A New Approach to Refine and Quality Control Correlations in Shale and Siltstone Formations Based on Principal Component Analysis of XRF Data*

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Abstract

Correlating stratigraphic surfaces and parasequence sets at regional scale in fine-grained marine deposits is challenged by limited lithological contrasts and commonly sparse biostratigraphy data. Recent publications on the Montney Formation of Western Canada demonstrate that despite a large body of work and a high density of well control, uncertainties remain even for major stratigraphic surfaces such as the Triassic Dienerian-Smithian third-order sequence boundary. A new workflow has been devised to help the geologist refine and quality control his correlation. The new approach has been first tested on a very detailed chemostratigraphy scheme established between two Montney cored wells (1,310 and 785 feet of cores) distant of some 5 miles in the basin dip direction. The units have been defined by sudden and substantial changes of the Ca/Mn ratio. The results, for the interval common to both wells, have been quality controlled by a new Principal Component Analysis approach comparing the Eigen Values of the first principal component (ev1) of all 26 elements measured with the ITRAX core scanner. Perfect match (i.e. R^2 >90%) was achieved when comparing the same units in both wells but not when comparing successive units in any of the two wells. The various elements are grouped into three categories (carbonate, clastics and TOC linked elements) based on their affinity as seen by a normal PCA analysis (EV1 vs. EV2). The regression lines of the ev1 per category can then be compared between units and used to assess the similarity between them (successive units in a single well or same units in different wells). Comparison between successive units exhibits changes in slopes of the category-based regression lines whereas no or very minor changes in slopes are seen in the same unit of the two distant wells. Practical applications of this new PCA approach using EV1 comparison was then performed on vertical and horizontal wells with cuttings analyzed every 5 m to 20m in the Montney, Duvernay, Lorraine and Utica Formations. Our analysis demonstrates that multiple ITRAX measurements per cutting vial provides a better sampling of lithological heterogeneity and a useful tool to refine or QC well to well correlations.

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A new approach to refine and quality control correlations in shale and siltstone formations based on Principal Component Analysis of XRF data

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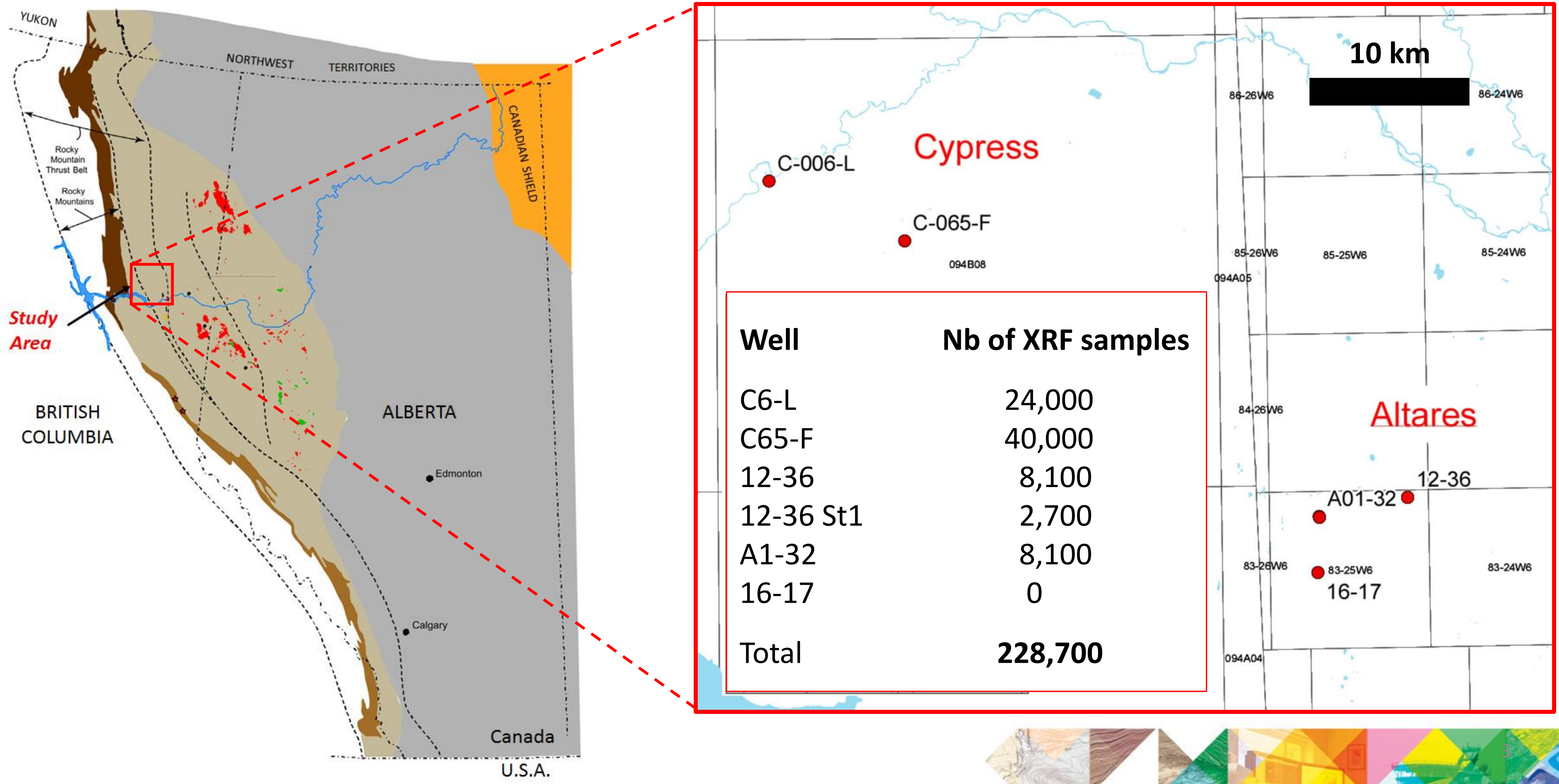
Talk outline

- Introduction of Montney study area
- Correlation based on Vanadium from XRF
- Detailed correlation based on Ca-Mn trend switches
- Principal component analysis (PCA)
- New variant of PCA for XRF studies
- Conclusions

Study Area and studied cored wells



Well	Nb of XRF samples
C6-L	24,000
C65-F	40,000
12-36	8,100
12-36 St1	2,700
A1-32	8,100
16-17	0
Total	**228,700**

