

Predicting Cumulative Production of Devonian Shale Gas Wells from Early Well Performance Data, Appalachian Basin of Eastern Kentucky

Brandon C. Nuttall

Kentucky Geological Survey

With contributions by Shannon Daugherty

Eastern Section AAPG, Lexington, Kentucky

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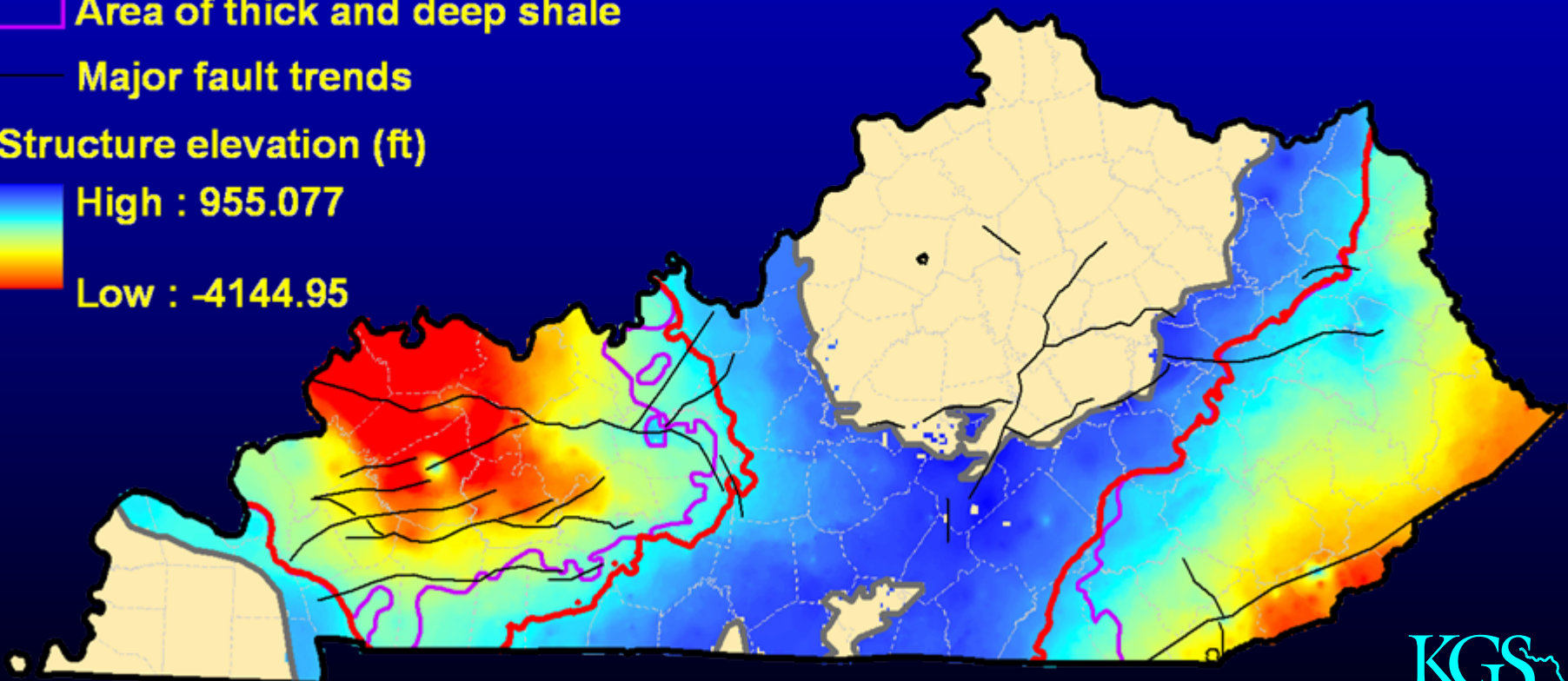


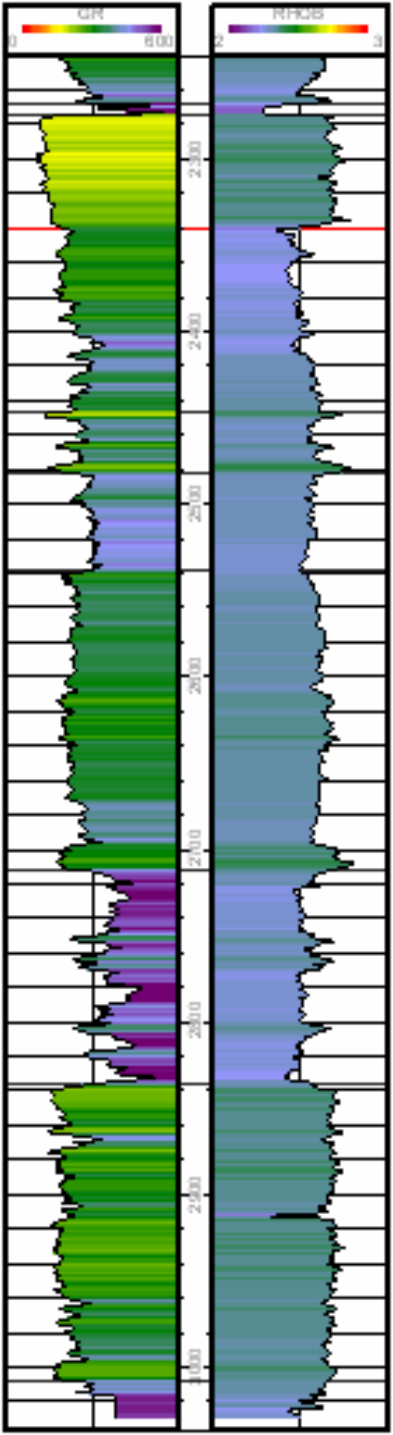
Geology of Devonian Shale

Key

- Limit of shale occurrence
- 1000 ft drilling depth
- Area of thick and deep shale
- Major fault trends

Structure elevation (ft)





Sunbury

Berea



Cleveland

Three Lick Bed

Upper Huron

Ohio

Middle Huron



Lower Huron

Olentangy

Rhinestreet

A “shale” well is...?

- Top Sunbury to top underlying carbonates



A photograph of a shale quarry. In the foreground, a green lawn is partially visible. A white sign on a metal frame stands on the right side of the lawn. The sign has red text that reads "Shale For Sale" followed by two phone numbers: "957-5909" and "543-5294". Behind the sign is a field of tall, dry, brown grass. In the background, a large pile of dark, layered shale rock is visible, with several trees scattered around it. Some trees have green needles, while others are bare or have brown leaves. The sky is overcast and grey. Power lines and a utility pole are visible in the upper right corner of the image.

Shale
For Sale
957-5909
543-5294

Early Performance Data

- **Well log and completion report**
 - Initial Open Flow
 - Rock Pressure
- **Monthly production** (*805 KAR 1:180, KRS 353.205*)
 - Maximum monthly production (Mcf)
 - First year cumulative production
 - 5 year cumulative production

Data Sets

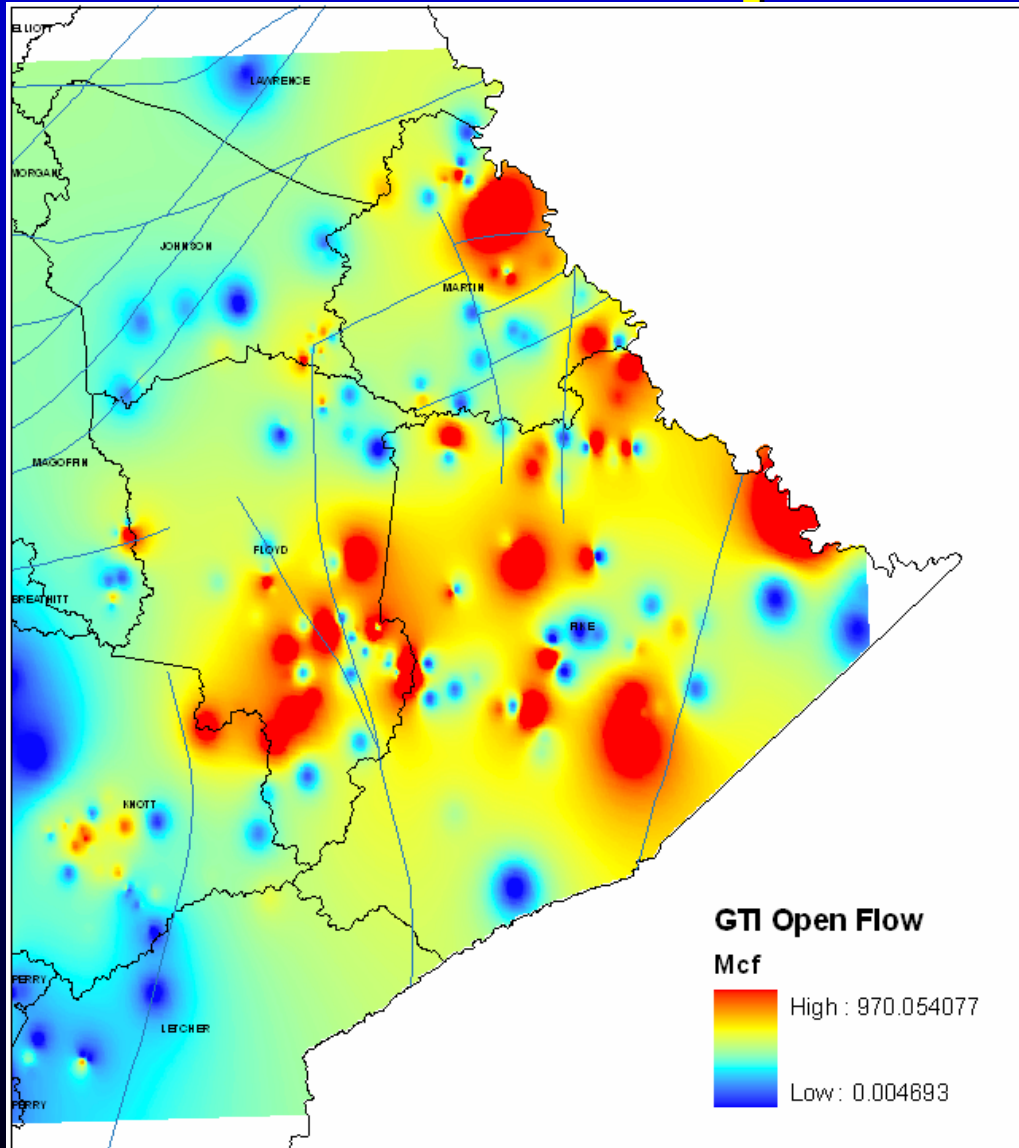
- **KGS online well completion data**
 - Location, completions, IOF, RP
- **Division of Oil and Gas**
 - Public production data by month (1997)
- **Gas Technology Institute (GRI)**
 - Historic, long-term production data
 - **Proprietary**, available to members and contractors

Production Data Selection

- Completed since 1-Jan-97
- Devonian shale only (not commingled)
- 60 or more months of non-zero data
- 310 wells

