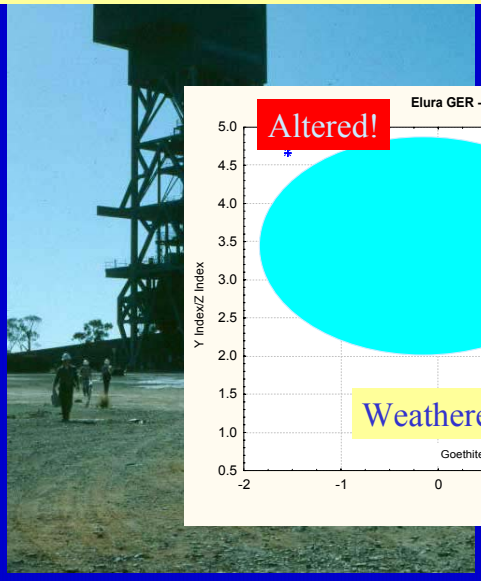
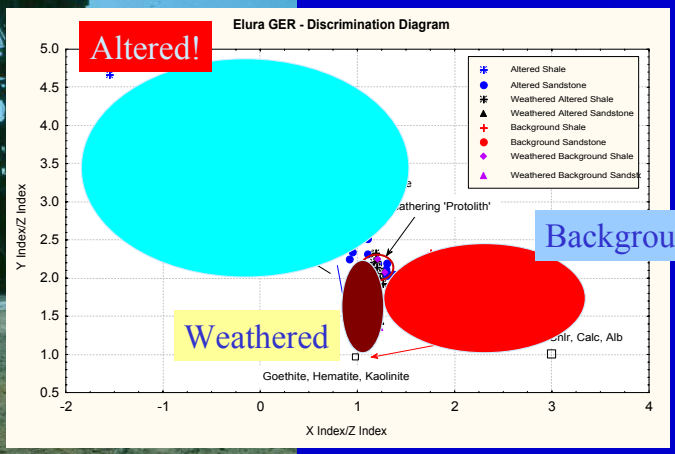
RATIO ANALYSIS IN LITHOGEOCHEMISTRY: QUANTIFYING ALTERATION AND INTEGRATING RESULTS INTO EXPLORATION EFFORTS





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PRESENTATION OUTLINE

- RATIONALE FOR LITHOGEOCHEMISTRY
- PEARCE ELEMENT RATIOS (PER)
  - Examples
  - Use in Exploration
- GENERAL ELEMENT RATIOS (GER)
  - Examples
  - Use in Exploration
- CONCLUSIONS

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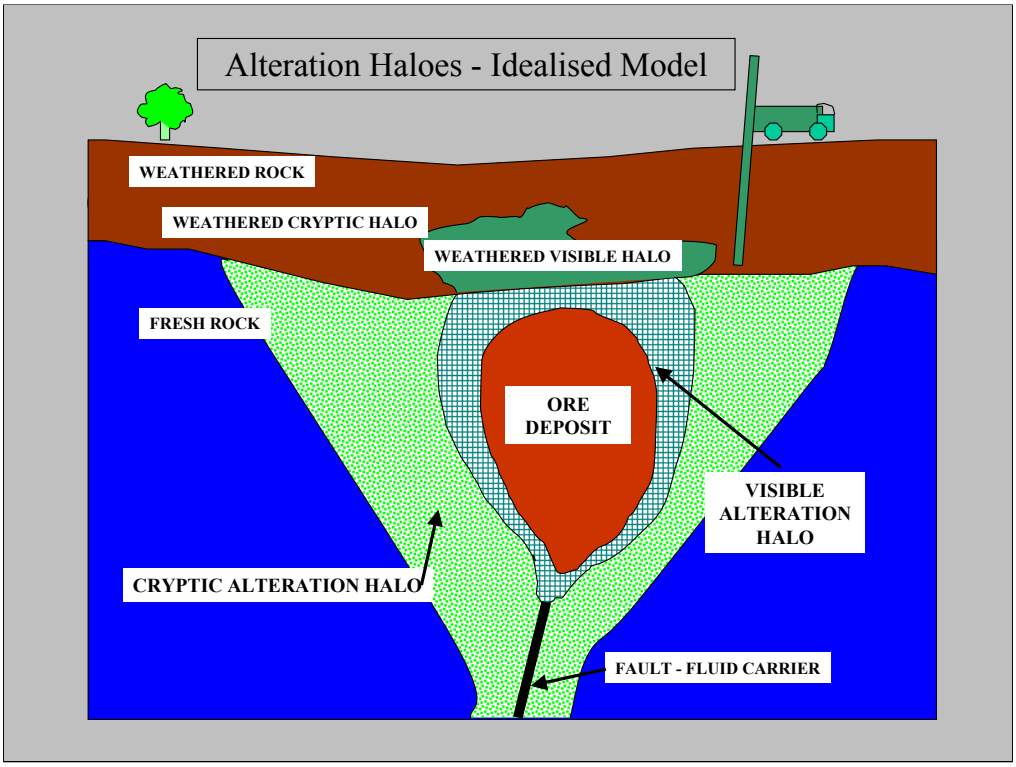


Cryptic Alteration - Those mineral and elemental changes resulting from fluid-rock interactions related to a mineralising event.. In particular that alteration which is not visible to the naked eye. You may also like to include alteration which is very difficult to quantify with the naked eye, despite its presence being readily detectable

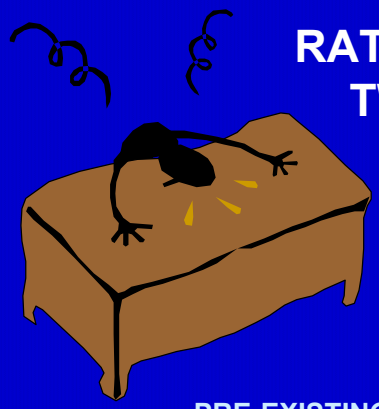
Fresh and Weathered

Extensive - greater footprint to target

Using the ratio methods, can accurately model mineral changes - no statistical assumptions

It is possible to calculate alteration strength or completeness - depending on the reactions involved.

