

An Investigation into
THE REMOVAL OF SILICATE GANGUE FROM A
RUBY CONCENTRATE FROM THE FISKENAESSET PROJECT

prepared for

TRUE NORTH GEMS

Project 13034-001 Report 4
April 4, 2012

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Executive Summary

A small-scale experiment was carried out on a 50g pulverized ruby sample with 30% silicate gangue to assess the products from HF leaching and neutralization. The tests were conducted in two phases, initially using boric acid and soda ash, and subsequently lime, as neutralizing agents. Soda ash and lime addition precipitate most metals in solution in the form of insoluble salts. In this report, “residue” refers to the undissolved material after HF leaching, “solution” refers to the liquid portion after neutralization, and “sludge” refers to the solid precipitate after neutralization.

The initial tests show that most of the silicate minerals present are dissolved by the HF with the exception of sapphirine which remains in the residue along with ruby after the HF attack. Other minerals that may not be dissolved and remain in the residue are mainly oxide minerals assumed to be magnetite, ilmenite, and chromite, that could not be identified by XRD as they occur at low levels (0.5 to 2%).

Many elements that might be considered an environmental hazard (As, Bi, Cd, Co, Mo, Pb, Sb, Se, Tl, U) are below detection limits in the solution, sludge and residue. A number of other elements (Ba, Cr, Li, Mn, Ni, Sn, Sr, V, Y, Zn) occur at relatively low levels. Sn is present in the residue possibly as cassiterite. Major elements in solution are Al, Ca, Cr, Mg, Fe, and K. Whether these solutions are safe to discharge depends on local regulations. Our lab experience is that similar acidic solutions can be neutralized and metals precipitated, leaving a solution that meets (Canadian) municipal regulations for discharge.

The use of lime to neutralize the solution increases the amount of metal precipitated, most likely as stable insoluble fluorides that are not considered to be environmental hazards. This study used aqua regia (a mixture of nitric and hydrochloric acid) to keep elements in solution (including Ca) to facilitate their identification and assess the effectiveness of the HF attack. In the HF treatment plant, where only hydrofluoric acid might be used, we would expect to see much greater precipitation of metals from solution with lime addition. This would include most of the Ca as insoluble calcium fluoride, leaving a relatively clean neutralised supernatant liquid. No nitrogen compounds would be present as nitric acid would not be used.

Recommendations for the next level study include testwork to remove sapphirine and oxide minerals and investigating the role of Cl in avoiding precipitates on the ruby surface. Further study would also focus on the production of a clean solution suitable for discharge to the environment and a better definition of the composition of the sludge.

Introduction

At the request of True North Gems (TNG), a study was initiated into the use of hydrofluoric acid (HF) for removal of silicate gangue material locked with ruby crystals and the subsequent neutralization of the products for disposal. TNG has used HF acid treatment in the past and in order to use this process to treat ruby concentrates from the Fiskenaasset ore they require more detailed data from the process to scale it up to a plant scale. One problem noted in earlier work was a precipitate assumed to be CaF on the surface of the rubies that was difficult to remove. This study is a first step to a more detailed metallurgical bench scale test program. The aim here is to understand what the products of the HF attack on the ruby and gangue material are, and once neutralized, what treatment they might require to be disposed safely.



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Testwork Summary

1. Sample Selection and Test Protocol

About 50 g of ruby crystals with about 30% gangue silicate material were carefully picked from a DMS ruby concentrate (DMS#1 +1.7 mm Non-mags) by SGS gemmologist Maria Mezei., to be representative of that concentrate.

Figure 1: Material selected for test work consisting of ruby crystals and gangue silicate minerals



This material was then pulverized to analytical fineness (-200 mesh) to ensure a homogenized sample for the testing protocol which is described in Table 1. In this report, “residue” refers to the undissolved material after HF leaching, “solution” refers to the liquid portion after neutralization, and “sludge” refers to the solid precipitate after neutralization.

Table 1: Protocol for Testing HF Extraction of Silicate Gangue on a Ruby Concentrate

	TEST	RESULTS
	Pulverize about 50g	Homogenized sample
1	XRF 76Z + C & S + XRD	Full mineralogical & chemical data (major oxides, C, S)
2a	2 g by AAS 21E with HF, liquor is neutralized with boric acid & analyzed for ICP12 elements + Si	chemical data for dissolved elements in liquor - 32 elements. Analysis on solution (sludge + solution)
3a	Residue is fused and analyzed for ICP 90 elements + Si	chemical data (29 elements)for residue
2b	2 g by AAS 21E with HF, liquor is neutralized with soda ash & analyzed for ICP12 elements + Si	chemical data for dissolved elements in liquor - 32 elements. Analysis on neutralized solution
3b	Residue is fused and analyzed for ICP 90 elements + Si	chemical data (29 elements) for residue & precipitated sludge
2c	2 g by AAS 21E with HF, liquor is neutralized with lime & analyzed for ICP12 elements + Si	chemical data for dissolved elements in liquor - 32 elements. Analysis on neutralized solution +F
3c	Residue is fused and analyzed for ICP 90 elements + Si, C, S, F	chemical data (29 elements)for residue & precipitated sludge
4	2 g by AAS 21E with HF, residue is dried and submitted for XRD	mineralogical data for residue

