HYPERSPECTRAL CORE IMAGING APPLICATIONS

- HIGH SULPHIDATION EPITHERMAL DEPOSITS -

September 2021

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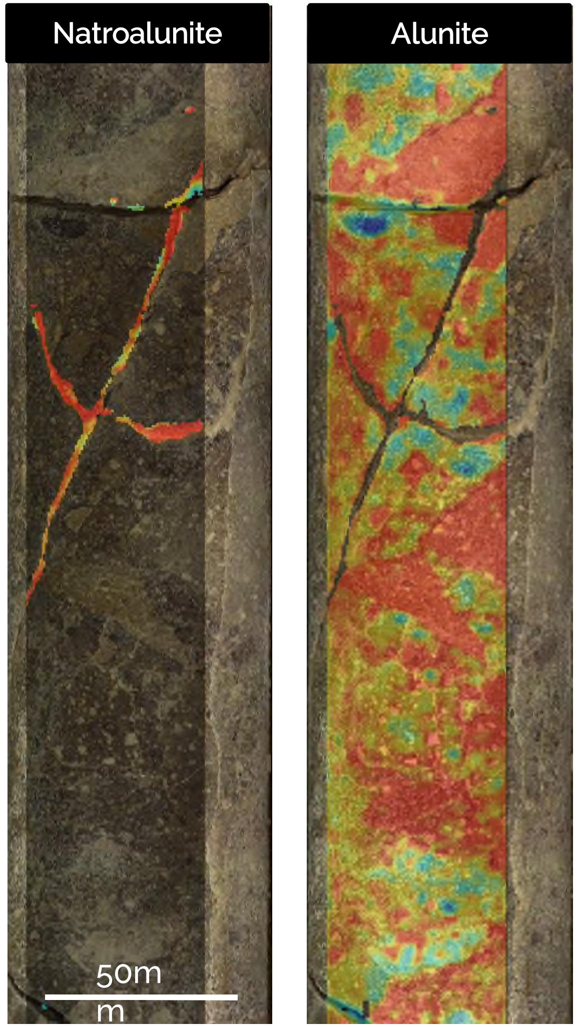
Contents



Hyperspectral Core Imaging Services

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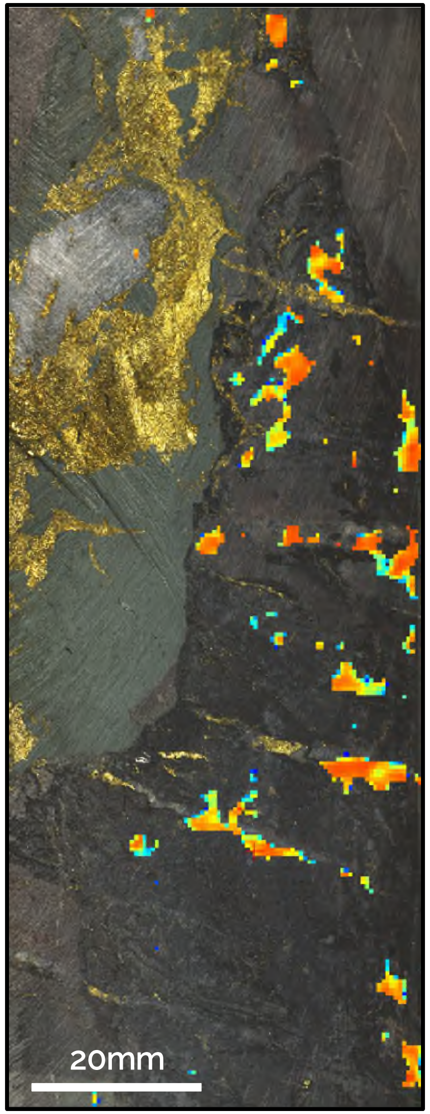
Mineral identification and mapping across the mining cycle:

- 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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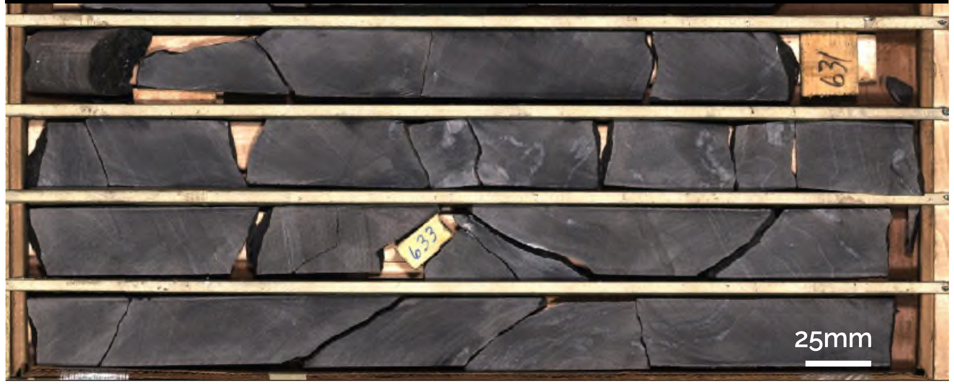
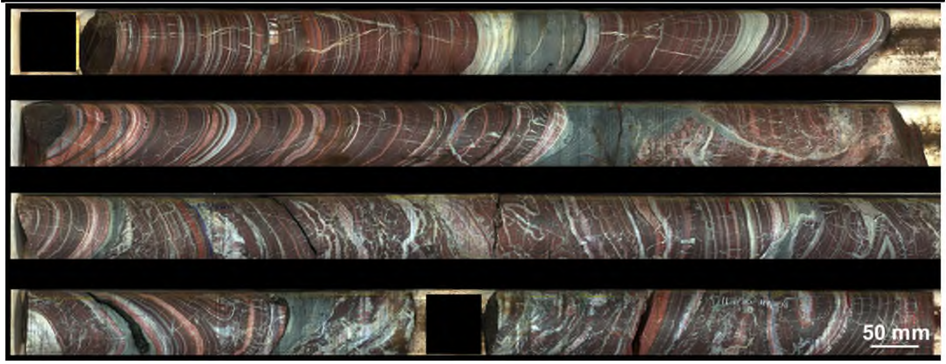
Cut / split core



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/

Continuous Hyperspectral Mineralogy

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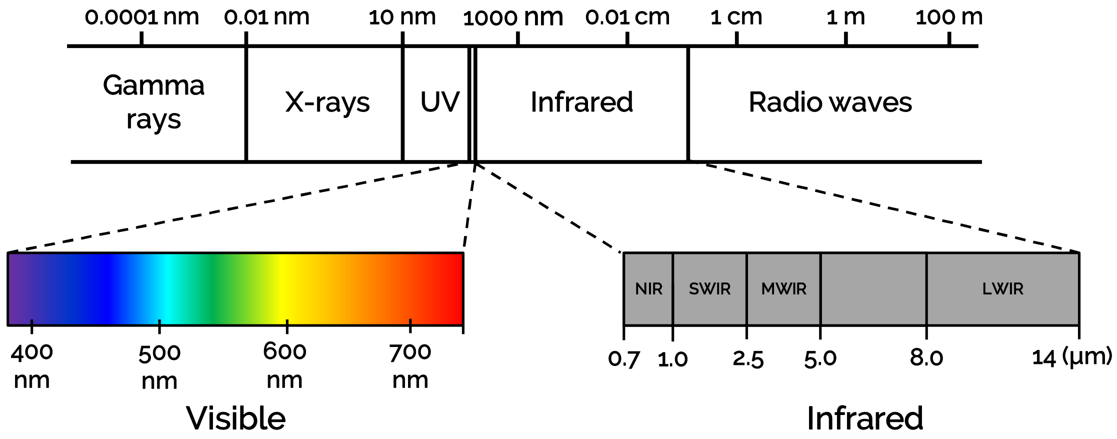
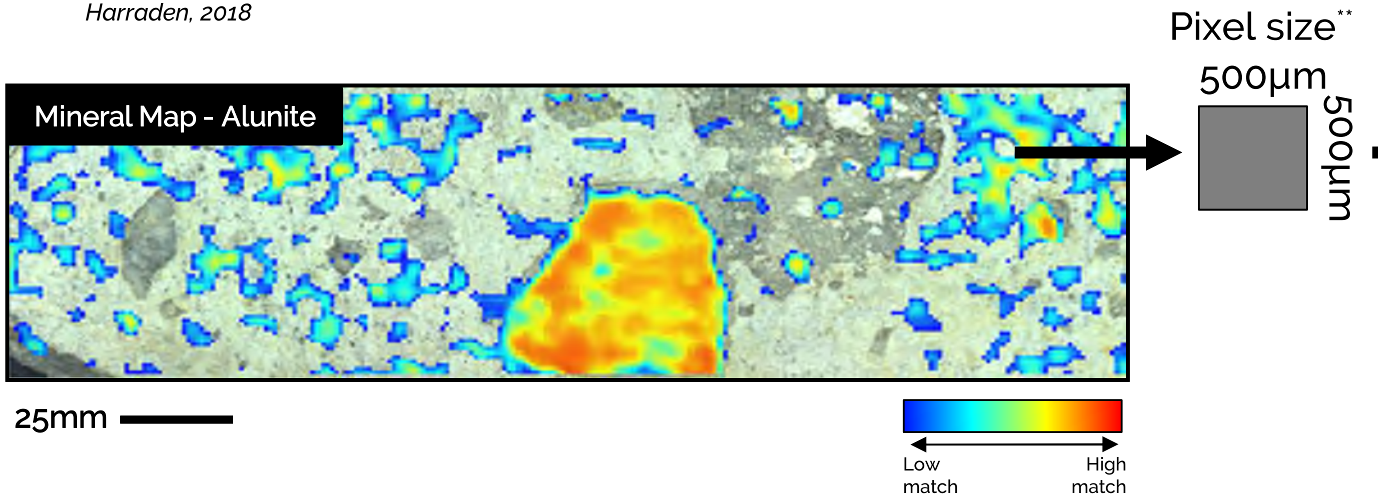
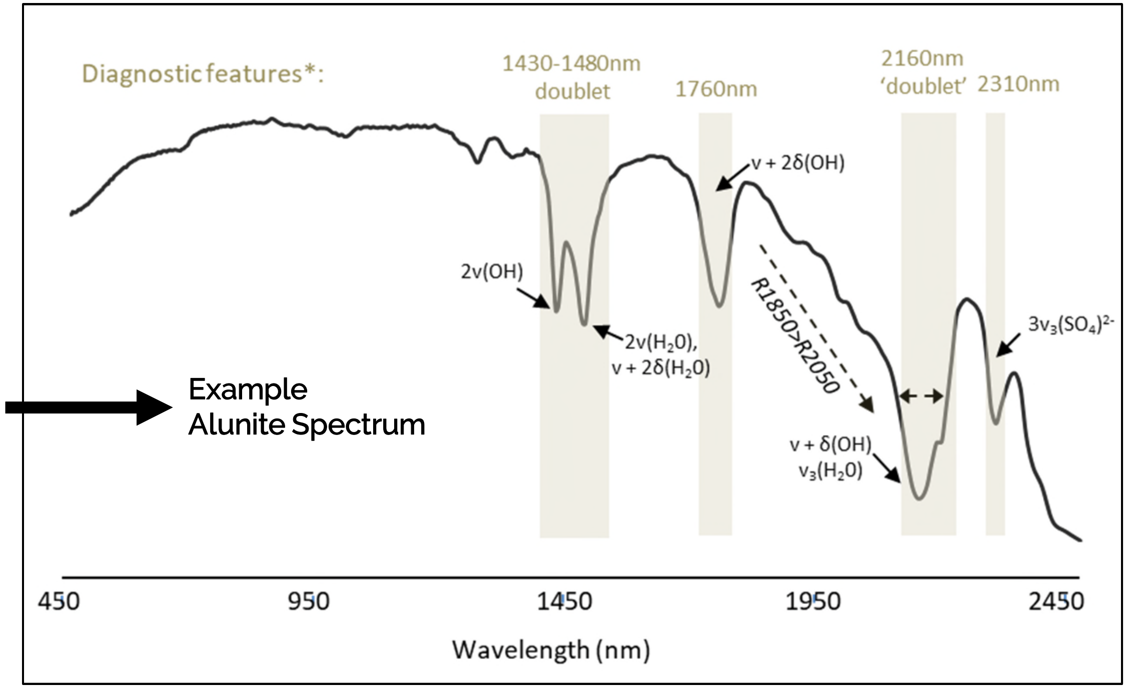
- Corescan's proprietary spectrometers measure hundreds of contiguous, narrow bands across the electromagnetic spectrum from 450nm to 2500nm, covering the Visible-Near Infrared (VNIR) and Short-Wave Infrared (SWIR) regions.



