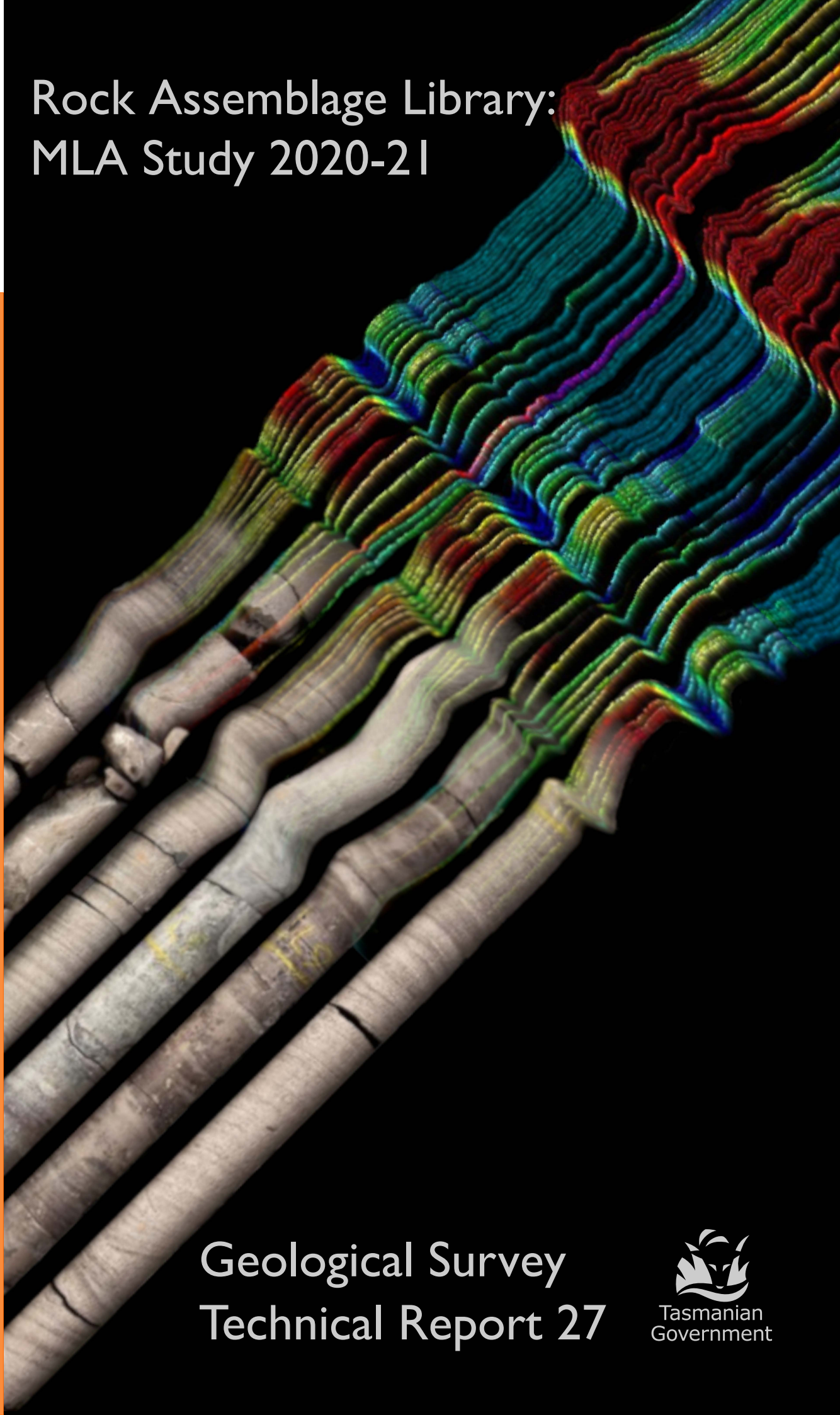
Rock Assemblage Library: MLA Study 2020-21



2021

Authors: D. Green, J. Moltzen, R. Reid
Date: 07/12/2021
Email: info@mrt.tas.gov.au
Website: www.mrt.tas.gov.au

REPORT No: TR27

Geological Survey Technical Report 27

Tasmanian Government

Mineral Resources Tasmania
Department of State Growth

Geological Survey Technical Report 27:

Rock Assemblage Library: MLA Study 2020-21

By David Green, Jake Moltzen and Robert Reid

National Virtual Core Library
Auscope
National Collaborative Research Infrastructure Strategy

While every care has been taken in the preparation of this report, no warranty is given as to the correctness of the information and no liability is accepted for any statement or opinion or for any error or omission. No reader should act or fail to act on the basis of any material contained herein. Readers should consult professional advisers. As a result the Crown in Right of the State of Tasmania and its employees, contractors and agents expressly disclaim all and any liability (including all liability from or attributable to any negligent or wrongful act or omission) to any persons whatsoever in respect of anything done or omitted to be done by any such person in reliance whether in whole or in part upon any of the material in this report. Crown Copyright reserved.

Contents

Acknowledgments....4
1. Introduction....5
2. Methods....5
Sample selection
Sample size
HyLogging
Mineral Liberation Analysis
3. Results....11
4. Discussion....30
Sample interpretations....30
Summary....32
Mineral proportions....36
Potential further work....45
5. Conclusions....46
References....47

Appendix 1. HyLogging and MLA results....48
Appendix 2. Full MLA results....67
Appendix 3. BSE images....78
Appendix 4. Summaries of results from pilot MLA study (Green and Reid 2021)....89
Appendix 5. Summaries of mineral identification results....97
Appendix 6. Digital files....99

Figures

Figure 1. TSG scatter plot showing 40 candidate samples as they were laid out....7
Figure 2. Candidate samples coloured by Felsic-mafic index....7
Figure 3. Candidate samples coloured by dCLST Mineral Group 1 and 2....9
Figure 4. Summaries of the results for each sample....12
Figure 5. Mineral proportion estimates from TIR: dCLST and XMOD....36
Figure 6. Mineral proportion estimates from dCLST, STSAT, uTSAT and XMOD/MINSQ....39
Figure 7. Mineral proportion estimates from SWIR: uTAS and XMOD....41
Figure 8. Mineral proportion estimates from sTSAS, uTSAS and XMOD/MINSQ....39
Figure 9. Mineral proportion estimates for the SWIR-active minerals....44

Tables

Table 1. Sample details....6
Table 2. Translation table mapping MLA minerals to TSG minerals....10
Table 3 Success or failure of mineral identification by dCLST....34
Table 4 Success or failure of mineral identification by uTSAS....35
Table 5. Linear regression statistics for dCLST modelling mineral proportions....28

Acknowledgements

We would like to acknowledge the following for their continued assistance during this project:

Mineral Resources Tasmania staff Peter Harding, Mirella Terrones, Lia Unwin, Ross King, Steve Newett, Ralph Bottrill and Till Gallagher.
Karsten Goeman of the University of Tasmania Central Science Laboratory.
State and Territory Geological Surveys for suggesting test samples.
Andy Green for running MOMA algorithms on the CorStruth database.
CSIRO staff Ian Lau and Carsten Laukamp for their support.

This work was supported by AuScope Pty Ltd and the National Virtual Core Library (NVCL) project, managed by CSIRO Mineral Resources.

"I've seen more core that's a drab triumph of understatement and subtlety than I care to remember."

Peter Mason

What's new in TSG, April 2008

1. Introduction

The AuScope NVCL Rock Assemblage Library project aims to validate the interpretation of HyLogger spectra for representative mineralogies. Up to 2020 (Moltzen & Bottrill 2018, Moltzen *et al.* 2020) the project validated HyLogger interpretations by calculating mineral proportions using the MINSQ algorithm from (a) XRD analysis to provide the mineral assemblage, (b) microprobe analysis to provide mineral compositions and (c) XRF analysis of the whole sample (Herrmann *et al.* 2002). Additional validation was provided by quantitative XRD and petrological thin section.

Subsequent validation (Green & Reid 2021) was done using mineral liberation analysis (MLA). The justification and a detailed description of the method are included in Green and Reid (2021).

In this study, HyLogger and MLA data was acquired from 15 samples identified as being potentially challenging for spectral analysis, providing a validated dataset to test unmixing algorithms.

Methods

Sample selection

Candidate rock types and sub-assemblages were identified at the NVCL community workshop, Sydney 2020, then firmed up with emails afterward. The rocks and assemblages were identified because they have been found to be challenging and/or give ambiguous results.

The 15 rocks/mineral assemblages identified for targeting were:

- Sandstone – micaceous
- Sandstone - calcareous
- (Black) shale – micaceous
- (Black) shale - crypto-micaceous
- Kaolin + White-mica
- Carbonate + White-mica
- Carbonate + Chlorite
- K-Feldspar + Plagioclase + Quartz
- K-Feldspar + White-mica + Plagioclase
- Chlorite + Carbonate + White mica
- Chlorite + Amphibole
- Chlorite + Biotite
- Chlorite + Biotite + Amphibole
- Chlorite + Epidote + Amphibole
- Biotite + Epidote + Amphibole

The sandstone and shale targets had been identified in Tasmanian drill core in 2019.

To find suitable examples of the target mineral assemblages, NVCL Analytics was used on Tasmanian drill holes. For a national search, Andy Green kindly built and ran tailored CorStruth MOMA algorithms (Green 2017) to identify the number of occurrences of candidate assemblages in all drill holes in the CorStruth database (as at April 2020) e.g.

- Kaolin + White-mica
  (White-mica wt > 0.3) AND
  (Kaolin wt > 0.3)

The search used the sjCLST unmixing algorithm with group level mineral weights.

The TSG files of candidate samples were inspected and samples selected based on closeness to equal proportions of the target minerals, mineral assemblage homogeneity, textural simplicity and core condition. The samples were extracted at the relevant state and territory core libraries and gathered at MRT in Tasmania.

In total, 21 samples were selected for study, including the 6 analysed in 2019-20 and reported in Green and Reid 2021 (table 1).

Table 1. Sample details. Start and end refer to TSG dataset sample id numbers. The first 6 samples were included in the report for 2019-20 (Green and Reid 2021). Spectra refers to the total number of HyLogger 4mm samples acquired from the face of the sample selected to be analysed by MLA. MRV – Mt Read Volcanics.

MRT Sample_ID	Target sub-assemblage	Lithology	Location	State	ddh id	Hole name	Start	End	Depth	Length (cm)	Spectra
G408251	Kaolinite + White mica	Mudstone	Tasmania Basin	Tas	6149	Thorp-1	70936	70954	263.25	7.2	165
G408275	K-feldspar + Plagioclase	Altered granodiorite	Gramalote Project	Colombia		Quarry	434	456	1.771	8.8	339
G408243	K-feldspar + Plagioclase + White mica (+ Quartz)	K-feldspar-altered dacite	White Spur, MRV	Tas	24998	WSP-14	102276	102285	347.19	3.6	151
G408265	Biotite + Epidote + Amphibole	Biotite-garnet-altered mafic	Cethana	Tas	29536	CETD4	68737	68748	477.88	8.8	183
G408264	Chlorite + Biotite	Biotite-altered mafic	Cethana	Tas	29536	CETD4	67704	67724	470.95	16	364
G408260	Shale - crypto-micaceous	Micaceous grey shale	Oonah prospect	Tas	15171	DD80OC3	7014	7033	74.658	15.2	219
G408245	Chlorite + Carbonate + White mica	Altered felsic volcanic	Mt Charter, MRV	Tas	13529	MCH1	73944	73949	533.75	4	160
G408246	Chlorite + Carbonate + White mica	Success Creek mudstone	Black River	Tas	6200	Forest-1	109397	109414	793.62	13.6	258
G408248	K-feldspar + Plagioclase + White mica (+ Quartz)	Felsic volcanic	Hatfield River, MRV	Tas	8484	HAT7	38045	38050	146.6	4	323
G408255	K-feldspar + Plagioclase + White mica (+ Quartz)	Felsic volcanic	White Spur, MRV	Tas	36739	WSP-16	33386	33397	109.71	4.4	251
G408276	K-feldspar + Plagioclase + White mica (+ Quartz)	Altered felsic volcanic	Ernest Henry	Qld	71763	550	83505	83525	738.55	13	549
G408277	K-feldspar + Plagioclase + White mica (+ Quartz)	Soldiers Creek Granite	Pine Creek	NT	8E+06	D007	21679	21701	185.03	15	436
G408249	Kaolinite + White mica	Altered felsic volcanic	Mackintosh, MRV	Tas	27812	MCD37	1468	1475	34.098	5.6	222
G408250	Kaolinite + White mica	Claystone	Tasmania Basin	Tas	6149	Thorp-1	70841	70851	262.93	4	185
G408253	Shale - crypto-micaceous	Crypto-micaceous shale (Mathinna Group)	Lefroy	Tas	19586	L4A	6226	6264	156.73	30.4	243
G408254	Sandstone - micaceous	Micaceous sandstone (Mathinna Group)	Lefroy	Tas	19586	L4A	7331	7349	164.44	14.4	297
G408261	Shale - graphitic	Carbonaceous shale	Oonah	Tas	15171	DD80OC3	41453	41494	321.05	16.4	132
G408262	Shale - graphitic	Carbonaceous shale	Oonah	Tas	15171	DD80OC3	11918	11929	110.67	4.4	301
G408266	Chlorite + Amphibole	Altered mafic volcanic	Cleveland	Tas	18532	C0631	77942	77964	283.31	8.8	147
G408268	Chlorite + Epidote + Amphibole	Altered mafic volcanic	Cleveland	Tas	18532	C0631	51238	51246	186.65	6.4	174
G408279	Chlorite + Biotite	Micaceous ultramafic (cumulate)	Yilgarn - Ravensthorp	WA	M0001 606	RAVD0120	66913	66918	519.21	4	98

Sample size

The optimal sample size for HyLogging validation tests should be sufficient to provide statistical robustness, but small enough to ensure homogeneity. An MLA sampling constraint is set by the cost of analysing large samples with sufficient but not excessive (i.e. costly) point density.

As discussed in Green and Reid (2021), the target sample size was 10cm x 5cm.

HyLogging

Samples were scanned by the MRT HyLogger-3 (visible, NIR, SWIR and TIR; Schodlok *et al.* 2016b) with a sample spacing of 4mm in both the down track and cross track directions (i.e. sampling chunked by 1 with tray sections separated by 4mm). Slab samples were scanned on both sides and the HyLogger results were used to select the side with the most homogeneous mineralogy for MLA (figures 1 and 2).

The Spectral Geologist (TSG v8.0.7.4, June 2020, incorporating TSA v7.0 with its dedicated TIR spectral library; Schodlok *et al.* 2016a) was used for basic spectral processing, to mask out compromised spectra (at sample edges and on cracks), calculate useful spectral scalars (e.g. spectral range and felsic-mafic index) and unmix the spectra to mineral proportions (figure 3). The dataset containing all scanned samples (including both the front sides and back sides of each slab) was used to select the surfaces to be analysed by MLA. Each selection was then exported to a separate TSG dataset for final unmixing. Unless otherwise specified, minimum weight and other unmixing parameters are the default TSG settings.

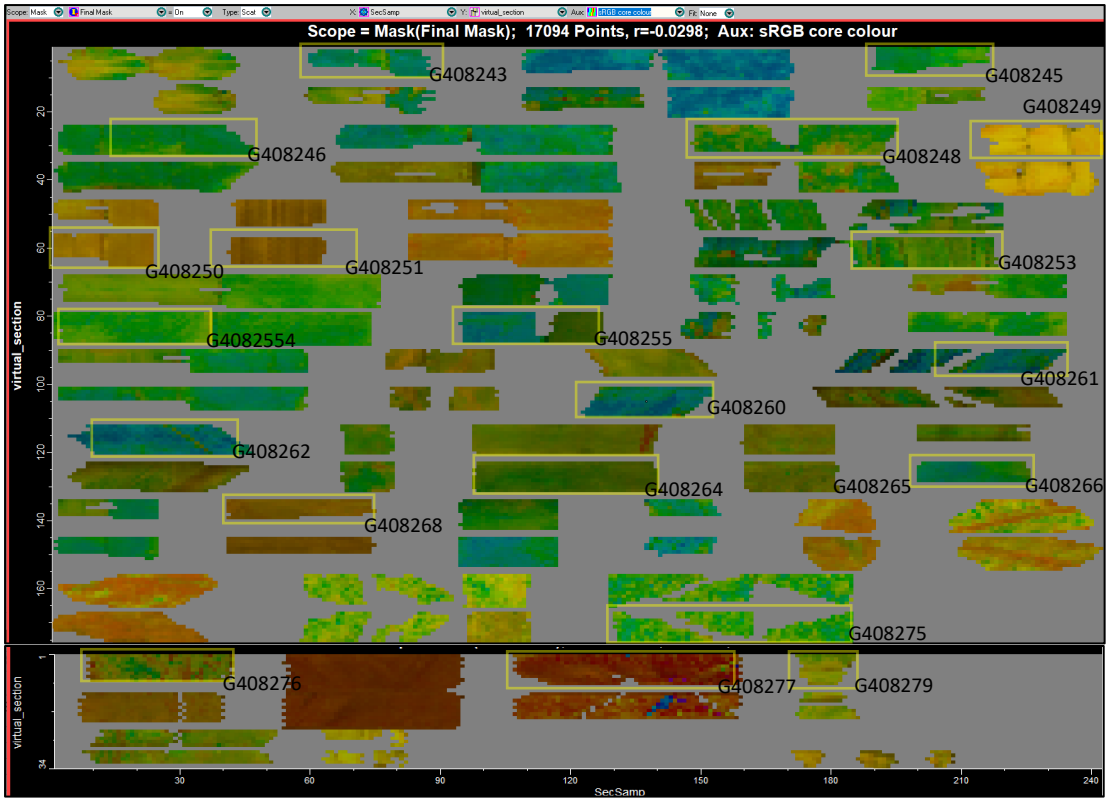


Figure 1. TSG scatter plot showing 40 candidate samples as they were laid out on 20 single-section core trays. Samples appear as pairs, showing both sides. The samples are naturally coloured with a high saturation enhancement (colour tot_sat (2) in TSG).

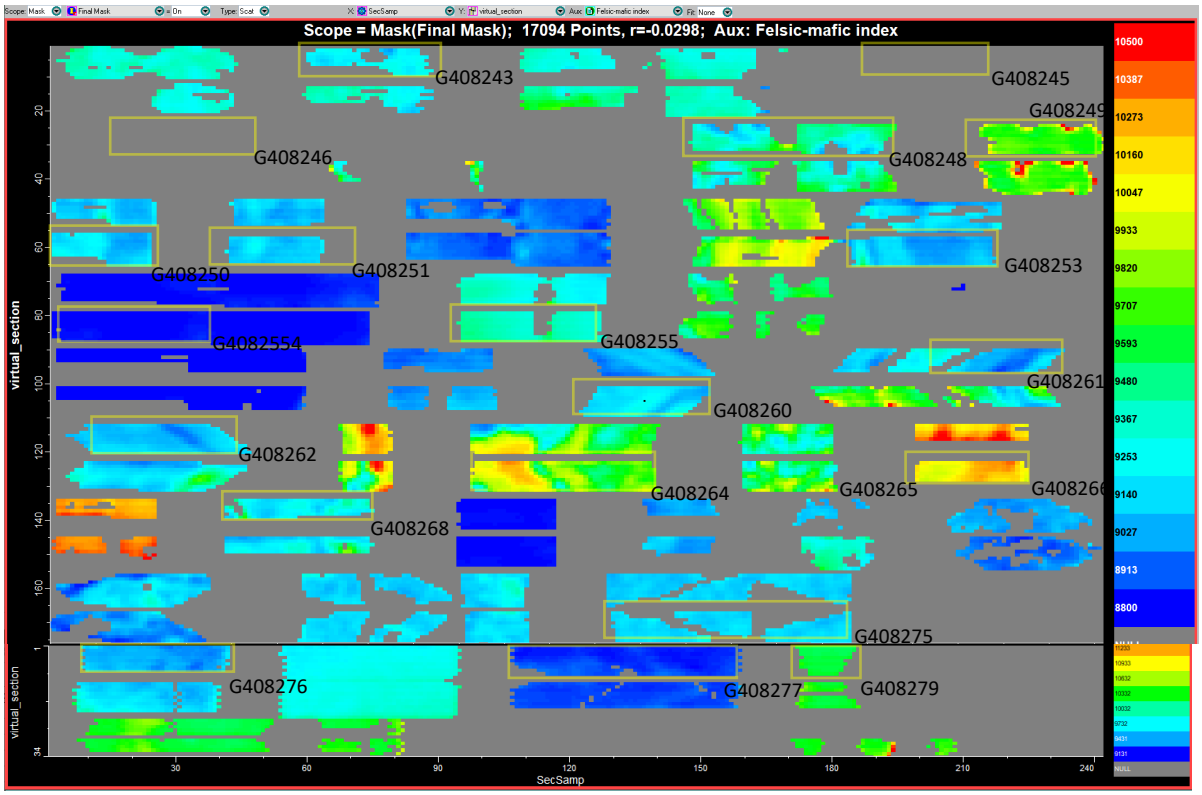


Figure 2. Candidate samples coloured by Felsic-mafic index, with the range of colours in each sample giving an indication of inhomogeneity.

The unmixing algorithms used were:

VNIR-SWIR

- **sTSAS+** (system SWIR TSA+, Berman & Bishof 1997, Berman *et al.* 2011, Berman *et al.* 2017, Green 2015)

  Automatic mixtures of 3. TSA+ with all minerals in the spectral library available (except brucite and palygorskite as is the default setting in TSG).

- **uTSAS** (user SWIR TSA+)

  Supervised mixtures of up to 3. TSA+ with all minerals in the spectral library available except those indicated by sTSA+ that are not supported by diagnostic spectral features, tailored scalars (to seek epidote, prehnite, etc) and/or corresponding TIR spectra or that are mostly aspectral or noisy. Brucite, palygorskite and quartz H2O are not included unless necessary.

- sTSAV (system VNIR TSA)

  Automatic mixtures of 2. TSA with all minerals in the spectral library available (except misc-silicates, carbonates, sulphates, sulphides, and clay-Cu as is standard). All samples were found to contain negligible amounts of VNIR-active minerals, so this was not reported.

- uTSAV (user VNIR TSA)

  Supervised mixtures of 2. Usually, no adjustments are made to sTSAV, so uTSAV was not calculated.

TIR

- **sTSAT**

  Automatic mixtures of 6 with all minerals in the spectral library available (except those not included in the default setting of TSG i.e. sillimanite 1 and 2, quartz 4, 5 and 6, microcline 4 and vonsenite).

  sjCLST (system TIR CLS, Green 2015)

  Automatic mixtures of 3. The restricted mineral set (RMS) is initially informed by sTSAS+, then the algorithm uses scalars and rules to modify the list.

- **dCLST** (user TIR CLS)

  Supervised CLS with mixtures of 6 using a single domain. Initiate the RMS with entire mineral groups identified by uTSAS+, then add entire mineral groups as needed to fit spectra, mainly using the RMS Error scalar, CLS Residual spectrum, Add 1 function and uTSAT with mix>6 and as many minerals available as possible i.e. all those not black listed by default.

  When adding mineral groups, some individual minerals are turned off by default unless specifically justified, as indicated by their being turned off in the default settings: quartz 4, 5, 6, opal and microcline 4.

  When adding mineral groups, some individual minerals and sub-groups are left turned off unless specifically justified because they are commonly used spuriously: glauconite, axinite, prehnite, pyrophyllite, topaz, amphibole-Na, amphibole-Mg-Fe-Mn-Li, carbonate-Cu, carbonate-Ba-Sr-Pb-Zn, gypsum, anhydrite, retgersite, barite, alunite and jarosite.

- **dTSAT** (user domained TIR TSA)

  Supervised mixtures of 6 with minimum weight = 0. TSA with an RMS provided by the CLS domain.

- **uTSAT** (user TIR TSA following the philosophy of SWIR TSA)

  TSA with mix>6 with as many minerals available as possible i.e. all those not black listed by default and excluding only minerals not supported by diagnostic spectral features, tailored scalars and/or corresponding SWIR interpretations. This algorithm was not used in this study.

Carbonates

- Carbonate minerals were further interpreted using the 14000, 11300 and 6500nm features as described in Green and Schodlok (2015) and if necessary, appended to the results (Appendix 1).

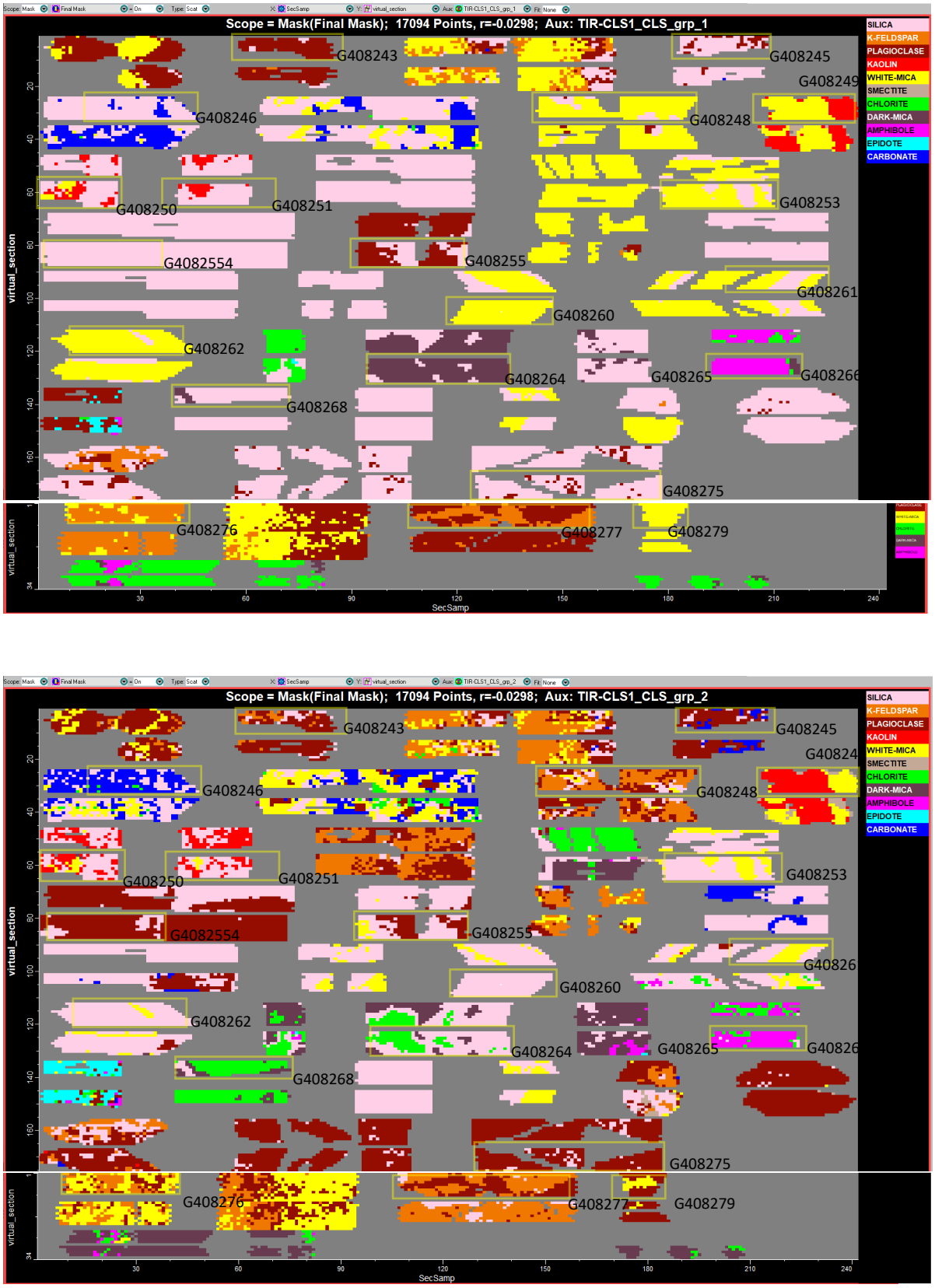


Figure 3. Candidate samples coloured by dCLST Mineral Group 1 (top) and Mineral Group 2 (bottom). The 21 selected samples are outlined in yellow as in figure 2.

Mineral Liberation Analysis (MLA)

The MLA method uses the EDX (energy dispersive X-ray spectroscopy) and backscatter electron image (BSE) functionality of a SEM to classify tens of thousands of spot analyses using a reference mineral library (Gu and Sugden 1995). It provides mineral proportions at a scale and from a similar volume as HyLogging and produces a result that is as close to truth as practical (Green and Reid 2021). MLA of rock slabs and HyLogging both analyse surfaces and return areal mineral proportions, but they are independent. MLA therefore provides a robust independent reference from which to compare the results of HyLogging unmixing algorithms.

The MLA method classifies spot X-ray spectra by matching with a spectral library. Typically, the reference library is based on standard rock-forming minerals and may be modified with information from inspecting the X-ray spectra, acquiring EDX analyses of some of the minerals or from external information. In this project, independence was paramount, so no additional information was provided to the SEM analyst, who used standard mineral libraries. The SEM analyst was however, informed about the desired specificity of mineral identification, given by HyLogger mineral classes e.g. paragonite, muscovite and phengite, and Fe-chlorite, Fe-Mg-chlorite and Mg-chlorite. The count time per spot was set to provide ~2000 X-ray spectra, just sufficient to reliably match with typical mineral libraries. Table 2 shows how MLA minerals classes were translated into TSG minerals and mineral groups.

The consequent practical constraints on MLA analysis resulted in ~35,000 analyses per sample, which nominally guarantees a mineral proportion uncertainty of less than 1%.

XMOD Mineral	TSG Group	TSG Mineral
Actinolite	AMPHIBOLE	Actinolite
Albite	PLAGIOCLASE	Albite
Alumina-Cal	PLAGIOCLASE	
Apatite	PHOSPHATE	Apatite
Biotite	DARK-MICA	Biotite
Ca-Al-Fe-Mg silicate	INVALID	
Calcite	CARBONATE	Calcite
Ca-REE carbonate	CARBONATE	Calcite
Chlorite	CHLORITE	Chlorite-FeMg
Chlorite_Fe	CHLORITE	Chlorite-Fe
Dolomite	CARBONATE	Dolomite
Epidote-Allanite	EPIDOTE	Epidote
Fe-oxide	OXIDE	OXIDE
Galena	OXIDE	OXIDE
Ilmenite-Mn	OXIDE	OXIDE
Kaolinite	KAOLIN	Kaolinite-WX
K-Feldspar	K-FELDSPAR	Orthoclase
Muscovite	WHITE-MICA	Muscovite
Muscovite_minorFe	WHITE-MICA	Phengite
Pl_or_Ab-Cal mix	PLAGIOCLASE	
Plagioclase	PLAGIOCLASE	Oligoclase
Pyrite	INVALID	OXIDE
Quartz	SILICA	Quartz
Rutile	OXIDE	Rutile
Spessartine	GARNET	Spessartine
Titanite	OXIDE	OXIDE
Zircon	MISC-SILICATE	Zircon

Table 2. Translation table mapping MLA minerals to TSG minerals. Chemical compositions are provided in Appendix 2.

Details of the MLA analysis, including a description of the specific XMOD (XMOD_STD) program used are included in Green and Reid (2021). The results of MLA were provided as mineral point counts and the derived area percentages (Appendix 2, which also includes instrument description and operating conditions).

3. Results

Complete mineral proportion results of the unmixing algorithms (sTSAS+, uTSAS+, sTSAT, sjCLST, dCLST and dTSAT) together with our best interpretation of the truth, from MLA using the XMOD program are provided in Appendix 1, with full XMOD results in Appendix 2. Figure 4 summarises the results in graphs and summary tables and includes line scan images. BSE images are provided in Appendix 3. Results from the 6 samples of the pilot MLA validation study (Green and Reid 2021) are included in similar format in Appendix 4.

Figure 4 (following pages).

Summaries of the results for each sample are illustrated, including:

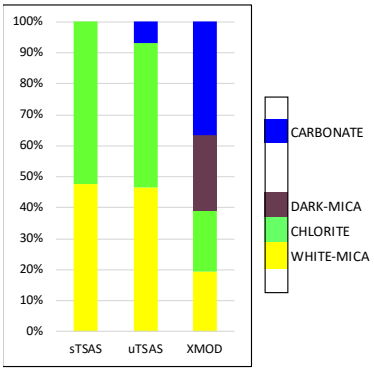
- Column graphs for each sample showing SWIR (top) and TIR (bottom), mineral group (left) and mineral species (right) proportion results from the spectral unmixing algorithms and MLA (using the XMOD program).
- Tables summarise the results of the 6 unmixing algorithms and XMOD.
- vis-SWIR and TIR spectra (in black) modelled by uTSAS and dCLST (in colour) respectively.
- Linescan image of the sample.

Any mineral with a maximum proportion for any unmixing method or XMOD less than 1% is not shown in the tables and any with less than 5% are not shown in the graphs. TSAS results classified as Invalid are shown at the Group level, but not at Mineral level, where the mineral proportions are re-normalised to total 100%. Colours are similar to those used in TSG.

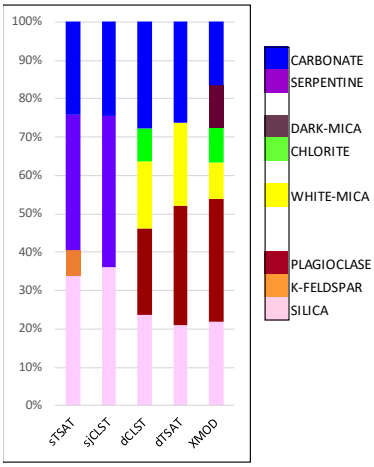
G408245 Altered felsic volcanic

Group

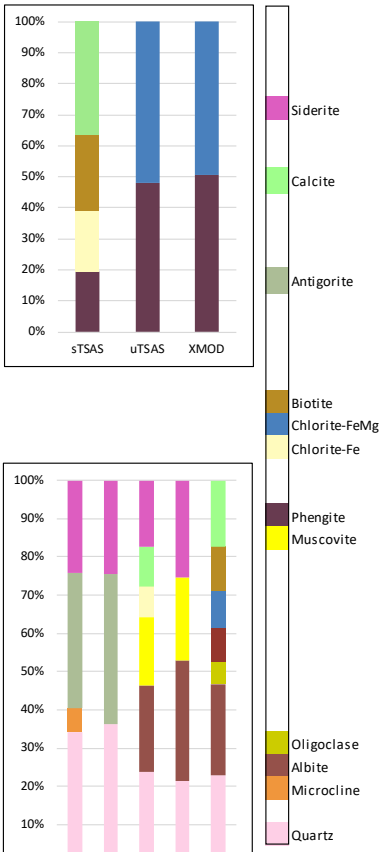
SWIR



TIR



Mineral



SWIR

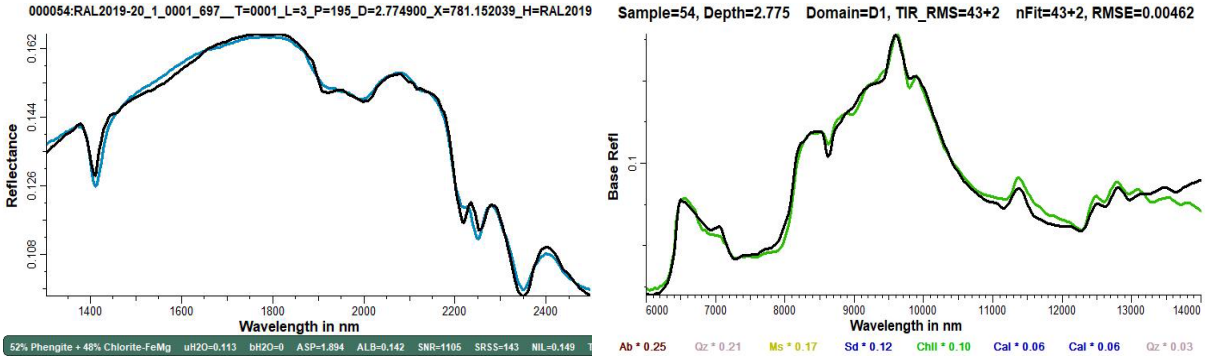
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	46.2%	46.7%	19.1%
CHLORITE	50.7%	46.4%	19.9%
DARK-MICA			24.1%
CARBONATE	2.8%	6.9%	36.2%

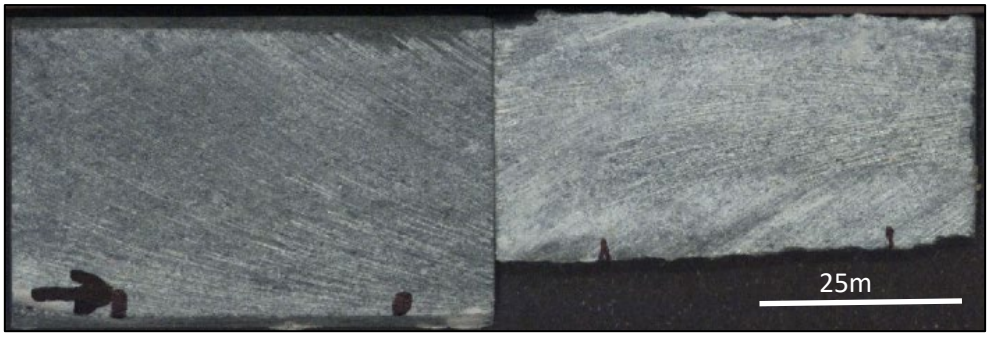
Minerals	sTSAS	uTSAS	XMOD
Muscovite			1.6%
Phengite	46.2%	46.7%	18.8%
Chlorite-Fe	0.6%	1.1%	19.6%
Chlorite-FeMg	50.1%	45.3%	0.3%
Biotite			23.7%
Ankerite	2.3%	2.9%	
Siderite	0.4%	3.8%	
Calcite	0.1%	0.2%	35.5%

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	33.3%	35.8%	23.7%	20.3%	21.7%
K-FELDSPAR	6.3%	0.6%			0.1%
PLAGIOCLASE	1.3%	0.6%	22.5%	30.0%	31.8%
WHITE-MICA			17.5%	20.9%	9.4%
CHLORITE	1.2%		8.5%	3.4%	9.1%
DARK-MICA					10.9%
SERPENTINE	34.4%	38.7%			
CARBONATE	23.6%	24.2%	27.7%	25.3%	16.3%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	33.3%	35.8%	23.7%	20.3%	22.7%
Microcline	6.3%	0.6%			
Albite	1.3%	0.6%	22.5%	30.0%	23.3%
Oligoclase					5.8%
Muscovite			17.5%	20.9%	0.8%
Phengite					9.0%
Chlorite-Fe			0.4%		9.4%
Chlorite-FeMg	1.2%		8.1%	3.4%	0.1%
Biotite					11.4%
Antigorite	34.4%	38.7%			
Siderite	23.6%	24.2%	17.2%	24.1%	
Calcite			10.5%	1.1%	17.1%

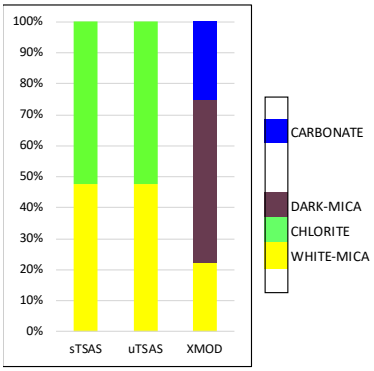




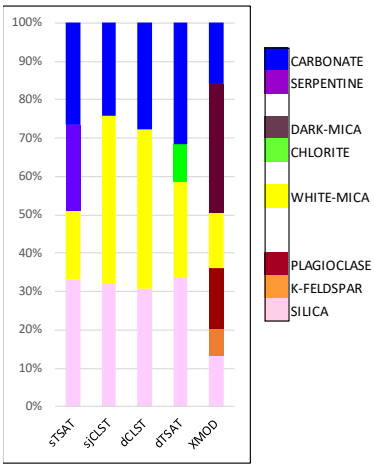
G408246 Mudstone

Group

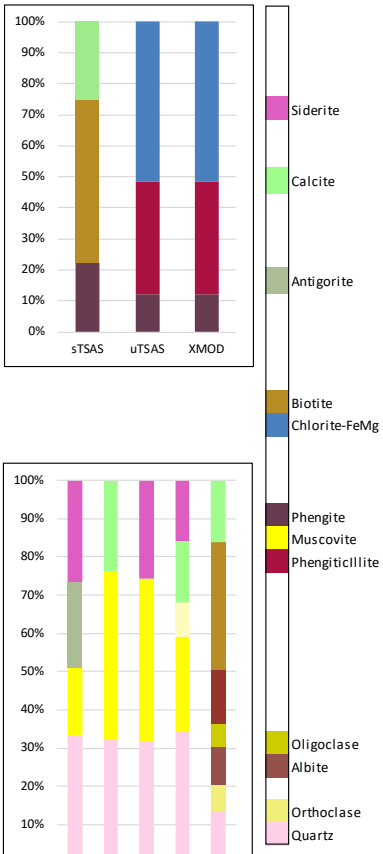
SWIR



TIR



Mineral



SWIR

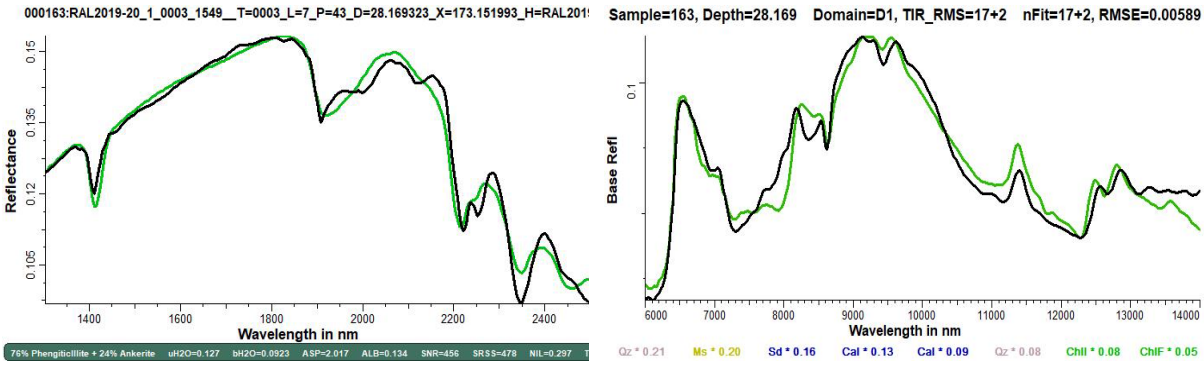
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	46.2%	46.7%	19.1%
CHLORITE	50.7%	46.4%	19.9%
DARK-MICA			24.1%
CARBONATE	2.8%	6.9%	36.2%

Minerals	sTSAS	uTSAS	XMOD
Muscovite			1.6%
Phengite	46.2%	46.7%	18.8%
Chlorite-Fe	0.6%	1.1%	19.6%
Chlorite-FeMg	50.1%	45.3%	0.3%
Biotite			23.7%
Ankerite	2.3%	2.9%	
Siderite	0.4%	3.8%	
Calcite	0.1%	0.2%	35.5%

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	33.3%	35.8%	23.7%	20.3%	21.7%
K-FELDSPAR	6.3%	0.6%			0.1%
PLAGIOCLASE	1.3%	0.6%	22.5%	30.0%	31.8%
WHITE-MICA			17.5%	20.9%	9.4%
CHLORITE	1.2%		8.5%	3.4%	9.1%
DARK-MICA					10.9%
SERPENTINE	34.4%	38.7%			
CARBONATE	23.6%	24.2%	27.7%	25.3%	16.3%

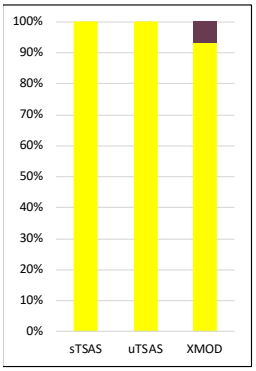
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	33.3%	35.8%	23.7%	20.3%	22.7%
Microcline	6.3%	0.6%			
Albite	1.3%	0.6%	22.5%	30.0%	23.3%
Oligoclase					5.8%
Muscovite			17.5%	20.9%	0.8%
Phengite					9.0%
Chlorite-Fe			0.4%		9.4%
Chlorite-FeMg	1.2%		8.1%	3.4%	0.1%
Biotite					11.4%
Antigorite	34.4%	38.7%			
Siderite	23.6%	24.2%	17.2%	24.1%	
Calcite			10.5%	1.1%	17.1%

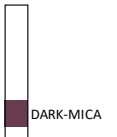


G408248 Felsic volcanic

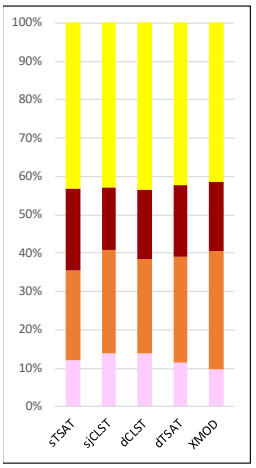
Group

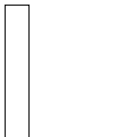
SWIR



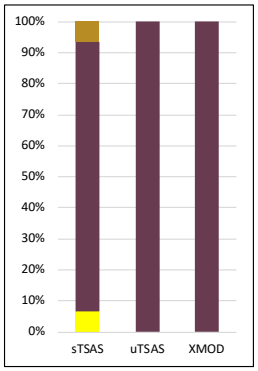


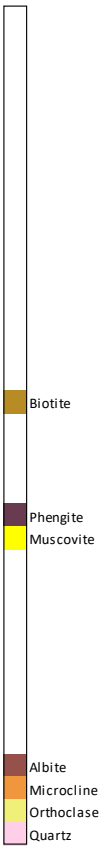
TIR

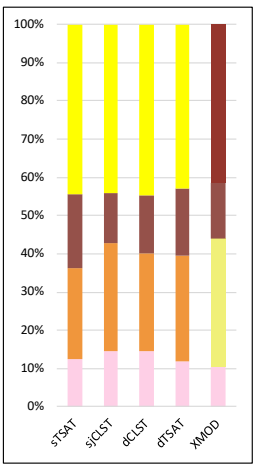




Mineral







SWIR

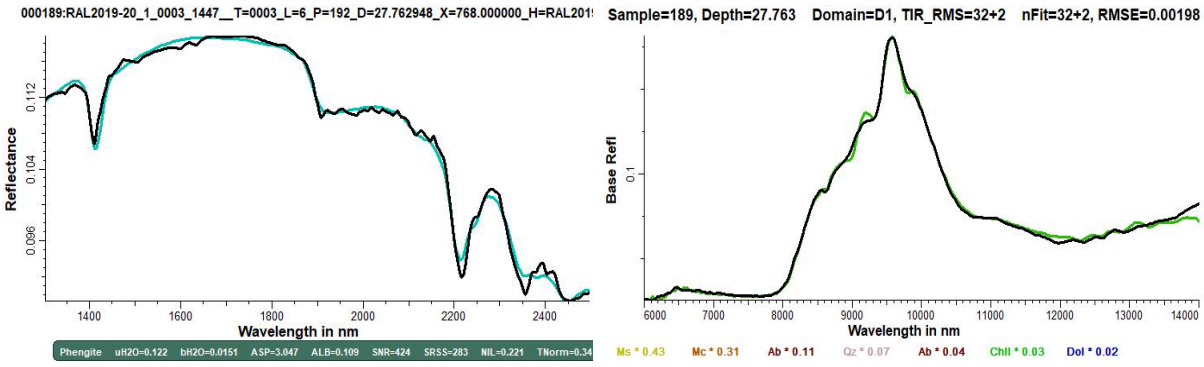
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	46.2%	46.7%	19.1%
CHLORITE	50.7%	46.4%	19.9%
DARK-MICA			24.1%
CARBONATE	2.8%	6.9%	36.2%

Minerals	sTSAS	uTSAS	XMOD
Muscovite			1.6%
Phengite	46.2%	46.7%	18.8%
Chlorite-Fe	0.6%	1.1%	19.6%
Chlorite-FeMg	50.1%	45.3%	0.3%
Biotite			23.7%
Ankerite	2.3%	2.9%	
Siderite	0.4%	3.8%	
Calcite	0.1%	0.2%	35.5%

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	33.3%	35.8%	23.7%	20.3%	21.7%
K-FELDSPAR	6.3%	0.6%			0.1%
PLAGIOCLASE	1.3%	0.6%	22.5%	30.0%	31.8%
WHITE-MICA			17.5%	20.9%	9.4%
CHLORITE	1.2%		8.5%	3.4%	9.1%
DARK-MICA					10.9%
SERPENTINE	34.4%	38.7%			
CARBONATE	23.6%	24.2%	27.7%	25.3%	16.3%

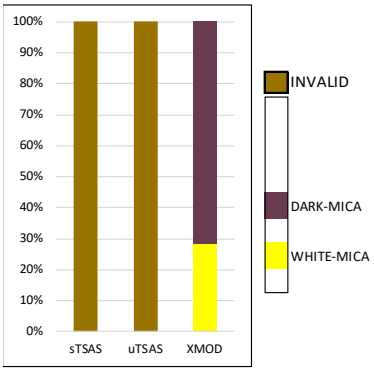
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	33.3%	35.8%	23.7%	20.3%	22.7%
Microcline	6.3%	0.6%			
Albite	1.3%	0.6%	22.5%	30.0%	23.3%
Oligoclase					5.8%
Muscovite			17.5%	20.9%	0.8%
Phengite					9.0%
Chlorite-Fe			0.4%		9.4%
Chlorite-FeMg	1.2%		8.1%	3.4%	0.1%
Biotite					11.4%
Antigorite	34.4%	38.7%			
Siderite	23.6%	24.2%	17.2%	24.1%	
Calcite			10.5%	1.1%	17.1%



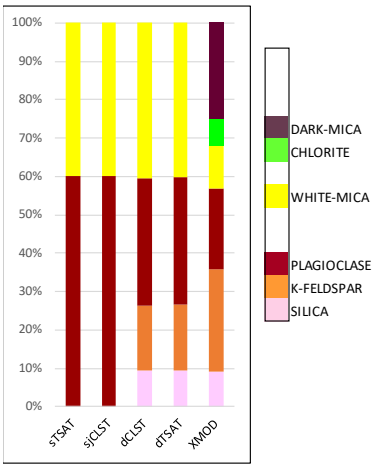
G408255 Felsic volcanic

Group

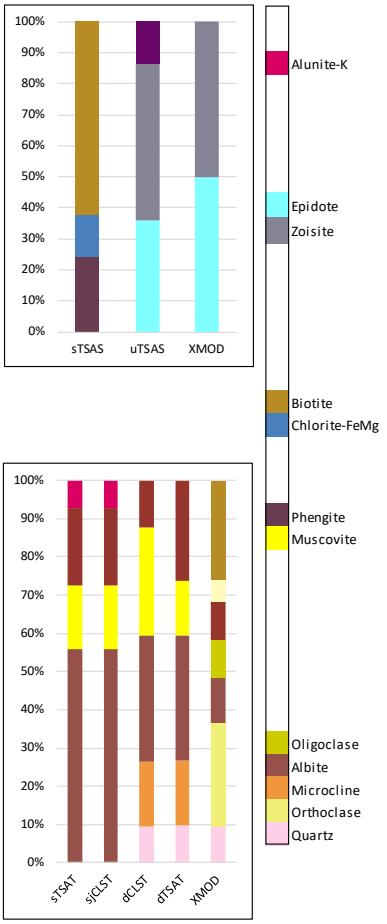
SWIR



TIR



Mineral



SWIR

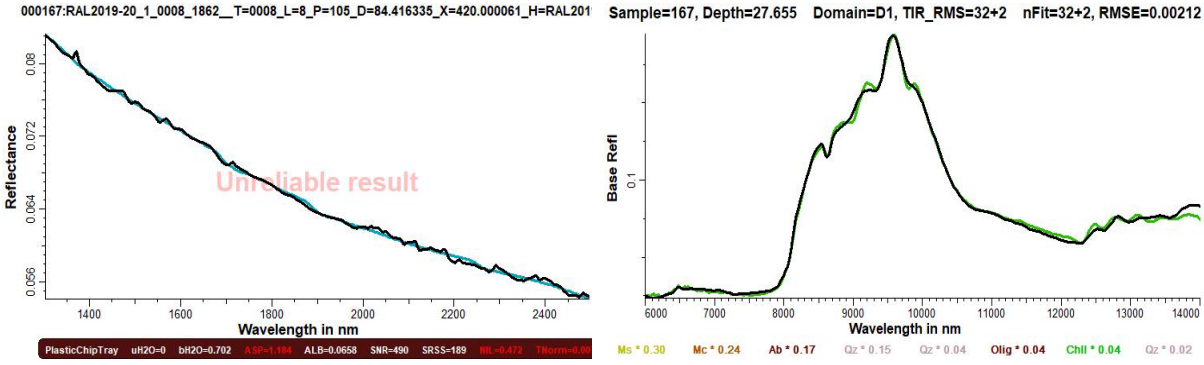
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA			26.9%
CHLORITE			2.9%
DARK-MICA			69.1%
EPIDOTE	1.0%	0.8%	
INVALID	98.4%	99.2%	0.0%

