Corescan Drill Core Library Repository Project

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DEPARTMENT OF NATURAL RESOURCES

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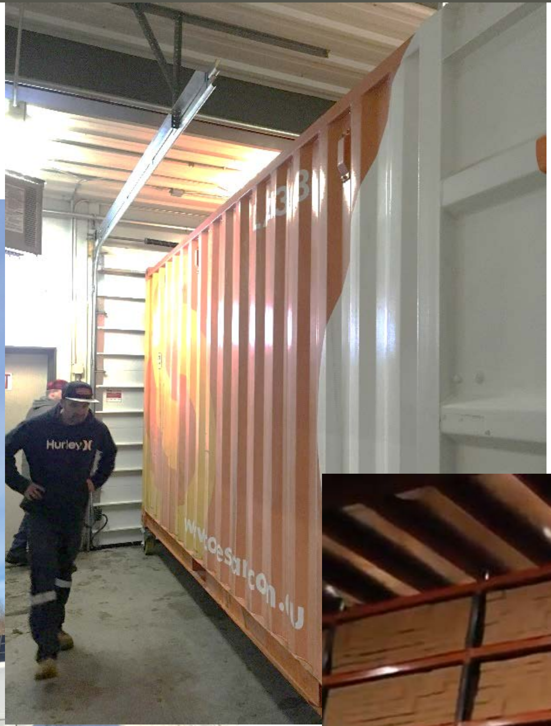
Procedure & Timeline

1. Lab arrival
2. Scanning
    1. QC & prep
3. Data Processing & Interpretation
4. Project Deliverables Summary

Lab Arrival

January 7th 2019 Arrival



Scanning Procedure - Prep

1. **Prep**
2. Calibrate
3. Scan
4. QC
5. Repeat

Figure 2a Core requiring washing

Figure 2b Core requiring brushing

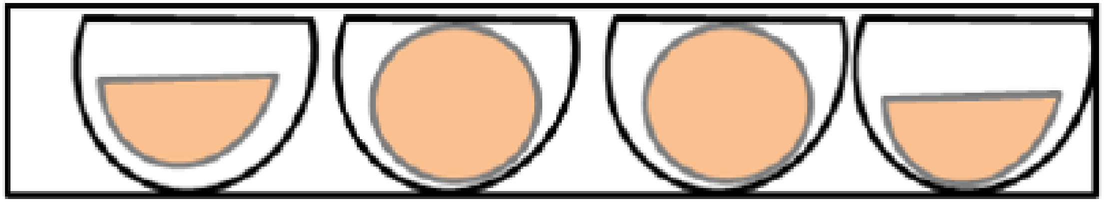


Figure 3 – Mixed core tray

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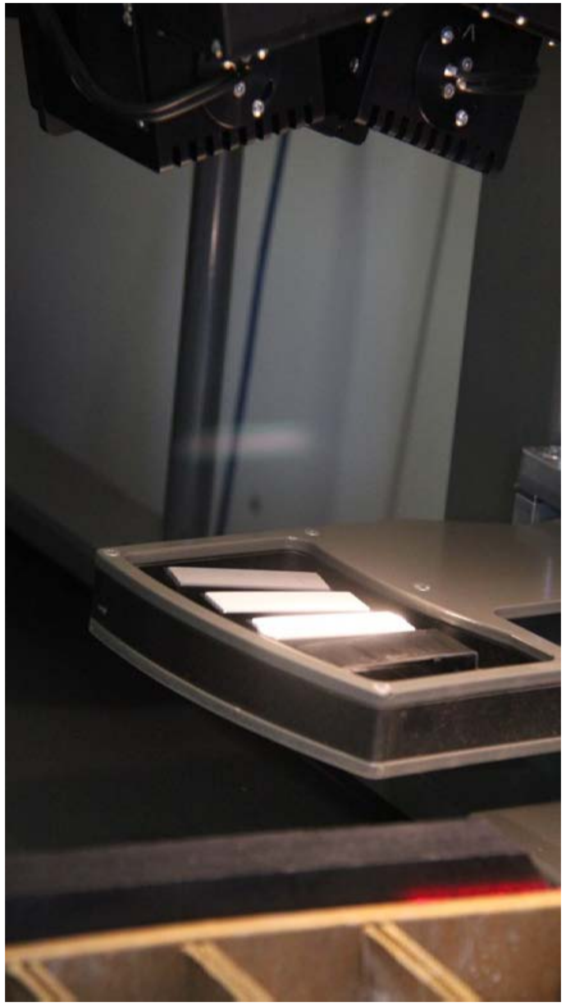
Scanning Procedure - Calibrate

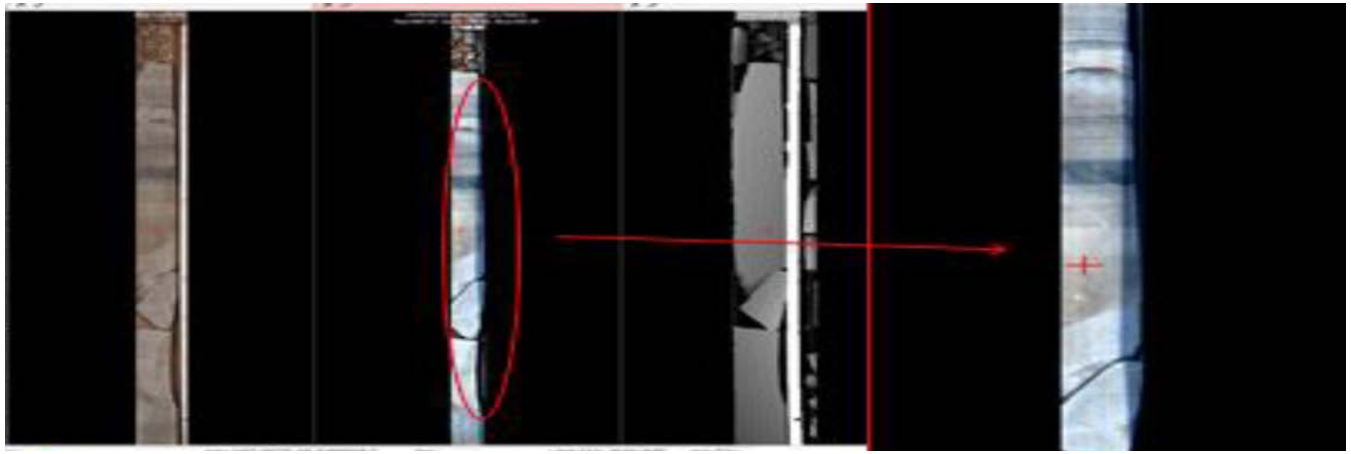
1. Prep
2. **Calibrate**
3. Scan
4. QC
5. Repeat



- The calibration of a spectrometer is necessary to correct for systematic error.
- As the electronic components heat up with continuous use, wavelength positions measured by the spectrometer tend to "drift".
- Calibration is done by comparing scanned wavelengths of a standard sample (NIST samples) to its published spectrum.
- The distinctive absorption features and identification of minerals and their composition are only as good as the calibration.
- Calibration should be done as often as possible without compromising the speed of data collection…."*garbage in garbage out"* sums up the importance of good calibration.

