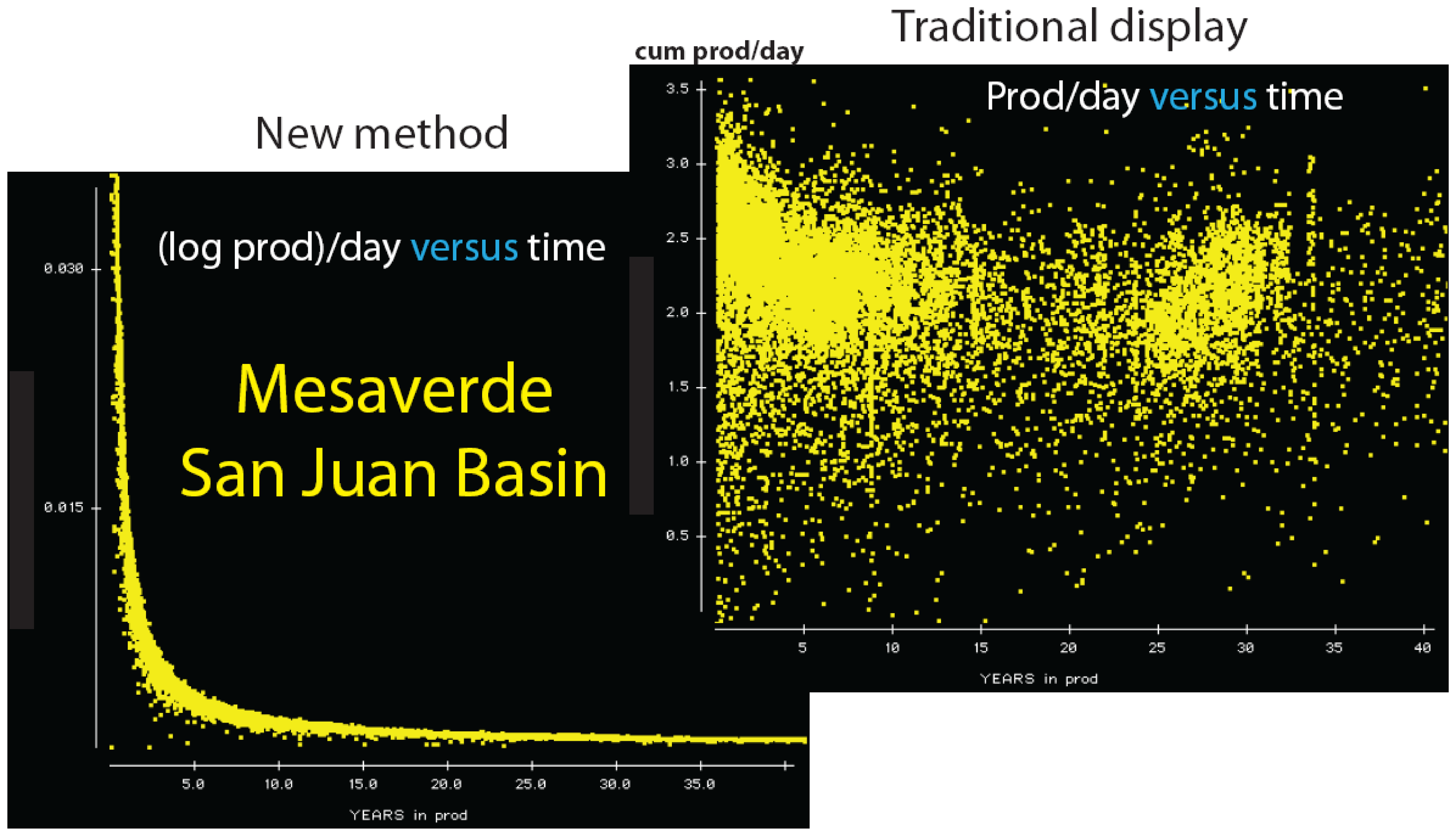
The new method can be used with:
a) Single values of cumulative production when compiling the data from numerous wells (tight sands example)
b) Random monthly production with precise hourly precision (example from the Montney Formation)
c) Typical monthly production, even if the exact amount of production hours is unknown (Barnett example)

In absence of hourly or daily precision for the production, a perfect inverse function curve fit is achieved when eliminating the first five months of production that start from the month of maximum rate.

