Great Scott! A Homebrewed Recipe for Regional Trend-Based Log Normalization: Various Examples from Rocky Mountain Basins*

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Abstract

Evaluation of large-scale resource plays often involves thousands of wells, covering a span of hundreds of miles. Proper characterization requires extremely accurate well logs. It is for this reason that log normalization continues to be one of the most important ‘first steps’ in an accurate log evaluation. However, log normalization is often underappreciated, treated as an enigmatic “black box” workflow, or simply avoided altogether. Even less appreciated or understood is a regional trend-based approach like those pioneered by Doveton and Bornemann (1981) and Kane, et al. (2005). In this presentation we address the necessity of accurate log normalization, discuss the various methods available, and present a simple workflow for regional trend-based normalization compatible with standard mapping software Although we present a workflow using Geographix software, the methodology can be used on most software platforms.

We begin the analysis similar to other methods by defining our zone of interest, preferably a zone with relatively consistent lithological and petrophysical characteristics over a large area. As an advantage over field-average, or single-well log normalization, this method accounts for regional variations attributed to depositional, and/or compaction trends. Next, cumulative frequency statistics are calculated in the zone of interest for each well and plotted as regional contour maps. Individual well data points that deviate significantly from the norm are then removed from the dataset through visual inspection and analysis of histograms. Using the refined list of datapoints, a set of maps is created using a series of trending algorithms. After selecting the map that best approximates regional trends related to deposition or compaction, the values are sampled back to all of the wells in the project. The values from the regional trend maps are then used as “field values” in a standard one or two-point field average normalization calculation. Upon completion, the normalized curves are evaluated to determine if they make geologic sense and to reduce variability due to log quality, type, or vintage. This simple approach allows a user to normalize a large set of wells in little time, while accounting for regional geologic variations otherwise ignored by traditional normalization workflows.

References Cited

Doveton J.H., and E. Bornemann, 1981, Log normalization by trend surface analysis: The Log Analyst, v. 22/4, p. 3-8.

Kane, J.A., and J.W. Jennings Jr., 2005, A Method To Normalize Log Data by Calibration to Large-Scale Data Trends: Presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, October 9-12, SPE-96091-MS. http://dx.doi.org/10.2118/96091-MS.

BACK TO THE ROCKIES

GREAT SCOTT! A HOMEBREWED RECIPE FOR REGIONAL TREND-BASED LOG NORMALIZATION:

VARIOUS EXAMPLES FROM ROCKY MOUNTAIN BASINS

Mark Millard – Rockies Resources LLC

Andy Hennes – Rockies Resources LLC

Preston Kerr – SM Energy

Riley Brinkerhoff – Wasatch Energy

Justin Brown – Rockies Resources LLC

Rockies Resources LLC

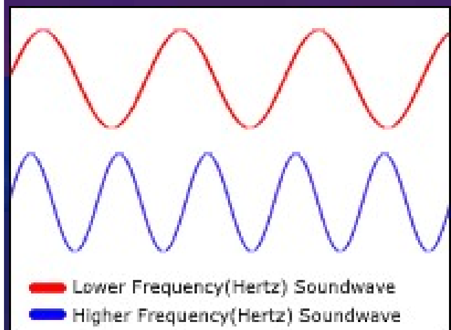
Google Image Search, Aug. 2019

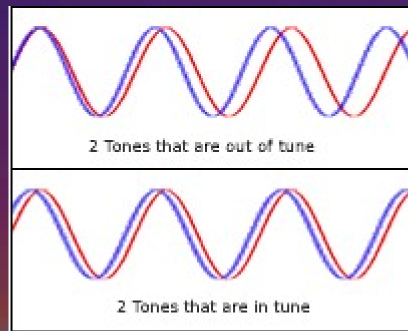
An Epoch Adventure of CRETACEOUS PROPORTIONS

Geology and Music

(or more specifically – Log Normalization and Guitars)

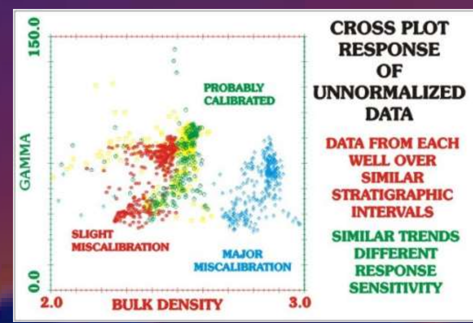
Guitar Tuning – Adjusting the pitch of the strings until they form a desired arrangement.

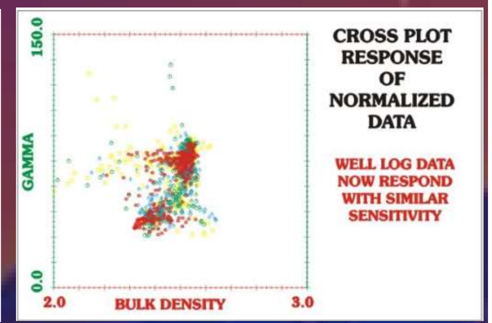




http://www.get-tuned.com/tuning_science.php

Log Normalization – Attempts to reduce non-geologic variability in log data.





http://www.hitchnerexplorationservices.com/normalization

Common causes of out of tune guitars:

-Changes in humidity.

-Strings wearing out.

-Poorly constructed nut or bridge.

-Failing tuning pegs, etc.

Google Image Search, Aug, 2019

Common causes of log errors **(Kane et al., 2005)**

-Miscalibration.

-Differing vendors.

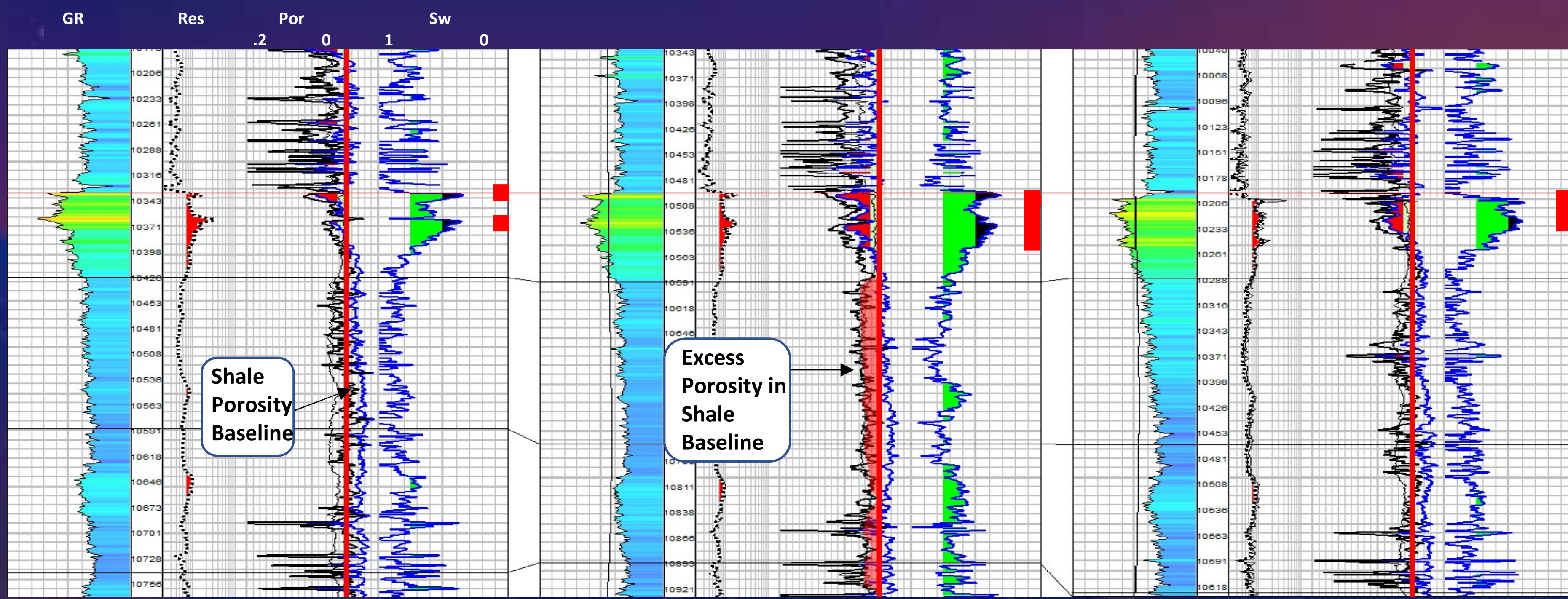
-Changes in tool design.

-Changes in the modeled tool response throughout the lifetime of the tool.

-Digitization errors (poor photocopies)

-Environmental corrections improperly done (or not at all).

The Need for Log Normalization - Porosity



Sussex Formation – PRB

-3 wells within walking distance.

-Similar log character (GR, Res, Phin, DT).

-Excessive RHOB in middle well.

