Department of Natural Resources, Mines and Energy

HyLogger for exploration

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Queensland Government

Acknowledgments

- Mineral Systems team
- Jon Huntington (Huntington Hyperspectral Pty Ltd)

Outline

- Why HyLogger?
- Approach to scanning within GSQ
- Where to find HyLogger data online
- Ernest Henry case study
- Hands on exercise

Objectives

- Provide increased understanding of the Geological Survey of Queensland's (GSQ) HyLogging methodology and available products
- Learn to access freely available mineral information various online sources
- Have a clear idea of how these products can be integrated into your workflows and the added value they provide
- Consider donating drill core to our GSQ Mineral Systems drill core collection – this core is a priority to be scanned and results integrated into other studies

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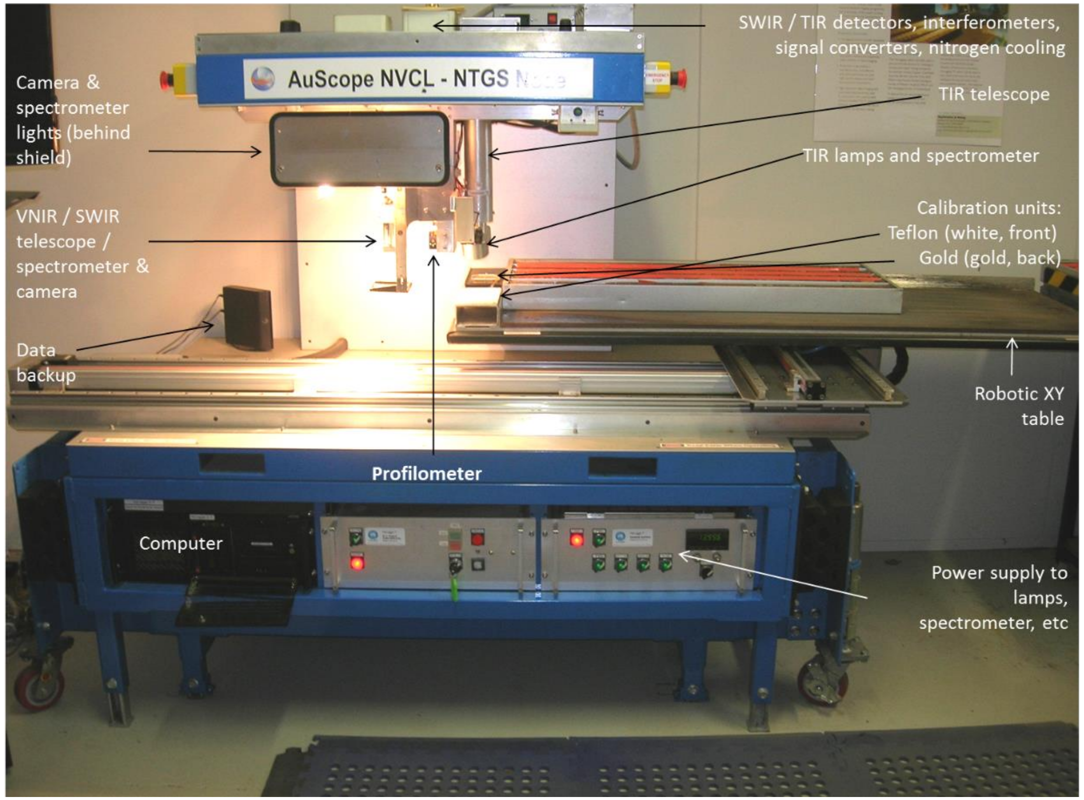
HyLogger in GSQ

Queensland Government

What is HyLogging?

A suite of hardware and software tools for the objective, voluminous hyperspectral logging and analysis of all drilled materials

- Reflectance spectroscopy
- Three spectrometers
  - 1 x grating, 2 x FTIR (LN_2 cooled)
  - Visible and Near Infrared (VNIR) - Shortwave Infrared (SWIR) - 380-2500 nm; 531 Ch
  - Thermal Infrared (TIR) -6000-14500 nm; 341Ch
- Core tray robotics
- Sampling
  - 125 samples/m
  - 10 x 18 mm overlapping pixels sampled every 8mm
- High Resolution Imaging
- TSG8 – Analysis Software



What we could achieve?

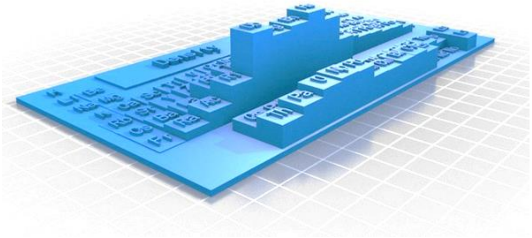
- Increased objectivity, increased consistency
- Increased sample density, increased confidence
- Reduced handling. Scanning in original core trays, with minimal sample preparation
- Allows geologist to focus on more important issues: interpretation, textures, paragenesis, etc.
- New knowledge. Seeing mineral distributions, assemblages and spatial trends not evident to the human eye
- Long-term archives – Applications in Greenfields exploration > Brownfields, Deposit delineation, Grade control, Geometallurgy and Mineral processing, Environment management.

Capabilities

- Targets **<u>mineralogical</u>** composition; not elemental composition

- Compares against standard library of mineral spectra

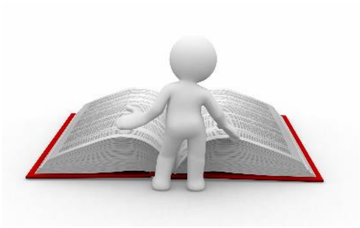
- Complementary to geochemical methods such as ICPMS, AAS, XRF, LIBS, etc., in that it provides information as to the source of deportment of elements



- Requires little or no sample preparation.
Samples must be dry

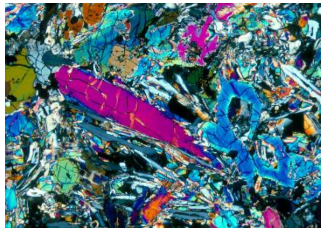
- Reasonably fast; Cores sampled at ~500 numbers of 10mm samples in 5 minutes or 4 meters of core in 5 minutes. 1000 to 3000 chip samples per day in SWIR.

Capabilities



- Provides very dense, spatially-contiguous and voluminous populations of mineralogy with high redundancy

- Only provides relative proportions (not modal abundances) unless calibrated against external standards



- Can “see” more minerals than a naked eye. Especially clays in low proportion. SWIR wavelengths can, to some extent, see into the volume of a rock. TIR wavelengths only responds to surface mineralogy

- Very objective that it operates the same way every day.

Target minerals – VNIR & SWIR

Iron Oxide Group Minerals

- hematite, goethite, massive magnetite

Al(OH) Group Minerals

- paragonite, muscovite, phengite, illite, pyrophyllite, kaolinite, halloysite, dickite, smectite varieties, gibbsite, etc.

Sulphates

- alunite, jarosite, gypsum

Si(OH) Group Minerals

- opaline silica
- hydrothermal quartz with fluid inclusions

Ammonium bearing minerals

- NH-alunite, buddingtonite, Na illite, etc.

Fe(OH) Group

- saponite, nontronite

Mg(OH) Group

- chlorites (Mg/Fe), biotite, phlogopite, antigorite, tremolite, actinolite, talc, hornblende, brucite, etc.

Carbonate Group Minerals

- calcite, dolomite, Fe-dolomite, magnesite, ankerite, siderite, malachite, Cu carbonates, etc.

Selected OH-bearing Silicates

- epidote, prehnite, tourmaline, topaz, etc

Selected Zn silicates / phosphates

- e.g. sauconite, tarbutite

Selected Zeolites

- laumontite, chabazite, etc.

