Longwave Infrared Imaging of Drillcore

Is it possible and practical?

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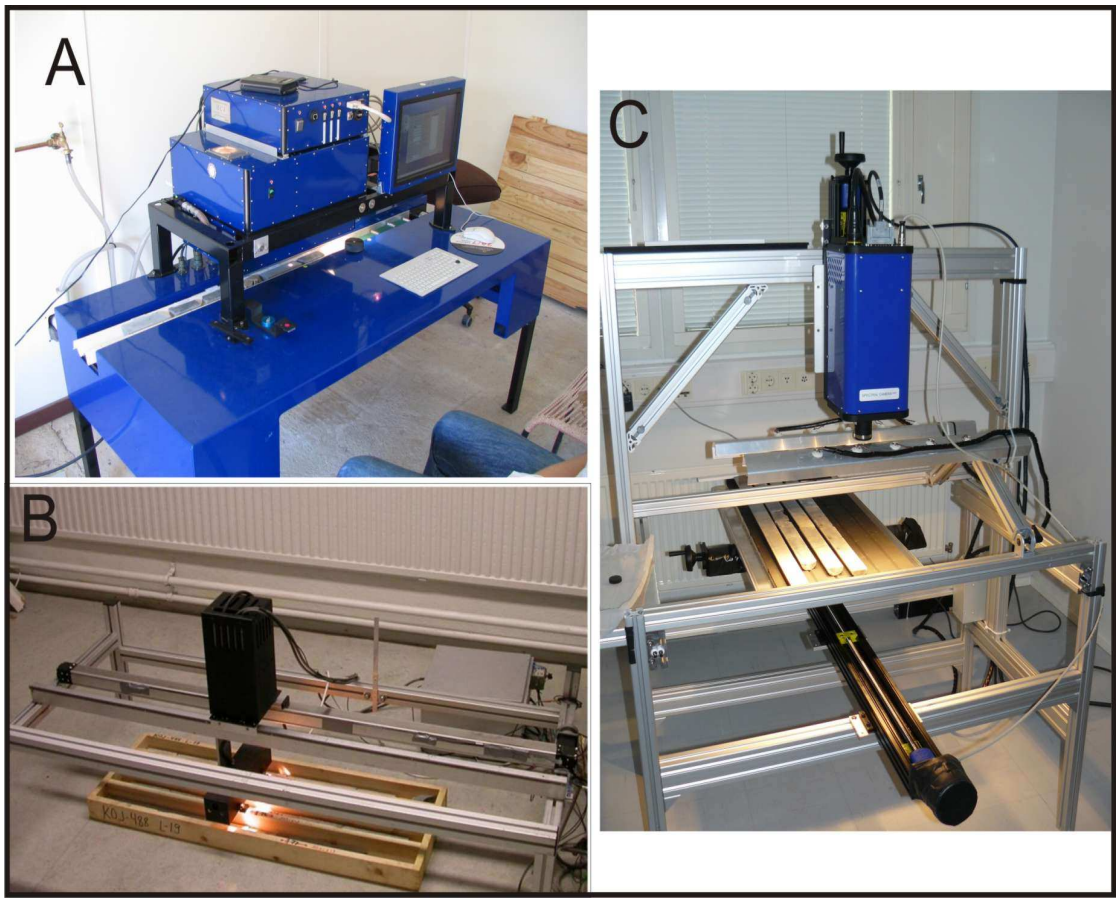
3 – Specim, Spectral Imaging

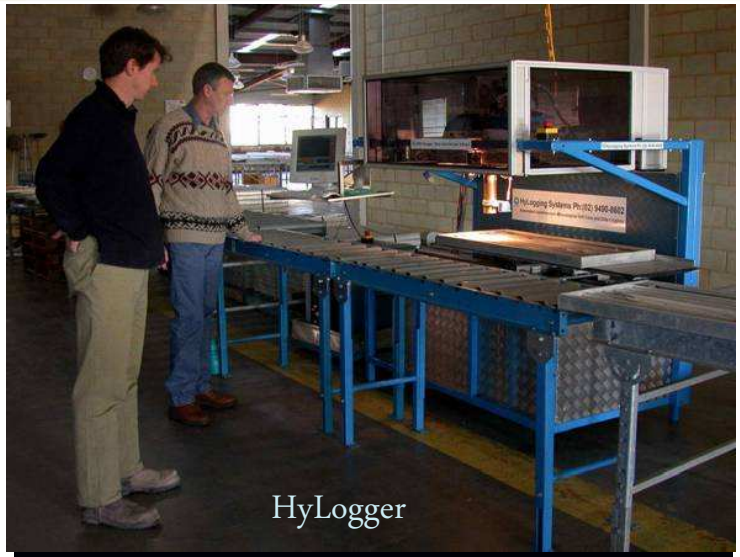
Presentation Outline

- **Why is the LWIR Important?**
  - Increases detection of geologically important minerals
- **Requirements & Experimental Setup**
  - Systems and methodologies
- **Results and Data Comparisons**
  - Explore the results and compare to NIR
- **Possible and Practical?**
  - Assess the potential, possibilities and practicalities
  - LWIR challenges

Infrared Core Logging: Emergent Application



A-HCI B-SpecCAM C-SisuROCK



Mineral Identification in the Infrared: Applications and Limitations

Type	Silicate Structure	Mineral Group	Example	VISNIR Response	SWIR Response	TIR Response
Silicates	Inosilicates	Amphibole	Actinolite	Non-Diagnostic	Good	Moderate
		Pyroxene	Diopside	Good	Moderate	Good
	Cyclosilicates	Tourmaline	Elbaite	Non-Diagnostic	Good	Moderate
	Nesosilicates	Garnet	Grossular	Moderate	Non-Diagnostic	Good
		Olivine	Forsterite	Good	Non-Diagnostic	Good
	Sorosilicates	Epidote	Epidote	Non-Diagnostic	Good	Moderate
	Phyllosilicates	Mica	Muscovite	Non-Diagnostic	Good	Moderate
		Chlorite	Clinochlore	Non-Diagnostic	Good	Moderate
		Clay Minerals	Illite	Non-Diagnostic	Good	Moderate
			Kaolinite	Non-Diagnostic	Good	Moderate
	Tectosilicates	Feldspar	Orthoclase	Non-Diagnostic	Non-Diagnostic	Good
			Albite	Non-Diagnostic	Non-Diagnostic	Good
		Silica	Quartz	Non-Diagnostic	Inferred	Good
Non-Silicates	Carbonates	Calcite	Calcite	Non-Diagnostic	Moderate	Good
		Dolomite	Dolomite	Non-Diagnostic	Moderate	Good
	Hydroxides		Gibbsite	Non-Diagnostic	Good	Moderate
	Sulphates	Alunite	Alunite	Moderate	Good	Moderate
			Gypsum	Non-Diagnostic	Good	Good
	Borates		Borax	Non-Diagnostic	Moderate	?
	Halides	Chlorides	Halite	Non-Diagnostic	?	?
	Phosphates	Apatite	Apatite	Moderate	Non-Diagnostic	Good
	Hydrocarbons		Bitumen	?	Moderate	?
	Oxides	Hematite	Hematite	Good	Non-Diagnostic	Non-Diagnostic
		Spinel	Chromite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic
	Sulphides		Pyrite	Inferred	Non-Diagnostic	Non-Diagnostic

Infrared Core Logging: Capabilities

SisuRock Core Imaging System Specifications	
Scanning System	
Wavelength Range	1000nm to 2500nm (Shortwave Infrared)
Spectral Resolution	6nm
Spatial Resolution	1.2mm x 1.2mm
Spectral Bands	240 bands
Image Dimensions	320 pixels
Rates and Volumes	
Scanning Speed	30-40 core boxes/hour
Spectral Data	~150Mb/box image (raw)
Calibration Data	~30Mb/image(raw)

LWIR Imaging: Requirements

- **Operational Requirements**
  - Rapid Measurement time (Reflectance measurements)
  - Minimal Core Handling (No special sample preparation)

- **Instrument Specifications**
  - Geological Applications
  - Including Mineral Composition (Airborne Applications)

