

RAPPORT**Karakterisering och klassificering av utvinningsavfall**

Gråberg och anrikningssand från brytning och anrikning av malm, Nunasvaara Södra

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BILAGA B

Assessment of the future leachate quality from waste rock at Nunasvaara South

BILAGA C

Talga Resources Vittangi Project Tailings Feasibility Study - Laboratory testing

BILAGA D

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BILAGA E

ALS resultatrapporter

1.0 INLEDNING

Denna rapport beskriver resultaten från hittills genomförda undersökningar av det utvinningsavfall som uppkommer vid brytning och anrikning av grafitmalm i Talga Graphene AB:s planerade verksamhet nära Vittangi, Kiruna kommun.

Med utvinningsavfall avses enligt utvinningsavfallsförordningen (2013:319) "avfall som har uppkommit som en direkt följd av prospektering, utvinning eller bearbetning eller en direkt följd av lagring av utvunnet material innan bearbetning av materialet avslutats". I rapporten redogörs även för klassificeringen av utvinningsavfallen i enlighet med bilaga 4 till avfallsförordningen (SFS 2011:927).

Utvinningsavfallet omfattar gråberg som uppkommer vid en framtida malmbrytning vid Nunasvaara Södra dagbrotten och den anrikningssand som uppkommer vid bearbetning och anrikning av malm i tillhörande anrikningsverk. Utöver de två typerna av utvinningsavfall uppkommer slam från vattenrening.

1.1 Om karakterisering av utvinningsavfall

Enligt 30 § i utvinningsavfallsförordningen ska den som driver en verksamhet som ger upphov till utvinningsavfall eller driver en utvinningsavfallsanläggning karakterisera det avfall som uppkommer eller hanteras i verksamheten så att avfallet kan hanteras på ett lämpligt och säkert sätt.

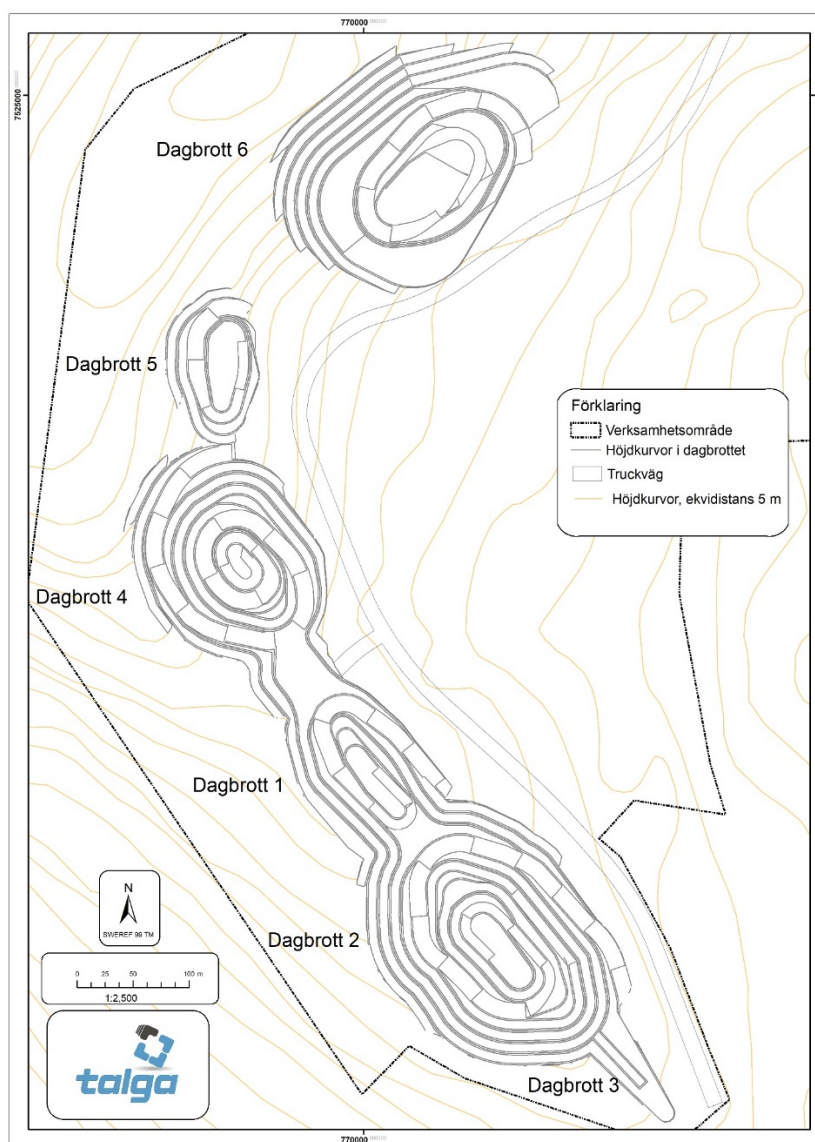
Enligt 31-36 §§ i utvinningsavfallsförordningen ska karakteriseringen enligt ovan dokumenteras och bl.a. innefatta:

- Information om fyndigheten och mineraliseringen samt geologiska förhållanden på utvinningsplatsen
- Mineraliseringens och utvinningsavfallens ursprung, mineralogiska, fysikaliska och geokemiska egenskaper
- Kemisk sammansättning hos lakvatten som avfallen ger upphov till.

2.0 BESKRIVNING AV VERKSAMHETEN SOM GER UPPHOV TILL UTVINNINGSAVFALL

Malmfyndigheten i Nunasvaara Södra planeras brytas i sex intilliggande dagbrott utmed mineraliseringen (Figur 1). För att frilägga malmen bryts omkringliggande ofyndigt berg (gråberg) i den utsträckning som erfordras för att erhålla stabila slänter i dagbrotten. Gråberg bryts även i löpande i takt med malmbrytningen.

Den planerade verksamheten omfattar brytning i dagbrott med två olika brytningsmetoder, blockbrytning och konventionell borrhning/sprängning, varav borrhning/sprängning kommer vara den dominerade metoden. Dessa två brytningsmetoder ger var för sig material till två separata processer som sker på plats: sågning av grafitkivor och anrikning av grafitkoncentrat (95 % renhet). Materialet från dessa processer kommer att transporteras till olika anläggningar för tillverkning av material till batterianoder och grafenprodukter. Gruvan och anrikningsprocesserna kommer att ha flexibilitet för att kunna producera grafitplattor och koncentrat för att möta efterfrågan på marknaden. Figur 2 ger en överblick över det planerade verksamhetsområdet. De planerade dagbrotten ligger väster om sjön Hosiojärvi.