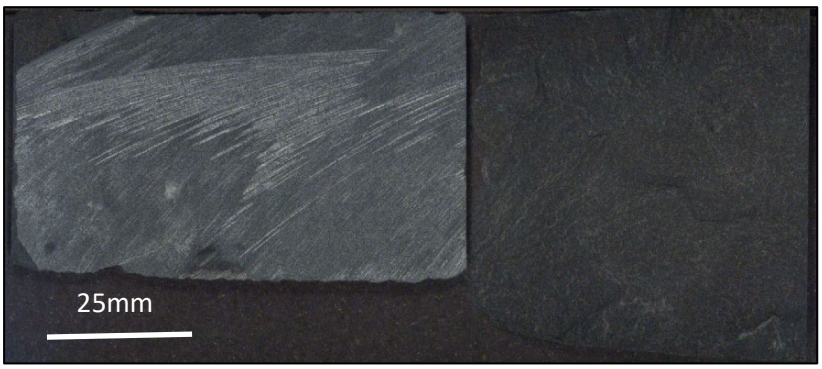
Minerals	sTSAS	uTSAS	XMOD
Muscovite			3.6%
Phengite			22.6%
Gibbsite	5.3%		
Chlorite-Fe			2.4%
Chlorite-FeMg			12.6%
Biotite			57.9%
Epidote	25.0%	50.0%	
Zoisite	35.4%	50.0%	
Jarosite	9.3%		
WhiteMarker	25.0%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	1.5%	1.5%	9.4%	9.6%	9.2%
K-FELDSPAR	0.2%	0.2%	17.1%	17.2%	26.3%
PLAGIOCLASE	51.5%	51.5%	33.0%	33.0%	21.0%
PYROXENE	4.1%	4.1%			
WHITE-MICA	34.2%	34.2%	40.5%	40.3%	11.3%
CHLORITE					6.5%
DARK-MICA					25.0%
SULPHATE	6.6%	6.6%			
OXIDE	1.9%	1.9%			0.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	1.5%	1.5%	9.4%	9.6%	9.2%
Microcline	0.0%	0.0%	17.1%	17.0%	
Orthoclase	0.2%	0.2%		0.2%	26.3%
Albite	51.5%	51.5%	32.9%	32.5%	11.3%
Oligoclase			0.1%	0.4%	9.8%
Augite	4.1%	4.1%			
Muscovite	15.5%	15.5%	28.4%	14.3%	1.6%
Phengite	18.7%	18.7%	12.2%	26.0%	9.8%
Chlorite-Fe					1.0%
Chlorite-FeMg					5.5%
Biotite					25.1%
Alunite-K	6.6%	6.6%			

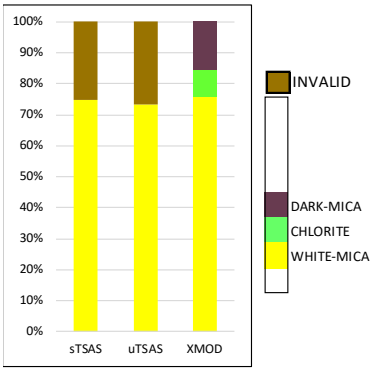




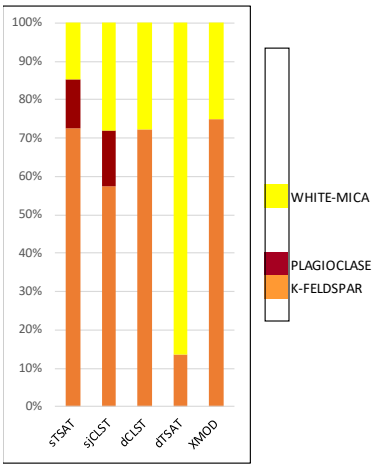
G408276 Altered felsic volcanic

Group

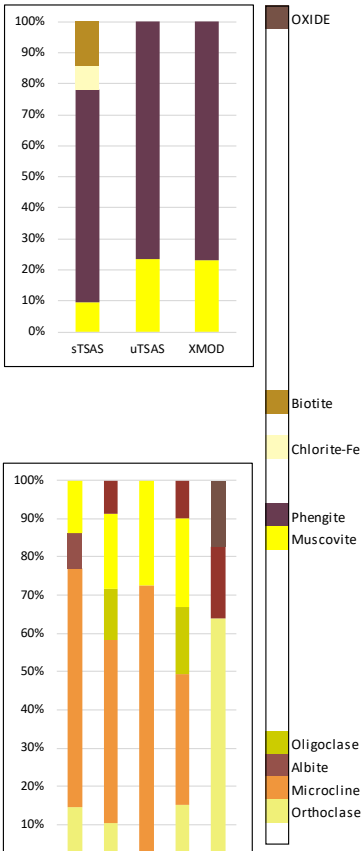
SWIR

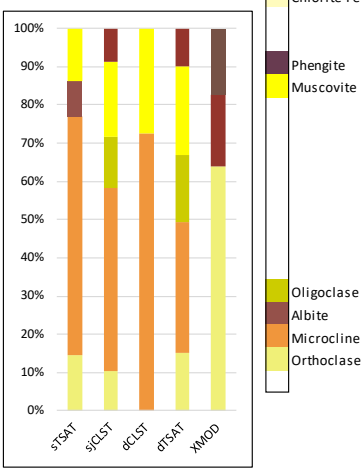


TIR



Mineral





SWIR

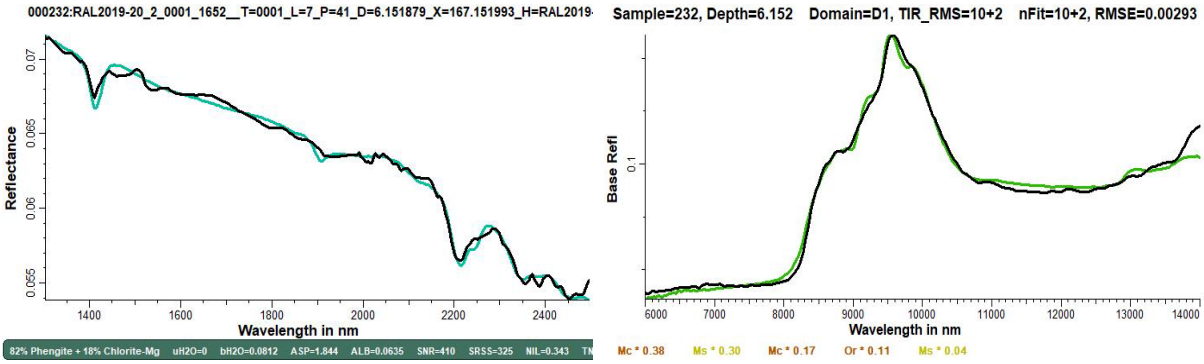
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	71.0%	71.2%	75.0%
SMECTITE	1.8%	1.7%	
CHLORITE	1.0%	1.1%	8.4%
DARK-MICA	0.2%		15.5%
TOURMALINE	1.1%		
INVALID	23.9%	25.6%	0.1%

Minerals	sTSAS	uTSAS	XMOD
Muscovite	21.9%	22.0%	9.6%
Phengite	71.4%	73.7%	67.6%
Montmorillonite	2.3%	2.2%	
Chlorite-Fe	0.3%	0.4%	7.6%
Biotite	0.3%		14.0%
Tourmaline-Fe	1.5%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA					1.4%
K-FELDSPAR	62.5%	57.2%	72.4%	13.5%	56.1%
PLAGIOCLASE	11.0%	14.7%			0.3%
WHITE-MICA	12.8%	27.9%	27.6%	86.5%	18.7%
CHLORITE	3.8%				1.9%
DARK-MICA	0.5%				3.4%
SERPENTINE	2.9%				
SULPHATE	4.0%				
PHOSPHATE	2.3%				0.0%
OXIDE	0.1%				16.4%
INVALID					1.0%

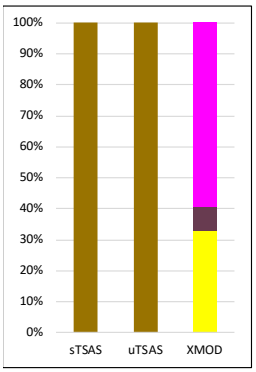
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz				0.9%	1.5%
Microcline	50.7%	47.1%	71.4%	33.3%	
Orthoclase	11.8%	10.2%	1.0%	14.9%	57.6%
Albite	7.6%	1.1%		0.3%	0.2%
Oligoclase	3.4%	13.3%		17.4%	0.1%
Muscovite	11.1%	19.4%	27.2%	22.6%	2.4%
Phengite	1.7%	8.5%	0.5%	9.8%	16.8%
Chlorite-Fe					1.9%
Chlorite-FeMg	3.8%				0.1%
Biotite	0.5%				3.5%
Antigorite	2.9%				
Alunite-K	3.9%				
Apatite	2.3%				0.0%
OXIDE	0.1%				15.8%

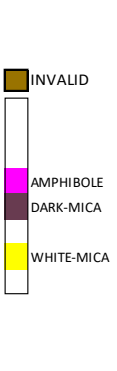


G408277 Granite

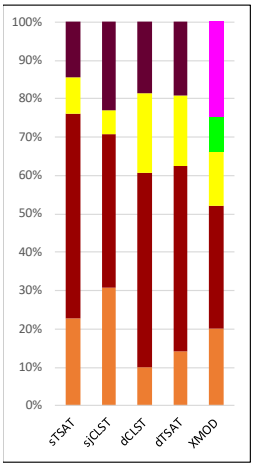
Group

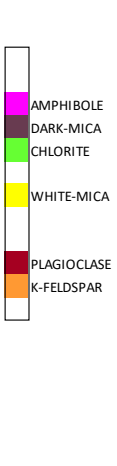
SWIR



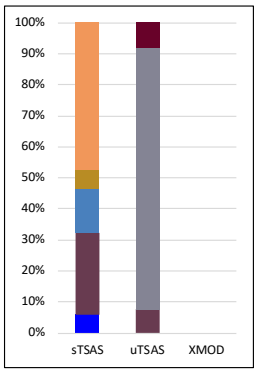


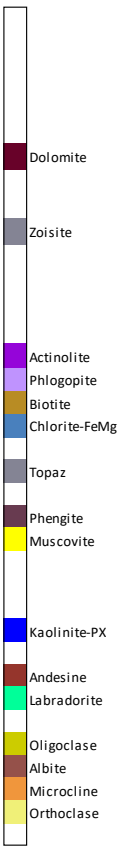
TIR

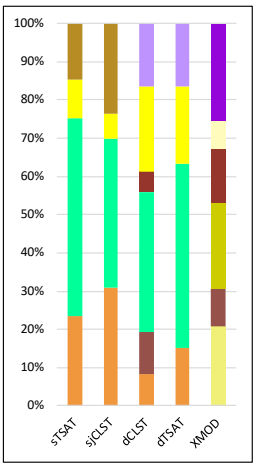




Mineral







SWIR

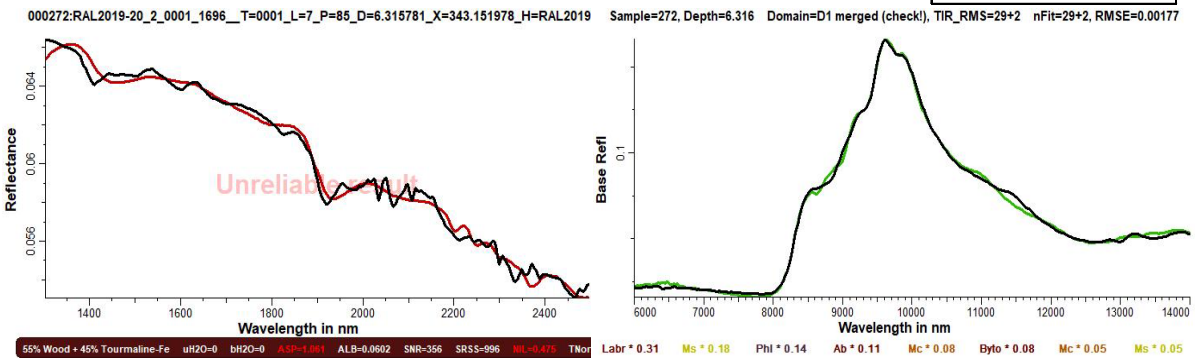
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	0.4%		31.1%
OTHER-ALOH	2.0%		
CHLORITE			3.7%
DARK-MICA			7.2%
AMPHIBOLE			55.7%
INVALID	96.1%	100%	1.7%

Minerals	sTSAS	uTSAS	XMOD
Kaolinite-PX	5.9%		
Muscovite	3.8%		0.8%
Phengite	5.9%		26.8%
Montmorillonite	4.8%		
Gibbsite	4.2%		
Topaz	46.1%		
Chlorite-Fe			3.2%
Chlorite-FeMg			14.4%
Biotite			6.2%
Actinolite			48.1%
Zoisite	19.6%		
Dolomite	6.1%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	2.6%	5.0%	0.0%	3.5%	1.4%
K-FELDSPAR	20.6%	26.5%	10.1%	13.6%	18.4%
PLAGIOCLASE	48.1%	34.1%	50.6%	46.8%	28.9%
PYROXENE	1.3%	1.4%			
WHITE-MICA	8.7%	5.4%	20.7%	17.9%	12.9%
CHLORITE	0.9%	0.3%			8.2%
DARK-MICA	13.0%	19.7%	18.5%	18.3%	2.9%
AMPHIBOLE	2.3%	4.5%			22.5%
OTHER-MGOH	2.3%				
SULPHATE		2.9%			
OXIDE					3.5%

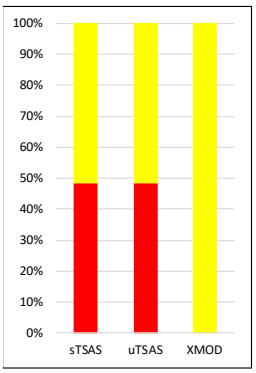
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	2.6%	5.0%	0.0%	3.5%	1.4%
Microcline	20.6%	25.8%	7.7%	13.4%	
Orthoclase		0.7%	2.4%	0.1%	18.8%
Albite	2.0%	1.0%	10.5%	3.9%	9.0%
Bytownite			5.1%	0.1%	
Labradorite	45.6%	32.5%	34.4%	42.7%	
Oligoclase	0.5%	0.5%	0.6%		20.5%
Augite	1.3%	1.4%			
Muscovite	8.7%	5.4%	20.7%	17.9%	0.4%
Phengite					12.8%
Chlorite-Fe	0.9%	0.2%			1.5%
Chlorite-FeMg		0.2%			6.9%
Biotite	13.0%	19.7%	2.8%	3.9%	3.0%
Phlogopite			15.6%	14.5%	
Actinolite					22.9%
Hornblende	0.1%	4.4%			
Riebeckite	2.2%	0.1%			
Talc	2.3%				
Jarosite		2.9%			

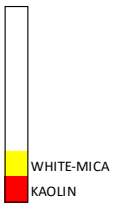


G408249 Altered felsic volcanic

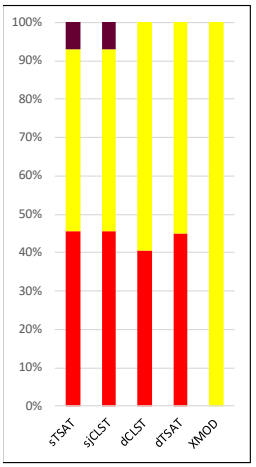
Group

SWIR

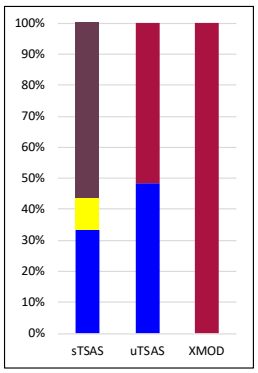


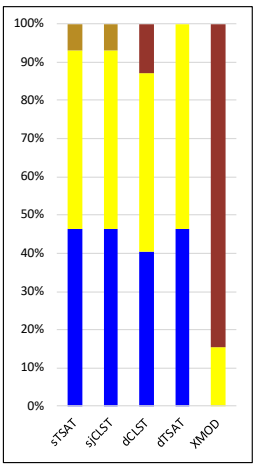


TIR



Mineral





SWIR

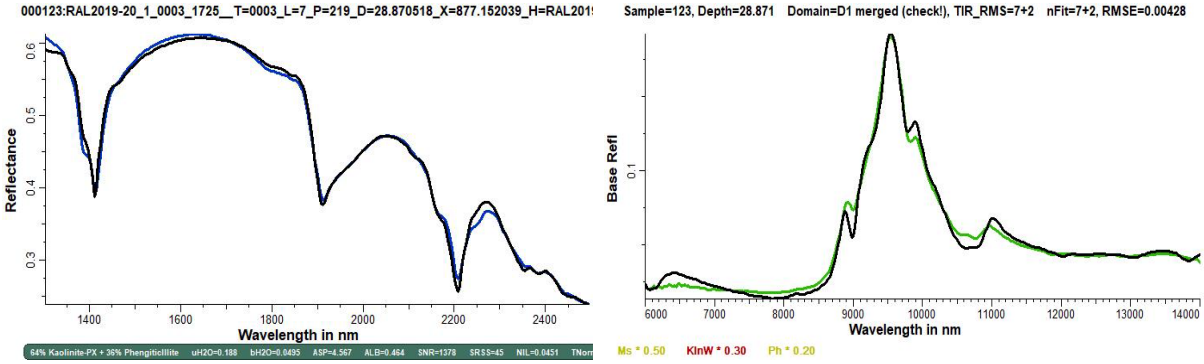
Groups	sTSAS	uTSAS	XMOD
KAOLIN	48.3%	48.3%	2.5%
WHITE-MICA	51.7%	51.7%	96.1%

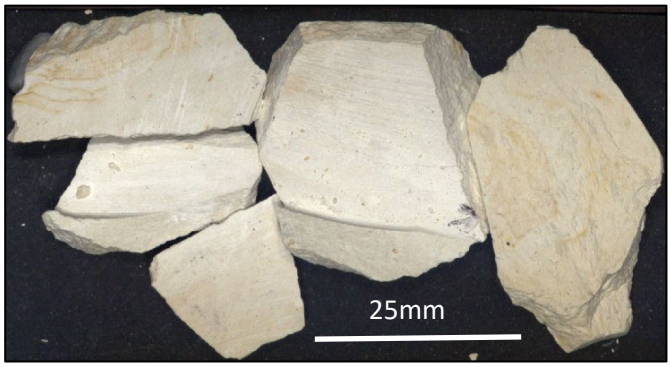
Minerals	sTSAS	uTSAS	XMOD
Kaolinite-PX	48.3%	48.3%	
Kaolinite-WX			2.1%
Muscovite			14.8%
Phengite	0.3%	0.3%	81.9%
PhengiticIllite	51.4%	51.4%	

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA					3.9%
PLAGIOCLASE					3.1%
KAOLIN	45.0%	45.0%	40.5%	44.9%	2.0%
WHITE-MICA	46.7%	46.7%	59.5%	55.1%	89.1%
DARK-MICA	6.9%	6.9%			0.2%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz			0.0%		3.9%
Albite					1.4%
Oligoclase					1.7%
Kaolinite-WX	45.0%	45.0%	40.5%	44.9%	2.0%
Muscovite	45.5%	45.5%	46.6%	51.8%	13.6%
Phengite	1.3%	1.3%	12.8%	3.2%	75.5%
Biotite	6.9%	6.9%			0.2%

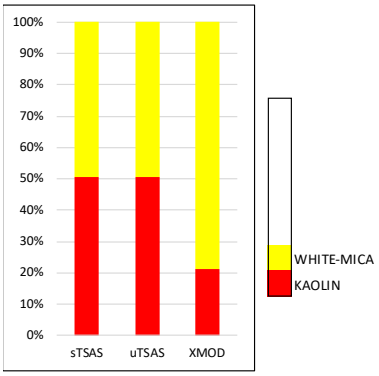




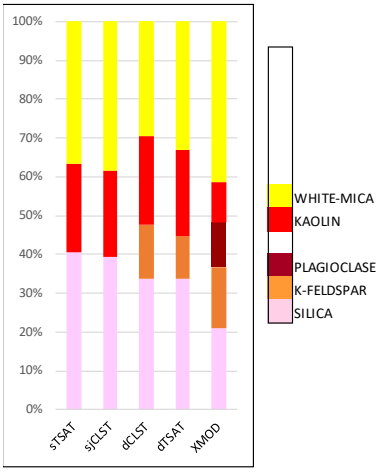
G408250 Claystone

Group

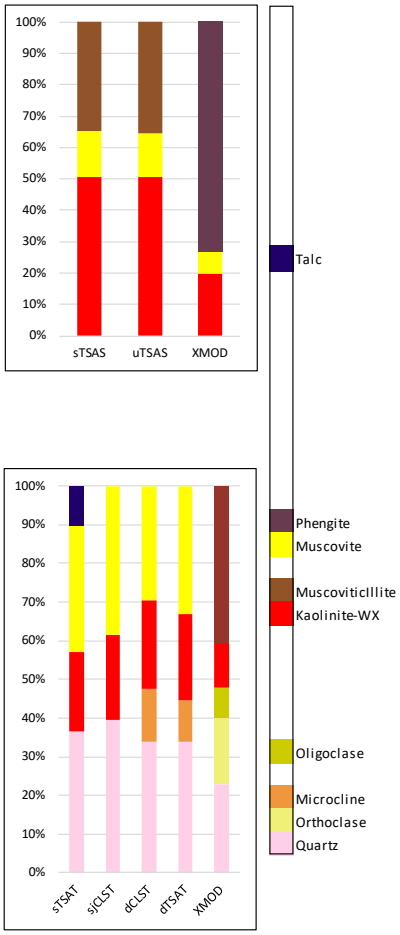
SWIR



TIR



Mineral



SWIR

Groups	sTSAS	uTSAS	XMOD
KAOLIN	50.7%	50.7%	20.8%
WHITE-MICA	49.3%	49.3%	76.2%
CHLORITE			1.2%
CARBONATE			1.1%

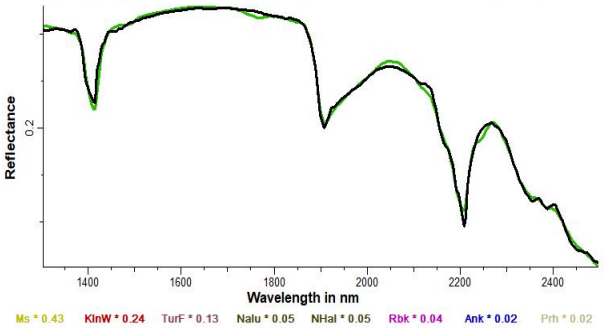
Minerals	sTSAS	uTSAS	XMOD
Kaolinite-WX	50.7%	50.7%	19.4%
Muscovite	14.4%	13.9%	6.8%
Phengite			71.2%
MuscoviticIllite	34.8%	35.4%	
Chlorite-Fe			1.1%

TIR

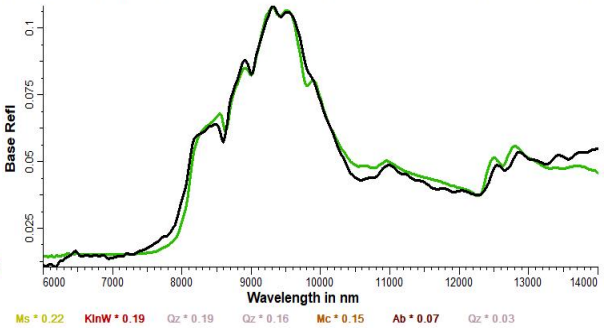
Groups	sTSAT	sjCLST	dClst	dTSAT	XMOD
SILICA	33.8%	33.9%	32.1%	33.8%	20.6%
K-FELDSPAR	4.7%	4.7%	13.2%	10.9%	15.4%
PLAGIOCLASE	2.3%	2.0%	4.9%		11.3%
KAOLIN	19.0%	19.0%	21.6%	22.3%	10.1%
WHITE-MICA	30.6%	32.9%	28.1%	33.0%	40.4%
OTHER-MGOH	9.4%	6.8%			

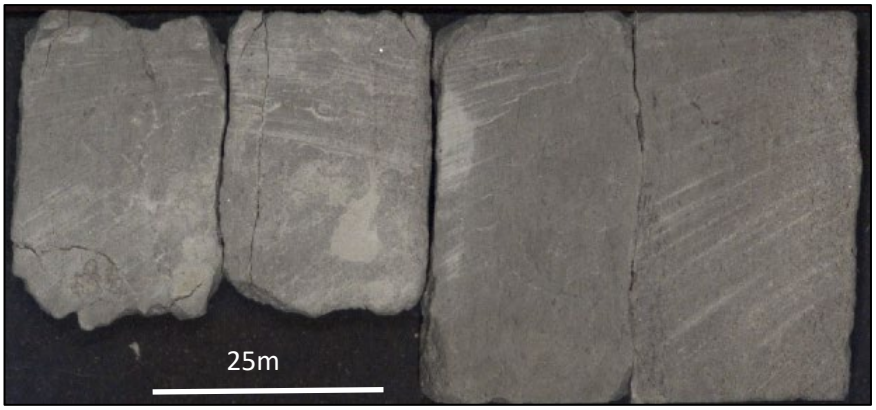
Minerals	sTSAT	sjCLST	dClst	dTSAT	XMOD
Quartz	33.8%	33.9%	32.1%	33.8%	20.7%
Microcline	4.4%	4.3%	13.2%	10.9%	
Orthoclase	0.3%	0.4%			15.5%
Albite	2.3%	2.0%	4.9%		4.3%
Oligoclase					7.0%
Kaolinite-WX	19.0%	19.0%	21.6%	22.3%	10.1%
Muscovite	30.2%	32.9%	28.1%	33.0%	3.5%
Phengite	0.3%				37.0%
Talc	9.4%				

Sample=297, Depth=61.102 Domain=D1, SWIR_RMS=56+8 nFit=56+8, RMSE=0.0095



Sample=297, Depth=61.102 Domain=D1, TIR_RMS=28+2 nFit=28+2, RMSE=0.00324

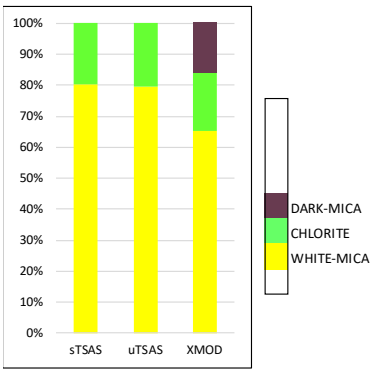




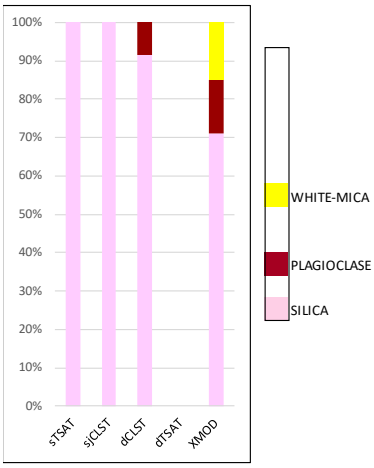
G408254 Micaceous sandstone

Group

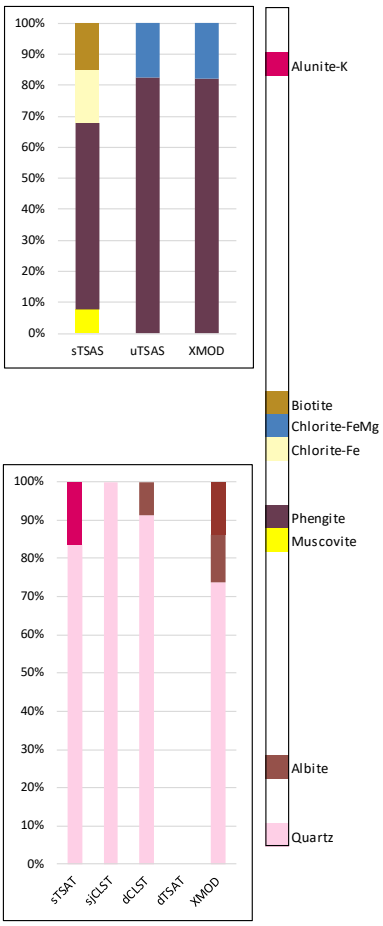
SWIR



TIR



Mineral



SWIR

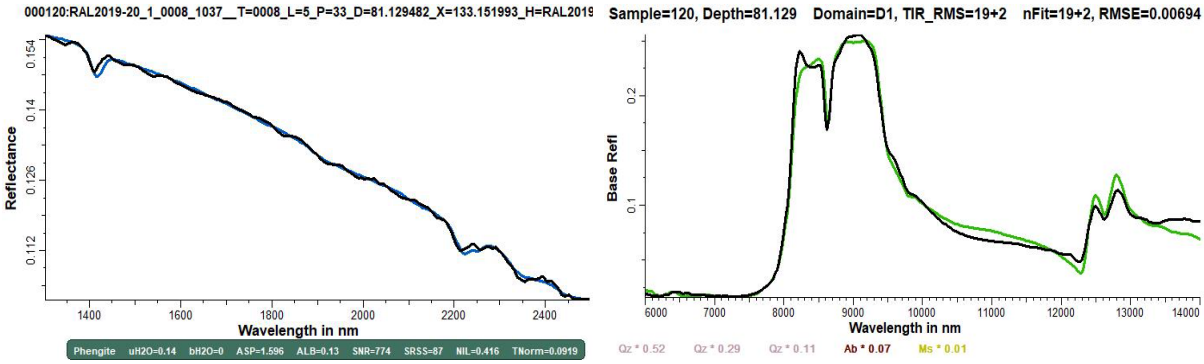
Groups	sTSAS	uTSAS	XMOD
KAOLIN		0.1%	1.4%
WHITE-MICA	76.2%	76.5%	63.2%
CHLORITE	18.8%	19.7%	18.0%
DARK-MICA	0.1%	0.2%	15.5%
AMPHIBOLE			1.6%
CARBONATE	2.4%	1.6%	0.0%
INVALID	1.4%	1.5%	0.2%

Minerals	sTSAS	uTSAS	XMOD
Kaolinite-WX			1.3%
Muscovite	3.1%	2.6%	7.5%
Phengite	74.2%	75.1%	58.6%
Chlorite-Fe	3.3%	3.6%	16.6%
Chlorite-FeMg	15.5%	16.2%	0.1%
Biotite	0.1%	0.2%	14.4%
Actinolite			1.5%
Ankerite	1.6%	1.3%	

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	81.5%	91.0%	90.2%		64.5%
K-FELDSPAR		1.2%			1.9%
PLAGIOCLASE	1.1%	2.5%	8.5%		12.5%
WHITE-MICA	0.2%	4.1%	1.3%		13.6%
CHLORITE		0.2%			3.5%
DARK-MICA					3.0%
SULPHATE	17.2%	0.9%			

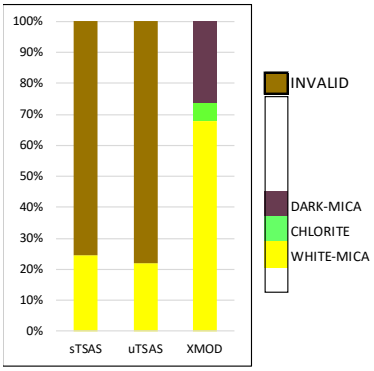
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	81.5%	91.0%	90.2%		64.7%
Microcline		1.2%			
Orthoclase					1.9%
Albite	1.1%	2.5%	8.5%		11.0%
Oligoclase					1.5%
Muscovite	0.2%	4.1%	1.3%		1.5%
Phengite					12.1%
Chlorite-Fe					3.4%
Biotite					3.0%
Alunite-K	16.0%	0.2%			
Alunite-Na	1.2%	0.7%			

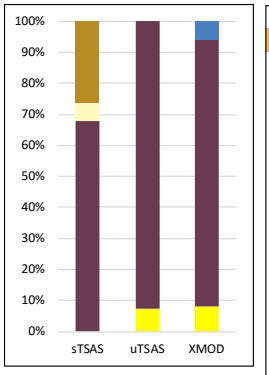


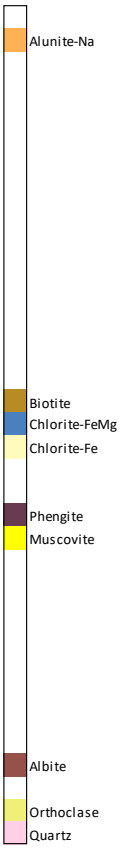
G408253 Crypto-micaceous shale

Group **Mineral**

SWIR





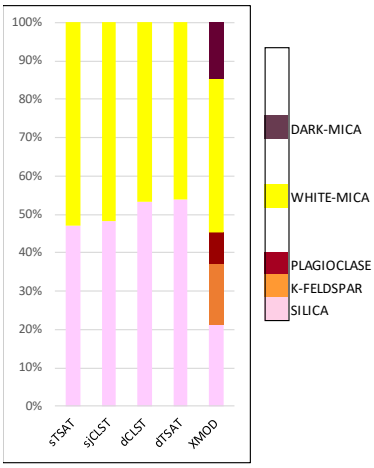


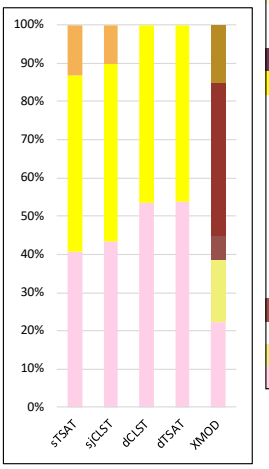
SWIR

Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	23.6%	21.6%	67.7%
OTHER-ALOH	1.1%	0.1%	
CHLORITE	1.3%	1.9%	5.6%
DARK-MICA			26.3%
INVALID	72.2%	76.2%	0.0%

Minerals	sTSAS	uTSAS	XMOD
Muscovite	6.3%	7.6%	3.2%
Phengite	78.7%	83.4%	65.5%
Montmorillonite	2.7%		
Topaz	3.4%	0.3%	
Chlorite-Fe	1.4%	2.6%	5.4%
Chlorite-FeMg	3.4%	5.4%	0.1%
Biotite			25.4%

TIR

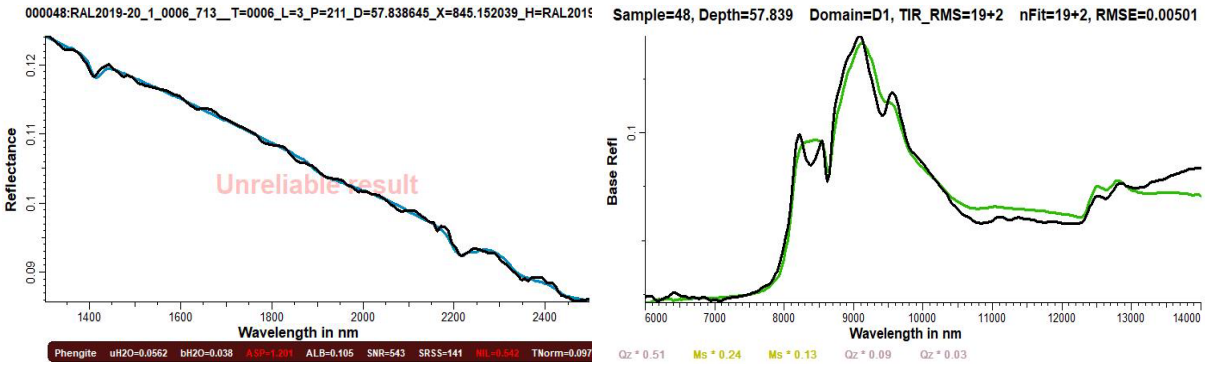


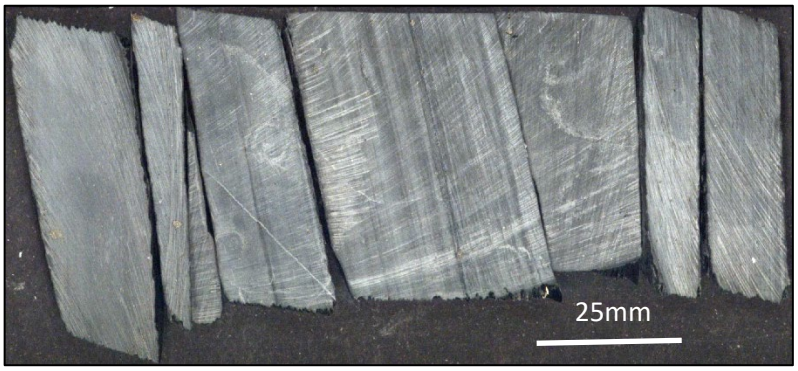


TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	38.9%	42.6%	53.1%	53.9%	20.6%
K-FELDSPAR					15.1%
PLAGIOCLASE					7.7%
WHITE-MICA	43.8%	45.5%	46.4%	46.1%	38.4%
CHLORITE		0.0%	0.5%		3.1%
DARK-MICA					14.2%
SULPHATE	17.1%	10.1%			
OXIDE	0.2%	1.2%			0.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	38.9%	42.6%	53.1%	53.9%	20.7%
Orthoclase					15.2%
Albite					5.9%
Oligoclase					1.9%
Muscovite	43.8%	45.5%	46.4%	46.1%	1.8%
Phengite					36.8%
Chlorite-Fe		0.0%	0.4%		3.0%
Biotite					14.3%
Alunite-K	4.4%				
Alunite-Na	12.7%	10.1%			
OXIDE	0.2%	1.2%			0.0%

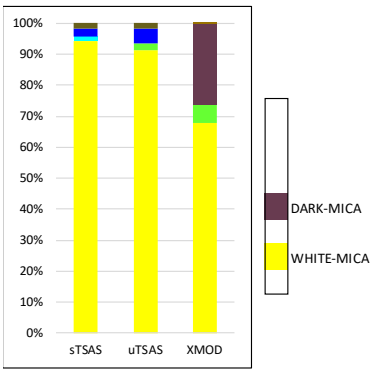




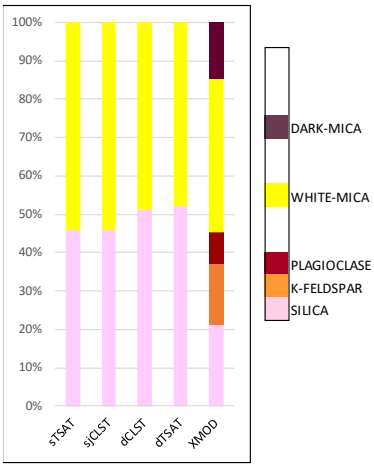
G408253av Crypto-micaceous shale (averaged to 21 spectra per bin)

Group

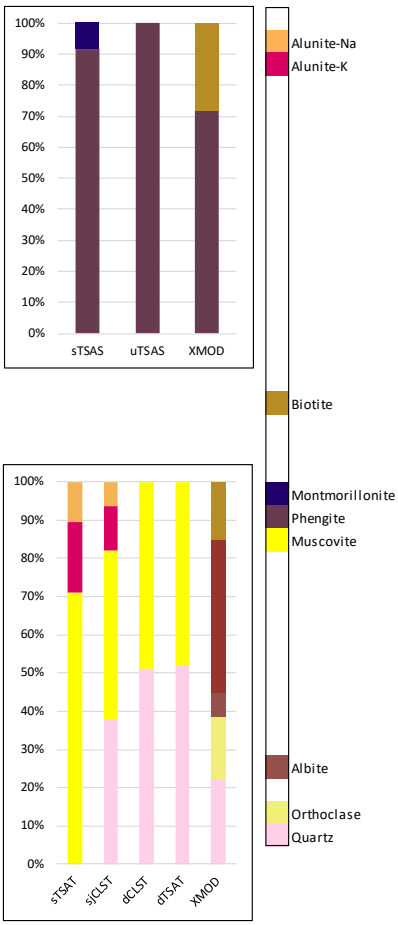
SWIR



TIR



Mineral



SWIR

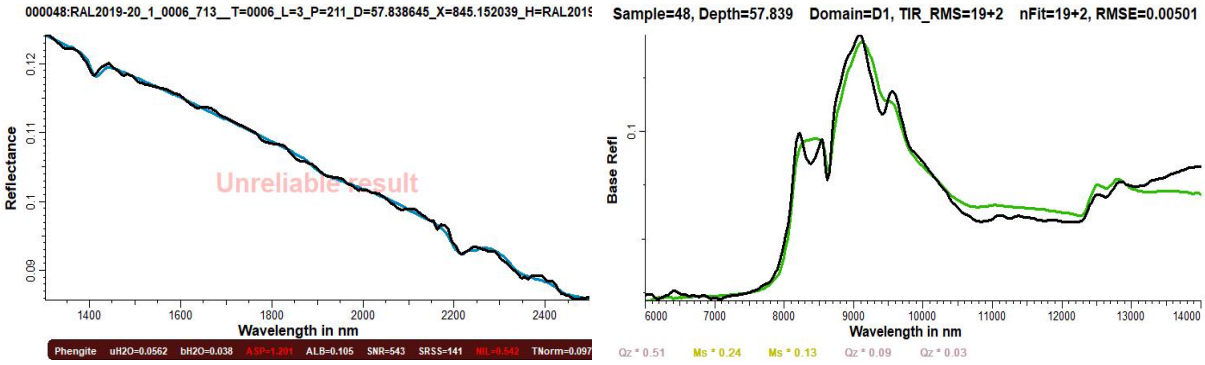
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	86.5%	91.4%	49.1%
SMECTITE	7.7%		0.0%
CHLORITE		2.0%	4.1%
DARK-MICA			19.0%
EPIDOTE	1.4%		0.0%
CARBONATE	2.5%	4.8%	0.0%
NOTAROK	1.8%	1.8%	0.0%

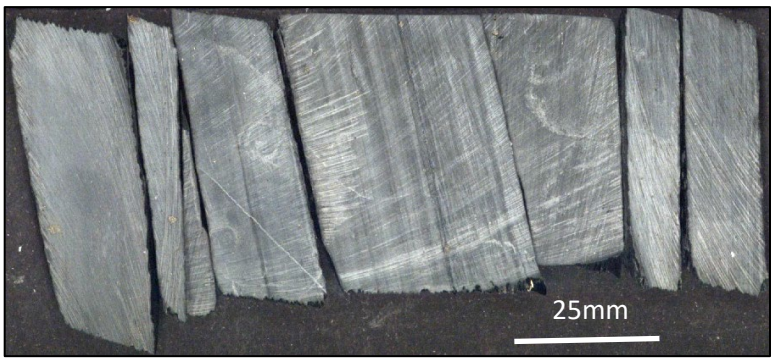
Minerals	sTSAS	uTSAS	XMOD
Muscovite			2.3%
Phengite	86.5%	91.4%	47.9%
Saponite	7.7%		
Chlorite-Fe			4.0%
Chlorite-FeMg		2.0%	0.1%
Biotite			18.6%
Zoisite	1.4%		
Ankerite	2.5%	4.8%	
Vegetation-Dry	1.8%	1.8%	

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	37.7%	37.7%	51.1%	52.1%	20.6%
K-FELDSPAR					15.1%
PLAGIOCLASE					7.7%
WHITE-MICA	44.3%	44.3%	48.9%	47.9%	38.4%
CHLORITE					3.1%
DARK-MICA					14.2%
SULPHATE	18.0%	18.0%			

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz		37.7%	51.1%	52.1%	20.7%
Orthoclase					15.2%
Albite					5.9%
Oligoclase					1.9%
Muscovite	44.3%	44.3%	48.9%	47.9%	1.8%
Phengite					36.8%
Chlorite-Fe					3.0%
Biotite					14.3%
Alunite-K	11.6%	11.6%			
Alunite-Na	6.5%	6.5%			

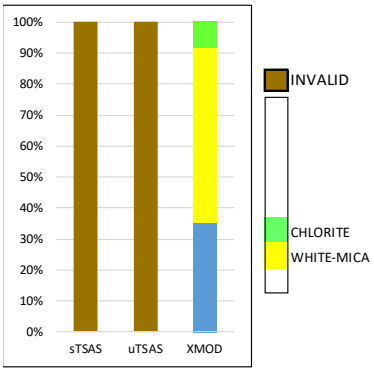




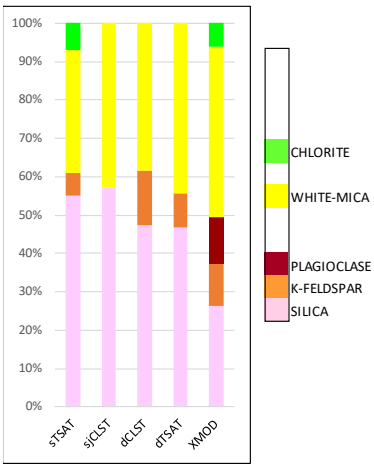
G408261 Carboaceous shale

Group

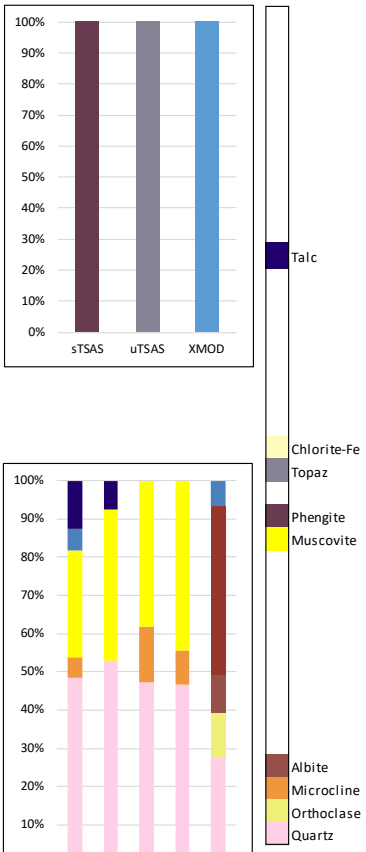
SWIR

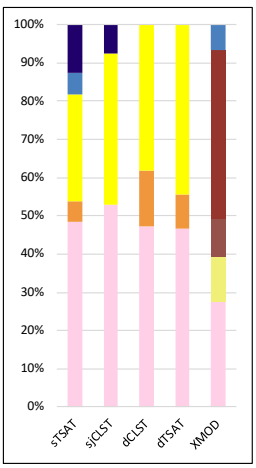


TIR



Mineral





SWIR

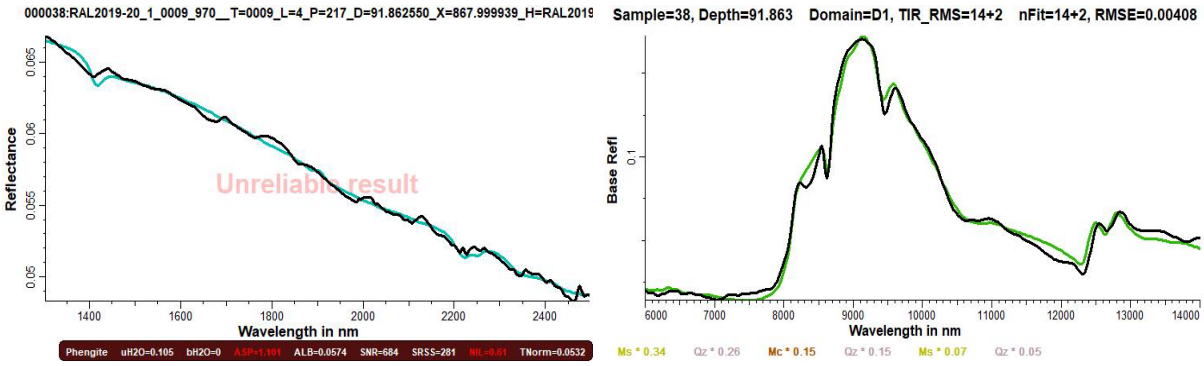
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA			83.2%
CHLORITE			12.3%
DARK-MICA			4.4%
INVALID	98.4%	100%	0.1%

Minerals	sTSAS	uTSAS	XMOD
Muscovite			7.7%
Phengite			60.3%
Topaz	50.0%		
Chlorite-Fe			17.1%
Biotite			14.8%
WhiteMarker	50.0%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	45.0%	47.5%	47.4%	46.7%	25.3%
K-FELDSPAR	5.0%	4.8%	14.3%	8.9%	10.5%
PLAGIOCLASE	0.5%	1.5%			11.9%
WHITE-MICA	26.2%	35.5%	38.3%	44.5%	42.6%
CHLORITE	5.6%	2.3%			6.0%
DARK-MICA					2.2%
AMPHIBOLE	1.3%				0.0%
OTHER-MGOH	11.8%	6.8%			
SULPHATE	4.6%	1.5%			
INVALID					1.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	45.0%	47.5%	47.4%	46.7%	25.6%
Microcline	5.0%	4.6%	14.3%	8.9%	
Orthoclase		0.2%			10.6%
Albite	0.4%	1.5%			9.5%
Oligoclase	0.1%				2.5%
Muscovite	26.2%	35.4%	38.3%	44.5%	2.2%
Phengite		0.1%			40.9%
Chlorite-Fe	5.1%	1.4%			6.0%
Chlorite-FeMg	0.5%	1.0%			
Biotite					2.2%
Talc	11.8%	6.8%			
Alunite-K	4.6%	0.3%			
Alunite-Na		1.2%			

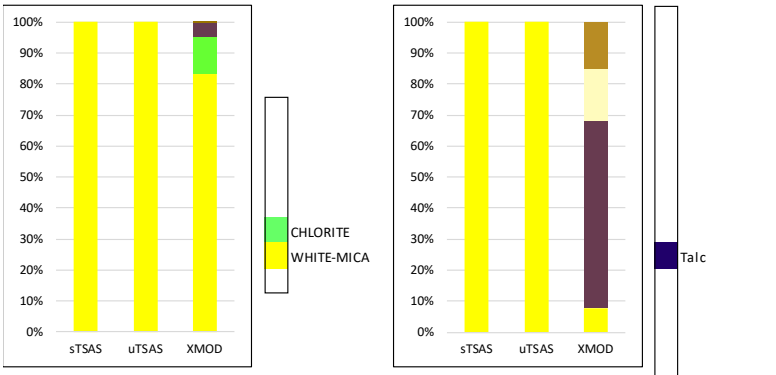


G408261av Carbonaceous shale (averaged to 21 spectra per bin)

Group

Mineral

SWIR

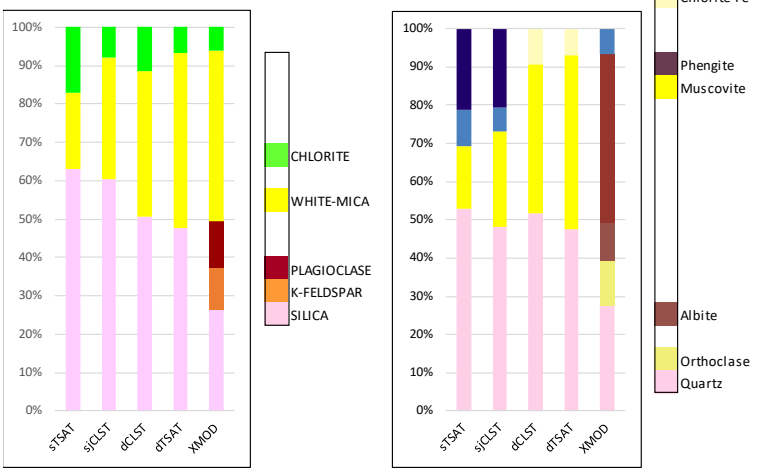


SWIR

Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	20.0%	20.0%	83.2%
CHLORITE			12.3%
DARK-MICA			4.4%
INVALID	80.0%	80.0%	0.1%

Minerals	sTSAS	uTSAS	XMOD
Kaolinite-WX			1.3%
Muscovite	20.0%	20.0%	7.6%
Phengite			59.5%
Chlorite-Fe			16.9%
Biotite			14.6%

