

Mineral Resources Tasmania

Laboratory Report

LJN2021-045

MINERALOGICAL ANALYSES, RAEBURN QUARRY, BREADALBANE



An unpublished Mineral
Resources Tasmania Report for:

**C. Mazengarb,
MRT**

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Lounejeva

Date: 1 October 2021

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SUMMARY

The samples are of two groups: Tertiary/Palaeogene laterite and basaltic rocks.

The fresh basalt comprises mostly augite, plagioclase, olivine (forsterite), magnetite and zeolites. It is probably a alkali olivine basalt, transitional to hawaiiite. Where altered it contains clays (saponite), with calcite and zeolites (natrolite and analcime, particularly in vesicles),

INTRODUCTION

Two rock samples were collected from the Breadalbane area by Colin Mazengarb and submitted for mineralogical and petrological analysis, with details shown in Table 1. The main issue is to determine the mineralogy and rock classification.

Table 1: Sample details.

Reg. No	Location	Description	
E203252	Maramanga Farm, Breadalbane	Possible ferricrete with tube-like structures	Xrd, TS
E203254	Raeburn Quarry, Breadalbane	Basalt with large white amygdules.	Xrd, TS, SEM

SAMPLE PREPARATION

The samples were both split into representative subsamples, and examined by stereomicroscopy, and analysed for mineralogy by XRD (X-Ray diffraction), in the Mineral Resources Tasmania (MRT) laboratories, Rosny. Subsamples were prepared for thin sections by the Utas, and described petrographically at MRT. E203254 was also analysed by XRF at MRT and by SEM/EDS in the CSL laboratories, UTas. E203252 was also analysed by pXRF at MRT.

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SAMPLE DESCRIPTIONS

E203252 is a hard red laterite or ferricrete with tubular structures containing some dark greenish brown smectite (Fig. 1). In thin section it is mostly amorphous hematite with some scattered grains of quartz to about 0.2mm (Fig. 2).

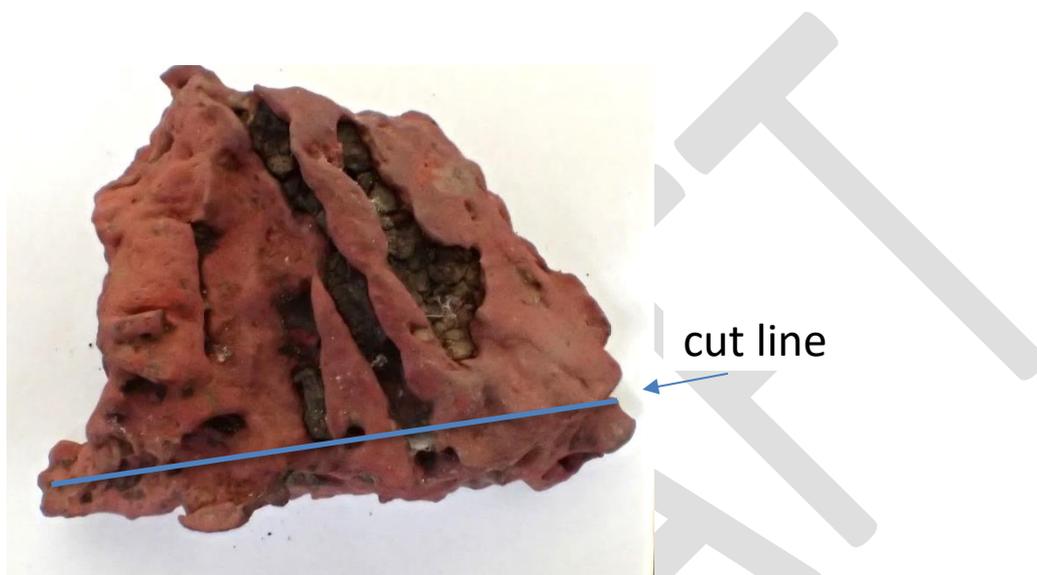


Fig. 1. E203252. Ferricrete, as received. FOV ~80mm.

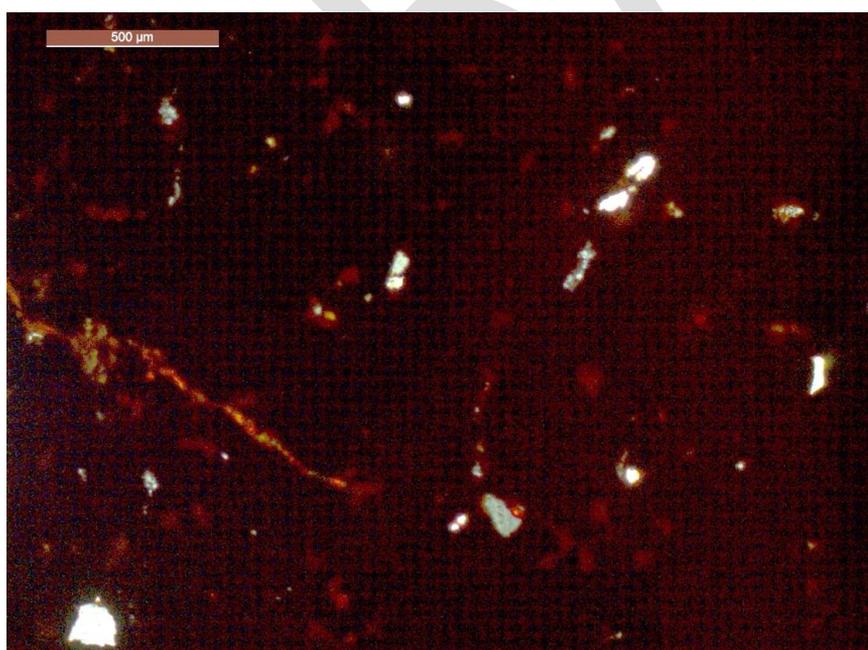


Fig. 2. E203252. Ferricrete, with quartz grains. XPTL (Cross polarised transmitted light).

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E203254 is a hard, fine grained basalt with vesicles to about 50mm, fully to partly filled with various crystalline zeolites and a bright white smectite (Fig. 3).



Figure 3: Sample E203254. White zeolites, clays and other minerals in vesicular basalt. FOV: about 180 mm.

In thin section this sample is mostly a well crystallised basaltic rock with sporadic well rounded to highly irregular vesicles and amygdales partly to completely filled with zeolites, calcite and clays (Fig. 4). The rock (Figs 4 – 7) contains:

- Plagioclase, calcic (~35%), colourless, subhedral laths, (<1mm).
- Clinopyroxene (augite?) (35%), pale pinkish brown, subhedral prisms, (<0.3mm).
- Olivine: ~10%, angular, anhedral to euhedral and skeletal (<1mm).
- opaques (magnetite and/or ilmenite), (~5%), skeletal (<0.2mm).
- zeolites (~10%), colourless anhedral to euhedral, in vesicles and interstitial to plagioclase (<1mm).
- Calcite (~2%), colourless to brown (siderite?), anhedral to euhedral, in vesicles and groundmass (<1mm).
- Smectite clay (~5%), green to colourless, interstitial and in vesicles (<0.05mm)

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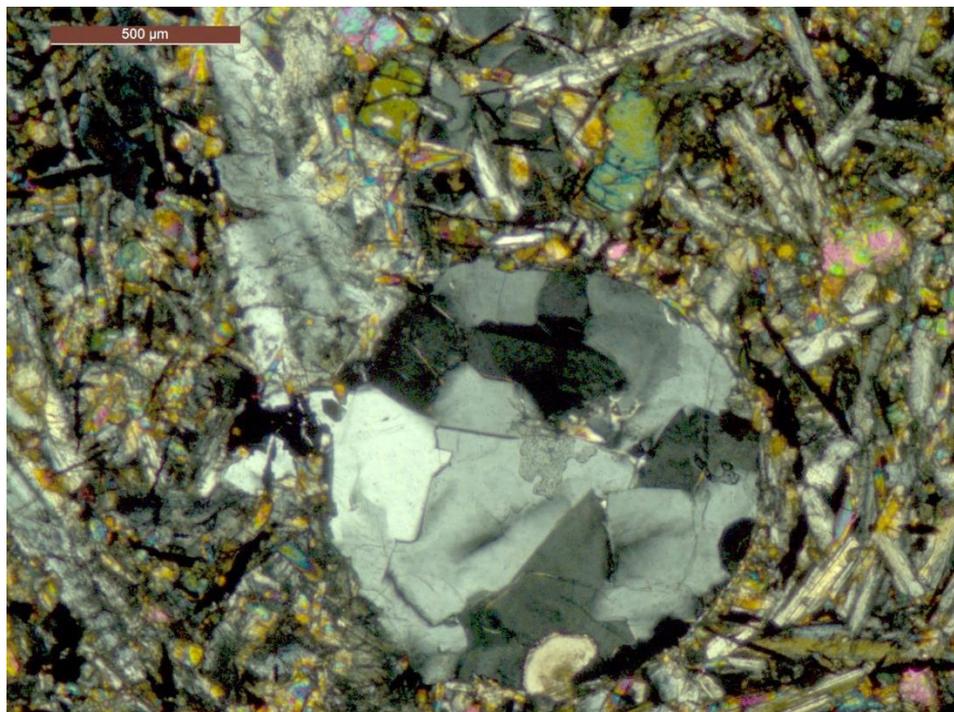


Fig. 4. E203252. Rounded zeolite-filled amygdale in basalt, with plagioclase, pyroxene and olivine. The amygdale is mostly filled with chabazite with some calcite (cream) near the bottom and analcime (black) in the lower right. XPTL (Cross polarised transmitted light).