Selected RRE-bearing minerals

- neodymium, praseodymium, etc

Selected massive sulphides

- sphalerite, pyrite, etc.

Target minerals – TIR

Feldspar Group

- K-feldspars
- Plagioclase feldspars

Quartz and varieties

Pyroxene Group

Olivine Group

- and broad Fo / Fa (Mg / Fe) variants

Garnets

- and Fe, Al, Ca, Mg and Mn compositional variants

Apatite

Barite

Zeolites

etc.

Miscellaneous silicates such as:

- Andalusite, Cordierite, Marialite, Meoinite, Zircon, Vesuvianite, Vonsenite, etc.

Plus many minerals also available in the Shortwave Infrared (SWIR):

Carbonates

- and chemical variants

Micas

Kaolinite

Sulphates

Talc

Chlorite

etc.

Which wavelength regions are best?

Mineral Group	VNIR	SWIR	TIR
	400-1000 nm	1000-2500 nm	6000-14500 nm
REEs			?
Iron Oxides			
Kaolins			
White Micas			
Smectites			
Other AlOH			
Pyrophyllite			
Prehnite			
Topaz			
Diaspore			
Axinite			
Gibbsite			
Chlorites			
Dark micas			
Amphiboles			
Serpentines			
Other MgOH			Some
Palygorskite			?
Talc			
Brucite			?
Mg-Clays			?
Epidotes			
Tourmalines			

Mineral Group	VNIR	SWIR	TIR
	400-1000 nm	1000-2500 nm	6000-14500 nm
Artefacts			
Carbonates			
Sulphates			
Phosphates			
Borates			
Oxides			
Sulphides			
Quartz			
K-Feldspars			
Plagioclases			
Garnets			
Pyroxenes			
Olivines			
Misc Anhydrous Silicates			Most
Vesuvianite			
Cordierite			
Andalusite			?
Oils			?
	No response		
	Weak or selective response		
Legend	OK response but other region better		
	Good responses but hard in mixtures		
	Clear unambiguous response		

What are spectral signatures controlled by?

- **Mineralogy** – combinations of absorptions i.e. AlOH, MgOH, FeOH, OH, H_2O, etc.
- **Cation composition** – e.g. Al vs Fe^{3+}, Mn, Cr, V in octahedral site in white micas (longer wavelength AlOH absorption feature)
- **Crystallinity (disorder)** – ‘sharpness’ of kaolin doublets or muscovite peaks
- **Water (free, structural)** – OH, H_2O features. H_2O is very strong feature that obliterates subtle absorptions (need DRY samples)
- **Particle size** – TIR effects (e.g. clinging fines on quartz, etc.)
- **Orientation** – TIR effects (e.g.; feldspars, micas)
- **Mineral mixtures** (Not always linear with abundance, e.g. talc dominates in spectral mixtures due to its absorption coefficient)
- **Opaques such as Organic Matter and Magnetite** – TOC (plastics also dominate spectral response (i.e. plastic trays / plastic linings) and must be masked out)

Quick Summary of Spectral Responses

- **Can identify spectrally active minerals**

  (hydroxylated silicates, carbonates in SWIR, silicates in TIR; carbonates in both)

- **Can identify semi-quantitative mineralogy**

  (based on strength of absorption features)

- **Can identify crystallinity**

  (kaolin crystallinity; illitic white micas) which can be from hydrothermal overprints

- **Can identify changes in mineralogy composition**

  (e.g. white micas, chlorites, carbonates) – may show different provenance.

BUT IT'S NOT A BLACK BOX

MAKE SURE THE MINERAL INTERPRETATIONS

MAKE SENSE AND/OR CAN BE JUSTIFIED

What added value can HyLogger data give you?

- Geological logging; digital output

- Software assisted interpretation - Consistent results

- Domaining (can be lithological, alteration or both) – gives better control over the mineral distribution

- Can integrate outputs into other programs (IoGas, Geoscience Analyst etc)

- High-density data cloud enables higher level of confidence

Limitations..

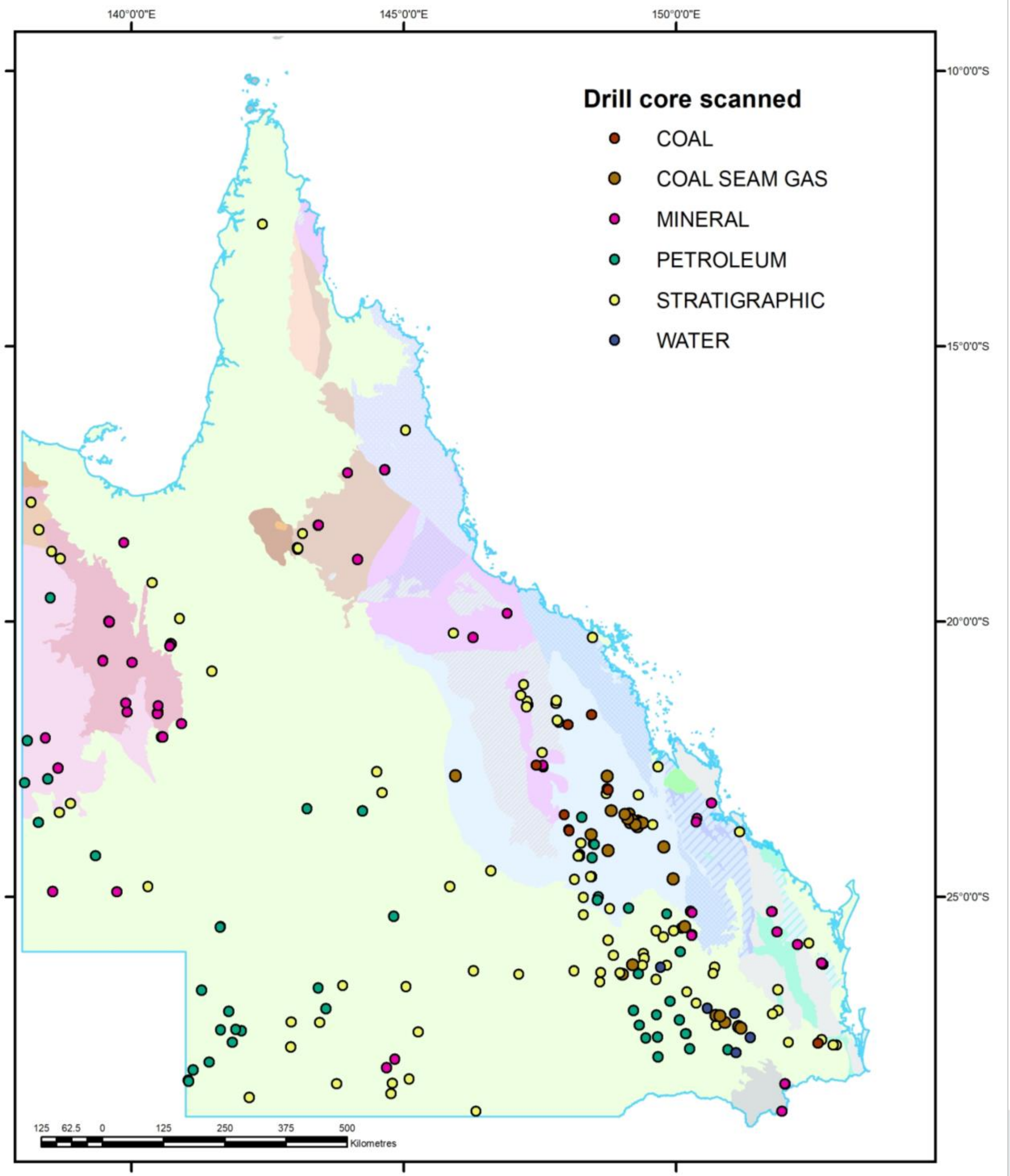
- Bulk mineralogical characterisation method – relies on well-characterised spectral mineral library.
- Superimposed metamorphic/alteration events hard to resolve
- SWIR see a few microns into a given target surface; TIR sees what's available on the surface
- Both instrument-derived spectra and software-derived interpretations need to be validated
- Generally, interpreted results do not measure modal mineralogy; unmixed spectral data can be a good guide when the bulk mineralogy is well represented on clean surface.
- Detection limits apply but varies on minerals
- Grain size, dark cores, surface roughness… all matters

