Power and Limitations of X-ray Fluorescence from Cuttings: A Test in the Utica and Lorraine Shales from Quebec*

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Abstract

Shale gas exploration in the Quebec Lowlands is in full swing. The present main target is a roughly 200-m-thick Utica Shale (carbonate-rich); a potential target for the future is the overlying Lorraine Shale, which can exceed 2500 meters in thickness. Both shale units are laterally extensive. Whereas the stratigraphy of the Utica is well understood, log analyses of the Lorraine have failed to provide any stratigraphic framework, as the gamma ray is relatively featureless in every well.

The drill cuttings of five wells have been systematically studied using X-ray fluorescence (XRF) at the INRS laboratory in Quebec City. For each studied cutting vial, a series of ten measurements has been taken that gives a representative view of possible compositional variations; this was thought to be essential when considering that the exact depth of each rock sample is only approximate. Data from twenty-two elements has been systematically recorded and analyzed individually, in combination with others, and in ratios. Within the Lorraine Shale, the best trends have been expressed by the following elements: K, Mn, S, Si, Ti, Rb, Fe, and Zr. The best ratios for the Lorraine Shale are Si/Ti, Mn/S and Al/Cu, and by far, the best discriminating displays are ternary diagrams using these three cited ratios. The best diagnostic ratios for Utica Shale are different. They are: K/Ca, Rb/Sr and Ca/Ti.

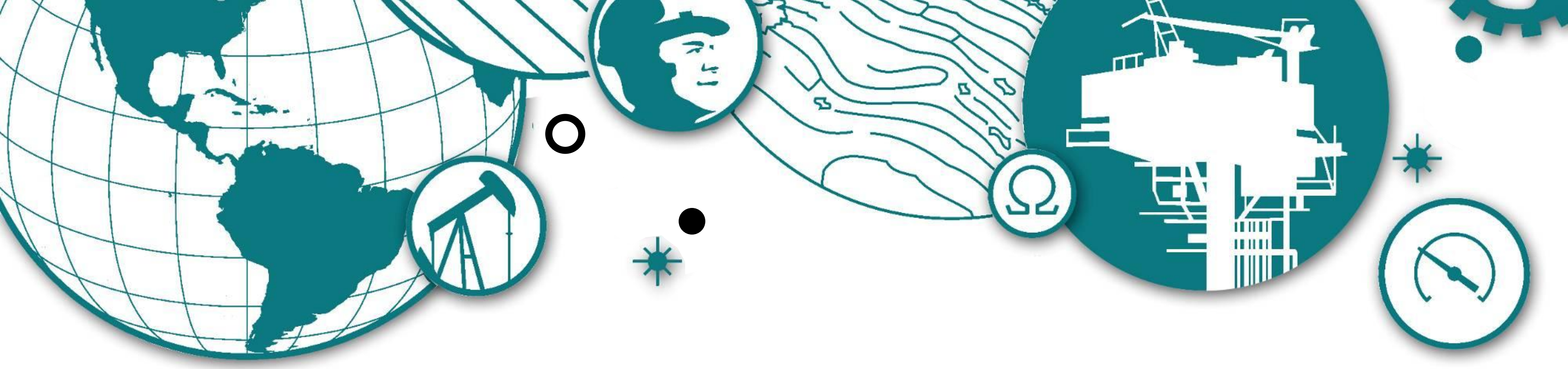
Within the Lorraine Shale, five large chemostratigraphic units have been identified and correlated across the study area with no single well presenting the complete sequence; only three chemostratigraphic units have been recognized in most of the studied wells.

In two of the wells, various sieve fractions have been analyzed to understand the influence of the “rock chip / grain size” on the analysis. Some discrepancies in the data are the result of different travel time to surface between finer and coarser fractions, the latter lagging the former.

The X-ray fluorescence study of two of the horizontal wells in the Utica has clearly demonstrated the vast potential of the analysis to accurately identify the position of the borehole within the Utica stratigraphic framework. The results of the integration with a log-based structural geology analysis are highly promising, making XRF a very useful tool for the successful development of shale gas resource plays.

Reference

Comeau, F.A., E. Asselin, R. Bertrand, M. Malo, and D. Kirkwood, 2004, Taconian mélanges in the Parautochthonous zone of the Quebec Appalachians revisited: Implications for foreland basin and thrust belt evolution, Canadian Journal Earth Science, v. 41/12, p. 1473-1490.



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a Test in the Utica and Lorraine Shales from Quebec

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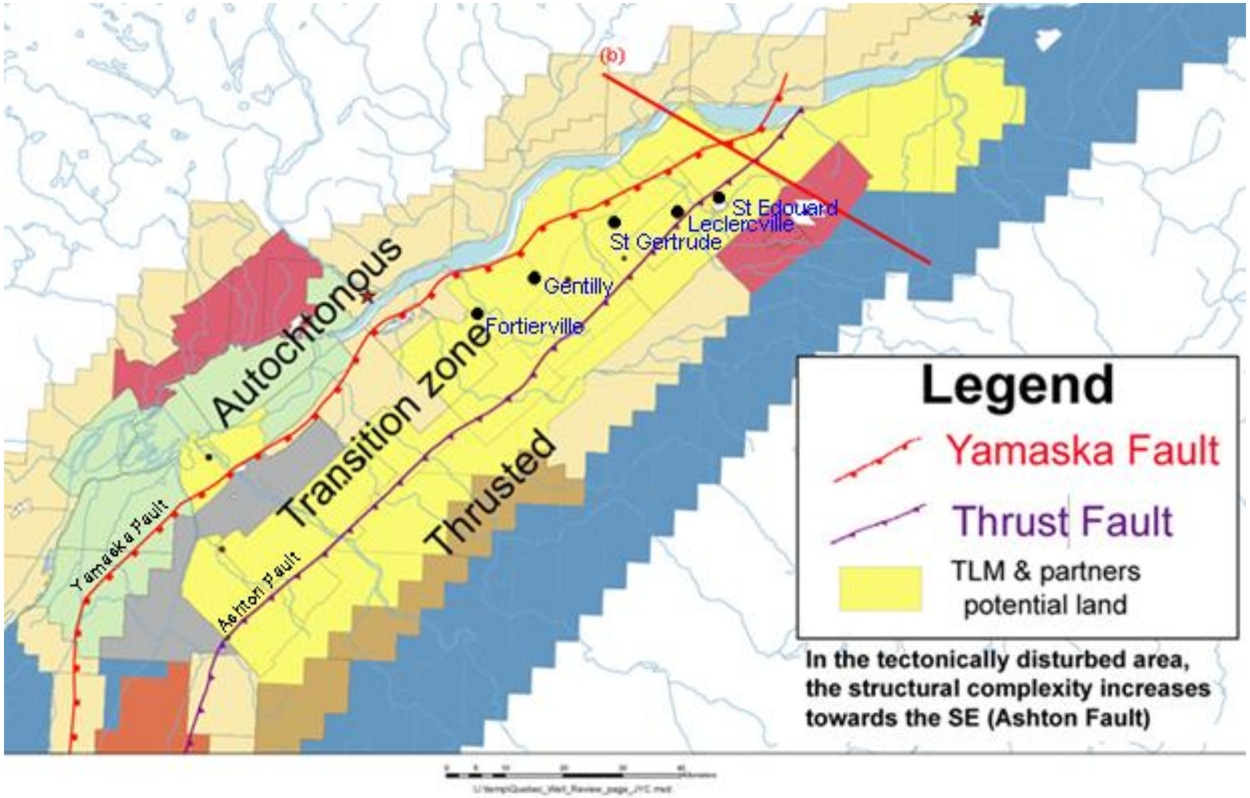
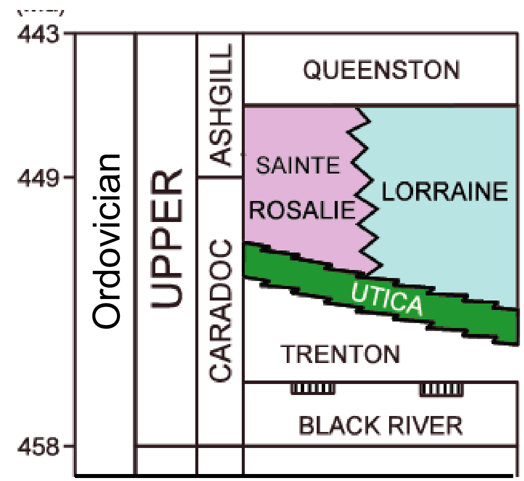
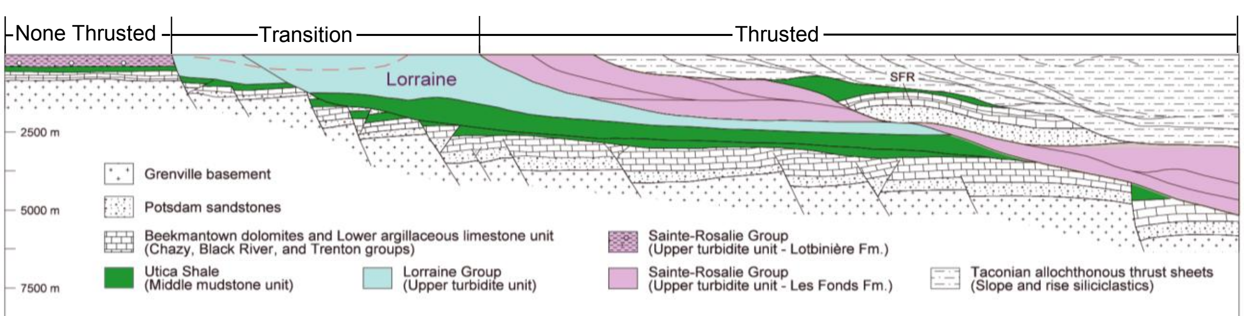
Outline

- Lorraine and Utica shales
  - Lorraine in vertical well
  - Utica in horizontal well
- Data analysis
  - Cores vs cuttings
  - Fine vs Coarse cutting fractions
- Conclusions on tool and analytical process