Specifications*	Geological Application (Mineral Composition)*
Spectral Range	7.6-14µm
Number of Bands	30-50
Spectral Resolution (FWHM)	100-300nm
Signal-to-Noise	400-1000

**Modified from Shimoni et al., 2007*

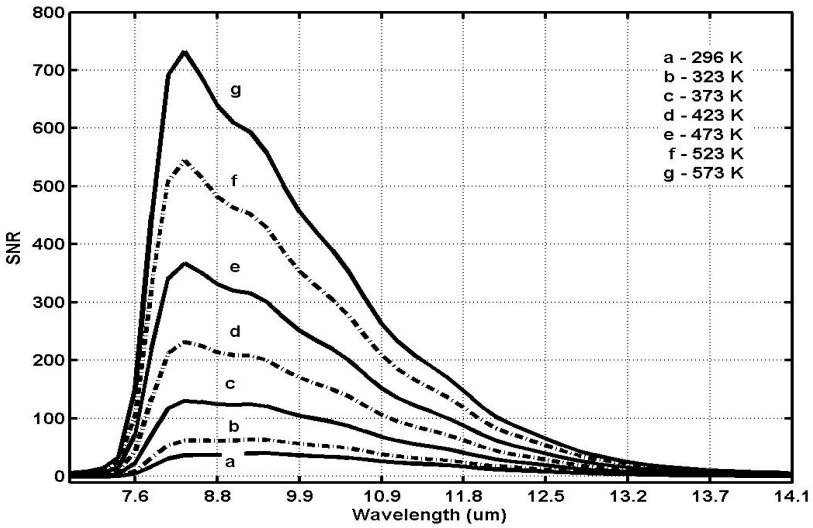
Imaging System: LWIR Instrumentation

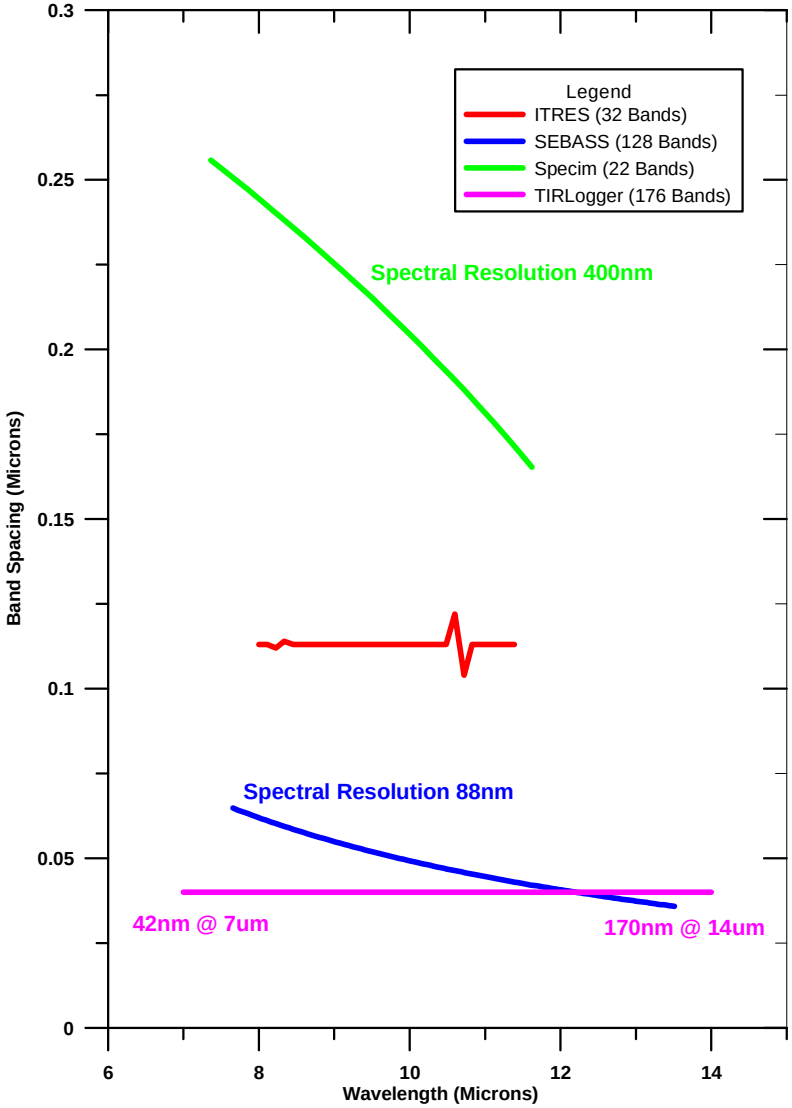
LWIR HS Camera	
Wavelength Range	7.8µm to 12.0µm
Bands (spectral pixels)	22 (30)
Spatial Pixels	384
Spectral Resolution	400nm
Detector Type	Microbolometer
Spectral Sampling	200nm (mean)
Instrument Temperature	300 K
Instr. Temp. Control	None
Camera Dimensions	55x130x125 (mm)
Camera Weight	2.5 kg

After Holma et al., 2009

LWIR Instrument Specifications: Signal-to-Noise & Spectral Resolution

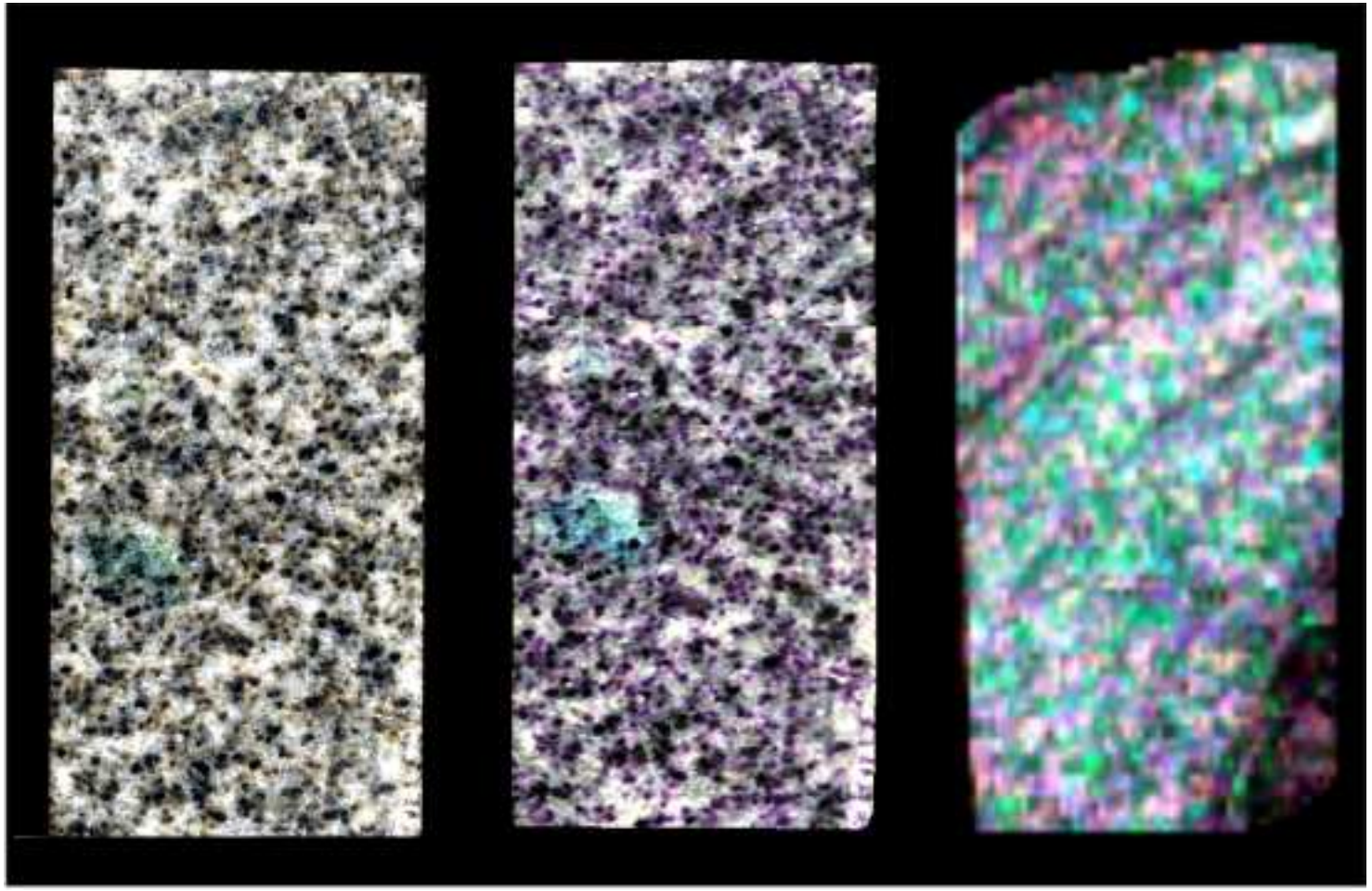
Target Temperature (K)	LWIR C SNR at 8µm
296	36
323	62
473	130
423	230
473	365
523	540
573	730





