Spectral Mapping of Alteration Minerals (SMAM)

A service provided by

Ab Scandinavian GeoPool Ltd

In co-operation with

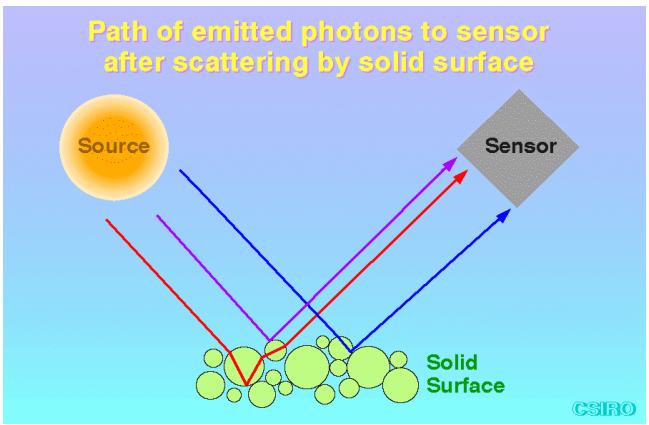
JIGSAW GEOSCIENCE

Table of contents

Spectral geology

Spectral geology is a means of getting mineral information from samples rapidly and cost effectively. It gives you far more comprehensive information in the alteration mineral assemblages in your project area. This means that you can map specific variations more accurately and objectively.

The variety of absorption processes and their wavelength dependence allows us to get information about the chemistry of a mineral from its reflected or emitted light. ***This makes specific mineral identification possible.***



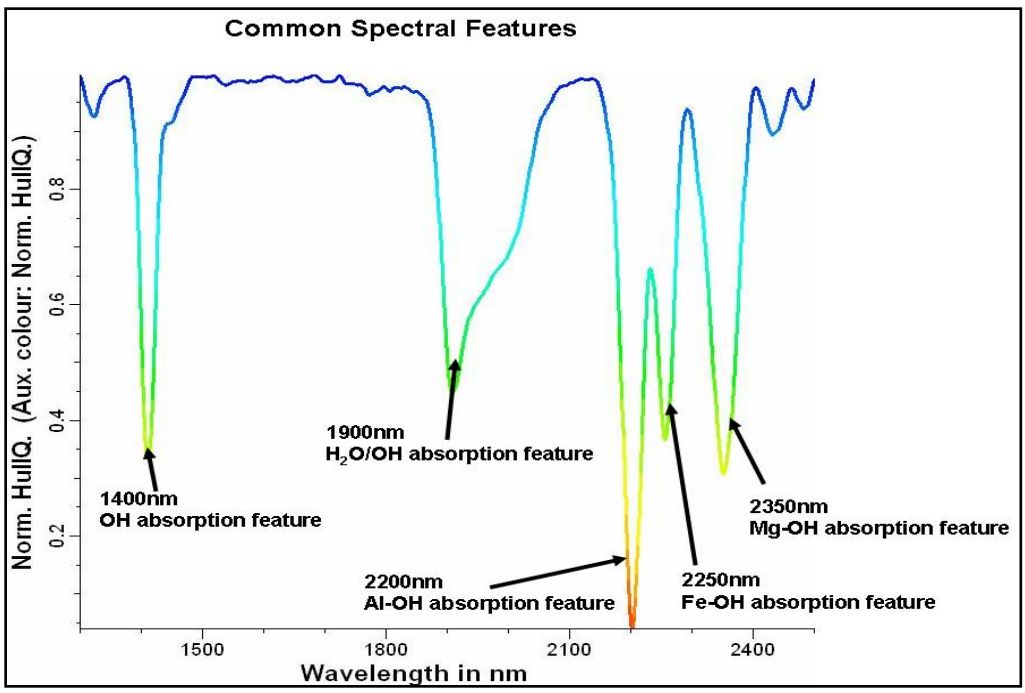
Spectral features relevant to mapping of alteration minerals:

Visible and near infrared (VNIR), 400 - 1100 nm (electronic processes)

- Ferric and ferrous oxides/silicates/sulphates/sulphides, REEs

Shortwave infrared (SWIR), 1100 - 2500 nm (vibrational processes)

- (OH) bearing minerals (clays, micas, chlorites, talc, epidote, amphiboles, sulphates), carbonates



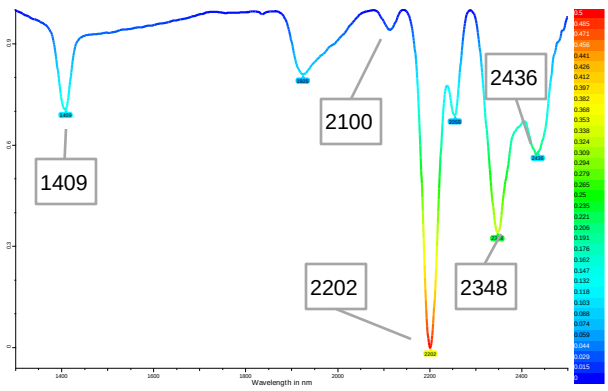
Common spectral features of water and hydroxyl ions (Halley, 2007).

