



SpecTIR™

ProspecTIR V-S Hyperspectral Imagery Mineral Mapping from Airborne, Outcrop, and Drill-Core Perspectives

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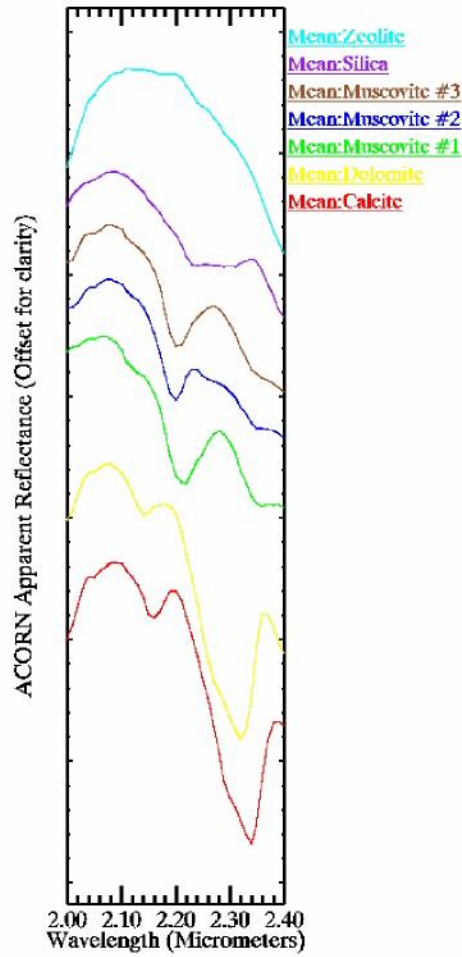
Presented at SIMENEX, Ouru Preto, Brazil -- 2010

end to end hyperspectral solutions

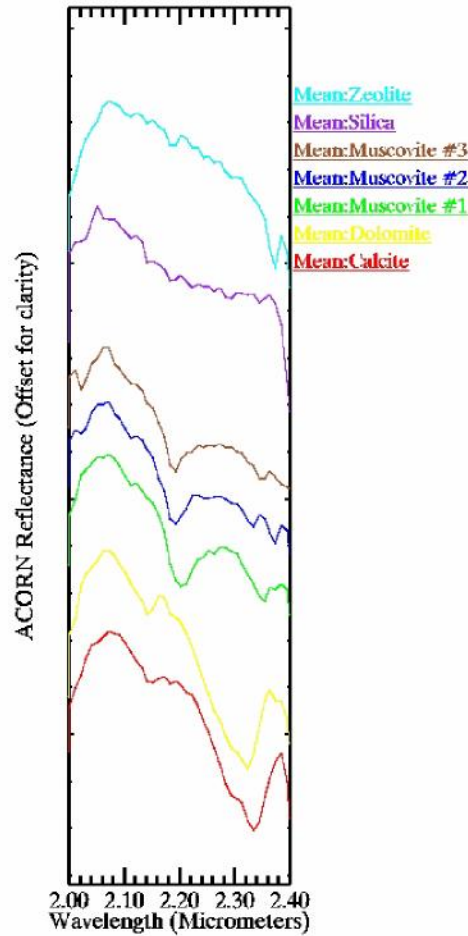


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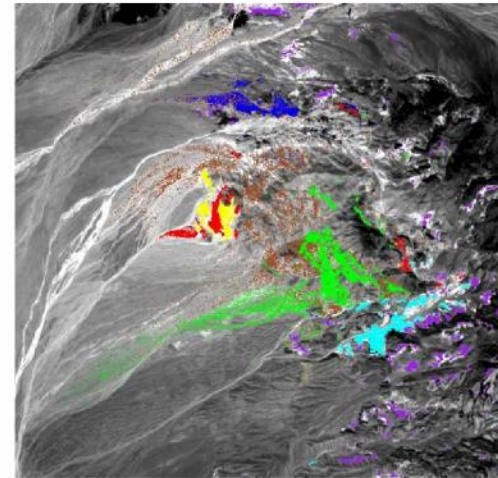
- Motivation
- ProSpecTIR HSI Instrument
- Trinity Mine Location and Overview
- Trinity Overflight Analysis
- Trinity Core Scan Analysis
- Trinity Mine Wall Scans
- Synthesis and Summary



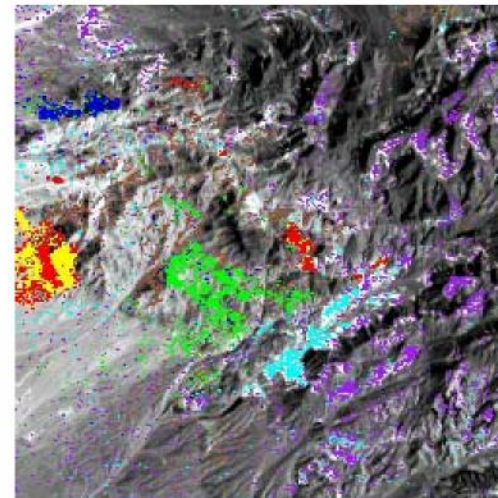
**AVIRIS
Endmembers**



**Hyperion
Endmembers**



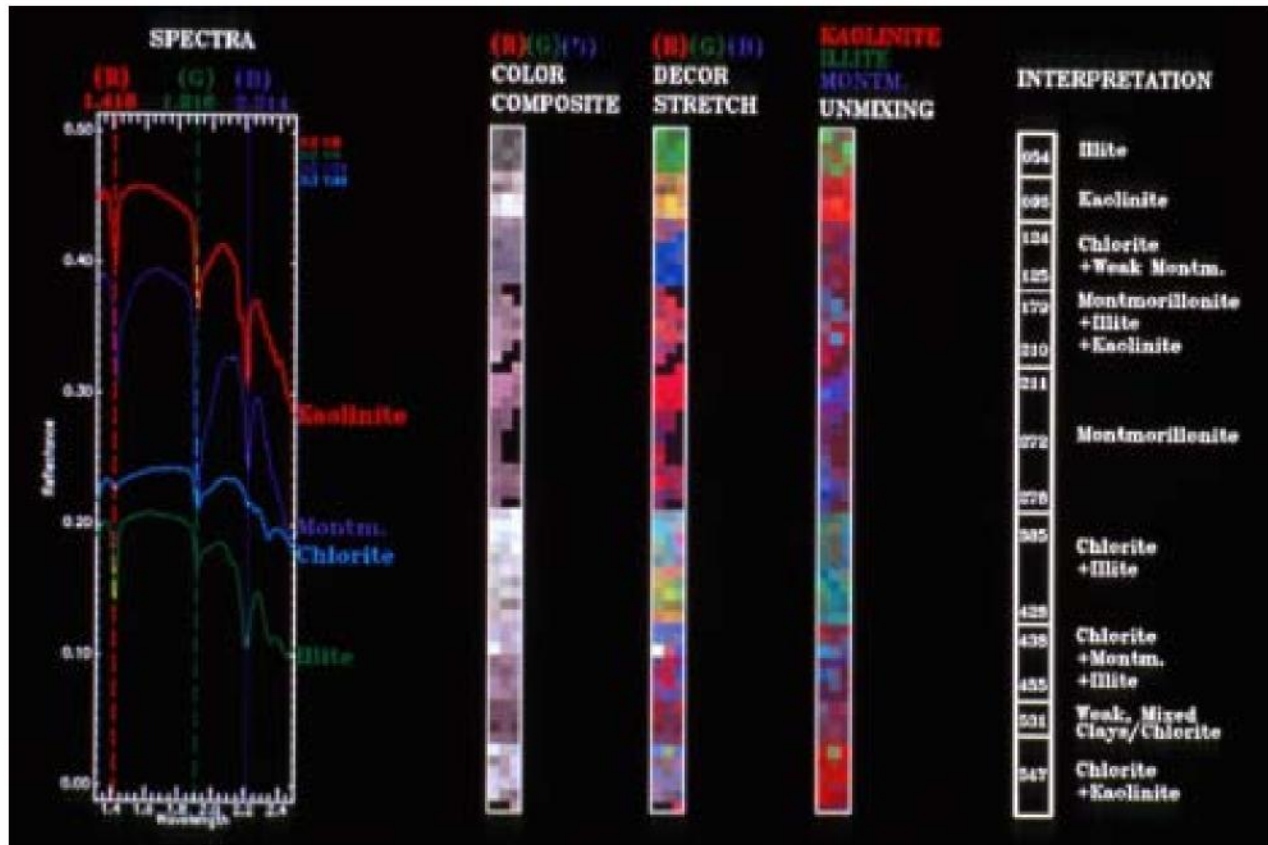
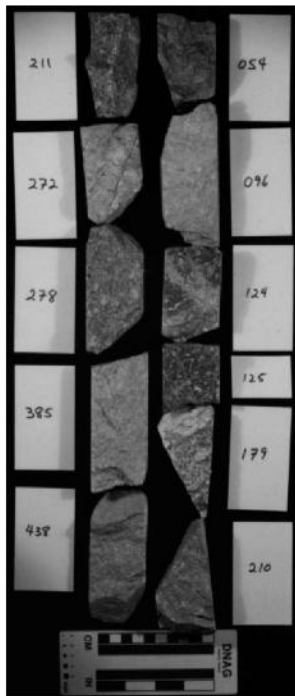
AVIRIS



Hyperion

Mineral Maps

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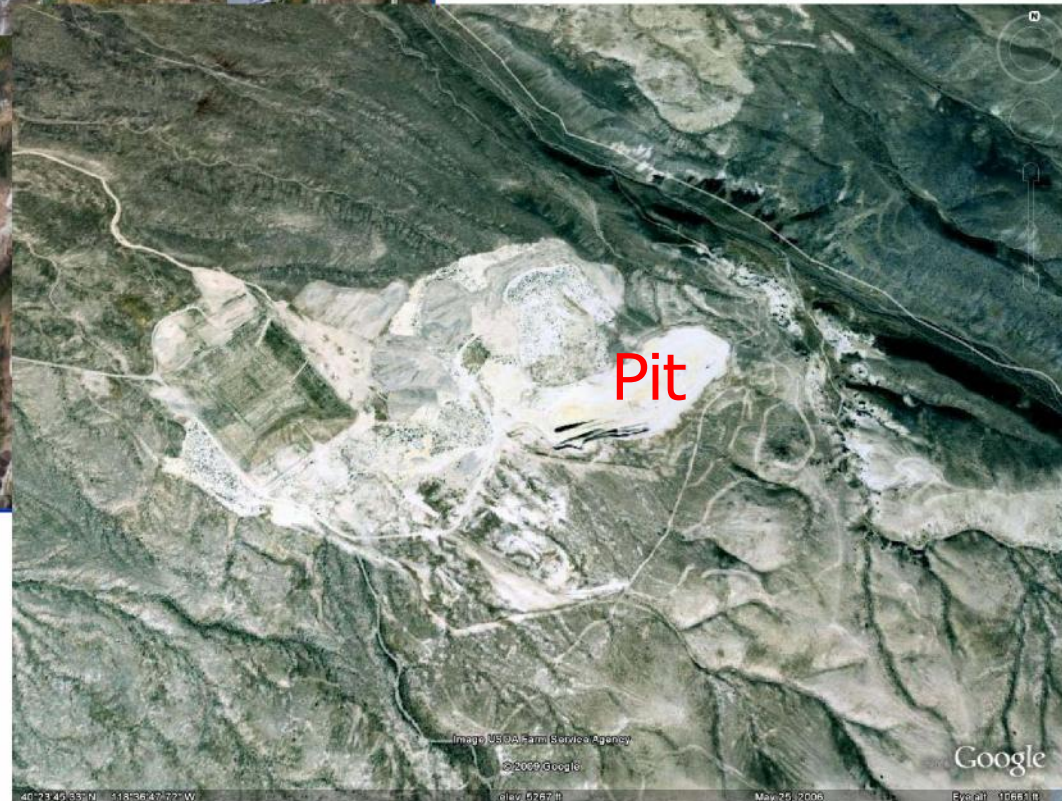
Kruse, F. A., 1996, Identification and mapping of minerals in drill core using hyperspectral image analysis of infrared reflectance spectra: International Journal of Remote Sensing, v. 17, no. 9, p. 1623 - 1632.