Lorraine Shale



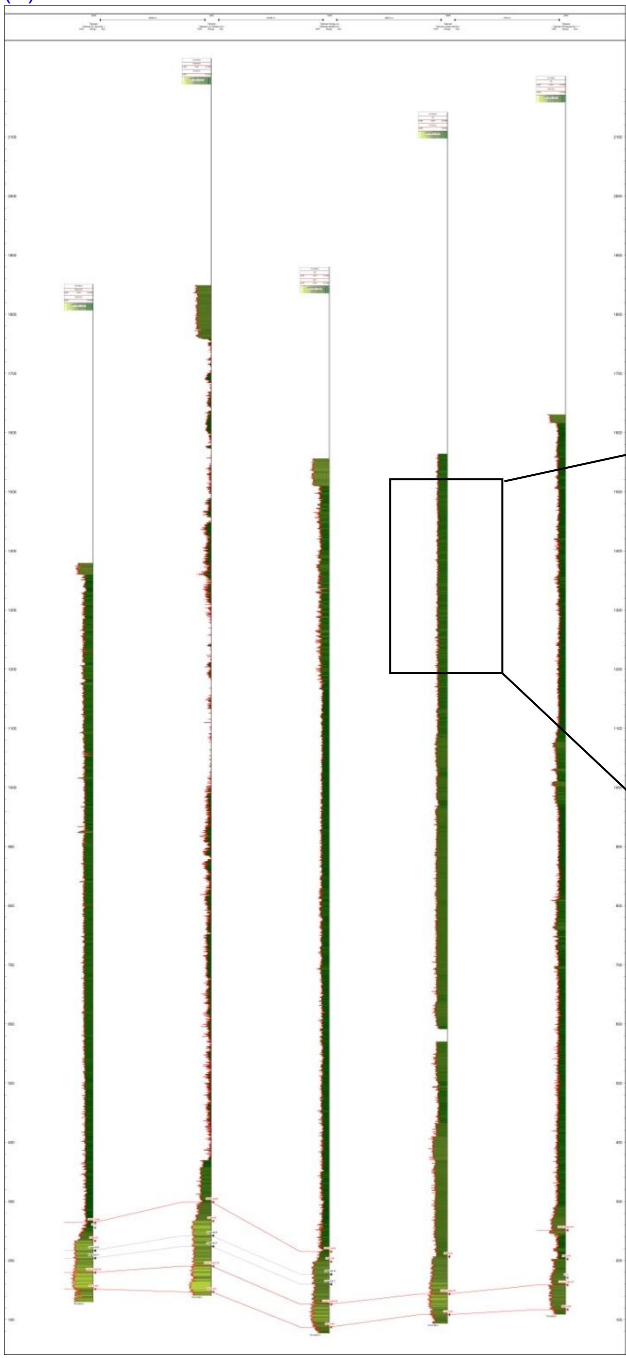




Modified after Comeau et al. Can. J. Earth Sci. Vol. 41, 2004

Lorraine Problem

(A)



2000m of prospective Lorraine shale with no paleontology for correlation.

Why XRF from cuttings in the Lorraine?

Define stratigraphy

Great potential for shale gas

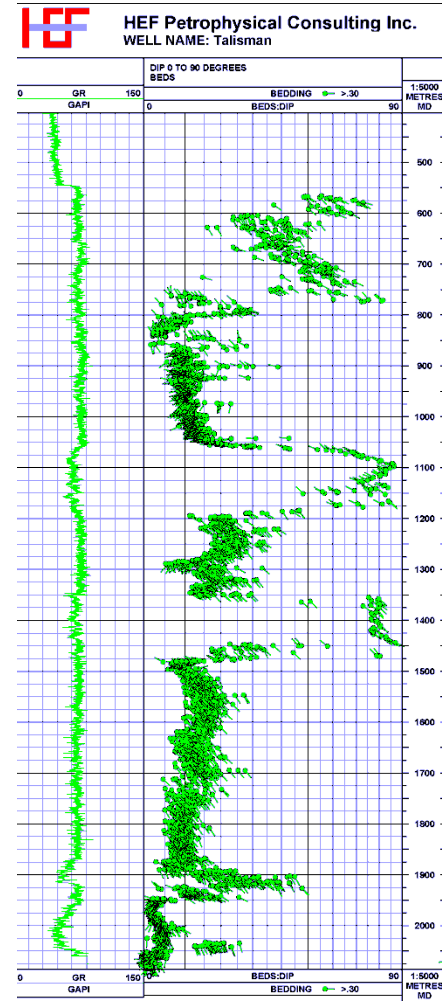
Identify target intervals

What are we dealing with

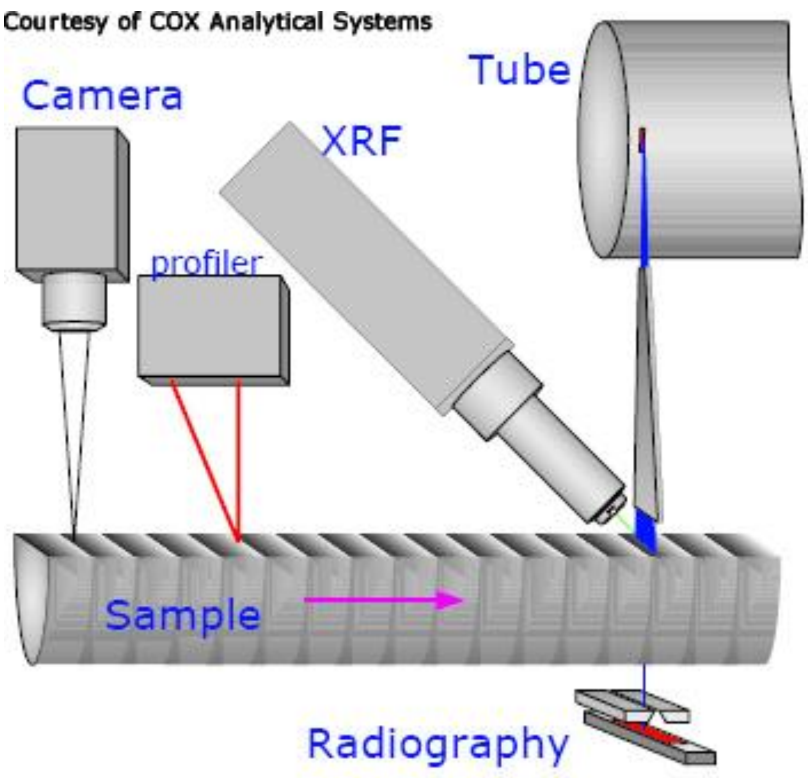
Rare & short Lorraine cores but drill cuttings in every well

No paleontology and a flat gamma-ray with no markers

Structural complexity



What is XRF?

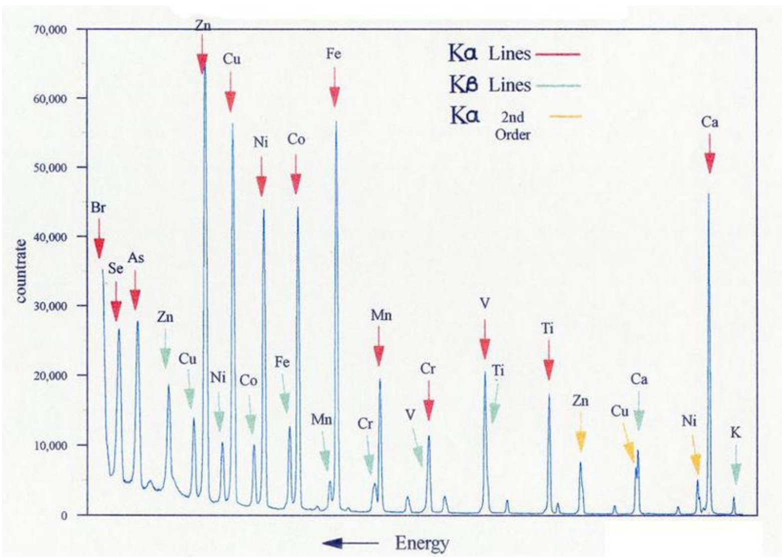


XRF measures the character

of

fluorescent/secondary

X-rays



XRF machine

INRS Quebec City

Machine designed for cores only

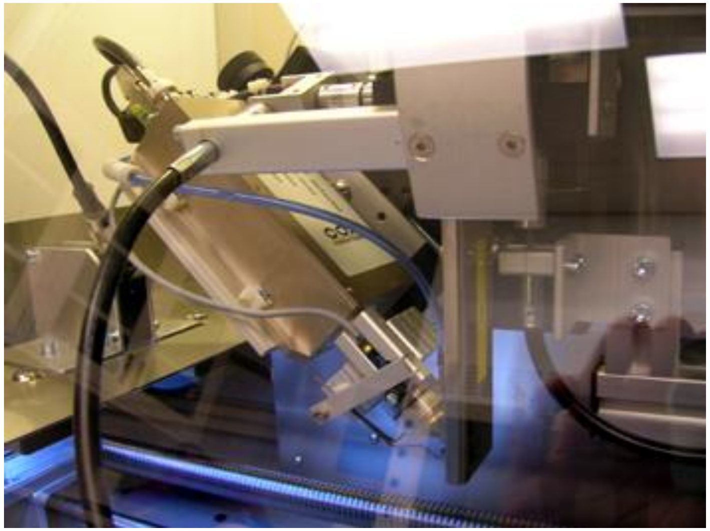
Modified for Talisman to accommodate drill cuttings.

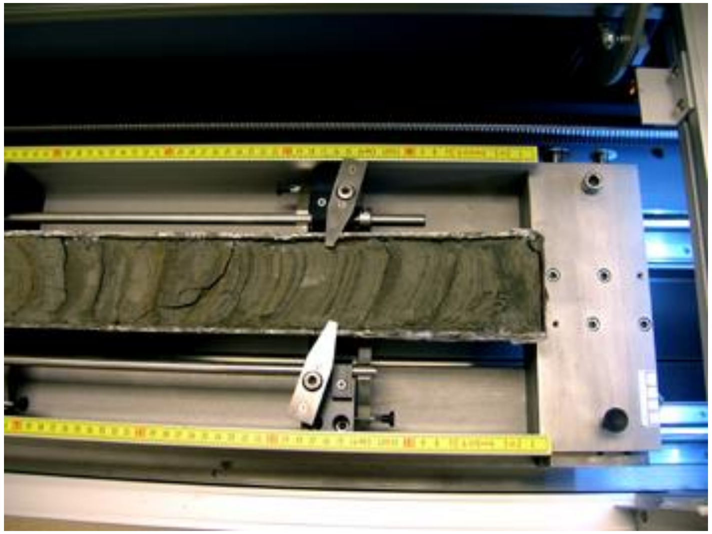
Each cutting sample cost around 30$

(with crushing)

10 individual measurements / sample

24 elements for each measurement





XFR on Drill Cuttings

· Offers a larger sample interval, entire well.

· Analytical resolution up to 5m intervals.