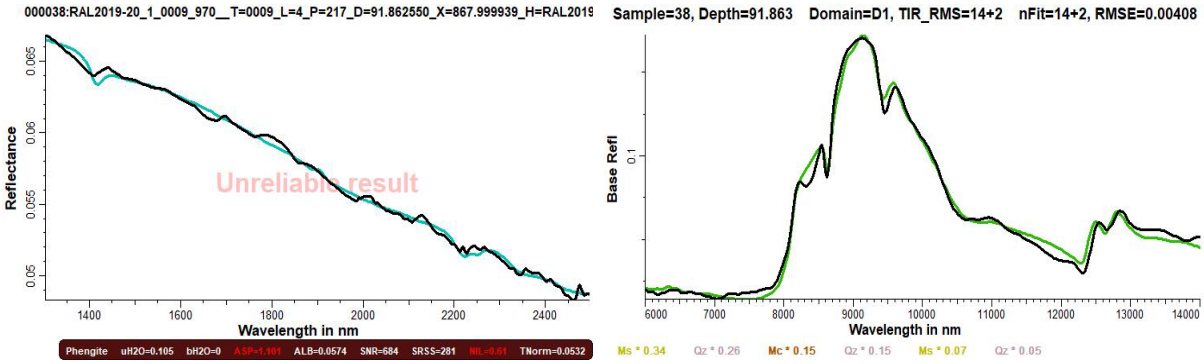
TIR



TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	49.3%	48.0%	50.6%	47.6%	25.3%
K-FELDSPAR	2.2%				10.5%
PLAGIOCLASE					11.9%
WHITE-MICA	15.3%	25.1%	37.9%	45.6%	42.6%
CHLORITE	13.4%	6.2%	11.4%	6.8%	6.0%
DARK-MICA					2.2%
OTHER-MGOH	19.7%	20.7%			
INVALID					1.0%

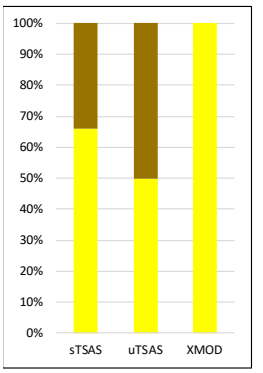
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	49.3%	48.0%	50.6%	47.6%	25.6%
Microcline	2.2%				
Orthoclase					10.6%
Albite					9.5%
Oligoclase					2.5%
Muscovite	15.3%	25.1%	37.9%	45.6%	2.2%
Phengite					40.9%
Chlorite-Fe	9.1%	6.2%	2.4%		6.0%
Chlorite-FeMg	4.4%		9.1%	6.8%	
Biotite					2.2%
Talc	19.7%	20.7%			



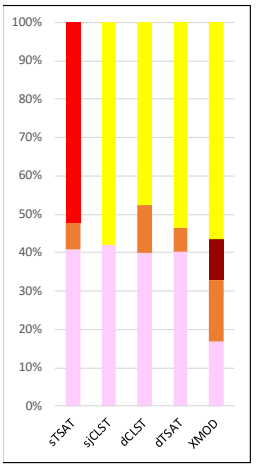
G408262 Carbonaceous shale

Group

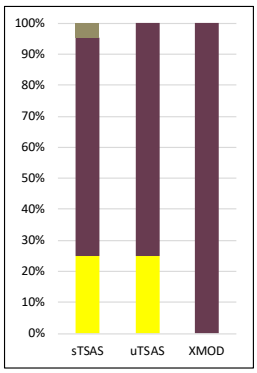
SWIR

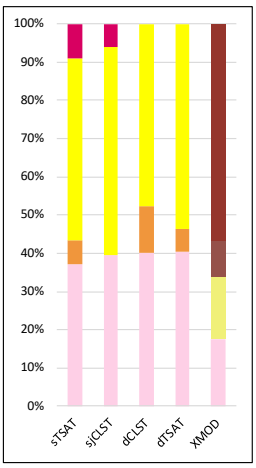


TIR



Mineral





SWIR

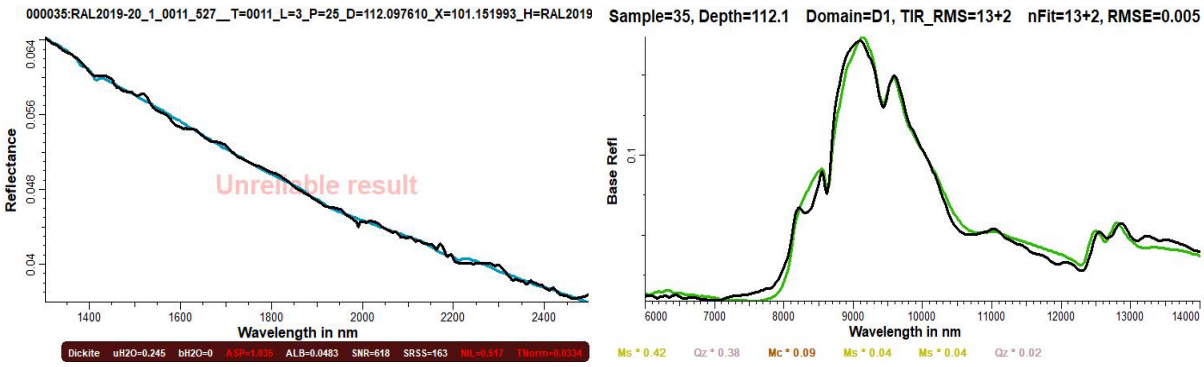
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	1.0%		97.3%
OTHER-ALOH	1.0%		
DARK-MICA			1.9%
INVALID	97.0%	100%	0.0%

Minerals	sTSAS	uTSAS	XMOD
Muscovite	22.2%		2.5%
Phengite	11.1%		94.9%
Montmorillonite	11.1%		
Topaz	33.3%		
Biotite			1.9%
WhiteMarker	11.1%		
Wood	11.1%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA		36.0%	40.1%	40.4%	16.6%
K-FELDSPAR		3.9%	12.4%	6.1%	15.6%
PLAGIOCLASE		1.9%			10.3%
WHITE-MICA		49.5%	47.6%	53.5%	55.2%
DARK-MICA					1.1%
OTHER-MGOH		3.1%			
SULPHATE		5.5%			

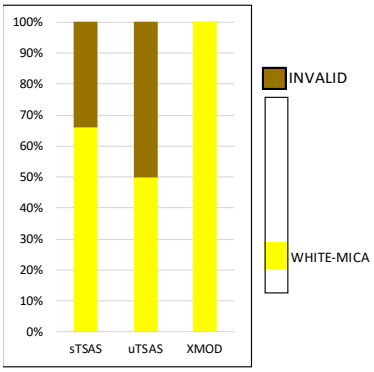
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz		36.0%	40.1%	40.4%	16.7%
Microcline		3.6%	12.4%	6.1%	
Orthoclase		0.2%	0.0%		15.7%
Albite		1.9%			9.1%
Oligoclase					1.3%
Muscovite		49.5%	47.6%	53.5%	1.4%
Phengite					54.2%
Biotite					1.1%
Talc		3.1%			
Alunite-K		5.4%			



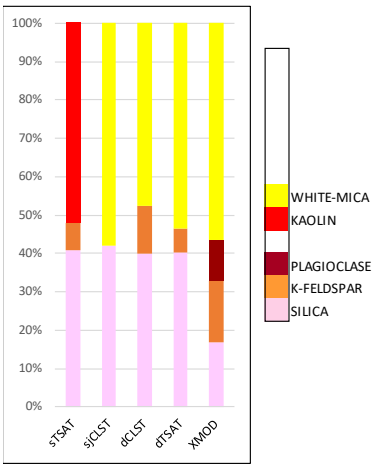
G408262av Carbonaceous shale (averaged to 21 spectra per bin)

Group

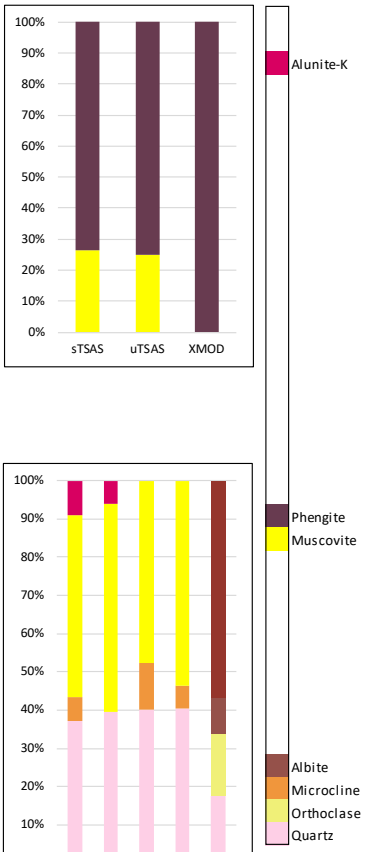
SWIR



TIR



Mineral



SWIR

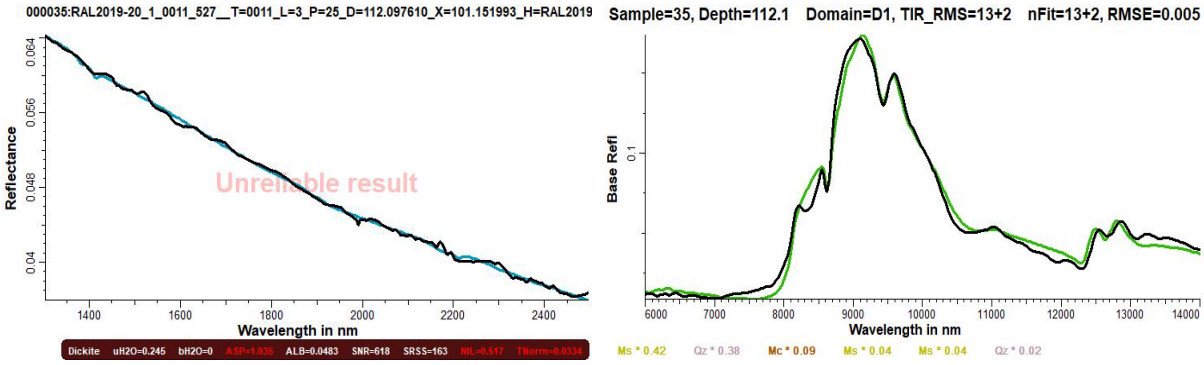
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	63.6%	50.0%	74.8%
DARK-MICA			1.5%
CARBONATE	3.1%		
INVALID	33.3%	50.0%	0.0%

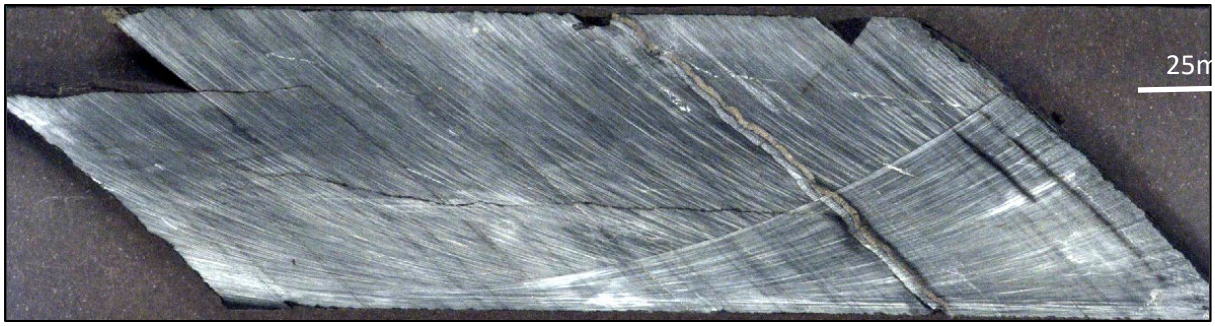
Minerals	sTSAS	uTSAS	XMOD
Muscovite	16.7%	12.5%	1.9%
Phengite	46.9%	37.5%	73.4%
Biotite			1.4%
Ankerite	3.1%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	35.5%	37.8%	39.8%	39.5%	16.6%
K-FELDSPAR	7.0%	5.9%			15.6%
PLAGIOCLASE		2.5%			10.3%
WHITE-MICA	44.3%	48.9%	60.2%	60.5%	55.2%
DARK-MICA					1.1%
AMPHIBOLE	1.1%				0.0%
OTHER-MGOH	3.1%	3.1%			
SULPHATE	8.9%	1.8%			

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	35.5%	37.8%	39.8%	39.5%	16.7%
Microcline	7.0%	5.9%			
Orthoclase					15.7%
Albite		2.5%			9.1%
Oligoclase					1.3%
Muscovite	44.3%	48.9%	60.2%	60.5%	1.4%
Phengite					54.2%
Biotite					1.1%
Edenite	1.1%				
Talc	3.1%	3.1%			
Alunite-K	8.9%	1.8%			

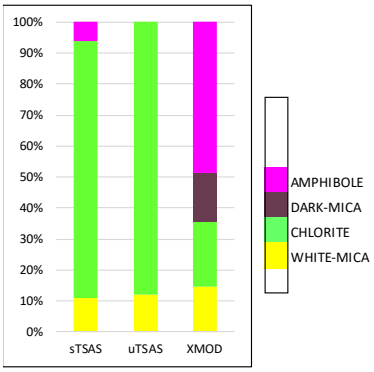




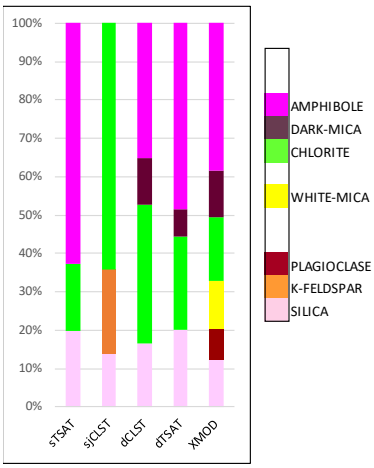
G408266 Altered mafic volcanic

Group

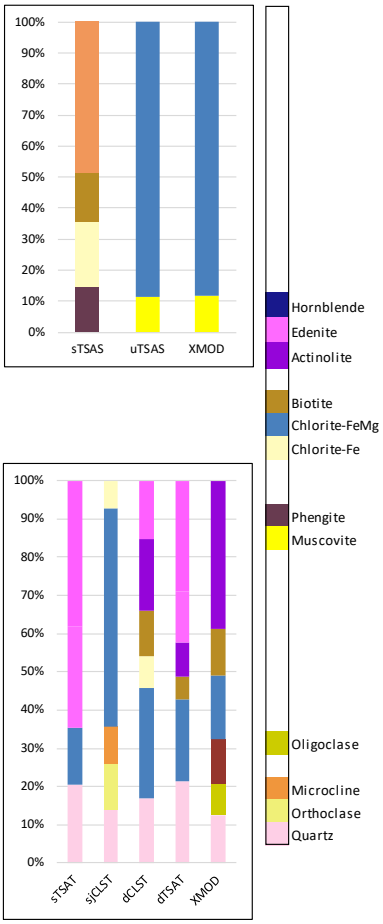
SWIR



TIR



Mineral



SWIR

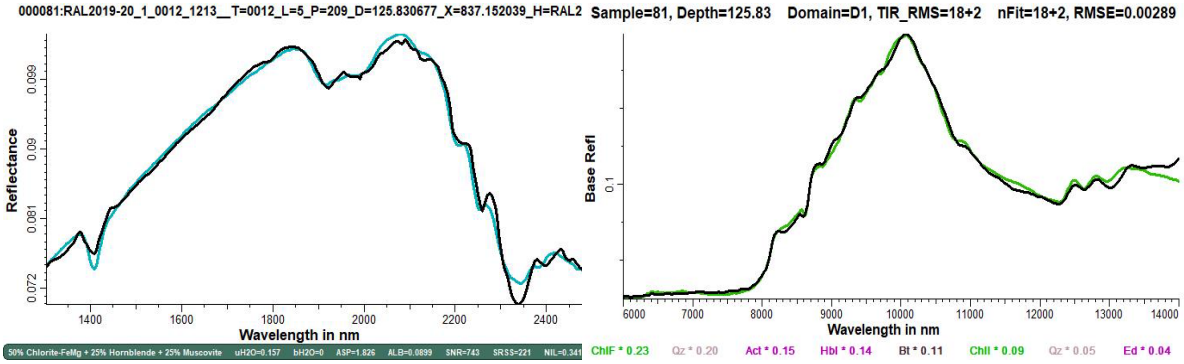
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	10.3%	10.9%	14.5%
CHLORITE	76.9%	78.3%	20.8%
DARK-MICA	3.1%	2.2%	15.5%
AMPHIBOLE	5.6%	4.0%	48.2%
TOURMALINE	1.4%		
INVALID	2.3%	4.5%	0.4%

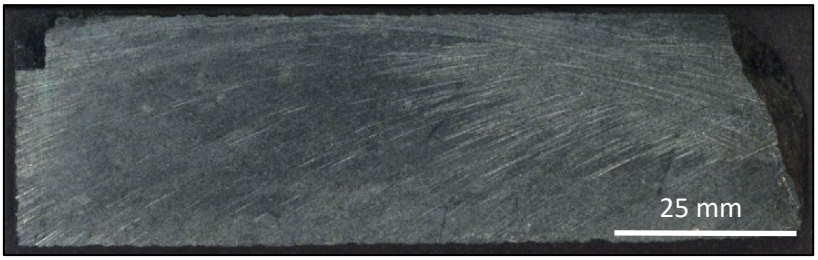
Minerals	sTSAS	uTSAS	XMOD
Muscovite	10.2%	10.8%	0.8%
Phengite	0.4%	0.5%	14.5%
Chlorite-Fe			20.7%
Chlorite-FeMg	78.6%	82.1%	0.0%
Biotite	1.7%	1.1%	15.4%
Phlogopite	1.4%	1.2%	
Actinolite			48.0%
Hornblende	3.8%	4.2%	
Riebeckite	1.9%		
Tourmaline-Fe	1.4%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	17.8%	12.0%	16.6%	20.3%	11.3%
K-FELDSPAR	3.5%	18.6%			2.5%
PLAGIOCLASE	1.0%				7.6%
PYROXENE	1.4%	4.6%			
WHITE-MICA		2.5%			11.2%
SMECTITE		1.4%			
CHLORITE	15.6%	55.0%	36.1%	24.2%	15.3%
DARK-MICA	1.7%	1.3%	12.2%	7.2%	11.3%
AMPHIBOLE	55.9%	3.8%	35.1%	48.4%	35.4%
EPIDOTE		0.2%			1.0%
SULPHATE	3.1%	0.7%			
OXIDE					2.8%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	17.8%	12.0%	16.6%	20.3%	11.9%
Microcline	2.4%	8.4%			
Orthoclase	1.1%	10.1%			2.6%
Andesine	1.0%				
Oligoclase					7.9%
Augite	1.4%				
Diopside		4.6%			
Muscovite		1.8%			0.6%
Phengite		0.7%			11.2%
Montmorillonite		1.4%			
Chlorite-Fe	12.6%	48.9%	28.0%	20.1%	16.0%
Chlorite-FeMg	2.9%	6.1%	8.1%	4.0%	0.0%
Biotite	1.7%	1.3%	11.5%	5.5%	11.9%
Phlogopite			0.7%	1.7%	
Actinolite		0.9%	18.4%	8.4%	37.1%
Edenite	23.0%	0.7%	1.6%	12.8%	
Hornblende	32.9%	1.3%	14.8%	27.2%	
Alunite-K	3.1%	0.4%			

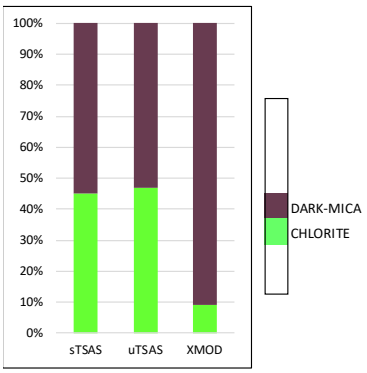




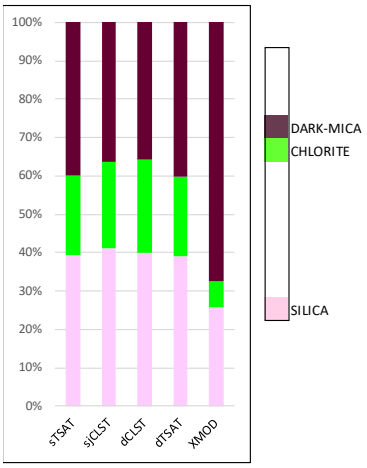
G408268 Altered mafic volcanic

Group

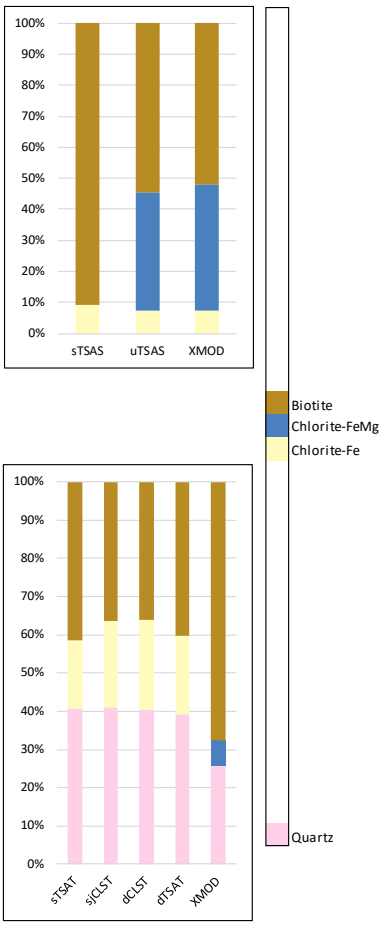
SWIR



TIR



Mineral



SWIR

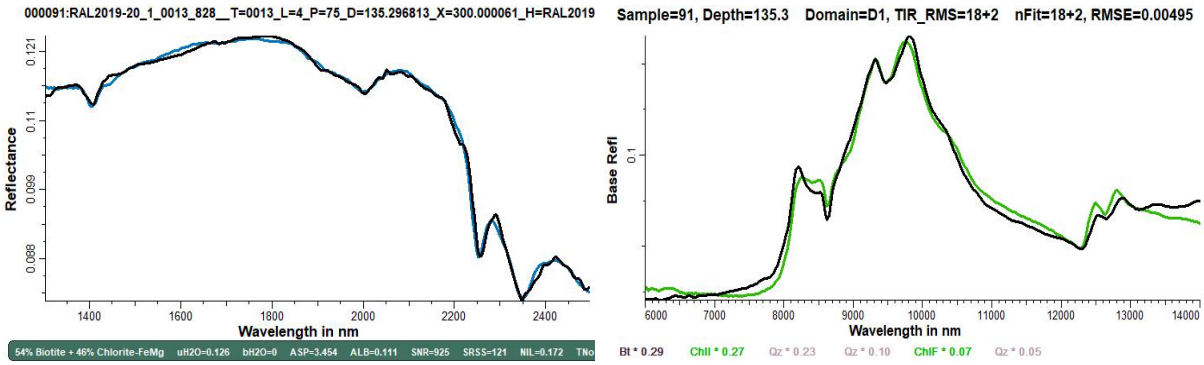
Groups	sTSAS	uTSAS	XMOD
CHLORITE	43.7%	46.6%	9.0%
DARK-MICA	53.5%	52.6%	90.5%
AMPHIBOLE	1.6%		0.1%

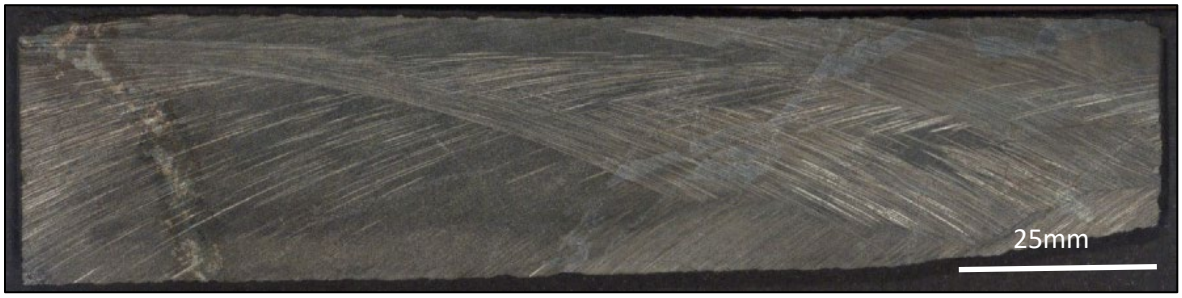
Minerals	sTSAS	uTSAS	XMOD
Chlorite-Fe	7.1%	7.2%	8.9%
Chlorite-FeMg	36.3%	39.1%	0.5%
Chlorite-Mg	1.0%	1.0%	
Biotite	51.8%	50.2%	90.1%
Phlogopite	1.7%	2.4%	
Actinolite			1.5%
Hornblende	1.6%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	38.2%	40.1%	39.9%	39.0%	25.1%
CHLORITE	20.0%	22.2%	24.2%	21.0%	6.9%
DARK-MICA	38.7%	35.4%	35.7%	40.1%	65.8%
OTHER-MGOH	2.8%				
CARBONATE		0.2%			1.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	38.2%	40.1%	39.9%	39.0%	25.2%
Chlorite-Fe	3.1%		1.4%	0.5%	6.6%
Chlorite-FeMg	16.9%	22.2%	22.9%	20.5%	0.4%
Biotite	38.7%	35.4%	35.7%	40.1%	66.1%
Talc	2.8%				
Rhodochrosite					1.0%

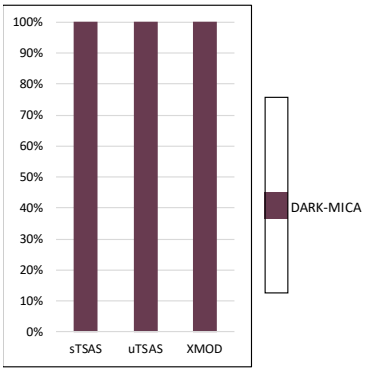




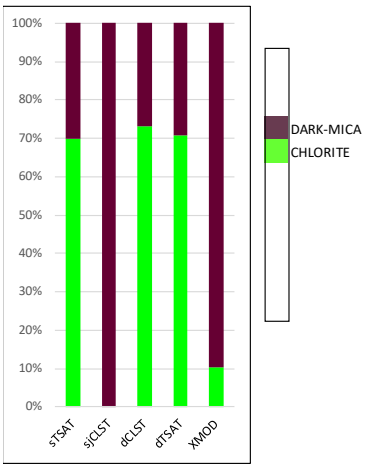
G408279 Micaceous ultramafic (in ultramafic cumulate)

Group

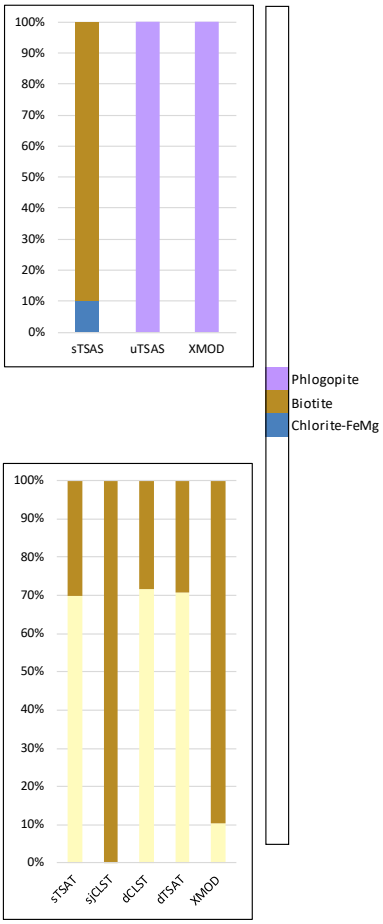
SWIR



TIR



Mineral



SWIR

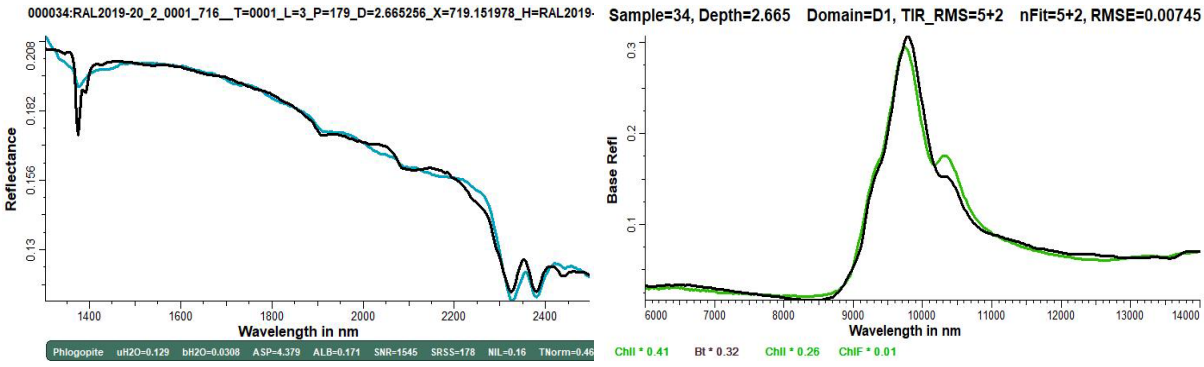
Groups	sTSAS	uTSAS	XMOD
CHLORITE	1.0%	1.0%	0.0%
DARK-MICA	99.0%	99.0%	97.7%
AMPHIBOLE			1.6%

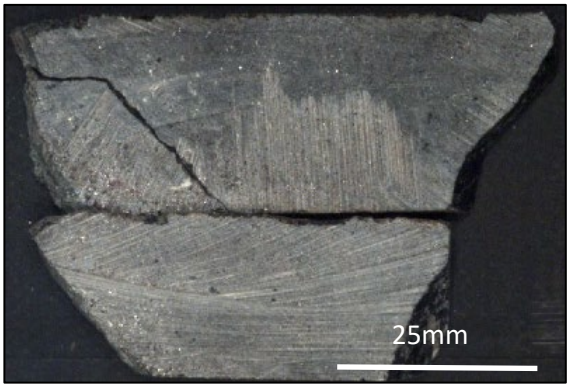
Minerals	sTSAS	uTSAS	XMOD
Chlorite-FeMg			10.3%
Chlorite-Mg	1.0%	1.0%	
Biotite			88.2%
Phlogopite	99.0%	99.0%	
Actinolite			1.5%

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
CHLORITE	69.9%	2.2%	73.1%	70.8%	10.2%
DARK-MICA	30.1%	97.7%	26.9%	29.2%	87.5%
AMPHIBOLE					1.5%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Chlorite-Fe		0.1%	4.7%		0.0%
Chlorite-FeMg	69.9%	2.2%	68.4%	70.8%	10.3%
Biotite	30.1%	97.7%	26.9%	29.2%	88.2%
Actinolite					1.5%





4. Discussion

The proportion of MLA spots classified as unknown were less than 1% for 19 of the 21 samples, with the other 2 returning 2.2% and 1.3% (G408246 mudstone and G408243 K-feldspar-altered dacite) respectively. The 6 fine grained samples (mudstone, shale and carbonaceous shale) returned less than 0.15% unknowns. These excellent results are due to adequate grain size with respect to beam size and mineralogies well represented by the X-ray spectral libraries.

The accuracy of the HyLogger mineralogy using the 6 SWIR and TIR unmixing algorithms relative to that determined by MLA (XMOD) is best examined in terms of mineral identification, which is the primary goal of HyLogging. The HyLogging system is not necessarily designed to measure mineral proportions, partly because the HyLogger IR spectral library has been normalised so each mineral has a maximum reflectance of 1, jettisoning information on their relative reflectance. Nevertheless, the statistical power generated by the high level of over-sampling that the HyLogging system produces builds confidence in averaged mineral proportion estimates (e.g. a 200m drill hole typically returns 50,000 spectra from 4mm samples).

Sample interpretations

G408251, G408275, G408243, G408265, G408264 and G408260 from the pilot study are included in Appendix 4.

G408246 Mudstone

This sample contained a challenging mineral assemblage, with biotite and chlorite in the SWIR and plagioclase, white mica, chlorite (and biotite) all with major features at similar TIR wavelengths (9500-9800nm: the 'Triangle of death').

TSAS and CLST both correctly identified all of the main mineral groups present.

Carbonate was identified as calcite by dCLST, but dTSAT identified calcite and siderite, and sjCLST interpreted only siderite, while XMOD identified the carbonate as calcite (although siderite was not included in the MLA library).

The proportion of carbonate over-estimated by all of the TIR algorithms, but was significantly under-estimated by TSAS. Quartz was over-estimated and plagioclase not identified in the TIR, and white mica and chlorite were also over-estimated with 31% biotite not identified.

G408248 Felsic volcanic

Both SWIR TSAS and TIR dCLST correctly identified the mineralogy. Relative proportions were also correct except that TIR CLS misclassified muscovite/phengite.

G408255 Felsic volcanic

The SWIR was aspectral, probably due to the fine-grained dark mineralogy and the TIR spectrum was characterised by the "Triangle of death". The TIR unmixing algorithms estimated relative proportions well, but missed the 25% biotite in the sample, with dCLST incorrectly preferring white mica.

G408276 Altered felsic volcanic

The SWIR unmixing algorithms correctly identified phengite but could not see the biotite comprising 15% of the sample. CLS correctly identified the 2 main minerals, with plagioclase identified by sTSAT and sjCLST not justified and left out of the RMS used by dCLST.

G408277 Granite

The SWIR system was unable to return spectra from the 13% mica and 22% amphibole in the sample. The TIR TSA and CLS algorithms correctly identified the mineralogy, but missed the amphibole, instead over-estimating dark mica. The plagioclase was incorrectly identified as labradorite instead of albite and oligoclase.

G408249 Altered felsic volcanic

SWIR TSAS, TIR sTSAT, sjTSAT and dCLST all detected the dominant white mica and minor kaolinite, but all over-estimating the latter. The white mica was spectrally interpreted as muscovite but MLA identified it as phengite.

G408250 Claystone

SWIR TSAS correctly identified white mica (muscovite) and kaolinite. In the TIR, dCLST added quartz and K-feldspar, but did not detect the 11% plagioclase. Plagioclase was a very minor mineral detected by sjCLST.

G408254 Micaceous sandstone

The white mica and chlorite dominating the mineralogy were identified correctly by SWIR TSA but the 15% (proportion of SWIR-active minerals) biotite was missed. In the TIR, 12% plagioclase identified by MLA was barely detected using dCLS and 14% white mica was missed using dCLS – the situation was reversed by sjCLST.

G408253 Crypto-micaceous shale

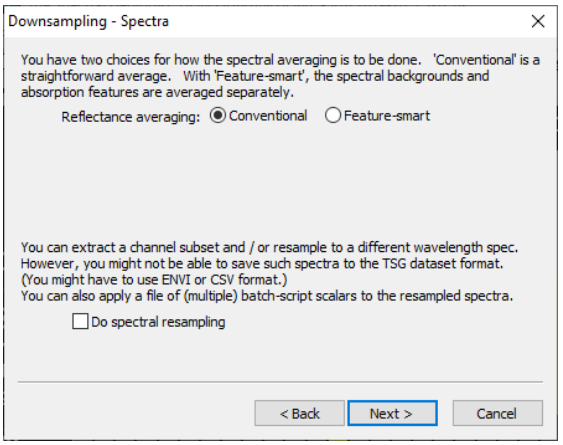
The SWIR spectrum was largely aspectral, but minor phengite and chlorite were detected. 26% biotite was missed. In the TIR, dCLST was closest to MLA, detecting quartz and white mica (ascribed to muscovite rather than the phengite identified by MLA), but missed 15% K-feldspar and 14% biotite.

G408253av Crypto-micaceous shale

(averaged to 21 spectra per bin)

When the spectra were averaged with a 21 bin (84mm) average, absorption features were not visibly enhanced but there were no aspectral results and all spectra could be unmixed by TSAS. The unmixing results were not an improvement on the un-averaged result, with biotite still not detected. The unmixing results from the averaged TIR spectra were unchanged from the original result.

Averaging was accomplished using the down sampling tool in TSG:



G408261 Carbonaceous shale

This grey, fine-grained sample was aspectral in the SWIR, missing absorption features for the 42% white mica and 6% chlorite in the sample. The TIR spectra contained features that were correctly unmixed to white mica, quartz and K-feldspar. Although 11% K-feldspar was detected, 12% plagioclase was not.

G408261av Carbonaceous shale

(averaged to 21 spectra per bin)

When the spectra were averaged, 20% of the spectra could be unmixed by TSAS, correctly returning white mica. Minor chlorite was not detected.

The TIR spectra appeared unchanged and the CLST results were similar to the un-averaged original, although minor chlorite was correctly added and minor K-feldspar incorrectly not detected.

G408262 Carbonaceous shale

This grey, fine-grained sample was aspectral in the SWIR, not seeing 55% white mica in the sample. The TIR spectra correctly unmixed to white mica, quartz and K-feldspar. 10% plagioclase was not detected.

G408262av Carbonaceous shale

(averaged to 21 spectra per bin)

When the spectra were averaged, 30% of the spectra could be unmixed by TSAS, correctly returning phengite.

In the TIR, the CLST results were similar to the un-averaged original, although the minor K-feldspar interpreted in the un-averaged spectra could not be justified in the RMS.

G408266 Altered mafic volcanic

The amphibole-chlorite-biotite-white mica assemblage was identified in the SWIR by TSAS. The proportion of amphibole was significantly under-estimated.
In the TIR, quartz was correctly added to the assemblage, but white mica was not detected by sTSA or sjCLST and not justified to add to the RMS for dCLST. Mineral proportions were approximately correct (once the absence of muscovite is accounted for).

G408268 Altered mafic volcanic

This biotite-rich sample was unmixed by TSAS to ~50:50 biotite:chlorite. The TIR unmixing algorithms correctly added significant quartz but also used far too much chlorite.

G408279 Micaceous ultramafic

This biotite-rich sample was correctly unmixed by TSAS to near 100% dark mica, but did specify phlogopite rather than biotite. The TIR unmixing algorithms correctly added 70% chlorite to the mix.

Summary

A graphical summary of the success of dCLST and uTSAS in identifying the mineralogy is presented in tables 5 and 6. For the purposes of the SWIR analysis the invalid SWIR group category was ignored and XMOD mineral proportions recalculated to include only SWIR active minerals.

Accurate identification was defined as dCLST or uTSAS and XMOD measuring proportions of a mineral within a factor of 2 and less accurate identification was indicated by dCLST/XMOD or uTSAS/XMOD outside these bounds. These are indicated in tables 5 and 6 with green, yellow and blue backgrounds.

Errors of commission were defined as dCLST or uTSAS returning more than 5 weight % (i.e. spectral weight, which is approximately areal proportion, at least for TIR spectra) and XMOD measuring less than 5% (areal proportion Errors of omission were defined as dCLST or uTSAS returning less than 5% and XMOD measuring more than 5%.

Two levels of commission or omission are indicated in tables 5 and 6:

- Significant error with a 15% threshold corresponding to the practical detection limit of TSA for individual spectra, indicated by the default settings in TSA, and displayed with the more highlighted symbology (with white font).
- Less significant error with a threshold of 5%, corresponding to the default minimum for the TSG summary screen, appropriate for collections of spectra.

The TIR system paired with the dCLST unmixing algorithm consistently identified mineral groups correctly, with a success rate of 92% with a 15% detection limit and 74% with a 5% detection limit. Failures include omitting significant (i.e. 15% or more) dark mica in 2 samples and significant K-feldspar and plagioclase in 1 sample each. Less significant failures (i.e. missing mineral groups comprising less than a 15% proportion) occurred for K-feldspar, plagioclase, white mica and dark mica. Significant errors of commission occurred for kaolin and dark mica in 1 sample each. Less significant errors of commission occurred for 1 sample each of chlorite and amphibole.

Small proportions of quartz, chlorite and carbonate were consistently identified, but similar proportions of plagioclase, white mica, epidote and dark mica were not.

At the mineral species level, phengite was commonly misidentified as muscovite, chlorite-Fe as chlorite-FeMg and oligoclase not separated from albite.

At the mineral level phengite was incorrectly identified as muscovite in 8 of 9 significantly white mica bearing samples. Similarly, chlorite-Fe was incorrectly identified as chlorite-FeMg. Significant proportions of oligoclase were not identified in 1 sample and under-estimated in another. Single sample inconsistencies occurred for oligoclase incorrectly identified as labradorite, and muscovite as kaolinite. The XMOD library did not allow testing of biotite versus phlogopite, actinolite versus hornblende, calcite versus siderite or orthoclase versus microcline.

The SWIR system paired with the uTSAS unmixing algorithm was less consistent in identifying mineral groups correctly, with a success rate of 65% with a 15% detection limit and 52% with a 5% detection limit. However, the detection limits relate to proportions of SWIR-active minerals only and 93% of the significant errors occur in samples in which there is less than 10% of the SWIR-active minerals.

Significant failures include omitting dark mica in 7 samples, white mica in 4 samples, amphibole in 2 samples and carbonate in 1 sample. Less significant omissions include muscovite in 2 samples and chlorite in 3 samples. Significant errors of commission occurred for chlorite in 2 samples and white mica in 1 sample. A less significant error occurred for white mica in 1 sample.

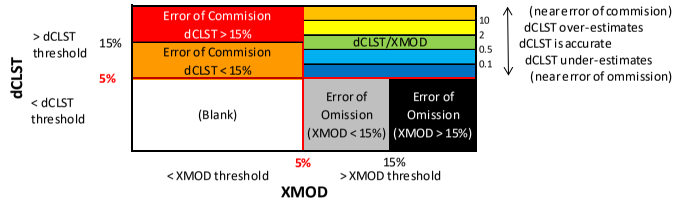
At the mineral level muscovite and phengite were commonly mis-identified, as were chlorite-Fe and chlorite-FeMg. Limitations of the XMOD library did not allow testing of biotite versus phlogopite, actinolite versus hornblende, kaolinite-wx versus kaolinite-px or calcite versus siderite.

A similar presentation that includes data from previous reports in this research program is included in appendix 5 (i.e. Green and Reid 2021, Moltzen and Bottrill 2018 and Moltzen et al 2020).

Tables 5, 6 (over page). Summaries illustrating the success or failure of mineral identification by dCLST and uTSAS.

TIR GROUPS		SILICA			K-FELDSPAR			PLAGIOCLASE			GARNET			KAOLIN			WHITE-MICA			CHLORITE			DARK-MICA			AMPHIBOLE			CARBONATE		
		dCLST/XMOD	CLST	XMOD	dCLST/XMOD	dCLST	XMOD	dclst/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dclst/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD
G408251	Mudstone	1.8	35%	19%	0.5	9%	18%	Omission	0%	8%		0%	0%	3.0	30%	10%	0.6	26%	44%		0%	0%		0%	0%		0%	0%		0%	0%
G408275	Altered granodiorite	2.0	45%	23%		0%	4%	0.8	48%	62%		0%	0%		0%	0%		0%	1%	Commision	6%	2%	Omission	0%	5%		0%	1%		0%	0%
G408243	K-feldspar altered dacite	1.4	19%	13%	0.7	34%	46%	1.2	41%	34%		0%	0%		0%	0%		4%	3%		1%	0%		0%	0%		0%	0%		1%	1%
G408265	Biote-garnet altered mafic	1.5	40%	26%		0%	0%		0%	0%	1.2	19%	16%		0%	0%		0%	2%		0%	2%	0.6	31%	48%	Commision	10%	0%		0%	0%
G408264	Biotite-altered mafic	1.6	23%	14%		0%	1%		0%	0%		0%	0%		0%	0%		0%	1%	6.2	55%	9%	0.3	22%	65%		0%	0%		0%	0%
G408260	Micaceous grey shale	1.5	34%	22%	0.7	15%	21%	Omission	0%	5%		0%	0%		0%	0%	1.1	51%	47%		0%	1%		0%	2%		0%	0%		0%	0%
G408245	Altered felsic volcanic	1.1	24%	22%		0%	0%	0.7	23%	32%		0%	0%		0%	0%	1.9	18%	9%	0.9	9%	9%	Omission	0%	11%		0%	0%	1.7	28%	16%
G408246	Mudstone	2.4	30%	12%	Omission	0%	7%	Omission	0%	15%		0%	0%		0%	0%	3.0	41%	14%		2%	3%	Omission	0%	31%		0%	1%	1.8	27%	15%
G408248	Felsic volcanic	1.5	14%	9%	0.8	24%	29%	1.0	17%	17%		0%	0%		0%	0%	1.1	42%	39%		2%	1%		0%	3%		0%	0%		0%	1%
G408255	Felsic volcanic	1.4	13%	9%	0.9	24%	26%	0.9	19%	21%		0%	0%		0%	0%	2.7	30%	11%	2.1	13%	7%	Omission	0%	25%		0%	0%		0%	0%
G408276	Altered felsic volcanic		0%	1%	1.3	72%	56%		0%	0%		0%	0%		0%	0%	1.5	28%	19%		0%	2%		0%	3%		0%	0%		0%	0%
G408277	Granite		0%	1%	0.5	10%	18%	1.7	51%	29%		0%	0%		0%	0%	1.6	21%	13%	Omission	0%	8%	Commision	19%	3%	Omission	0%	23%		0%	0%
G408249	Altered felsic volcanic		0%	4%		0%	1%		0%	3%		0%	0%	Commision	41%	2%	0.7	59%	89%		0%	0%		0%	0%		0%	0%		0%	0%
G408250	Claystone	1.6	32%	21%	0.9	13%	15%	Omission	5%	11%		0%	0%	2.1	22%	10%	0.7	28%	40%		0%	1%		0%	0%		0%	0%		0%	1%
G408254	Micaceous sandstone	1.4	90%	65%		0%	2%	0.7	8%	12%		0%	0%		0%	0%	Omission	1%	14%		0%	3%		0%	3%		0%	0%		0%	0%
G408253	Crypto-micaceous shale	2.6	53%	21%	Omission	0%	15%	Omission	0%	8%		0%	0%		0%	0%	1.2	46%	38%		0%	3%	Omission	0%	14%		0%	0%		0%	0%
G408261	Carbonaceous shale	1.9	47%	25%	1.4	14%	11%	Omission	0%	12%		0%	0%		0%	0%	0.9	38%	43%	Omission	0%	6%		0%	2%		0%	0%		0%	0%
G408262	Carbonaceous shale	2.4	40%	17%	0.8	12%	16%	Omission	0%	10%		0%	0%		0%	0%	0.9	48%	55%		0%	0%		0%	1%		0%	0%		0%	0%
G408266	Altered mafic volcanic	1.5	17%	11%		0%	3%	Omission	0%	8%		0%	0%		0%	0%	Omission	0%	11%	2.4	36%	15%	1.1	12%	11%	1.0	35%	36%		0%	0%
G408268	Altered mafic volcanic	1.6	40%	25%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%	3.5	24%	7%	0.5	36%	66%		0%	0%		0%	1%
G408279	Micaceous ultramafic		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%	7.1	73%	10%	0.3	27%	88%		0%	1%		0%	0%

TIR Mins	Quartz			Microcline/Orthoclase			Albite			Oligoclase			Labradorite			Spessartine			Kaolinite-WX-PX			Muscovite			Phengite			Chlorite-Fe			Chlorite-FeMg			Biotite/Phlogopite			Actinolite/Hornblend			Calcite/Siderite		
	dCLST/XMOD	CLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dclst/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dCLST/XMOD	dCLST	XMOD	dclst/XMOD	dCLST	XMOD	dCLST/XMOD	CLST	XMOD	dCLST/XMOD	dCLST	XMOD
G408251	1.8	35%	19%	0.5	9%	18%	Omission	0%	8%		0%	0%		0%	0%		0%	0%	3.0	30%	10%	Commision	26%	4%	Omission	0%	39%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%
G408275	2.0	45%	23%		0%	4%	Commision	23%	3%	0.4	26%	60%		0%	0%		0%	0%		0%	0%		0%	0%		0%	1%		0%	0%	Commision	6%	2%	Omission	0%	5%		0%	1%		0%	0%
G408243	1.4	19%	14%	0.7	34%	47%	1.0	34%	35%	Commision	7%	0%		0%	0%		0%	0%		0%	0%		4%	1%		0%	3%		0%	0%		1%	0%		0%	0%		0%	0%		1%	1%
G408265	1.5	40%	26%		0%	0%		0%	0%		0%	0%		0%	0%	1.2	19%	16%		0%	0%		0%	2%		0%	0%		0%	2%		0%	0%	0.6	31%	49%		10%	0%		0%	0%
G408264	1.6	23%	15%		0%	1%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	1%	0.9	8%	9%	Commision	47%	0%	0.3	22%	66%		0%	0%		0%	0%
G408260	1.5	34%	22%	0.7	15%	21%		0%	4%		0%	1%		0%	0%		0%	0%		0%	0%	4.9	51%	10%	Omission	0%	37%		0%	1%		0%	0%		0%	2%		0%	0%		0%	0%
G408245	1.0	24%	23%		0%	0%	1.0	23%	23%	Omission	0%	6%		0%	0%		0%	0%		0%	0%	Commision	18%	1%	Omission	0%	9%	Omission	0%	9%	Commision	8%	0%	Omission	0%	11%		0%	0%	1.6	28%	17%
G408246	2.4	30%	13%	Omission	0%	7%	Omission	0%	10%	Omission	0%	5%		0%	0%		0%	0%		0%	0%	Commision	41%	0%	Omission	0%	14%		0%	3%		2%	0%	Omission	0%	32%		0%	1%	1.8	27%	15%
G408248	1.5	14%	9%	0.8	24%	29%	1.1	14%	13%		3%	4%		0%	0%		0%	0%		0%	0%	Commision	42%	3%	Omission	0%	36%		0%	1%		2%	0%		0%	3%		0%	0%		0%	1%
G408255	1.4	13%	9%	0.9	24%	26%	1.7	19%	11%	Omission	0%	10%		0%	0%		0%	0%		0%	0%	Commision	30%	2%	Omission	0%	10%		0%	1%	2.5	13%	5%	Omission	0%	25%		0%	0%		0%	0%
G408276		0%	1%	1.3	72%	58%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%	Commision	27%	2%	Omission	0%	17%		0%	2%		0%	0%		0%	3%		0%	0%		0%	0%
G408277		0%	1%	0.5	10%	19%	1.7	16%	9%	Omission	1%	21%	Commision	34%	0%		0%	0%		0%	0%	Commision	21%	0%	Omission	0%	13%		0%	2%	Omission	0%	7%	Commision	18%	3%	Omission	0%	23%		0%	0%
G408249		0%	4%		0%	1%		0%	1%		0%	2%		0%	0%		0%	0%	Commision	41%	2%	3.4	47%	14%	0.2	13%	76%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%
G408250	1.6	32%	21%	0.9	13%	15%		5%	4%	Omission	0%	7%		0%	0%		0%	0%	2.1	22%	10%	Commision	28%	4%	Omission	0%	37%		0%	1%		0%	0%		0%	0%		0%	0%		0%	1%
G408254	1.4	90%	65%		0%	2%	0.8	8%	11%		0%	2%		0%	0%		0%	0%		0%	0%		1%	2%	Omission	0%	12%		0%	3%		0%	0%		0%	3%		0%	0%		0%	0%
G408253	2.6	53%	21%	Omission	0%	15%	Omission	0%	6%		0%	2%		0%	0%		0%	0%		0%	0%	Commision	46%	2%	Omission	0%	37%		0%	3%		0%	0%	Omission	0%	14%		0%	0%		0%	0%
G408261	1.9	47%	26%	1.3	14%	11%	Omission	0%	10%		0%	2%		0%	0%		0%	0%		0%	0%	Commision	38%	2%	Omission	0%	41%	Omission	0%	6%		0%	0%		0%	2%		0%	0%		0%	0%
G408262	2.4	40%	17%	0.8	12%	16%	Omission	0%	9%		0%	1%		0%	0%		0%	0%		0%	0%	Commision	48%	1%	Omission	0%	54%		0%	0%		0%	0%		0%	1%		0%	0%		0%	0%
G408266	1.4	17%	12%		0%	3%		0%	0%	Omission	0%	8%		0%	0%		0%	0%		0%	0%		0%	1%	Omission	0%	11%	1.7	28%	16%	Commision	8%	0%	1.0	12%	12%	0.9	35%	37%		0%	0%
G408268	1.6	40%	25%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%	Omission	1%	7%	Commision	23%	0%	0.5	36%	66%		0%	0%		0%	0%
G408279		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		0%	0%		5%	0%	6.7	68%	10%	0.3	27%	88%		0%	1%		0%	0%