- In field and drilling need for distance measurements
 - During field checking of airborne data understanding of distant walls and rock outcrops were difficult
- ProSpecTIR HSI Scanner & Data Overview
 - ProSpecTIR (AISA) Dual HSI
 - 367 bands total (0.4 – 2.45 μ m)
 - ~5-nm spacing
 - Data calibrated to radiance using a NIST-traceable integrating sphere and for wavelength accuracy using a monochromator
- Three different ProSpecTIR Data Sets collected
 - Overflight data at approximately 1m spatial resolution
 - Core scans utilizing a custom scanning bed at ~2mm resolution
 - Mine wall scans using a truck-mounted configuration to ~4cm resolution
 - wavelength accuracy using a monochromator



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Trinity Mine True-Color Image (Google Earth)

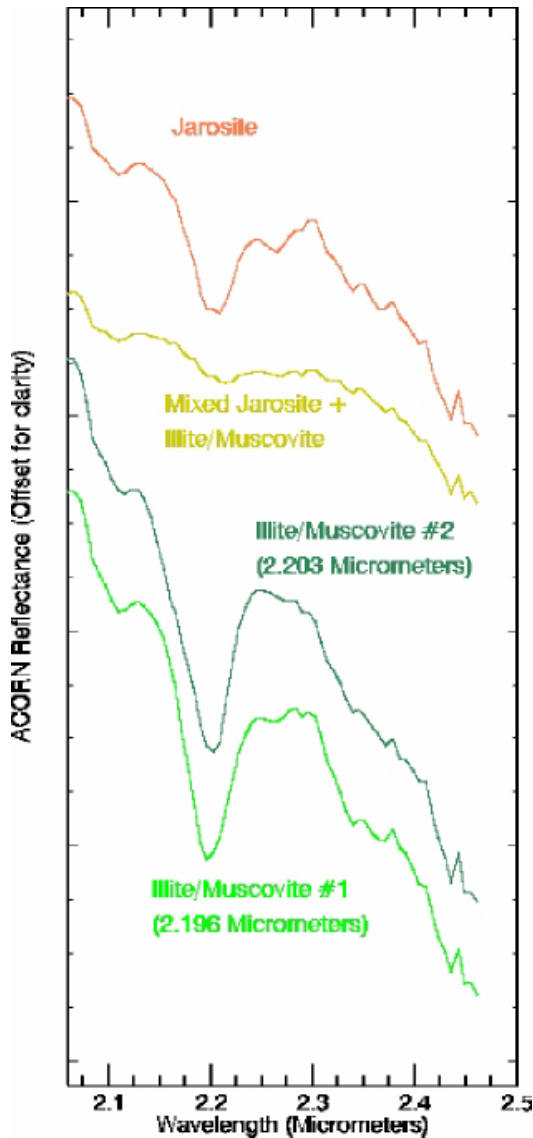


Location: Pershing County, NEVADA,
Approximately 150km NE of Reno

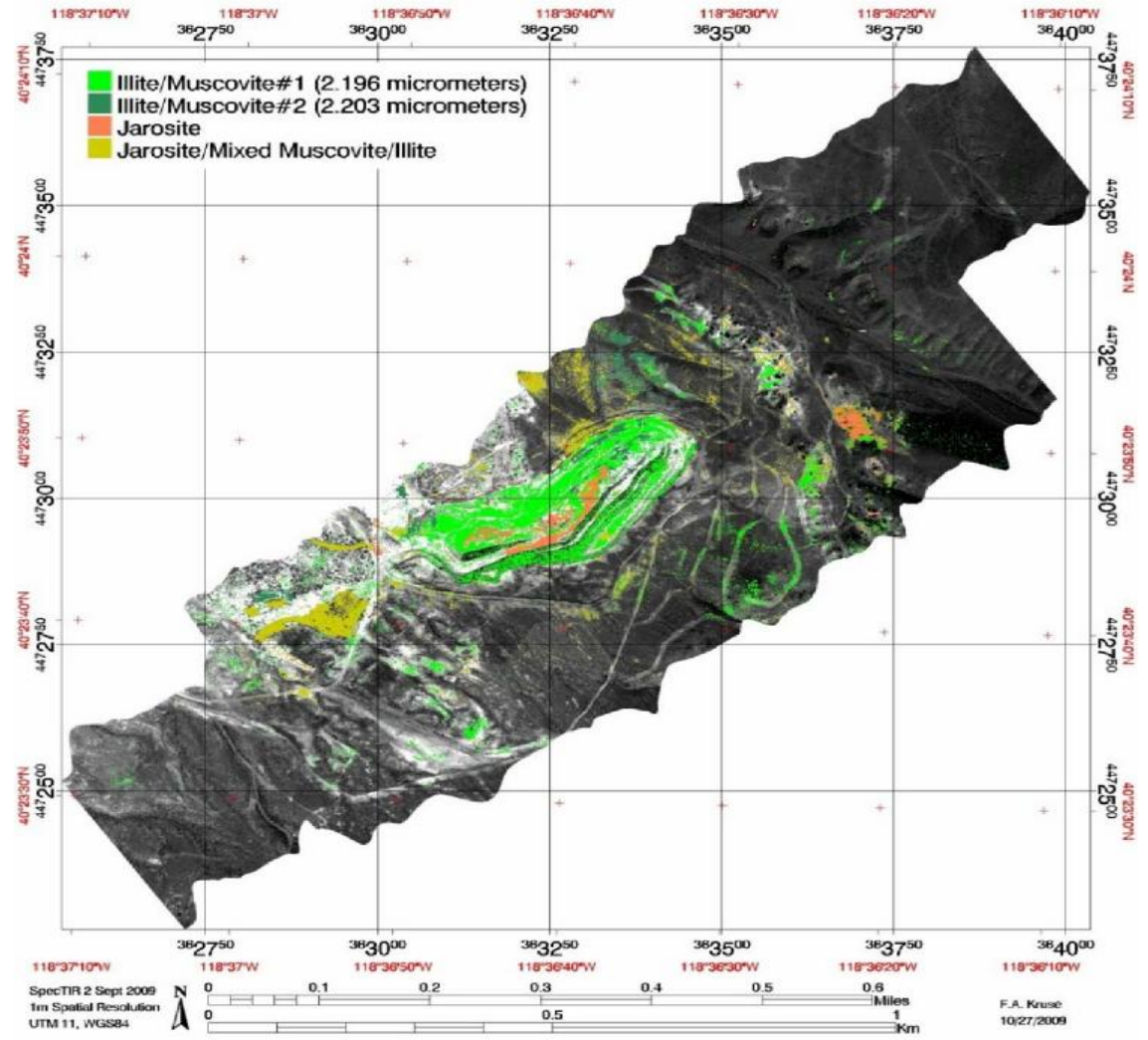
- The Trinity Silver Deposit was mined in the late 1980's by US Borax and actively mined for only 18 months. For one quarter it was the biggest silver producer in the USA.
- Geologically it is hosted in a high Sn rhyolite with silver selenides in breccias. This is very similar in occurrence to silver deposits in the Bolivian Tin Belt that includes some of the largest silver deposits in the world (Bedell, written communication, 2009)
- The age of mineralization was dated to be Oligocene ($^{40}\text{Ar}/^{39}\text{Ar}$ age of 25.111 ± 0.064 Ma) which is the same age as the Majuba Hill porphyry deposit to the north (John and Muntean, 2006)
- Structure in the pit is complex and not all relationships are understood. There are many faults at a variety of attitudes and orientations (Hudson, 2006).



- Several flightlines of VNIR/SWIR ProSpecTIR V-S data collected on 2 Sept 2009
- Calibrated to radiance using standard SpecTIR Process™
- Corrected to reflectance using ACORN atmospheric model
- VNIR/SWIR analyzed separately using end member extraction and MTMF to produce mineral maps
- Additional analysis of SWIR band depths and MF Abundance
- Geocorrected and mosaicked



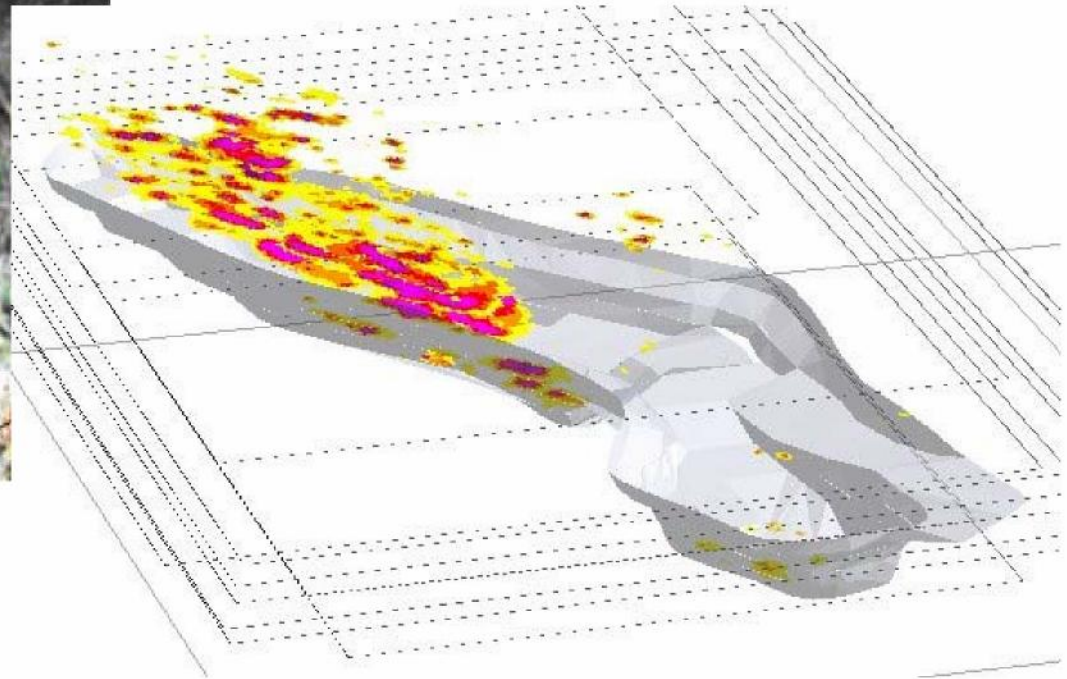
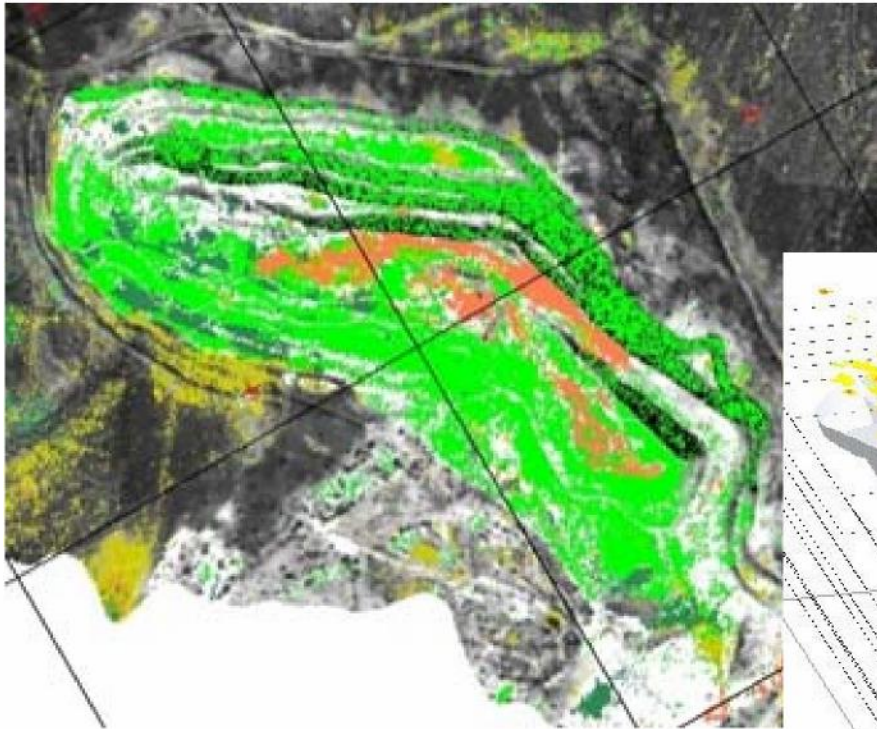
Trinity Mine, Pershing County, Nevada - SpecTIR SWIR MTMF Mineral Map