RAW LOGS

<u>Reservoir Parameters:</u>

60 ft Net Pay

8.8 MMBOE/640 OOIP

NORMALIZED

<u>Reservoir Parameters:</u>

33 ft Net Pay

4.2 MMBOE/640 OOIP

Side Note - GR correction of 10 API would add/subtract 1 MMBOE/640 OOIP

Uncorrected RHOB results in overestimation of 4.6 MMBOE/640 **(Generic OOIP Calculation)**

Industry Normalization Methods

Field Average

"Probably the Most Widely Used Normalization Method in Industry."
-Mark Millard

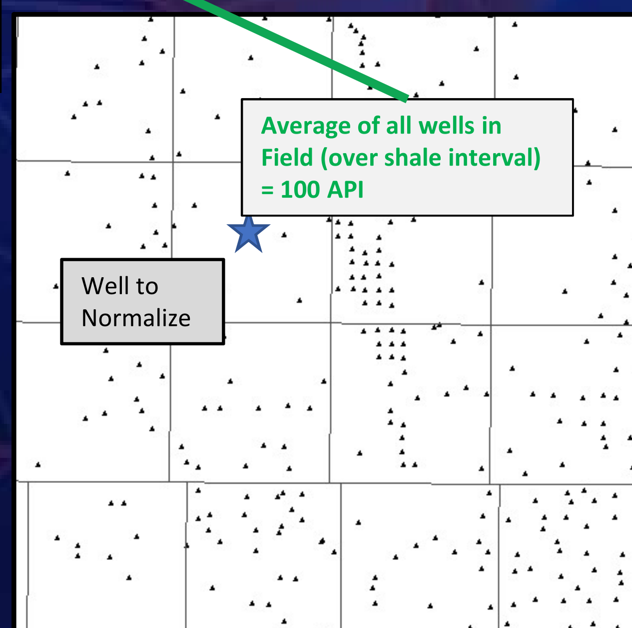
1 Point Normalization Using Mechanical Shift

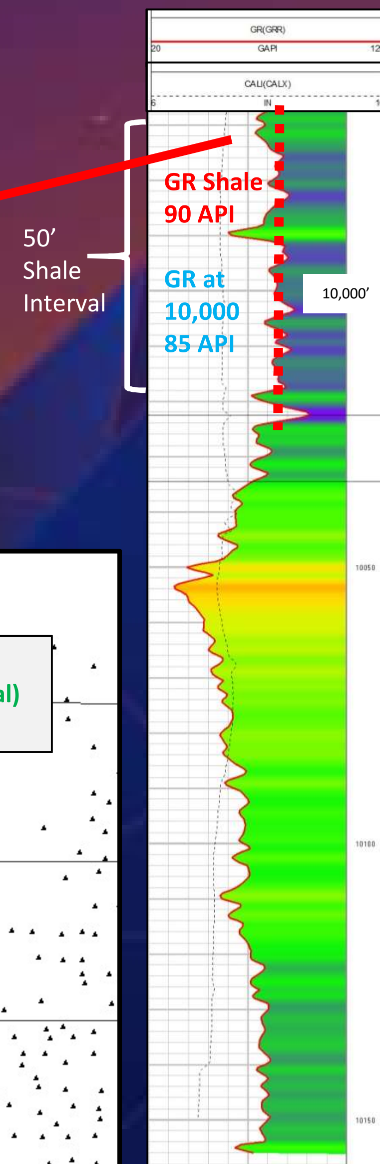
Normalized Curve =
GR Value at Each Depth + Field Average – Well Average

Example:
GR Norm at 10,000' = 85 + 100 – 90
GR Norm at 10,000' = 95

Pros
-Easy to calculate.
-Takes multiple wells into consideration - "strength in numbers."

Cons
-Erroneous wells are included in Field Average.
-Works locally, but does not capture regional geologic variation in normalization interval.





Even more Geology and Music

<u>GUITARS</u>

Changing scale length:

-Affects string angle

-Affects string tension

-Affects tuning

Google Image Search, Aug, 2019

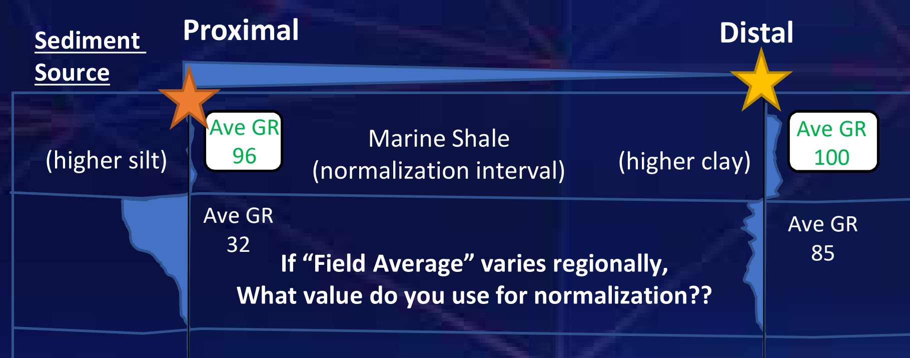
<u>LOG NORMALIZATION</u>

Changing size of field AOI:

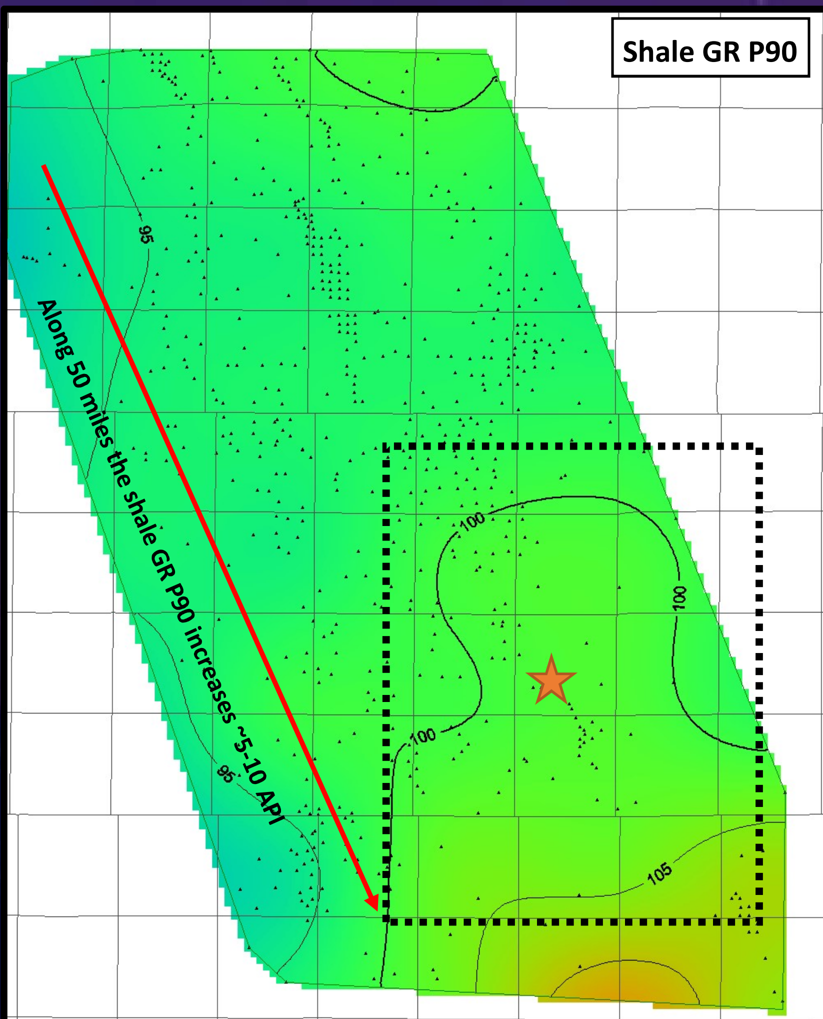
-Affects field average

-Most marine gray shales vary slightly over a regional scale (ie. distal vs proximal).

https://deeptimemaps.com/wp-content/uploads/2016/05/wiscretcon.png

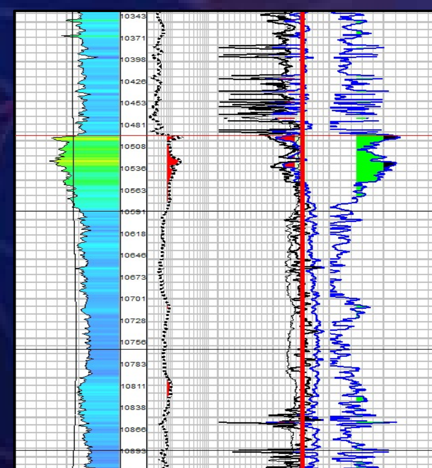


Problem with Using Field Average for Regional Studies – Gamma Ray/Vshale



Increasing size of AOI results in variation of 0.4 MMBOE/640

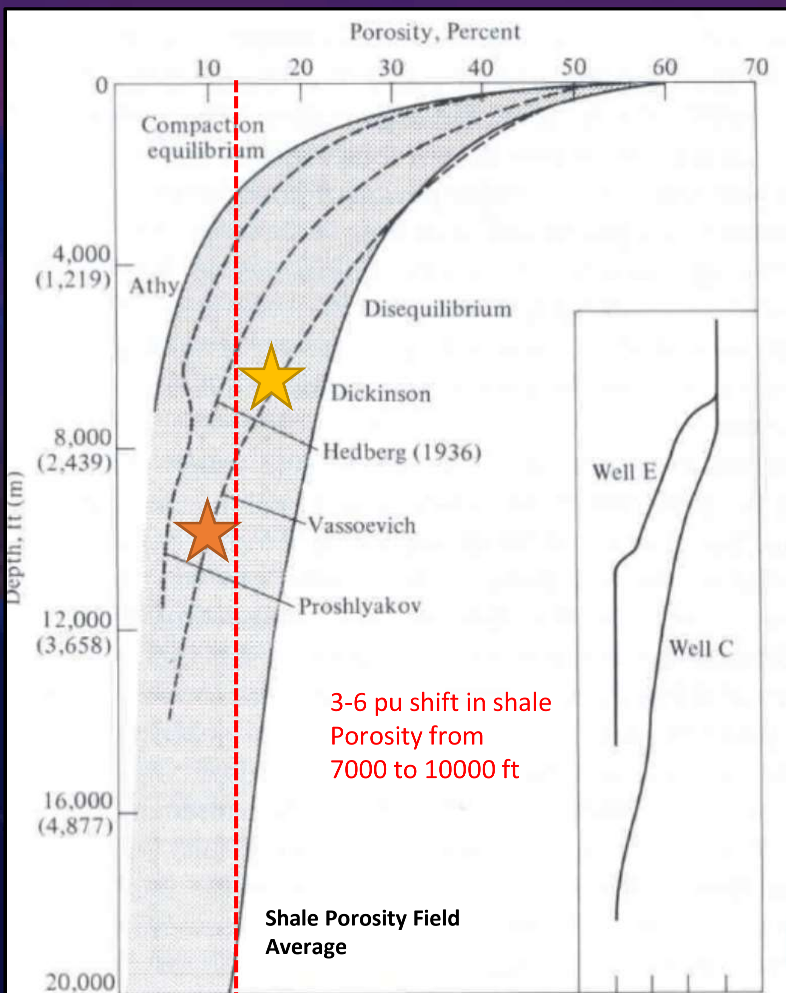
17 Township AOI
Field Average
GR Normalization
GR Field Ave (P90) – 102
19% Vshale
1.26 SoPhiH
4.2 MMBOE