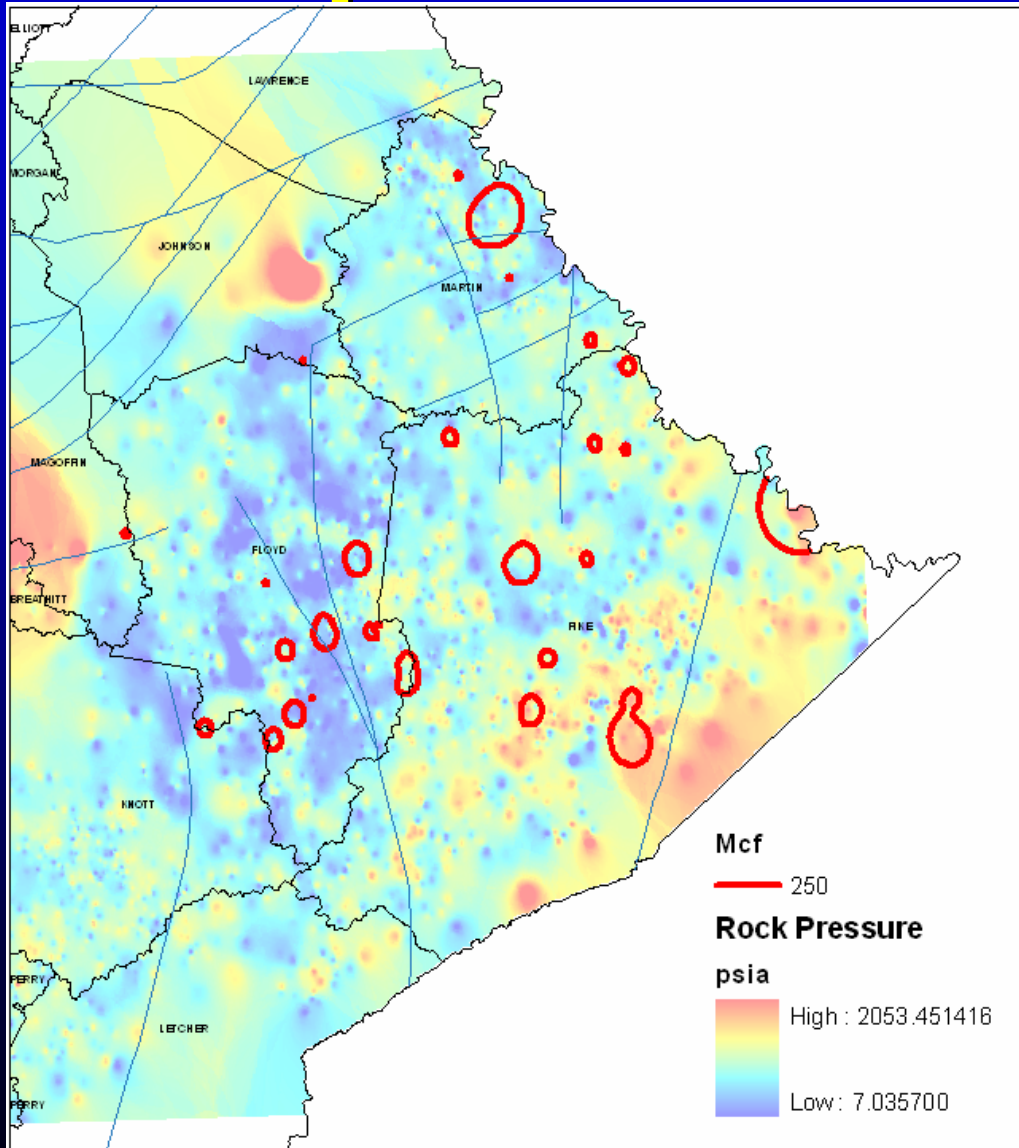


Initial Open Flow Data



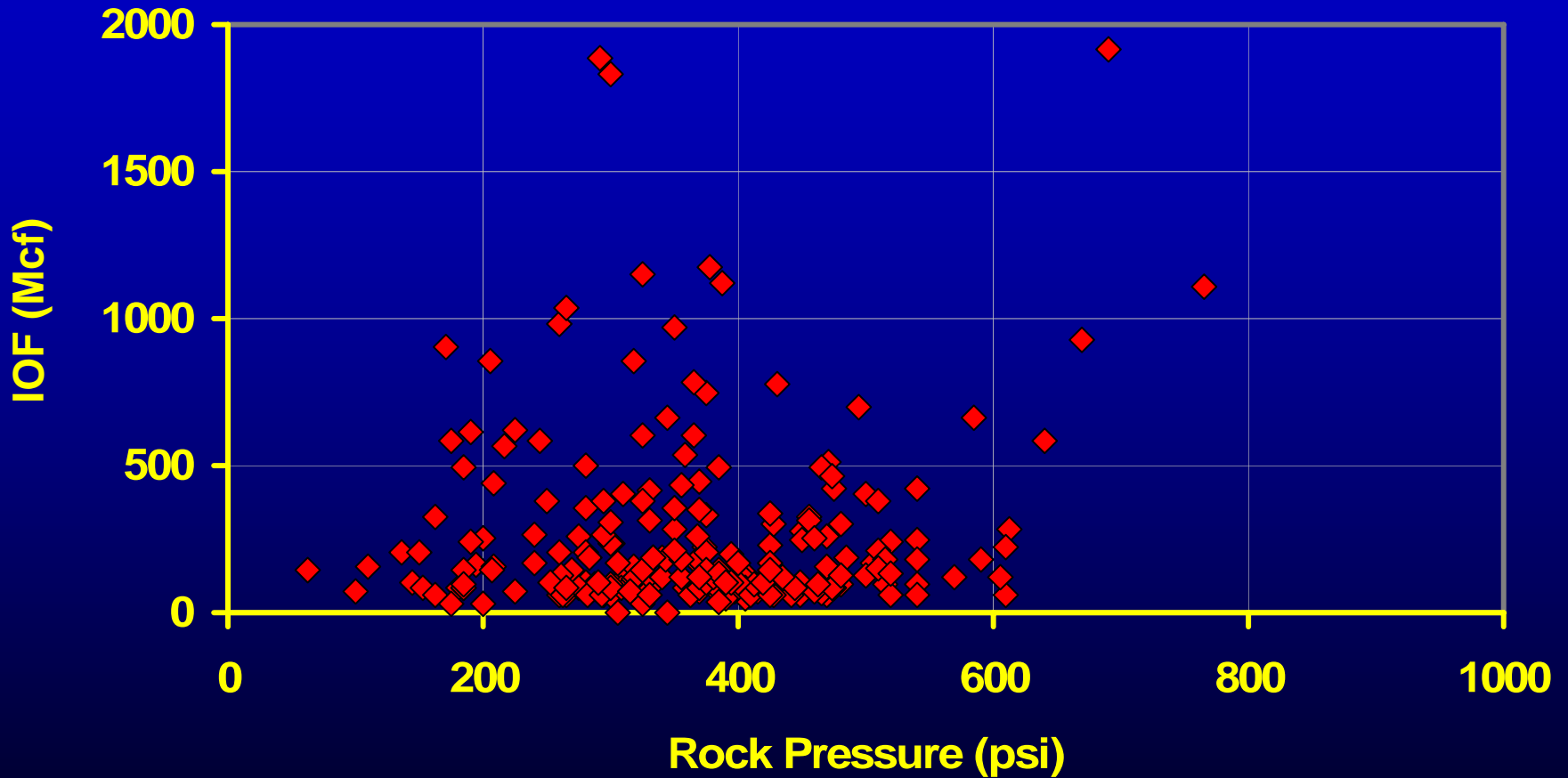
- Exhibits only weak trends
- No uniform method of acquiring

Reported “Rock Pressure”