· Cost effective

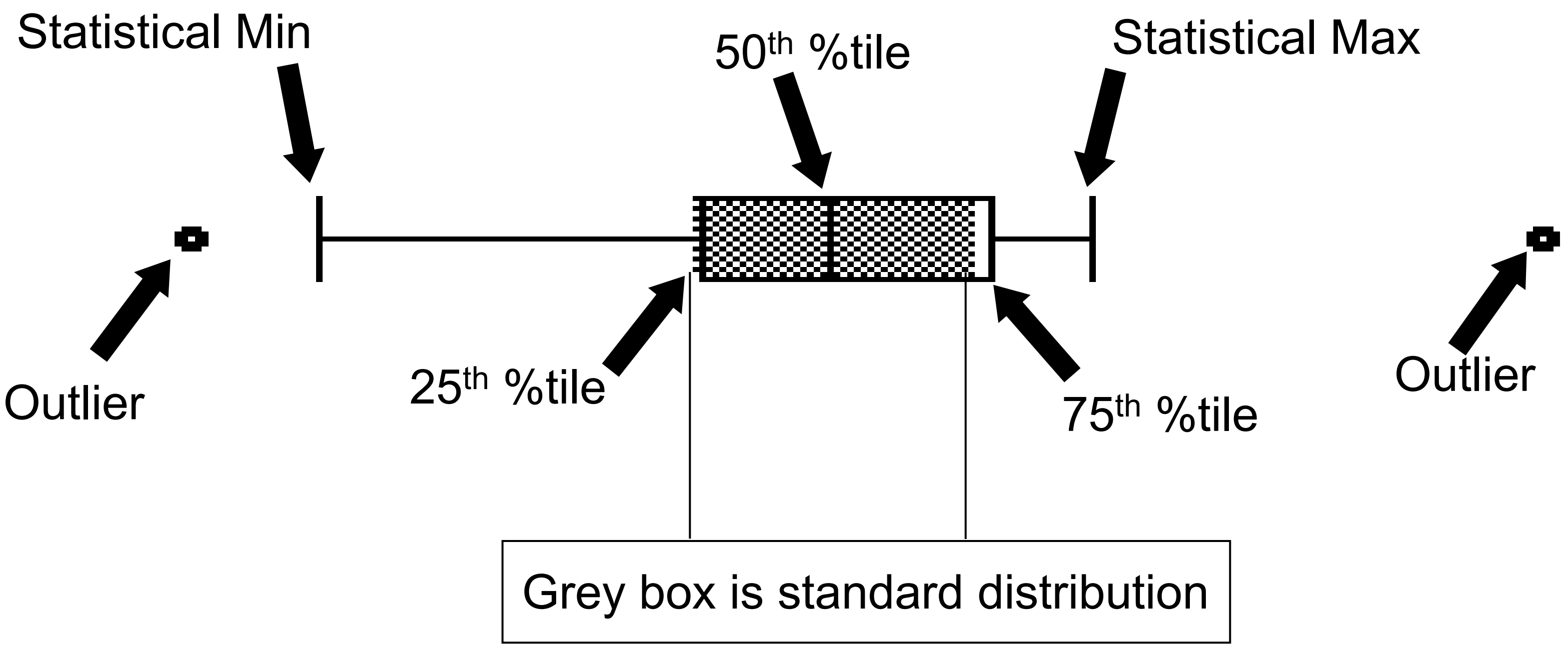
· Unlike core samples, drill cuttings require preparation crushing, (standard size cuttings)

· Testing drill cuttings of a finer fraction.

·**On average 10 measurements per sample (at different locations on the crushed cuttings)**

Data Analysis

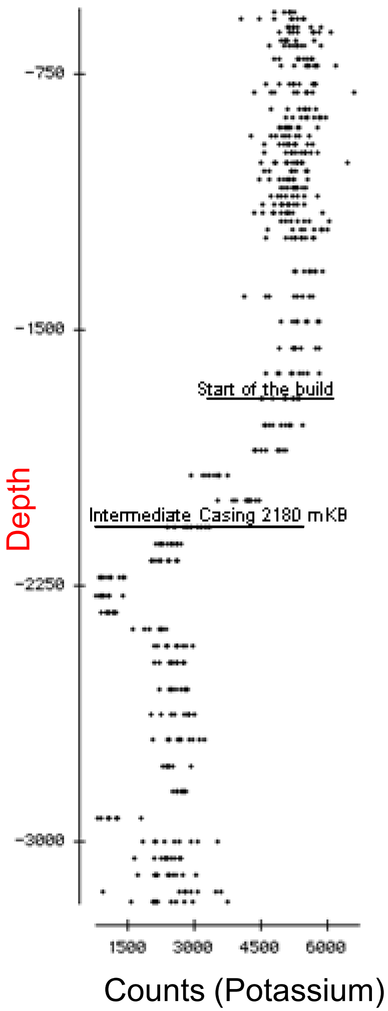
Box Plots



Statistics and Data manipulation

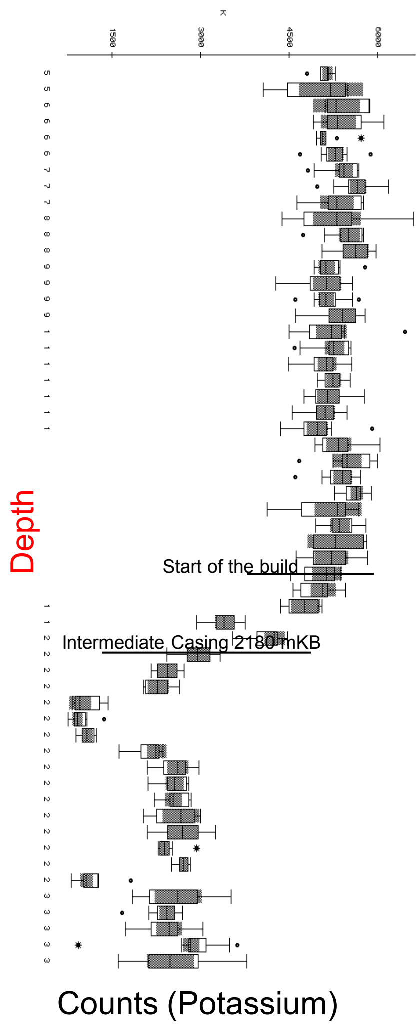
Raw Data (e.g. Potassium)

10 measurements / sample



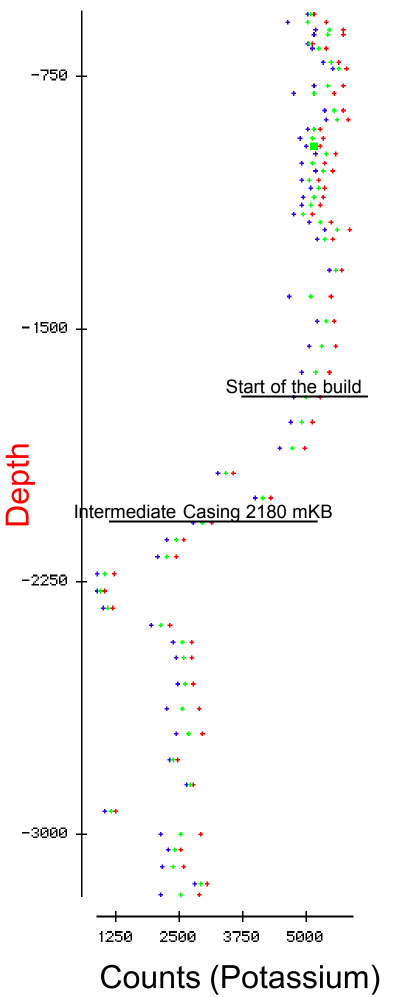
Box Plot of raw data

“fake vertical scale”



reduction to 25th, 50th, & 75th percentile

Extracted Stats



Drill cutting samples

Crushing the drill cuttings is time consuming

Testing only a finer fraction reduces costs and speeds up the process

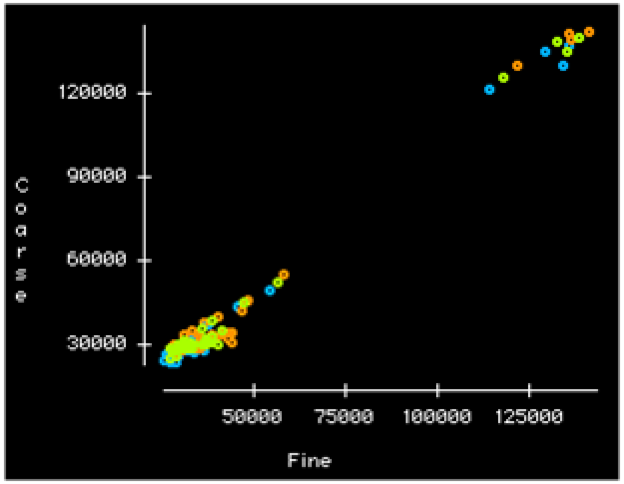
3 Wells tested using **fine** and **crushed coarse** drill cuttings

Fine vs. Coarse: checking consistency of results

Recent wells are done using only the finer fraction

Fine vs. Coarse: (Iron)

coarse



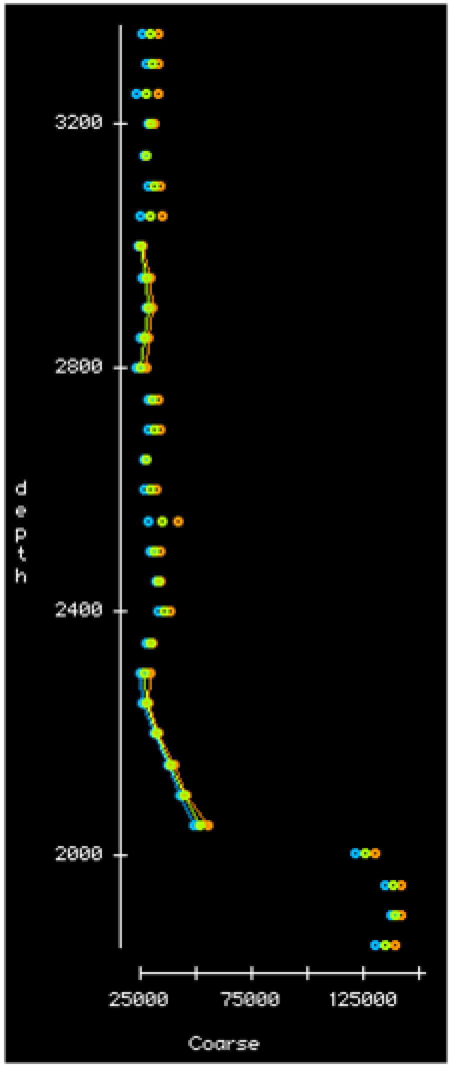
fine

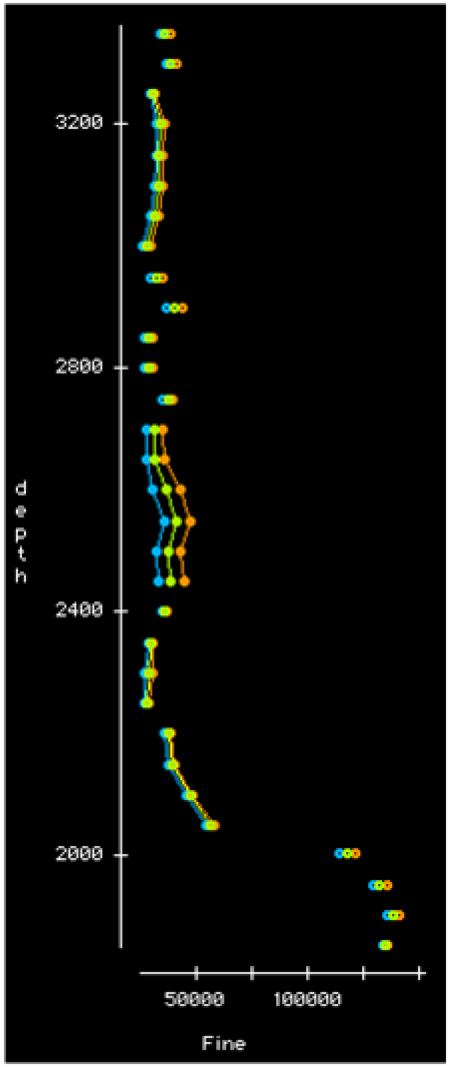
Good correlation

between

fine and coarse fraction

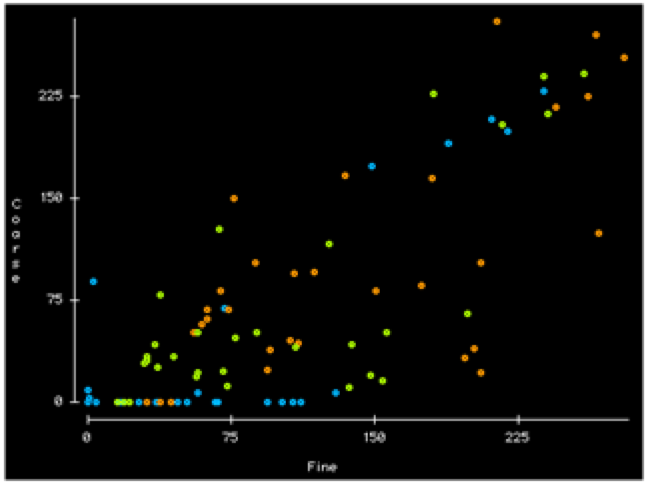
Iron





Fine vs. Coarse: (Aluminum)