2. Head Characterization

A portion of the homogenized sample was submitted for whole rock XRF analysis plus carbon and sulphur. These results are summarized in Table 2 and in Appendix B. Another portion was submitted for XRD analysis the results of which are in Appendix A.

The XRF data (see Table 2) show 81% alumina in the sample, which is interpreted as indicating about 70% from ruby and the rest coming from the Al in silicate minerals attached to the ruby crystals. The Sum at 101.1% is acceptable as it is within the precision range of +/- 2% of 100%. No S was detected and the low C indicates either limited carbonate or perhaps graphite that might be expected in certain

metamorphic rocks. The LOI is likely to be predominantly from the (OH) contained in hydrated minerals such as mica or amphibole.

The XRD analysis confirms corundum as the main mineral with sapphirine and mica as minor minerals. The XRD spectrum is very crowded and hence it is difficult to confirm the presence of other minerals listed in the XRD report in Appendix A, particularly when they are close to their XRD detection limits that can be as high as 2%. Quite likely some amphibole (reported as ferrogedrite), pyroxene, and oxide minerals such as ilmenite and magnetite are also present.

3. Results from Acid Attack on the Sample

Table 2: Major Element Data for Head Sample (XRF), Leach Solutions and Residue plus Sludge (ICP-OES)

Sample ID	As-rec'd Sample - XRF (1)	Ruby 1 - HF - Boric Neutral. (2A)SOL	Ruby 2 - HF - Na ₂ CO ₃ Neutral (2B)SOL	Ruby 3 - HF - Lime Neutral (2C)SOL	Ruby 1 - HF - Boric Neutral. (3A)RES	Ruby 2 - HF - Na ₂ CO ₃ Neutral (3B)RES	Ruby 3 - HF - Lime Neutral (3C)RES XRF	% dissolved 2A
SiO ₂ XRF %	9.3						1.06	
Al ₂ O ₃ XRF %	81						88.4	
Fe ₂ O ₃ XRF %	1.82	1.267	1.246	1.271	0.486	0.488	0.58	70%
MgOXRF %	5.18	3.656	2.141	1.365	1.415	2.647	3.39	71%
CaOXRF %	1	1.012	0.960	NA	0.000	0.056	0.05	101%
Na ₂ OXRF %	0.28						< 0.01	
K ₂ OXRF %	0.39	0.384	0.405	0.411	0.000	0.000	< 0.01	99%
TiO ₂ XRF %	0.11	0.055	0.052	0.052	0.048	0.049	0.05	50%
P ₂ O ₅ XRF %	0.01						< 0.01	
MnOXRF %	< 0.01	0.012	0.011	0.012	0.002	0.002	< 0.01	
Cr ₂ O ₃ XRF %	1.03	0.149	0.145	0.156	0.788	0.794	0.99	14%
V ₂ O ₅ XRF %	0.03	0.008	0.008	0.009	0.008	0.007	< 0.01	27%
LOIXRF %	1.05						5.96	
Sum %	101.1						100.5	
S %	< 0.01							
C Tot C(t) %	0.2							
F				19000 ppm			4.38%	

The samples were all leached in the same way with 15 mL aqua regia and 2 mL (48%) HF. The aqua regia has little or no effect on either the ruby or silicate minerals in the sample. The HF serves to break apart the silicates and the extracted elements are kept in solution by the aqua regia. In reaction 2A the boric acid complexes the HF at the end of the acid attack, but retains all elements in solution. This gives us an indication of what the sludge composition would be. The sludge is the very fine grained solid material that would be precipitated from the spent HF solution by addition of a neutralization agent. Based on lab experience in Canada, precipitation of the metals leaves a solution that does not contain heavy metals and meets municipal regulations for sewer discharge. In the ruby treatment plant the neutralization of the spent HF would likely be done after removal of the ruby concentrate to avoid sludge precipitation on the ruby.

In the results for 2B and 2C it can be seen how the addition of soda ash and lime respectively at the end of the reaction serve to neutralize the solution and precipitate those elements that are not soluble in a pH neutral solution. In this study, however, the presence of chloride and nitrate ions in the solution served to keep some metals ions such as Ca in solution.

