HYPERSPECTRAL CORE IMAGING APPLICATIONS

- SKARN DEPOSITS -

September 2021

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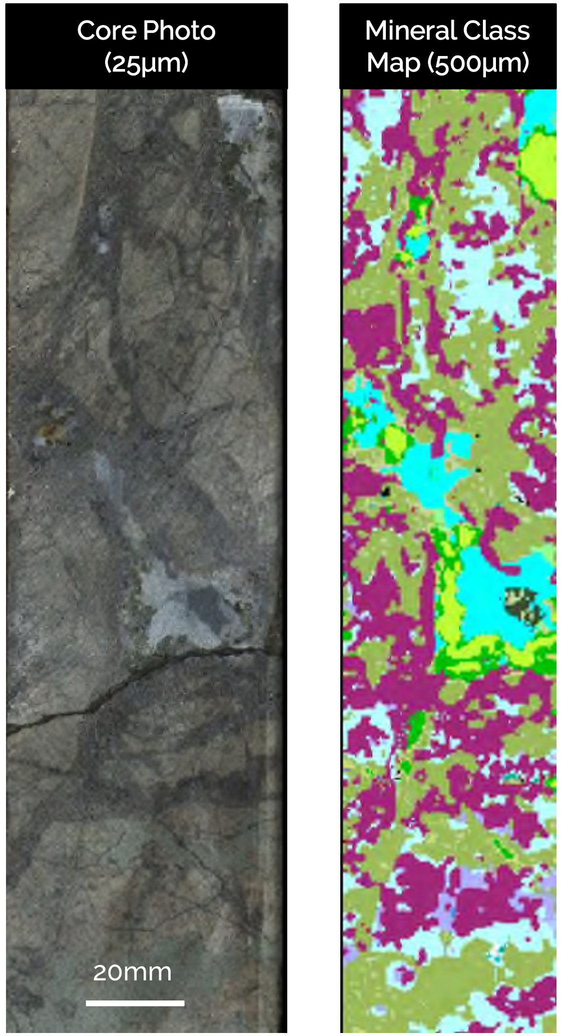
Structural Features



Hyperspectral Core Imaging Services

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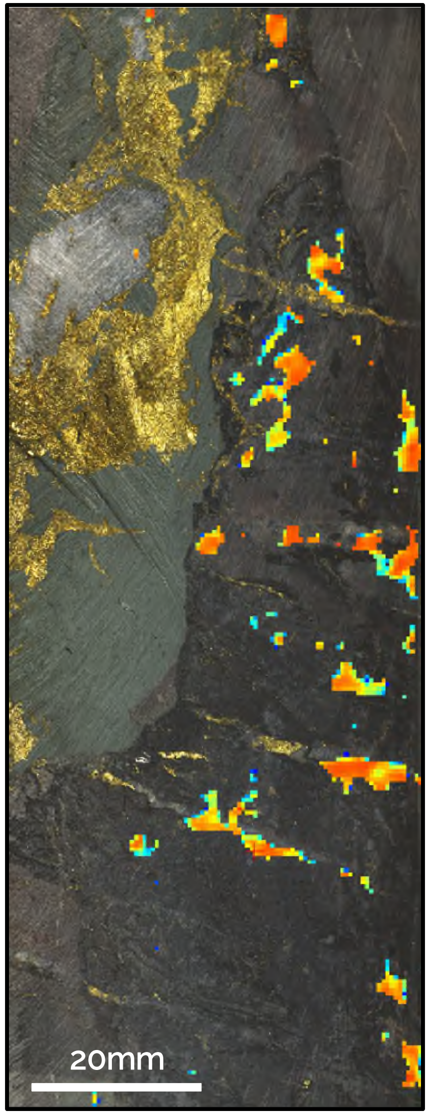
Mineral identification and mapping across the mining cycle:

- Improved alteration domains and mineral assemblages.
- Metallurgical and geochemical sample selection and characterization.
- Geotechnical measurements for mine design and engineering.
- Identification of alteration vectors for exploration targeting.
- Ore and gangue characterization for mineral processing and optimisation.
- Ground truthing of airborne hyperspectral surveys.

Corescan's Hyperspectral Core Imagers (HCI) integrates high resolution reflectance spectroscopy, visual imagery and 3D surface profiling to map mineralogy, mineral composition and core morphology, delivering enhanced geological knowledge.

Summary timeline:

- Sensor engineering commenced 2001.
- Commercial operations commenced 2011.
- 580+ projects / 1.5 million metres successfully scanned, processed and delivered...



Hyperspectral Core Imaging: Material Types

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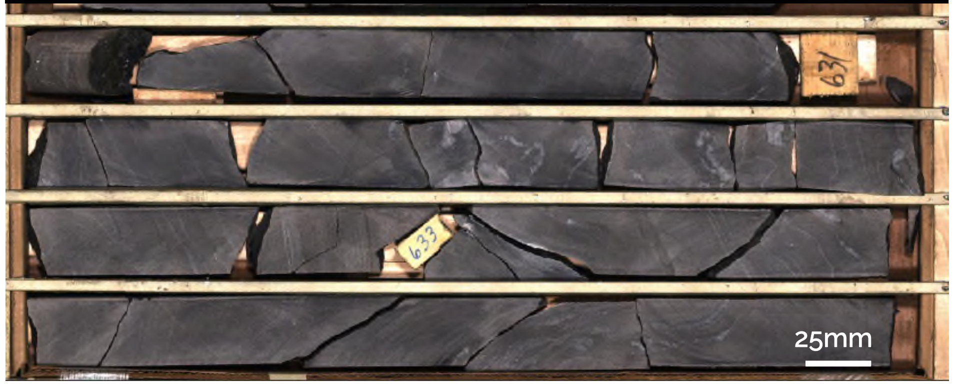
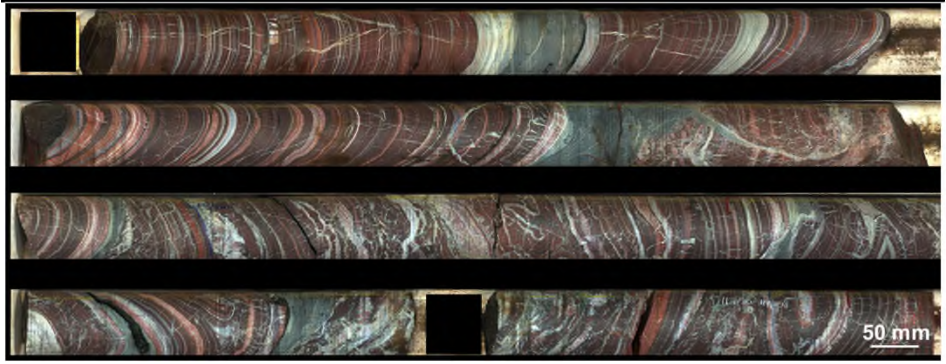
Cut / split core



Hand samples

Soils

Uncut / whole core



Chips, cuttings, blast holes

Hyperspectral Core Imager: Models 3 & 4

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Specifications	HCI-3.2	HCI-4.1	HCI-4.2
RGB photography - spatial resolution	50 µm	25 µm	25 µm
Surface profiling - spatial resolution	500 µm	50 µm	50 µm
Spectrometer type	Imaging	Imaging	Imaging
Imaging spectrometer - spatial resolution	500 µm	500 µm	250 µm
Spectra per meter (1000mm x 60mm)	240,000	240,000	960,000
Spectral range – VNIR (nm)	450 – 1,000	450 – 1,000	450 – 1,000
Spectral range – SWIR (nm)	1,000 – 2,500	1,000 – 2,500	1,000 – 2,500
Spectral resolution (nm)	4nm	4nm	2nm
Core tray length (maximum)	1,550mm	1,550mm	1,550mm
Core tray width (maximum)	600mm	600mm	700mm
Supports material weighing	-	-	Yes
Supports pass-through workflow	-	-	Yes
Scanning speed	~10mm per second	~25mm per second	~18mm per second

For further information please visit: https://corescan.com.au/products/hyimager/

AP0001

Continuous Hyperspectral Mineralogy

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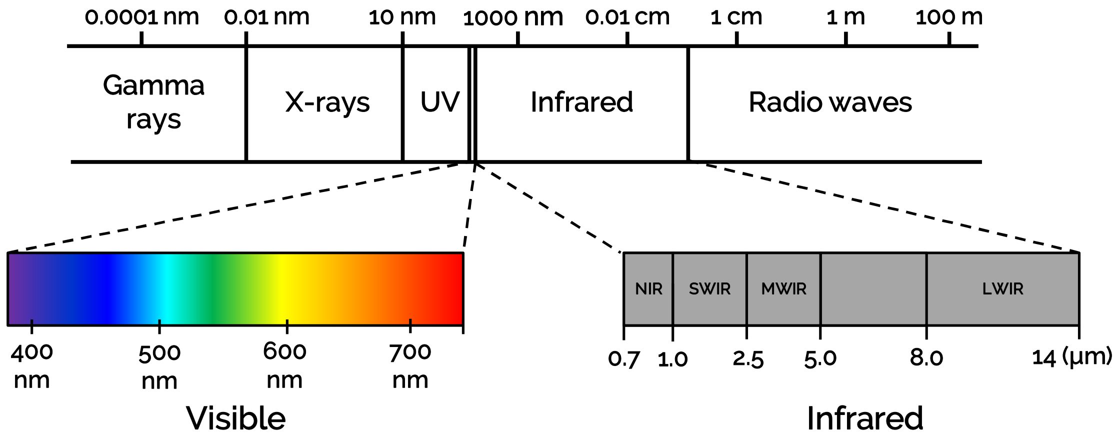
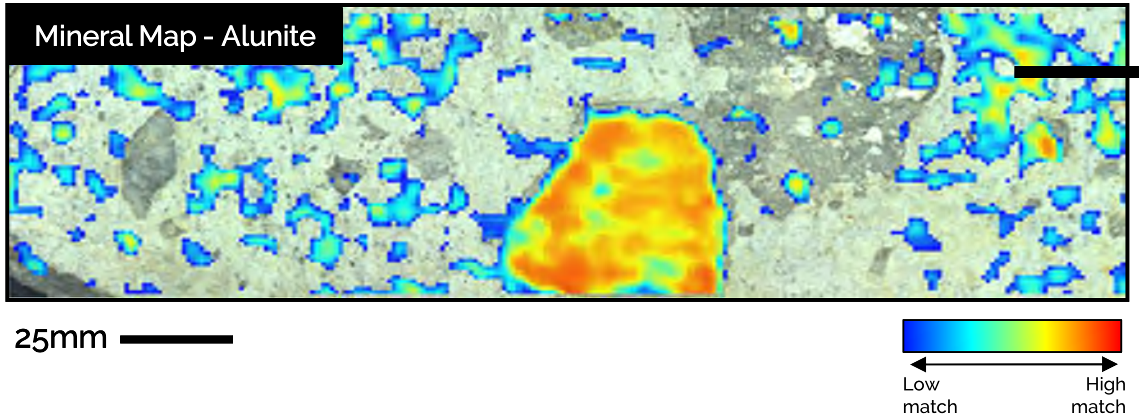
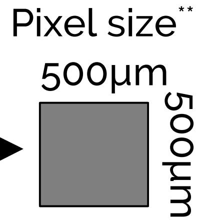
- Corescan's proprietary spectrometers measure hundreds of contiguous, narrow bands across the electromagnetic spectrum from 450nm to 2500nm, covering the Visible-Near Infrared (VNIR) and Short-Wave Infrared (SWIR) regions.