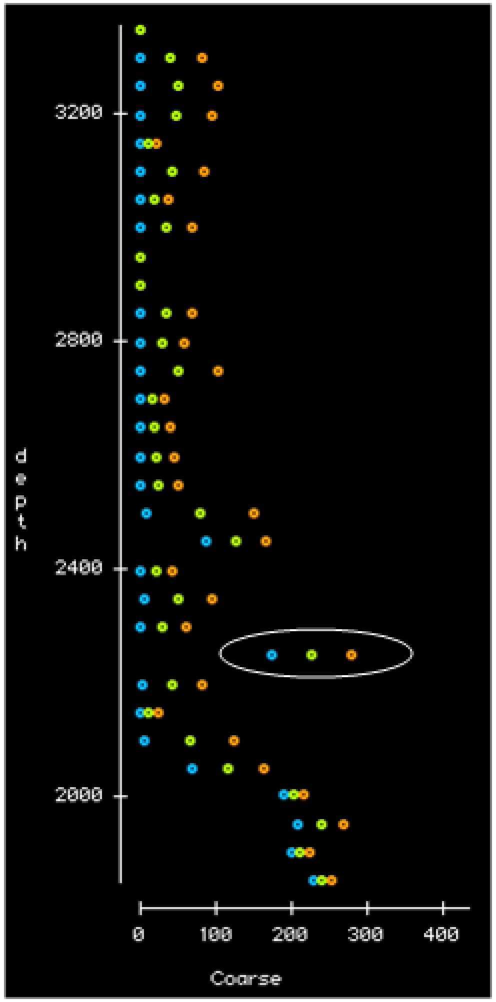
coarse

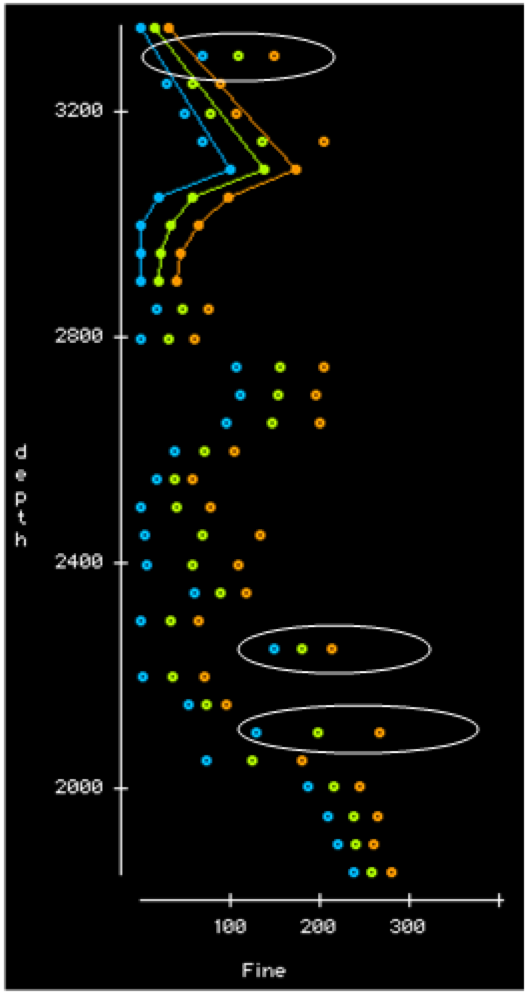


fine

Poor correlation between

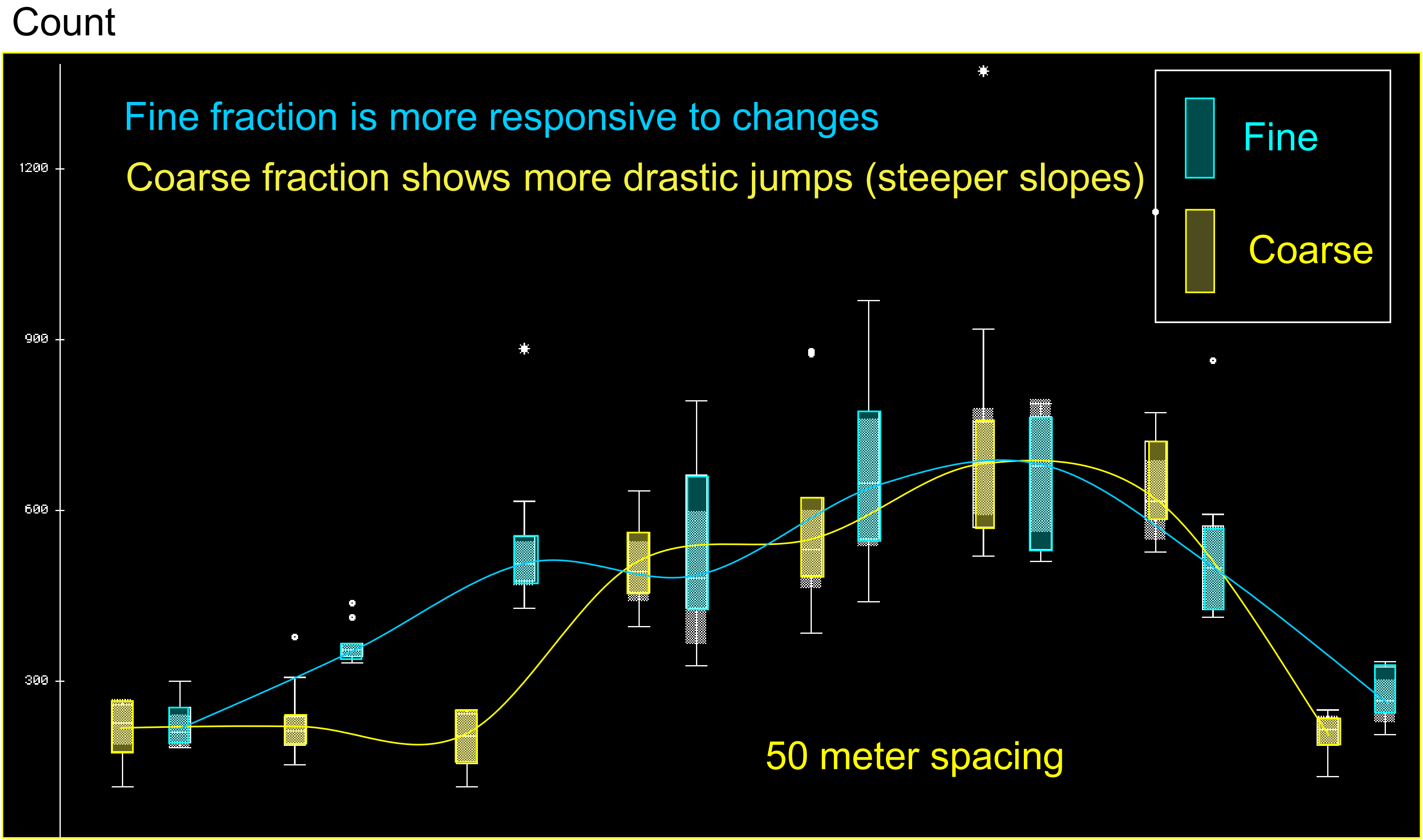
coarse and fine fraction





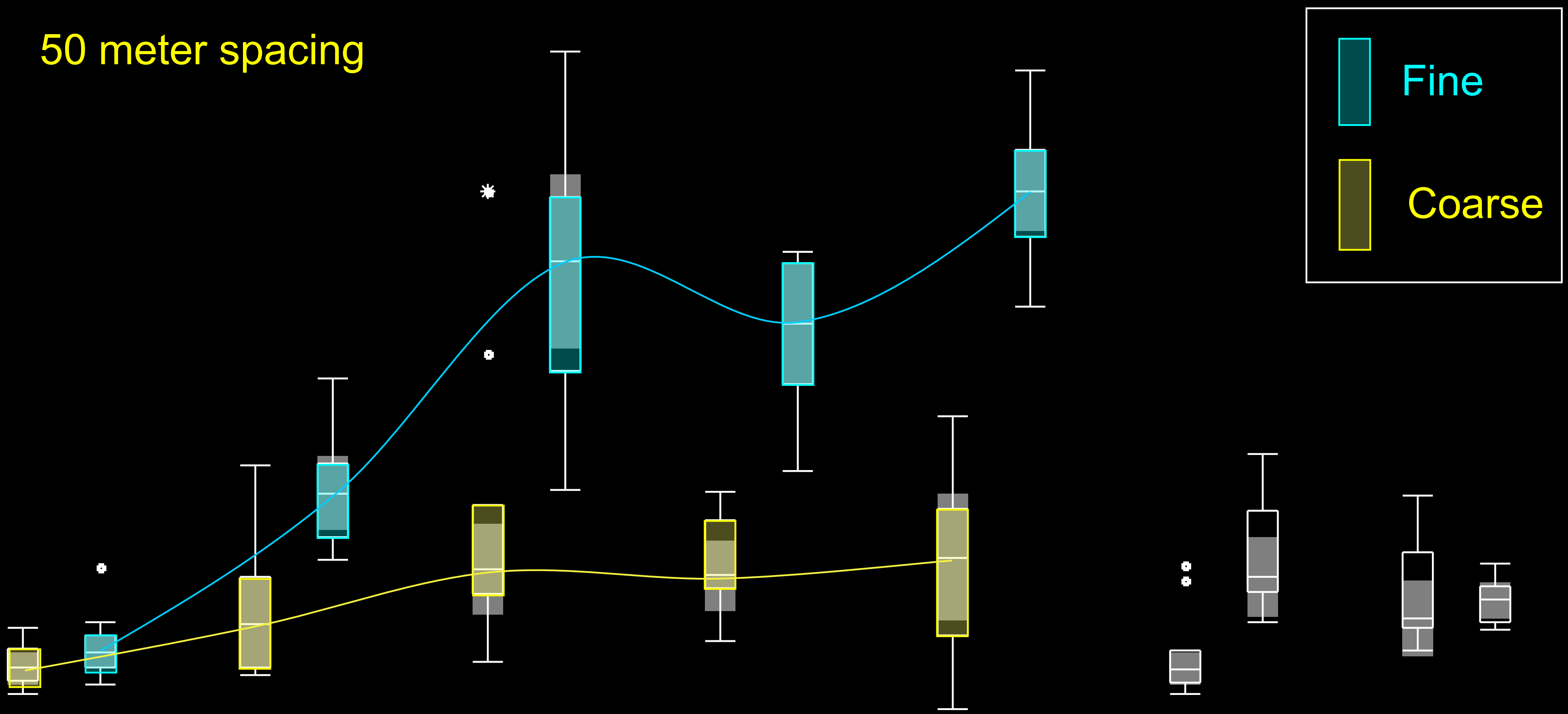
Aluminum

Rubidium



Count
1200
900
600
300
Fine fraction is more responsive to changes
Coarse fraction shows more drastic jumps (steeper slopes)
Fine
Coarse
50 meter spacing