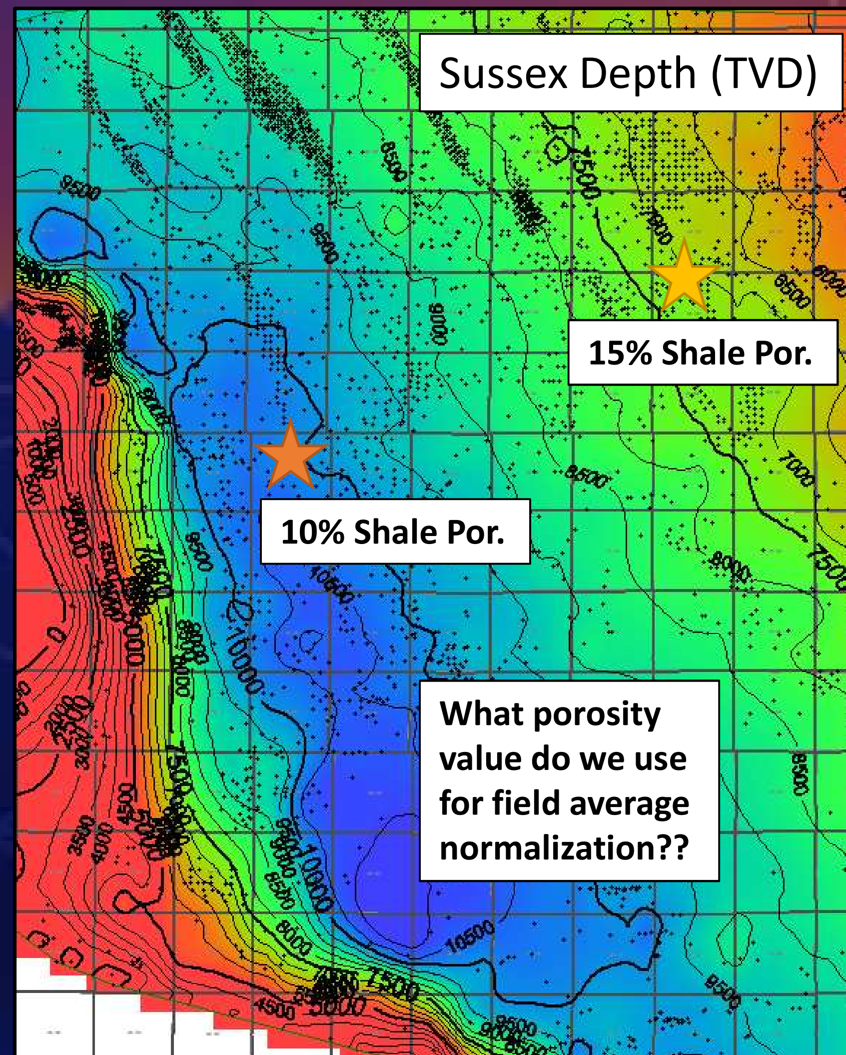
80 Township AOI
Field Average
GR Normalization
GR Field Ave (P90) - ~97
17% Vshale
1.4 SoPhiH
4.6 MMBOE/640

Real Life Implications - Shale Porosity

Why Field Average DOES NOT WORK WELL for Porosity Normalization



Hunt, 1995



Industry Normalization Methods

Regional Trend Surface Analysis (Doveton and Bornemann, 1981)

"Probably the best normalization method I have seen this summer. Two thumbs up."
-Mark Millard

1 Point Normalization Using Mechanical Shift

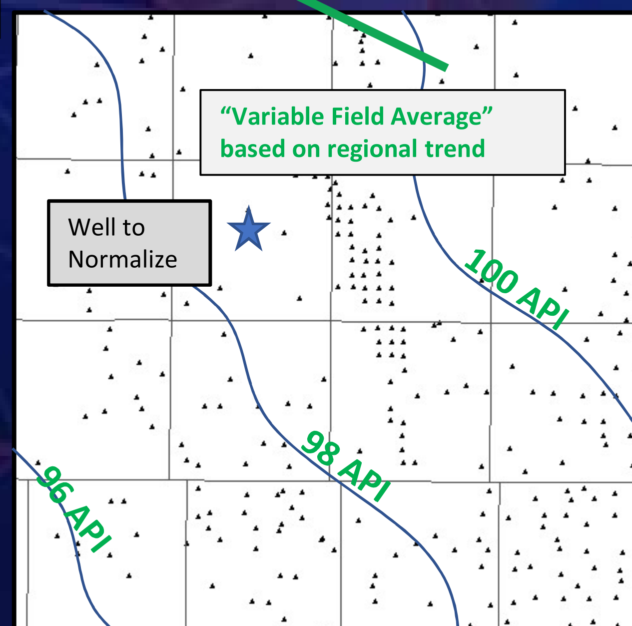
Normalized Curve =
GR Value at Each Depth + "Variable Field Average" – Well Average

Example:
GR Norm at 10,000' = 85 + 98 – 90
GR Norm at 10,000' = 93

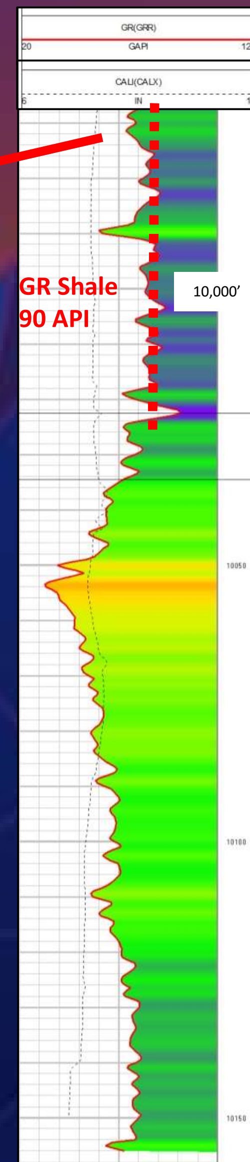
"Best Honors Geology"

-Assumes that the log character of your normalization interval (ie. marine shale) varies regionally due to changes in:

- -Lithology
- -Depth (compaction)
- -Diagenetic variations



Smoothed Regional Trend Map



Regional Trend Surface Analysis using Geographix Software

- Workflow is a culmination of work done by Doveton and Bornemann, 1981; Kane, et al., 2005; and in house ‘homebrewing’

Workflow

1. Define zone of interest
2. Calculate statistics
3. Create maps of calculated statistic
4. Filter erroneous data and use ‘Trend’ Filters to smooth out grids
5. Sample grids to wells
6. Use standard normalization equation (substituting static “field average” for variable “field average” based on grids)