The analytical data for the leach solutions and the residue and sludge are in Appendix B and in Tables 2 and 3 reported in g/t (ppm). All determinations are by ICP-OES (except the residue and sludge from the lime neutralization which was analyzed by XRF); Si could not be determined in the ICP analyses. While Si data is useful to understand what is happening to the silicates during the HF attack, other elements are available to indicate what silicates are dissolved, i.e. K occurs in mainly mica and the 99% dissolved in Table 2 suggests total dissolution of mica in the sample. Fluorine in solution and residue & sludge was only determined in the lime neutralization experiment; no chloride determinations were carried out. Ca is not reported in solution 2C due to high levels in solution from the lime addition.

The residues were in excess of 1 g and because of their size only a small portion was fused with sodium peroxide for the ICP determination. One point to be noted is that the Al being very high in both solution and residue is outside the normal ICP calibration range, and therefore the values reported will have a significant error and for this reason are not discussed in this report. XRF analysis of the residue from the lime neutralization shows Al₂O₃ at 88%, indicating that the chemical removal of silicates has increased the Al (and by extension the ruby) grade.

XRD analysis of the sample following HF attack and prior to neutralization (Test 4) is reported in Appendix A. It shows that most of the silicates apart from sapphirine were removed by the HF attack. Some trace phases remain but cannot be definitively identified due to their low abundance. Many of these might be well known refractory minerals occurring as inclusions. Their presence in the residue can be inferred from the chemical data. For example, Sn is much higher in the residue than in solution suggesting it is present in the residue possibly as cassiterite.

About 70% of the Fe is extracted, some of that will precipitate in the sludge. The undissolved Fe is likely to be in oxide minerals (ilmenite, chromite, and magnetite) that are probably less than 2% of the mineral mass as they were not identified in the XRD analysis of the residue. These minerals will also host the undissolved Ti, Cr and V.

Only 71% of the Mg is extracted, and the remainder of the Mg is in sapphirine (identified in the XRD residue) and possibly also in the oxide minerals. Some Mg will precipitate in the sludge. Incomplete dissolution of the sapphirine by HF suggests it might be a somewhat refractory silicate, which is not uncommon in medium to high grade metamorphic rocks.

Ca is completely extracted suggesting complete dissolution of the calc-silicates (pyroxenes & amphibole) that will also be a source of Fe, Cr, Ti and V in solution. Some Ca precipitates into the sludge. The presence of CaF was not noted in the residue plus sludge XRD and this is interpreted as indicating that most of the Ca is retained in solution. K is completely extracted and remains in solution, suggesting complete dissolution of mica.

Table 3: ICP-OES Data for Leach Solutions and Residues for Major, Minor, and Trace Elements

	SOLUTION			RESIDUE		
	Ruby 1 -HF - Boric Neutral (2A) AVG	Ruby 2 - HF - Na ₂ CO ₃ Neutral (2B) AVG	Ruby 3 - HF - LIME Neutral (2C)	Ruby 1 - HF - Boric Neutral (3A) AVG	Ruby 2 - HF - Na ₂ CO ₃ Neutral (3B) AVG	Ruby 3 - HF - LIME Neutral (3C)
Ag g/t	< 2	< 2		0	0	< 2
Al g/t	355000	368500	13494	248720	267818	467972
As g/t	< 30	< 30	<30	0	0	< 30
Ba g/t	37	35	36	0	2	41.4
Be g/t	0	0	<0.1	0	0	0.05
Bi g/t	< 20	< 20	<20	0	0	< 20
Ca g/t	7207	6972		0	396	357
Cd g/t	< 2	< 2	<2	0	0	< 2
Co g/t	< 6	< 6	<6	0	0	< 6
Cr g/t	1007	983	1070	5339	5391	5900
Cu g/t	5	6	6	0	0	6.3
Fe g/t	8770	8854	8890	3394	3403	12200
K g/t	3185	3380	3410	0	0	3770
Li g/t	22	27	21	0	0	21
Mg g/t	21994	13238	8230	8492	15853	31700
Mn g/t	90	88	94	15	18	116
Mo g/t	< 5	< 5	<5	0	0	< 5
Ni g/t	37	35	38	0	0	38
Pb g/t	< 20	< 20	<20	0	0	< 20
Sb g/t	< 10	< 10	<10	0	0	< 10
Se g/t	< 30	< 30	<30	0	0	< 30
Sn g/t	28	26	28	411	435	619
Sr g/t	12	11	15	0	0	17.4
Ti g/t	326	311	343	286	293	629
Tl g/t	< 30	< 30	<30	0	0	< 30
U g/t	< 20	< 20	<20	0	0	< 20
V g/t	44	44	49	45	41	90
Y g/t	2	2	2.5	0	0	2.5
Zn g/t	18	17	24	84	83	109

Based on the analysis of the leachant solutions in Table 3 many elements that might be considered an environmental hazard are below detection (As, Bi, Cd, Co, Mo, Pb, Sb, Se, Tl, U). A number of other elements (Ba, Cr, Li, Mn, Ni, Sn, Sr, V, Y, Zn) occur at relatively low levels. Major elements present in solution are Al, Ca, Cr, Mg, Fe, K.