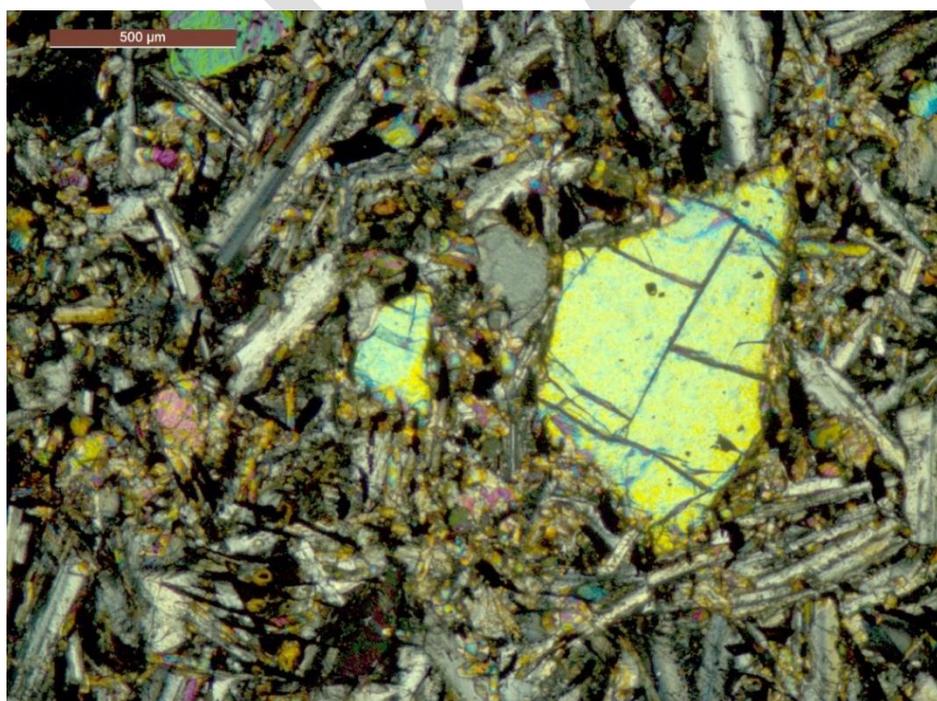


Fig. 5. E203252. Angular, anhedral olivine crystals in basalt, with plagioclase, pyroxene and magnetite. XPTL

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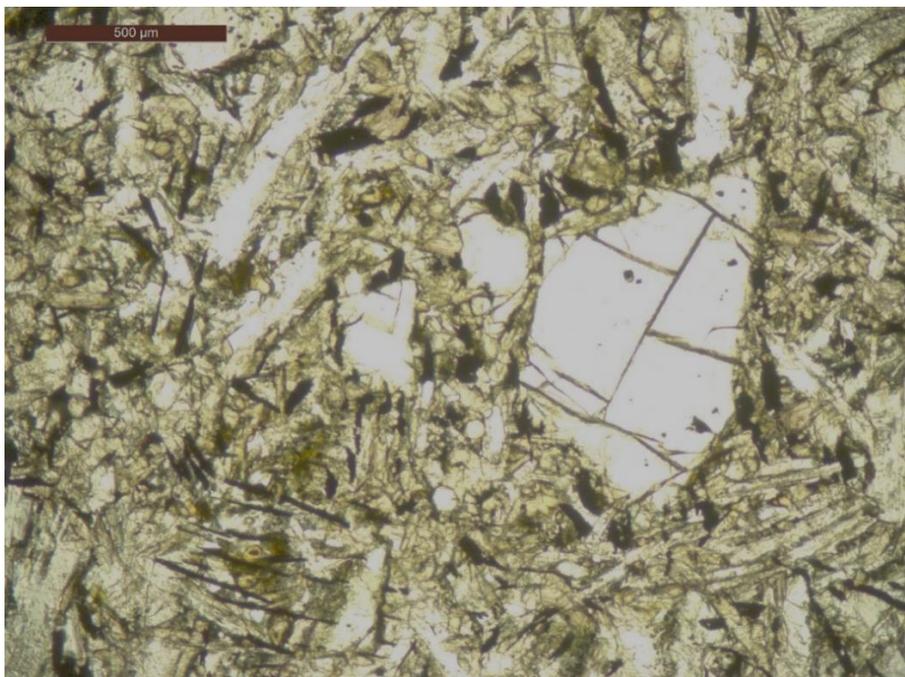


Fig. 6. E203252. Same area as Fig. 4, with colourless olivine, laths of plagioclase, and finer pyroxene (very pale brown) and skeletal magnetite (black). Some fine grained brownish green material in the matrix is mostly clay minerals (smectite) and carbonates, eg. towards the lower left. PPTL (Plane polarised transmitted light).



Fig. 7. E203252. Close up showing very fine green pyroxenes (aegirine-augite?) with possible zeolites (colourless), skeletal magnetite (black) and brown augite, interstitial to laths of plagioclase. PPTL

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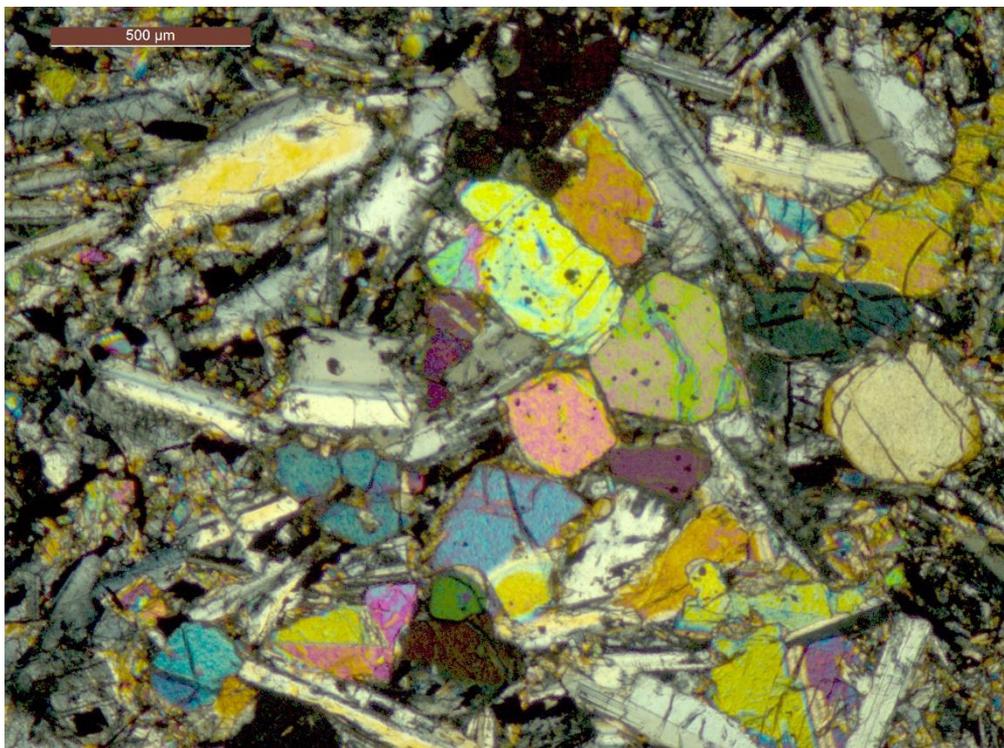


Fig. 8. E203252. Angular, anhedral aggregates of olivine-augite-plagioclase, in basalt. XPTL

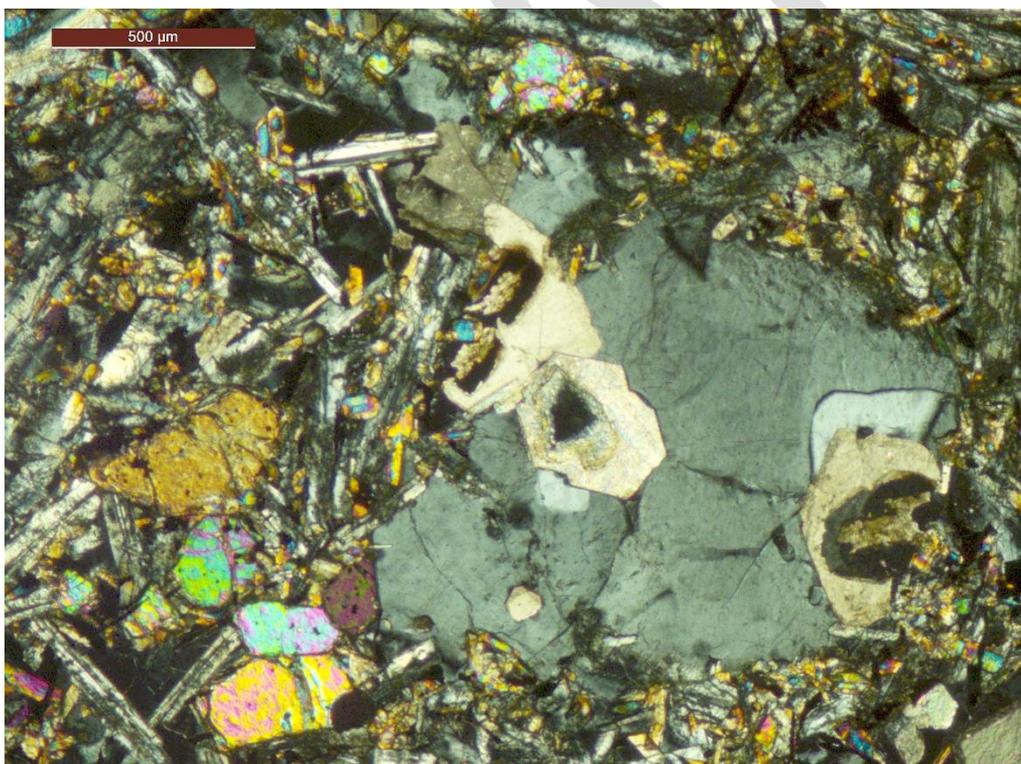


Fig. 9. E203252. Angular, anhedral aggregates of olivine-augite-plagioclase, in basalt. XPTL

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The matrix is relatively homogenous, with some flow banding shown by plagioclase laths, and dispersed, broken olivine microphenocrysts. Pyroxene appears to be mostly fine grained, weakly titaniferous, augite, with a little finer grained, later green aegirine-augite(?). There are sparse xenolith-like patches of coarser, more Ti-poor augite with olivine and plagioclase (Fig. 8).

The zeolites are largely rhombic (chabazite?), some lath-like (thomsonite?) and some euhedral and isotropic (analcime?). The calcite varies from botryoidal to euhedral, and is zoned in part, with brown zones. clays (Fig. 9). The rock contains some disseminated green clays (smectite?) in the matrix, some intergrown with carbonates and zeolites.

The mineralogy is typical of moderately alkaline basalts.

XRD ANALYSES

The samples were prepared, examined and analysed in the MRT laboratories, Rosny Park, Tasmania. They were run on a Rigaku Miniflex 600 X-Ray Diffractometer system: a 600W generator 150mm goniometer with a Cu tube; 40kV/15mA, sample spinner and a Scintillation counter (SC) with Be window, -3° to $145^{\circ} 2\theta$ scanning range and 2° - $145^{\circ} 2\theta$ measuring range, with a scanning speed of 0.01 to 100°/min, a graphite counter monochromator and a K β Ni- filter. The analysis software used is the PDXL2 using the ICCD database.

The results are shown in Appendix 1, and summarised below.

E203252 contains mostly haematite with minor amounts of quartz.

The vesicle-filling material in E203254 comprises mostly a smectite (saponite) with various zeolites, mostly chabazite (the main rhombic crystals), with lesser thomsonite and phillipsite.

The basaltic material in E203254 comprises mostly plagioclase, olivine and clinopyroxene, with minor zeolites, magnetite, smectite and other very minor

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phases (Table 2). Based on whole rock chemistry and Minsq, the pyroxene is interpreted to be low-Ca, Na and Fe-rich augite; plagioclase may be a K- and Ca-rich albite (~An₃₇Ab₄₈Or₁₄), too calcic to be “anorthoclase”.

Table 2: XRD results, with comparison to petrology. ND: not detected.