Applications of spectral geology

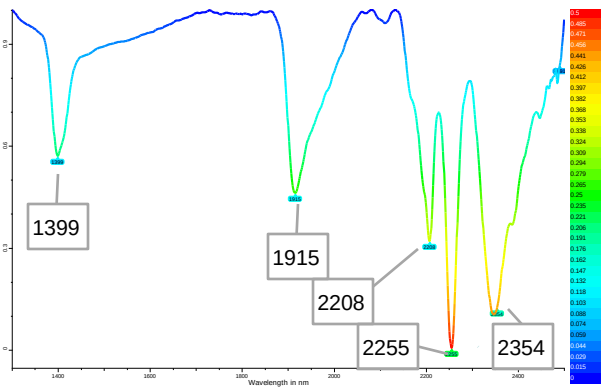
Once the spectral data has been obtained it can be used to identify alteration zoning, changes in mineral proportions, mineral occurrence and mineral composition. **Most importantly, the results are easy to understand** and can be presented in many different formats e.g. maps, scatter plots, sections and charts.

1. Alteration zoning

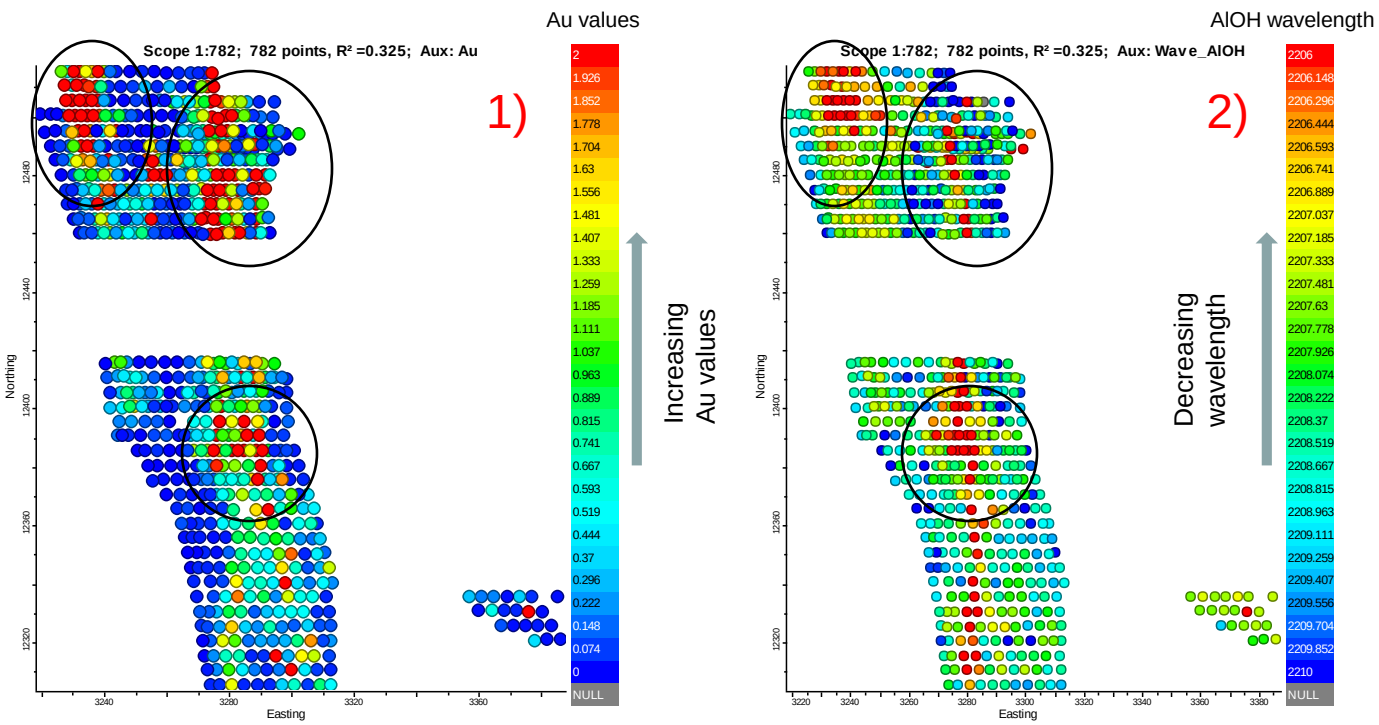
In broad alteration systems infrared spectral data can be used to describe and map the distribution of various alteration assemblages, e.g. smectite, chlorite, biotite, illite, muscovite, kaolinite etc.



Muscovite *with spectral features at 1409, 2100, 2202, 2348 and 2436 nm.*



Biotite *with spectral features at 1399, 1915, 2255 and 2354 nm. The dip at 2208 nm indicates that the sample also contains muscovite.*



TSG scatter plot of Au values (1) and AlOH wavelength (2), horizontal section. The relationship between high Au values (red and yellow dots) and low AlOH wavelengths (red and yellow dots) are highlighted in the pictures (© Copyright CSIRO Australia, 2008).