Scanning Procedure – Scan & QC

1. Prep
2. Calibrate
3. Scan
4. QC
5. Repeat



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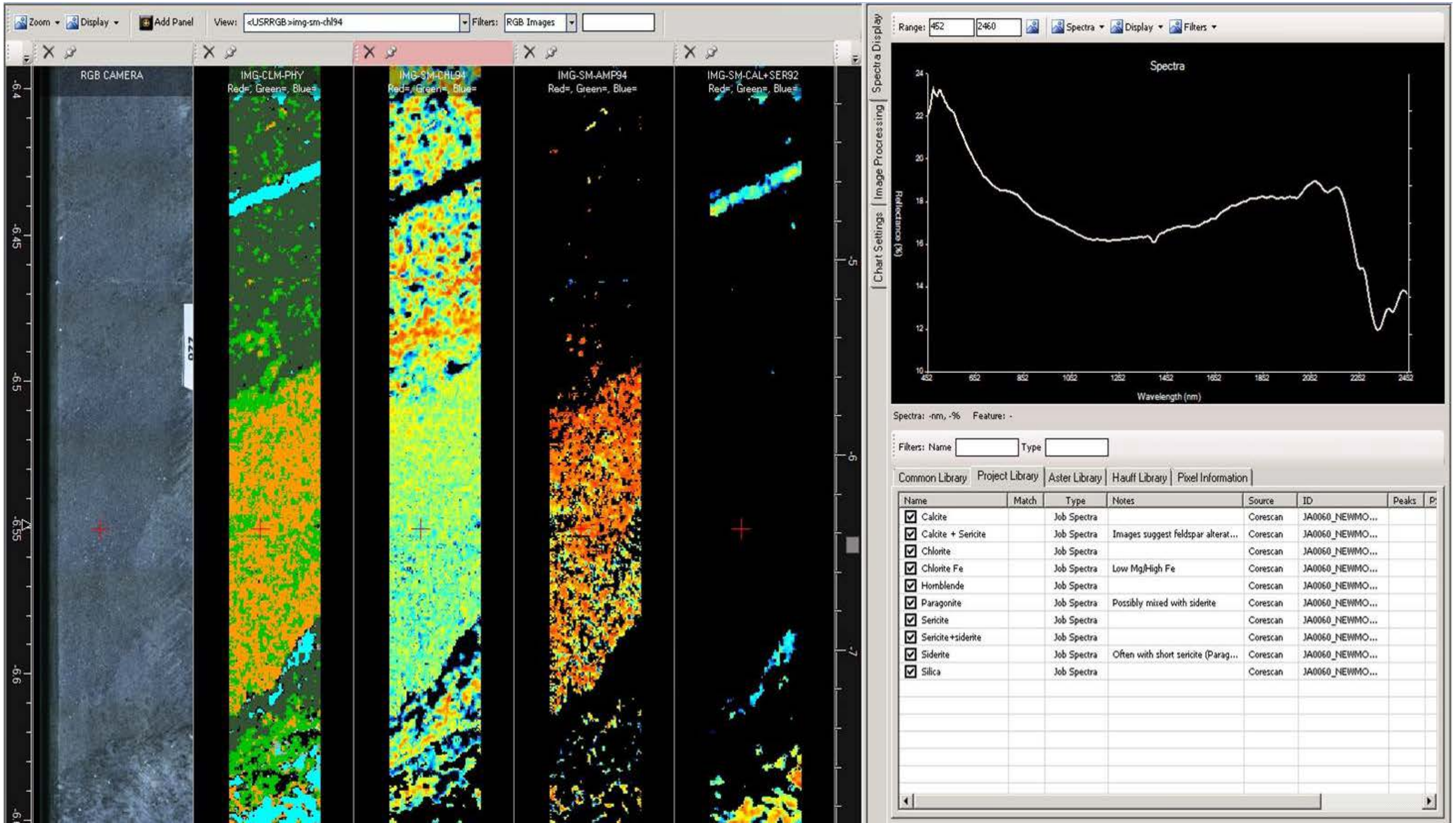
Data Processing and Interpretation



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DELIVERABLES

- Product & Project Summary Report
- Focus Area Summaries
- Mineral Keys
  1. Match Images
  2. Mineral keys
- Mineral Logs
- Public Coreshed *Global unveiling!*

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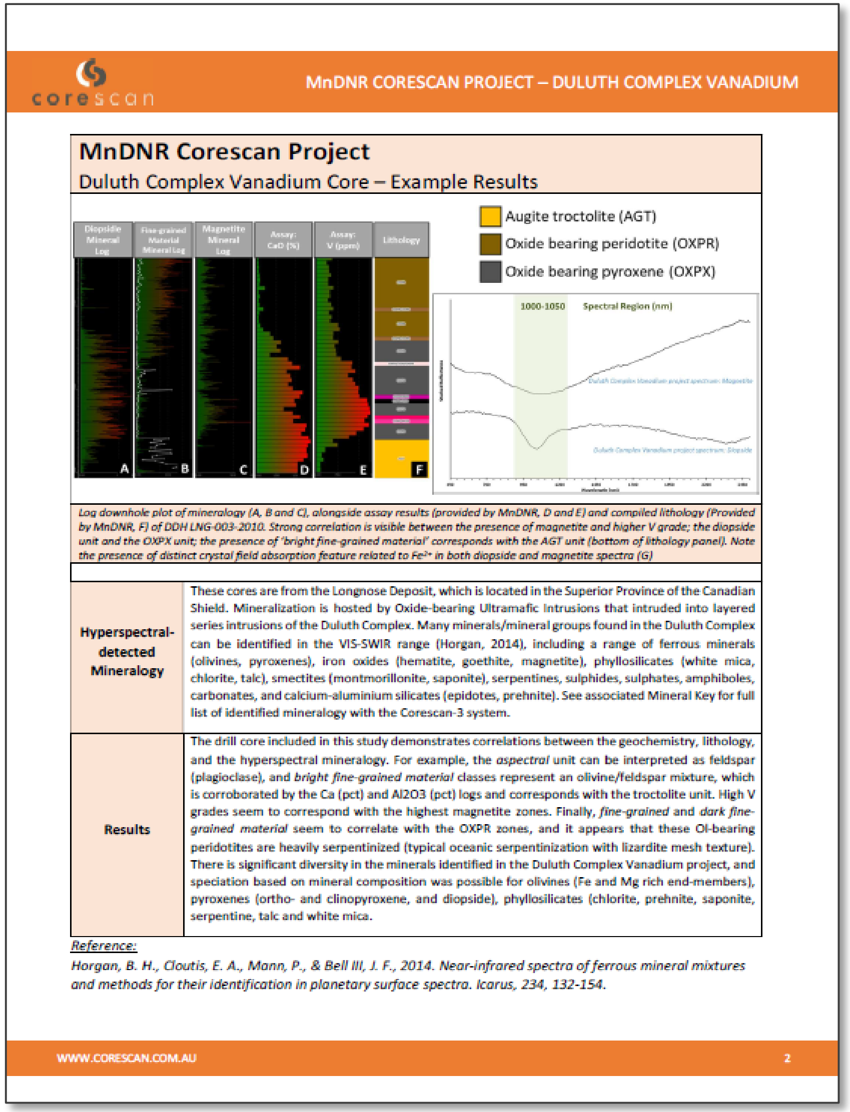
Project Summary Report