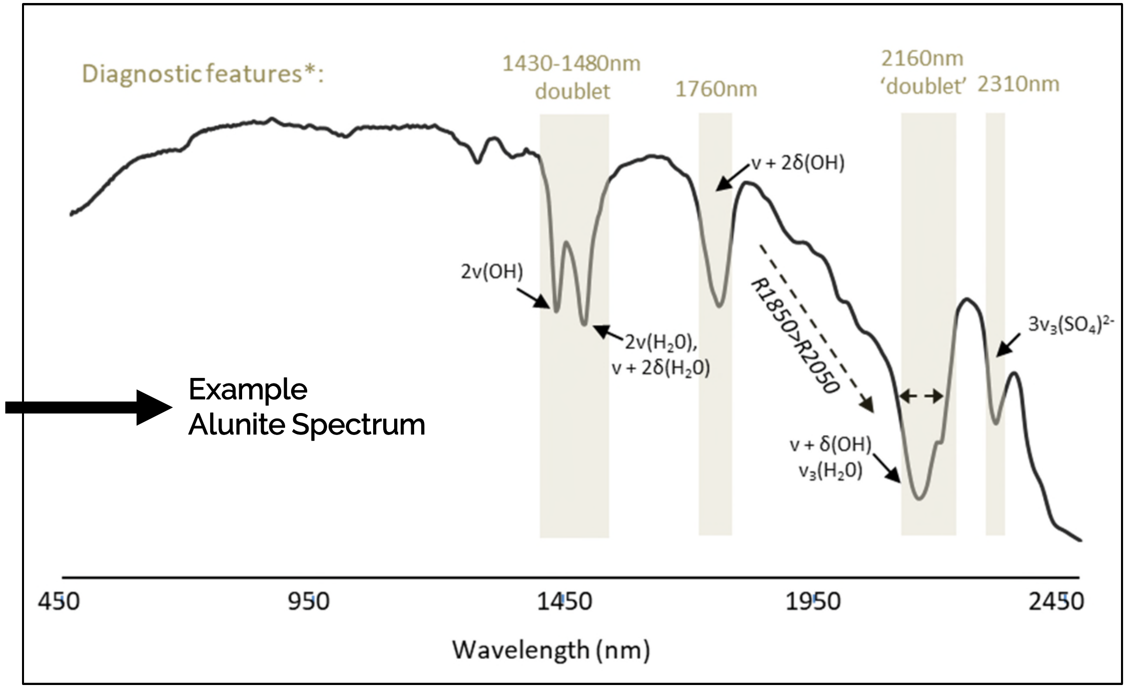
Harraden, 2018

- The surface of the core is imaged at ~250,000 pixels per meter*; with each 500µm x 500µm pixel* measuring a unique spectral signature.





Example Alunite Spectrum



*HCI-3 instrument specifications ** Not to scale

VNIR-SWIR: Electronic and Vibrational Features

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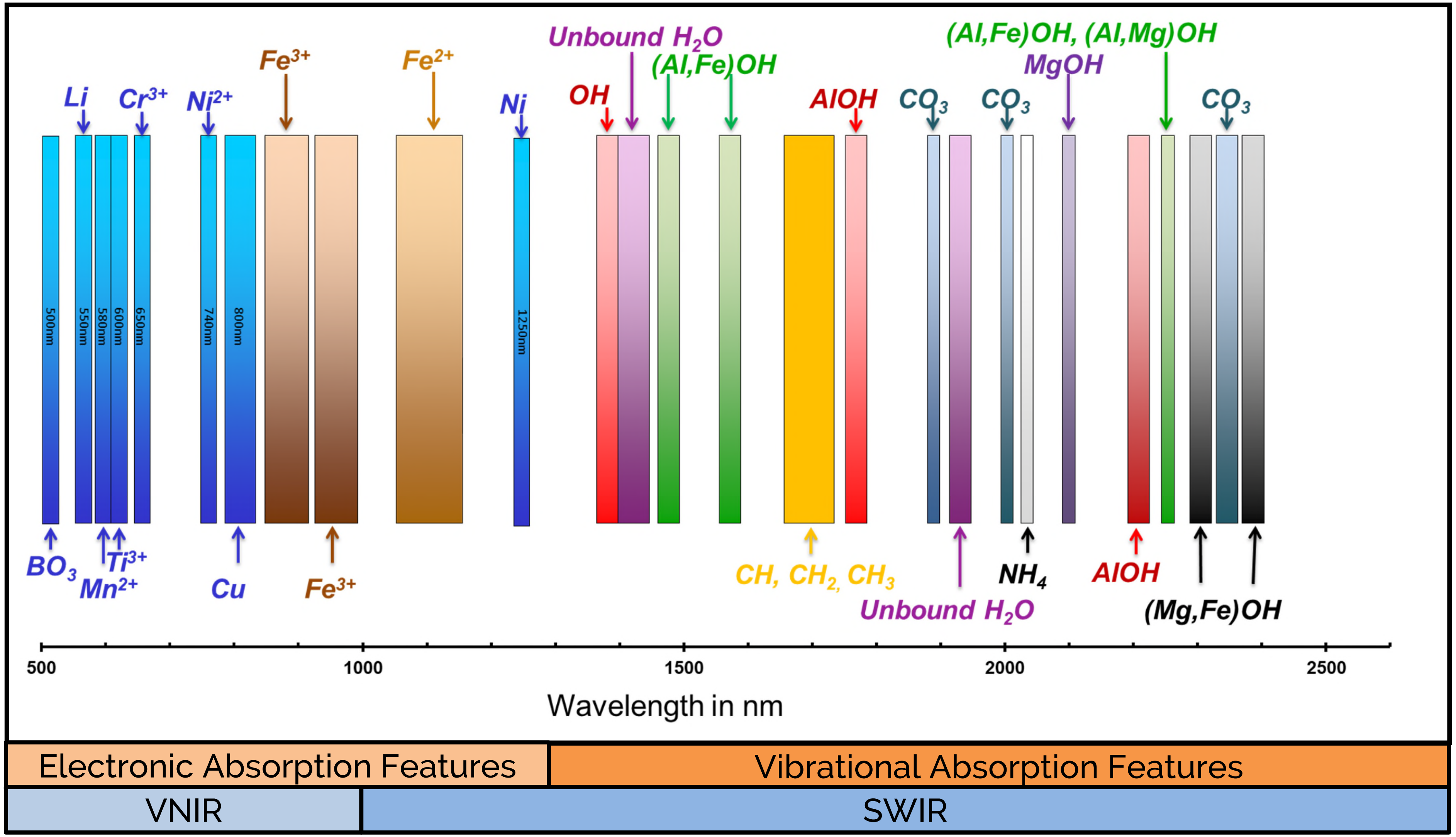
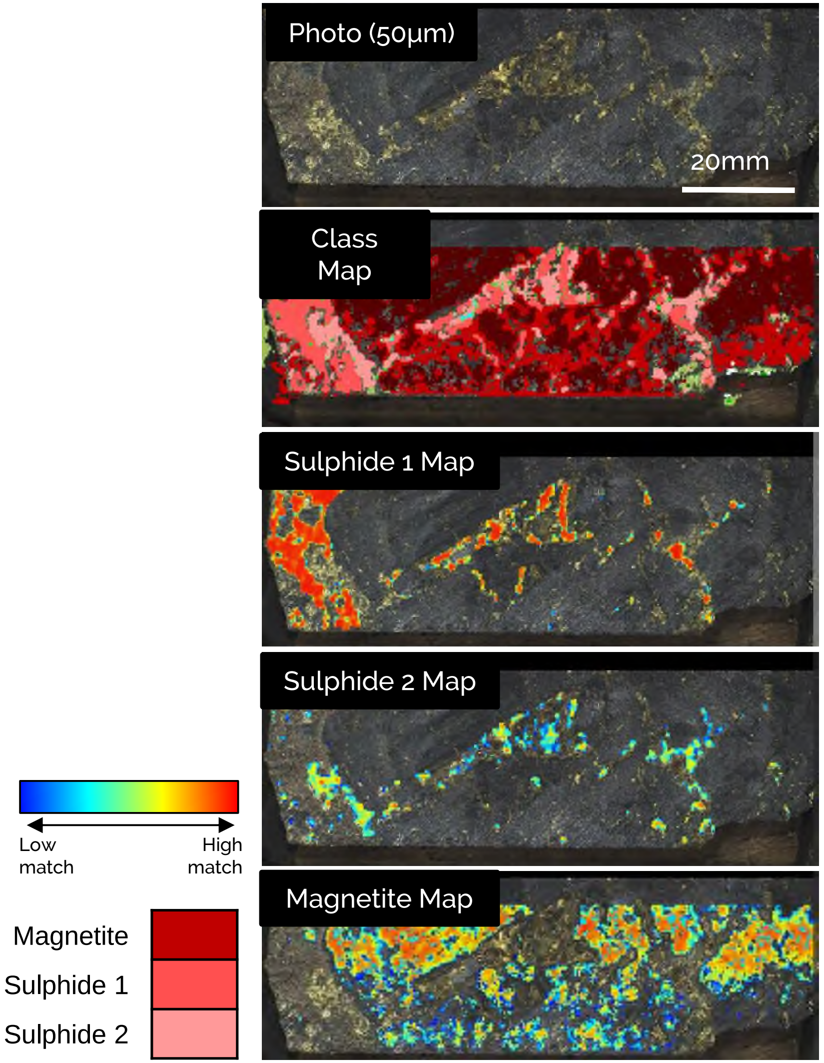


Introduction to Skarn Deposits

- Skarns deposits are highly variable class of mineral deposits and economically important sources of Fe, W, Au, Cu, Zn, Mo and Sn.
- Deposits form during regional or contact metamorphism and can occur in a range of different geological settings.
- A common characteristic of all deposits is the occurrence of calc-silicate mineral assemblages, particularly garnet and pyroxene.
- Mineralogical zonation patterns are well established for a range of skarn types and can be an important tool for exploration at the deposit- or district-scale.
- Key mineralogical characteristics can be identified and mapped using VNIR-SWIR hyperspectral core imaging technology. This includes calc-silicate phases (prograde) as well as hydrous (retrograde) mineralogy such as epidote, chlorite, vesuvianite, etc.



VNIR-SWIR Active Skarn Mineralogy

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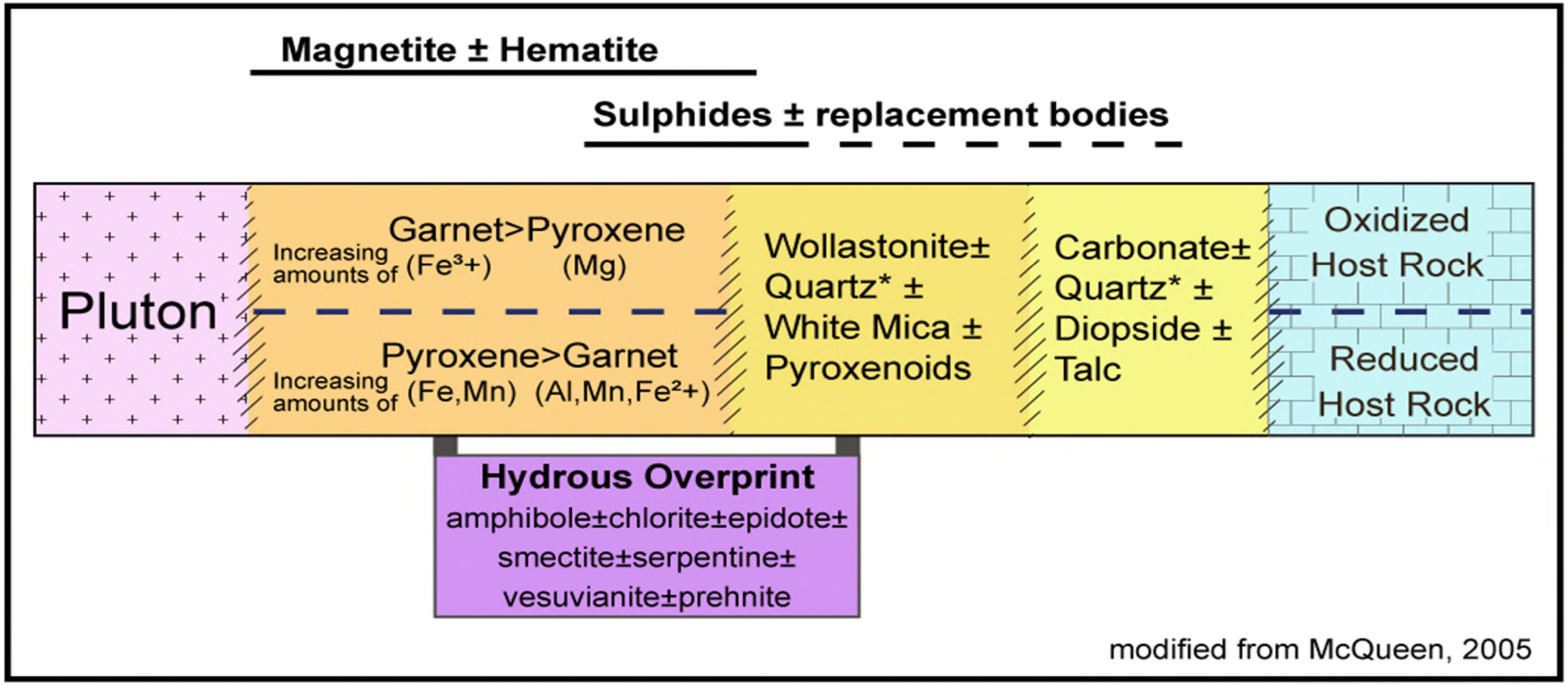

*Quartz is not strictly active in the VNIR-SWIR, however, if it contains water inclusions it can be mapped using a combination of a negative slope and the 1900nm feature. It is also mapped as a combined "Featureless Slope" group that also includes anhydrous feldspars.