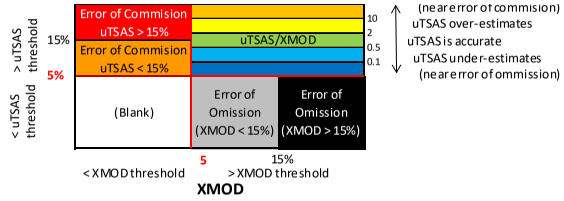


SWIR GROUPS

			KAOLIN			WHITE-MICA			CHLORITE			DARK-MICA			AMPHIBOLE			CARBONATE		
			uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD
G408251	Kaol+Musc	Mudstone	2.5	50%	20%	0.6	50%	78%		0%	1%		0%	1%		0%	0%		0%	0%
G408275	Qtz+Plag	Altered granodiorite	Omission	1%	6%	6.4	53%	8%	Commision	17%	2%	0.4	29%	68%	Omission	0%	12%		0%	4%
G408243	Kfs+Plag+Musc	K-feldspar altered dacite	Omission	0%	6%	1.4	91%	67%	Omission	2%	11%		0%	0%		0%	0%	0.4	7%	17%
G408265	Biot+Gnt	Biote-garnet altered mafic		0%	0%	Commision	12%	1%		0%	4%	0.9	88%	95%		0%	0%		0%	0%
G408264	Chl+Biot	Biotite-altered mafic		0%	0%		0%	1%	4.4	52%	12%	0.6	48%	87%		0%	0%		0%	1%
G408260	Kfs+Musc	Micaceous grey shale		0%	0%	1.1	100%	91%		0%	3%	Omission	0%	6%		0%	0%		0%	0%
G408245	Carb+Plag+Musc+Chl	Altered felsic volcanic		0%	0%	2.4	47%	19%	2.3	46%	20%	Omission	0%	24%		0%	1%	0.2	7%	36%
G408246	Musc+Carb	Mudstone		0%	0%	2.3	48%	21%	Commision	52%	5%	Omission	0%	49%		0%	1%	Omission	0%	24%
G408248	Musc+Kfs+Plag	Felsic volcanic		0%	0%	1.1	97%	88%		1%	4%	Omission	0%	6%		0%	0%		1%	2%
G408255	Musc+Kfs+Plag+Chl	Felsic volcanic		0%	0%	Omission	0%	27%		0%	3%	Omission	0%	69%		0%	1%		0%	0%
G408276	Kfs+Musc	Altered felsic volcanic		0%	0%	1.3	98%	75%	Omission	2%	8%	Omission	0%	16%		0%	0%		0%	1%
G408277	Plag+Musc+Biot	Granite		0%	0%	Omission	0%	32%		0%	4%	Omission	0%	7%	Omission	0%	57%		0%	0%
G408249	Musc+Kaol	Altered felsic volcanic	Commision	48%	3%	0.5	52%	96%		0%	1%		0%	0%		0%	1%		0%	0%
G408250	Musc+Kaol	Claystone	2.4	51%	21%	0.6	49%	76%		0%	1%		0%	0%		0%	0%		0%	1%
G408254	Qtz	Micaceous sandstone		0%	1%	1.2	78%	63%	1.1	20%	18%	Omission	0%	16%		0%	2%		2%	0%
G408253	Qtz+Musc	Crypto-micaceous shale		0%	0%	1.3	91%	68%	1.4	8%	6%	Omission	0%	26%		0%	0%		1%	0%
G408261	Qtz+Musc	Carbonaceous shale		0%	1%	Omission	0%	83%	Omission	0%	12%		0%	4%		0%	0%		0%	0%
G408262	Musc+Qtz	Carbonaceous shale		0%	0%	Omission	0%	97%		0%	1%		0%	2%		0%	0%		0%	0%
G408266	Chl+Amph+Biot	Altered mafic volcanic		0%	0%	0.8	11%	15%	3.9	82%	21%	Omission	2%	16%	Omission	4%	48%		0%	1%
G408268	Biot+Chl	Altered mafic volcanic		0%	0%		1%	0%	5.2	47%	9%	0.6	53%	91%		0%	0%		0%	0%
G408279	Chl+Biot	Micaceous ultramafic		0%	0%		0%	0%		1%	0%	1.0	99%	98%		0%	2%		0%	0%

SWIR Minerals

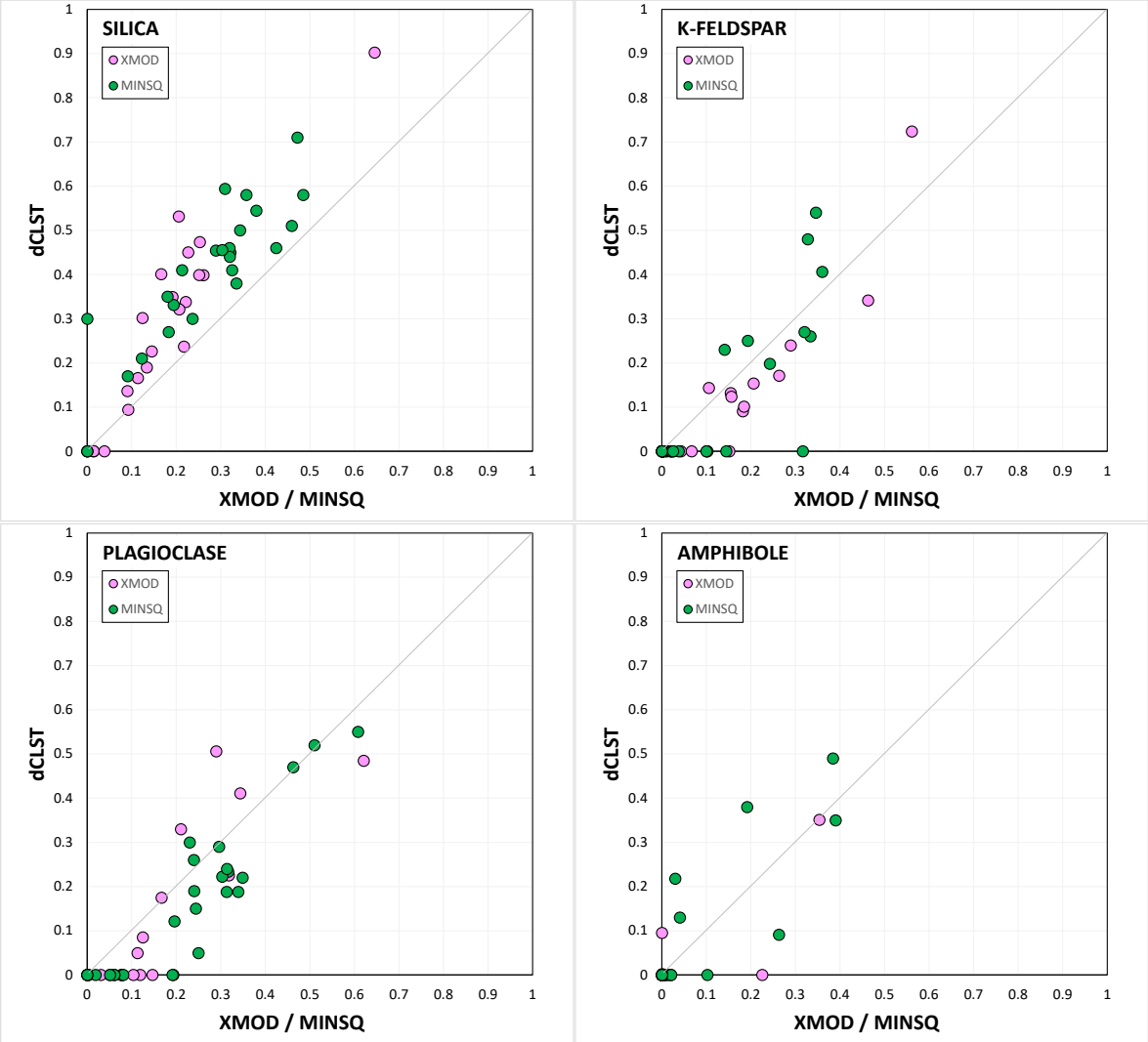
			Muscovite/Muscovitic			Phengite/Phengitic illite			Chlorite-Fe			Chlorite-FeMg		
			uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD
G408251	Kaol+Musc	Mudstone	6.3	50%	8%	Omission	0%	72%		0%	1%		0%	0%
G408275	Qtz+Plag	Altered granodiorite	Commision	52%	2%	Omission	0%	7%		0%	1%	0.4	8%	19%
G408243	Kfs+Plag+Musc	K-feldspar altered dacite	Omission	0%	12%	1.5	91%	59%	Omission	0%	9%		2%	0%
G408265	Biot+Gnt	Biote-garnet altered mafic	Commision	9%	3%		3%	1%		0%	4%		0%	0%
G408264	Chl+Biot	Biotite-altered mafic		0%	0%		0%	1%	Omission	2%	11%	Commision	46%	0%
G408260	Kfs+Musc	Micaceous grey shale	Omission	0%	20%	1.4	100%	72%		0%	3%		0%	0%
G408245	Carb+Plag+Musc+Chl	Altered felsic volcanic		0%	2%	2.5	47%	19%	Omission	1%	20%	Commision	45%	0%
G408246	Musc+Carb	Mudstone		0%	0%	2.3	48%	21%		1%	5%	Commision	51%	0%
G408248	Musc+Kfs+Plag	Felsic volcanic	Omission	0%	6%	1.2	97%	83%		0%	3%		1%	0%
G408255	Musc+Kfs+Plag+Chl	Felsic volcanic		0%	4%	Omission	0%	23%		0%	2%	Omission	0%	13%
G408276	Kfs+Musc	Altered felsic volcanic	2.3	22%	10%	1.1	74%	68%	Omission	0%	8%		1%	0%
G408277	Plag+Musc+Biot	Granite		0%	1%	Omission	0%	27%			3%	Omission		14%
G408249	Musc+Kaol	Altered felsic volcanic	Omission	0%	15%	0.6	52%	82%		0%	0%		0%	0%
G408250	Musc+Kaol	Claystone	7.3	49%	7%	Omission	0%	71%		0%	1%		0%	0%
G408254	Qtz	Micaceous sandstone	Omission	3%	7%	1.3	75%	59%	Omission	4%	17%	Commision	16%	0%
G408253	Qtz+Musc	Crypto-micaceous shale	Commision	8%	3%	1.3	83%	65%	Omission	3%	5%	Commision	5%	0%
G408261	Qtz+Musc	Carbonaceous shale	Omission	0%	7%	Omission	0%	59%	Omission		17%			0%
G408262	Musc+Qtz	Carbonaceous shale		0%	2%	Omission	0%	95%			1%			0%
G408266	Chl+Amph+Biot	Altered mafic volcanic	Commision	11%	1%	Omission	1%	14%	Omission	0%	21%	Commision	82%	0%
G408268	Biot+Chl	Altered mafic volcanic		0%	0%		0%	0%	0.8	7%	9%	Commision	39%	0%
G408279	Chl+Biot	Micaceous ultramafic		0%	0%		0%	0%		0%	0%	Omission	0%	10%

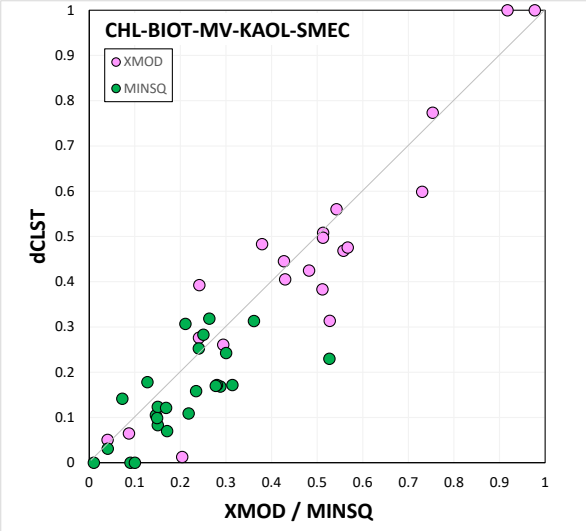


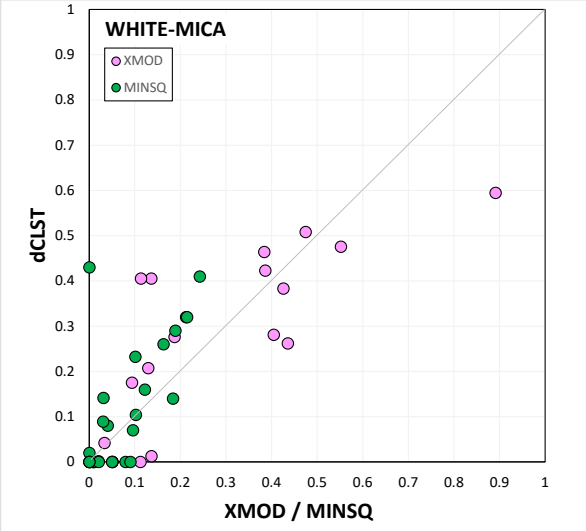
Mineral proportions

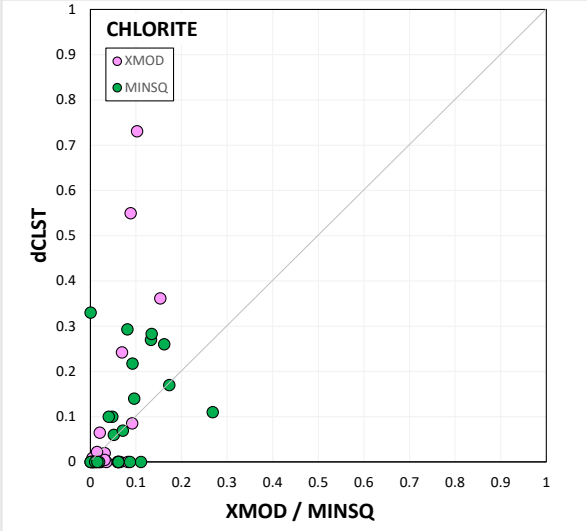
Mineral proportions from the TIR unmixing algorithm dCLST are compared with MLA in figure 5. There is a linear relationship between the measured XMOD mineral proportions and the results of dCLST for silica, K-feldspar, plagioclase, amphibole and white mica. This is not the case for chlorite, dark mica and kaolin. However, when the minerals with a single major TIR feature ('Triangle of death') i.e. white mica, chlorite, dark mica, kaolin and smectite are added together, a linear relationship is indicated.

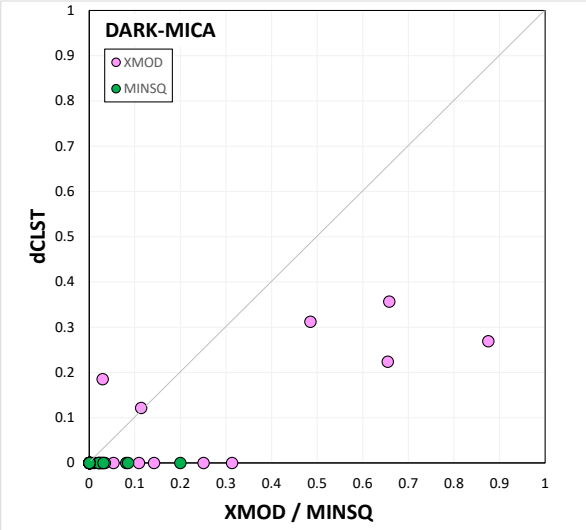
Figure 5 (below). Summary plots for each mineral group comparing mineral proportion estimates from TIR HyLogging (dCLST) with MLA (in pink) or MINSQ (in green).

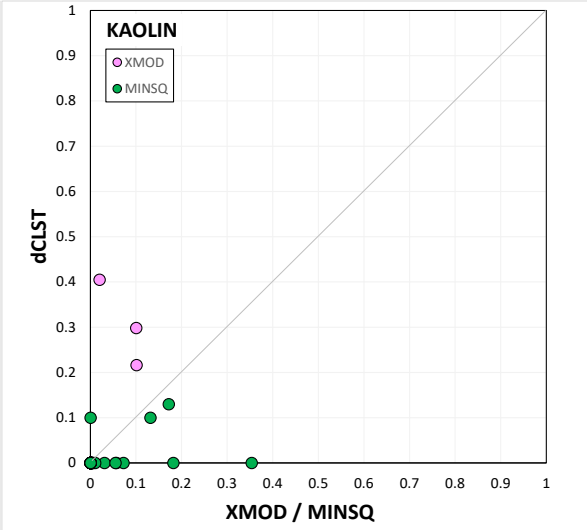



CHL-BIOT-MV-KAOL-SMEC
XMOD
MINSQ
dCLST
XMOD / MINSQ


WHITE-MICA
XMOD
MINSQ
dCLST
XMOD / MINSQ


CHLORITE
XMOD
MINSQ
dCLST
XMOD / MINSQ


DARK-MICA
XMOD
MINSQ
dCLST
XMOD / MINSQ


KAOLIN
XMOD
MINSQ
dCLST
XMOD / MINSQ

Estimates of the linear relationships are provided in table 6. Minerals that are significantly over-estimated by dCLST are chlorite and silica, and dark mica is significantly under-estimated. K-feldspar, plagioclase, white mica, amphibole and white mica + chlorite + dark mica + kaolin ('Triangle of death' minerals) were better estimated.

Table 6. Linear regression statistics for dCLST modelling mineral proportions measured by XMOD or MINSQ.

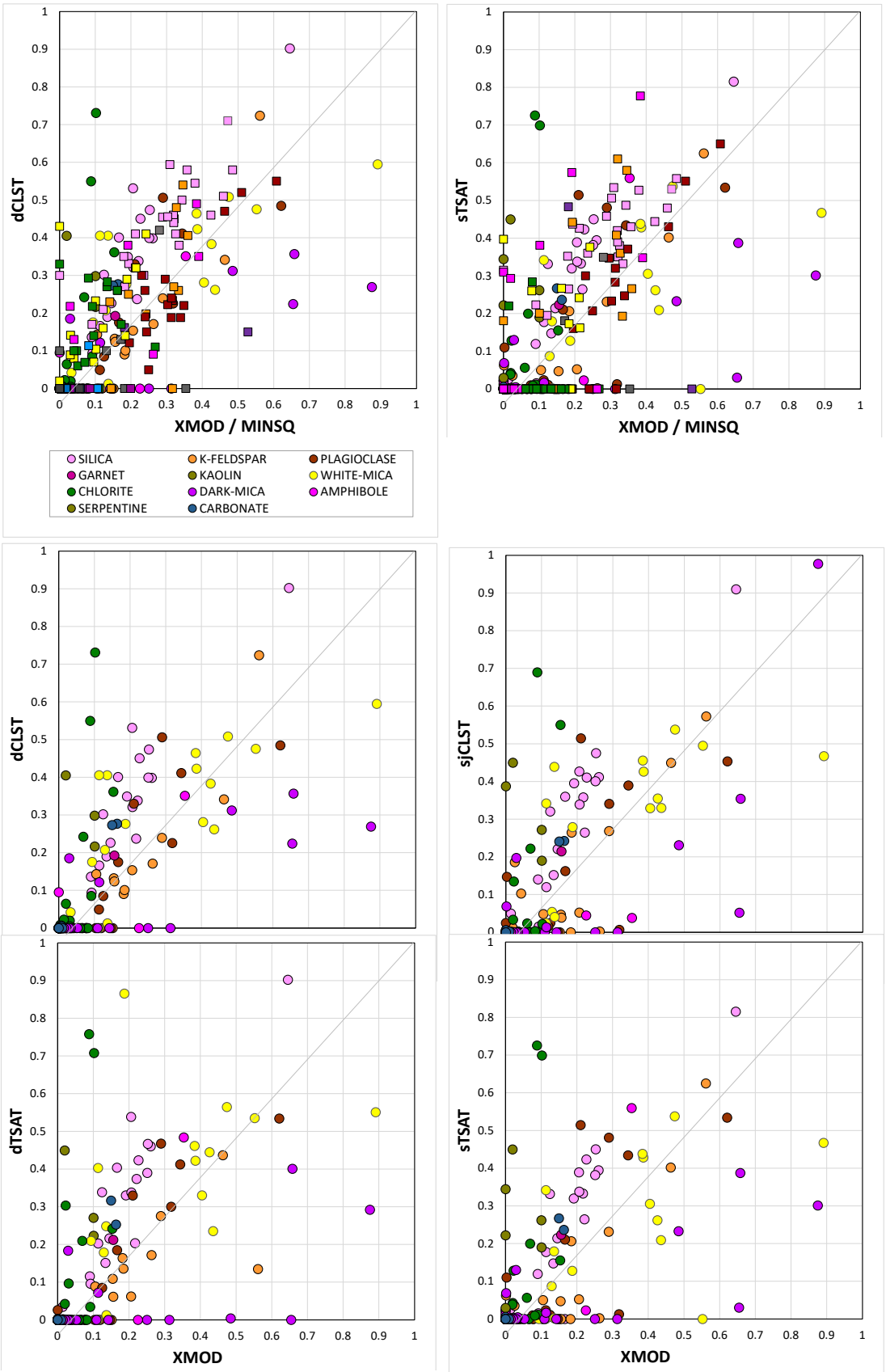
	Slope	N	R^2	Uncertainty in slope	F statistic
SILICA	1.45	31	0.96	3.6%	791
K-FELDSPAR	1.06	12	0.92	8.6%	135
PLAGIOCLASE	0.91	19	0.93	6.5%	235
WHITE-MICA	0.90	14	0.90	9.0%	124
CHLORITE	1.60	3	0.89	24.8%	16
DARK-MICA	0.41	4	0.91	17.9%	31
AMPHIBOLE	1.13	4	0.94	15.1%	44
CHL-BIOT-MV-KAOL-SMEC	0.93	30	0.96	4.0%	626

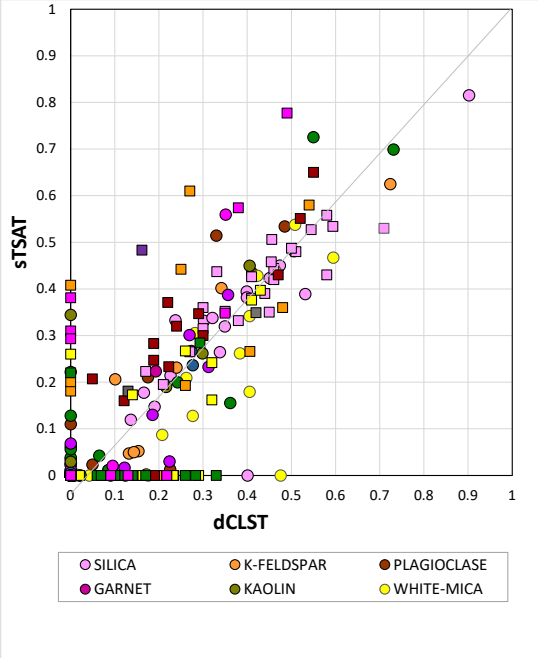
Mineral proportions from the 4 HyLogging TIR unmixing algorithms are compared with MLA and also compared with each other in figure 6. Data from previous reports in this research program are included (i.e. Green and Reid 2021, Moltzen and Bottrill 2018 and Moltzen et al 2020).

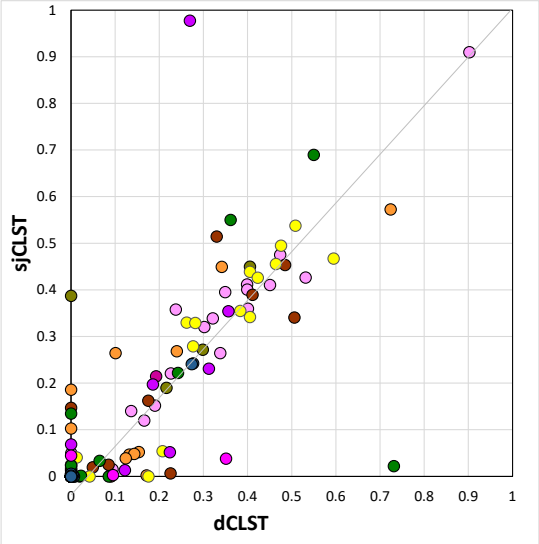
Improvements can be seen in moving from sTSAT to sjCLST, sjCLST to dCLST (and from sTSAT to dTSAT), especially for chlorite + biotite and carbonate. It is especially notable that dTSAT did not improve on dCLST and was prone to not using some minerals used by CLS, especially dark mica, but also plagioclase and K-feldspar when they comprised less than 15% of the sample.

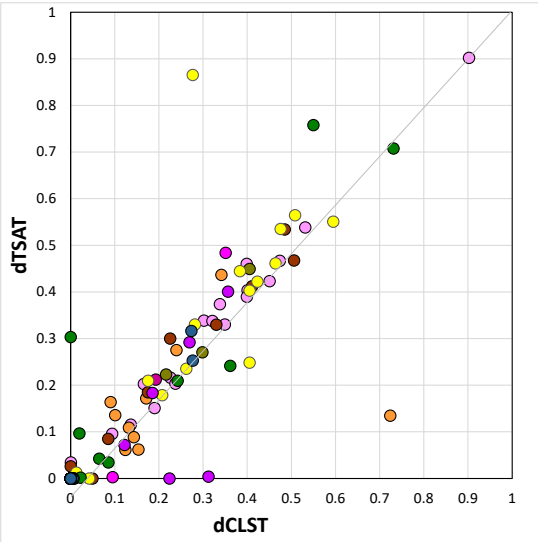
Sample G408245 altered felsic volcanic featured the most complicated assemblage, comprising 32% albite, 21% quartz, 17% calcite, 10% biotite, 9% phengite and 9 % Fe-chlorite. The sample was used to test the effect of varying the dTSAT parameters (detailed results are included in appendix 1). In sTSAT, Mixture level and Minimum item weight are set at 3 and 15% respectively. CLS and TSA both failed to detect the biotite in all settings. Of the 5 remaining minerals, white mica was the most likely to be omitted when the mixture level was reduced from 6 toward 3. Any mix of more than 3 gave similar overall mineral proportions for the sample. A minimum item weight of 0% gave a slightly more accurate result than 15%. This is consistent with the practice of using a 0% minimum item weight for collections of spectra and reserving the 15% minimum for considering individual spectra, but a more definitive result would require a similar analysis of many samples.

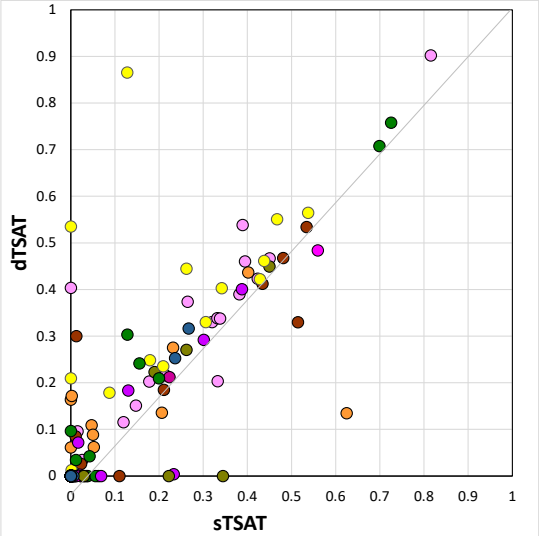
Figure 6 (below). Summary plots for all mineral groups comparing mineral proportion estimates from the various TIR unmixing algorithms with MLA or MINSQ and comparing the algorithms with each other. Data from XMOD (circles) and MINSQ (squares) measurements are included only for the 3 graphs dCLST vs XMOD / MINSQ, sTSAT vs XMOD / MINSQ and sTSAT vs dCLST.

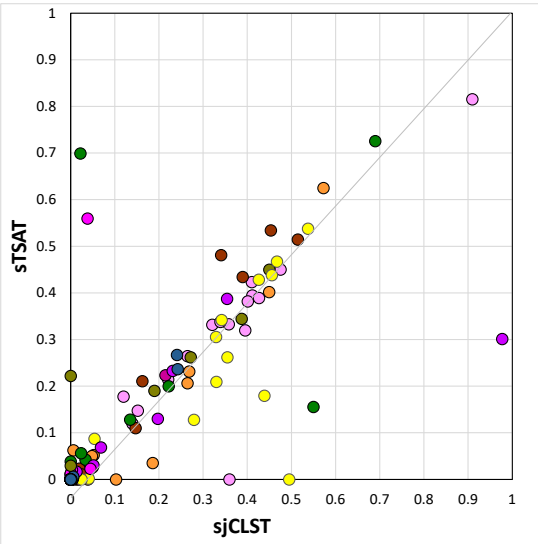


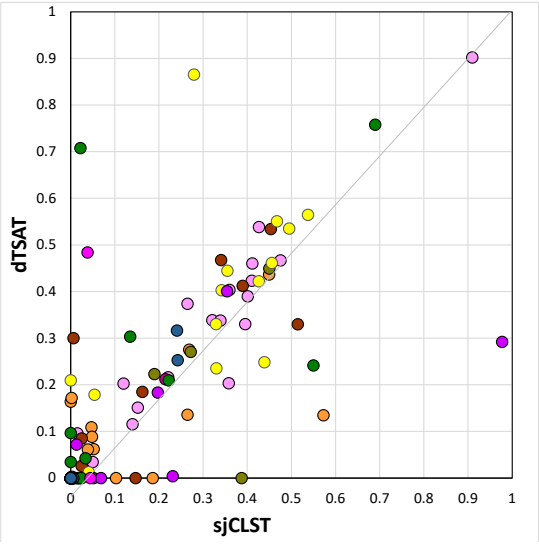

sTSAT
dCLST
SILICA
K-FELDSPAR
PLAGIOCLASE
GARNET
KAOLIN
WHITE-MICA


sjCLST
dCLST


dTSAT
dCLST


dTSAT
sTSAT

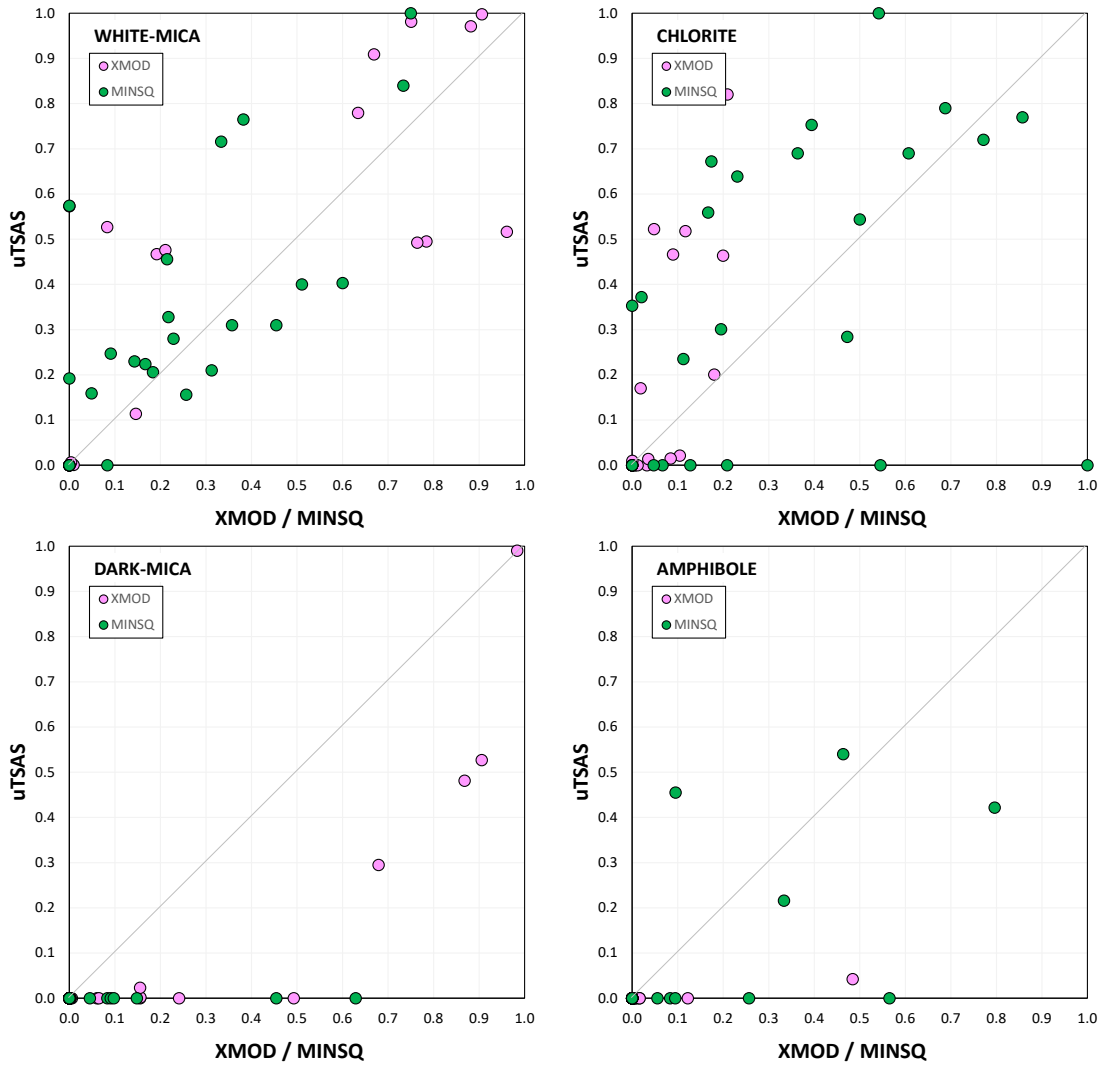

sTSAT
sjCLST

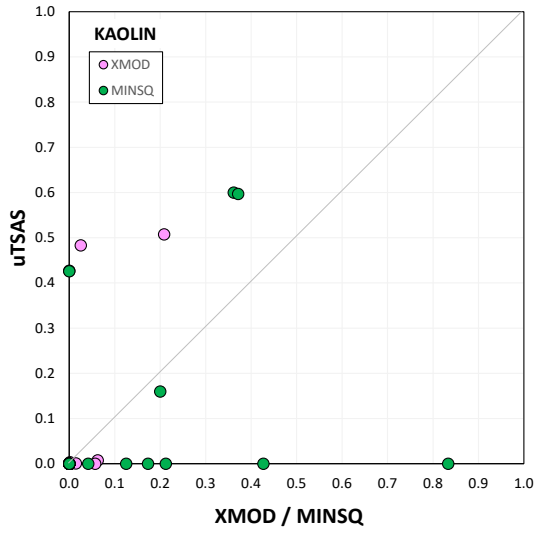

dTSAT
sjCLST

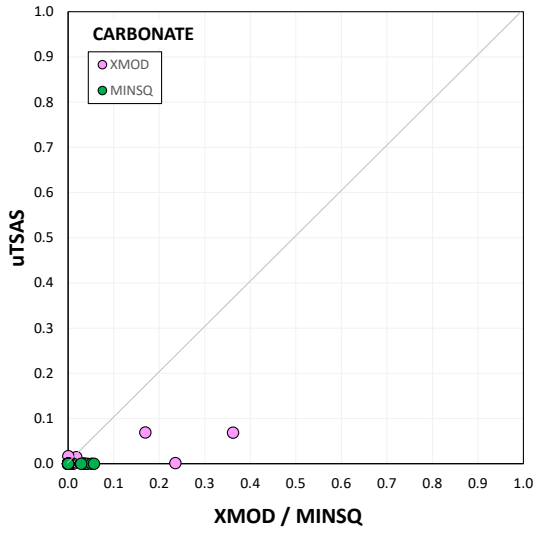
Mineral proportions from the SWIR unmixing algorithm uTSAS are compared with MLA in figure 7. There are linear relationships between the measured XMOD or MINSQ mineral proportions and the results of uTSAS for all minerals and chlorite / (chlorite + white mica), but all are of poor quality.

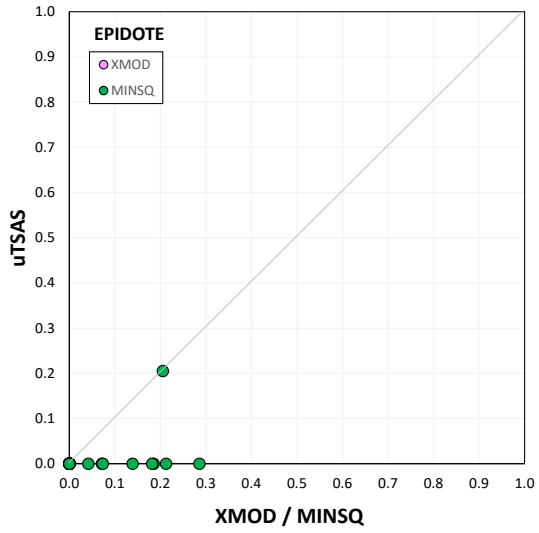
Estimates of white mica and chlorite proportions were better than those for dark mica, amphibole, kaolin, carbonate and epidote. Dark mica, carbonate and epidote were significantly under-estimated.

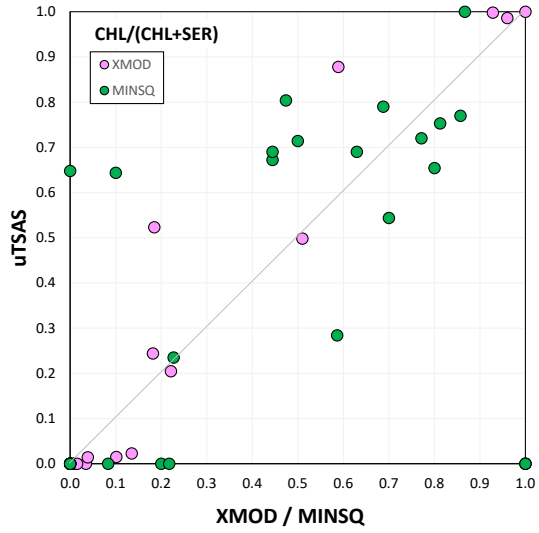
Figure 7 (below). Summary plots comparing mineral proportion estimates from SWIR uTSAS with MLA. MLA mineral proportions have been normalised so that the total of SWIR-active minerals sums to 100%. Samples with >50% Invalid are not plotted.




KAOLIN
XMOD
MINSQ
uTSAS
XMOD / MINSQ

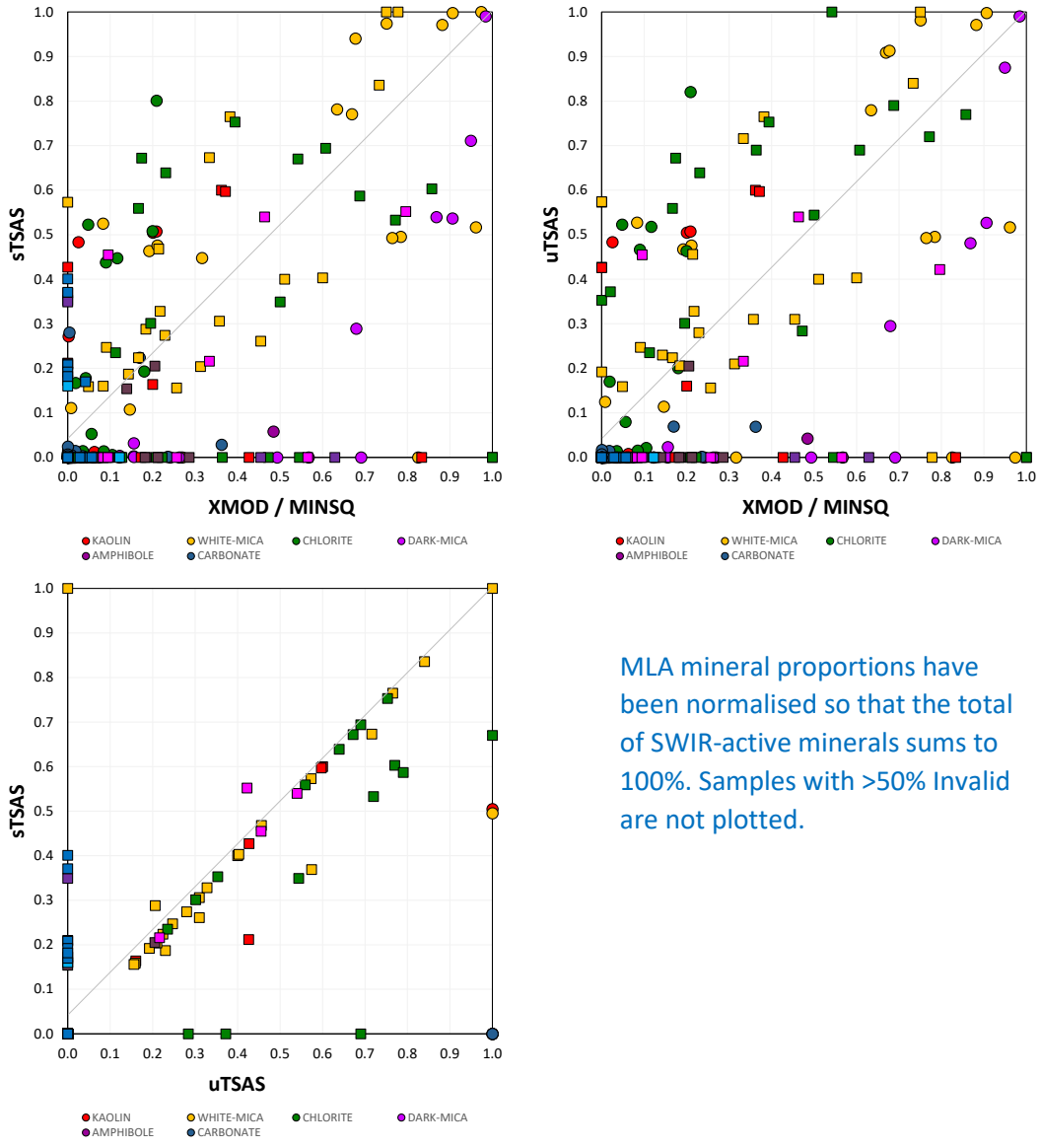

CARBONATE
XMOD
MINSQ
uTSAS
XMOD / MINSQ


EPIDOTE
XMOD
MINSQ
uTSAS
XMOD / MINSQ


CHL/(CHL+SER)
XMOD
MINSQ
uTSAS
XMOD / MINSQ

Mineral proportions from the 2 HyLogging SWIR unmixing algorithms are compared with each other in figure 8. sTSAS and uTSAS produced similar results, with most differences arising from errors of commission for carbonate and omission for chlorite.

Figure 8 (below). Summary plots comparing mineral proportion estimates from SWIR HyLogging with MLA (circles) and MINSQ (squares) and comparing the 2 HyLogging unmixing algorithms with each other.

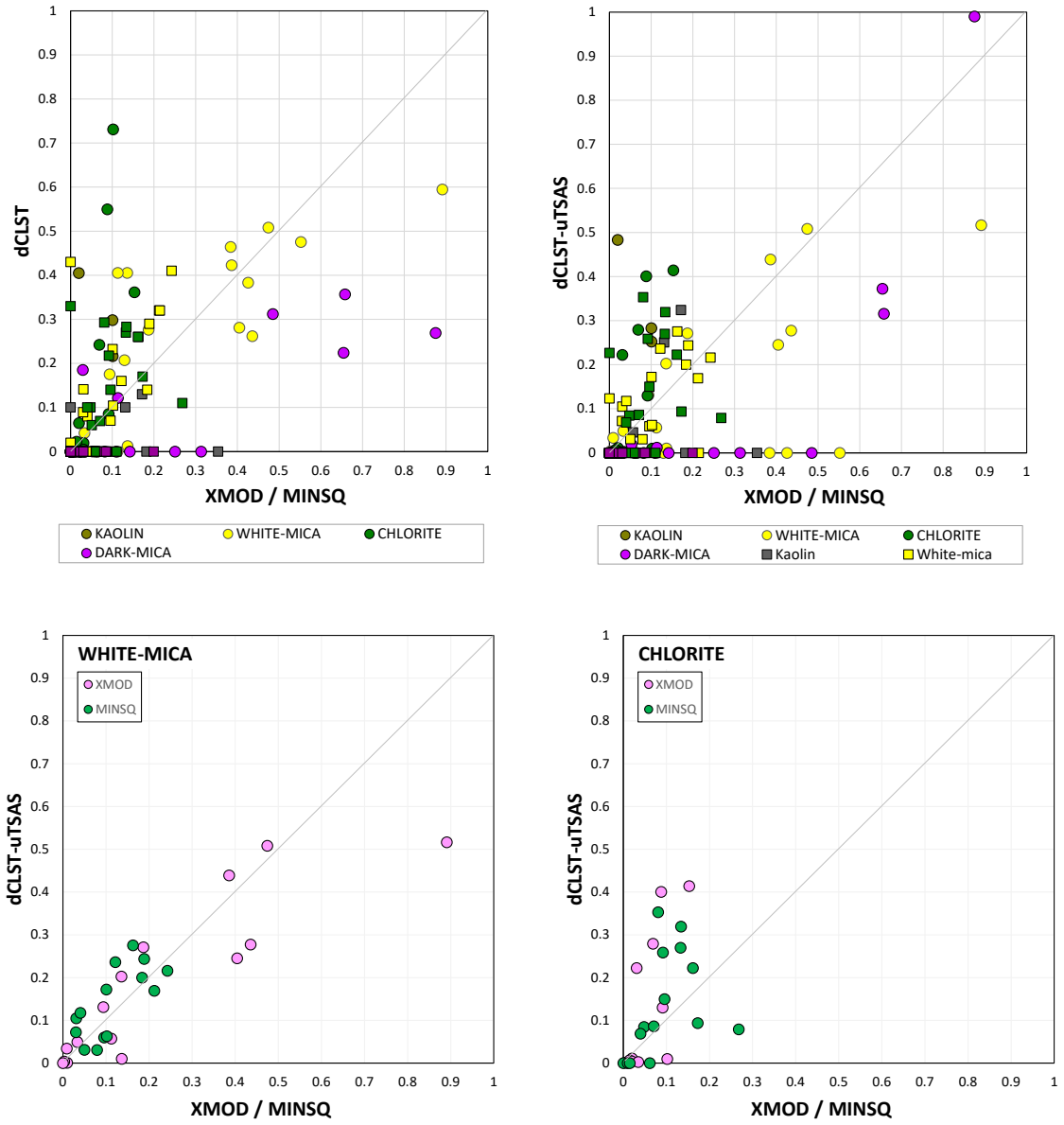


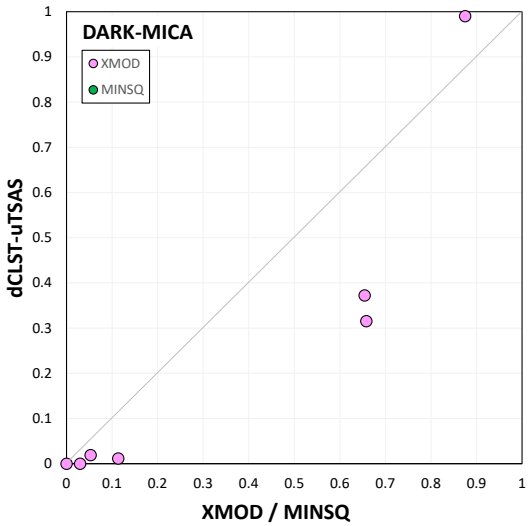
MLA mineral proportions have been normalised so that the total of SWIR-active minerals sums to 100%. Samples with >50% Invalid are not plotted.

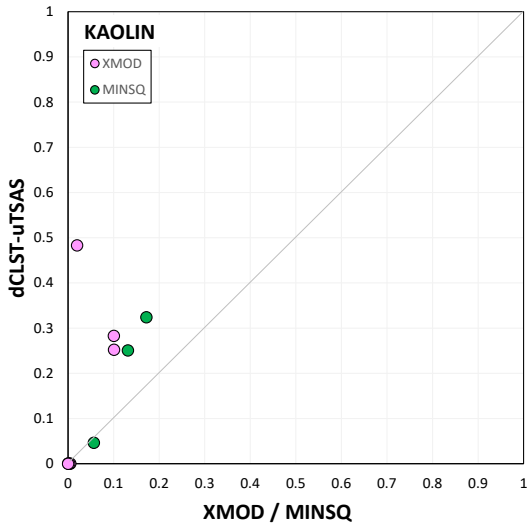
White mica, chlorite, dark mica, kaolin and smectite are all characterised by a single spectral feature in the TIR ('Triangle of death') and the unmixing results for these minerals might be improved by incorporating information from the SWIR. Figure 5 indicates that there is an improved correlation of dCLST with XMOD when the total of white mica, chlorite, dark mica and kaolin was calculated.

Figure 9 plots mineral proportion estimates for the SWIR-active minerals white mica, chlorite, dark mica and kaolin calculated from uTSAS proportions and applied to the TIR white mica + kaolin + chlorite + dark mica total proportion. Significant improvement (compared to results illustrated in figure 5) is apparent for white mica and chlorite, but less so for dark mica and kaolin.

Figure 9 (below). Summary plots comparing mineral proportion estimates for the SWIR-active minerals white mica, chlorite, dark mica and kaolin calculated from uTSAS proportions applied to the TIR white mica + chlorite + dark mica + kaolin total proportion. Samples with >50% Invalid are not included in the plots for individual minerals.







Potential further work

A TSG file collating all 46 samples from Moltzen and Bottrill (2018), Moltzen et al (2020), Green and Reid (2021) and this report is included in Appendix 6. Each sample is augmented with the XMOD/MINSQ results, facilitating efficient testing of existing and new unmixing methods.

Opportunities for further work on the data, or on the samples includes:

- Compare the performance of other unmixing methods e.g. MFEM scalars (Multiple Feature Extraction Method, Laukamp *et al.* 2010), and sTSAT and uTSAT with all minerals turned on.
- Vary the dTSAT parameters Mixture level and Minimum item weight to (i) determine the minimum mixture level to use when applying uTSAT with all minerals available (which rapidly becomes unfeasible as the mixture level increases) and (ii) to test the practice of using a 0% minimum item weight for collections of spectra and reserving the 15% minimum for considering individual spectra.
- Determine the most accurate method for calculating chlorite:white mica, e.g. CLST, TSAT, TSAS and feature depths.
- Use the polished, coated samples:
  - Test mineral identification at the mineral species level by microprobing the MLA mounts for white mica, chlorite, carbonate, dark mica and amphibole. XRD could be used to test kaolins (kaolinite-wx, kaolinite-px) and K-feldspar (microcline, orthoclase).
- Unpolish the samples:
  - MIR scanning.
- Destroy the polished, coated samples:
  - Compare MLA with the validation methods used previously: Crush the samples and analyse them by XRD, MINSQ (from XRD, XRF and microprobe analyses) and thin sections.
- Analyse new samples aiming to extend the rock assemblage library to include epidotes, pyroxenes, garnets, smectites, other AlOH minerals (prehnite, pyrophyllite and topaz), amphiboles, serpentines, tourmalines, alunites, oxides and white mica-chlorite mixtures.

5. Conclusions

HyLogger and MLA data was acquired from 21 samples identified as being potentially challenging for spectral analysis. These were added to 25 less challenging samples previously validated by MINSQ (a least squares mineral weights solution to XRF and mineral composition data). Care was taken to use matched homogenous surfaces of an extent to ensure statistical significance (10cm x 5cm). MLA produced estimates of mineral proportions accurate to within 2% and with an insignificant proportion that could not be identified. HyLogger data was processed with 3 TIR and 2 SWIR spectral unmixing algorithms.

Mineral identifications benefitted from applying the more advanced processing techniques uTSAS and dCLST. However, dTSAT did not improve on dCLST and was prone to not using some minerals used by CLS, especially dark mica.

Minerals identified by the unmixing algorithms were overwhelmingly validated by the MLA at the mineral group level. Exceptions were omitting significant dark mica in 2 samples and K-feldspar and plagioclase in 1 sample each and commissioning kaolin and dark mica in 1 sample each. Less significant failures occurred for K-feldspar, plagioclase, white mica and dark mica (all omitted) and chlorite and amphibole (commissioned).

Small proportions of quartz, chlorite and carbonate were consistently identified in both the SWIR and TIR, but similar proportions of plagioclase, white mica, epidote and dark mica were not.

At the mineral species level, phengite was commonly misidentified as muscovite, chlorite-Fe as chlorite-FeMg and oligoclase not identified in albite-oligoclase mixtures.

Three fine grained samples had significant aspectral SWIR character (carbonaceous shale and crypto-micaceous shale) and returned more than 70% invalid TSA results. Downsampling the spectra to 21 bin averages decreased the number of spectra but significantly increased the proportion of samples that could be unmixed by 20-100%, correctly identifying white mica. The enhancement technique could not detect 14% dark mica or 6% chlorite.

Estimates of mineral proportions improved from sjCLST to dCLST, but dTSAT resulted in poorer estimates, especially for chlorite + biotite and carbonate. The SWIR unmixing techniques sTSAS and uTSAS produced similar results. The proportions of K-feldspar, plagioclase, white mica and amphibole were accurately estimated by dCLST (and dTSAT). Quartz and chlorite ware typically over-estimated relative to MLA by a factor of 1.5 and 1.6 respectively and dark mica was under-estimated by a factor of 0.4.

The relative proportions of common minerals with single features in the 9100-9800nm TIR region (white mica, chlorite, dark mica, smectite and kaolin, the “Triangle of death”) is slightly better estimated using SWIR (TSAS) compared to TIR (TSAT or CLST), especially for the assemblages with significant proportions of white mica and chlorite.

Detailed analysis of dTSAT parameters for a sample comprising 6 common minerals showed that any mix of more than 3 gave similar overall mineral proportions for the sample and that a minimum item weight of 0% gave a slightly more accurate result than 15%.

MLA validation of 21 samples analysed by the HyLogging system has provided valuable dataset that has been used to test unmixing algorithms for a range of simple and challenging mineral assemblages.