After Holma et al., 2009, Kirkland et al., 2001, Cudahy et al., 2009

LWIR Instrument Specifications: Spatial Resolution



Visible-Infrared Image
VNIR
50µm/pixel

Shortwave Infrared Image
SWIR
170µm/pixel

Longwave Infrared Image
VNIR
750µm/pixel

VNIR Camera SPECIM
400-1000nm @ 2.8nm
50µm/pixel
RGB: 650:550:450nm

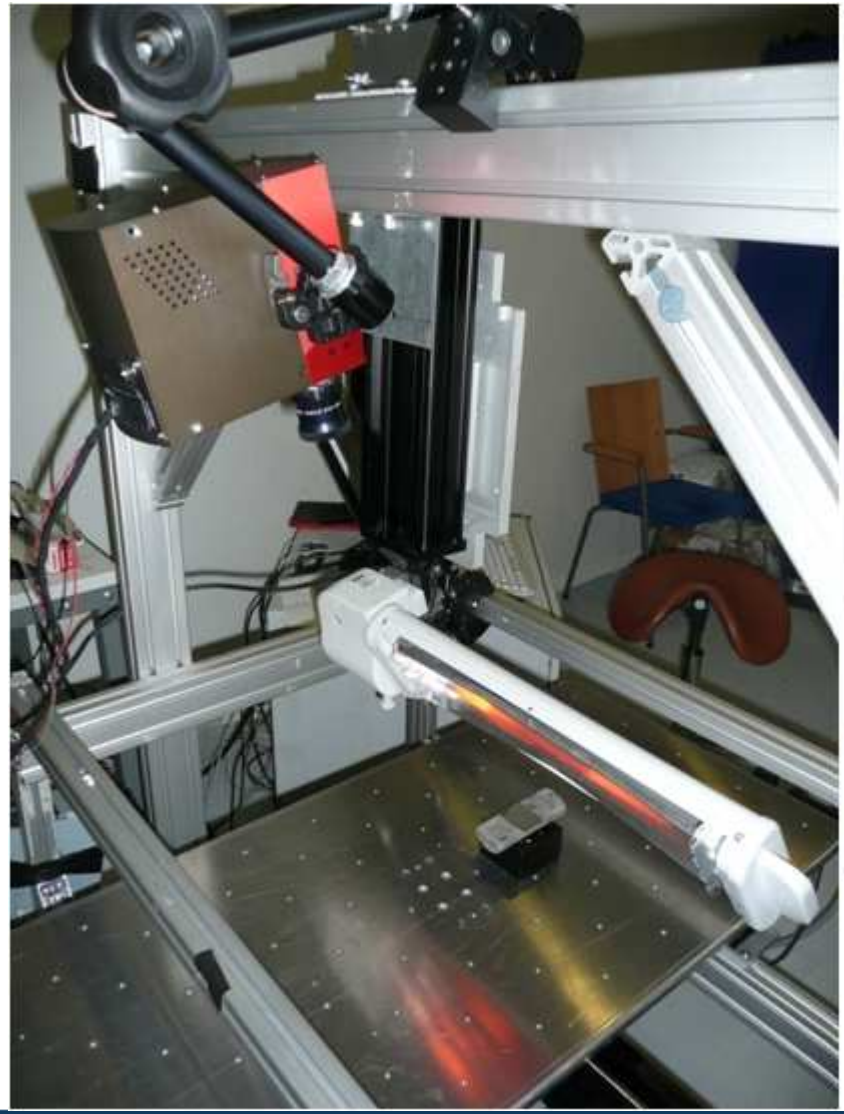
SWIR Camera SPECIM
1000-2500nm @ 6.3nm
170µm/pixel
RGB: 2180:1700:1480nm

