HyLogger for exploration

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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
HyLogger in GSQ
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 (LN₂ cooled)
  - Visible and Near Infrared (VNIR) - Shortwave Infrared (SWIR) - 380-2500 nm; 531 Ch
  - Thermal Infrared (TIR) - 6000-14500 nm; 341 Ch
- 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 **mineralogical** 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?

<table>
<thead>
<tr>
<th>Mineral Group</th>
<th>VNIR</th>
<th>SWIR</th>
<th>TIR</th>
<th>Mineral Group</th>
<th>VNIR</th>
<th>SWIR</th>
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<td>Olivines</td>
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<td>Misc Anhydrous Silicates</td>
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<td>Most</td>
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<td>Vesuvianite</td>
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<td>Yellow-Green</td>
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Legend:
- OK response but other region better: Weak or selective response
- Good responses but hard in mixtures: Legend
- Clear unambiguous response: No response
What are spectral signatures controlled by?

- **Mineralogy** – combinations of absorptions i.e. AlOH, MgOH, FeOH, OH, H$_2$O, 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$_2$O features. H$_2$O 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)
- 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)

<table>
<thead>
<tr>
<th>Sodium Potassic Cycles</th>
<th>Widely preserved outside mine lease</th>
<th>Concentrated around mine lease</th>
<th>Restricted to orebody</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na alteration: albitization</td>
<td>Distal K-feldspar veining</td>
<td>Proximal K-feldspar alteration</td>
<td></td>
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<tr>
<td>Na-Ca alteration</td>
<td>Garnet-rich veining</td>
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<tr>
<td>Biotite-magnetite alteration</td>
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</tbody>
</table>

Mark et al, 2006

Stage 1 | Stage 2 | Stage 3
Magnetite | Hematite

Distal Proximal Ore

Cycle 1 | Cycle 2
Sodic-calcic | Potassic

- Albite
- Biotite
- Magnesite
- Amphibole
- Chlorite
- Scapolite
- Epidote
- Quartz
- Pyrite
- Tourmaline
- Garnet
- White Mica
- Carbonate
- K-feldspar
- Sphalerite
- Arsenopyrite
- Chalcopyrite
- Fluorite
- Apatite
- Hematite
- Molybdenite
- Barite
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
- 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
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)
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)