References

Berman, M., and Bishof, L. (1997) The algorithms underlying the Spectral Assistant software, CSIRO/AMIRA Project P435 report.

Berman, M., Bischof, L., Lagerstron, R., Guo, Y., Huntington, J., Mason, P. (2011) An unmixing algorithm based on a large library of shortwave infrared spectra, in: Technical Report EP117468, CSIRO Mathematics, Informatics and Statistics, URL: https://publications.csiro.au/rpr/pub?list=SEA&pid=csiro:EP117468.

Berman, M., Bischof, L., Lagerstrom, R., Guo, Y., Huntington, J., Mason, P., Green, A. (2017). A comparison between three sparse unmixing algorithms using a large library of shortwave infrared mineral spectra. IEEE Transactions on Geoscience and Remote Sensing, v.55 (6), p. 3588-3610.

Green, A. (2015) TSA+ and jCLST. URL: http://www.corstruth.com.au/information/FAQ.html#jCLST

Green, A. (2017) mineral occurrence maps of Australia – MOMAs. URL: http://www.corstruth.com.au/information/MOMAs.html

Green, D. and Reid, R. (2021) Rock assemblage library: MLA pilot study. MRT Report Technical Report 23

Gu, Y. and Sugden, T. (1995) A highly integrated SEM-EDS-IP system automated quantitative mineral analysis, Proceedings of the third biennial symposium on SEM imaging and analysis: applications and techniques, University of Melbourne. (Australian Society of Electron Microscopy)

Herrmann, W., Blake, M., Doyle, M., Huston, D., Kamprad, J., Merry, N. and Pontual. S. (2001) Short wavelength infrared (SWIR) spectral analysis of hydrothermal alteration zones associated with base metal sulfide deposits at Rosebery and Western Tharsis, Tasmania, and Highway-Reward, Queensland. Economic geology v. 96, p. 939-955.

Hermann, W. and Berry, R.F. (2002) MINSQ – A least squares spreadsheet method spreadsheet for calculating mineral proportions from whole rock major element analysis. Geochemistry: Exploration, Environment, Analysis, v.2, p, 361-368.

Huntington, J., Yang, K., Quigley, M., Schodlok. M. (2009) Validation of interpreted HyLogging mineralogical results: Parts 1 to 3. GeM^{III} (AMIRA P843) Technical Report 3, chapter 11.

Laukamp, C., Cudahy T., Caccetta M., *et al.* (2010). The uses, abuses and opportunities for hyperspectral technologies and derived geoscience information. AIG Bulletin, 51 (Geo-Computing 2010 Conference, Brisbane, September 2010): p.73-76.

Moltzen, J. and Bottrill, R. (2018): Rock assemblage Library – Report 2018.

Moltzen, J., Bottrill, R., Unwin, L. and Coyte, T. (2020) NVCL Activity 2: Spectral libraries and additional validation of rock assemblage data. Rock Assemblage Library: FY2019/20. NSW Geological Survey Report, June 2020.

Schodlok, M., Green, A., Huntington, J. (2016a). A reference library of thermal infrared mineral reflectance spectra for the HyLogger-3 drill core logging system. Australian Journal of Earth Sciences, v. 63 (8), p.941-949.

Schodlok, M., Whitbourn, L., Huntington, J., Mason, P., Green, A., Berman, M., Coward, D., Connor, P., Wright, W., Jolivet, M., Martinez, R. (2016b) HyLogger-3, a visible to shortwave and thermal infrared reflectance spectrometer system for drill core logging: functional description. Australian Journal of Earth Sciences, v. 63 (8), p.929-940.

Appendix 1. HyLogging and MLA results

Tables below. Results of HyLogger analysis and MLA point counting. Full MLA results are included as Appendix 2.

Note: 0.0% indicates less than 0.1%, blank indicates not detected at all. XMOD sums to less than 100% when there are unlisted non-mineral classes, i.e. unknown, poor spectra, pen marks, sample holder.

	G408251	G408275	G408243
	Kaol+White mica	K-feldspar+Plag	K-feldspar+Plag+White mica(+Qtz)
	Tasmania Basin, Tas	Gramalote Project, Colombia	White Spur, Tas
Number of HyLogger spec	165	338	149
Number of MLA points	35025	38380	117816

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA	32.0%	39.5%	34.9%	33.0%	19.1%	42.3%	41.0%	45.0%	42.3%	22.7%	14.7%	15.2%	19.0%	15.1%	13.4%
K-FELDSPAR			9.1%	16.4%	18.2%		10.3%			4.3%	40.2%	44.9%	34.1%	43.7%	46.3%
PLAGIOCLASE					7.8%	53.4%	45.3%	48.5%	53.4%	62.1%	43.4%	39.0%	41.1%	41.2%	34.3%
GARNET															
PYROXENE															
OLIVINE															
ZEOLITE															
KAOLIN	26.2%	27.2%	29.8%	27.0%	10.0%					0.5%					0.2%
WHITE-MICA	20.9%	33.0%	26.2%	23.5%	43.5%					0.9%			4.2%		3.3%
SMECTITE	11.9%	0.3%									0.3%	0.4%			
OTHER-ALOH															
CHLORITE					0.3%	4.3%	3.3%	6.5%	4.3%	2.0%			0.9%		0.4%
DARK-MICA					0.3%			0.0%		5.3%					
AMPHIBOLE										1.0%					
SERPENTINE															
OTHER-MGOH	3.0%														
EPIDOTE					0.3%										
TOURMALINE															
CARBONATE					0.2%					0.3%			0.7%		0.7%
SULPHATE	6.0%										1.4%	0.5%			
PHOSPHATE					0.0%					0.2%					0.0%
BORATE															
OXIDE										0.2%					
PAL-SEP															
INVALID					0.1%					0.7%					1.3%
	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz	32.0%	39.5%	34.9%	33.0%	19.2%	42.3%	41.0%	45.0%	42.3%	22.9%	14.7%	15.2%	19.0%	15.1%	13.5%
Anorthoclase													0.0%	0.9%	
Microcline			9.1%	16.4%			10.3%				33.4%	38.7%	34.1%	34.7%	
Orthoclase					18.2%					4.3%	6.8%	6.2%		8.1%	46.9%
Albite					7.8%	27.5%	14.5%	22.8%	27.5%	2.5%	41.8%	33.2%	34.0%	39.6%	34.8%
Bytownite															
Labradorite							2.1%								
Andesine						3.9%	6.2%		3.9%						
Oligoclase						22.0%	22.6%	25.7%	22.0%	60.1%	1.6%	5.8%	7.1%	1.6%	
Almandine															
Spessartine															
Augite															
Diopside															
Analcime															
Natrolite															
Phillipsite															
Kaolinite-WX	26.2%	27.2%	29.8%	27.0%	10.1%					0.5%					0.2%
Muscovite	19.6%	33.0%	26.2%	23.5%	4.3%					0.2%			4.2%		0.6%
Phengite	1.3%				39.3%					0.7%					2.8%
Glauconite															
Montmorillonite	11.9%	0.3%													
Nontronite											0.3%	0.4%			
Pyrophyllite															
Topaz															
Chlorite-Fe					0.3%	0.4%		0.0%	0.4%	0.1%					0.4%
Chlorite-FeMg						3.8%	3.3%	6.4%	3.8%	1.9%			0.9%		
Biotite					0.3%			0.0%		5.3%					
Phlogopite															
Stilpnomelane															
Actinolite										1.0%					
AmphiboleML48															
Edenite															
Hornblende															
Riebeckite															
Antigorite															
Lizardite															
Talc	3.0%														
Epidote					0.3%										
Zoisite															
Rhodochrosite															
Siderite													0.7%		
Calcite					0.2%					0.3%					0.7%
Magnesite															
Alunite-K	2.9%										1.4%	0.5%			
Alunite-Na	3.1%														
Gypsum															
Jarosite															
Apatite					0.0%					0.2%					0.0%
Rutile															
OXIDE															
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Siderite

	G408251	G408275	G408243
	Kaol+White mica	K-feldspar+Plag	K-feldspar+Plag+White mica(+Qtz)
	Tasmania Basin, Tas	Gramalote Project, Colombia	White Spur, Tas
Number of HyLogger spec	165	338	149
Number of MLA points	35025	38380	117816

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA									
KAOLIN	50.5%	50.5%	19.9%	1.1%	0.7%	5.9%			4.4%
WHITE-MICA	49.5%	49.5%	77.7%	46.9%	47.2%	7.8%	66.9%	90.9%	51.2%
SMECTITE									
OTHER-ALOH									
CHLORITE			0.7%	15.0%	15.2%	1.7%	0.5%	2.1%	8.0%
DARK-MICA			0.5%	25.9%	26.4%	63.7%			
AMPHIBOLE				0.3%		11.4%			
SERPENTINE				0.1%					
OTHER-MGOH									
EPIDOTE			0.7%	0.4%			0.5%		
TOURMALINE				1.4%					
CARBONATE			0.4%	0.3%		3.3%	19.4%	6.9%	12.9%
SULPHATE							11.8%		
PAL-SEP									
NOTAROK				0.1%			0.9%		
INVALID			0.2%	8.6%	10.4%	6.2%			23.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal									
Dickite									
Kaolinite-PX				0.9%	0.6%				
Kaolinite-WX	50.5%	50.5%	18.3%	0.3%	0.2%	4.9%			5.0%
Nacrite									
Muscovite	25.8%	25.8%	7.8%	34.2%	35.0%	2.4%			11.8%
Paragonite				0.5%	0.7%				
Phengite			71.8%			6.5%	67.5%	90.9%	59.0%
MuscoviticIllite	23.7%	23.7%		16.7%	17.1%				
ParagoniticIllite									
PhengiticIllite									
Montmorillonite									
Saponite									
Diaspore									
Gibbsite									
Topaz									
Chlorite-Fe			0.6%			1.4%			9.2%
Chlorite-FeMg				7.9%	8.2%	18.9%	0.5%	2.1%	
Chlorite-Mg				8.4%	8.9%				
Biotite			0.5%	0.3%	0.2%	53.5%			
Phlogopite				28.0%	29.3%				
Actinolite						9.6%			
Hornblende				0.2%					
Riebeckite				0.1%					
Serpentine				0.1%					
Epidote			0.6%	0.4%					
Zoisite							0.5%		
Tourmaline-Fe				1.6%					
Ankerite				0.1%			17.5%	4.8%	
Siderite				0.1%					
Calcite			0.3%	0.1%		2.8%	2.0%	2.0%	14.9%
Dolomite							0.2%	0.2%	
Magnesite									
Alunite-NH							11.9%		
Gypsum									
Jarosite									
Palygorskite									
Vegetation-Dry									
WhiteMarker									
Wood									
YellowMarker									
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	G408265	G408264	G408260
	Biot+Epid+Amph	Chl+Biot	Shale - crypto-micaceous
	Cethana, Tas	Cethana, Tas	Oonah Prospect, Tas
Number of HyLogger spec	183	364	219
Number of MLA points	39091	37025	35465

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA	39.5%	41.1%	39.9%	46.0%	26.1%	21.4%	22.1%	22.6%	21.6%	14.5%	26.5%	26.5%	33.8%	37.4%	22.1%
K-FELDSPAR					0.3%	0.3%	0.4%			1.1%	5.2%	5.2%	15.4%	6.2%	20.6%
PLAGIOCLASE					0.1%	2.3%	2.5%		2.6%	0.0%					5.1%
GARNET	22.3%	21.5%	19.3%	21.2%	15.6%										
PYROXENE															
OLIVINE															
ZEOLITE				1.7%											
KAOLIN					0.0%					0.1%					0.0%
WHITE-MICA		0.1%	0.2%	0.1%	2.0%					1.0%	53.8%	53.8%	50.8%	56.4%	47.4%
SMECTITE															
OTHER-ALOH		0.4%													
CHLORITE	12.8%	13.5%		30.3%	2.2%	72.6%	69.0%	55.0%	75.8%	8.8%					1.3%
DARK-MICA	23.3%	23.1%	31.2%	0.4%	48.5%	3.0%	5.2%	22.4%		65.4%					2.5%
AMPHIBOLE	2.1%	0.3%	9.5%	0.3%	0.0%	0.3%	0.5%								0.0%
SERPENTINE						0.1%	0.4%								
OTHER-MGOH															
EPIDOTE		0.1%								8.0%					
TOURMALINE															
CARBONATE					0.0%					0.4%					
SULPHATE											14.6%	14.6%			
PHOSPHATE					0.4%					0.5%					0.0%
BORATE															
OXIDE					4.1%										0.2%
PAL-SEP															
INVALID					0.7%					0.2%					0.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz	39.5%	41.1%	39.9%	46.0%	26.3%	21.4%	22.1%	22.6%	21.6%	14.5%	26.5%	26.5%	33.8%	37.4%	22.3%
Anorthoclase															
Microcline						0.3%	0.4%				5.2%	5.2%	14.1%	6.2%	
Orthoclase					0.3%					1.1%			1.2%		20.7%
Albite					0.0%	2.2%	2.3%		2.4%	0.0%					3.9%
Bytownite															
Labradorite															
Andesine															
Oligoclase					0.1%	0.1%	0.2%		0.2%						1.2%
Almandine		0.2%													
Spessartine	22.3%	21.2%	19.3%	21.2%	15.7%										
Augite															
Diopside															
Analcime				0.2%											
Natrolite				0.5%											
Phillipsite				1.0%											
Kaolinite-WX					0.0%					0.1%					0.0%
Muscovite		0.1%	0.2%		1.6%					0.3%	53.8%	53.8%	50.8%	56.4%	10.5%
Phengite					0.4%					0.7%					37.3%
Glauconite				0.1%											
Montmorillonite															
Nontronite															
Pyrophyllite															
Topaz		0.4%													
Chlorite-Fe	0.8%	0.1%			2.2%	0.9%	2.4%	7.6%	0.9%	8.8%					1.3%
Chlorite-FeMg	12.0%	13.3%		30.3%	0.1%	71.7%	66.6%	47.4%	74.9%						0.0%
Biotite	23.3%	23.1%	31.2%		48.9%	3.0%	5.2%	0.0%		65.6%					2.5%
Phlogopite								22.1%							
Stilpnomelane				0.4%				0.2%							
Actinolite			4.4%		0.0%	0.3%	0.0%								0.0%
AmphiboleML48															
Edenite	1.3%	0.3%	5.0%			0.0%	0.4%								
Hornblende			0.1%	0.3%			0.1%								
Riebeckite	0.7%														
Antigorite															
Lizardite						0.1%	0.4%								
Talc															
Epidote										8.0%					
Zoisite		0.1%													
Rhodochrosite															
Siderite															
Calcite					0.0%					0.4%					
Magnesite															
Alunite-K											13.9%	13.9%			
Alunite-Na															
Gypsum											0.7%	0.7%			
Jarosite															
Apatite					0.4%					0.5%					0.0%
Rutile															
OXIDE					4.0%										0.2%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	G408265	G408264	G408260
	Biot+Epid+Amph	Chl+Biot	Shale - crypto-micaceous
	Cethana, Tas	Cethana, Tas	Oonah Prospect, Tas
Number of HyLogger spec	183	364	219
Number of MLA points	39091	37025	35465

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA									
KAOLIN			0.0%			0.1%			0.1%
WHITE-MICA	0.3%	0.0033	0.8%		0.1%	0.8%	99.8%	99.8%	90.6%
SMECTITE									
OTHER-ALOH									
CHLORITE	2.2%		4.2%	25.0%	27.7%	10.5%			3.2%
DARK-MICA	2.2%	2.3%	94.9%	30.2%	25.8%	78.4%			6.0%
AMPHIBOLE			0.0%	0.3%					0.0%
SERPENTINE				0.1%					
OTHER-MGOH									
EPIDOTE				0.4%		9.6%			
TOURMALINE	0.1%			0.1%					
CARBONATE			0.0%	0.4%		0.5%	0.2%	0.2%	
SULPHATE				0.1%					
PAL-SEP									
NOTAROK		0.1%		0.6%	0.6%				
INVALID	95.1%	97.3%	0.0%	42.9%	45.8%	0.1%			0.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal									
Dickite									
Kaolinite-PX									
Kaolinite-WX			0.0%			0.1%			0.1%
Nacrite									
Muscovite	7.0%	9.2%	3.1%			0.4%			20.3%
Paragonite									
Phengite		3.3%	0.7%		0.1%	0.8%	52.1%	52.1%	72.2%
MuscoviticIllite									
ParagoniticIllite									
PhengiticIllite							47.7%	47.7%	
Montmorillonite									
Saponite									
Diaspore									
Gibbsite									
Topaz									
Chlorite-Fe	34.0%		4.1%	2.1%	2.4%	10.5%			2.6%
Chlorite-FeMg	11.3%		0.1%	38.2%	45.8%				0.0%
Chlorite-Mg				4.0%	2.9%				
Biotite	45.4%	87.5%	91.9%	50.4%	44.6%	78.2%			4.8%
Phlogopite				3.1%	2.9%				
Actinolite			0.0%	0.1%					0.0%
Hornblende				0.4%					
Riebeckite				0.1%					
Serpentine				0.1%					
Epidote				0.4%		9.5%			
Zoisite				0.2%					
Tourmaline-Fe	2.2%			0.2%					
Ankerite				0.5%			0.2%	0.2%	
Siderite				0.2%					
Calcite			0.0%			0.5%			
Dolomite									
Magnesite									
Alunite-NH									
Gypsum									
Jarosite				0.1%					
Palygorskite									
Vegetation-Dry									
WhiteMarker									
Wood									
YellowMarker									
	100.0%	100.0%	100.0%	100.0%	98.8%	100.0%	100.0%	100.0%	100.0%

						G408245						
						Chl+Carb+White mica						
						Mt Charter, MRV						
Number of HyLogger spec						160						
Number of MLA points						33404						
TIR				dTSAT Mix=6	dTSAT Mix=5	dTSAT Mix=4	dTSAT Mix=3	dTSAT Mix=6	dTSAT Mix=5	dTSAT Mix=4	dTSAT Mix=3	
Groups	sTSAT	sjCLST	dCLST	Min=0	Min=0	Min=0	Min=0	Min=0.15	Min=0.15	Min=0.15	Min=0.15	XMOD
MISC-SILICATE												
SILICA	33.3%	35.8%	23.7%	19.9%	19.8%	20.5%	33.6%	20.3%	20.3%	20.6%	33.7%	21.7%
K-FELDSPAR	6.3%	0.6%										0.1%
PLAGIOCLASE	1.3%	0.6%	22.5%	30.1%	30.3%	29.6%	3.9%	30.0%	30.0%	29.5%	3.6%	31.8%
GARNET												
PYROXENE												
OLIVINE												
ZEOLITE												
KAOLIN												0.0%
WHITE-MICA			17.5%	21.4%	21.2%	21.2%		20.9%	20.9%	20.9%		9.4%
SMECTITE												
OTHER-ALOH												
CHLORITE	1.2%		8.5%	2.3%	2.4%	3.7%	37.6%	3.4%	3.4%	4.0%	37.9%	9.1%
DARK-MICA												10.9%
AMPHIBOLE												0.3%
SERPENTINE	34.4%	38.7%										
OTHER-MGOH												
EPIDOTE												
TOURMALINE												
CARBONATE	23.6%	24.2%	27.7%	26.4%	26.3%	25.0%	24.8%	25.3%	25.3%	24.9%	24.8%	16.3%
SULPHATE												
PHOSPHATE												0.1%
BORATE												
OXIDE												0.0%
PAL-SEP												
INVALID												0.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Minerals	sTSAT	sjCLST	dCLST									XMOD
Opal												
Quartz	33.3%	35.8%	23.7%	19.9%	19.8%	20.5%	33.6%	20.3%	20.3%	20.6%	33.7%	22.7%
Anorthoclase												
Microcline	6.3%	0.6%										
Orthoclase												0.1%
Albite	1.3%	0.6%	22.5%	30.1%	30.3%	29.6%	3.9%	30.0%	30.0%	29.5%	3.6%	23.3%
Bytownite												
Labradorite												
Andesine												
Oligoclase												5.8%
Almandine												
Spessartine												
Augite												
Diopside												
Analcime												
Natrolite												
Phillipsite												
Kaolinite-WX												0.0%
Muscovite			17.5%	21.4%	21.2%	21.2%		20.9%	20.9%	20.9%		0.8%
Phengite												9.0%
Glauconite												
Montmorillonite												
Nontronite												
Pyrophyllite												
Topaz												
Chlorite-Fe			0.4%	0.3%								9.4%
Chlorite-FeMg	1.2%		8.1%	2.0%	2.4%	3.7%	37.6%	3.4%	3.4%	4.0%	37.9%	0.1%
Biotite												11.4%
Phlogopite												
Stilpnomelane												
Actinolite												0.3%
AmphiboleML48												
Edenite												
Hornblende												
Riebeckite												
Antigorite	34.4%	38.7%										
Lizardite												
Talc												
Epidote												
Zoisite												
Rhodochrosite								0.1%	0.1%			
Siderite	23.6%	24.2%	17.2%	23.1%	23.2%	24.9%	24.8%	24.1%	24.1%	24.9%	24.8%	
Calcite			10.5%	3.3%	3.2%	0.1%		1.1%	1.1%			17.1%
Magnesite												
Alunite-K												
Alunite-Na												
Gypsum												
Jarosite												
Apatite												0.1%
Rutile												
OXIDE												
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
								Calcite				

	G408245 Chl+Carb+White mica Mt Charter, MRV
Number of HyLogger spec	160
Number of MLA points	33404

SWIR

Groups	sTSAS	uTSAS	XMOD
SILICA			
KAOLIN			0.0%
WHITE-MICA	46.2%	46.7%	19.1%
SMECTITE			
OTHER-ALOH			
CHLORITE	50.7%	46.4%	19.9%
DARK-MICA			24.1%
AMPHIBOLE			0.6%
SERPENTINE			
OTHER-MGOH			
EPIDOTE			
TOURMALINE			
CARBONATE	2.8%	6.9%	36.2%
SULPHATE			
PAL-SEP			
NOTAROK	0.2%		
INVALID			0.2%
	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD
Opal			
Dickite			
Kaolinite-PX			
Kaolinite-WX			0.0%
Nacrite			
Muscovite			1.6%
Paragonite			
Phengite	46.2%	46.7%	18.8%
MuscoviticIllite			
ParagoniticIllite			
PhengiticIllite			
Montmorillonite			
Saponite			
Diaspore			
Gibbsite			
Topaz			
Chlorite-Fe	0.6%	1.1%	19.6%
Chlorite-FeMg	50.1%	45.3%	0.3%
Chlorite-Mg			
Biotite			23.7%
Phlogopite			
Actinolite			0.5%
Hornblende			
Riebeckite			
Serpentine			
Epidote			
Zoisite			
Tourmaline-Fe			
Ankerite	2.3%	2.9%	
Siderite	0.4%	3.8%	
Calcite	0.1%	0.2%	35.5%
Dolomite			
Magnesite			
Alunite-NH			
Gypsum			
Jarosite			
Palygorskite			
Vegetation-Dry	0.1%		
WhiteMarker			
Wood	0.1%		
YellowMarker			
	100.0%	100.0%	100.0%

	Chl+Carb+White mica Black River	K-feldspar+Plag+White mica(+Qtz) Hatfield River, MRV	K-feldspar+Plag+White mica(+Qtz) White Spur, MRV
Number of HyLogger spec	258	323	251
Number of MLA points	33825	64051	42736

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	dTSAT (No Chl, Biot) sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA	33.2%	32.1%	30.2%	33.9%	12.4%	11.9%	14.0%	13.6%	11.6%	9.0%	1.5%	1.5%	9.4%	9.6%	9.2%
K-FELDSPAR					6.7%	23.1%	26.9%	23.9%	27.5%	28.9%	0.2%	0.2%	17.1%	17.2%	26.3%
PLAGIOCLASE					14.6%	21.1%	16.2%	17.5%	18.5%	16.7%	51.5%	51.5%	33.0%	33.0%	21.0%
GARNET															
PYROXENE											4.1%	4.1%			
OLIVINE															
ZEOLITE															
KAOLIN					0.2%					0.0%					0.1%
WHITE-MICA	17.9%	43.9%	40.5%	24.9%	13.6%	42.8%	42.6%	42.3%	42.2%	38.6%	34.2%	34.2%	40.5%	40.3%	11.3%
SMECTITE						0.1%									
OTHER-ALOH						0.1%									
CHLORITE			2.0%	9.6%	3.1%		0.1%	2.2%	0.2%	1.4%					6.5%
DARK-MICA					31.3%	0.3%				2.6%					25.0%
AMPHIBOLE					0.6%	0.1%				0.0%					0.3%
SERPENTINE	22.2%					0.1%									
OTHER-MGOH															
EPIDOTE															
TOURMALINE															
CARBONATE	26.7%	24.1%	27.3%	31.6%	15.0%		0.2%	0.4%		0.7%					0.1%
SULPHATE						0.3%					6.6%	6.6%			
PHOSPHATE					0.0%	0.1%				0.3%					0.1%
BORATE															
OXIDE					0.1%					0.0%	1.9%	1.9%			0.0%
PAL-SEP															
INVALID					2.2%					1.6%					0.0%
	100.0%	100.0%	100.0%	100.0%	99.8%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	99.9%

Biotite not used, even when offered

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz	33.2%	32.1%	30.2%	33.9%	12.7%	11.9%	14.0%	13.6%	11.6%	9.2%	1.5%	1.5%	9.4%	9.6%	9.2%
Anorthoclase															
Microcline						23.1%	26.9%	23.9%	27.4%		0.0%	0.0%	17.1%	17.0%	
Orthoclase					6.8%	0.1%		0.0%	0.2%	29.4%	0.2%	0.2%		0.2%	26.3%
Albite					9.5%	18.9%	12.6%	14.0%	17.3%	12.8%	51.5%	51.5%	32.9%	32.5%	11.3%
Bytownite															
Labradorite						0.1%	0.1%	0.1%	0.1%						
Andesine															
Oligoclase					5.5%	2.1%	3.5%	3.4%	1.1%	4.2%			0.1%	0.4%	9.8%
Almandine															
Spessartine															
Augite											4.1%	4.1%			
Diopside															
Analcime															
Natrolite															
Phillipsite															
Kaolinite-WX					0.2%					0.0%					0.1%
Muscovite	17.9%	43.9%	40.5%	24.9%	0.2%	42.8%	42.3%	41.9%	42.2%	2.8%	15.5%	15.5%	28.4%	14.3%	1.6%
Phengite					13.7%		0.3%	0.4%		36.5%	18.7%	18.7%	12.2%	26.0%	9.8%
Glauconite															
Montmorillonite						0.1%									
Nontronite															
Pyrophyllite						0.1%									
Topaz															
Chlorite-Fe				0.5%	3.1%		0.0%	0.1%		1.5%					1.0%
Chlorite-FeMg			2.0%	9.1%	0.1%		0.1%	2.2%	0.2%						5.5%
Biotite					32.1%	0.3%				2.7%					25.1%
Phlogopite															
Stilpnomelane															
Actinolite					0.7%					0.0%					0.3%
AmphiboleML48															
Edenite															
Hornblende						0.1%									
Riebeckite															
Antigorite	22.2%					0.1%									
Lizardite															
Talc															
Epidote															
Zoisite															
Rhodochrosite															
Siderite	26.6%	0.4%	24.3%	15.7%			0.2%	0.4%							
Calcite	0.1%	23.7%	3.0%	15.9%	15.3%			0.0%		0.7%					0.1%
Magnesite															
Alunite-K						0.3%					6.6%	6.6%			
Alunite-Na															
Gypsum															
Jarosite															
Apatite					0.0%	0.1%				0.3%					0.1%
Rutile											1.9%	1.9%			
OXIDE											1.9%	1.9%			
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	101.9%	101.9%	100.0%	100.0%	100.0%
			Calcite					Calcite							

	G408246	G408248	G408255
	Chl+Carb+White mica	K-feldspar+Plag+White mica(+Qtz)	K-feldspar+Plag+White mica(+Qtz)
	Black River	Hatfield River, MRV	White Spur, MRV
Number of HyLogger spec	258	323	251
Number of MLA points	33825	64051	42736

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA									
KAOLIN			0.3%			0.1%			0.2%
WHITE-MICA	47.5%	47.5%	20.4%	97.0%	97.0%	87.7%			26.9%
SMECTITE									
OTHER-ALOH							0.1%		
CHLORITE	52.2%	52.2%	4.6%	1.4%	1.4%	3.5%			2.9%
DARK-MICA			47.6%			6.4%			69.1%
AMPHIBOLE			1.0%			0.0%			0.8%
SERPENTINE									
OTHER-MGOH									
EPIDOTE	0.2%	0.2%		0.2%	0.2%		1.0%	0.8%	
TOURMALINE									
CARBONATE	0.1%	0.1%	22.8%	1.5%	1.5%	1.8%			0.2%
SULPHATE							0.2%		
PAL-SEP									
NOTAROK							0.4%		
INVALID			3.3%			0.6%	98.4%	99.2%	0.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal									
Dickite									
Kaolinite-PX									
Kaolinite-WX			0.3%			0.1%			0.1%
Nacrite									
Muscovite			0.3%			6.4%			3.6%
Paragonite									
Phengite	12.0%	12.0%	21.0%	94.3%	94.3%	82.5%			22.6%
MuscoviticIllite									
ParagoniticIllite									
PhengiticIllite	35.5%	35.5%		2.7%	2.7%				
Montmorillonite									
Saponite									
Diaspore									
Gibbsite							5.3%		
Topaz									
Chlorite-Fe	1.2%	1.2%	4.8%	0.1%	0.1%	3.3%			2.4%
Chlorite-FeMg	50.9%	50.9%	0.1%	1.3%	1.3%				12.6%
Chlorite-Mg									
Biotite			49.1%			6.1%			57.9%
Phlogopite									
Actinolite			1.0%			0.0%			0.6%
Hornblende									
Riebeckite									
Serpentine									
Epidote	0.2%	0.2%		0.1%	0.1%		25.0%	50.0%	
Zoisite				0.1%	0.1%		35.4%	50.0%	
Tourmaline-Fe									
Ankerite	0.1%	0.1%		1.3%	1.3%				
Siderite									
Calcite			23.4%			1.7%			0.2%
Dolomite				0.2%	0.2%				
Magnesite									
Alunite-NH									
Gypsum									
Jarosite							9.3%		
Palygorskite									
Vegetation-Dry									
WhiteMarker							25.0%		
Wood									
YellowMarker									
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	G408276					G408277					G408249				
	K-feldspar+Plag+White mica(+Qtz)					K-feldspar+Plag+White mica(+Qtz)					Kaol+White mica				
	Ernest Henry					Pine Creek					Mackintosh, MRV				
Number of HyLogger spec	549					436					222				
Number of MLA points	22779					40975					27658				

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA					1.4%	2.6%	5.0%	0.0%	3.5%	1.4%					3.9%
K-FELDSPAR	62.5%	57.2%	72.4%	13.5%	56.1%	20.6%	26.5%	10.1%	13.6%	18.4%					0.8%
PLAGIOCLASE	11.0%	14.7%			0.3%	48.1%	34.1%	50.6%	46.8%	28.9%					3.1%
GARNET															
PYROXENE						1.3%	1.4%								
OLIVINE															
ZEOLITE															
KAOLIN					0.0%					0.1%	45.0%	45.0%	40.5%	44.9%	2.0%
WHITE-MICA	12.8%	27.9%	27.6%	86.5%	18.7%	8.7%	5.4%	20.7%	17.9%	12.9%	46.7%	46.7%	59.5%	55.1%	89.1%
SMECTITE	0.0%	0.0%					0.1%				0.9%	0.9%			
OTHER-ALOH						0.1%	0.2%								
CHLORITE	3.8%				1.9%	0.9%	0.3%			8.2%					0.5%
DARK-MICA	0.5%				3.4%	13.0%	19.7%	18.5%	18.3%	2.9%	6.9%	6.9%			0.2%
AMPHIBOLE					0.0%	2.3%	4.5%			22.5%					0.5%
SERPENTINE	2.9%														
OTHER-MGOH						2.3%									
EPIDOTE		0.1%													
TOURMALINE															
CARBONATE					0.2%					0.2%	0.6%	0.6%			
SULPHATE	4.0%						2.9%								
PHOSPHATE	2.3%				0.0%	0.0%									0.0%
BORATE															
OXIDE	0.1%				16.4%					3.5%					0.0%
PAL-SEP															
INVALID					1.0%					0.7%					0.0%
	100.0%	100.0%	100.0%	100.0%	99.4%	100.0%	100.0%	100.0%	100.0%	99.8%	100.0%	100.0%	100.0%	100.0%	99.9%

Goethite used when offered, magnetite not used

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz				0.9%	1.5%	2.6%	5.0%	0.0%	3.5%	1.4%			0.0%		3.9%
Anorthoclase				0.4%											
Microcline	50.7%	47.1%	71.4%	33.3%		20.6%	25.8%	7.7%	13.4%						
Orthoclase	11.8%	10.2%	1.0%	14.9%	57.6%		0.7%	2.4%	0.1%	18.8%					0.8%
Albite	7.6%	1.1%		0.3%	0.2%	2.0%	1.0%	10.5%	3.9%	9.0%					1.4%
Bytownite								5.1%	0.1%						
Labradorite		0.2%				45.6%	32.5%	34.4%	42.7%						
Andesine		0.1%		0.3%			0.1%	0.1%	0.1%						
Oligoclase	3.4%	13.3%		17.4%	0.1%	0.5%	0.5%	0.6%		20.5%					1.7%
Almandine															
Spessartine															
Augite						1.3%	1.4%								
Diopside															
Analcime															
Natrolite															
Phillipsite															
Kaolinite-WX					0.0%					0.1%	45.0%	45.0%	40.5%	44.9%	2.0%
Muscovite	11.1%	19.4%	27.2%	22.6%	2.4%	8.7%	5.4%	20.7%	17.9%	0.4%	45.5%	45.5%	46.6%	51.8%	13.6%
Phengite	1.7%	8.5%	0.5%	9.8%	16.8%					12.8%	1.3%	1.3%	12.8%	3.2%	75.5%
Glauconite															
Montmorillonite		0.0%					0.1%				0.1%	0.1%			
Nontronite	0.0%										0.8%	0.8%			
Pyrophyllite						0.1%									
Topaz							0.2%								
Chlorite-Fe					1.9%	0.9%	0.2%			1.5%					0.4%
Chlorite-FeMg	3.8%				0.1%		0.2%			6.9%					0.0%
Biotite	0.5%				3.5%	13.0%	19.7%	2.8%	3.9%	3.0%	6.9%	6.9%			0.2%
Phlogopite								15.6%	14.5%						
Stilpnomelane								0.1%							
Actinolite					0.0%					22.9%					0.5%
AmphiboleML48															
Edenite															
Hornblende						0.1%	4.4%								
Riebeckite						2.2%	0.1%								
Antigorite	2.9%														
Lizardite															
Talc						2.3%									
Epidote															
Zoisite		0.1%													
Rhodochrosite															
Siderite															
Calcite					0.2%					0.2%					
Magnesite											0.6%	0.6%			
Alunite-K	3.9%														
Alunite-Na	0.2%														
Gypsum															
Jarosite							2.9%								
Apatite	2.3%				0.0%	0.0%									0.0%
Rutile	0.1%														
OXIDE	0.1%				15.8%					2.6%					
	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	G408276	G408277	G408249
	K-feldspar+Plag+White mica(+Qtz)	K-feldspar+Plag+White mica(+Qtz)	Kaol+White mica
	Ernest Henry	Pine Creek	Mackintosh, MRV
Number of HyLogger spec	549	436	222
Number of MLA points	22779	40975	27658

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA									
KAOLIN	0.3%	0.2%	0.2%	0.2%		0.2%	48.3%	48.3%	2.5%
WHITE-MICA	71.0%	71.2%	75.0%	0.4%		31.1%	51.7%	51.7%	96.1%
SMECTITE	1.8%	1.7%		0.2%					
OTHER-ALOH	0.2%			2.0%					
CHLORITE	1.0%	1.1%	8.4%			3.7%			0.6%
DARK-MICA	0.2%		15.5%			7.2%			0.2%
AMPHIBOLE			0.0%			55.7%			0.6%
SERPENTINE									
OTHER-MGOH									
EPIDOTE				0.8%					
TOURMALINE	1.1%								
CARBONATE	0.4%		0.8%	0.2%		0.4%			
SULPHATE	0.1%	0.1%		0.1%					
PAL-SEP									
NOTAROK									
INVALID	23.9%	25.6%	0.1%	96.1%	100.0%	1.7%			0.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal									
Dickite	0.1%	0.1%							
Kaolinite-PX	0.2%	0.2%		5.9%			48.3%	48.3%	
Kaolinite-WX			0.1%			0.2%			2.1%
Nacrite	0.1%								
Muscovite	21.9%	22.0%	9.6%	3.8%		0.8%			14.8%
Paragonite									
Phengite	71.4%	73.7%	67.6%	5.9%		26.8%	0.3%	0.3%	81.9%
Muscoviticlllite									
Paragoniticlllite									
Phengiticlllite							51.4%	51.4%	
Montmorillonite	2.3%	2.2%		4.8%					
Saponite	0.1%	0.1%							
Diaspore	0.1%								
Gibbsite	0.1%			4.2%					
Topaz				46.1%					
Chlorite-Fe	0.3%	0.4%	7.6%			3.2%			0.5%
Chlorite-FeMg	0.9%	0.9%	0.4%			14.4%			0.0%
Chlorite-Mg	0.1%	0.1%							
Biotite	0.3%		14.0%			6.2%			0.2%
Phlogopite									
Actinolite			0.0%			48.1%			0.5%
Hornblende									
Riebeckite									
Serpentine									
Epidote									
Zoisite				19.6%					
Tourmaline-Fe	1.5%								
Ankerite	0.4%								
Siderite	0.1%								
Calcite			0.7%			0.3%			
Dolomite	0.1%			6.1%					
Magnesite									
Alunite-NH									
Gypsum				3.6%					
Jarosite	0.2%	0.2%							
Palygorskite									
Vegetation-Dry									
WhiteMarker									
Wood									
YellowMarker									
	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%

	G408250	G408254
	Kaol+White mica	Sandstone - micaceous
	Tasmania Basin	Lefroy
Number of HyLogger spec	185	297
Number of MLA points	22779	35623

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE										
SILICA	33.8%	33.9%	32.1%	33.8%	20.6%	81.5%	91.0%	90.2%		64.5%
K-FELDSPAR	4.7%	4.7%	13.2%	10.9%	15.4%		1.2%			1.9%
PLAGIOCLASE	2.3%	2.0%	4.9%		11.3%	1.1%	2.5%	8.5%		12.5%
GARNET										
PYROXENE										
OLIVINE										
ZEOLITE										
KAOLIN	19.0%	19.0%	21.6%	22.3%	10.1%					0.3%
WHITE-MICA	30.6%	32.9%	28.1%	33.0%	40.4%	0.2%	4.1%	1.3%		13.6%
SMECTITE							0.1%			
OTHER-ALOH										
CHLORITE					0.6%		0.2%			3.5%
DARK-MICA					0.1%					3.0%
AMPHIBOLE					0.1%					0.3%
SERPENTINE										
OTHER-MGOH	9.4%	6.8%								
EPIDOTE										
TOURMALINE										
CARBONATE					0.5%					0.0%
SULPHATE						17.2%	0.9%			
PHOSPHATE	0.3%	0.7%			0.0%					0.2%
BORATE										
OXIDE					0.5%					0.0%
PAL-SEP										
INVALID					0.2%					0.1%
	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%		99.8%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal										
Quartz	33.8%	33.9%	32.1%	33.8%	20.7%	81.5%	91.0%	90.2%		64.7%
Anorthoclase										
Microcline	4.4%	4.3%	13.2%	10.9%			1.2%			
Orthoclase	0.3%	0.4%			15.5%					1.9%
Albite	2.3%	2.0%	4.9%		4.3%	1.1%	2.5%	8.5%		11.0%
Bytownite										
Labradorite										
Andesine										
Oligoclase					7.0%					1.5%
Almandine										
Spessartine										
Augite										
Diopside										
Analcime										
Natrolite										
Phillipsite										
Kaolinite-WX	19.0%	19.0%	21.6%	22.3%	10.1%					0.3%
Muscovite	30.2%	32.9%	28.1%	33.0%	3.5%	0.2%	4.1%	1.3%		1.5%
Phengite	0.3%				37.0%					12.1%
Glauconite										
Montmorillonite							0.1%			
Nontronite										
Pyrophyllite										
Topaz										
Chlorite-Fe					0.6%					3.4%
Chlorite-FeMg							0.2%			0.0%
Biotite					0.1%					3.0%
Phlogopite										
Stilpnomelane										
Actinolite					0.1%					0.3%
AmphiboleML48										
Edenite										
Hornblende										
Riebeckite										
Antigorite										
Lizardite										
Talc	9.4%									
Epidote										
Zoisite										
Rhodochrosite										
Siderite										
Calcite					0.5%					0.0%
Magnesite										
Alunite-K						16.0%	0.2%			
Alunite-Na						1.2%	0.7%			
Gypsum										
Jarosite										
Apatite	0.3%	0.7%			0.0%					0.2%
Rutile										
OXIDE					0.5%					0.0%
	100.0%	93.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%

	G408250	G408254
	Kaol+White mica	Sandstone - micaceous
	Tasmania Basin	Lefroy
Number of HyLogger spec	185	297
Number of MLA points	22779	35623

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA						
KAOLIN	50.7%	50.7%	20.8%		0.1%	1.4%
WHITE-MICA	49.3%	49.3%	76.2%	76.2%	76.5%	63.2%
SMECTITE				0.1%	0.1%	
OTHER-ALOH				0.2%		
CHLORITE			1.2%	18.8%	19.7%	18.0%
DARK-MICA			0.3%	0.1%	0.2%	15.5%
AMPHIBOLE			0.2%			1.6%
SERPENTINE						
OTHER-MGOH						
EPIDOTE				0.2%	0.2%	
TOURMALINE				0.2%		
CARBONATE			1.1%	2.4%	1.6%	0.0%
SULPHATE				0.1%		
PAL-SEP						
NOTAROK				0.3%		
INVALID			0.3%	1.4%	1.5%	0.2%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal						
Dickite					0.1%	
Kaolinite-PX						
Kaolinite-WX	50.7%	50.7%	19.4%			1.3%
Nacrite						
Muscovite	14.4%	13.9%	6.8%	3.1%	2.6%	7.5%
Paragonite						
Phengite			71.2%	74.2%	75.1%	58.6%
MuscoviticIllite	34.8%	35.4%				
ParagoniticIllite						
PhengiticIllite						
Montmorillonite				0.1%	0.1%	
Saponite						
Diaspore						
Gibbsite				0.2%		
Topaz						
Chlorite-Fe			1.1%	3.3%	3.6%	16.6%
Chlorite-FeMg				15.5%	16.2%	0.1%
Chlorite-Mg				0.2%	0.2%	
Biotite			0.3%	0.1%	0.2%	14.4%
Phlogopite						
Actinolite			0.2%			1.5%
Hornblende						
Riebeckite						
Serpentine						
Epidote				0.2%	0.2%	
Zoisite						
Tourmaline-Fe				0.2%		
Ankerite				1.6%	1.3%	
Siderite				0.2%	0.2%	
Calcite			1.0%			0.0%
Dolomite				0.3%	0.2%	
Magnesite				0.3%		
Alunite-NH				0.1%		
Gypsum						
Jarosite				0.1%		
Palygorskite						
Vegetation-Dry						
WhiteMarker				0.2%		
Wood				0.1%		
YellowMarker						
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	G408253					G408261					G408262				
	Shale - crypto-micaceous					Shale - graphitic					Shale - graphitic				
	Lefroy					Oonah					Oonah				
Number of HyLogger spec	243					132					301				
Number of MLA points	33219					35623					37147				

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA	38.9%	42.6%	53.1%	53.9%	20.6%	49.3%	48.0%	50.6%	47.6%	25.3%		36.0%	40.1%	40.4%	16.6%
K-FELDSPAR					15.1%	2.2%				10.5%		3.9%	12.4%	6.1%	15.6%
PLAGIOCLASE					7.7%					11.9%		1.9%			10.3%
GARNET															
PYROXENE															
OLIVINE															
ZEOLITE															
KAOLIN					0.1%					0.4%					0.1%
WHITE-MICA	43.8%	45.5%	46.4%	46.1%	38.4%	15.3%	25.1%	37.9%	45.6%	42.6%		49.5%	47.6%	53.5%	55.2%
SMECTITE		0.4%										0.1%			
OTHER-ALOH		0.2%										0.1%			
CHLORITE		0.0%	0.5%		3.1%	13.4%	6.2%	11.4%	6.8%	6.0%					0.3%
DARK-MICA					14.2%					2.2%					1.1%
AMPHIBOLE					0.1%					0.0%					0.0%
SERPENTINE															
OTHER-MGOH						19.7%	20.7%					3.1%			
EPIDOTE															
TOURMALINE															
CARBONATE										0.0%					
SULPHATE	17.1%	10.1%										5.5%			
PHOSPHATE					0.0%					0.0%					0.0%
BORATE															
OXIDE	0.2%	1.2%			0.0%					0.0%					
PAL-SEP															
INVALID					0.5%					1.0%					0.7%
	100.0%	100.0%	100.0%	100.0%	99.8%	99.9%	100.0%	99.9%	100.0%	99.9%		100.0%	100.0%	100.0%	100.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz	38.9%	42.6%	53.1%	53.9%	20.7%	49.3%	48.0%	50.6%	47.6%	25.6%		36.0%	40.1%	40.4%	16.7%
Anorthoclase															
Microcline						2.2%						3.6%	12.4%	6.1%	
Orthoclase					15.2%					10.6%		0.2%	0.0%		15.7%
Albite					5.9%					9.5%		1.9%			9.1%
Bytownite															
Labradorite															
Andesine															
Oligoclase					1.9%					2.5%					1.3%
Almandine															
Spessartine															
Augite															
Diopside															
Analcime															
Natrolite															
Phillipsite															
Kaolinite-WX					0.1%					0.4%					0.1%
Muscovite	43.8%	45.5%	46.4%	46.1%	1.8%	15.3%	25.1%	37.9%	45.6%	2.2%		49.5%	47.6%	53.5%	1.4%
Phengite					36.8%					40.9%					54.2%
Glauconite															
Montmorillonite		0.4%										0.1%			
Nontronite															
Pyrophyllite															
Topaz		0.2%										0.1%			
Chlorite-Fe		0.0%	0.4%		3.0%	9.1%	6.2%	2.4%		6.0%					0.3%
Chlorite-FeMg			0.0%		0.1%	4.4%	1.0%	9.1%	6.8%						0.0%
Biotite					14.3%					2.2%					1.1%
Phlogopite															
Stilpnomelane															
Actinolite					0.1%					0.0%					0.0%
AmphiboleML48															
Edenite															
Hornblende															
Riebeckite															
Antigorite															
Lizardite															
Talc						19.7%	20.7%					3.1%			
Epidote															
Zoisite															
Rhodochrosite															
Siderite															
Calcite										0.0%					
Magnesite															
Alunite-K	4.4%											5.4%			
Alunite-Na	12.7%	10.1%													
Gypsum												0.0%			
Jarosite															
Apatite					0.0%					0.0%					0.0%
Rutile	0.2%	1.2%													
OXIDE	0.2%	1.2%			0.0%					0.0%					
	100.2%	101.2%	100.0%	100.0%	100.0%	100.0%	101.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%

	G408253			G408261			G408262		
	Shale - crypto-micaceous			Shale - graphitic			Shale - graphitic		
	Lefroy			Oonah			Oonah		
Number of HyLogger spec	243			132			301		
Number of MLA points	33219			35623			37147		

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA									
KAOLIN			0.1%						0.2%
WHITE-MICA	23.6%	21.6%	67.7%	20.0%	20.0%	83.2%	1.0%		97.3%
SMECTITE	0.7%						0.3%		
OTHER-ALOH	1.1%	0.1%					1.0%		
CHLORITE	1.3%	1.9%	5.6%			12.3%			0.5%
DARK-MICA			26.3%			4.4%			1.9%
AMPHIBOLE			0.3%						0.1%
SERPENTINE									
OTHER-MGOH									
EPIDOTE	0.4%								
TOURMALINE									
CARBONATE	0.2%	0.2%							
SULPHATE	0.1%								
PAL-SEP									
NOTAROK	0.3%						0.7%		
INVALID	72.2%	76.2%	0.0%	80.0%	80.0%	0.1%	97.0%	100.0%	0.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal						33.1%			
Dickite									
Kaolinite-PX									
Kaolinite-WX			0.1%			0.3%			0.2%
Nacrite									
Muscovite	6.3%	7.6%	3.2%	20.0%	20.0%	1.8%	22.2%		2.5%
Paragonite									
Phengite	78.7%	83.4%	65.5%			14.2%	11.1%		94.9%
MuscoviticIllite									
ParagoniticIllite									
PhengiticIllite									
Montmorillonite	2.7%						11.1%		
Saponite									
Diaspore									
Gibbsite	0.6%								
Topaz	3.4%	0.3%					33.3%		
Chlorite-Fe	1.4%	2.6%	5.4%			4.0%			0.5%
Chlorite-FeMg	3.4%	5.4%	0.1%			0.0%			0.0%
Chlorite-Mg									
Biotite			25.4%			3.5%			1.9%
Phlogopite									
Actinolite			0.3%			0.4%			0.1%
Hornblende									
Riebeckite									
Serpentine									
Epidote	0.9%								
Zoisite	0.5%								
Tourmaline-Fe									
Ankerite	0.6%	0.7%							
Siderite									
Calcite						0.0%			
Dolomite									
Magnesite									
Alunite-NH	0.4%								
Gypsum									
Jarosite									
Palygorskite									
Vegetation-Dry	0.5%								
WhiteMarker							11.1%		
Wood	0.6%						11.1%		
YellowMarker									
	100.0%	100.0%	100.0%	20.0%	20.0%	57.3%	100.0%		100.0%

	G408266					G408268					G408279				
	Chl+Amph					Chl+Amph					Chl+Biot				
	Cleveland					Cleveland					Yilgarn - Ravensthorp				
Number of HyLogger spec	147					174					98				
Number of MLA points	39994					40827					30752				

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA	17.8%	12.0%	16.6%	20.3%	11.3%	38.2%	40.1%	39.9%	39.0%	25.1%					0.0%
K-FELDSPAR	3.5%	18.6%			2.5%					0.1%					
PLAGIOCLASE	1.0%				7.6%	0.3%	0.5%			0.2%					0.0%
GARNET												0.1%			
PYROXENE	1.4%	4.6%					0.1%								
OLIVINE															
ZEOLITE															
KAOLIN					0.0%					0.0%					
WHITE-MICA		2.5%			11.2%	0.1%	0.1%			0.3%					
SMECTITE		1.4%													
OTHER-ALOH															
CHLORITE	15.6%	55.0%	36.1%	24.2%	15.3%	20.0%	22.2%	24.2%	21.0%	6.9%	69.9%	2.2%	73.1%	70.8%	10.2%
DARK-MICA	1.7%	1.3%	12.2%	7.2%	11.3%	38.7%	35.4%	35.7%	40.1%	65.8%	30.1%	97.7%	26.9%	29.2%	87.5%
AMPHIBOLE	55.9%	3.8%	35.1%	48.4%	35.4%		0.4%	0.2%		0.0%					1.5%
SERPENTINE	0.1%						0.1%								
OTHER-MGOH						2.8%									
EPIDOTE		0.2%			1.0%										
TOURMALINE															
CARBONATE					0.4%		0.2%			1.0%					
SULPHATE	3.1%	0.7%					0.2%								
PHOSPHATE					0.3%					0.0%					
BORATE															
OXIDE					2.8%		0.7%			0.3%					0.0%
PAL-SEP															
INVALID					0.5%					0.1%					0.6%
	100.0%	100.0%	100.0%	100.0%	99.6%	100.0%	100.0%	100.0%	100.0%	99.8%	100.0%	100.0%	100.0%	100.0%	99.8%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz	17.8%	12.0%	16.6%	20.3%	11.9%	38.2%	40.1%	39.9%	39.0%	25.2%					0.0%
Anorthoclase															
Microcline	2.4%	8.4%													
Orthoclase	1.1%	10.1%			2.6%					0.1%					
Albite					0.1%	0.3%	0.5%			0.1%					0.0%
Bytownite															
Labradorite															
Andesine	1.0%														
Oligoclase					7.9%					0.0%					0.0%
Almandine												0.1%			
Spessartine															
Augite	1.4%						0.1%								
Diopside		4.6%													
Analcime															
Natrolite															
Phillipsite															
Kaolinite-WX					0.0%					0.0%					
Muscovite		1.8%			0.6%	0.1%	0.1%			0.0%					
Phengite		0.7%			11.2%					0.3%					
Glauconite															
Montmorillonite		1.4%													
Nontronite															
Pyrophyllite															
Topaz															
Chlorite-Fe	12.6%	48.9%	28.0%	20.1%	16.0%	3.1%		1.4%	0.5%	6.6%		0.1%	4.7%		0.0%
Chlorite-FeMg	2.9%	6.1%	8.1%	4.0%	0.0%	16.9%	22.2%	22.9%	20.5%	0.4%	69.9%	2.2%	68.4%	70.8%	10.3%
Biotite	1.7%	1.3%	11.5%	5.5%	11.9%	38.7%	35.4%	35.7%	40.1%	66.1%	30.1%	97.7%	26.9%	29.2%	88.2%
Phlogopite			0.7%	1.7%											
Stilpnomelane															
Actinolite		0.9%	18.4%	8.4%	37.1%			0.2%		0.0%					1.5%
AmphiboleML48			0.3%												
Edenite	23.0%	0.7%	1.6%	12.8%											
Hornblende	32.9%	1.3%	14.8%	27.2%			0.4%								
Riebeckite		0.8%													
Antigorite							0.1%								
Lizardite	0.1%														
Talc						2.8%									
Epidote															
Zoisite		0.2%													
Rhodochrosite										1.0%					
Siderite							0.1%								
Calcite					0.4%		0.1%								
Magnesite															
Alunite-K	3.1%	0.4%													
Alunite-Na															
Gypsum															
Jarosite		0.2%					0.2%								
Apatite					0.3%					0.0%					
Rutile							0.7%								
OXIDE							0.7%			0.0%					0.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	G408266	G408268	G408279
	Chl+Amph	Chl+Amph	Chl+Biot
	Cleveland	Cleveland	Yilgarn - Ravensthorp
Number of HyLogger spec	147	174	98
Number of MLA points	39994	40827	30752