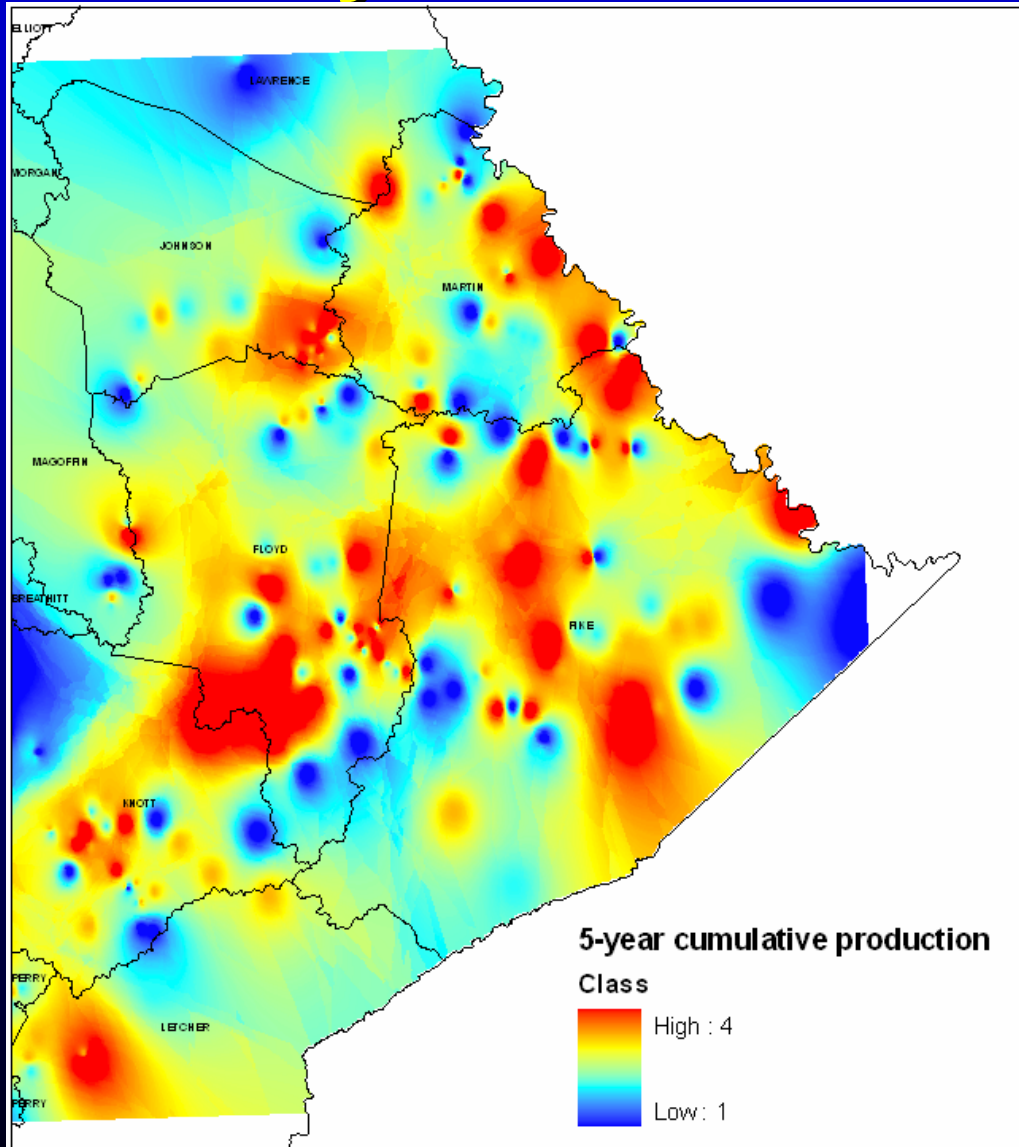


- High and low open flows occur in areas of both high and low rock pressure

Rock Pressure vs IOF



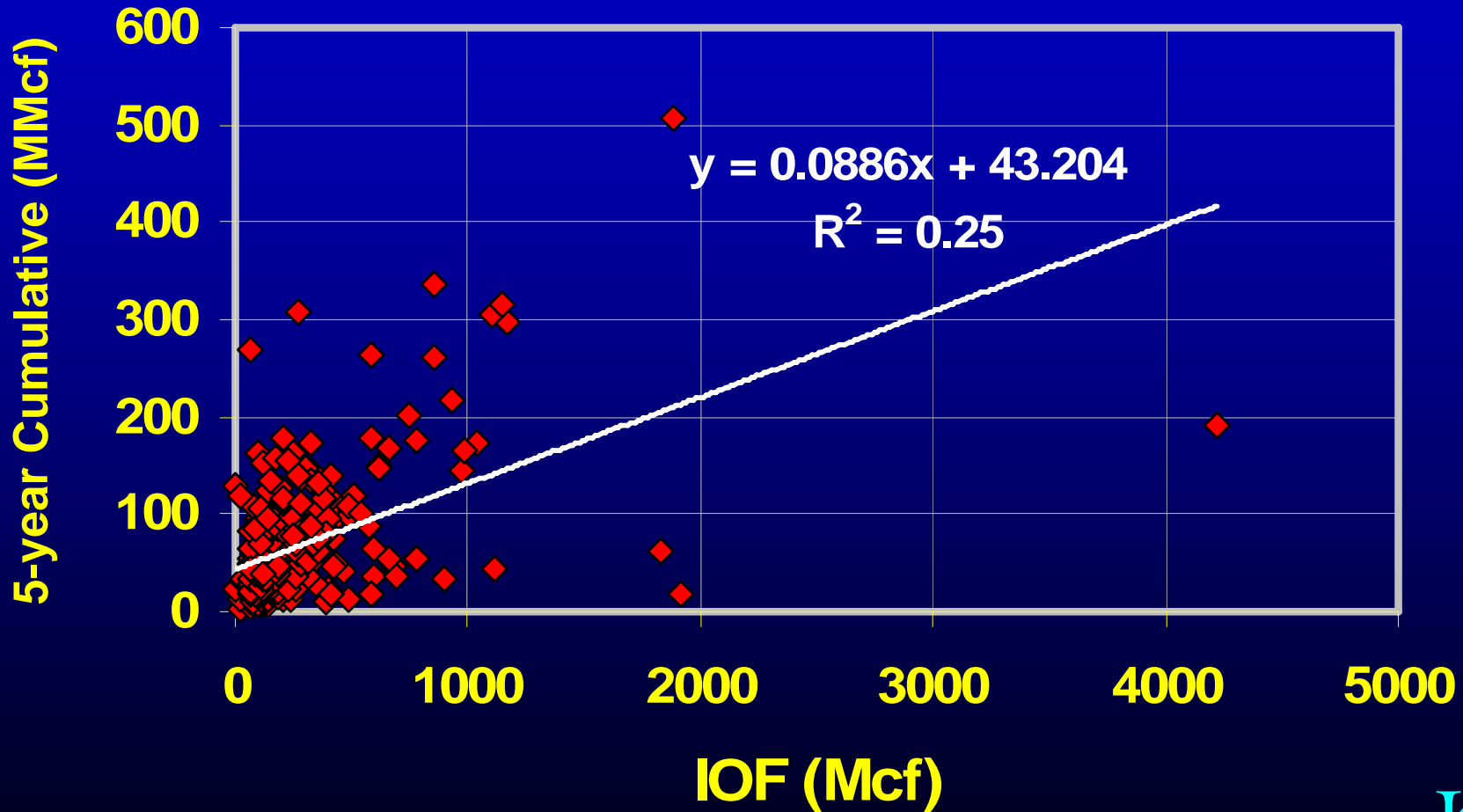
Five-year Cumulative Production



- Again, weak trends
- Areas with higher and lower production are often adjacent

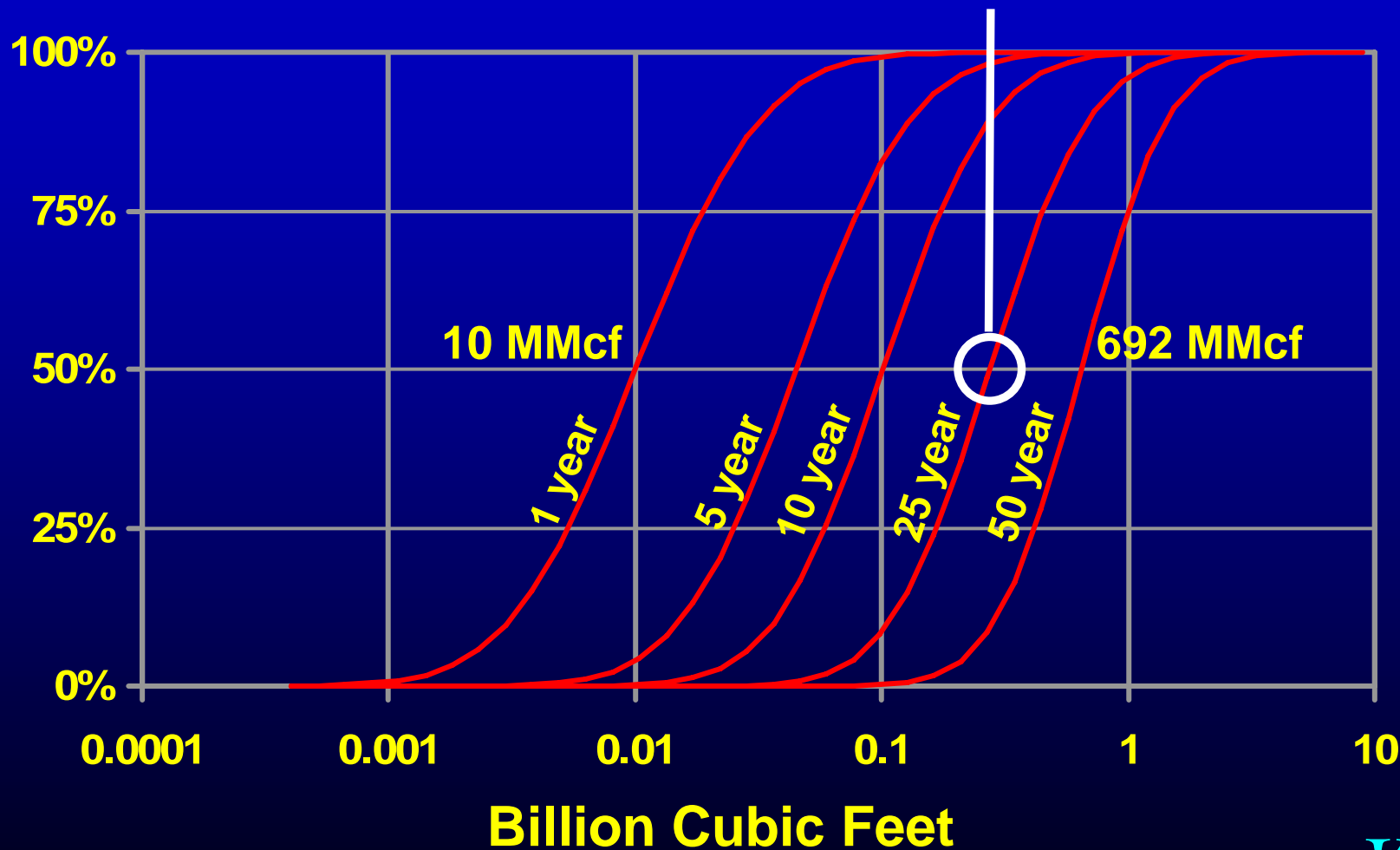
Initial Open Flow

Correlation is statistically significant, but weak

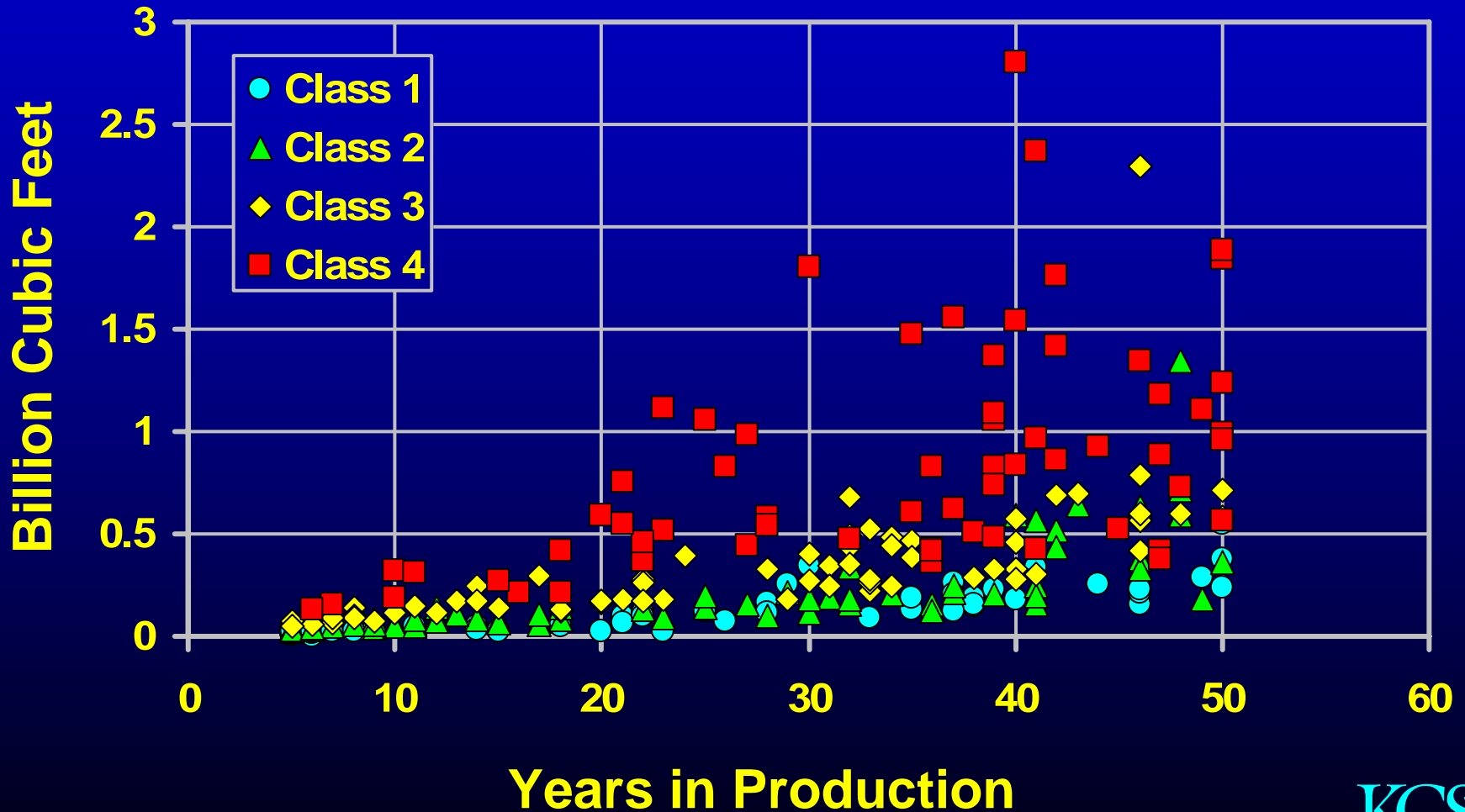


GTI Cumulative Production

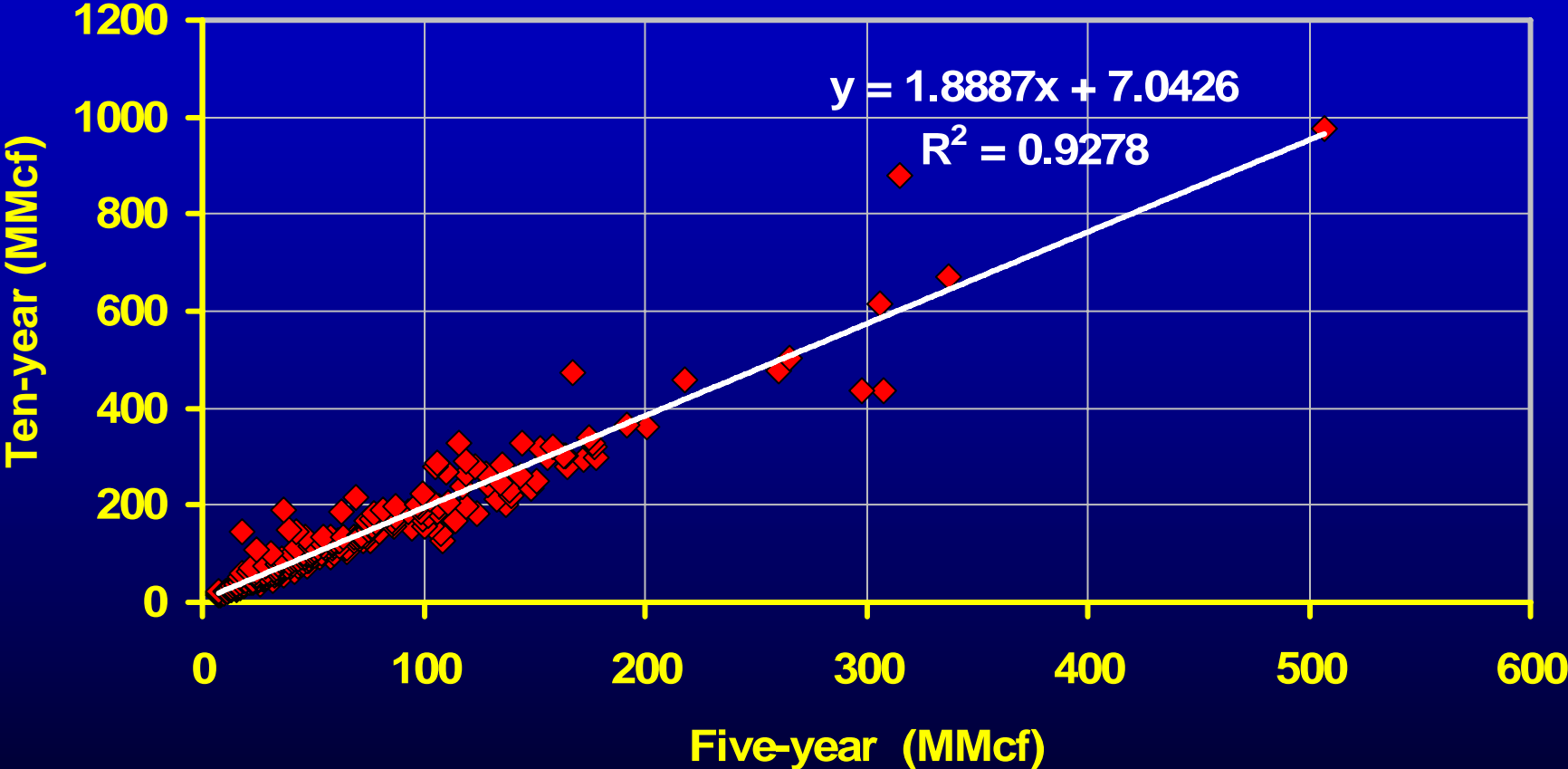
Industry rule of thumb is 300 MMcf per well