G409252	XRD	Siroquant	Min SQ	Petrology
Augite	26	~23-27	22	~35
Olivine	12	11-15	11.2	10
Plagioclase	42 plag	~50 Plag	39	~35
K-spar	possible?		6.5 (in plag?)	
Magnetite	2	1-3	5.7	2-5
Smectite	~5	4.4	5	5
Zeolites	16	ND	5	10
ilmenite	2.5	3-4	2.5	2-5
Quartz	ND	ND	1.3	ND
Siderite	ND	ND	1	ND
Apatite	ND	ND	1	ND
Calcite	ND	ND	0.5	2

SEM/EDAX ANALYSES

The sample E203254 was analysed by SEM-EDS, in the CSL, University of Tasmania, with analytical conditions shown in Appendix 2. The results are given in Appendix 3, and indicate the sample contains:

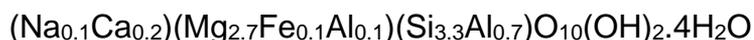
White Saponite-Ca

The average analysis of this botryoidal to massive mineral gives a formula:



Pale green Saponite-Ca

The average analysis of this botryoidal mineral (Fig. 10) gives the formula:



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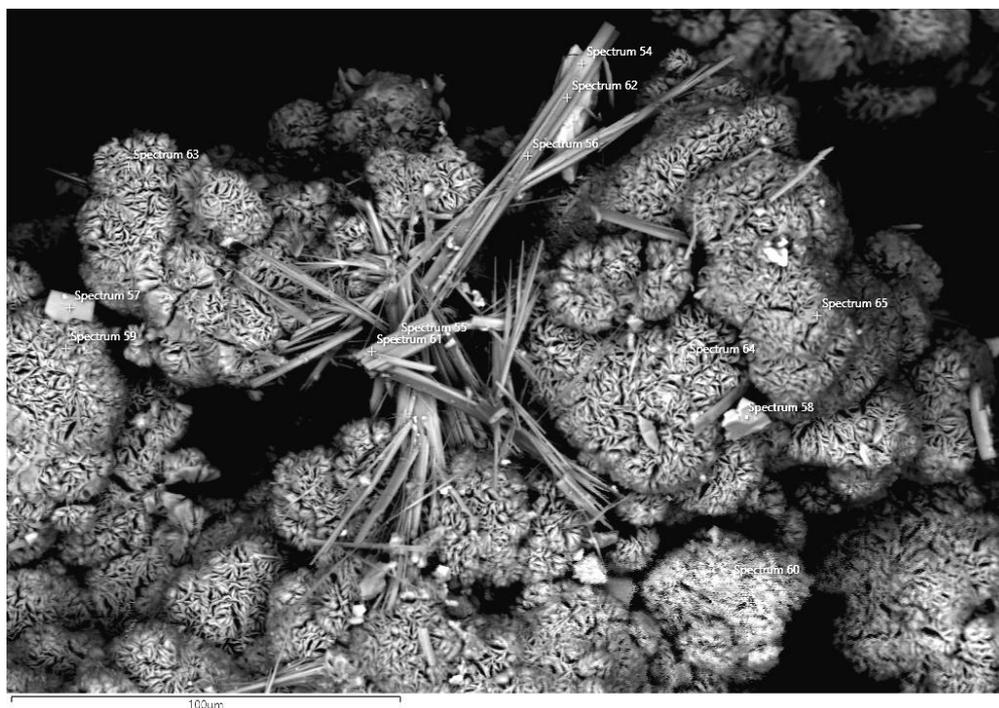


Fig. 10. Bladed thomsonite crystals, with some botryoidal saponite. Backscattered electron image (BSE).

Green saponite-ferrosaponite-Ca

The average analysis of this botryoidal mineral gives the formula:

$(\text{Na}_{0.1}\text{Ca}_{0.2})(\text{Mg}_{1.7}\text{Fe}_{1.0}\text{Al}_{0.1})(\text{Si}_{3.4}\text{Al}_{0.6})\text{O}_{10}(\text{OH})_2 \cdot 4\text{H}_2\text{O}$ Saponite-Ca. Some analyses give $\text{Fe} > \text{Mg}$, so is ferrosaponite in part.

Thomsonite-Ca

The average analysis of this bladed mineral (Fig. 10) gives a formula: $(\text{Na}_{1.2}\text{Ca}_{1.6})(\text{Si}_{5.4}\text{Al}_{4.6})\text{O}_{24} \cdot 6\text{H}_2\text{O}$

Chabazite

The average analysis of this botryoidal mineral (Fig. 11) gives a formula:

$(\text{Na}_{1.2}\text{K}_{0.3}\text{Ca}_{1.2})(\text{Si}_{7.8}\text{Al}_{4.2})\text{O}_{24} \cdot 4\text{H}_2\text{O}$: mostly Chabazite-Ca but also some Chabazite-Na.

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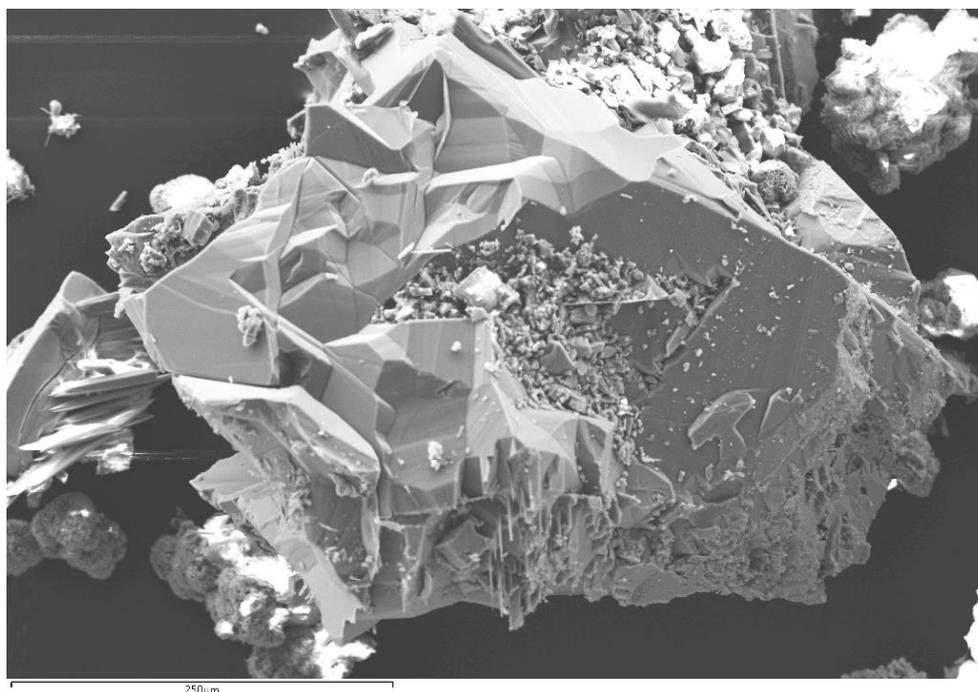


Fig. 11. Chabazite crystals, with some botryoidal saponite (lower left) and a little bladed thomsonite (near centre left).

XRF

The sample was analysed for trace elements on a pressed pellet, and major elements on a pressed powder, in a Bruker ASX58 XRF, with proprietary Bruker software and a series of commercial standards. The results are shown in Appendix 4.

The alkali-silica plot is shown in Fig. 12, indicating this basalt is borderline between basalt and trachybasalt. Other basaltic rocks in this district are dominantly alkaline basalts, but some are basanites or rarely are hawaiiite (which plot as trachyandesites on this diagram). A hawaiiite composition is consistent with the normative plagioclase (from Minsq calculations) having $Na > Ca$ and whole rock $Na > K$, but does not fit the bulk chemistry. The plots in Figs 13 & 14 confirm that the two basaltic rocks tested are definitely alkaline.

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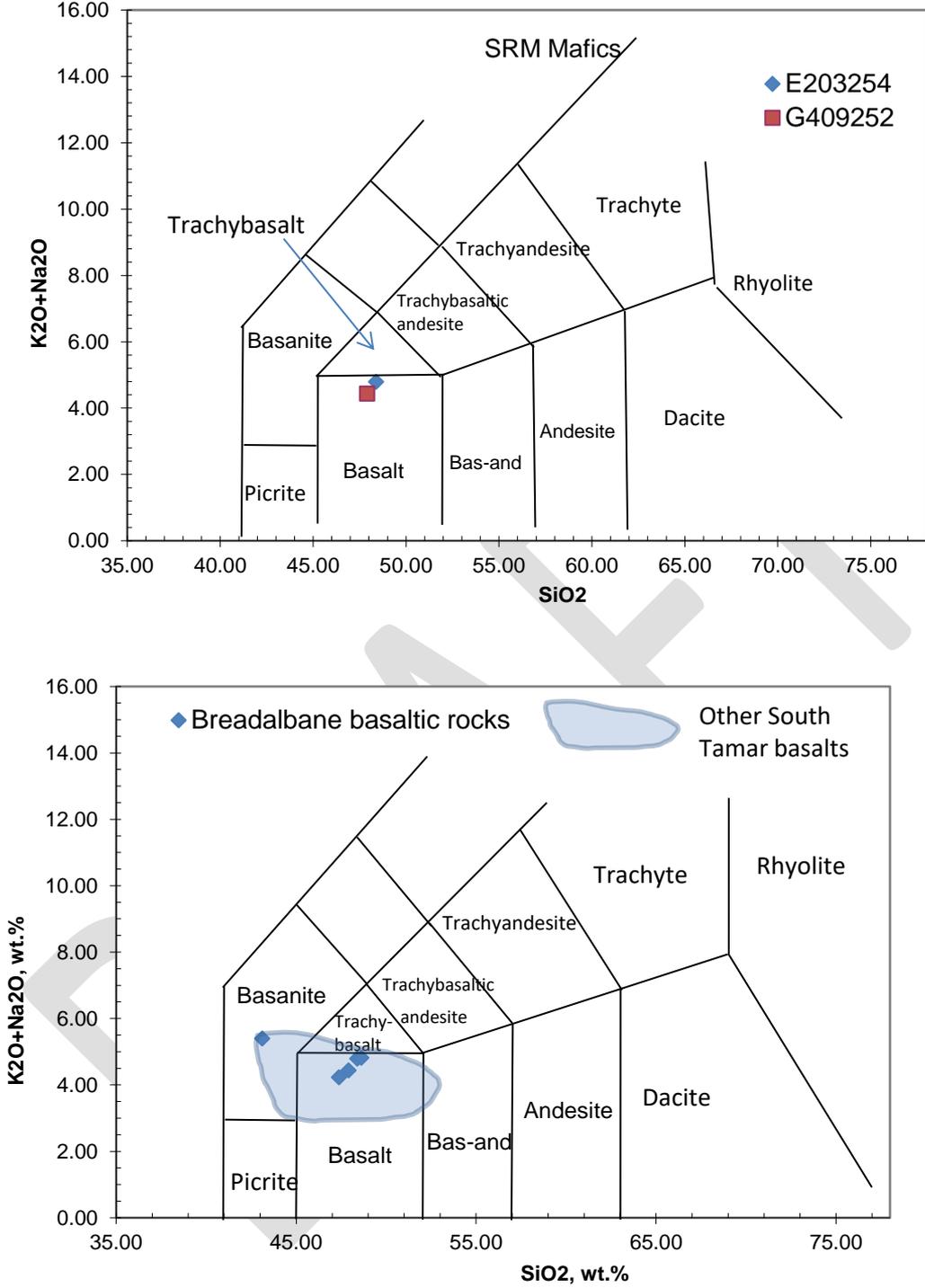


Fig. 12. TAS discrimination plot of alkalis vs SiO_2 (Floyd & Winchester, 1975) for the analysed samples (top) and other basalts in the district (bottom).