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA									
KAOLIN			0.0%			0.0%			
WHITE-MICA	10.3%	10.9%	14.5%	0.7%	0.7%	0.4%			
SMECTITE									
OTHER-ALOH									
CHLORITE	76.9%	78.3%	20.8%	43.7%	46.6%	9.0%	1.0%	1.0%	0.0%
DARK-MICA	3.1%	2.2%	15.5%	53.5%	52.6%	90.5%	99.0%	99.0%	97.7%
AMPHIBOLE	5.6%	4.0%	48.2%	1.6%		0.1%			1.6%
SERPENTINE				0.2%					
OTHER-MGOH									
EPIDOTE	0.4%			0.1%	0.1%				
TOURMALINE	1.4%								
CARBONATE	0.1%		0.5%	0.3%					
SULPHATE									
PAL-SEP									
NOTAROK									
INVALID	2.3%	4.5%	0.4%			0.1%			0.6%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal									
Dickite									
Kaolinite-PX									
Kaolinite-WX			0.0%			0.0%			
Nacrite									
Muscovite	10.2%	10.8%	0.8%	0.3%	0.3%	0.0%			
Paragonite									
Phengite	0.4%	0.5%	14.5%	0.4%	0.4%	0.4%			
MuscoviticIllite									
ParagoniticIllite									
PhengiticIllite									
Montmorillonite									
Saponite									
Diaspore									
Gibbsite									
Topaz									
Chlorite-Fe			20.7%	7.1%	7.2%	8.9%			0.0%
Chlorite-FeMg	78.6%	82.1%	0.0%	36.3%	39.1%	0.5%			10.3%
Chlorite-Mg				0.3%	0.3%		1.0%	1.0%	
Biotite	1.7%	1.1%	15.4%	51.8%	50.2%	90.1%			88.2%
Phlogopite	1.4%	1.2%		1.7%	2.4%		99.0%	99.0%	
Actinolite			48.0%			0.1%			1.5%
Hornblende	3.8%	4.2%		1.6%					
Riebeckite	1.9%								
Serpentine				0.2%					
Epidote	0.4%			0.1%	0.1%				
Zoisite									
Tourmaline-Fe	1.4%								
Ankerite				0.1%					
Siderite									
Calcite	0.2%		0.5%	0.2%					
Dolomite									
Magnesite									
Alunite-NH									
Gypsum									
Jarosite									
Palygorskite									
Vegetation-Dry									
WhiteMarker									
Wood									
YellowMarker									
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	408253av	G408261av	G408262av
	Shale - crypto-micaceous	Shale - graphitic	Shale - graphitic
	Lefroy	Oonah	Oonah
Number of HyLogger spec	243	132	301
Number of MLA points	33219	35623	37147

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
MISC-SILICATE															
SILICA	37.7%	37.7%	51.1%	52.1%	20.6%	49.3%	48.0%	50.6%	47.6%	25.3%	35.5%	37.8%	39.8%	39.5%	16.6%
K-FELDSPAR					15.1%	2.2%				10.5%	7.0%	5.9%			15.6%
PLAGIOCLASE					7.7%					11.9%		2.5%			10.3%
GARNET															
PYROXENE															
OLIVINE															
ZEOLITE															
KAOLIN					0.1%					0.4%					0.1%
WHITE-MICA	44.3%	44.3%	48.9%	47.9%	38.4%	15.3%	25.1%	37.9%	45.6%	42.6%	44.3%	48.9%	60.2%	60.5%	55.2%
SMECTITE															
OTHER-ALOH															
CHLORITE					3.1%	13.4%	6.2%	11.4%	6.8%	6.0%					0.3%
DARK-MICA					14.2%					2.2%					1.1%
AMPHIBOLE					0.1%					0.0%	1.1%				0.0%
SERPENTINE															
OTHER-MGOH						19.7%	20.7%				3.1%	3.1%			
EPIDOTE															
TOURMALINE															
CARBONATE										0.0%					
SULPHATE	18.0%	18.0%									8.9%	1.8%			
PHOSPHATE					0.0%					0.0%					0.0%
BORATE															
OXIDE					0.0%					0.0%					
PAL-SEP															
INVALID					0.5%					1.0%					0.7%
	100.0%	100.0%	100.0%	100.0%	99.8%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Opal															
Quartz		37.7%	51.1%	52.1%	20.7%	49.3%	48.0%	50.6%	47.6%	25.6%	35.5%	37.8%	39.8%	39.5%	16.7%
Anorthoclase															
Microcline						2.2%					7.0%	5.9%			
Orthoclase					15.2%					10.6%					15.7%
Albite					5.9%					9.5%		2.5%			9.1%
Bytownite															
Labradorite															
Andesine															
Oligoclase					1.9%					2.5%					1.3%
Almandine															
Spessartine															
Augite															
Diopside															
Analcime															
Natrolite															
Phillipsite															
Kaolinite-WX					0.1%					0.4%					0.1%
Muscovite	44.3%	44.3%	48.9%	47.9%	1.8%	15.3%	25.1%	37.9%	45.6%	2.2%	44.3%	48.9%	60.2%	60.5%	1.4%
Phengite					36.8%					40.9%					54.2%
Glauconite															
Montmorillonite															
Nontronite															
Pyrophyllite															
Topaz															
Chlorite-Fe					3.0%	9.1%	6.2%	2.4%		6.0%					0.3%
Chlorite-FeMg					0.1%	4.4%		9.1%	6.8%						0.0%
Biotite					14.3%					2.2%					1.1%
Phlogopite															
Stilpnomelane															
Actinolite					0.1%					0.0%					0.0%
AmphiboleML48															
Edenite											1.1%				
Hornblende															
Riebeckite															
Antigorite															
Lizardite															
Talc						1969.6%	20.7%				3.1%	3.1%			
Epidote															
Zoisite															
Rhodochrosite															
Siderite															
Calcite										0.0%					
Magnesite															
Alunite-K	11.6%	11.6%									8.9%	1.8%			
Alunite-Na	6.5%	6.5%													
Gypsum															
Jarosite															
Apatite					0.0%					0.0%					0.0%
Rutile															
OXIDE					0.0%					0.0%					
	62.3%	100.0%	100.0%	100.0%	100.0%	2049.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	408253av			G408261av			G408262av		
	Shale - crypto-micaceous			Shale - graphitic			Shale - graphitic		
	Lefroy			Oonah			Oonah		
Number of HyLogger spec	243			132			301		
Number of MLA points	33219			35623			37147		

SWIR

Groups	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
SILICA						34.0%			
KAOLIN			0.1%			0.6%			0.1%
WHITE-MICA	86.5%	91.4%	49.1%	20.0%	20.0%	54.4%	63.6%	50.0%	74.8%
SMECTITE	7.7%								
OTHER-ALOH									
CHLORITE		2.0%	4.1%			8.0%			0.4%
DARK-MICA			19.0%			2.9%			1.5%
AMPHIBOLE			0.2%			0.0%			0.0%
SERPENTINE									
OTHER-MGOH									
EPIDOTE	1.4%								
TOURMALINE									
CARBONATE	2.5%	4.8%				0.0%	3.1%		
SULPHATE									
PAL-SEP									
NOTAROK	1.8%	1.8%							
INVALID			0.0%	80.0%	80.0%	0.1%	33.3%	50.0%	0.0%
	100.0%	100.0%	72.4%	100.0%	100.0%	100.1%	100.0%	100.0%	76.9%

Minerals	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD	sTSAS	uTSAS	XMOD
Opal						33.1%			
Dickite									
Kaolinite-PX									
Kaolinite-WX			0.1%			0.3%			0.1%
Nacrite									
Muscovite			2.3%	20.0%	20.0%	1.8%	16.7%	12.5%	1.9%
Paragonite									
Phengite	86.5%	91.4%	47.9%			14.2%	46.9%	37.5%	73.4%
MuscoviticIllite									
ParagoniticIllite									
PhengiticIllite									
Montmorillonite									
Saponite	7.7%								
Diaspore									
Gibbsite									
Topaz									
Chlorite-Fe			4.0%			4.0%			0.4%
Chlorite-FeMg		2.0%	0.1%			0.0%			0.0%
Chlorite-Mg									
Biotite			18.6%			3.5%			1.4%
Phlogopite									
Actinolite			0.2%			0.4%			0.0%
Hornblende									
Riebeckite									
Serpentine									
Epidote									
Zoisite	1.4%								
Tourmaline-Fe									
Ankerite	2.5%	4.8%					3.1%		
Siderite									
Calcite						0.0%			
Dolomite									
Magnesite									
Alunite-NH									
Gypsum									
Jarosite									
Palygorskite									
Vegetation-Dry	1.8%	1.8%							
WhiteMarker									
Wood									
YellowMarker									
	100.0%	100.0%	73.1%	20.0%	20.0%	57.3%	66.7%	50.0%	77.3%

Appendix 2. Full MLA results

MLA data was acquired at the University of Tasmania Central Science Laboratory using an FEI MLA650 SEM. The SEM was equipped with a Bruker Quantax Esprit 1.9 EDS system with two XFlash 5030 SDD detectors. The MnKα resolution was 133eV and the system had a combined throughput was up to 800kcps.

Operating conditions were 20keV, dead time around 30%, 400 kcps throughput, 13 mm working distance. The spot size was less than 1 μm.

The MLA analytical settings were 5ms count time per spot and 210-450 μm step size (70 and 150 pixels) depending on the overall sample area. BSE imagery was acquired with a CBS solid state detector.

Table A2.1. Mineral compositions used in the XMOD reference mineral library.

Mineral		Al (%)	C (%)	Ca (%)	Ce (%)	Cl (%)	F (%)	Fe (%)	H (%)	K (%)	La (%)	Mg (%)	Mn (%)	Na (%)	Nd (%)	O (%)	P (%)	Pb (%)	RE (%)	S (%)	Si (%)	Ti (%)	Zr (%)	Density
Quartz	SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.26	0.00	0.00	0.00	0.00	46.74	0.00	0.00	2.63
Albite	NaAlSi3O8	10.77	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.30	0.00	48.66	0.00	0.00	0.00	0.00	31.50	0.00	0.00	2.62
Plagioclase	Ca0.4Na0.6Al1.4Si2.6O8	14.06	0.00	5.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.14	0.00	47.65	0.00	0.00	0.00	0.00	27.19	0.00	0.00	2.67
Pl_or_Ab-Cal mix	Ca0.4Na0.6Al1.4Si2.6O8Ca(CO3)	10.24	3.26	15.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.74	0.00	47.73	0.00	0.00	0.00	0.00	19.81	0.00	0.00	0.00	2.70
K-Feldspar	KAlSi3O8	9.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00	0.00	0.00	0.00	0.00	45.99	0.00	0.00	0.00	0.00	30.28	0.00	0.00	2.56
Actinolite	Ca2Mg3Fe2+2Si8O22(OH)2	1.39	0.00	8.59	0.00	0.00	0.00	8.57	0.23	0.00	0.00	9.71	0.12	0.59	0.00	35.34	0.00	0.00	0.00	0.00	35.34	0.11	0.00	3.04
Muscovite	KAl3Si3O10(OH)1.9F0.1	20.30	0.00	0.00	0.00	0.00	0.95	0.00	0.45	9.80	0.00	0.00	0.00	0.00	0.00	47.36	0.00	0.00	0.00	0.00	21.13	0.00	0.00	2.83
Muscovite_minorFe	KAl3Si3O10(OH)1.9F0.1	20.30	0.00	0.00	0.00	0.00	0.95	0.00	0.45	9.80	0.00	0.00	0.00	0.00	0.00	47.36	0.00	0.00	0.00	0.00	21.13	0.00	0.00	2.83
Biotite	KMg2.5Fe2+0.5AlSi3O10(OH)1.75F0.25	6.22	0.00	0.00	0.00	0.00	1.09	6.44	0.40	9.01	0.00	14.02	0.00	0.00	0.00	43.38	0.00	0.00	0.00	0.00	19.44	0.00	0.00	3.10
Chlorite	(Mg,Fe)3(Si,Al)4O10(OH)2·(Mg,Fe)3(OH)6	8.34	0.00	0.00	0.00	0.00	0.00	25.91	1.25	0.00	0.00	11.28	0.00	0.00	0.00	44.53	0.00	0.00	0.00	0.00	8.69	0.00	0.00	2.95
Chlorite_Fe	(Fe2+,Mg,Fe3+)5Al[Si3Al]O10·(OH,O)8	8.21	0.00	0.00	0.00	0.00	0.00	28.34	0.61	0.00	0.00	6.17	0.00	0.00	0.00	43.84	0.00	0.00	0.00	0.00	12.83	0.00	0.00	2.80
Kaolinite	Al2Si2O5(OH)4	20.90	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	0.00	0.00	0.00	0.00	55.78	0.00	0.00	0.00	0.00	21.75	0.00	0.00	2.60
Epidote-Allanite	Ca2Al2(Fe3+,Al)(SiO4)(Si2O7)O(OH)	14.39	0.00	17.10	0.00	0.00	5.96	0.22	0.00	0.00	0.00	0.00	0.00	44.37	0.00	0.00	0.00	17.97	0.00	0.00	0.00	0.00	0.00	3.45
Spessartine	Mn2+3Al2(SiO4)3	10.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.29	0.00	0.00	38.78	0.00	0.00	0.00	0.00	17.02	0.00	0.00	0.00	4.18
Calcite	Ca(CO3)	0.00	12.00	40.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.71
Dolomite	CaMg(CO3)2	0.00	13.02	21.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.18	0.00	0.00	0.00	52.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.85
Ca-REE carbonate	Ca(Ce,Nd,La)(CO3)2F	0.00	7.50	12.52	14.59	0.00	5.93	0.00	0.00	0.00	14.46	0.00	0.00	0.00	15.02	29.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
Alumina-Cal		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Ca-Al-Fe-Mg silicate	Ca2(Mg,Fe,Al)5(Al,Si)8O22(OH)2	17.68	0.00	9.27	0.00	0.00	10.76	0.23	0.00	0.00	4.68	0.00	0.00	0.00	44.39	0.00	0.00	0.00	0.00	12.99	0.00	0.00	0.00	2.90
Titanite	CaTiSiO5	2.72	0.00	19.26	0.00	0.00	0.96	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.65	0.00	0.00	3.64	0.00	14.20	18.16	0.00	3.48
Apatite	Ca5(PO4)(F,Cl,OH)	0.00	0.00	39.37	0.00	2.32	1.24	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	38.76	18.25	0.00	0.00	0.00	0.00	0.00	0.00	3.19
Ilmenite-Mn	Fe0.7Mn0.3TiO3	0.00	0.00	0.00	0.00	0.00	0.00	25.81	0.00	0.00	0.00	0.00	10.88	0.00	0.00	31.69	0.00	0.00	0.00	0.00	0.00	31.62	0.00	4.72
Rutile	TiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.05	0.00	0.00	0.00	0.00	0.00	59.95	0.00	4.25
Fe-oxide	Fe3O4	0.00	0.00	0.00	0.00	0.00	0.00	72.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15
Pyrite	Fe2+S2	0.00	0.00	0.00	0.00	0.00	0.00	46.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.46	0.00	0.00	0.00	5.01
Galena	PbS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.60	0.00	13.40	0.00	0.00	0.00	7.40
Zircon	ZrSiO4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.91	0.00	0.00	0.00	0.00	15.32	0.00	49.76	4.65

G408251			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.11	38
Quartz	18.58	19.12	6696
Albite	7.56	7.79	2729
K-Feldspar	17.23	18.18	6366
Muscovite	4.48	4.28	1500
Muscovite_minorFe	41.07	39.27	13753
Biotite	0.32	0.28	97
Chlorite_Fe	0.34	0.33	116
Kaolinite	9.66	10.03	3514
Epidote-Allanite	0.42	0.33	116
Calcite	0.18	0.18	62
Dolomite	0.00	0.00	0
Rutile	0.06	0.04	13
Apatite	0.04	0.03	12
Ca-REE carbonate	0.01	0.01	2
Zircon	0.02	0.01	5
Pyrite	0.03	0.01	5
Galena	0.01	0.00	1
Total	100.00	100.00	35025

G408275			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.51	197
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	22.19	22.66	8695
Albite	2.47	2.52	968
Plagioclase	59.32	59.54	22853
K-Feldspar	4.08	4.27	1638
Actinolite	1.08	0.95	365
Muscovite	0.25	0.24	92
Muscovite_minorFe	0.68	0.65	248
Biotite	6.13	5.30	2033
Chlorite	2.06	1.87	717
Chlorite_Fe	0.15	0.14	55
Kaolinite	0.47	0.49	187
Titanite	0.28	0.21	82
Calcite	0.28	0.27	105
Dolomite	0.00	0.00	0
Rutile	0.00	0.00	0
Apatite	0.23	0.20	75
Ca-REE carbonate	0.01	0.01	2
Zircon	0.03	0.02	6
Pyrite	0.30	0.16	62
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	38380

G408243			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	1.28	1504
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	13.66	13.37	15748
Albite	35.03	34.34	40455
K-Feldspar	46.12	46.26	54507
Muscovite	0.61	0.56	655
Muscovite_minorFe	3.06	2.78	3273
Chlorite_Fe	0.47	0.43	512
Kaolinite	0.24	0.24	279
Calcite	0.74	0.70	828
Dolomite	0.00	0.00	0
Rutile	0.03	0.02	24
Apatite	0.02	0.02	19
Ca-REE carbonate	0.02	0.01	12
Total	100.00	100.00	117816

G408265			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.02	7
Quartz	21.30	26.09	10197
Albite	0.01	0.01	5
Plagioclase	0.06	0.07	26
K-Feldspar	0.24	0.31	120
Spessartine	20.25	15.57	6087
Ca-Al-Fe-Mg silicate	0.53	0.59	230
Actinolite	0.02	0.02	7
Muscovite	1.42	1.62	633
Muscovite_minorFe	0.35	0.39	154
Biotite	46.75	48.47	18947
Chlorite	0.07	0.08	30
Chlorite_Fe	1.87	2.15	841
Kaolinite	0.01	0.02	7
Titanite	0.00	0.00	0
Ilmenite-Mn	0.16	0.11	43
Fe-oxide	6.37	3.97	1553
Calcite	0.01	0.01	5
Dolomite	0.00	0.00	0
Rutile	0.00	0.00	1
Apatite	0.38	0.38	149
Ca-REE carbonate	0.00	0.00	0
Zircon	0.02	0.01	5
Pyrite	0.18	0.11	44
Galena	0.00	0.00	0
Total	100.00	100.00	39091

G408260			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.01	4
Quartz	21.17	22.12	7846
Albite	3.70	3.87	1372
Plagioclase	1.16	1.19	421
K-Feldspar	19.21	20.58	7299
Actinolite	0.01	0.01	3
Muscovite	10.70	10.39	3685
Muscovite_minorFe	38.14	37.03	13133
Biotite	2.79	2.47	876
Chlorite	0.03	0.03	9
Chlorite_Fe	1.35	1.32	469
Kaolinite	0.04	0.04	14
Titanite	0.00	0.00	0
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.32	0.17	61
Calcite	0.00	0.00	0
Dolomite	0.00	0.00	0
Rutile	0.02	0.01	5
Apatite	0.02	0.01	5
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	1
Pyrite	1.35	0.74	262
Galena	0.00	0.00	0
Total	100.00	100.00	35465

G408264			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.07	26
Quartz	12.58	14.49	5365
Albite	0.02	0.02	7
K-Feldspar	0.91	1.08	399
Muscovite	0.28	0.30	110
Muscovite_minorFe	0.64	0.68	252
Biotite	67.09	65.43	24226
Chlorite_Fe	8.15	8.80	3257
Kaolinite	0.08	0.09	34
Epidote-Allanite	9.09	7.97	2951
Calcite	0.35	0.39	146
Dolomite	0.00	0.00	0
Rutile	0.00	0.00	0
Apatite	0.54	0.51	190
Ca-REE carbonate	0.00	0.00	0
Zircon	0.06	0.04	14
Pyrite	0.21	0.13	47
Galena	0.01	0.00	1
Total	100.00	100.00	37025

G408245			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.07	23
Quartz	20.81	21.69	7244
Albite	21.35	22.29	7446
Plagioclase	5.38	5.51	1842
Pl_or_Ab-Cal mix	3.94	3.99	1333
K-Feldspar	0.11	0.11	38
Actinolite	0.28	0.25	84
Muscovite	0.75	0.72	241
Muscovite_minorFe	8.93	8.65	2888
Biotite	12.32	10.87	3632
Chlorite	0.14	0.13	43
Chlorite_Fe	9.21	9.00	3006
Kaolinite	0.01	0.01	3
Titanite	0.00	0.00	1
Calcite	16.18	16.33	5456
Dolomite	0.00	0.00	0
Rutile	0.11	0.07	23
Apatite	0.13	0.11	37
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	0
Pyrite	0.35	0.19	64
Galena	0.00	0.00	0
Total	100.00	100.00	33404

G408246			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	2.18	738
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	11.79	12.42	4200
Albite	8.80	9.29	3141
Plagioclase	5.17	5.35	1811
K-Feldspar	6.18	6.68	2258
Actinolite	0.70	0.64	215
Muscovite	0.21	0.20	68
Muscovite_minorFe	13.69	13.39	4530
Biotite	35.11	31.31	10589
Chlorite	0.06	0.06	20
Chlorite_Fe	3.07	3.03	1026
Kaolinite	0.19	0.20	67
Titanite	0.10	0.08	28
Ilmenite-Mn	0.01	0.00	1
Fe-oxide	0.00	0.00	0
Calcite	14.66	14.95	5058
Dolomite	0.19	0.18	62
Carbonate-FeMg	0.00	0.00	0
Rutile	0.02	0.01	5
Apatite	0.02	0.02	6
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	0
Pyrite	0.01	0.00	1
Chalcopyrite	0.00	0.00	0
Galena	0.01	0.00	1
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	33825

G408248			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.23	72.50
Low_Counts	0.00	0.00	0.00
No_XRay	0.00	0.00	0.00
Quartz	8.66	9.00	2933.00
Albite	12.06	12.57	4103.50
Plagioclase	4.00	4.09	1266.50
K-Feldspar	27.12	28.93	9284.00
Actinolite	0.00	0.00	1.00
Muscovite	2.87	2.77	922.00
Muscovite_minorFe	37.06	35.82	11325.00
Biotite	2.98	2.63	844.00
Chlorite	0.00	0.00	0.00
Chlorite_Fe	1.47	1.43	461.00
Kaolinite	0.02	0.02	7.00
Allanite	0.08	0.05	18.00
Titanite	0.00	0.00	0.00
Ilmenite-Mn	0.03	0.02	5.50
Fe-oxide	0.00	0.00	0.00
Calcite	0.72	0.72	227.50
Dolomite	0.00	0.00	0.00
Carbonate-FeMg	0.00	0.00	0.00
Rutile	0.12	0.08	25.50
Apatite	0.31	0.26	85.00
Ca-REE carbonate	0.00	0.00	0.00
Zircon	0.00	0.00	1.00
Pyrite	2.49	1.36	443.00
Chalcopyrite	0.00	0.00	0.50
Galena	0.00	0.00	0.00
Pen	0.00	0.00	0.00
Pen_2	0.00	0.00	0.00
Alumina-Cal	0.00	0.00	0.00
NiP_holder	0.00	0.00	0.00
	100.00	100.00	64051

G408255			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.00	2
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	8.70	9.20	3931
Albite	10.65	11.28	4821
Plagioclase	9.39	9.76	4171
K-Feldspar	24.26	26.30	11240
Actinolite	0.30	0.27	117
Muscovite	1.59	1.56	666
Muscovite_minorFe	9.94	9.77	4175
Biotite	27.97	25.04	10703
Chlorite	5.81	5.46	2335
Chlorite_Fe	1.05	1.04	444
Kaolinite	0.05	0.06	25
Titanite	0.00	0.00	0
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.00	0.00	0
Calcite	0.07	0.07	30
Dolomite	0.04	0.04	18
Carbonate-FeMg	0.00	0.00	0
Rutile	0.03	0.02	7
Apatite	0.09	0.08	34
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	1
Pyrite	0.05	0.03	13
Chalcopyrite	0.01	0.00	2
Galena	0.01	0.00	1
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	42736

G408276			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.02	8
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	1.20	1.41	561
Albite	0.18	0.21	84
Plagioclase	0.05	0.06	24
K-Feldspar	46.61	56.12	22257
Actinolite	0.00	0.01	2
Muscovite	2.13	2.32	920
Muscovite_minorFe	14.99	16.36	6488
Biotite	3.40	3.38	1341
Chlorite	0.09	0.10	38
Chlorite_Fe	1.67	1.84	730
Kaolinite	0.03	0.03	13
Allanite	0.07	0.05	21
Titanite	0.23	0.20	81
Rutile	0.00	0.00	1
Pyrophanite	1.16	0.76	301
Ilmenite-Mn	0.17	0.11	45
Fe-oxide	25.65	15.35	6087
Calcite	0.16	0.18	70
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.01	0.01	2
Ca-REE carbonate	0.00	0.00	1
Apatite	0.03	0.03	10
Barite	0.05	0.04	14
Zircon	0.01	0.01	2
Pyrite	1.55	0.95	378
Chalcopyrite	0.31	0.23	91
Galena	0.00	0.00	0
Fluorite	0.23	0.22	89
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	39659

G408277			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.70	286
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	1.30	1.41	578
Albite	8.12	8.80	3607
Plagioclase	18.93	20.14	8254
K-Feldspar	16.60	18.42	7546
Actinolite	24.09	22.51	9222
Muscovite	0.38	0.38	157
Muscovite_minorFe	12.48	12.55	5142
Biotite	3.19	2.92	1198
Chlorite	6.98	6.72	2755
Chlorite_Fe	1.46	1.48	608
Kaolinite	0.06	0.07	29
Titanite	0.79	0.65	265
Ilmenite-Mn	0.59	0.36	146
Fe-oxide	4.57	2.52	1032
Calcite	0.15	0.15	63
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.29	0.21	86
Rutile	0.00	0.00	1
Apatite	0.00	0.00	0
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	0
Pyrite	0.00	0.00	0
Chalcopyrite	0.00	0.00	0
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	40975

G408249			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.03	8
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	3.61	3.86	1068
Albite	1.29	1.38	383
Plagioclase	1.61	1.70	469
K-Feldspar	0.70	0.77	213
Actinolite	0.53	0.49	136
Muscovite	13.72	13.63	3771
Muscovite_minorFe	75.96	75.47	20873
Biotite	0.18	0.16	44
Chlorite	0.02	0.02	5
Chlorite_Fe	0.44	0.44	122
Kaolinite	1.83	1.98	547
Titanite	0.00	0.00	0
Ilmenite-Mn	0.01	0.01	2
Fe-oxide	0.00	0.00	0
Calcite	0.00	0.00	0
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.01	0.00	1
Rutile	0.07	0.04	12
Apatite	0.00	0.00	1
Ca-REE carbonate	0.01	0.00	1
Zircon	0.01	0.01	2
Pyrite	0.00	0.00	0
Chalcopyrite	0.00	0.00	0
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	27658

G408250			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.15	34
Quartz	20.00	20.65	4703
Albite	4.14	4.28	975
Plagioclase	6.91	7.01	1597
K-Feldspar	14.58	15.44	3516
Actinolite	0.11	0.10	22
Muscovite	3.67	3.52	802
Muscovite_minorFe	38.49	36.92	8409
Biotite	0.16	0.14	31
Chlorite	0.00	0.00	0
Chlorite_Fe	0.59	0.57	130
Kaolinite	9.67	10.08	2296
Titanite	0.02	0.01	3
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.96	0.50	115
Calcite	0.52	0.52	119
Dolomite	0.00	0.00	0
Rutile	0.05	0.03	7
Apatite	0.04	0.04	8
Ca-REE carbonate	0.00	0.00	0
Zircon	0.04	0.02	5
Pyrite	0.06	0.03	7
Galena	0.00	0.00	0
Total	100.00	100.00	22779

G408253			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.01	3
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	19.41	20.56	6829
Albite	5.53	5.87	1949
Plagioclase	1.81	1.88	625
K-Feldspar	13.91	15.11	5019
Actinolite	0.16	0.14	48
Muscovite	1.81	1.79	593
Muscovite_minorFe	37.18	36.59	12154
Biotite	15.82	14.18	4712
Chlorite	0.08	0.07	24
Chlorite_Fe	3.04	3.02	1004
Kaolinite	0.06	0.07	22
Titanite	0.00	0.00	0
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.02	0.01	4
Calcite	0.00	0.00	0
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.33	0.23	76
Rutile	0.00	0.00	0
Apatite	0.01	0.01	3
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	0
Pyrite	0.82	0.46	152
Chalcopyrite	0.01	0.01	2
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	33219

G408254			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.05	20
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	63.26	64.50	28541
Albite	10.72	10.95	4844
Plagioclase	1.52	1.53	676
K-Feldspar	1.81	1.90	839
Actinolite	0.35	0.31	135
Muscovite	1.63	1.54	682
Muscovite_minorFe	12.77	12.10	5354
Biotite	3.44	2.97	1316
Chlorite	0.03	0.02	11
Chlorite_Fe	3.60	3.44	1521
Kaolinite	0.26	0.27	120
Titanite	0.00	0.00	0
Ilmenite-Mn	0.00	0.00	1
Fe-oxide	0.01	0.00	2
Calcite	0.00	0.00	1
Dolomite	0.03	0.03	14
Carbonate-FeMg	0.09	0.06	26
Rutile	0.11	0.07	31
Apatite	0.20	0.16	73
Ca-REE carbonate	0.01	0.00	2
Zircon	0.04	0.02	10
Pyrite	0.11	0.06	26
Chalcopyrite	0.01	0.01	3
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	44248

G408261			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.04	16
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	24.14	25.28	9006
Albite	9.00	9.44	3363
Plagioclase	2.38	2.45	873
K-Feldspar	9.80	10.52	3748
Actinolite	0.02	0.02	7
Muscovite	2.23	2.17	772
Muscovite_minorFe	41.53	40.41	14395
Biotite	2.43	2.15	767
Chlorite	0.00	0.00	0
Chlorite_Fe	6.08	5.97	2125
Kaolinite	0.40	0.42	150
Titanite	0.00	0.00	0
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.02	0.01	4
Calcite	0.00	0.00	1
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.08	0.06	21
Rutile	0.03	0.02	7
Apatite	0.02	0.02	7
Ca-REE carbonate	0.00	0.00	0
Zircon	0.01	0.01	2
Pyrite	1.83	1.00	358
Chalcopyrite	0.00	0.00	1
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	35623

G408262			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.00	1
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	15.86	16.61	6171
Albite	8.58	9.00	3343
Plagioclase	1.30	1.34	497
K-Feldspar	14.52	15.59	5793
Actinolite	0.04	0.03	13
Muscovite	1.45	1.41	525
Muscovite_minorFe	55.26	53.78	19977
Biotite	1.19	1.06	392
Chlorite	0.03	0.02	9
Chlorite_Fe	0.30	0.29	108
Kaolinite	0.09	0.09	34
Titanite	0.00	0.00	0
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.00	0.00	0
Calcite	0.00	0.00	0
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.00	0.00	0
Rutile	0.02	0.01	4
Apatite	0.01	0.01	2
Ca-REE carbonate	0.00	0.00	0
Zircon	0.01	0.01	2
Pyrite	1.35	0.74	276
Chalcopyrite	0.00	0.00	0
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	37147

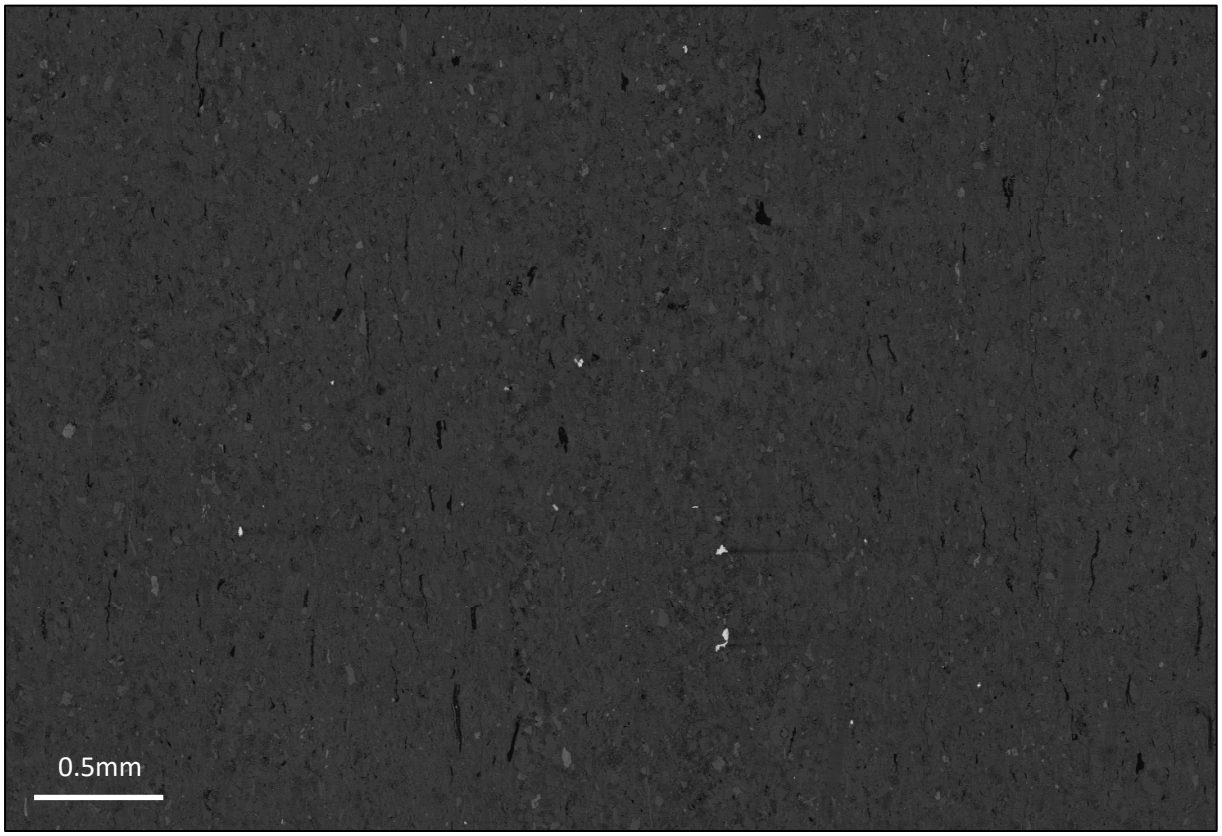
G408266			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.30	119
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	10.13	11.34	4535
Albite	0.07	0.08	33
Plagioclase	6.85	7.54	3015
K-Feldspar	2.18	2.51	1003
Actinolite	36.57	35.35	14138
Epidote	1.15	0.98	392
Muscovite	0.55	0.57	228
Muscovite_minorFe	10.24	10.65	4260
Biotite	11.97	11.34	4537
Chlorite	0.03	0.03	11
Chlorite_Fe	14.55	15.27	6106
Kaolinite	0.01	0.01	5
Titanite	0.44	0.37	147
Ilmenite-Mn	3.88	2.42	967
Fe-oxide	0.00	0.00	0
Calcite	0.35	0.38	153
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.00	0.00	0
Rutile	0.00	0.00	0
Apatite	0.28	0.26	104
Ca-REE carbonate	0.00	0.00	1
Zircon	0.00	0.00	0
Pyrite	0.26	0.15	61
Chalcopyrite	0.03	0.02	9
Galena	0.00	0.00	0
Fluorite	0.45	0.42	169
Cassiterite	0.01	0.00	1
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	39994

G408268			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.05	21
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	22.26	25.11	10250
Albite	0.13	0.15	60
Plagioclase	0.03	0.03	13
K-Feldspar	0.12	0.14	57
Actinolite	0.05	0.04	18
Muscovite	0.02	0.02	10
Muscovite_minorFe	0.26	0.27	111
Biotite	68.88	65.79	26861
Chlorite	0.36	0.36	147
Chlorite_Fe	6.16	6.52	2661
Kaolinite	0.02	0.03	11
Titanite	0.00	0.00	0
Ilmenite-Mn	0.41	0.26	105
Fe-oxide	0.00	0.00	1
Calcite	0.00	0.00	0
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.04	0.03	12
Ankerite-Mn	1.03	1.00	410
Rutile	0.07	0.05	20
Apatite	0.04	0.04	15
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	1
Pyrite	0.00	0.00	0
Chalcopyrite	0.00	0.00	0
Galena	0.00	0.00	0
Fluorite	0.11	0.11	43
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	40827

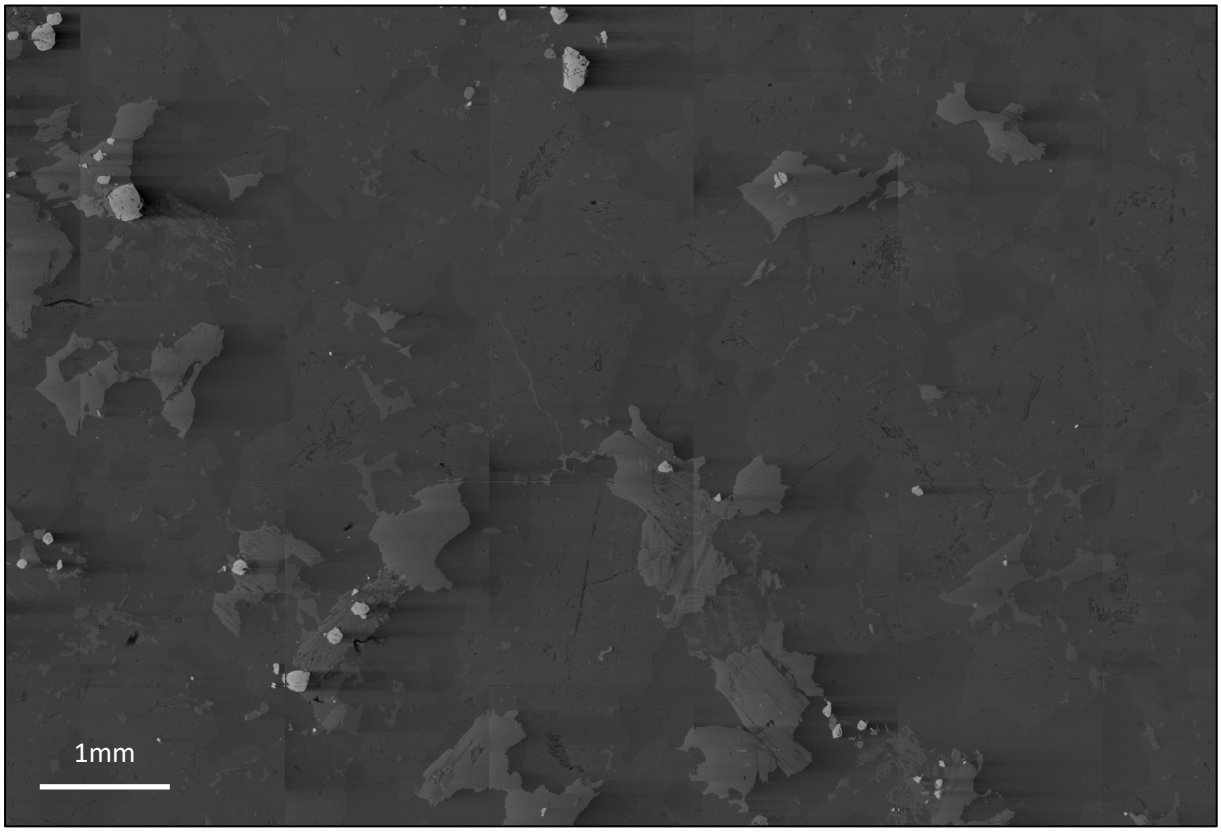
G408279			
Mineral	Wt%	Area%	Point Count
Unknown	0.00	0.56	173
Low_Counts	0.00	0.00	0
No_XRay	0.00	0.00	0
Quartz	0.00	0.00	1
Albite	0.00	0.00	1
Plagioclase	0.01	0.01	3
K-Feldspar	0.00	0.00	0
Actinolite	1.44	1.45	447
Muscovite	0.00	0.00	0
Muscovite_minorFe	0.00	0.00	0
Biotite	88.32	87.49	26905
Chlorite	9.80	10.20	3138
Chlorite_Fe	0.01	0.01	2
Kaolinite	0.00	0.00	0
Titanite	0.00	0.00	1
Ilmenite-Mn	0.00	0.00	0
Fe-oxide	0.03	0.02	5
Fe-Cr_oxide	0.31	0.20	61
Chromite	0.01	0.00	1
Calcite	0.00	0.00	0
Dolomite	0.00	0.00	0
Carbonate-FeMg	0.00	0.00	0
Rutile	0.00	0.00	0
Apatite	0.00	0.00	0
Ca-REE carbonate	0.00	0.00	0
Zircon	0.00	0.00	0
Pyrite	0.00	0.00	0
Chalcopyrite	0.00	0.00	0
Pentlandite	0.07	0.05	14
Galena	0.00	0.00	0
Pen	0.00	0.00	0
Pen_2	0.00	0.00	0
Alumina-Cal	0.00	0.00	0
NiP_holder	0.00	0.00	0
Total	100.00	100.00	30752