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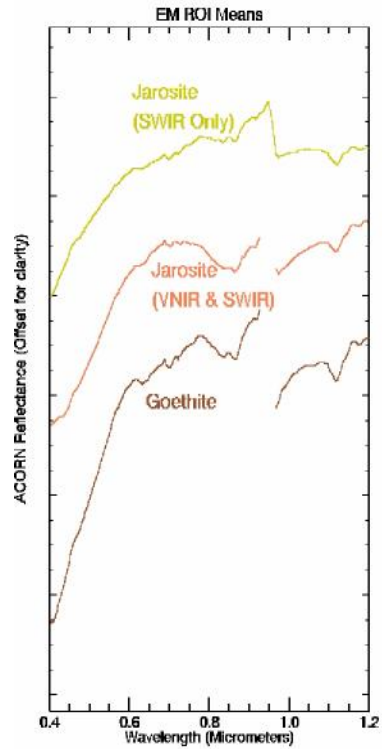
Trinity Mine SpectTIR SWIR Mineral Map vs Ore Grade



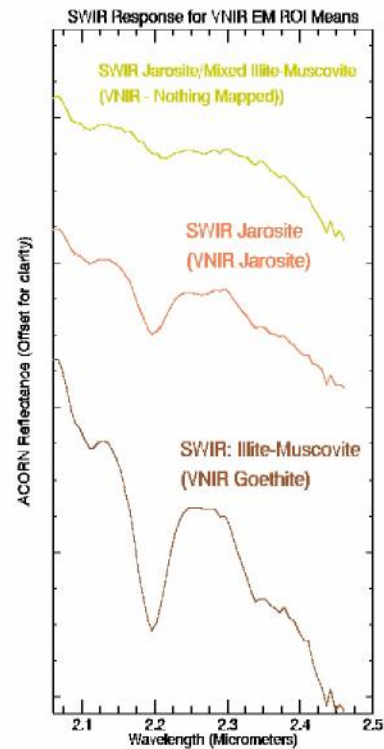
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Trinity Mine SpecTIR VNIR Mineral Map

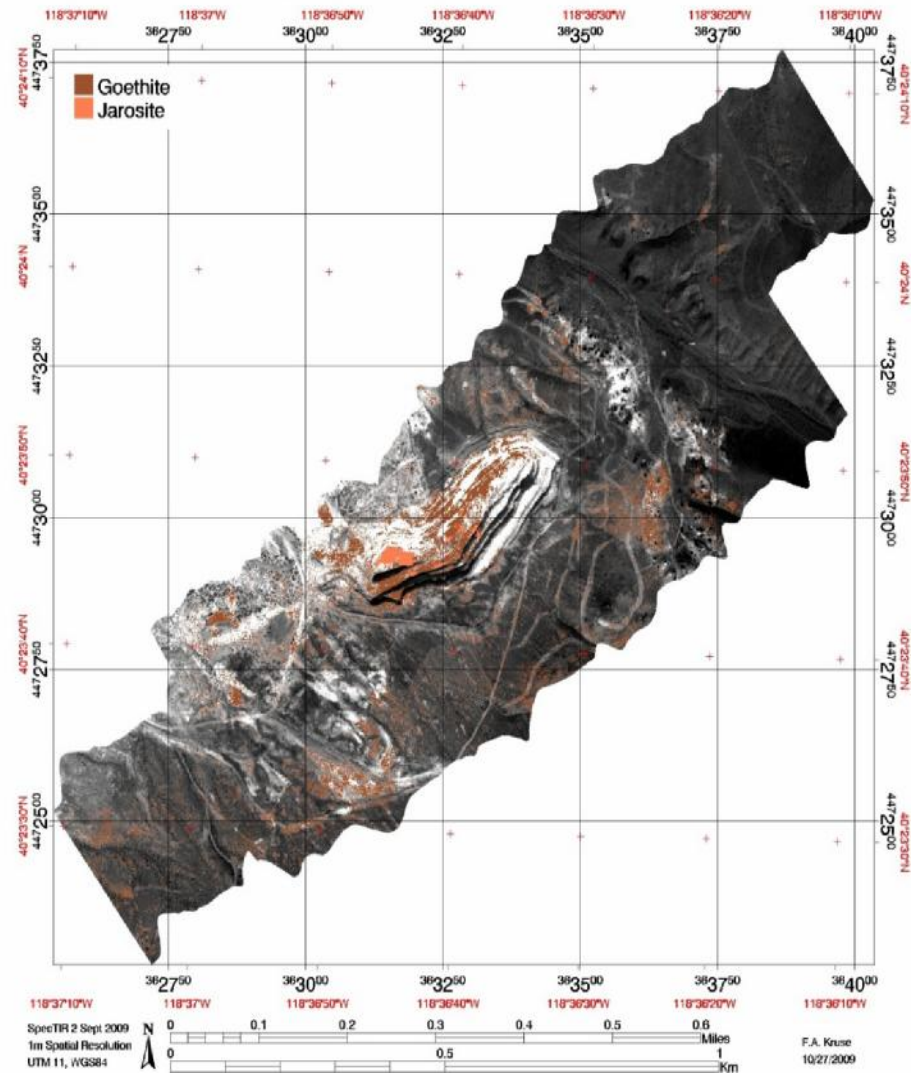


SWIR (not shown)



VNIR (see map)

Trinity Mine, Pershing County, Nevada - SpecTIR VNIR MTF Mineral Map

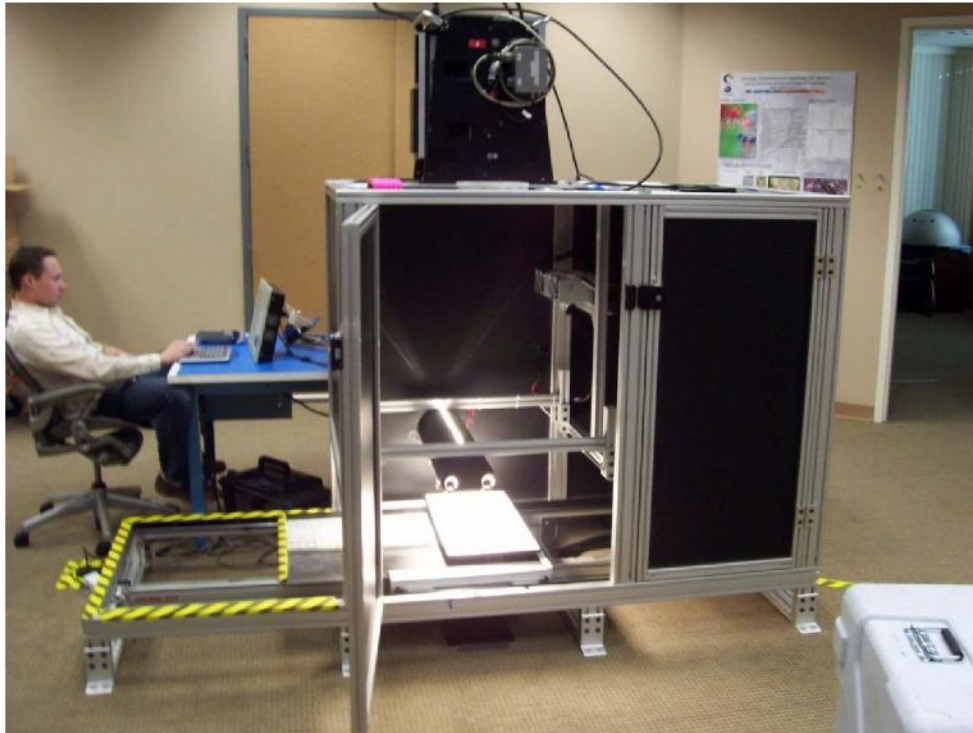


- SWIR shows principally illite-muscovite alteration with some jarosite
 - Evidence for possible Al substitution in illite-muscovite (short wavelength)
 - SWIR minerals mostly limited to the mined exposures on benches, but some possible extensions away from the mine
- VNIR shows Goethite, Jarosite
- Mixed, low concentration jarosite seen in SWIR data
- Jarosite correlation w/probable sulfide ore?



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Trinity Mine Drill Core Collection and Processing



- ProSpecTIR Scanner in custom configuration with scanning bed
- Scan core in boxes and acquire scan of Spectralon in same scan. (VNIR/SWIR test scans (357 bands 0.4– 2.45 micrometer), and several SWIR-only (236 bands, 0.98 – 2.45 micrometer) core scans performed
- Calibrate to radiance using standard SpecTIR Process™