Combine with other pathfinders or key indicators to maximise potential of Discovery.



RATIO ANALYSIS SOLVES TWO BIG PROBLEMS

CLOSURE

AN ARTEFACT INDUCED IN DATA BY THE SUMMATION OF COMPONENTS TO 100%

PRE-EXISTING LITHOGEOCHEMICAL TRENDS

CHEMICAL VARIATIONS IN THE HOST ROCK WHICH EXISTED PRIOR TO THE ORE FORMING EVENT.

THESE CAN BE GREATER IN MAGNITUDE THAN VARIATION DUE TO ALTERATION.

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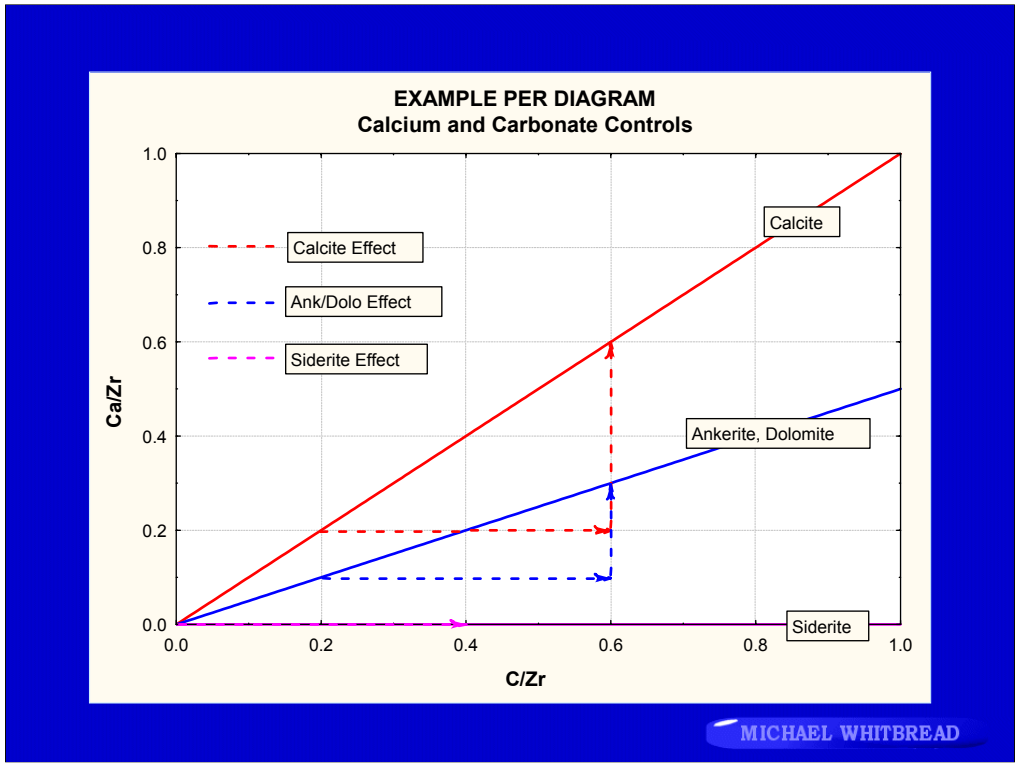

Minerals as Vectors

Conserved Denominator

Molar Values

CASE STUDY EXAMPLES: LOCATIONS AND SUMMARY

Elura:

Devonian Turbidite Host, Vertical Pods Crosscut Stratigraphy

45mt @ 8.5%Zn, 5.3%Pb, and 69ppm Ag

Century:

Proterozoic Shales and Siltstones (Shelf), Faulted or Erosional Truncations, Stratiform but Mildly Transgressive

118mt @ 10.2%Zn, 1.5%Pb, 36ppm Ag

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Elura Pods have a NNW trend to them 700m long. 7 Pods, with northern 5 400m below surface

Elura main and second pod are exposed to the weathering profile

Deposit possibly located at the tip of a blind thrust

Dilational Model and Fluid Mixing Models proposed for Ore Formation

Metal Carrying Solutions likely deep basinal.. Reduced acd???, possibly basement influence

CSA Siltstone Bland - Lower Greenschist Metamorphism, good for lack of interfering metaomatism

Half of the resource currently mined

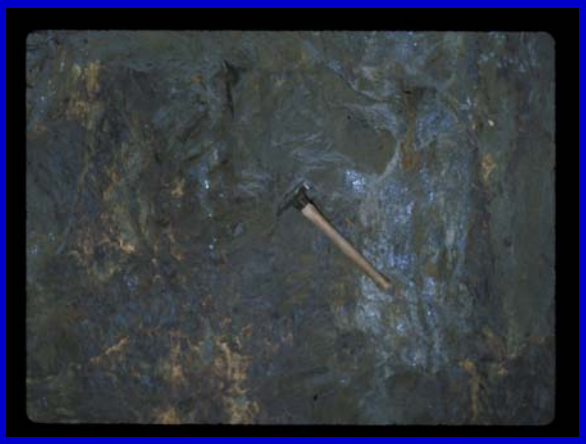
Century - large resource, no natural terminations, no equivalent of the ore sequence with 8 kilometres of the deposit.

H4s shelf sediments - Proterozoic. Overlain by Cambrian Carbonate

Low Fe Sphalerite, Sulphides parallel sediment layering, but mineralisation as a whole shallowly transgresses stratigraphy. Thermochemical Sulphate Reduction Model Theory of Oxidised near neutral brines.