Core coverage for present study

Continuous XRF with average every cm

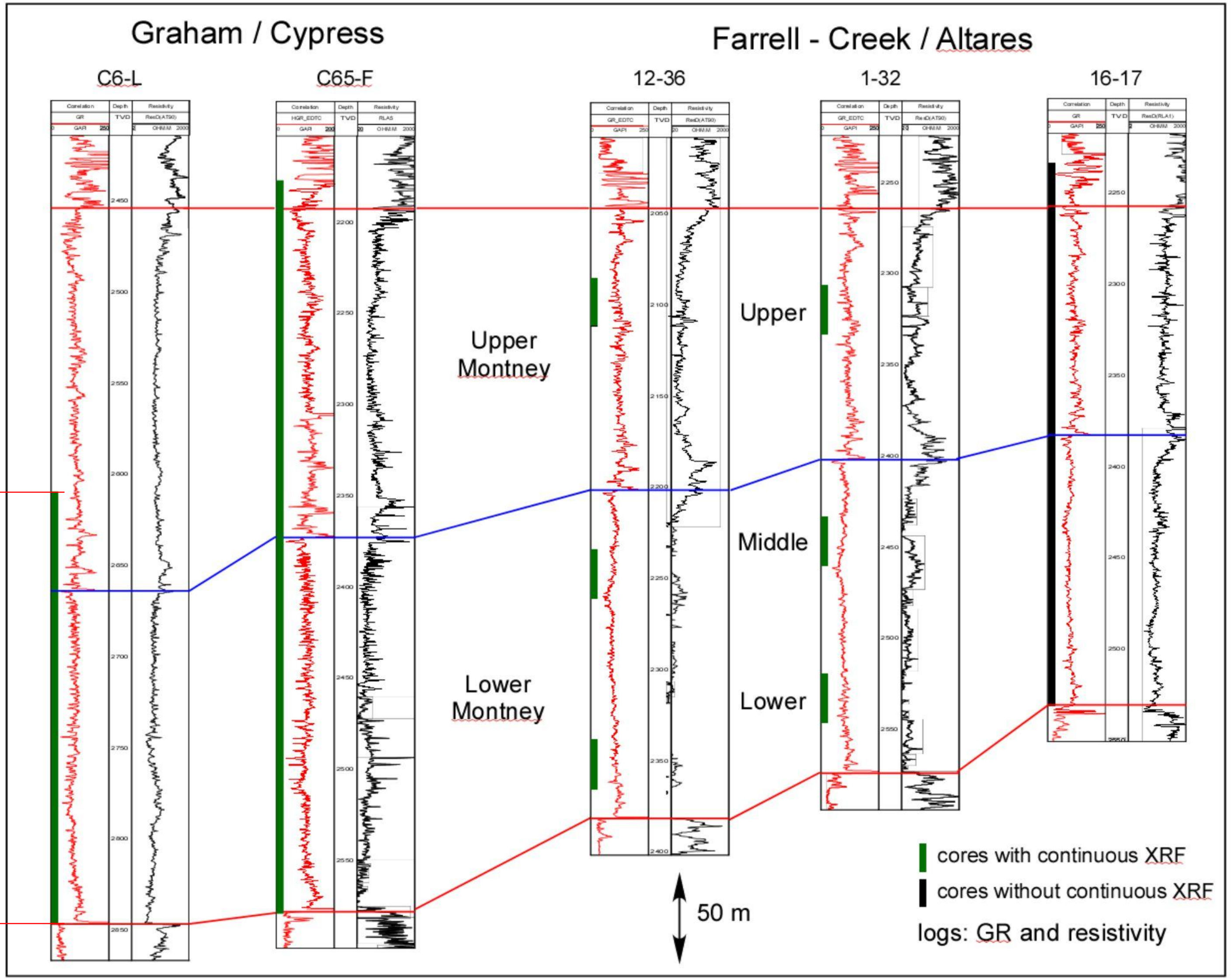
Very detailed comparison

of XRF elemental composition

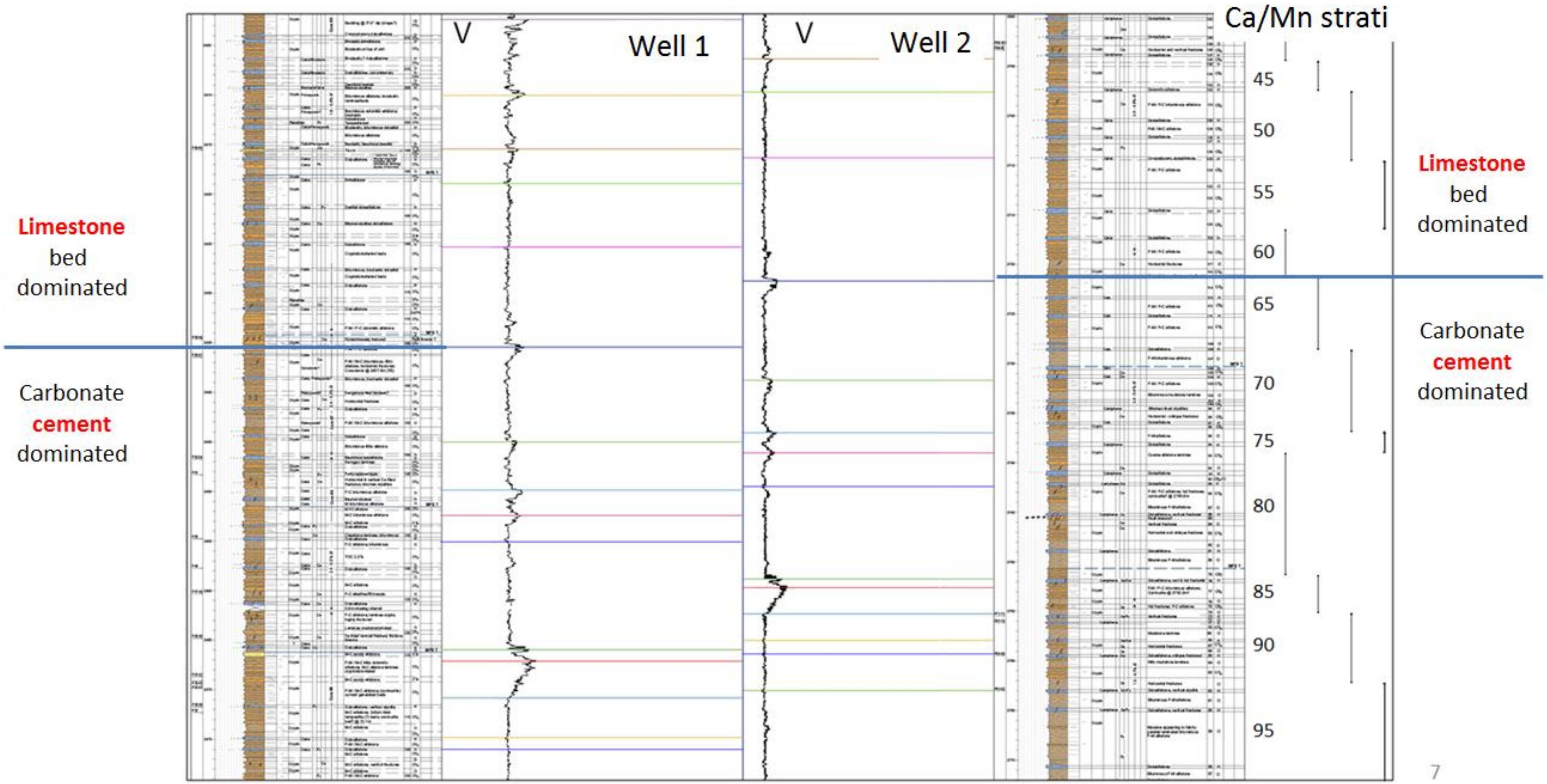
between 240 m of stratigraphy

covered by cores in both

Cypress wells (C6L and C65F)



Correlation markers using Vanadium, Zirconium and Manganese XRF profiles



Perfect correlation using XRF chemostratigraphy

One 27 m thick core:

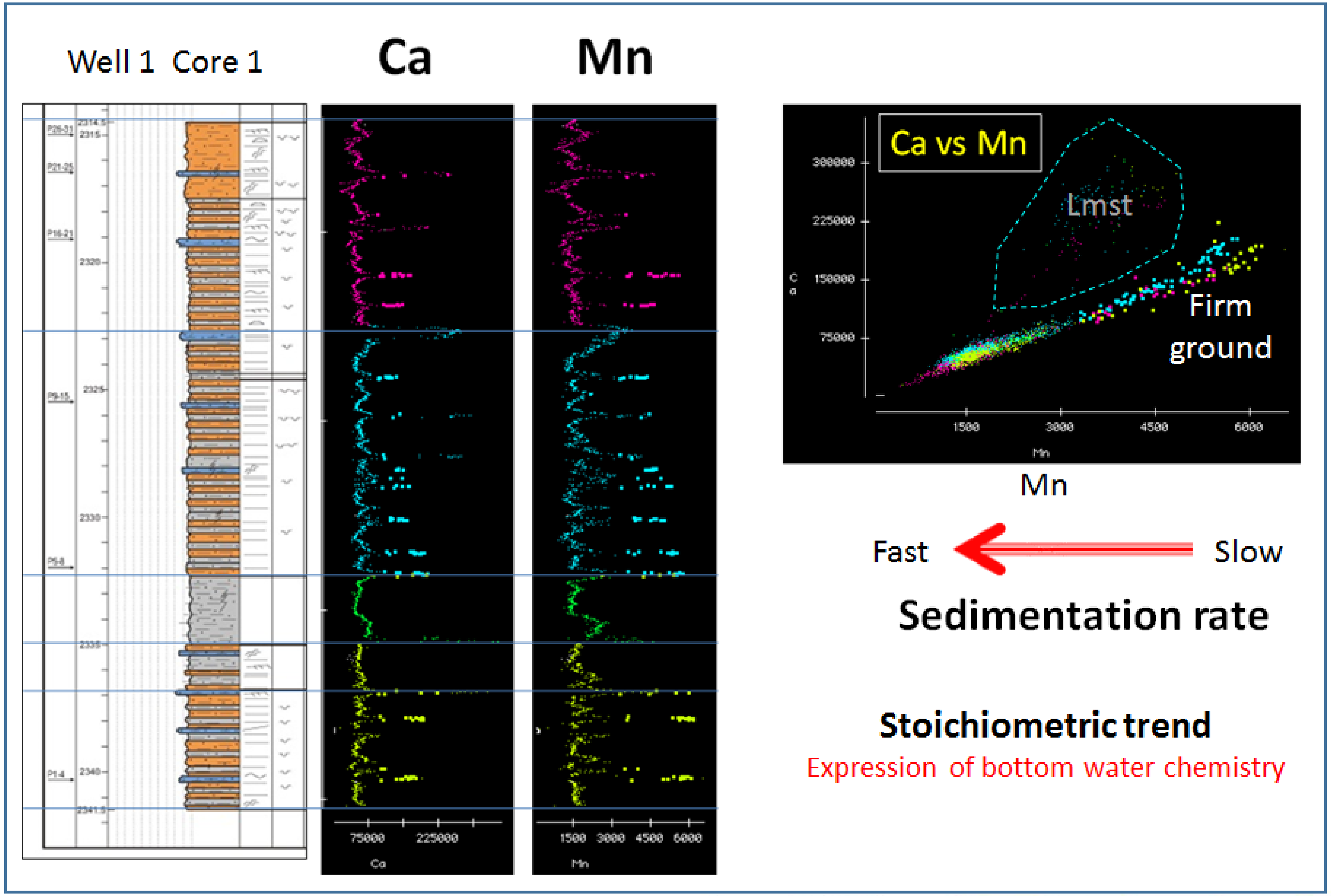
2700 XRF samples

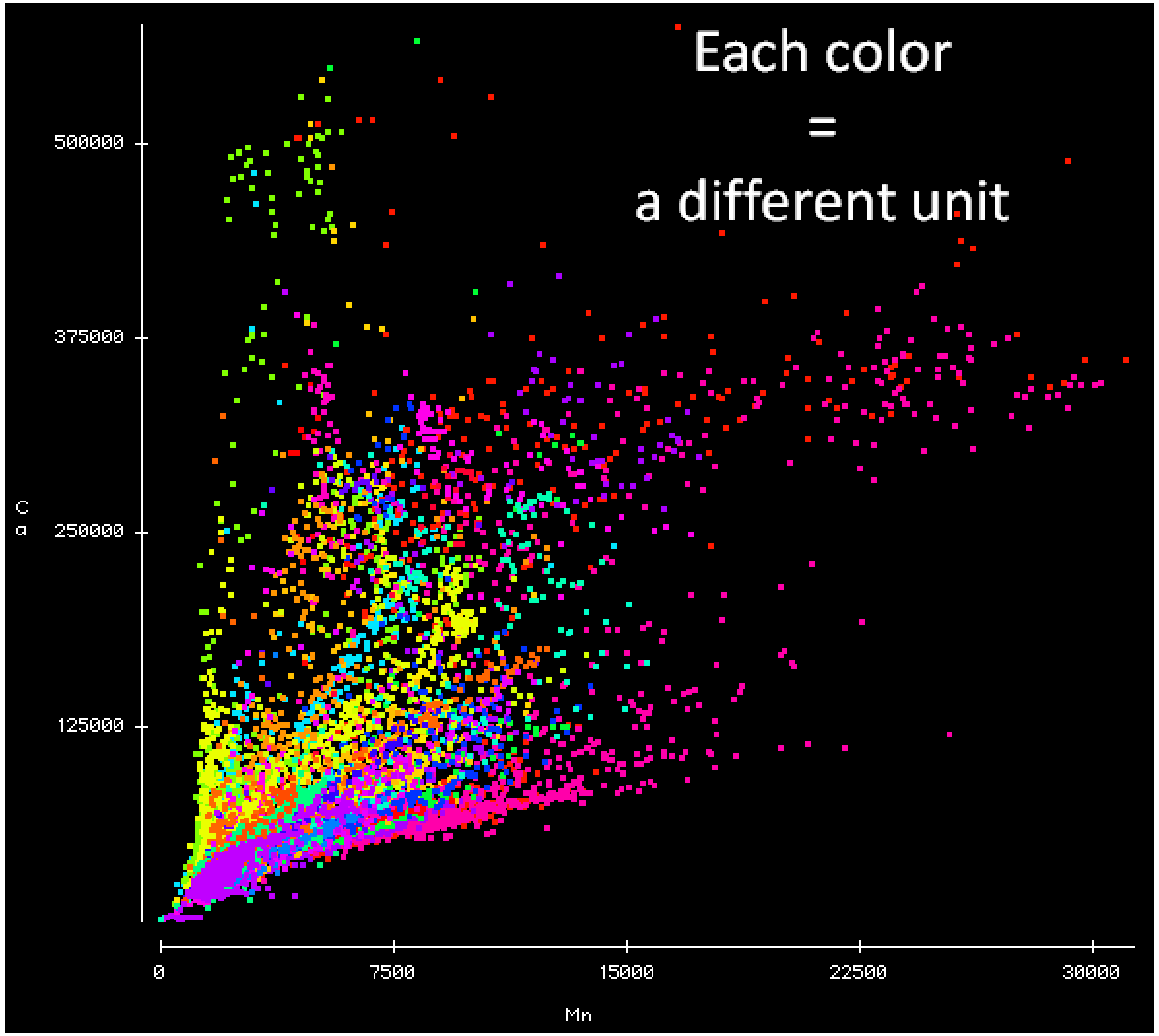
Samples = averages

of 100 successive

XRF measurements

every 0.1 mm (100 microns)





High variety of Ca-Mn trends

Switch between any 2 trends

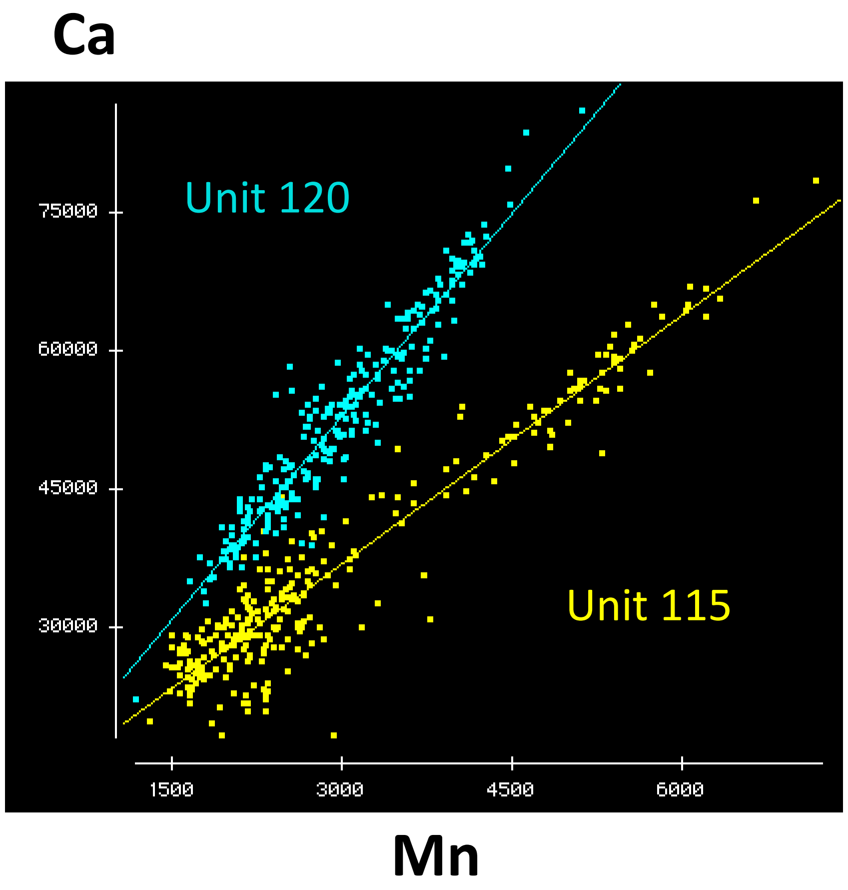
is marked by a significant angle:

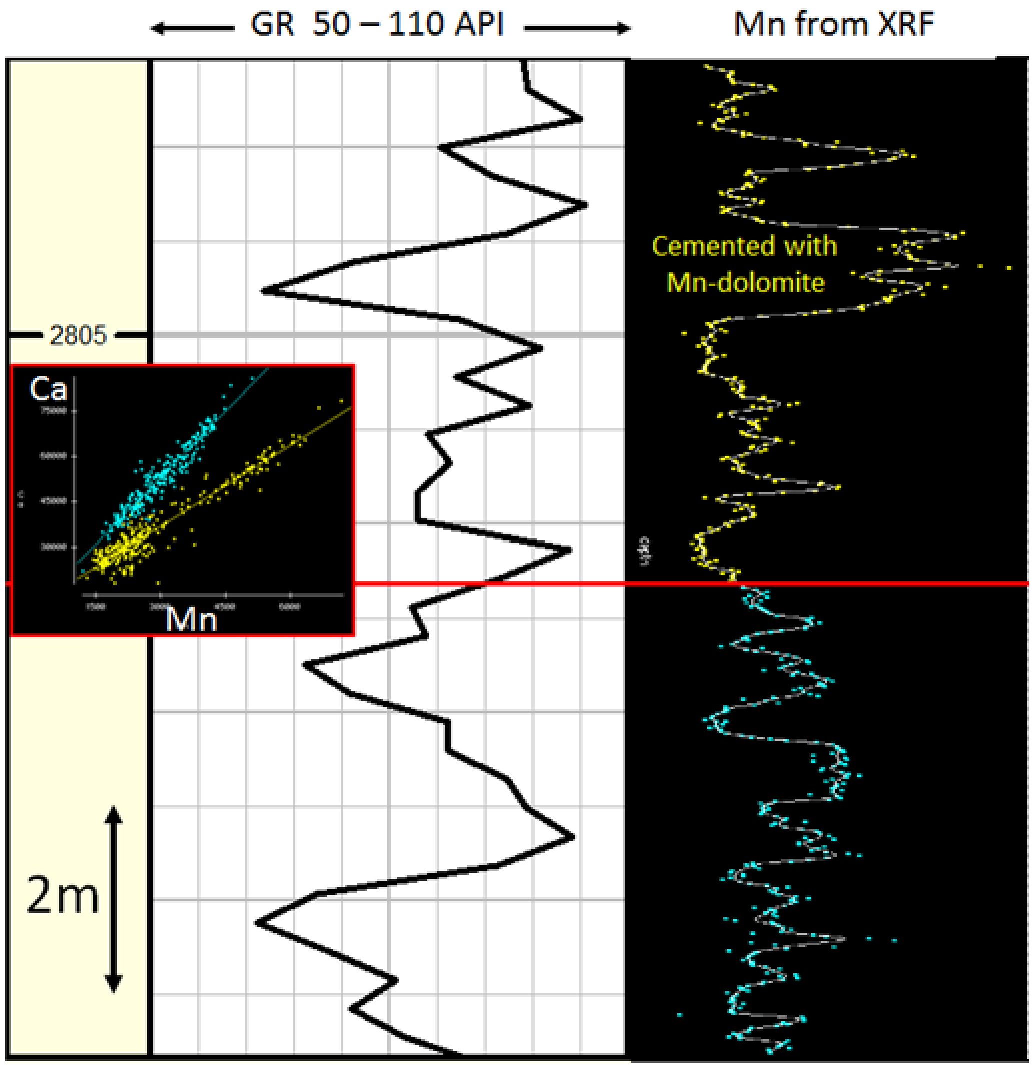
This interpreted marked

and sudden changes in

bottom water compositions

Example of a typical switch in bottom water composition





Units based

Exclusively

on XRF

Match with

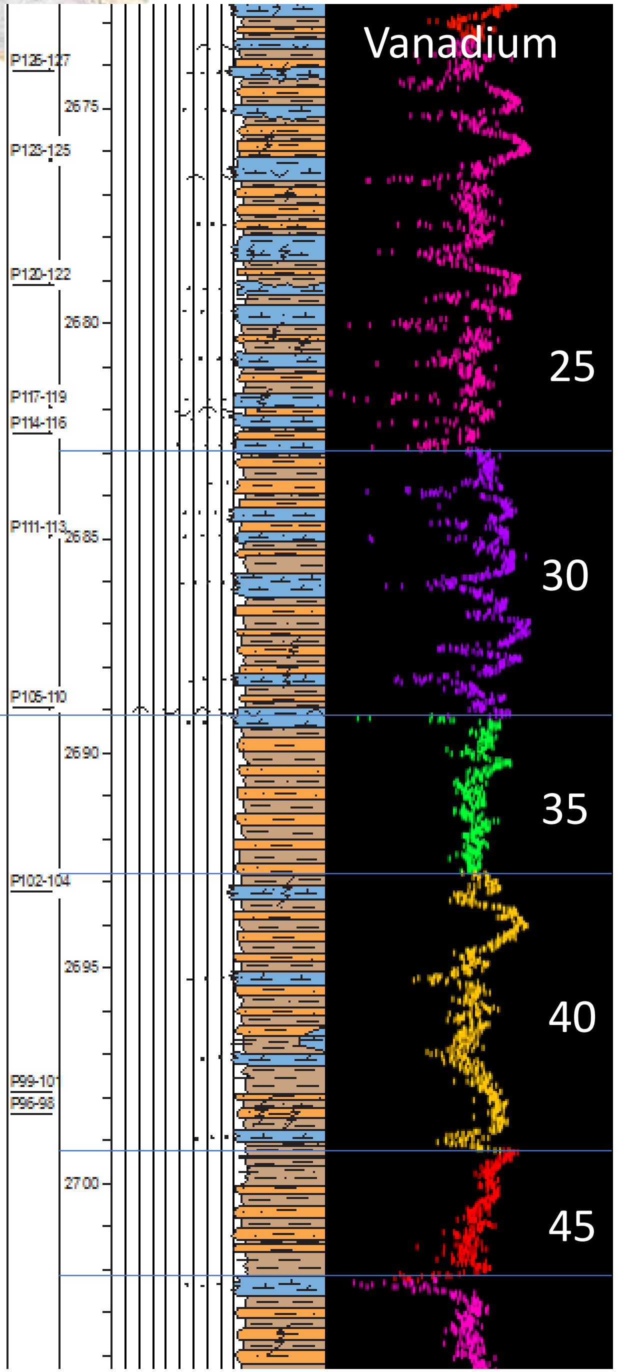
description

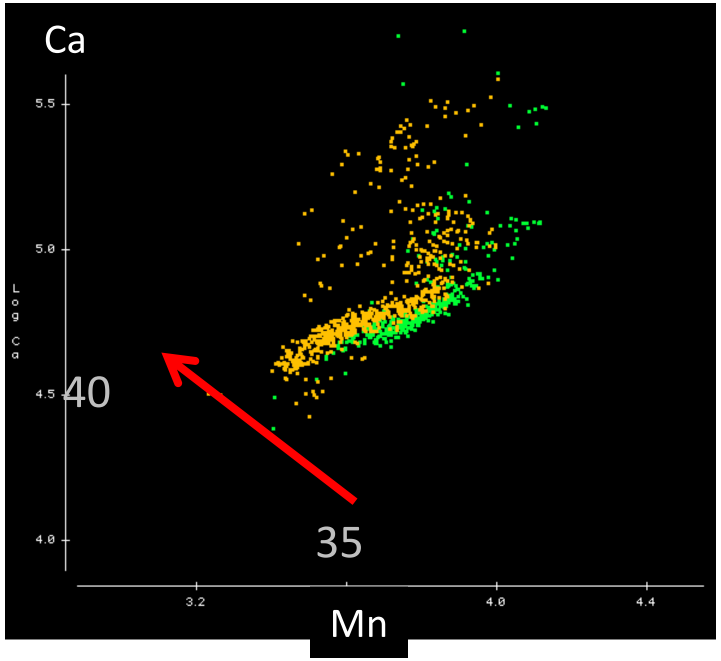
obtained later

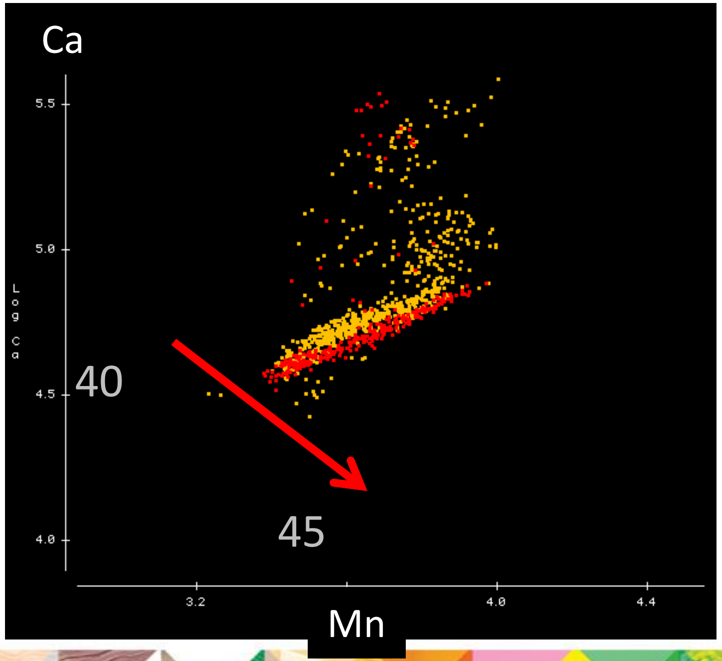
Well Cypress C6-L

Vanadium constant

Vanadium trend