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.





*HCI-3 instrument specifications   ** Not to scale

AP0001

VNIR-SWIR: Electronic and Vibrational Features

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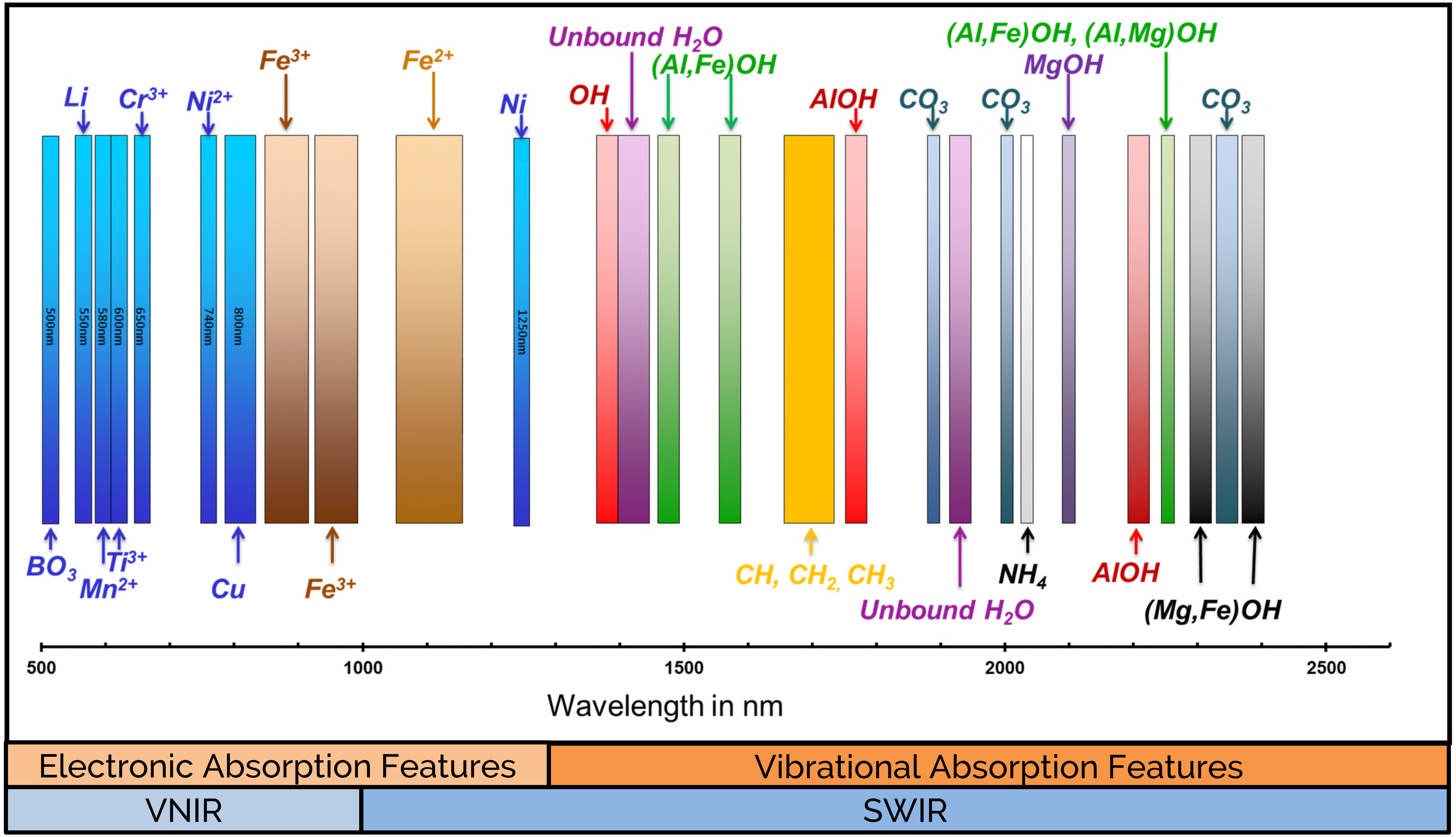

High Sulphidation Epithermal Systems

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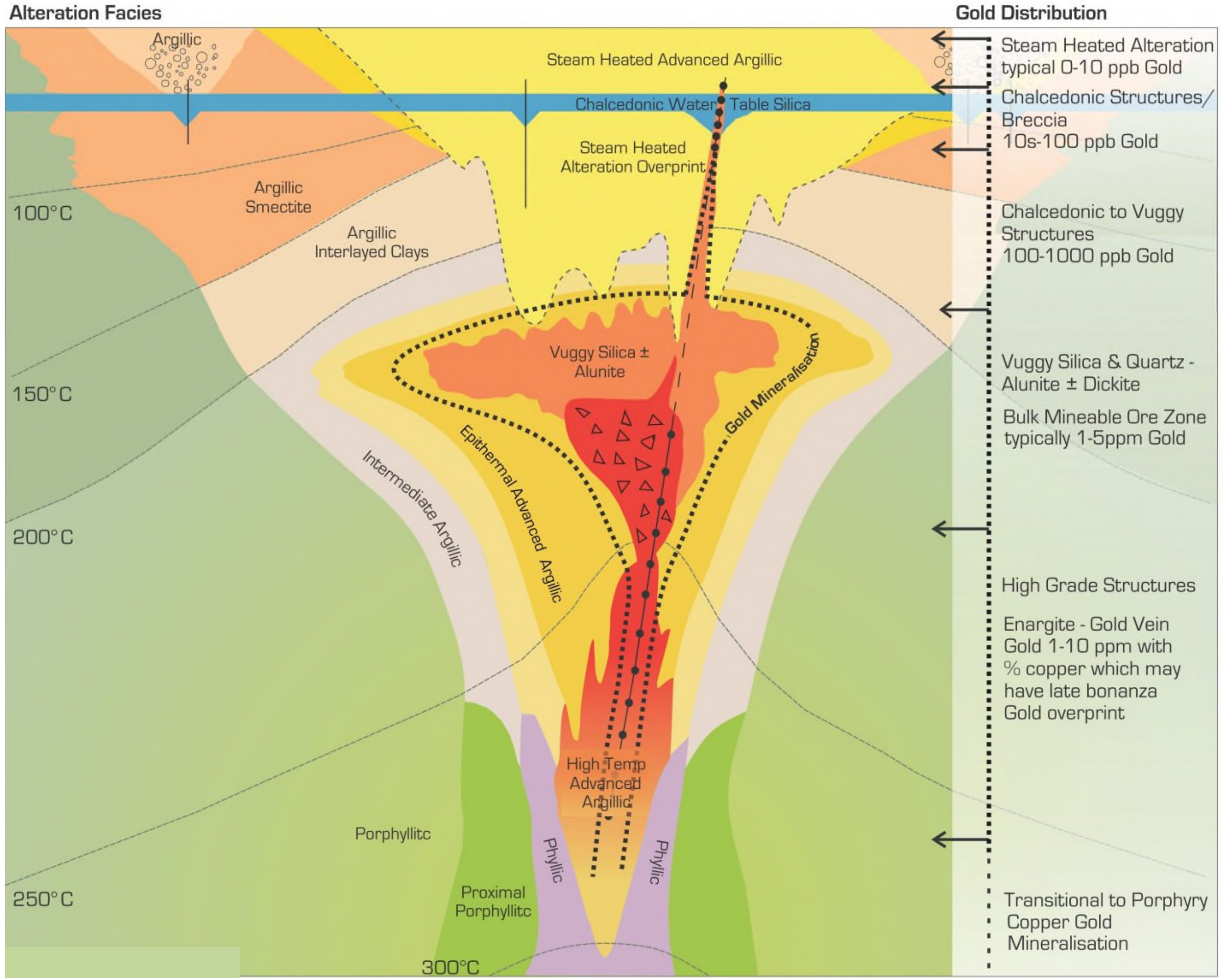
- High sulphidation epithermal systems are characterized by the presence of minerals diagnostic of high sulphidation states (e.g. enargite and luzonite) and acidic hydrothermal conditions (e.g. alunite, kaolinite and pyrophyllite).
- These deposits can be associated with andesitic volcanism whose surface manifestation includes high temperature fumaroles and acid sulphate-chloride hot springs and crater lakes.