Weathering variable, certainly not the extensive preservation as at Cobar

ELURA



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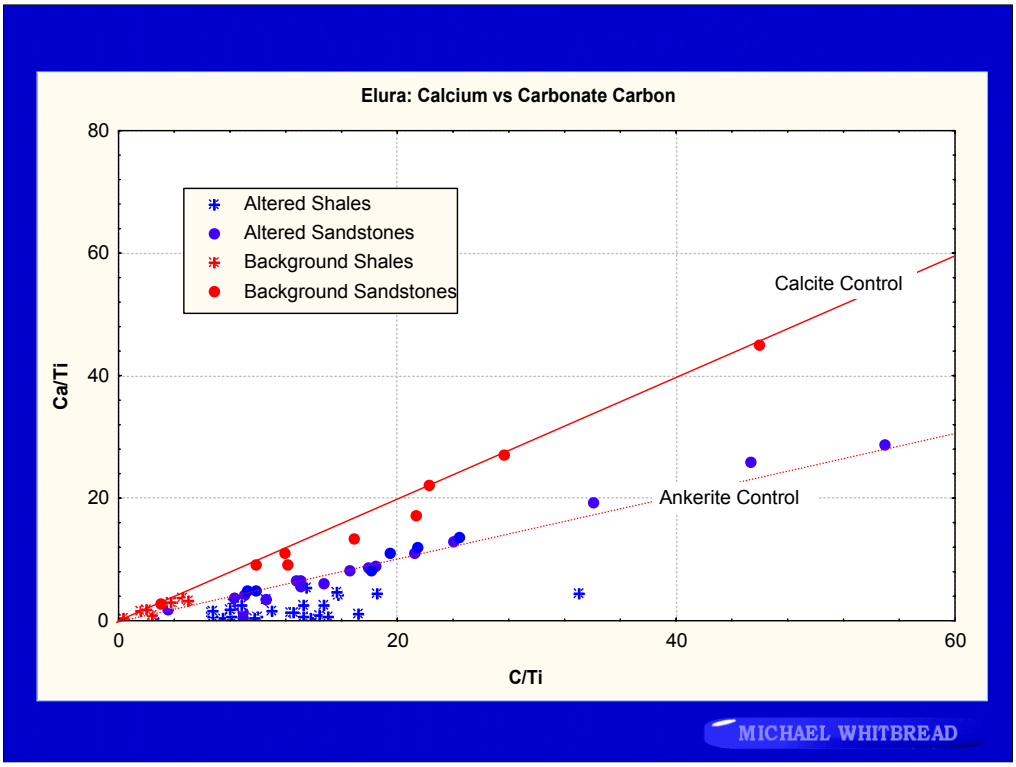
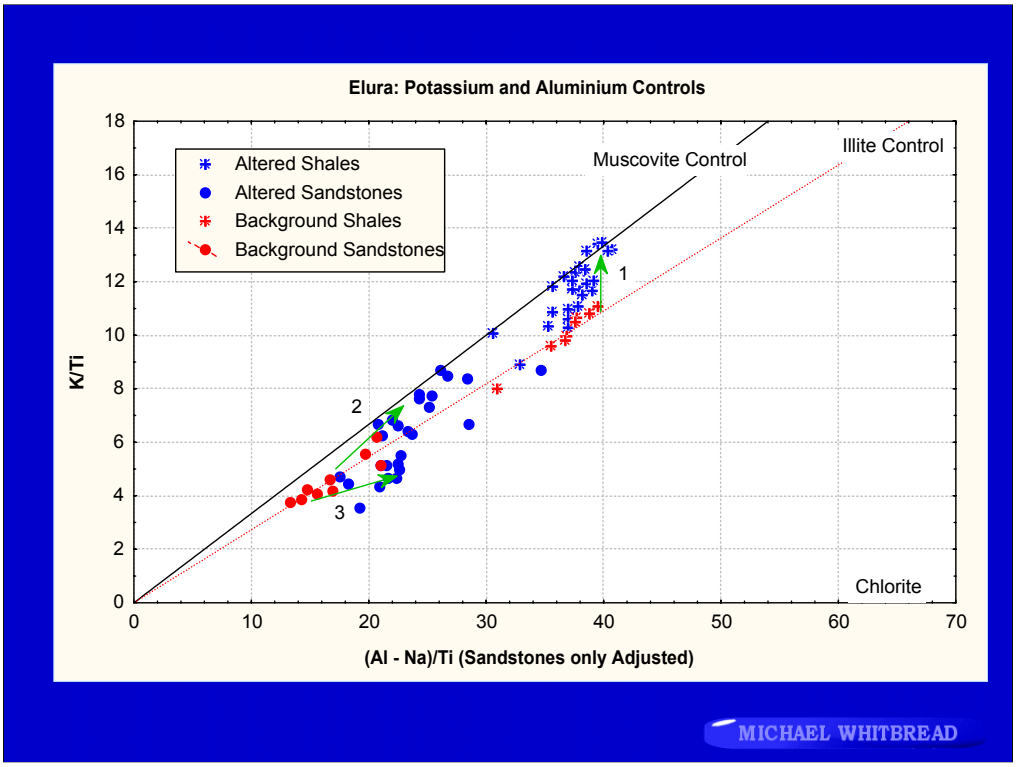


Note background altered and shale-sandstone split. No C addition to sands, but C addition in shales. Minor Ca loss, but not much.



Split by lithology/lithotype and altered/background

Shales muscovite

Sandstones two paths - two resulting chemistries.


MAKING IT EXPLORATION-FRIENDLY
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MAKING THE RATIOS USEFUL

TWO BROAD WAYS TO DO THIS…..