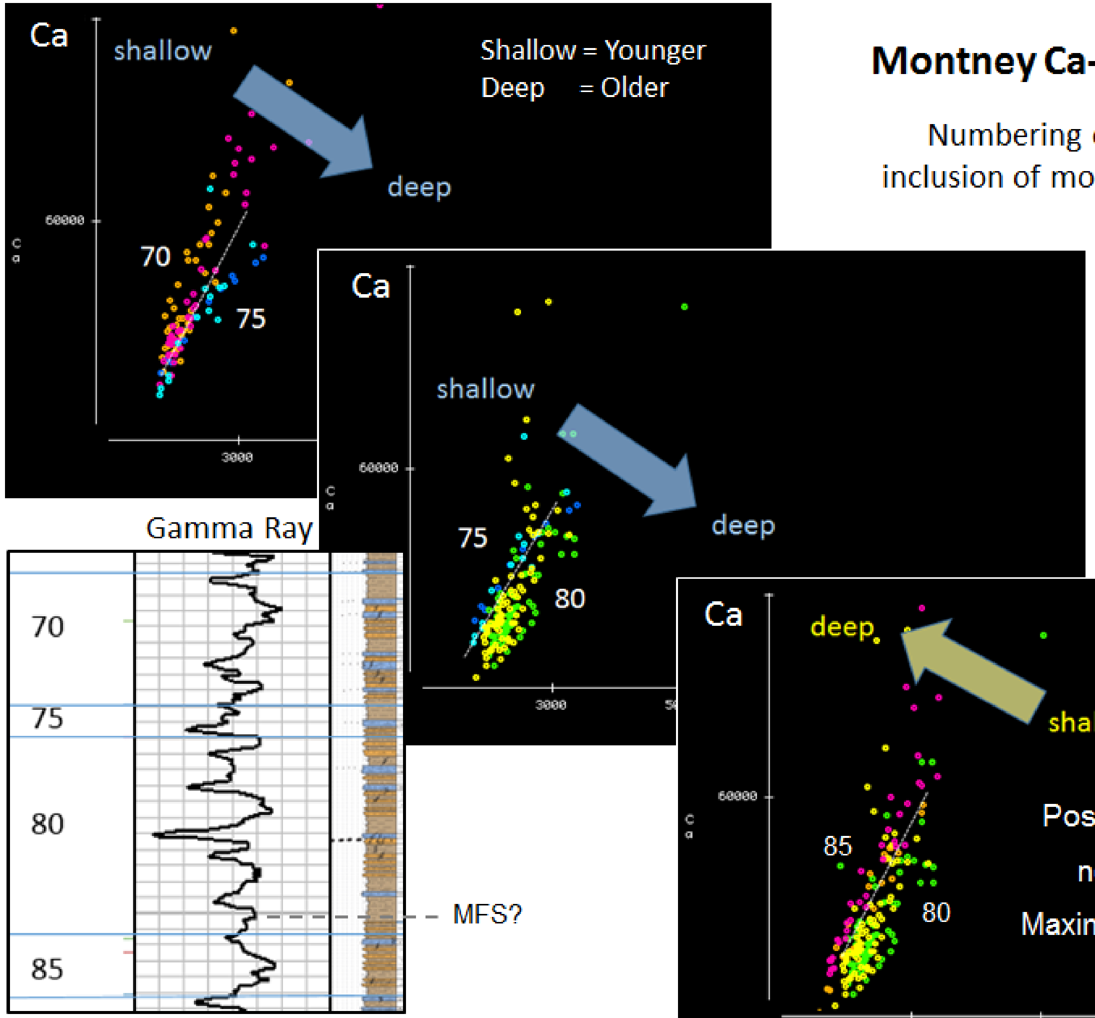


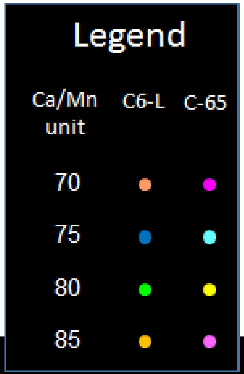


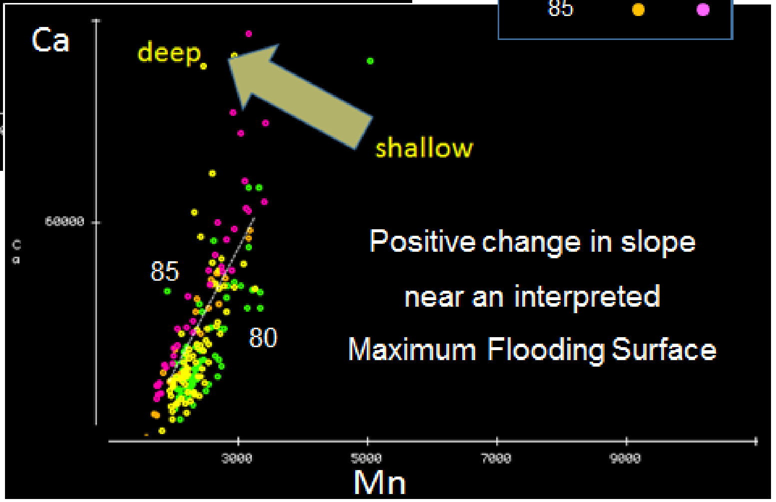


Montney Ca-Mn Stratigraphy

Numbering every 5 allows for inclusion of more units in the future





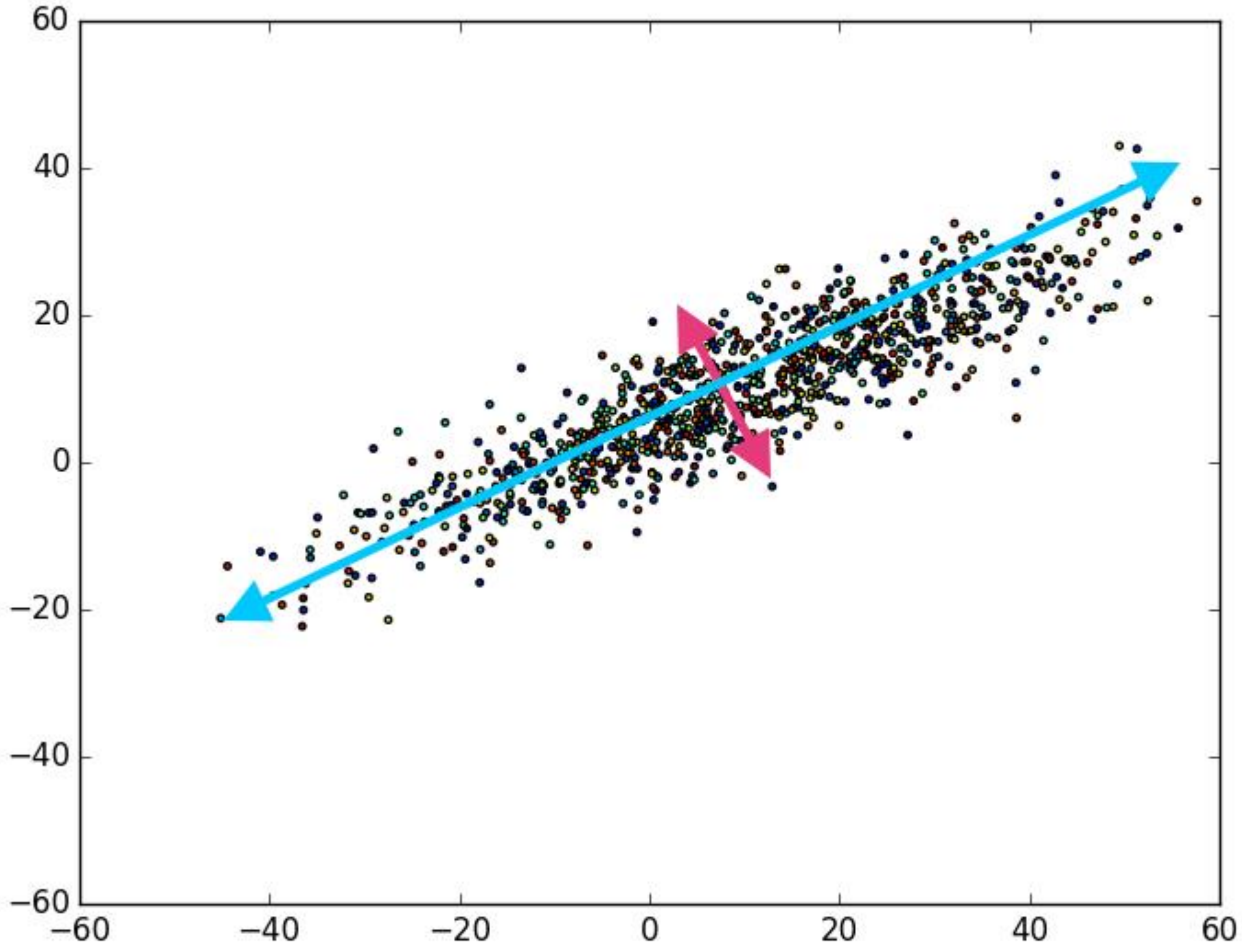


Principal Component Analysis (PCA)

Traditional PCA ev1 vs ev2

New Approach ev1 vs ev1

Principal component Analysis



Search for a plane in n-dimensions

The first component plane (ev1)