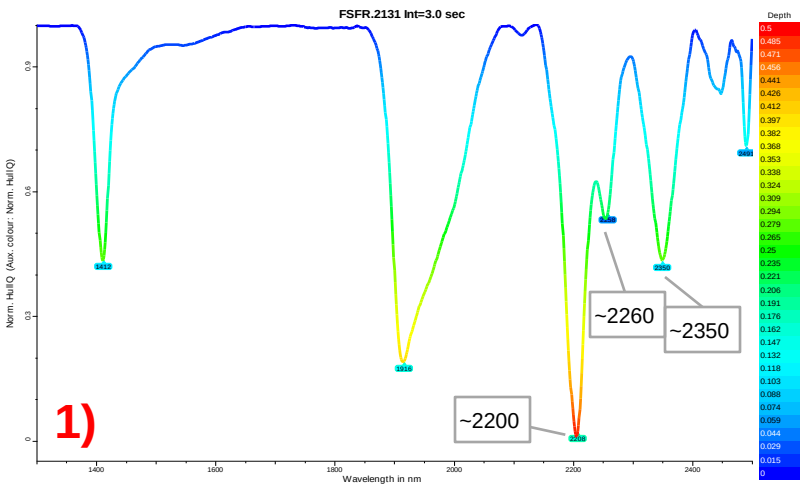
2. Changes in mineral proportions

The determination of minerals is done by comparing spectral features at different wavelengths. Interpreting these mineral spectra makes it also possible to recognize variations in mineral proportions and composition.

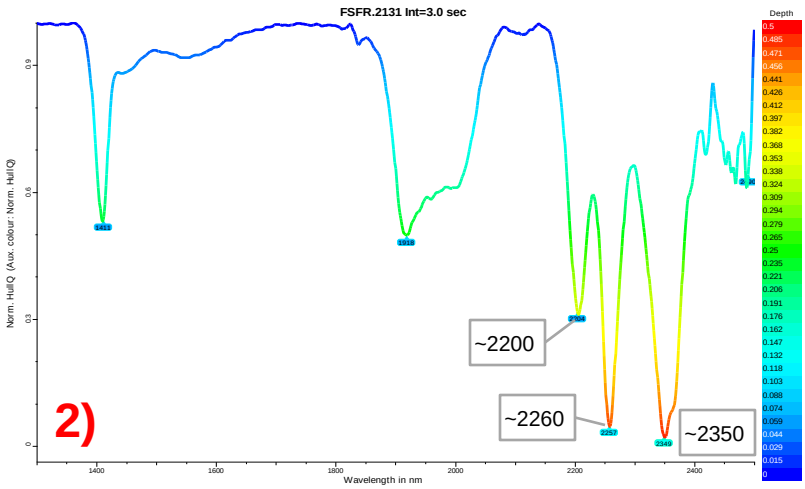
Example of Fe-chlorite + illite and Fe-chlorite + muscovite spectra with weight ratios calculated by software :

The two major absorption features for Fe-chlorite are at ~2260 nm and ~2350 nm. Another significant feature, which also helps to identify chlorite, occurs near 2000 nm. Muscovite features are similar to those for illite, though normally with less well developed water absorption features at ~1410 nm and ~1900 nm.

*Spectra showing **Fe-chlorite** with major absorption features at 2258 nm and 2350 nm, and **illite** with a major absorption feature at 2208 nm. Weight ratios in the sample are 0.6 Fe-chlorite and 0.4 illite.*



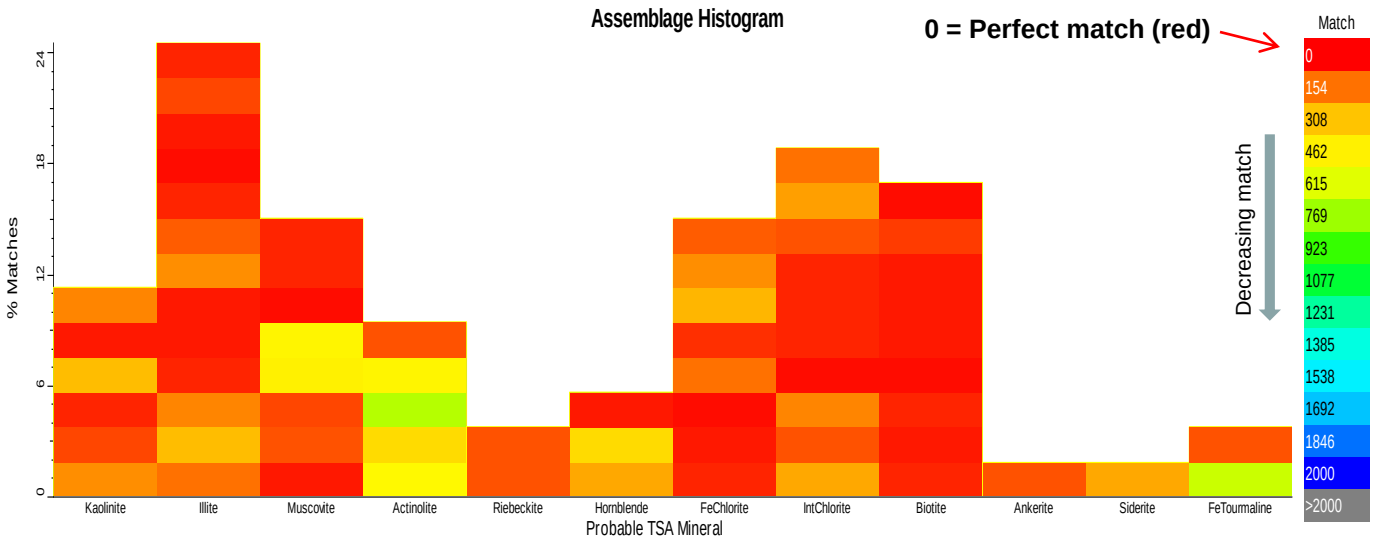
*Spectra showing **Fe-chlorite** with major absorption features at 2257 nm and 2349 nm, and **muscovite** with a major absorption feature at 2204 nm. Weight ratios in the sample are 0.83 Fe-chlorite and 0.17 muscovite.*