- 20+ page document detailing…
  - the Corescan instrumentation (spectral and spatial resolution) of cameras (x4) and laser profiler
  - Geotechnical data
  - Hyperspectral data & Processed products
    - RGB imagery
    - Mineral imagery/maps

Focus Area Summary Reports



MnDNR Corescan Project

Duluth Complex Vanadium Core – Example Results

Log downhole plot of mineralogy (A, B and C), alongside assay results (provided by MnDNR, D and E) and compiled lithology (Provided by MnDNR, F) of DDH LNG-003-2010. Strong correlation is visible between the presence of magnetite and higher V grade; the diopside unit and the OXPX unit; the presence of 'bright fine-grained material' corresponds with the AGT unit (bottom of lithology panel). Note the presence of distinct crystal field absorption feature related to Fe^{2+} in both diopside and magnetite spectra (G)

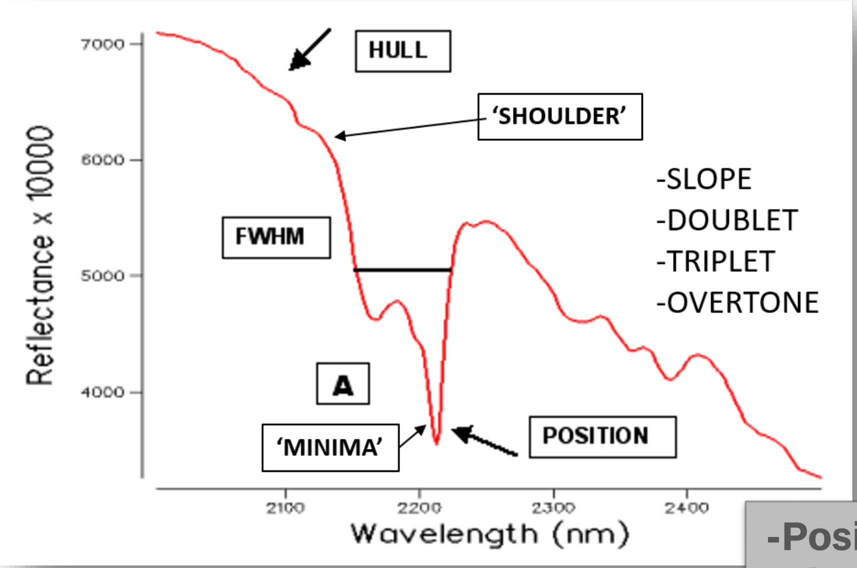
Hyperspectral-detected Mineralogy	These cores are from the Longnose Deposit, which is located in the Superior Province of the Canadian Shield. Mineralization is hosted by Oxide-bearing Ultramafic Intrusions that intruded into layered series intrusions of the Duluth Complex. Many minerals/mineral groups found in the Duluth Complex can be identified in the VIS-SWIR range (Horgan, 2014), including a range of ferrous minerals (olivines, pyroxenes), iron oxides (hematite, goethite, magnetite), phyllosilicates (white mica, chlorite, talc), smectites (montmorillonite, saponite), serpentines, sulphides, sulphates, amphiboles, carbonates, and calcium-aluminium silicates (epidotes, prehnite). See associated Mineral Key for full list of identified mineralogy with the Corescan-3 system.
Results	The drill core included in this study demonstrates correlations between the geochemistry, lithology, and the hyperspectral mineralogy. For example, the *aspectral* unit can be interpreted as feldspar (plagioclase), and *bright fine-grained material* classes represent an olivine/feldspar mixture, which is corroborated by the Ca (pct) and Al2O3 (pct) logs and corresponds with the troctolite unit. High V grades seem to correspond with the highest magnetite zones. Finally, *fine-grained* and *dark fine-grained material* seem to correlate with the OXPR zones, and it appears that these Ol-bearing peridotites are heavily serpentinized (typical oceanic serpentinization with lizardite mesh texture). There is significant diversity in the minerals identified in the Duluth Complex Vanadium project, and speciation based on mineral composition was possible for olivines (Fe and Mg rich end-members), pyroxenes (ortho- and clinopyroxene, and diopside), phyllosilicates (chlorite, prehnite, saponite, serpentine, talc and white mica.

Reference:

Horgan, B. H., Cloutis, E. A., Mann, P., & Bell III, J. F., 2014. Near-infrared spectra of ferrous mineral mixtures and methods for their identification in planetary surface spectra. Icarus, 234, 132-154.

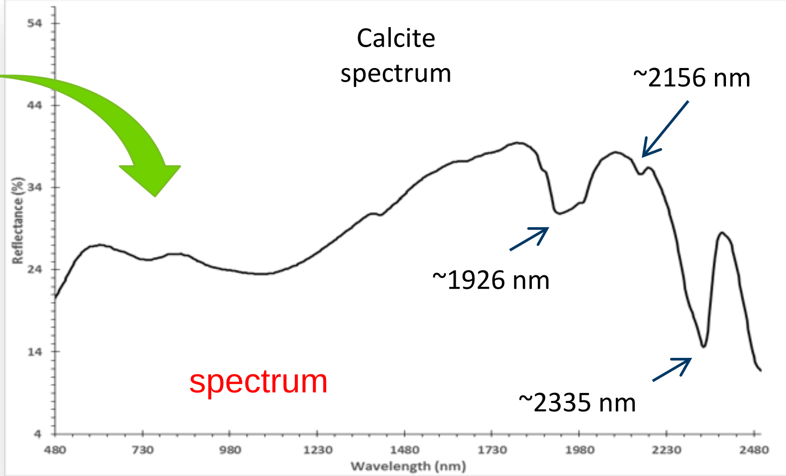
Mineral Keys Step #1: Match images

- Spectral signatures are mineral "fingerprints"
- Each spectrum from pixel making up the hyperspectral image is compared to the mineral library