HyLogger in the Survey

- GSQ has had HyLogger for 10 years – ~205,000m scanned
- Focused on Auscope transects and stratigraphic holes
- Drill cores, chips and pulps were scanned
- Industry, researchers, GSQ getting core and samples scanned – focus on just making data available

Existing mineral drill core holdings

- Spread of drill core and chips scanned primarily in SE and SW Queensland
- Coverage due to availability of drill core in our core sheds and focus of Industry core offered for scanning
collect



HyLogger in the Survey

- Minerals space – no focus within GSQ to systematically scan drill core, ad hoc scanning of cores from deposits (often only 1 or 2 drill holes)

- Joint CSIRO-GSQ study in 2011 on the Kalman Cu-Au deposit was first attempt to collect HyLogger on a number of representative cores

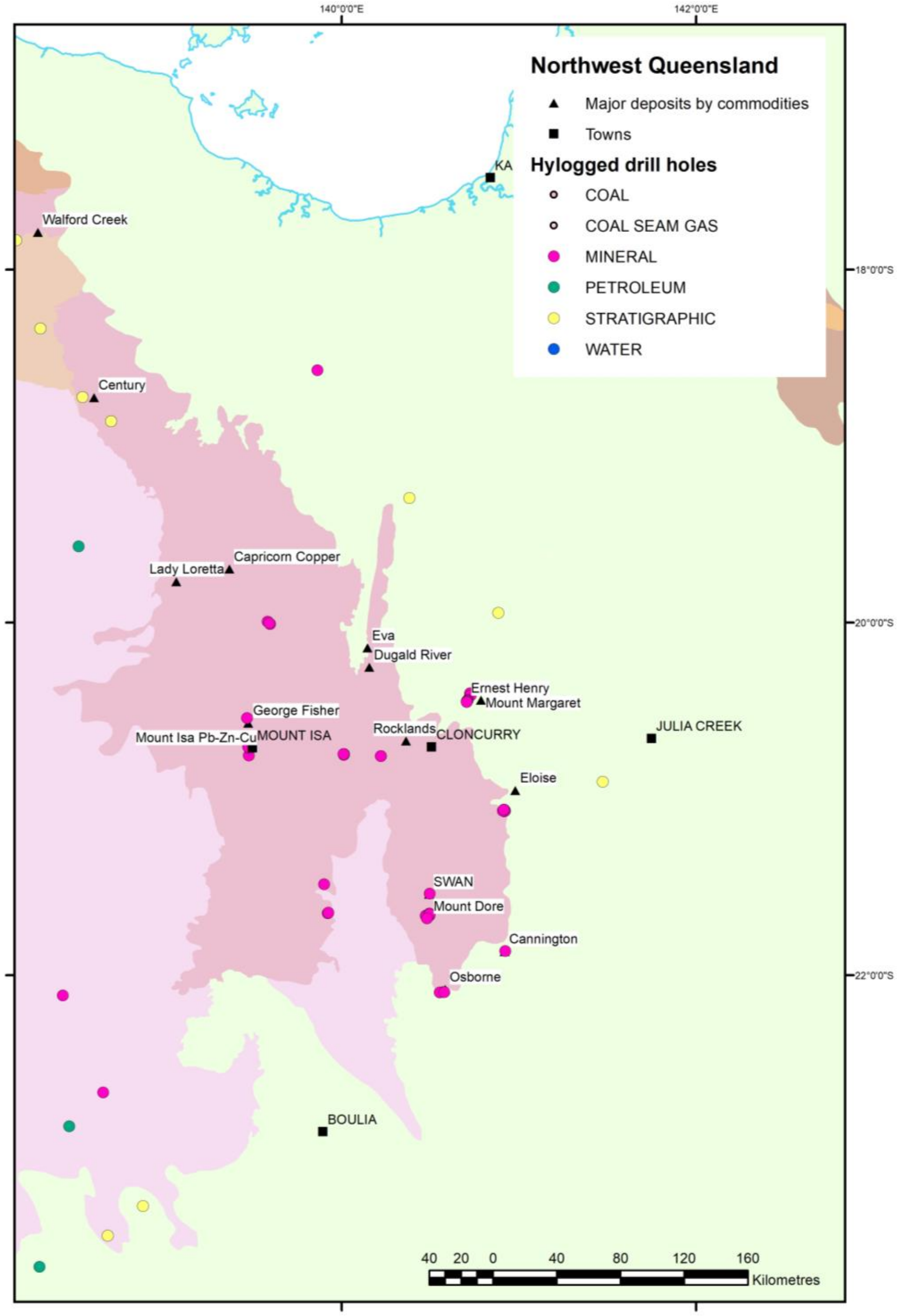
- Hylogger is currently only scanning core from NW Qld as part of the GSQ Mineral Systems collection

Existing mineral drill core holdings

- Since 2018-2019, 10.7km of core has been scanned (21 drill holes) - doubled existing coverage in NW Qld

- Initial focus on two areas - Mount Isa/George Fisher and Ernest Henry

- Next areas to scan – SWAN/Mount Elliott and Little Eva/Roseby



Future plans

- Create a region-specific spectral library for NW Qld
  - can re-process existing data with scalars reflecting mineral variations within region
  - will be considered a test case to assess usefulness before rolling out in other parts of QLD
- Provide drill core and outcrop sample data
  - currently TSG software is suited towards continuous data acquisition so need to develop better ways of delivering this data
- Visualise data in 3D
  - update existing drill hole databases to link survey data with all drill core scanned
- Create alerts/process to let people know when data is available

Online data access

Access to data

- CorStruth (http://www.corstruth.com.au/)
- AuScope portal (http://portal.auscope.org/portal/gmap.html)
- AUSGIN portal (http://portal.geoscience.gov.au/gmap.html)
- EFTF portal (https://portal.ga.gov.au/)

CorStruth

- Automated interpretation of HyLogger data
- Mineral group data is provided as 1m bins (intervals) in csv format
- Mosaic of core tray photos downhole, can view each tray one by one
- A4 plots showing hydrous and anhydrous mineral groups downhole (both TIR and SWIR)
- Demo link

AuScope Portal

- Original online delivery system for the National Virtual Core Library (NVCL), managed by Auscope, considered a developmental portal now
- Can download both scalars and imagery
- Run analytics over entire core library e.g. picking out particular minerals at a certain depth
- Demo link

AUSGIN Portal

- Online delivery system for national geological datasets, managed by Geoscience Australia

- Can plot and view scalars downhole within web browser

- Similar high level functionality as The Spectral Geologist (TSG) software

- Demo link

EFTF Portal

- Online delivery system for national geological datasets, managed by Geoscience Australia, with a focus on data acquired through the Exploring for the Future Program

- No inbuilt visualisation of drill core or mineralogy

- Demo link

Worked example using TSG software:

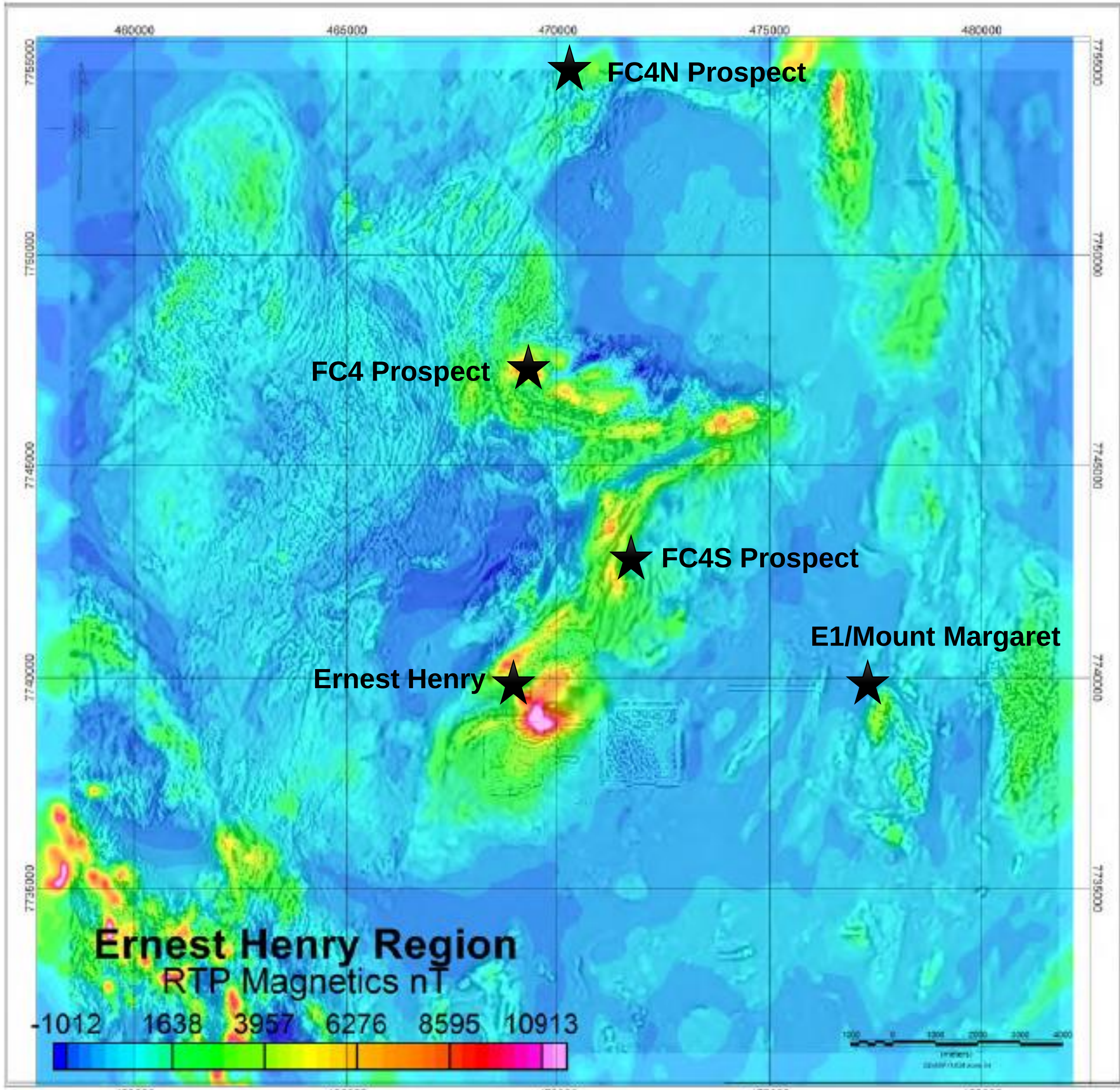
Ernest Henry

Case study

Ernest Henry Cu-Au system

- ‘typical’ iron oxide copper gold (IOCG) deposit in the Eastern Succession
- one major deposit (Ernest Henry), with satellite deposits (E1) and similar (?) prospects (FC targets)

How far away can you see the alteration signature of the Ernest Henry deposit?



NWQMP Deposit Atlas, 2018

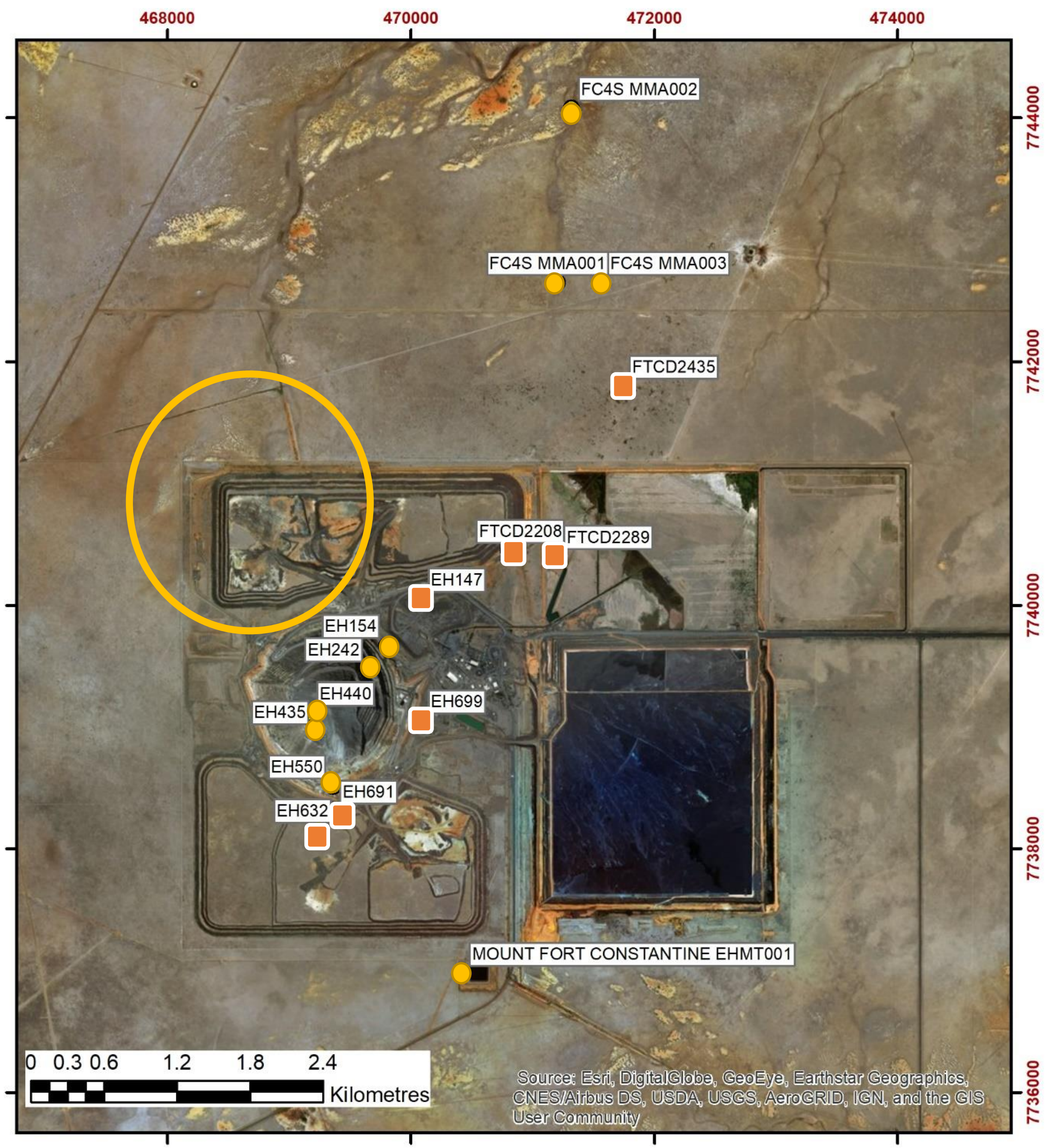
Representative drill holes

Glencore

- five through orebody
- two within the inner halo
- four proximal to distal holes
- one deep drill hole ~1.7km to the south (distal? background?)