- PLOT VALUES IN A SPATIAL SENSE
- COMBINE VALUES IN CHEMICAL SPACE TO VIEW MULTIPLE ALTERATION INDICATORS IN ONE PLOT

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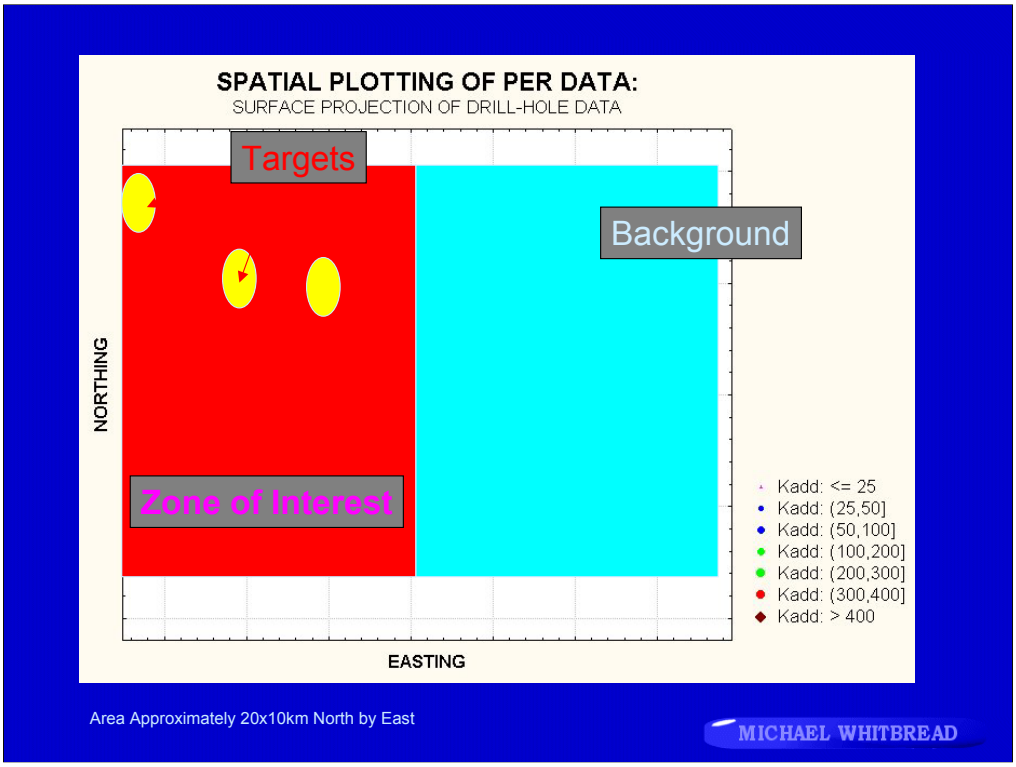

Area Approximately 20x10km North by East

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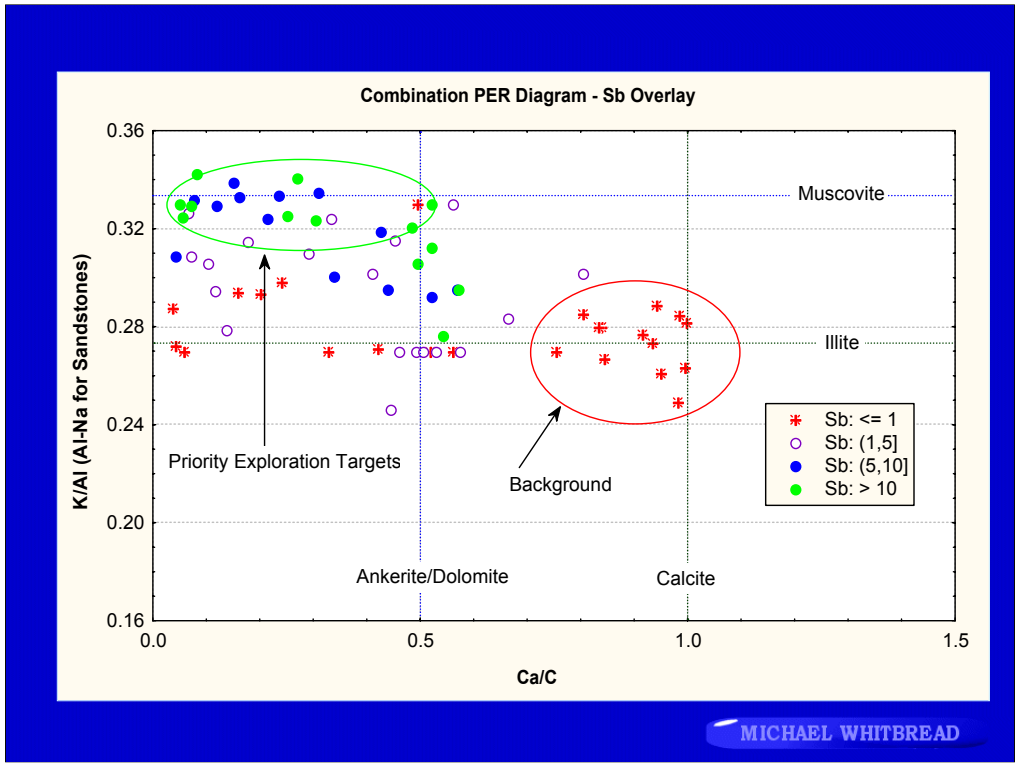
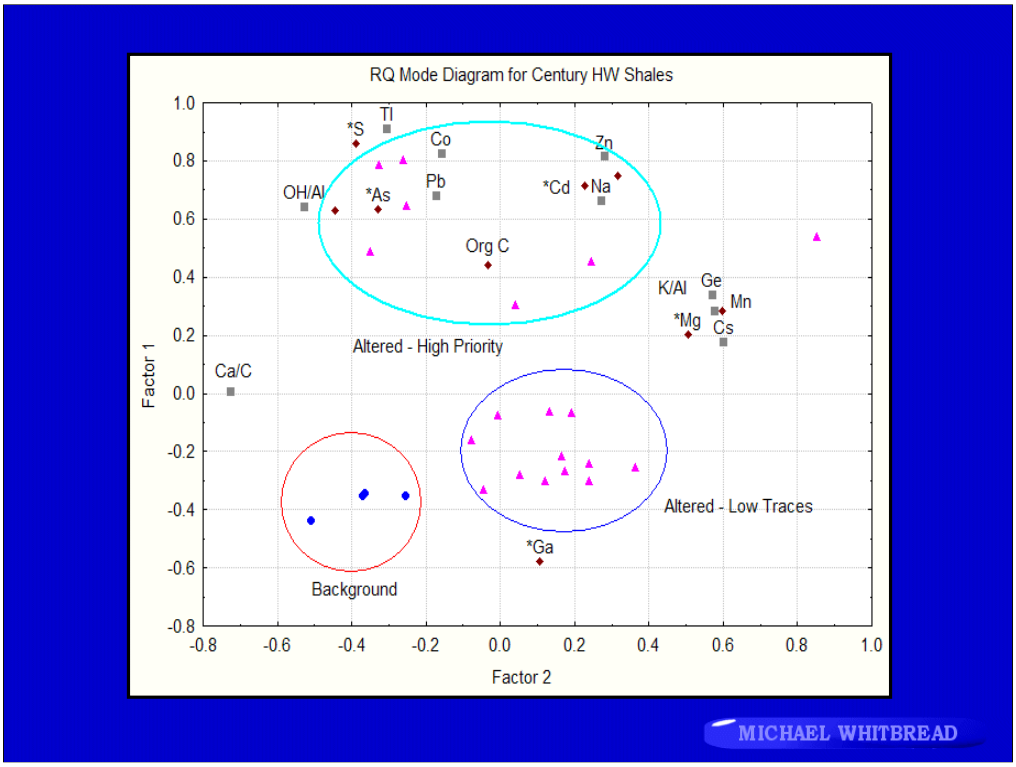