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SpecTIR™

Trinity Mine Drill Core Collection and Processing



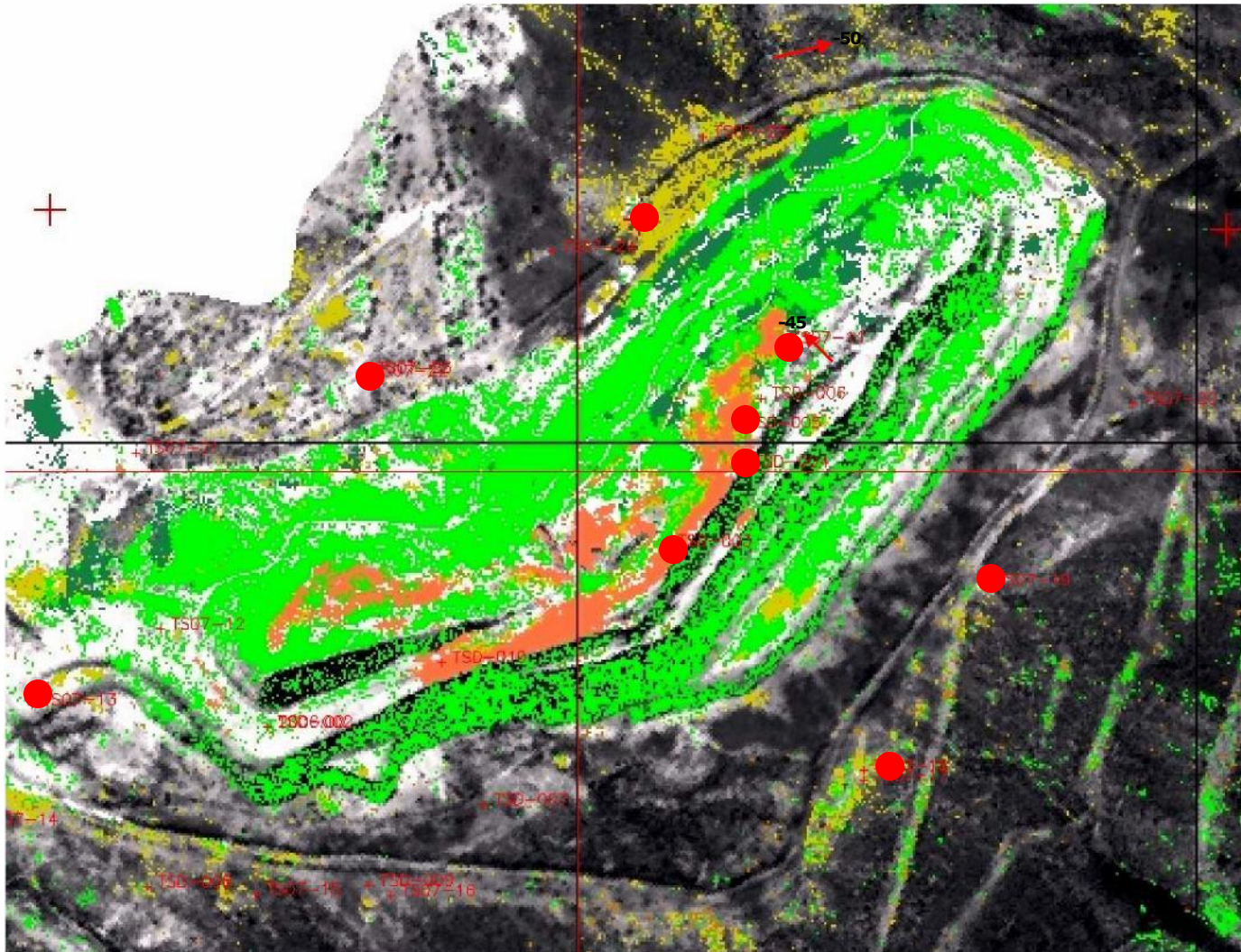
- Correct to reflectance using the Spectra Ion Panel
- Analyze full core boxes and/or stacked cores using endmember extraction and MTMF

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Trinity Mine Exploration Drill Locations



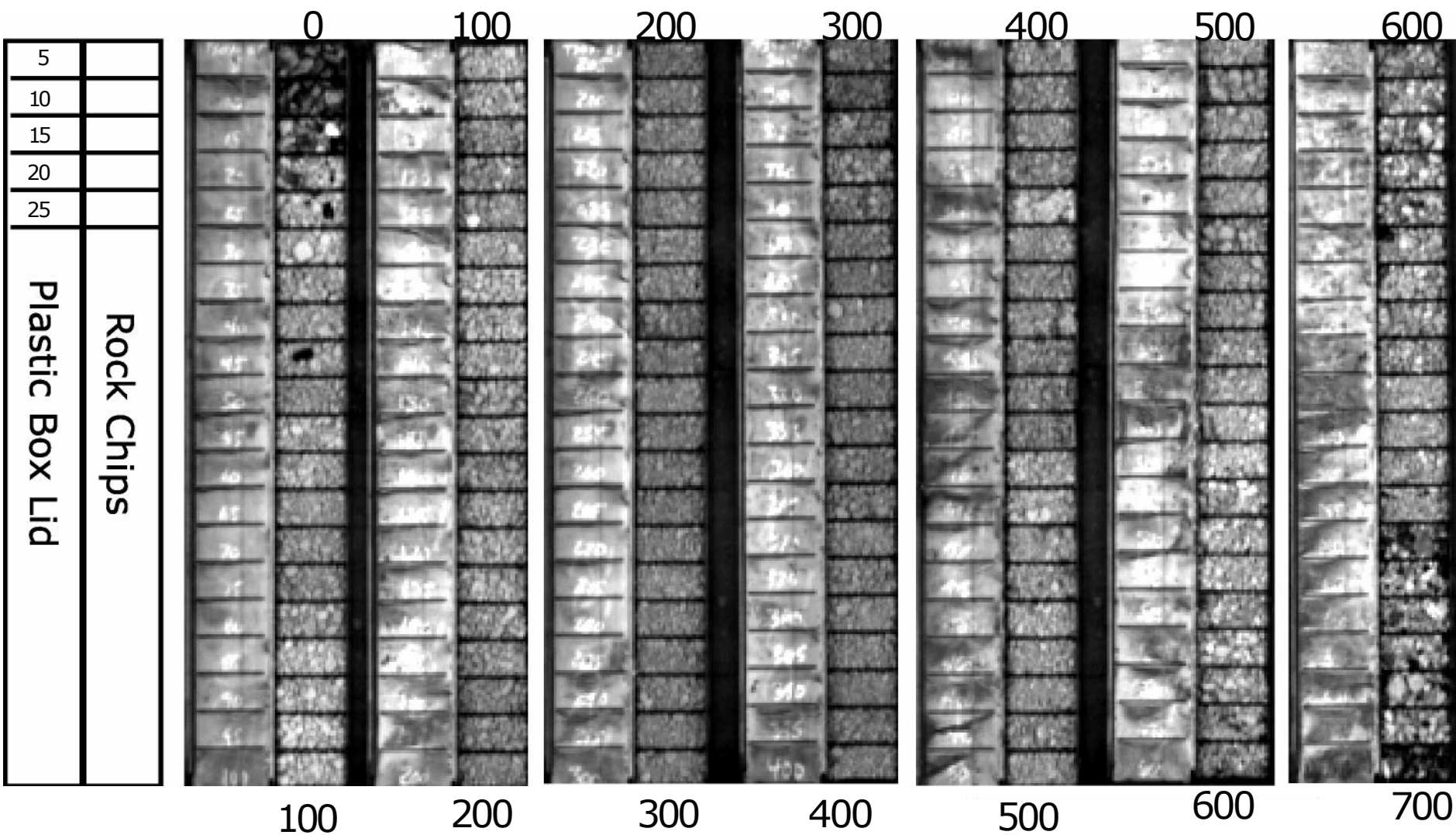
end to end hyperspectral solutions

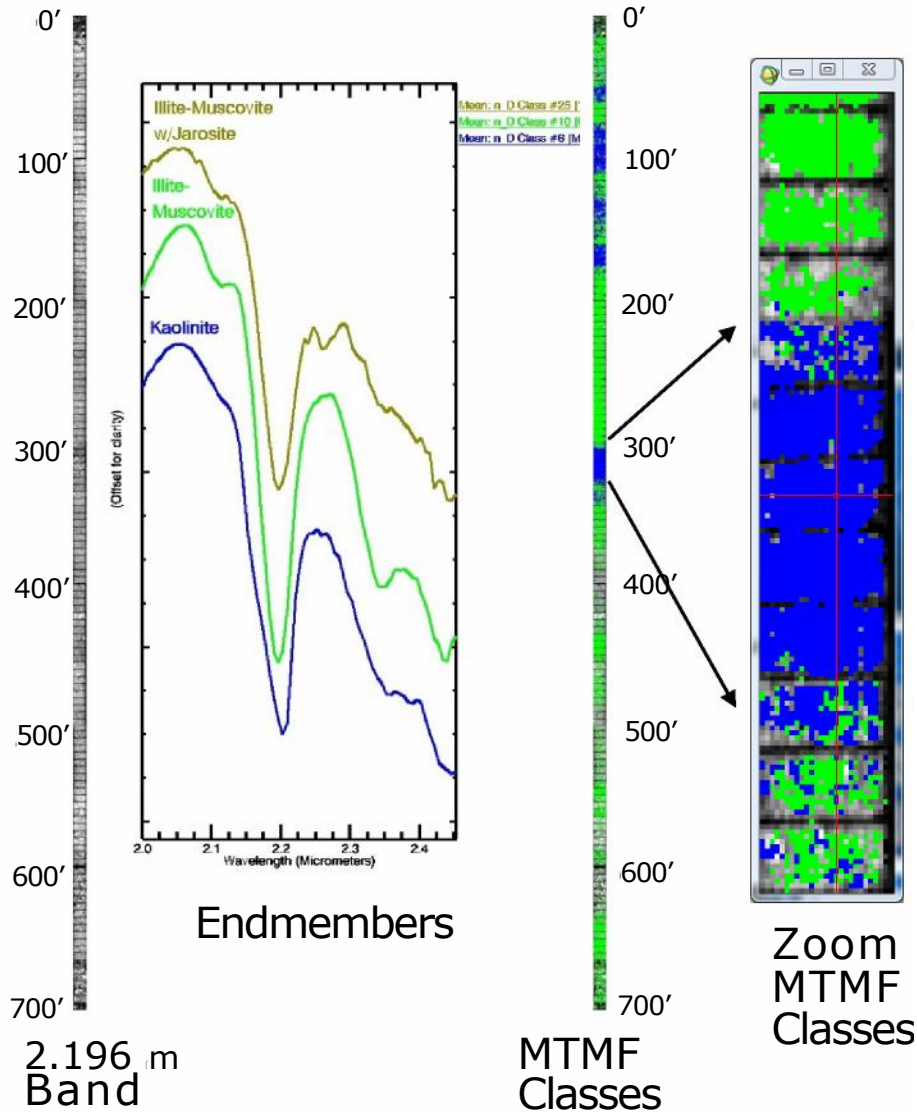


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Trinity Mine Exploration Rock Chips

Scans, Band 2.196 m



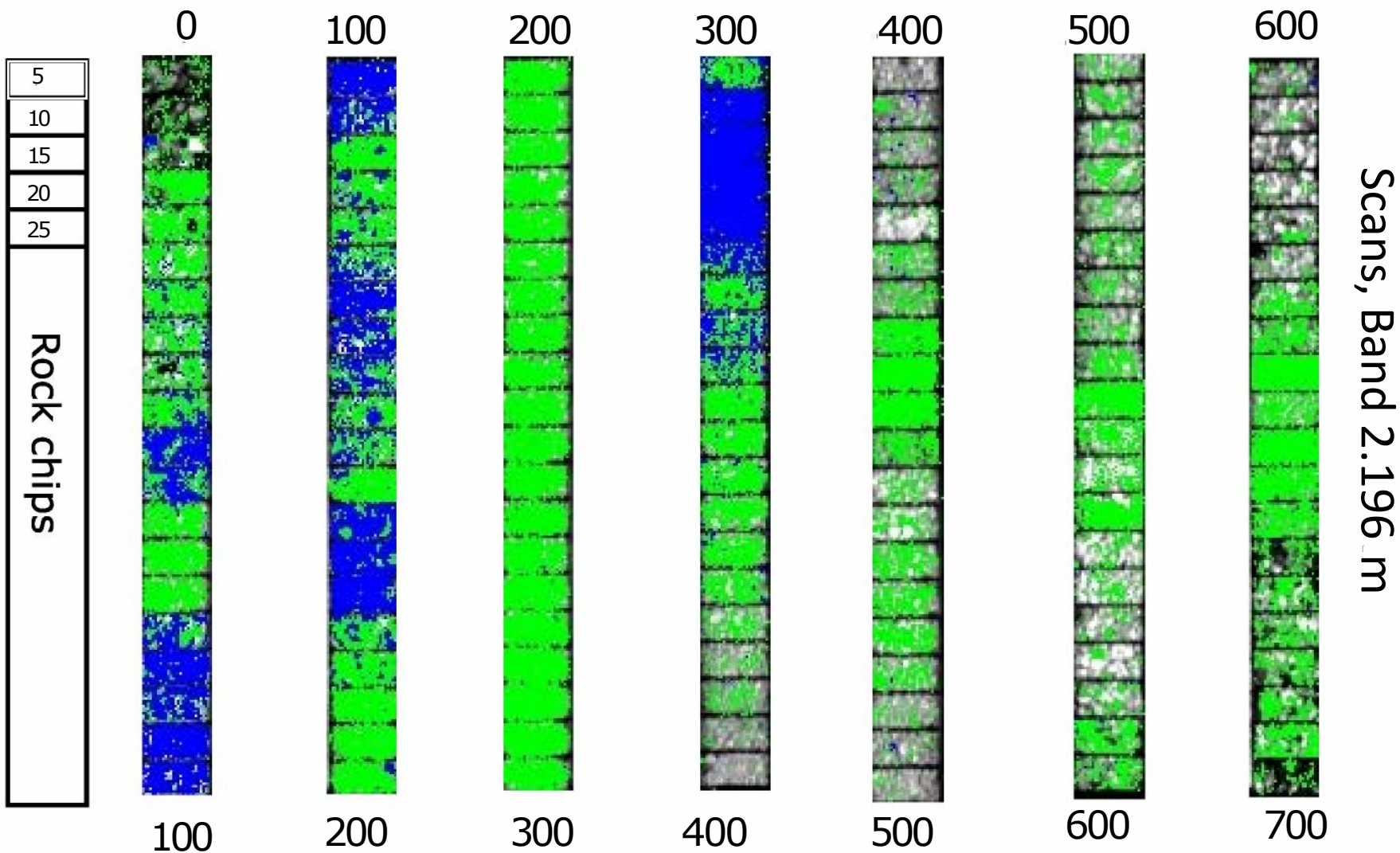


Rock Chip Boxes show known mineralization at a depth of identified ore body



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Core Results – SWIR – TS07-25