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ADS0003

Hypogene Environment Alteration Mineralogy

High Sulphidation Epithermal Deposits: Alteration

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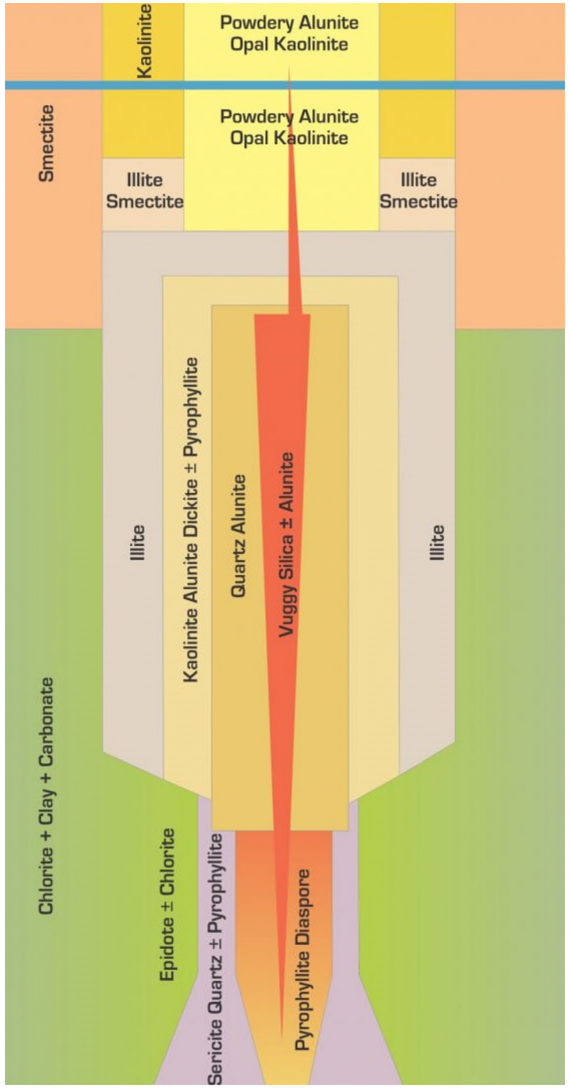
- High sulphidation systems are zoned from a highly oxidized and acidic fluid source outwards to where fluid neutralization occurs due to wall-rock buffering.
- The majority of hypogene ore is contained in the vuggy silica core and within advanced an argillic alteration envelope.
- Ore is also contained within supergene alteration and oxide zones.

Alteration Mineral Assemblage



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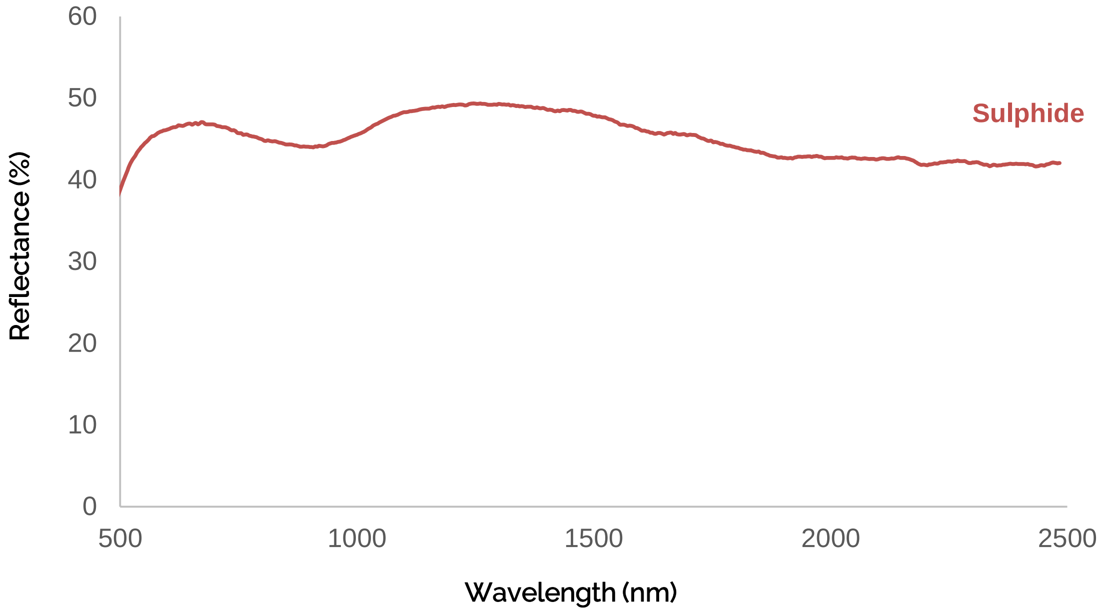
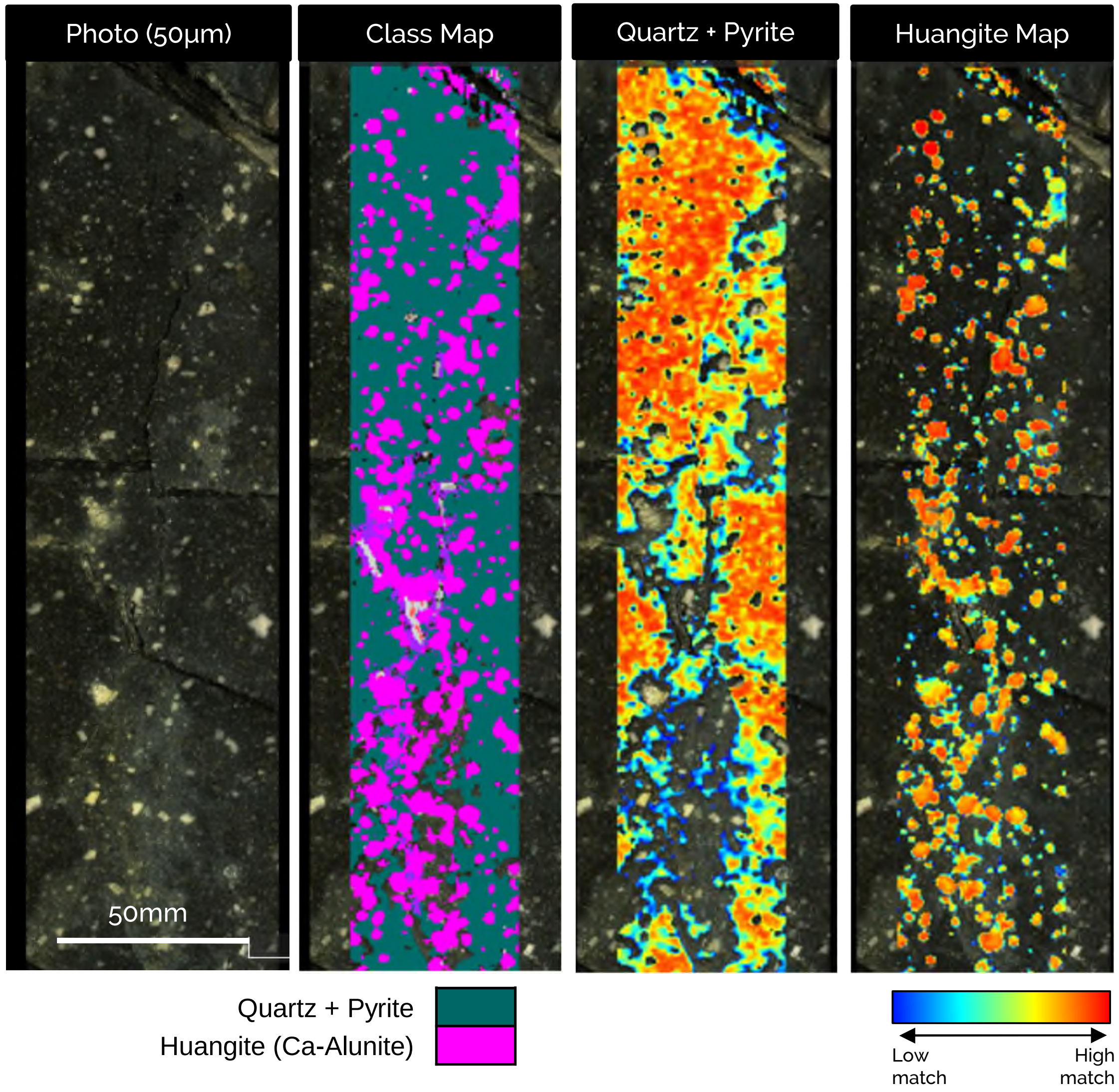
Ore Zone Mineralization: Sulphides

- Iron sulphides (e.g., pyrite and chalcopyrite) lack diagnostic spectral absorption features in the VNIR-SWIR range, however, the overall shape of the spectra (plus texture – veined, massive etc.) allows for the general discrimination and identification of sulphides using high resolution hyperspectral imaging, particularly in the case of coarser grained materials.