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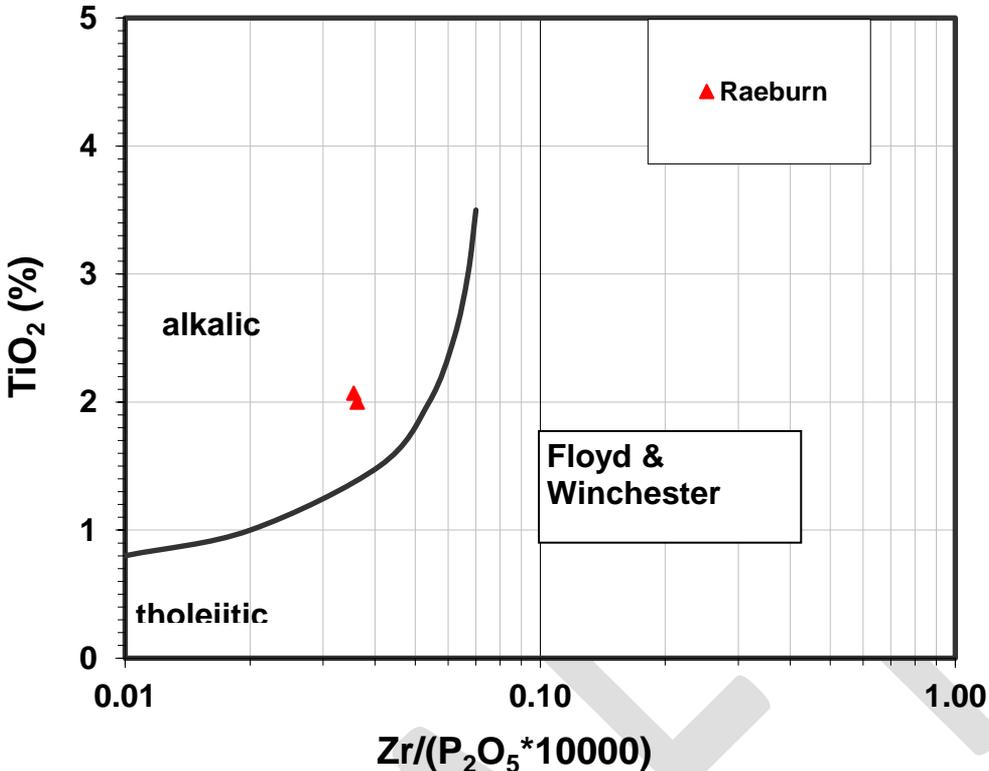


Fig. 13 Ti-Zr discrimination plot of Floyd and Winchester (1975) for the basalts.

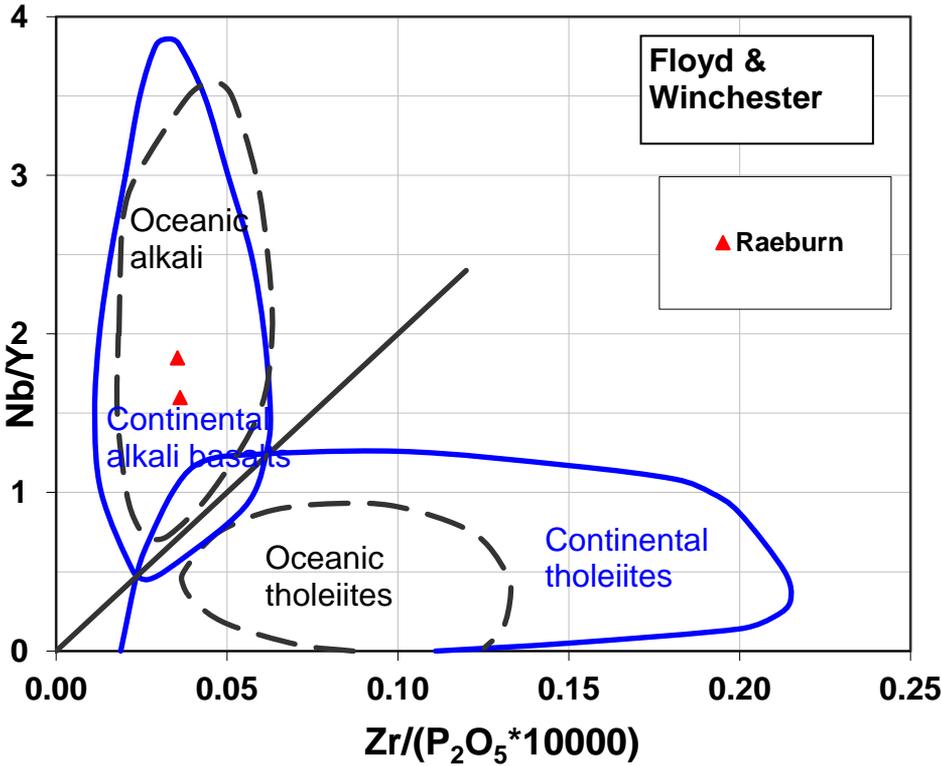


Fig. 14. Nb/Y vs Zr/P discrimination plot of Floyd and Winchester (1975) for the basalts.

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PXRF

The sample was analysed for major and trace elements using an Olympus Vanta M Series pXRF. The instrument uses a 4-Watt X-ray tube with application optimized anode material (rhodium Rh and tungsten W): 8-50 kV with a large area Silicon Drift Detector. The instrument uses the built-in Olympus Vanta analysis software version 3.12.34.

The results are shown in Table 5 and the red rock is high in Fe, with lesser Al and Si. Al minerals were not detected by XRD and the speciation is uncertain, perhaps partly aluminous hematite (which can contain >10% Al). The black clay in the tubes contains more Si and less Fe; it may be nontronite. The analyses are low in immobile basaltic elements including Ti, Cr, Nb and V.

DISCUSSION AND CONCLUSIONS

E203252 (Maramanga Farm, Breadalbane). This is a Tertiary ferricrete or laterite with tube-like structures containing a black clay. The chemistry suggests no direct links to the basalts.

E203254 (Raeburn Quarry, Breadalbane). This is an alkaline basalt, borderline to hawaiite, with large white amygdules containing various zeolites, calcite and saponite. The rock itself contains mostly Fe-rich augite, intermediate, potassic plagioclase and Mg-rich olivine with minor zeolites, magnetite, smectite and other trace phases.

Other samples previously tested from this quarry by MRT were found to be very similar but to variably also contain minor natrolite, quartz and aragonite (Bottrill & Coyte, 2019).

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REFERENCES

Bottrill, R.S. and Coyte, T, 2019. Mineralogical Analyses, Raeburn Quarry, Breadalbane. MRT Laboratory Report. LJM2019-118

Floyd, P.A. and Winchester, J.A. (1975) Magma Type and Tectonic Setting Discrimination Using Immobile Elements. Earth and Planetary Science Letters, 27, 211-218.

Rollinson, H. R. (1993) Using Geochemical Data: Evaluation, Presentation, Interpretation, Longman Group Limited, UK.

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This and other data collected in MRT laboratories may enter the MRT databases but every attempt will be made to ensure it remains closed file and not be available externally, unless at your request.

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Appendix 1: Laboratory Report: XRD Analyses

Client: Ralph Bottrill

Method: X-Ray Diffraction

Sample Source: Raeburn Quarry,
Breadalbane

Analyst: E Lounejeva

MRT Job Number: LJN2021-045

Lab Manager: R Bottrill

Analysis: Approximate Mineralogy

Date: 11/6/21

XRD RESULTS- E203254A-WHITE SOFT CLAY

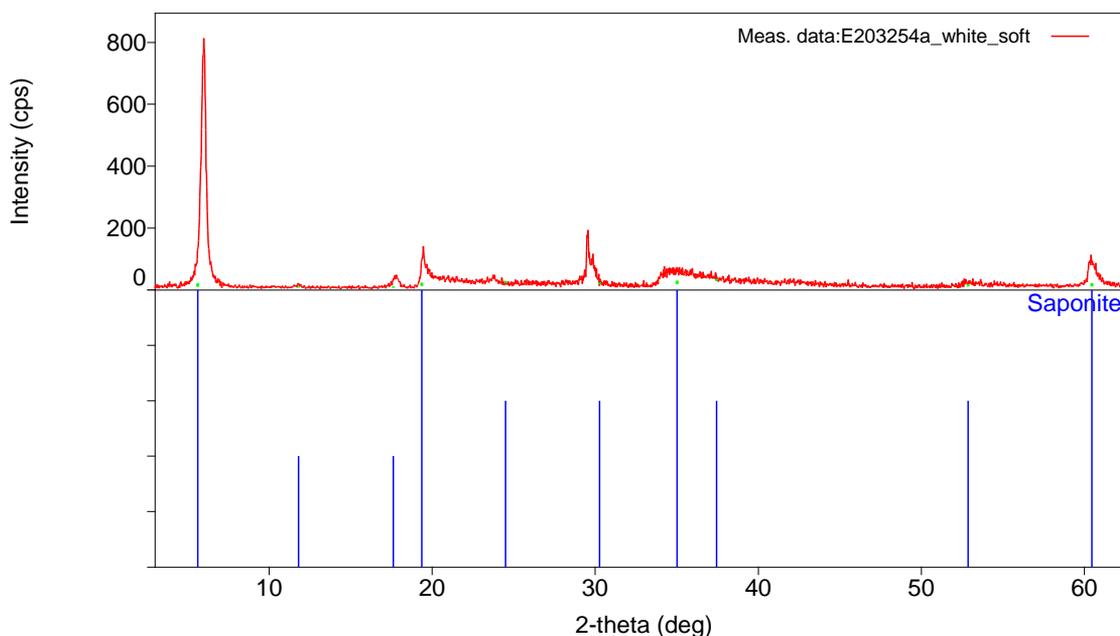
General Information

Analysis date	2021/06/15 10:18:48		
Sample name	E203254a_white_soft	Measurement date	2021/05/05 14:54:47
File name	E203254a_white_soft.ras	Operator	e-lounejeva
Comment	Soft white mineral inside a vesicle:		

Analysis Results

Phase name	Content	Formula
Saponite	Major dominant	$\text{Ca}_{0.25}(\text{Mg,Fe})_3((\text{Si,Al})_4\text{O}_{10})(\text{OH})_2 \cdot n\text{H}_2\text{O}$

Phase Data Pattern



Peak List

No.	2-theta (deg)	d (ang.)	Phase name	Rel. int. I (a.u.)	Rel. height (a.u.)
2	11.84(8)	7.47(5)	Saponite	0.82	0.89
3	17.727(17)	4.999(5)	Saponite	4.74	4.29
4	19.446(8)	4.5611(19)	Saponite	21.48	10.85
7	34.73(3)	2.5808(19)	Saponite	29.16	5.42

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XRD RESULTS- E203254B-CRYSTALLINE GEODE

General Information

Measurement date:	2021/05/06	Interpretative date:	2021/05/12
Job Number/Client:	LJN2020-045	XRD	Rigaku Miniflex 600
Registration Number:	E203254b	Analyst:	e-lounejeva
Quantitative Method:	XPlot	Process Medium:	Wholerock
Sample Holder:	Silicon	Speed (deg/min):	0.5
Comment:	Mineral forming euhedral crystals inside a vesicle.		