By comparing these two spectra, it is evident that the white mica absorption peak at ~2200 nm increases in depth as white mica proportion increases from 0.17 (2) to 0.40 (1). At the same time, as the proportion of Fe-chlorite increases from 0.60 to 0.83, the absorption features at ~2260 nm and ~2350 nm becomes stronger (2).

3. Mineral occurrence

Spectral mineral mapping is a very fast method for identifying mineral assemblages. This so-called digital mineralogy provides a means for mapping the distribution and/or determining estimates of a particular mineral species for e.g. grade control, mill feed applications or because the specific mineral of interest has an established relationship with the target mineralization.



An overview of the mineral distribution of an entire target area. From the assemblage histogram it is easy to compare the amount of specific minerals. The spectra showing two minerals are also included, and the total exceeds therefore 100 %.

4. Mineral composition

Trends in mineral crystallinity and composition can also be identified in the spectra. These can be very important indicators in alteration systems, for example when looking for vectors towards prospective parts of the alteration system.

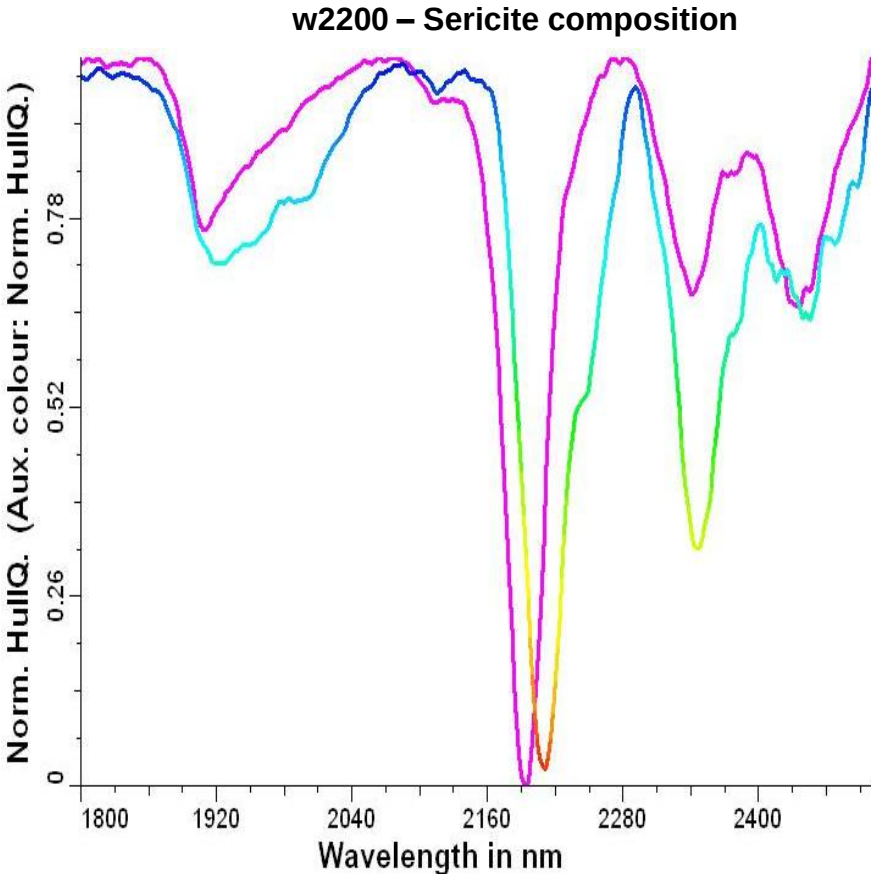
Large data sets of spectra can be compiled quickly and at low cost allowing an in-depth evaluation of the alteration system to be carried out. This provides discrimination of different phases of the same mineral, based on variations in composition and/or crystallinity, i.e. allowing discrimination of the signatures of overprinting and background mineralogies from the alteration mineralogies.