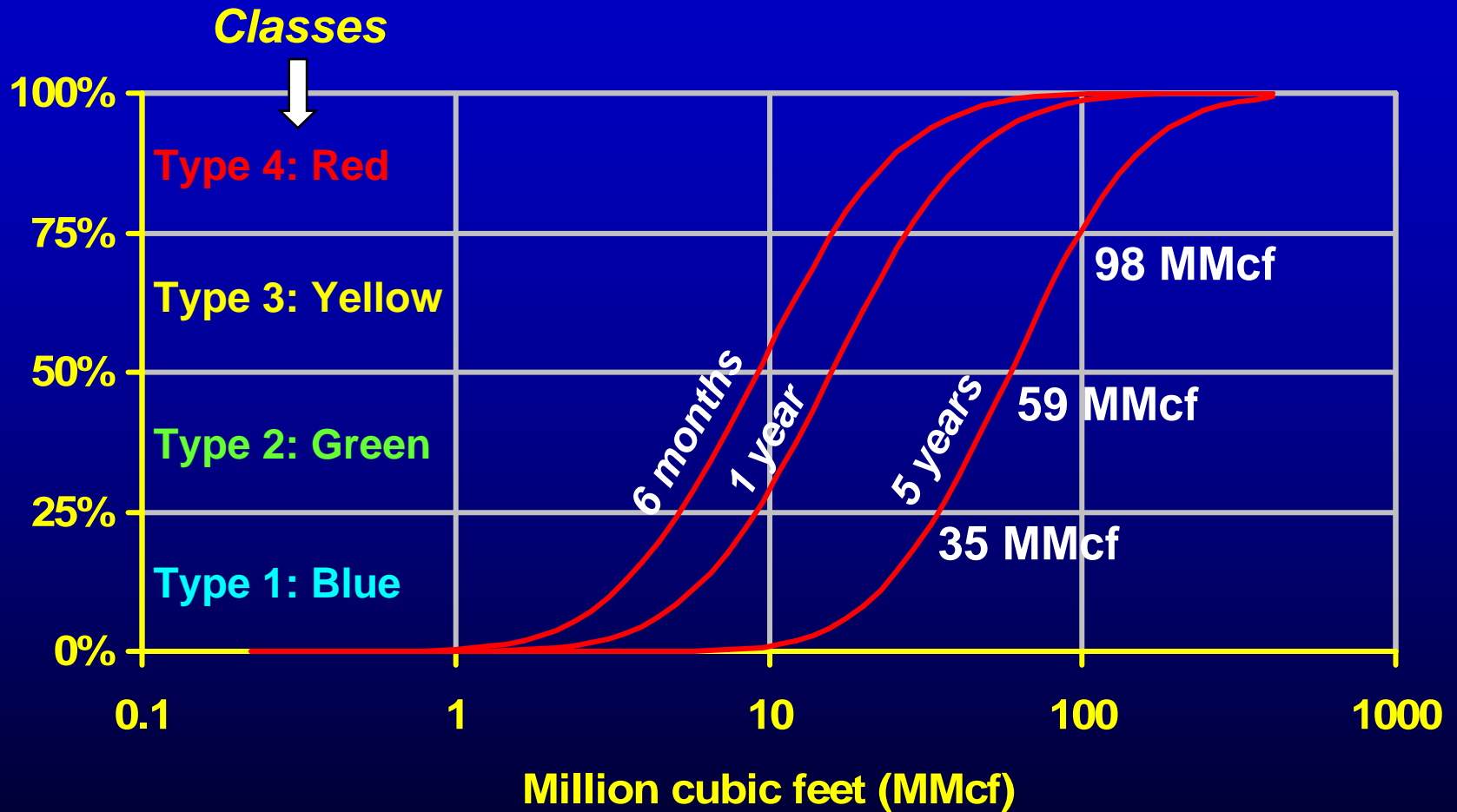
Cumulative Gas Production



Cumulative Production Over Time



Public Production Data



General Decline Model (Arps)

Hyperbolic:

$$q_t = \frac{q_i}{\left(1 + bD_i t\right)^{\frac{1}{b}}}$$

Best fit parameters:

q_i – initial production

D_i – nominal decline

b – decline exponent

Special cases:

Exponential, $b=0$: $q_t = \frac{q_i}{e^{D_i t}}$ Harmonic, $b=1$: $q_t = \frac{q_i}{(1 + D_i t)}$

Solving

Exponential:

Least squares $\ln(q_t) = \ln(q_i) + D_i t$

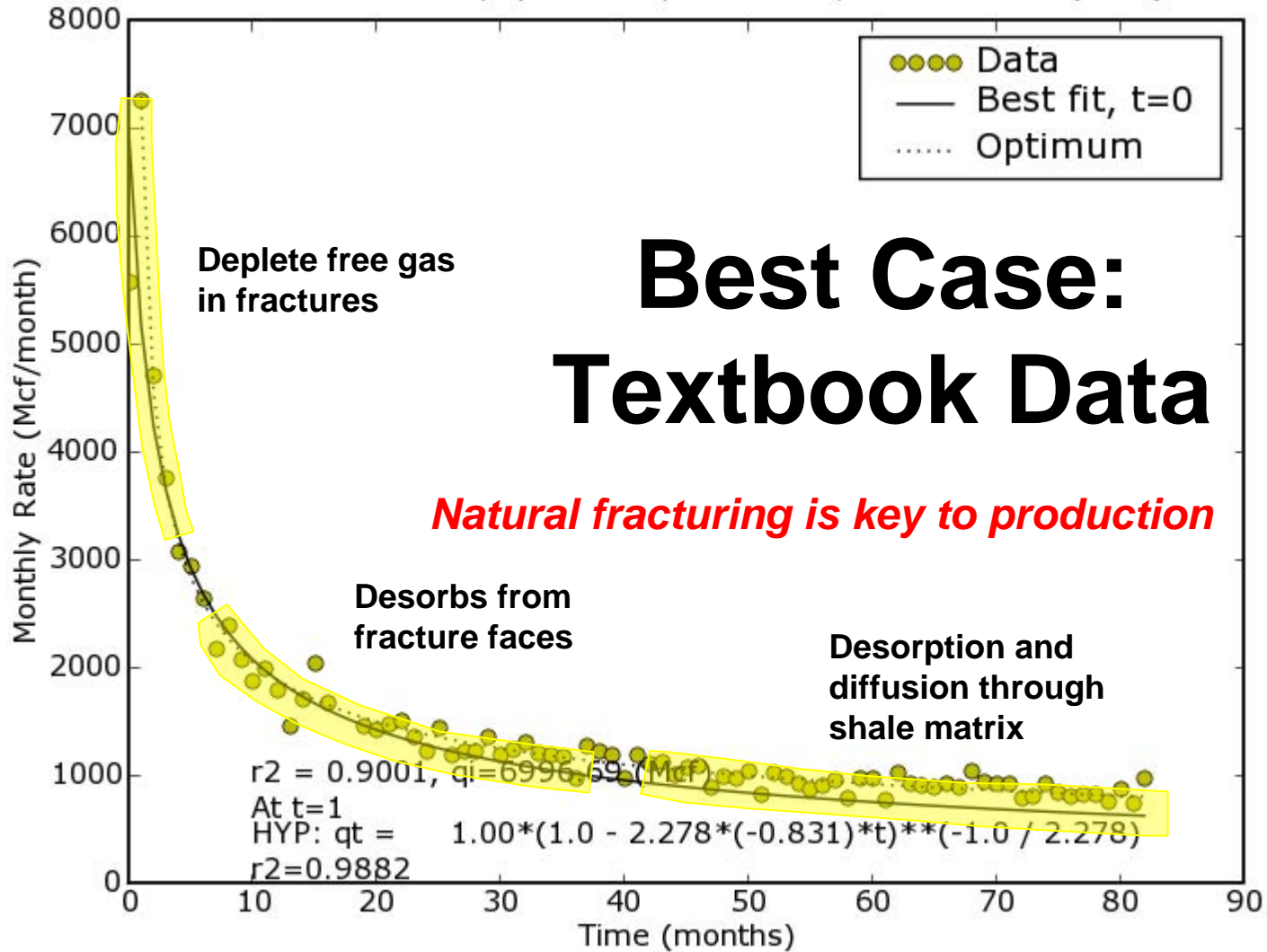
Hyperbolic:

Optimization

Linear Programming

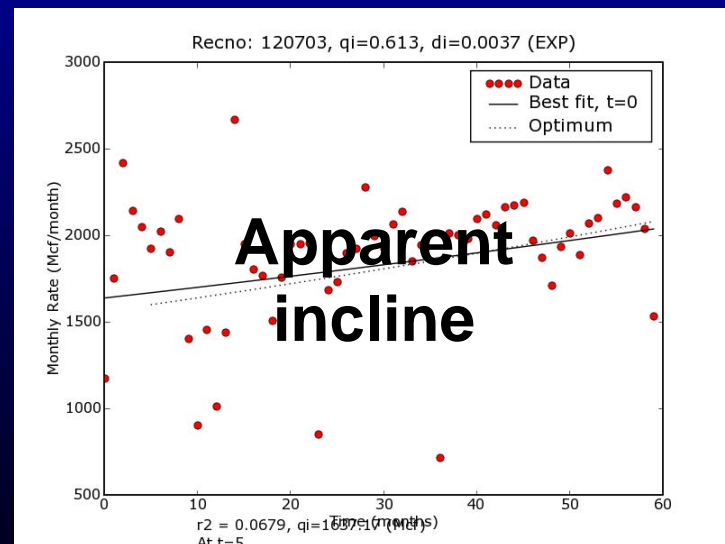
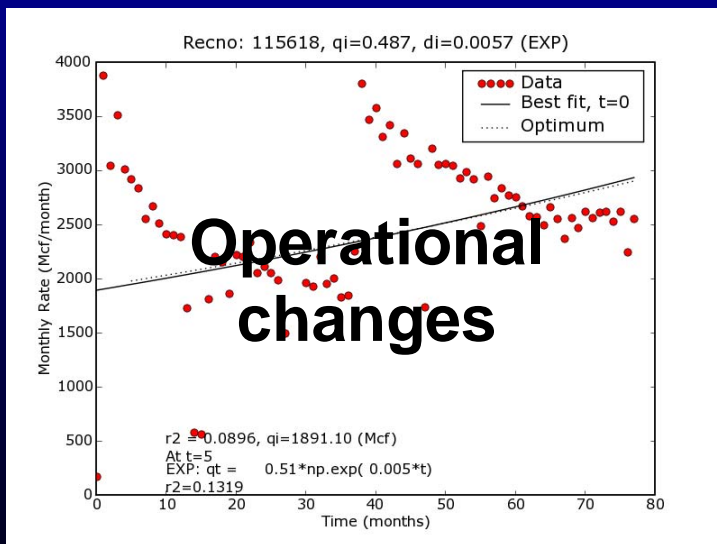
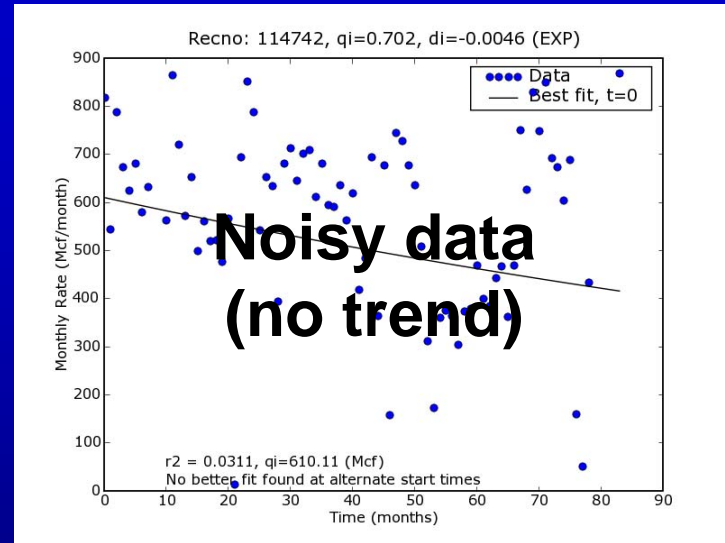
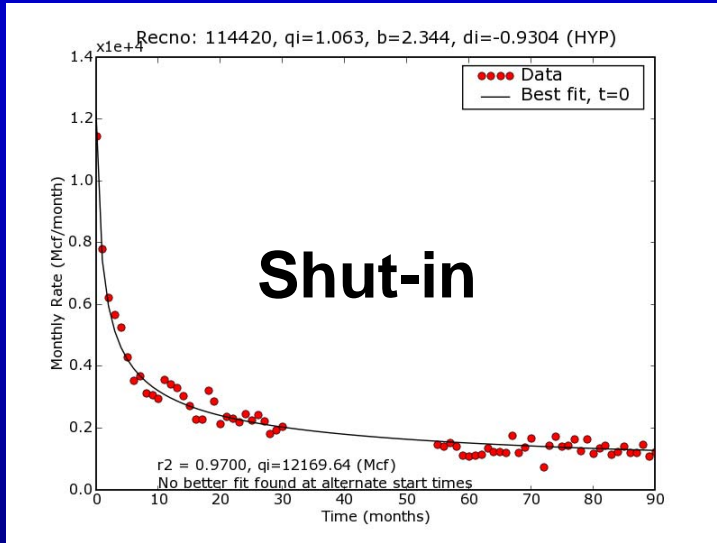
Both can easily be done with the built-in functions supplied with spreadsheets, but...

Recno: 115246, qi=0.964, b=1.642, di=-0.3887 (HYP)

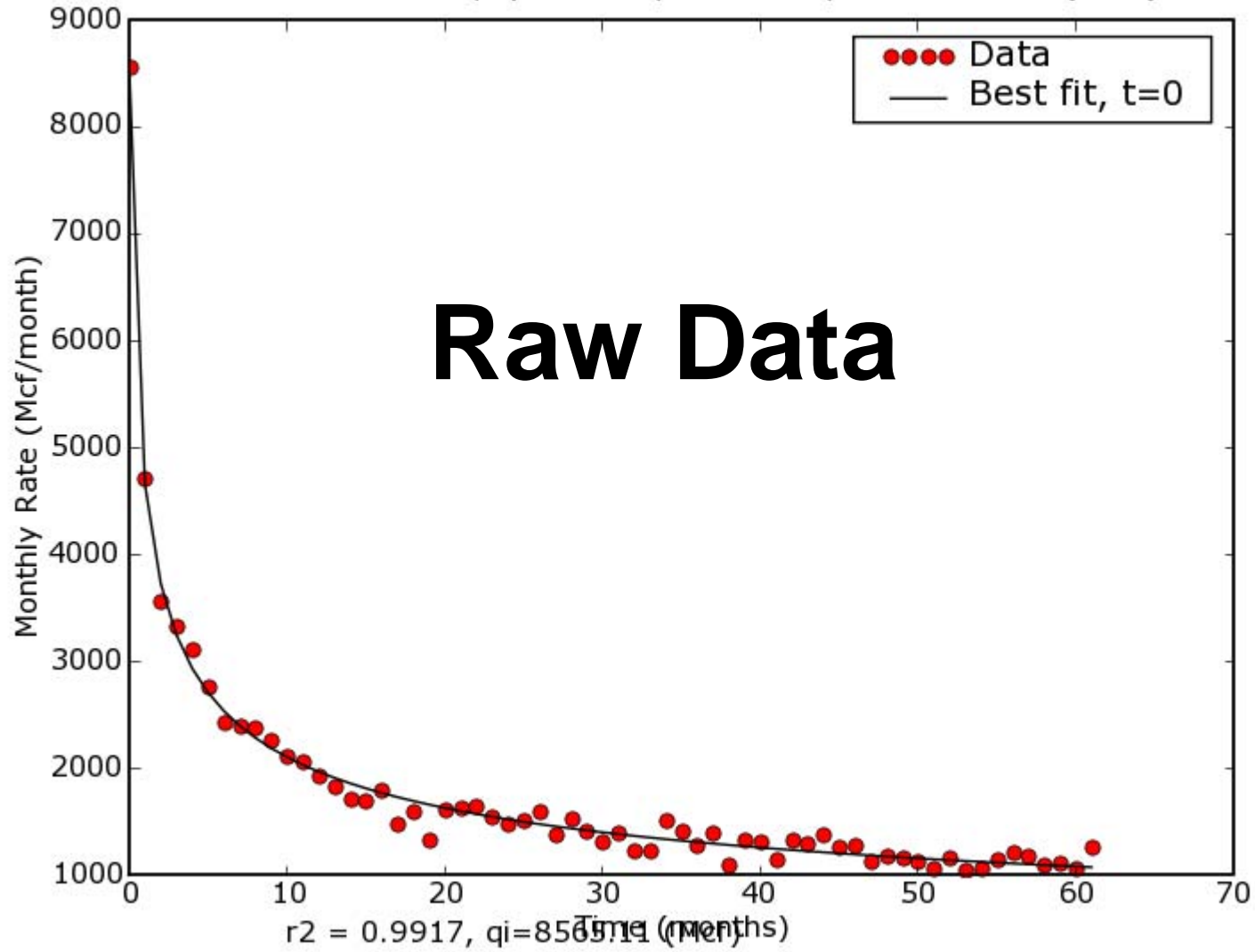




Challenges



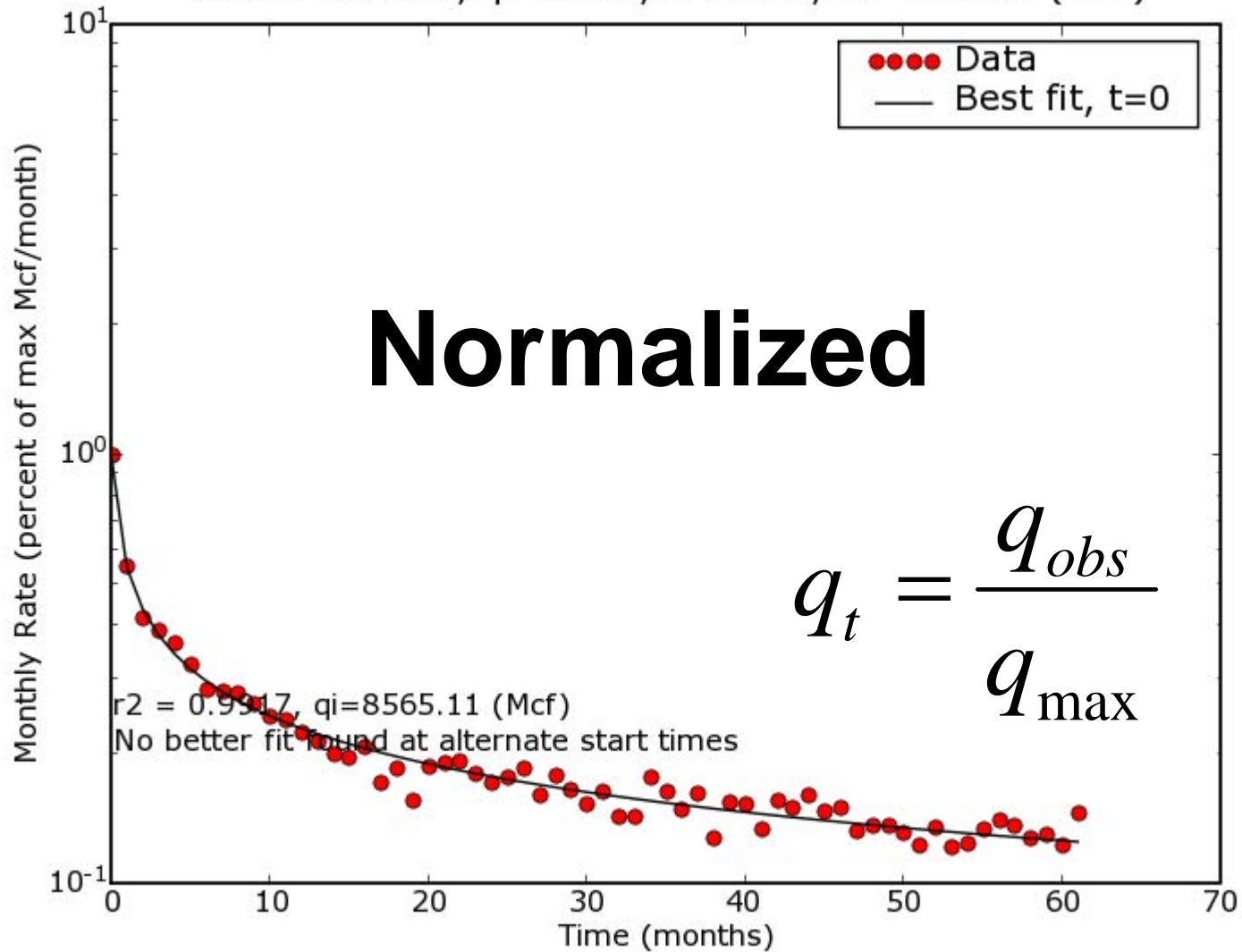
Recno: 120560, qi=1.000, b=2.646, di=-1.5235 (HYP)