Step 1 – Define Zone to Normalize

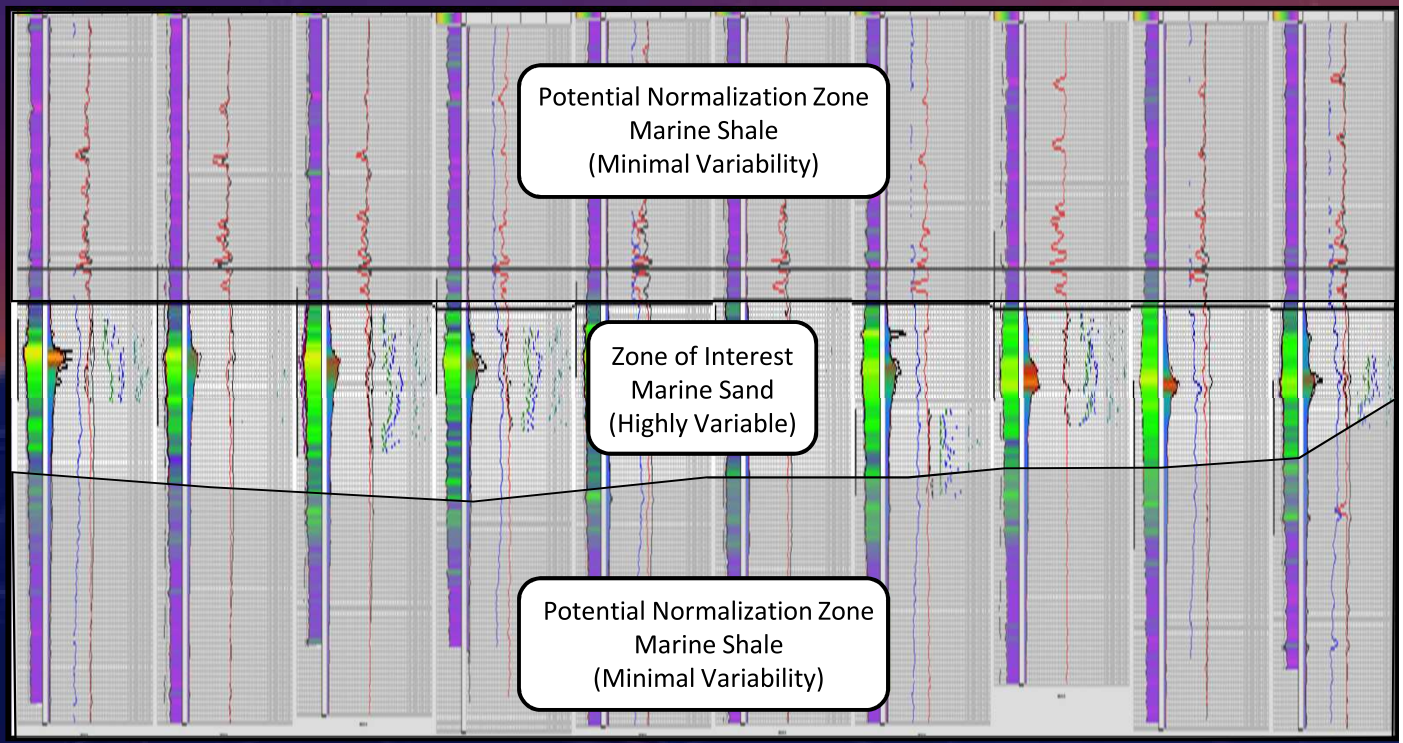
<u>Considerations</u>

-Near zone of interest.

- Geologically as consistent as possible (ie. marine shale, regional “tight limestone”).

-Other considerations

- Log coverage
- Logging runs
- Casing



Step 1b – Define Statistic that Makes Sense for Normalization Zone

-Average, min, max, P50, P10, P90, etc.

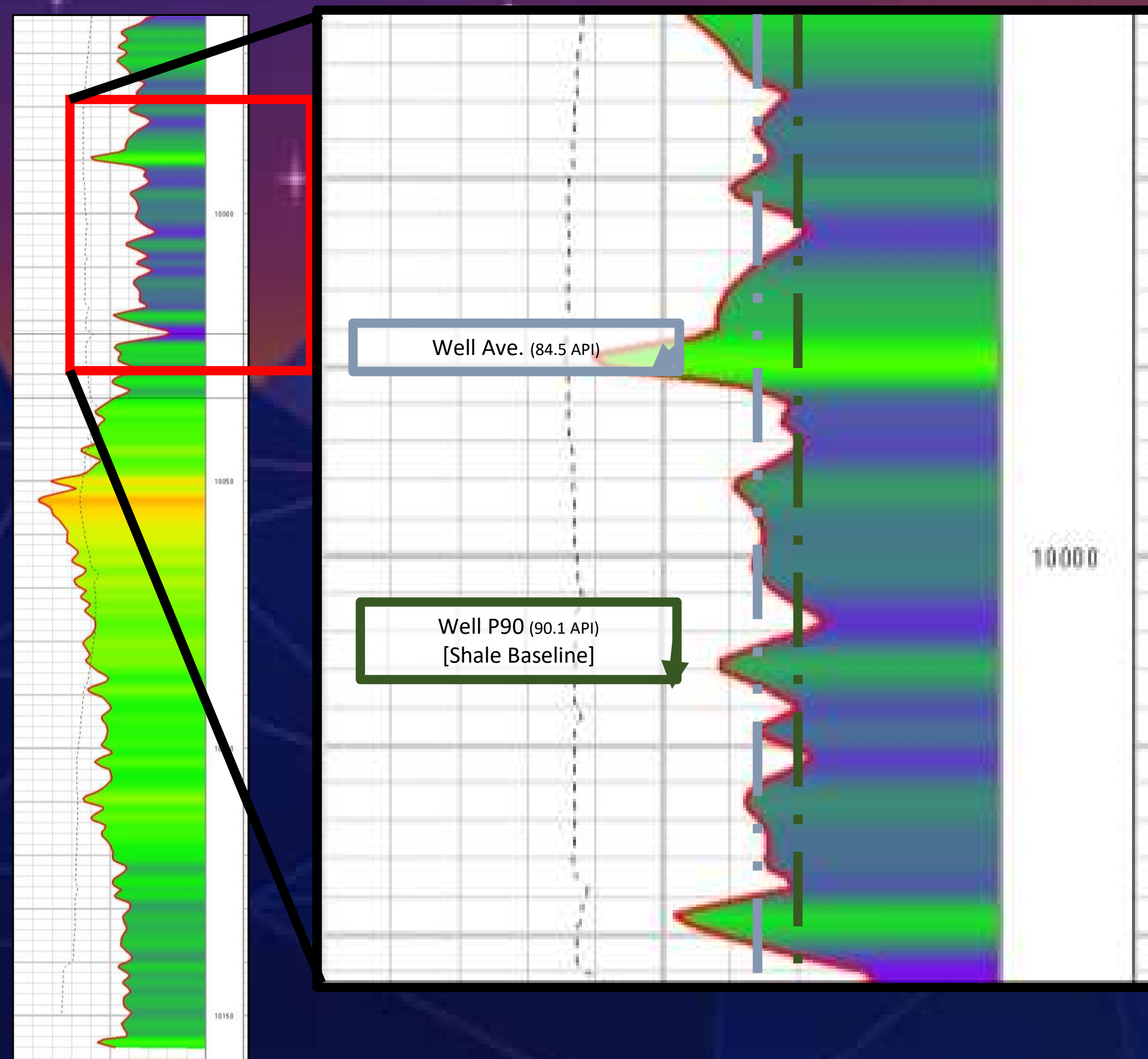
-Recommend P90(ish) for hot zones

-Recommend P10(ish) for clean zone

-Be aware of potential issues

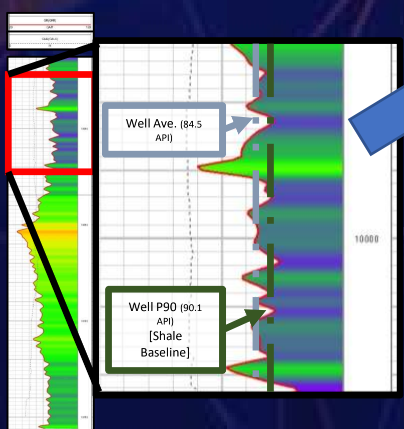
-Log coverage & casing

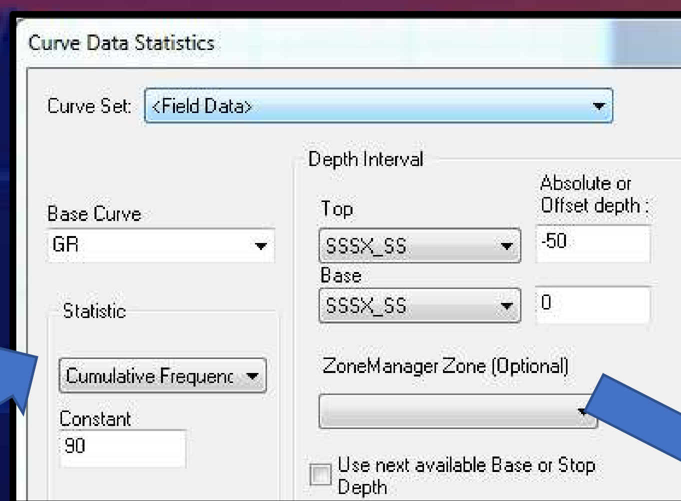
-These statistics are specific to each and every prospect and should make sense



Step 2 – Calculate Statistics into a "Zone" in Mapping Software

- Calculate P90 for normalized zone in <u>EACH WELL</u> and store in "zone manager."





Well ID	GRcfq90SX
49005256810000	96.241
49005252730000	106.925
49009207330000	104.186
49009281230000	111.413
49005264020000	118.827
49005251960000	99.208
49009228940000	118.210
49019206720000	85.488
49005255210000	101.981
49009225690000	102.572
49005270710000	92.708
49005050230000	57.029
49009212260000	99.997
49019205950000	95.973

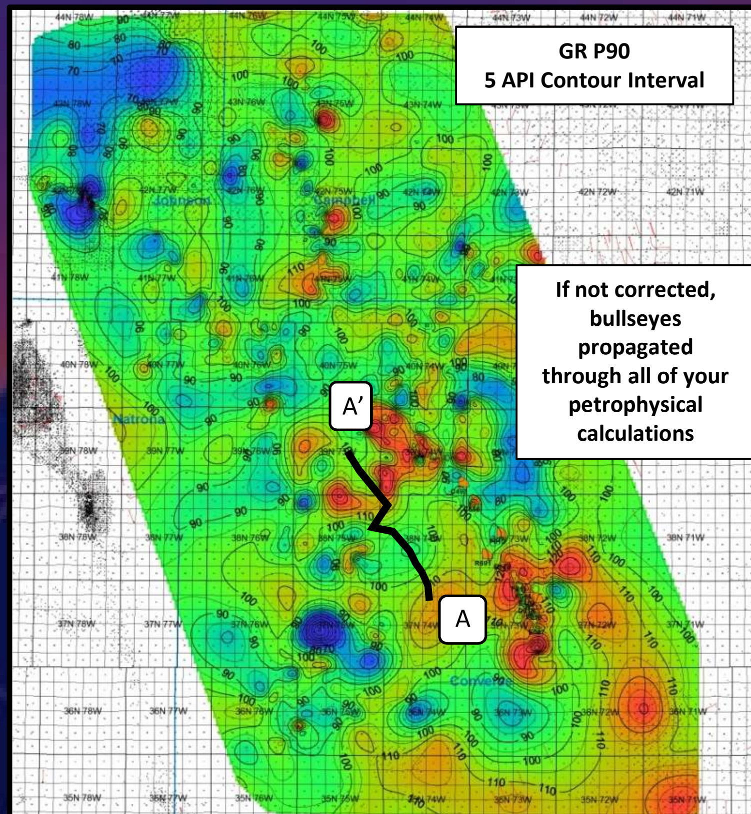
Step 3 – Create Map of 'GR P90'