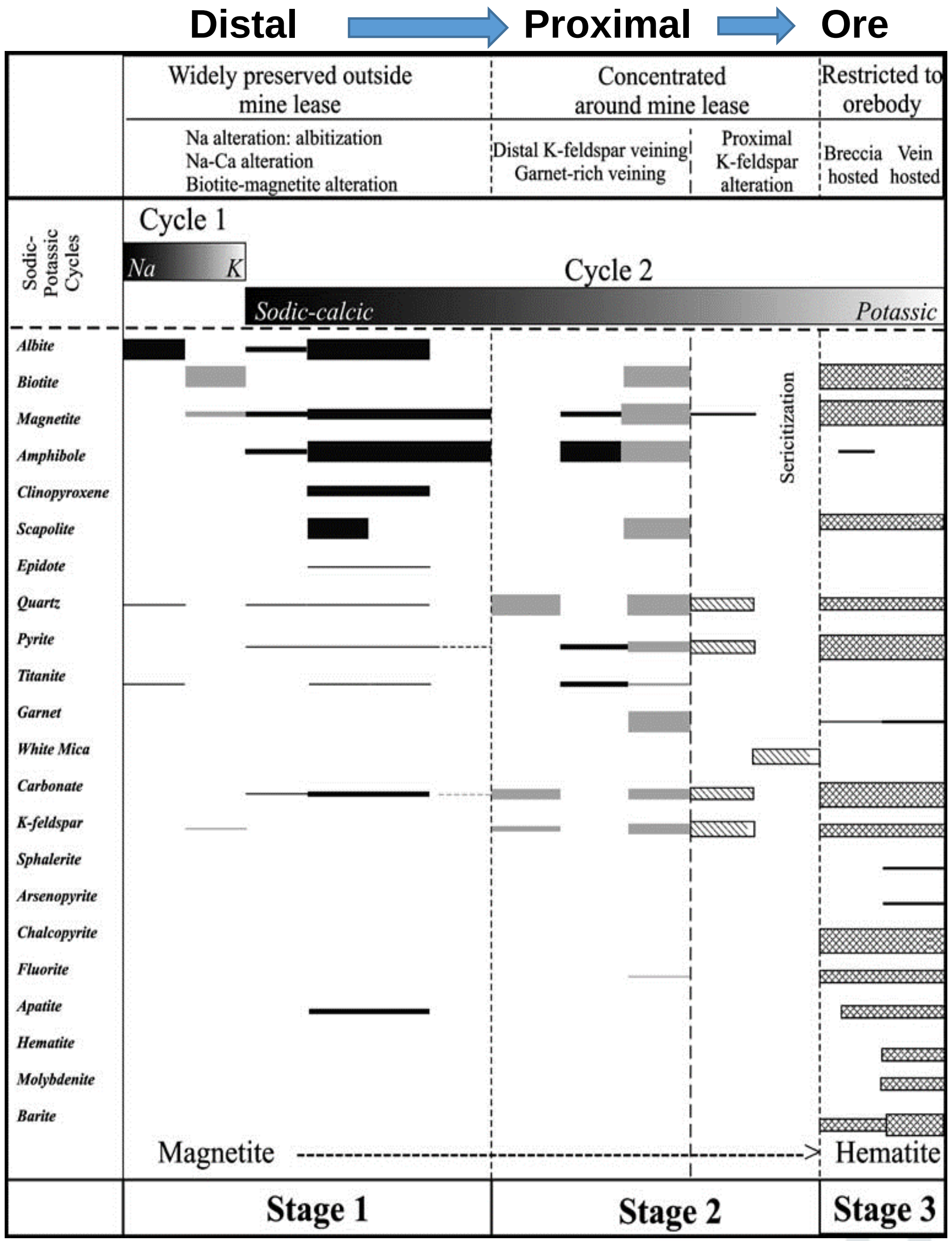
GBM Resources

- three drill holes from FC4S target



So why HyLogger?

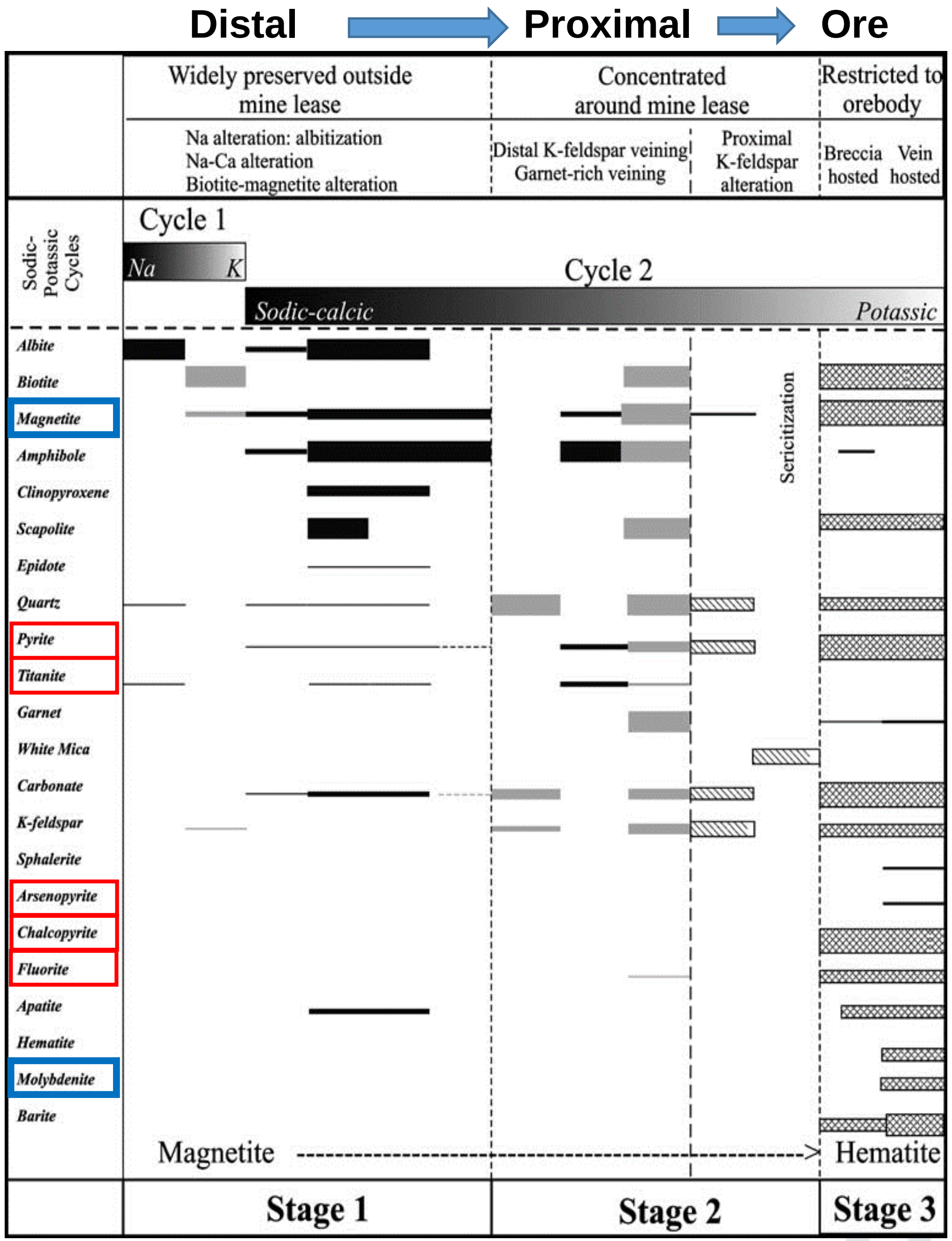
- Consistently identify minerals across and around deposit
  - Can reprocess existing data with new scalars as needed
- Identifies minerals not seen in hand specimen
  - Also can help pull out changes in mineral composition
- Integration with other datasets
  - XRF, TIMA, petrophysics, multi-element geochemistry undertaken on the same sample (where possible)