With the addition of lime there is an increase in all of the metals precipitated, many of them as fluorides as the fluoride content of the sludge is 4.38%. The only metal that does not show an increase is Ca which stays in solution. Most likely this is because of the presence of Cl ions from the aqua regia. In the absence of Cl, or if excess lime was added to increase the pH, it is likely that the Ca would precipitate in the sludge as CaF₂.

Some elements (Fe, K, Mn, Sn, Ti) reported for the lime neutralization experiment have levels in solution similar to the other two experiments, but spike in the residue. The increase in the sludge can be explained by the lime neutralization precipitating more metal out of solution. There should be a corresponding reduction of the metal in solution but this has not happened. The reason for this is not clear – it could be an inhomogeneous aliquot used for this experiment, or an artefact of the experimental process.

Conclusions and Recommendations

The study into the dissolution of gangue silicates locked with ruby crystals indicates that HF treatment will remove most of the silicates, bar saphirine. It is recommended that the future bench top metallurgical study examine carefully the kinetics of the HF attack so that saphirine is removed. Dissolution of the oxide phases also requires some consideration.

It is thought that the presence of Cl ions from the aqua regia is the main reason for keeping many elements in solution, particularly Ca. It is recommended that the bench top study examine in detail how the precipitation of CaF₂ on the corundum surface can be avoided by having Cl ions available in the solution.

The resulting solutions from the HF leach do not appear to contain elements that might present environmental hazards. Most appear to be below detection limits. Whether these solutions can be discharged safely depends on local regulations.

Neutralization of the spent acidic cleaning solution can easily be achieved using common bases such as soda ash or lime. The latter seems to offer the most practical solution from an operating point of view as the major elements are precipitated in the form of insoluble salts (sludge). The composition of this material is indicated by the elements in solution in the boric acid neutralization. The bench top study will need to generate sufficient material for environmental testing (e.g. Reg 347) to verify that it that can be disposed of safely in landfills.

This study has shown that lime addition increases the metals precipitated and suggests that in the absence of Cl ions in solution, or in the presence of excess lime, most metals would be completely precipitated.

Disposal of the remaining solution can be safely completed by evaporation of the water and shipping the small quantity of remaining salts to a special disposal facility, although further testwork may demonstrate that economical processes are available to reduce the ion concentrations sufficiently to permit discharge to the environment.