-Position
-Shape
-Depth
-Width

50µm Core Photo



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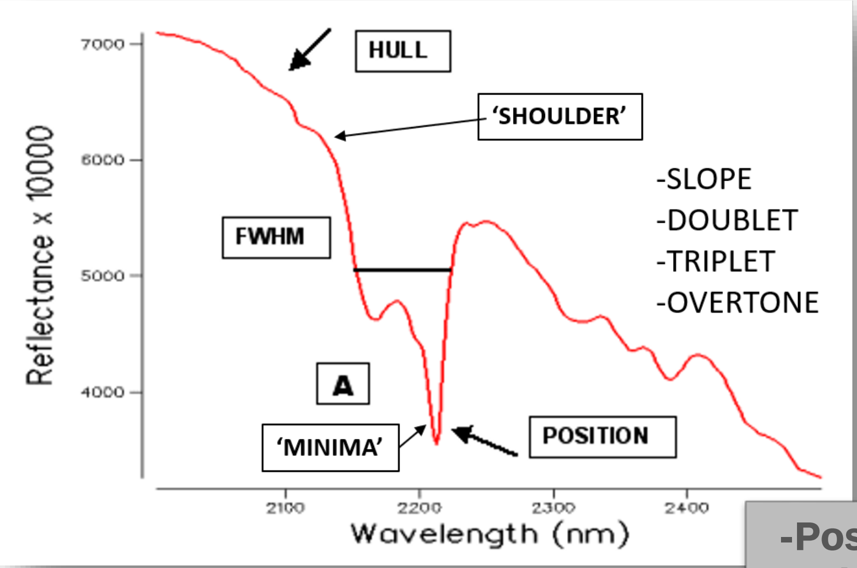
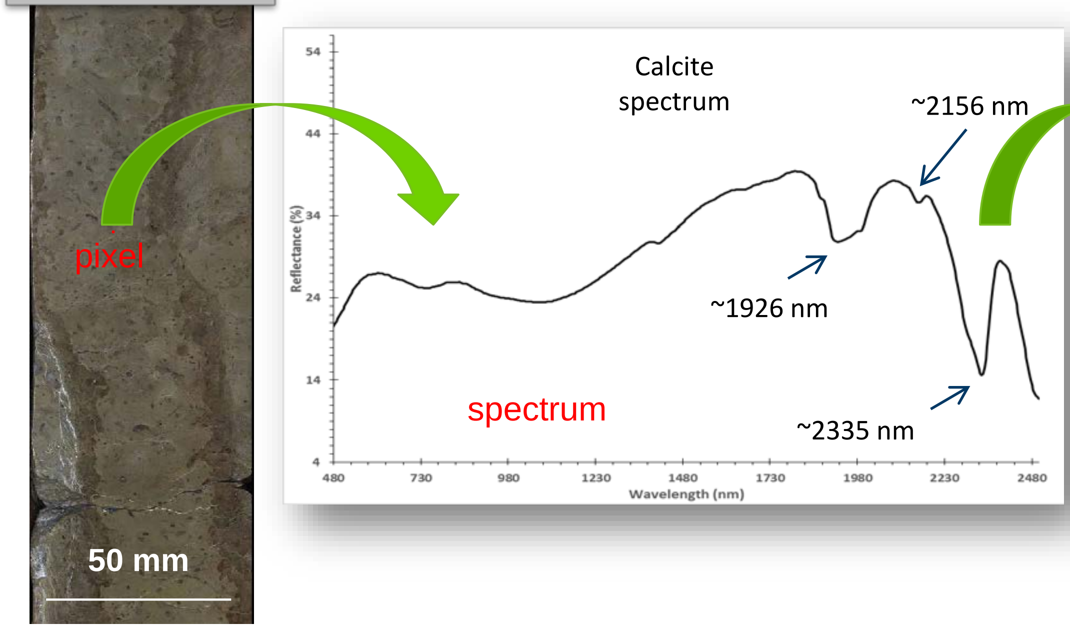
Mineral Keys Step #1: Match images

- How well each spectrum matches the library mineral is then assigned to each pixel (as a match value)
- Pixels coloured by match values create a "match map"