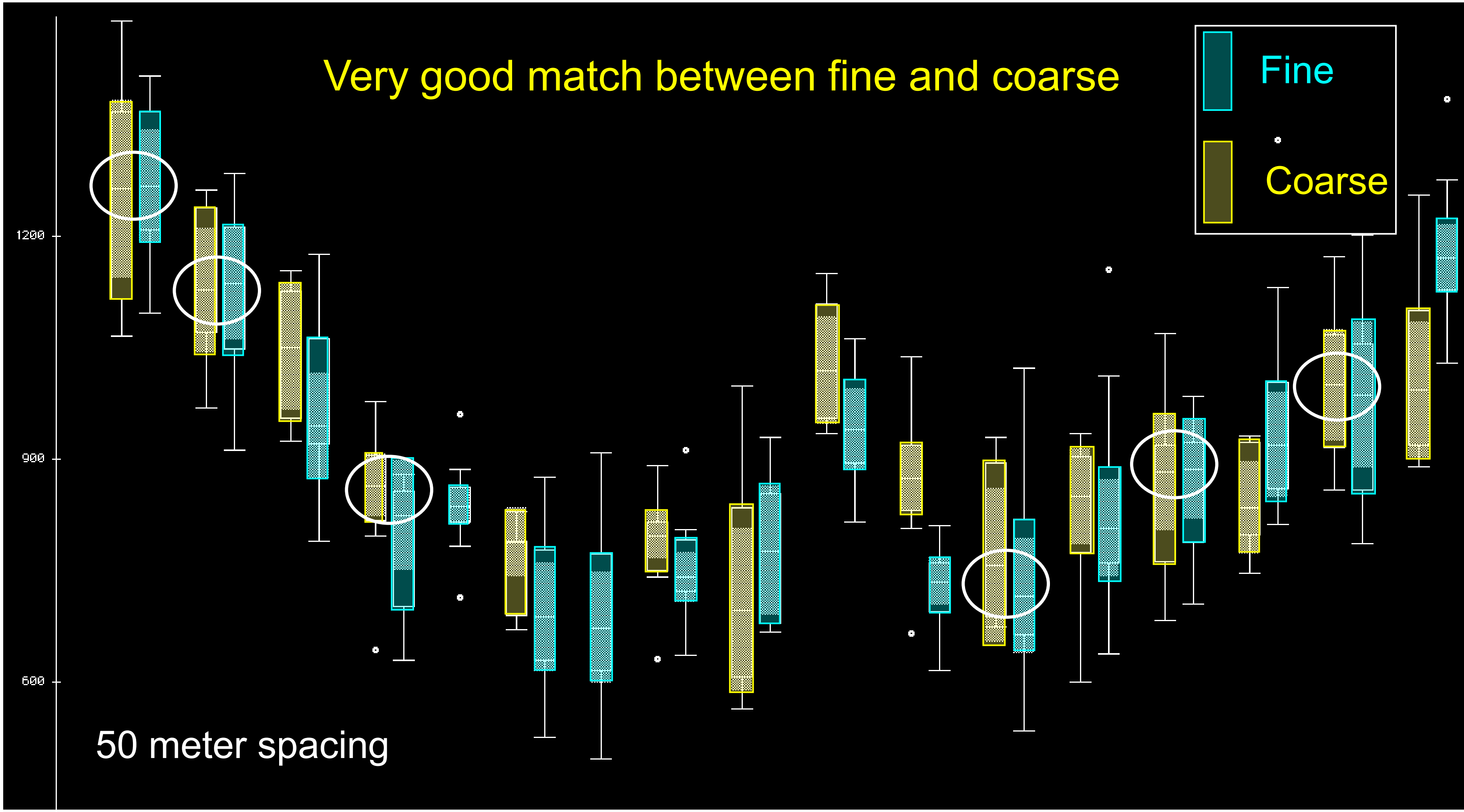
Fine vs. coarse grain sampling



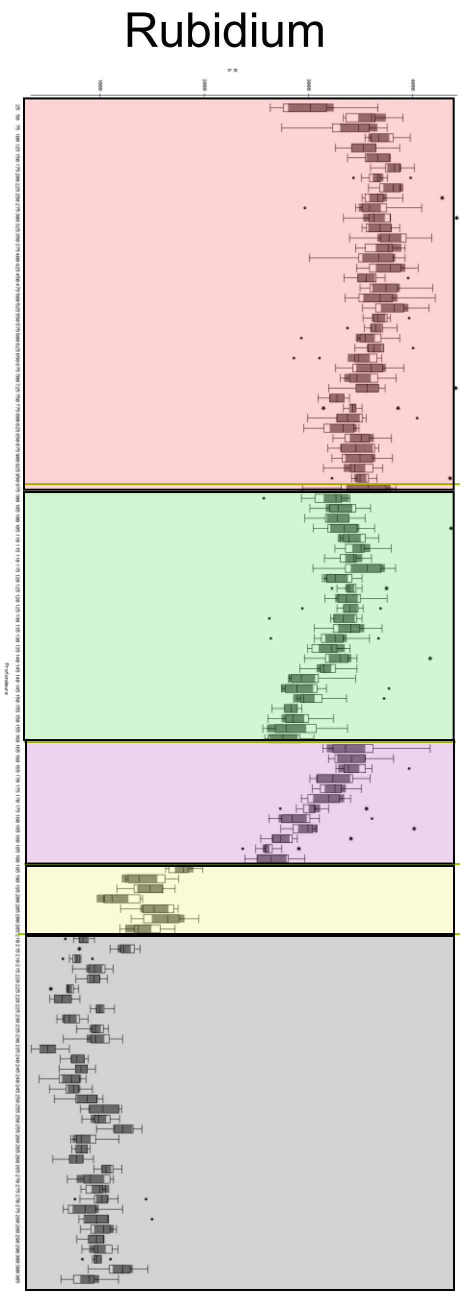
Strontium shows large discrepancy between **fine** and **coarse** fraction