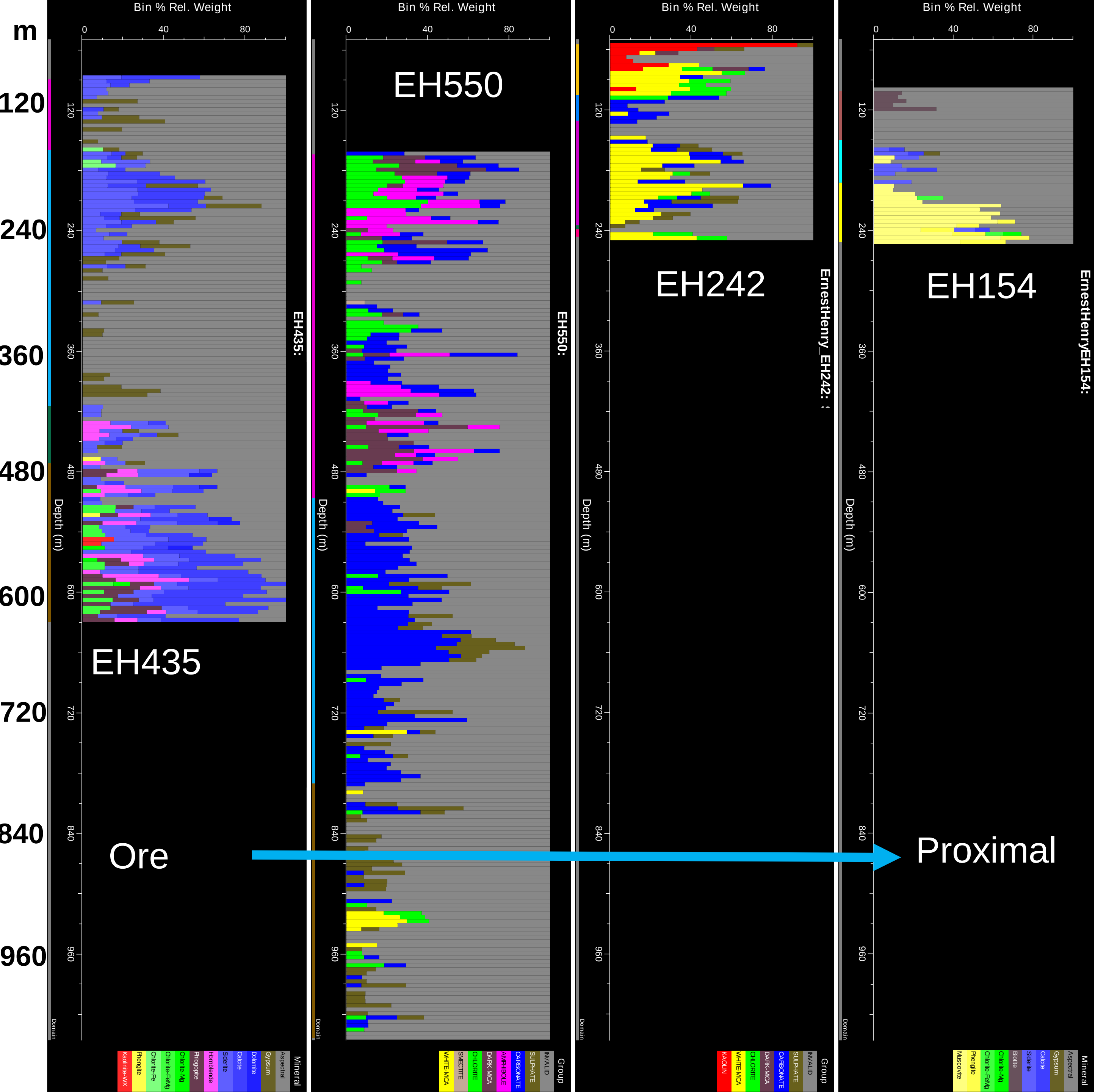
Mark et al, 2006

Detectable minerals

- Highlighted minerals (red) not detectable
- Minerals (blue) are only detectable when massive
- Can create scalars based on base reflectance to reflect sulphide distribution
- Enhanced core colour scalars can be used to compare hematite dusted K-feldspar vs K-feldspar etc