LWIR Camera SPECIM
7.8-12.0µm @ 0.2µm
750µm/pixel
RGB: 8.6:9.5:10.5µm

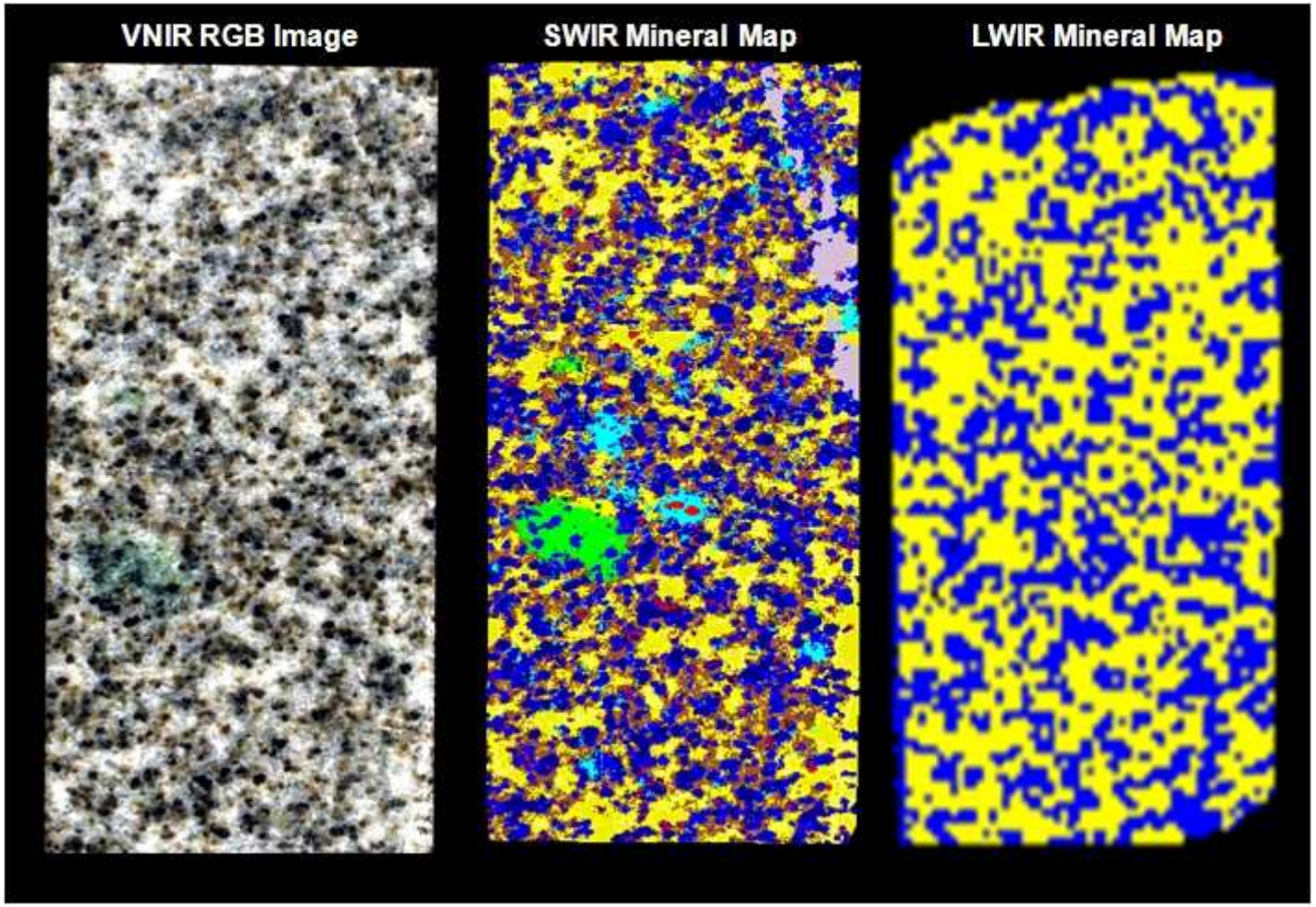
Leuconorite

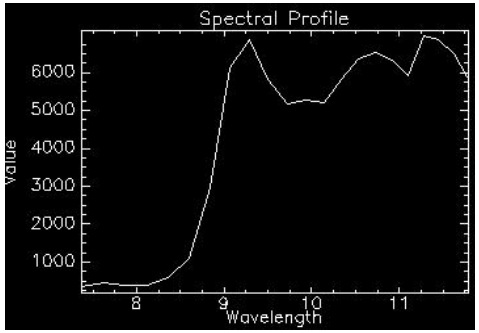
40mm

LWIR Imaging System: Experimental Setup

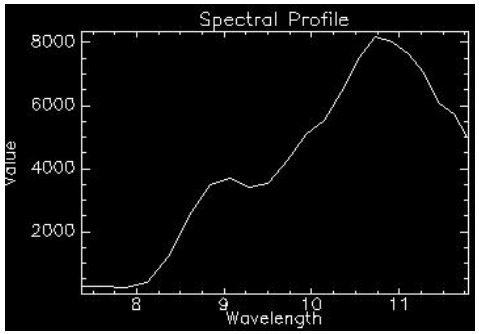


LWIR Imaging: Data Results I





Orthopyroxene

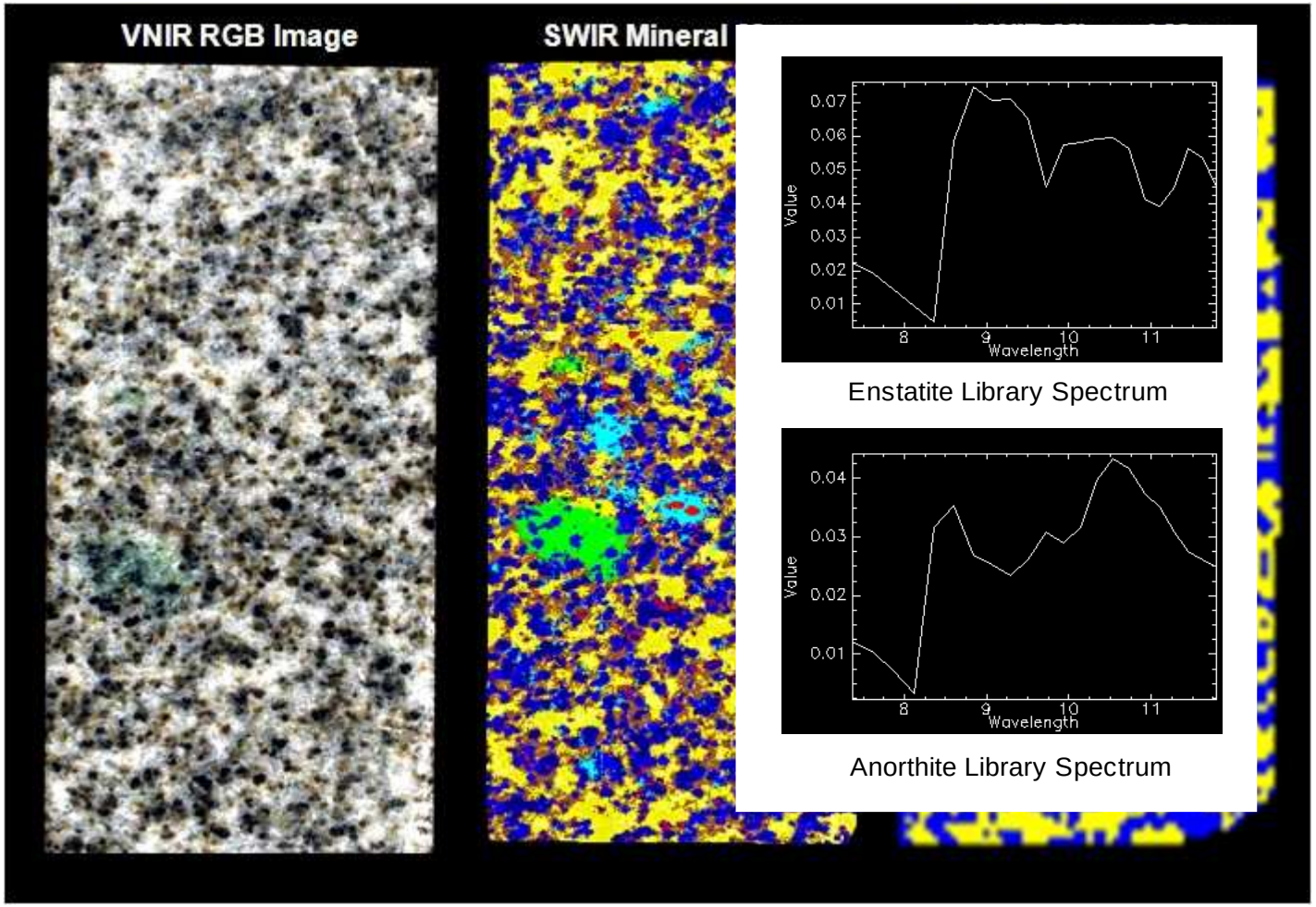


Plagioclase

Pyroxene-Phyllosilicate **Clinopyroxene** **Plagioclase** **Pyroxene-Feldspar**
Orthopyroxene **Talc-Pyroxene** **Prehnite**