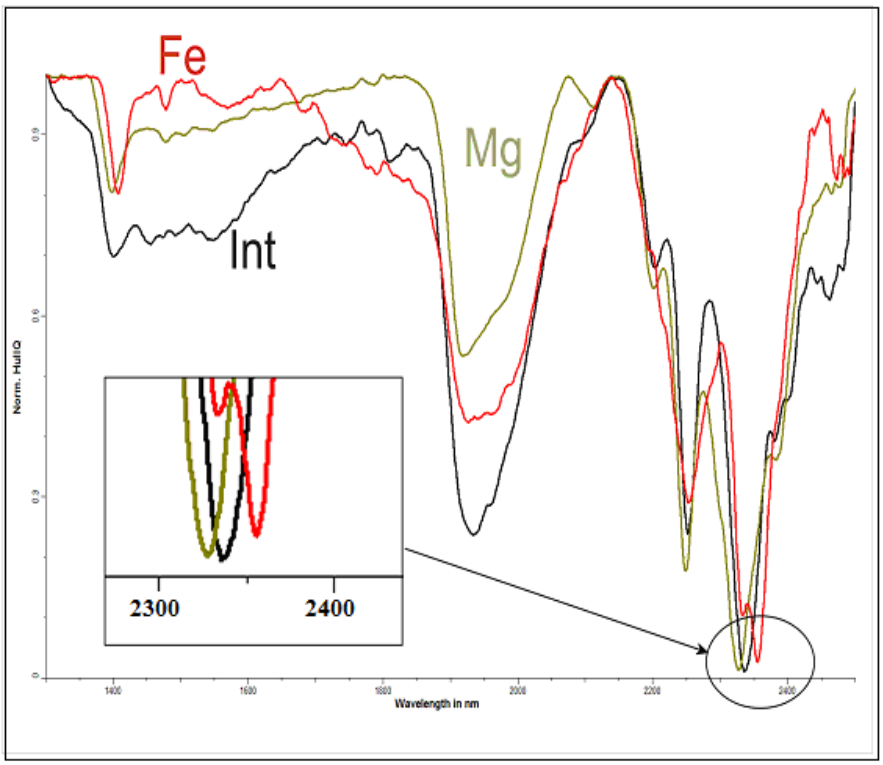
Example of variations in white mica and chlorite composition:

*Spectra of two different mica samples. The multicolored spectrum is **phengite** with an AlOH absorption at 2218nm. The magenta line is a **muscovite** with an AlOH absorption at 2190nm.*

The wavelength of the AlOH absorption is a measure of the degree of Fe and Mg substitution for Al in the octahedral sites in sericite.

The presence of acid pushes the equilibrium towards muscovite, neutral pH pushes it to phengite.





*Major absorption features of **Mg-, Fe- and intermediate chlorite** at 2250-2260 nm, 2330-2350 nm and near 2000 nm.*

In the enhancement you can see the change in composition from Mg- to Fe- chlorite, as the wavelength increases from 2330 nm towards 2350 nm.

SMAM

Ab Scandinavian GeoPool Ltd uses an ASD TerraSpec® VNIR-SWIR spectrometer for various applications in spectral geology. The TerraSpec spectrometer is light and therefore also field portable. We use TerraSpec with The Spectral Geologist (TSG™) software to optimize our service in spectral mapping of alteration minerals.

Spectral mapping of alteration minerals (SMAM)

• TerraSpec is created specifically for determining the mineralogy of rocks and soils. It can be used on e.g. core, rock chips, grab specimens, powders, outcrops and soils.

• We can map various types of minerals and mineral properties e.g. phylosilicates, clays, chlorites, serpentine, hydroxilated silicates, silica varieties, sulphates and carbonates. We can also identify specific mineral compositions and relative proportions.

• The method is suitable for analyzes of a wide variety of deposit types from epithermal to porphyries, kimberlites, IOCG systems, carbonate hosted base metals, greenschist belts, shear veins, skarns, and disseminated gold systems.