Proximal Mineralogy: Advanced Argillic Alteration

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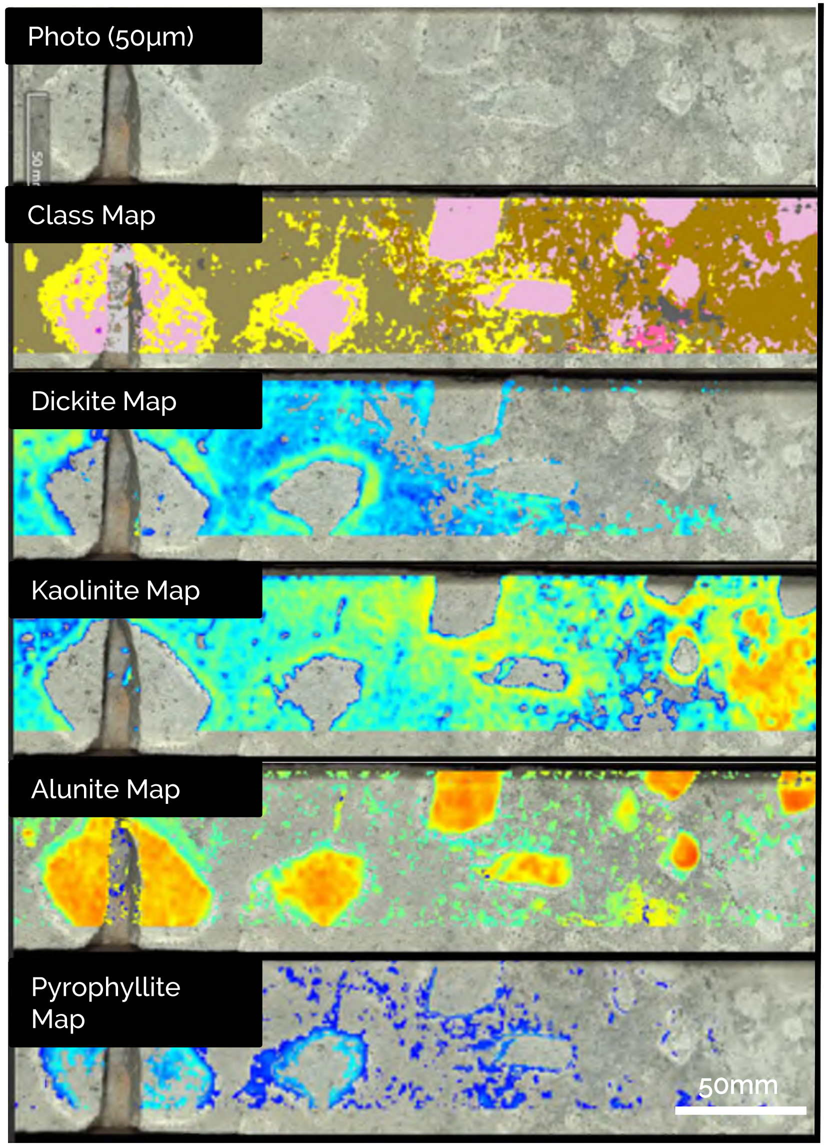
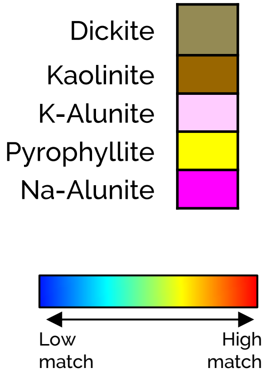
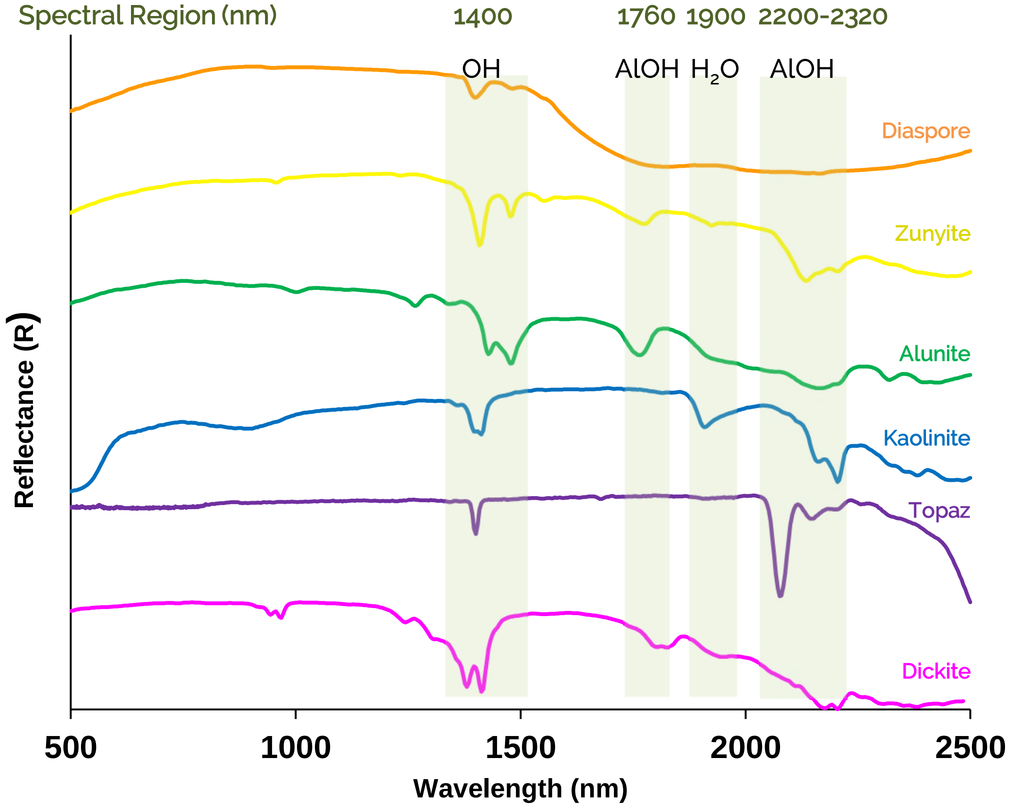




- Alunite, pyrophyllite, dickite, diaspore, topaz and zunyite are common proximal alteration minerals in high sulphidation systems.
- This alteration is characterized by relatively high oxygen fugacity and temperature, and low pH.



Alteration Vectors: Alunite Chemistry

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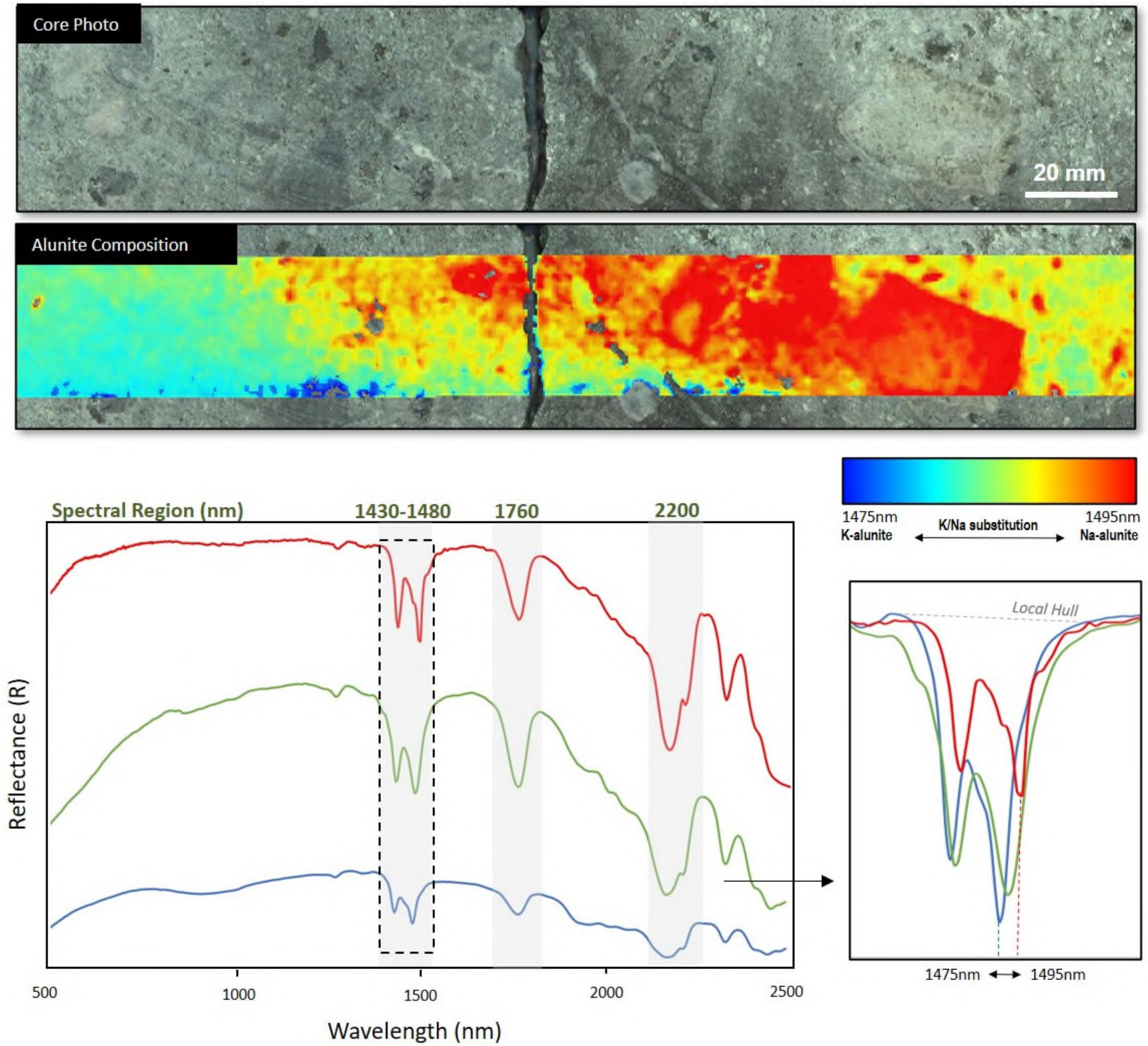
- Compositional variations in the alunite group minerals are tracked using the wavelength of the ~1480nm absorption feature.
- The alunite (K) – naturoalunite (Na) solid solution is a temperature dependent alkali exchange reaction, whereby higher temperatures correlate to an increase in Na (Stoffregen and Cygan, 1990).