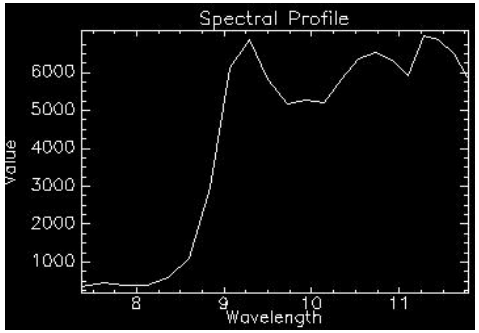
Leuconorite *40mm*

LWIR Imaging: Data Results I

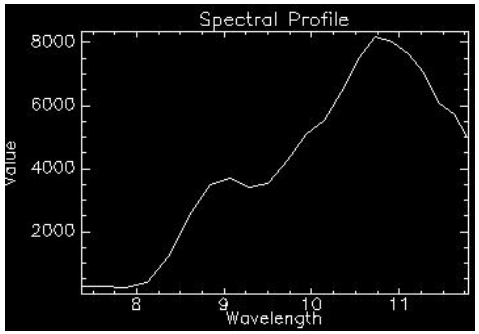


Enstatite Library Spectrum

Anorthite Library Spectrum



Orthopyroxene



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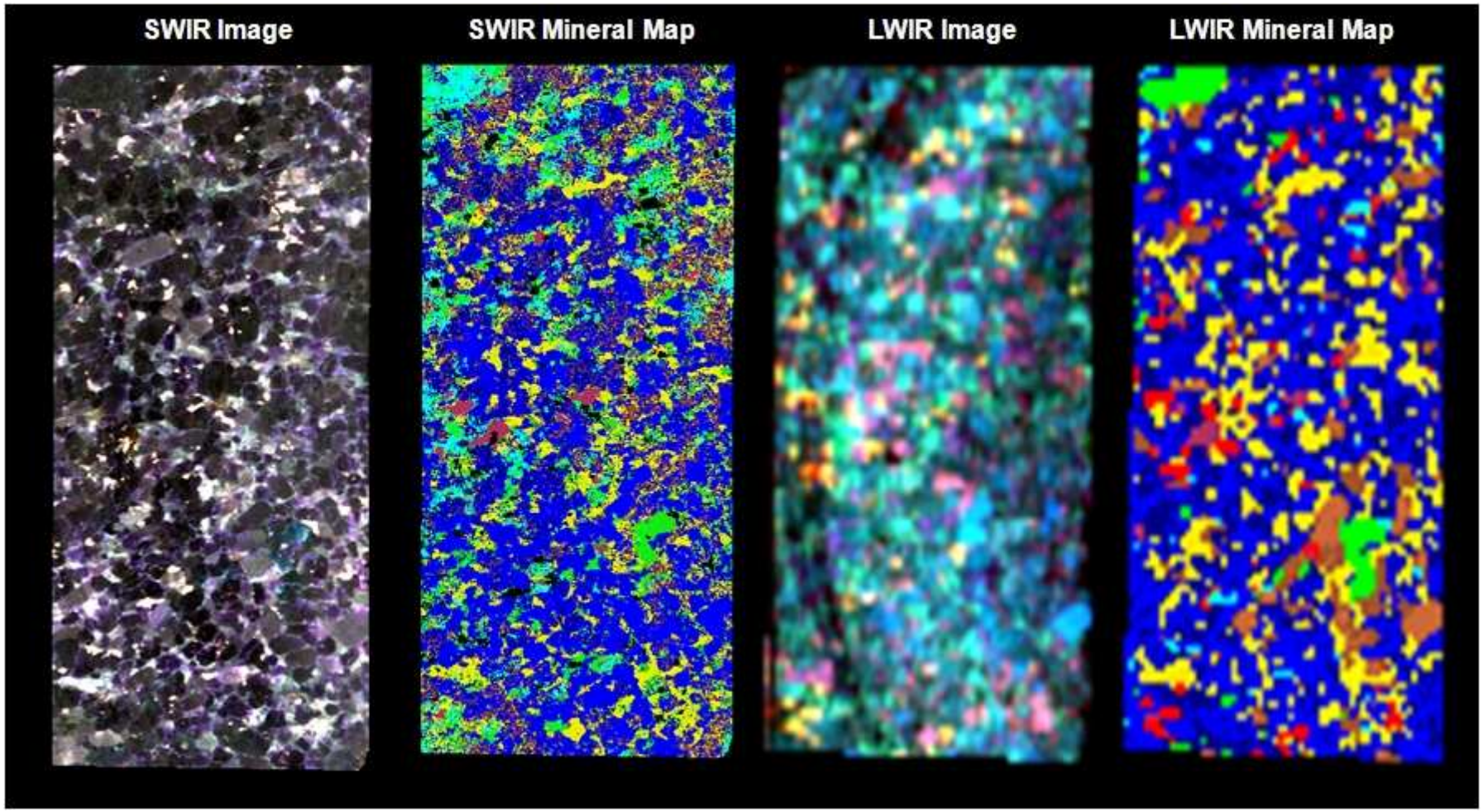
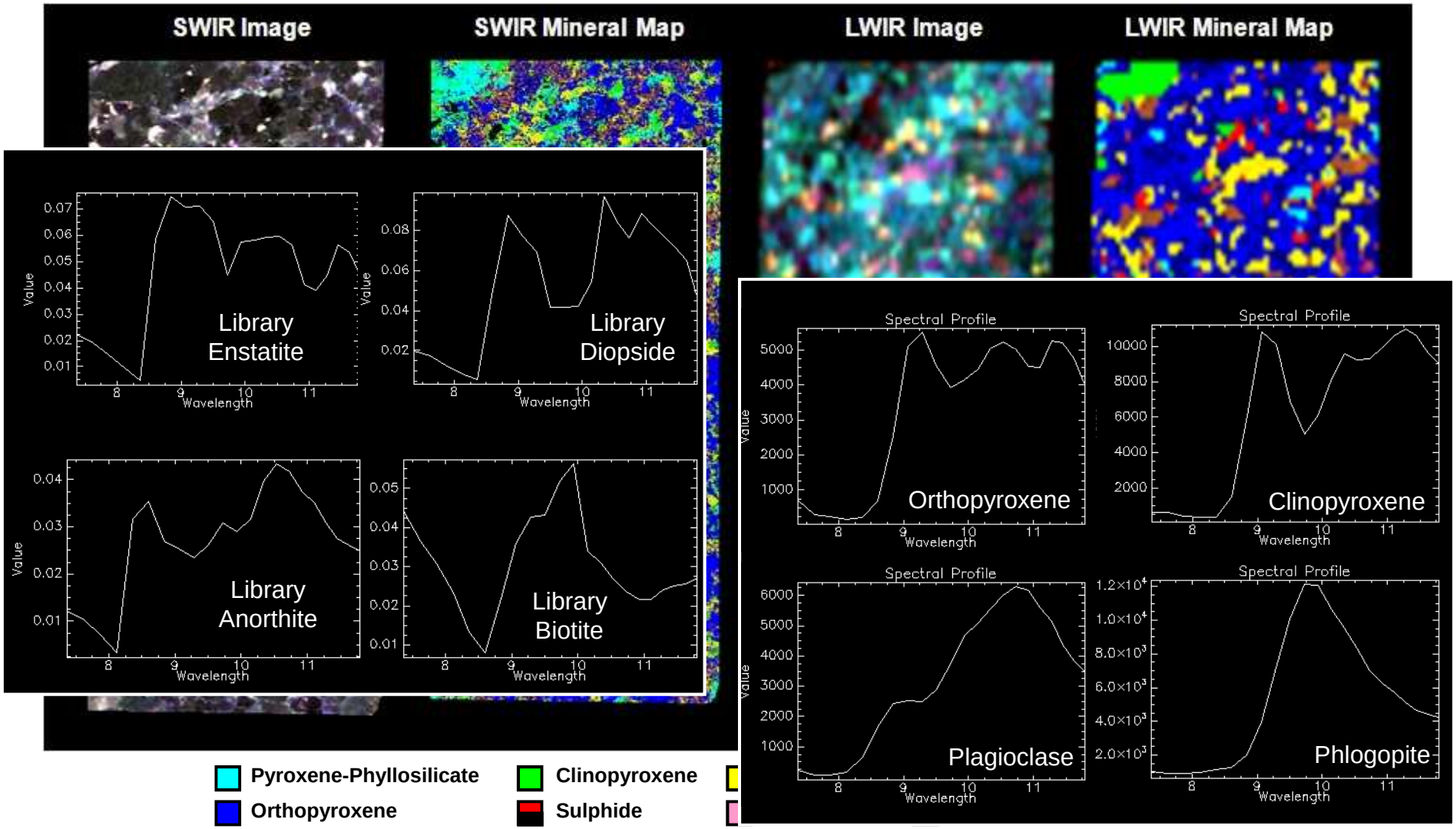
Leuconorite *40mm*