Combined Method - best samples lie in the ellipse - Carb, K and Sb indicators.
'Chloritic' sands should be monitored on this diagram, may plot outside the ellipse.



RQ mode PCA used to combine PER scores with trace element pathfinder responses.

Good way to combine a lot of variables into one plot.. Should be used with caution, as assumptions need to be made during construction.

THINGS TO KEEP IN MIND

- SLOPES ON PER DIAGRAMS CAN BE USED TO QUANTIFY ALTERATION
- ONCE QUANTIFIED, THE MINERALOGICALLY AND CHEMICALLY CONSTRAINED ALTERATION NUMBER CAN BE PLOTTED LIKE ANY OTHER RAW ANALYSIS
  - Except that it is far more informative!
  - No closure effects
  - and background has been removed!
- RESULTS CAN BE MADE SIMPLE ENOUGH FOR EXPLORATION TO USE!

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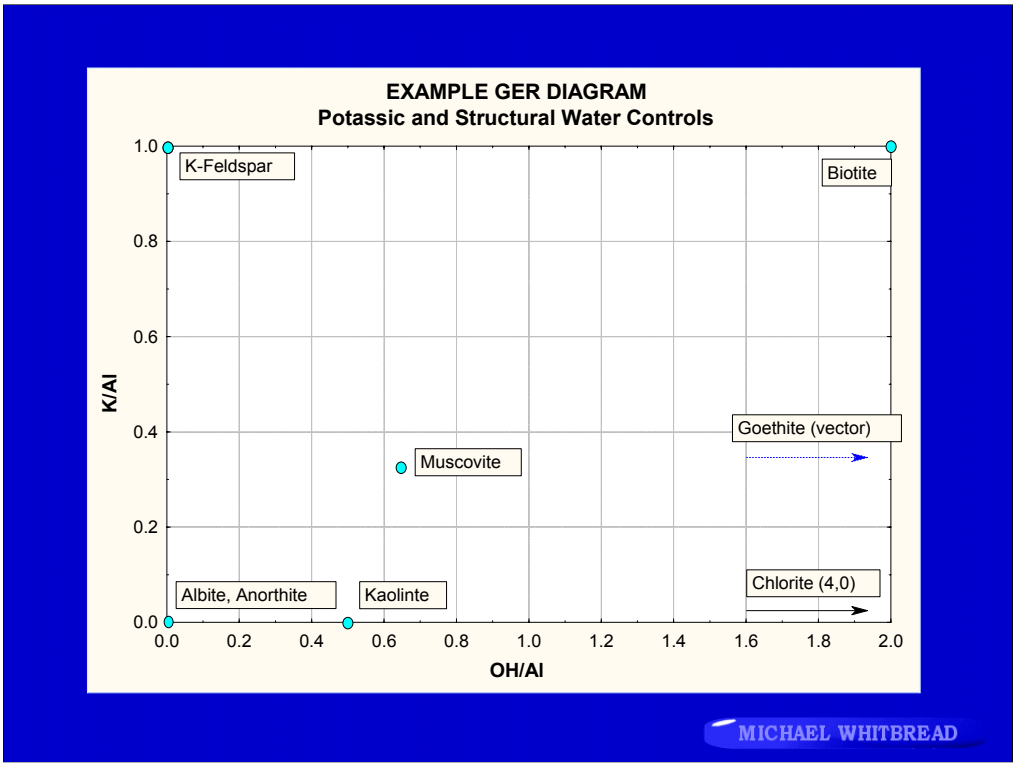

