

Lithological Discrimination in Deeply Weathered Terrains Using Multielement Geochemistry – An Example from the Yanfolila Gold Project, SW Mali



To be the global leader in sustainable gold mining

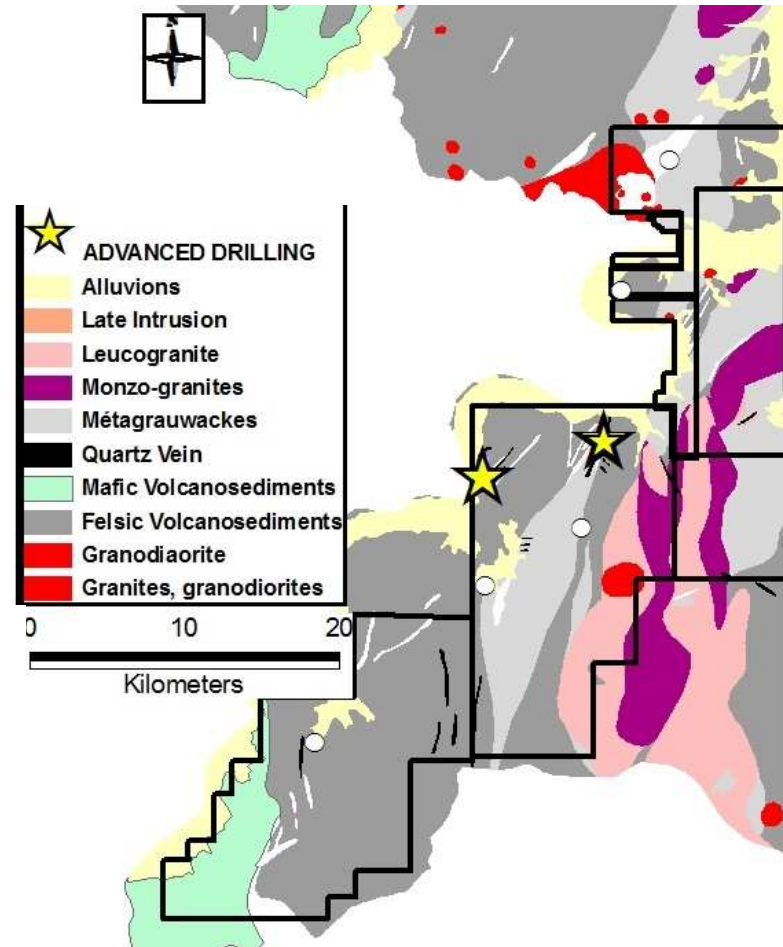
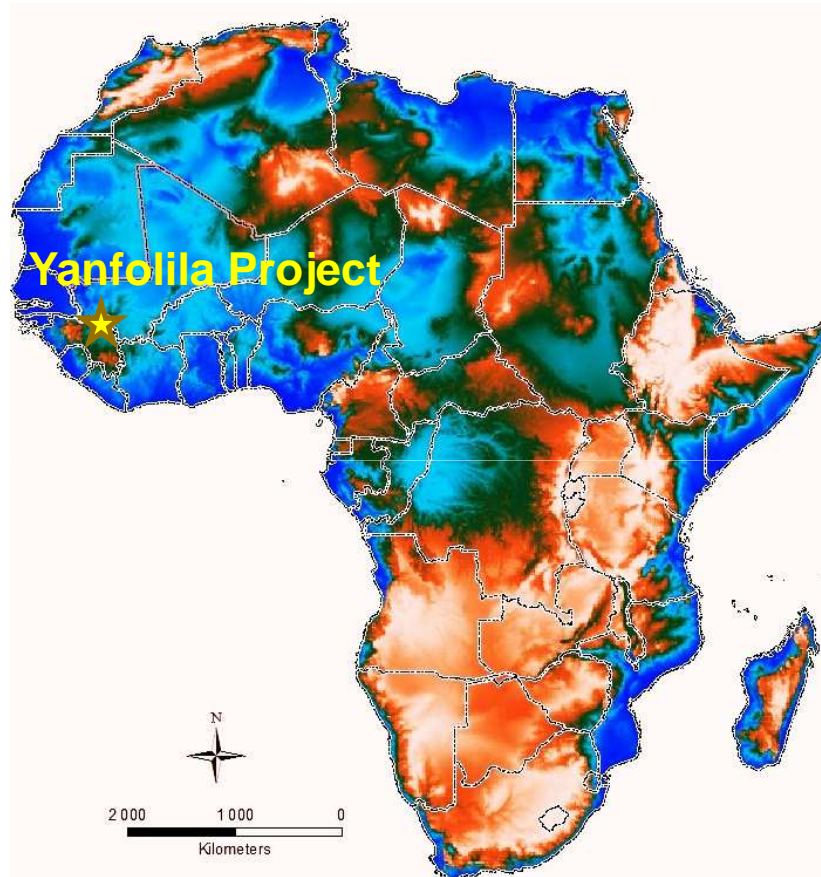
Chris Benn, Neil Jones, Kiril Mugerma, James Bell, David Weeks

25th International Applied Geochemistry Symposium, Finland, 2011

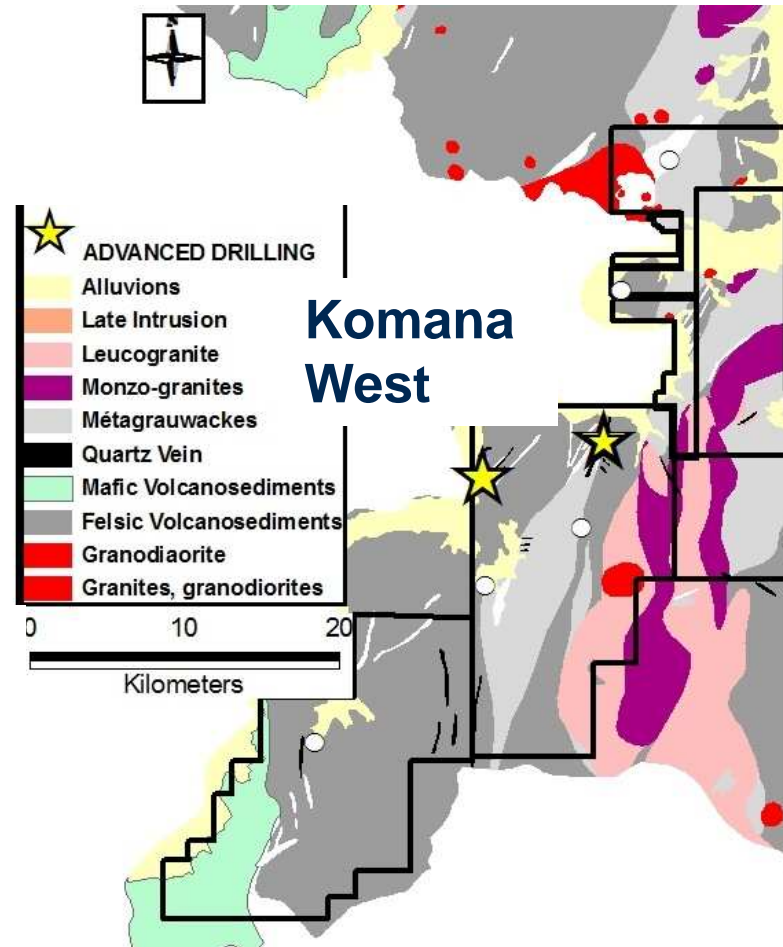
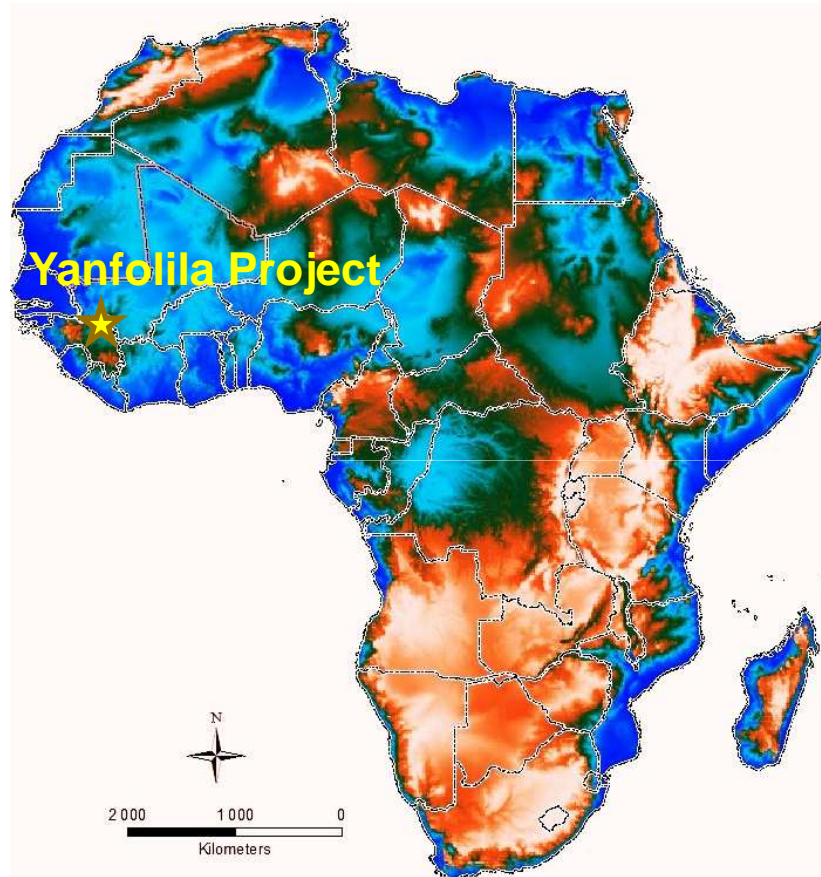


GOLD FIELDS

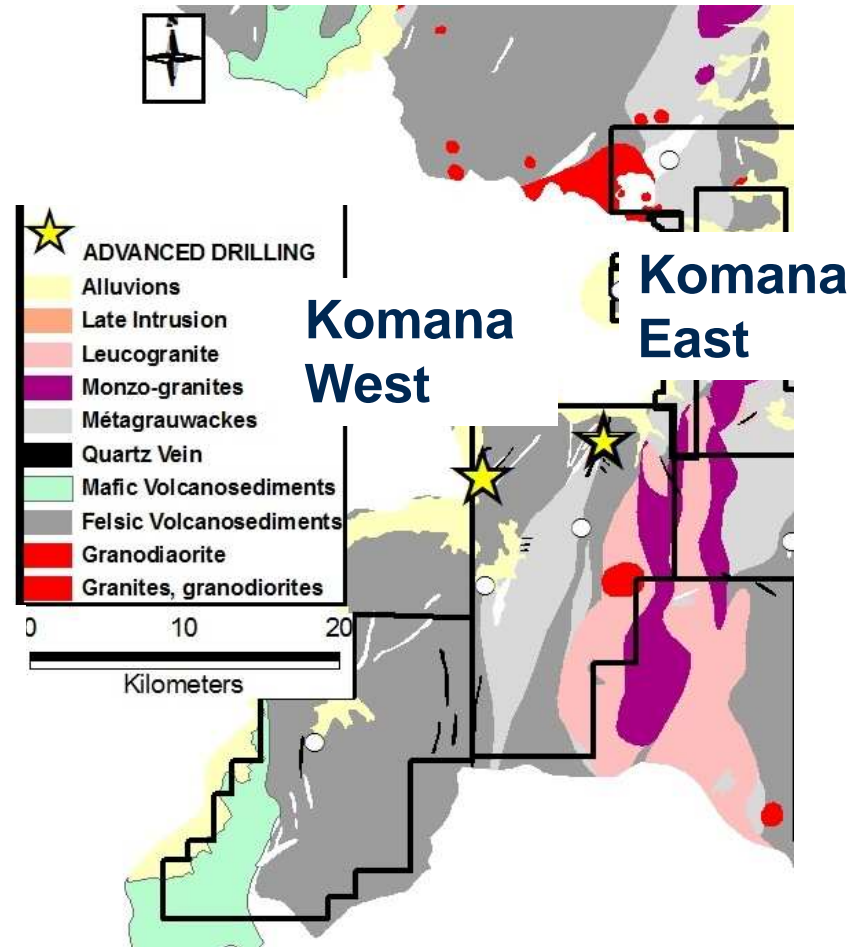
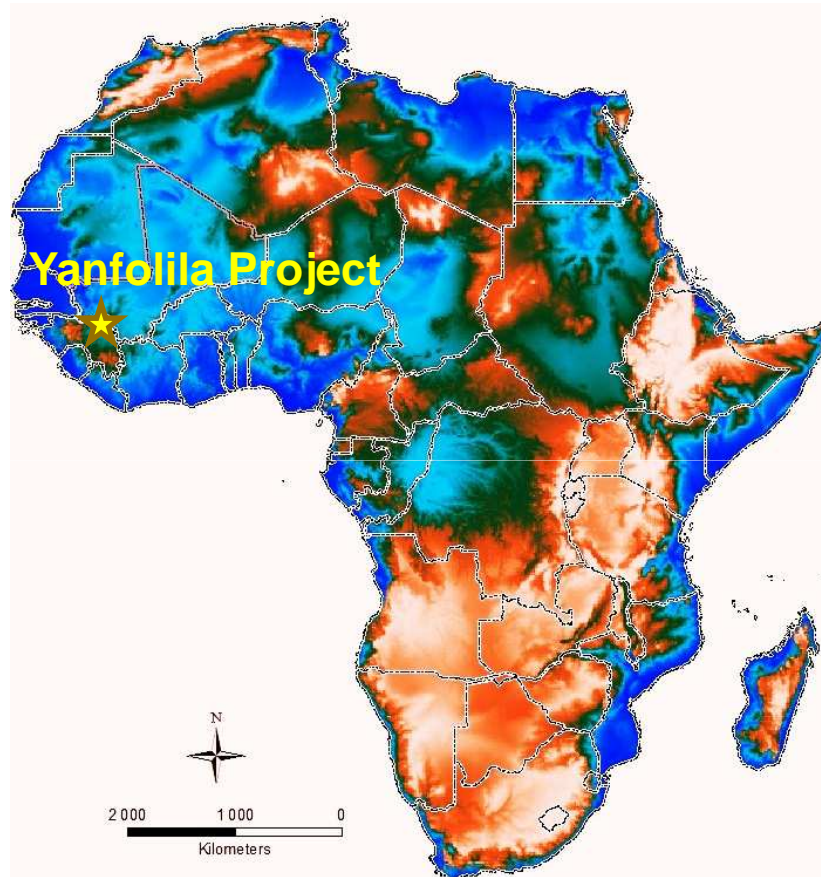
Yanfolila Gold Project, SW Mali - Location



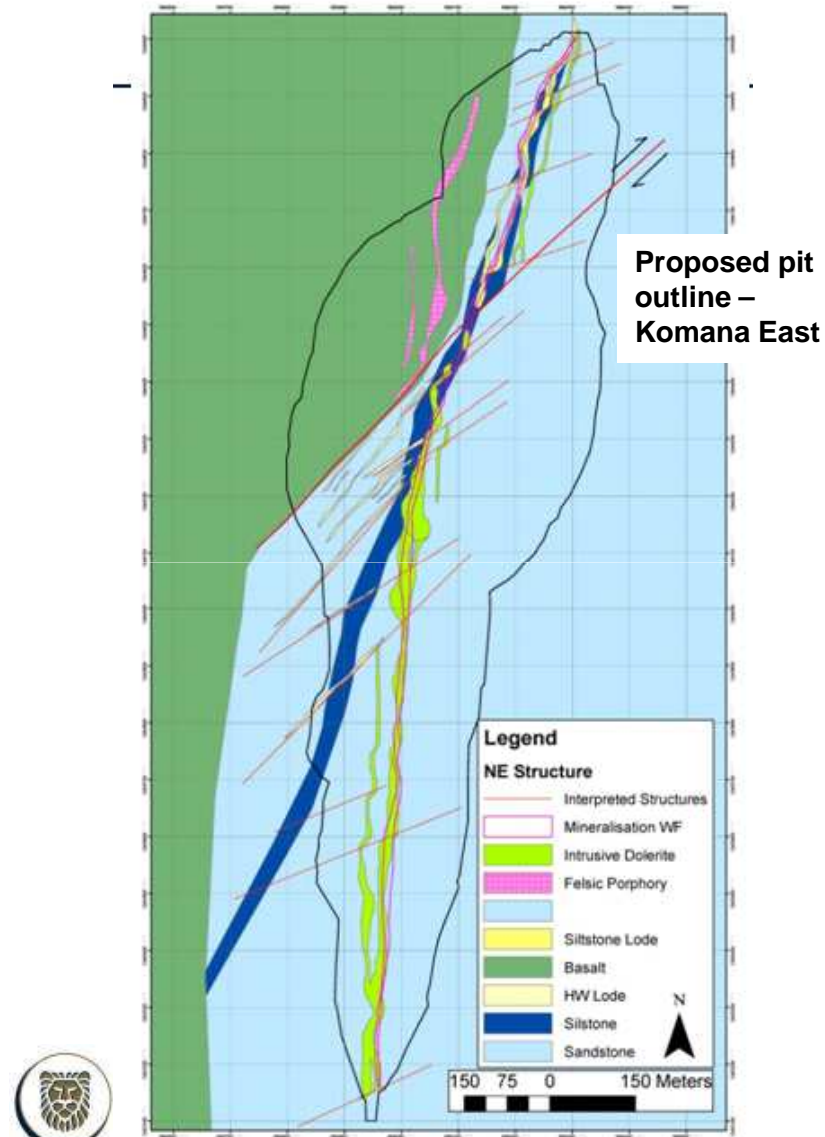
Yanfolila Gold Project, SW Mali - Location



Yanfolila Gold Project, SW Mali - Location



Komana East



Stratigraphy from west to east at Komana East is basalt, sandstones and siltstones, intrusive dolerite and sandstones.

Structural control on mineralization is from a splay of a major shear zone on the margin of a regional granite

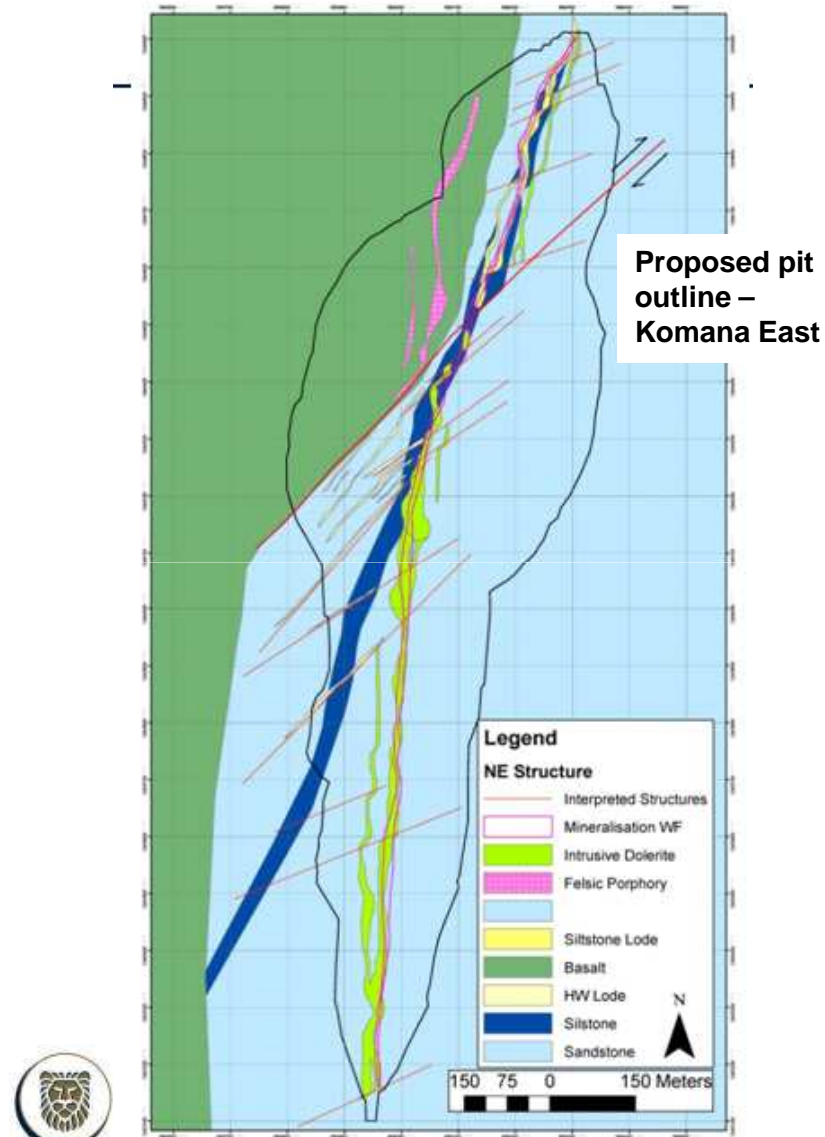
Mineralization is hosted in siltstones and intrusive dolerite

Gold is associated with pyrite and albite/K – feldspar alteration.