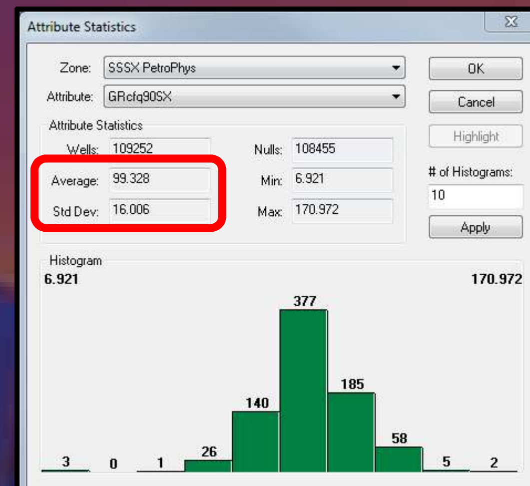
-Create grid of datapoints.

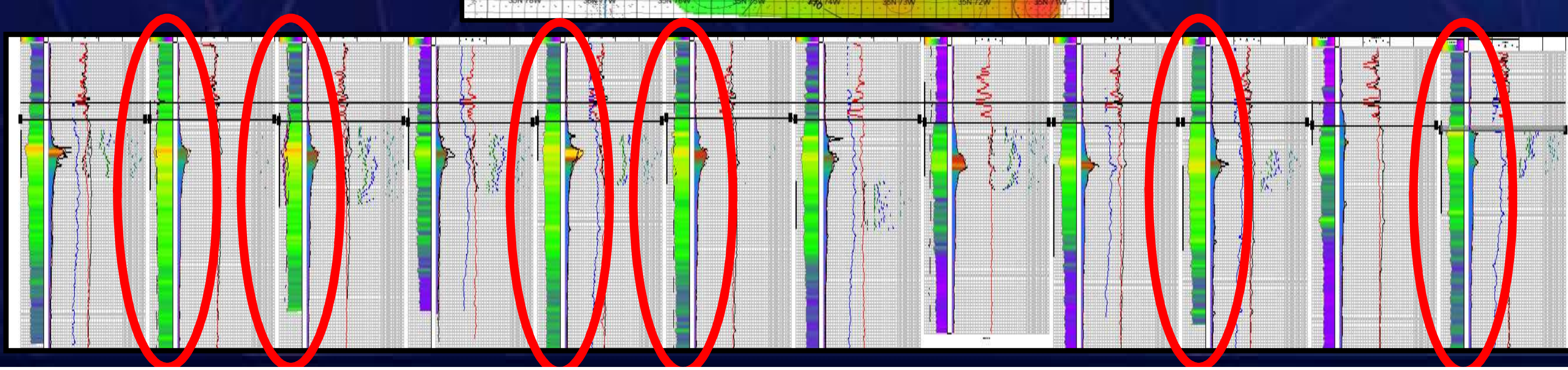
-Use reasonable grid size (1000'-2000').

-Capture raw grid in PPT.

-Map shows bullseyes throughout.







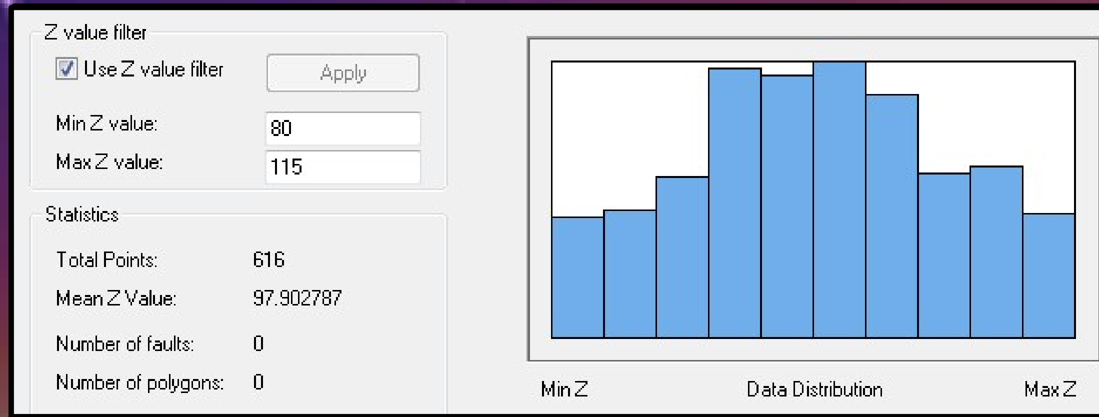
Step 4 – 'Clean up' GR P90 Map

- Time to put on your "interpreter" hat.

- Remove (clip) extreme outliers
  - Automatically (histogram)

    or

  - Manually (well by well)

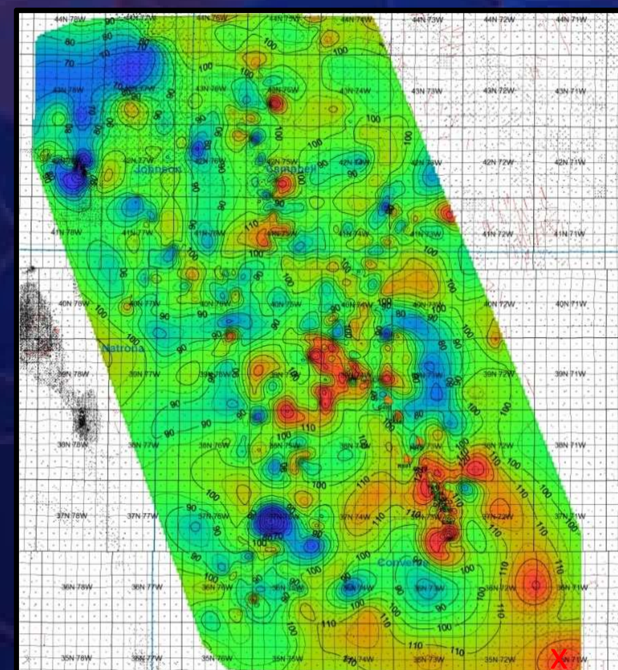


<u>Disclaimer:</u> This part of the method is highly subjective.

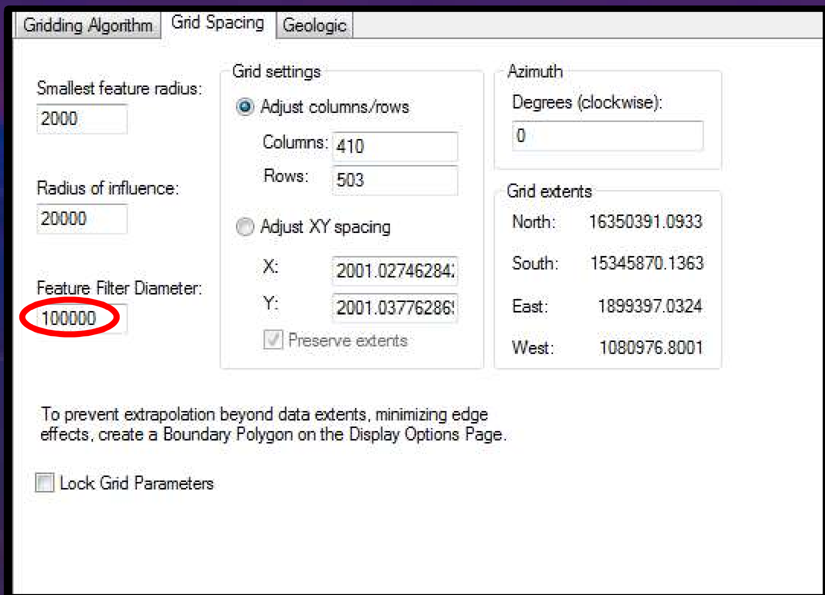
The point here is that we are trying to eliminate tool/environmentally induced variation in the log response and maintain any geologic induced variation in the log response.

This answer will never be perfect, As long as it is an improvement, it is better than what we started with.

-Winston Churchill(?)