Appendix A – XRD Results

Head Sample XRD

Summary of Qualitative X-ray Diffraction Results

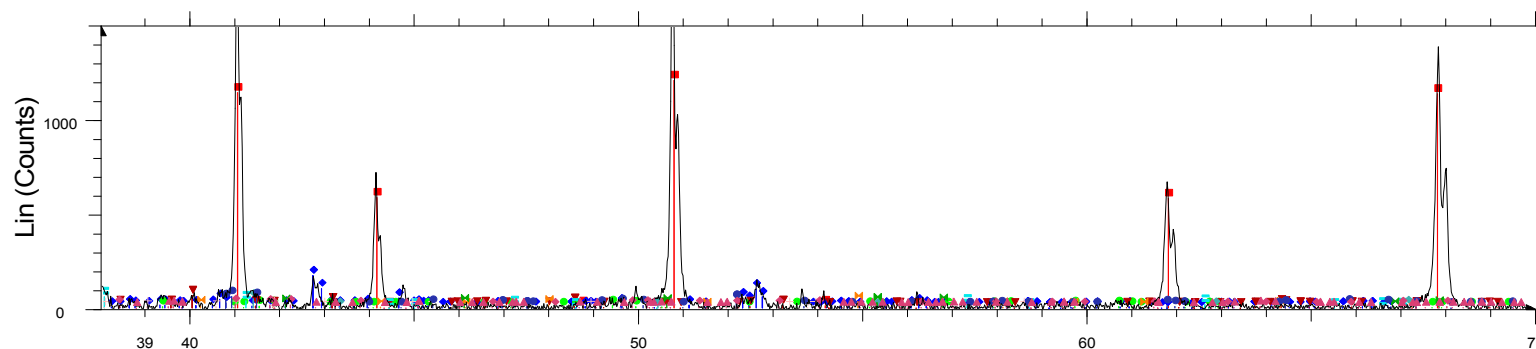
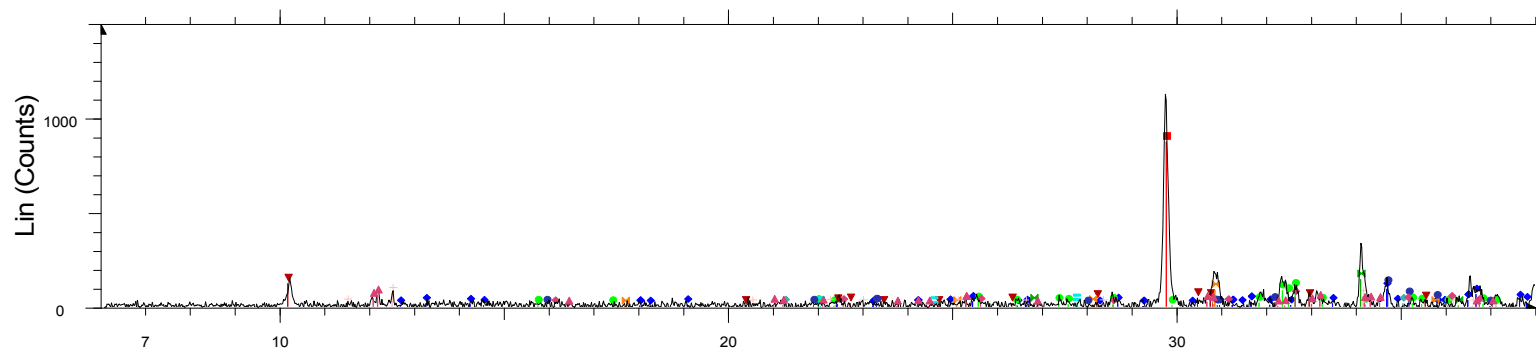
Crystalline Mineral Assemblage (relative proportions based on peak height)

Sample ID	Major	Moderate	Minor	Trace
Ruby Sample #1	corundum	-	sapphirine, mica, *calcite	*plagioclase, *danalite, *ilmenite, *magnetite, *cordierite, *ferrogedrite, *pyroxene, *ferrosilite

* tentative identification due to low concentrations, diffraction line overlap or poor crystallinity

Mineral	Composition
Calcite	CaCO ₃
Cordierite	(Mg,Fe) ₂ Al ₄ Si ₅ O ₁₈ *nH ₂ O
Corundum	Al ₂ O ₃
Danalite	Fe ₈ Be ₆ Si ₆ O ₂₄ S ₂
Ferrogedrite	Fe ₅ Al ₄ Si ₆ O ₂₂ (OH) ₂
Ferrosilite	(Fe,Mg)SiO ₃
Ilmenite	FeTiO ₃
Magnetite	Fe ₃ O ₄
Mica	K(Mg,Fe)Al ₂ Si ₃ AlO ₁₀ (OH) ₂
Plagioclase	(NaSi,CaAl)AlSi ₂ O ₈
Pyroxene	(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al) ₂ O ₆
Sapphirine	(Mg _{3.78} Al _{4.22})(Si _{1.91} Al _{4.09} O ₂₀)

Ruby Sample #1



2-Theta - Scale

- | | |
|---|--|
| <ul style="list-style-type: none"> √ Ruby Sample #1 - File: Nov4500-1.raw - Type: 2Th/Th locked ■ 01-088-0883 (C) - Corundum - from Froland, Norway - Al_{1.98}Cr_{0.02}O₃ ◆ 01-076-0536 (C) - Sapphirine - (Mg_{3.78}Al_{4.22})(Si_{1.91}Al_{4.09})O₂₀ ● 00-041-1486 (*) - Anorthite, ordered - CaAl₂Si₂O₈ ▼ 01-085-2271 (C) - Phlogopite - KMg₃Si₃AlO₁₀(F,OH)₂ ◻ 01-084-0745 (C) - Danalite - Fe₈Be₆Si₆O₂₄S₂ ▢ 01-075-0519 (C) - Ilmenite - FeTiO₃ ◆ 01-087-2334 (C) - Magnetite - synthetic - Fe₃O₄ | <ul style="list-style-type: none"> ▲ 01-083-1385 (C) - Cordierite - Mg_{1.80}Fe_{0.136}Al_{3.843}Si_{4.838}O₁₈(H₂O)_{0.86} ⊕ 00-031-0617 (*) - Ferrogdrite - Fe₅Al₄Si₆O₂₂(OH)₂ ◻ 01-086-2340 (C) - Calcite - Ca(CO₃) ● 01-087-2070 (C) - Diopside (Fe-bearing) - from Chelyabinsk coal basin, S.Urals, - (Fe_{0.35}Al ◆ 00-031-0634 (I) - Ferrosilite, magnesian - (Fe,Mg)SiO₃ |
|---|--|