Rubidium

Count

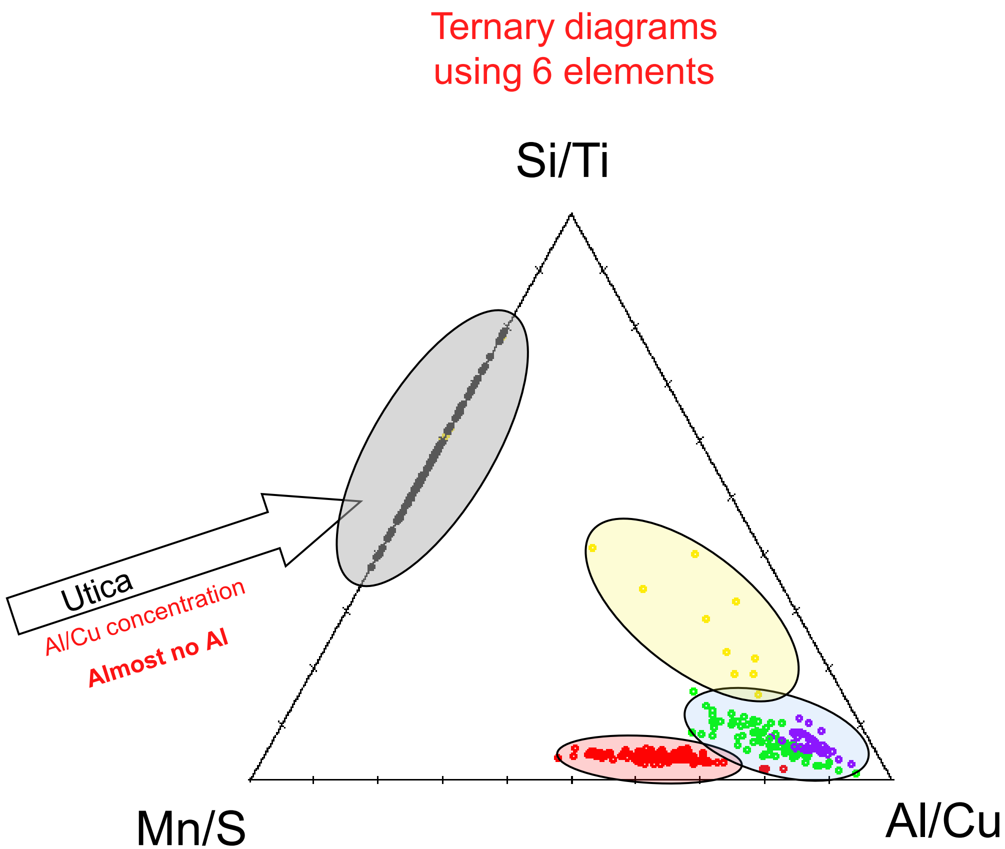


Tools and Observations



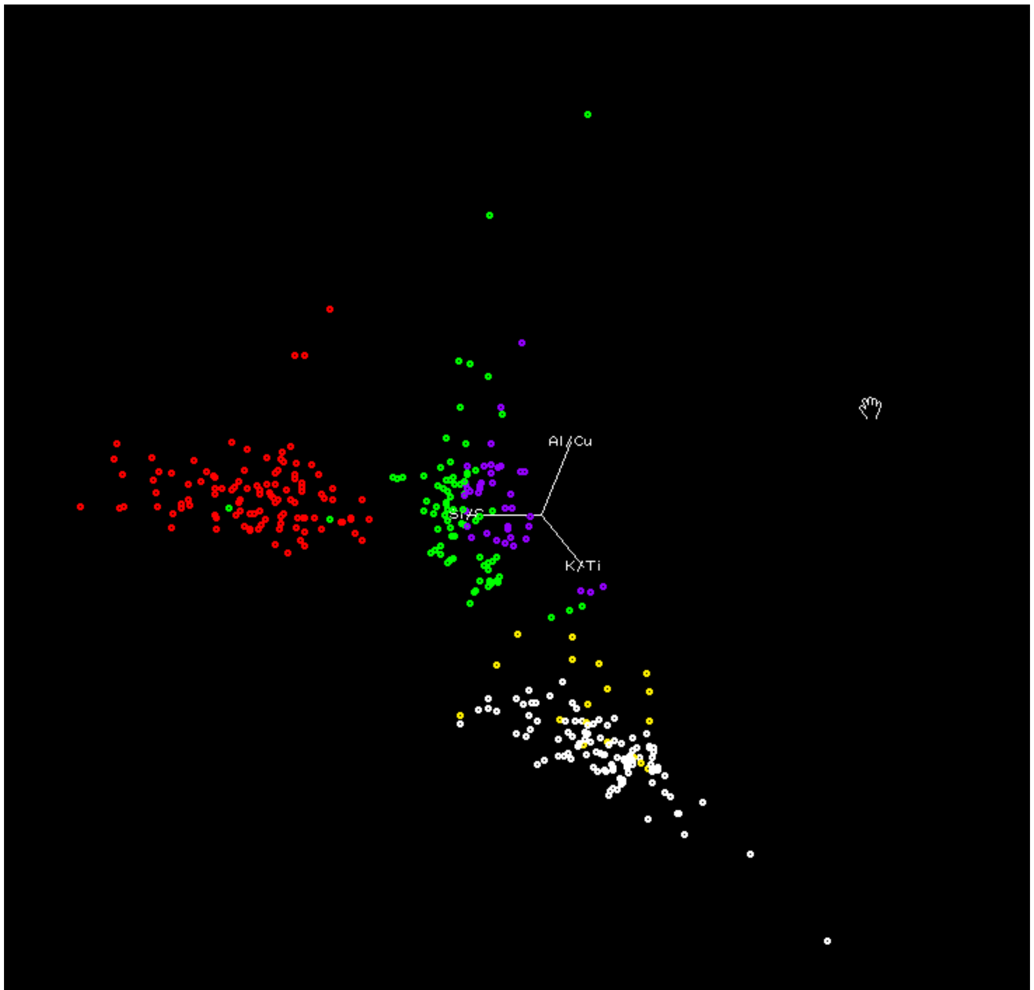
Box plots help identify Chemostrat packages.

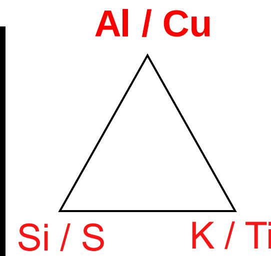
Confirmed by ternary diagrams using ratios



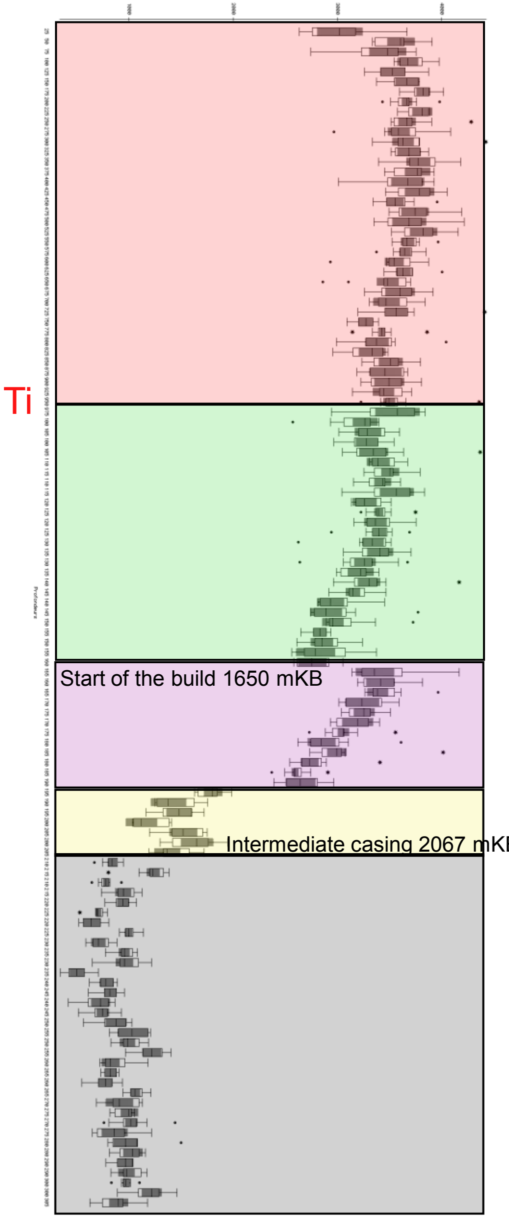
Additional Tools

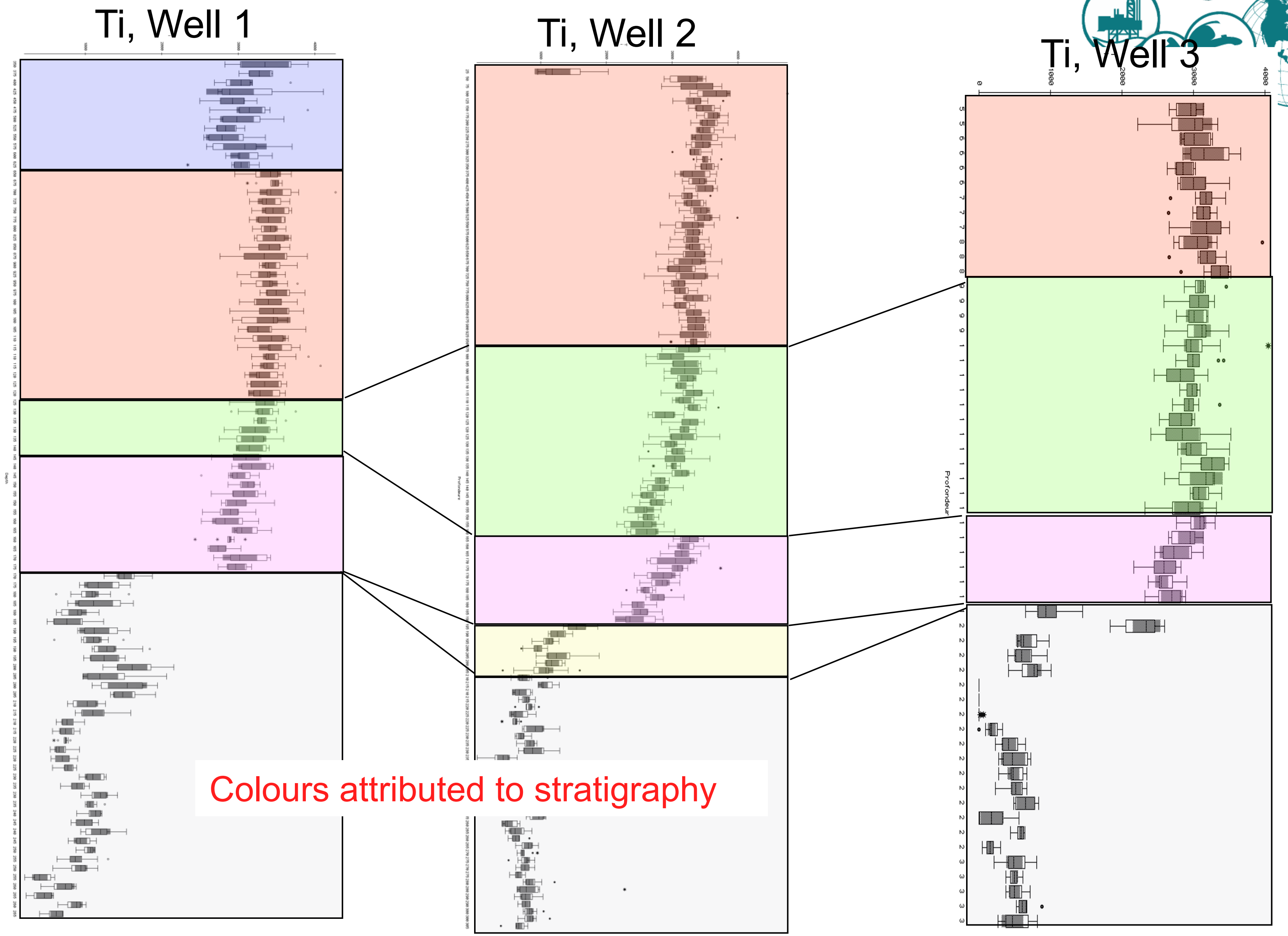
Cross plots, ternary diagrams & 3-D projections