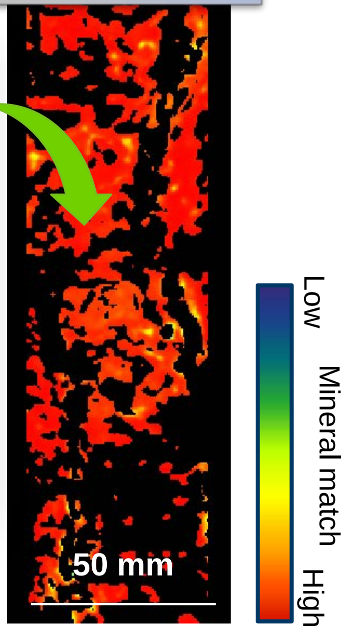


-Position
-Shape
-Depth
-Width

50µm Core Photo



Calcite Match



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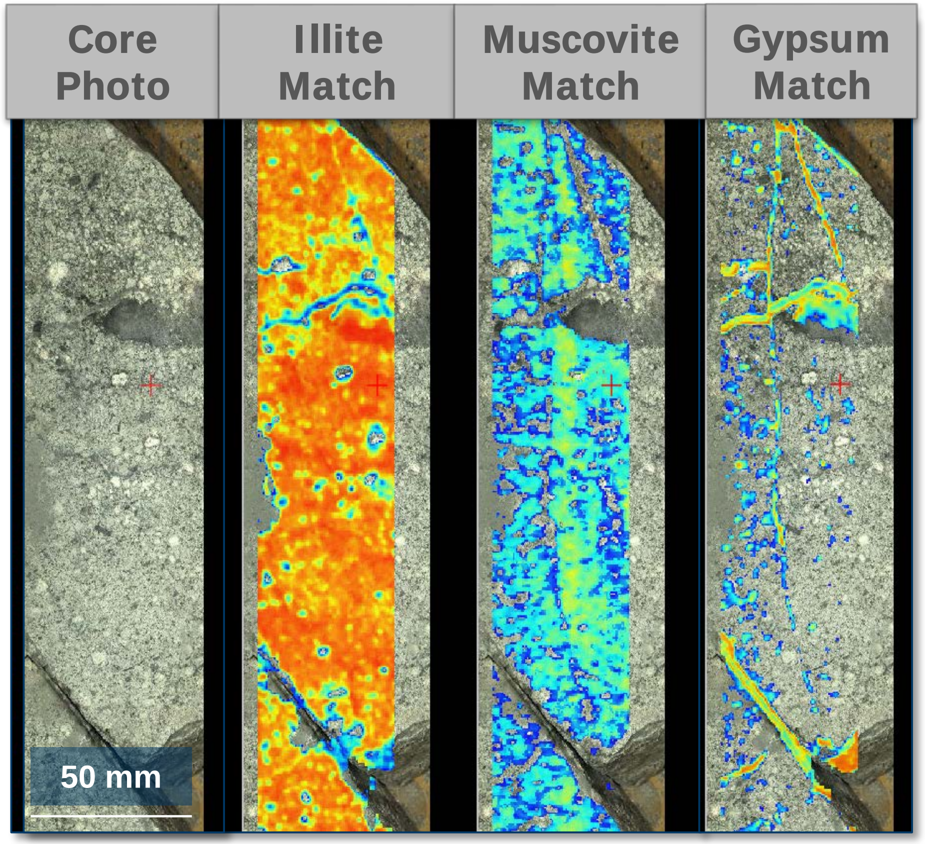
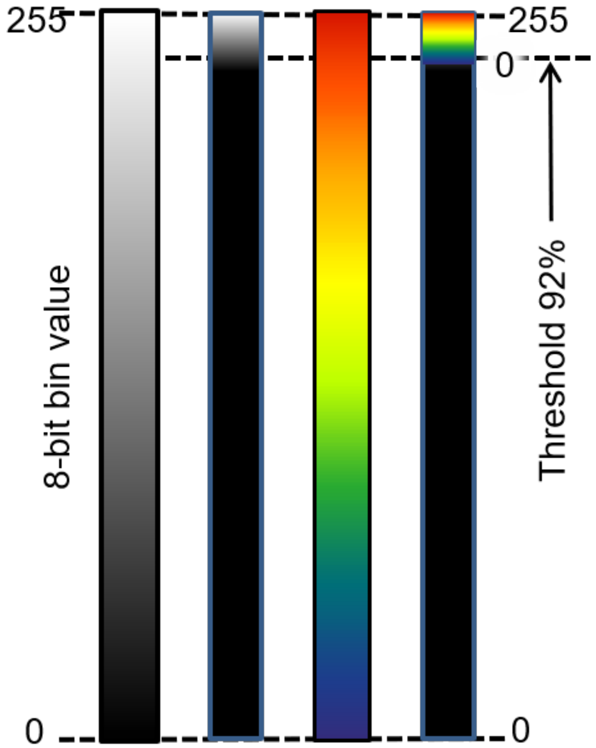
Mineral Keys Step #1: Match images

Create match images and verify quality of match

- Thresholds selected by quantitative comparison to known spectral behaviour as well as qualitative mapping processes





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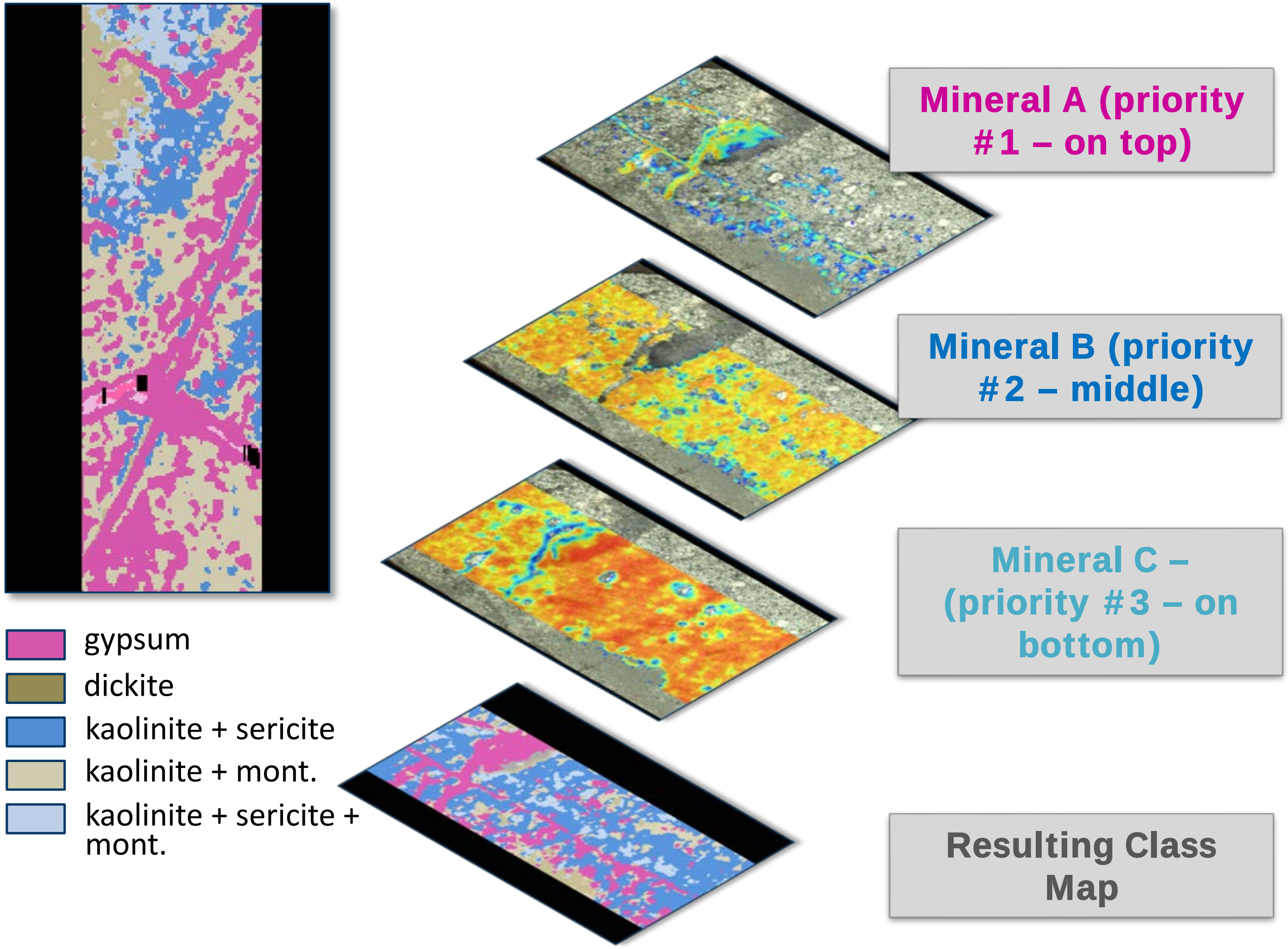
Mineral Keys Step #2: Class Maps

Create mineral class map

- Considers minerals matched at each pixel and allocates colour based on mineral with the highest priority (defined by spectral geologist)
- Priority selected to enhance texture/mineral relationships