Appendix 3. BSE images

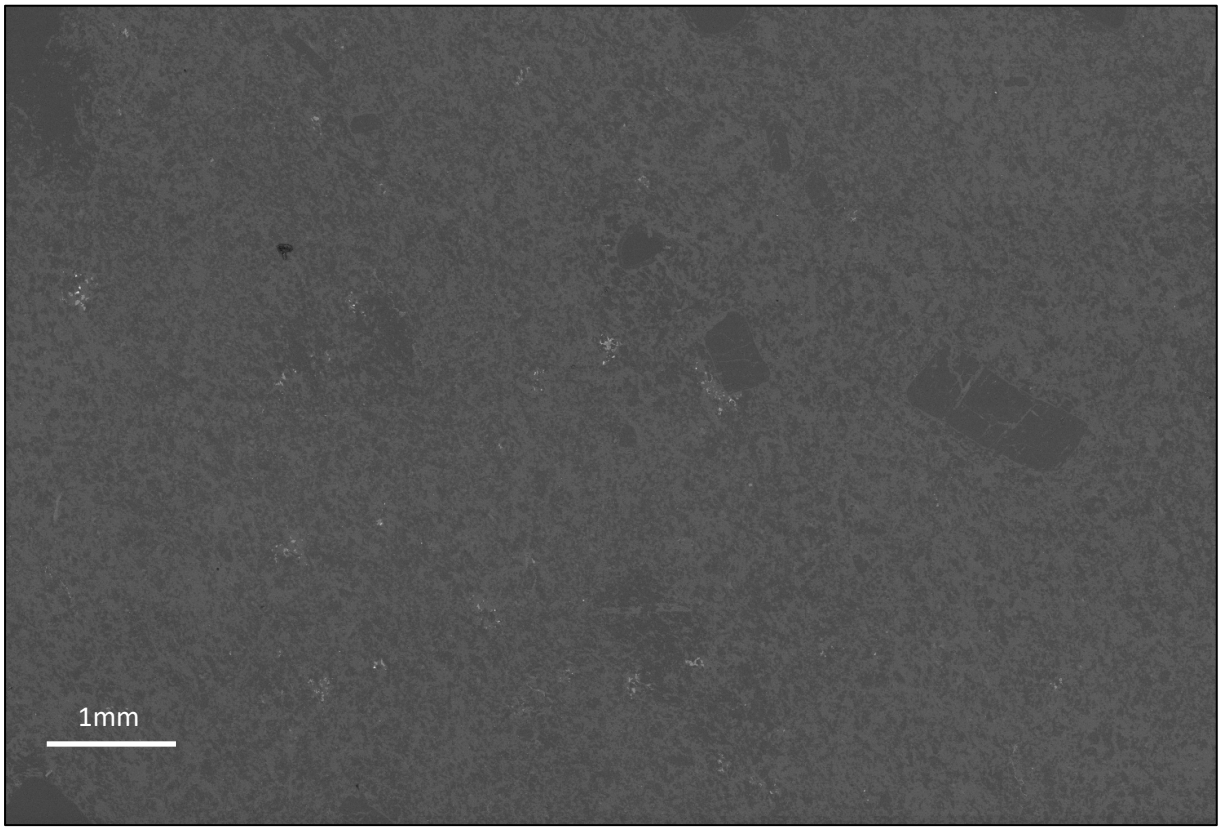
G408251



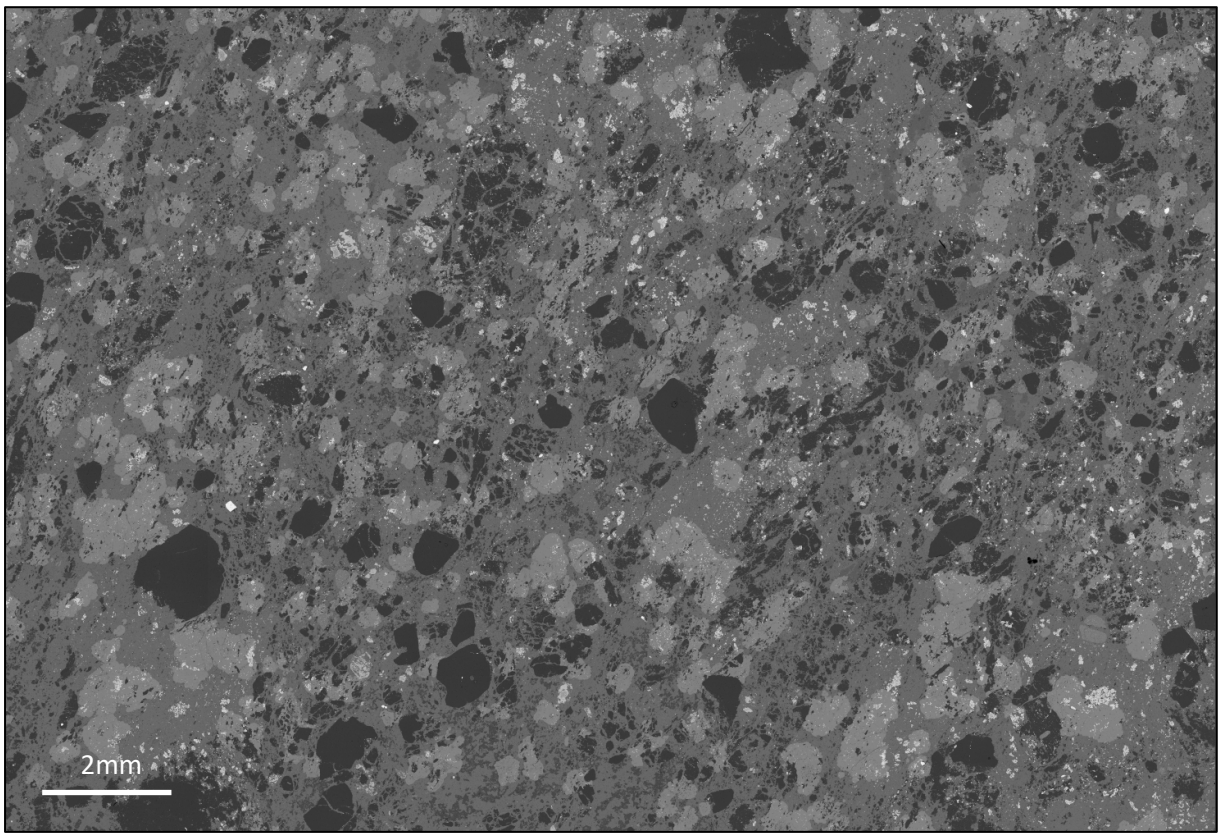
G408275



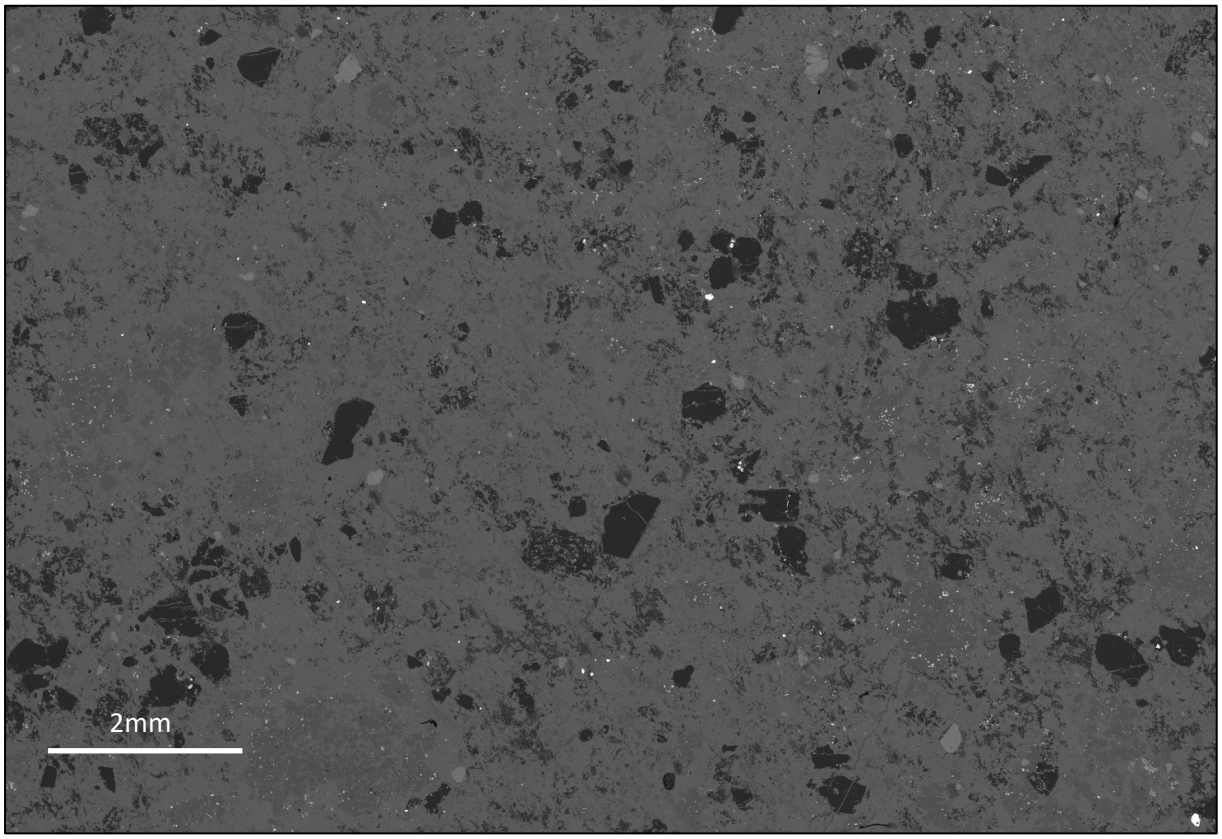
G408243



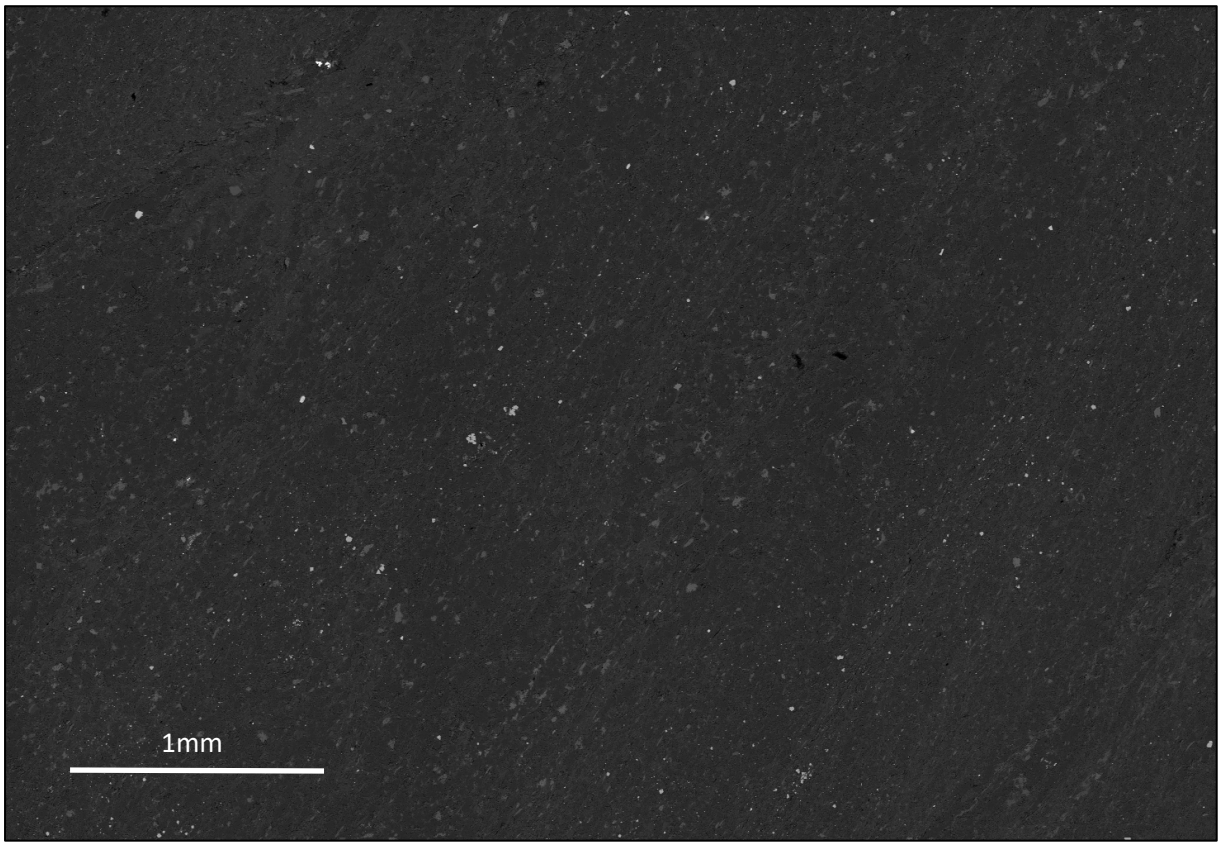
G408265



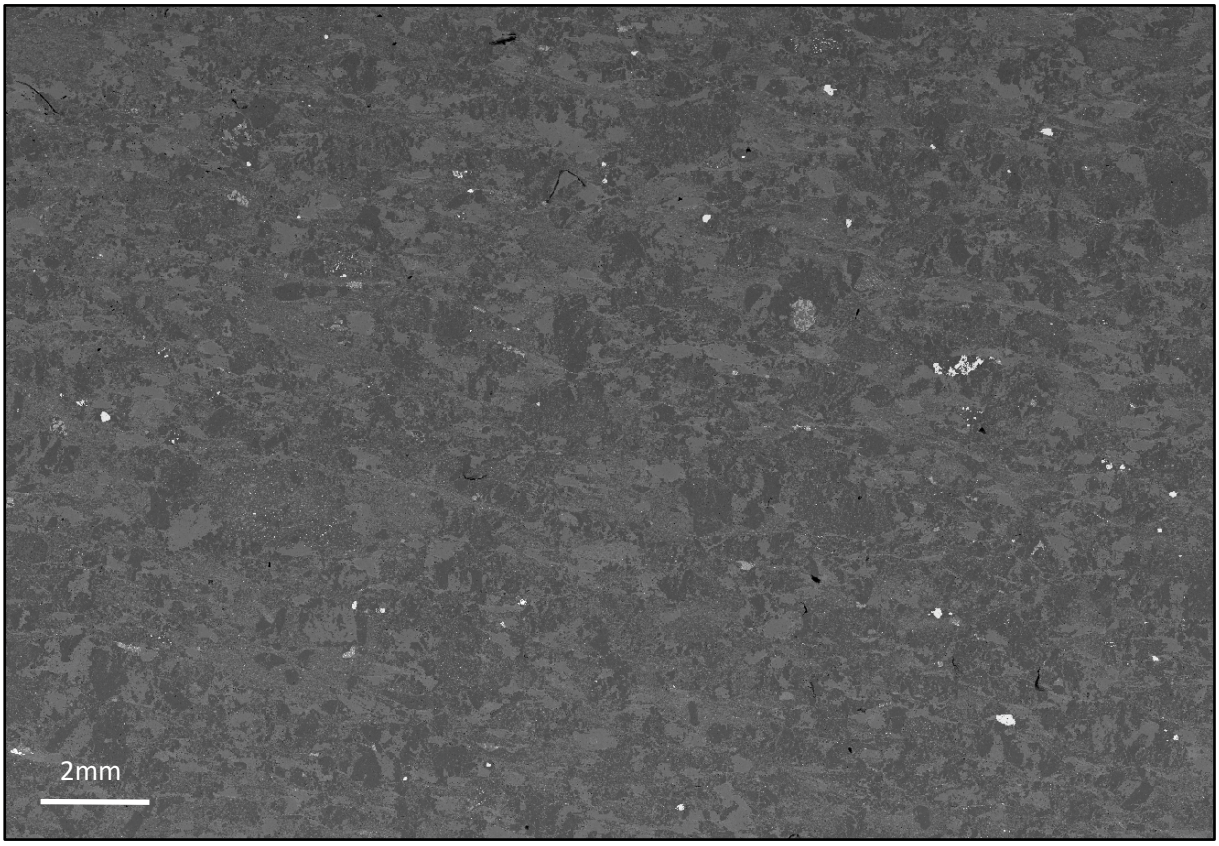
G408264



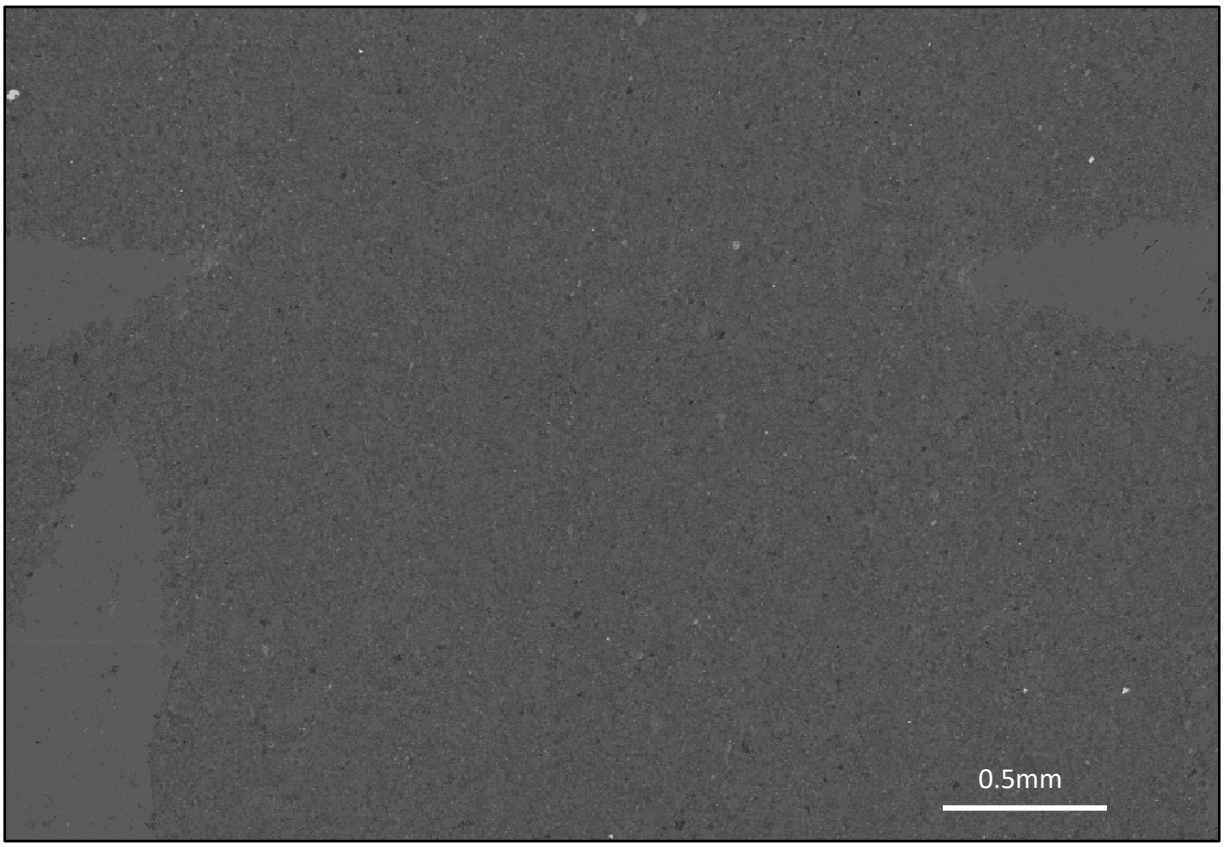
G408260



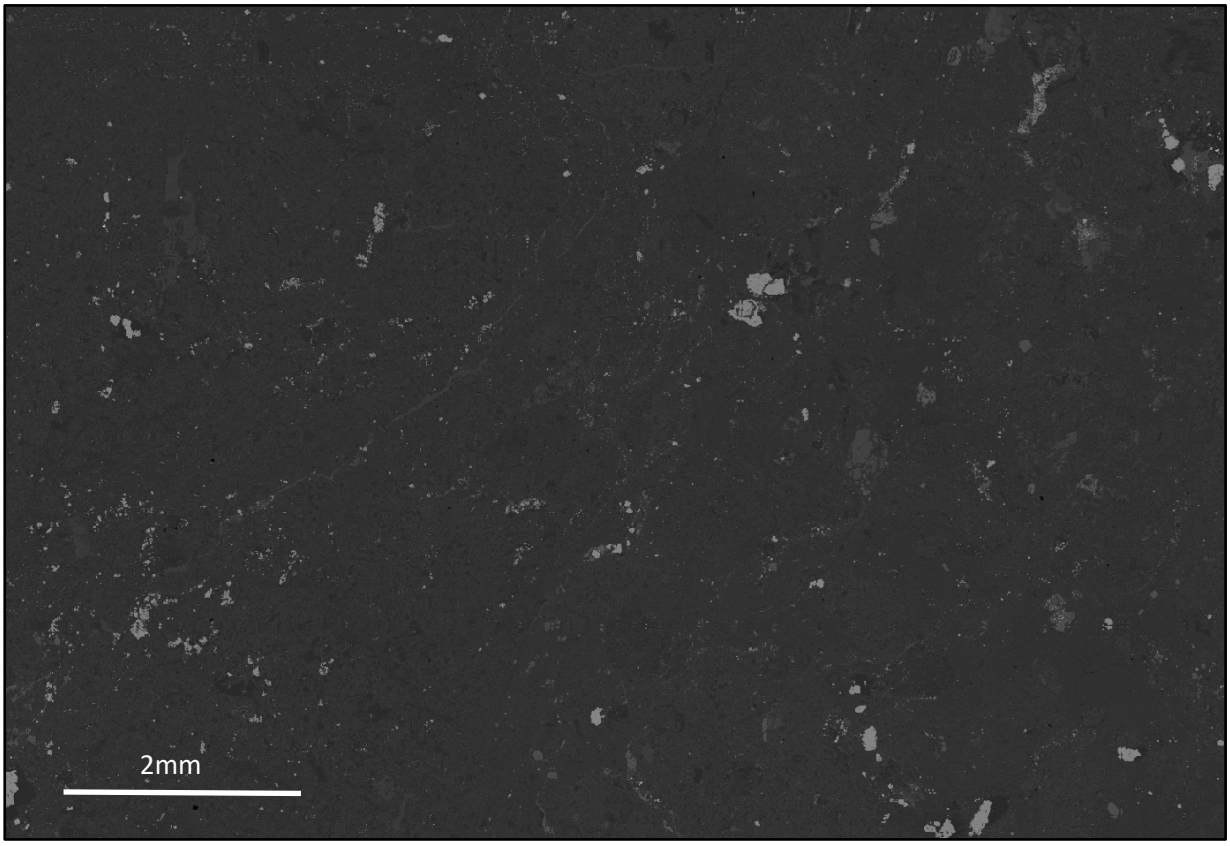
G408245



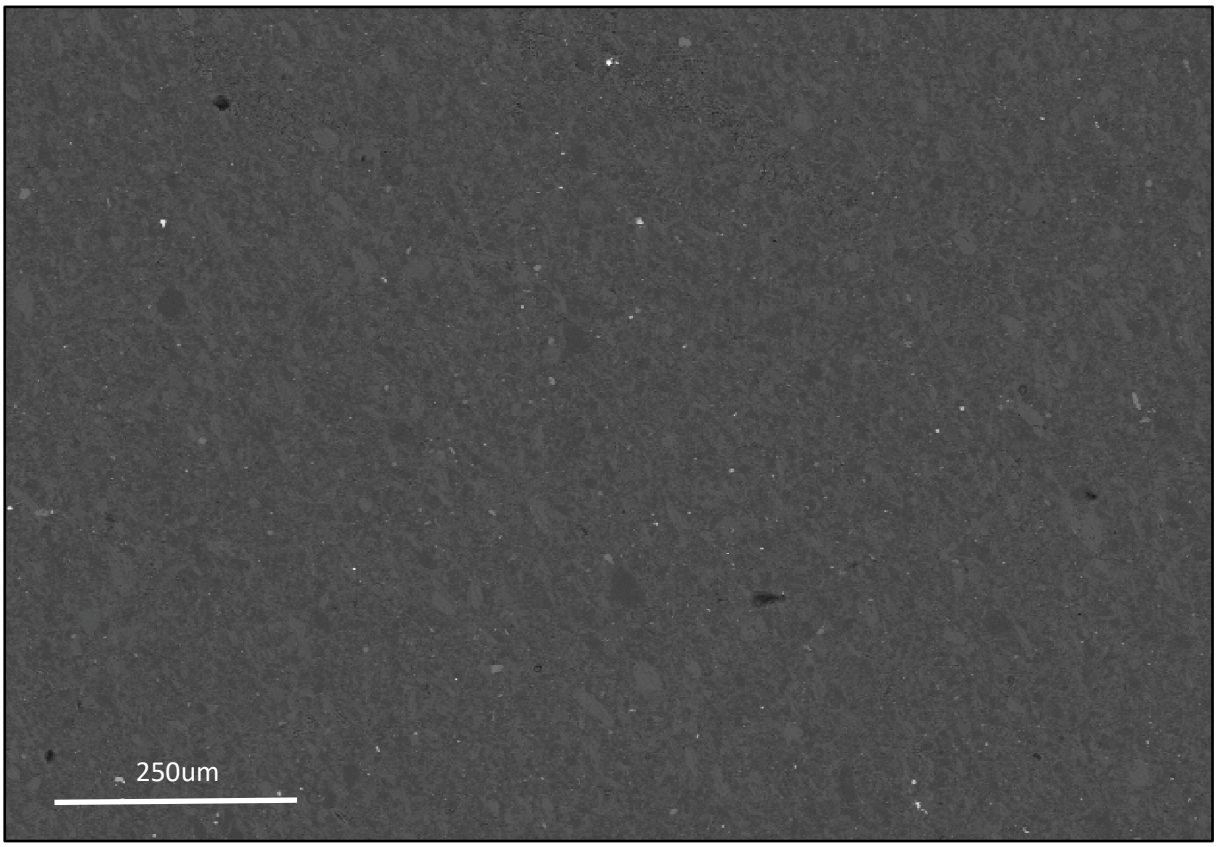
G408246



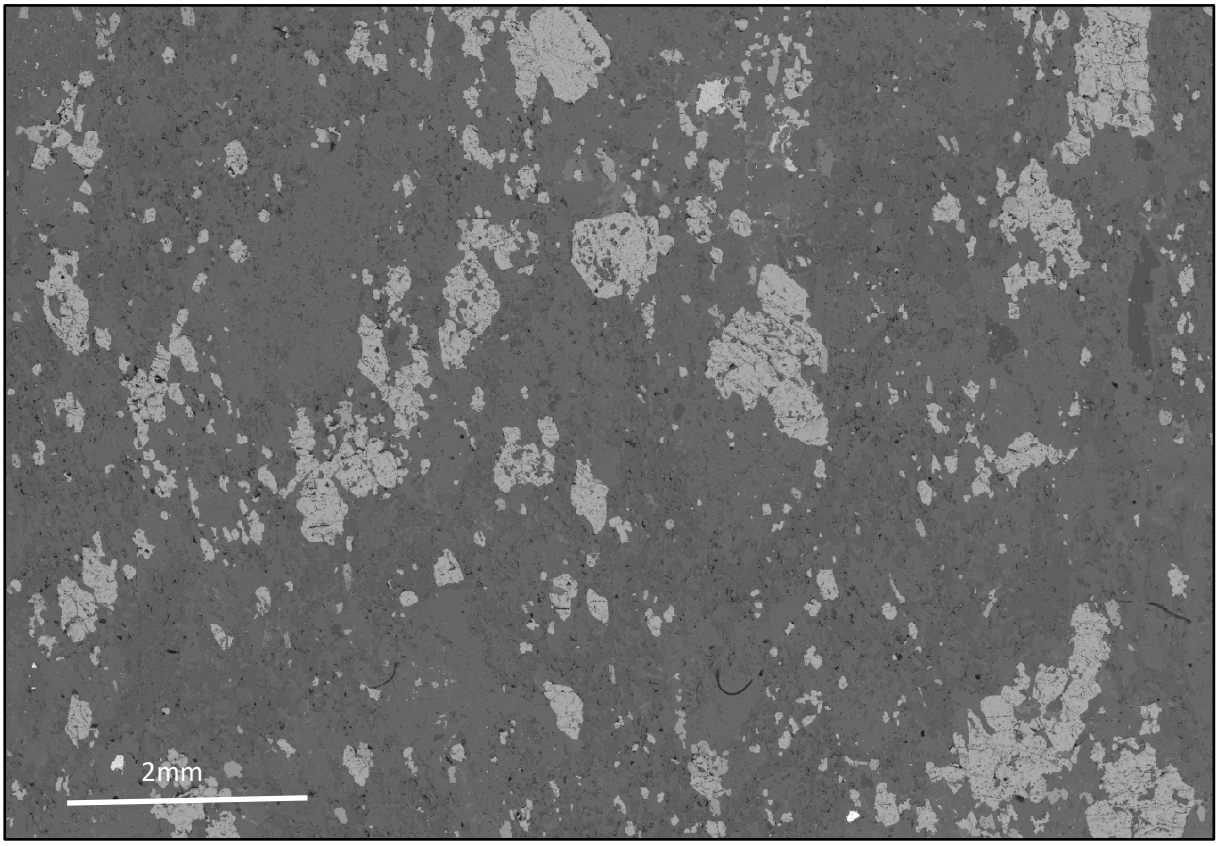
G408248



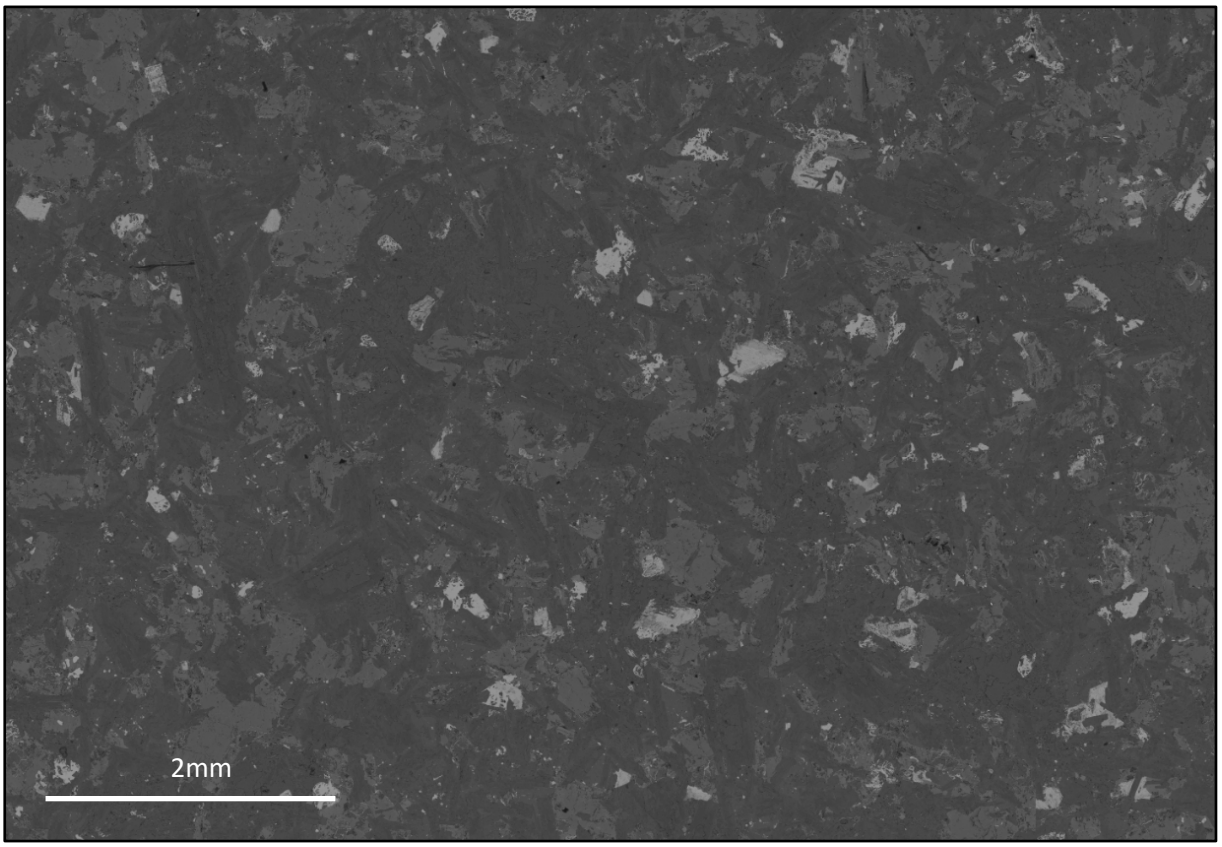
G408255



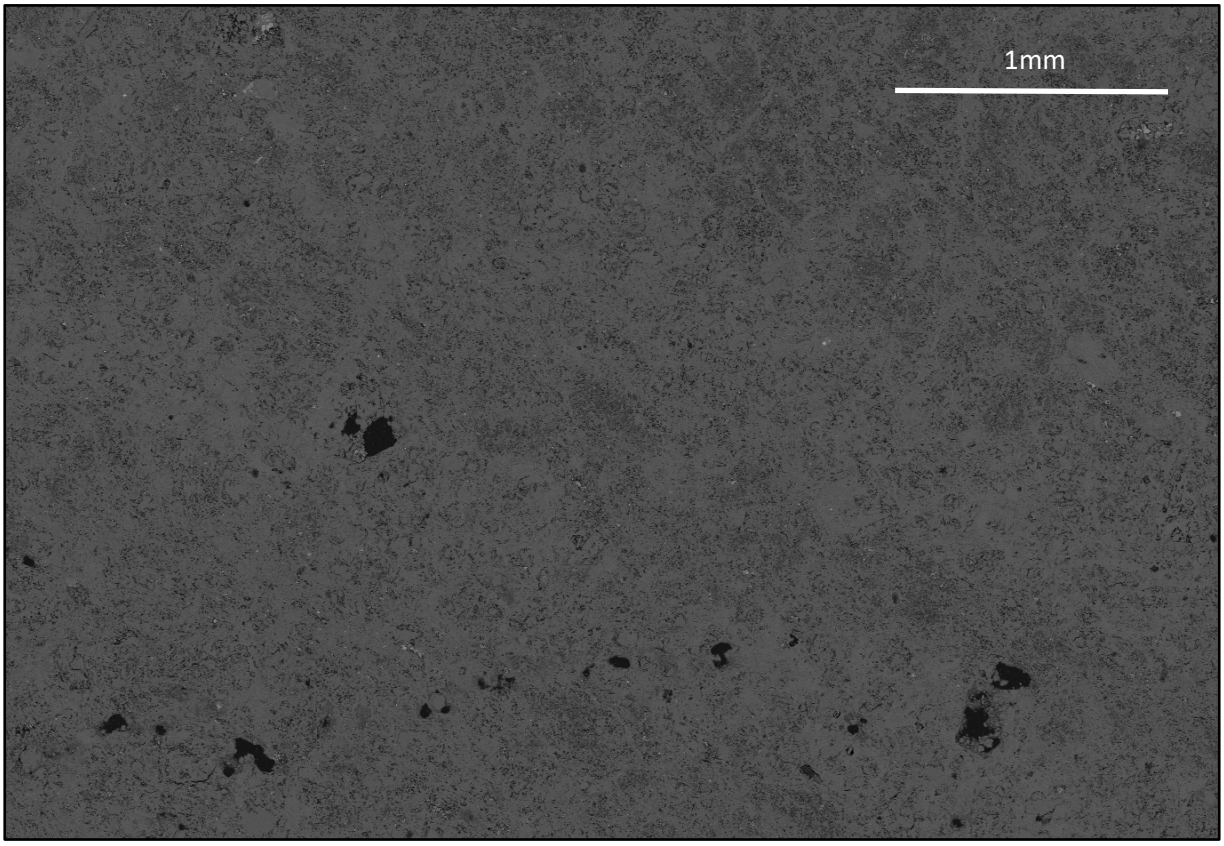
G408276



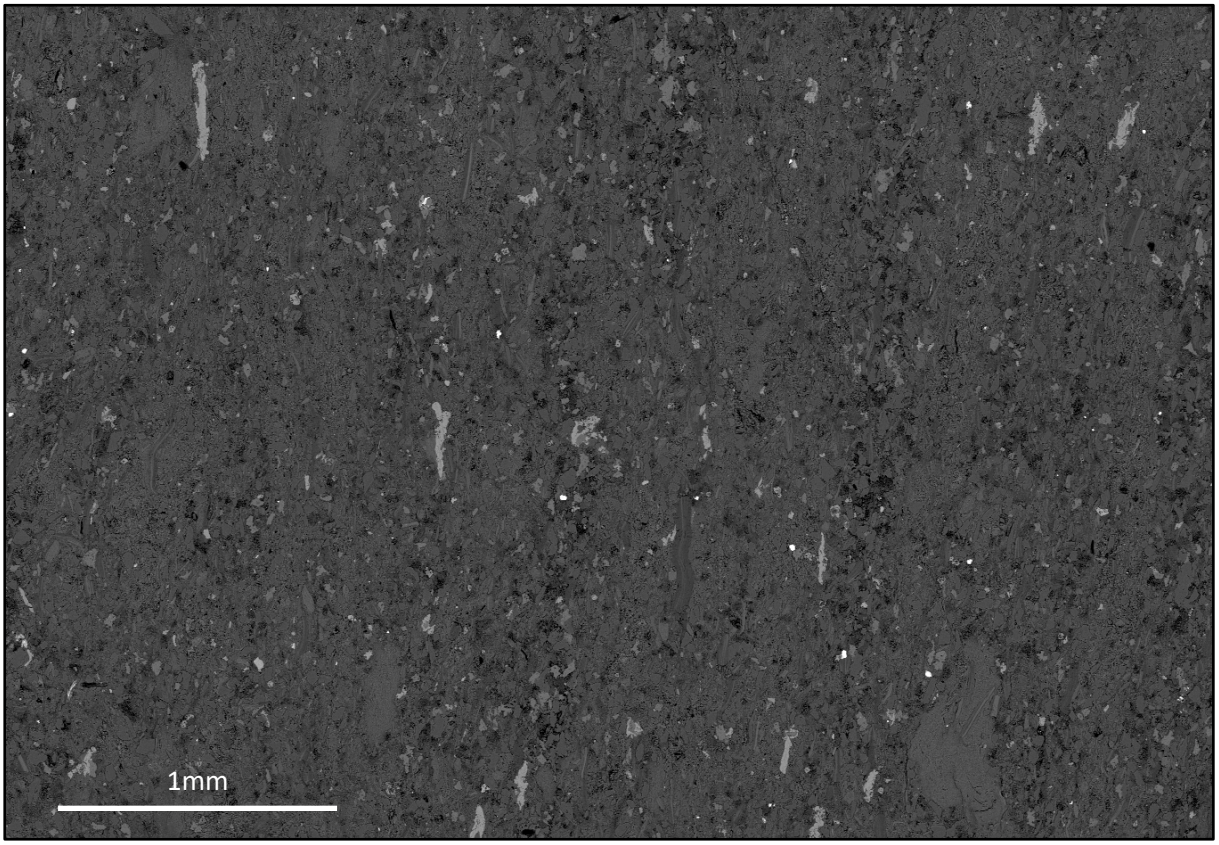
G408277



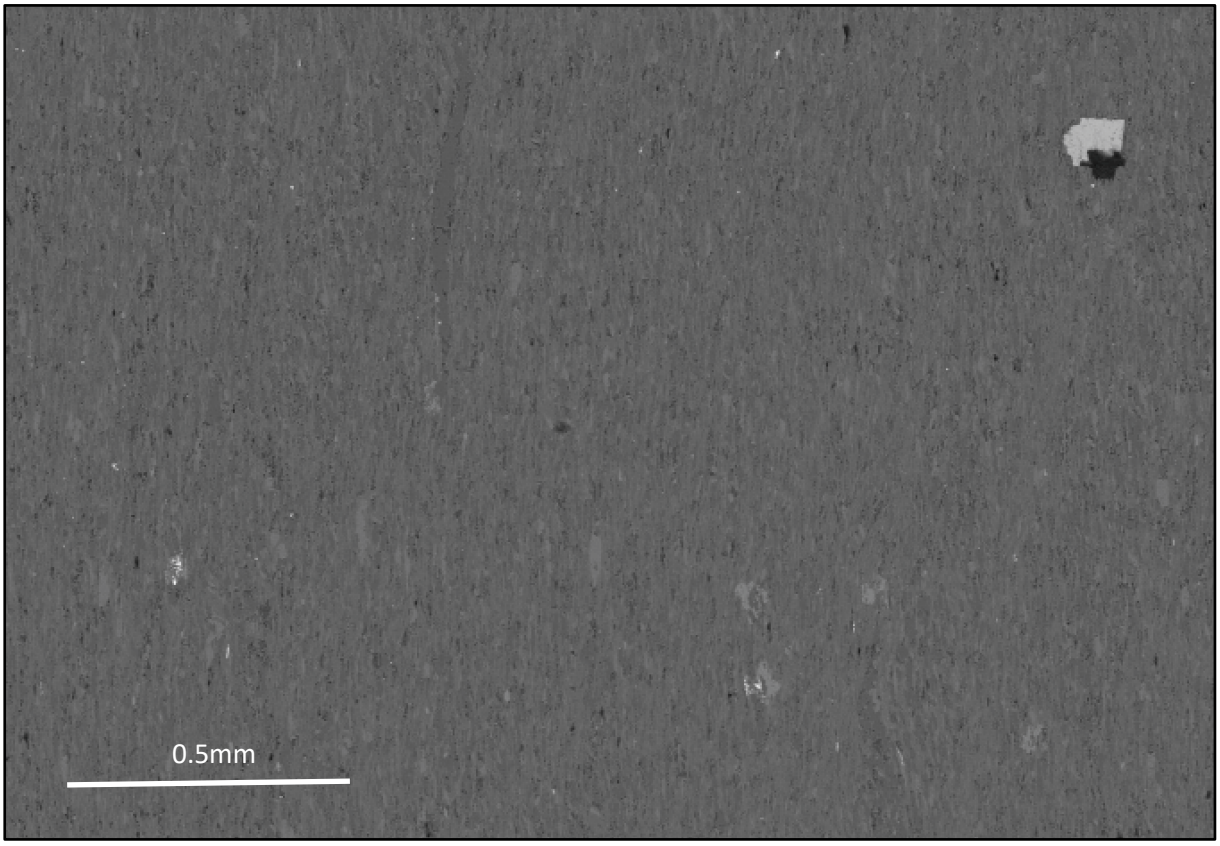
G408249



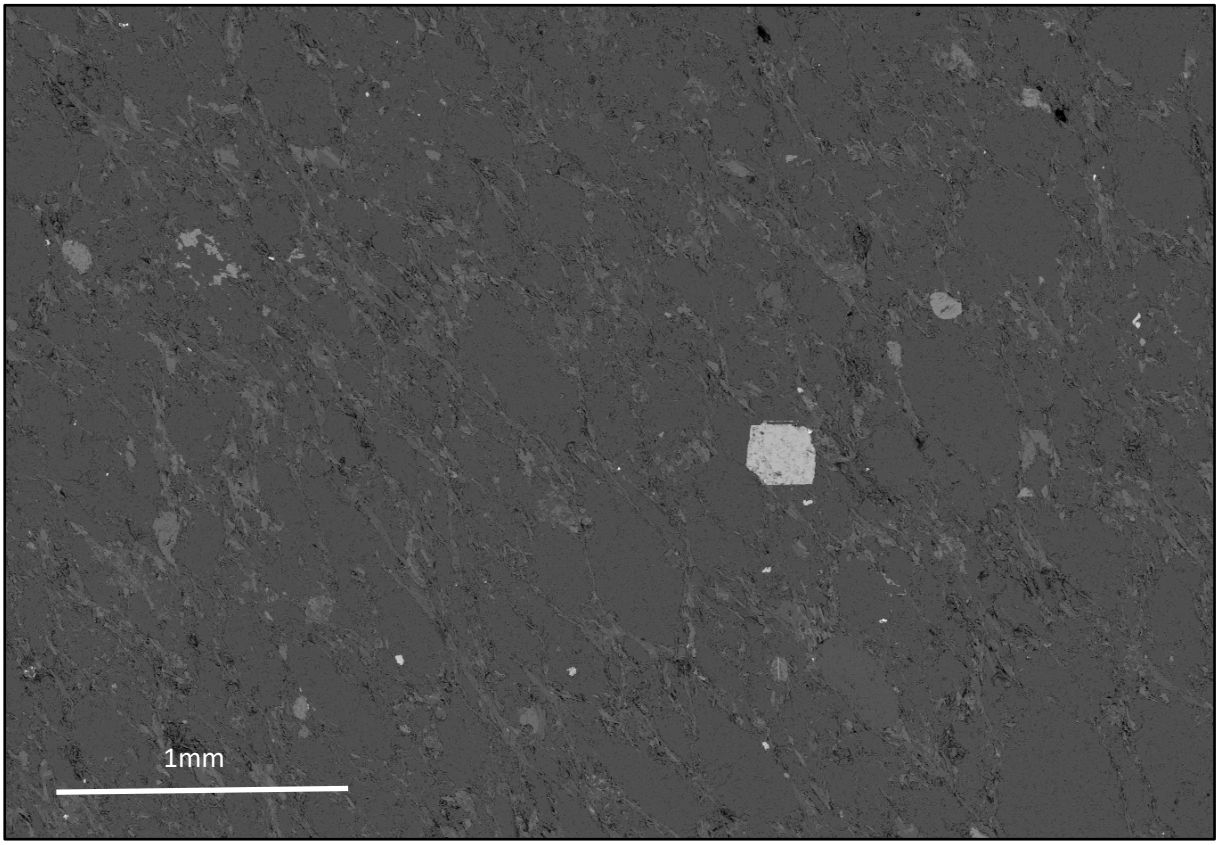
G408250



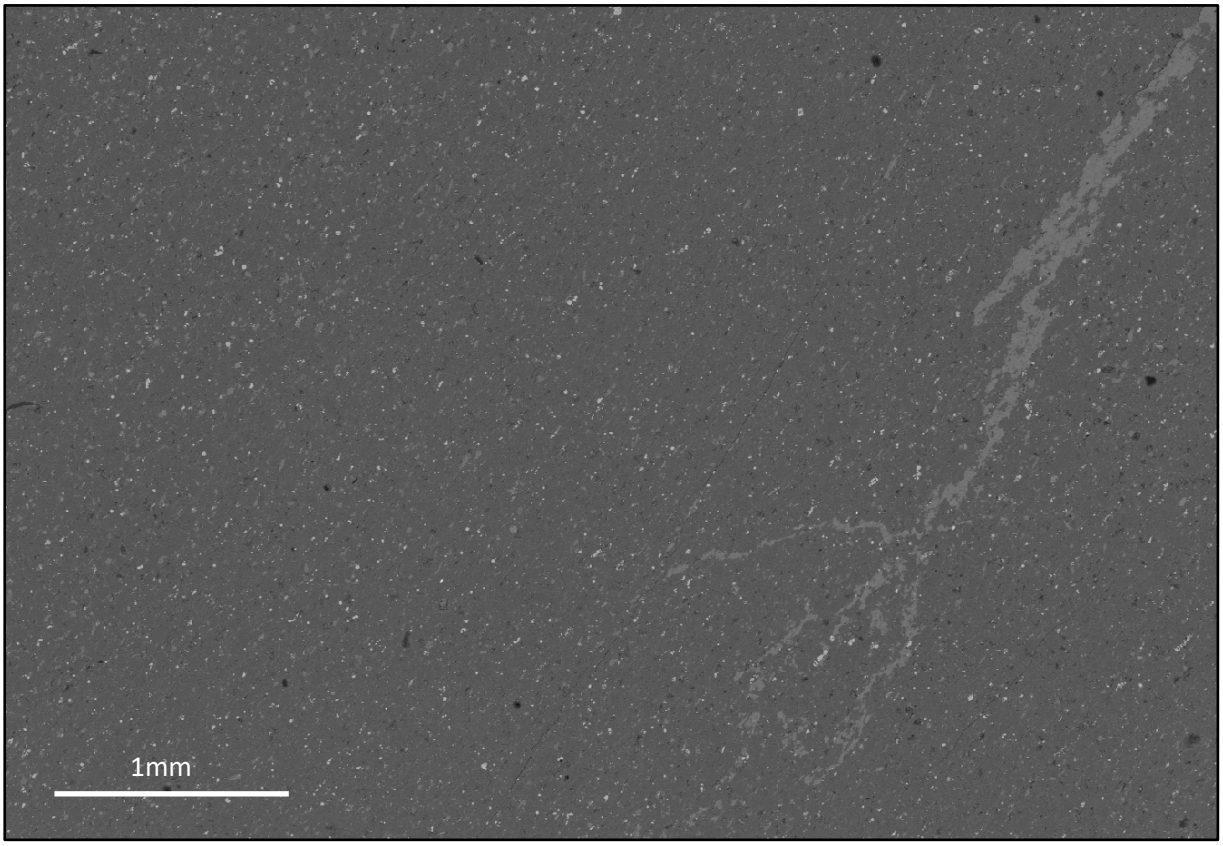
G408253



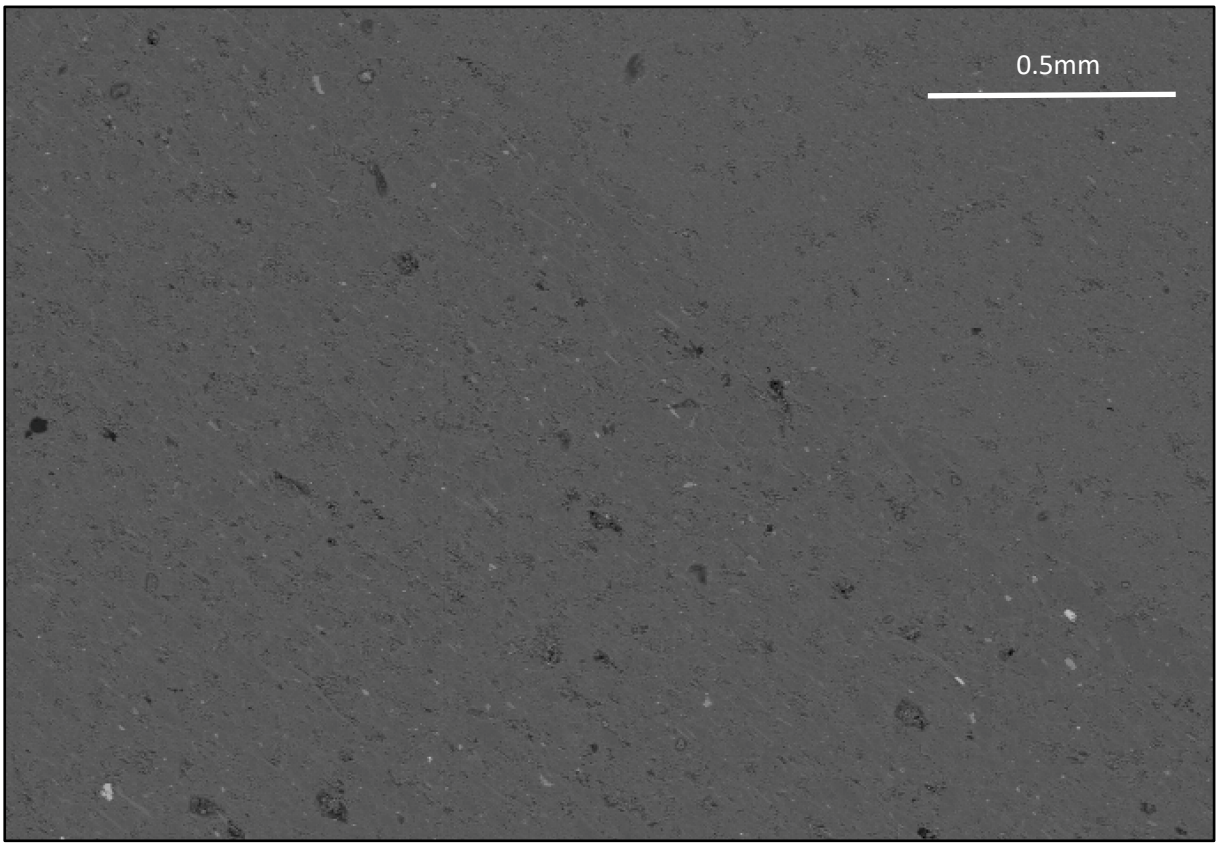
G408254



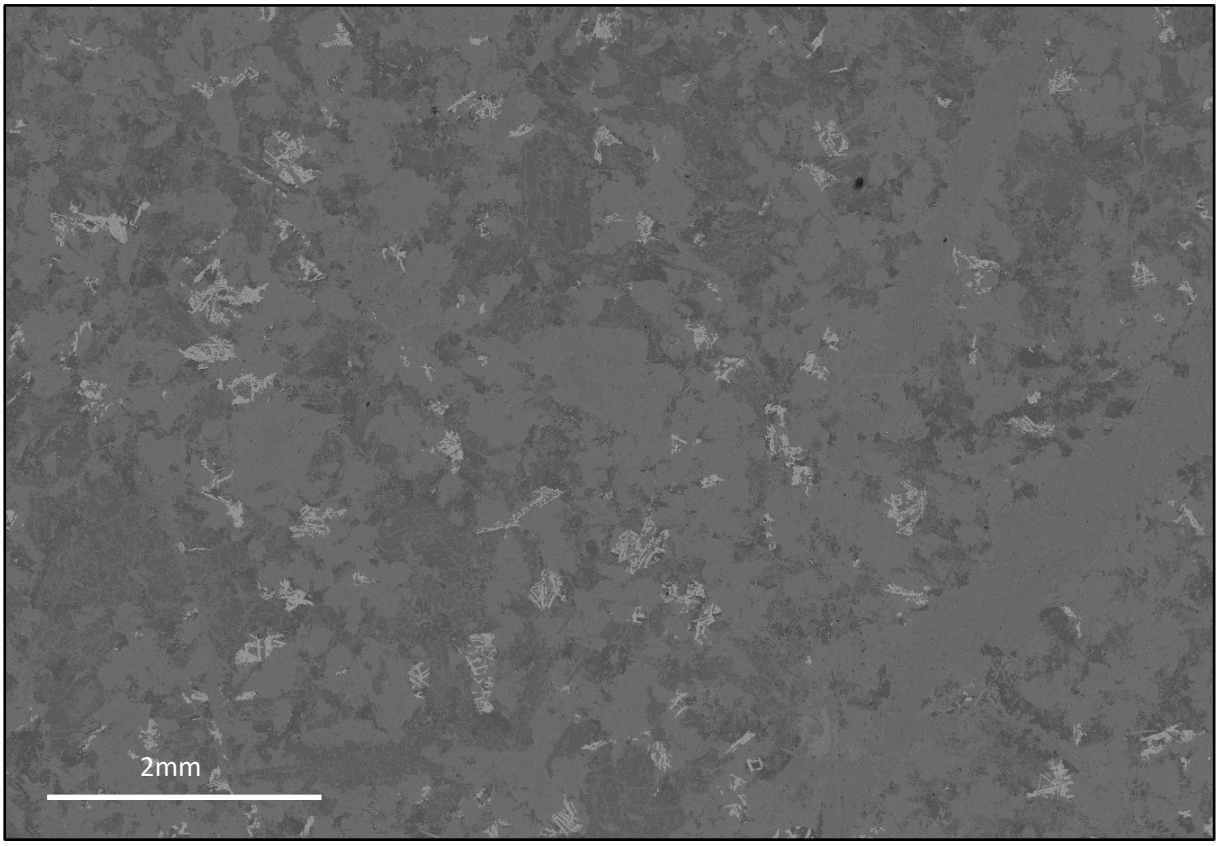
G408261



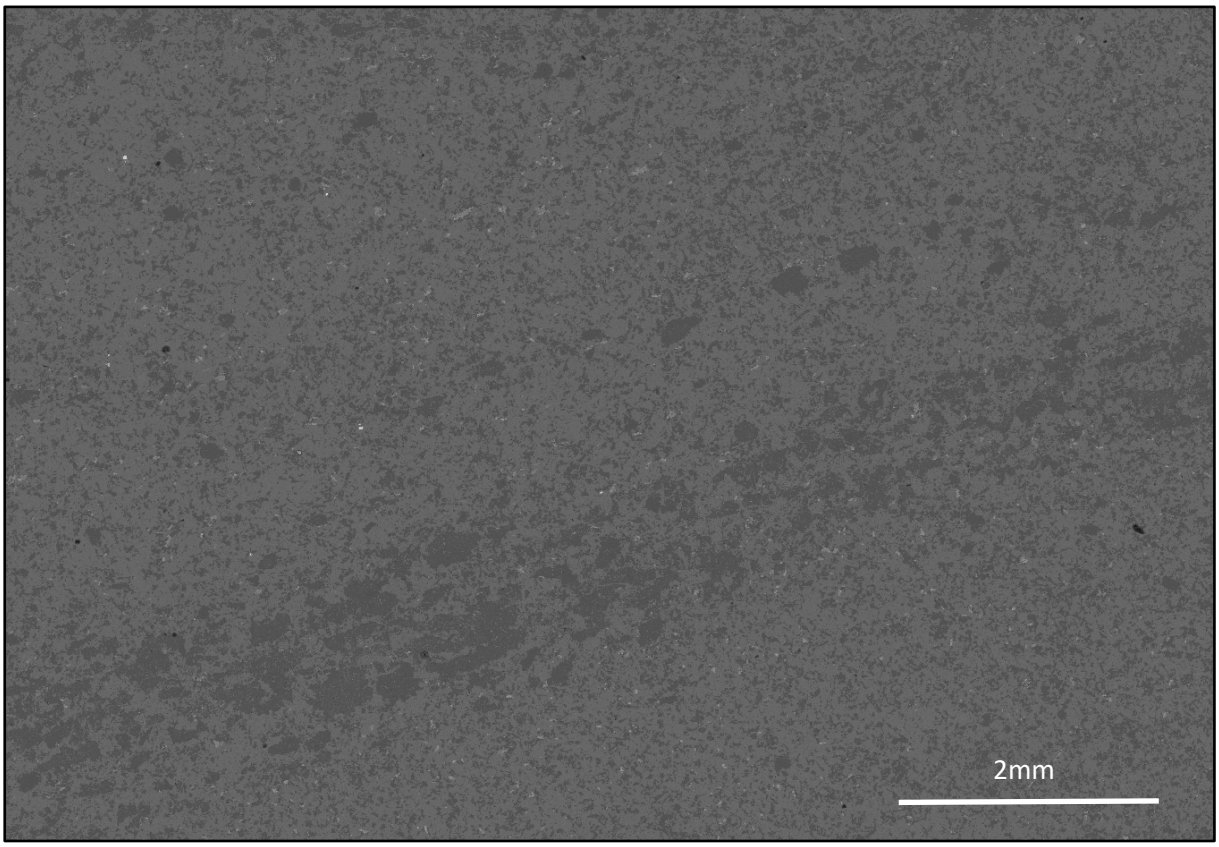
G408262



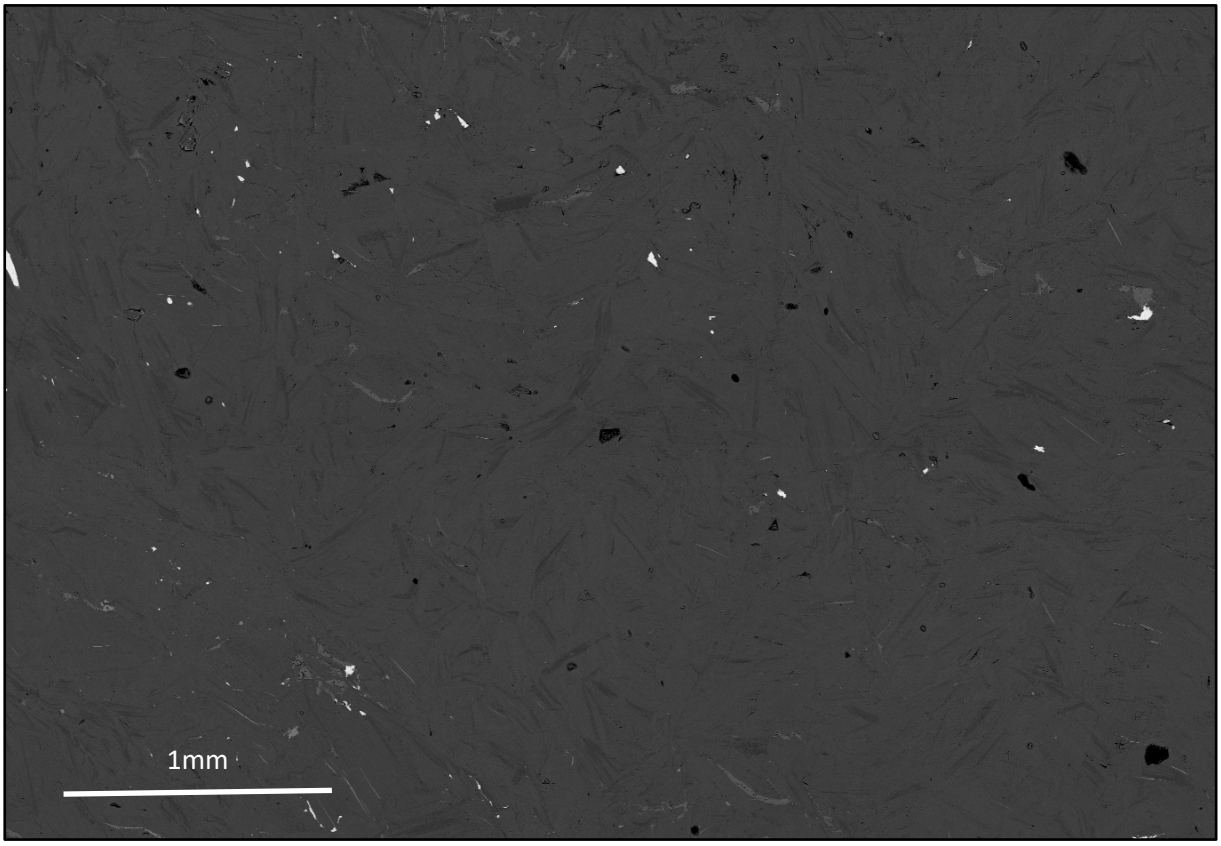
G408266



G408268

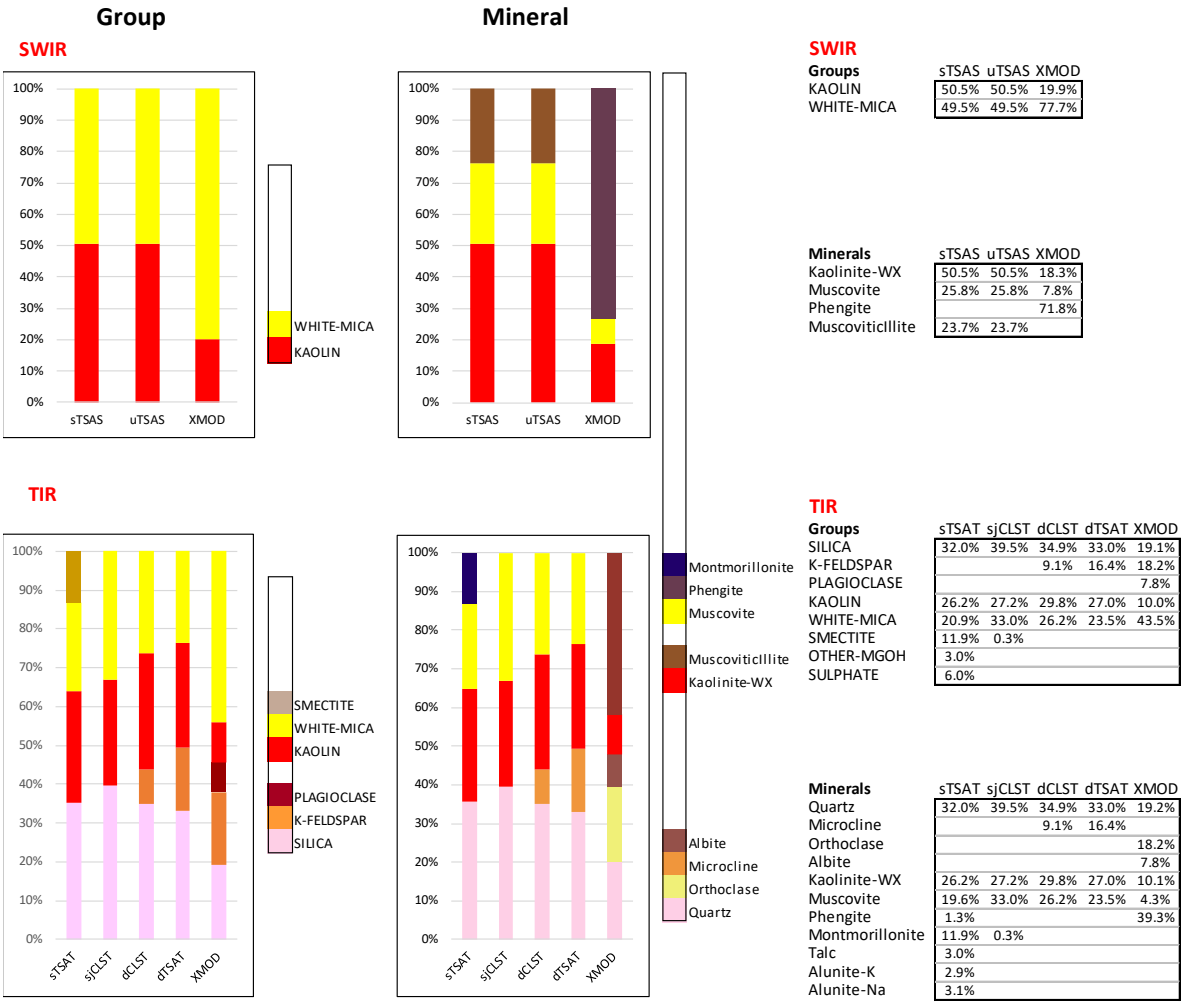


G408279



Appendix 4. Summaries of results from pilot MLA study

G408251 Mudstone



SWIR

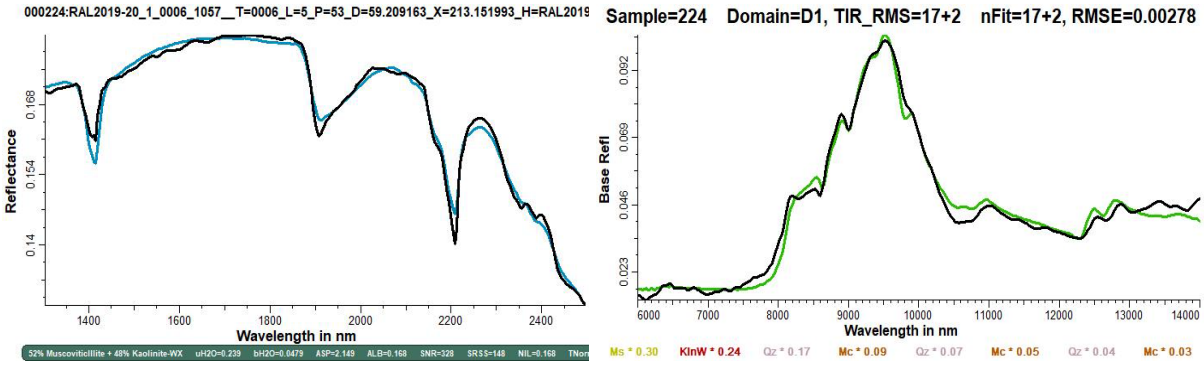
Groups	sTSAS	uTSAS	XMOD
KAOLIN	50.5%	50.5%	19.9%
WHITE-MICA	49.5%	49.5%	77.7%