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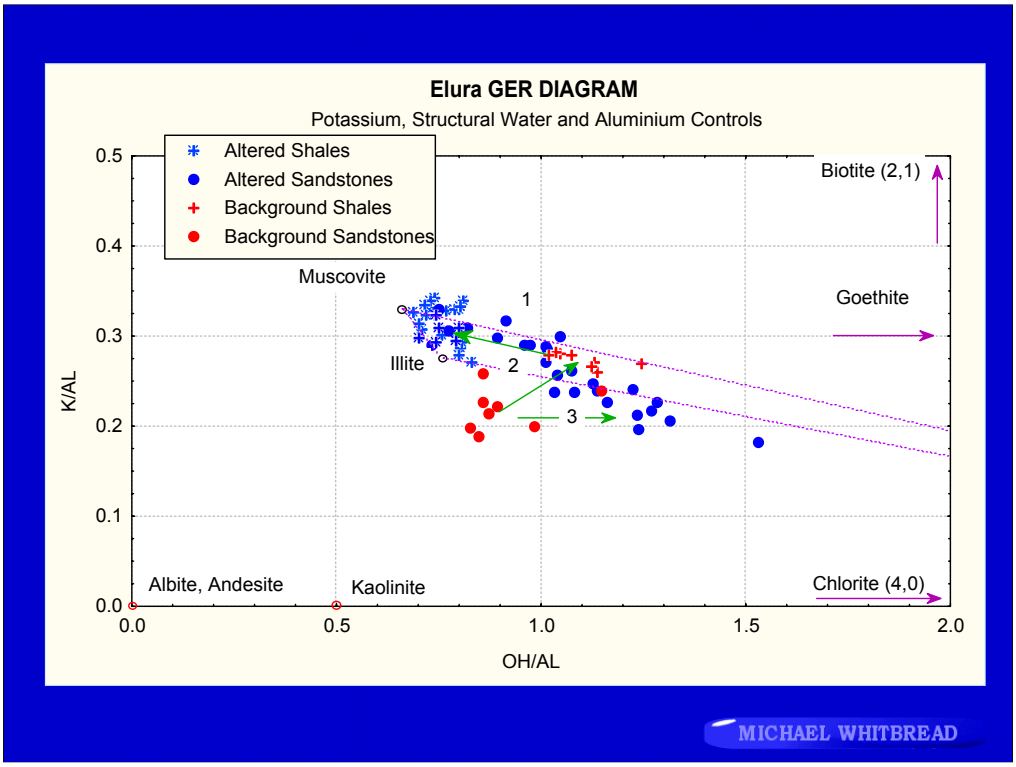
Elura GER DIAGRAM
Potassium, Structural Water and Aluminium Controls
Altered Shales
Altered Sandstones
Background Shales
Background Sandstones
Biotite (2,1)
Goethite
Muscovite
Illite
Albite, Andesite
Kaolinite
Chlorite (4,0)
1
2
3
K/AL
OH/AL
0.0
0.1
0.2
0.3
0.4
0.5
0.0
0.5
1.0
1.5
2.0
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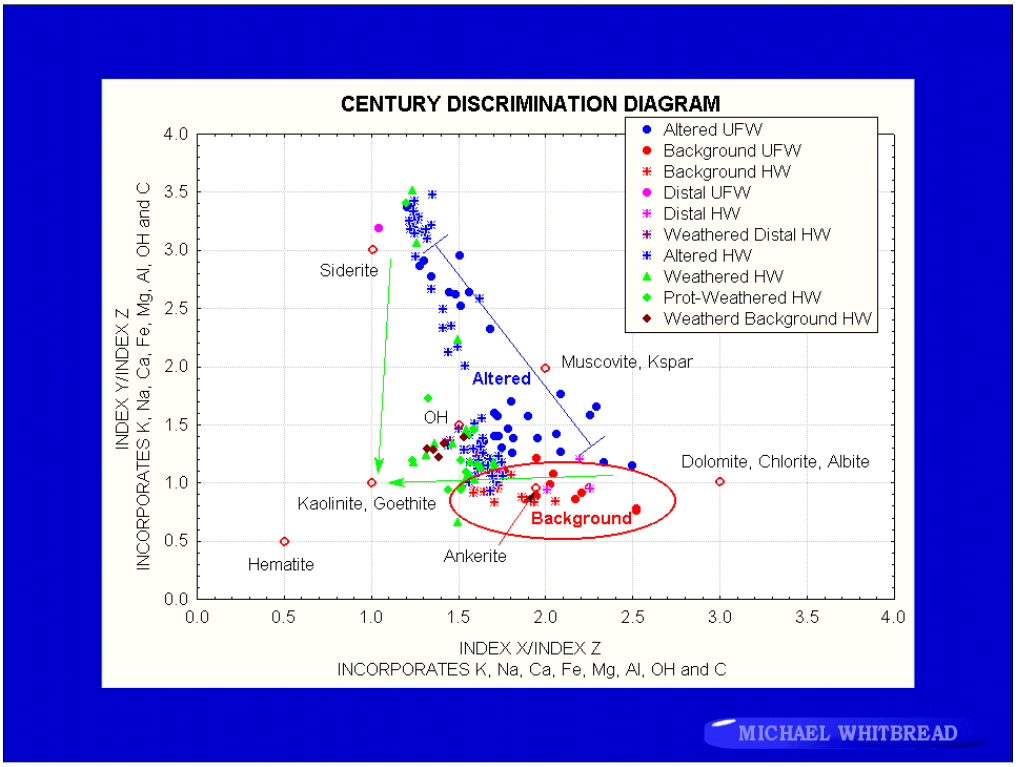
Photo Courtesy of PASMINCO