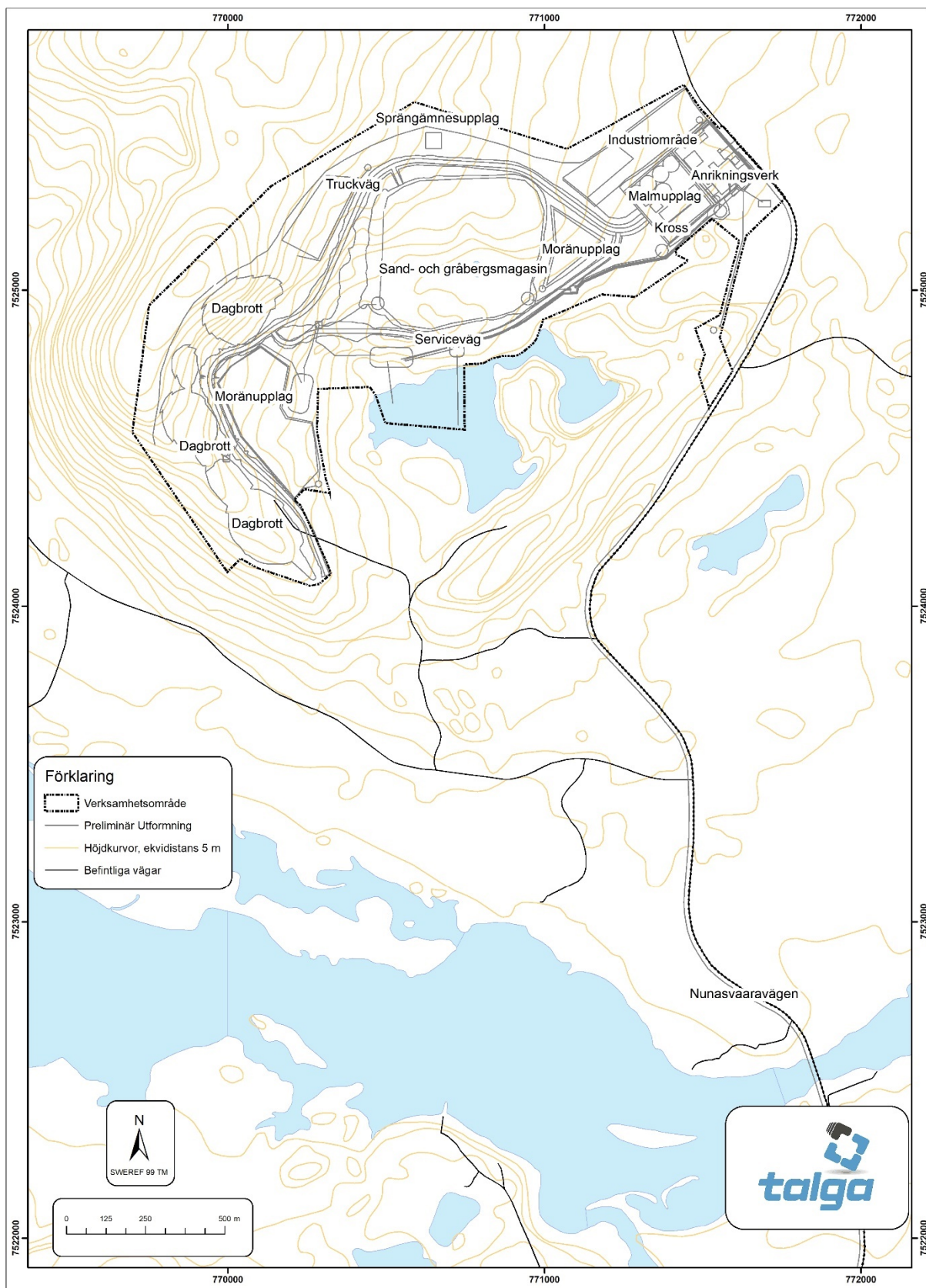


Figur 1: Utformning av planerade dagbrott vid Nunasvaara Södra-fyndigheten. Siffrorna i bilden anger i den ordning dagbrotten planeras att brytas.

Gråberg körs till ett särskilt upplagsområde medan malmen körs till krossning. Efter krossning transporteras malmen till anrikningsverket. Den krossade malmen lagras i en malmlada i anslutningen till anrikningsverket, låghaltig malm lagras i ett upplag vid industriområdet och blandas med malm inför anrikningen vid behov.

Inför anrikningen körs malmen genom den andra krossen. Därefter mals materialet i en kvarn ned till en kornstorlek som motsvarar sand och finare fraktioner. Sedan förs materialet in i den första flotationskretsen, blandat med återvunnet processvatten och flotationskemikalier. I primärflotationen uppkommer ett avfall som är en grövre anrikningssand. Malmkoncentratet som har utvunnits i första steget undergår ytterligare en malning. Som vid primärflotationen blandas materialet med processvatten och kemikalier till en slurry.

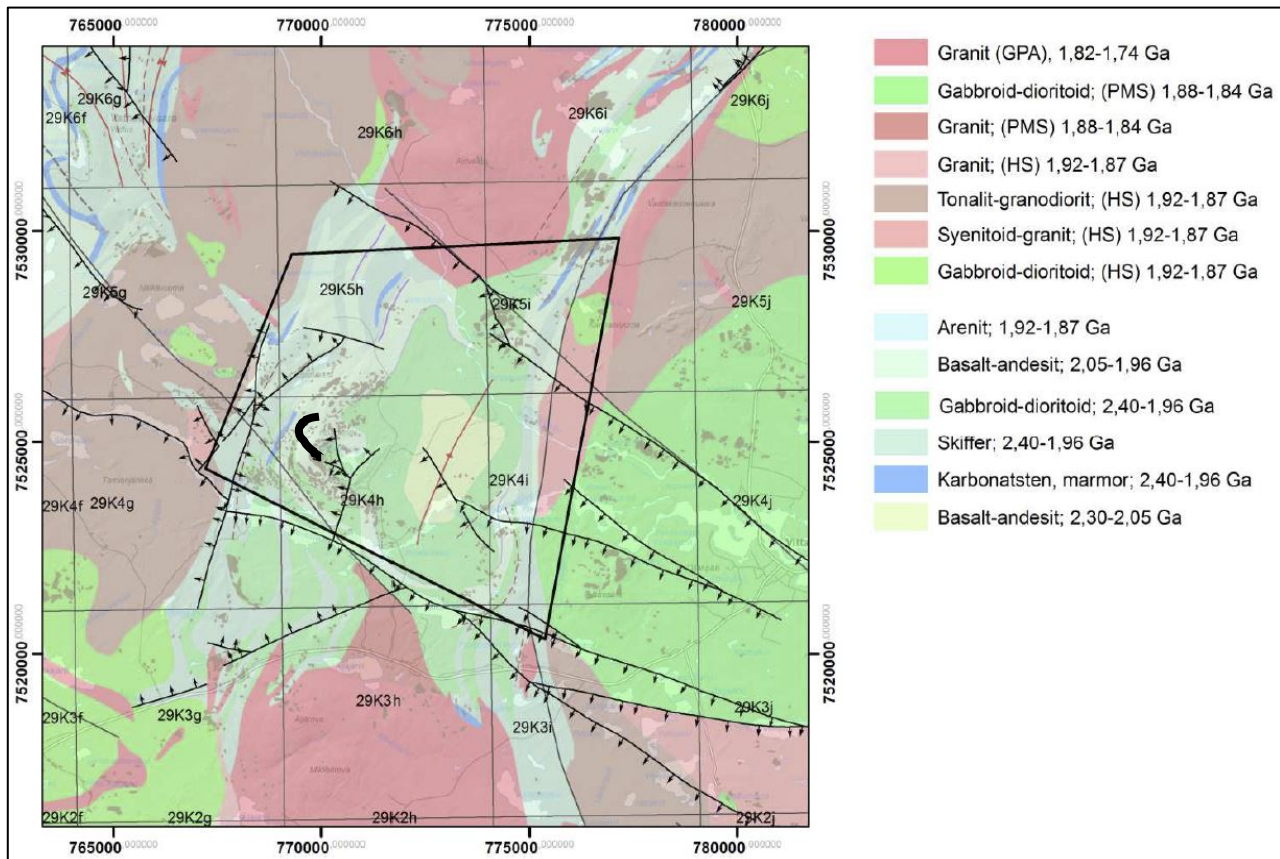
Anrikningssanden från båda flotationsstegen förs till en blandare och vidare till en förtjockare för att avvattna slurryn och öka fastgodshalten. Membranpressfiltrering används för att filtrera bort vattnet. Efter avvattning innehåller anrikningssanden 25-30 vikt-% vatten och är ganska kompakt. Anrikningssanden lastas på truckar och körs till sand- och gråbergsmagasinet.



Figur 2: Planerade verksamhetsområde med dagbrotten, sand- och gråbergsmagasin, industriområde och andra tillhörande ytor som upplag för avrymningsmassor.

3.0 GEOLOGISKA FÖRHÅLLANDEN OCH FÖRUTSÄTTNINGAR

Områdets geologi domineras av grönsten (basalt till andesit), metasediment (kvartsit, skiffer, marmor) samt metadolerit som formar en del av Vittangi grönstengrupp och tillhör paleoproterozoiska vulkanosedimentära domänen i norra Sverige (ca 2,40–1,96 Ga) som ligger på arkaisk undergrund (Lynch och Jörnberger, 2013). Den regionala berggrundskartan redovisas i Figur 3.