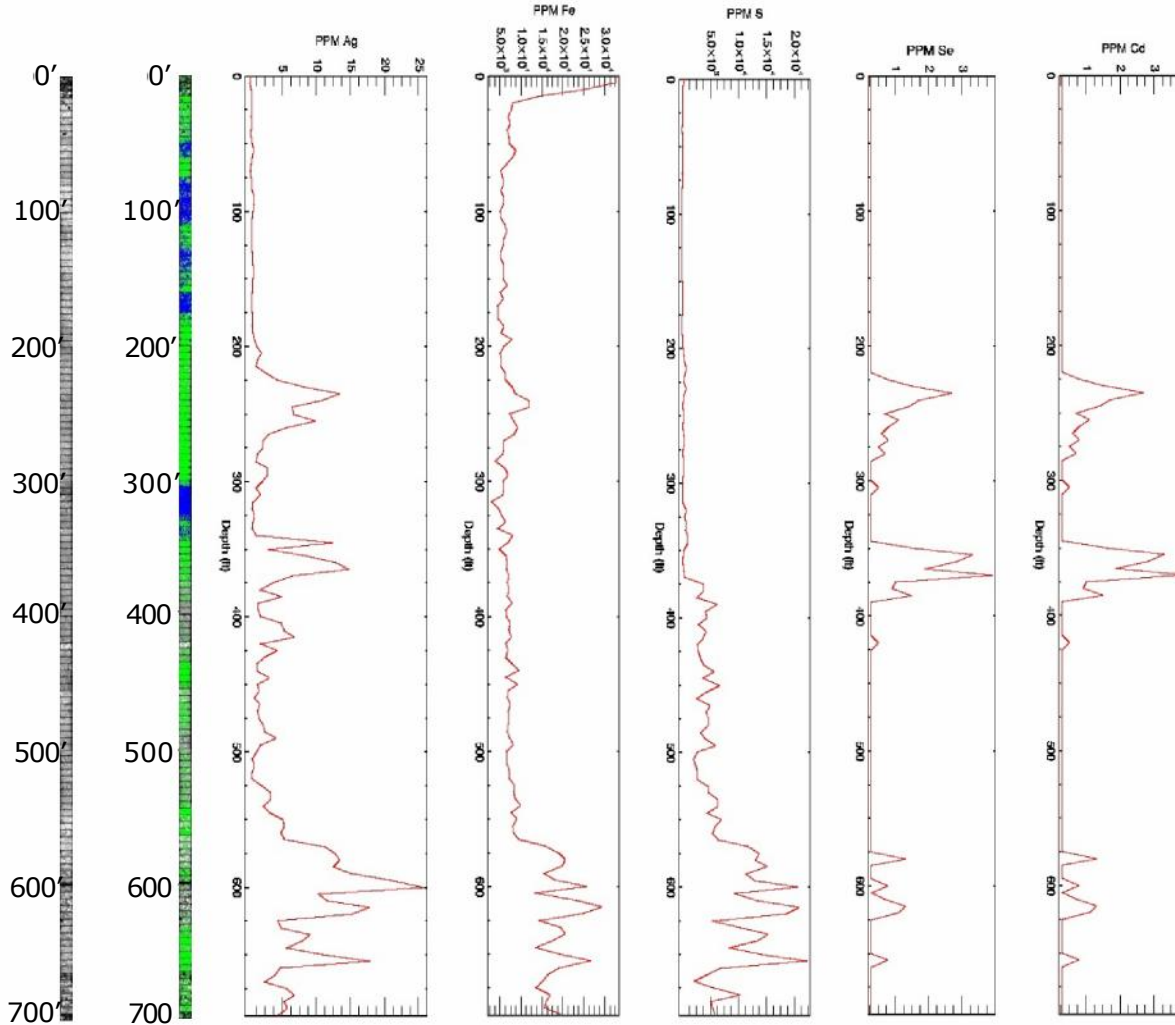




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Elemental Analysis Comparison (Illite/Muscovite)

Core Results – SWIR – TS07-25:



2.196 m
Band

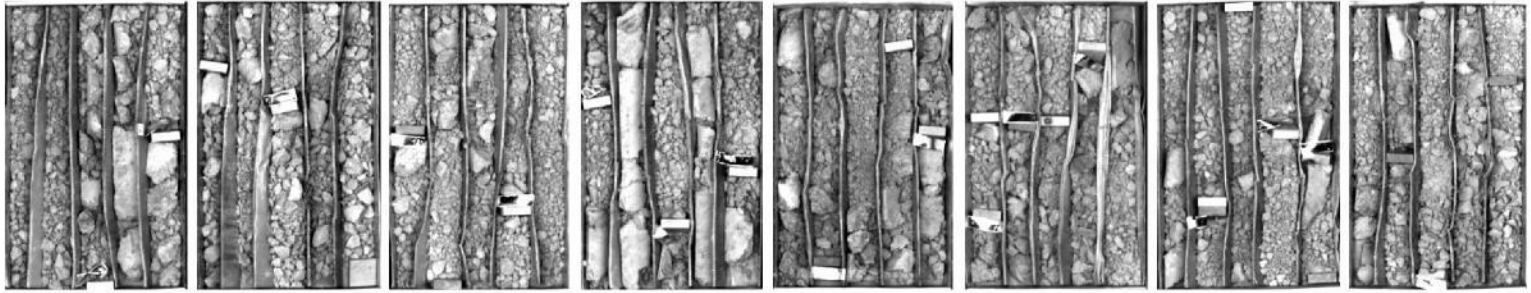
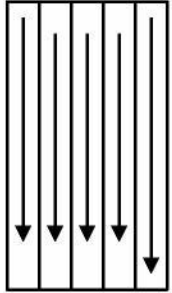
Illite-Muscovite Correlated w/selected elements (Ag)
Lesser correlations with: Sr, Sn, Sb, Pb, Zn, U, Tl



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Core Results – SWIR – TSD-006

TOP



Bottom

34

42

51

61

71

87

101

109

109

118

132

141

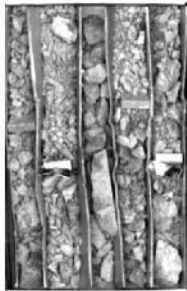
151

161

171

183

192



118

132

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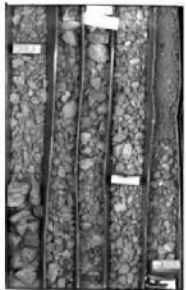
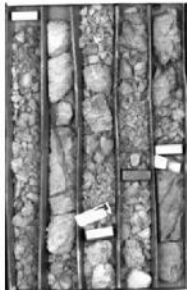
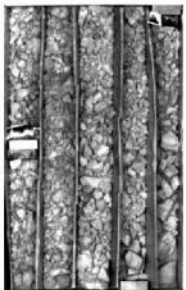
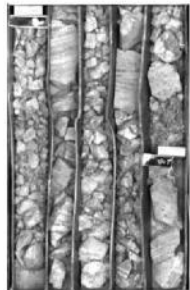
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212

220

231

242



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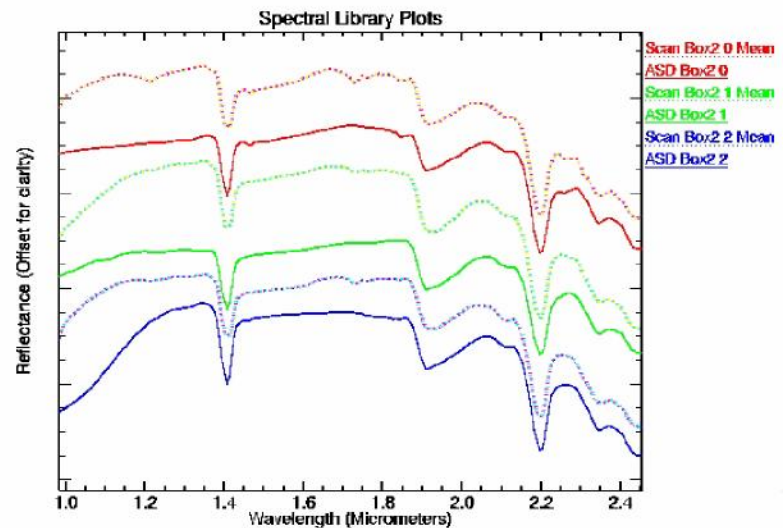
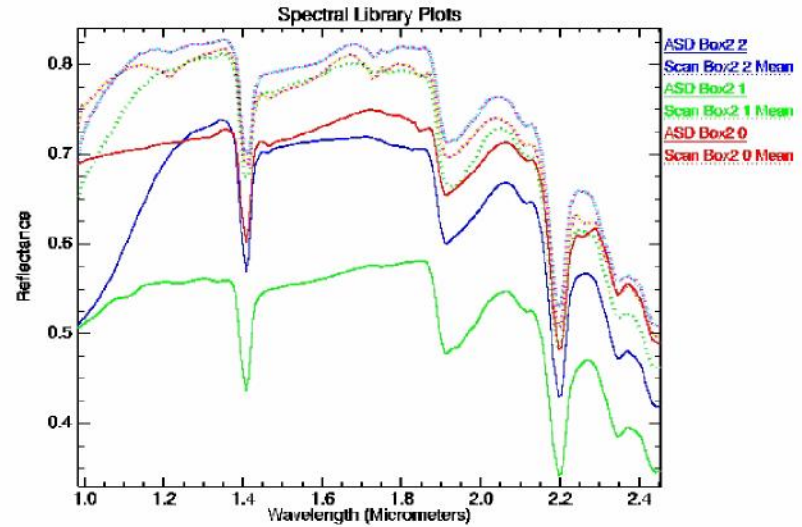
Scans, Boxed Core
Band 2.196