LWIR Imaging : Data Results II



Plagioclase Pyroxenite — *40mm*

LWIR Imaging : Data Results II



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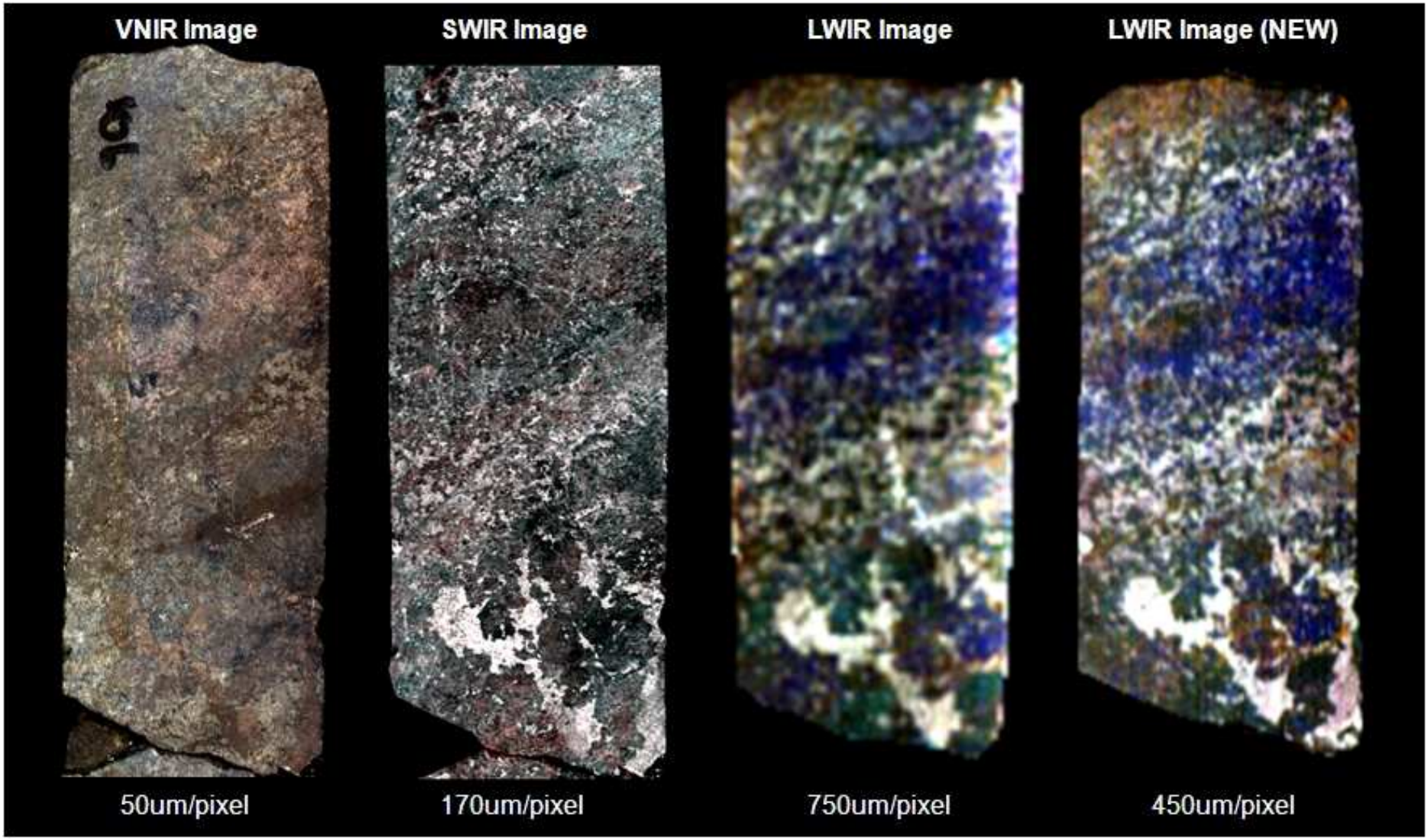
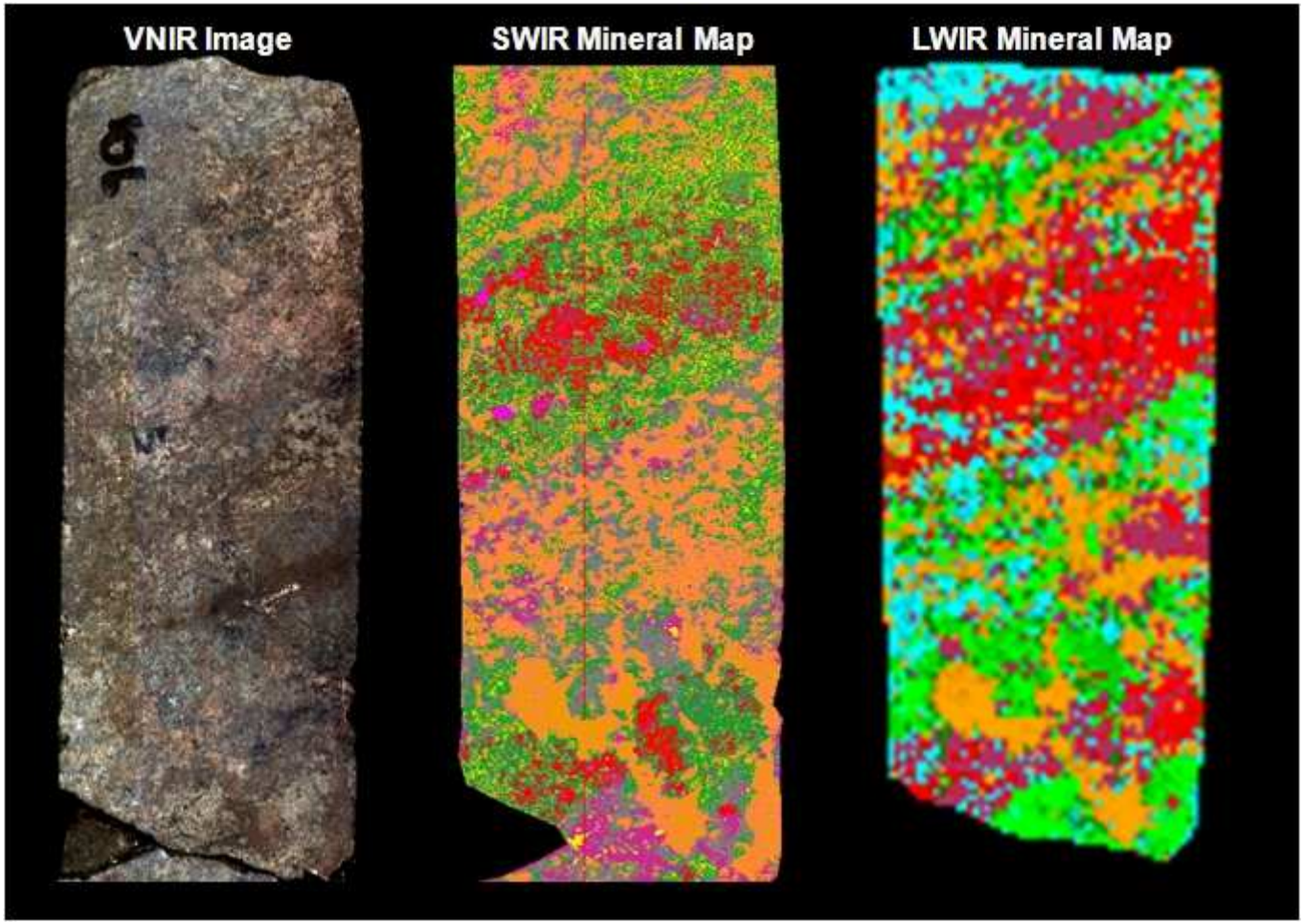
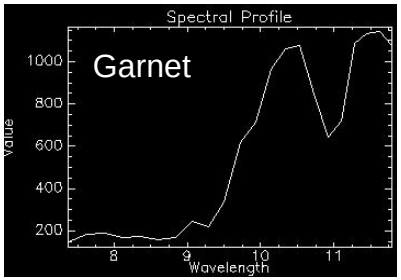
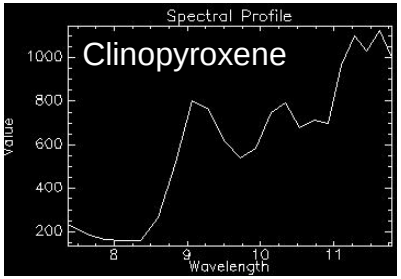
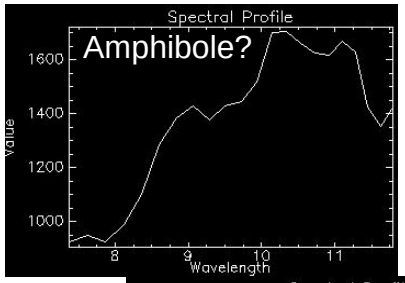