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International Falls Mineral Key & Match Thresholds

Mineral Name	Colour	RGB Code
Tourmaline		167,37,255
Garnet		255,151,151
Green Mica		58,102,156
Talc		0,255,0
Epidote		188,255,55
Prehnite		155,187,89
Zeolite		255,237,105
Biotite		128,0,0
Amphibole		52,82,52
Carbonate (Fe-rich)		185,255,255
Carbonate		0,255,255
Sepiolite		196,215,155
Hydrous Silica/Quartz		250,250,250
Montmorillonite		175,175,175
White Mica + Chlorite*		148,138,84
White Mica + Aspectral*		188,207,230
Gypsum		213,87,171
White mica		83,141,213
Chlorite		0,191,0
Amphibole (Fe-rich)		45,95,45
Orthopyroxene		112,104,64
Clinopyroxene		168,128,0
Aspectral		209,209,209
Aspectral 2		166,166,166
Aspectral (Fe-rich)		0,108,105

First

Display Priority

Last

***Only displayed in the class map**

Image	Measurement*	Lower Threshold	Upper Threshold
Amphibole 2310nm wavelength	L2310	2310nm	2334nm
Biotite 2250nm wavelength	L2250	2245nm	2252nm
Carbonate (all) 2340nm wavelength	L2340	2315nm	2345nm
Chlorite 2250nm wavelength	L2250	2249nm	2262nm
Epidote 1550nm wavelength	L1550	1548nm	1558nm
Tourmaline 2200nm wavelength	L2200	2200nm	2205nm
Tourmaline 2350nm crystallinity	$(D2350^2)/A2350$	0.0001	0.001
Tourmaline 2350nm wavelength	L2350	2350nm	2365nm
Tourmaline Fe-slope	R1850/R1350	0.75	1.25
White Mica (all) 220nm crystallinity	$(D2200^2)/A2200$	0.001	0.008
White Mica (all) 2200nm wavelength	L2200	2195nm	2215nm

*L = wavelength (in nm) at feature minimum, R = reflectance, A = area, D = depth at feature minimum

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Cuyuna Range Manganese Mineral Key & Match Thresholds

Mineral Name	Colour	RGB Code
Amphibole		52,82,52
Chlorite		0,192,0
Carbonate		0,255,255
Goethite		255,153,0
White Mica (NH4-rich)		70,70,220
Carbonate (Fe-rich)		0,108,105
Smectite (Fe-rich)		95,100,200
Nontronite		105,105,255
Montmorillonite		175,175,255
White Mica		58,102,156
Hydrous Silica/Quartz		0,176,240
Kaolinite		148,138,84
Chert		209,209,209
Jasper		255,0,0
Microplaty Hematite		168,128,0
Hematite		204,102,0
Magnetite		95,95,95
Sediment		128,0,0
Sediment Mn?		168,0,0
Dark Sediment		88,0,0

**Only displayed in the class map*

First

Display Priority

Last

Image	Measurement*	Lower Threshold	Upper Threshold
Carbonate (all) 2340nm wavelength	L2340	2330nm	2338nm
Chlorite 2250nm wavelength	L2250	2245nm	2255nm
Iron oxide 900nm wavelength	L900	860nm	920nm
Kaolinite 2284nm crystallinity	R2184/R2164	0.94	1.01
White Mica 2200nm crystallinity	$(D2200^2)/A2200$	0	0.003
White Mica 2200nm wavelength	L2200	2200nm	2215nm

*L = wavelength (in nm) at feature minimum, R = reflectance, A = area, D = depth at feature minimum

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Duluth Complex Vanadium Mineral Key & Match Thresholds

Mineral Name	RGB Code	Colour
Sulphide 1	255,0,255	
Sulphide 2	167,37,255	
Iddingsite*	151,71,0	
Goethite	255,153,0	
Hematite	204,102,0	
Natrolite	190,160,200	
Saponite	70,70,220	
Smectite (Mg-rich)	105,105,255	
Montmorillonite	175,175,255	
White Mica + Chlorite*	188,207,230	
White Mica	58,102,156	
Epidote	196,215,155	
Chlorite	155,187,89	
Calcite	0,255,255	
Prehnite	83,141,213	
Amphibole	50,50,80	
Talc (Fe-rich)	255,151,151	
Talc	255,200,200	
Phlogopite	237,185,220	
Antigorite	44,109,0	
Serpentine 2	45,95,45	
Serpentine 1	52,82,52	
Serpentinised Olivine	200,220,115	
Serpentinised Pyroxene	0,108,105	
Magnetite	95,95,95	
Orthopyroxene	191,183,143	
Clinopyroxene	0,219,214	
Diopside	0,176,172	
Olivine (Fe-rich)	255,255,20	
Olivine (MgFe-rich)	223,255,159	
Olivine (Mg-rich)	188,255,55	
Aspectral	209,209,209	
Bright Fine-grained Material	255,0,0	
Fine-grained Material	128,0,0	
Dark Fine-grained Material	88,0,0	

*only displayed in the class map

Display Priority: *First* (top) → *Last* (bottom)

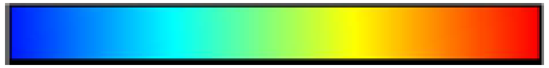

Image	Measurement*	Lower Threshold	Upper Threshold
Pyroxene – Olivine 1000nm wavelength	L1000nm	900	1100

*L = wavelength (in nm) at feature minimum, R = reflectance, A = area, D = depth at feature minimum

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Mineral Logs

It's just counting

Hyperspectral cube = 100% of VNIR-SWIR minerals

Mineral interpretation

Pixel Count →

2
5
5

= **12**

Assumptions and facts:

- Unclassified is not a mixed pixel
- In mixed pixels each mineral contributes equally to the spectrum of that pixel, not an incorrect assumption as we statistically work with very large populations

Mineral logs

Pixel Count →

1+1=2
1+½+1+1+½=4
½+1+½+1+1=4

= **10**

Convert to percentage(%)

