

Rapid field identification of LCT pegmatite mineralogy: Application of portable Raman spectroscopy

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SUMMARY

Rapid field identification of mineralogy is critical for exploration and ore extraction. For LCT pegmatites, a significant challenge is presented as many dominant minerals are visually similar and many of these minerals cannot be identified by commonly used methods such as SWIR or pXRF analysis. Therefore, being able to readily identify full mineralogy, especially of key lithium bearing minerals such as eucryptite, petalite and spodumene, is invaluable.

Field portable Raman spectroscopy was evaluated, and an application developed to identify and delineate the dominant mineralogy of the Pioneer Sinclair deposit. Raman is a form of vibrational spectroscopy and can readily identify key pegmatite minerals such as quartz, feldspars, micas, Li-silicates, beryls, tourmalines etc.

Over 8,000 Raman spectra were collected from RC, diamond drill holes and grade control samples. The main mineral components were identified by spectral matching to a custom LCT pegmatite reference library and were further delineated by the extraction of key spectral features.

The mineralogical results from these samples were then applied for the identification of pegmatite zones and the development of mineralogical maps of the deposit. Raman analysis of grade control samples identified the core pollucite zone in agreement with pXRF analysis and is being used to augment geological mapping and mineral zonation definition ahead of further exploration. Field portable Raman spectroscopy was found to be a powerful tool for rapid mineral identification and will have useful applications for the exploration and mining of LCT pegmatites and other commodities.

Key words: Raman spectroscopy, lithium, spodumene, mineral exploration, Sinclair caesium deposit

INTRODUCTION

Exploration into lithium rich deposits, such as lithium-caesium-tantalum (LCT) pegmatites, has expanded rapidly in the last 4 years. Rapid field identification of mineralogy is critical to understand the mineralogical system for real time decision making. As many of the dominant minerals are visually very similar (varying shades of white), this can be challenging for the exploration of LCT pegmatites.

Spectroscopic methods are commonly used to aid rapid mineral identification. Due to the anhydrous nature of many key pegmatite minerals, commonly used analytical methods such as short-wave infrared (SWIR), and if they contain lithium, pXRF, are blind to a large portion of minerals. This inhibits the development of a rigorous mineralogical model for an entire deposit.

Given the demand for rapid and non-destructive mineral identification, portable Raman spectroscopy was evaluated for field applications. The application of Raman spectroscopy in earth sciences has been well documented (Dubessy, 2012), however its use in industry for exploration and mining applications is not widely developed. Raman spectroscopy is deemed suitable for the analysis of pegmatites as it can readily identify minerals such as quartz, most feldspars, white micas, Li-bearing minerals, pollucite, garnet, topaz, beryl, carbonates, apatite, etc.

Raman is a form of vibrational spectroscopy, where a monochromatic light from a laser is directed onto a sample (Neuville, 2014). Most of this light scatters and remains the same frequency, however a very small percentage is absorbed and re-emitted as a process of vibrating (bending and stretching) the chemical bonds in the sample. This process changes the energy (frequency) of the re-emitted light, and this subtle change in frequency is measured by the Raman spectrometer as Raman Shift. The vibrational modes and their associated energies are defined for each mineral, generating a unique spectrum for identification of the sample. Identification or verification of a mineral can be executed through spectral matching to a library of reference spectra. Raman analysis requires no sample preparation and can be applied to RC chips, diamond core, powders and hand samples.

A 785 nm laser is a common choice for Raman spectrometers as it can detect both organic and inorganic compounds (Neuville, 2014). A trade-off for the use of a higher energy laser, is the propensity to trigger the emission of varying levels of fluorescence. As a much stronger response, the fluorescence tends to flood the Raman detector and overpower the Raman signal. This effect has been documented for some key lithium bearing pegmatite minerals such as eucryptite (Charoy et al., 2001). The development of Sequentially Shifted Excitation (SSE) algorithms has helped to mitigate fluorescence from spectra and has enabled the measurement of a wider range of minerals (Cooper et al., 2013).

The discovery of pollucite (Pioneer, 2016), a rare mineral with high economic value attributed to its high caesium content (~29.66% Cs₂O) and the subsequent development of the Sinclair Mine (Pioneer, 2018), has provided a unique

opportunity to develop and apply field portable Raman spectroscopy to mineralogical identification of pegmatites.