Mark et al, 2006

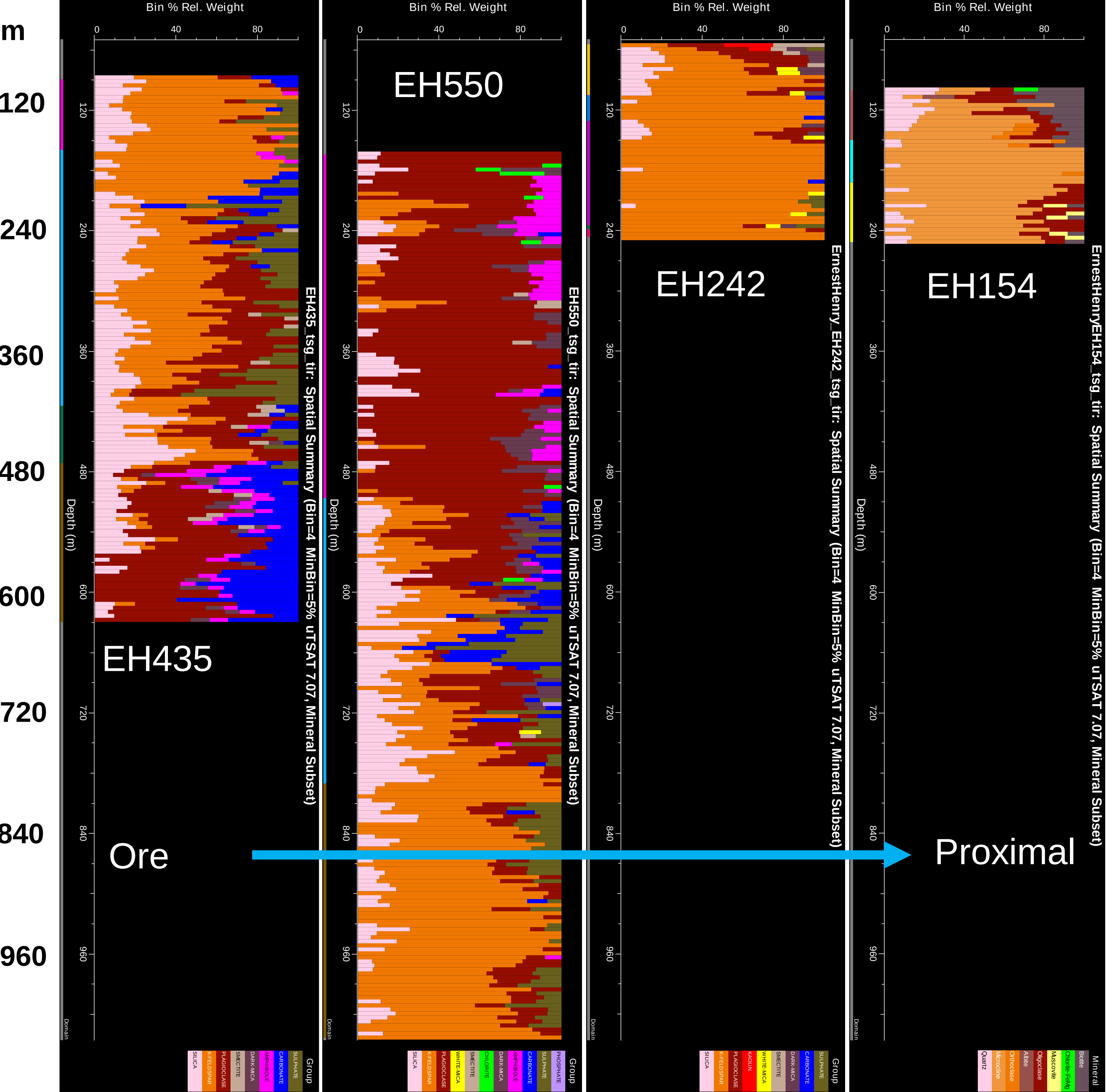


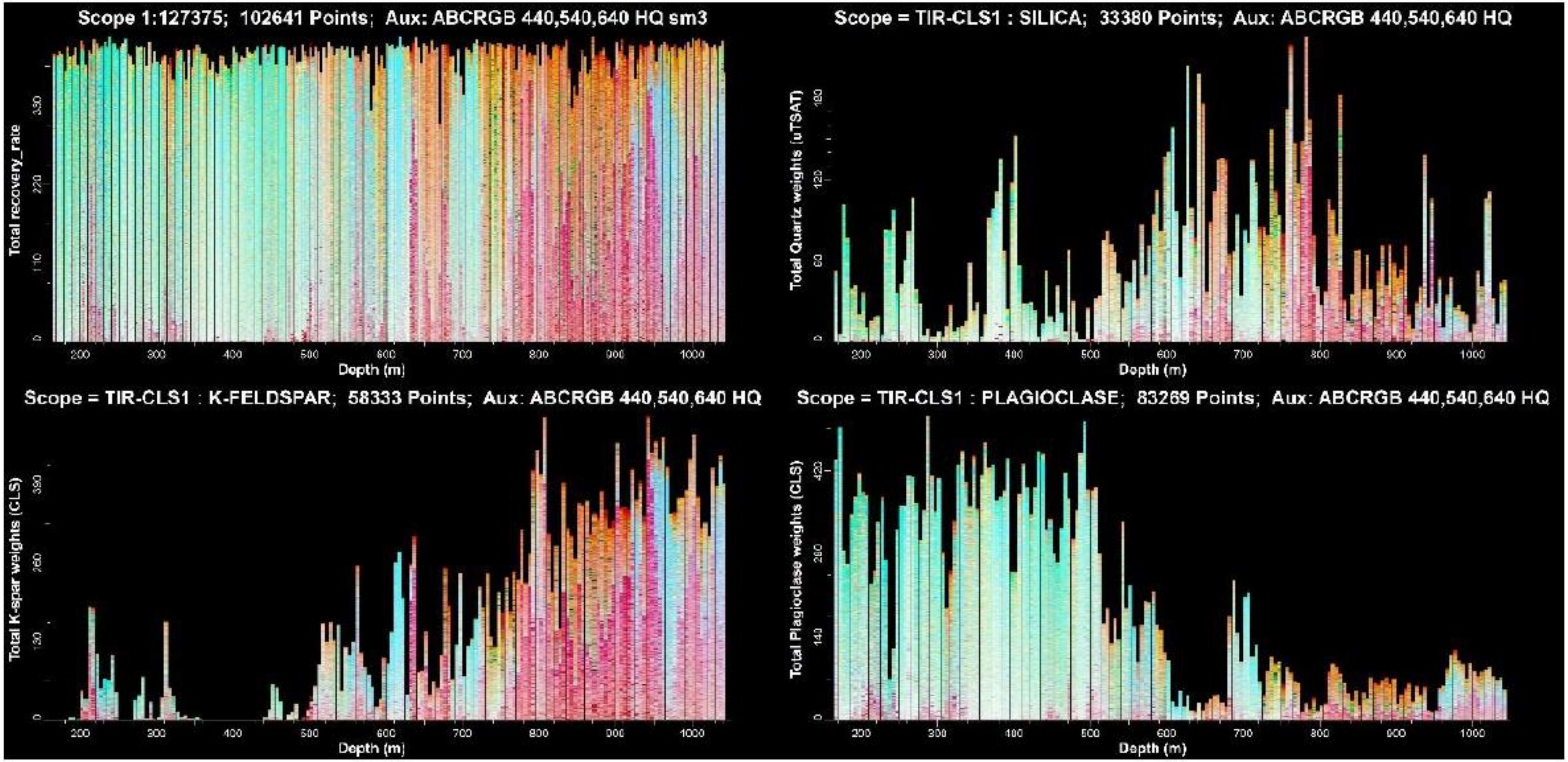
Hydrous minerals

- Decrease in carbonate trending away from ore
- EH435 and EH550 – larger proportion of aspectral minerals compared to proximal drill holes
- Surface weathering effects (Kaolinite)

Anhydrous minerals

- Dominance of K-feldspar trending away from ore zone
- Opposite trends between K-feldspar vs plagioclase (+/- quartz) within EH435 and EH550