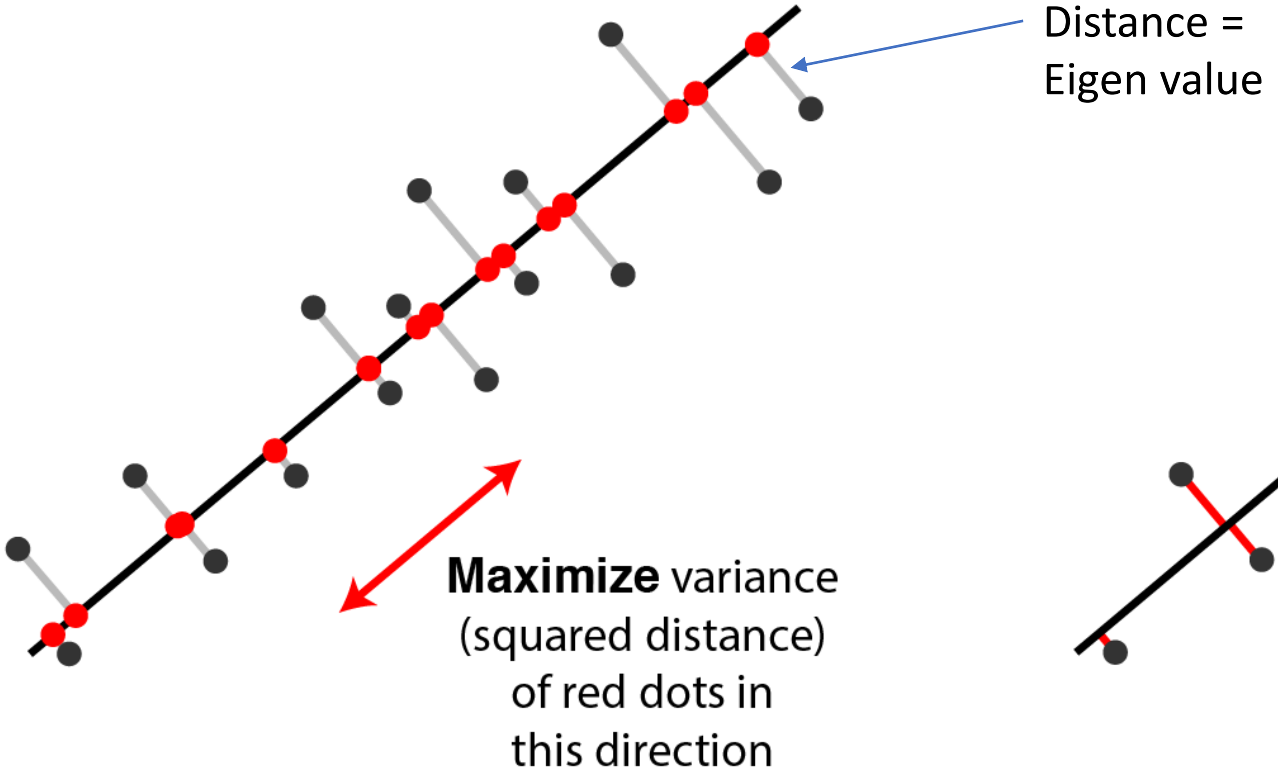
maximize the variance

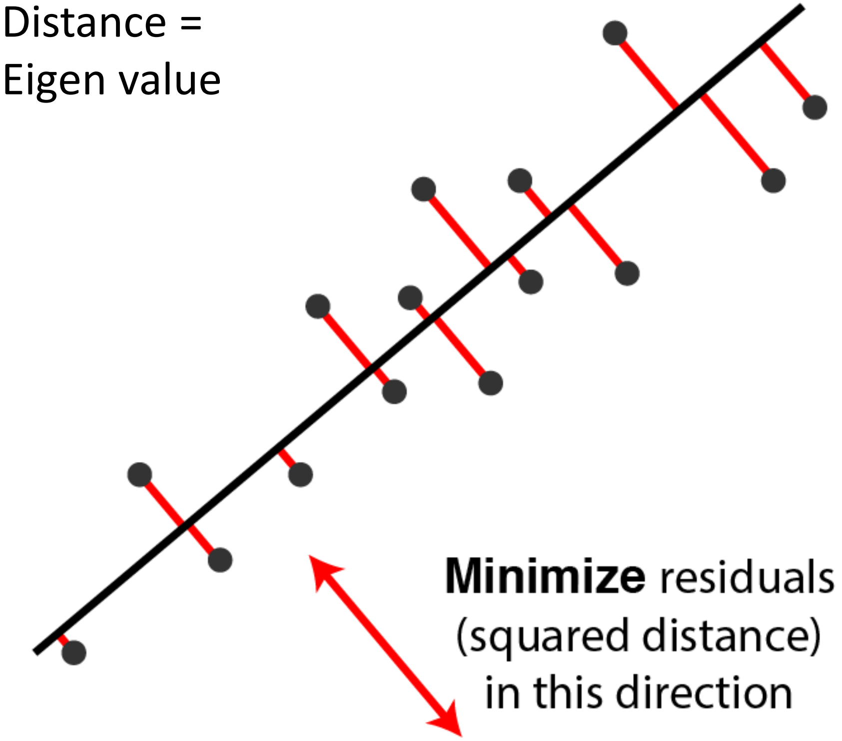
and

minimize the residuals

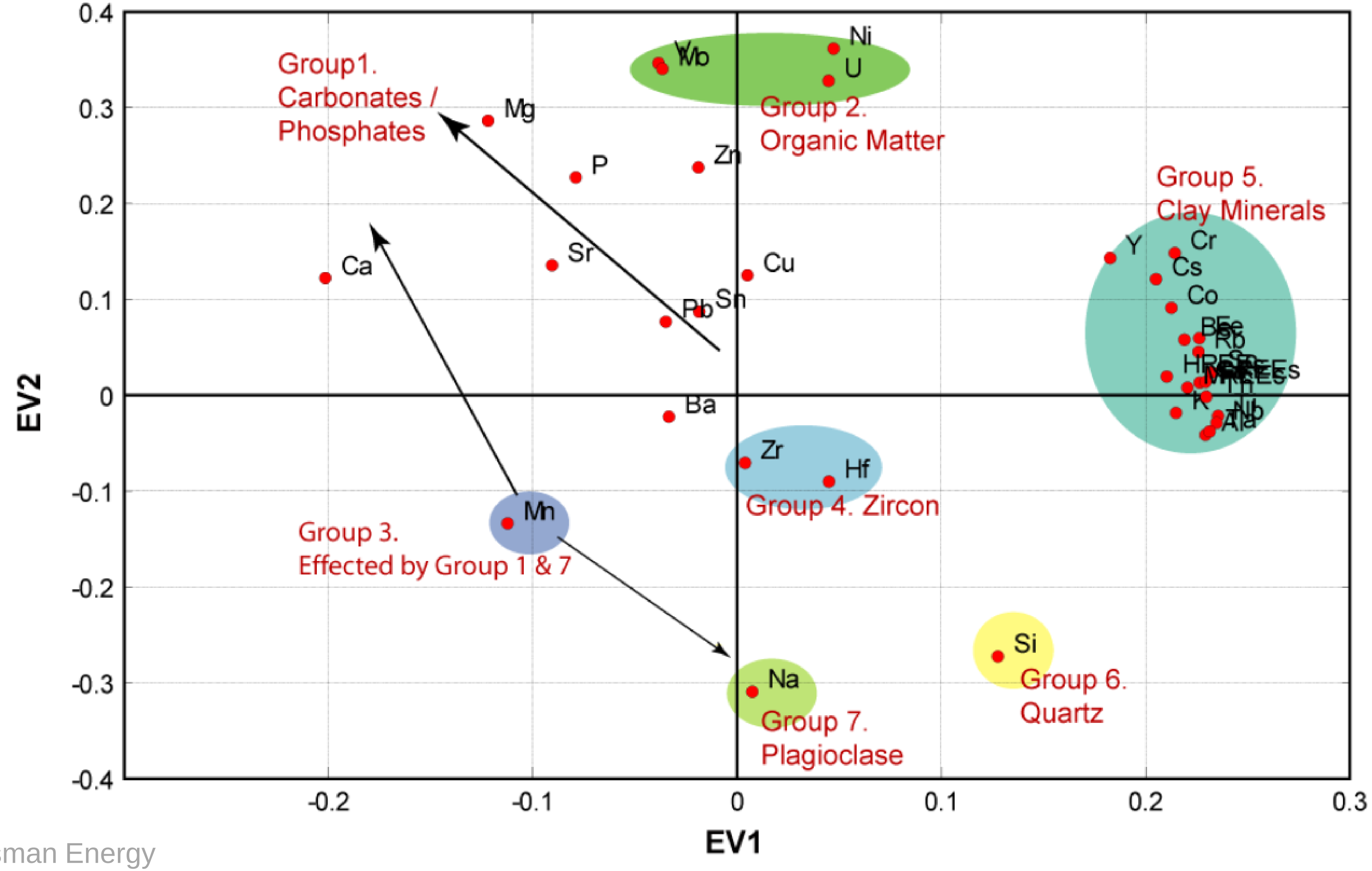
For XRF we can work with 25+ elements

Principal component Analysis





EV1 VS EV2



Courtesy Talisman Energy

Principal Component Analysis of Cores

- Eigen Values involving many elements
  - Need to have at least as many samples as the number of elements chosen for the analysis, i.e. number of parameters to be compared
  - More elements = more in-depth analysis
  - This is a major problem with handheld or benchtop XRF to compare units
    - if one unit has only 5 samples => only 5 elements can be used to compare the units
  - This is easily done with XRF core scanner
    - Sample every cm

Principal Components /Eigen Values

- Complete Formation: Montney
  - Close proximity in E1-E2 plots = affinity
- 400m thick core with 40,000 XRF measurements
- 3 main options
  - E1 vs E2 for complete data set in one well
  - E1 comparison between two successive units
  - E1 comparison between same unit in different wells

Principal Components /Eigen Values

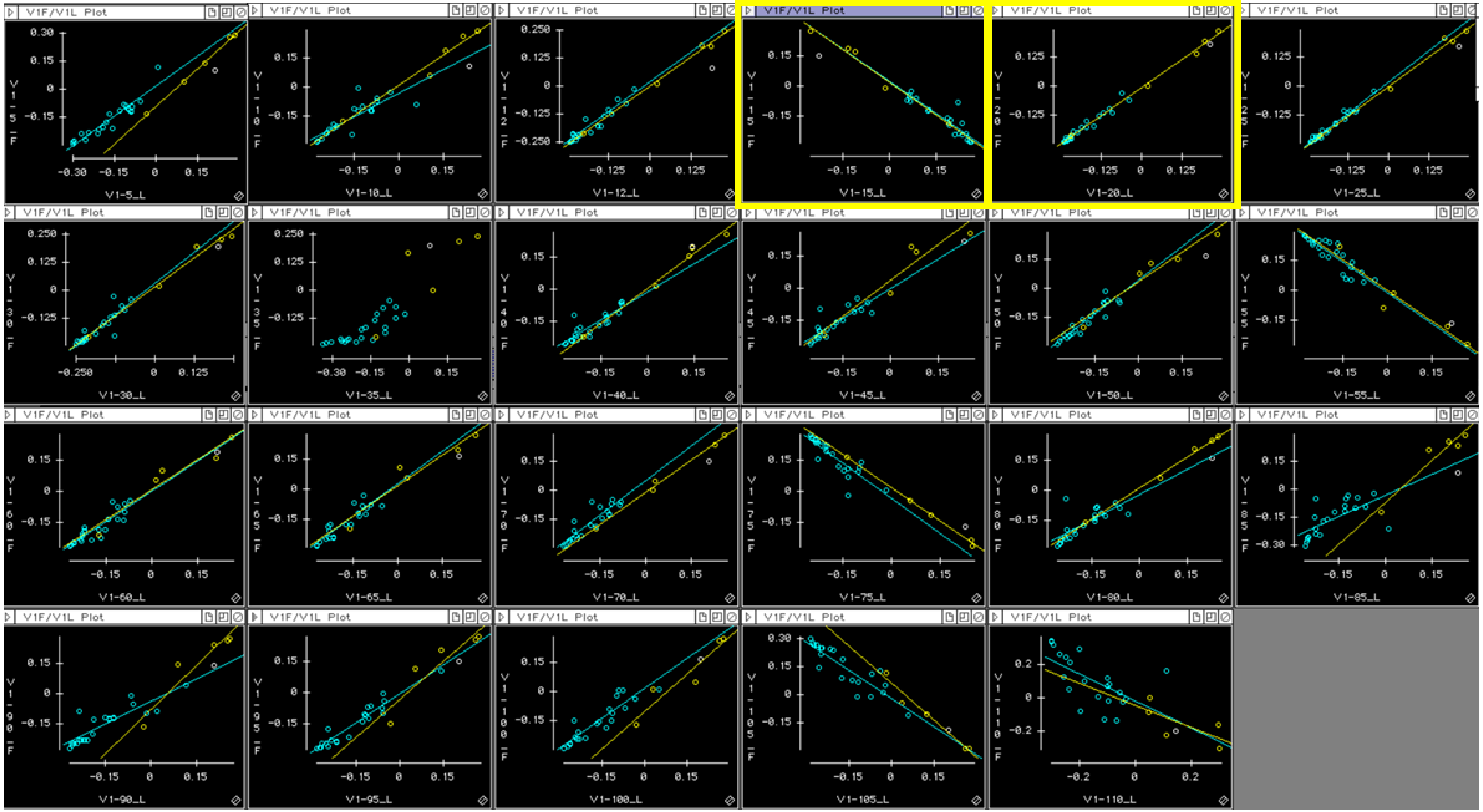
- EV1 Vs EV1
  - a new approach
  - Eigen values of the first principal component are by far the most important
  - If EV1 have a linear relationship between two units or two data sets that means near identical composition for the two compared “sets”
  - A split by affinities (e.g. carbonates, siliciclastics, organic matter) can reveal subtle sedimentological changes