The only pathfinder element is W.



Komana East



Stratigraphy from west to east at Komana East is basalt, sandstones and siltstones, intrusive dolerite and sandstones.

Structural control on mineralization is from a splay of a major shear zone on the margin of a regional granite

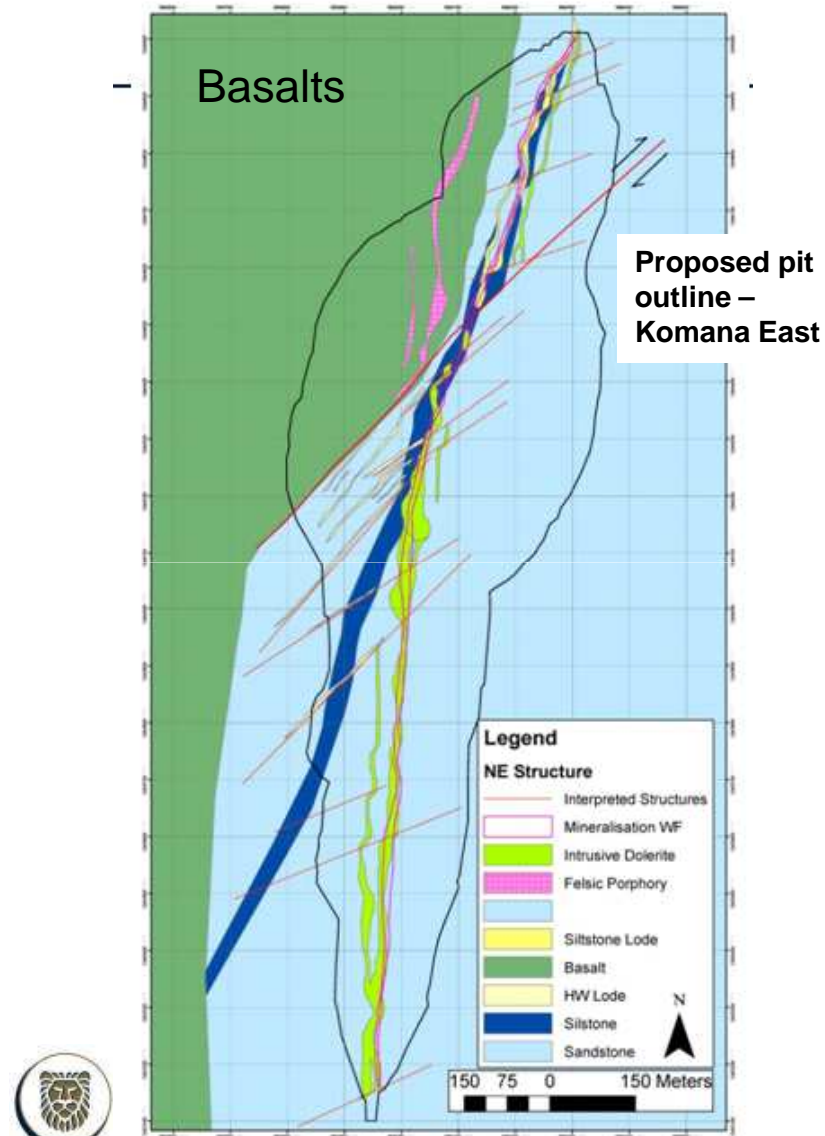
Mineralization is hosted in siltstones and intrusive dolerite

Gold is associated with pyrite and albite/K – feldspar alteration.

The only pathfinder element is W.



Komana East



Stratigraphy from west to east at Komana East is basalt, sandstones and siltstones, intrusive dolerite and sandstones.

Structural control on mineralization is from a splay of a major shear zone on the margin of a regional granite

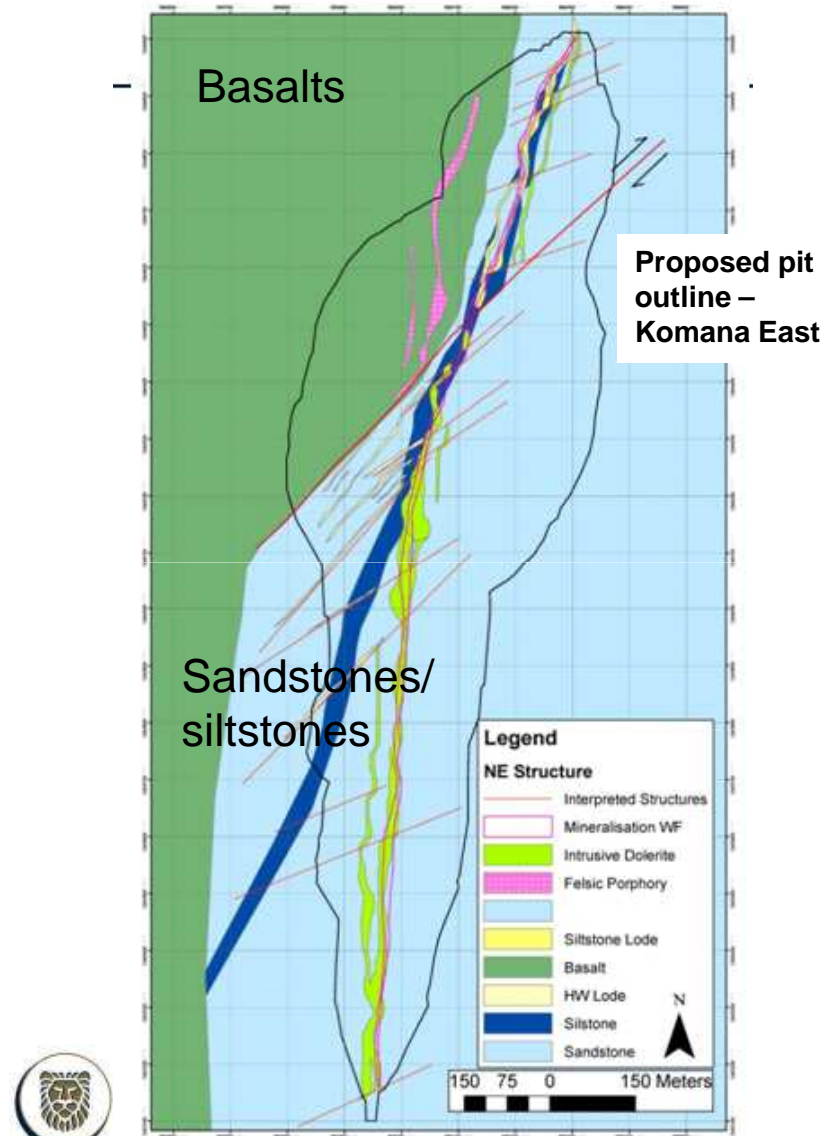
Mineralization is hosted in siltstones and intrusive dolerite

Gold is associated with pyrite and albite/K – feldspar alteration.

The only pathfinder element is W.



Komana East



Stratigraphy from west to east at Komana East is basalt, sandstones and siltstones, intrusive dolerite and sandstones.

Structural control on mineralization is from a splay of a major shear zone on the margin of a regional granite

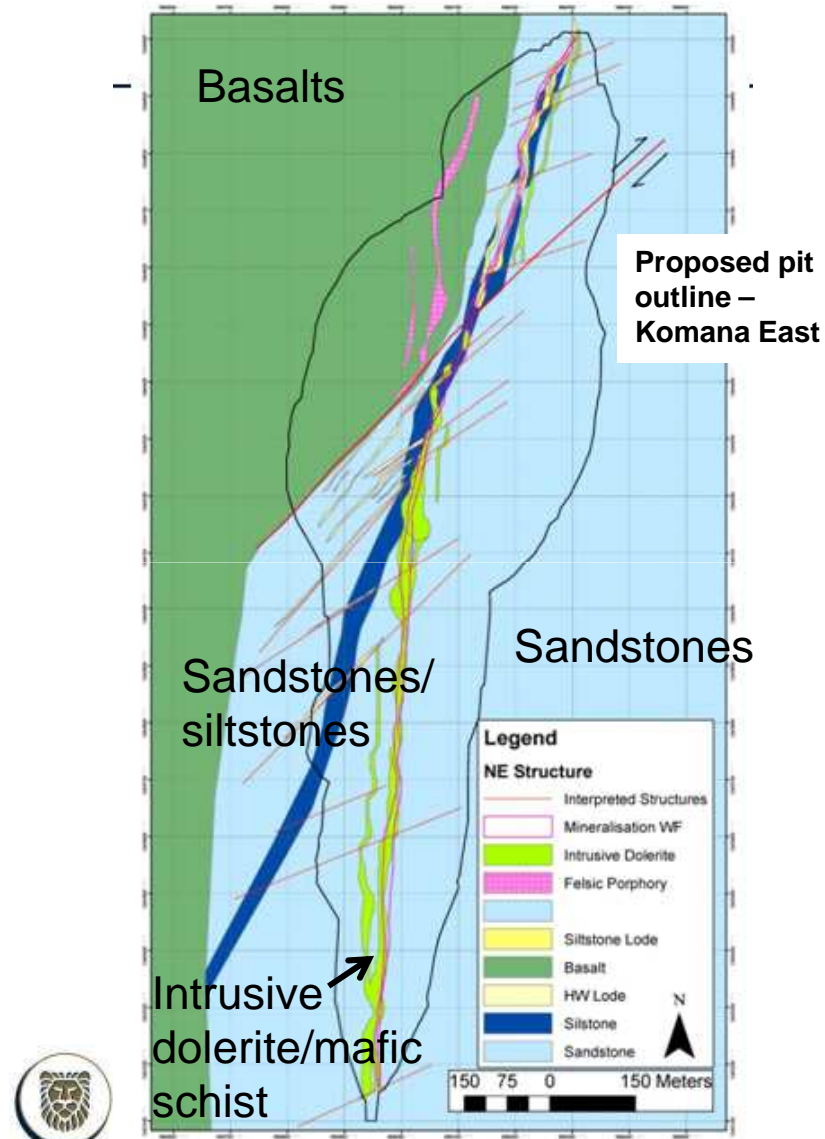
Mineralization is hosted in siltstones and intrusive dolerite

Gold is associated with pyrite and albite/K – feldspar alteration.

The only pathfinder element is W.



Komana East



GOLD FIELDS

Stratigraphy from west to east at Komana East is basalt, sandstones and siltstones, intrusive dolerite and sandstones.

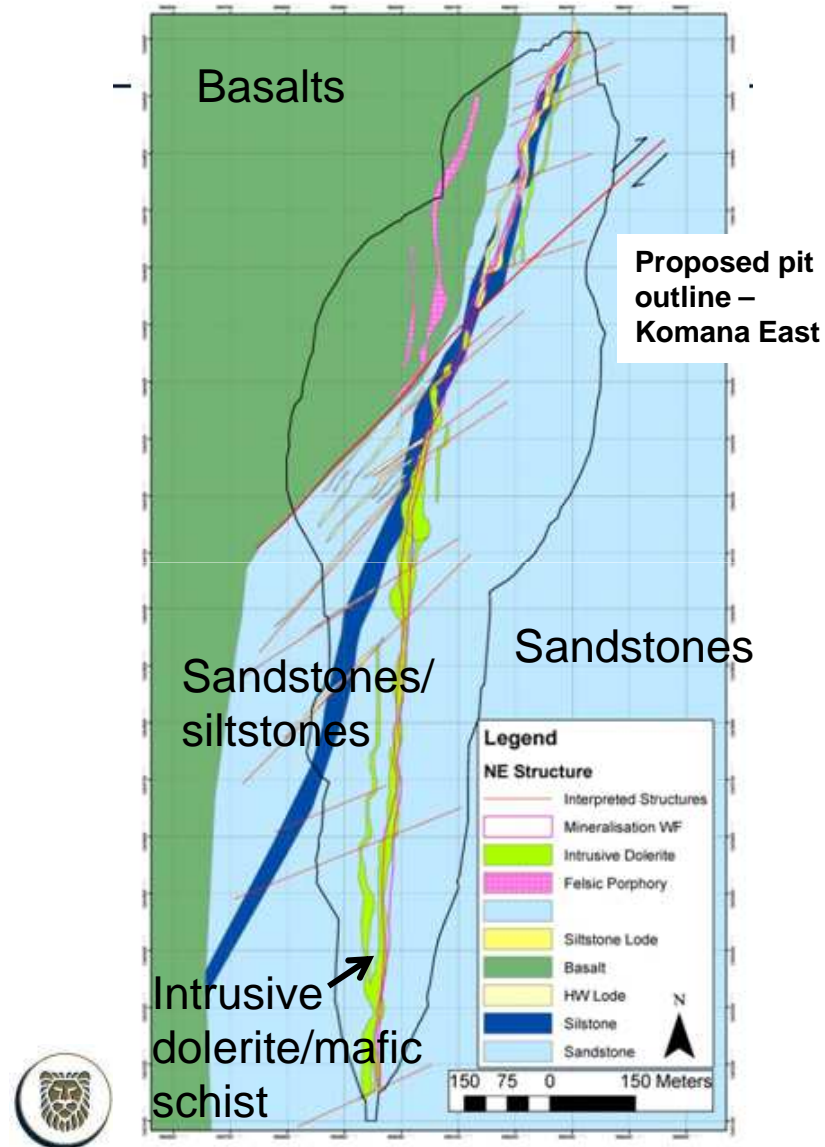
Structural control on mineralization is from a splay of a major shear zone on the margin of a regional granite

Mineralization is hosted in siltstones and intrusive dolerite

Gold is associated with pyrite and albite/K – feldspar alteration.

The only pathfinder element is W.

Komana East



GOLD FIELDS

Stratigraphy from west to east at Komana East is basalt, sandstones and siltstones, intrusive dolerite and sandstones.

Structural control on mineralization is from a splay of a major shear zone on the margin of a regional granite

Mineralization is hosted in siltstones and intrusive dolerite

Gold is associated with pyrite and albite/K – feldspar alteration.

The only pathfinder element is W.

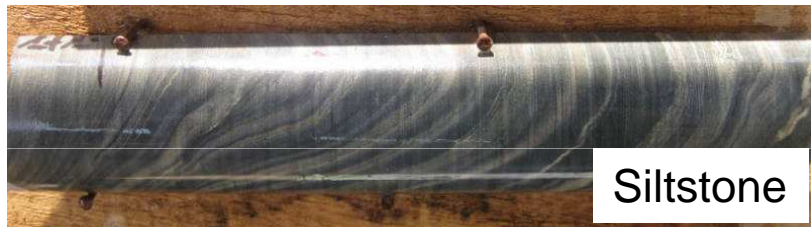
Yanfolila Project – Komana East – Example of Different Fresh Lithologies



Yanfolila Project – Komana East – Example of Different Fresh Lithologies



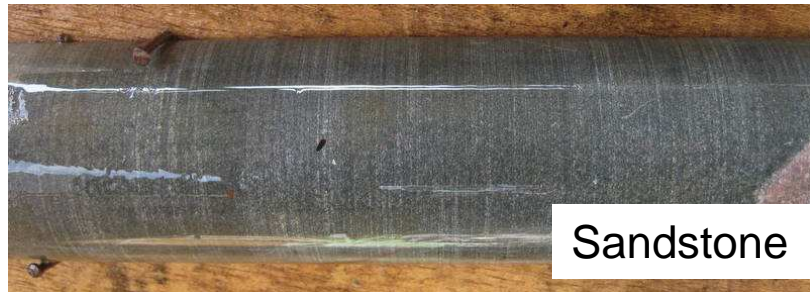
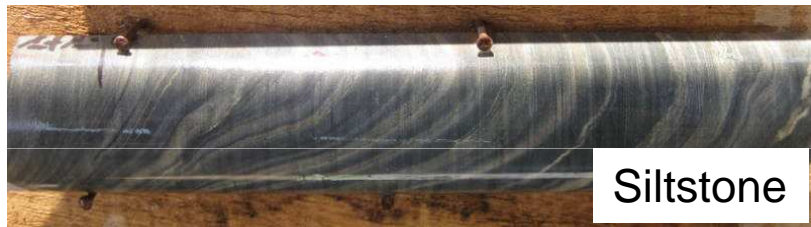
Yanfolila Project – Komana East – Example of Different Fresh Lithologies



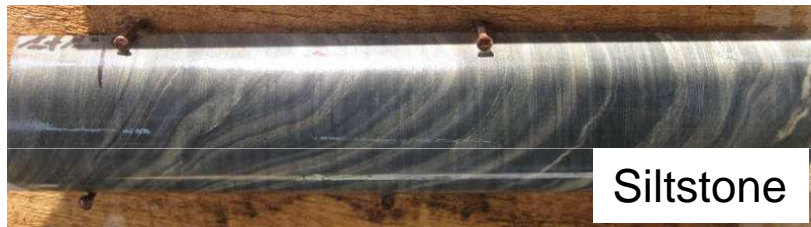
Yanfolila Project – Komana East – Example of Different Fresh Lithologies



Yanfolila Project – Komana East – Example of Different Fresh Lithologies



Yanfolila Project – Komana East – Example of Different Fresh Lithologies



Geochemical Challenges- Yanfolila Project

A major challenge is to log lithologies on a consistent basis. And this becomes particularly difficult in the weathered zone. For example basalt can sometimes be difficult to differentiate from sandstones and/or siltstones – even colour is not reliable.

Can robust templates be established for discrimination of rock types in fresh samples and applied to the weathered zone and even to surface soil sampling?

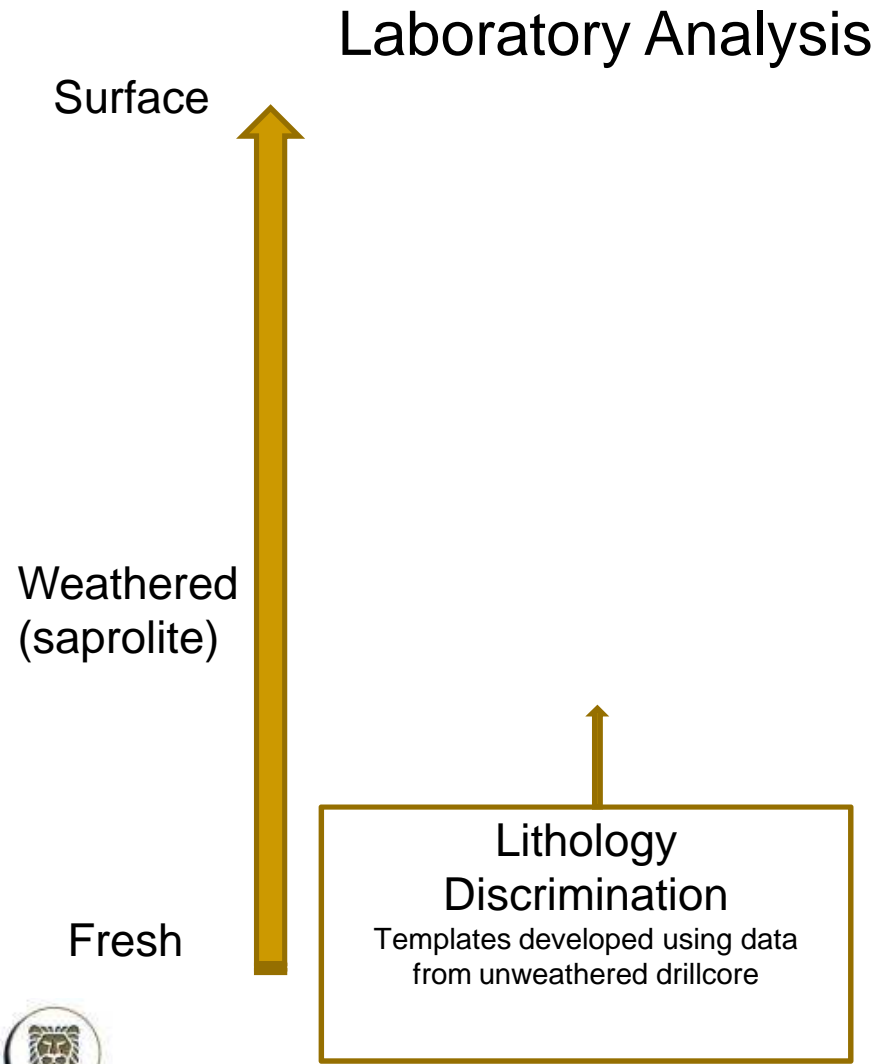
If successful can these templates be used or modified for use with a field portable XRF instrument?



