# Mining and processing of micro spodumene-quartz intergrowths at the Tanco pegmatite, Manitoba


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## 1. Introduction

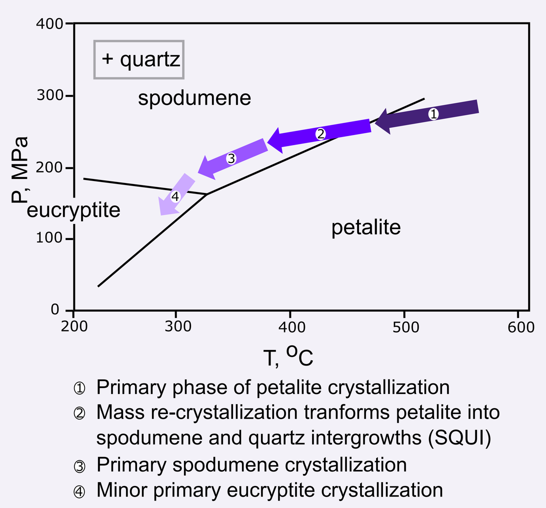


*Figure 1 - Lithium silicate phase diagram showing Tanco pegmatite crystallization path (adapted from London, 1984)*

The Li-Cs-Ta (LCT) Tanco pegmatite in southeastern Manitoba is Canada's only current lithium-producing mine with spodumene as the main targeted ore at the deposit. This is typically found as spodumene and quartz intergrowths (SQUI). There are two dominant textural varieties of SQUI at Tanco including classic SQUI which hosts elongated and oriented growths of spodumene often infilling relic parental crystal outlines (see Fig. 1 for formation conditions). Classic SQUI is the most abundant variety at Tanco. A second textural variety of SQUI found at Tanco is termed micro SQUI due to the small-scale nature of the intergrowths which typically make individual crystals indistinguishable in hand sample. This textural variety is of particular importance as it is much more resistant to mineral processing than the larger intergrowth textures of the deposit. Therefore, understanding the origins and spatial relations of this variety of SQUI is of economic importance for processing estimations.

## 2. Methods

- Thin section petrography was used to characterize micro SQUI textural relationships (Fig. 2i, ii).
- Cathodoluminescence (CL) imaging was used to characterize zonation within spodumene grains (Fig. 3 i, ii, iii, iv).
- Electron probe micro analyses (EPMA) was used to collect geochemical point data for internal LA-ICP-MS calibration.
- Laser Ablation Inductively Couple Mass Spectroscopy (LA-ICP-MS) point measurements were taken to compare trace element geochemistry of classic SQUI to micro SQUI. Two ablations were used per point to minimise data error (Low Resolution (LR): 55 µm, Medium Resolution (MR): 80 µm).
- Electron backscatter diffraction (EBSD) was used to assess crystallographic orientations of SQUI.

## 3a. Results: Thin section petrography and Cathodoluminescence

**Thin Section Petrography**

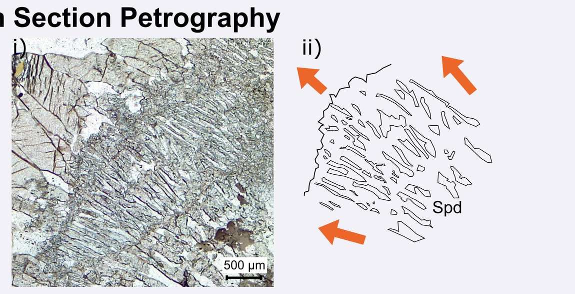


*Figure 2i) - PPL image of micro SQUI, ii) Digitization of representative micro SQUI (highlighted with orange arrows). Spd = spodumene*

Micro SQUI crystals (Fig. 2) are milky white, massive and microcrystalline in hand sample. This SQUI variety represents symplectic intergrowths of internally mottled spodumene (with abundant inclusions of quartz, zircon and mica) and quartz. Localized radial elongated fans are characteristic of symplectite (100 µm – 600 µm) but of very fine intergrowths with no obvious elongated crystals of spodumene (<20 µm - 50 µm) are also common. Samples of micro SQUI have a high internal textural variability and are in both sharp and gradational breakdown contacts with classic SQUI.