Economic caesium deposits are extremely rare, with only three mining operations that have produced commercial quantities of pollucite; the Bernic Lake Mine (Manitoba, Canada), Bikita Mine (Zimbabwe) and the Sinclair Mine (Western Australia) (Bradley et al., 2013). Caesium-rich LCT pegmatites only form through extreme fractionation (London, 2018) and are commonly associated with a rich diversity of minerals including microcline, quartz, lepidolite, albite and muscovite along with biotite, zinnwaldite, amblygonite, petalite, eucryptite, spodumene, tourmaline and beryl.

A key objective of the Raman application was to verify the presence of and distinguish between the white silicate minerals of petalite, eucryptite and spodumene. Raman identification of dominant mineral components could be used for exploration and mining applications such as the logging of drill core and RC chips, mineral mapping and grade control classification.

METHOD AND RESULTS

For mineral identification by Raman spectroscopy, it was necessary to develop a custom spectral library of dominant and associated LCT pegmatite minerals. This library was used for mineral identification and verification by spectral matching to the reference spectra. The Bruker BRAVO Raman spectrometer, with its field portable design, was used for all sample analysis. It has a dual laser system (785 nm and 852 nm) and uses SSE algorithms for fluorescence mitigation (Bruker, 2018). This allowed us to readily distinguish between key minerals such as eucryptite, petalite and spodumene were (Figure 1) where visual identification was difficult.

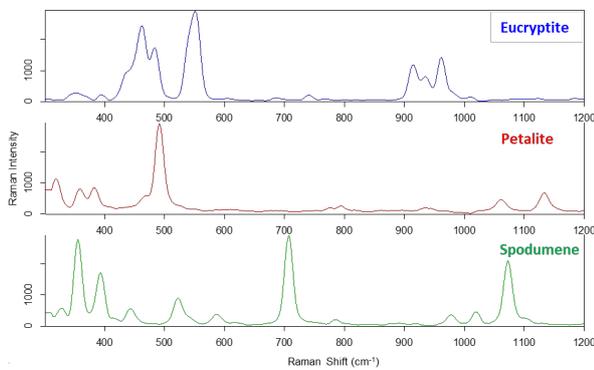


Figure 1. Reference spectra for the three dominant white lithium silicate minerals. Eucryptite (blue), petalite (red) and spodumene (green).

The automated spectral matching to the custom LCT pegmatite library is generally quite accurate, however, the top match is not always correct with the spectra being matched to an incorrect mineral or missing a component in a mixed spectrum. While the user can look at the individual spectra and select the right match for small data sets, for bulk analysis this is impractical. To support the automated spectral matching for mineral identification, we developed spectral ‘scalars’ to extract key spectral features for both mineral identification and delineation (Figure 2). The extraction of spectral features allowed for the differentiation of two different feldspars (microcline and albite) and micas (muscovite and lepidolite), giving a far more detailed analysis of the deposit.

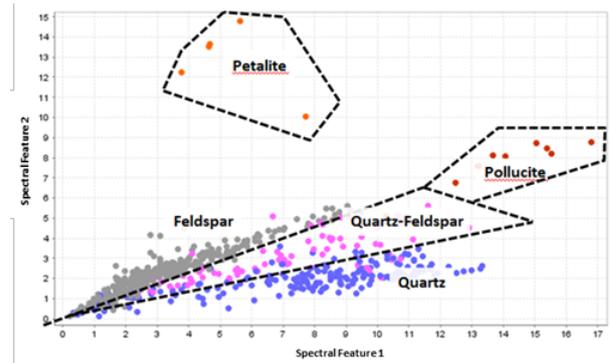


Figure 2. Delineation of key LCT pegmatite minerals by the extraction of spectral features.

For this study, we measured over 8,000 spectra using field portable spectroscopy to map the distribution of key minerals at Sinclair. A series of RC and diamond drill holes were selected to give a representative coverage of the deposit, with a concentrated focus around the pollucite zones. Using automated spectral matching to the custom LCT pegmatite library and spectral ‘scalars’, the mineral components were identified down hole, and used to model pegmatite zonation (Figure 3). The identified mineral phases were then extrapolated to develop predictive 3D models that mapped the Sinclair deposit (Figure 4).