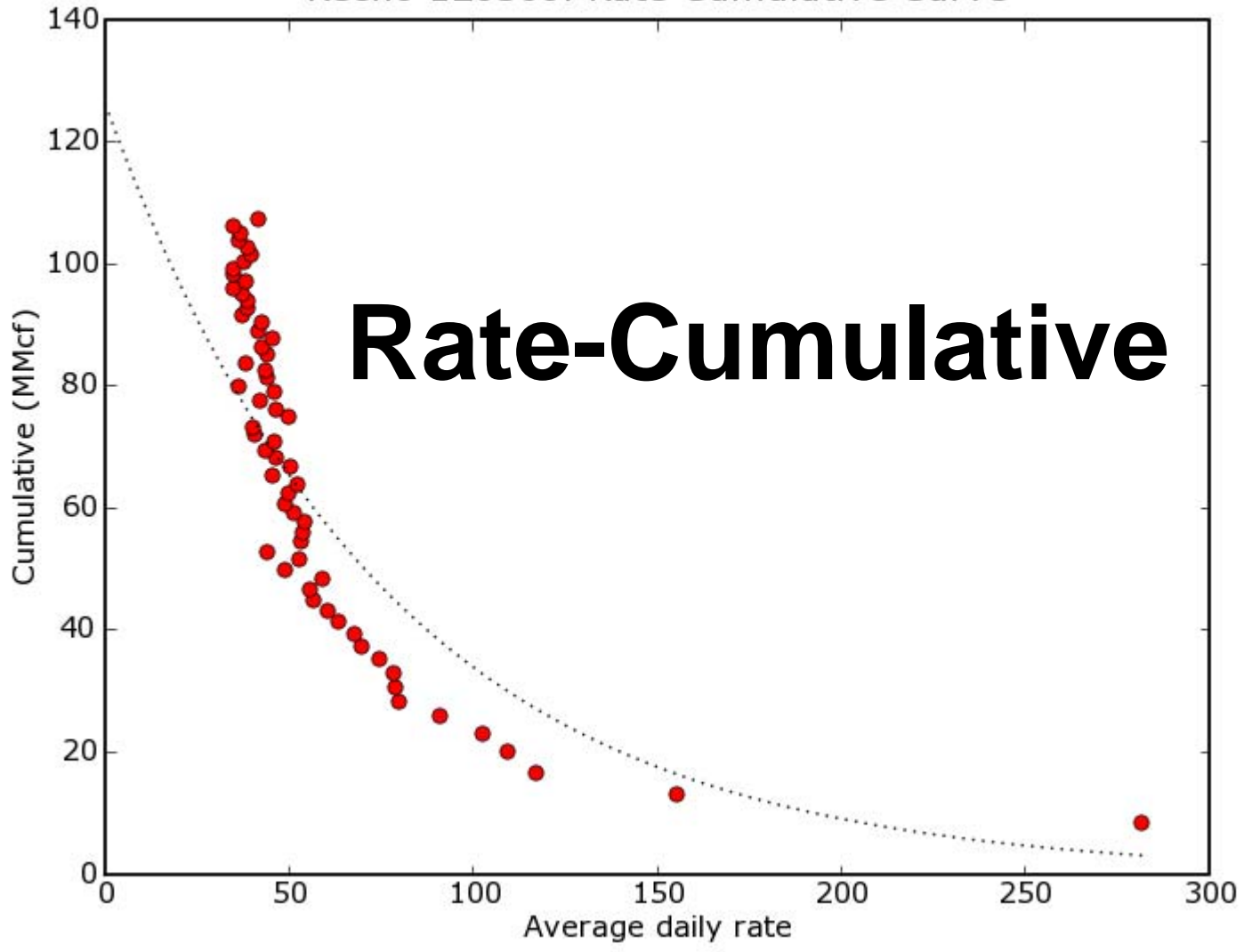
Raw Data

No better fit found at alternate start times

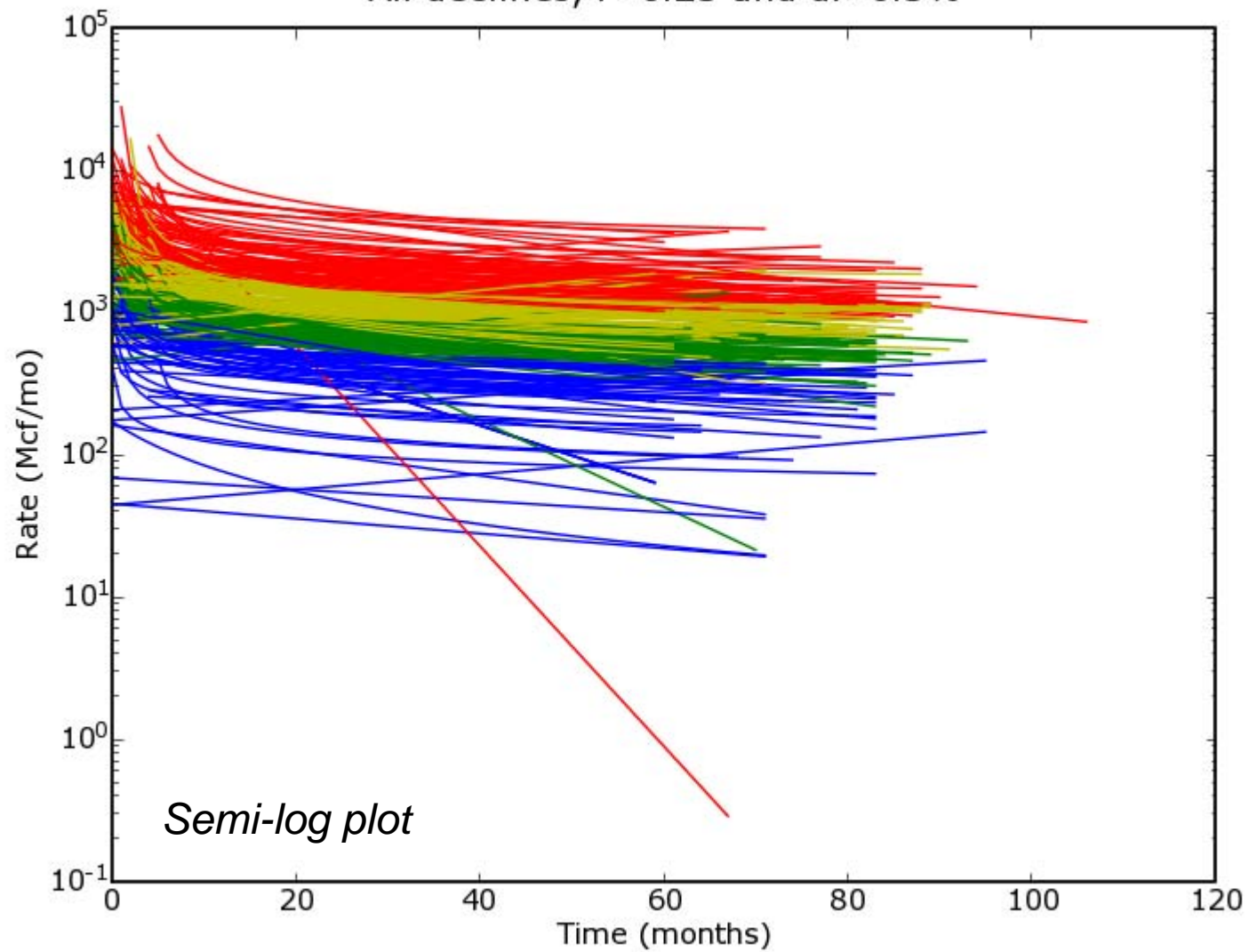
Recno: 120560, qi=1.000, b=2.646, di=-1.5235 (HYP)