Step 4b – Creation of Sequential "Trend Filter" Grids



Too Variable

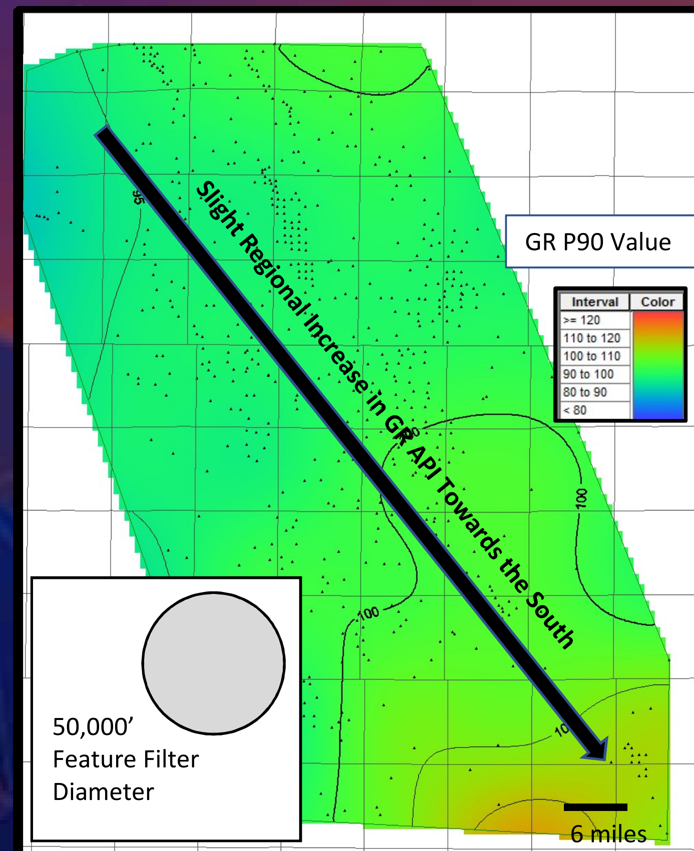
Better

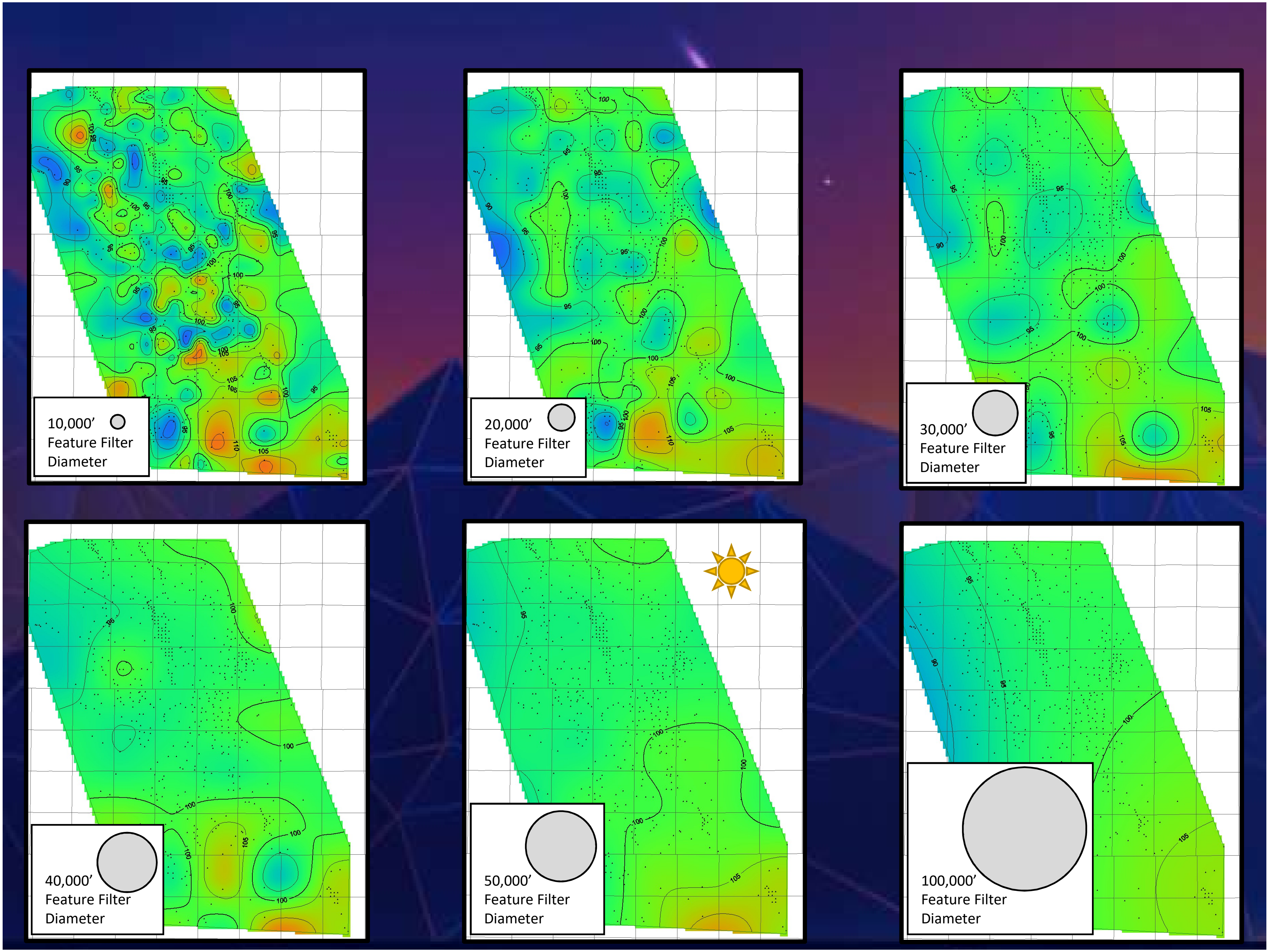
Even Better

Almost There

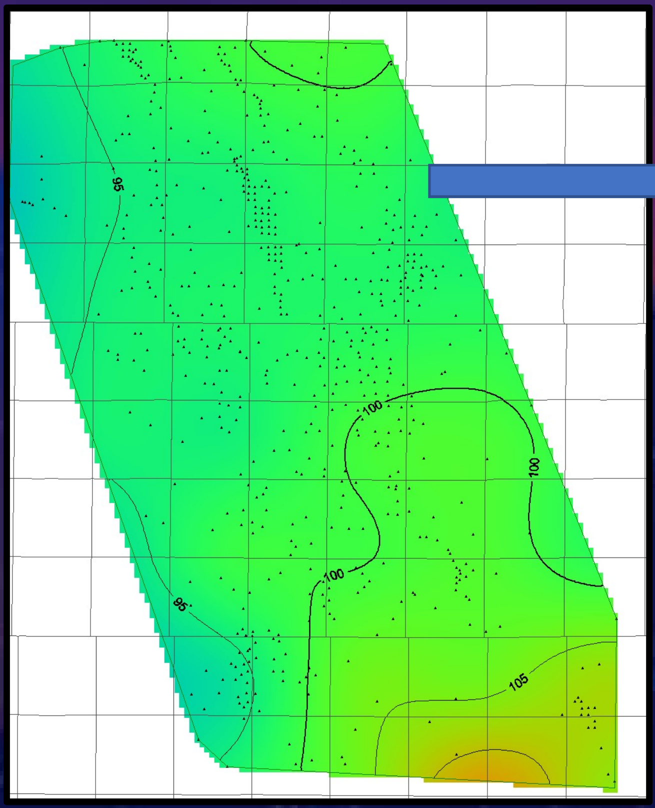
Just Right

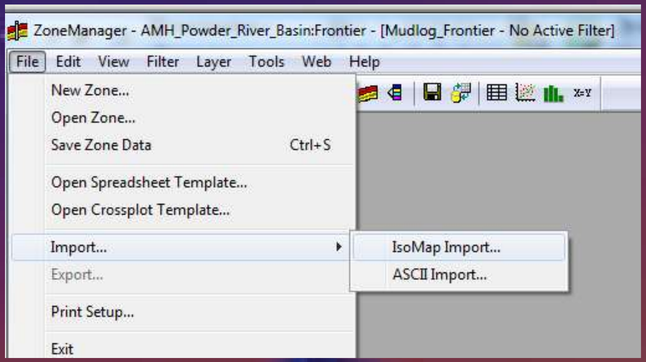
Too Plain

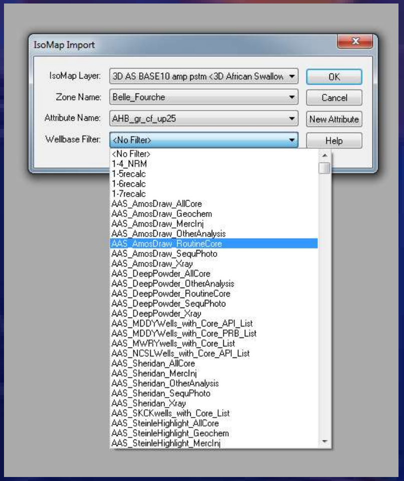


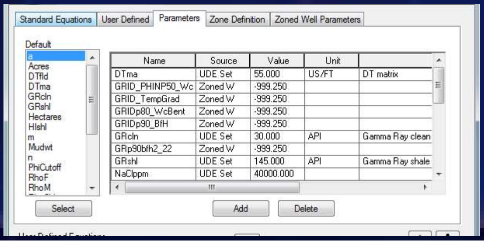

10,000’ Feature Filter Diameter
20,000’ Feature Filter Diameter
30,000’ Feature Filter Diameter
40,000’ Feature Filter Diameter
50,000’ Feature Filter Diameter
100,000’ Feature Filter Diameter

Step 5 – Sample Grid Back to All Wells

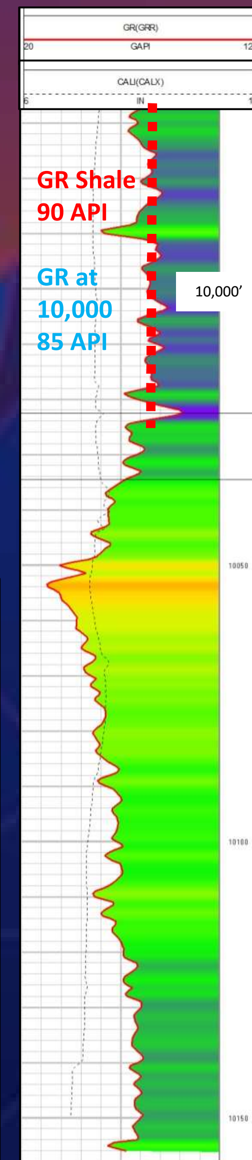








Step 5b –Return to Our Origins (Canned Normalization Equations)