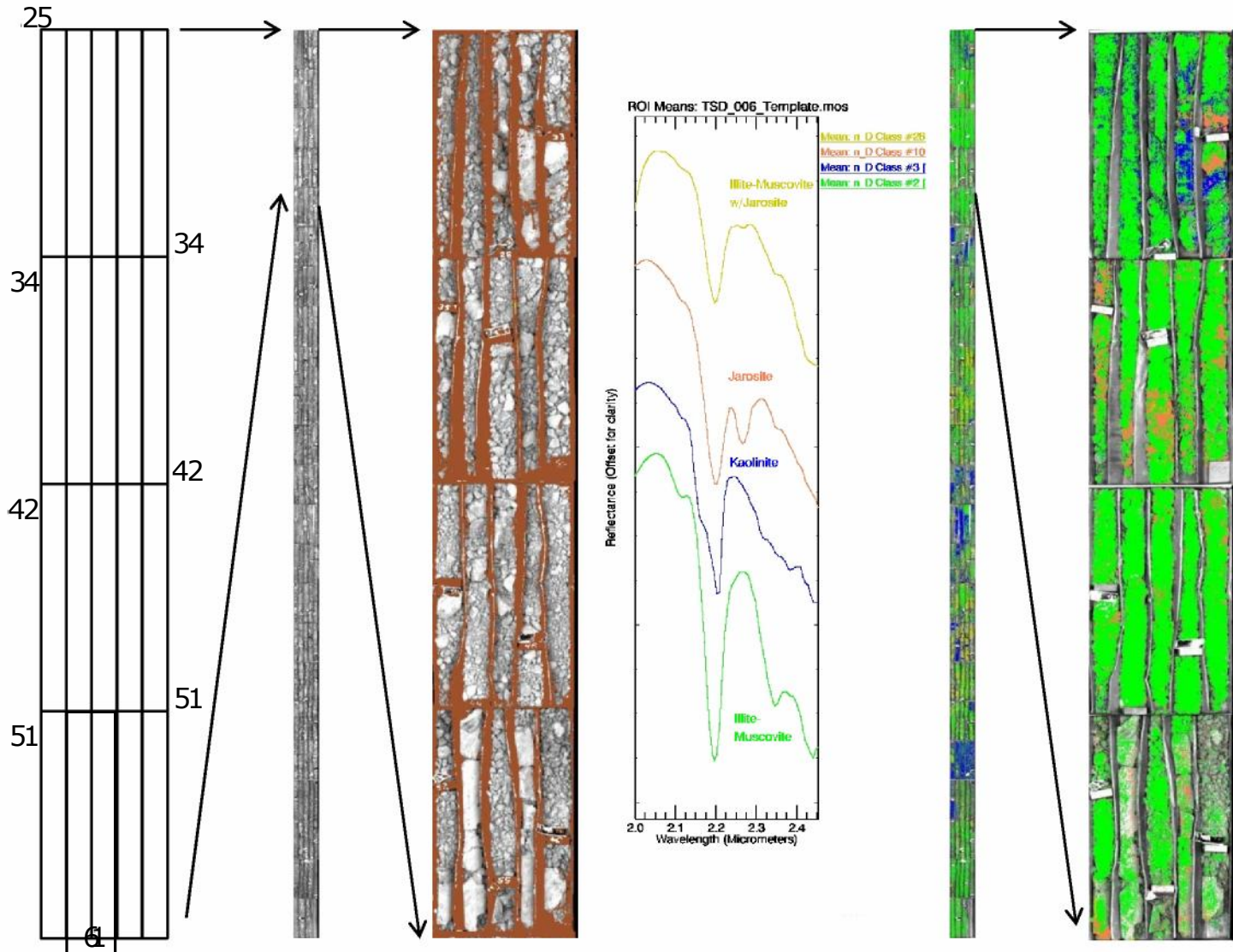


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Trinity Mine Comparison

of Drill Core Scans and ASD FieldSpecPro Spectra

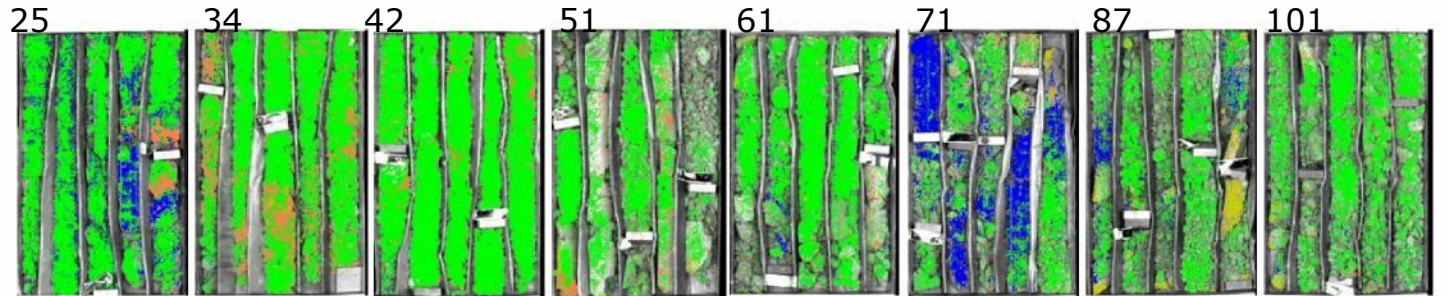




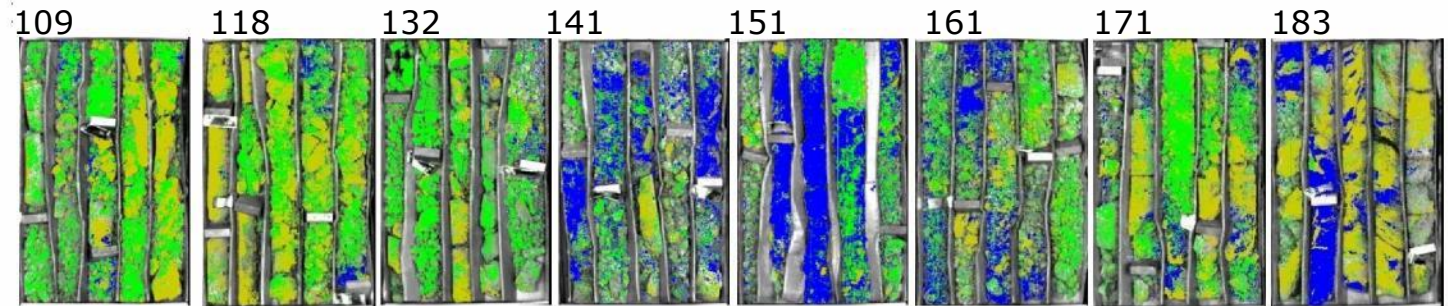


SpecTIR™

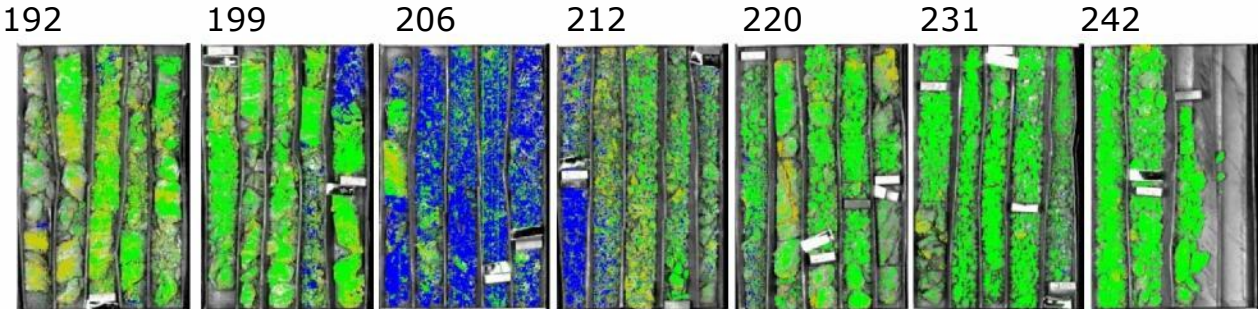
SWIR Scan, Boxed Core, TSD-006



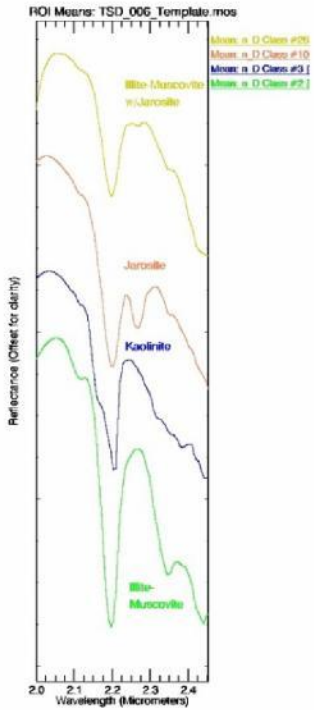
34 42 51 61 71 87 101 109



118 132 141 151 161 171 183 192

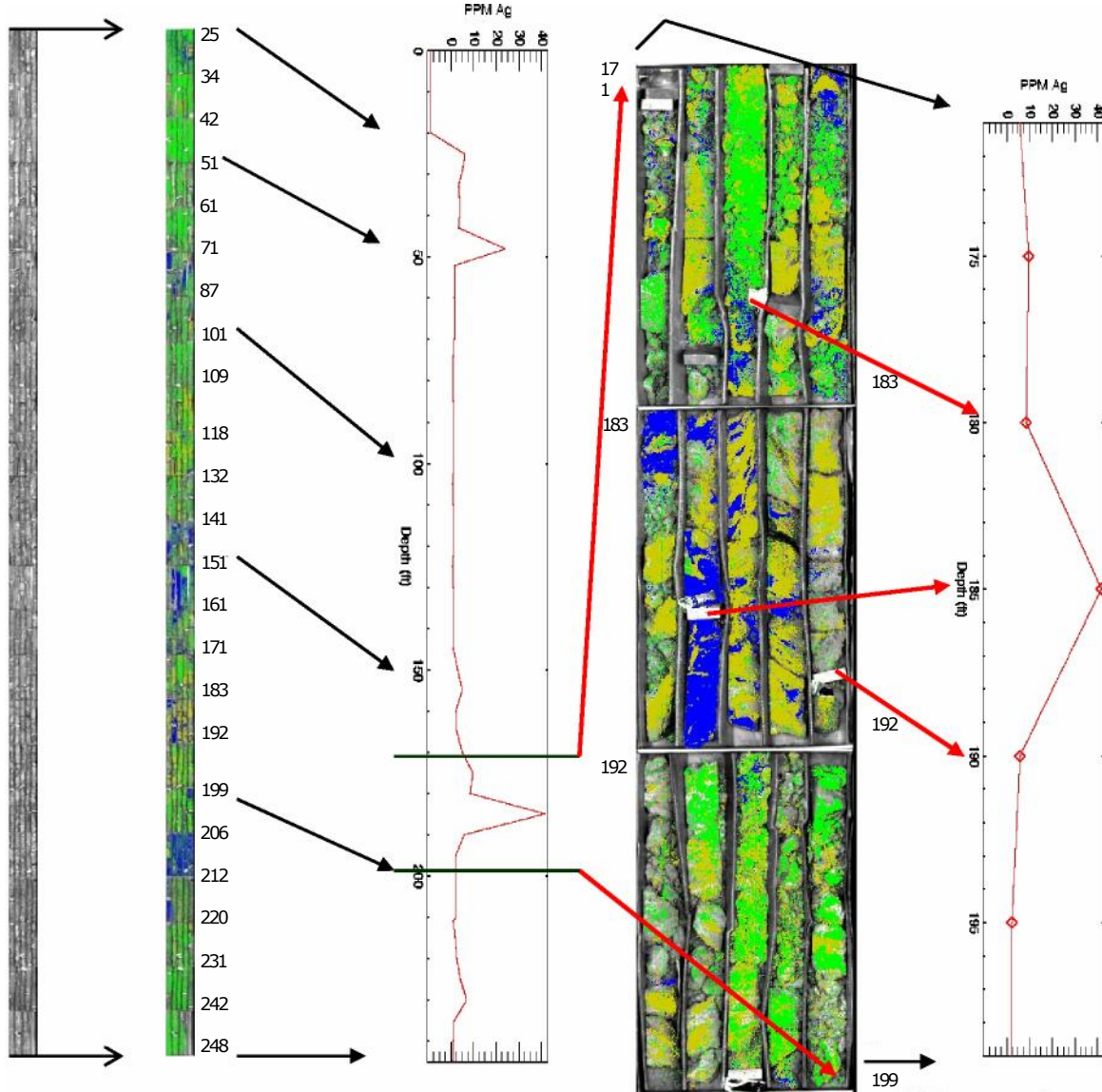


199 206 212 220 231 242 248





Mosaicked Scans, Boxed Core, Band 2.196



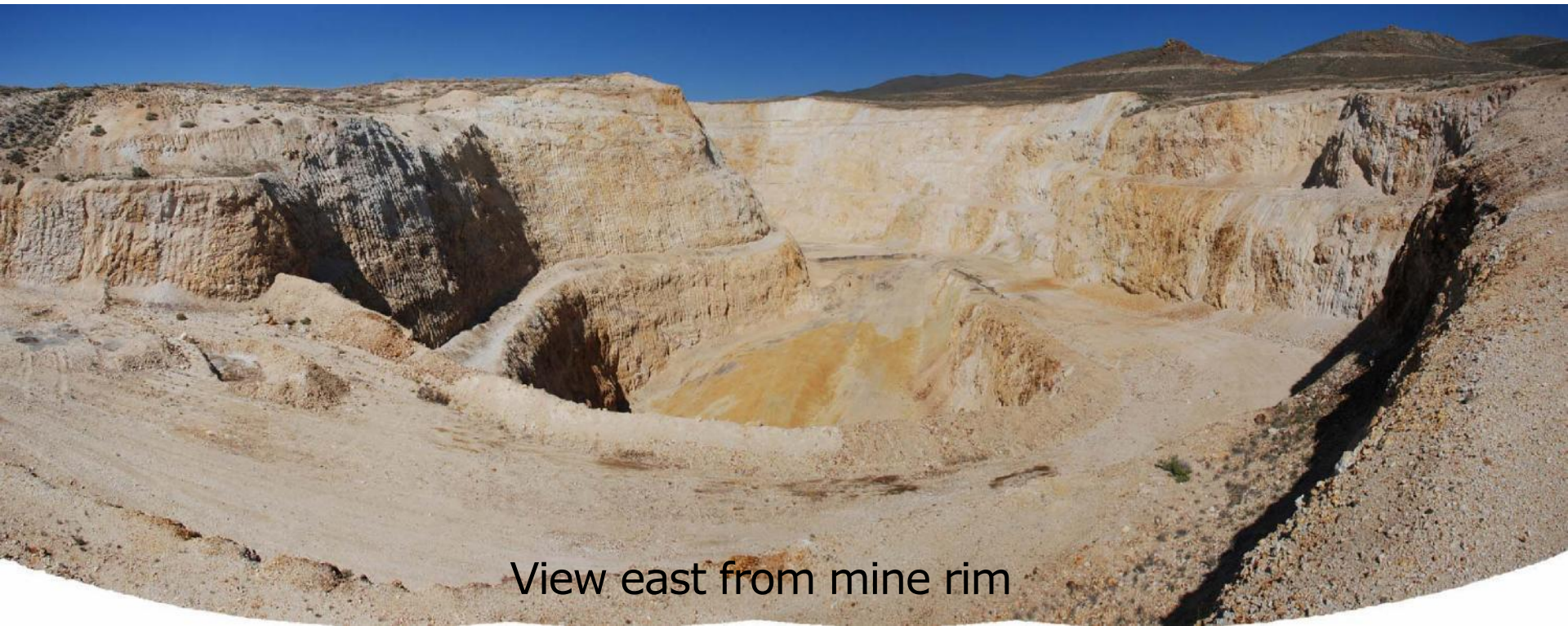
- Core measured in two configurations
 - Reverse Circulating, Rock chips in trays
 - Core in boxes
- Endmember spectra extracted for each core
- Mineral mapping using MTMF
- Scan Mineralogy
 - IlliteMuscovite
 - Kaolinite – Jarosite
 - IlliteMuscovite Mixed with Jarosite
- Comparison with core logs shows general correspondence eg: scan clay and scan jarosite correlated with log clay and log sulfides respectively)
- Increased information from scans – eg: jarosite mapped by scans, not noted in logs. Higher sampling rate (resolution).
- Variability of mineralogy clearly shown
- Some correlation with elemental analysis
 - TS0725: Ag, Fe, S, Se, Cd, Sr, Sn, Sb, Pb, Zn, U, Tl and IlliteMuscovite (Kaolinite/no Jarosite=no correlation)
 - TSD006: Ag and Kaolinite with Mixed Illite/Muscovite w/Jarosite



SpecTIR™