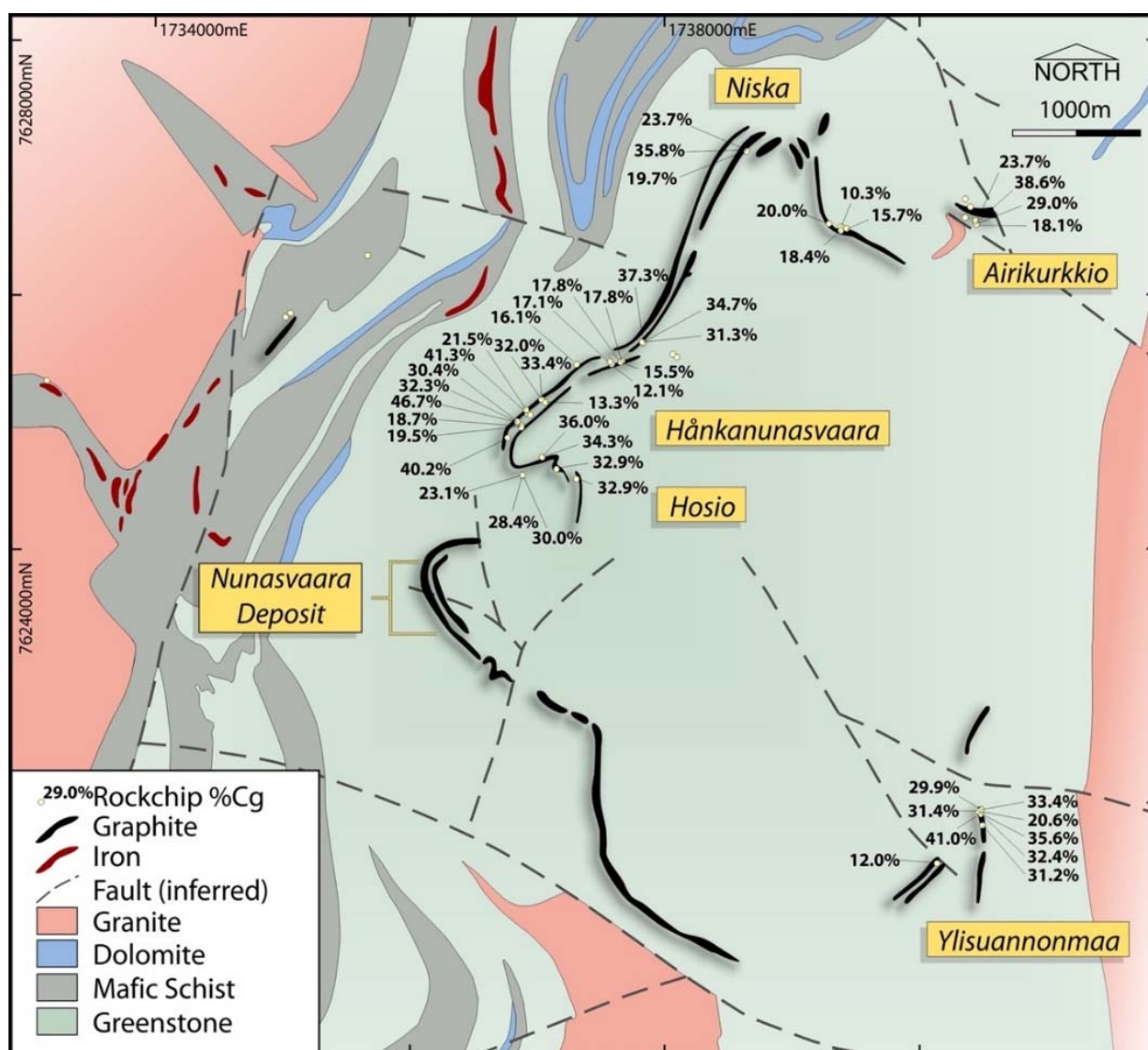


Figur 3: Regional geologi av området. Nunasvaara södra är markerat med svart. (Lynch & Jörnberger, 2013)

Grafitmineraliseringen av Nunasvaara Södra förekomsten består av subvertikala, 20 till >30 m breda, 1200 m långa, litologiskt genomgående enheter av mycket finkornig grå till svart grafitberg innehållande 10-46 % grafitiskt kol. Resursen har modellerats till ett djup på ~200 m och mineraliseringen förblir öppen både längs strykningen och på djupet. Hängväggen består av mafiska vulkanoklastar och tuffitiska enheter och liggväggen består av en mafisk gång (gabbro/dolerit).

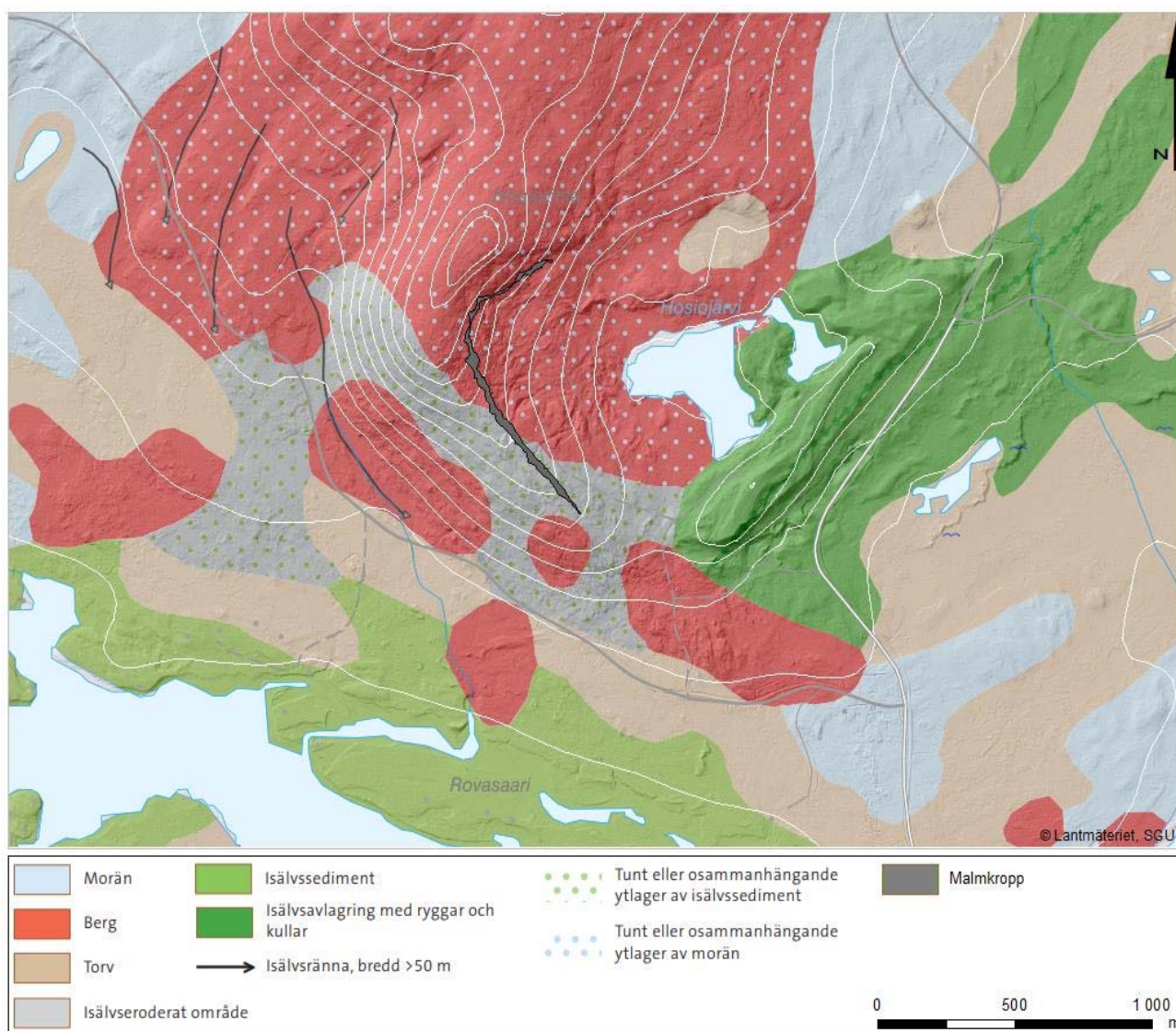
Tunnslipar visar att det utöver huvudmineralen grafit, albit och mindre mängder amfibol, glimmer, titanit, sulfider (pyrit, magnetkis och spår av kopparkis) också förekommer järnoxider och apatit. I vissa prover förekommer små mängder kvarts. I vissa fall observeras även skapolit, mikroklin och rutil. Grafiten förekommer som mycket små, tunna ark eller flingor. De är ganska jämnt spridda och omslutna av alla andra mineraler. Kristalllängden är 1–60 µm där de flesta grafitflingor är cirka 10 µm långa.

Grafitenheterna sträcker sig över ett större område (Figur 4). I genomsnitt har de en andel grafitiskt kol av 26,2 % med halter upp till 46,7 %. Grafiten består av exceptionellt jämnt fördelade, mycket fina flingor (klassificerade som mikrokristallina flingor).



Figur 4: Geologisk översikt över Vittangi-området. Halter av grafitisk kol från ytlig provtagning av berg är angivna för en del malmkroppar i området.

Jordarterna i området består av moränavlagringar i väst, nord och öst om Hosiorinta och Nunasvaara med torvavlagringar i lägre terräng. Sydost om Hosiojärvi ligger en sanddyn bestående av sand- och grusavlagringar. Söder om Hosiorinta finns eroderade områden bestående av sandigt och grusigt material med märken av isälvsrännor från högre till lägre terräng. Enstaka isälvsrännor förekommer även i nordlig riktning. Centrala delen av området utgörs av berg med tunt moräntäcke (Figur 5).



Figur 5: Jordarter i området runt Nunasvaara Södra fyndigheten (SGU).