Proximal Mineralogy: Argillic Alteration

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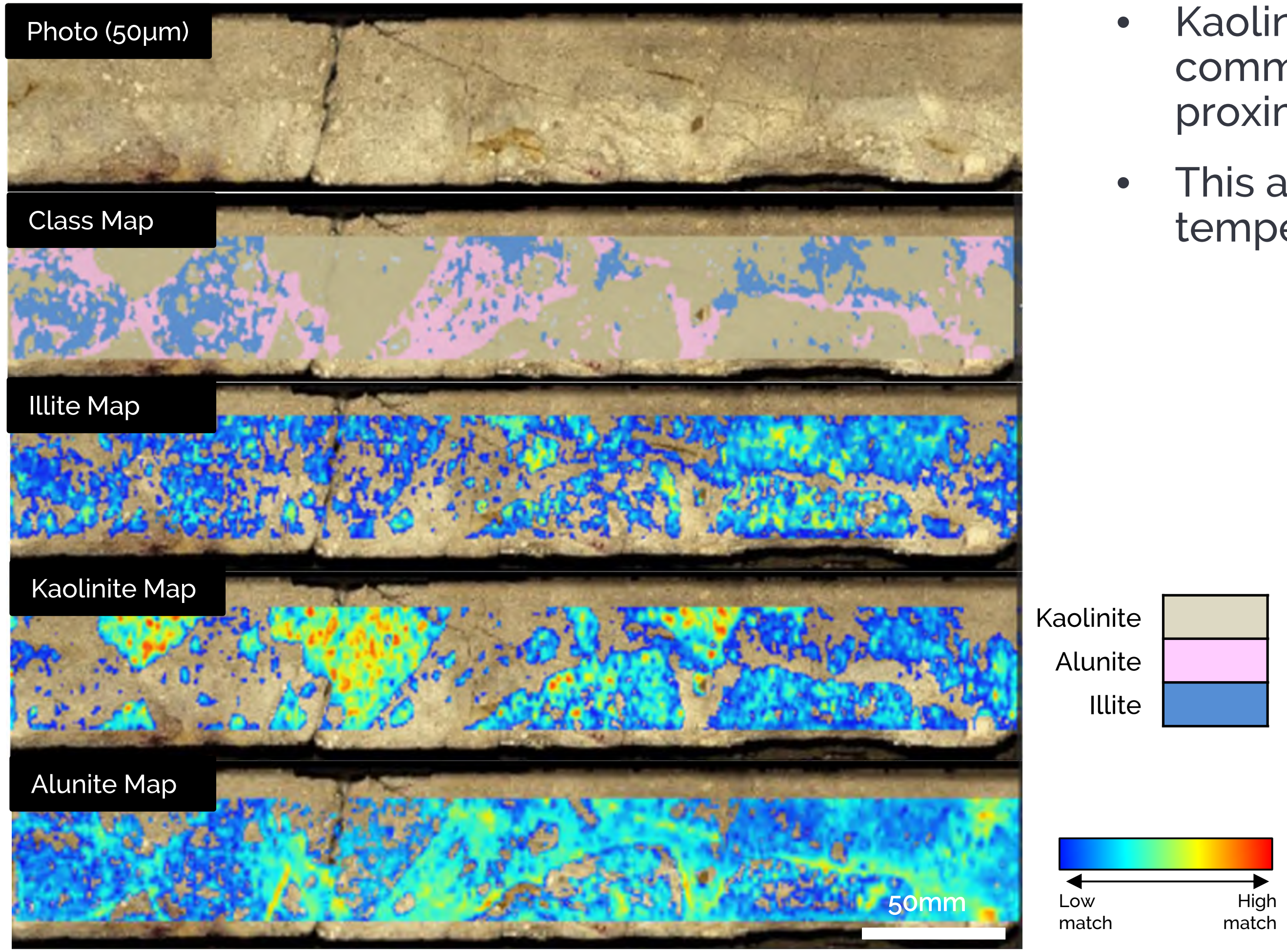
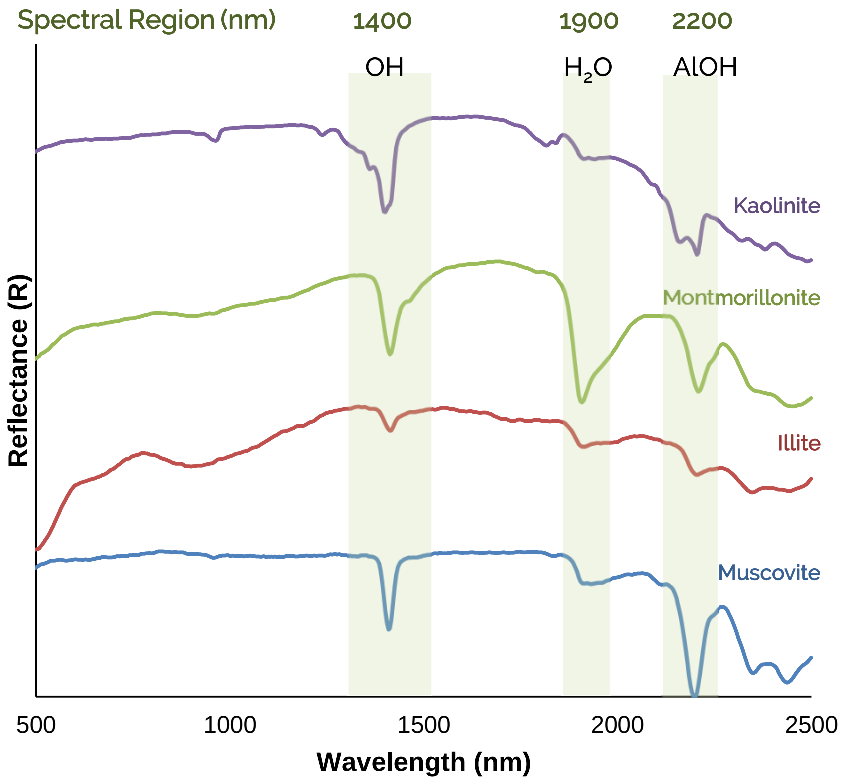


- Kaolinite, white micas (including illite) and smectites are common alteration minerals that straddle the distal and proximal alteration zones in high sulphidation systems.
- This alteration is characterized by moderate to high temperatures, low pH and oxidizing conditions.



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Distal Mineralogy: Propylitic Alteration

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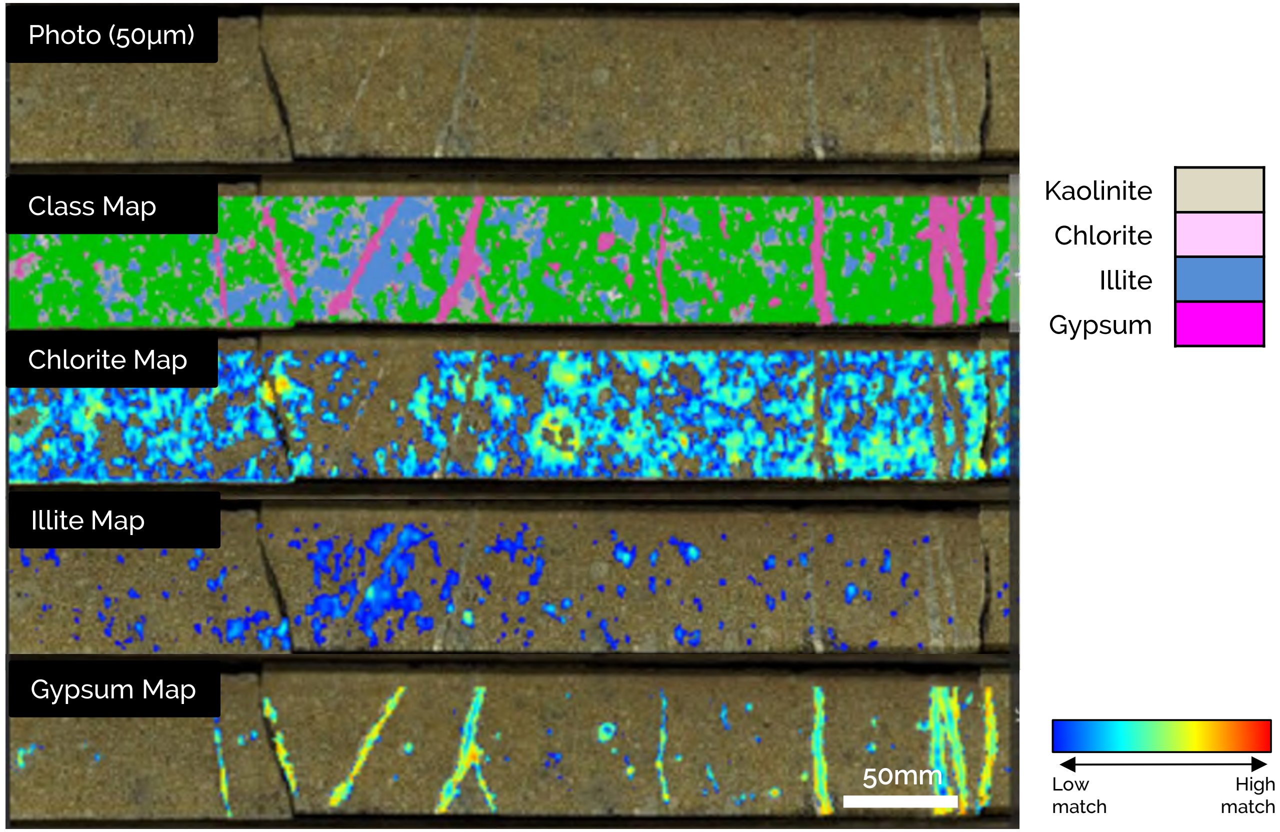
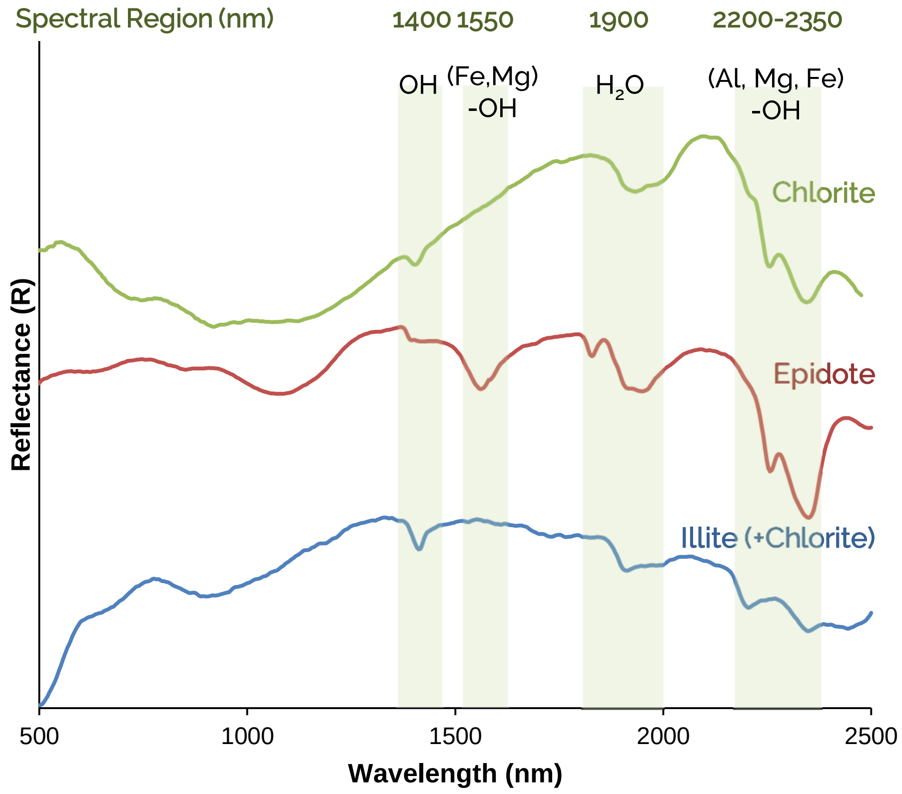
- Chlorite, montmorillonite, carbonate and epidote are common propylitic and distal alteration minerals in high sulphidation systems.
- These minerals are characterized by formation under less oxidized and more neutral pH conditions being more distal to the source fluids and the larger degree of rock buffering of the hydrothermal fluid.