CENTURY DISCRIMINATION DIAGRAM
Altered UFW
Background UFW
Background HW
Distal UFW
Distal HW
Weathered Distal HW
Altered HW
Weathered HW
Prot-Weathered HW
Weatherd Background HW
INDEX Y/INDEX Z
INCORPORATES K, Na, Ca, Fe, Mg, Al, OH and C
INDEX X/INDEX Z
INCORPORATES K, Na, Ca, Fe, Mg, Al, OH and C
Siderite
Muscovite, Kspar
Altered
OH
Dolomite, Chlorite, Albite
Kaolinite, Goethite
Background
Hematite
Ankerite
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
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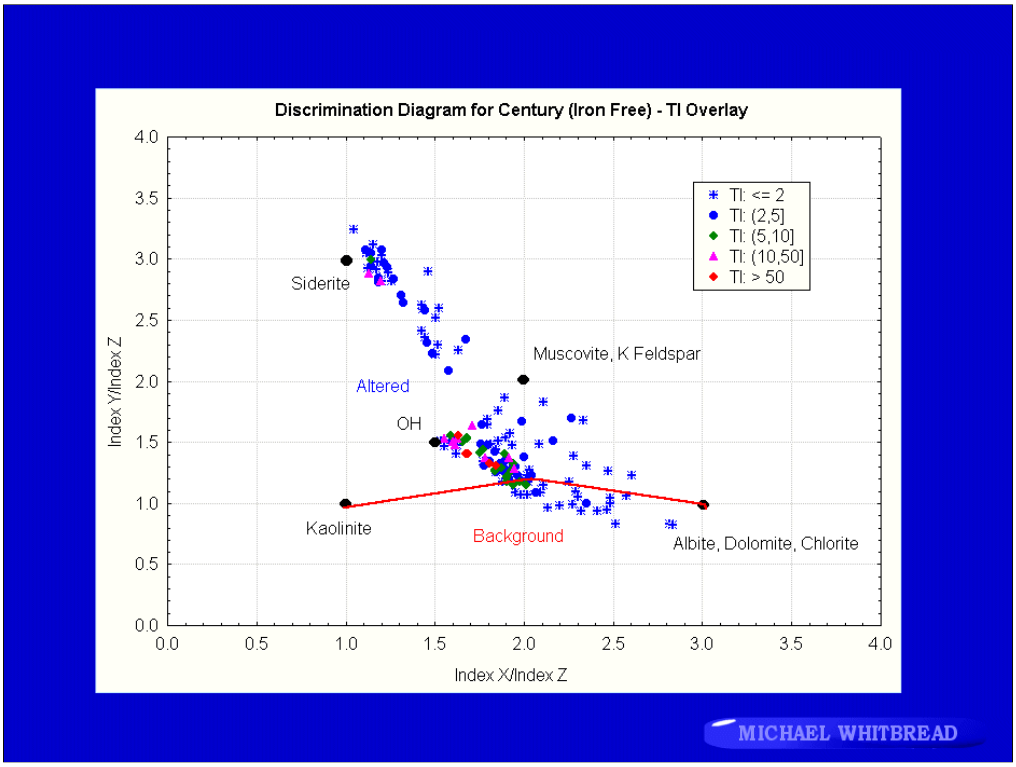

Bit blurry because of new statistica format.. Sorry :/

Diagram used to show how elemental pathfinders can be overlain on the complicated GER diagrams

IMPORTANT POINTS

- GERs CAN BE USED AS A TEMPLATE TO PLOT TRACES, ISOTOPE RESULTS ETC ONTO
- USING GERs AS A TEMPLATE GIVES GOOD MINERALOGICAL CONTROL ON INTERPRETATIONS
- GERs OFTEN HARDER TO REDUCE TO A SINGLE NUMBER - LACK OF SIMPLE SLOPES
- HOWEVER IT IS POSSIBLE TO ZONE GER DIAGRAMS AND CODE SPATIAL PLOTS BY THESE ZONES

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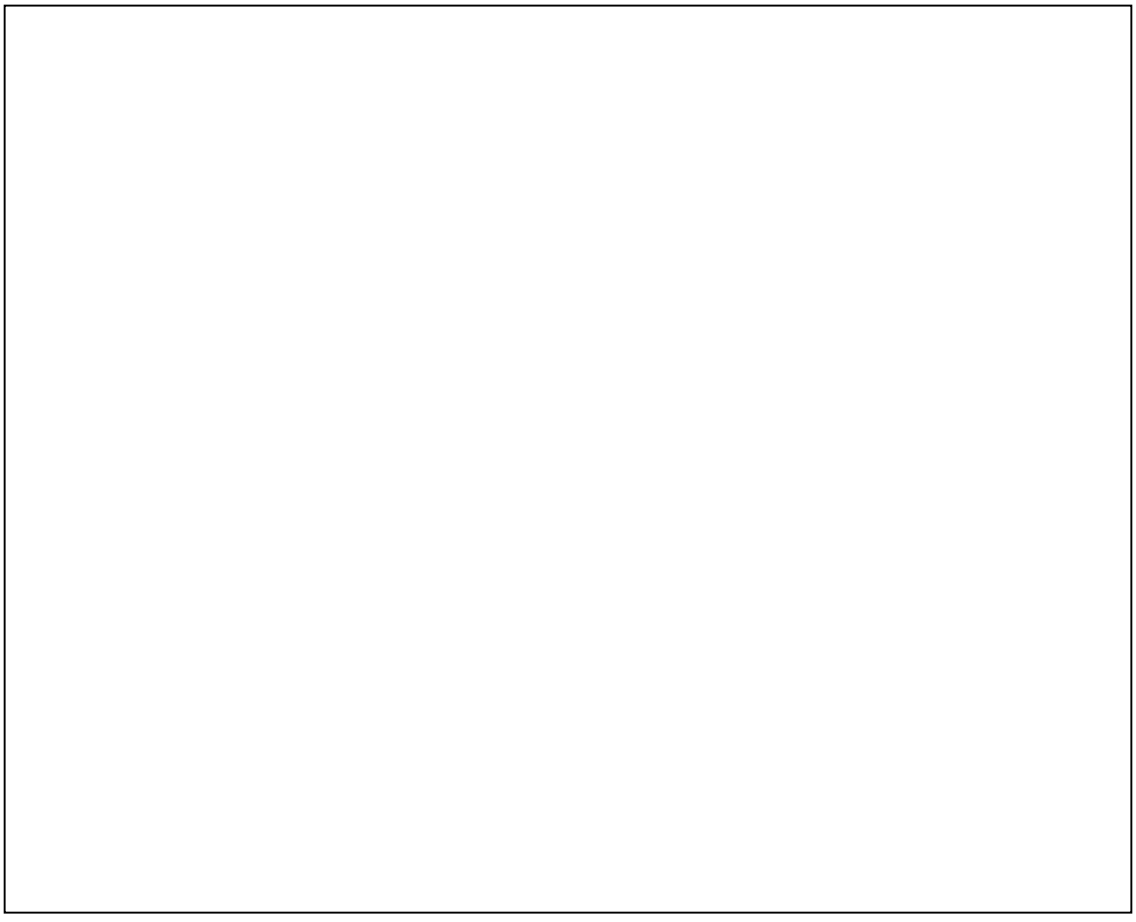