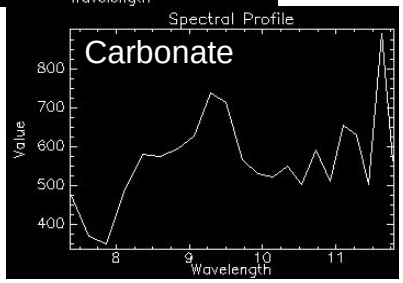
LWIR Imaging: Data Results IV







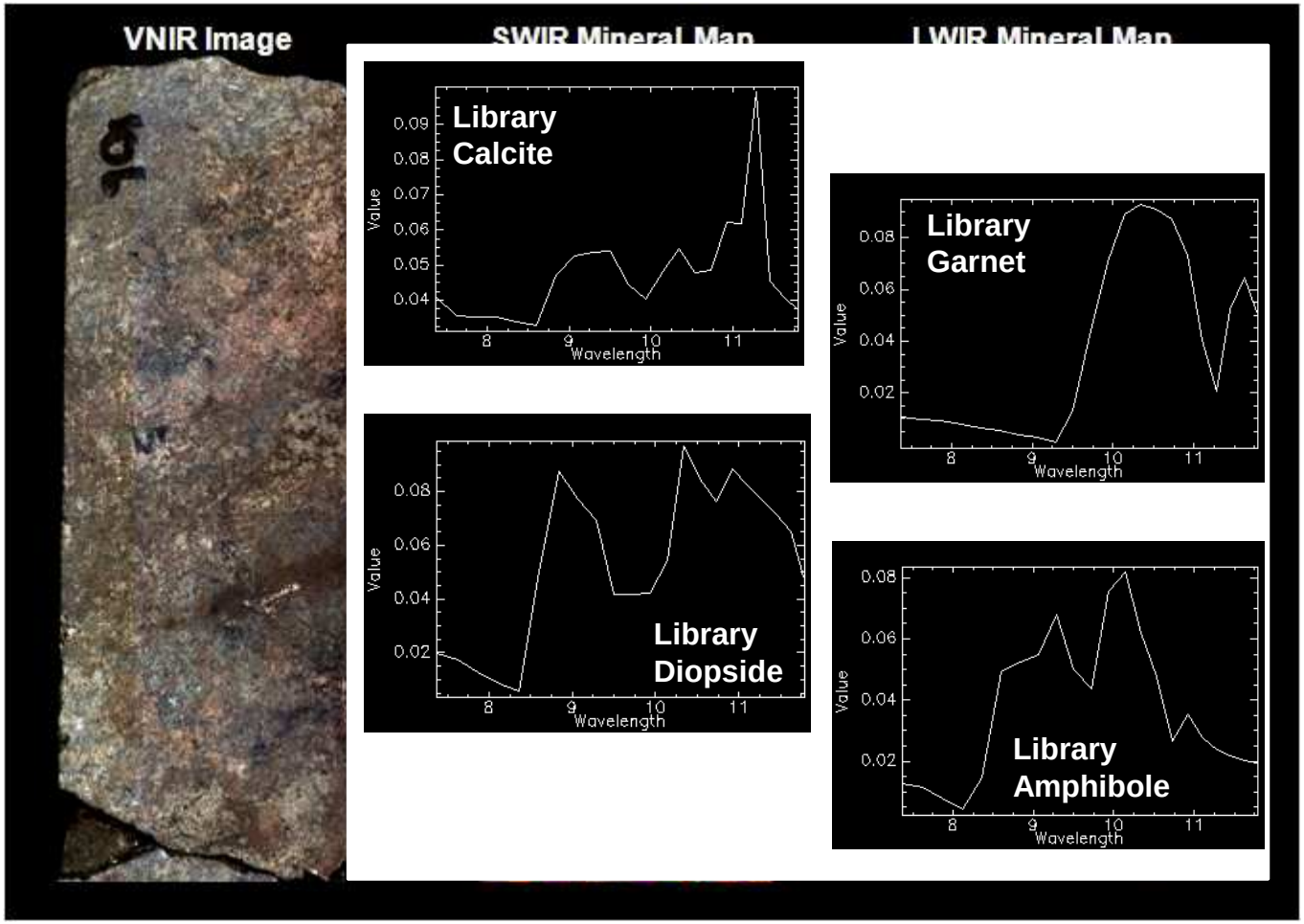


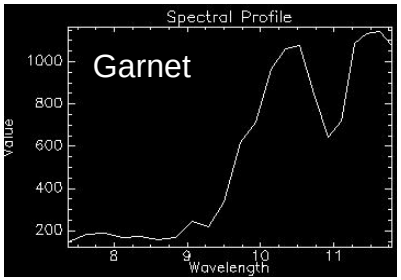


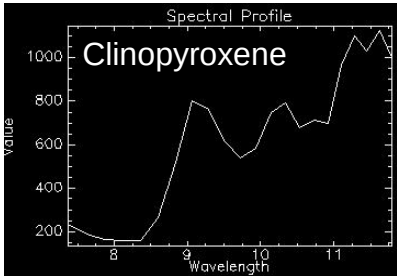
- Carbonate
- Sulphide
- Clinopyroxene
- Garnet
- Quartz
- Phyllosilicate (Amphibole?)

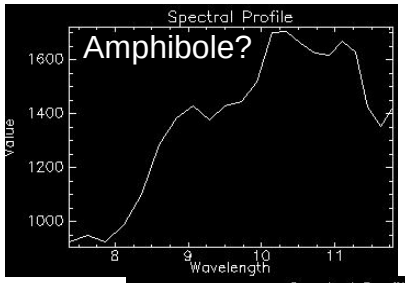
Skarn Assemblage — *40mm*

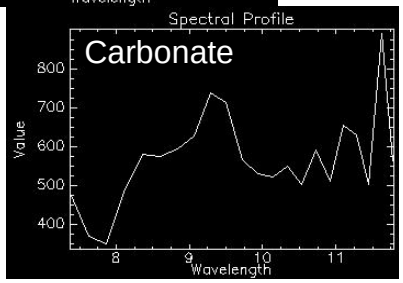
LWIR Imaging: Data Results IV







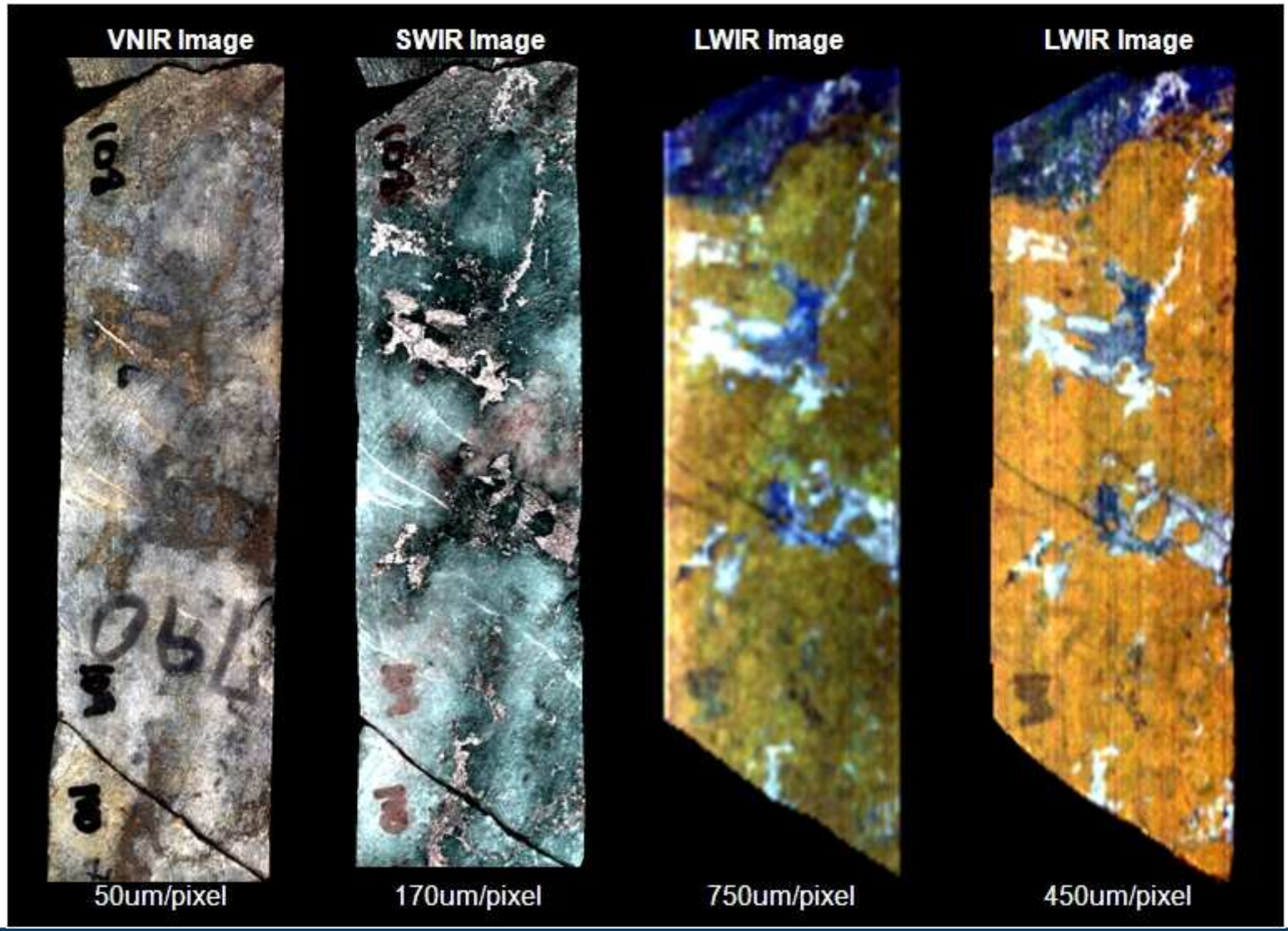




Carbonate
Clinopyroxene
Quartz
Sulphide
Garnet
Phyllosilicate (Amphibole?)