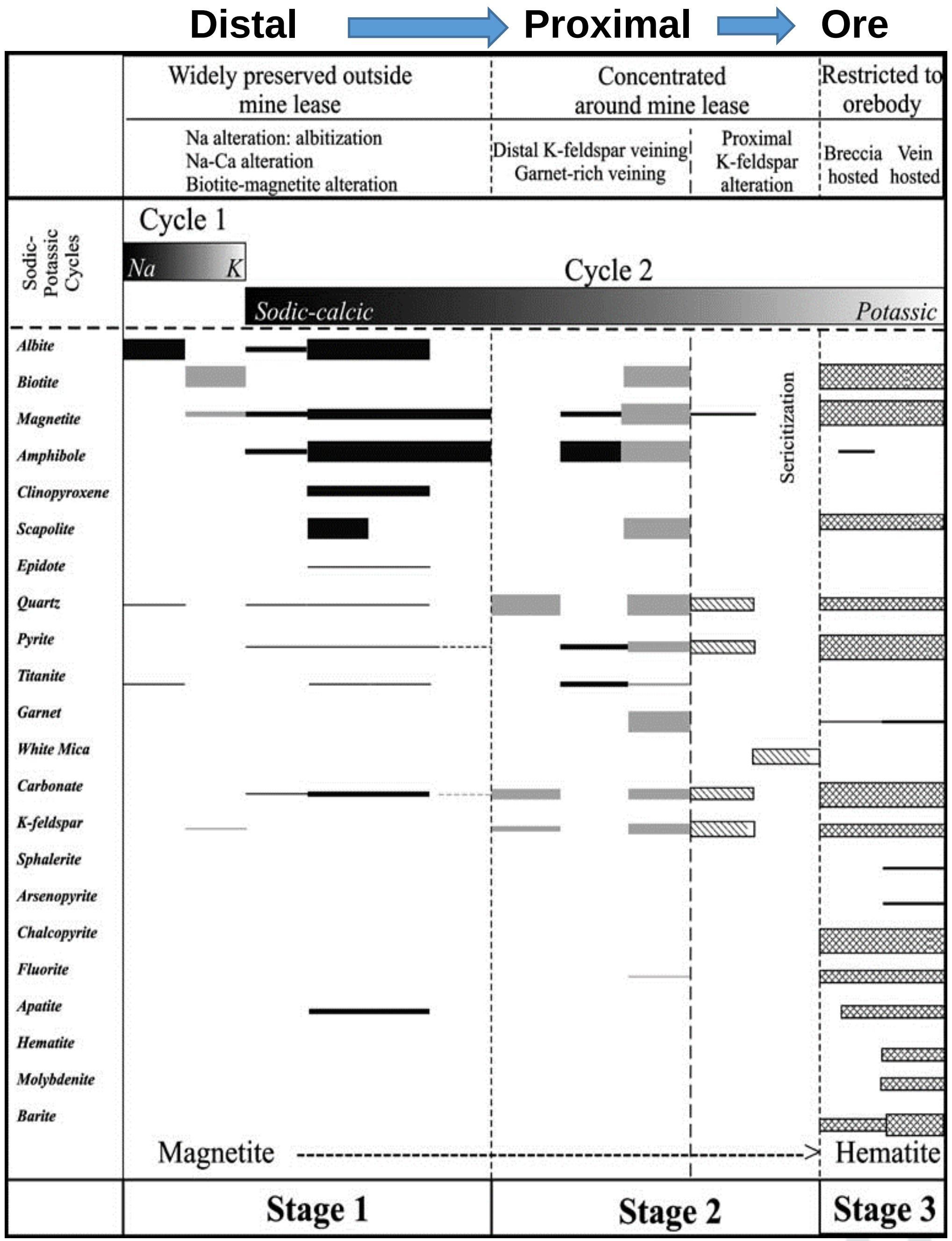


Drill hole EH550 ABCRGB enhanced core colour for distributions of quartz and feldspars.

Using a normalised hull quotient colour, converted to Any-Band-Colour-Red-Green-Blue scalar

Initial findings

- Epidote and garnet more extensive within the proximal and mineralised zones
- Actinolite consistently seen in proximal to distal samples
- Trace element geochemistry (with CODES) indicates a general similarity within pyrite across the area. Hematite within ore zone at EH is significantly different from that within FC4S.

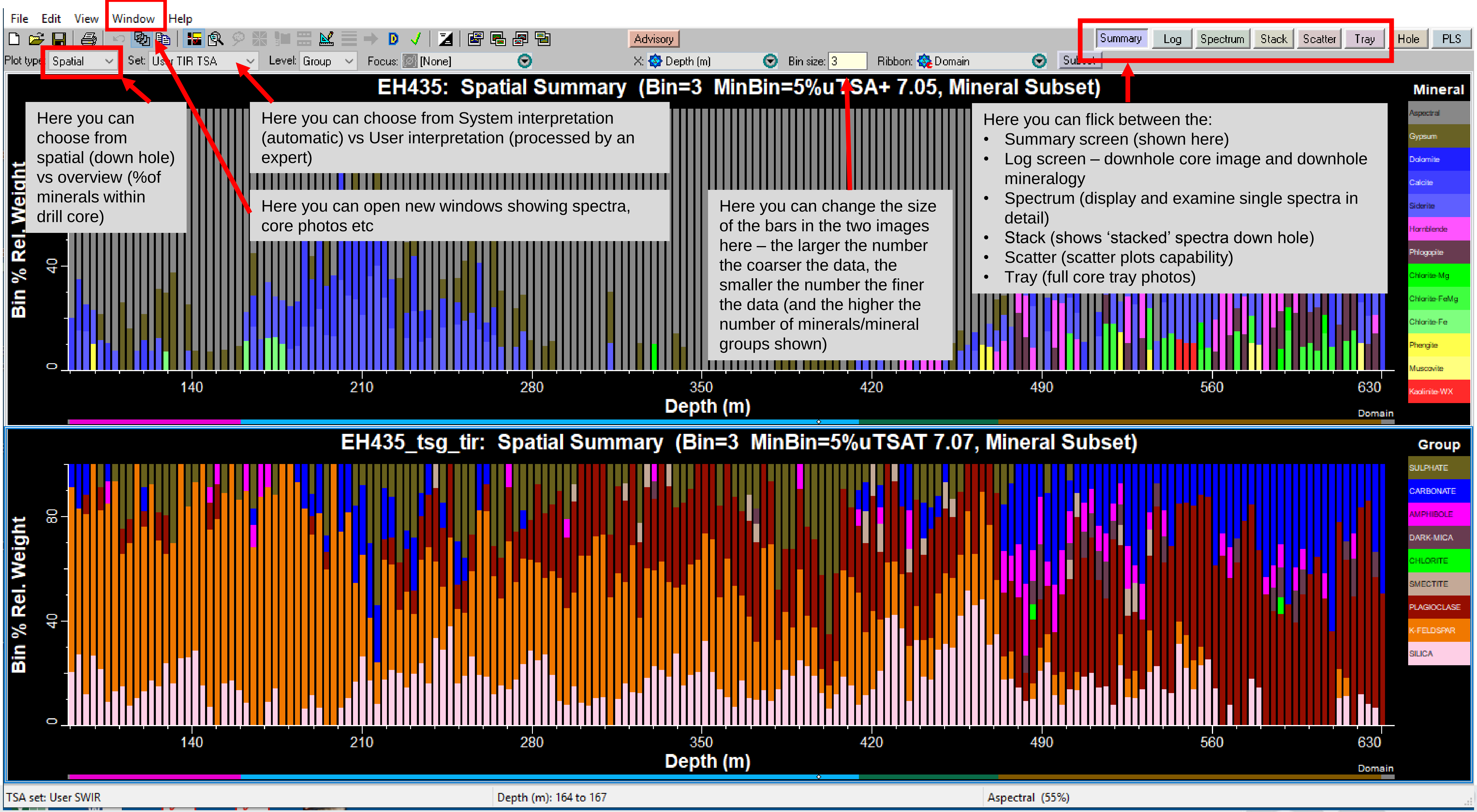


Mark et al, 2006

Exercise

TSG basics

- Loading TSG files
- Summary screen – overview vs spatial
- System data vs User data
- Loading log data (geological logs, assays etc)
- Floater windows


File Edit View Window Help
Advisory
Summary Log Spectrum Stack Scatter Tray Hole PLS
Plot type: Spatial
Set: User TIR TSA
Level: Group
Focus: [None]
X: Depth (m)
Bin size: 3
Ribbon: Domain
EH435: Spatial Summary (Bin=3 MinBin=5%uTSA+ 7.05, Mineral Subset)
Here you can choose from spatial (down hole) vs overview (%of minerals within drill core)
Here you can choose from System interpretation (automatic) vs User interpretation (processed by an expert)
Here you can open new windows showing spectra, core photos etc
Here you can change the size of the bars in the two images here – the larger the number the coarser the data, the smaller the number the finer the data (and the higher the number of minerals/mineral groups shown)
Here you can flick between the:
• Summary screen (shown here)
• Log screen – downhole core image and downhole mineralogy
• Spectrum (display and examine single spectra in detail)
• Stack (shows 'stacked' spectra down hole)
• Scatter (scatter plots capability)
• Tray (full core tray photos)
Bin % Rel. Weight
Depth (m)
140 210 280 350 420 490 560 630
Domain
Mineral
Aspectral
Gypsum
Dolomite
Calcite
Siderite
Hornblende
Phlogopite
Chlorite-Mg
Chlorite-FeMg
Chlorite-Fe
Phengite
Muscovite
Kaolinite-WX
EH435_tsg_tir: Spatial Summary (Bin=3 MinBin=5%uTSAT 7.07, Mineral Subset)
Bin % Rel. Weight
0 40 80
Depth (m)
140 210 280 350 420 490 560 630
Domain
Group
SULPHATE
CARBONATE
AMPHIBOLE
DARK-MICA
CHLORITE
SMECTITE
PLAGIOCLASE
K-FELDSPAR
SILICA
TSA set: User SWIR
Depth (m): 164 to 167
Aspectral (55%)

Exercise

1. Can you identify mineralisation/ore zones?
2. Can you pick the major alteration boundaries? (10 mins)

Add assay data into TSG (step through process together)

3. Plot up Au, Cu, Mo, U in scatter plots

4. Apply scalars for magnetite (step through process together)