(2/10)*100=20%
(4/10)*100=40%
(4/10)*100=40%

= **100**

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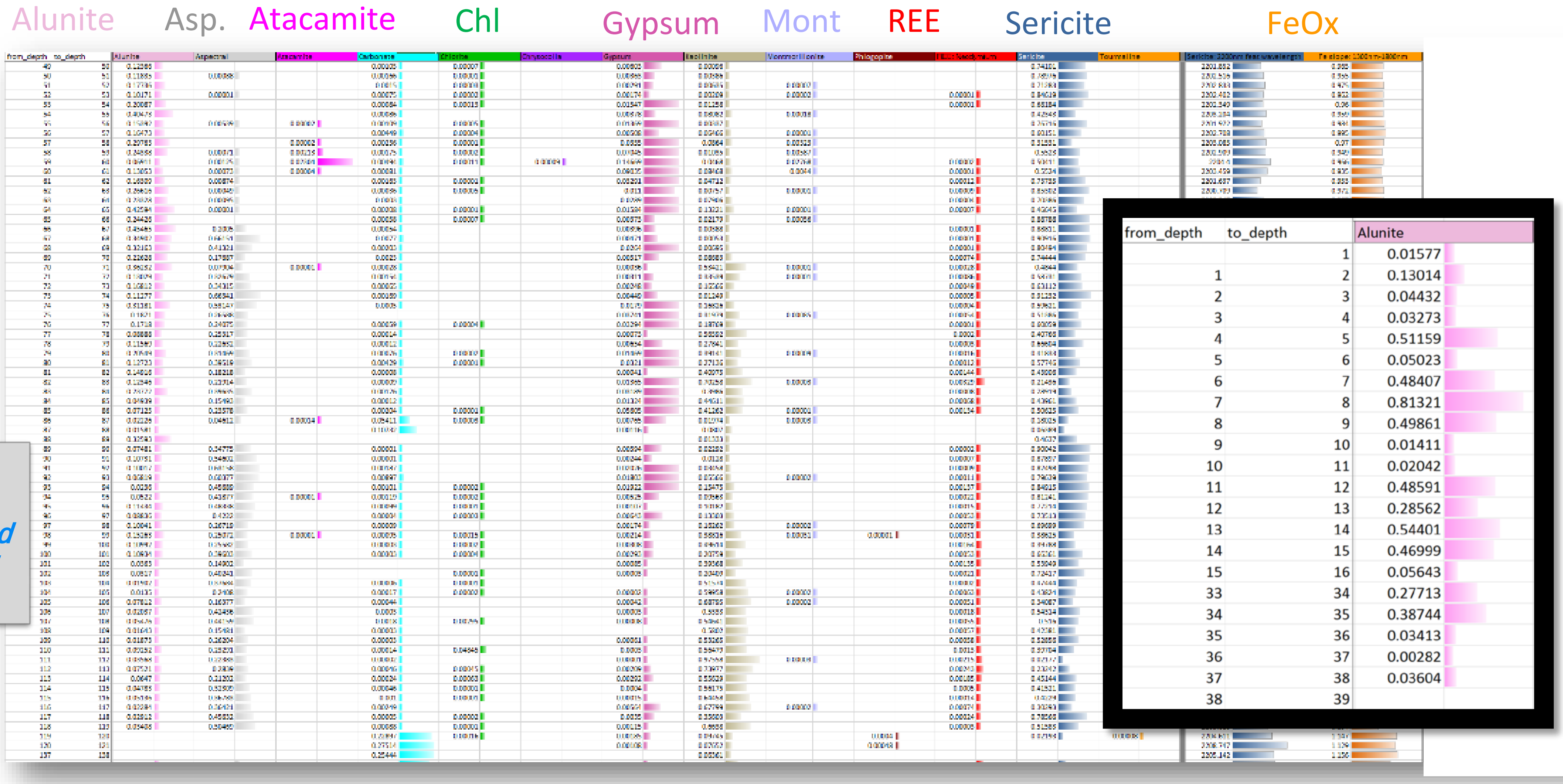
Quantitative Spectroscopy

Hundreds of thousands mineralogical datapoints exported into .csv files at desired intervals

Easy import into third-party software for statistical and 3D analysis

Used to build improved, consistent geological models and optimise process and metallurgy



from_depth	to_depth	Alunite
	1	0.01577
1	2	0.13014
2	3	0.04432
3	4	0.03273
4	5	0.51159
5	6	0.05023
6	7	0.48407
7	8	0.81321
8	9	0.49861
9	10	0.01411
10	11	0.02042
11	12	0.48591
12	13	0.28562
13	14	0.54401
14	15	0.46999
15	16	0.05643
33	34	0.27713
34	35	0.38744
35	36	0.03413
36	37	0.00282
37	38	0.03604
38	39	

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Coreshed

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Admin Mode | Britt Bluemel | Log Out

Dashboard | Drill Hole View | Core Tray View

Project

mdnr

Name	Region
MDNR - Animikie	Minnesota
MDNR - Animikie SEDEX	Minnesota
MDNR - Biwabik Iron Formation	Minnesota
MDNR - Cuyuna Range Manganese	Minnesota
MDNR - Duluth Complex Vanadium	Minnesota
MDNR - International Falls Greenstone Belt Gold	Minnesota

Showing 6 of 487 projects

Drill Hole

Details

- Project: MDNR - Animikie
- Project: MDNR - Animikie SEDEX
- Project: MDNR - Biwabik Iron Formation
- Project: MDNR - Cuyuna Range Manganese
- Project: MDNR - Duluth Complex Vanadium
- Project: MDNR - International Falls Greenstone Belt Gold

Project id	MDNR Core Library
Project name	MDNR - International Falls Greenstone Belt Gold
Project description	-
Customer id	MDNR
Location	USA
Region	Minnesota
Deposit type	Orogenic Gold
Record last updated	2/24/2019, 19:25:20