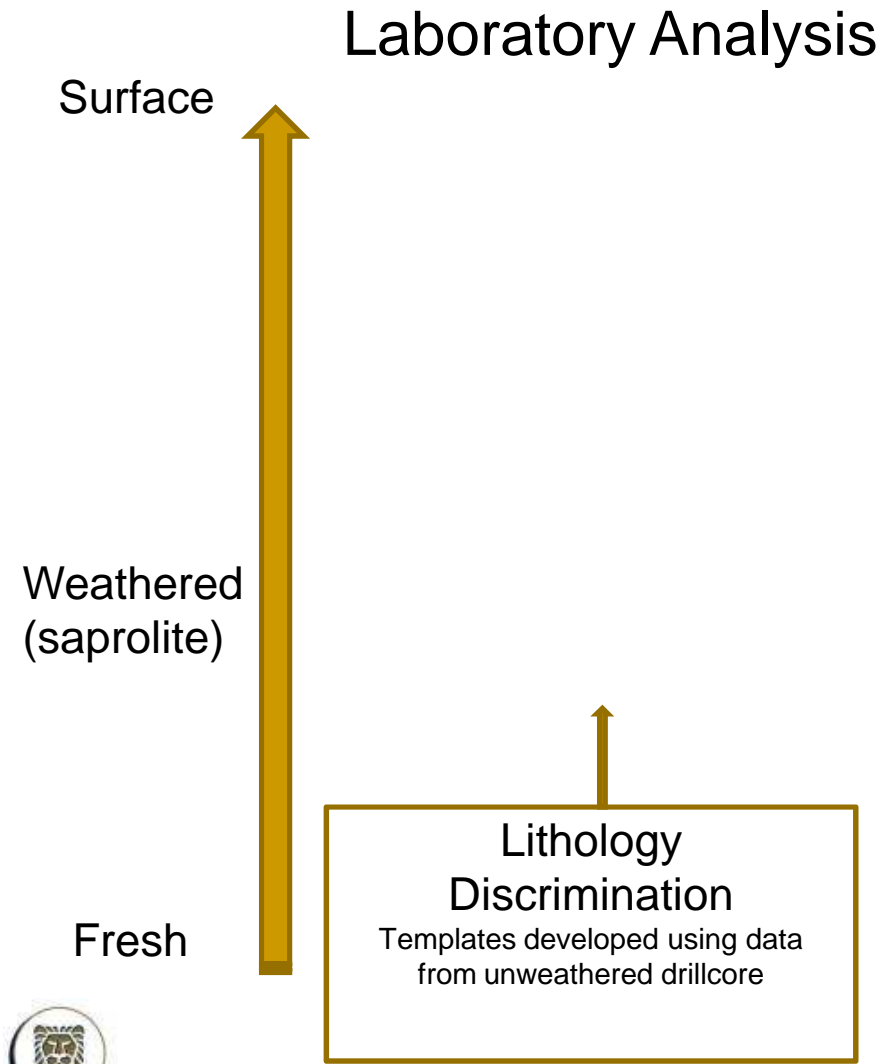
Workflow – Lithological Discrimination



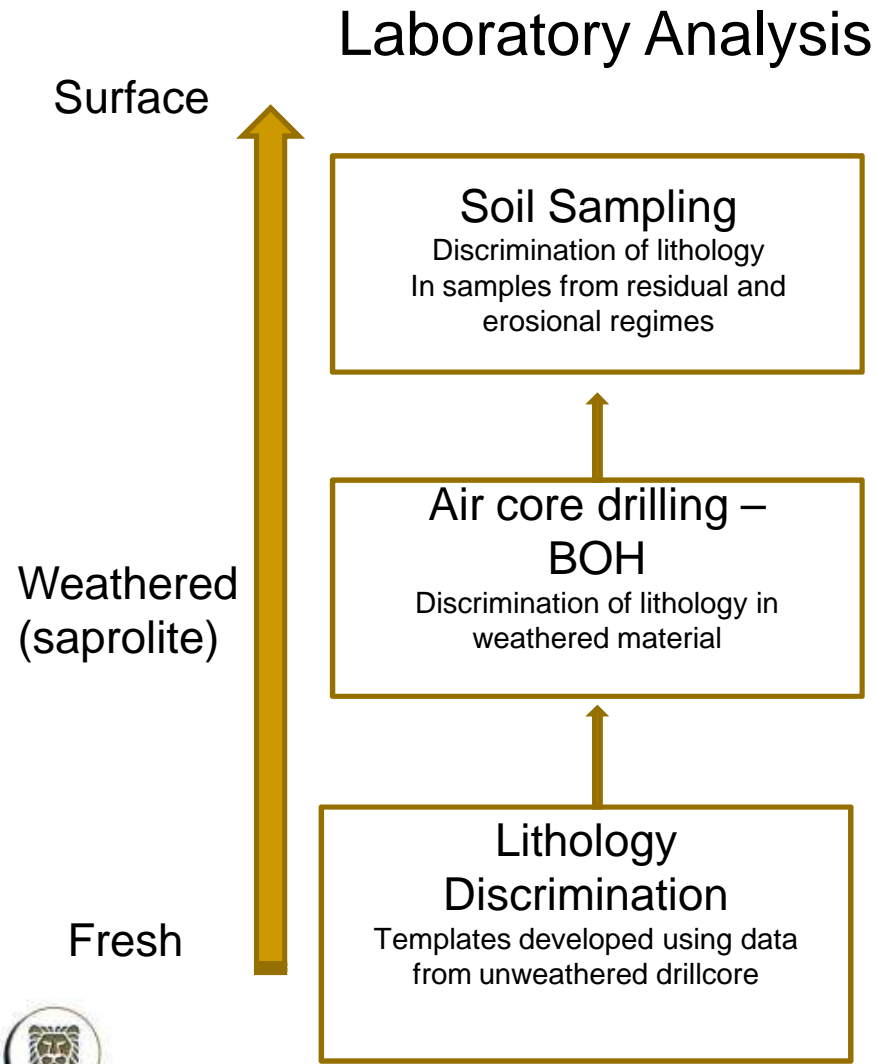
Workflow – Lithological Discrimination



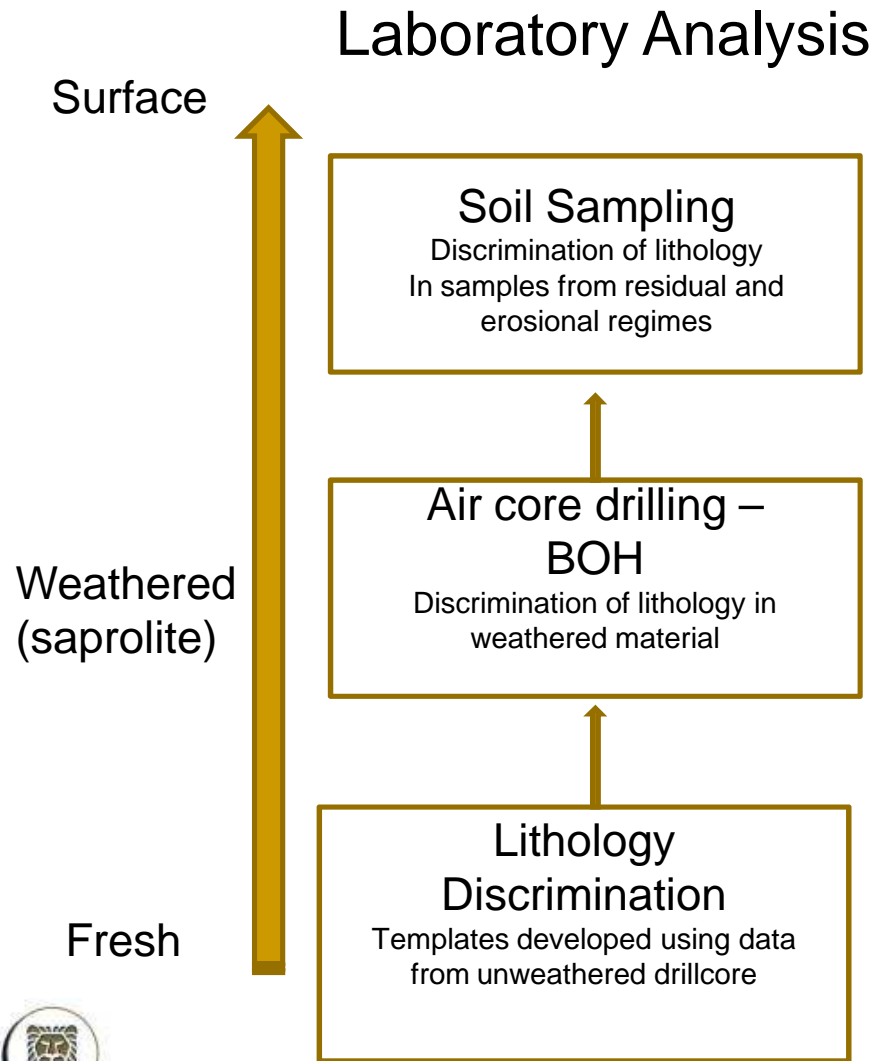
Workflow – Lithological Discrimination



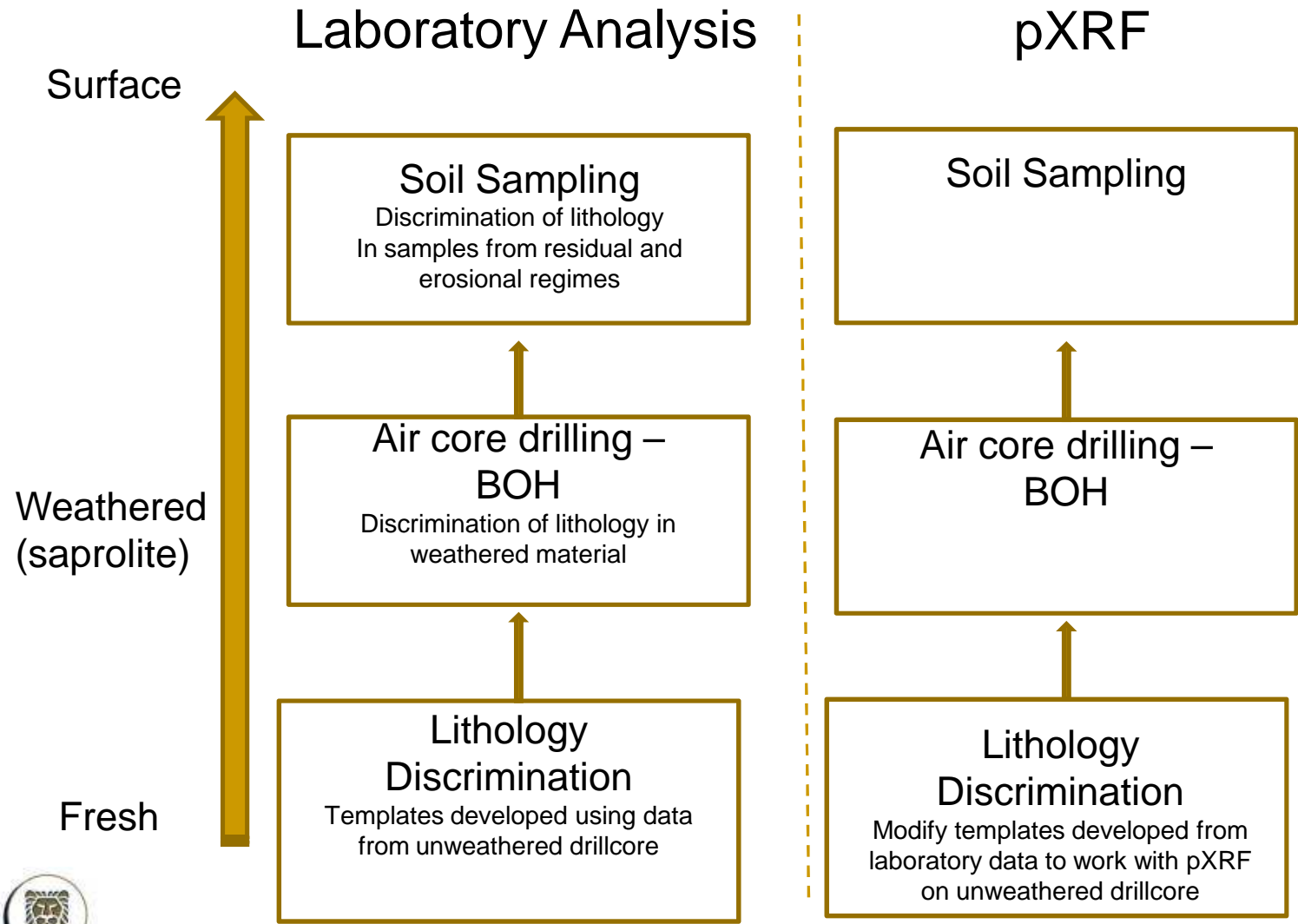
Workflow – Lithological Discrimination



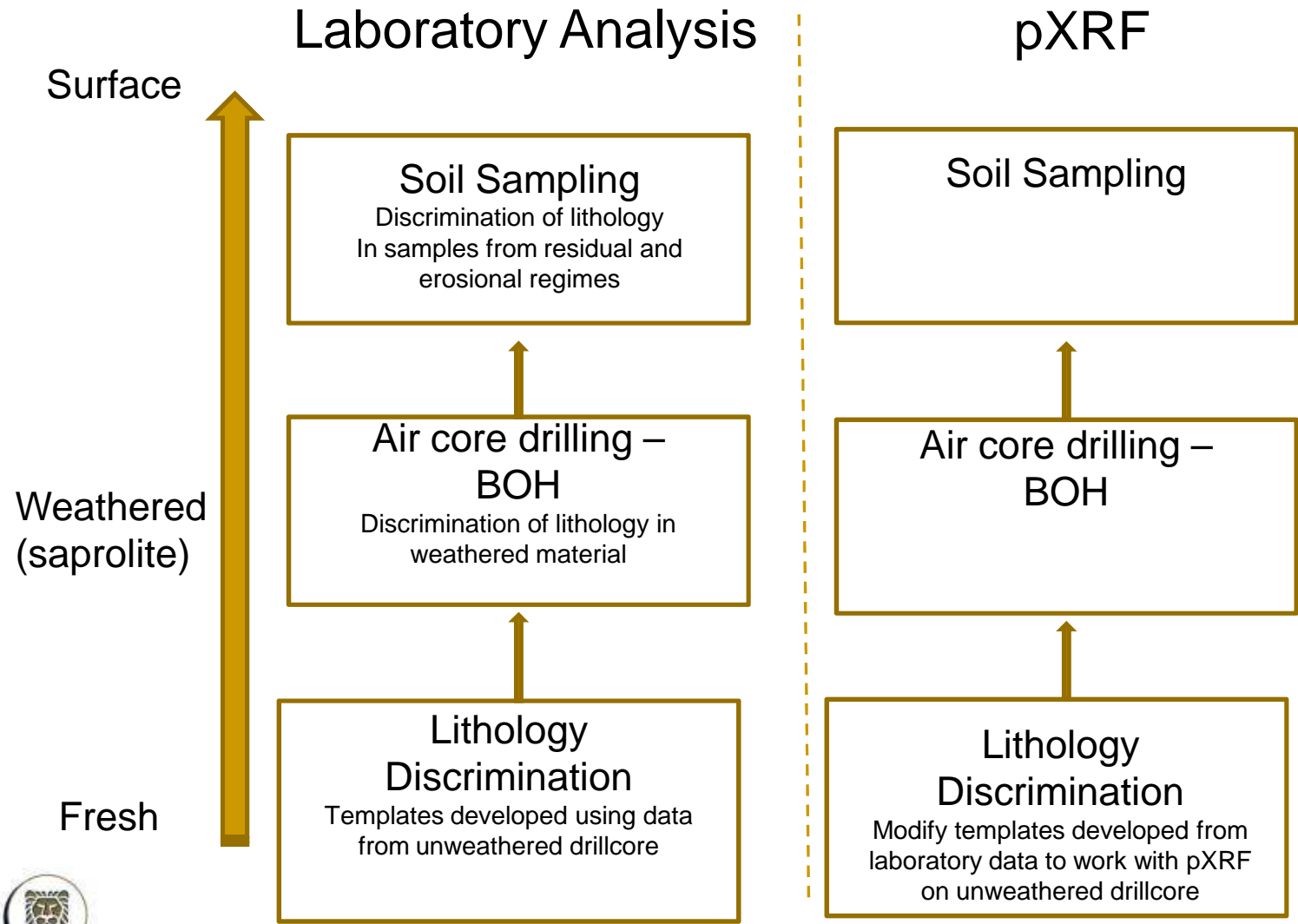
Workflow – Lithological Discrimination



Workflow – Lithological Discrimination



Workflow – Lithological Discrimination



Template - Laboratory Data – 4 acid/ICPMS fresh samples



GOLD FIELDS

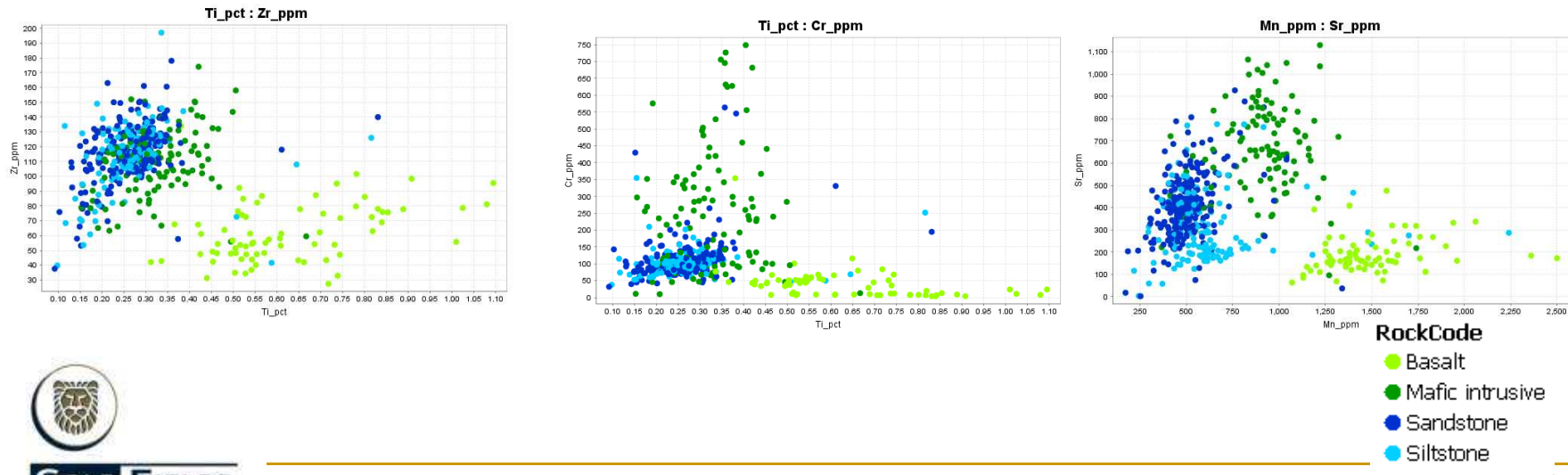
Template - Laboratory Data – 4 acid/ICPMS fresh samples

Robust characterization of lithologies with the following elements

Rock Type	ME-MS61- High Values	ME-MS61- Low Values	Detectable by pXRF - High Values
Mafic schist	Cr, Cs, Ni, P, Sr		Cr, Sr
Basalts	Mn, Sc, Ti, V,	Ce, La, Th, Zr	Mn, Ti, V
Sandstones/siltstones	Rb, Th		Rb, Th

Based on 2230 samples

Degree of separation of lithologies determined by bivariate plots



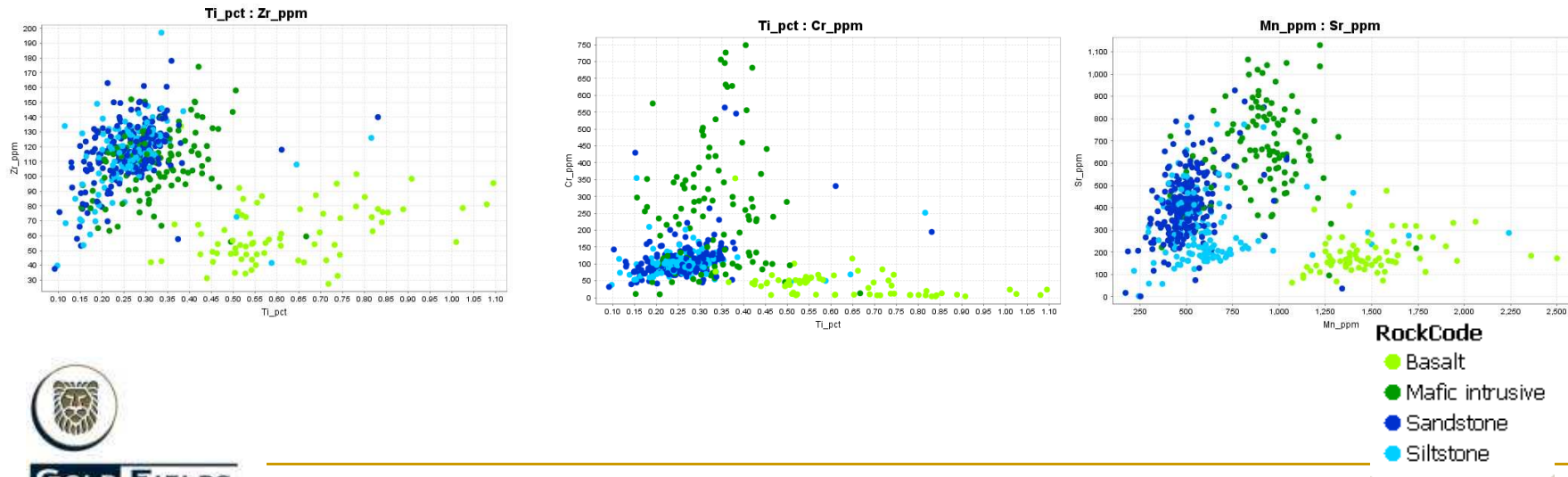
Template - Laboratory Data – 4 acid/ICPMS fresh samples

Robust characterization of lithologies with the following elements

Rock Type	ME-MS61- High Values	ME-MS61- Low Values	Detectable by pXRF - High Values
Mafic schist	Cr, Cs, Ni, P, Sr		Cr, Sr
Basalts	Mn, Sc, Ti, V,	Ce, La, Th, Zr	Mn, Ti, V
Sandstones/siltstones	Rb, Th		Rb, Th

Based on 2230 samples

Degree of separation of lithologies determined by bivariate plots



Templates Laboratory Data – 4 acid/ICPMS fresh samples

Discrimination diagrams constructed in ioGAS.