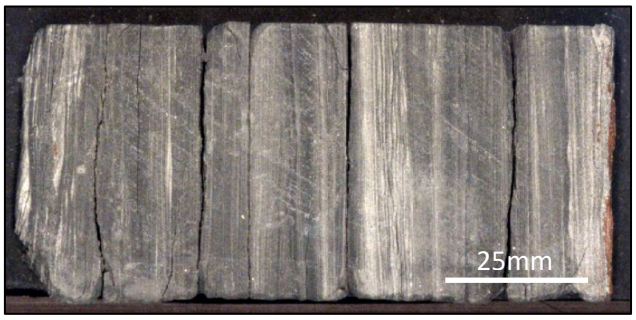
Minerals	sTSAS	uTSAS	XMOD
Kaolinite-WX	50.5%	50.5%	18.3%
Muscovite	25.8%	25.8%	7.8%
Phengite			71.8%
MuscoviticIllite	23.7%	23.7%	

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	32.0%	39.5%	34.9%	33.0%	19.1%
K-FELDSPAR			9.1%	16.4%	18.2%
PLAGIOCLASE					7.8%
KAOLIN	26.2%	27.2%	29.8%	27.0%	10.0%
WHITE-MICA	20.9%	33.0%	26.2%	23.5%	43.5%
SMECTITE	11.9%	0.3%			
OTHER-MGOH	3.0%				
SULPHATE	6.0%				

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	32.0%	39.5%	34.9%	33.0%	19.2%
Microcline			9.1%	16.4%	
Orthoclase					18.2%
Albite					7.8%
Kaolinite-WX	26.2%	27.2%	29.8%	27.0%	10.1%
Muscovite	19.6%	33.0%	26.2%	23.5%	4.3%
Phengite	1.3%				39.3%
Montmorillonite	11.9%	0.3%			
Talc	3.0%				
Alunite-K	2.9%				
Alunite-Na	3.1%				

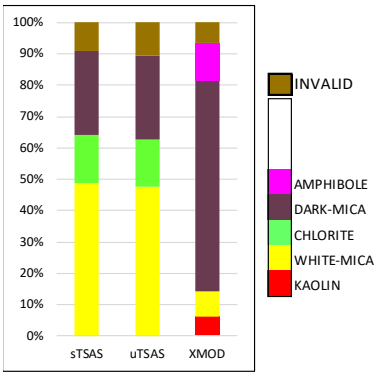




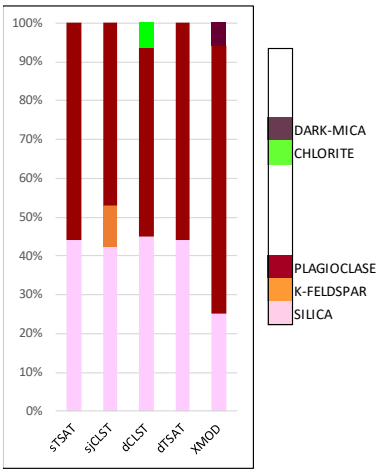
G408275 Altered granodiorite

Group

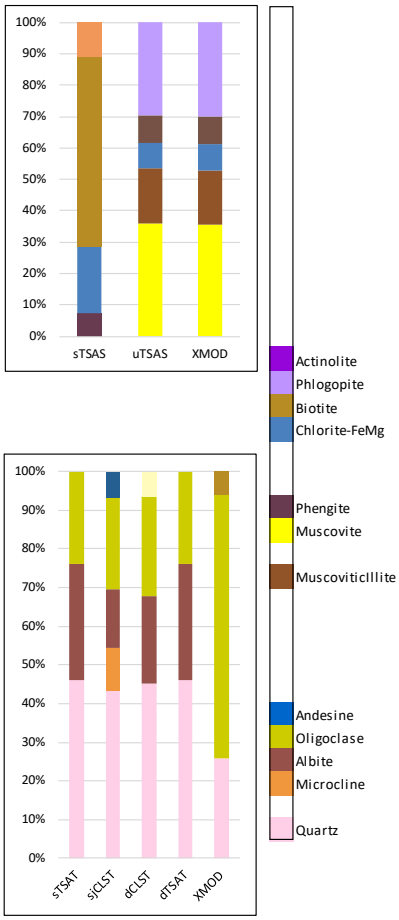
SWIR



TIR



Mineral



SWIR

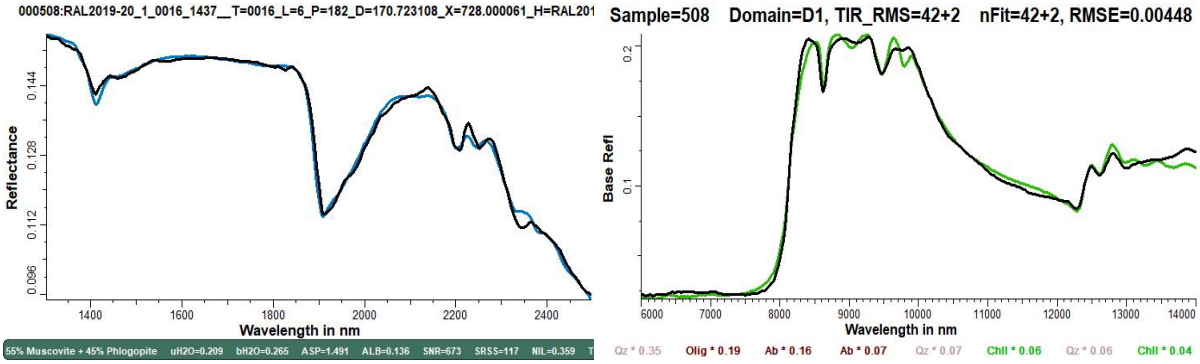
Groups	sTSAS	uTSAS	XMOD
KAOLIN	1.1%	0.7%	5.9%
WHITE-MICA	46.9%	47.2%	7.8%
CHLORITE	15.0%	15.2%	1.7%
DARK-MICA	25.9%	26.4%	63.7%
AMPHIBOLE	0.3%		11.4%
TOURMALINE	1.4%		
CARBONATE	0.3%		3.3%
INVALID	8.6%	10.4%	6.2%

Minerals	sTSAS	uTSAS	XMOD
Kaolinite-WX	0.3%	0.2%	4.9%
Muscovite	34.2%	35.0%	2.4%
Phengite			6.5%
MuscoviticIllite	16.7%	17.1%	
Chlorite-Fe			1.4%
Chlorite-FeMg	7.9%	8.2%	18.9%
Chlorite-Mg	8.4%	8.9%	
Biotite	0.3%	0.2%	53.5%
Phlogopite	28.0%	29.3%	
Actinolite			9.6%
Tourmaline-Fe	1.6%		
Calcite	0.1%		2.8%

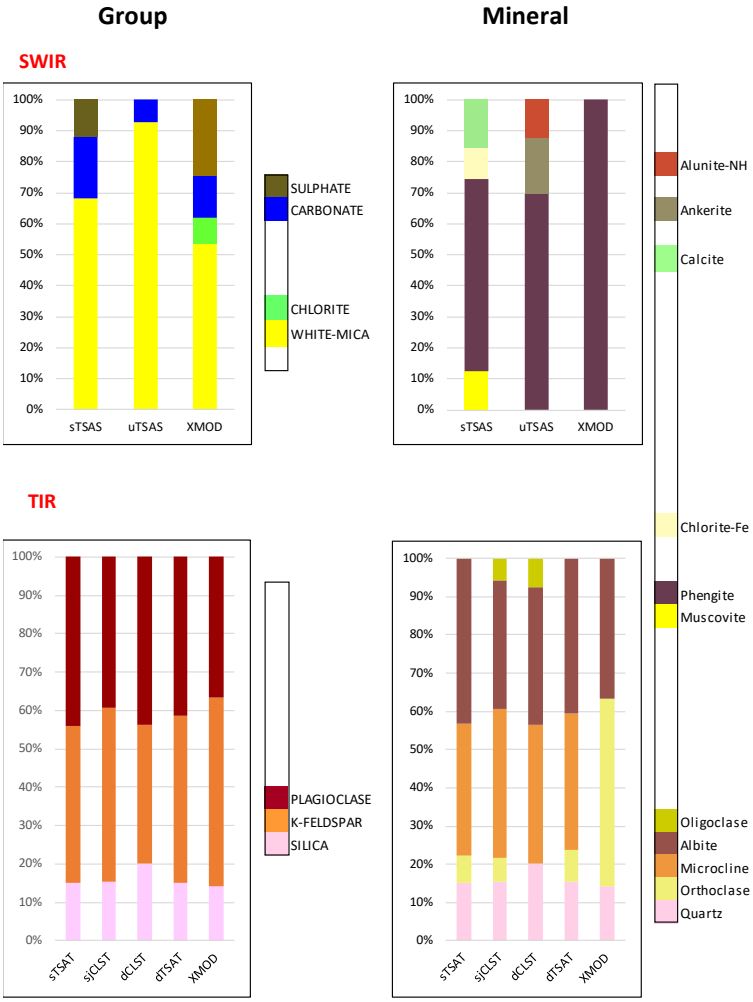
TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	42.3%	41.0%	45.0%	42.3%	22.7%
K-FELDSPAR		10.3%			4.3%
PLAGIOCLASE	53.4%	45.3%	48.5%	53.4%	62.1%
CHLORITE	4.3%	3.3%	6.5%	4.3%	2.0%
DARK-MICA			0.0%		5.3%
AMPHIBOLE					1.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	42.3%	41.0%	45.0%	42.3%	22.9%
Microcline		10.3%			
Orthoclase					4.3%
Albite	27.5%	14.5%	22.8%	27.5%	2.5%
Labradorite		2.1%			
Andesine	3.9%	6.2%		3.9%	
Oligoclase	22.0%	22.6%	25.7%	22.0%	60.1%
Chlorite-FeMg	3.8%	3.3%	6.4%	3.8%	1.9%
Biotite			0.0%		5.3%
Actinolite					1.0%



G408243 K-feldspar-altered dacite



SWIR

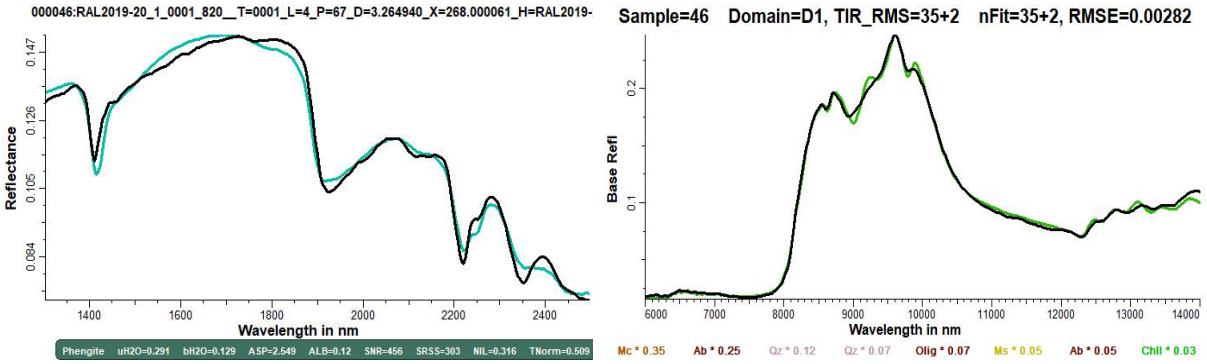
Groups	sTSAS	uTSAS	XMOD
KAOLIN			4.4%
WHITE-MICA	66.9%	90.9%	51.2%
CHLORITE	0.5%	2.1%	8.0%
CARBONATE	19.4%	6.9%	12.9%
SULPHATE	11.8%		
INVALID			23.5%

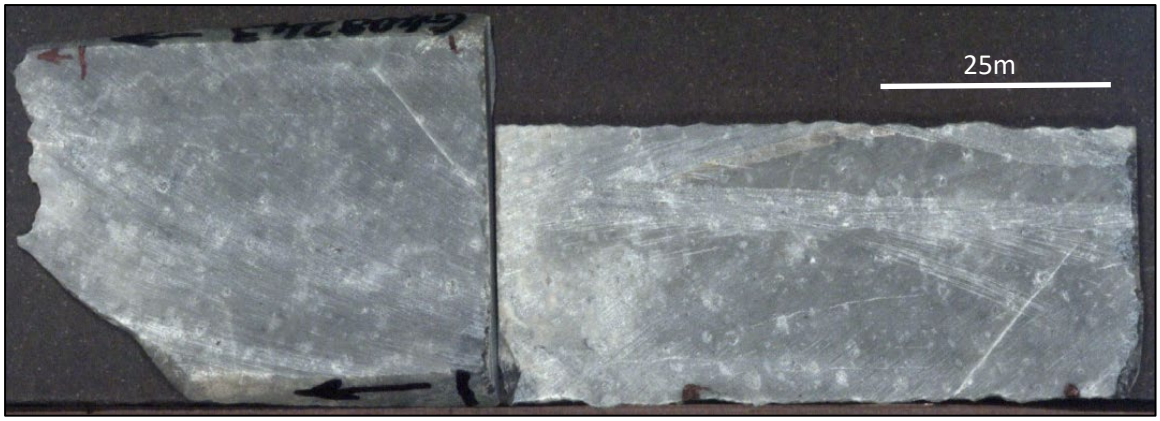
Minerals	sTSAS	uTSAS	XMOD
Kaolinite-WX			5.0%
Muscovite			11.8%
Phengite	67.5%	90.9%	59.0%
Chlorite-Fe			9.2%
Chlorite-FeMg	0.5%	2.1%	
Ankerite	17.5%	4.8%	
Calcite	2.0%	2.0%	14.9%
Alunite-NH	11.9%		

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	14.7%	15.2%	19.0%	15.1%	13.4%
K-FELDSPAR	40.2%	44.9%	34.1%	43.7%	46.3%
PLAGIOCLASE	43.4%	39.0%	41.1%	41.2%	34.3%
WHITE-MICA			4.2%		3.3%
SULPHATE	1.4%	0.5%			
INVALID					1.3%

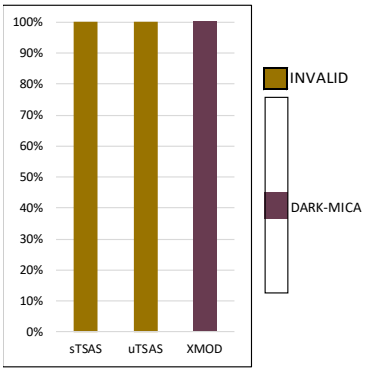
Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	14.7%	15.2%	19.0%	15.1%	13.5%
Microcline	33.4%	38.7%	34.1%	34.7%	
Orthoclase	6.8%	6.2%		8.1%	46.9%
Albite	41.8%	33.2%	34.0%	39.6%	34.8%
Oligoclase	1.6%	5.8%	7.1%	1.6%	
Muscovite			4.2%		0.6%
Phengite					2.8%
Alunite-K	1.4%	0.5%			

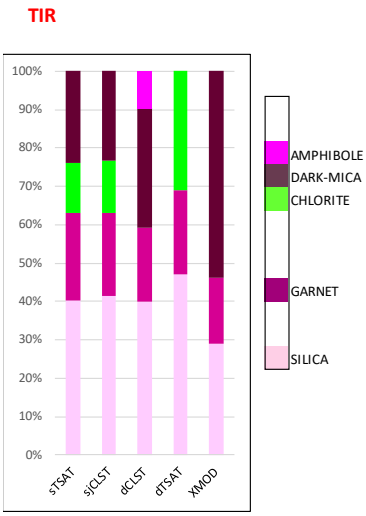




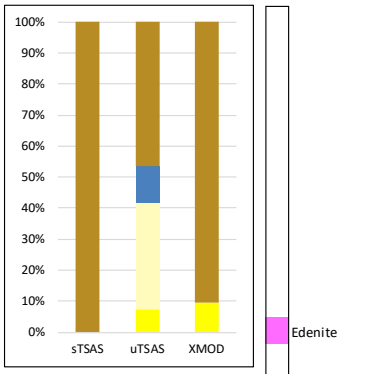
G408265 Biotite-garnet-altered mafic

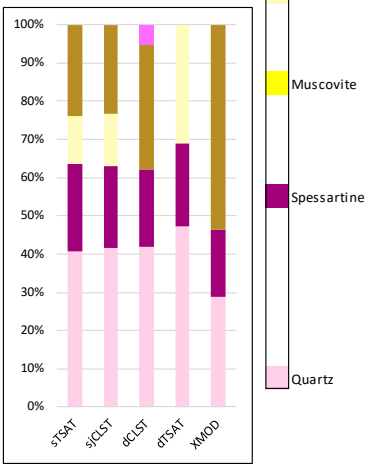
Group

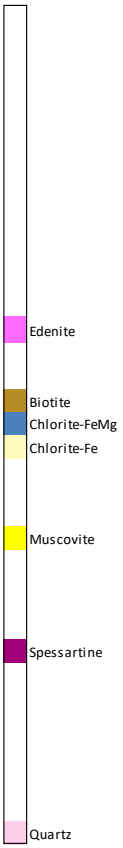




Mineral







SWIR

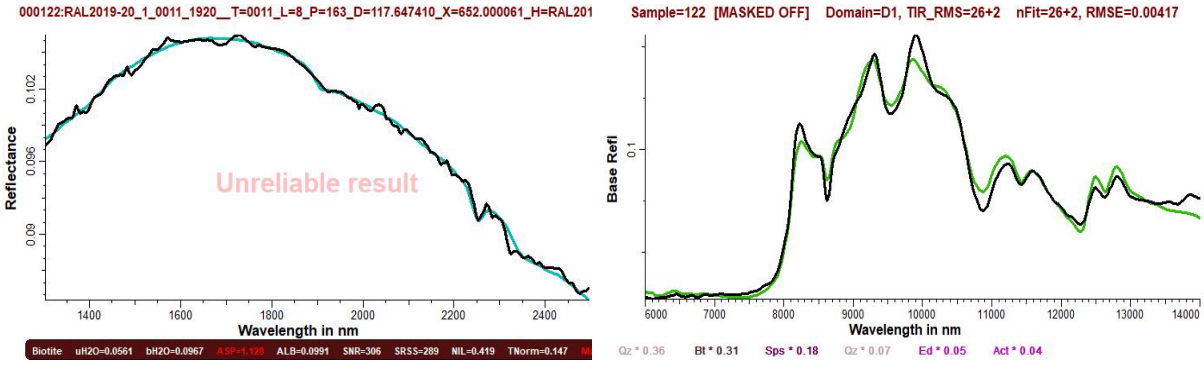
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	0.3%		
CHLORITE	2.2%		4.2%
DARK-MICA	2.2%	2.3%	94.9%
INVALID	95.1%	97.3%	0.0%

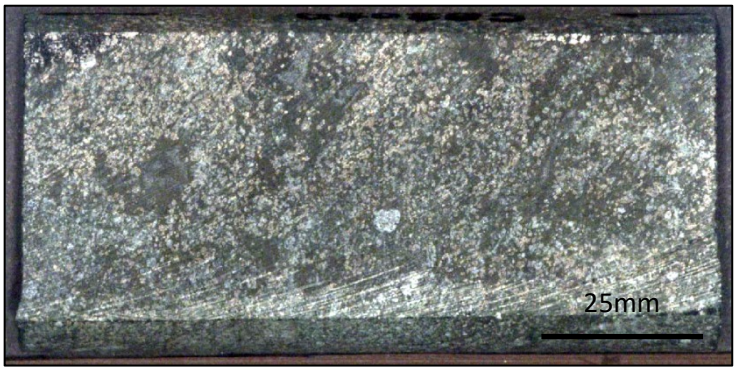
Minerals	sTSAS	uTSAS	XMOD
Muscovite	7.0%	9.2%	2.5%
Phengite		3.3%	0.6%
Chlorite-Fe	34.0%		3.3%
Chlorite-FeMg	11.3%		
Biotite	45.4%	87.5%	81.4%
Tourmaline-Fe	2.2%		0.0%

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	39.5%	41.1%	39.9%	46.0%	26.1%
GARNET	22.3%	21.5%	19.3%	21.2%	15.6%
ZEOLITE				1.7%	
WHITE-MICA		0.1%	0.2%	0.1%	2.0%
CHLORITE	12.8%	13.5%		30.3%	2.2%
DARK-MICA	23.3%	23.1%	31.2%	0.4%	48.5%
AMPHIBOLE	2.1%	0.3%	9.5%	0.3%	0.0%
OXIDE					4.1%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	39.5%	41.1%	39.9%	46.0%	26.3%
Spessartine	22.3%	21.2%	19.3%	21.2%	15.7%
Phillipsite				1.0%	
Muscovite		0.1%	0.2%		1.6%
Chlorite-Fe	0.8%	0.1%			2.2%
Chlorite-FeMg	12.0%	13.3%		30.3%	0.1%
Biotite	23.3%	23.1%	31.2%		48.9%
Actinolite			4.4%		0.0%
Edenite	1.3%	0.3%	5.0%		
OXIDE					4.0%

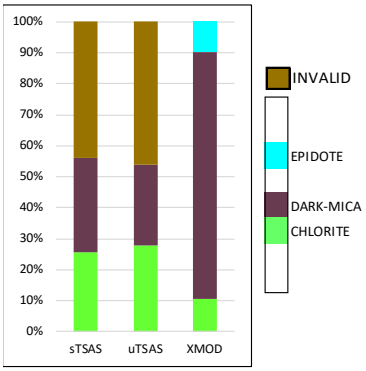




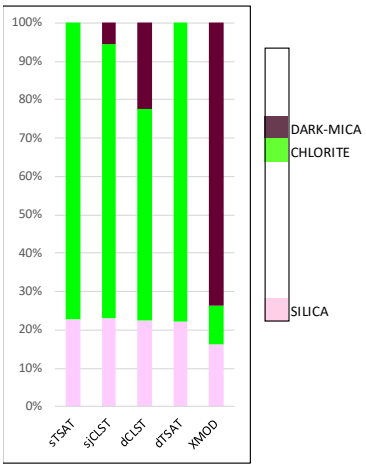
G408264 Biotite-altered mafic

Group

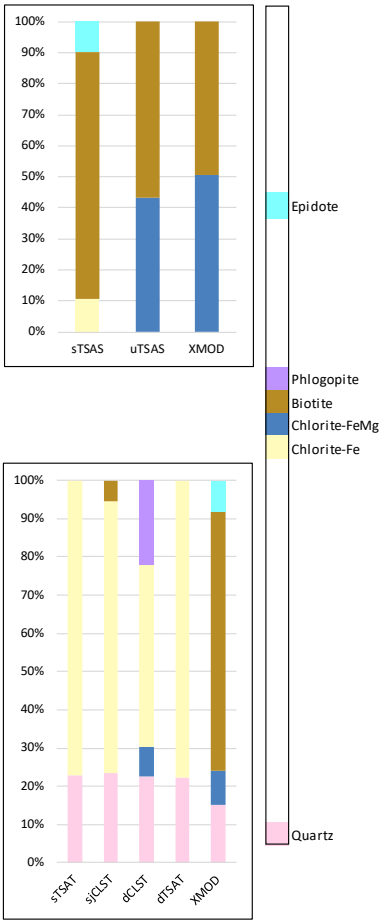
SWIR



TIR



Mineral



SWIR

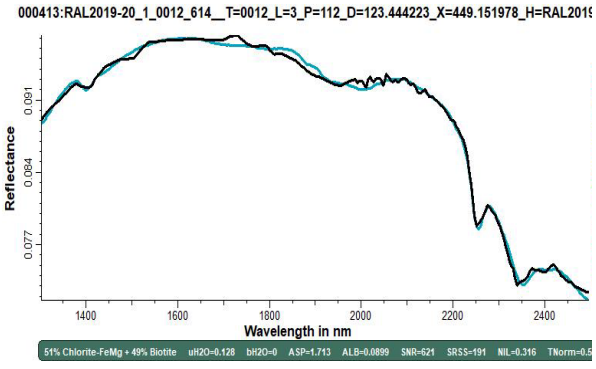
Groups	sTSAS	uTSAS	XMOD
CHLORITE	25.0%	27.7%	10.5%
DARK-MICA	30.2%	25.8%	78.4%
EPIDOTE	0.4%		9.6%
INVALID	42.9%	45.8%	0.1%

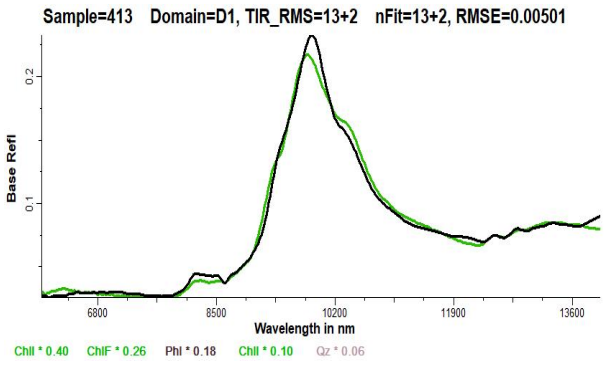
Minerals	sTSAS	uTSAS	XMOD
Chlorite-Fe	2.1%	2.4%	10.5%
Chlorite-FeMg	38.2%	45.8%	
Chlorite-Mg	4.0%	2.9%	
Biotite	50.4%	44.6%	78.2%
Phlogopite	3.1%	2.9%	
Epidote	0.4%		9.5%

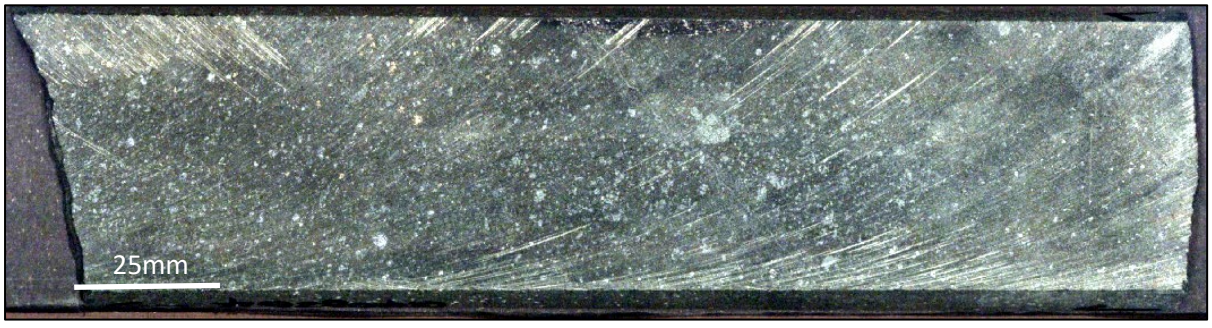
TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	21.4%	22.1%	22.6%	21.6%	14.5%
K-FELDSPAR	0.3%	0.4%			1.1%
PLAGIOCLASE	2.3%	2.5%		2.6%	0.0%
WHITE-MICA					1.0%
CHLORITE	72.6%	69.0%	55.0%	75.8%	8.8%
DARK-MICA	3.0%	5.2%	22.4%		65.4%
EPIDOTE					8.0%

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	21.4%	22.1%	22.6%	21.6%	14.5%
Orthoclase					1.1%
Albite	2.2%	2.3%		2.4%	0.0%
Chlorite-Fe	0.9%	2.4%	7.6%	0.9%	8.8%
Chlorite-FeMg	71.7%	66.6%	47.4%	74.9%	
Biotite	3.0%	5.2%	0.0%		65.6%
Phlogopite			22.1%		



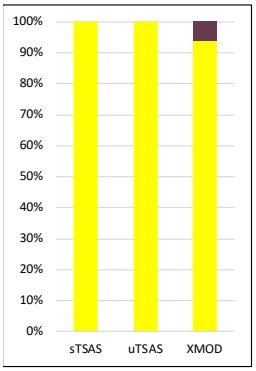




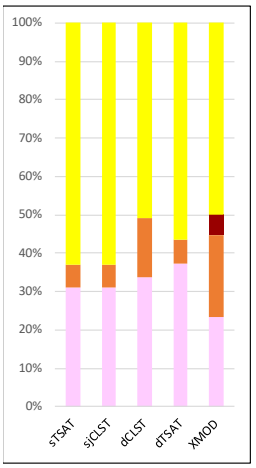
G408260 Micaceous black shale

Group

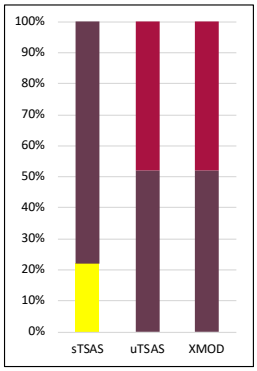
SWIR

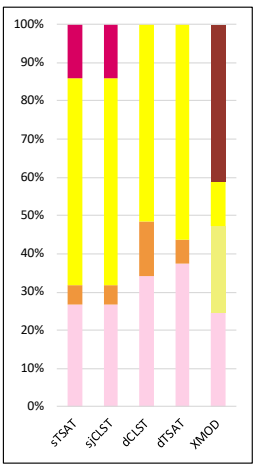


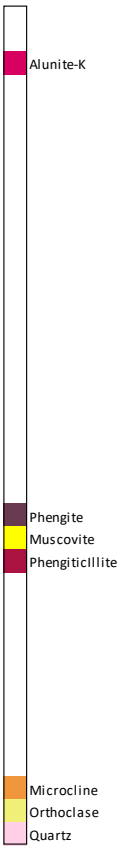
TIR



Mineral







SWIR

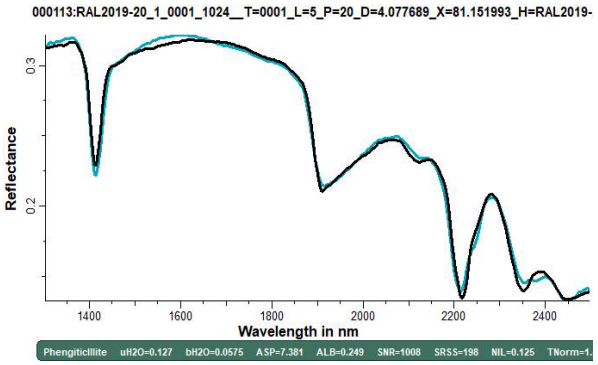
Groups	sTSAS	uTSAS	XMOD
WHITE-MICA	99.8%	99.8%	90.6%
CHLORITE			3.2%
DARK-MICA			6.0%

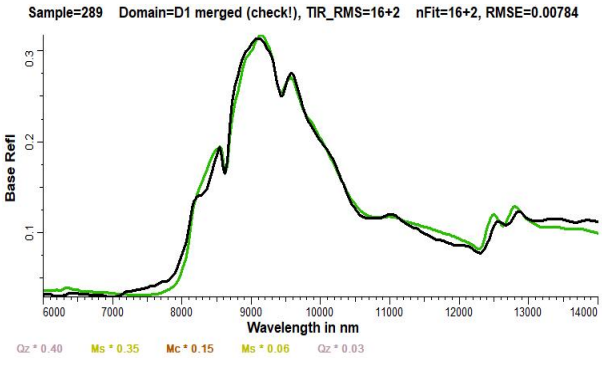
Minerals	sTSAS	uTSAS	XMOD
Muscovite			20.3%
Phengite	52.1%	52.1%	72.2%
PhengiticIllite	47.7%	47.7%	
Chlorite-Fe			2.6%
Biotite			4.8%

TIR

Groups	sTSAT	sjCLST	dCLST	dTSAT	XMOD
SILICA	26.5%	26.5%	33.8%	37.4%	22.1%
K-FELDSPAR	5.2%	5.2%	15.4%	6.2%	20.6%
PLAGIOCLASE					5.1%
WHITE-MICA	53.8%	53.8%	50.8%	56.4%	47.4%
CHLORITE					1.3%
DARK-MICA					2.5%
SULPHATE	14.6%	14.6%			

Minerals	sTSAT	sjCLST	dCLST	dTSAT	XMOD
Quartz	26.5%	26.5%	33.8%	37.4%	22.3%
Microcline	5.2%	5.2%	14.1%	6.2%	
Orthoclase			1.2%		20.7%
Albite					3.9%
Oligoclase					1.2%
Muscovite	53.8%	53.8%	50.8%	56.4%	10.5%
Phengite					37.3%
Chlorite-Fe					1.3%
Biotite					2.5%
Alunite-K	13.9%	13.9%			





Sample interpretation (from Green and Reid 2021)

G408251 Mudstone

TSAS and CLST both correctly identified mineral groups. TSAS overestimated the proportion of white mica by a factor of 1.6 and apportioned all of it to muscovite (or illitic muscovite), but XMOD identified 90% of the white mica as phengitic.

CLST (and TSAT) correctly identified significant white mica, but like the SWIR algorithms, incorrectly identified the white mica as muscovite. A small proportion of plagioclase included in XMOD could not be justified in the RMS for the dCLST, although was not severely penalised if included in addition to, or instead of K-feldspar. The TIR algorithms over-estimated quartz by a factor of 1.8.

G408275 Altered granodiorite

TSAS and CLST both correctly identified mineral groups and mineral species. TSAS made a good estimate of the chlorite proportion, but overestimated white mica by a factor of 6 and underestimated dark mica by a factor of 2.

White mica was not used by CLS, even when feldspars, chlorite, kaolin and dark mica were not made available. CLS overestimated quartz:plagioclase by a factor of 1.7. sjCLST identified a low proportion of K-feldspar that was not backed up by dCLS, but was validated by XMOD. A small proportion of chlorite (3-7%) interpreted by the TIR unmixing algorithms was a surprisingly good estimate of the true proportion (6%). CLST (and TSAT) interpreted plagioclase as albite plus oligoclase, but XMOD identified 96% as oligoclase.

G408243 K-feldspar-altered granite

TSAS and CLST both correctly identified mineral groups and mineral species and their relative proportions (including quartz) to within 8%.

The carbonate was identified as siderite using the 14,000 and 11,300nm features. MLA interpreted it as calcite, but siderite was not included in the mineral library.

G408265 Biotite-garnet-altered mafic

TSAS was unable to determine the mineralogy of over 90% of the spectra, interpreting them as aspectral, but MLA indicated a high proportion of biotite. Although a deep crystal field feature was apparent, features in the SWIR were noisy. Smoothing the spectra did reveal prominent FeOH and MgOH absorptions at 2252nm (biotite or chlorite) and 2339nm (more consistent with chlorite). When aspectral results were disregarded, as presented in the mineral species results, biotite becomes dominant.

In the TIR, sjCLST and dCLST did a good job at identifying mineral groups, including biotite and garnet. However dTSAT favoured chlorite over biotite. Minor amphibole was incorrectly identified and used by dCLST, but not by dTSAT. Quartz was over-estimated by a factor of 1.9.

G408264 Biotite-altered mafic

Dark mica (biotite) and chlorite were correctly identified by the TSAS algorithms, but chlorite was over-estimated relative to biotite. Both the SWIR and TIR algorithms were unable to see the epidote (9%) in the sample.

sjCLST, dCLST and uTSAT all incorrectly interpreted chlorite rather than biotite. Quartz was over-estimated by a factor of 1.8.

G408260 Micaceous black shale

The SWIR algorithms correctly identified white mica as the dominant mineral. MLA apportioned 70% to phengite (or illitic phengite) and 20% to muscovite, but TSA found only phengite (or illitic phengite).

sjCLST, dCLST and udTSAT all correctly identified white mica, quartz and K-feldspar, but sjCLST incorrectly added minor sulphate (alunite). The proportion of white mica was accurately estimated by all

algorithms, K-feldspar was best estimated by dCLST and quartz was over-estimated by a factor of 1.6.

G408245 Altered felsic volcanic

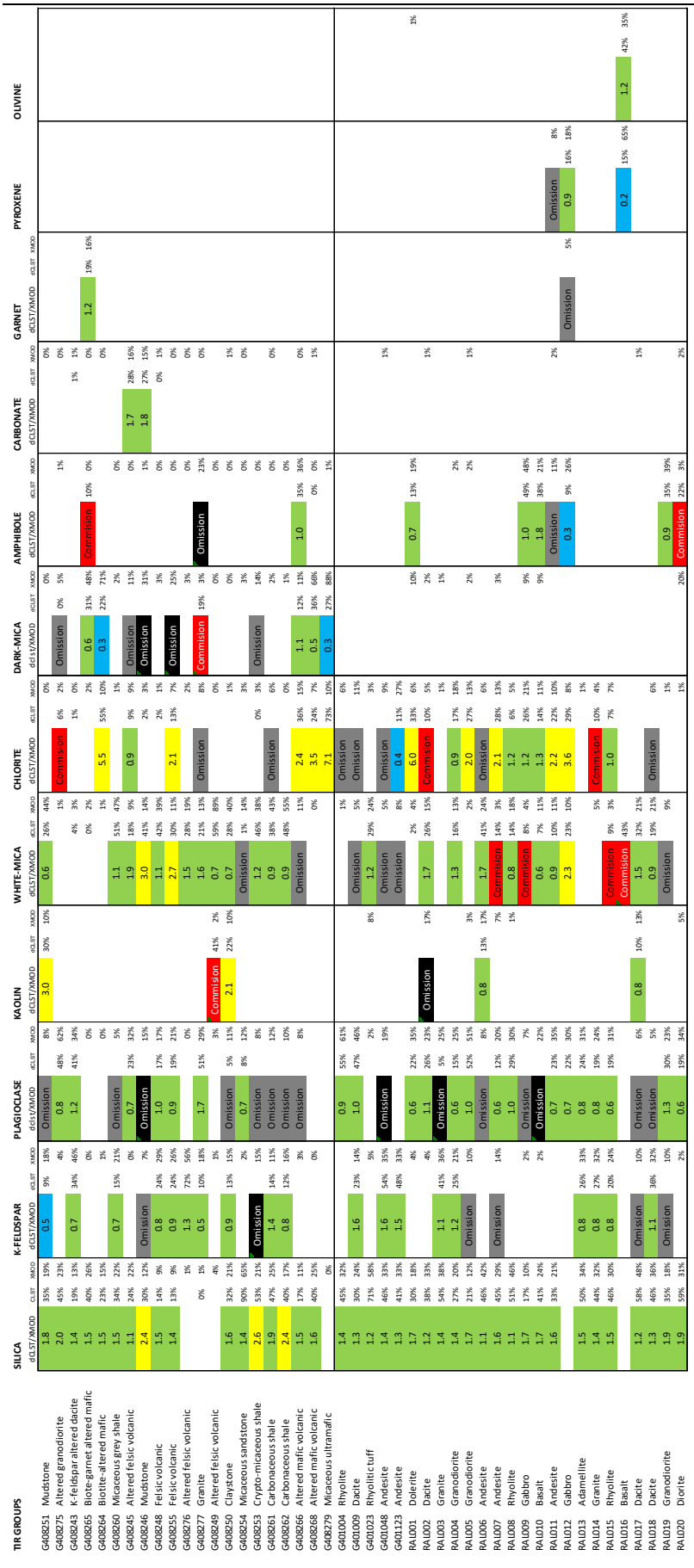
This sample contained a challenging mineral assemblage, with biotite and chlorite in the SWIR and plagioclase, white mica, chlorite (and biotite) all with major features at similar TIR wavelengths (9500-9800nm: the 'Triangle of death').

TSAS and CLST both correctly identified all but one of the main mineral groups present, both missing dark mica, which comprised 24% of the sample.

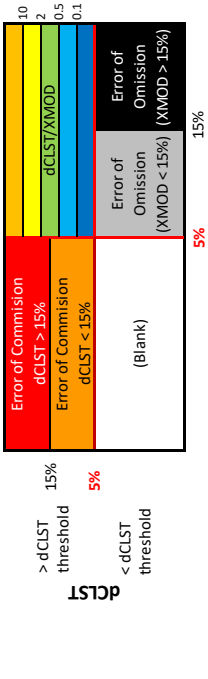
Carbonate was identified as siderite by sTSAT and dCLST, which was supported by the diagnostic wavelength of the $\nu 4$ in-plane bend feature at 11,385nm. However, XMOD identified the carbonate as calcite, which was the result from sjCLST. dTSAT returned equal proportions of siderite and calcite.

The proportion of carbonate was correctly estimated by dCLST (and dTSAT) but was significantly under-estimated by TSAS. Proportions of quartz and plagioclase were well estimated by dCLST, but white mica and chlorite(/biotite) were significantly over-and under-estimated respectively.

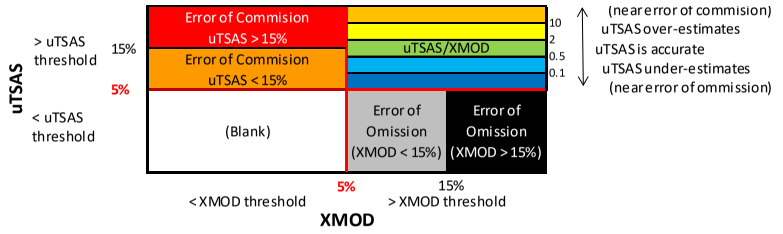
Appendix 5. Summaries of mineral identification results



Tables illustrating the success of mineral identification by dCLST and uTSAS, including results from previous reports in this research program (Green and Reid 2021, Moltzen and Bottrill 2018 and Moltzen et al 2020).



SWIR GROUPS		KAOLIN			WHITE-MICA			CHLORITE			DARK-MICA			AMPHIBOLE			CARBONATE			EPIDOTE			OTHER-ALOH		
		uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD	uTSAS/XMOD	uTSAS	XMOD						
G408251	Mudstone	2.5	50%	20%	0.6	50%	78%			1%			1%						0%						
G408275	Altered granodiorite	Omission	1%	6%	6.4	53%	8%	Commision	17%	2%	0.4	29%	68%	Omission		12%			4%						
G408243	K-feldspar altered dacite	Omission		6%	1.4	91%	67%	Omission	2%	11%							0.4	7%	17%						
G408265	Biote-garnet altered mafic			0%	Commision	12%	1%			4%	0.9	88%	95%			0%			0%						
G408264	Biotite-altered mafic			0%		0%	1%	4.4	52%	12%	0.6	48%	87%						1%						
G408260	Micaceous grey shale			0%	1.1	100%	91%			3%	Omission		6%			0%		0%							
G408245	Altered felsic volcanic			0%	2.4	47%	19%	2.3	46%	20%	Omission		24%			1%	0.2	7%	36%						
G408246	Mudstone			0%	2.3	48%	21%	Commision	52%	5%	Omission		49%			1%	Omission	0%	24%						
G408248	Felsic volcanic			0%	1.1	97%	88%		1%	4%	Omission		6%			0%		1%	2%						
G408255	Felsic volcanic			0%	Omission		27%			3%	Omission		69%			1%			0%						
G408276	Altered felsic volcanic		0%	0%	1.3	98%	75%	Omission	2%	8%	Omission		16%			0%			1%						
G408277	Granite			0%	Omission		32%			4%	Omission		7%	Omission		57%			0%						
G408249	Altered felsic volcanic	Commision	48%	3%	0.5	52%	96%			1%			0%			1%									
G408250	Claystone	2.4	51%	21%	0.6	49%	76%			1%			0%			0%			1%						
G408254	Micaceous sandstone		0%	1%	1.2	78%	63%	1.1	20%	18%	Omission	0%	16%			2%		2%	0%						
G408253	Crypto-micaceous shale			0%	1.3	91%	68%	1.4	8%	6%	Omission		26%			0%		1%							
G408261	Carbonaceous shale			1%	Omission		83%	Omission		12%			4%			0%			0%						
G408262	Carbonaceous shale			0%	Omission		97%			1%			2%			0%									
G408266	Altered mafic volcanic			0%	0.8	11%	15%	3.9	82%	21%	Omission	2%	16%	Omission	4%	48%			1%						
G408268	Altered mafic volcanic			0%		1%	0%	5.2	47%	9%	0.6	53%	91%			0%									
G408279	Micaceous ultramafic								1%	0%	1.0	99%	98%			2%									
G401004	Rhyolite				1.6	23%	14%	0.9	77%	86%															
G401009	Dacite				0.7	21%	31%	1.1	79%	69%															
G401023	Rhyolitic tuff	0.8	16%	20%	1.1	84%	73%	Omission		7%															
G401048	Andesite				0.9	31%	36%	1.1	69%	61%									4%						
G401123	Andesite				1.2	28%	23%	0.9	72%	77%															
RAL001	Dolerite	Omission		83%	Commision	19%		Commision	35%					4.8	46%	10%				Omission		7%			
RAL002	Dacite	Omission		43%	2.6	100%	38%	Omission		11%			4%						3%						
RAL003	Granite	Commision	43%		Commision	57%		Omission		55%	Omission		45%												
RAL004	Granodiorite				2.1	72%	33%	0.6	28%	47%				Omission		6%				Omission		14%			
RAL005	Granodiorite	Omission		13%	Omission		8%	1.8	100%	54%	Omission		8%	Omission		8%			4%			4%			
RAL006	Andesite	1.7	60%	36%	0.8	40%	51%	Omission		13%															
RAL007	Andesite	Omission		21%	2.7	25%	9%	1.9	75%	39%	Omission		9%							Omission		21%			
RAL008	Rhyolite			4%	1.3	100%	75%	Omission		21%															
RAL009	gabbro				Commision	16%	5%	1.5	30%	20%	Omission		10%	1.2	54%	46%				Omission		7%	Omission		12%
RAL010	Basalt				1.3	22%	17%	3.4	56%	17%	Omission		15%	0.6	22%	33%				Omission		19%			
RAL011	Andesite				0.6	16%	26%	2.8	64%	23%				Omission		26%	Omission		5%	1.0	21%	21%			
RAL012	Gabbro				1.5	33%	22%	3.9	67%	17%				Omission		57%									4%
RAL013	Adamellite	Commision	43%		Commision	57%		Omission		100%															
RAL014	Granite				0.7	31%	45%	1.9	69%	36%										Omission		18%			
RAL015	Rhyolite				2.1	46%	21%	1.1	54%	50%										Omission		29%			
RAL016	Basalt				Omission		100%																		
RAL017	Dacite	1.6	60%	37%	0.7	40%	60%												3%						
RAL018	Dacite				1.3	100%	78%	Omission		22%															
RAL019	Granodiorite				1.1	21%	18%	Commision	37%	2%				0.5	42%	80%									
RAL020	Diorite	Omission		17%						5%	Omission		63%	Omission		9%	Omission		6%						



Appendix 6. Digital files

Excel files

Samples (Table 1).xlsx
Summary results (Figure 4).xlsx
Mineral identification success table (Tables 5, 6) - Colour coded.xlsx
HyLogging and MLA results - All data.xlsx
HyLogging and MLA results (Appendix 1) - Summary.xlsx
Full MLA results (Appendix 2).xlsx
Mineral identification success table (Appendix 5) - Compilation, colour coded.xlsx

TSG datasets

Individual samples (408279, 408242, 408245, 408246, 408248, 408249, 408250, 408253, 408253av, 408254, 408255, 408261, 408261av, 408262, 408262av, 408266, 408268, 408276, 408277)

Collated RAL 2016-21 samples
Collated RAL 2020-21 samples

XMOD

Individual samples (G408279, G408245, G408246, 408248A, 408248B, G408249, G408250, G408253, G408254, G408255, G408261, G408262, G408266, G408268, G408276, G408277)

For each sample:

XMOD_STD_MINERAL_SAMPLE.tif
Mineral_colour_legend.tif (Sample point map coloured by mineral)
Modal_mineralogy.xlsx (Summary statistics)
XMOD_STD.csv (Sample points table)
XMOD_STD_BSE_SAMPLE.tif (Backscatter image)

Tasmanian Government

Mineral Resources Tasmania
PO Box 56 Rosny Park
Tasmania Australia 7018
Ph: +61 3 6165 4800

info@mrt.tas.gov.au www.mrt.tas.gov.au