“Prograde” Skarn Assemblage Example

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Garnet
Datolite
Featureless 1
Featureless 2
Sulphide
Pyroxene
Wollastonite
Quartz

"Retrograde" Skarn Assemblage Example

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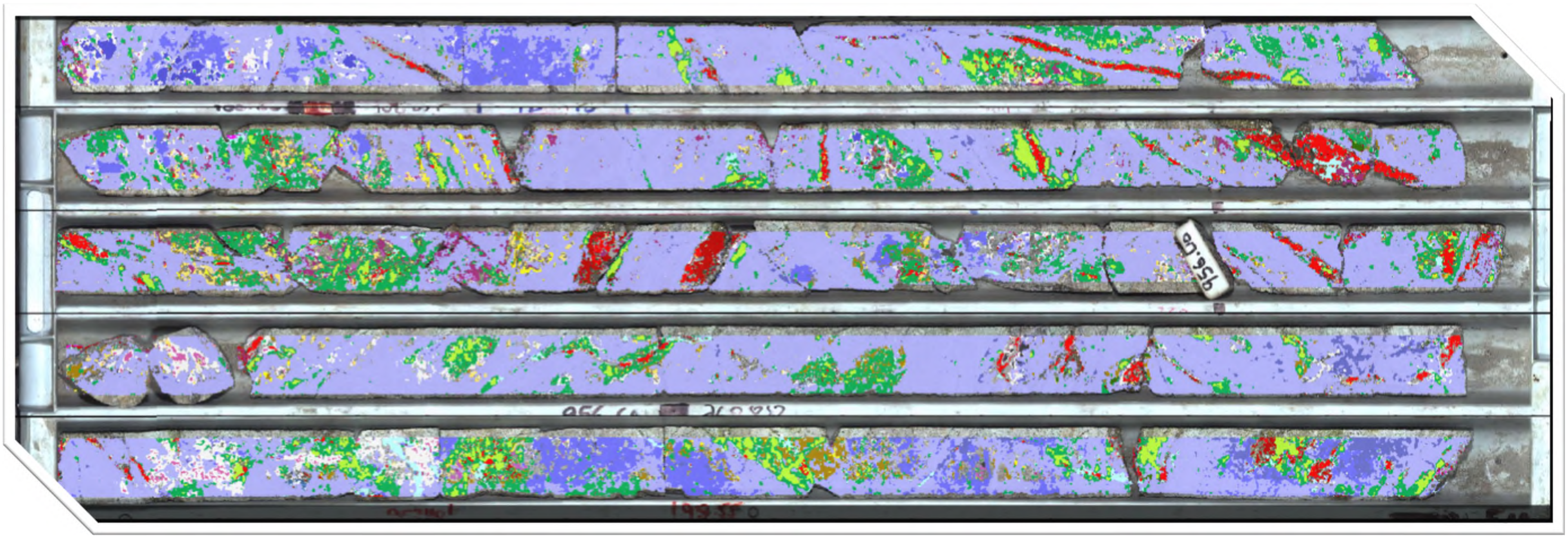

Garnet
Beidellite
Epidote
Chlorite
Sulphide
Montmorillonite
Wollastonite
Quartz

Skarn Deposits - Ore Zone Mineralogy

Sulphide Mapping in Skarns

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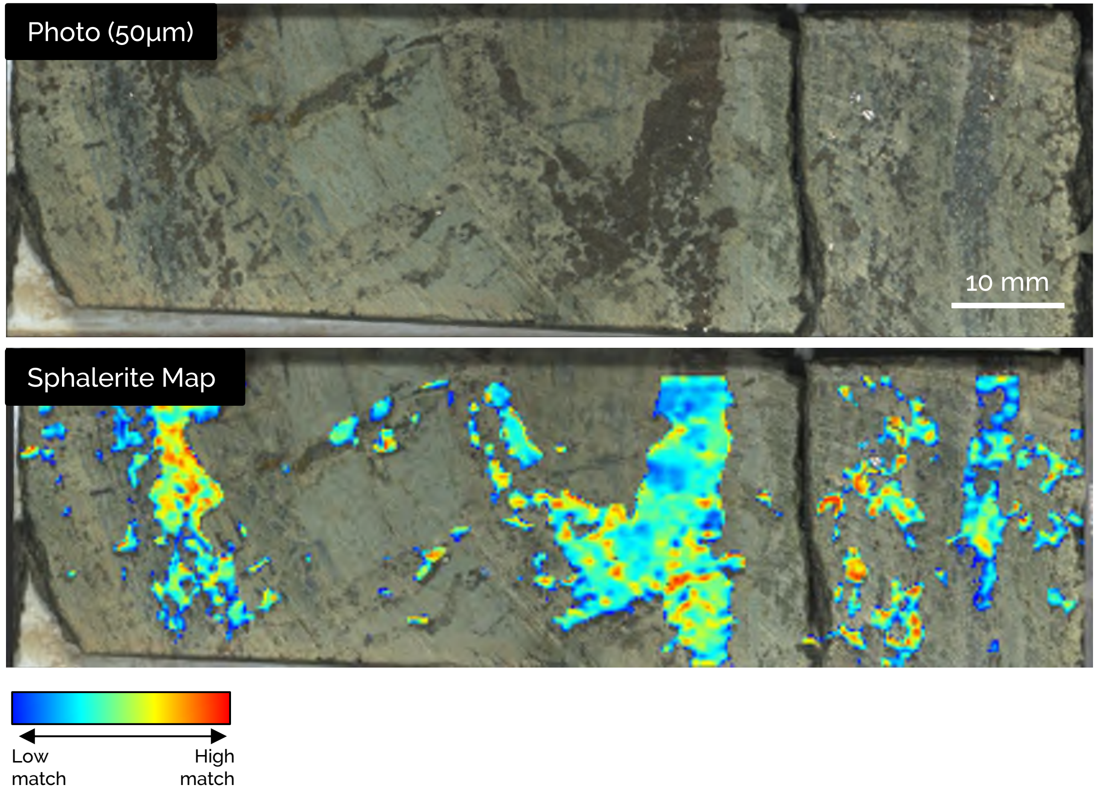
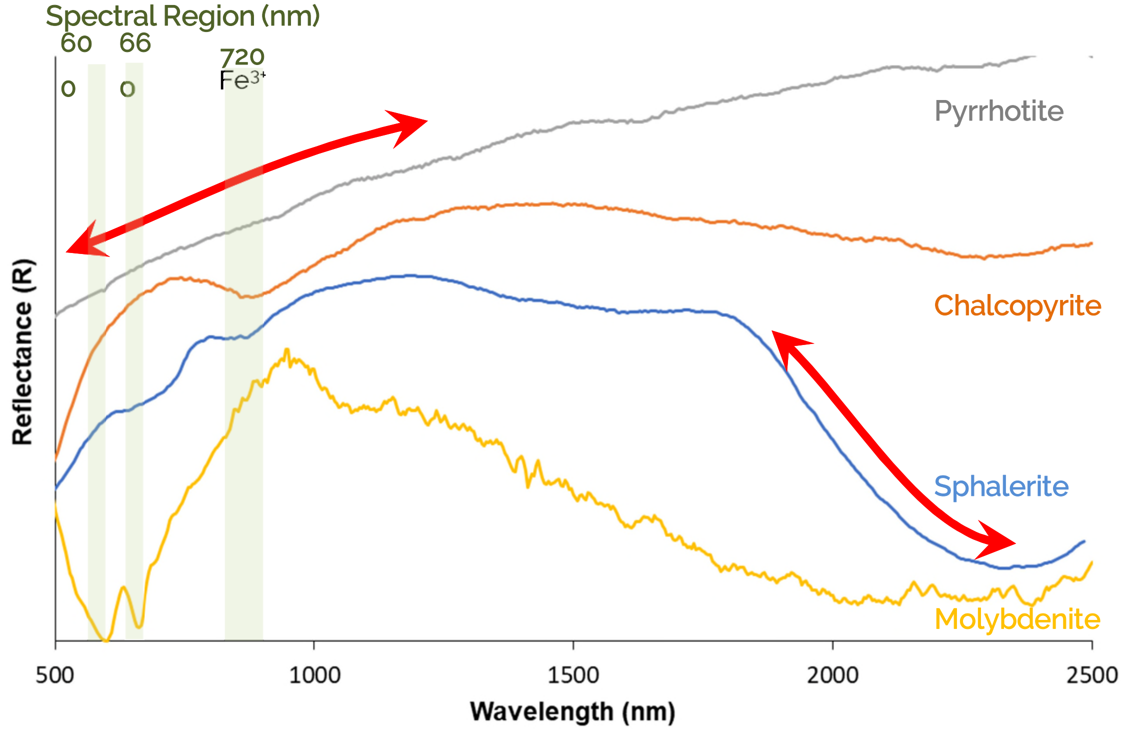
- Iron sulphides and sphalerite are commonly found in many types of skarns.
- Whereas most sulphides do not have identifiable absorption features in the VNIR-SWIR, both sphalerite and molybdenite have identifiable spectral features; sphalerite has a unique spectral profile in the SWIR and molybenite has mappable Mo features in the VNIR.