**Cathodoluminescence Images**

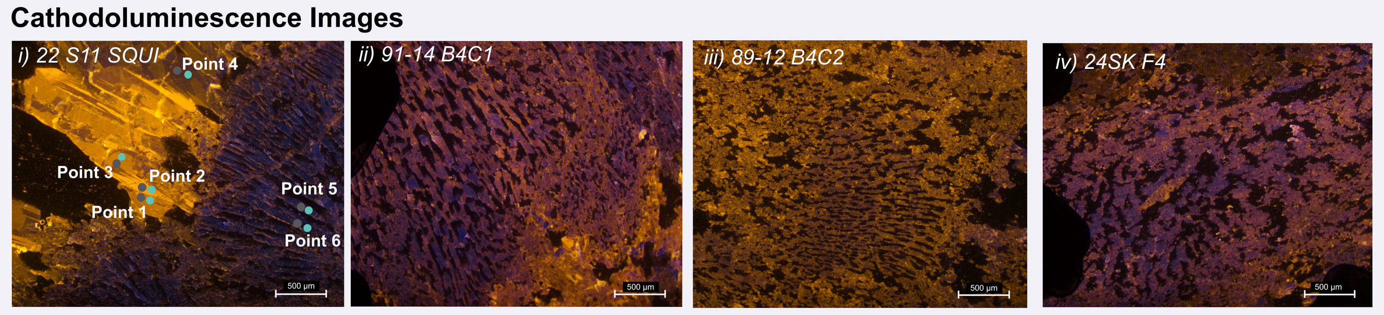


*Figure 3i) Sample 22 SII SQUI A showing classic SQUI (yellow crystals) and second generation of micro SQUI Growth (blue symplectite fan), ii, iii and iv)Micro SQUI texture of Samples: 91-14 B4C1 C, 89-12 B4C2 and 24SK F4. Grey point = LR LA-ICP-MS ablation point, Teal = MR LA-ICP-MS ablation point.*

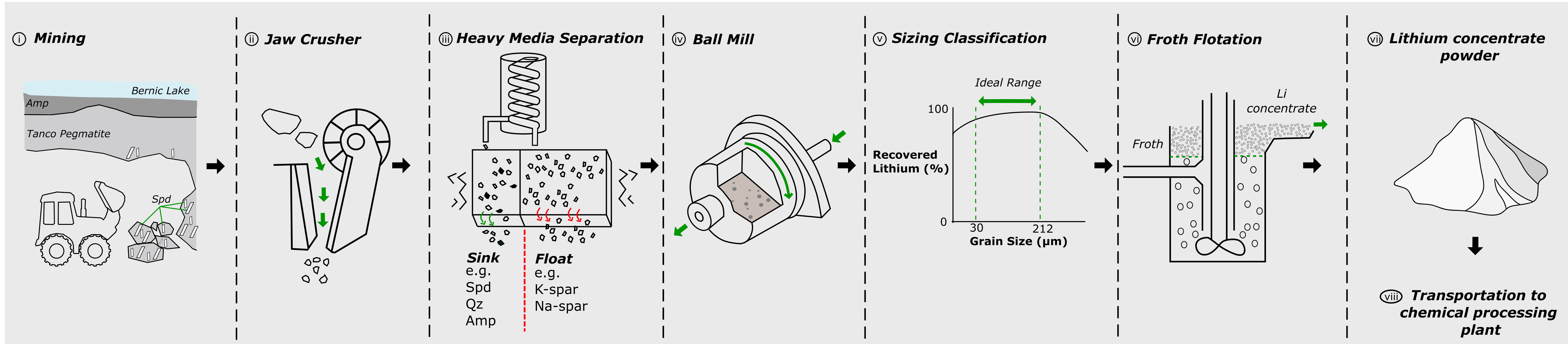


*Figure 5 - Schematic showing the process of mining and mineral processing of spodumene ore. i) Spodumene is blasted and retrieved from underground, ii) material is reduced in size using a jaw crusher, iii) rock chips go through heavy media separator separating sinks (>2.65 g/cm³) from floats (<2.65 g/cm³), iv) rock chips are ground down into powder, v) grains are separated based on size, vi) powder undergoes froth flotation, vii) lithium concentrate powder is recovered, viii) lithium concentrate is transported to a chemical processing plant. Spd - spodumene, Qz - Quartz, Amp - amphibolite, K-spar - potassium feldspar, Na-spar - plagioclase*