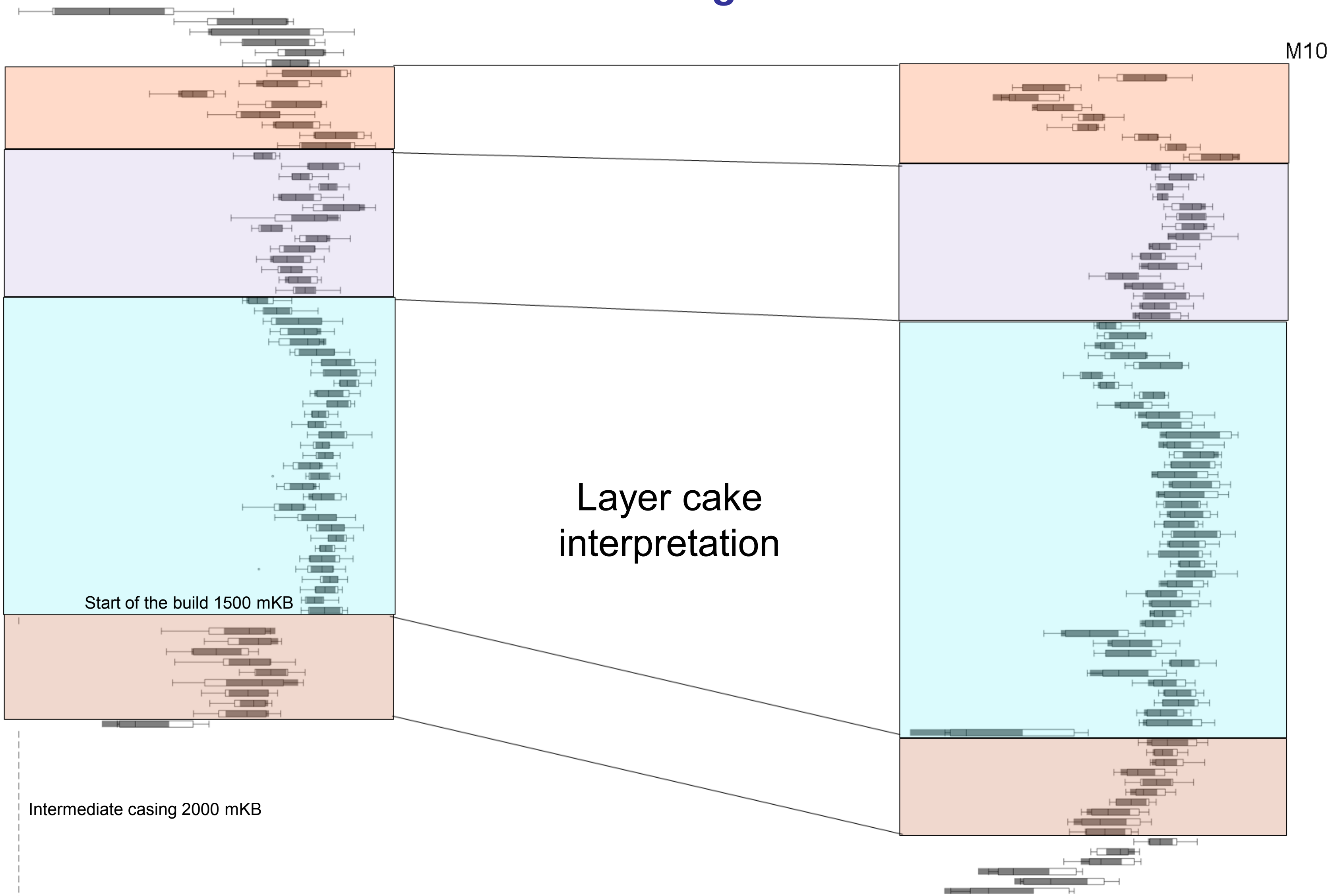
Rubidium





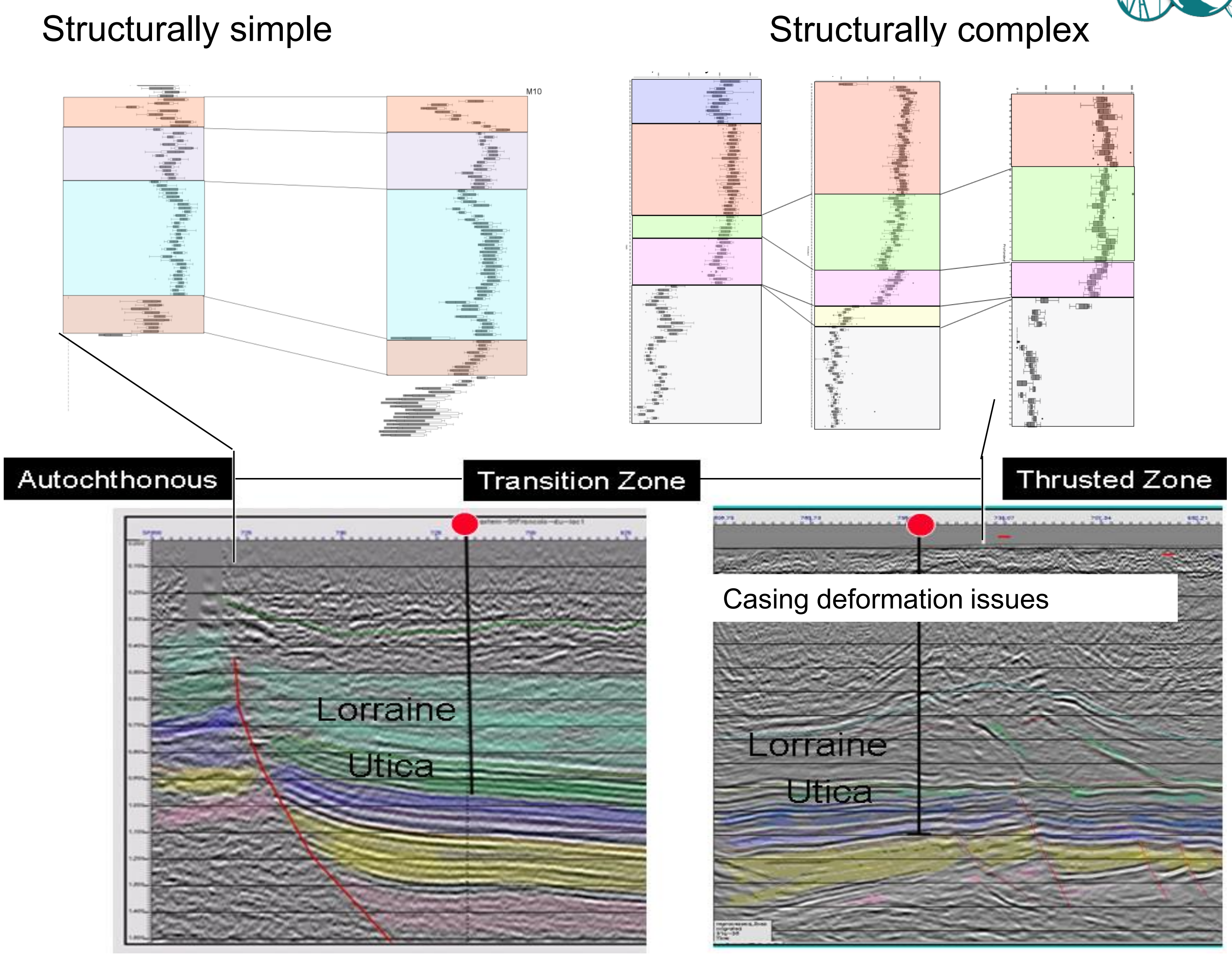
Colours attributed to stratigraphy

4 elements together



Box Plots on this illustration correspond to the sum of the counts generated from Iron, Titanium, Potassium, and Rubidium