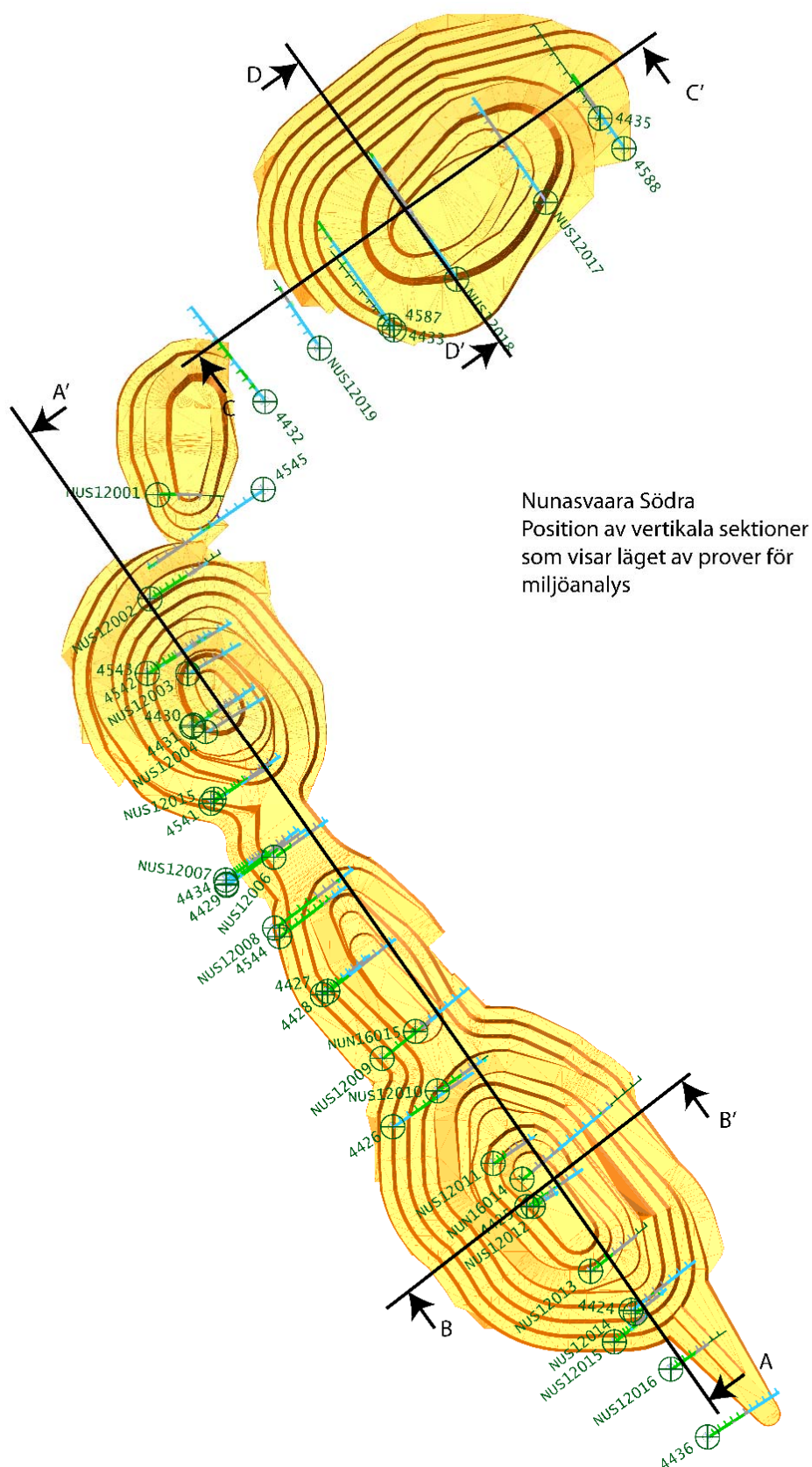
4.0 GENOMFÖRDA PROVTAGNINGAR OCH ANALYSER

4.1 Beskrivning av provpunkter

Från borrhkampanjen år 2012 valdes prover (cirka 2 m intervall) ut från 19 borrhkärnor längs Nunasvaara Södra fyndigheten. 32 prover togs ut för vidare analyser och tester. I Tabell 1 är alla prover listade med tillhörande bergart, position i borrhkärnan och svavelhalt. Positionerna av uttagna prover redovisas också i Figur 6 till Figur 8.

Tabell 1: Analyserade borrhälar från Nunasvaara Södra. Position, bergart och svavelhalt.

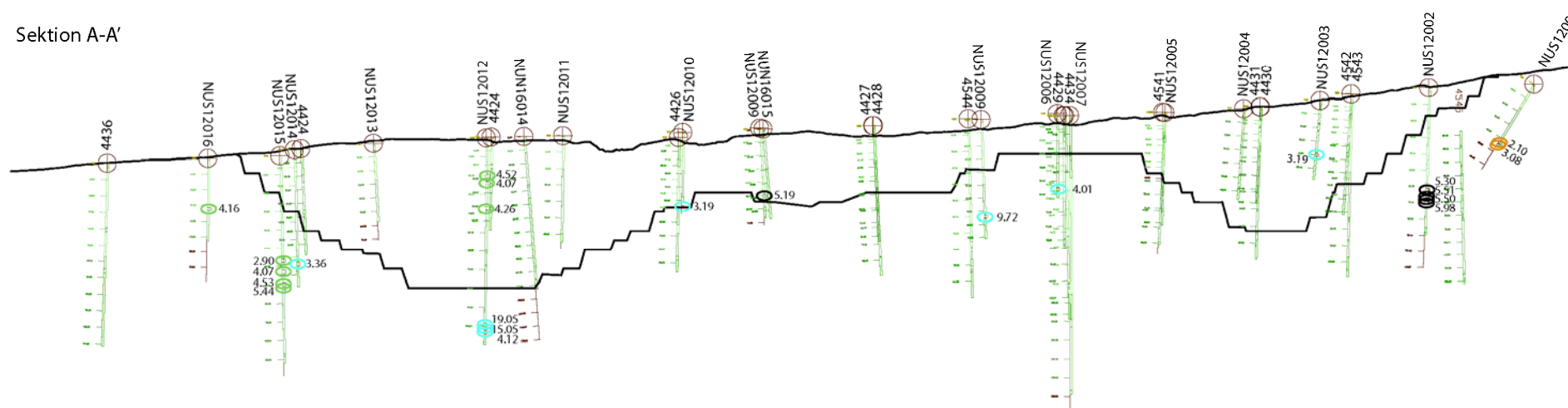
Borrhål ID	Intervall (m)	Bergart		S %	Borrhål ID	Intervall (m)	Bergart		S %
NUS12002	46-48	Mafisk tuff (Hängvägg)	Vtf	0,22	NUS12001	42,25-44	Doleritgång	Dyke	2,19
NUS12006	16-18			0,55	NUS12001	53-55			1,08
NUS12008	45-47			0,17	NUS12006	38,5-40,5			0,29
NUS12008	73,25-75			9,72	NUS12006	40,5-42,85			0,47
NUS12011	12-14			2,15	NUS12018	79,68-81,8			9,73
NUS12016	31,4-33,4			4,16	NUS12019	44,3-46			1,32
NUS12016	33,4-35,4			2,77	NUS12001	21-23	Grafitmalm	Sgr	1,19
NUS12019	66,17-68,			1,19	NUS12002	65-67			5,51
NUS12019	74-76			0,35	NUS12005	54-56			8,18
NUS12014	59,9-61,18			2,74	NUS12010	44-46			0,68
NUS12003	38,3-40	Gabbro/mafisk Dolerit (Liggvägg)	Pgb	3,19	NUS12017	83-85			3,49
NUS12005	78,7-81			1,75	NUS12018	52-54			0,23
NUS12007	104-106			0,11	NUS12018	60-62			1,54
NUS12015	107-108,35			2,47	NUS12014	30,5-32,5	Grafitmalm (LG)		3,51
NUS12017	53,13-55			24,1					
NUS12019	38-40			0,15					
NUS12019	48-50			9,16					
NUS12014	68-70			1,63					



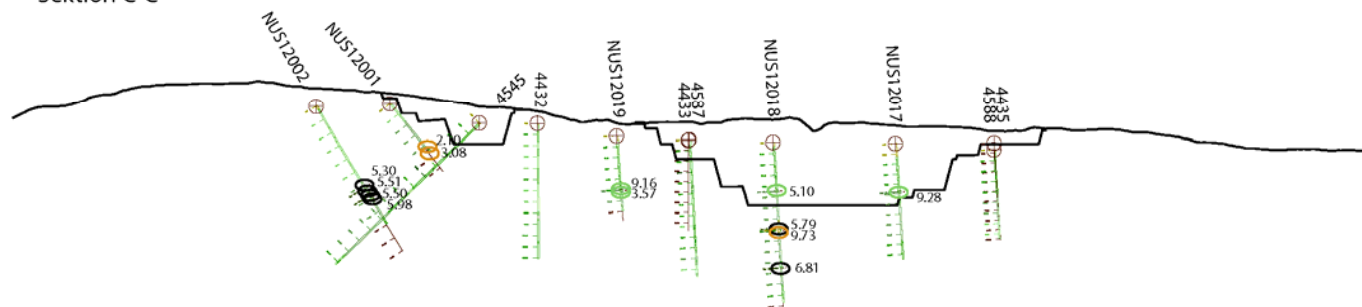
Figur 6: Översikt över positionerna av borrhälor uttagna från Nunasvaara Södra. Prover från borrhälor som börjar på NUS12 ingår i den här karakteriseringen. De svarta strecken visar profilerna som redovisas i Figur 7 och Figur 8.