## 3b. Results: LA-ICP-MS

| | | Classic 1 | 2 | 3 | 4 | Micro 5 | 6 |
|---|---|---|---|---|---|---|---|
| | Mg | * | * | * | * | **41.5** ± 9 | * |
| | Mn | **102.4** ± 4 | **224.4** ± 3.7 | **78.6** ± 2.4 | **37.2** ± 1.4 | **12.82** ± 0.96 | **9.94** ± 0.76 |
| LR | Sn | **10** ± 1.3 | **9.62** ± 0.66 | **41.2** ± 1.4 | **96** ± 3.4 | **3.46** ± 0.66 | **4.06** ± 0.63 |
| | Cs | * | * | **0.182** ± 0.071 | * | **2.03** ± 0.26 | **0.93** ± 0.11 |
| | Ta | * | **0.452** ± 0.072 | **0.261** ± 0.034 | **7.93** ± 0.37 | **0.536** ± 0.089 | **0.267** ± 0.052 |
| | Na | **330** ± 24 | **833** ± 39 | **399.6** ± 7.6 | **507** ± 17 | **470** ± 20 | **457** ± 21 |
| MR | K | * | **27.5** ± 7.9 | * | * | **17.6** ± 7.3 | * |
| | Fe | **49** ± 3.8 | **185.1** ± 7.8 | **41.3** ± 2.1 | **75.6** ± 3.1 | **63.8** ± 4.8 | **16.8** ± 3 |
| | Ge | **5.7** ± 3.2 | **7.9** ± 2.1 | **6.1** ± 1.6 | **7.9** ± 2.3 | **4.2** ± 2.1 | **4.1** ± 2.2 |

*Table 1 - LA-ICP-MS point ablation data of classic vs micro SQUI. Highlighted values in red indicate notable variations in geochemistry between SQUI types content from the same thin section. Locations of points are indicated on Figure 3 i). External Standard: NIST 610 synthetic glass, Internal Standard: Silicate values, Known 'Unknown': BCR Basalt (400 ppm Li).*

## 3c. Results: Electron Backscatter Diffraction (EBSD)

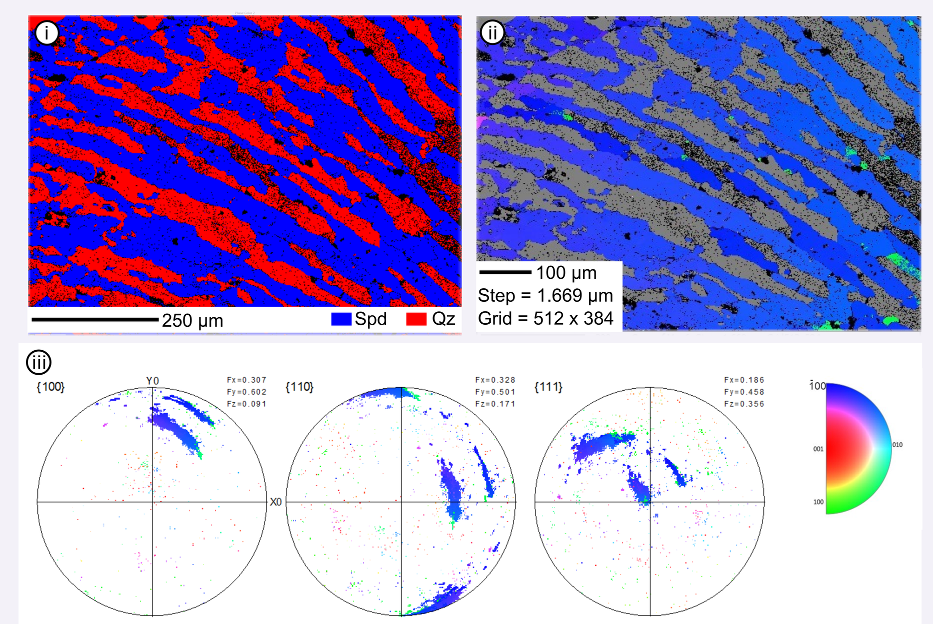


*Figure 4 - EBSD of micro SQUI sample 22 SII. Spodumene is monoclinic.*

*i) Phase map showing 68.4% spodumene (blue) and 31.6% quartz (red)*

*ii) Inverse Pole Figure (IPF) Y showing spodumene crystallographic orientations. Quartz is shown in grey.*

*iii) Pole plots of spodumene with IPF Y colouring scheme. The spread of grouped poles highlight radial nature of crystal orientations.*

## 4. Discussion

Thin section petrography revealed that micro SQUI is comprised of radial symplectic intergrowths which commonly show textural evidence of reactive crystallization fronts. Complimentary cathodoluminescence imaging revealed that micro SQUI represents a second generation of crystallization that post-dated classic SQUI. LA-ICP-MS highlighted the geochemical similarity of classic SQUI and micro SQUI. Sample 22 SII shows the crystallization of micro SQUI generally hosting elevated levels of Cs and relative depletion of Mn and Sn (Table 1). EBSD results show the strong crystallographic orientation of micro SQUI in radial symplectic fans (Fig. 4 i, ii, iii).