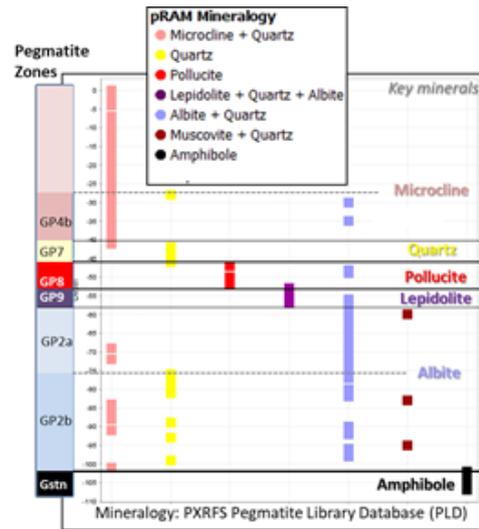


Figure 3. Key mineral phases identified using field portable Raman spectroscopy plotted down hole for the determination of mineral zonation.

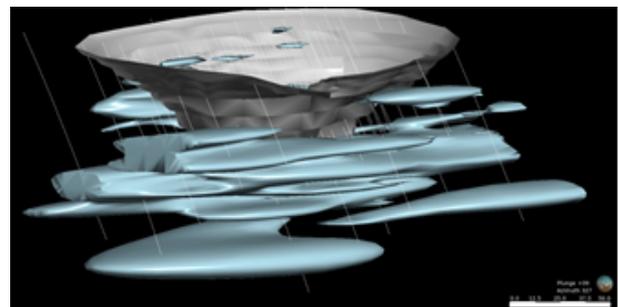


Figure 4. Modelled distribution of albite (cleavelandite), identified by field portable Raman spectroscopy in relation to the Sinclair open pit and exploration drill holes. The white line represents 50 m.

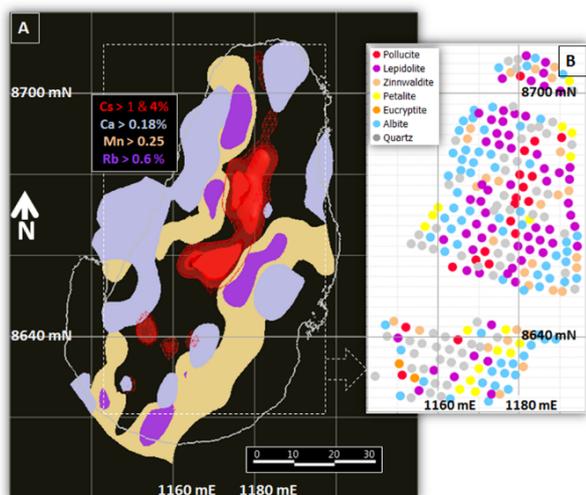


Figure 5. Plan section of Sinclair at 295 mRL showing a) selected element concentration analysed by pXRF and b) dominant mineral phase identified by Raman spectroscopy. Both data sets showing element and mineral zonation associated with the pollucite in the central core zone.

CONCLUSIONS

Rapid field analysis by portable Raman spectroscopy proved successful at identifying dominant mineralogy for LCT pegmatites. The Raman proved critical in the identification and differentiation of the key lithium silicates, eucryptite, petalite and spodumene.

While Raman analysis of the Sinclair deposit proved successful at identifying key minerals, there were some limitations of the technique that had to be considered. The field portable Raman spectrometer has a small window with a diameter of just 0.5 cm. This needs to be considered when designing a sampling program to ensure results are representative. Some minerals were disposed to fluoresce excessively which could not be mitigated by the Raman's SSE algorithms. This tended to be particularly prevalent in the lower zone K-feldspar and inhibited Raman identification by spectral matching.

Data generated from the Raman logging of drill holes were representative of those generated from geological logs and chemistry data. The mineralogical maps also provided direction for further targeted exploration.

The analysis of grade control samples provided an unprecedented high-density mineralogical map of the ore body which gave valuable insight, in conjunction with XRF data, into the mineralogical system. It also added confidence to the separation of valuable lithium and caesium minerals and those of lesser value such as quartz. Therefore, field portable Raman spectroscopy can be recommended for the rapid identification

of LCT pegmatite mineralogy. This could then be applied to core logging and mapping applications.

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