Nunasvaara Södra, Läget av prover för miljöanalys

Sektion A-A'



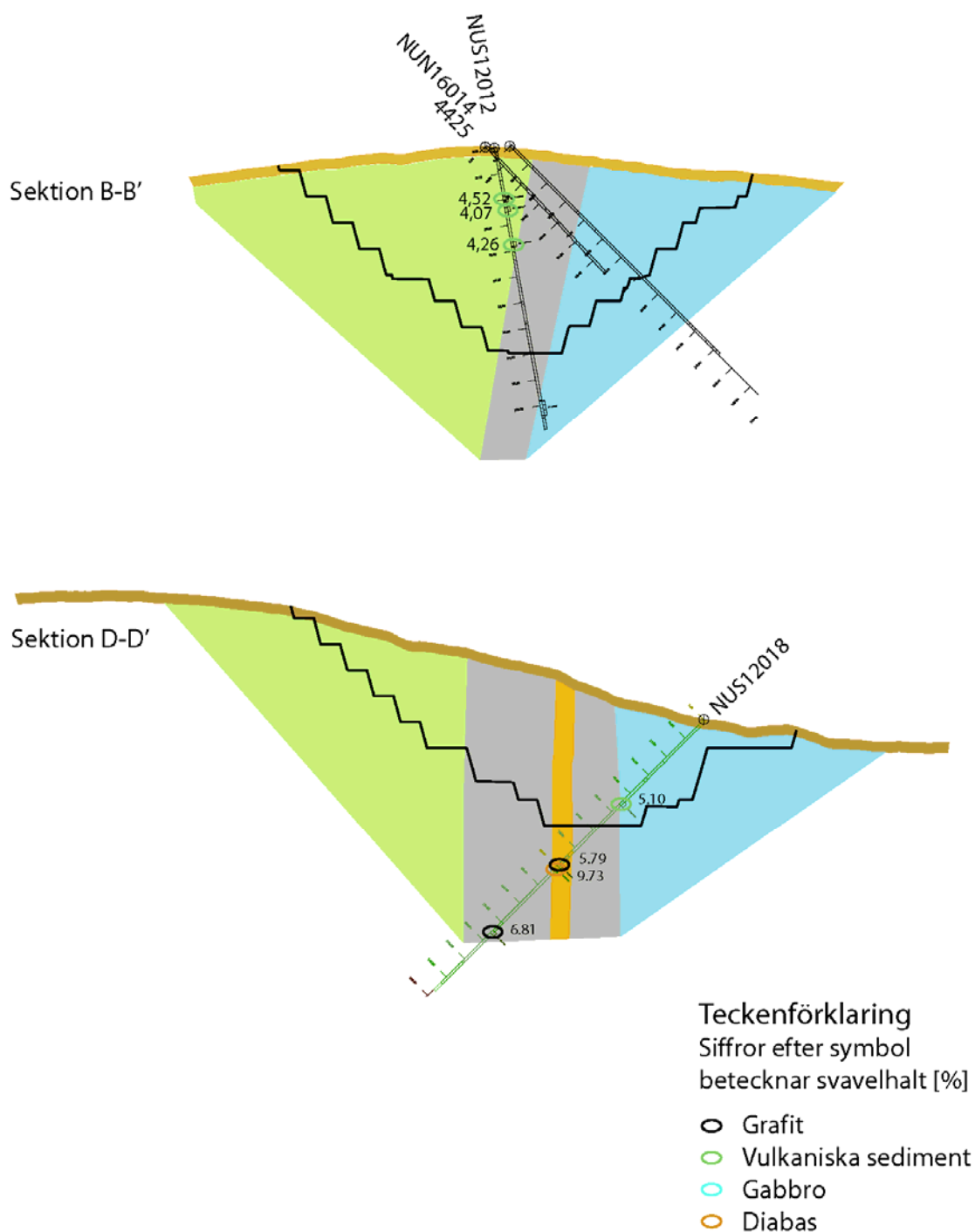
Sektion C-C'



Teckenförklaring
Siffror efter symbol
betecknar svavelhalt [%]

- Grafit
- Vulkaniska sediment
- Gabbro
- Diabas

Figur 7: Längdprofiler genom dagbrotten. Uttagna prover är markerat med ringar (färgat enligt bergart). Svavelhalten är angiven bredvid.

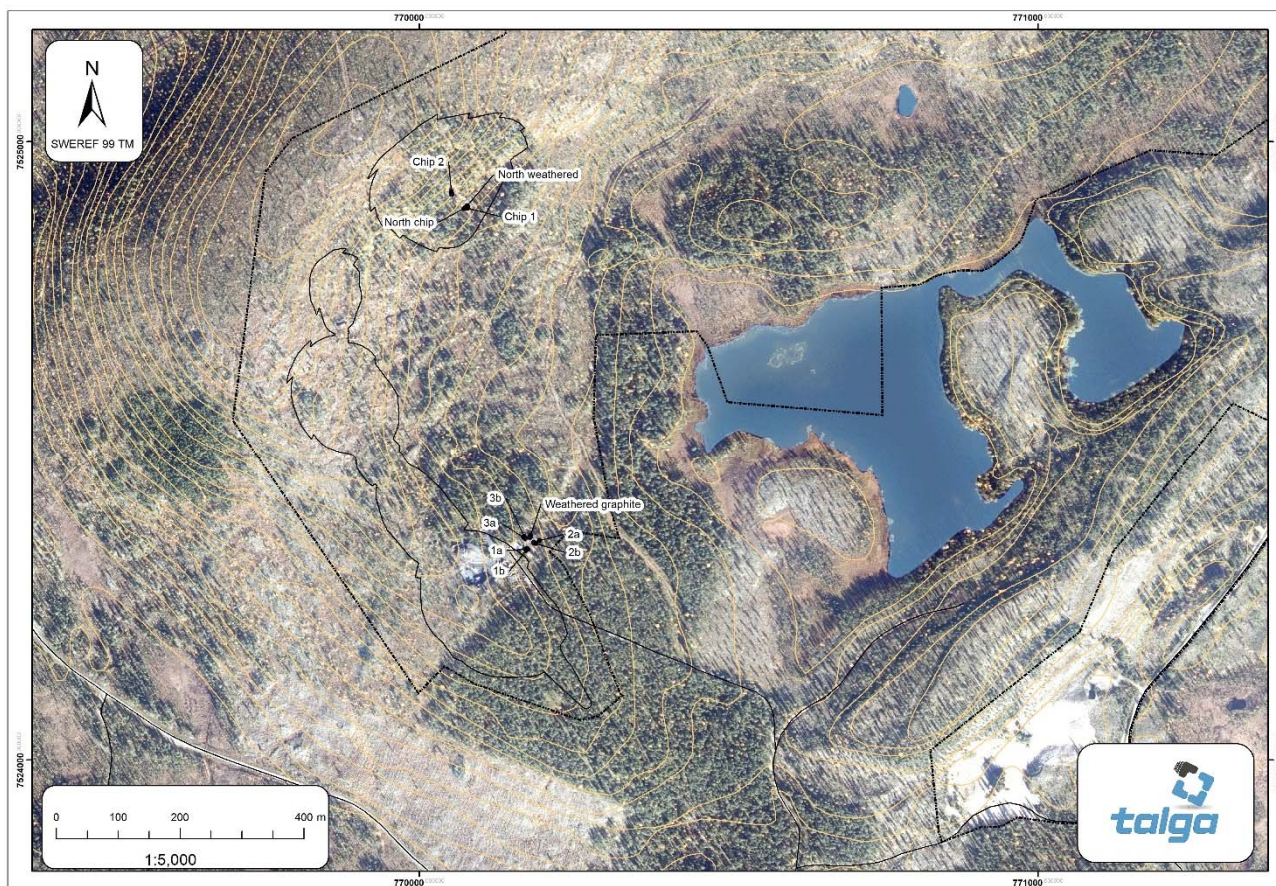


Figur 8: Två exempelprofiler över planerade dagbrott. Uttagna prover är markerade med ringar (färgat enligt bergart).

I juni 2018 har prover tagits från ett äldre, mindre gråbergssupplag som förmodligen uppkom vid en provbrytning under 80-talet. Materialet har varit utsatt för fritt syre och nederbörd i cirka 40 år och kan därför betraktas som ett "worst case"-scenario när det gäller vittring av materialet som kommer uppkomma vid brytning av malm i området.

Totalt har 7 prover analyserats från det äldre upplaget nära provbrytningsområdet: ett prov med vittrat grafit och från varje av de tre provgroparna ett samlingsprov med relativt ovittrat material och ett prov av finare material. I det gamla upplaget är mycket fint material inblandat som är förmodligen moränmaterial. Utöver proverna från

provbrytningsområdet har upplag i norra delen av koncessionsområdet provtagits. Fyra samlingsprover med vittrat och ovittrat material har analyserats. Alla uttagna prover är listade i Tabell 2 och lokalerna där proverna togs visas i Figur 9.



Document Name: WMP-FX-Sv Waste Sampling Map

Figur 9: Provpunkter där ytliga prover har tagits ut (Bergskraft, 2019).

Tabell 2: Ytliga prover uttagit år 2018 av Bergskraft.

Provbeteckning	Material	Kommentar
1a	Ovittrat gråberg	Provgrop 1, samlingsprov
1b	Fint material	Provgrop 1, samlingsprov
2a	Ovittrat gråberg	Provgrop 2, samlingsprov
2b	Fint material	Provgrop 2, samlingsprov
3a	Ovittrat gråberg	Provgrop 3, samlingsprov
3b	Fint material	Provgrop 3, samlingsprov
Vittrat grafit	Vittrat malm	
North chip	Ovittrat	Chips, samlingsprov

Provbeteckning	Material	Kommentar
North weathered	Vittrat	samlingsprov
Chip 1		samlingsprov
Chip 2		samlingsprov

4.2 Genomförd karakterisering

År 2012 analyserades gråbergsprover från borrhkampanjen utförd under samma år avseende totalhalter av ALS. Ytterligare analyser på gråberg utfördes år 2018 av Graeme Campbell där ABA- och NAG-test ingick liksom mineralogisk undersökning. Analyserna utfördes på samma material som användes av ALS 2012. Materialet hade sparats. Under lagringen hade en del av materialet börjat vittra. Därför maldes proverna för att få fram ett mer ovittrat material. På utvalda prover utfördes också rullförsök där lakvattnet analyserades.