Trinity Mine Wall Data Acquisition and Analysis

- Truck-mounted ProSpecTIR Scanner in custom configuration, GPS positions noted, and distances to mine walls measured using laser rangefinder
- Spectralon standard included in scan field of view
- Collection of VNIR/SWIR data scans for multiple locations inside the pit



View east from mine rim



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Mine Wall Scan Configuration – 7 May 2009



- ProSpecTIR (AISA) Dual HSI
 - 367 bands (0.4– 2.5 μ m) – 5-nm spacing
- Imager placed on rotating turntable – SWIR instrument left showing lens
 - VNIR instrument right, lens within the rectangular port to the right
- ~45-degree scan indicated by lines on white base plate
 - "along-track" left to right
 - "cross-track" top to bottom
- Computer control behind the instrument
- View screen top center facing right
- 31 x 62 cm Spectra Ion™ reference panel on tripod
- ~30 min/site including setup

end to end hyperspectral solutions



SpecTIR™

Trinity Mine Wall Data Acquisition and Analysis

- Calibrate to radiance using standard SpecTIR approaches
- Correct to reflectance using the Spectralon Panel average divided into each mine wall spectrum
- Analyze using endmember extraction and MTMF

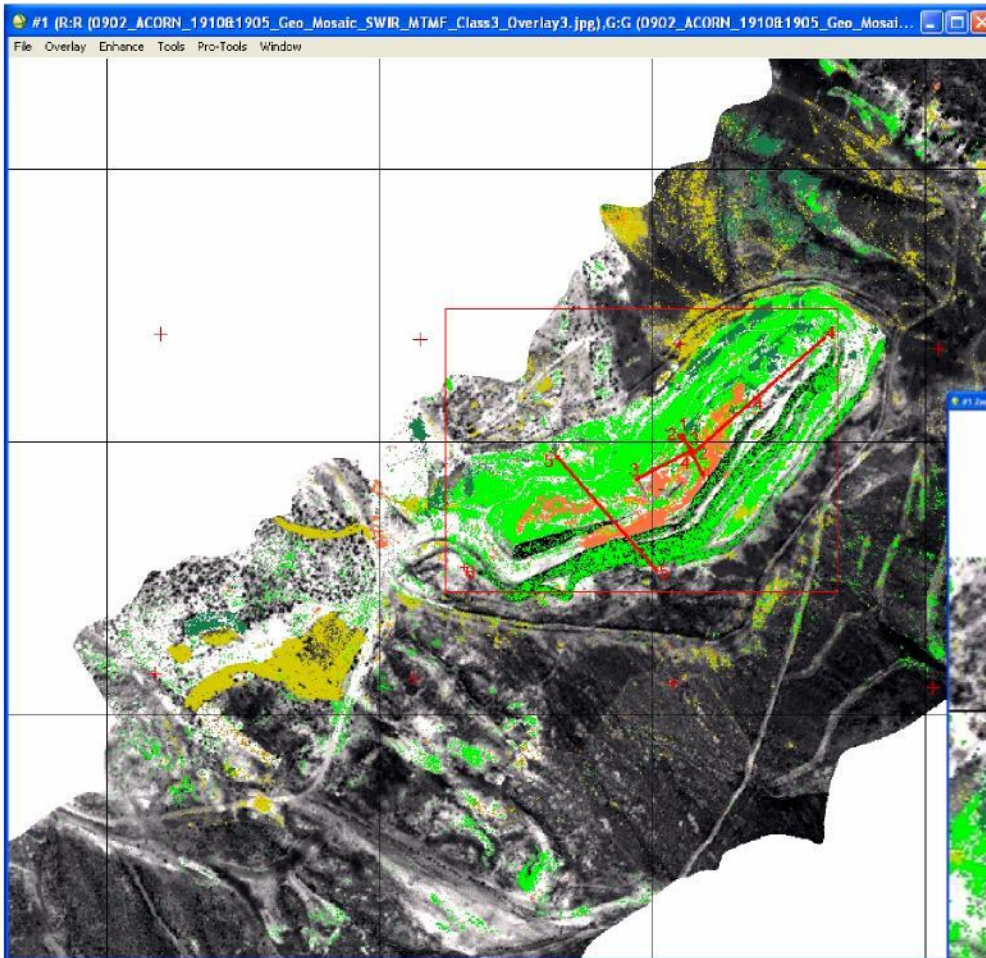


View east from mine rim

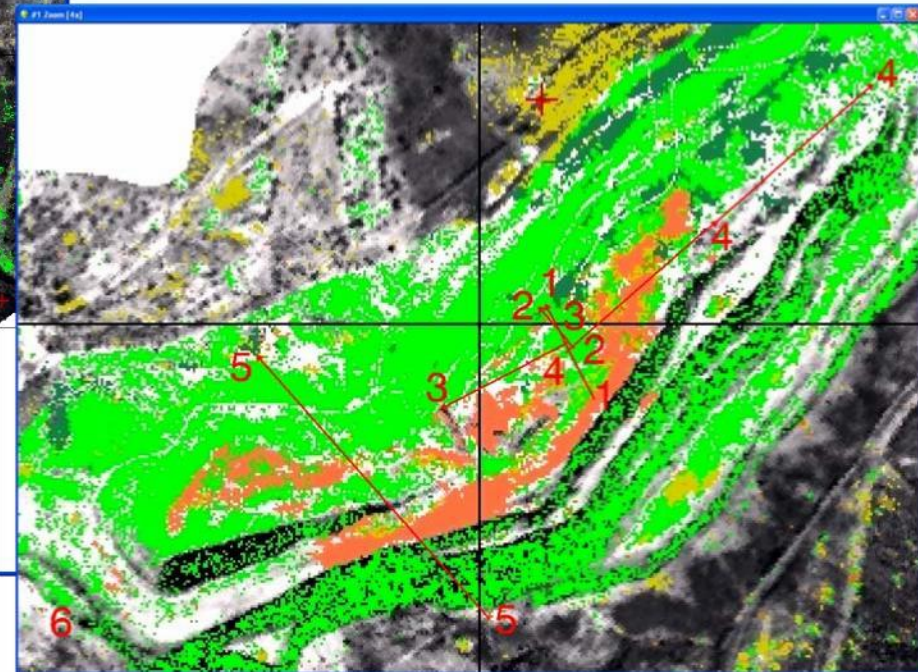


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ProSpecTIR Mine Wall Locations