Ore Mineralogy in Skarns

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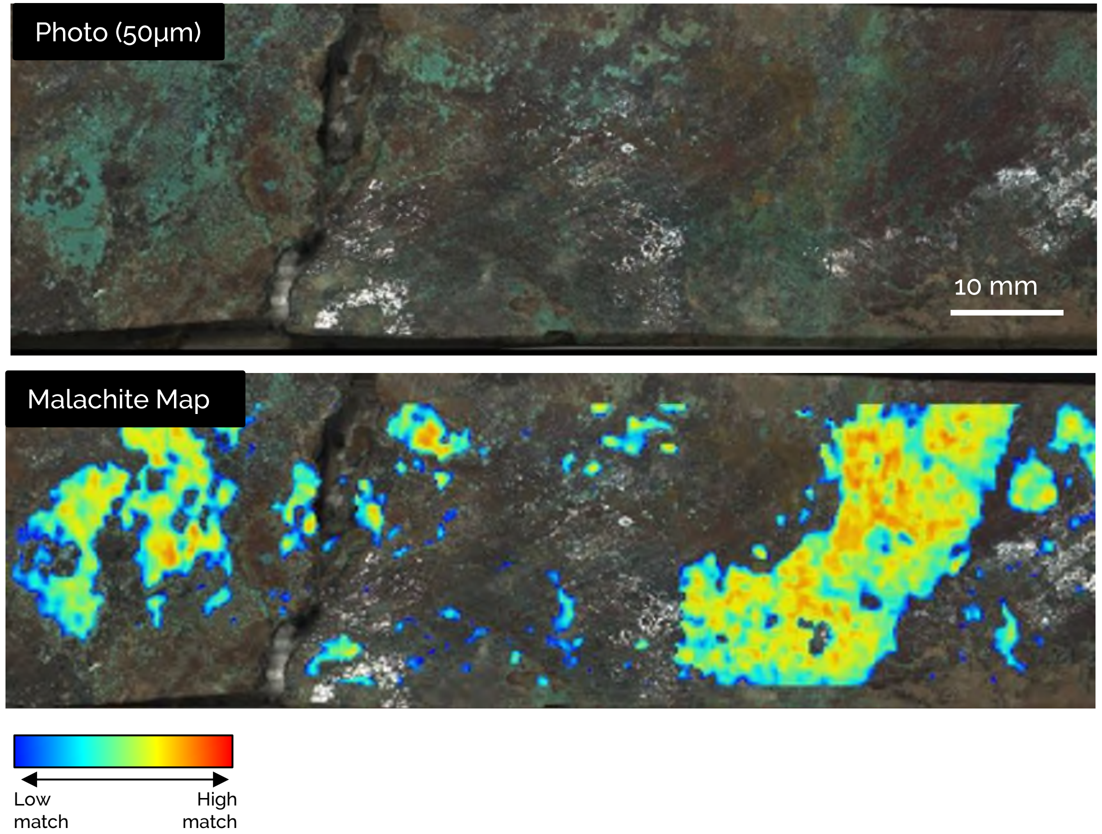
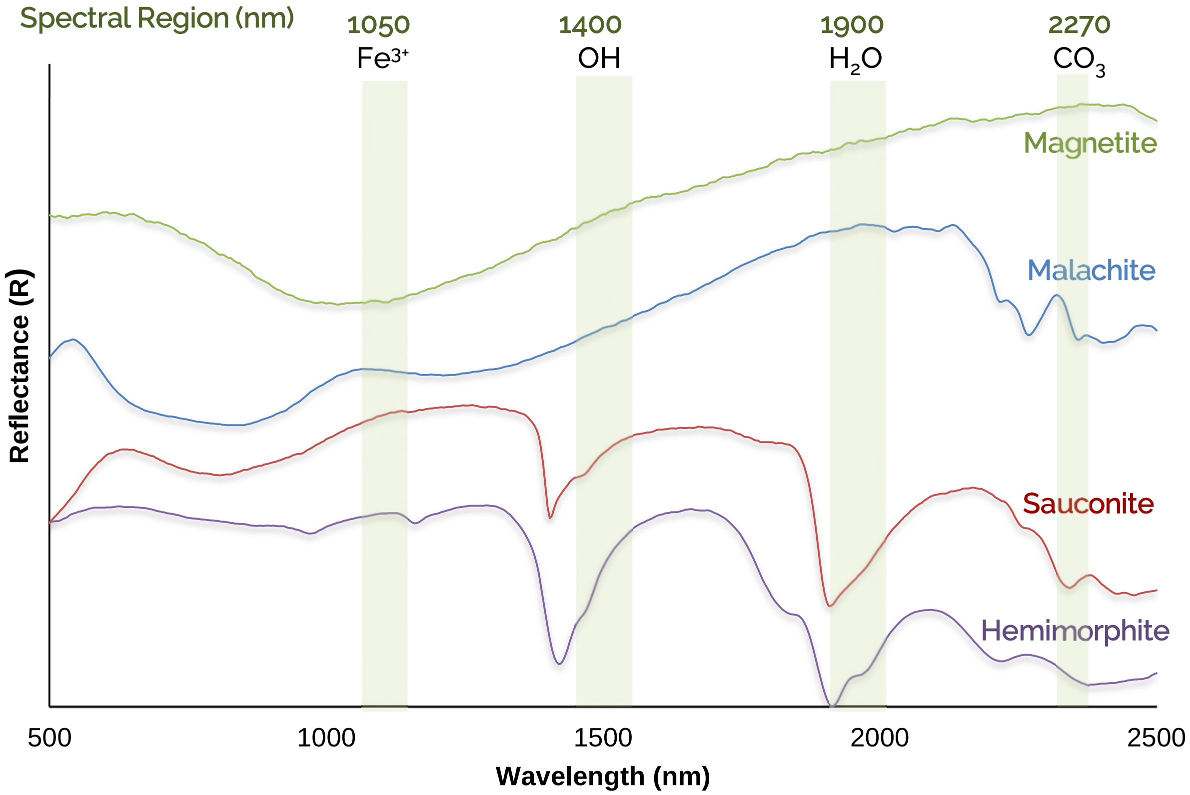
- In addition to sulphides, skarn ore minerals can include oxides (e.g., magnetite), carbonates (e.g., malachite) and a wide range of silicates (e.g., sauconite and hemimorphite).





Skarn Deposits - Protolith and Calc-Silicate Mineralogy

Protolith Skarn Mineralogy: Carbonates

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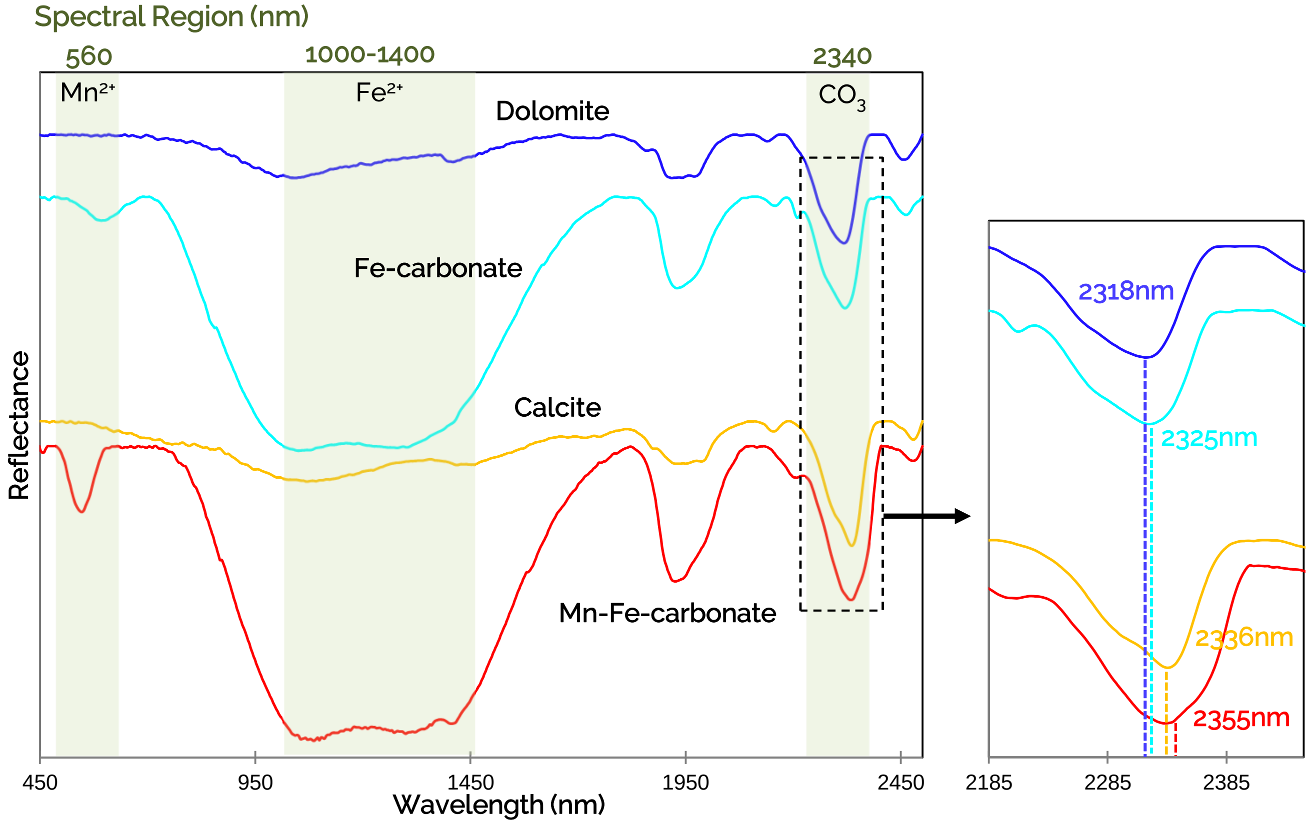
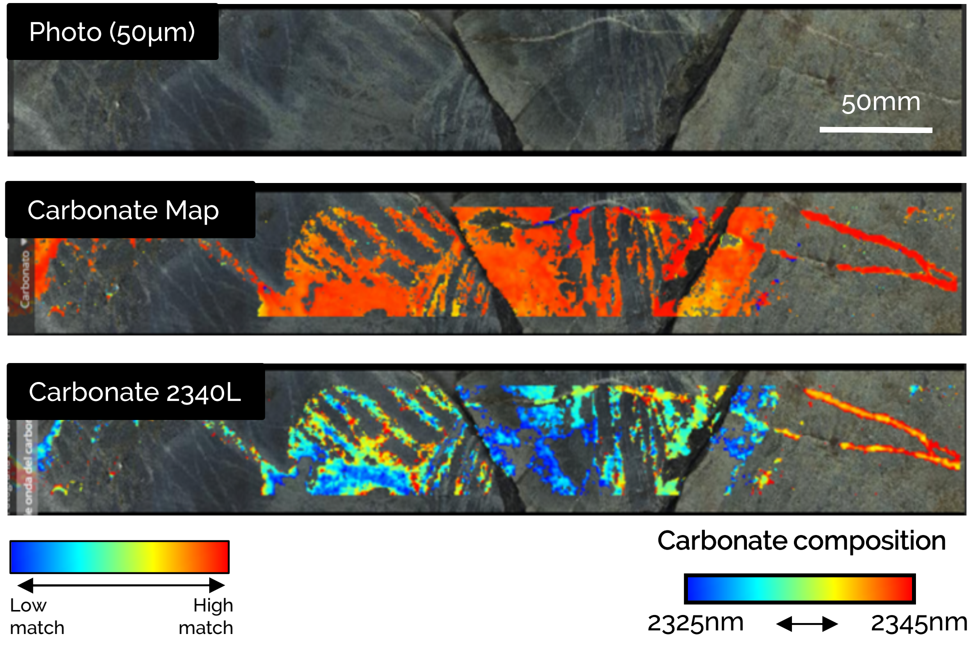
- Many different species of carbonates, particularly dolomite, calcite and Fe-rich varieties, are common in skarn systems.





- Mg-metasomatism (calcite to dolomite) can be traced in Ca-Mg carbonate varieties using variations in the ~2340nm absorption feature.
- Fe substitution in carbonate also results in a distinctive spectral feature in the VNIR that can be mapped using Corescan's HCI system.