There are multiple methods of symplectite genesis noted to the right. Due to the textural and geochemical relationships described above, post-crystallization hydrothermal alteration appears to represent the most likely origin of micro SQUI. Hydrothermal symplectites that are visually similar to micro SQUI have been experimentally recreated by Spruzeniece et al (2017), in support of the hydrothermal symplectite origin.

**Methods of symplectite formation**

- Hydrothermal (Spruzeniece et al, 2017)
- Crystallization from a melt (e.g. Hibbard, 1979)
- Solid-state break down initiated by a P-T change (e.g. Cruciani et al, 2008)
- Exsolution during cooling (Moseley, 1984)

## 5. Economic Processing Implications

Due to the fine intergrowth textures and remarkable hardness of micro SQUI, this leads to multiple issues occurring in the mining and processing of spodumene (Fig. 4). The main issues which arise include:

**Mine**
Due to the hard nature of micro-SQUI, mining machinery is often strained, and breakages occur during drilling and blasting. This leads to additional expenses in part replacement.

**Mill**
Again, due to the hardness of micro SQUI, it is more resistant to milling than classic SQUI, requiring more energy and time to process.

**Recovery**
Poor recovery arises due to fine-scale nature of intergrowths leading to a lack of surface area exposure to bind to surfactant during the froth flotation process.

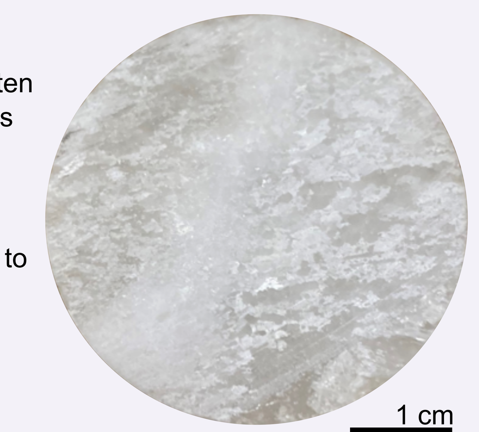


*Figure 6 - Picture of Drillcore containing classic SQUI with central micro SQUI vein*

## 6. Conclusions

- Thin section petrography and EBSD highlight the symplectic fan textures of micro SQUI.
- CL highlights classic SQUI as a zoned primary crystallization followed by a second generation of micro-SQUI.
- LA-ICP-MS revealed the loss of Mn and Sn, and the enrichment of Cs as a result of this recrystallization.
- Micro SQUI formed via a post-crystallization reactive hydrothermal fluid altering classic SQUI.
- The presence of micro SQUI has a signficant economic impact on mineral processing of spodumene.

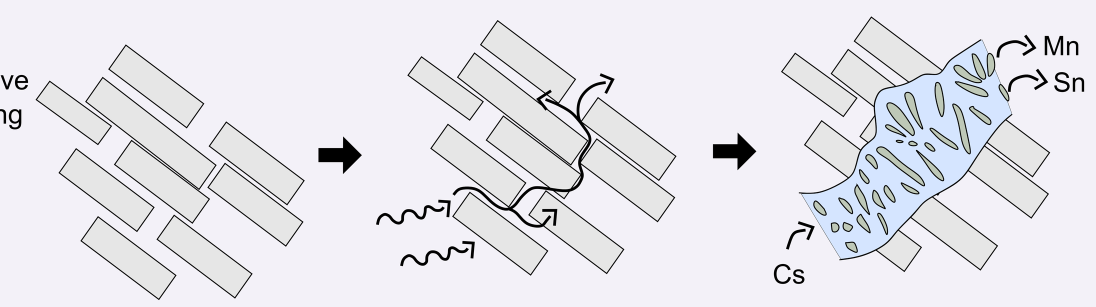


*Figure 7- Schematic showing elongate grey spodumene crystals of classic SQUI being altered by hydrothermal fluids leading to micro-SQUI formation*

## 7. Future work

Future work will investigate the spatial distributions of the different SQUI types at the Tanco pegmatite to provide insight into where micro SQUI is found. Indicator minerals and textures surrounding micro SQUI will also be investigated to aid in improving micro SQUI location predictions.

## 8. Acknowledgements and References


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