Steam-Heated Alteration

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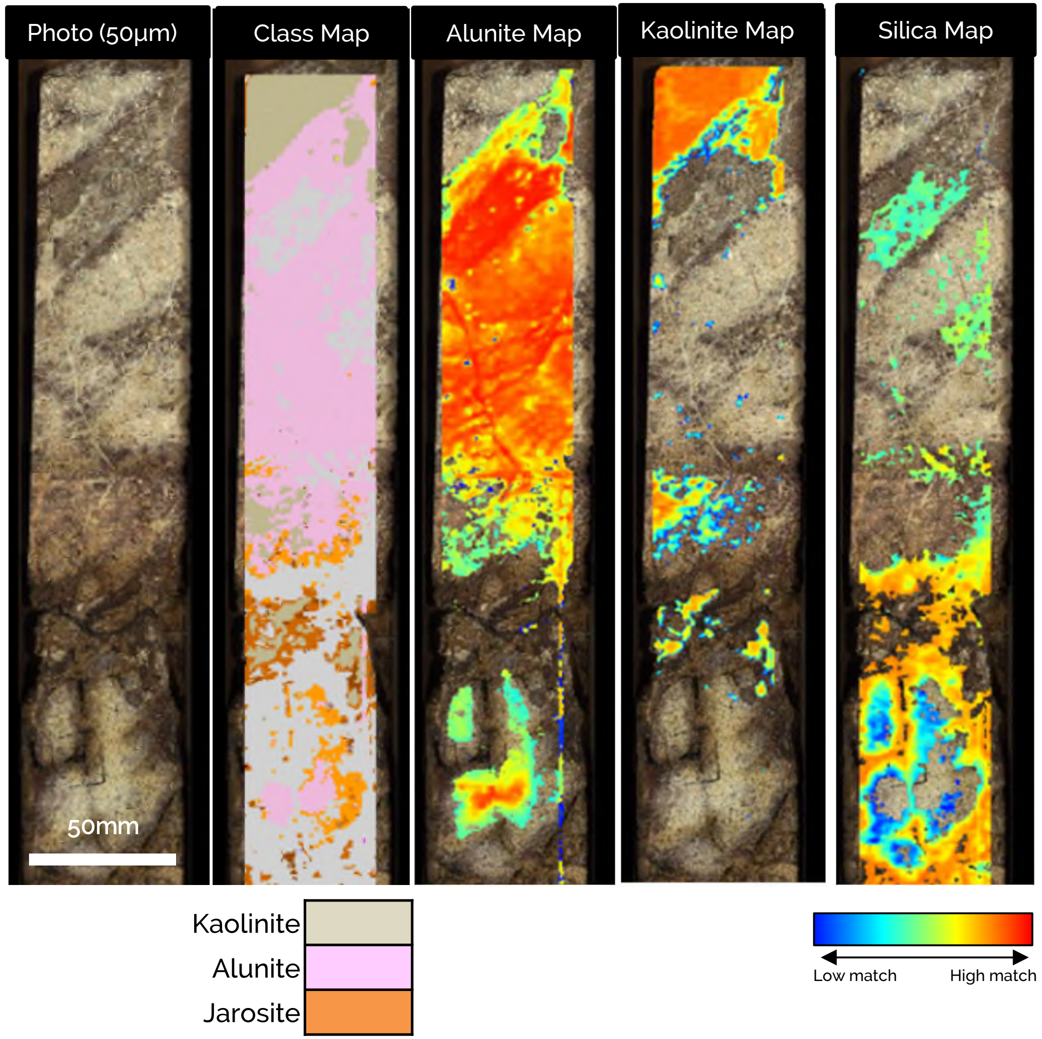
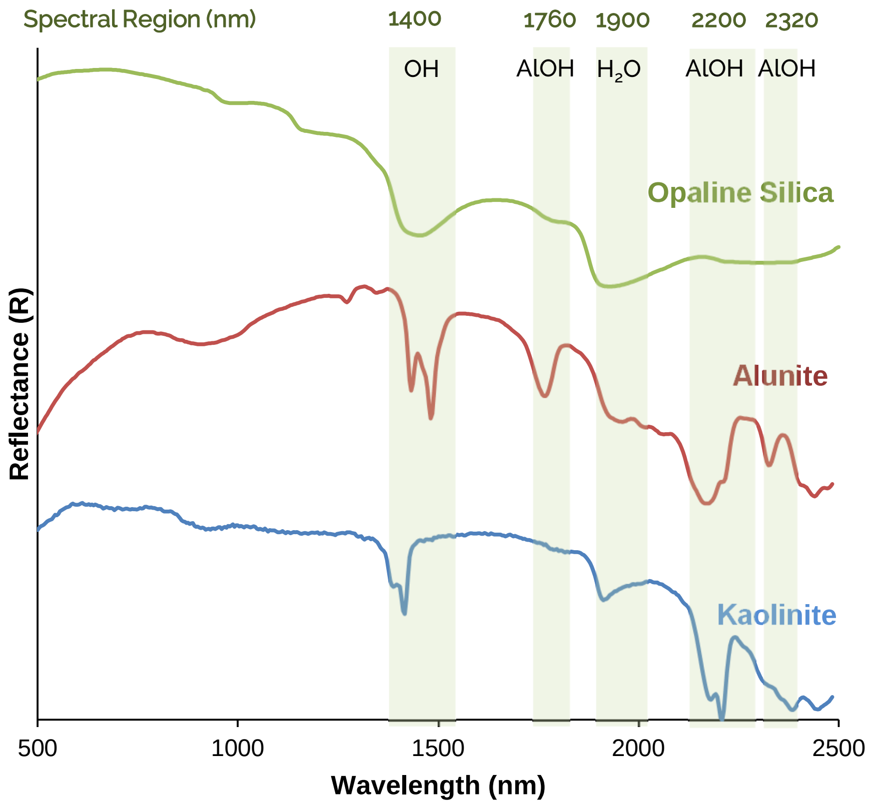


- Steam heated alteration caps are characterized by thick (100s of meters), extensive (10s of square kilometers) of a sheet-like advanced argillic body (powdery alunite, kaolinite, opaline silica, native sulphur) that are generally poor in mineralization, but often anomalous in epithermal pathfinder elements (e.g. As, Sb, Te, Hg, and/or Ba).