C6L vs C65F

Two Cypress Montney wells

EV1 vs EV1

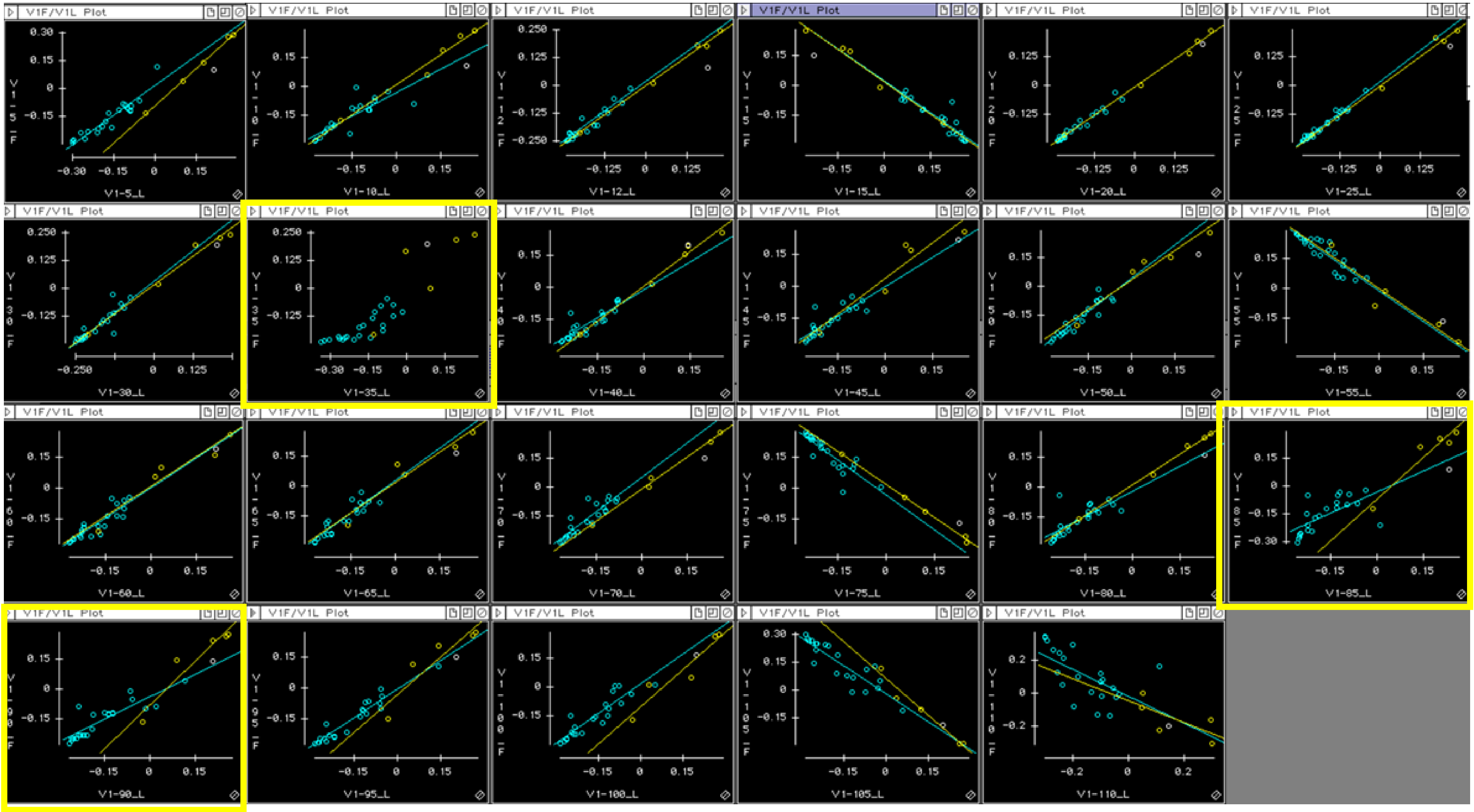
23 units compared between two wells   Y = Well 65F   X = Well C6L



Extremely similar Eigen values between same units in two distant wells

Check needed in 3 units among 23 compared between two wells

EV1 vs EV1



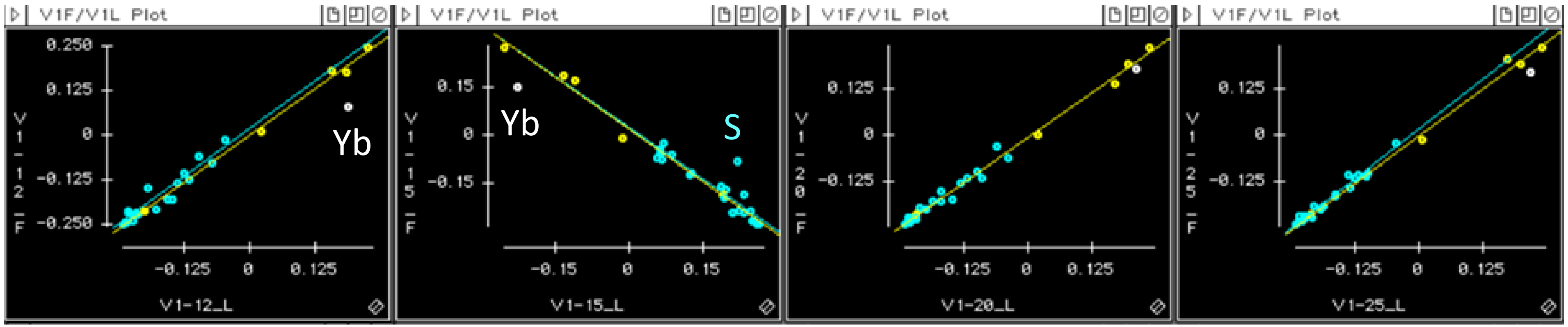
Differences may be linked to sedimentology, i.e. more erosion or more cement in proximal setting

EV1 vs EV1

Comparison of same intervals in two wells

- C65F (F) vs C6-L (L)
- Stratigraphy based on Ca-Mn XRF slopes

Unit 12 **Unit 15** **Unit 20** **Unit 25**



Ytterbium (Yb) commonly an outlier (see units 12 & 15)

Slight difference in sulfur between the two wells

Perfect match between units from two wells

Very good match between units from two wells

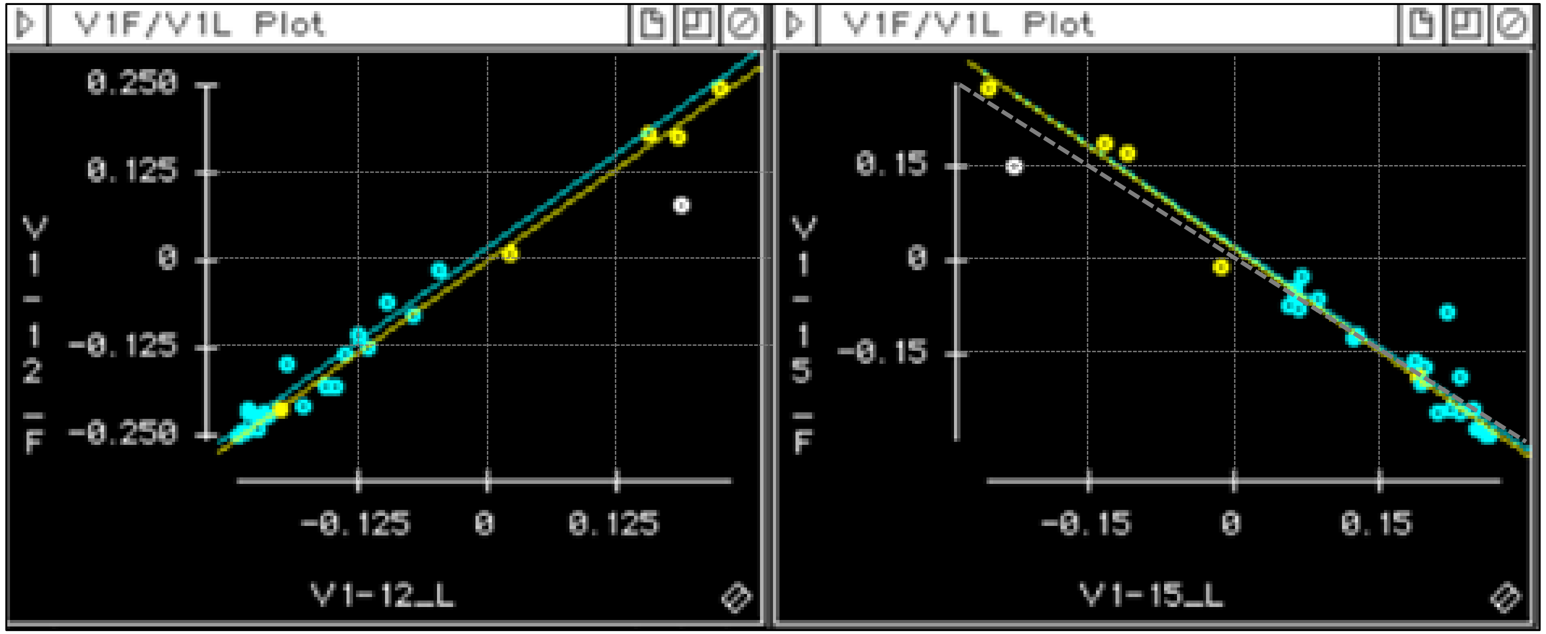
EV1 vs EV1

Quality control of correlation between two wells

Near perfect match between EV1 of same units in two wells

Unit 12 **Unit 15**

EV1 from C65F



EV1 from C65F

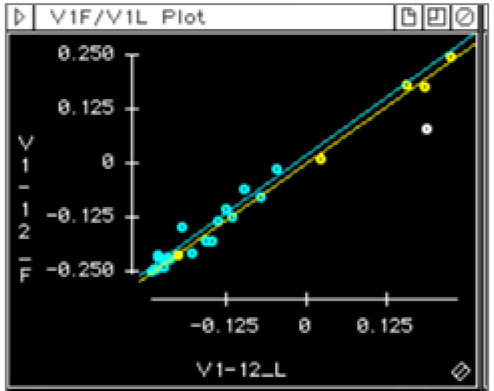
EV1 from C6L

EV1 from C6L

Yellow regression line perfectly overlying the 1 to 1 ratio line
=> Near identical carbonate composition

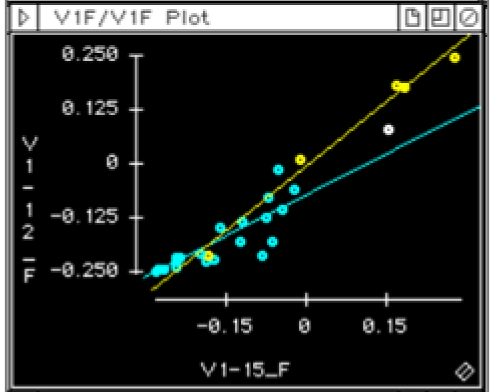
Comparisons between successive units 12 and 15