Fuktkammarförsök utfördes på samlingsprover av de tre dominerande bergarterna och malm 2018-19 i 30 veckor (Bergskraft, 2019). Samlingsproverna undersöktes dessutom genom ABA-test, totalhaltsanalys och mineralogisk undersökning tillsammans med prover från äldre upplag i området. Proverna från äldre upplag kan anses som ett exempel på hur materialet beter sig när det är exponerat fritt för vittring genom luftsyre och nederbörd.

En sammanställning av genomförda analyser finns i Tabell 3.

Utöver gråbergsproverna har anrikningssand från provanrikning på grafitmalm från Nunasvaara Södra analyserats genom geotekniska undersökningar (GTI Perth, 2019) och geokemiska analyser. Från de två flotationsstegen uppkommer två typer av anrikningssand, där sanden från primäranrikningen är något grövre. På grund av en kontamination med kvarnmaterial från malningen inför sekundärflotationen har inte alla analyser utförts på anrikningssand från sekundärflotationen. Mineralogin har undersökts på de båda flotationsstegen. Totalhaltsanalys, ABA-test och laktest har dock bara utförts på anrikningssand från primärflotation.

En rad analyser har dessutom genomförts på slammet som uppkommer under rening av processvatten från anrikningen. Reningsförsöket utfördes efter anrikningsförsöket på processvattnet som hade uppkommit. Slammet har undersökts på sin mineralogi och totalhalten av ämnen. Processvattnet har undersökts avseende kemisk sammansättning.

Originalrapporterna är bifogade som BILAGA A till BILAGA E.

Tabell 3: Översikt över genomförda analyser på de olika materialen.

Material		Mineralogi	Total-halt	ABA	NAG	Statiska lakförsök	Fuktkammar-försök
Gråberg (borrkärnor)	ALS (2012), GCA (2018), Bergskraft (2019)	X	X	X	X	X	X (30 veckor)
Gråberg (äldre upplag)	Bergskraft (2019)	X	X	X			
Anrikningssand	Core (2019), GTI Perth (2019)	X	X	X		X	
Processvatten	Core (2019)		X				
Slam	Core (2019)	X	X			X	
Morän	Golder (2019)		X	X		X	

4.3 Beskrivning av metoder

De analyser och tester som genomförts och som tillsammans utgör utvinningsavfallskaraktiseringen har inkluderat:

- Mineralogisk undersökning (XRD)

Vid undersökningen bestrålas provet med röntgenstrålning. Genom att studera diffraktionsmönstret för röntgenstrålningen kan förekommande mineraltyper bestämmas.

- Totalhaltsanalys (ex. ME-MS61, four acid digestion ICP-OES/MS/ICP-AES, 48 element)

Provmaterialet genomgår en nära fullständig upplösning med fyra olika syror (HNO_3 , HF, HClO_4 , och HCl) och analyseras med ICP-OES/MS (spektroskopi/masspektroskopi) som är en kvantitativ analysmetod av förekommande element i materialet.

I denna rapport jämföras halterna från totalanalysen med medelhalter i morän från Norrbotten (SGU, 2018). Analysen av moränen skiljer sig dock från totalanalysen och halterna från den här karakteriseringen kan då vara högre än vad de hade varit med samma analysmetod från moränanalysen.

- ABA-test (EN 15875:2011) och NAG-test

I ABA-testen bestäms materialets syrabildande potential (AP) och materialets neutraliseringspotential (NP). Förenklat kan metoden beskrivas som en bestämning av materialets totala syrabildande kapacitet utifrån dess sulfidsvavelinnehåll och materialets syraneutraliserande kapacitet utifrån den mängd tillsatt syra som materialet kan neutralisera. Genom att subtrahera materialets syrabildande potential från materialets neutraliseringspotential kan man teoretiskt bestämma materialets nettoneutraliserande potential (NNP). Vidare kan kvoten beräknas mellan neutraliseringspotentialen och syrabildningspotentialen (NPR). Om denna kvot är mindre än 1 så är materialet potentiellt syrabildande, dvs. det anses troligt att materialet i en framtid kommer att bilda sura lakvatten. Är kvoten större än 3 anses det inte sannolikt att materialet i en framtid kommer att bilda

sura lakvatten. I intervallet mellan 1 och 3 är det ovisst huruvida materialet kommer att bilda sura lakvatten eller inte och att ytterligare försök kan behöva göras för att bättre kunna beskriva materialets syrabildningspotential.

I ABA- testen ingår även beräkningen av karbonathalt (oorganisk kol, CO_3) svavelspeciering (totalsvavel, sulfidsvavel, sulfat). Vid svavelspeciering bestäms totala mängden svavel i ett prov samt i vilken form detta svavel föreligger, dvs. om det föreligger i sulfidform eller i form av sulfat.

Vid NAG-test (Net Acid Generating) bestäms materialets förmåga att neutralisera den syra som bildas då sulfiderna i materialet oxideras genom tillsats av väteperoxid. Normalt anses ett material inte vara potentiellt syrabildande om ett NAG-pH >4,5 uppmäts.

Varken ABA-tester eller NAG-tester ger svar på hur produktion av syrabildande komponenter utvecklas över tiden (dvs. kinetiken) vid omväxlande exponering för luftens syre och vatten. För detta används istället fuktkammarförsök (se nedan).

■ Laktest EN12457-3 (L/S 2, L/S 8 och kumulativ utlakning) och rullförsök

Laktest enligt EN12457-3 är den europeiska standarden för att undersöka ett materials utlakningsegenskaper vid kontakt med vatten. Vid försöken används avjoniserat vatten vid en L/S-kvot (liquid to solid) om 2 respektive 8 liter vätska per kg provmaterial. Utlakningen utförs i två steg där lakvattnet från utlakning vid L/S2 efter filtrering analyseras genom ICP-OES/MS varpå materialet utsätts för andra utlakningssteget vid den högre L/S-kvoten L/S8. Sedan analyseras lakvattnet från steg 2. Den sammanlagda L/S-kvoten (L/S2 + L/S8) blir då L/S10.

Vid rullförsöket rullas provbehållaren med en blandning av gråberg och vatten (L/S 2) i 24 timmar för att uppnå en jämn blandning. Därefter vilar provet i 24 timmar för att låta sedimentera finare partiklar. Lakvattnet analyseras genom ICP-OES/MS.

■ Fuktkammarförsök

Fuktkammarförsök är s.k. kinetiska försök där hastigheten som olika reaktioner sker med i miljöer där syretransporten inte är begränsande för reaktionshastigheten studeras. Vid fuktkammarförsök utsätts provmaterialet för omväxlande fuktig och torr miljö under en längre tid. Lakvatten från fuktkammaren uttas regelbundet och analyseras med avseende på pH, aciditet, alkalinitet, konduktivitet, sulfat samt med ICP-OES/MS för analys av spårämnen/metaller. Genom att kombinera resultat från fuktkammarförsök (reaktionshastigheter) med resultat från kemiska analyser och statistiska försök går det att uppskatta hur lång tid det tar att omsätta olika mineral. Fuktkammarförsöken syftar till att skapa underlag för en kvantitativ bedömning av den metall- och sulfatmängd som kan förväntas mobiliseras och eventuellt transporteras ut från materialet över tid för ett valt scenario.

■ Analys av processvattensammansättning och vatten från vattenreningsprocessen (ICP-OES/MS)

Vid de provanrikningsförsök som gjorts i pilotskala har prover på anrikningssandens vattenfas tagits ut och analyserats med avseende på sammansättning/kvalitet för och efter reningen.

5.0 BESKRIVNING AV UTVINNINGSAVFALLETS FYSIKALISKA OCH KEMISKA EGENSKAPER

5.1 Gråberg

5.1.1 Fysikaliska och geotekniska egenskaper

Någon fysisk karakterisering av gråberg från Nunasvaara Södra har inte gjorts eftersom de fysiska egenskaperna för kristallint gråberg/sprängstensmassor är väl kända. Gråberget utgörs av lossprängt berg med en stor spännvidd på förekommande styckefall, alltifrån block på upp till 1 meter i diameter till siltpartiklar med en partikeldiameter av storleksordningen 10 µm. Huvuddelen av gråbergsmaterialet utgörs dock av grov sten och grus.

Porositet för denna typ av materialblandning ligger normalt på ca 35-40 vol-% med en normal dränerad vattenhalt på ca 8-12 vol-%. Densiteten brukar ligga vid 1,8 ton/m³. Friktionsvinkeln är cirka 38-45 grader.

Gråbergets kornstorleksfördelning och dess goda dränerande egenskaper ger ett geoteknisk stabilt material med låg vattenhållande förmåga.