Calc-Silicate Mineralogy: Garnet and Pyroxene

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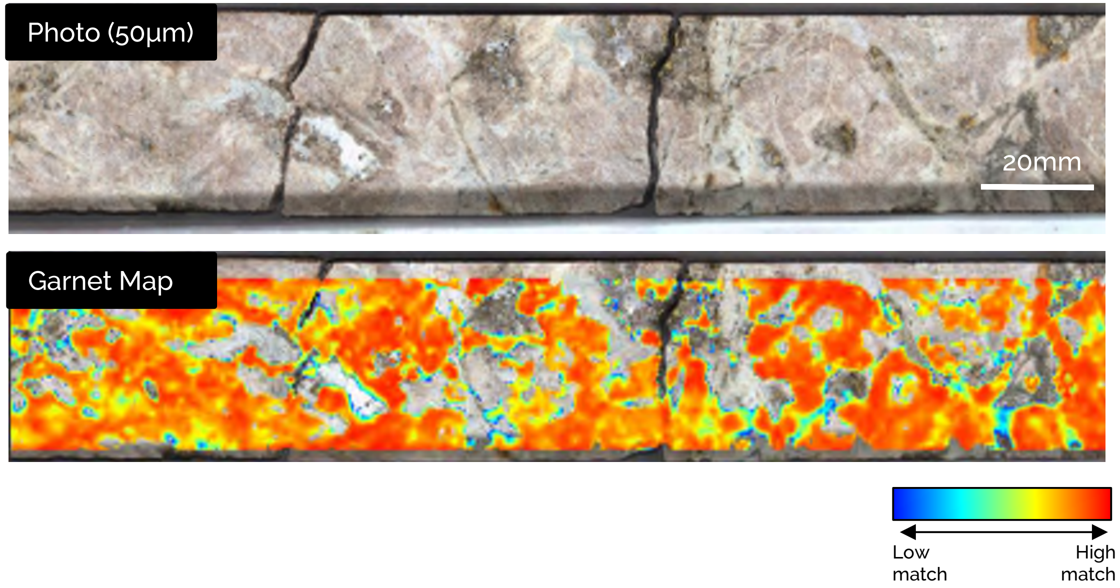
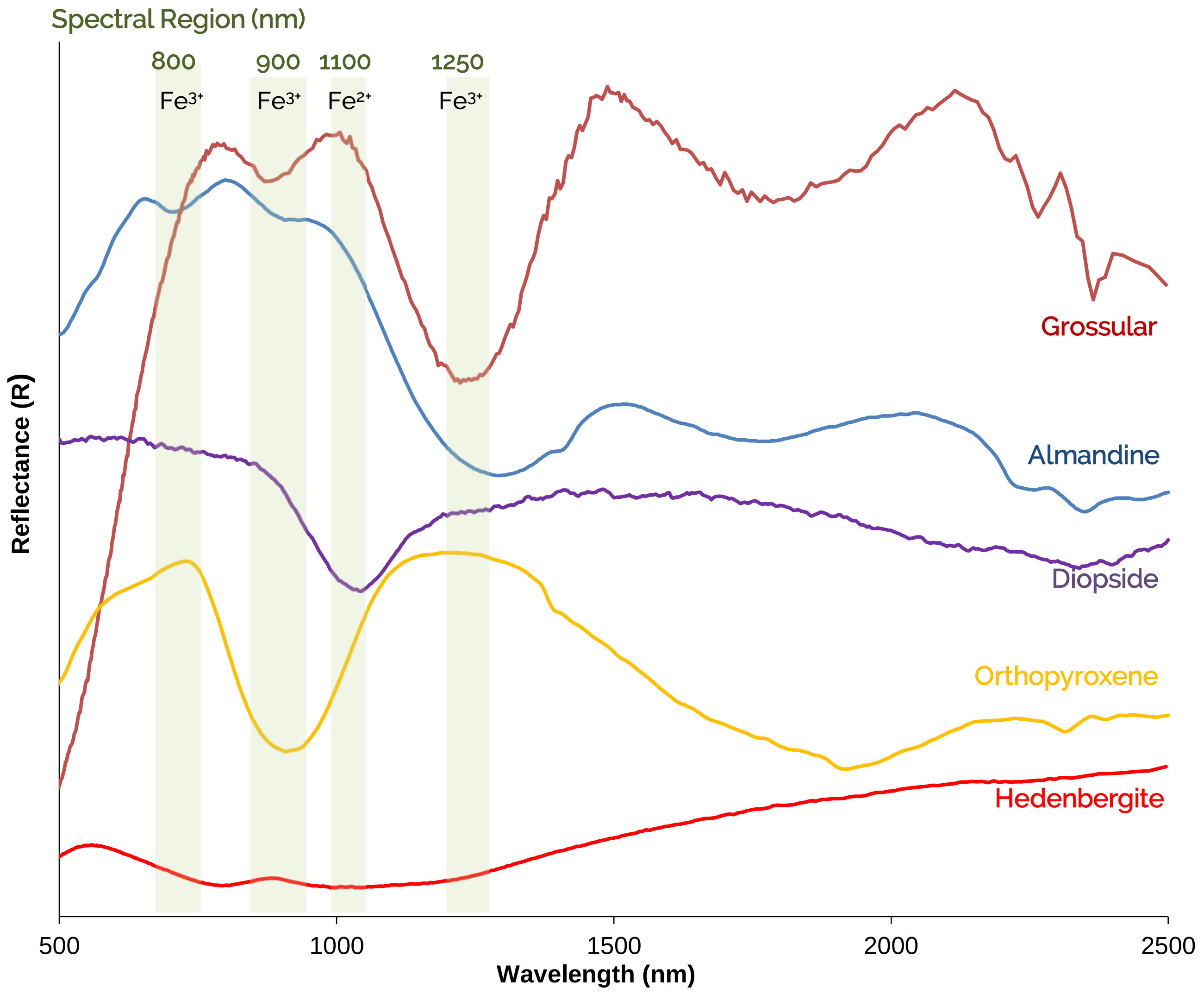
- Garnets and pyroxenes are characteristic components of most skarn deposits.
- They have distinct, but variable, VNIR features due to Fe and transition metals incorporated in the mineral's structure.
- Garnets and pyroxenes are often featureless across the SWIR region unless mixed with other minerals as a result of overprinting or alteration.

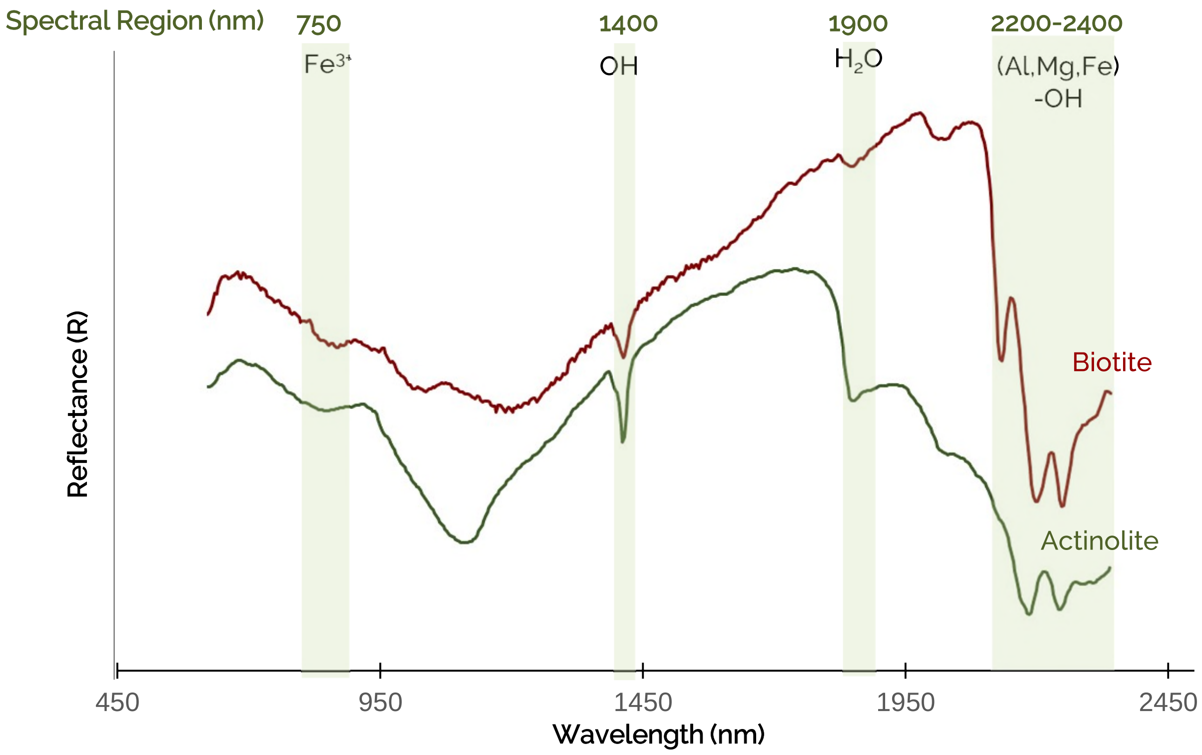


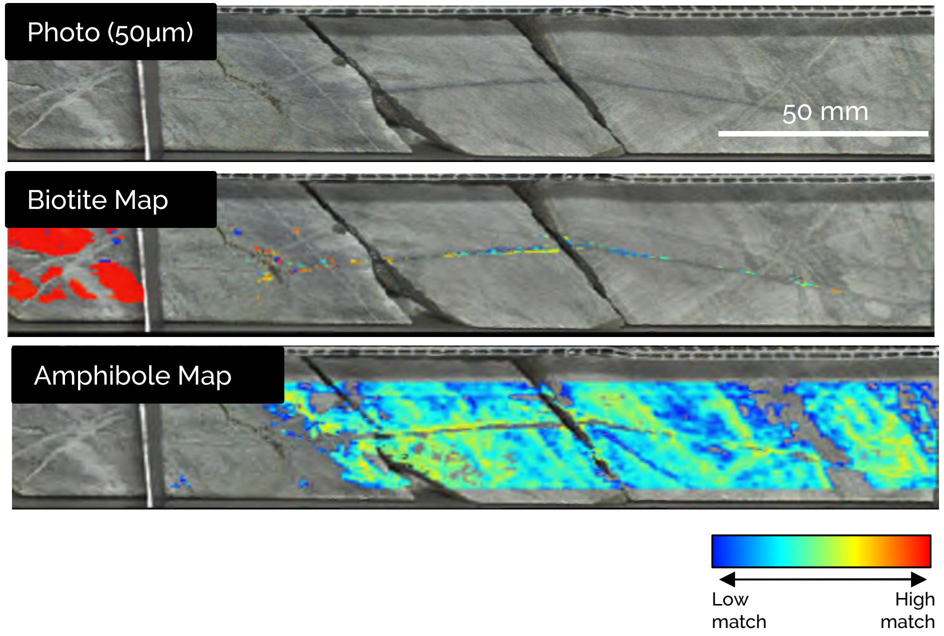


Skarn Deposits - Hydrous Overprinting Mineralogy

Hydrous Mineralogy: Biotite and Amphibole

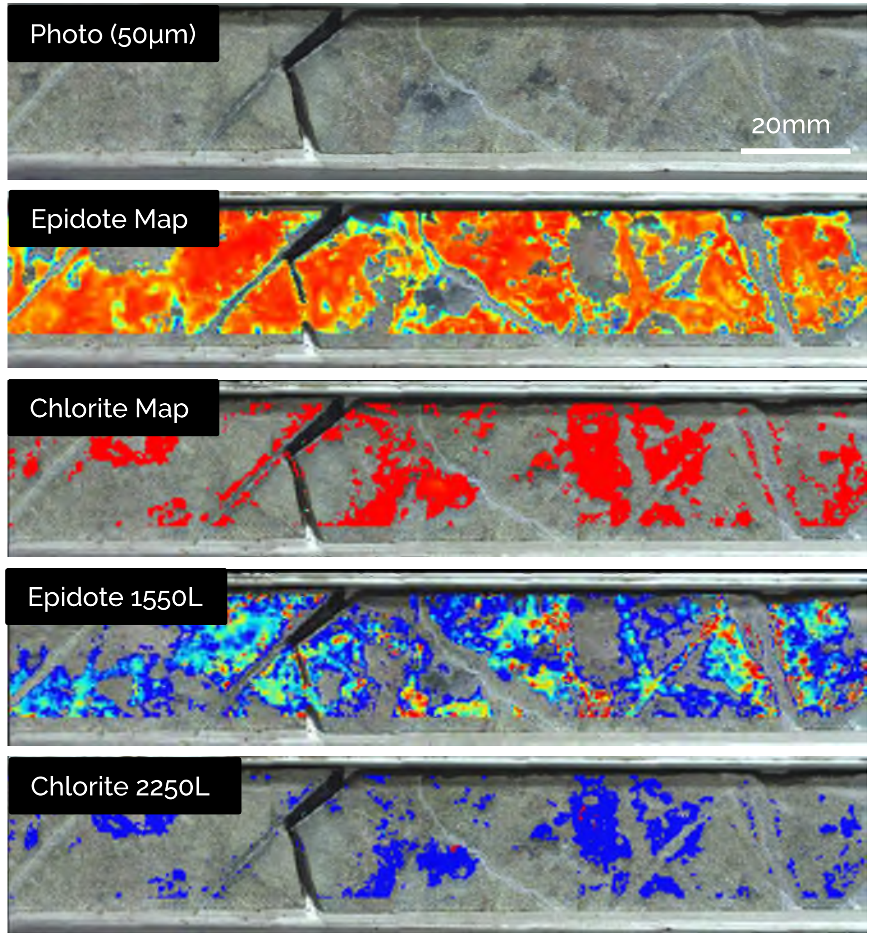
- Biotite and amphibole are common skarn minerals. While not necessarily vectors to ore proximity, understanding amphibole distribution is important because of potential geo-environmental concerns during mining (asbestos).
- Biotite and amphibole group minerals are readily identifiable using VNIR and SWIR features having distinct features that correlate to Fe/Mg content.

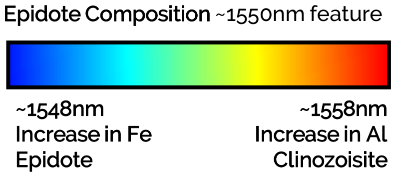


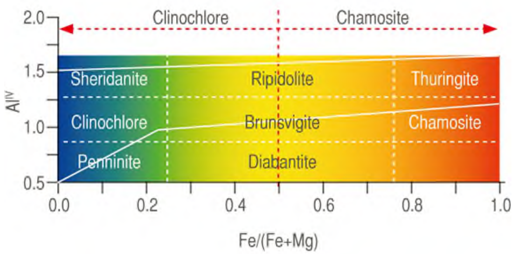


Hydrous Mineralogy: Chlorite-Epidote

- Epidote and chlorite are common skarn minerals, more typical of retrograde assemblages.







- Chlorite and epidote have distinctive SWIR features. Compositional variations can be tracked using the wavelength positions of key absorption features.