Residue Sample XRD (Test 4)

Qualitative X-Ray Diffraction	
Report Prepared for:	True North Gems
Project Number/ LIMS No.	13034-001/MI4508-NOV11
Reporting Date:	November 24, 2011
Instrument:	BRUKER AXS D8 Advance Diffractometer
Test Conditions:	Co radiation, 40 kV, 35 mA Regular Scanning: Step: 0.02°, Step time:0.2s, 2θ range: 3-70°
Interpretations:	PDF2/PDF4 powder diffraction databases issued by the International Center for Diffraction Data (ICDD). DiffracPlus Eva software.
Detection Limit:	0.5-2%. Strongly dependent on crystallinity.

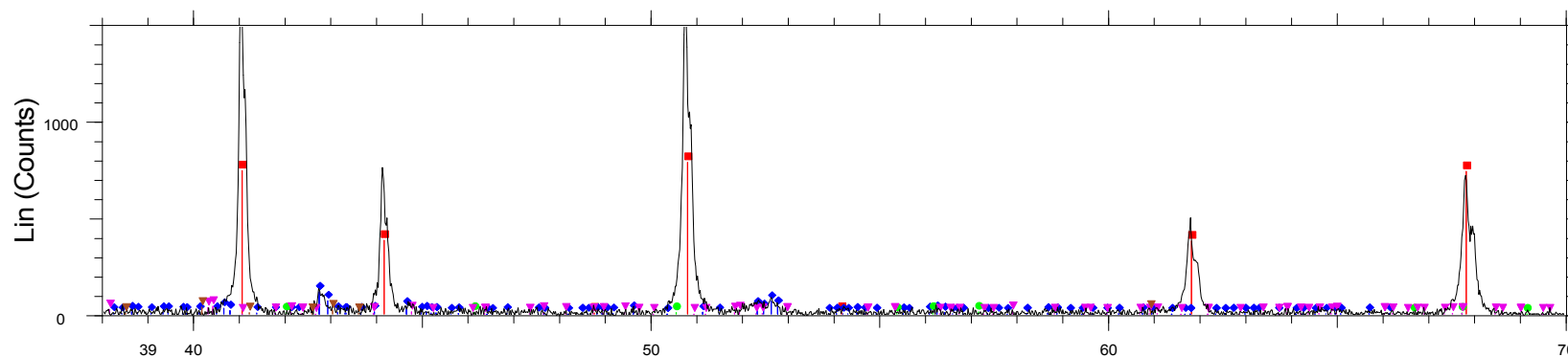
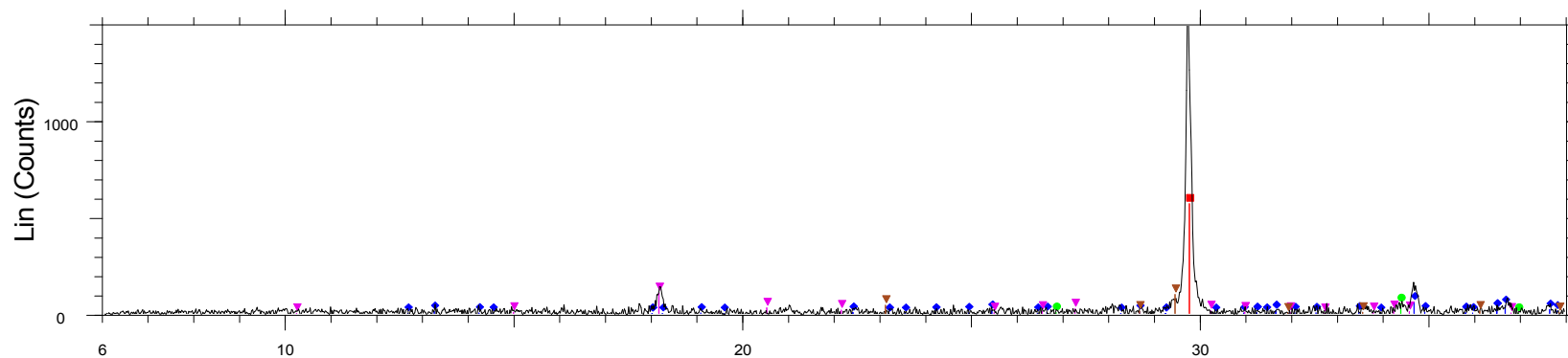
Summary of Qualitative X-ray Diffraction Results**Crystalline Mineral Assemblage (relative proportions based on peak height)**