Supergene Environment Mineralogy

Zonation in High Sulphidation Epithermal Systems

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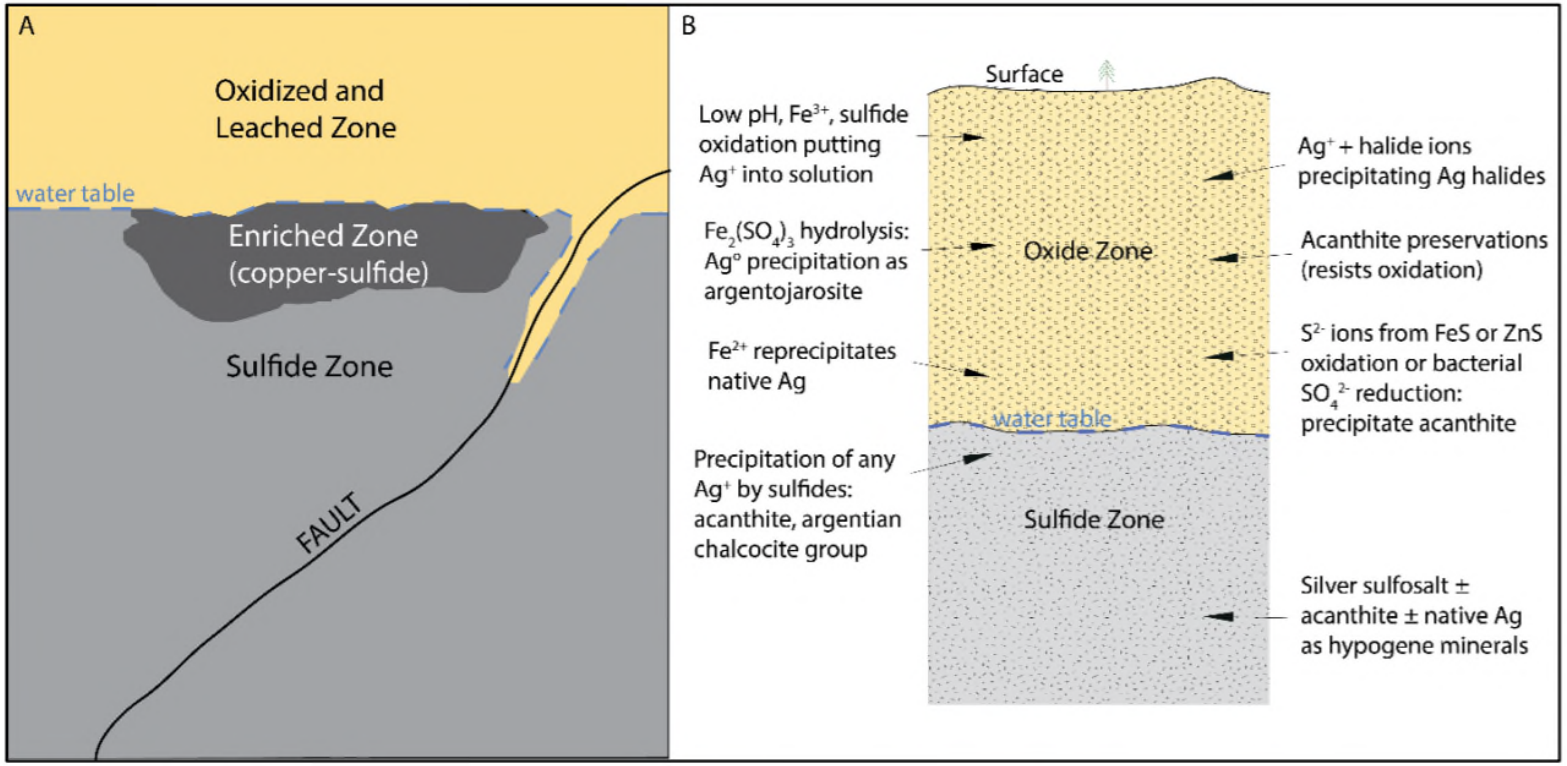
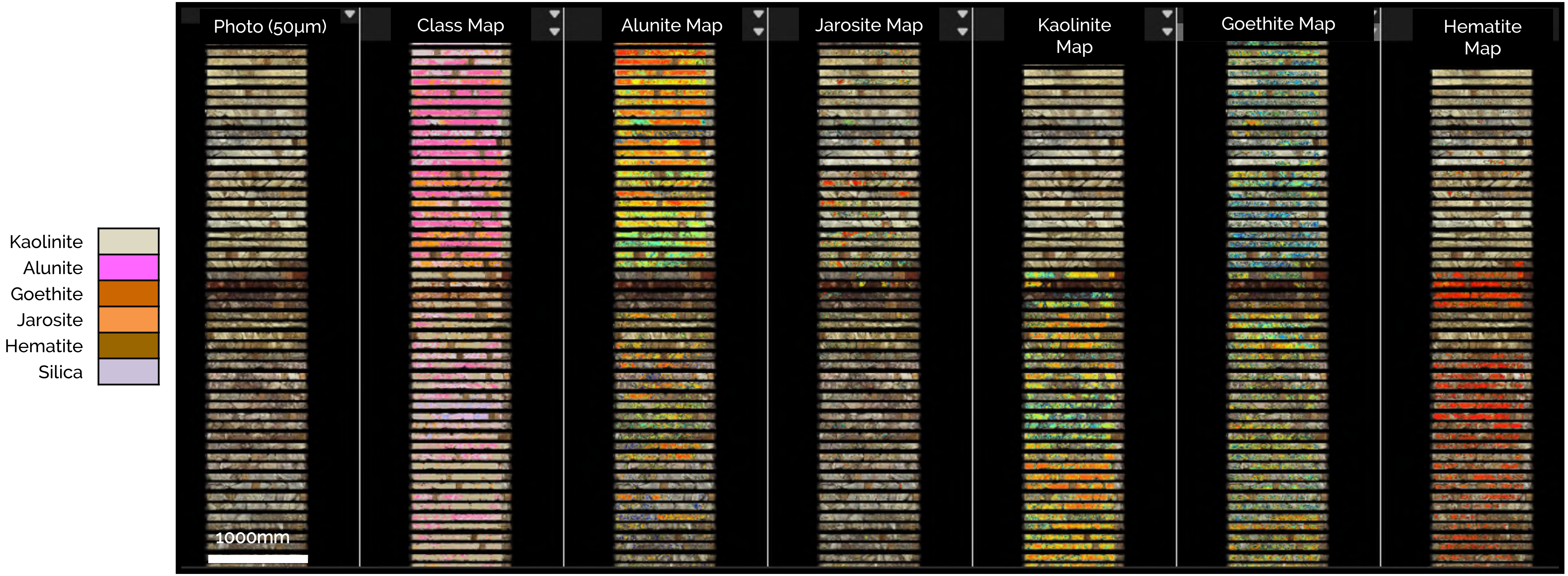
- Supergene and hypogene gangue minerals are distinguished by mineral modes, crystal forms and compositions (chemical and isotopic), by textural and paragenetic relationships including the presence or absence of sulphide minerals, by age and by position relative to the erosion surface or paleowater table.



Anderson (1982), Sillitoe (2009)

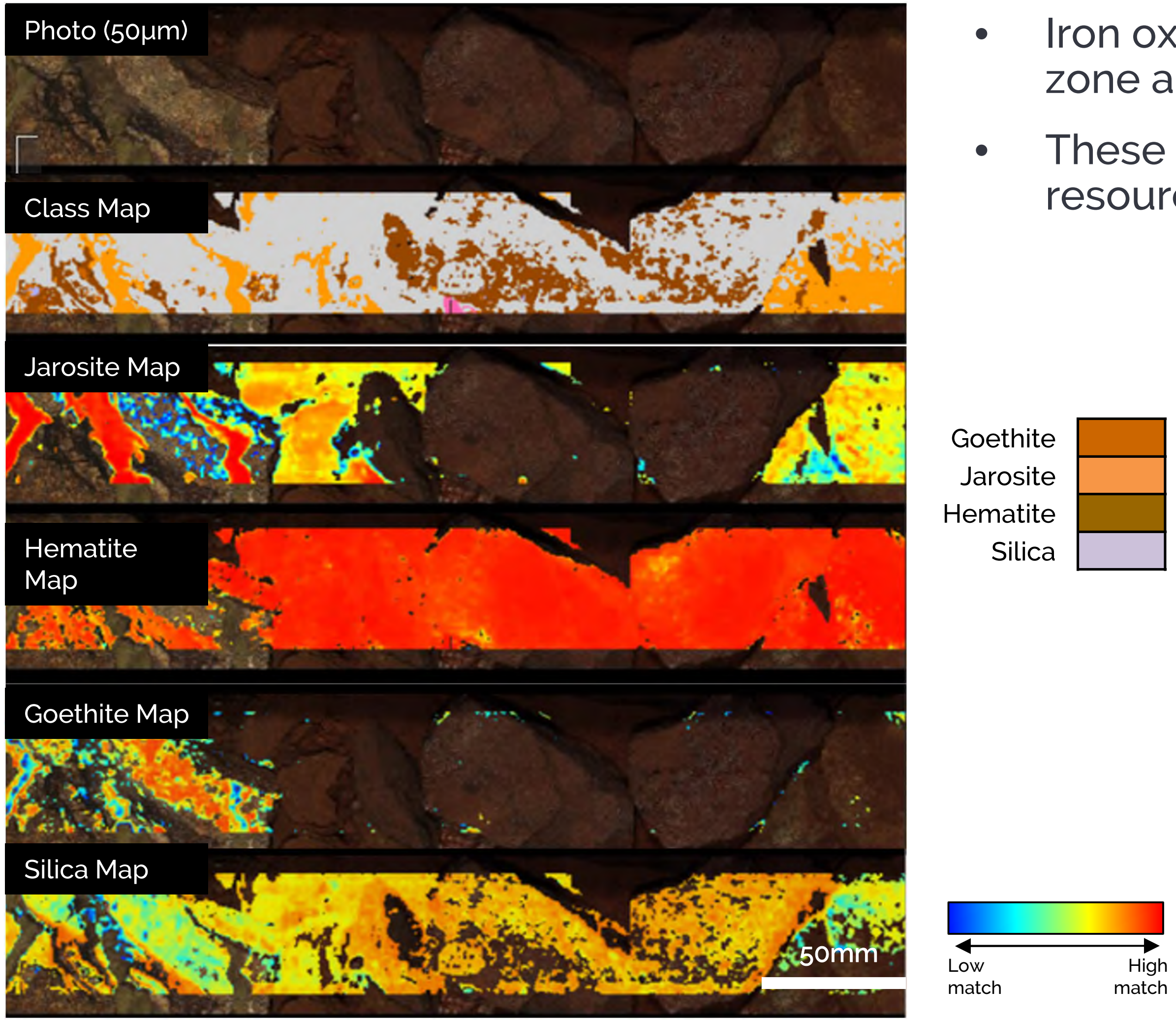
Oxide Zone: Overprinting Assemblage Example

- Regardless of gold enrichment, the mining of some low-grade gold deposits has been enabled by near-surface oxidation of pyrite and other sulphide minerals. Weathering has converted gold, electrum and gold telluride inclusions and intergrowths with sulphide minerals into discrete gold particles in aggregates of porous iron oxide minerals, facilitating recovery by low-cost, high-extraction cyanidation and making low-grade deposits minable (John et al., 2010).