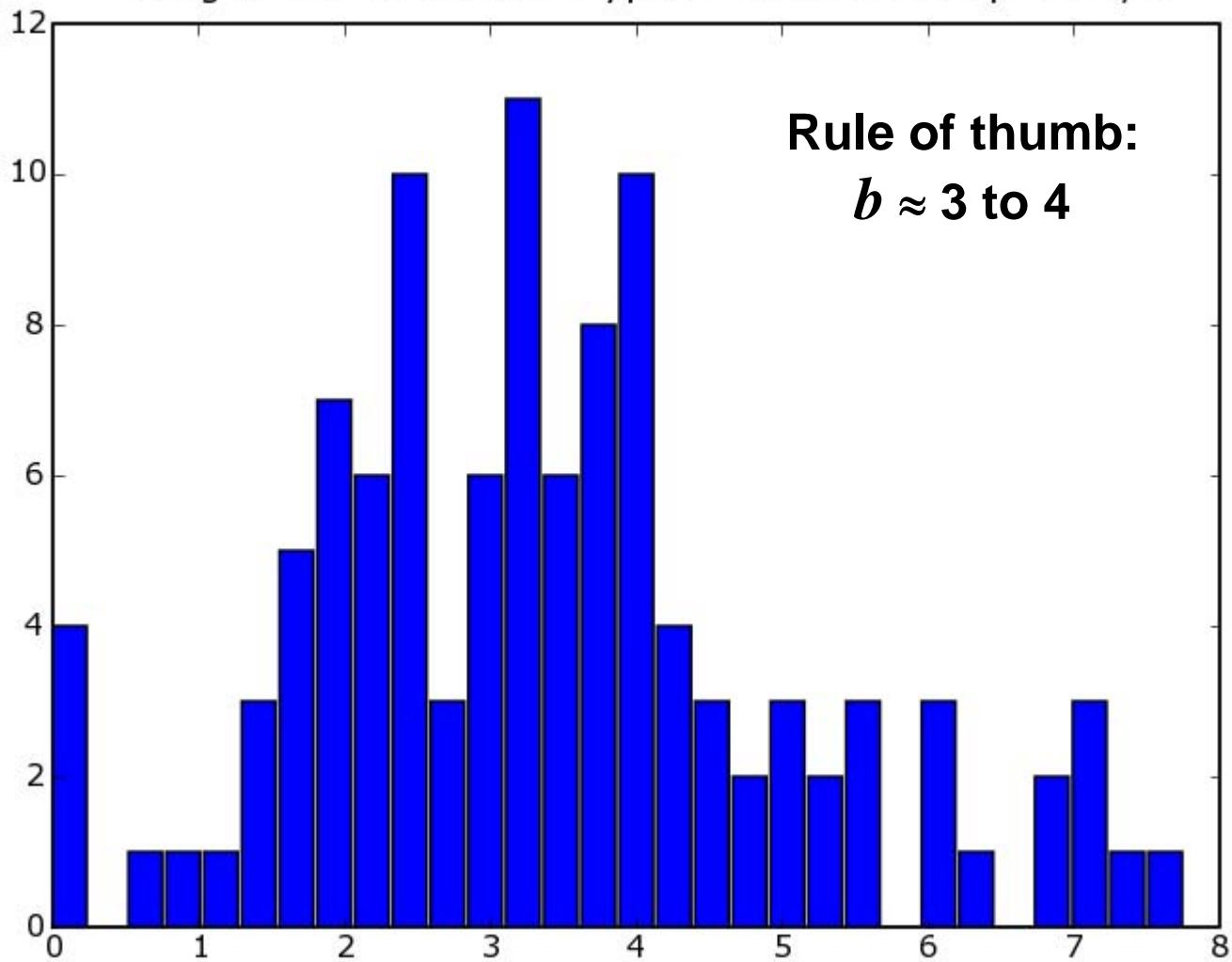
Recno 120560: Rate-Cumulative Curve

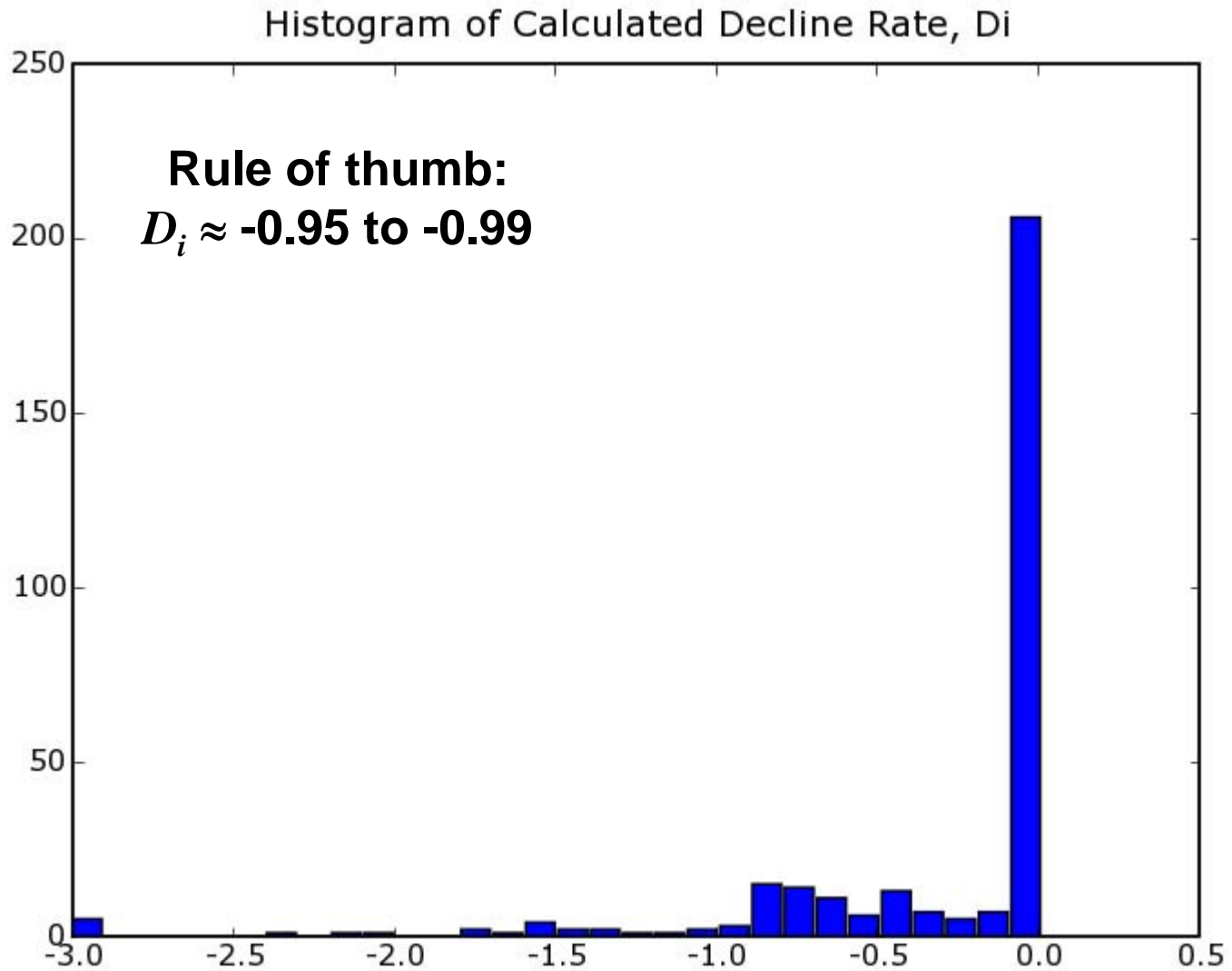


All declines, $r > 0.25$ and $d_i > 0.5\%$



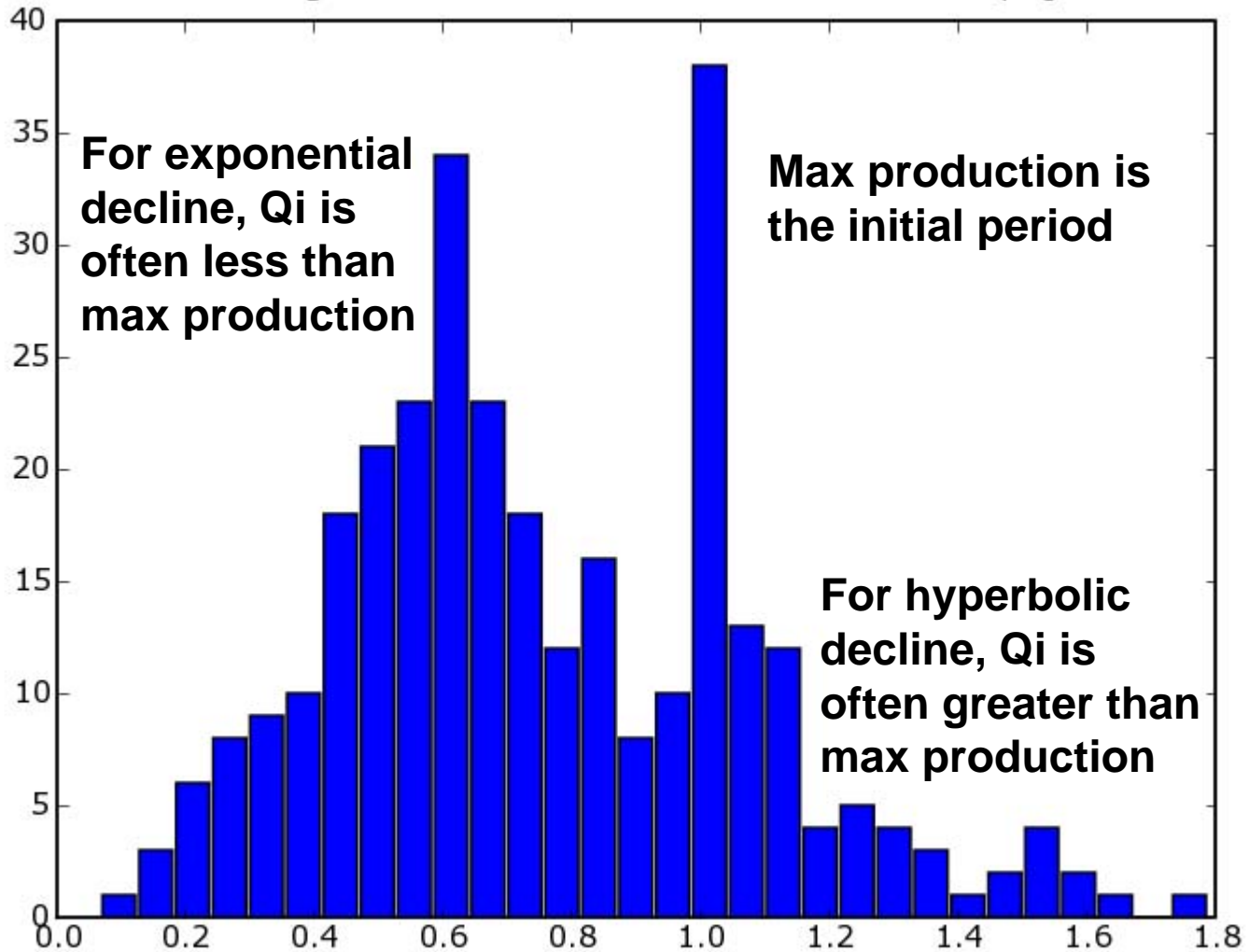
Histogram of Calculated Hyperbolic Decline Exponent, b