Sample ID	Major	Moderate	Minor	Trace
(1) Ruby Sample #2 (2388.3)	corundum	-	sapphirine	*calcite *magnesiocarpholite *grossite

* tentative identification due to low concentrations, diffraction line overlap or poor crystallinity

Mineral	Composition
Calcite	CaCO ₃
Corundum	Al ₂ O ₃
Grossite	CaAl ₄ O ₇
Magnesiocarpholite	MgAl ₂ Si ₂ O ₆ (OH) ₄
Sapphirine	(Mg,Al) ₈ (Al,Si) ₆ O ₂₀

Ruby Sample #2(2388.3)



2-Theta - Scale

- Ruby Sample #2(2388.3) - File: Nov4508-1.raw - Type: 2Th/Th locked - Start: 6.000 ° - End: 70.006 ° - Step: 0.019 ° - Step time: 12. s - Temp.: 25 °C (Room) - Time Started: 18 s - 2-Theta: 6
 Operations: Background 1.000,1.000 | Import
- 01-088-0883 (C) - Corundum - from Froland, Norway - Al1.98Cr0.02O3
 - ◆ 01-076-0537 (C) - Sapphire - (Mg3.78Al4.22)(Si1.91Al4.09)O20
 - 01-072-1650 (C) - Calcite - CaCO3
 - ▼ 01-083-1944 (C) - Magnesiochlorophyllite - Mg.796Fe.204Al2Si2O6(OH)4
 - ▼ 00-046-1475 (I) - Grossite - CaAl4O7

Appendix B – ANALYTICAL DATA

HEAD CHARACTERIZATION XRF DATA

Sample ID	As-rec'd Sample - no leach XRF (1)
SiO2XRF %	9.3
Al2O3XRF %	81
Fe2O3XRF %	1.82
MgOXRF %	5.18
CaOXRF %	1
Na2OXRF %	0.28
K2OXRF %	0.39
TiO2XRF %	0.11
P2O5XRF %	0.01
MnOXRF %	< 0.01
Cr2O3XRF %	1.03
V2O5XRF %	0.03
LOIXRF %	1.05
Sum %	101.1
S %	< 0.01
C_Tot C(t) %	0.2

ICP-OES DATA FROM SOLUTIONS & RESIDUES

Sample ID	Ruby 1 -HF - Boric Neutral. (2A & 3A)	Ruby 2 - HF - Na2CO3 Neutral (2B & 3B)	Ruby 1 -HF - Boric Neutral. (dup)	Ruby 2 - HF - Na2CO3 Neutral (dup)	Ruby 1 -HF - Boric Neutral. (2A & 3A) AVG	Ruby 2 - HF - Na2CO3 Neutral (2B & 3B) AVG
Ag g/t SOL	< 2	< 2	< 2	< 2	< 2	< 2
Ag g/t RES	0	0	0	0	0	0
Al g/t SOL	361000	367000	353000	369000	357000	368000
Al g/t RES	253668	272272	247071	266334	250370	269303
As g/t SOL	< 30	< 30	< 30	< 30	< 30	< 30
As g/t RES	0	0	0	0	0	0
Ba g/t SOL	37.3	35.5	36.8	35.3	37.05	35.4
Ba g/t RES	0	2	0	2	0	2
Be g/t SOL	0.04	0.03	0.04	0.03	0.04	0.03
Be g/t RES	0	0	0	0	0	0
Bi g/t SOL	< 20	< 20	< 20	< 20	< 20	< 20
Bi g/t RES	0	0	0	0	0	0
Ca g/t SOL	7279.192	6648.433	7182.585	7079.758	7230.889	6864.096
Ca g/t RES	0	403.448	0	392.95	0	398.199
Cd g/t SOL	< 2	< 2	< 2	< 2	< 2	< 2
Cd g/t RES	0	0	0	0	0	0
Co g/t SOL	< 6	< 6	< 6	< 6	< 6	< 6
Co g/t RES	0	0	0	0	0	0
Cr g/t SOL	1040.492	1016.907	995.714	971.83	1018.103	994.3685
Cr g/t RES	5501.15	5516.542	5284.761	5349	5392.956	5432.771
Cu g/t SOL	5	6	4.6	6.3	4.8	6.15
Cu g/t RES	0	0	0	0	0	0
Fe g/t SOL	9034.176	8422.289	8681.85	8998	8858.013	8710.145
Fe g/t RES	3415.809	3431.434	3387.172	3393.7	3401.491	3412.567
K g/t SOL	3200	3320	3180	3400	3190	3360
K g/t RES	0	0	0	0	0	0
Li g/t SOL	22	27	22	27	22	27
Li g/t RES	0	0	0	0	0	0
Mg g/t SOL	22170.43	12267.73	21934.56	13561.36	22052.5	12914.55
Mg g/t RES	8623.613	16182.71	8448.421	15743.65	8536.017	15963.18
Mn g/t SOL	91.553	90.035	89.333	87.565	90.443	88.8
Mn g/t RES	15.439	19.89	15.3	17.6	15.3695	18.745
Mo g/t SOL	< 5	< 5	< 5	< 5	< 5	< 5
Mo g/t RES	0	0	0	0	0	0
Ni g/t SOL	38	36	37	35	37.5	35.5
Ni g/t RES	0	0	0	0	0	0
Pb g/t SOL	< 20	< 20	< 20	< 20	< 20	< 20
Pb g/t RES	0	0	0	0	0	0
Sb g/t SOL	< 10	< 10	< 10	< 10	< 10	< 10
Sb g/t RES	0	0	0	0	0	0
Se g/t SOL	< 30	< 30	< 30	< 30	< 30	< 30
Se g/t RES	0	0	0	0	0	0
Sn g/t SOL	26.806	29.16	27.763	25.28	27.2845	27.22
Sn g/t RES	424.403	448.026	406.808	430.3	415.6055	439.163
Sr g/t SOL	12.2	11.7	12.2	11.3	12.2	11.5
Sr g/t RES	0	0	0	0	0	0