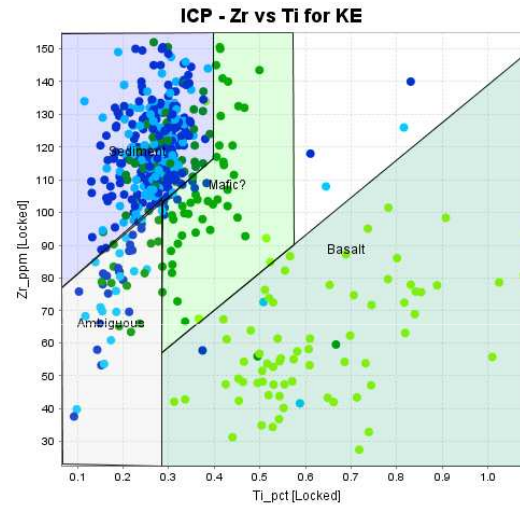
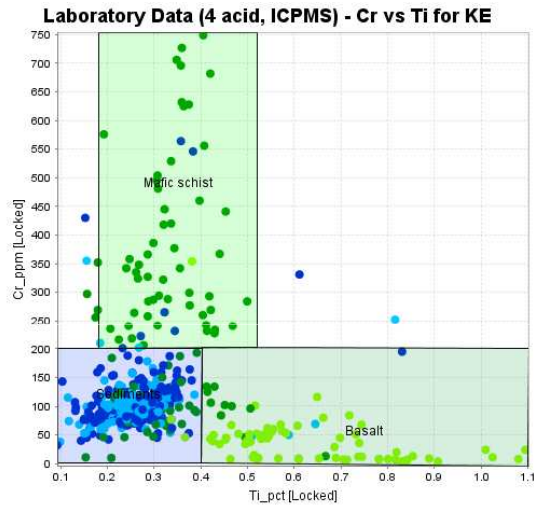
Examples:



GOLD FIELDS

Templates Laboratory Data – 4 acid/ICPMS fresh samples

Discrimination diagrams constructed in ioGAS.
Examples:



RockCode

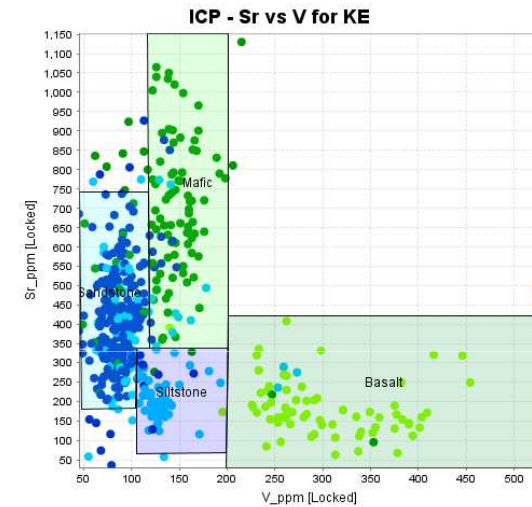
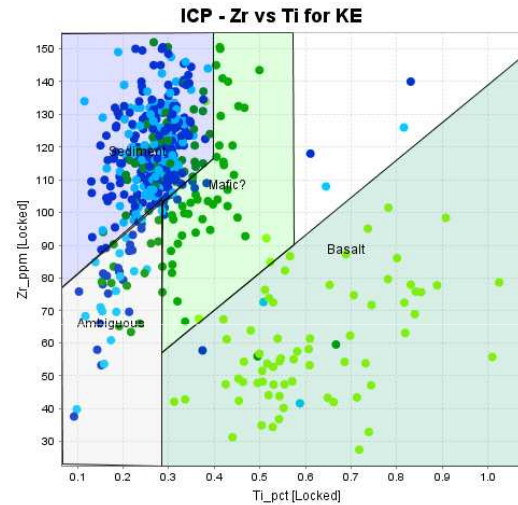
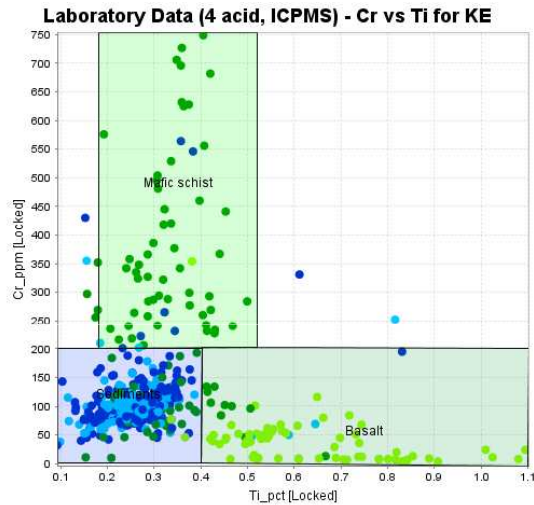
- Basalt
- Mafic intrusive
- Sandstone
- Siltstone



GOLD FIELDS

Templates Laboratory Data – 4 acid/ICPMS fresh samples

Discrimination diagrams constructed in ioGAS.
Examples:

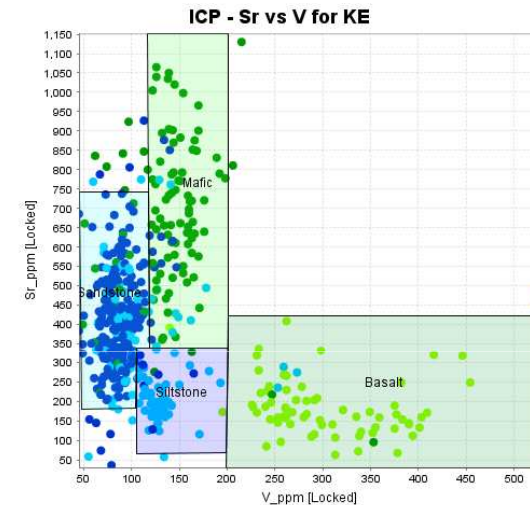
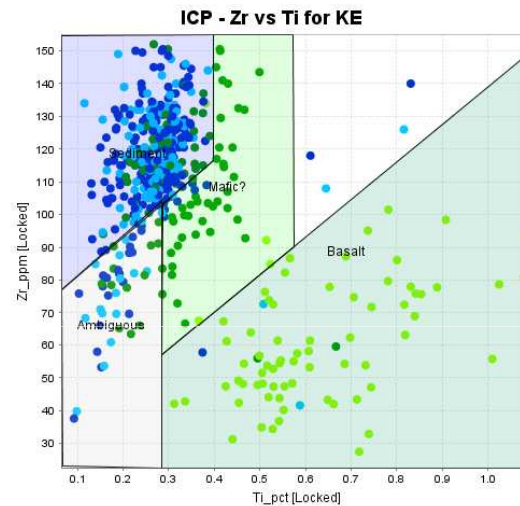
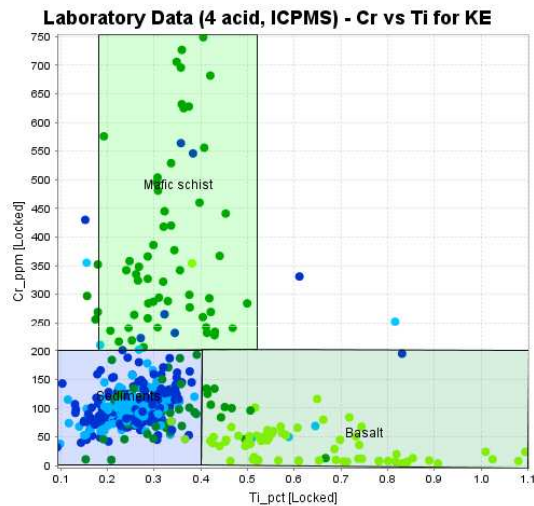


- RockCode**
- Basalt
 - Mafic intrusive
 - Sandstone
 - Siltstone



Templates Laboratory Data – 4 acid/ICPMS fresh samples

Discrimination diagrams constructed in ioGAS.
Examples:



Cr-Ti diagram shows particularly good separation and this is used mostly in the rest of the presentation

RockCode

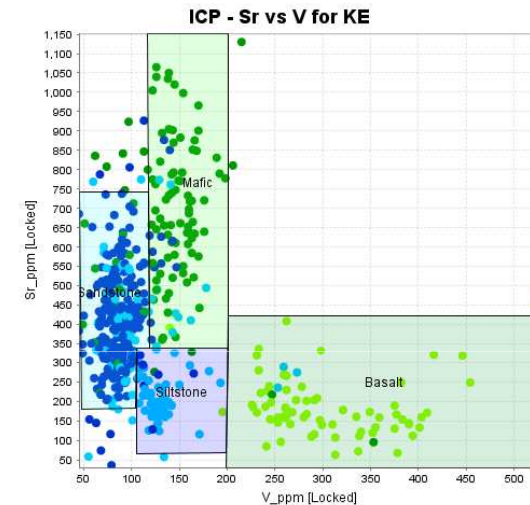
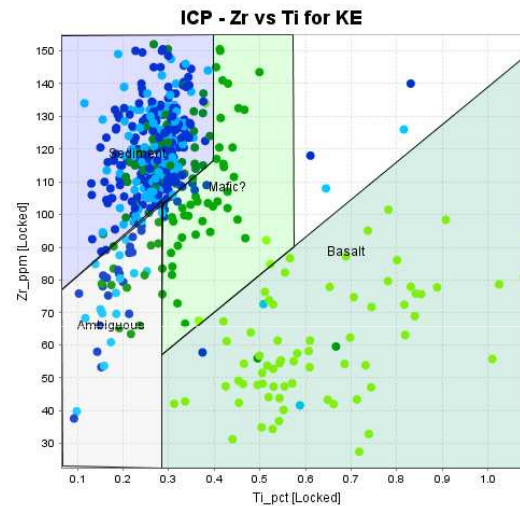
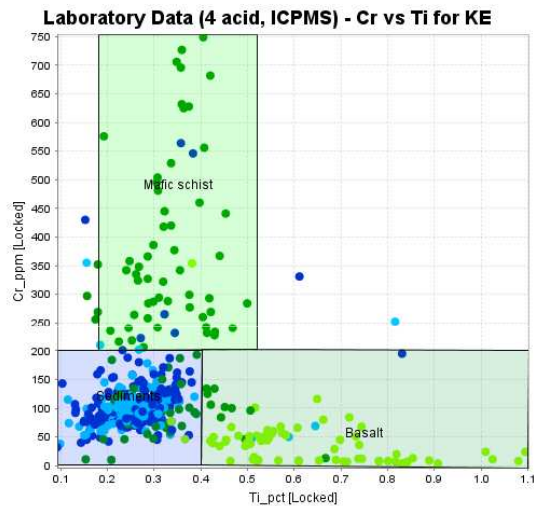
- Basalt
- Mafic intrusive
- Sandstone
- Siltstone



GOLD FIELDS

Templates Laboratory Data – 4 acid/ICPMS fresh samples

Discrimination diagrams constructed in ioGAS.
Examples:



Cr-Ti diagram shows particularly good separation and this is used mostly in the rest of the presentation

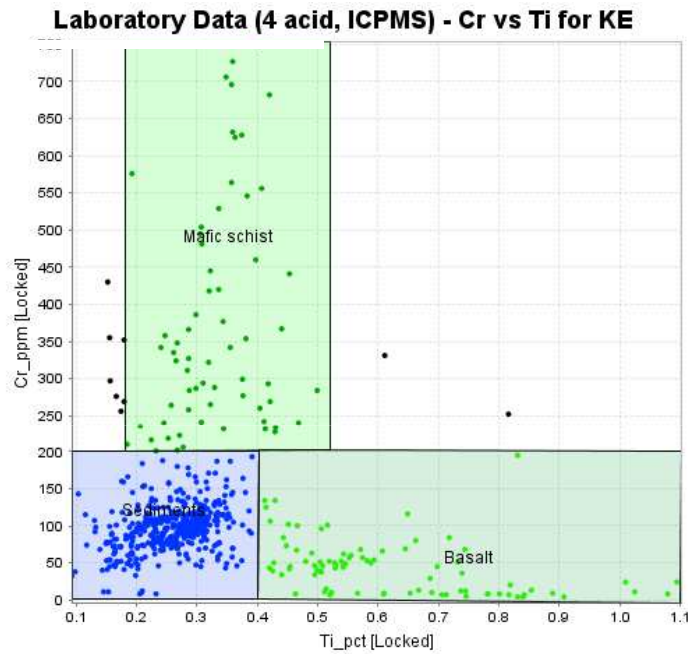
RockCode

- Basalt
- Mafic intrusive
- Sandstone
- Siltstone

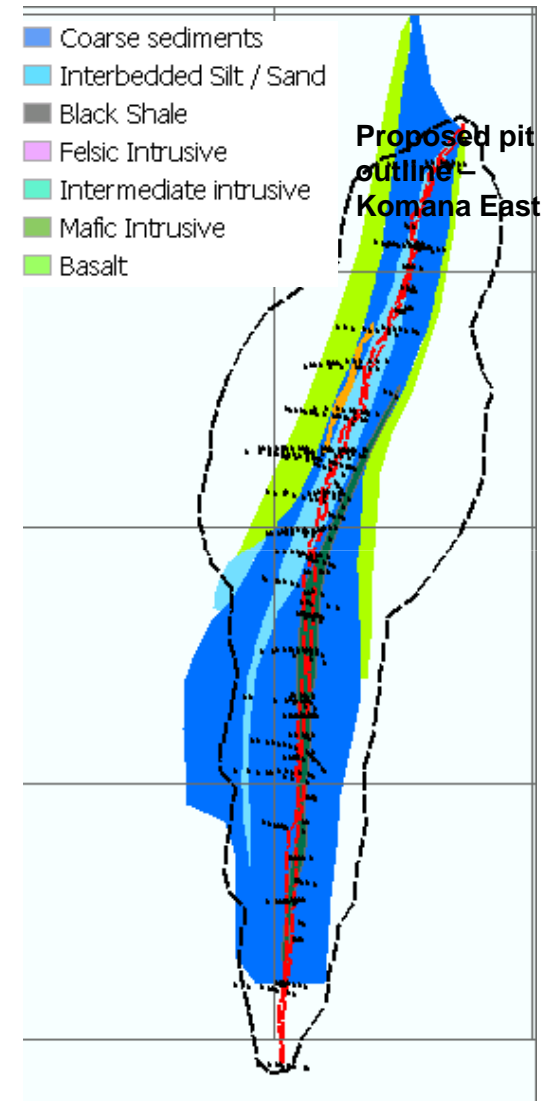


GOLD FIELDS

Laboratory Data – 4 acid/ICPMS fresh samples



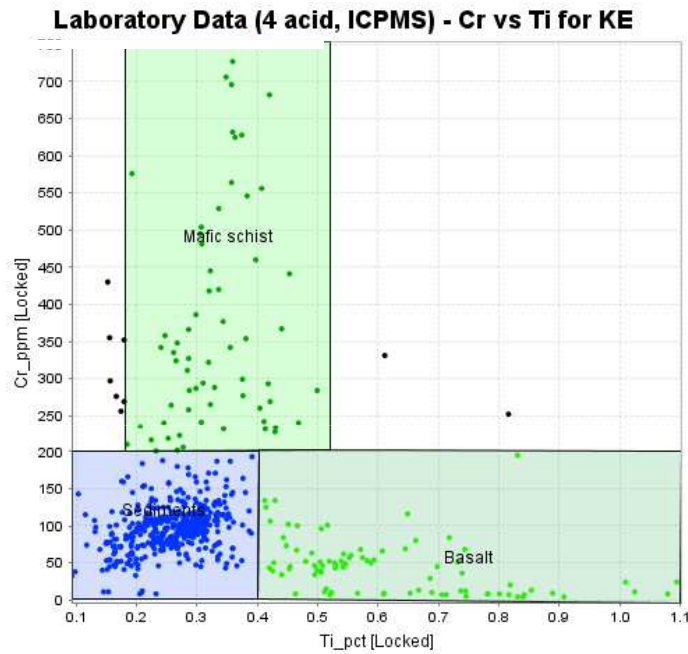
- RockCode**
- Basalt
 - Mafic intrusive
 - Sandstone
 - Siltstone



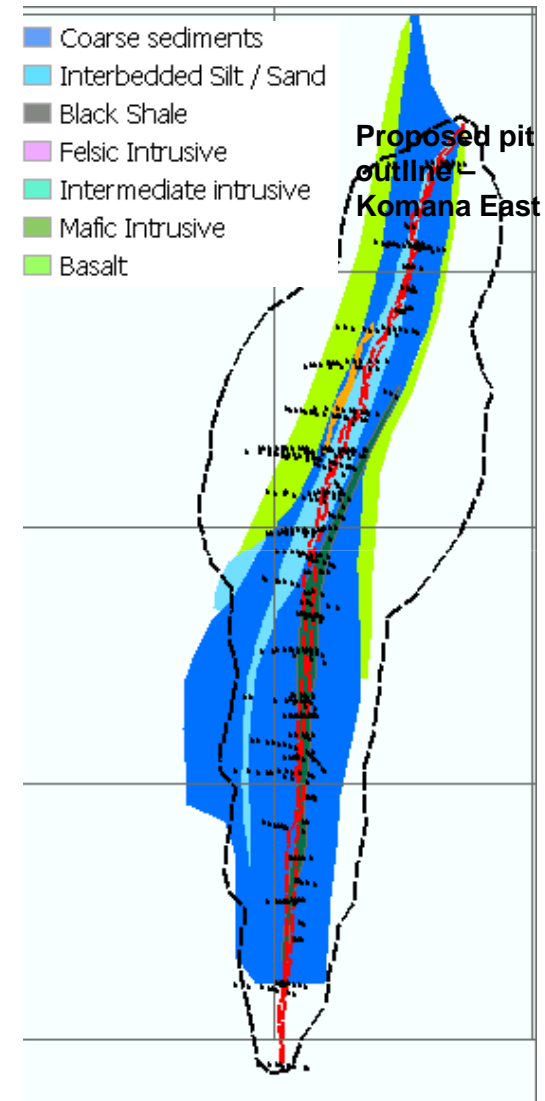
GOLD FIELDS

200 m

Laboratory Data – 4 acid/ICPMS fresh samples



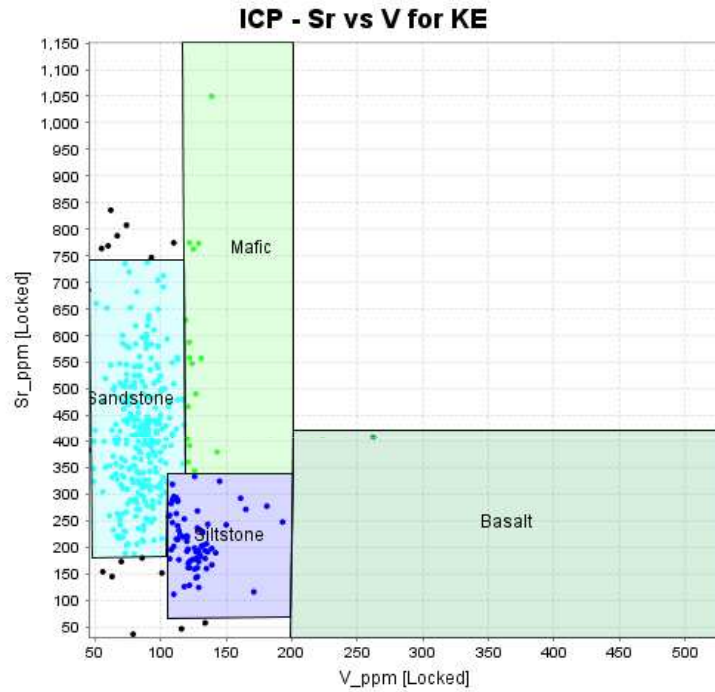
- RockCode**
- Basalt
 - Mafic intrusive
 - Sandstone
 - Siltstone