5.1.2 Mineralogisk undersökning

I Tabell 4 redovisas resultaten från mineralogisk undersökning med XRD av fyra borrhärneprover (Graeme Campbell, 2019) och fyra samlingsprover från borrhärnor (Bergskraft, 2019). Resultaten i sin helhet ingår i BILAGA A och BILAGA B.

De huvudsakliga gråbergsmineralen är plagioklas (albit), skapolit (marialit) och amfibol (tremolit). Fördelningen varierar något mellan hängvägg (mafisk tuff), liggvägg (gabbro/dolerit) och den intrusiva gången (dolerit). De vanligast förekommande sulfidmineralen är magnetkis och pyrit, men det förekommer även andra sulfidmineral som kopparkis och zinkblände.

Tabell 4: Mineralogisk undersökning (XRD) på fyra enstaka prover (Graeme Campbell, 2019) och fyra samlingsprover (Bergskraft, 2019). Andel <0,1 % är inte redovisat i tabellen.

Prov	Bergart	Dominerande (>10 %)	Sparsam (1-10 %)	Påvisbar (<1 %)
NUS12016 33,4-35,4 m	Mafisk tuff (Vtf)	Plagioklas, marialit (20-50 %), tremolite, klorit (10-20 %)	Pyrit, magnetkis, grafit, biotit	Kopparkis, rutil
NUS12017 53,13-55 m	Gabbro/Dolerit (Pgb)	Magnetkis, tremolit (20-50 %), markasit, marialit, goetit (10-20 %)	Kalcit, gips, biotit, kvarts	Pyrit, kopparkis, violarit
NUS12018 79,68-81,8 m	Dolerit (Dyke)	Plagioklas, marialit (20-50 %), tremolit, biotit (10-20 %)	Pyrit, magnetkis, jarosit, grafit, klorit, goetit	Kopparkis, rutil
NUS12002 65-67 m	Grafitmalm (Sgr)	Plagioklas, tremolit, grafit (20-50 %)	Pyrit, magnetkis, klorit, K-fältspat, goethit	
Hängvägg	Mafisk tuff (Vtf)	Magnetkis, albit, skapolit, tremolit	Pyrit, amfibol, cummingtonit, diopsit, flogopit, kvarts, titanit	Kopparkis, rutil, kalcit, apatit, biotit, klorit, K-fältspat, plagioklas, talk
Liggvägg	Gabbro/Dolerit (Pgb)	Magnetkis, albit, skapolit	Pyrit, amfibol, biotit, klorit, diopsit, flogopit, kvarts, titanit, tremolit	Kopparkis, ilmenit, järnhydroxid, kalcit, apatit, chamosit, K-fältspat, plagioklas
Gång	Dolerit (Dyke)	Magnetkis, amfibol, skapolit	Pyrit, kalcit, albit, biotit, diopsit, flogopit, titanit, tremolit	Kopparkis, ilmenit, apatit, chamosit, klorit, K-fältspat, muskovit, kvarts
Malm	(Sgr)	Albit, tremolit, grafit	Magnetkis, pyrit, amfibol, flogopit, klorit, diopsit, K-fältspat, kvarts, skapolit, titanit	Kopparkis, zinkblände, rutil, kalcit, apatit, biotit, chamosit, plagioklas, prenit

5.1.3 Totalhalter

För bestämningen av totalhalter genomgår provmaterialet en nära fullständig upplösning med fyra olika syror (HNO₃, HF, HClO₄, och HCl) och analyseras med ICP-OES/MS (spektroskopi/masspektroskopi) som är en kvantitativ analysmetod av förekommande element i materialet.

Totalhaltsanalysen utfördes på samtliga prover av ALS år 2012. Kompletterande analyser utfördes av GSL år 2018. Resultaten redovisas i Tabell 5 och Tabell 6 och jämföras med genomsnittliga halter i morän från Norrbotten (SGU, 2018), utförliga resultat återfinns i BILAGA A (Graeme Campbell, 2019). Om halterna är 5 gånger högre än i moränen kan detta ses som en indikation på att ämnet i fråga förekommer i sådan halt att det skulle kunna utgöra ett miljöproblem vid en oaksam hantering eller ogynnsamma förutsättningar i övrigt. Man

ska dock beakta att analysmetoden för moränhalterna skiljer sig från gråbergsanalysen och halterna i gråberget kan vara högre på grund av metodens högre grad av uppslutning före analysen.

Halterna av huvudelementen är höga jämfört med moränens medelhalt. Detta beror förmodligen på den starkare uppslutningsmetoden vid analysen av gråberget som gör att även svårlösliga mineral går i lösning. Generellt är det kobolt, krom, koppar och nickel som förekommer i höga halter i de flesta av de analyserade proverna. I några prover från hängväggen, liggväggen och gången är molybden och vanadium förhöjda. Molybden visar höga halter i alla malmprov. I ett prov från hängväggen uppvisar arsenik halter som ligger 100 gånger högre än i andra prover.

Tabell 5: Resultat från totalhaltsanalysen på gråberg från Nunasvaara Södra hängvägg och liggvägg (GCA, 2018) jämfört med medelhalten i morän från Norrbotten (SGU, 2018). Gul markering där moränhalten överskrids 5 gånger.

Borrhål ID	Enhet	Hängvägg (Vtf)										Liggvägg (Pgb)								Morän Norrbotten
		NUS12002 46-48	NUS12006 16-18	NUS12008 45-47	NUS12008 73,25-75	NUS12011 12-14	NUS12016 31,4-33,4	NUS12016 33,4-35,4	NUS12019 66,17-68	NUS12019 74-76	NUS12014 59,9-61,18	NUS12003 38,3-40	NUS12005 78,7-81	NUS12007 104-106	NUS12015 107-108,35	NUS12017 53,13-55	NUS12019 38-40	NUS12019 48-50	NUS12014 68-70	
C	%	0,69	1,84	0,04	0,37	0,07	0,1	0,36	0,18	0,22	6,11	0,57	0,09	0,4	0,45	0,05	0,11	0,21	0,04	
S (IR08)	%	0,22	0,55	0,17	9,72	2,15	4,16	2,77	1,19	0,35	2,74	3,19	1,75	0,11	2,47	24,1	0,15	9,16	1,63	
S (ICP)	%	0,21	0,6	0,15	7,66	1,6	3,63	2,66	1,13	0,34	2,7	2,67	1,41	0,09	2,01	0	0,11	6,76	1,3	0,0031
TIC	%	0,04	1,16	0	0	0	0	0,05	0,11	0,08	0,4	0,04	0	1,02	0	1,62	0,06	0,08	0,05	
Ca	%	3,84	11	5	1,51	3,08	3,67	2,86	5,19	5,52	4,52	1,55	5,15	10,8	3,25	5,81	5,4	5,48	3,78	0,59
Mg	%	5,98	3,67	4,76	4,38	6,3	6,84	3,95	4,99	4,84	3,56	4,27	4	3,53	3,77	2,72	3,79	2,34	3,36	0,43
K	%	0,49	0,78	0,25	0,57	0,68	1,22	0,23	0,83	0,41	1,06	2,43	0,5	0,67	1,64	0,37	1,09	0,29	1,19	0,15
Na	%	2,37	1,92	2,87	2,04	1,89	3,23	4,92	3,93	3,06	3,47	3,68	4,49	1,55	4,36	0,87	4,2	4,03	4,33	0,04
Fe	%	9,41	7,92	9,37	16,25	9,2	7,39	4,59	3,56	8,38	6,08	6,89	4,51	7,67	4,59	34,7	7,35	14,4	8,15	2,5
Al	%	7,68	7,44	7,89	5,7	7,32	7,37	7,33	7,44	7,14	7,7	7,5	7,79	7,09	7,85	2,2	7,25	6	8	1,19
Si (GLS)	%	25,4	20,9	19,3	18	21,3	18,8	26,1	22,3	24,6	22,8	23,9	26,2	21,7	23,7	6,4	22,2	17,8	24,6	
Ti	%	0,67	0,54	0,61	0,3	0,66	0,44	0,26	0,59	0,55	0,51	0,84	1	0,51	0,34	0,16	0,77	0,41	1,04	0,24
Ag	mg/kg	0	0,01	0,02	0,81	0,06	0,18	0,1	0	0	0,02	0	0,02	0,01	0,02	0,06	0,02	0,01	0,02	0,039
As	mg/kg	0	6	0	1,7	1,6	6,6	181	0,6	0,5	2,6	0,9	0,6	6	1,2	2,8	0,2	1,2	0,8	2,4
Au	mg/kg	0,004	0	0	0,004	0	0,02	0,014	0,011	0,012	0	0	0	0	0,052	0,005	0	0,011	0	
B (GLS)	mg/kg	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	
Ba	mg/kg	110	160	70	90	180	160	40	70	70	240	210	70	210	190	20	250	20	150	57
Be	mg/kg	0,56	0,5	0,33	1,09	0,38	0,76	1,36	0,78	0,45	1,16	1,1	0,76	0,59	1,25	0,23	0,57	1,02	0,94	
Bi	mg/kg	0,08	0,26	0,05	0,13	0,15	1,16	0,27	0,08	0,07	0,17	0,04	0,01	0,17	0,12	0,29	0,02	0,07	0,08	0,1