Analysis Results

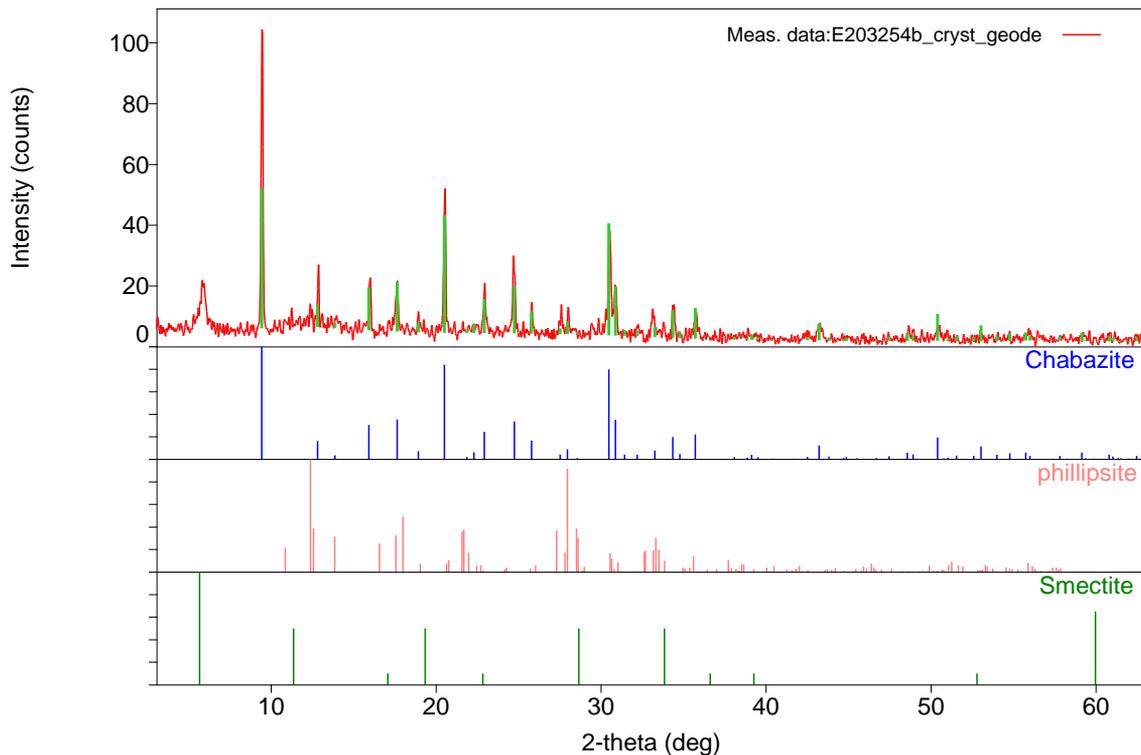
Phase name	Content wt%	Formula
Chabazite	Major dominant	$(Ca,K_2,Na_2,Mg)Al_2Si_4O_{12} \cdot 6H_2O$
Saponite	Major	$Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$
Phillipsite	minor	$(Ca,K_2,Na_2)_3Al_6Si_{10}O_{32} \cdot 12H_2O$

Notes: Peak overlap may interfere with identifications and quantitative calculations.

Amorphous minerals and minerals present in trace amounts may not be detected.

*Smectite: probably saponite $Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$ (“soapy” mineral)

Phase Data Pattern



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XRD RESULTS- E203254C-PALE GREEN GEODE

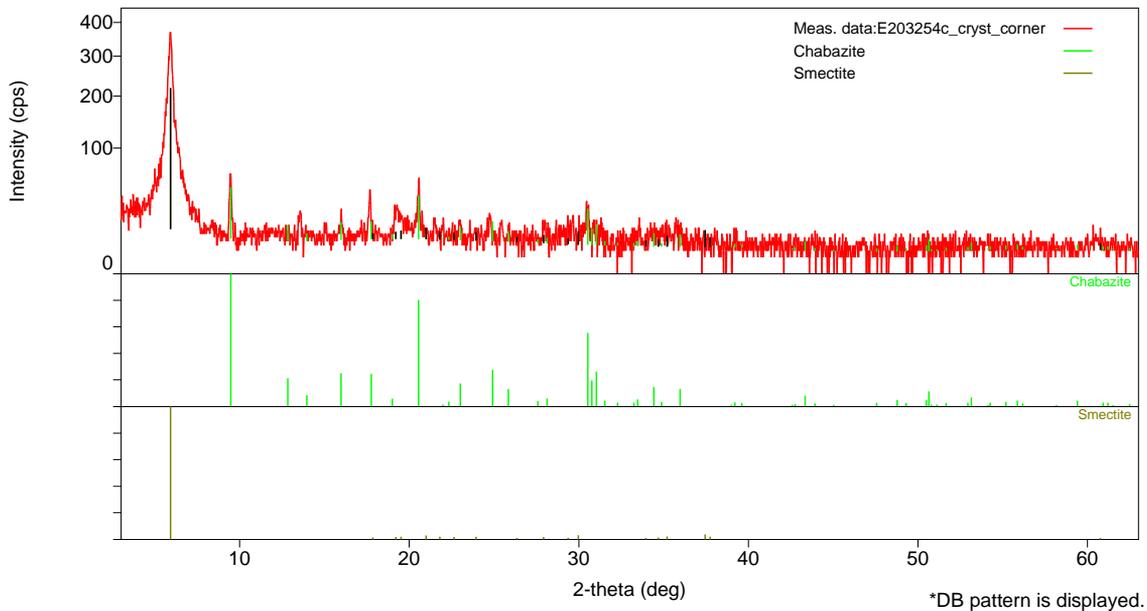
General Information

Measurement date:	2021/05/06	Interpretative date:	2021/05/12
Job Number/Client:	LJN2020-045	XRD	Rigaku Miniflex 600
Registration Number:	E203254b	Analyst:	e-lounejeva
Quantitative Method:	XPlot	Process Medium:	Wholerock
Sample Holder:	Silicon	Speed (deg/min):	0.5
Comment:	Mineral forming pale green botryoidal aggregates inside a vesicle.		

Analysis Results

Phase name	Content wt%	Formula
Saponite	Major	$\text{Ca}_{0.25}(\text{Mg,Fe})_3((\text{Si,Al})_4\text{O}_{10})(\text{OH})_2 \cdot n\text{H}_2\text{O}$
Chabazite	Minor	$(\text{Ca,K}_2,\text{Na}_2,\text{Mg})\text{Al}_2\text{Si}_4\text{O}_{12} \cdot 6\text{H}_2\text{O}$

Phase Data Pattern



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XRD RESULTS- E203254D-WHITE BALLS

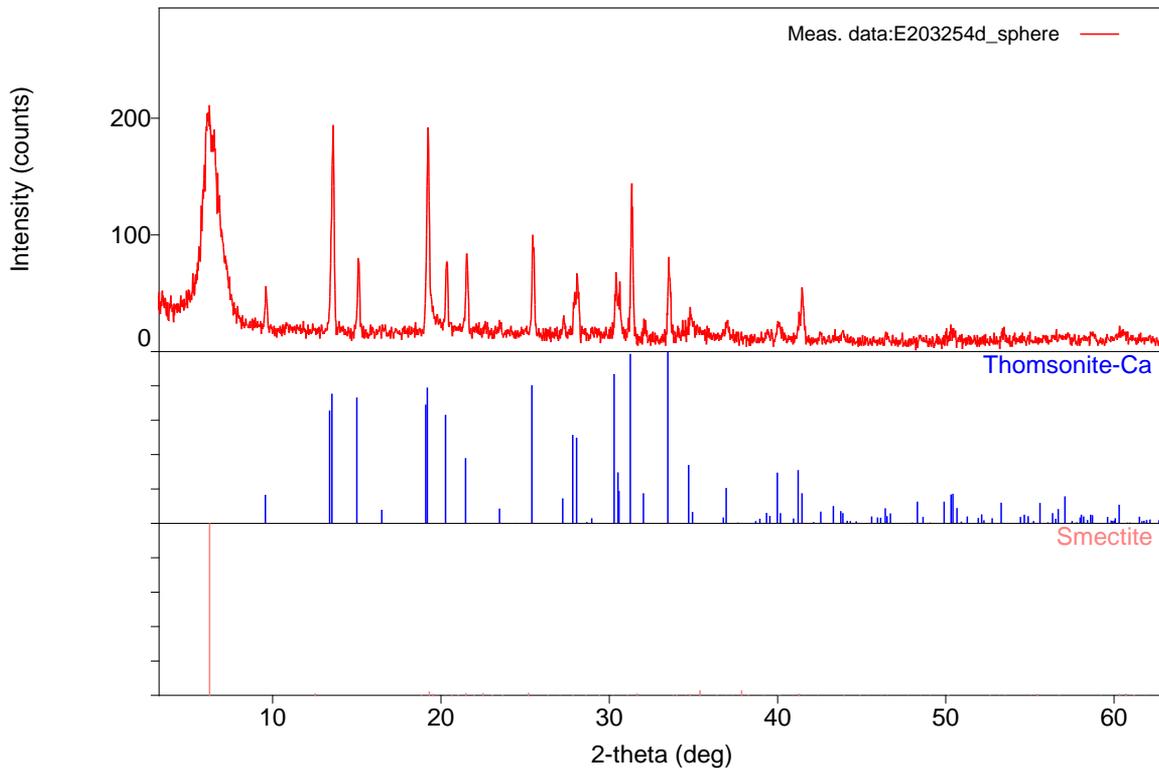
General Information

Measurement date:	2021/05/06	Interpretative date:	2021/05/12
Job Number/Client:	LJN2020-045	XRD	Rigaku Miniflex 600
Registration Number:	E203254d	Analyst:	e-lounejeva
Quantitative Method:	XPlot	Process Medium:	Wholerock
Sample Holder:	Silicon	Speed (deg/min):	0.5
Comment:	Mineral forming small spherical crystalline aggregates inside a vesicle		