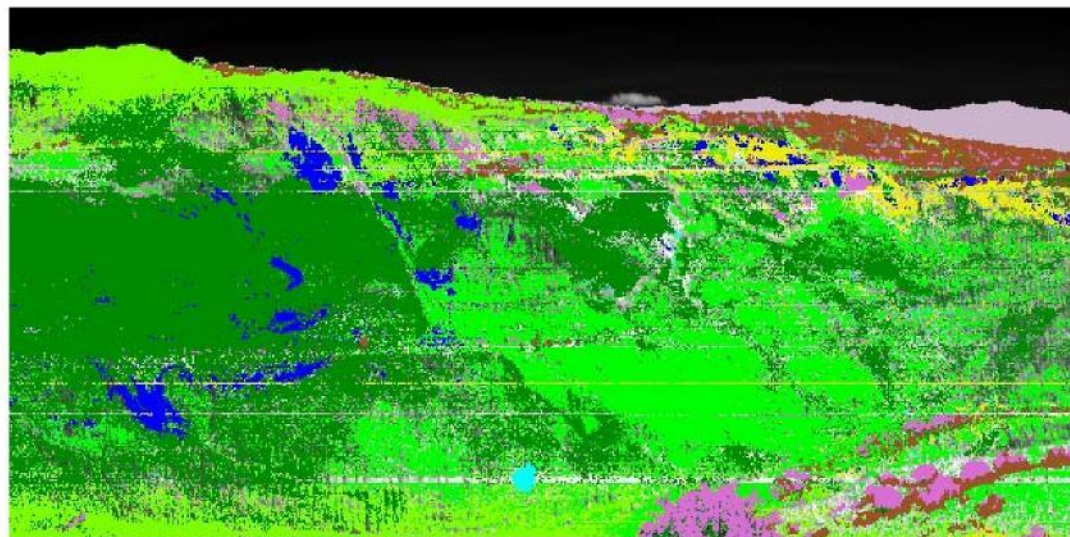
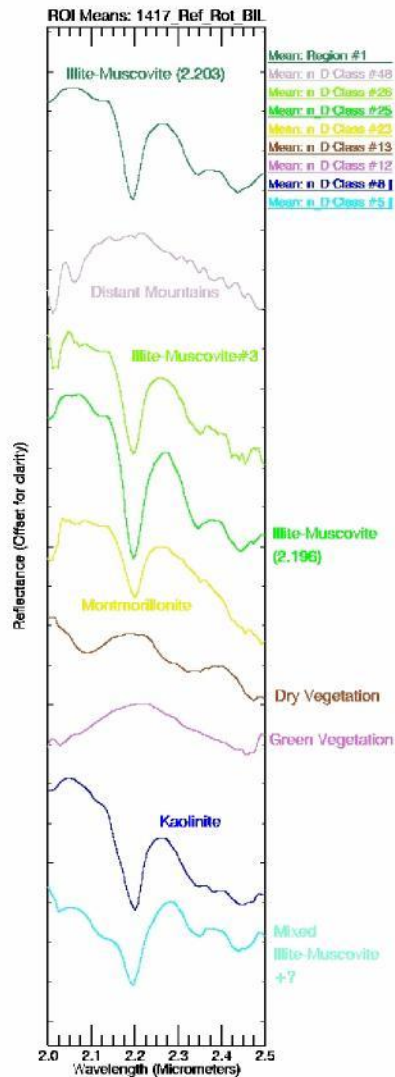


Location	Mine Wall Scan ID
Site 1	1145 (38m) to NNW
Site 2	1223 (19m) (same as 1, closer)
Site 3	1241 (56m) to SE
Site 4	1254 (160m), 1256 (80m) NE
Site 5	1417, 1430, to NNW
Site 6	1541, 1548 (250m) ?





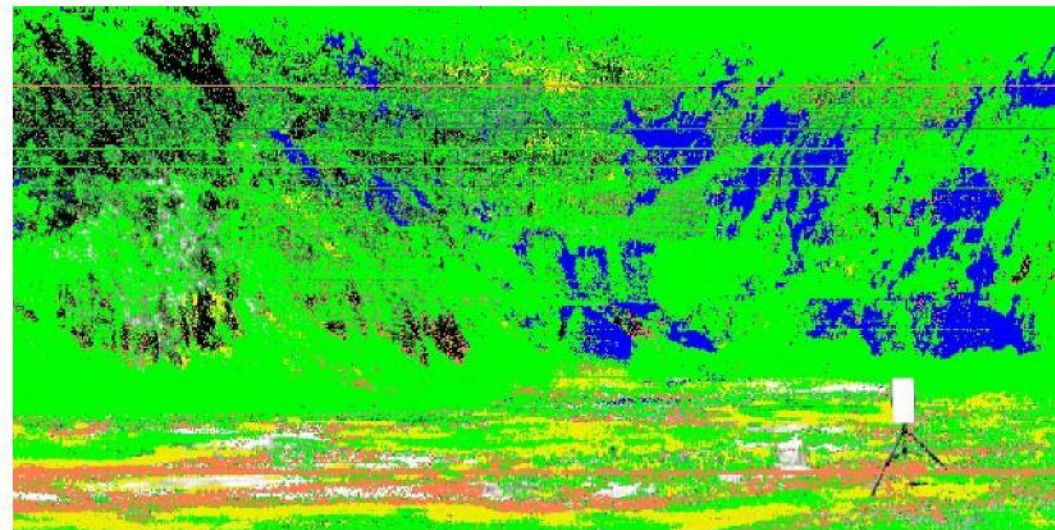
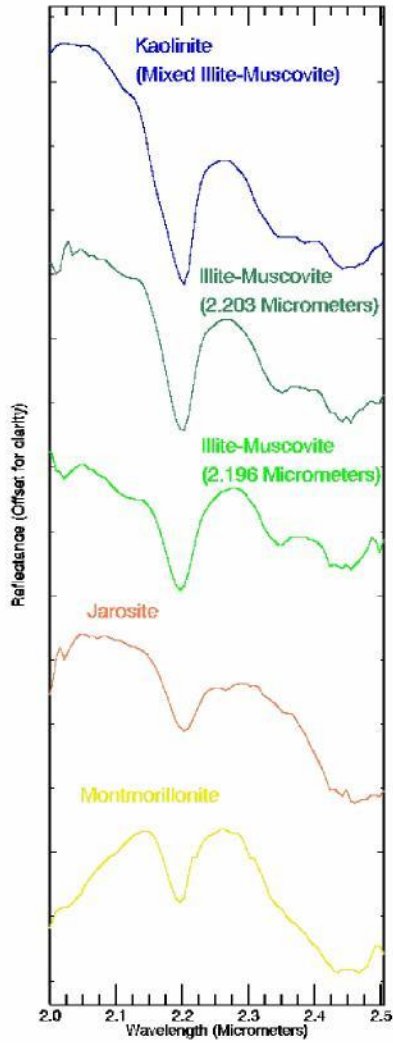
1417 SWIR Results



Variable Spatial Resolution Across Pit



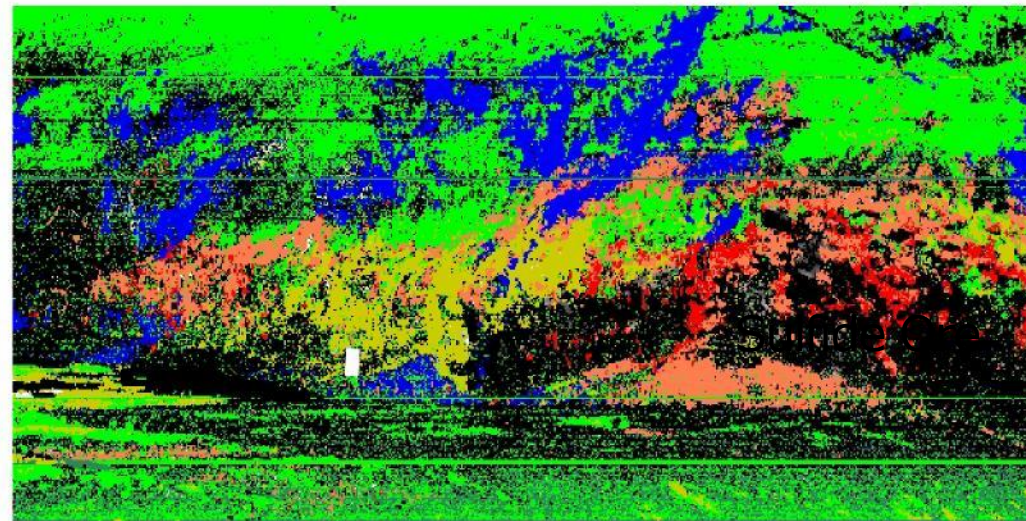
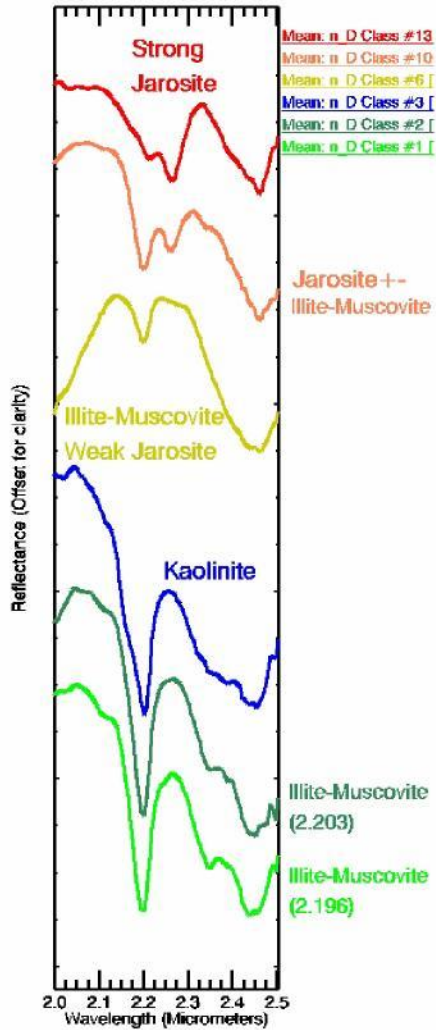
#1256 SWIR Results



(~8 cm Spatial Resolution @80m)



#1145 SWIR (sulfide body)



(~4cm Spatial Resolution @38m)

- Detailed mineral mapping and view not available from any other source (3cm – 8cm resolution)
- Shows distribution of illite-muscovite, jarosite, montmorillonite, kaolinite. Mineralogy at depth along benches similar to core observations
- Possible Al substitution in illite-muscovite based on shift of 2.2 micrometer band
- Association of jarosite with known sulfides and clear mineral zoning around sulfide ore
- Association of some mineral boundaries with apparent structural boundaries (Kaolinite alteration along fractures)

- Technology demonstration of ProspecTIR scanner data applied to several levels of mineral mapping for geological characterization
- Standardized analysis approaches applied to overflight data, core scans, and mine wall scans
 - Overflight mapping results show distribution of surface mineralogy, highlighting association of most alteration with pit exposures. Some areas of interest outside the pit.
 - Core mapping allows detailed mineral characterization with depth for specific locations. There appears to be an association of specific minerals (Illite-Muscovite and Kaolinite-Jarosite) with elevated Ag.
 - Mine wall scans show relationships between structure and mineralogy & association of jarosite with known sulfide ore
- Synthesis of all datasets shows consistent mineralogy. Alteration mapping for all 3 modalities is much improved over previously available information.
- Results provide new insight to relations between alteration, structure, and ore. Future exploration and production?



- Development of automated approaches for analysis of core in depth spatial context
- Analysis of additional cores and mine wall scans, including additional VNIR and SWIR analysis and combined VNIR/SWIR analysis
- Application of other (feature-based) methods to data analysis of all three modalities
- Additional integration of HSI datasets with ancillary information (geologic maps, core logs, elemental analysis)
- Further field verification using ASD spectrometer and conventional methods
- Development of combined visualization and analysis approaches