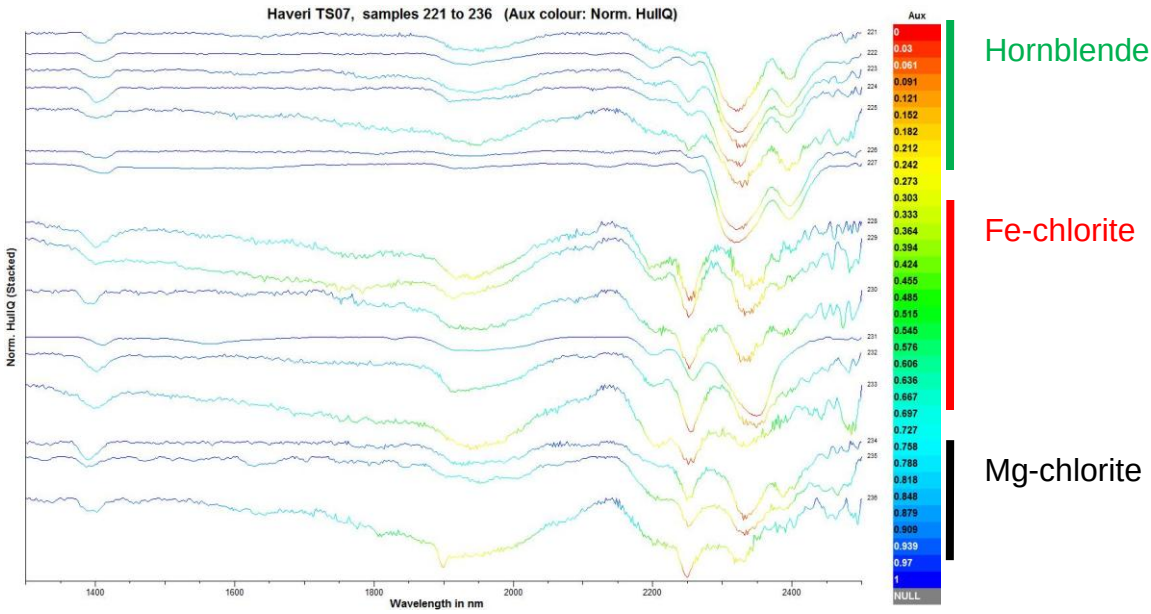
SMAM provided by Scandinavian GeoPool is an accurate service, but since we are able to map 1500 m of drill-core a day, it is also very rapid and cost effective.

Typical working procedure

1. **The project starts with collecting spectral data from for example drill-core or grab specimens. One measurement takes only a few seconds.**

ASD TerraSpec spectrometer.

2. **The data is then imported into The Spectral Geologist software for interpretation. In TSG you can view your results e.g. as spectra, scatter plots, charts etc.**



Collected mineral samples viewed with TSG software.

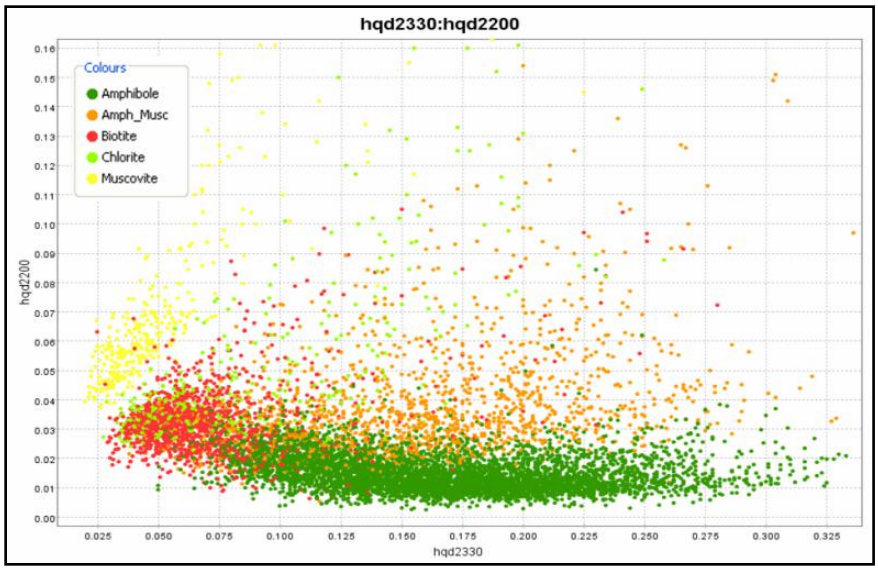
Since the TSG data can be exported for use in other software, the integration of spectral and geochemical data allows relationships between target mineralization and the spectral characteristics of the alteration to be investigated. On the other hand, you can also work in the opposite direction by importing other necessary data into TSG.