<u>1 Point Normalization Using Mechanical Shift</u>

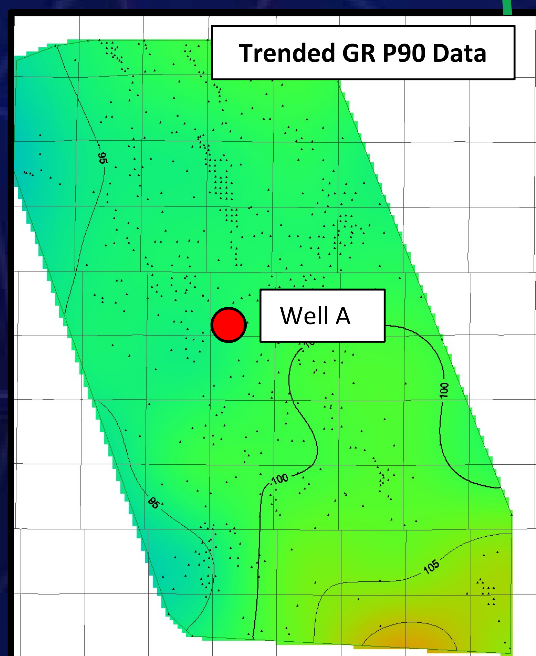
Normalized Curve =

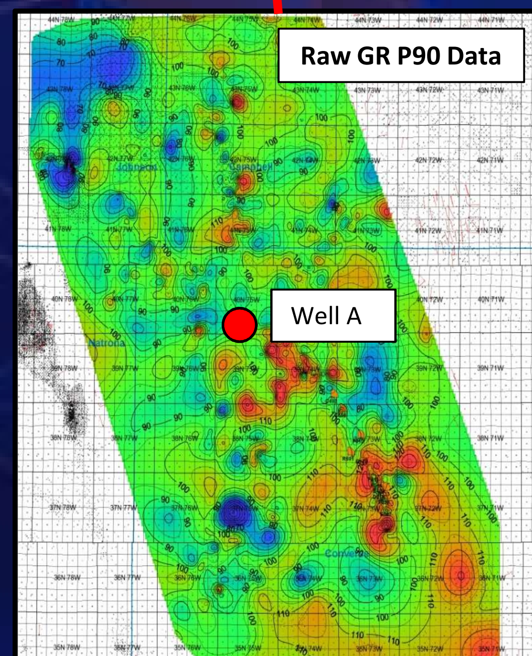
GR Value at Each Depth + "Variable Field Average" – Well Average

Example:

GR Norm at 10,000' = 85 + 98 – 90

GR Norm at 10,000' = 93



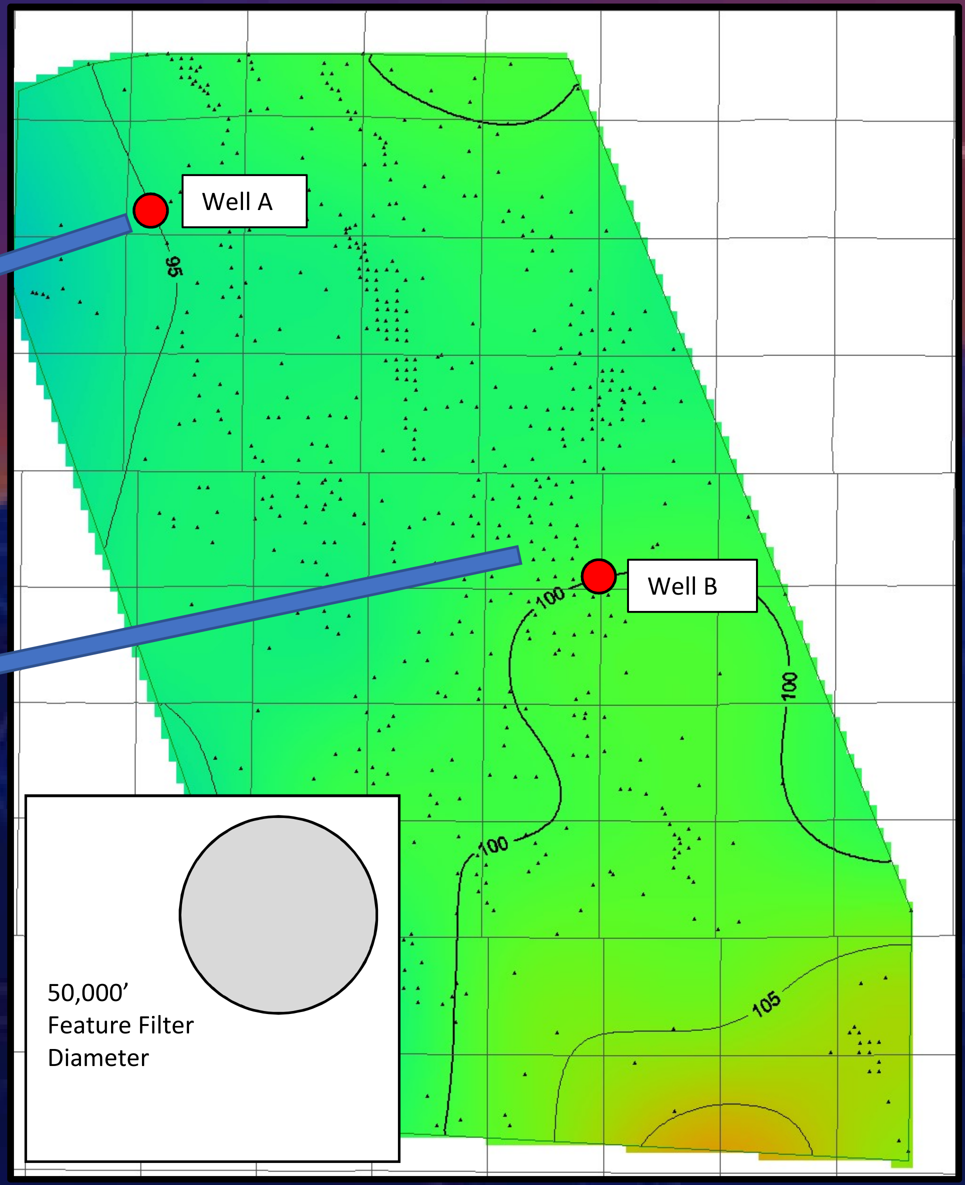


Example from Two Wells

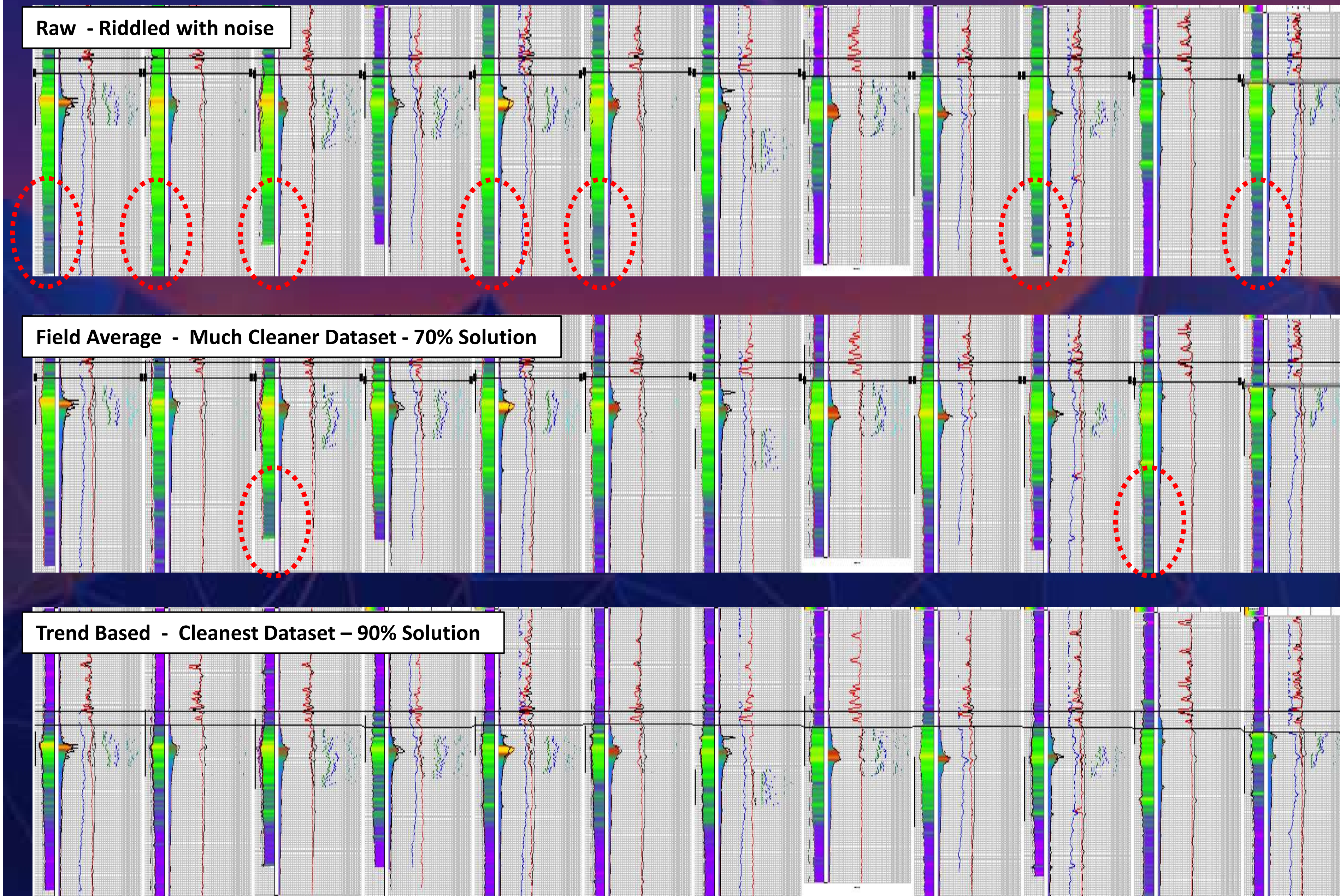
Normalized Curve = **GR Value at Each Depth** + **"Variable Field Average"** – **Well Average**