GOLD FIELDS

200 m

Laboratory Data – 4 acid/ICPMS fresh samples



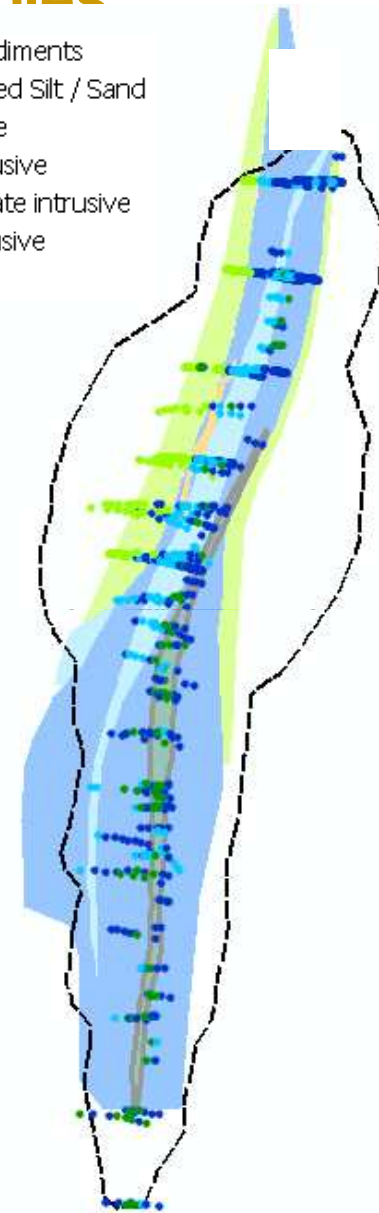
RockCode

- Basalt
- Mafic intrusive
- Sandstone
- Siltstone



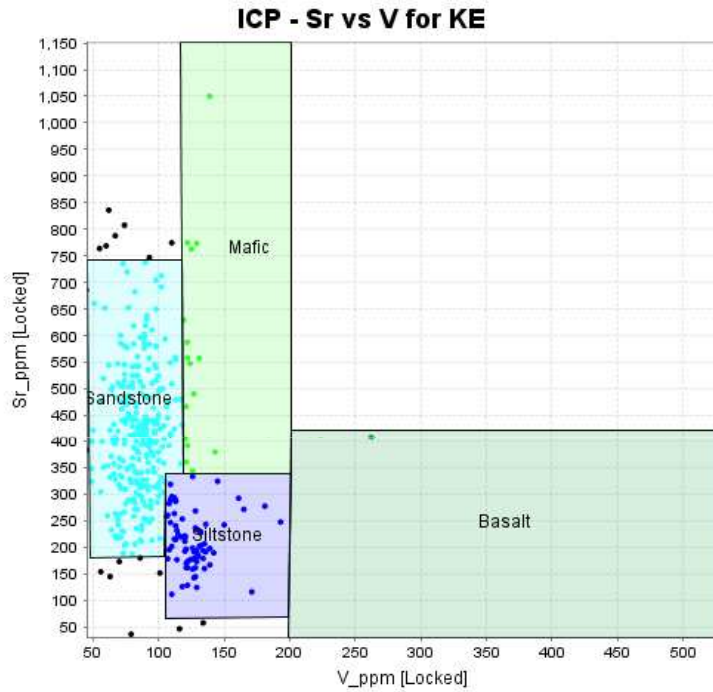
GOLD FIELDS

- Coarse sediments
- Interbedded Silt / Sand
- Black Shale
- Felsic Intrusive
- Intermediate intrusive
- Mafic Intrusive
- Basalt



200 m

Laboratory Data – 4 acid/ICPMS fresh samples

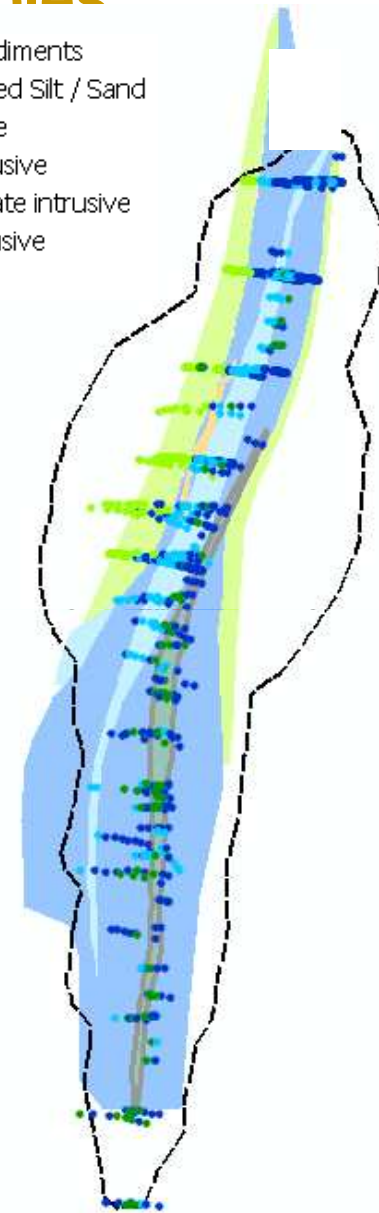


- RockCode**
- Basalt
 - Mafic intrusive
 - Sandstone
 - Siltstone



GOLD FIELDS

- Coarse sediments
- Interbedded Silt / Sand
- Black Shale
- Felsic Intrusive
- Intermediate intrusive
- Mafic Intrusive
- Basalt



200 m

Field Portable XRF – Can this be used in a similar way?



Innov-X
Delta Premium

- Instrument is a step change for exploration geochemistry
- Portable – get results at the actual sample location or at the field camp
- Portable XRF can quickly and effectively detect and quantify the elements from Mg to U on the periodic table.
- Typical suite of elements detectable from sample matrix at Yanfolila

*As, Ca, Co, Cu, Cr, Fe, K, Mn,
Pb, Rb, Sr, Ti, Th, V, Zn, Zr*



Field Portable XRF – Can this be used in a similar way?



Innov-X
Delta Premium



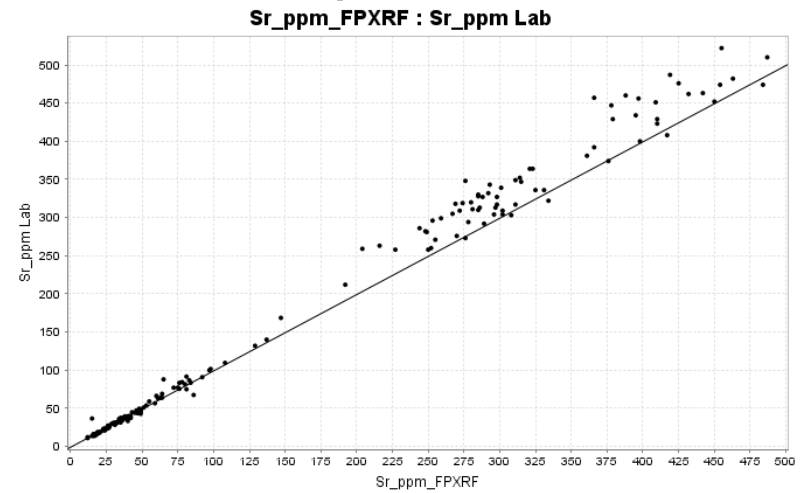
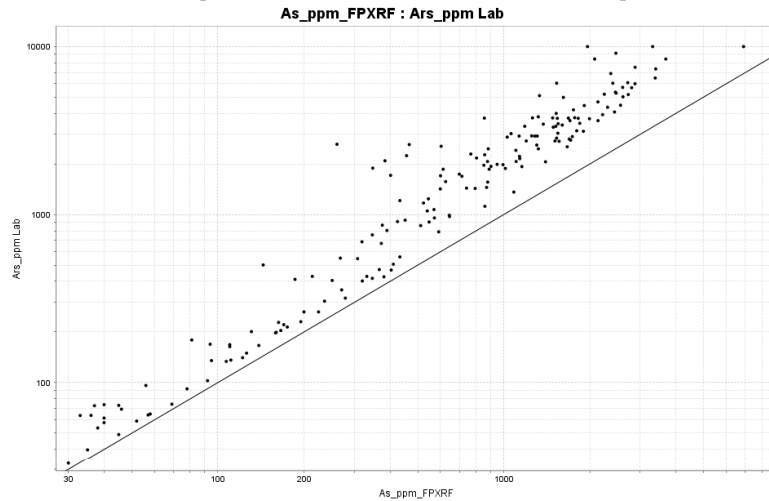
- Instrument is a step change for exploration geochemistry
- Portable – get results at the actual sample location or at the field camp
- Portable XRF can quickly and effectively detect and quantify the elements from Mg to U on the periodic table.
- Typical suite of elements detectable from sample matrix at Yanfolila

*As, Ca, Co, Cu, Cr, Fe, K, Mn,
Pb, Rb, Sr, Ti, Th, V, Zn, Zr*



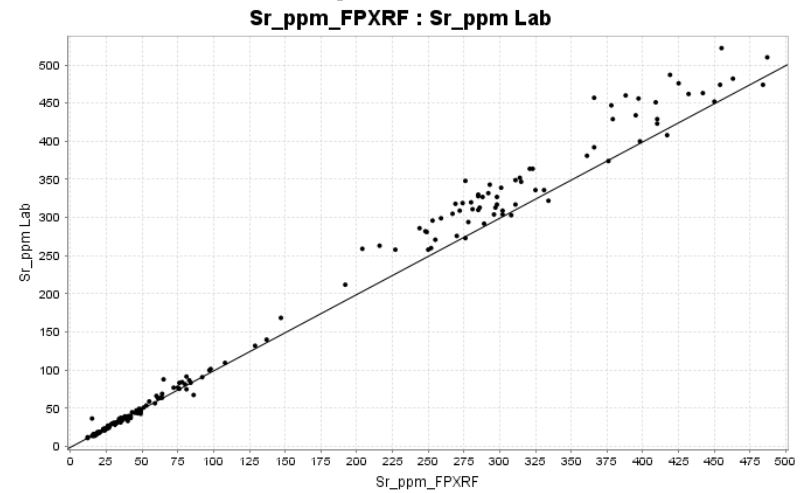
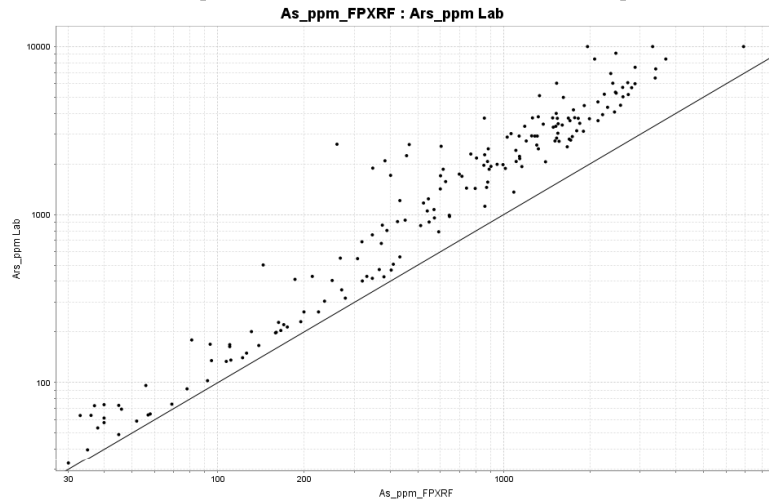
Field Portable XRF - fresh drillcore samples – validation

Comparison of samples from the lab and pXRF

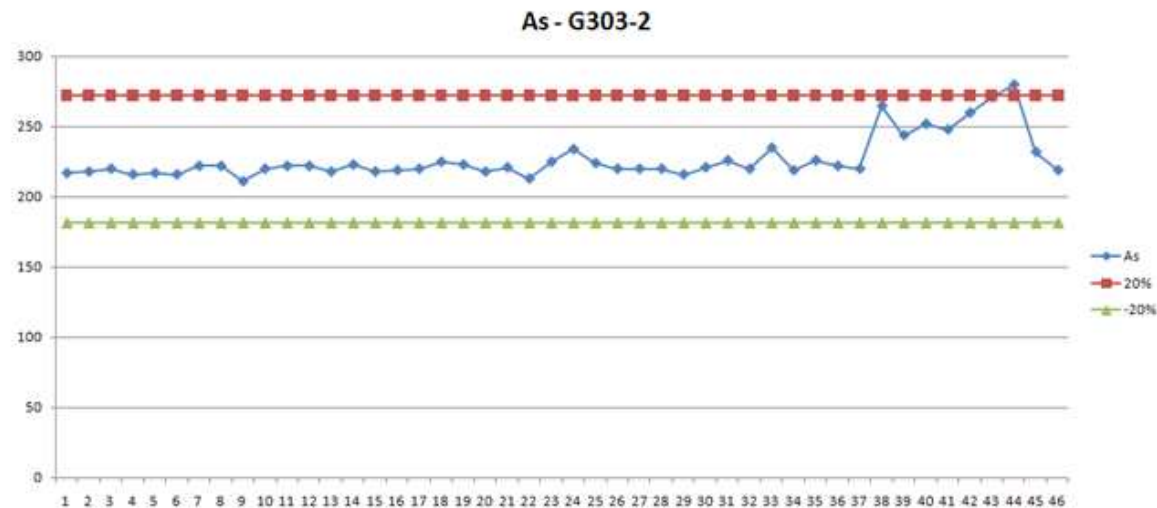


Field Portable XRF - fresh drillcore samples – validation

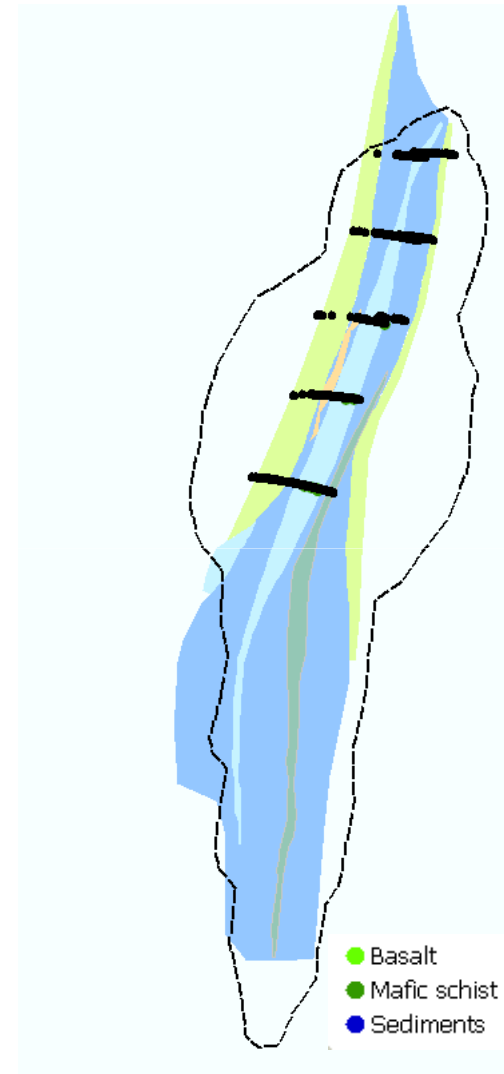
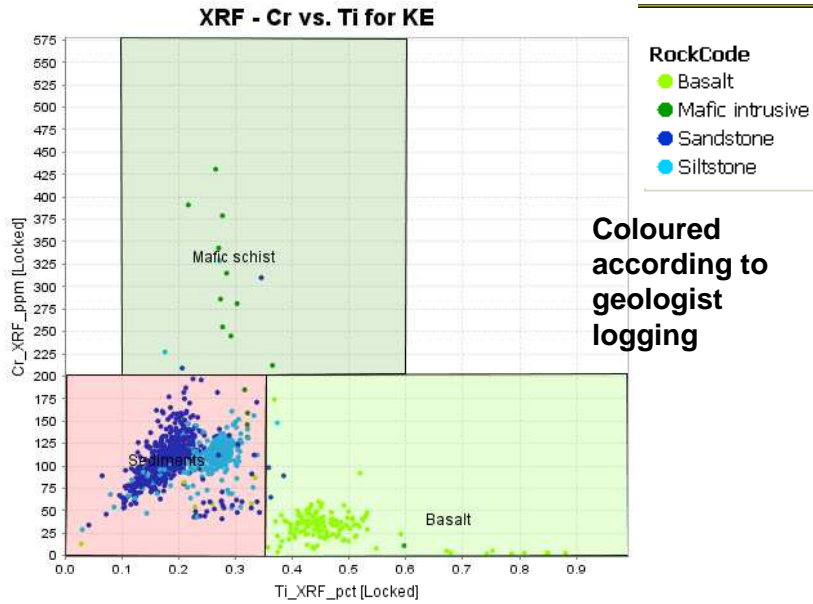
Comparison of samples from the lab and pXRF



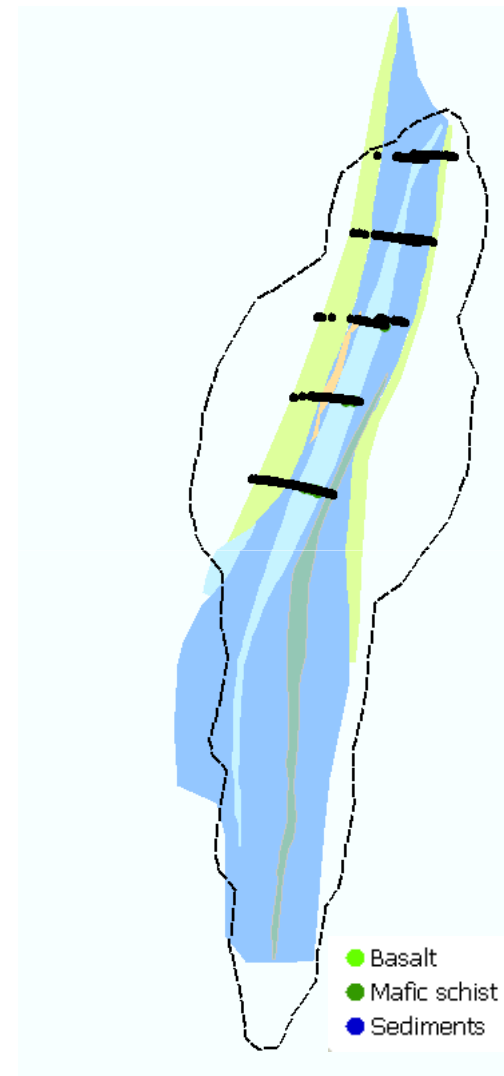
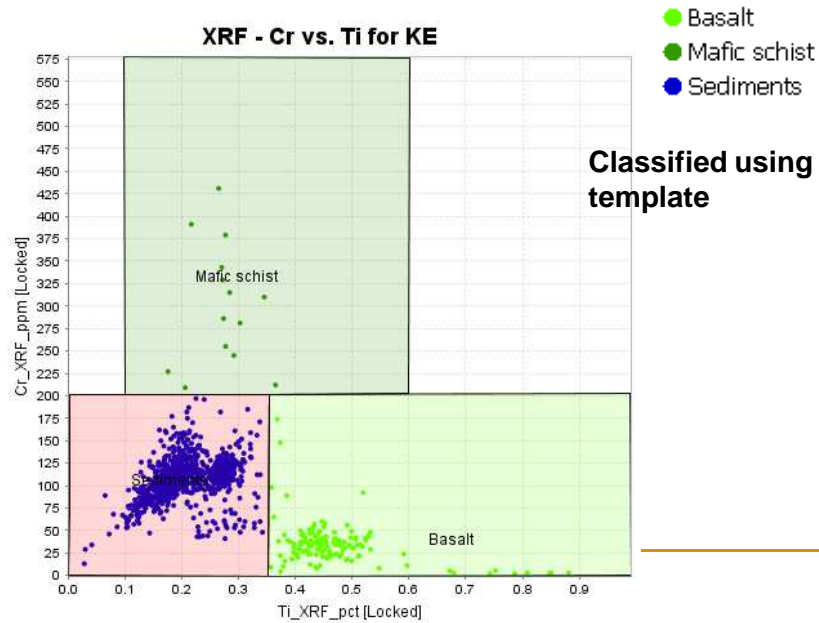
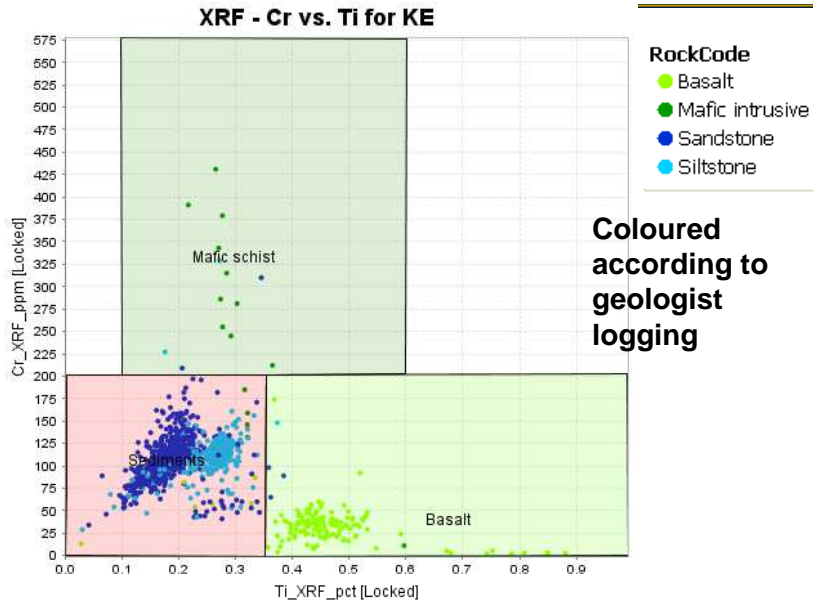
QAQC protocols – standards and instrument duplicates