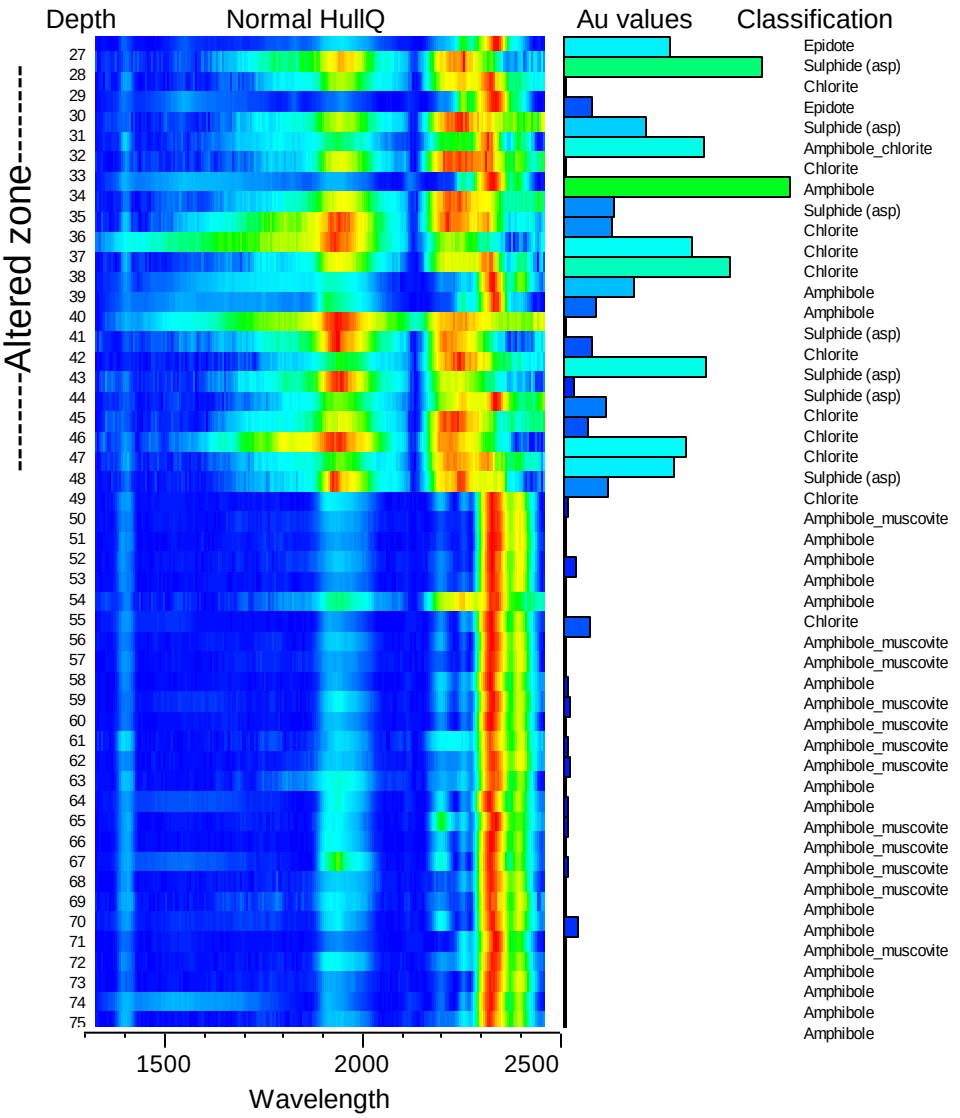
3. **The combined information can then be presented in different formats, for example:**

Scatter plots

Plot of the 2230 nm depth against the 2200 nm depth.

Muscovite (yellow) plots as a separate group. In this plot, the samples that contain muscovite as well as amphibole (orange group) plot above the amphibole-only group (dark green).

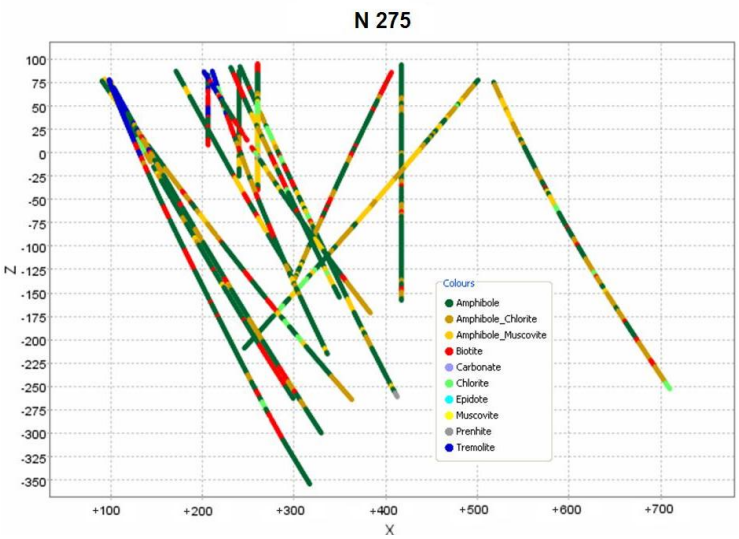




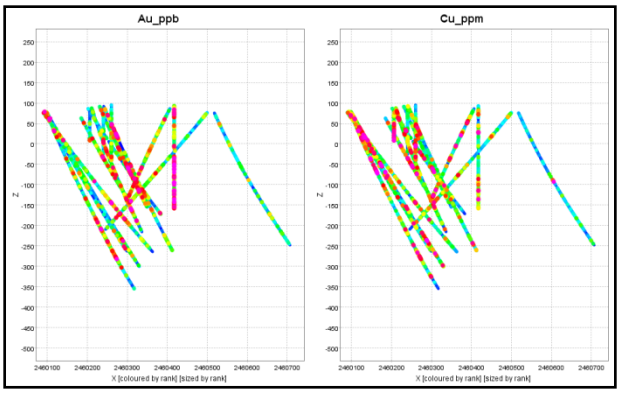
Integration of spectral and geochemical data

Down hole direction

Interpretations of spectral data is an excellent way of comparing the presence of ore related to mineralogy and alteration.