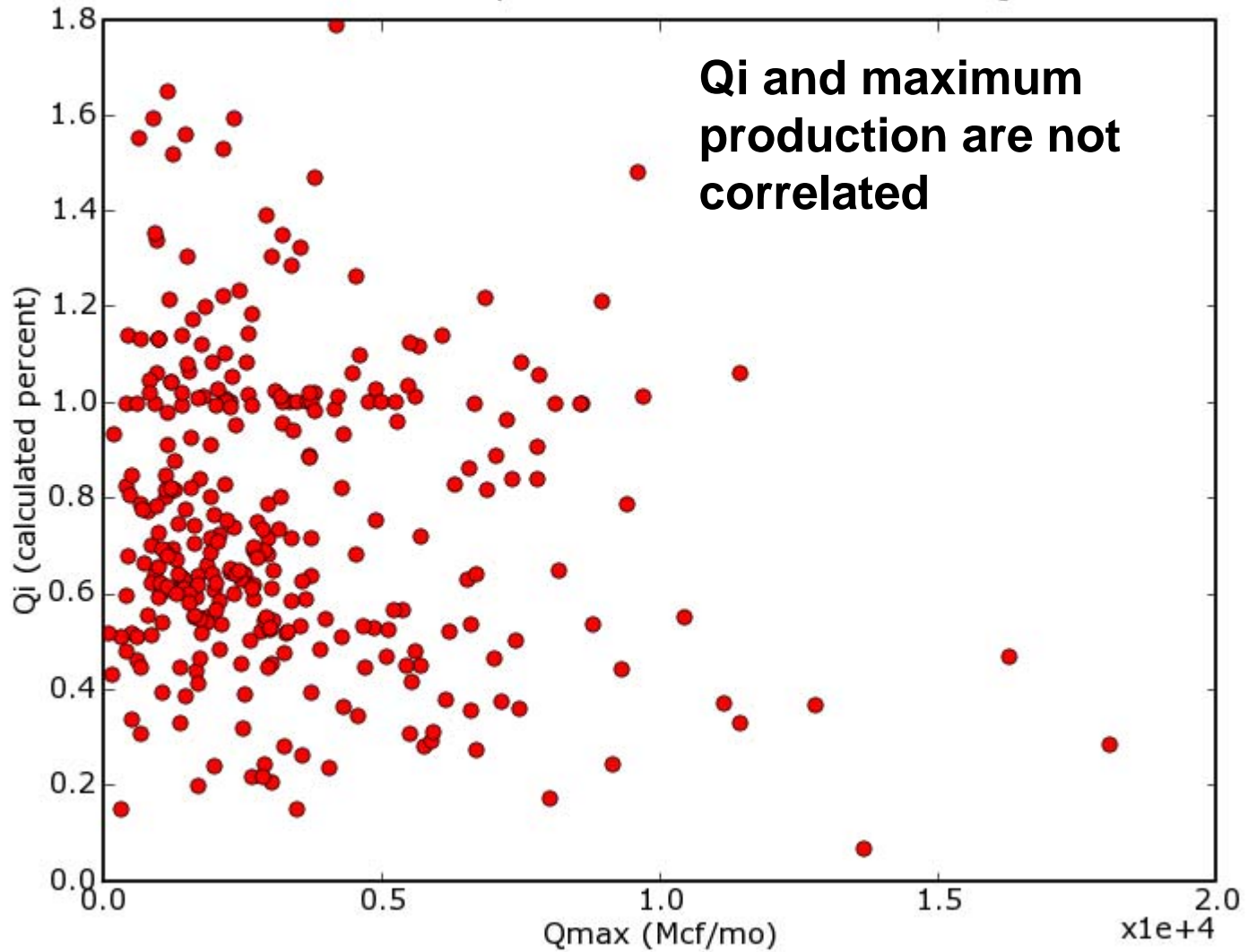


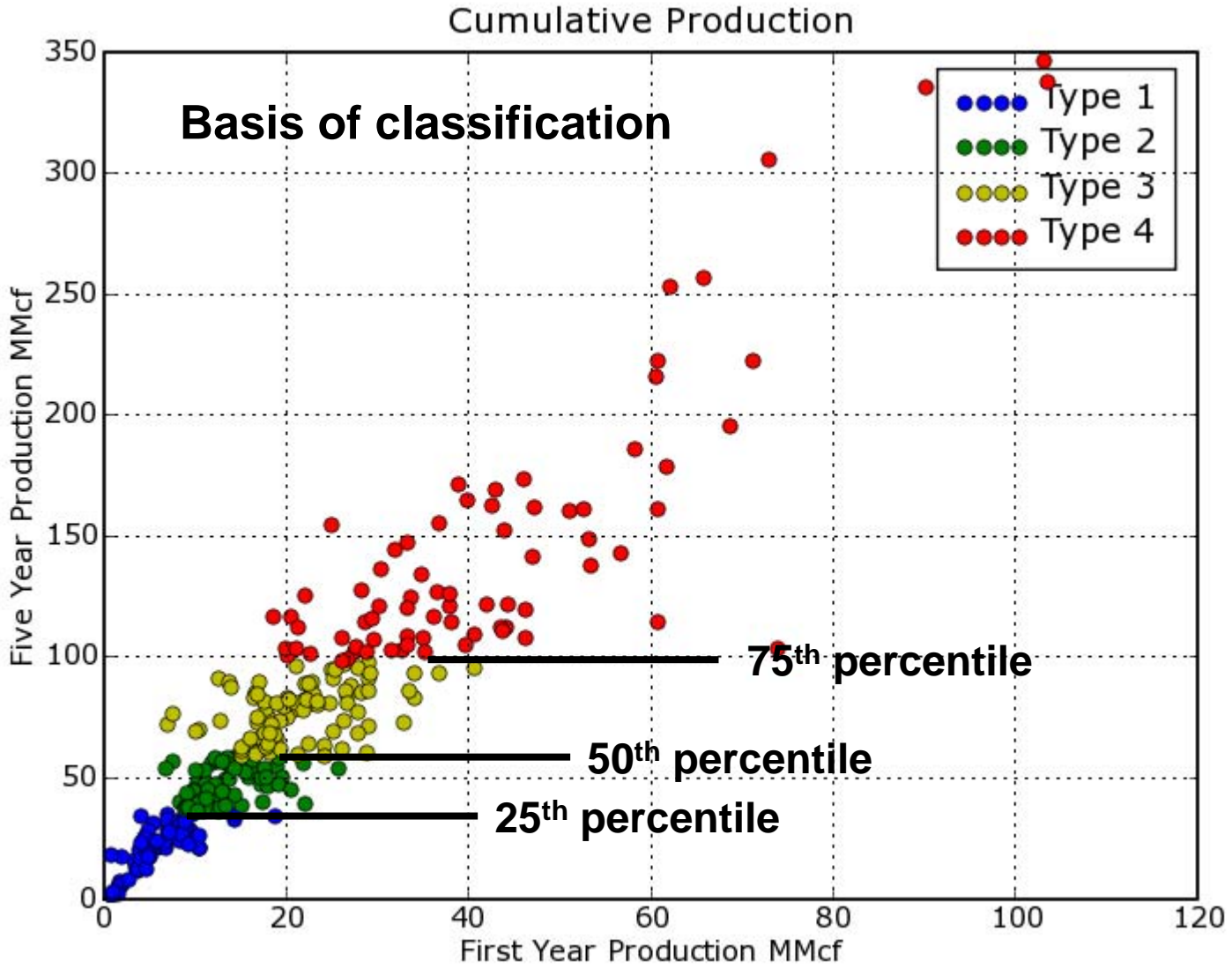
Many data sets have a “decline” (i.e., slope) that is not statistically different from 0 (no correlation).

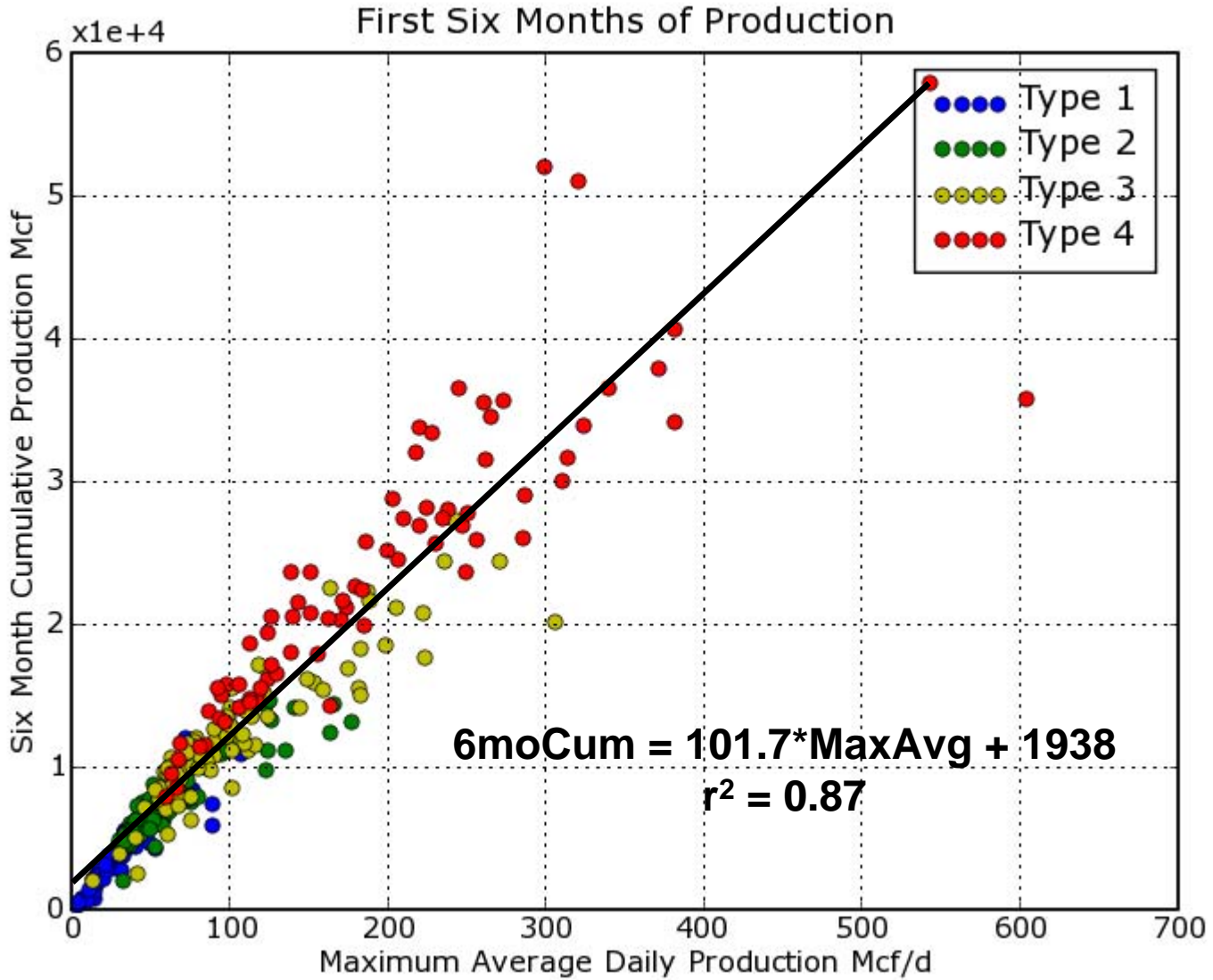
Histogram of Calculated Initial Production, Q_i



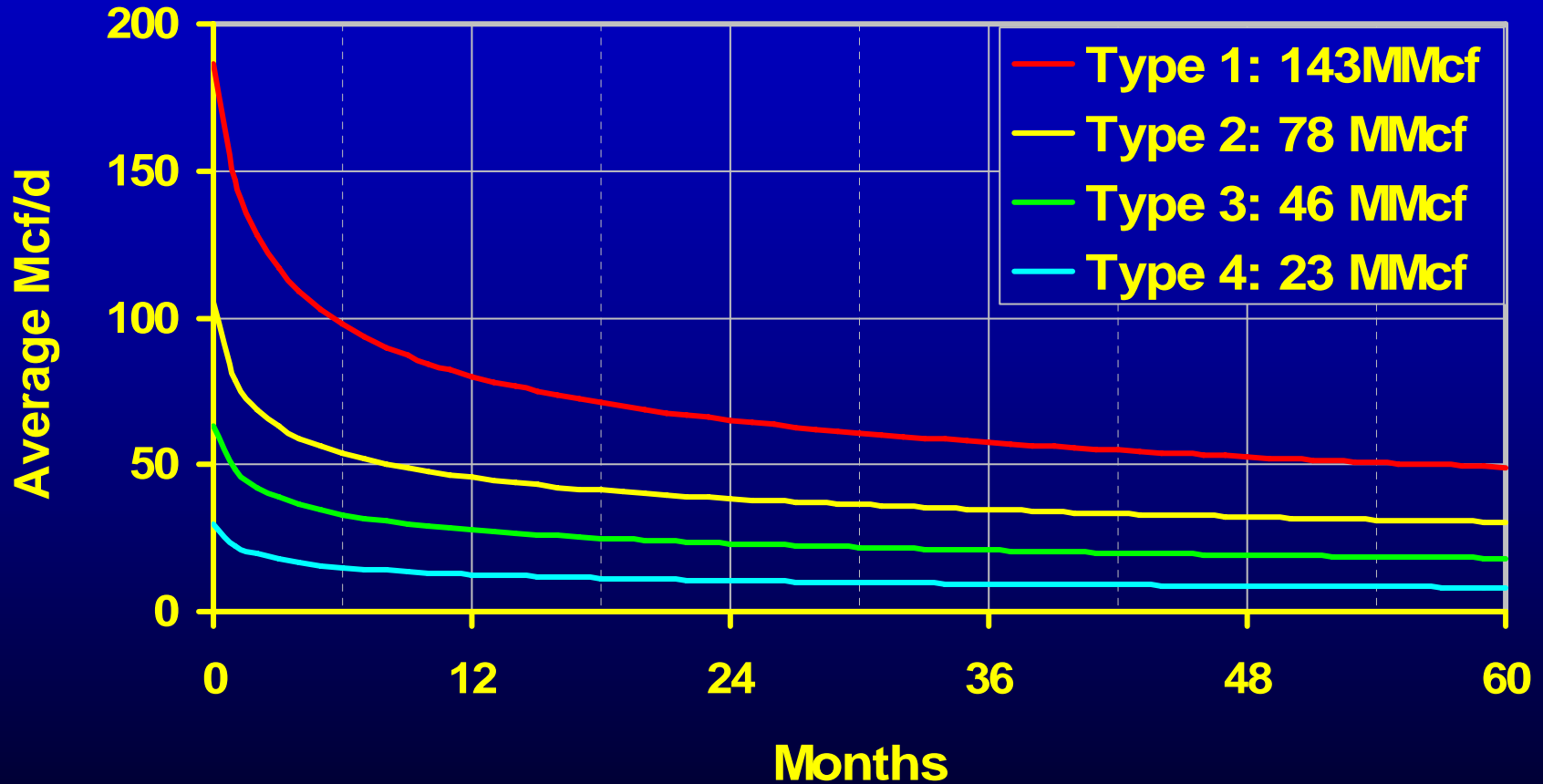
Maximum production and Calculated Qi







Type Declines



Five-year cumulative production in million cubic feet



Conclusions

- **Shale production data is messy**
- **Decline curve analysis and reserves projection is an art**
- **Maximum average daily production during the first 6 months is an adequate indicator of future well performance**
- **Best wells can be expected to make:**
 - **20 MMcf in first year**
 - **100 MMcf after 5 years**

Thanks

- www.uky.edu/kgs
- bnuttall@uky.edu
- Oil and gas well search with production data
 - kgsweb.uky.edu/DataSearching/OilGas/OGSearch.asp
- Oil and gas well interactive mapping
 - kgsmap.uky.edu/website/KGSGeology/viewer.asp
- Project web page
 - www.uky.edu/KGS/emsweb/devsh/production/index.htm