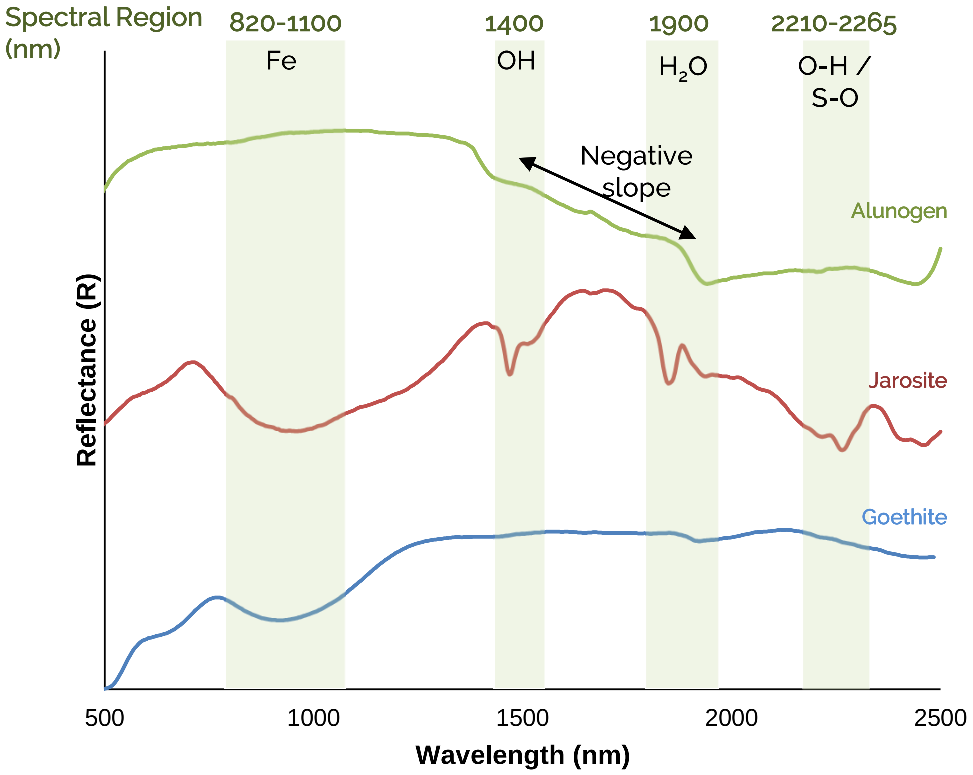


Advanced argillic assemblage with Fe-oxide overprint

Oxide Zone Mineralogy



- Iron oxides and a large range of sulphates are common oxide zone alteration minerals in high sulphidation systems.
- These zones can be high-grade and are often an important resource.



Structural Features

Detection and Mapping of Faults

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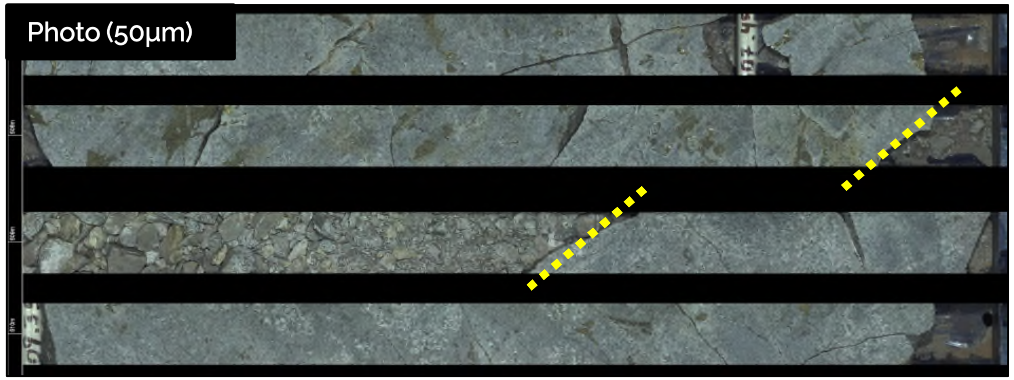
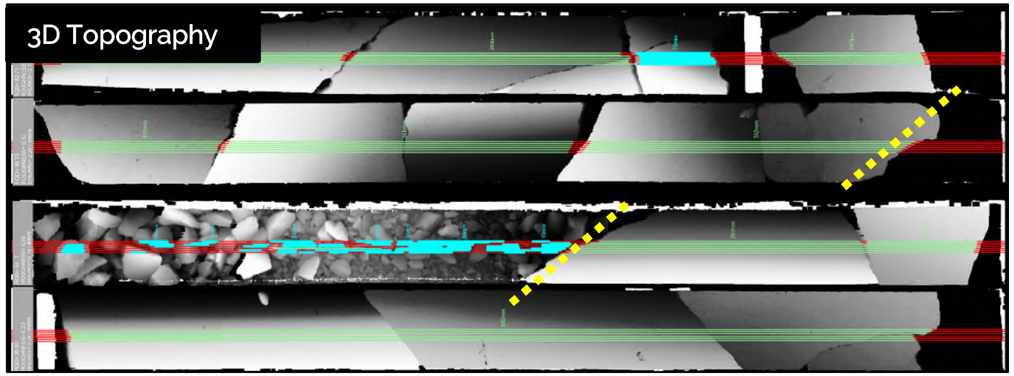
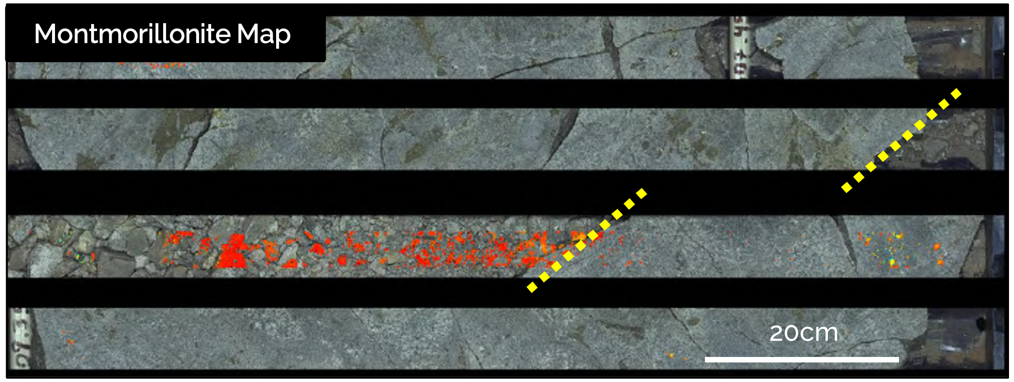
- Sharp mineralogical changes and rubble zones in the core may indicate the presence of faults and fault gouge.
- Clays (smectites, kaolinite, illite) are common fault gouge minerals, all of which are identified by diagnostic SWIR features.
- Laser profiler (3D topography) data can used to calculate 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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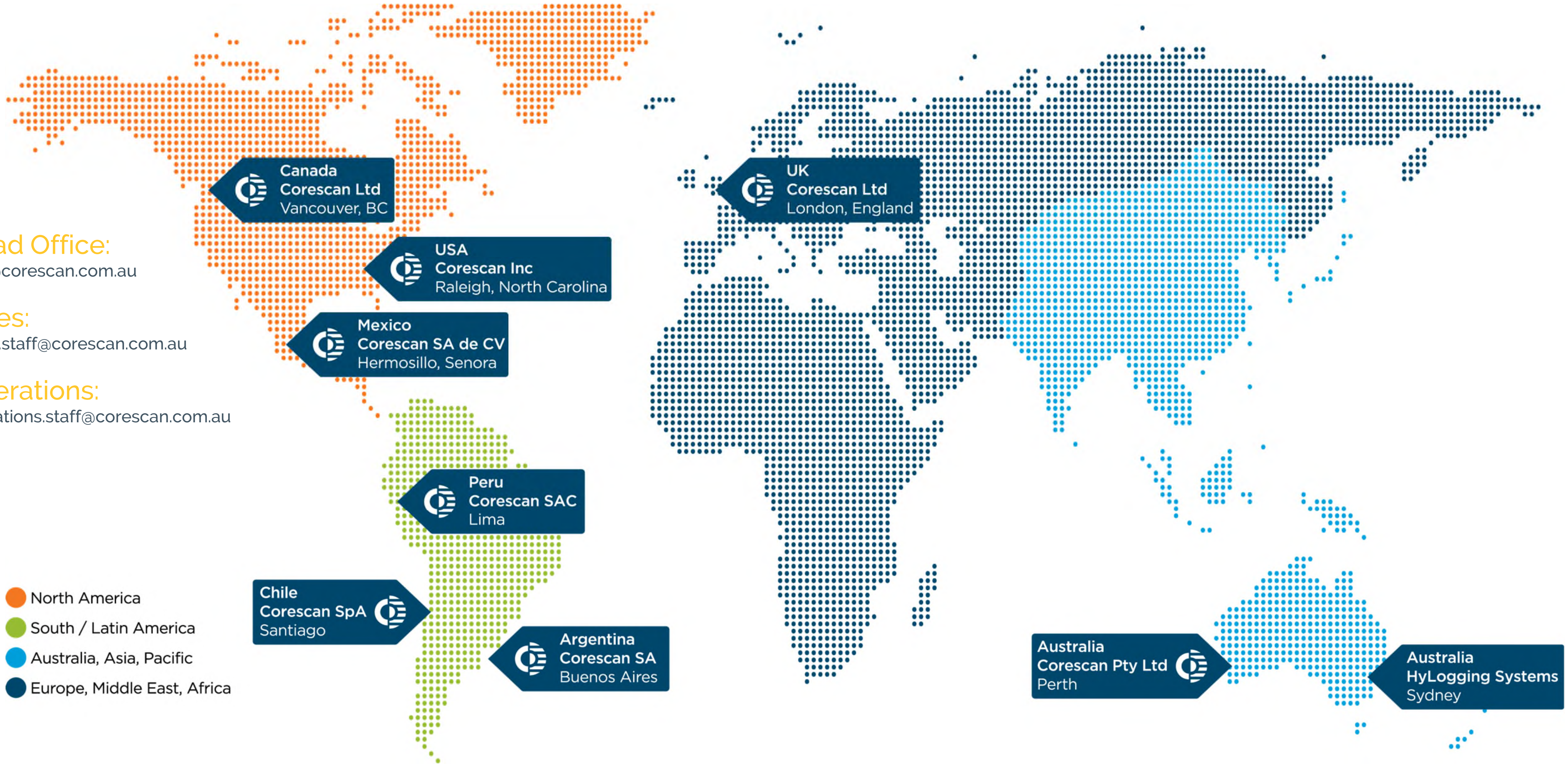

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