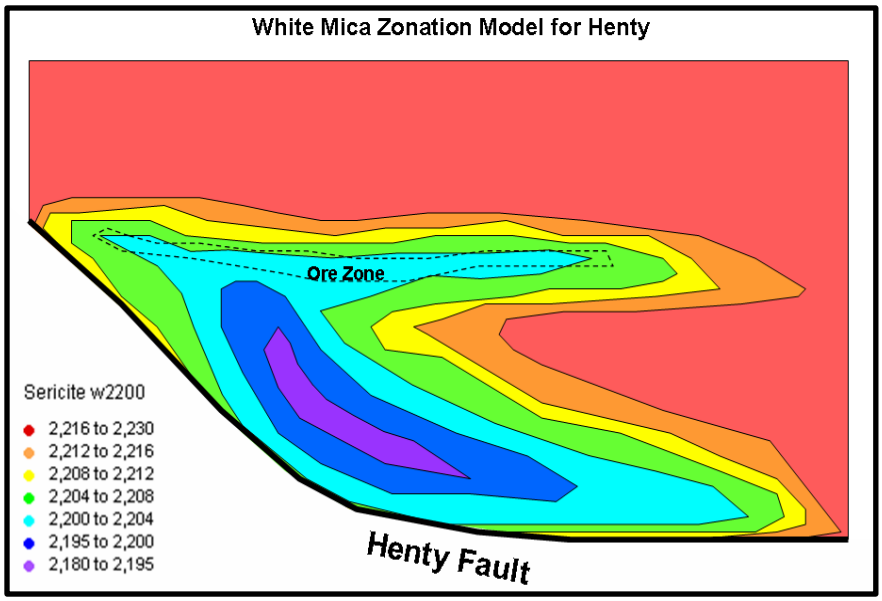
Drill-core sections



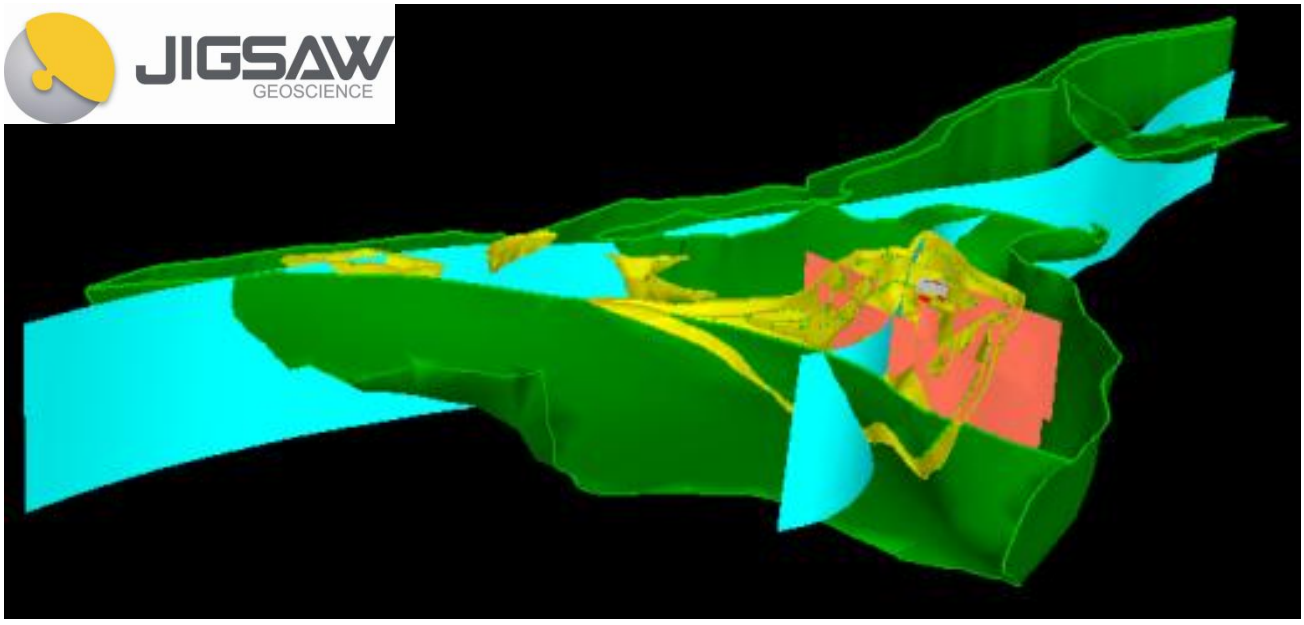
Looking through drill-core sections it is possible to correlate for example gold or copper grades with particular mineral associations.

2D maps

The spectral data can be used when compiling geological maps and/or 3D models.



3D models



TerraSpec® (ASD Inc.) product specifications:

- Spectral range 350-2500 nm (VIS-SWIR).
- Scanning time 100 milliseconds/spectrum.
- Since it's introduction in early 2004, the TerraSpec has become the mining industry's standard in field-portable exploration instrumentation.

The Spectral Geologist (TSG™), Core version:

- Analyses from small (<100) to very large (50,000+) spectral data sets.
- Turn 1000's of spectra into calculated mineralogical indices for analysis of specific mineral characteristics (such as composition).
- Automate mineral interpretation with The Spectral Assistant (TSA™) or the Aux Match function.
- Integrate spectrally-derived mineral data with imported geochemical and geological log data.
- Visualize and Plot your results in many different formats and views, including down hole, or as sections, maps and scatter plots.

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