WELL A
50' shale interval
GR at 10,000' = 85
GR Norm at 10,000' = 85 + 95 – 90
GR Norm at 10,000' = 90

WELL B
50' shale interval
GR at 10,000' = 85
GR Norm at 10,000' = 85 + 100 – 90
GR Norm at 10,000' = 95



Results



Raw - Riddled with noise
Field Average - Much Cleaner Dataset - 70% Solution
Trend Based - Cleanest Dataset – 90% Solution

Other Examples in the Rockies

Each Basin/Formation Brings Their Own Set of Challenges

- Williston Basin – Normalization in Predominately Carbonate Basin
- Uinta Basin – Highly Variable Stratigraphy (Lacustrine)

Google Image Search, Aug, 2019

Google Image Search, Aug, 2019

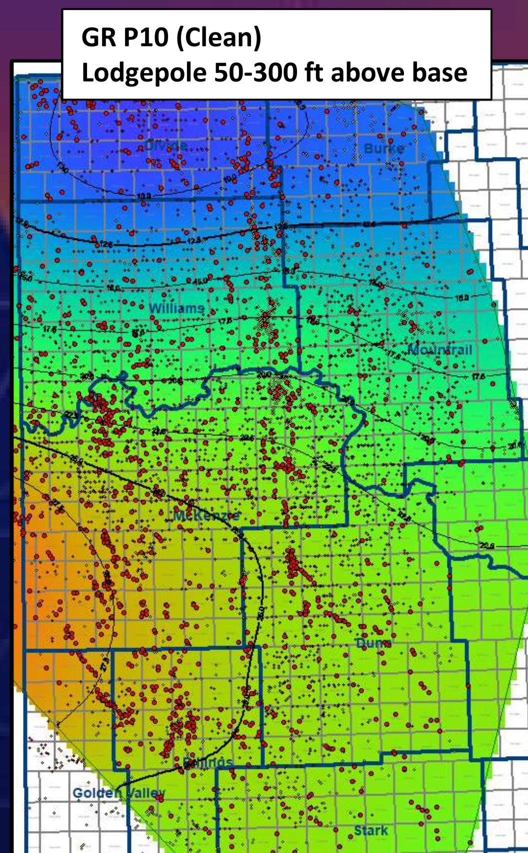
Williston Basin – Normalization in Predominately Carbonate Basin

Challenge:

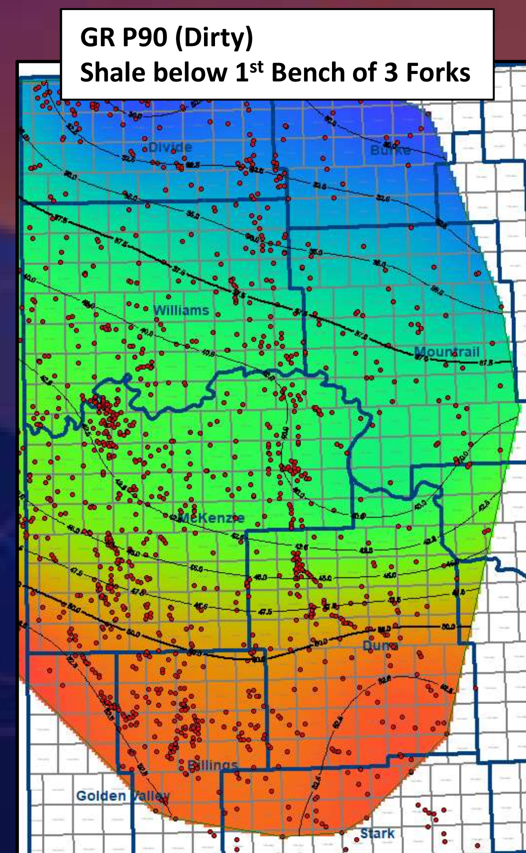
Unlike the PRB, few regionally consistent shale packages.

How to Tackle the Problem (GR):

- 2 Point Normalization using Clean Carbonate (Nisku or Lodgepole) and Shale (3 forks shale)



*Color scales not consistent on initial and final map



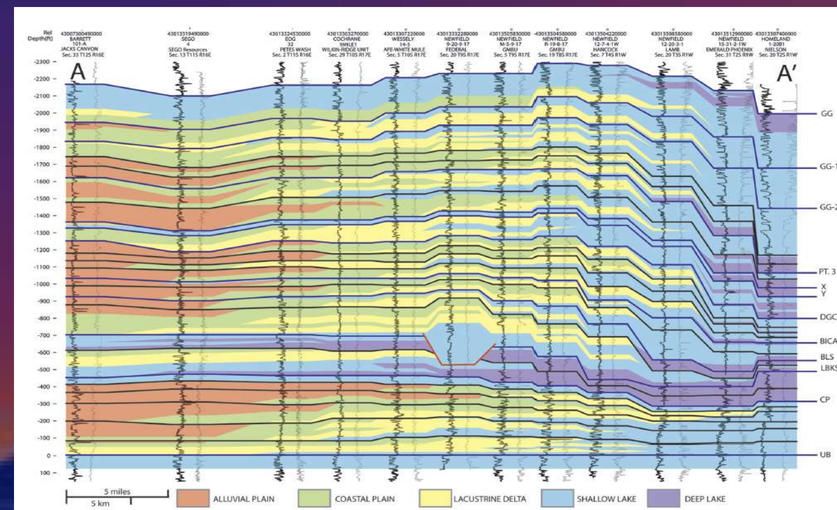
*Color scales not consistent on initial and final map

Uinta Basin – Highly Variable Stratigraphy (Lacustrine)

Challenge: No consistent marine shale, tight lime, or other marker across basin.

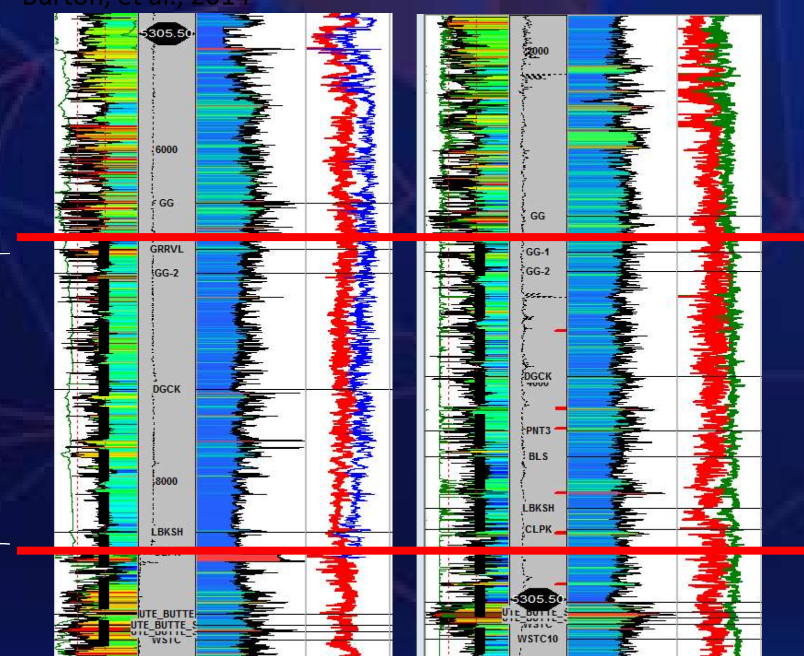
How to Tackle the Problem (GR and PHIN):

-1 point trend-based normalization (shale baseline evident across 1500’ of sand and shale). Also applied resistivity cutoff.



Burton, et al., 2014

1500’ interval of sand and shale



Final Considerations

-Log Normalization isn't a 100% solution. It isn't meant to "correct" logs, but remove the influence of non-geologic factors.

<u>Many</u> different methods for <u>many</u> different situations (choose your weapon).

Regional Trend-Based Normalization is the most 'Geologically Honest' method of log normalization.

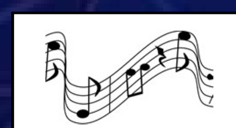
Potentially accounts for:

- **-Regional Compaction Trends**
- **-Regional Diagenesis**
- **-Regional Facies Variations**

Remember – It is an interpretation….Which <u>AFFECTS</u> every other calculation down the line…And doing it incorrectly (or not at all) can have significant implications… No Pressure….

Google Image Search, Aug, 2019

And Now…An Easy Way to Remember to NORMALIZE….



When your logs are all corrupt,
normalize them up!

Talk to me after this talk or find me on LinkedIn if you want a copy of this presentation as a reference to the trend-based normalization workflow