Analysis Results

Phase name	Content wt%	Formula
Thomsonite	Major	$(Ca,K_2,Na_2,Mg)Al_2Si_4O_{12} \cdot 6H_2O$
Saponite	Major	$Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$

Phase Data Pattern



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XRD RESULTS- E203252-RED ROCK

General Information

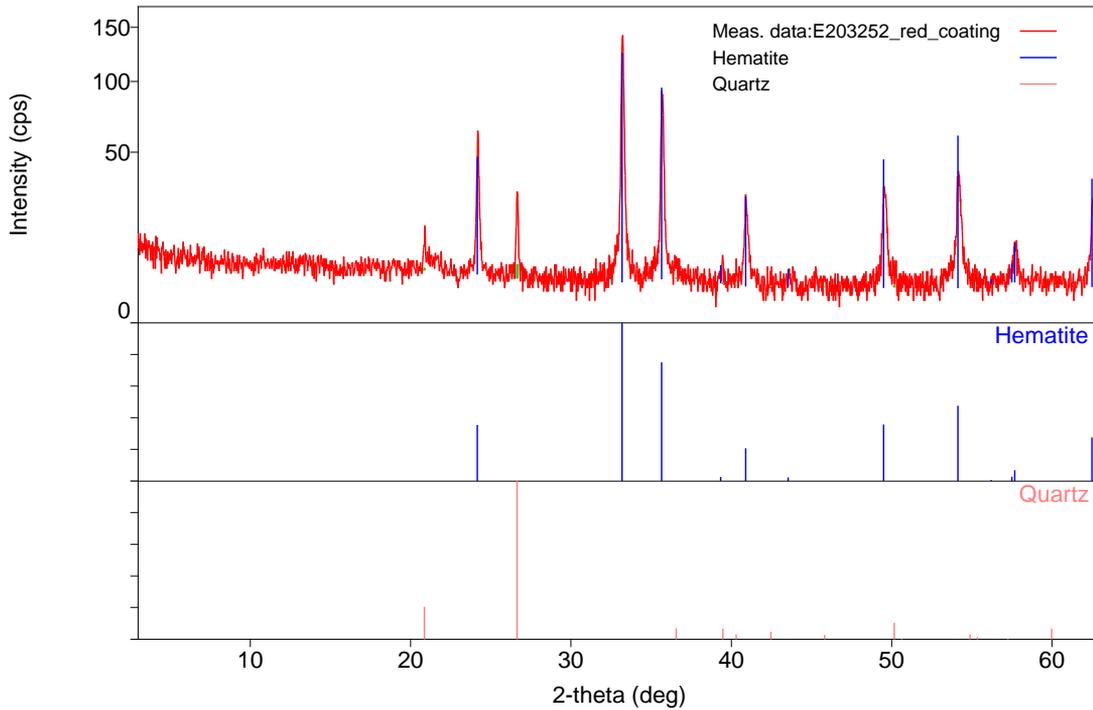
Measurement date:	2021/05/11	Interpretative date:	2021/05/12
Job Number/Client:	LJN2020-045	XRD	Rigaku Miniflex 600
Registration Number:	E203252-redcoating	Analyst:	e-lounejeva
Quantitative Method:	XPlot	Process Medium:	Wholerock
Sample Holder:	Silicon	Speed (deg/min):	0.5
Comment:	Red laterite		

Analysis Results

Phase name	Content wt%	Formula
Hematite	~90	Fe ₂ O ₃
Quartz	~10	SiO ₂

Notes: Peak overlap may interfere with identifications and quantitative calculations. Amorphous minerals and minerals present in trace amounts may not be detected.

Phase Data Pattern



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XRD Results G409252_QA1

General Information

Analysis date	2021/06/15-18	Measurement date	2021/06/15
Sample name	G409252	Operator	e-lounejeva
Filename	G409252.ras		
Comment	Basaltic rock		

Analysis Results

Semi quant results based on RIR to Al₂O₃ (from PDXL-2)

Phase name	Content wt%(±error)	Formula
Anorthite, Na-bearing	42(2)	(Ca _{2.1} Na _{1.9})(Si ₁₀ Al ₆)O ₃₂
Augite	26(2)	Ca(Fe,Mg)Si ₂ O ₆
Forsterite	12(2)	Mg _{1.6} Fe _{0.4} (SiO ₄)
Analcime	8.2(5)	Na(AlSi ₂ O ₆)(H ₂ O)
Smectite (probably saponite or montmorillonite)	No RIR available	(Mg ₂ Al)(Si ₃ Al)O ₁₀ (OH) ₂ · 4 H ₂ O
phillipsite-K	7.5(7)	K _{0.9} (Na _{0.8} Ca _{0.3}) (Al ₃ Si ₅ O ₁₆) 5.5(H ₂ O)
Magnetite	2.2(14)	Fe ₃ O ₄
Ilmenite	2.5(14)	FeTiO ₃

Notes:

Peak overlap may interfere with identifications and quantitative calculations. Amorphous minerals and minerals present in trace amounts may not be detected.

Semi quant results based on Rietveld refinement (from Siroquant)

#	ID	Phase	Weight%
1	155	Anorthite	48.3
2	708	Augite 2	23.4
3	216	Forsterite	14.8
4	134	Analcite	4.0
5	868	Smectite-chlorite, regul.	4.4
6	50	Magnetite	1.5
7	1724	Ilmenite, natural, -Ti,Mg	3.6

#	ID	Phase	Weight%
1	155	Anorthite	54.1
2	622	Augite 1	23.9
3	216	Forsterite	13.0
4	868	Smectite-chlorite, regul.	0.5
5	134	Analcite	4.4
6	50	Magnetite	0.1
7	16	Ilmenite	4.0

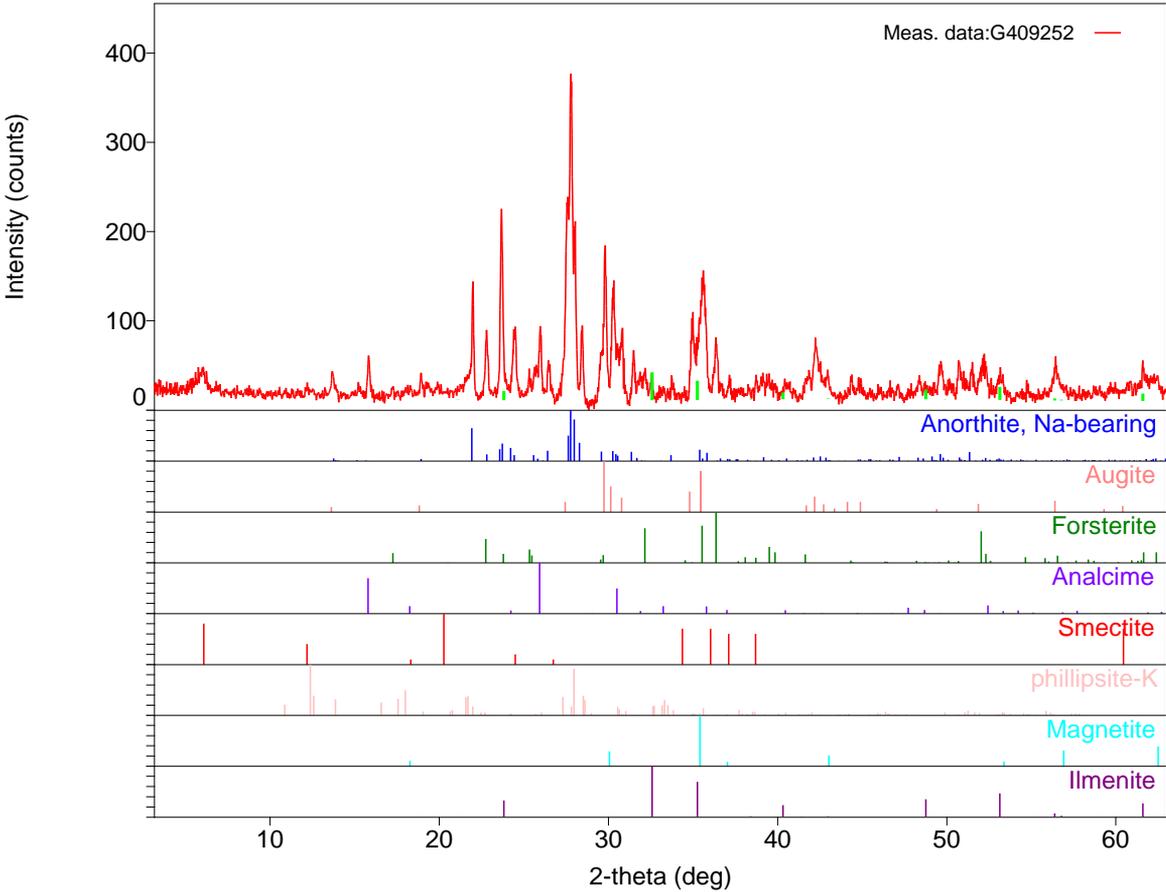
#	ID	Phase	Weight%
1	155	Anorthite	50.8
7	708	Augite 2	27.3
2	216	Forsterite	11.5
6	16	Ilmenite	3.7
4	134	Analcite	3.7
5	50	Magnetite	2.7
3	868	Smectite-chlorite, regul.	0.5

Augite 1 (Mg/Fe=3, Ca/Na=10)