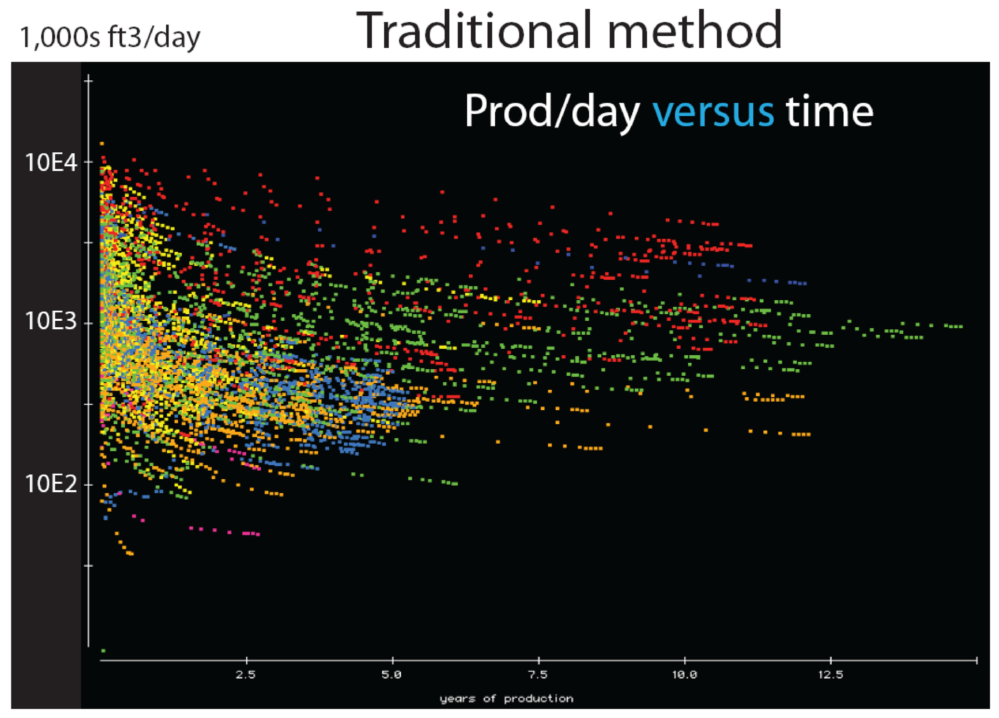
Wells with shorter production record (time) will give more positive results than wells will longer production record. Thus keeping the comparison to similar time span greatly improves the validity of the results and the match between data and curve fit.

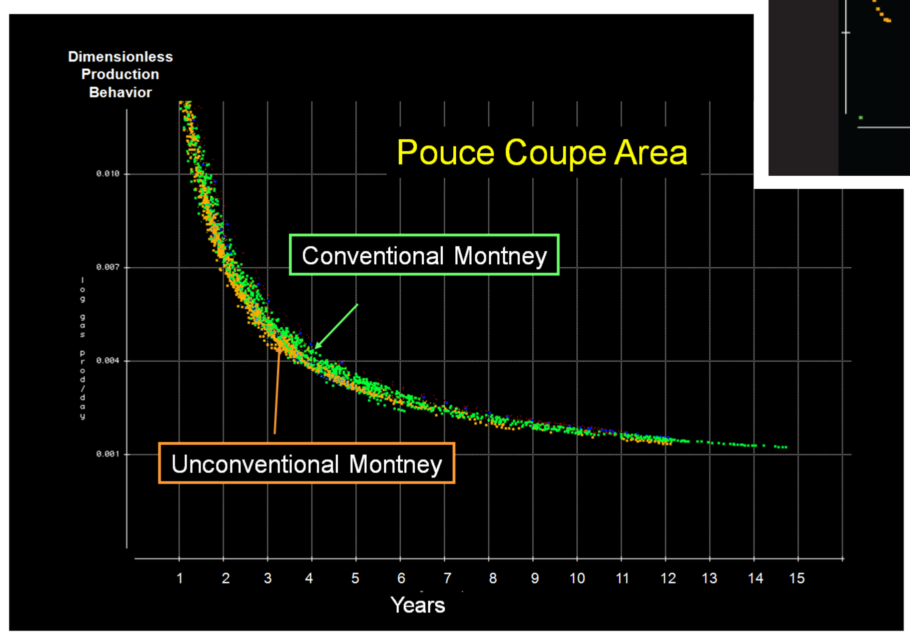
Acknowledgments

We would like to thank Talisman Energy Inc. for permission to present this material



Montney
Hybrid Shale





Barnett
Shale