Calc-Silicate Mineralogy: Vesuvianite

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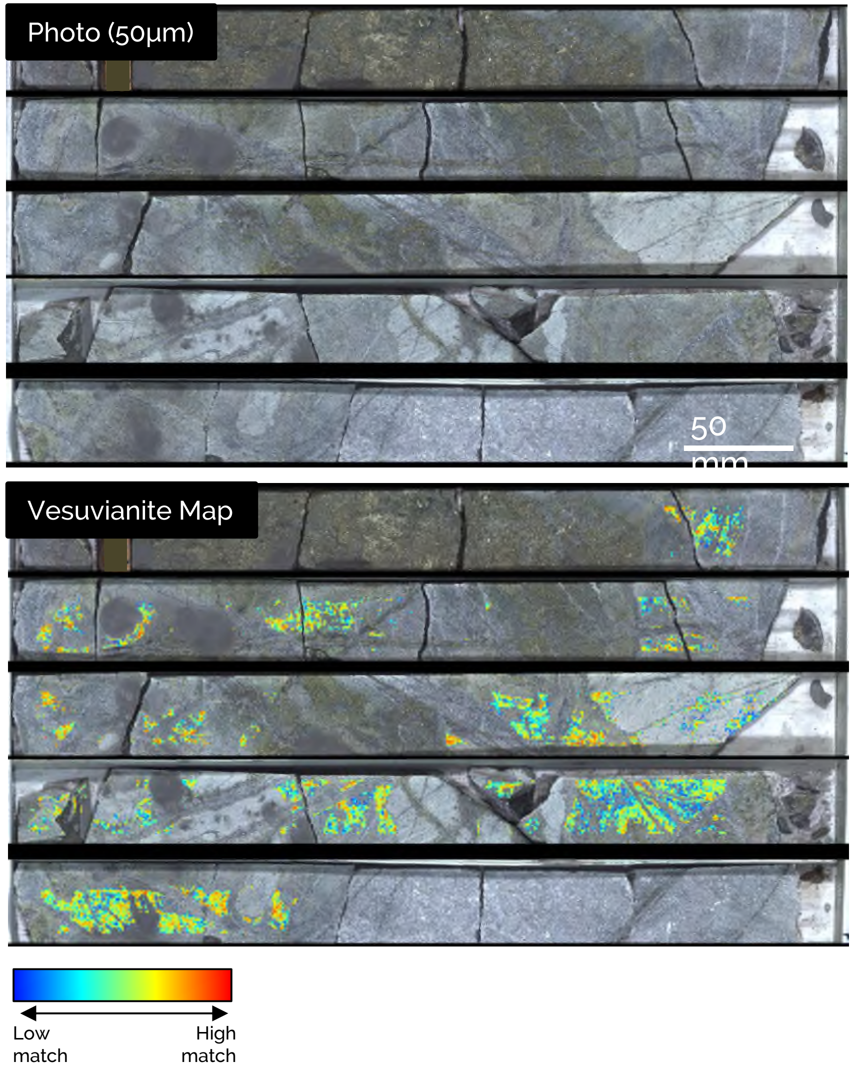
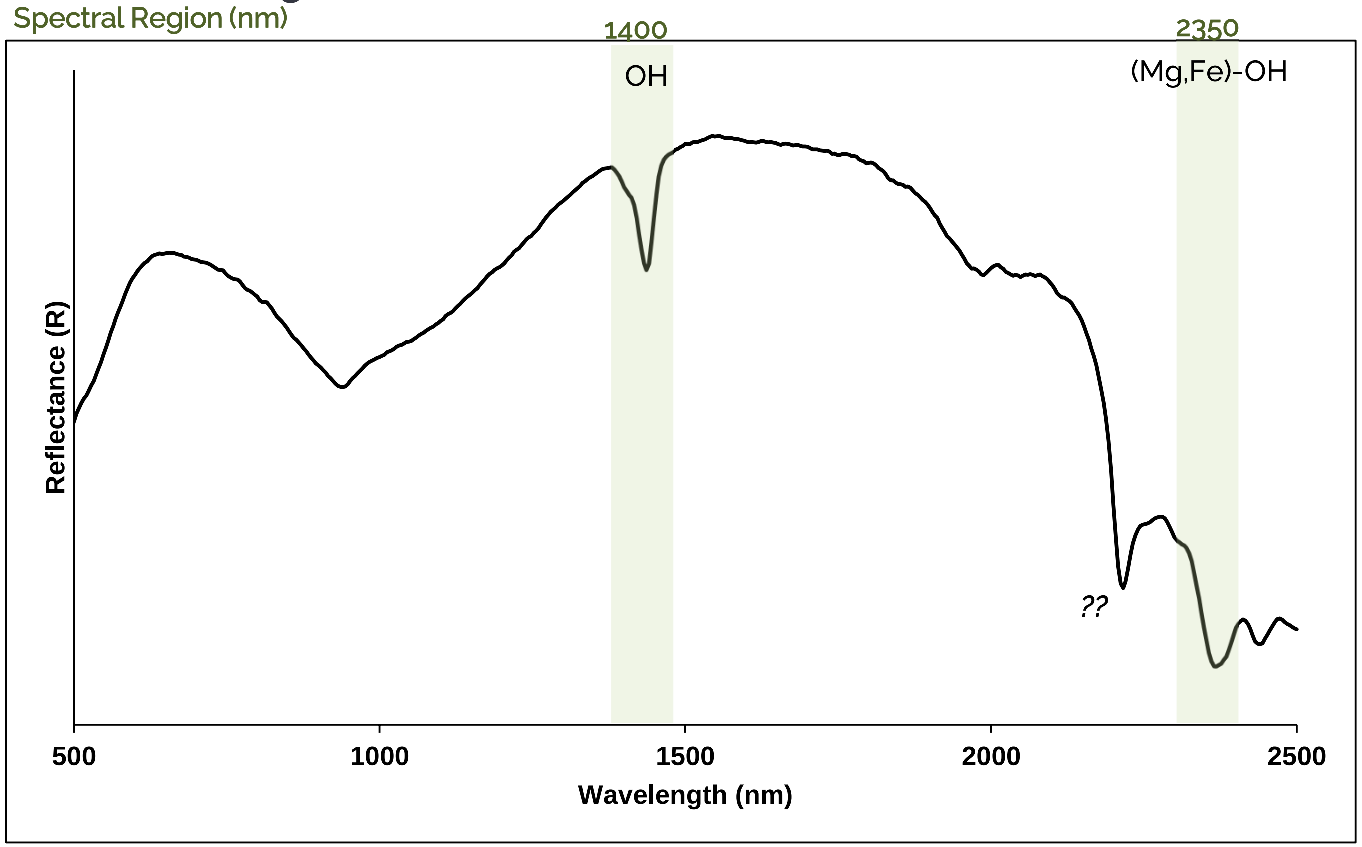


- Vesuvianite can either be a relatively early metasomatic mineral in skarn systems, found in proximity to garnets and wollastonite, or part of the overprinting hydrous (retrograde) assemblage.



Hydrous Mineralogy: Smectites

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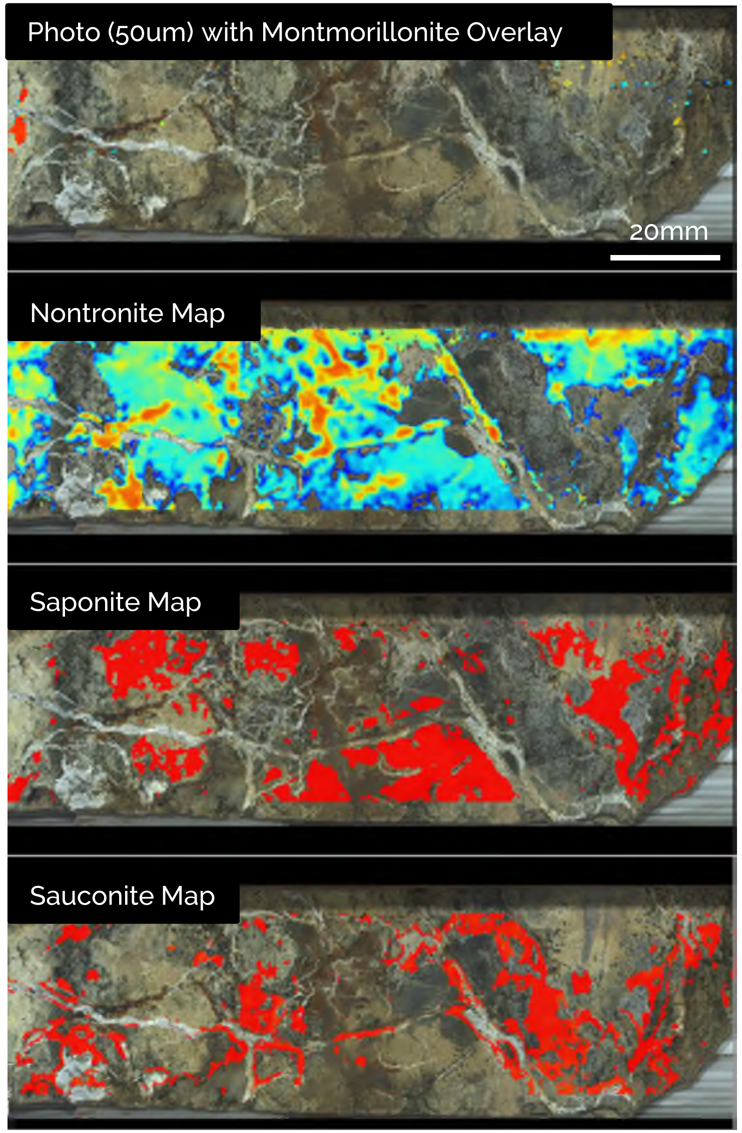
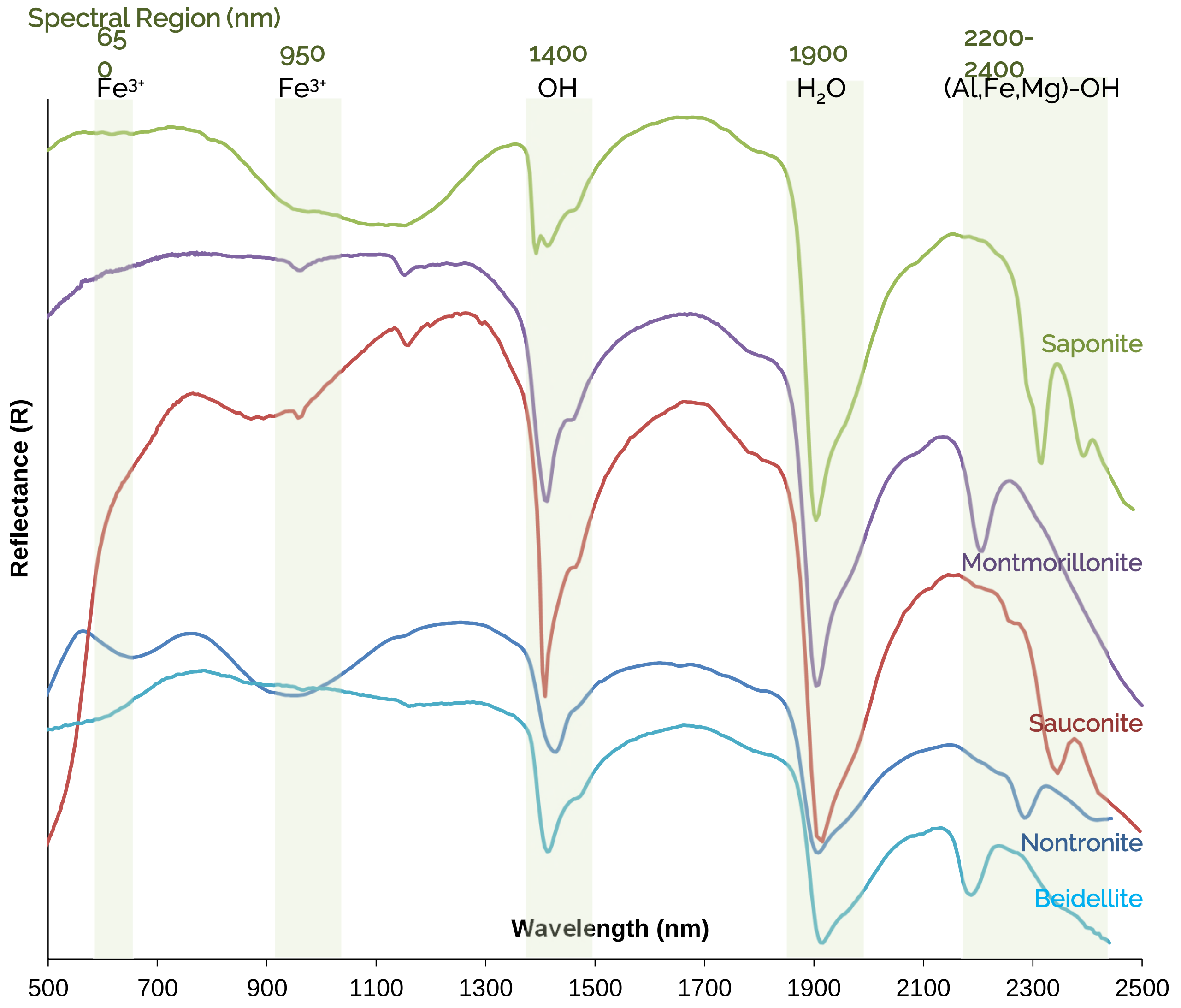
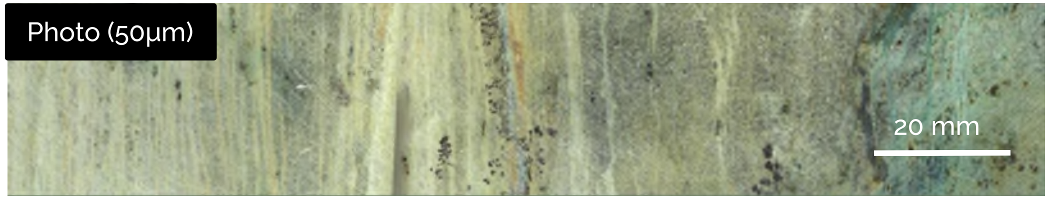