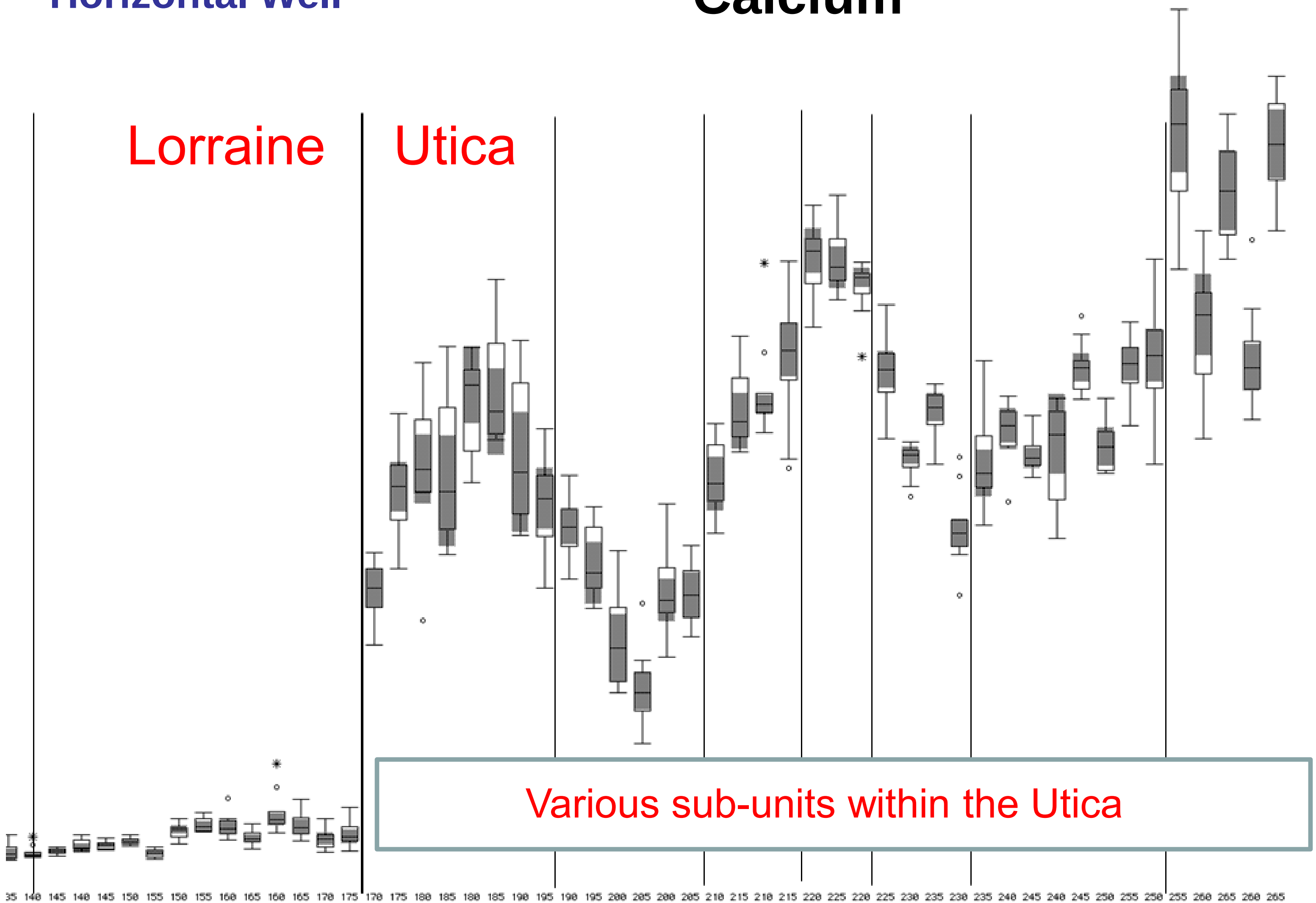
Structure styles between wells



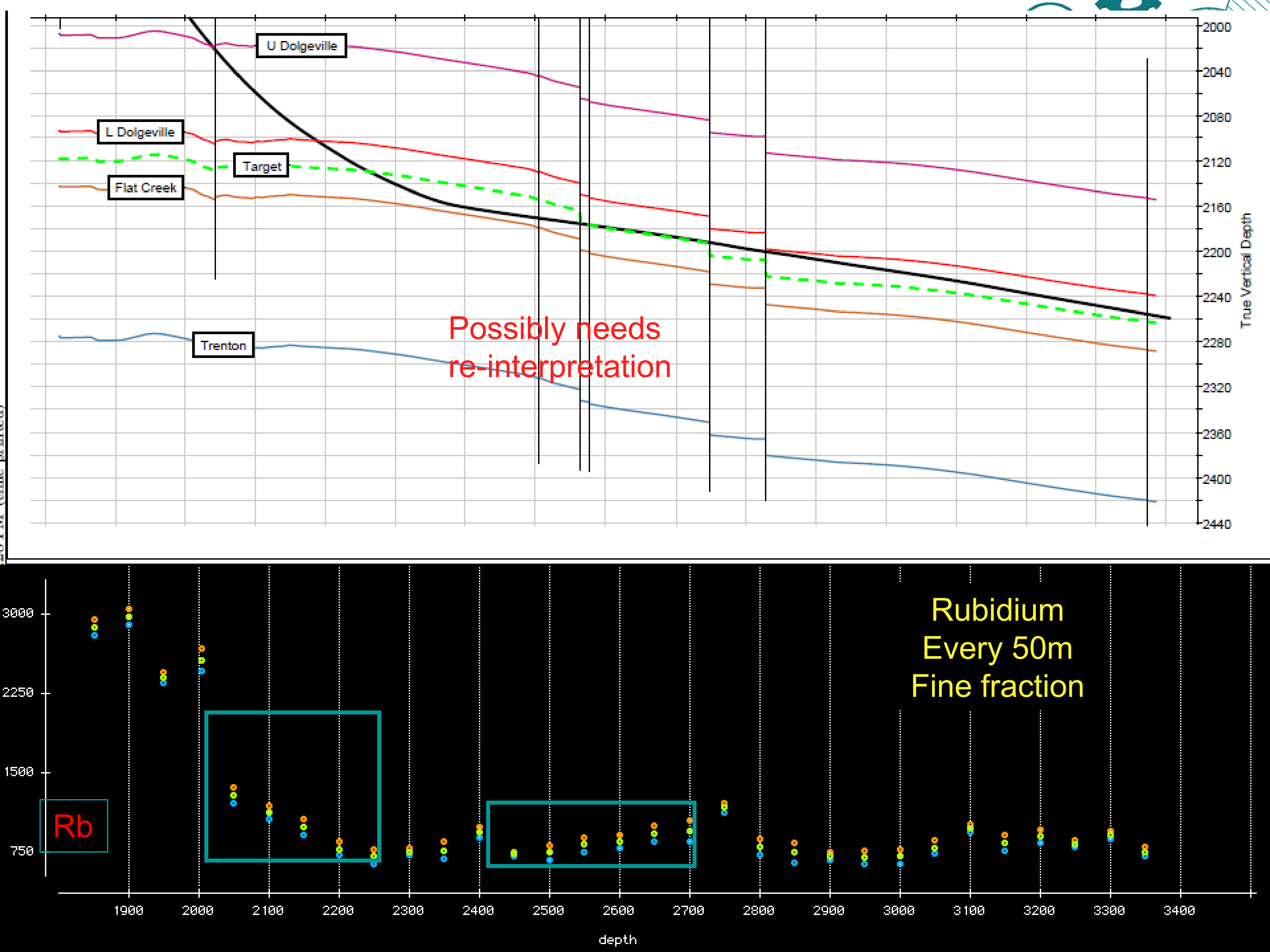
XRF Hz box plots

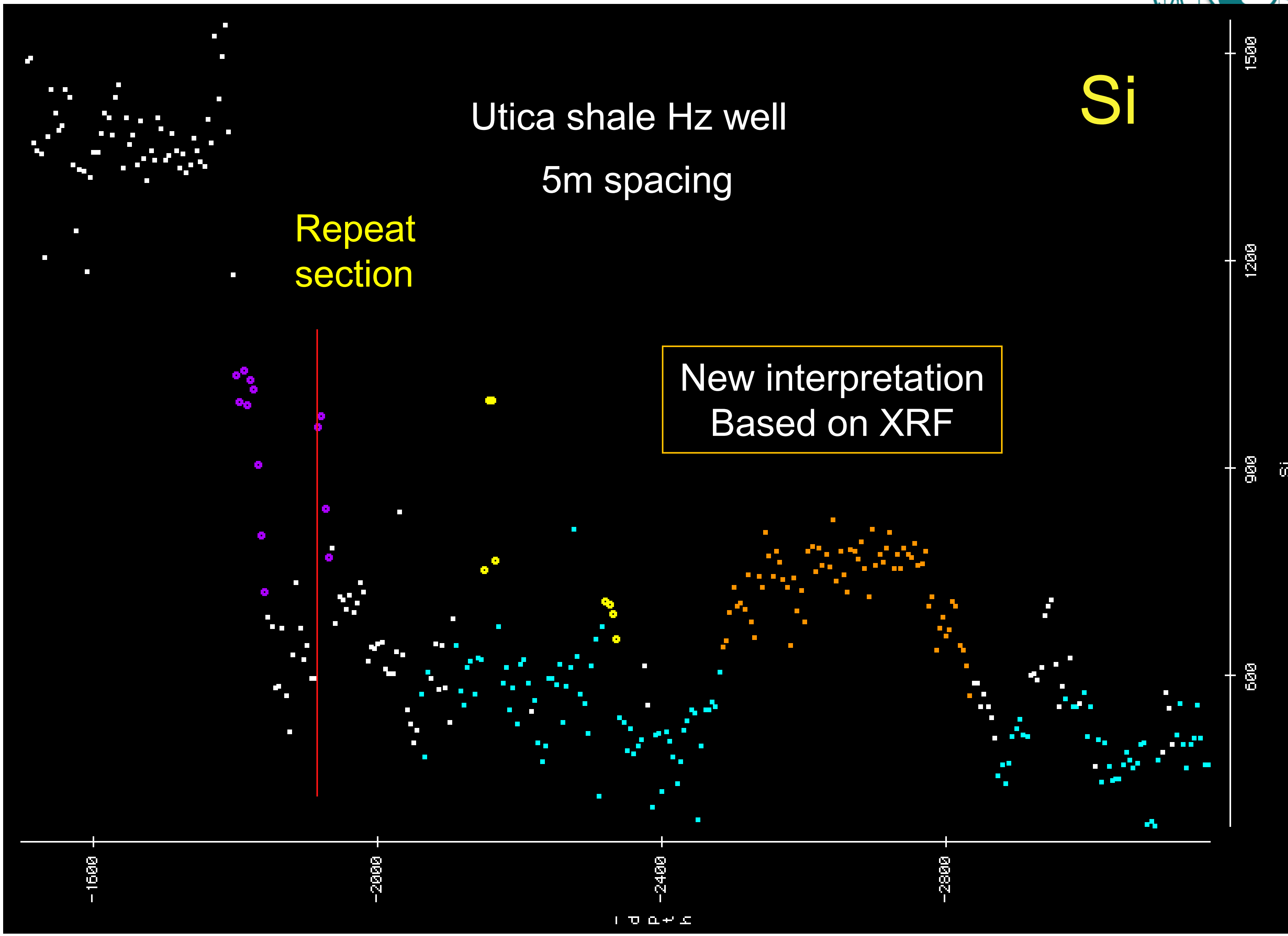
Horizontal Well

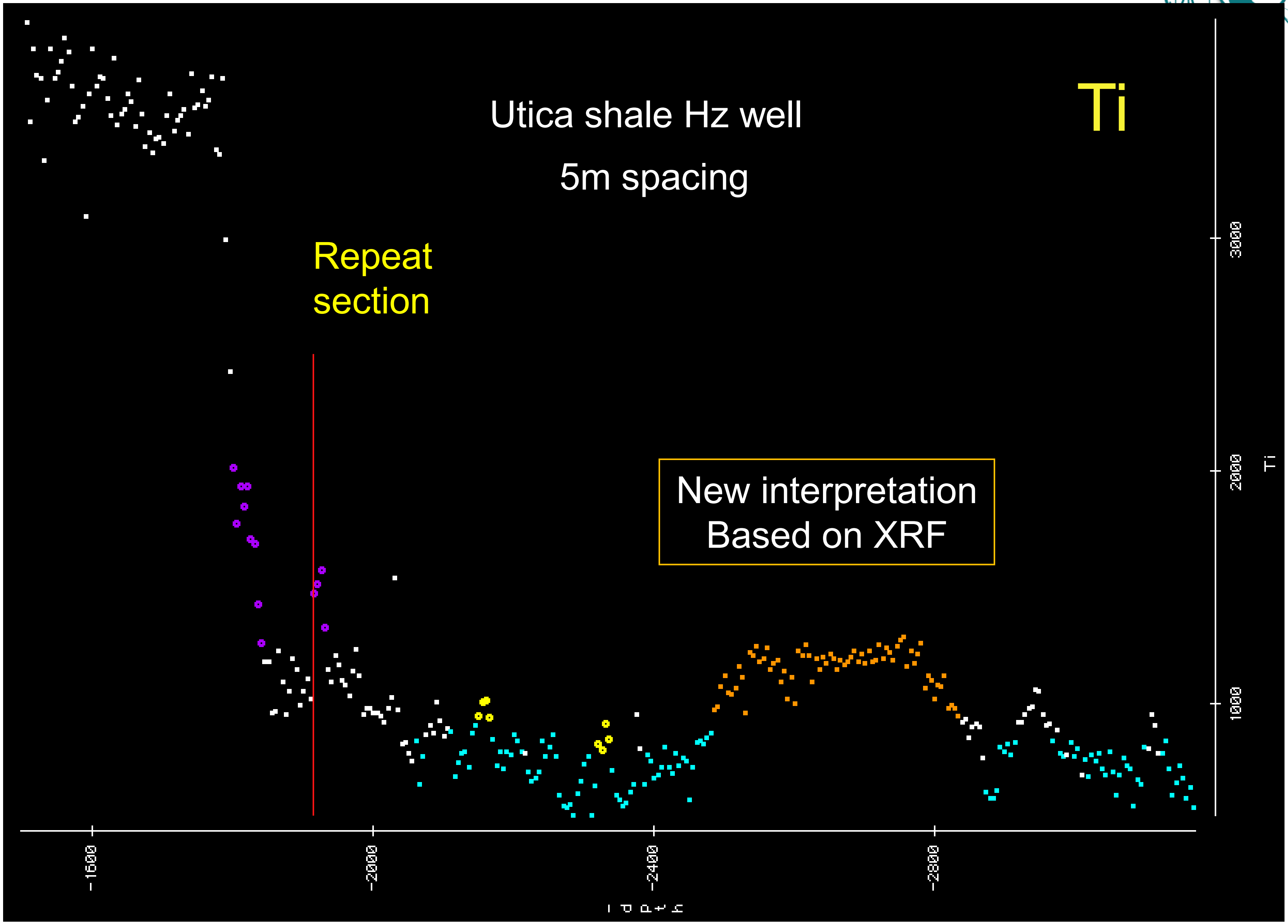
Calcium



50 meter spacing


U Dolgeville
L Dolgeville
Target
Flat Creek
Trenton
Possibly needs
re-interpretation
True Vertical Depth
2000
2040
2080
2120
2160
2200
2240
2280
2320
2360
2400
2440
Rubidium
Every 50m
Fine fraction
Rb
3000
2250
1500
750
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
depth


Utica shale Hz well
5m spacing
Si
Repeat section
New interpretation
Based on XRF
1500
1200
900
600
Si
-1600
-2000
-2400
-2800


Utica shale Hz well
5m spacing
Ti
Repeat section
New interpretation Based on XRF
3000
2000
1000
Ti
-1600
-2000
-2400
-2800

Conclusions 1:

- XRF on drill cuttings is very cheap
- Finer fraction of the cuttings does not need crushing
- The finer cutting fraction gives a reliable picture of the elemental composition
- Best results obtained from using all 10 measurements for each sample
- Box plots are ideal analytical displays
- Samples every 50 meters can be sufficient on horizontal wells as a first pass

Conclusions 2:

- XRF can be incredibly valuable when no logs exist in a horizontal well
- XRF can be calibrated and then used to select the best intervals to frac
- Samples every 5 meters can be of great help to identify faults in horizontal wells
- To date this tool is restricted to a laboratory and thus cannot be used for real time well steering

Acknowledgment:

We would like to thank

Talisman Energy Inc.

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