Inventory

Show all

Drill Holes

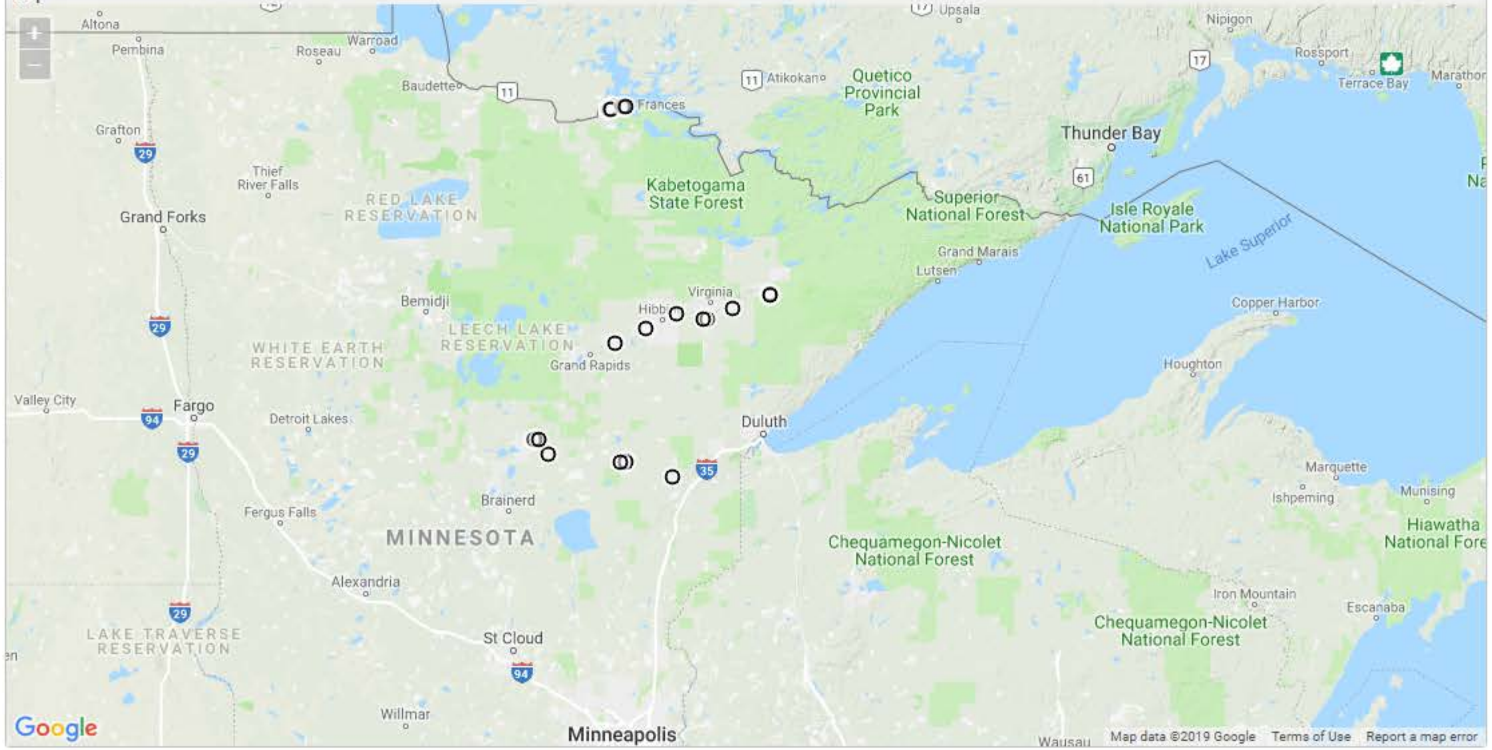
Drill holes	4996
Total length	839,919m (840km)

Products

Products	547696
Storage space used	29.2TB

Archive Storage

Map



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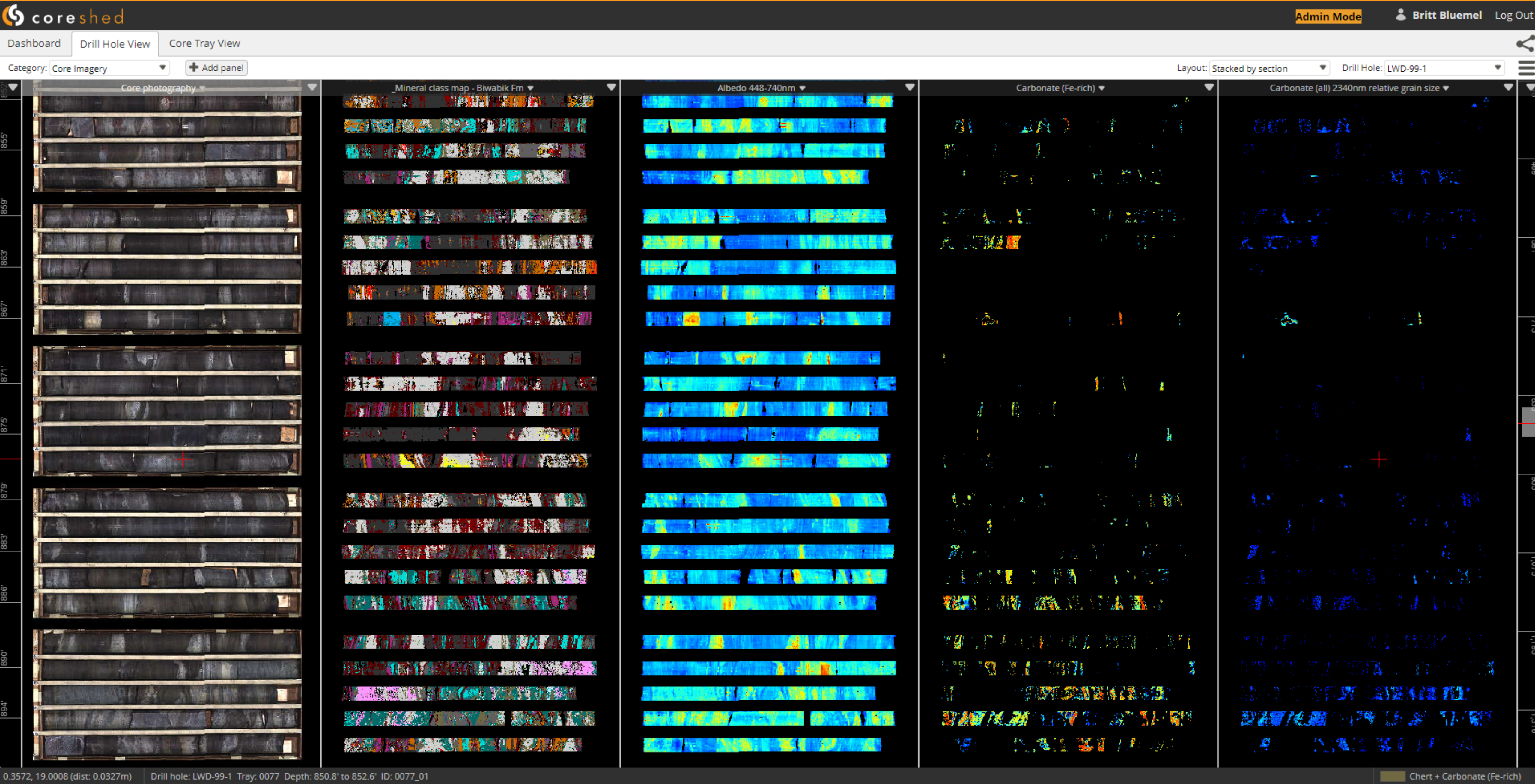

coreshed
Admin Mode
Britt Bluemel
Log Out
Dashboard
Drill Hole View
Core Tray View
Category: Core Imagery
Add panel
Layout: Stacked by section
Drill Hole: LWD-99-1
Core photography
_Mineral class map - Biwabik Fm
Albedo 448-740nm
Carbonate (Fe-rich)
Carbonate (all) 2340nm relative grain size
855'
859'
863'
867'
871'
875'
879'
883'
886'
890'
894'
0.3572, 19.0008 (dist: 0.0327m)
Drill hole: LWD-99-1 Tray: 0077 Depth: 850.8' to 852.6' ID: 0077_01
Chert + Carbonate (Fe-rich)

Final Product

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Thank you!

Britt Bluemel, MSc | Principal Geochemist, Corescan

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