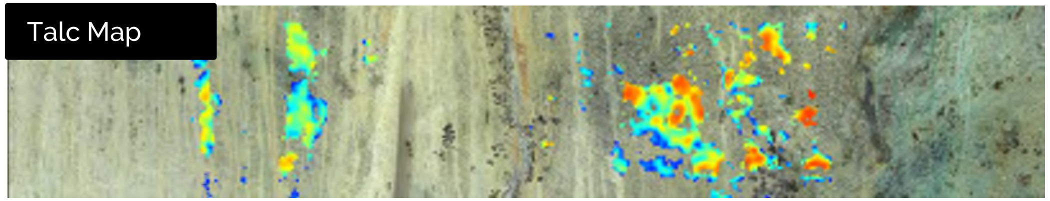
- A large variety of smectite-group minerals can occur in skarn systems from Ca±Na-bearing montmorillonite, to Fe-rich nontronite, to Mg-rich saponite and to Zn-rich sauconite.
- These smectite species have distinct SWIR absorption features that allow mineral identification and spatial mapping.

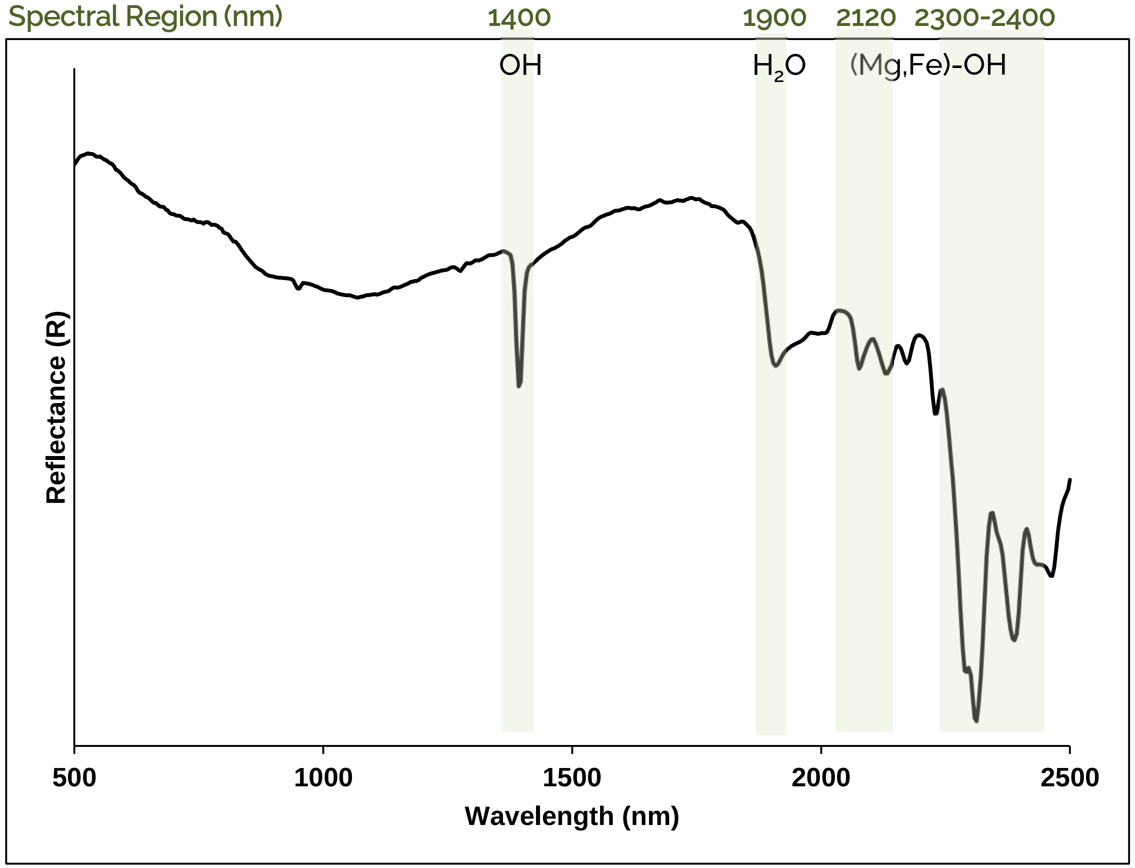


Hydrous Mineralogy: Talc

- Talc is predominantly formed during retrograde hydrothermal alteration in Mg-rich carbonate protoliths, although it can also be formed during the prograde stage through reaction between dolomite and silica.



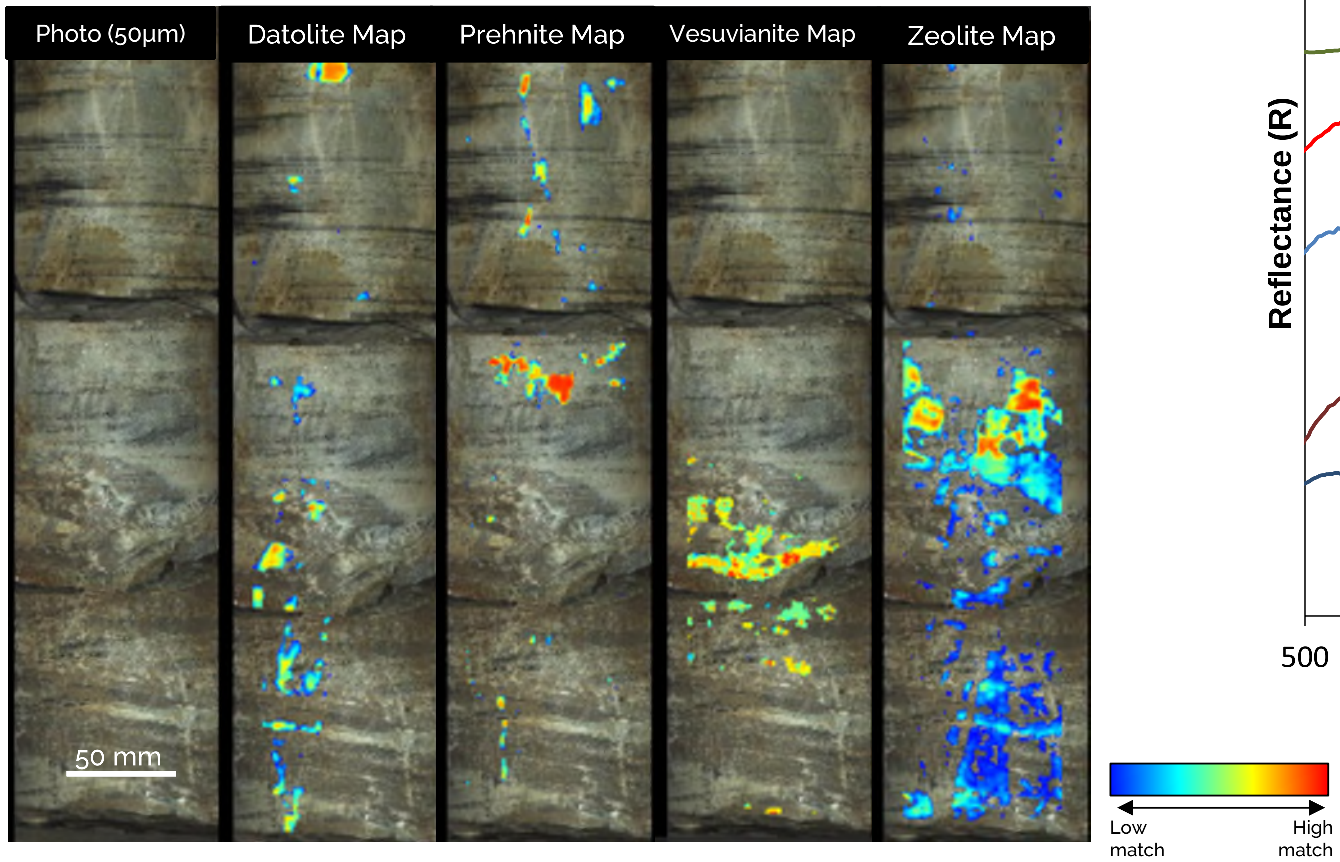


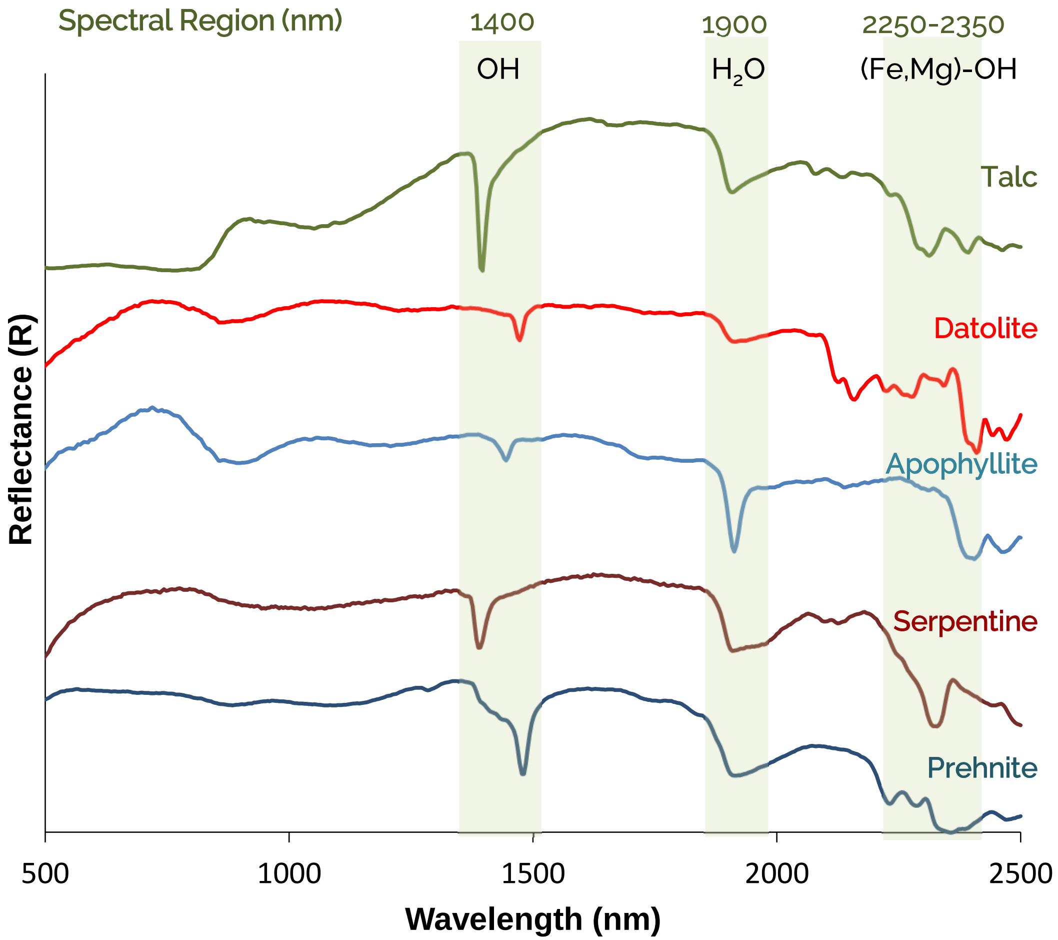


- The sharp triplets around 2120nm and doublets at 2310nm / 2385nm are diagnostic absorption features for talc and are identifiable in high resolution SWIR spectra.