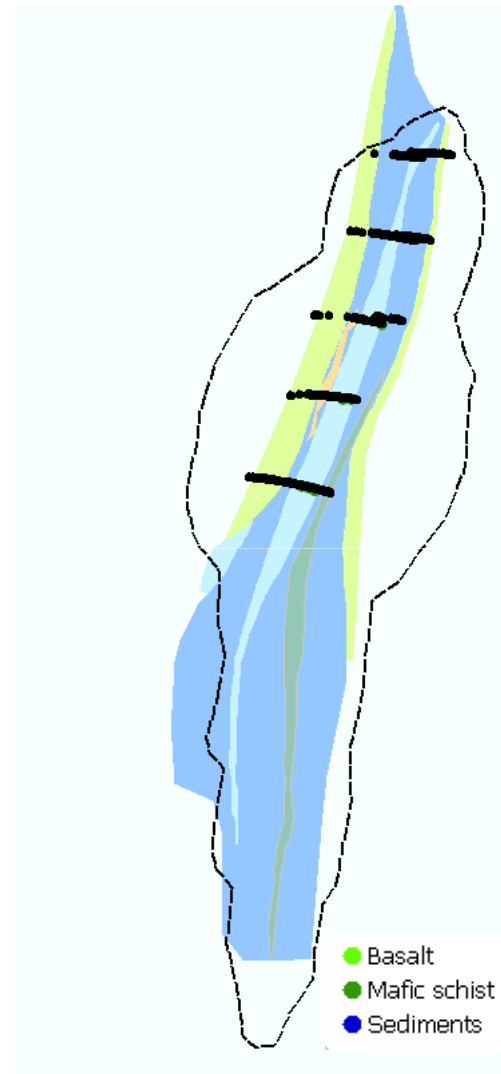
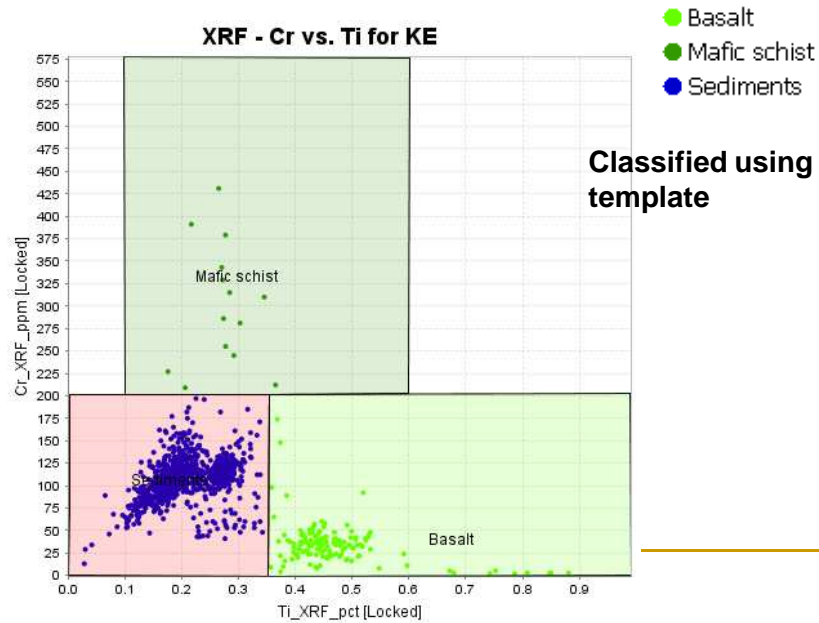
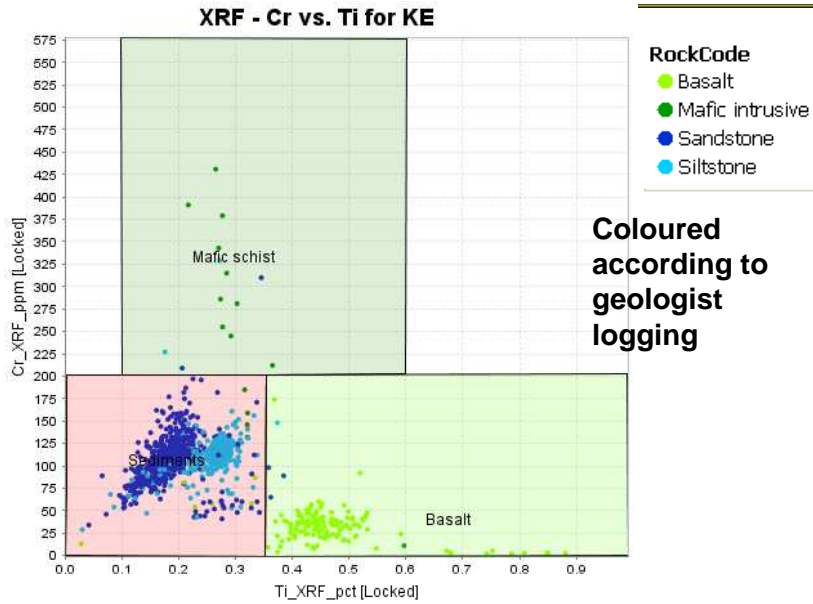
Field Portable XRF - fresh drillcore samples



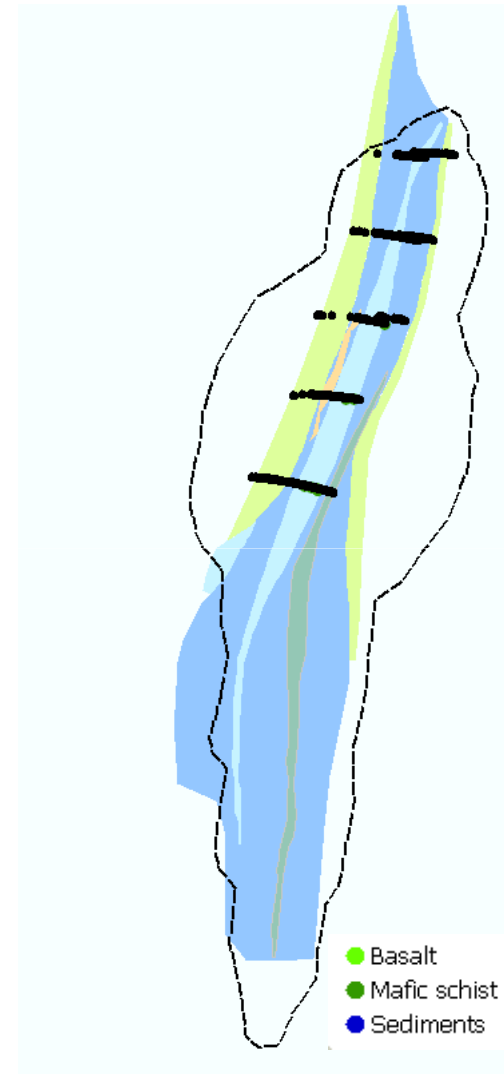
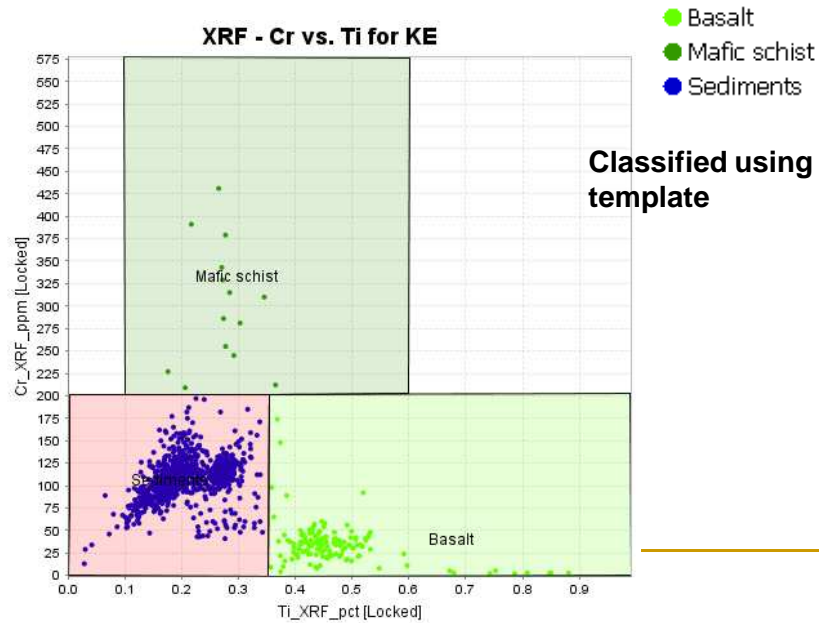
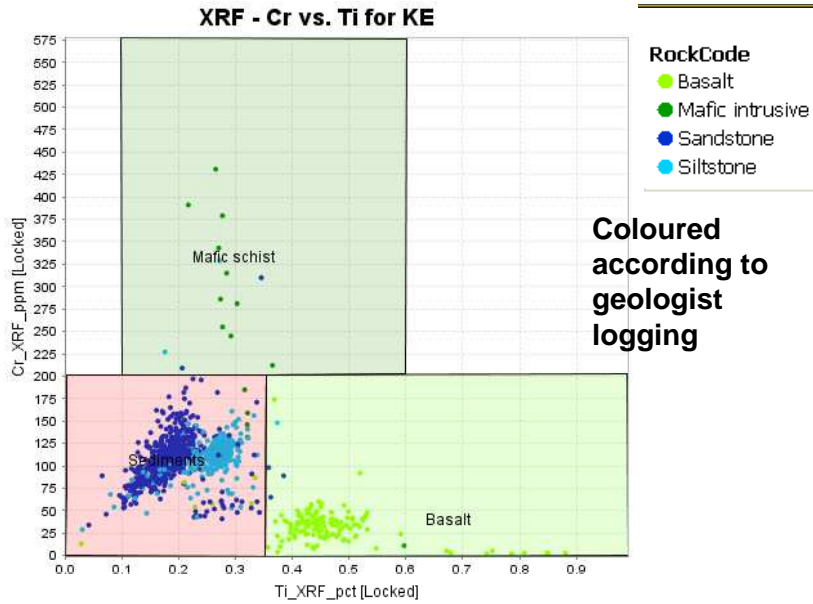
Field Portable XRF - fresh drillcore samples



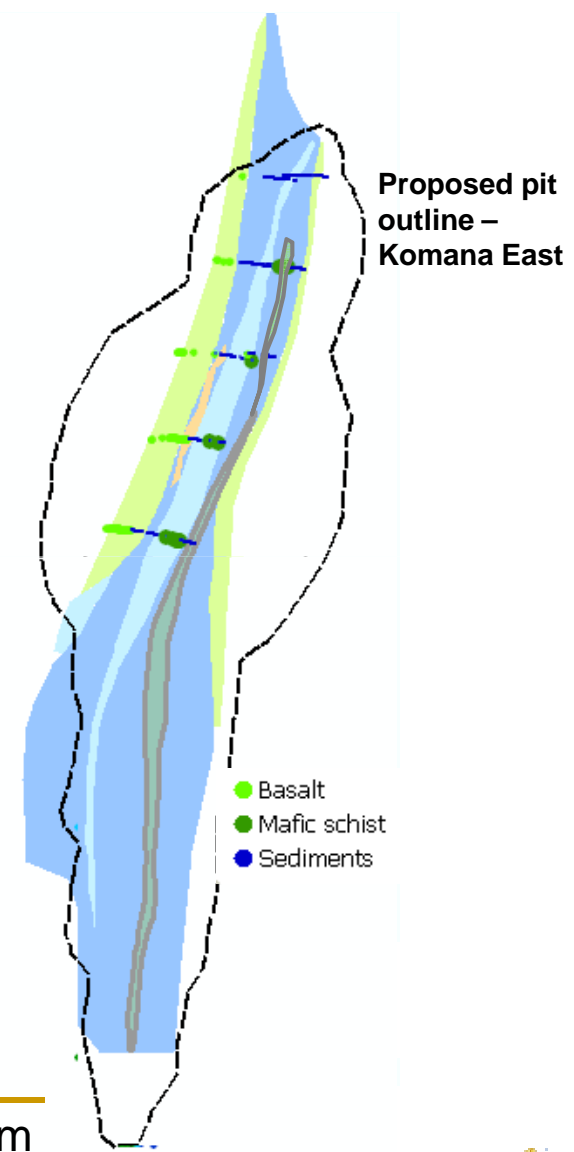
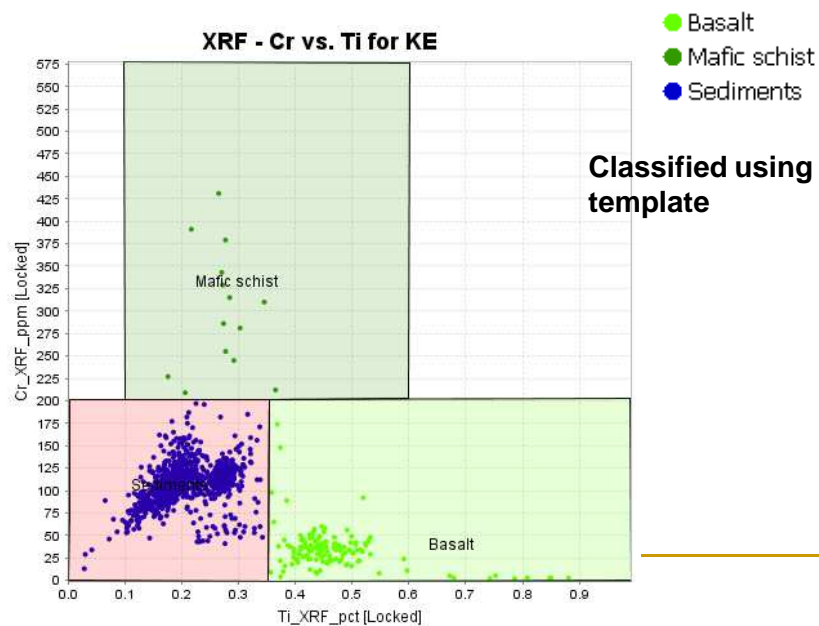
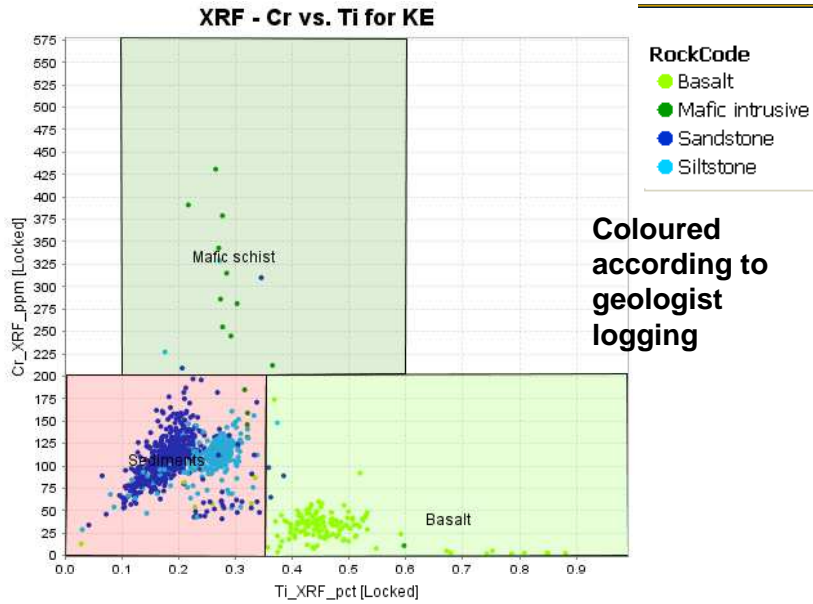
Field Portable XRF - fresh drillcore samples



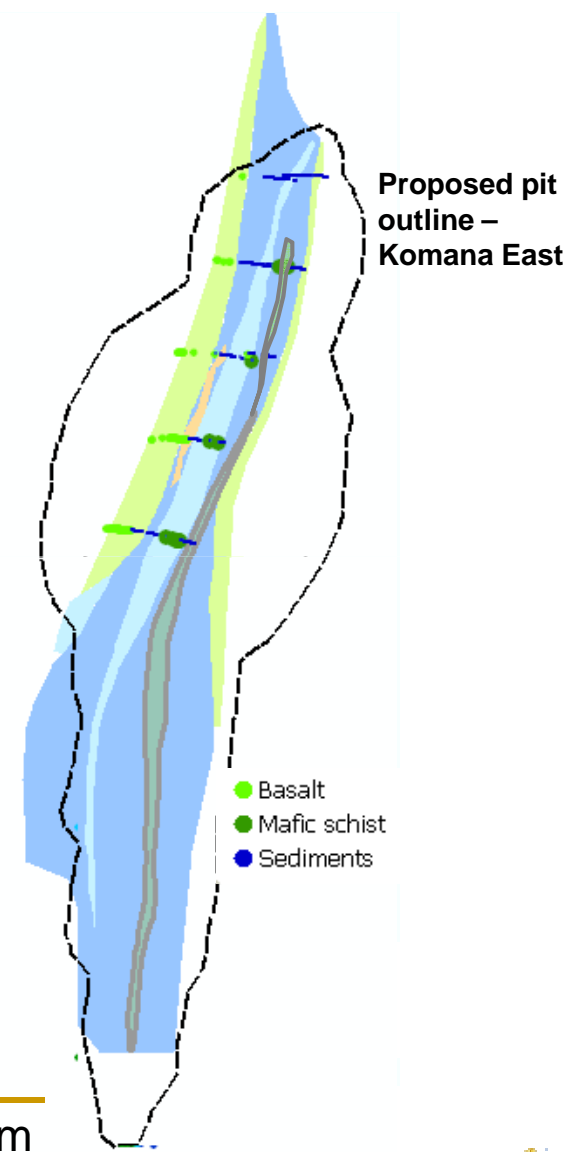
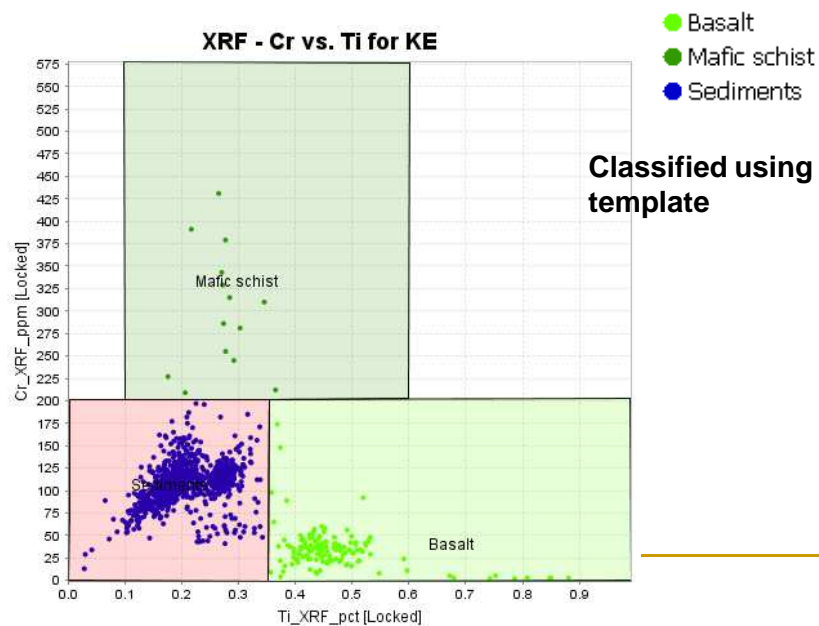
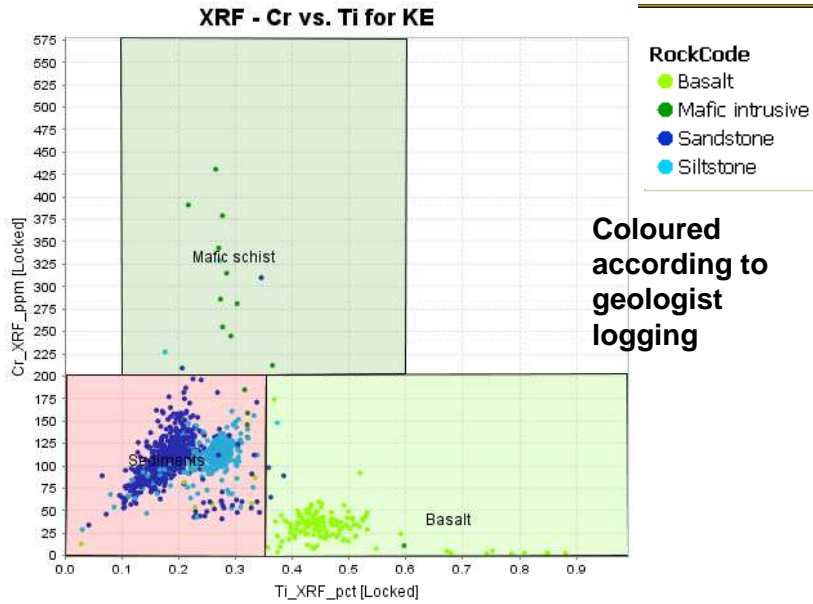
Field Portable XRF - fresh drillcore samples



Field Portable XRF - fresh drillcore samples



Field Portable XRF - fresh drillcore samples



Weathered Material - Saprolite



Air core drilling to weathered bedrock is used extensively at the Yanfolila project and it is often very difficult to be sure about the primary lithology

Can the templates using relatively immobile trace elements developed for fresh material be used for the determination of lithology in weathered samples (saprolite)?