EV1 vs EV1

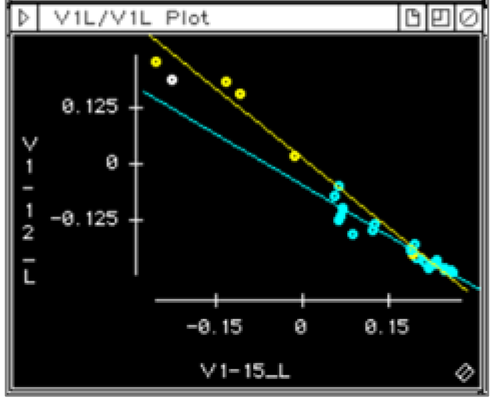


Ev1 compared between Unit 12
in two wells

Very nice match between the two Montney wells



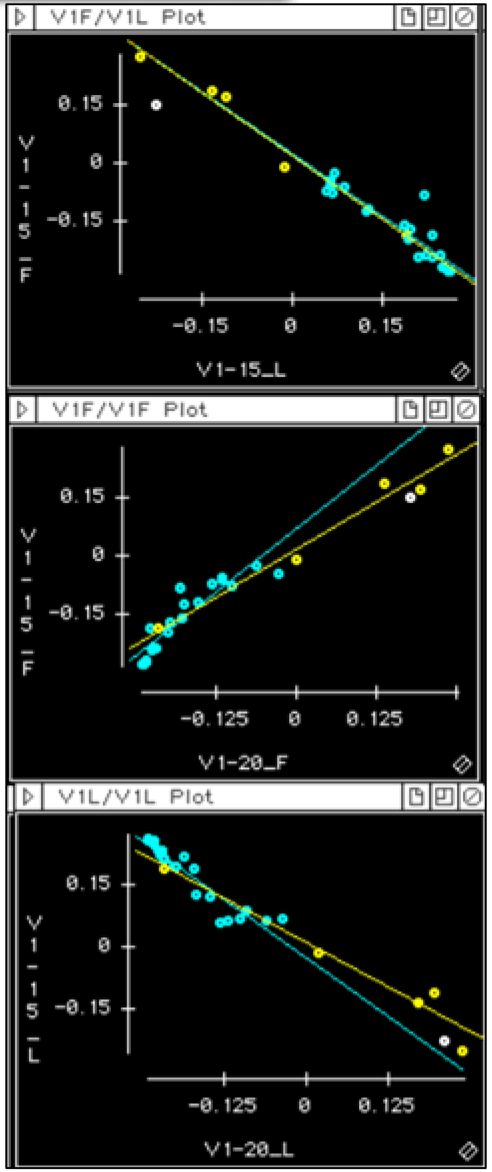
Ev1 compared between successive units (12 and 15)
in well C65-F



Ev1 compared between successive units (12 and 15)
in well C6-L

Major compositional changes between Unit 12 and Unit 15 in both studied wells

Comparisons between successive units 15 and 20



EV1 vs EV1

Ev1 compared between Unit 15
in two wells

Very nice match between the two Montney wells

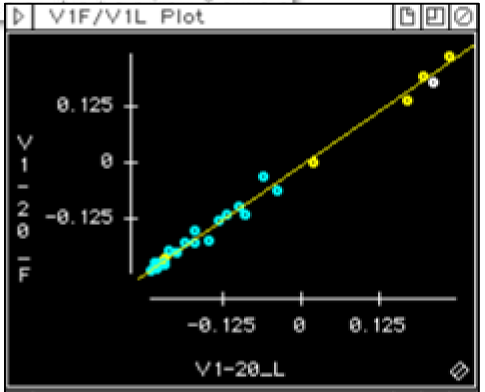
Ev1 compared between successive units (15 and 20)
in well C65-F

Ev1 compared between successive units (15 and 20)
in well C6-L

Major compositional changes between Unit 15 and Unit 20 in both studied wells

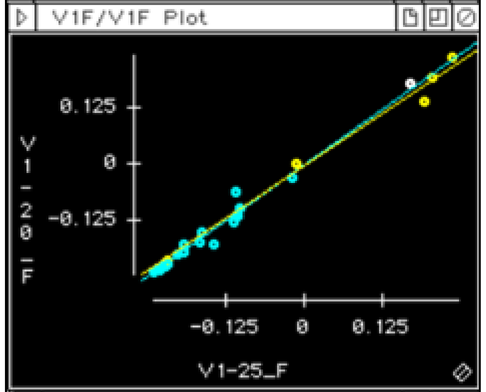
Comparisons between successive units 20 and 25

EV1 vs EV1

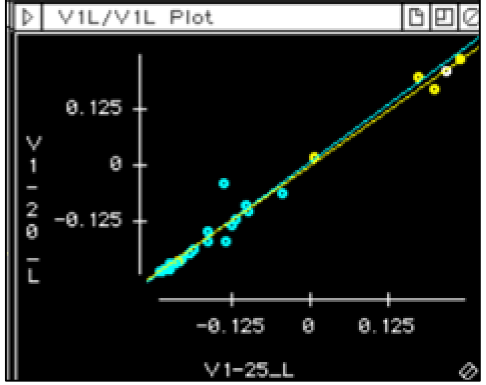


Ev1 compared between Unit 20
in two wells

Very nice match between the two Montney wells



Ev1 compared between
2 successive units (20 and 25)
in well C65-F



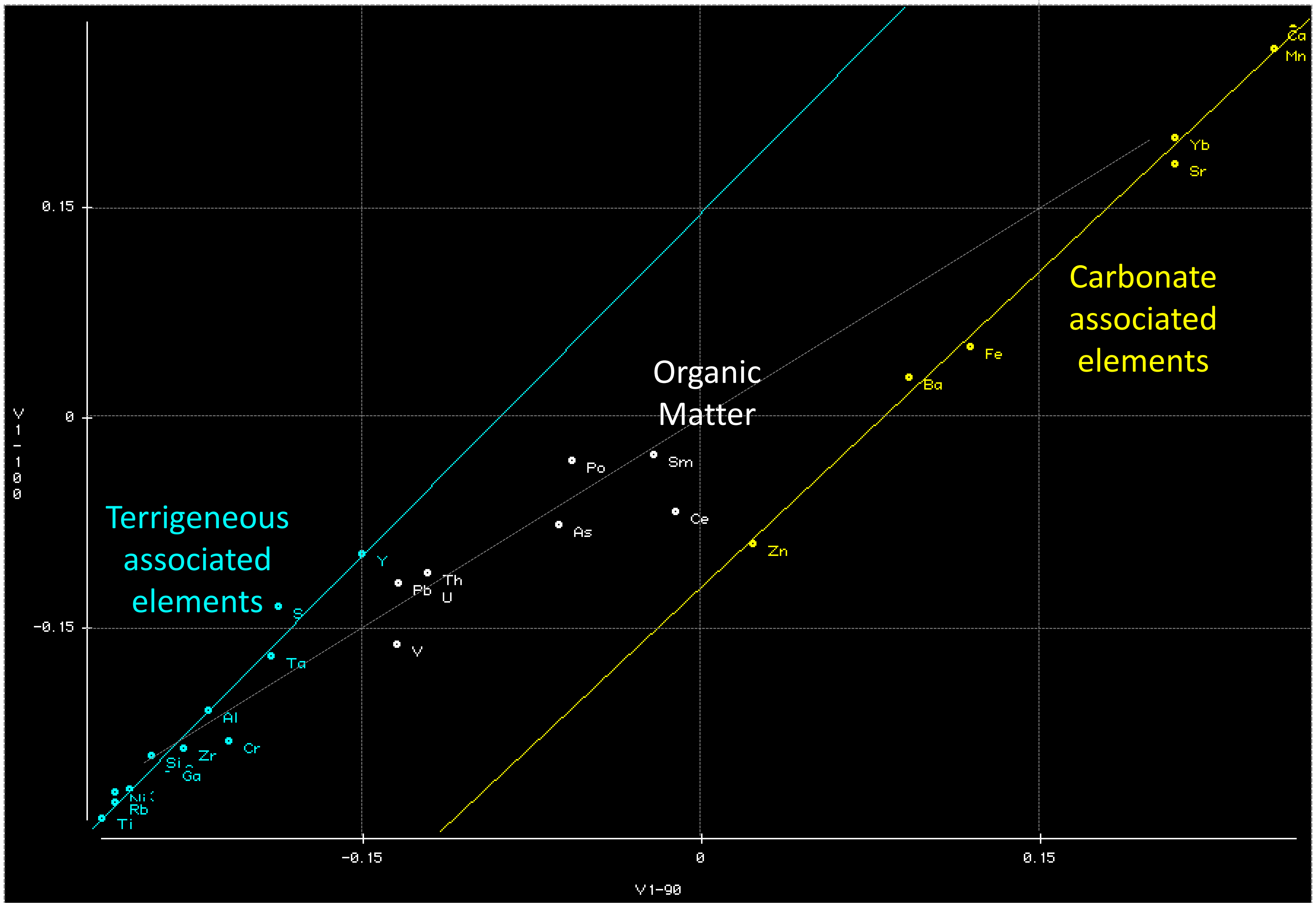
Ev1 compared between
2 successive units (20 and 25)
in well C6-L

There might be no need to distinguish between Unit 20 and Unit 25

NO NEED TO HAVE TWO UNITS
On the basis of EV1 vs EV1

Unit 100 vs Unit 90 V1

EV1 vs EV1



Note that EV1 vs EV1 for Unit 95 against units 90 or 100 shows no trends or patterns

Conclusions

- If you have enough measurements per unit (or per cuttings) you can compare the first components between units (ev1 vs ev1)
- You can QC the correlation between wells
- You can infer compositional changes between units or between wells
- You can identify the units with similar origin and compositions
- Continuous XRF is the ideal tool for cores and for cuttings (20+ measurements per cutting vial) to perfectly characterize your sediments