Additional Hydrous Minerals Found in Skarns

- Fe- and Mg-bearing clays, micas and silicates are common in skarn deposits. They can occur as overprinting (retrograde) assemblages, distal to core of the skarn system, and / or along fluid conduits.





Prehnite: A Potential Vector in Au Skarn

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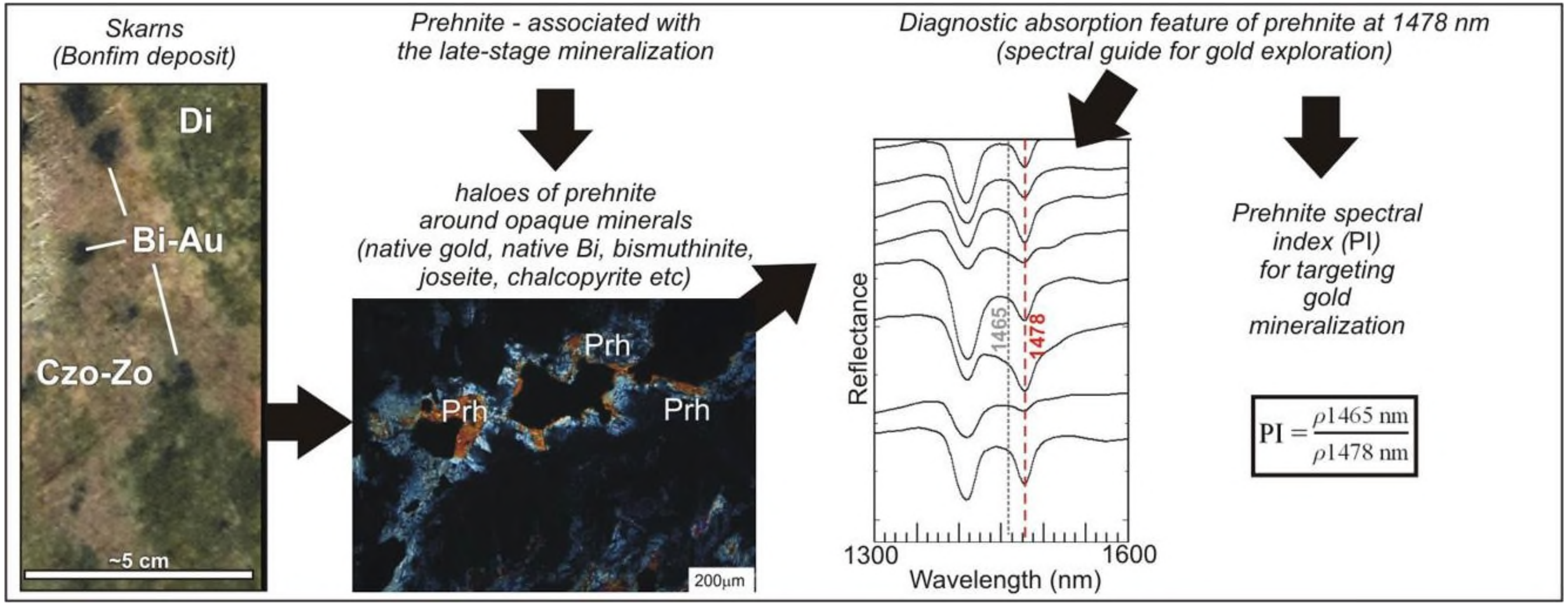
- Prehnite {$Ca_2Al(AlSi_3O_{10})(OH)_2$} is a relatively common component of many Au skarns. It can be difficult to identify visually but has a very distinct SWIR signature and easily mapped using high resolution hyperspectral imaging.
- The intensity of prehnite alteration (based on spectral absorption features) may be used as a vector to Au mineralization.
- See a recent example from the Bonfim W-Mo-Au-Bi-Te skarn, Brazil (de Mesquita et al., 2019).



de Mesquita et al., 2019

Structural Features

Detection and Mapping of Faults

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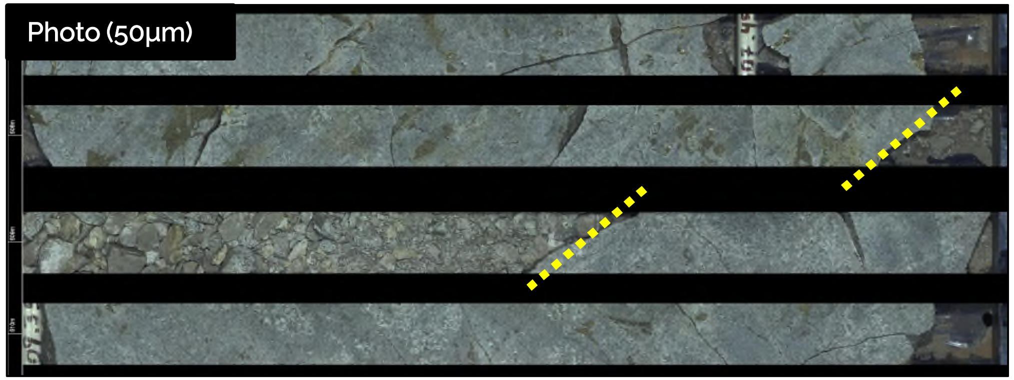
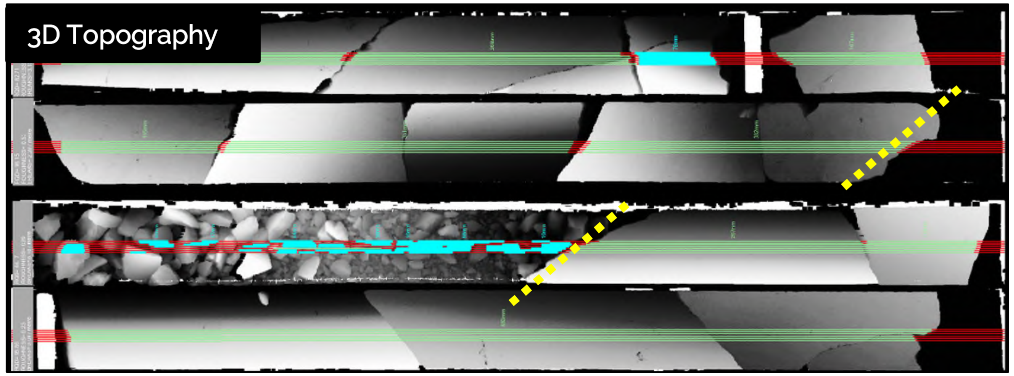
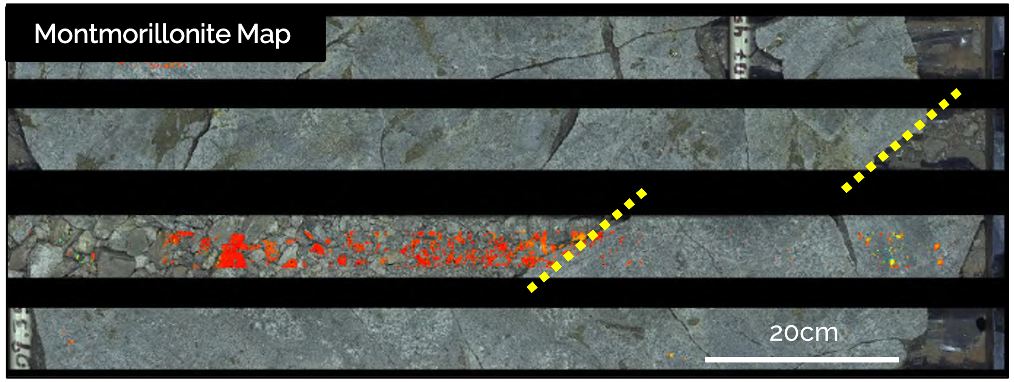
- Sharp mineralogical changes and rubble zones in the core may indicate the presence of faults and fault gouge.
- Clays (smectites, kaolinite, illite) are common fault gouge minerals, all of which are identified by diagnostic SWIR features.
- Laser profiler (3D topography) data can used to calculate simple geotechnical variables (labelled 'pseudo' to distinguish these from traditional geotechnical measurements).
- Average breaks per meter, surface roughness proxies, and pseudo-RQD values are products calculated from the surface profiler measurements.

Image Label	Description
RQD	Σlength core>10cm/total length of core interval (after Deere et al., 1957)
Breaks	Fracture identification via detection of core heights below a set gradient threshold limit (includes both natural and mechanical breaks)
Roughness	Based on variations in height along the core surface (below a set gradient threshold)







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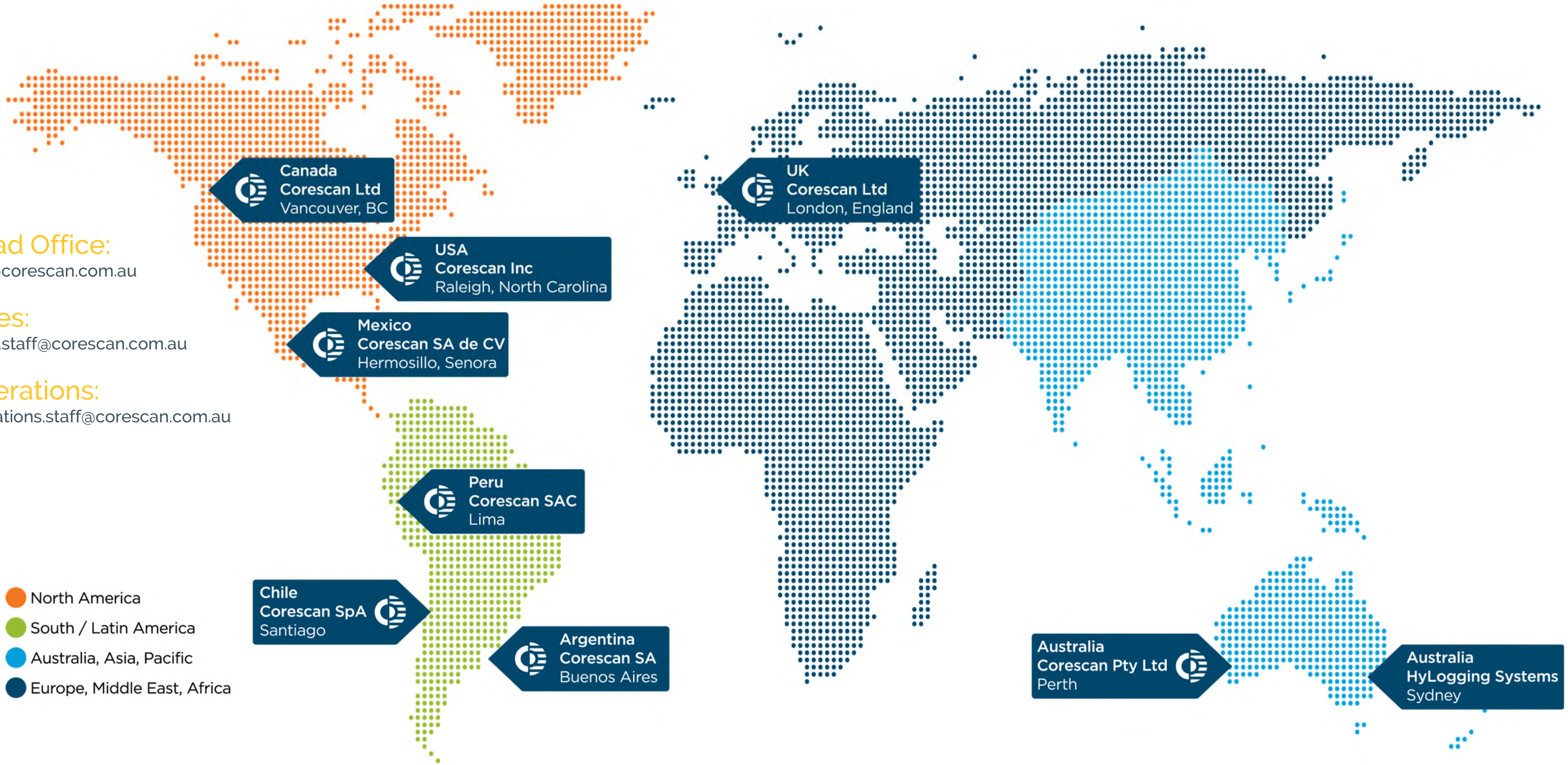

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