Weathered Material - Saprolite



Air core drilling to weathered bedrock is used extensively at the Yanfolila project and it is often very difficult to be sure about the primary lithology

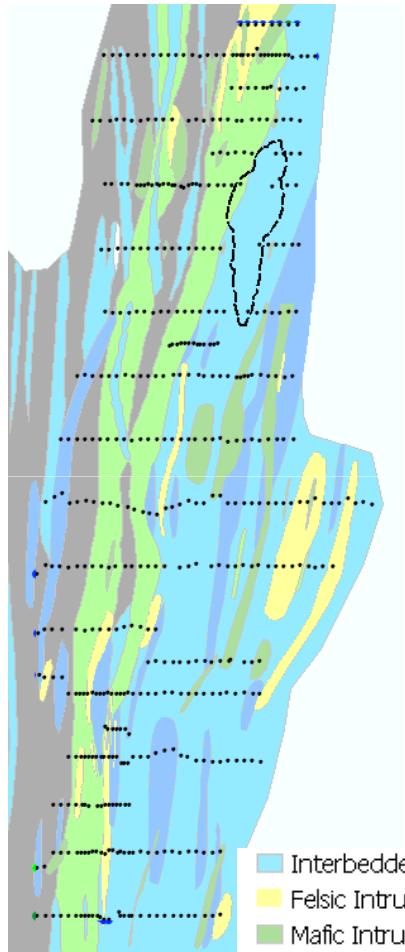


Can the templates using relatively immobile trace elements developed for fresh material be used for the determination of lithology in weathered samples (saprolite)?

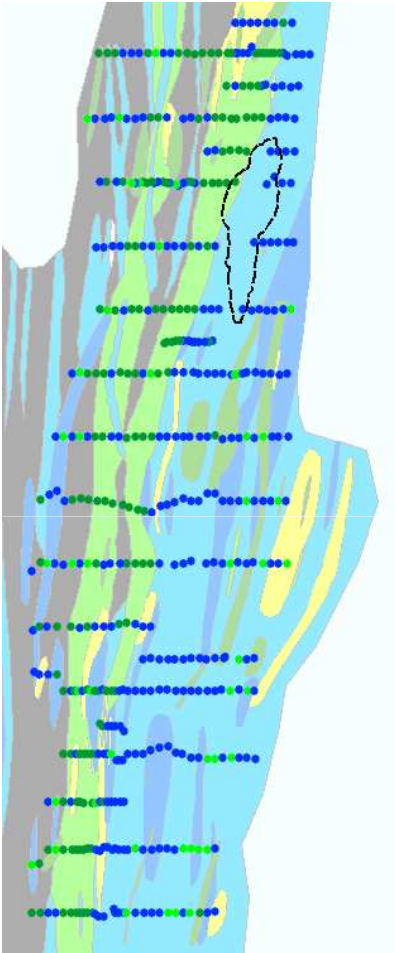
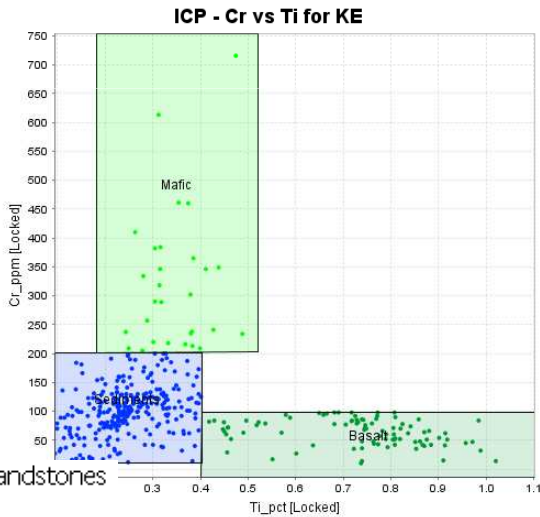


Laboratory Data – 4 acid/ICPMS weathered (saprolite) samples

Air Core Drilling –BOH Geochemistry



Classified using Cr – Ti KE Diagram



- Interbedded Siltstones/Sandstones
- Felsic Intrusive
- Mafic Intrusive
- Interbedded sandstones/siltstones
- Basalt
- Siltstones/shales

- Laboratory Data (4 acid, ICPMS) - Cr vs Ti for KE
- Basalt
 - Sediments
 - Mafic schist

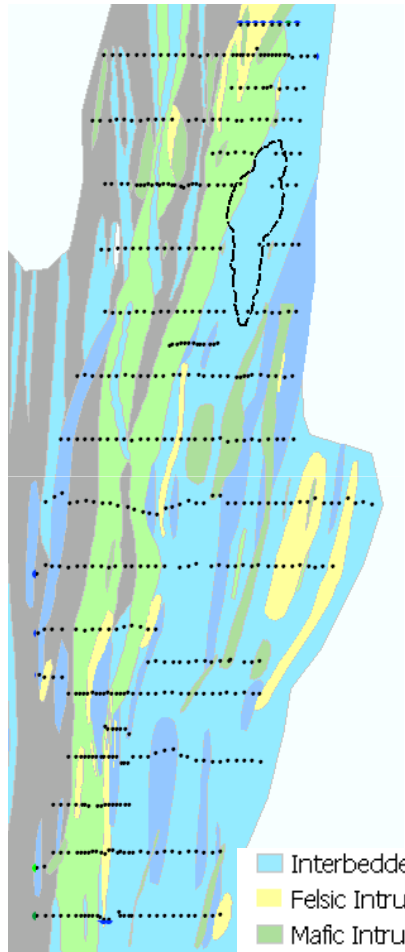
1 km



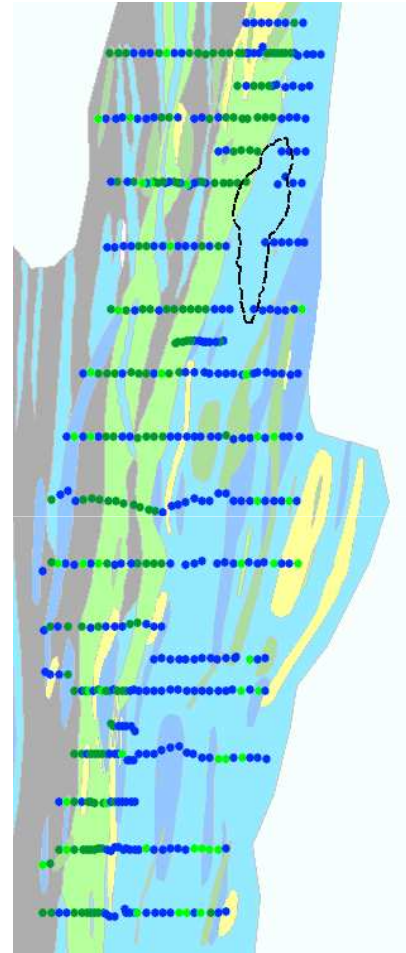
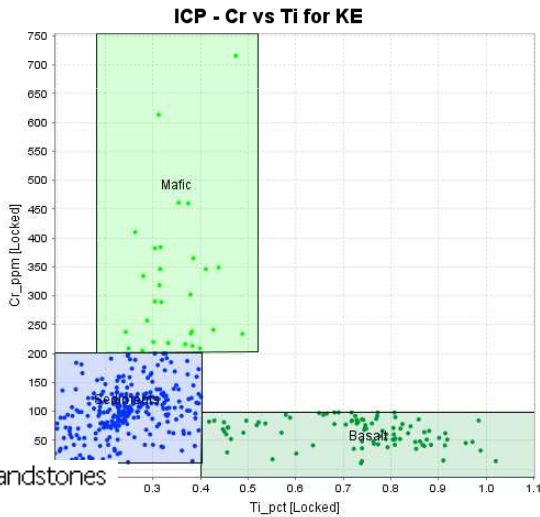
Apply classification diagram to BOH Air Core Drilling

Laboratory Data – 4 acid/ICPMS weathered (saprolite) samples

Air Core Drilling –BOH Geochemistry



Classified using Cr – Ti KE Diagram



- Interbedded Siltstones/Sandstones
- Felsic Intrusive
- Mafic Intrusive
- Interbedded sandstones/siltstones
- Basalt
- Siltstones/shales

- Laboratory Data (4 acid, ICPMS) - Cr vs Ti for KE
- Basalt
 - Sediments
 - Mafic schist

1 km



Apply classification diagram to BOH Air Core Drilling

Field Portable XRF - weathered (saprolite) samples

Traverse – air core drillholes from Komana West to East

Komana West

Komana East

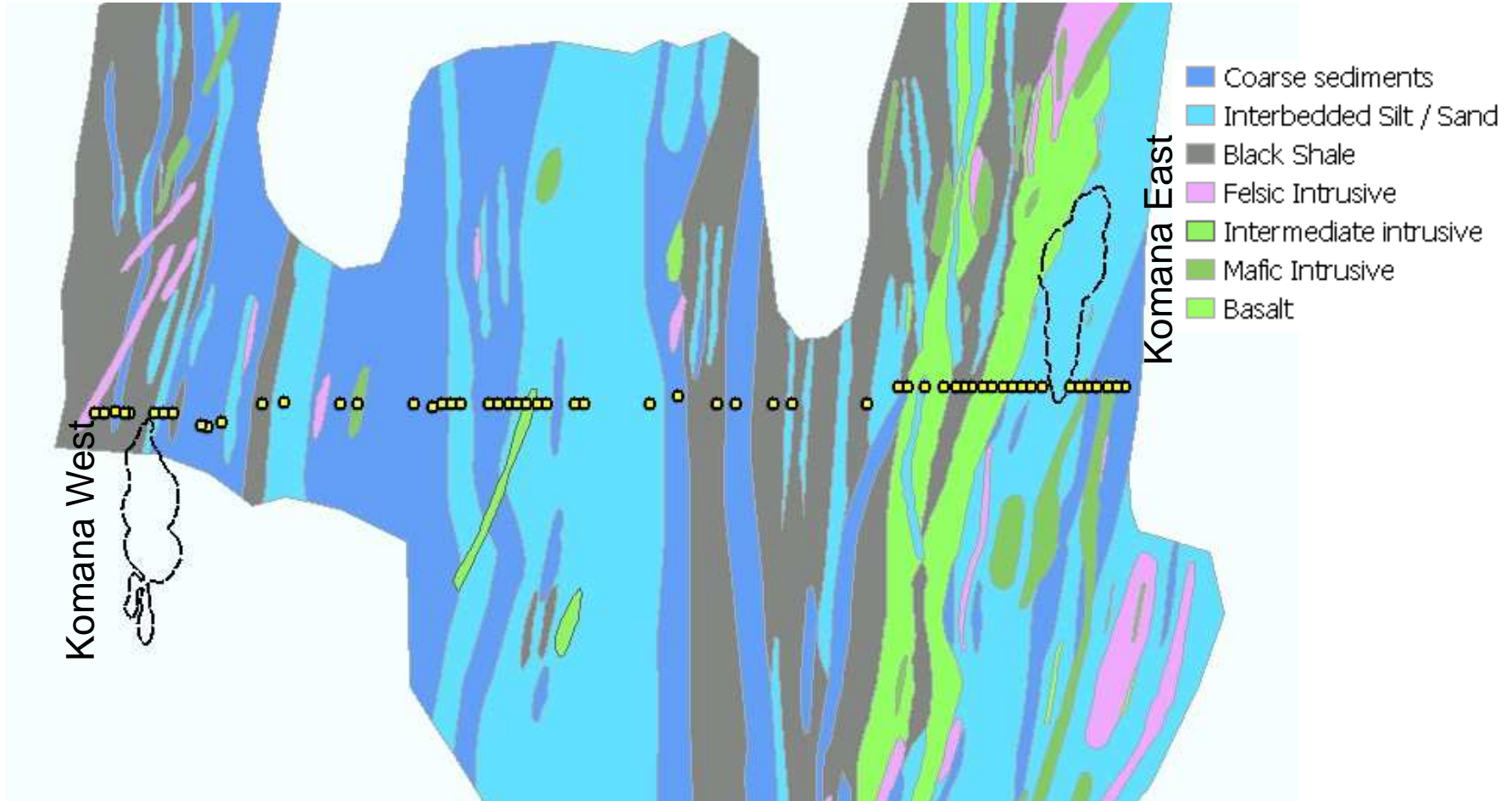


GOLD FIELDS

1 km

Field Portable XRF - weathered (saprolite) samples

Traverse – air core drillholes from Komana West to East



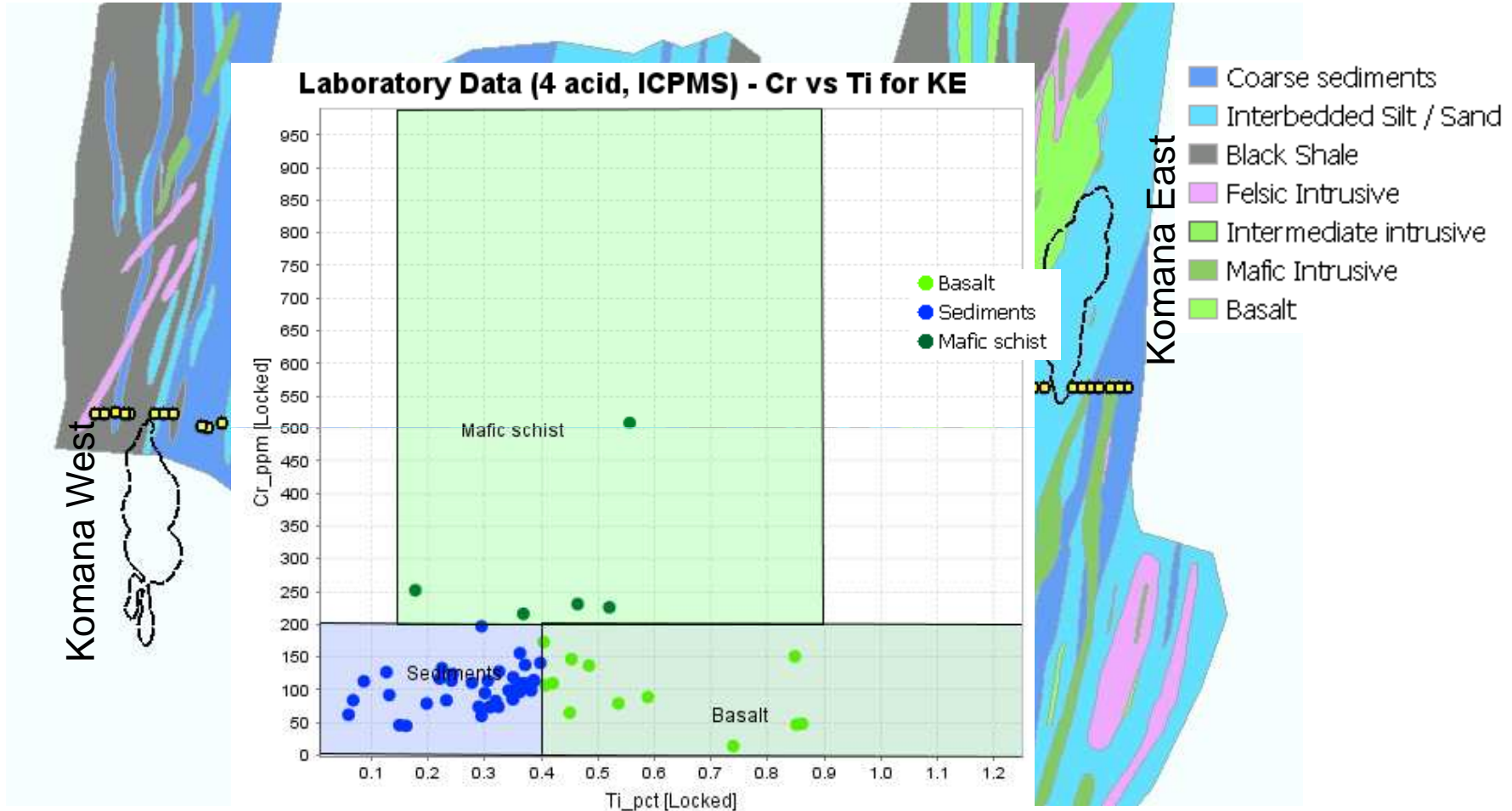
1 km



GOLD FIELDS

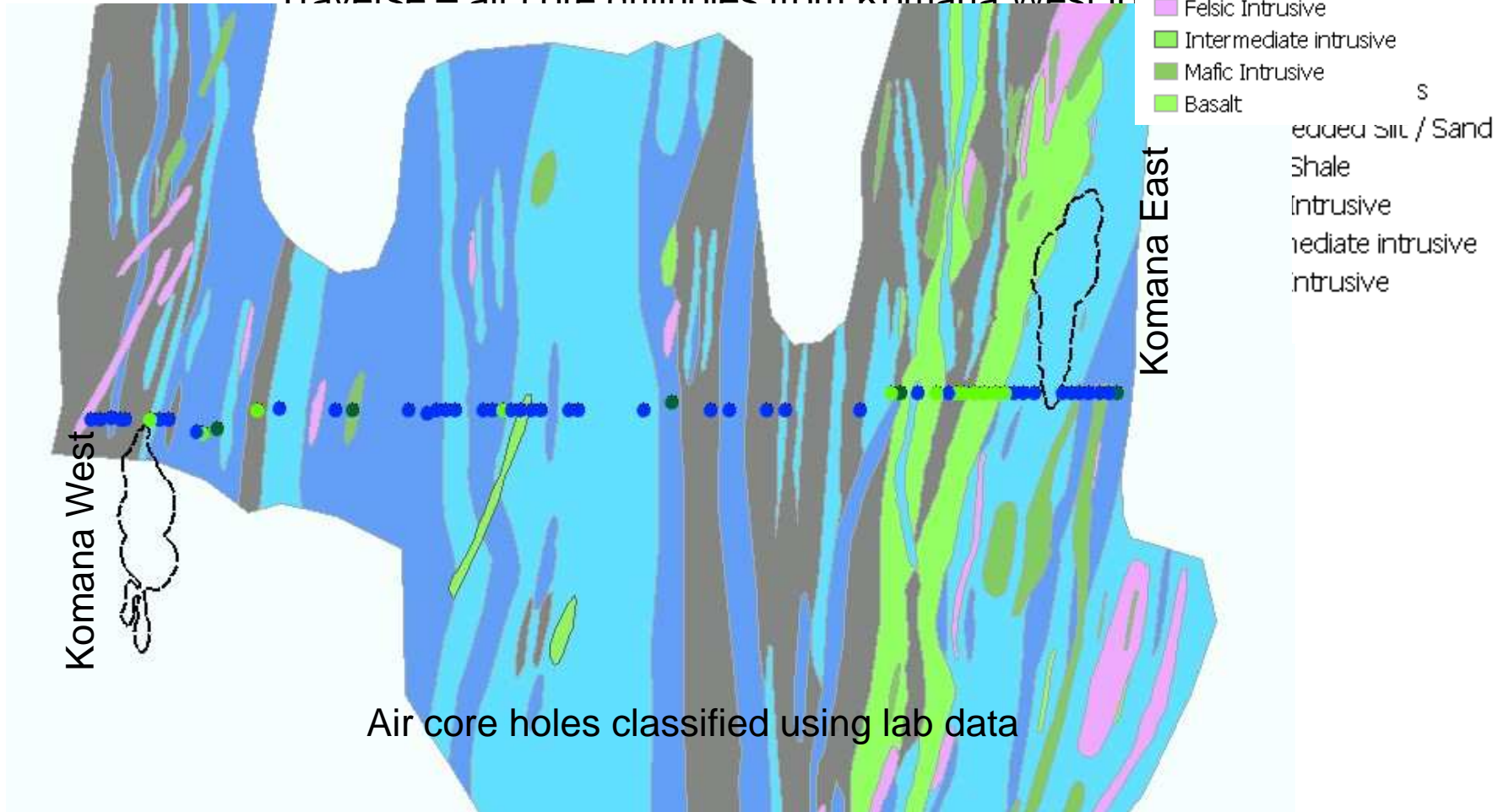
Field Portable XRF - weathered (saprolite) samples