Ti g/t SOL	329.842	317.046	324.596	309.37	327.219	313.208
Ti g/t RES	294.444	297.852	282.667	291.75	288.5555	294.801
Tl g/t SOL	< 30	< 30	< 30	< 30	< 30	< 30
Tl g/t RES	0	0	0	0	0	0
U g/t SOL	< 20	< 20	< 20	< 20	< 20	< 20
U g/t RES	0	0	0	0	0	0
V g/t SOL	45.223	44.708	43.945	43.53	44.584	44.119
V g/t RES	45.168	42.129	44.702	40.5	44.935	41.3145
Y g/t SOL	1.9	1.7	1.9	1.7	1.9	1.7
Y g/t RES	0	0	0	0	0	0
Zn g/t SOL	21.18	18.706	16.819	16.34	18.9995	17.523
Zn g/t RES	88.638	85.007	81.88	82.75	85.259	83.8785

Ruby 3 Filtrate - Lime Neutralization ICP-OES (2C)			Ruby 3 Residue - Lime Neutralization (3C)	
Al ppm	13494	SiO2	XRF %	1.06
As ppm	<30	Al2O3	XRF %	88.4
Ba ppm	36	Fe2O3	XRF %	0.58
Be ppm	<0.1	MgO	XRF %	3.39
Bi ppm	<20	CaO	XRF %	0.05
Cd ppm	<2	Na2O	XRF %	< 0.01
Co ppm	<6	K2O	XRF %	< 0.01
Cr ppm	1070	TiO2	XRF %	0.05
Cu ppm	6	P2O5	XRF %	< 0.01
Fe ppm	8890	MnO	XRF %	< 0.01
K ppm	3410	Cr2O3	XRF %	0.99
Li ppm	21	V2O5	XRF %	< 0.01
Mg ppm	8230	LOI	%	5.96
Mn ppm	94	Sum	%	100.5
Mo ppm	<5	Ag	ICP g/t	< 2
Na ppm	2030	As	ICP g/t	< 30
Ni ppm	38	Ba	ICP g/t	41.4
P ppm	<30	Be	ICP g/t	0.05
Pb ppm	<20	Bi	ICP g/t	< 20
Sb ppm	<10	Cd	ICP g/t	< 2
Se ppm	<30	Co	ICP g/t	< 6
Sn ppm	28	Cr	ICP g/t	5900
Sr ppm	15	Cu	ICP g/t	6.3
Ti ppm	343	Fe	ICP g/t	12200
Tl ppm	<30	K	ICP g/t	3770
U ppm	<20	Li	ICP g/t	21
V ppm	49	Mg	ICP g/t	31700
Y ppm	2.5	Mn	ICP g/t	116
Zn ppm	24	Mo	ICP g/t	< 5
		Na	ICP g/t	2030
		Ni	ICP g/t	38
		P	ICP g/t	< 30
		Pb	ICP g/t	< 20
		Sb	ICP g/t	< 10
		Se	ICP g/t	< 30
		Sn	ICP g/t	619
		Sr	ICP g/t	17.4
		Ti	ICP g/t	629
		Tl	ICP g/t	< 30
		U	ICP g/t	< 20
		V	ICP g/t	90
		Y	ICP g/t	2.5
		Zn	ICP g/t	109
		S	%	***
		C(t)	%	***
		F	%	4.38