Augite 2 Mg/Fe~1.5, low Ca, no Na

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Phase Data Pattern



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Peak List

N o.	2-theta(deg)	d(ang.)	Phasename	Rel.int.I(a.u.)	Rel.height(a.u.)
1	6.01(5)	14.69(11)	Saponite-15A,Al+3-bearing(0,0,1)	40.08	7.65
2	8.85(8)	9.98(9)	Unknown	2.36	0.76
3	10.951(7)	8.073(5)	phillipsite-K(1,0,-1)	1.01	2.93
4	12.165(19)	7.270(11)	Saponite-15A,Al+3-bearing(0,0,2),phillipsite-K(0,0,1)	2.84	2.62
5	12.509(18)	7.071(10)	phillipsite-K(1,1,0)	1.05	2.04
6	13.667(9)	6.474(4)	Anorthite, Na-bearing(1,-1,0),Augite(1,1,0),phillipsite-K(0,1,1)	8.56	7.55
7	15.21(3)	5.820(12)	Anorthite, Na-bearing(1,1,-1)	3.84	4.75
8	15.814(18)	5.599(6)	Anorthite, Na-bearing(1,-1,-1),Analcime(2,1,1)	9.25	13.96
9	17.269(16)	5.131(5)	Forsterite(0,2,0)	2.64	4.24
10	18.27(4)	4.851(10)	Analcime(2,2,0),Saponite-15A,Al+3-bearing(0,0,3),phillipsite-K(2,0,-	5.37	2.23
11	18.909(5)	4.6895(12)	Anorthite, Na-bearing(0,2,-1),Augite(2,0,0),Ilmenite(0,0,3)	2.81	9.33
12	19.295(17)	4.596(4)	Unknown	1.89	3.22
13	20.06(5)	4.423(11)	Anorthite, Na-bearing(0,2,1),Forsterite(1,1,0),Saponite-	25.62	3.13
14	21.80(4)	4.074(7)	phillipsite-K(1,1,1),Ilmenite(1,0,1)	24.15	7.26
15	21.9947(17)	4.0380(3)	Anorthite, Na-bearing(2,0,-1),phillipsite-K(2,0,-2)	19.46	47.06
16	22.826(3)	3.8927(6)	Anorthite, Na-bearing(1,-1,1),Forsterite(0,2,1),phillipsite-K(2,1,0)	19.37	24.65
17	23.662(10)	3.7571(15)	Anorthite, Na-bearing(1,1,1),Forsterite(1,0,1)	56.03	74.06
18	24.439(17)	3.639(2)	Anorthite, Na-bearing(2,0,0),Saponite-15A,Al+3-bearing(0,0,4),phillipsite-K(1,2,-2)	28.84	25.68
19	25.306(14)	3.5166(19)	Forsterite(1,1,1),phillipsite-K(2,2,-2)	4.81	8.37
20	25.67(3)	3.467(4)	Anorthite, Na-bearing(1,-3,-1),phillipsite-K(0,1,2)	17.04	9.78
21	25.957(10)	3.4298(13)	Analcime(4,0,0),phillipsite-K(2,3,-1)	17.6	29.56
22	26.437(8)	3.3687(10)	Anorthite, Na-bearing(1,-1,-2),Saponite-15A,Al+3-bearing(1,0,3)	9.85	13.39
23	27.608(18)	3.228(2)	Anorthite, Na-bearing(2,-2,0),Augite(2,2,0),phillipsite-K(1,4,0)	100	68.65
24	27.786(6)	3.2081(7)	Anorthite, Na-bearing(0,4,0),phillipsite-K(3,0,-1)	42.2	100
25	27.990(7)	3.1852(8)	Anorthite, Na-bearing(0,0,2),phillipsite-K(0,2,2)	45.16	58.94
26	28.420(13)	3.1380(14)	Anorthite, Na-bearing(2,2,0),phillipsite-K(3,1,-1)	16.67	27.64
27	29.69(3)	3.006(3)	Anorthite, Na-bearing(1,-3,1),Augite(2,2,-1),Forsterite(1,2,1)	34.48	20.7
28	29.799(9)	2.9958(8)	Unknown	17.7	47.49

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29	30.276(12)	2.9497(11)	Anorthite, Na-bearing(0,4,-1),Augite(3,1,0),Analcime(3,3,2),Magnetite(2,2,0)	36.49	37.27
30	30.690(17)	2.9109(16)	Anorthite, Na-bearing(0,2,-2),Augite(3,1,-1),phillipsite-K(3,2,-1)	28.26	20.02
31	31.464(11)	2.8410(10)	Anorthite, Na-bearing(1,3,1),phillipsite-K(2,1,1)	9.74	18.08
32	31.82(3)	2.810(2)	Anorthite, Na-bearing(2,-2,-2),Analcime(4,2,2),phillipsite-K(2,1,-3)	8.39	7.75
33	32.14(2)	2.7825(19)	Anorthite, Na-bearing(0,4,1),Forsterite(1,3,0)	7.78	9.27
34	32.522(16)	2.7510(13)	phillipsite-K(1,0,2),Ilmenite(1,0,4)	4.89	8.03
35	33.1515	2.70011	Anorthite, Na-bearing(2,0,1),Analcime(4,3,1),phillipsite-K(1,1,2)	2.94	4.83
36	33.744(15)	2.6540(11)	Anorthite, Na-bearing(1,-3,-2),phillipsite-K(3,3,-2)	3.78	10.96
37	34.986(7)	2.5626(5)	Augite(1,3,-1),Forsterite(0,4,0),phillipsite-K(1,2,2)	20.04	27.31
38	35.632(17)	2.5176(12)	Anorthite, Na-bearing(2,-2,1),Augite(2,2,1),Forsterite(1,3,1),Analcime(5,2,	82.33	40.16
39	36.380(9)	2.4676(6)	Anorthite, Na-bearing(1,1,2),Forsterite(1,1,2),phillipsite-K(2,3,1)	17.29	20.16
40	36.705(15)	2.4465(10)	Anorthite, Na-bearing(2,-4,0)	2.09	4.93
41	37.159(8)	2.4176(5)	Anorthite, Na-bearing(1,5,-1),Saponite-15A,Al+3-bearing(0,0,6),Magnetite(2,2,2)	3.16	7.6
42	38.266(10)	2.3502(6)	Anorthite, Na-bearing(1,-5,-1),Saponite-15A,Al+3-bearing(1,1,3),phillipsite-	0.89	6.66
43	38.737(14)	2.3227(8)	Anorthite, Na-bearing(1,1,-3),phillipsite-K(4,0,-3)	3.02	8.13
44	39.048(14)	2.3049(8)	phillipsite-K(4,1,-1)	2.88	7.99
45	39.43(10)	2.283(6)	Anorthite, Na-bearing(3,-3,-1),Forsterite(1,2,2),phillipsite-K(4,1,-3)	14.53	4.06
46	40.437(18)	2.2289(10)	phillipsite-K(0,5,2)	1.82	4.77
47	40.61(7)	2.220(4)	Anorthite, Na-bearing(3,3,-2),Analcime(6,1,1),phillipsite-K(4,2,-	6.07	3.19
48	41.696(18)	2.1644(9)	Anorthite, Na-bearing(3,-3,-2),Augite(3,3,0),Forsterite(2,1,1),Analcime(6,2,0),	10.33	6.94
49	42.190(9)	2.1402(4)	Anorthite, Na-bearing(1,5,-2),Augite(3,3,-1),phillipsite-K(2,6,-1)	20.05	18.26
50	42.55(14)	2.123(7)	Anorthite, Na-bearing(1,3,2),Forsterite(1,4,1),Analcime(5,4,1),p	10.56	5.63
51	42.922(15)	2.1054(7)	Anorthite, Na-bearing(1,3,-3),Augite(4,2,-1)	3.88	6.46
52	44.389(13)	2.0392(5)	Augite(0,4,1),Forsterite(2,2,1),phillipsite-K(4,0,0)	4.04	6.19
53	44.90(2)	2.0169(9)	Anorthite, Na-bearing(1,-5,-2),Augite(2,0,2),Analcime(6,3,1),phillipsite-K(4,4,-	4.71	4.05
54	45.5	1.99192	Anorthite, Na-bearing(1,-3,-3),Analcime(4,4,4),phillipsite-K(1,0,3)	2.88	2.62
55	46.0303	1.9702	Anorthite, Na-bearing(0,2,3),Forsterite(2,3,0),phillipsite-K(0,4,3)	4.82	4.39
56	46.7121	1.94301	Anorthite, Na-bearing(3,3,-3),Forsterite(0,4,2),Analcime(5,4,3),phillipsite-	4.86	4.42
57	47.11(2)	1.9274(8)	Anorthite, Na-bearing(4,-2,-1),phillipsite-K(1,2,3),Magnetite(3,3,1)	2.38	3.99
58	48.397(18)	1.8792(7)	Anorthite, Na-bearing(2,2,2),phillipsite-K(2,7,-1)	3.2	5.19

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59	48.86(12)	1.862(4)	Anorthite, Na-bearing(2,-6,0),Forsterite(2,0,2),Analcime(7,2,1),phillipsite-	9.77	2.28
60	49.650(19)	1.8347(7)	Anorthite, Na-bearing(2,-4,-3),Augite(5,1,0),Forsterite(2,1,2),Analcime(6,4,2),	11.71	11.66
61	50.19(4)	1.8162(15)	Anorthite, Na-bearing(0,4,-3),Forsterite(1,1,3),phillipsite-K(2,7,0)	5.53	3.56
62	50.735(13)	1.7980(4)	Anorthite, Na-bearing(1,1,3),Forsterite(1,5,1),phillipsite-K(4,5,-	9.2	14.71
63	51.39(4)	1.7765(14)	Anorthite, Na-bearing(3,-5,-2),phillipsite-K(3,6,0)	14.95	5.89
64	52.19(3)	1.7513(9)	Anorthite, Na-bearing(4,-2,-3),Augite(1,5,0),Forsterite(2,2,2),Analcime(7,3,2),	20.17	11.69
65	52.633(6)	1.73752(19)	Anorthite, Na-bearing(2,2,-4),Forsterite(1,2,3)	1.67	8.24
66	53.17(3)	1.7213(9)	Anorthite, Na-bearing(1,-3,3),Analcime(8,0,0),phillipsite-	11.38	7.4
67	55.795(14)	1.6463(4)	Anorthite, Na-bearing(1,3,3),phillipsite-K(1,8,-2),Ilmenite(1,2,-1)	0.82	4.17
68	56.44(3)	1.6290(8)	Anorthite, Na-bearing(1,3,-4),Augite(2,2,-3),Forsterite(1,3,3),phillipsite-	21.11	10.88
69	59.984(12)	1.5410(3)	Anorthite, Na-bearing(4,-2,-4),phillipsite-K(5,3,0)	2.37	3.79
70	60.729(6)	1.52384(14)	Anorthite, Na-bearing(4,2,1),phillipsite-K(2,4,3)	2.3	6.69
71	61.590(6)	1.50458(13)	Anorthite, Na-bearing(2,-6,2)	6.71	12.08
72	62.41(3)	1.4869(6)	Anorthite, Na-bearing(2,8,-1),Forsterite(1,4,3),Analcime(8,4,2),phillipsite-	23.02	5.16

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Appendix 2: Laboratory Report –SEM analytical conditions

Hitachi SU-70 analytical field emission SEM

- Installed February 2011
- Schottky thermal field emission source
- ultra-high resolution (1.0 nm @ 15kV, 1.6 nm @ 1kV for SE imaging)
- high vacuum operation only (i.e. no variable pressure in chamber)
- Hitachi in-chamber and in-lens scintillation detectors, Super ExB filter, beam deceleration
- Hitachi in-chamber 5-segment solid state BSE detector, retractable
- in-column Faraday cup with picoammeter for beam current measurement
- anticontamination cold plate, liquid nitrogen cooled
- 5 axis motorised fully eucentric stage, XYZ range 110x110x40mm
- Oxford AZtec EDS/EBSD system with
 - X-Max 80 SDD EDS, MnKa 125 eV resolution, elements B-U, large area hyperspectral mapping, standardless and standards-based quantification, feature analysis
 - HKL NordlysNano EBSD camera & foreshatter detector system, HKL & Channel 5 software packages, Synergy EDS/EBSD integration, HKL, ICSD & American Mineralogist phase databases
- Gatan ChromaCL2 colour cathodoluminescence imaging system with integrated BSE detector, Digital Micrograph 3 software, automated mosaic acquisition, simultaneous acquisition of SE, iBSE and colour CL images.