Traverse – air core drillholes from Komana West to East



Field Portable XRF - weathered (saprolite) samples

Traverse – air core drillholes from Komana West to Komana East



Air core holes classified using lab data

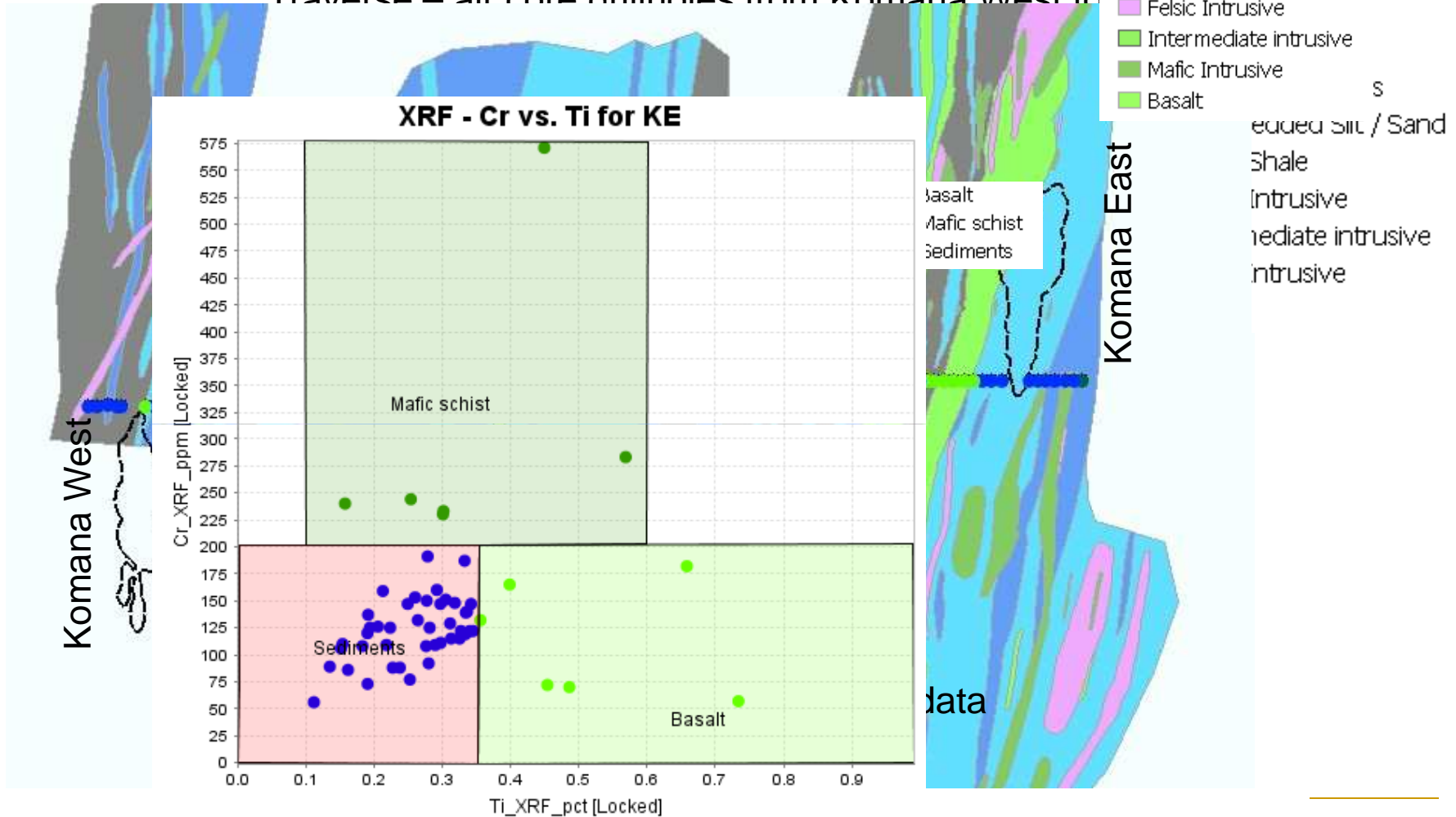


GOLD FIELDS

1 km

Field Portable XRF - weathered (saprolite) samp

Traverse – air core drillholes from Komana West to

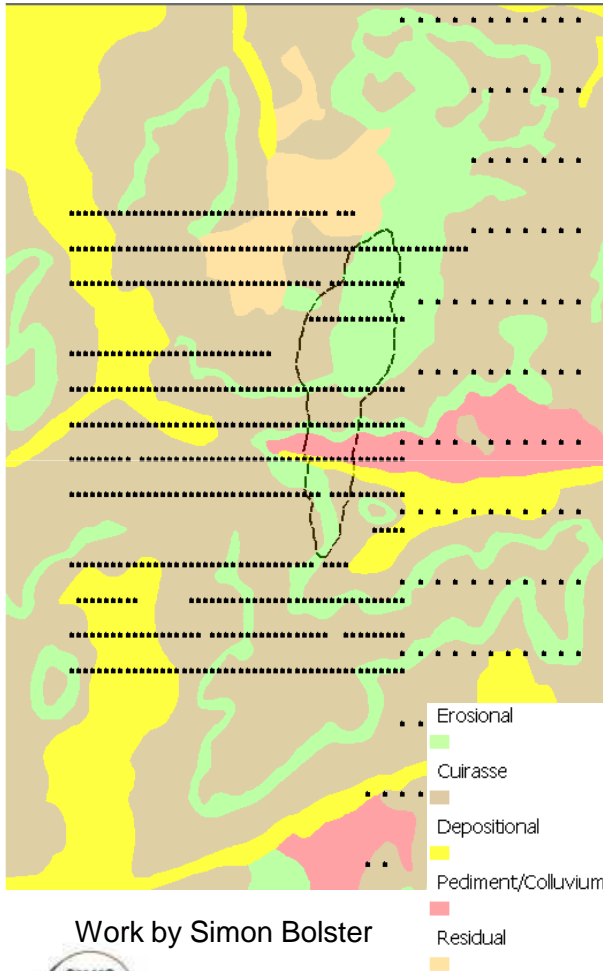


GOLD FIELDS

1 km

Laboratory Data – 4 acid/ICPMS soil samples

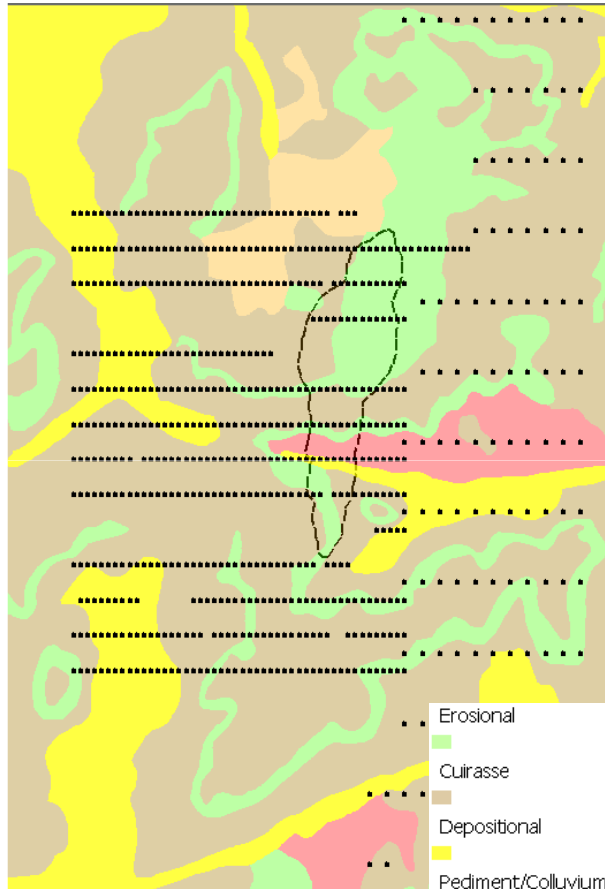
Regolith Map



GOLD FIELDS

Laboratory Data – 4 acid/ICPMS soil samples

Regolith Map



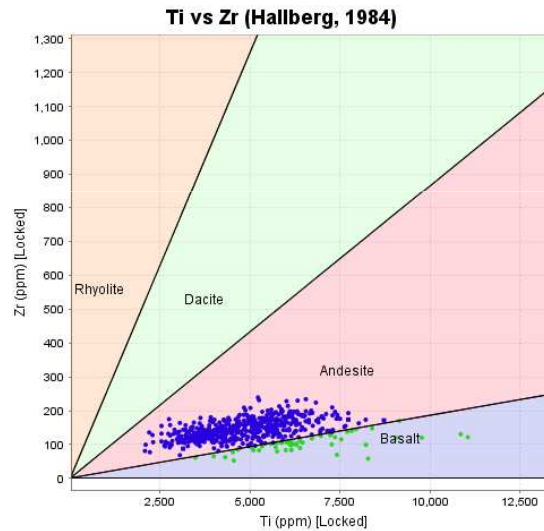
Work by Simon Bolster



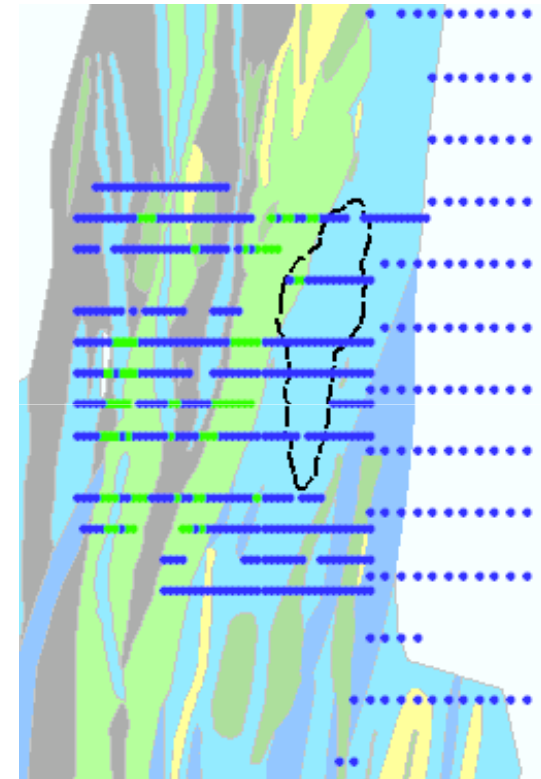
GOLD FIELDS

Depositional regime removed

Classification using Ti-Zr template



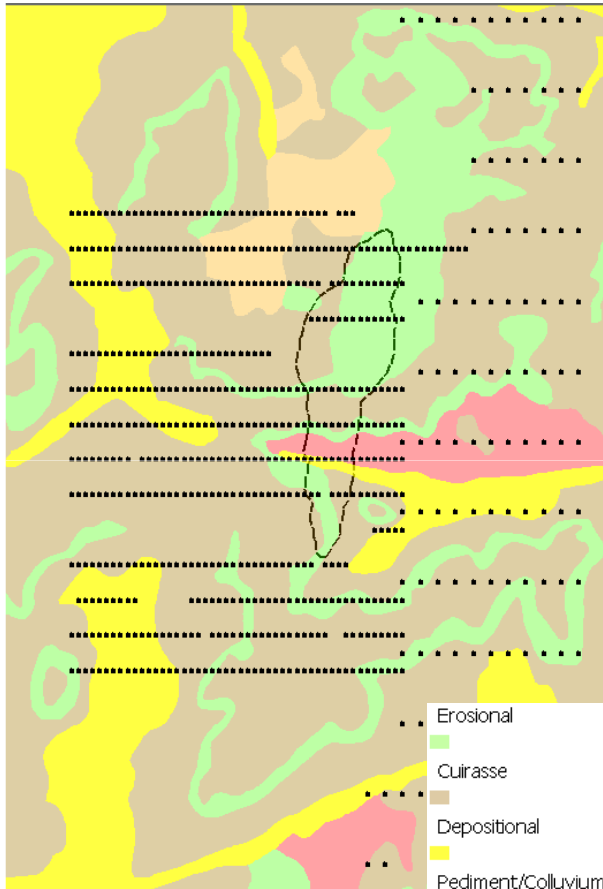
1 km



- Interbedded Siltstones/Sandstones
- Felsic Intrusive
- Mafic Intrusive
- Interbedded sandstones/siltstones
- Basalt
- Siltstones/shales

Laboratory Data – 4 acid/ICPMS soil samples

Regolith Map



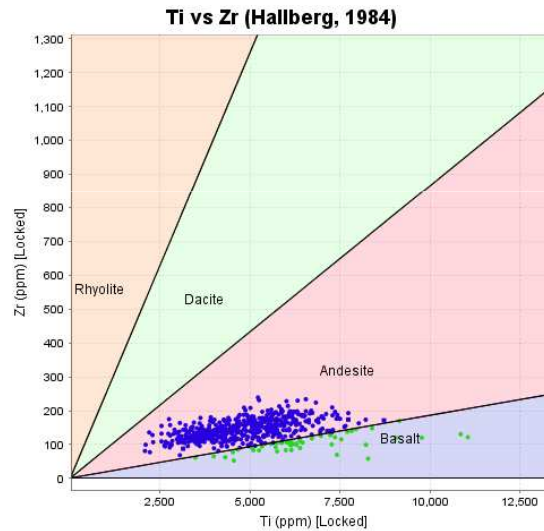
Work by Simon Bolster



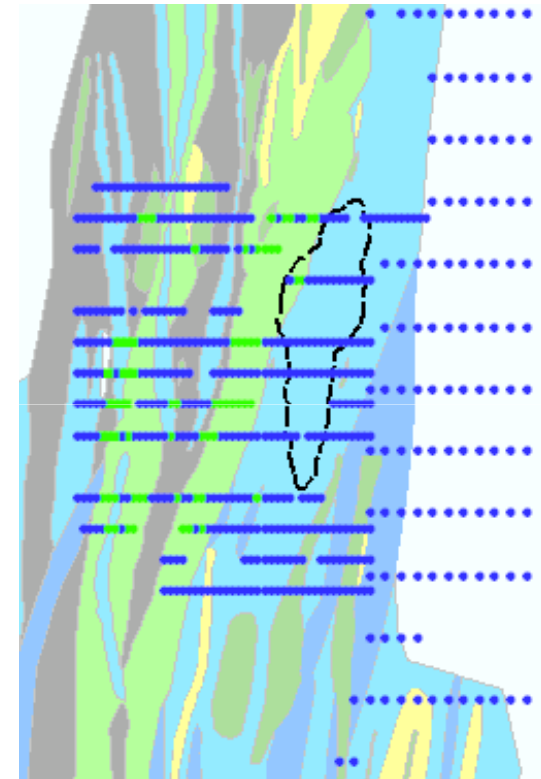
GOLD FIELDS

Depositional regime removed

Classification using Ti-Zr template



1 km



- Interbedded Siltstones/Sandstones
- Felsic Intrusive
- Mafic Intrusive
- Interbedded sandstones/siltstones
- Basalt
- Siltstones/shales

pXRF Data – 4 acid/ICPMS soil samples

Linear regression
carried out
between
laboratory and
pXRF data

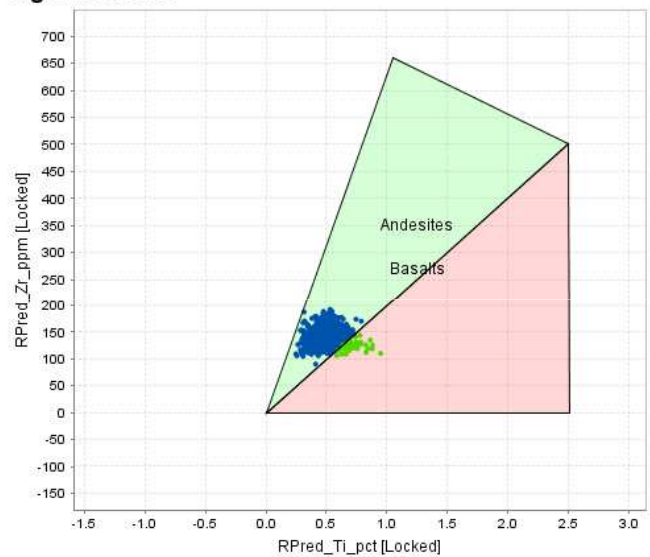
XRF values
“corrected” using
regression
equation and
same template
used as for
laboratory data.



pXRF Data – 4 acid/ICPMS soil samples

Linear regression carried out between laboratory and pXRF data

XRF values “corrected” using regression equation and same template used as for laboratory data.



Depositional regime removed

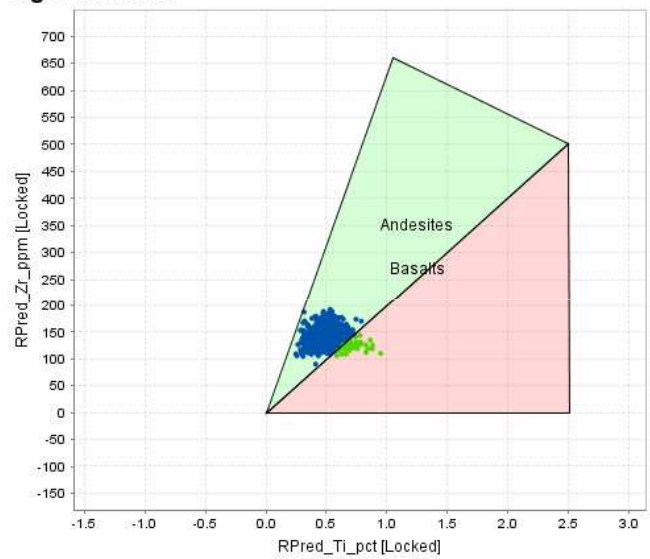


pXRF Data – 4 acid/ICPMS soil samples

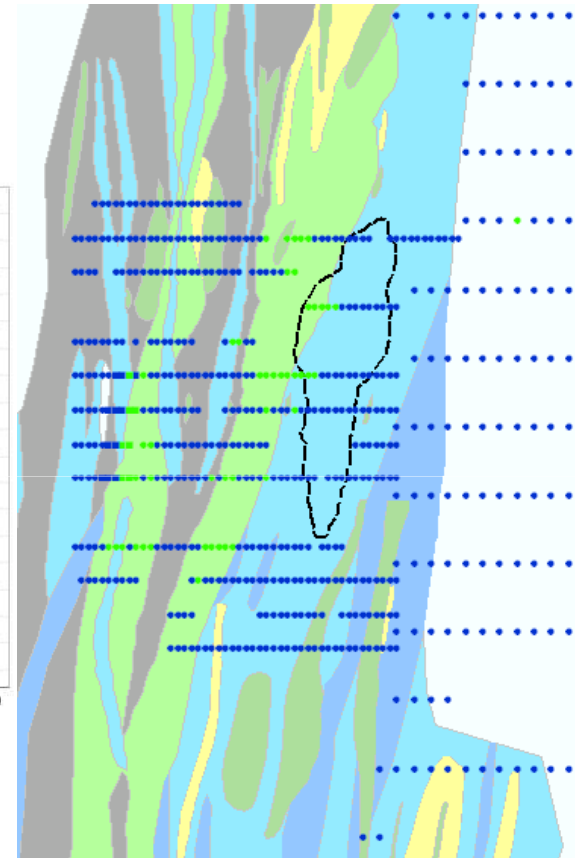
Classification according to XRF data

Linear regression carried out between laboratory and pXRF data

XRF values “corrected” using regression equation and same template used as for laboratory data.



Depositional regime removed



- Interbedded Siltstones/Sandstones
- Felsic Intrusive
- Mafic Intrusive
- Interbedded sandstones/siltstones
- Basalt
- Siltstones/shales

1 km



SUMMARY

This talk has described an example from SW Mali of how multielement geochemistry can be used to distinguish between different lithologies in fresh rock with scatterplots of relatively immobile elements such Cr, Ti, Zr.

These templates can be applied in the weathered environment where it is often difficult to identify the primary lithology

Discrimination of basalts from sediments can also be achieved with the surface soil samples

Careful application of a field portable XRF can produce the same outcomes as the lab data.

The real time nature of the field portable XRF and easy to use templates in ioGAS have resulted in very useful field geochemical techniques for discriminating between lithologies particularly when these are highly weathered.



Acknowledgements

Gold Fields Yanfolila team and in particular Neil Jones, Lazare Pare, Kiril Mugerma, David Weeks, James Bell