Skarn Assemblage — *40mm*

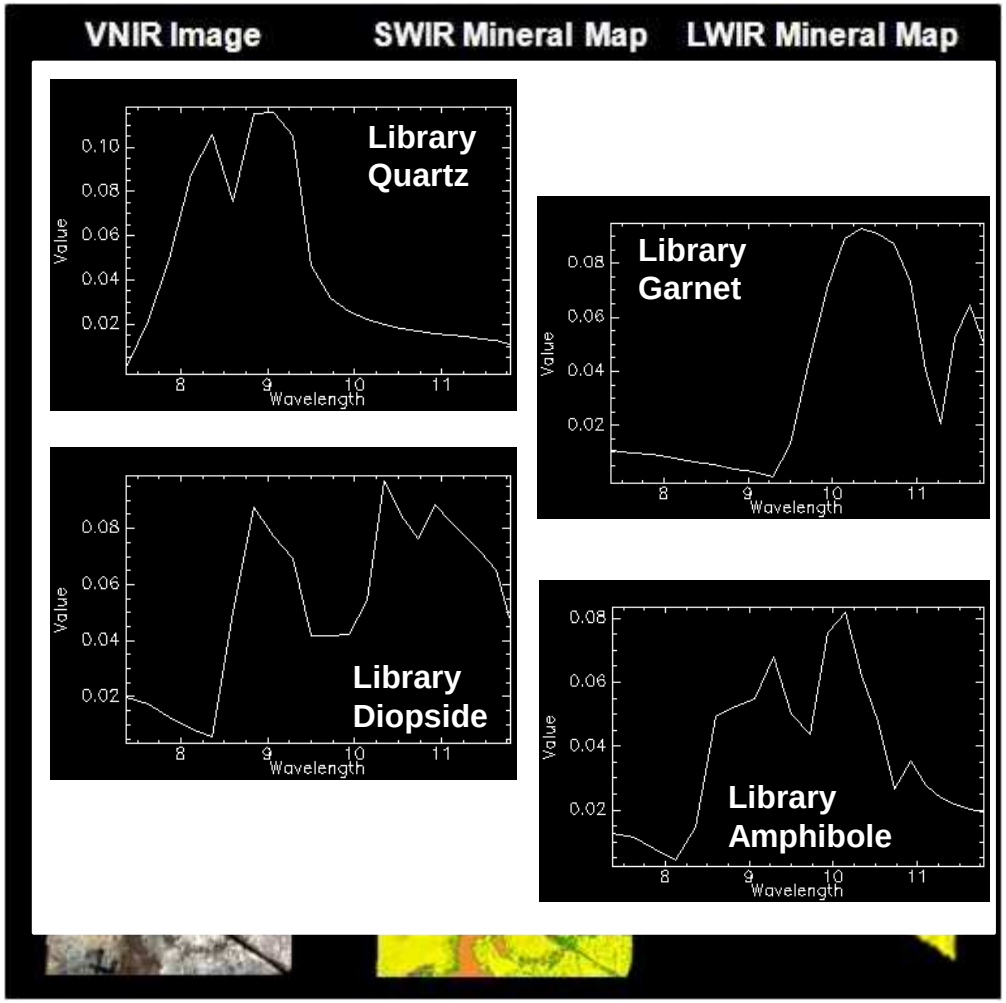
LWIR Imaging: Data Results V

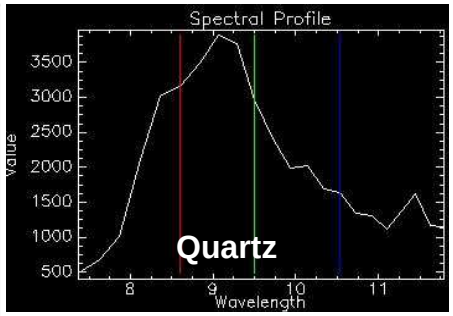


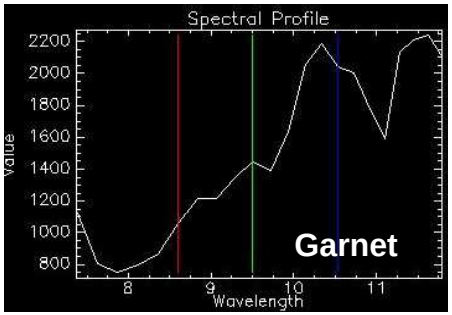
Quartz-Skarn Assemblage

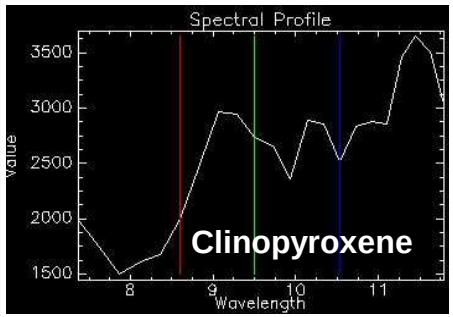
40mm

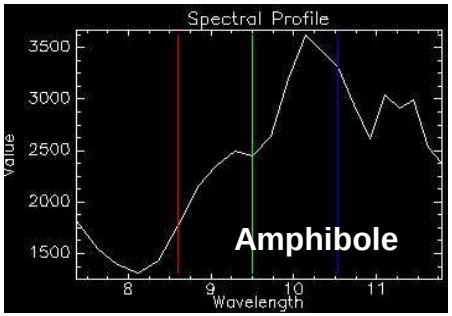
LWIR Imaging: Data Results VI











Carbonate
Sulphide
Clinopyroxene
Garnet
Quartz
Phyllosilicate (Amphibole?)
Unknown?

Potential Options: Higher Resolution Systems

LWIR Cameras	LWIR C	LWIR HS
Wavelength Range	7.8µm to 12.0µm	8.0µm to 12.0µm
Bands (spectral pixels)	22 (30)	84
Spatial Pixels	384	384
Spectral Resolution	400nm	100nm
Detector Type	Microbolometer	MCT
Spectral Sampling	200nm (mean)	48nm
Instrument Temperature	300 K	300 K
Instr. Temp. Control	None	Stabilized
Camera Dimensions	55x130x125 (mm)	220x200x220 (mm)
Camera Weight	2.5 kg	8.5 kg

Wavelength	LWIR HS SNR@300K
8µm	450
10µm	580
12µm	215

Wavelength	TIRLogger SNR CSIRO*
7µm	100
8-11µm	400-500
12µm	200
14µm	100

After Holma et al., 2009 and Cudahy et al., 2009.*

LWIR Drillcore Imaging: Is it Possible and Practical?

- **Is it Possible?**
  - Demonstrates potential for certain applications-requires validation
  - Higher resolution system required for broader range of applications
- **Is it Stand-alone or Complimentary?**
  - Comparison of data ranges suggests that it compliments other infrared data
  - It supplements where other infrared data has not detected certain minerals
- **Is it Practical?**
  - Illumination source stability/calibration
  - Dealing with reflectance data and issues of specular reflectance
  - Is the data worth the financial investment?