CONCLUSIONS

- RATIO ANALYSIS, ie PER, GER, ARE EXCELLENT TOOLS FOR INDENTIFYING AND QUANTIFYING ALTERATION
- PER, GER RESULTS CAN BE COMBINED WITH OTHER GEOCHEMICAL AND SPATIAL INFORMATION - EASY TO INCORPORATE INTO EXPLORATION EFFORTS
- PER AND GER DIAGRAMS AVOID CLOSURE, MODEL MINERALOGY AND CAN ACCOUNT FOR BACKGROUND VARIATION - THEY SHOULD BECOME THE STANDARD DATA ANALYSIS METHOD IN LITHOGEOCHEMISTRY

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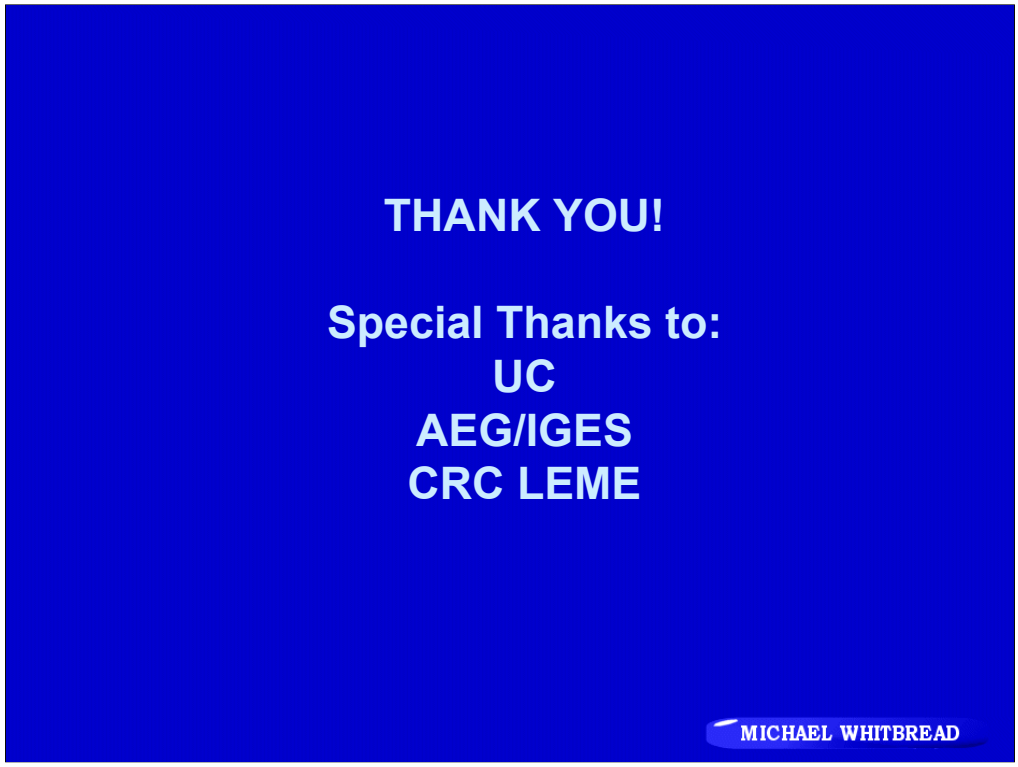

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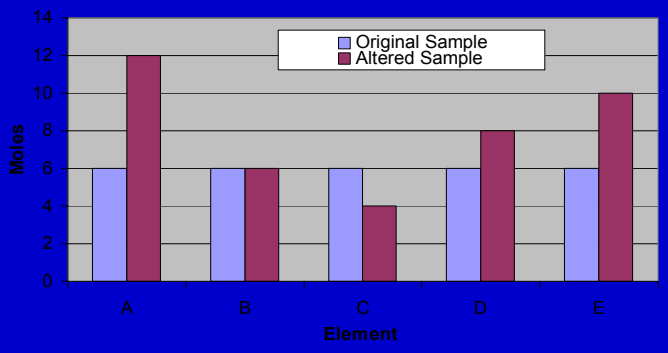
CLOSURE EXAMPLE!

Extensive

Moles in Original and Altered Samples



Intensive

Mole % in Original and Altered Samples

Note how there are differences between concentration values, and the absolute values.