Label:	am 179
Element List Type:	Current
Processing Option:	All Elements
Specimen Coating:	On
Beam Calibration Element Coating:	Off
Coating Element:	Carbon
Coating Thickness:	20 nm
Coating Density:	2.25 g/cm ³
Automatic Line Selection:	Disabled
Normalization:	Enabled
Thresholding:	Sigma level = 1
Detector Window Correction:	Enabled
Deconvolution Elements:	None
Selected Standards:	Minerals_15kV_2017-10-20 [User]
Pulse Pile Up Correction:	Succeeded
Detector file:	X-Max 3
Efficiency:	File based

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Appendix 3: Laboratory Report –SEM Analyses

Client: Grange Resources

Sample Location: Pt Latta Plant

Job Number: LJN2021-045

Analyses: Mineral chemistry

Methods: SEM-EDS

Analyst: R Bottrill

Date: 3/6/2021

Table 1: Pale green saponite EDS analyses (at%, Mg+Fe+Al+Si=7).

Label	Mg	Fe	Al	Si	Na	K	Ca	Ti	Mn
19	2.84	0.11	0.76	3.18	0.13	0.00	0.16	0.00	0.00
20	2.78	0.13	0.74	3.22	0.10	0.00	0.22	0.00	0.00
21	2.84	0.08	0.72	3.28	0.10	0.00	0.18	0.00	0.00
24	2.84	0.11	0.78	3.15	0.14	0.00	0.14	0.00	0.00
26	2.71	0.09	0.74	3.38	0.08	0.00	0.21	0.00	0.00
27	2.71	0.06	0.70	3.47	0.06	0.00	0.19	0.00	0.00
28	2.66	0.14	0.75	3.30	0.10	0.01	0.17	0.00	0.00
29	2.77	0.11	0.77	3.25	0.06	0.00	0.19	0.00	0.00
30	2.67	0.14	0.74	3.30	0.12	0.00	0.18	0.00	0.00
31	2.62	0.16	0.72	3.35	0.09	0.00	0.20	0.00	0.00
33	2.84	0.07	0.75	3.28	0.10	0.00	0.18	0.00	0.00
35	2.50	0.18	0.68	3.47	0.07	0.00	0.25	0.00	0.00
36	2.79	0.13	0.74	3.20	0.11	0.00	0.15	0.00	0.00
37	2.74	0.13	0.74	3.27	0.09	0.00	0.19	0.00	0.00
38	2.78	0.08	0.74	3.32	0.10	0.00	0.19	0.00	0.00
48	2.85	0.12	0.76	3.15	0.13	0.00	0.16	0.00	0.00
49	2.70	0.14	0.74	3.28	0.13	0.00	0.19	0.00	0.00
50	2.70	0.14	0.74	3.29	0.07	0.00	0.20	0.00	0.00
52	2.62	0.13	0.90	3.23	0.16	0.00	0.20	0.00	0.00
59	2.83	0.12	0.75	3.18	0.14	0.00	0.16	0.00	0.00
63	2.68	0.15	0.75	3.27	0.10	0.00	0.19	0.00	0.00
64	2.49	0.23	0.69	3.37	0.07	0.00	0.29	0.00	0.00
65	2.75	0.13	0.74	3.25	0.11	0.00	0.17	0.00	0.00
ave.	2.73	0.12	0.75	3.28	0.10	0.00	0.19	0.00	0.00

Table 2: Green saponite-nontronite EDS analyses (at%, Mg+Fe+Al+Si=7).

Label	Mg	Fe	Al	Si	Na	K	Ca
12	Mg	Fe	Al	Si	Na	K	Ca
13	1.64	0.96	0.88	3.17	0.08	0.02	0.25
14	1.47	1.17	0.97	3.10	0.00	0.01	0.28
15	1.37	1.48	0.63	3.21	0.07	0.08	0.15
17	1.46	1.22	0.66	3.26	0.07	0.04	0.29
18	1.48	1.29	0.58	3.36	0.06	0.02	0.21
ave.	1.66	1.00	0.71	3.35	0.06	0.03	0.20

Table 3: White Saponite EDS analyses (at%, Mg+Fe+Al+Si=7).

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Label	Mg	Fe	Al	Si	Na	K	Ca	Ti	Mn
1	2.87	0.02	0.73	3.35	0.09	0.00	0.21	0.00	0.00
2	2.89	0.02	0.72	3.35	0.10	0.00	0.21	0.00	0.00
4	2.92	0.02	0.73	3.31	0.11	0.00	0.18	0.00	0.00
5	2.91	0.00	0.71	3.38	0.12	0.00	0.17	0.00	0.00
6	2.93	0.00	0.71	3.36	0.12	0.00	0.16	0.00	0.00
7	2.95	0.01	0.72	3.30	0.11	0.00	0.17	0.00	0.00
8	2.97	0.02	0.69	3.30	0.11	0.00	0.16	0.00	0.00
9	2.95	0.01	0.73	3.29	0.09	0.00	0.19	0.00	0.00
10	2.96	0.00	0.73	3.30	0.12	0.00	0.16	0.00	0.00
11	2.91	0.00	0.73	3.36	0.12	0.00	0.17	0.00	0.00
ave.	2.93	0.01	0.72	3.33	0.11	0.00	0.18	0.00	0.00

Table 4: Chabazite EDS analyses (at%, Al+Si=12).

Label	Mg	Fe	Al	Si	Na	K	Ca
73	0.00	0.00	4.26	7.74	1.29	0.29	1.16
74	0.00	0.00	4.13	7.87	1.18	0.35	1.18
75	0.00	0.00	4.15	7.85	1.08	0.31	1.27
76	0.00	0.00	4.27	7.73	1.22	0.31	1.24
77	0.15	0.00	4.18	7.82	1.41	0.31	1.24
78	0.00	0.00	4.13	7.87	1.10	0.31	1.24
Ave.	0.03	0.00	4.19	7.81	1.21	0.31	1.22

Table 5: Thomsonite EDS

analyses (at%, Al+Si=10).

Label	Mg	Fe	Al	Si	Na	K	Ca
45	0.37	0.04	4.63	5.37	1.22	0.00	1.54
47	0.97	0.06	4.41	5.59	0.79	0.00	1.84
51	0.31	0.06	4.53	5.47	1.06	0.08	1.67
53	0.43	0.05	4.73	5.27	1.39	0.00	1.51
55	0.00	0.00	4.69	5.31	1.63	0.00	1.28
56	0.23	0.00	4.57	5.43	0.85	0.00	1.52
61	0.28	0.05	4.65	5.35	1.31	0.00	1.50
62	0.83	0.08	4.34	5.66	1.04	0.00	1.44
79	0.00	0.00	4.65	5.35	0.83	0.00	1.85
80	0.00	0.00	4.63	5.37	0.96	0.00	1.67
81	0.00	0.00	4.70	5.30	1.46	0.00	1.40
82	0.00	0.00	4.71	5.29	1.36	0.00	1.45
83	0.00	0.00	4.64	5.36	0.87	0.00	1.78
84	0.00	0.00	4.76	5.24	1.30	0.00	1.59
85	0.00	0.00	4.74	5.26	1.26	0.00	1.79
Ave.	0.23	0.02	4.63	5.37	1.15	0.01	1.59

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Appendix 4: Laboratory Report –XRF Analyses

Client: MRT

Sample Location: Raeburn Quarry, Breadalbane

Job Number: LJN2021-045

Analyses: Whole rock chemistry: XRF

Date: 10/6/2021

Analyst: E Lounejeva

Reg. #	DL	G409252 Raeburn 20/14	E203254
SiO2 wt.%	0.10	47.90	48.39
TiO2 wt.%	0.01	2.07	2.00
Al2O3 wt.%	0.20	14.21	14.23
Fe2O3TOT wt.%	0.10	11.82	11.71
MnO wt.%	0.01	0.16	0.16
MgO wt.%	0.02	9.20	9.02
CaO wt.%	0.01	9.05	8.68
Na2O wt.%	0.10	3.25	3.66
K2O wt.%	0.01	1.19	1.13
P2O5 wt.%	0.01	0.49	0.45
LOI wt.%		0.69	0.58
TOTAL wt.%		100.23	100.22
As ppm	5	<5	<5
Ba ppm	5	303	282
Bi ppm	2	3	2
Ce ppm	6	59	52
Co ppm	4	50	49
Cr ppm	4	326	389
Cs ppm	4	<4	<4
Cu ppm	5	52	45
Ga ppm	1	21	20
La ppm	5	28	29
Mo ppm	2	4	4
Nb ppm	2	37	32
Nd ppm	5	29	31
Ni ppm	7	161	148
Pb ppm	3	9	8
Rb ppm	3	26	26
Sb ppm	2	<2	<2
Sc ppm	2	21	21
Sn ppm	2	<2	<2
Sr ppm	4	648	564
Th ppm	2	6	6
U ppm	1	2	2
V ppm	2	175	181
W ppm	3	<3	<3
Y ppm	2	20	20
Zn ppm	6	104	107
Zr ppm	6	174	163

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Appendix 5: MRT Laboratory Report

Client: MRT

Sample Location: Raeburn

Job Number: LJN20201-045

Analyses: Approximate Chemistry

Methods: pXRF

Analyst: L Unwin

Lab Manager: R Bottrill

Date: 15/6/2021

Sample ID	DL	Red Rock	Black Materials within Red Rock
Date	-	8/6/21	8/6/21
Time	-	15:24:05	15:25:09
Method	-	Geochem(2)	Geochem(2)
SiO ₂ (%)	9	(9)	14.0
TiO ₂ (%)	0.2	0.3	0.4
Al ₂ O ₃ (%)	5	5.7	5.9
Fe ₂ O ₃ (%)	1.0	67.8	34.0
MnO (%)	0.1	0.2	0.2
MgO (%)	1.5	(1.5)	(1)
CaO (%)	1.0	(0.3)	(0.2)
K ₂ O (%)	2.0	(0)	(0.1)
P ₂ O ₅ (%)	0.5	(0.1)	(0)
S (%)	1.0	(0.1)	(0)
As (ppm)	100	(0)	(0)
Cr (ppm)	50	(0)	(0)
Cu (ppm)	50	(0)	(24)
Mo (ppm)	100	(46)	(16)
Nb (ppm)	30	(0)	(16)
Ni (ppm)	30	(0)	(0)
Pb (ppm)	10	207	59
Rb (ppm)	10	29	38
Sb (ppm)	100	(0)	(0)
Sn (ppm)	100	(0)	(0)
Sr (ppm)	10	26	43
Th (ppm)	100	(0)	(21)
U (ppm)	50	56	(16)
V (ppm)	100	(35)	(56)
W (ppm)	150	(0)	(0)
Y (ppm)	20	(0)	32
Zn (ppm)	20	(0)	68
Zr (ppm)	50	81	207
LE (%)	-	43.9	65.2

Disclaimer: pXRF results are unreliable and only provide an indication of the geochemistry. Accuracies and detection limits listed here are only for ideal analytical conditions. Sample preparation, grain size, porosity and composition will significantly affect the validity of the results.

Results with the format '(30)', means those results are below the detection limits.