Borrhål ID	Enhet	Hängvägg (Vtf)										Liggvägg (Pgb)								Morän Norrbotten
		NUS12002 46-48	NUS12006 16-18	NUS12008 45-47	NUS12008 73,25-75	NUS12011 12-14	NUS12016 31,4-33,4	NUS12016 33,4-35,4	NUS12019 66,17-68	NUS12019 74-76	NUS12014 59,9-61,18	NUS12003 38,3-40	NUS12005 78,7-81	NUS12007 104-106	NUS12015 107-108,35	NUS12017 53,13-55	NUS12019 38-40	NUS12019 48-50	NUS12014 68-70	
Cd	mg/kg	0	0,02	0	18,8	0,03	0,12	0	0	0	0	0	0,02	0,04	0	0	0	0	0	0,05
Ce	mg/kg	15,1	15,6	9,27	30,3	11,05	15,3	54,3	37,5	11,3	32	32	34,9	12,2	11,75	14,8	22,9	75	37,1	81
Co	mg/kg	50,9	49,5	50,9	153	48,3	227	255	31,1	55,6	48,5	41,5	39,6	40,3	37,5	378	41,4	255	43,9	8
Cr	mg/kg	268	221	209	98	180	237	210	187	173	127	103	42	235	123	158	96	88	68	28
Cs	mg/kg	0,87	1,04	0,37	0,6	0,87	2,71	0,37	4	0,6	0,53	3,03	0,36	0,7	1,11	0,63	1,43	1,02	0,9	0,8
Cu	mg/kg	90,5	194	112	1,6	125	1,56	1,18	327	153	380	274	385	67,6	354	5,91	68,6	1,68	175	16
Cu (GLS)	mg/kg	99,7	169	161	1,49	113	1,45	1,06	256	133	459	234	327	75,6	274	4,61	76,3	1,39	166	
F (GLS)	mg/kg	347	384	306	504	375	751	571	646	273	465	732	408	490	222	899	257	184	420	
Ga	mg/kg	17,3	15,15	16,85	12,95	17,3	15,35	16,4	16,65	16,05	17,9	20,7	20	14,8	20,6	7,29	17,4	12,5	20,7	5
Ge	mg/kg	0,09	0,09	0,09	0,1	0,1	0,08	0,1	0,12	0,07	0,07	0,11	0,14	0,06	0,05	0,11	0,09	0,15	0,07	
Hf	mg/kg	1,7	1,4	1,2	2,3	1,7	1,4	3,4	2	1,6	1,9	2,9	3	1,2	1,6	0,9	1,3	2,4	2,1	0,4
Hg (GLS)	mg/kg	0,004	0,003	0,001	0,001	<0,001	<0,001	<0,001	0,002	0,003	0,003	0,009	0,005	0,002	0,002	<0,001	0,002	<0,001	0,006	
In	mg/kg	0,065	0,073	0,062	0,023	0,04	0,106	0,038	0,027	0,088	0,039	0,01	0,045	0,065	0,017	0,033	0,062	0,011	0,057	
La	mg/kg	6,4	6,7	3,5	10,3	4,3	8,8	24,7	16,8	6	14,1	13,3	14,1	5,1	4,5	7,3	9,3	30,2	14,8	35
Li	mg/kg	12,2	9,8	13,3	61,7	18,9	24,3	10,2	7	3,5	9,9	11,3	2,5	11,1	10,7	3,9	3,5	2,6	8	10
Mn	mg/kg	1,27	1,28	1,6	554	1,3	737	272	246	1,24	329	174	492	1,45	184	337	1,02	61	822	282
Mo	mg/kg	0,34	0,73	0,55	38	0,15	2,15	12,6	5,72	0,83	2	0,98	3,14	0,83	0,84	1,68	0,99	38,6	0,67	0,5
Mo (GLS)	mg/kg	0,37	0,68	0,62	38,9	0,2	1,85	11,9	4,49	0,12	2,34	0,64	3,89	0,7	0,53	1,28	1,18	51,5	0,47	
Nb	mg/kg	4,3	5,4	3,3	2,6	4,1	2,1	3,3	4,5	3,1	2,3	4,4	10,3	3,9	0,7	1,2	7	4,5	9,8	4,1
Ni	mg/kg	166	164	127	668	130	335	232	112	116	174	103	79,9	145	159	1,16	84,3	414	69,8	12

Borrhål ID	Enhet	Hängvägg (Vtf)										Liggvägg (Pgb)								Morän Norrbotten
		NUS12002 46-48	NUS12006 16-18	NUS12008 45-47	NUS12008 73,25-75	NUS12011 12-14	NUS12016 31,4-33,4	NUS12016 33,4-35,4	NUS12019 66,17-68	NUS12019 74-76	NUS12014 59,9-61,18	NUS12003 38,3-40	NUS12005 78,7-81	NUS12007 104-106	NUS12015 107-108,35	NUS12017 53,13-55	NUS12019 38-40	NUS12019 48-50	NUS12014 68-70	
P	mg/kg	360	390	330	650	390	360	320	410	310	590	780	740	320	480	810	570	960	760	970
Pb	mg/kg	0,7	1,2	0,7	3,04	6,4	8,4	5	0,9	0,3	1,5	0,6	3,1	1,1	0,9	1,7	0,8	2,7	0,7	7
Pd	mg/kg	0,003	0,007	0,011	0,026	0,005	0,009	0,027	0,005	0,008	0,022	0	0,001	0,006	0,027	0,034	0	0,012	0	
Pt	mg/kg	0,011	0,01	0,009	0	0,01	0	0,006	0,012	0,012	0,011	0	0	0	0,017	0	0	0	0	
Rb	mg/kg	22,3	31,4	8,9	14,9	24,4	45,9	6,9	61,3	17,3	32,4	98	18,6	27,6	30,6	23,1	40,4	6,6	52,8	17
Re	mg/kg	0,006	0,009	0,002	0,102	0,005	0,007	0,035	0,006	0,003	0,018	0,002	0,007	0	0,006	0,012	0,005	0,092	0,002	
Sb	mg/kg	0	0,22	0,06	0,18	0,08	0,37	0,25	0	0,05	0,19	0	0,16	0,12	0,17	0,13	0,1	0	0,24	0,2
Sc	mg/kg	41,2	38	46,5	25,3	45,8	38,1	35,7	44,5	42,5	45	30,6	31	38	53,2	14,7	28,1	20	28	5
Se	mg/kg	2	5	1	10	10	7	16	5	3	11	9	4	2	7	14	1	19	3	13
Se (GLS)	mg/kg	1,27	3,53	1,91	8,54	6,74	6,21	15,4	3,47	1,74	12,2	7,31	3,29	1,03	5,61	11,5	0,26	17,1	1,71	
Sn	mg/kg	0,5	0,7	0,3	0	0	1,7	0,5	0	0,5	1,4	0	2,9	0,6	0,3	0,2	0,5	0	0,5	1,2
Sr	mg/kg	59,6	55,1	62	43,8	51,6	73,5	54,4	176	57,9	86,1	78,1	110	49,3	154	33	198	125	110	27
Ta	mg/kg	0,29	0,37	0,21	0,25	0,26	0,18	0,33	0,35	0,23	0,19	0,35	0,7	0,26	0,06	0,1	0,5	0,42	0,74	
Te	mg/kg	0,72	2,36	0,27	0,99	0,52	1,25	0,88	0,56	0,56	0,62	0,24	0,18	1,11	0,43	6,82	0	1,71	0,19	13
Te (GLS)	mg/kg	0,83	2,65	1,7	1,15	0,59	0,73	0,48	0,75	0,25	0,85	0,31	0,22	1,14	0,52	8,37	<0,05	1,86	0,21	
Th	mg/kg	1,3	1,3	0,3	3	0,6	0,6	5,1	1,3	0,6	2,2	1,3	1,4	0,6	0,2	2,1	0,9	3,3	1,6	8,1
Tl	mg/kg	0,05	0,12	0	0,04	0,11	0,3	0	0,09	0,05	0,05	0,27	0,02	0,09	0,13	0,17	0,14	0,02	0,12	0,1
U	mg/kg	0,6	1	0,1	6	0,2	0,9	5,4	1,6	1,1	1,5	0,5	0,9	0,5	0,4	1,1	0,4	7,6	0,4	2,1
V	mg/kg	277	236	297	194	297	278	201	272	239	297	273	230	240	390	524	203	150	259	49
W	mg/kg	0,2	0,5	0,2	0,9	0	0,7	1,2	0,3	0,2	0,7	0,4	1,1	0,7	0,6	4,6	0,4	1,5	0,5	0,4

Borrhål ID	Enhet	Hängvägg (Vtf)										Liggvägg (Pgb)								Morän Norrbotten
		NUS12002 46-48	NUS12006 16-18	NUS12008 45-47	NUS12008 73,25-75	NUS12011 12-14	NUS12016 31,4-33,4	NUS12016 33,4-35,4	NUS12019 66,17-68	NUS12019 74-76	NUS12014 59,9-61,18	NUS12003 38,3-40	NUS12005 78,7-81	NUS12007 104-106	NUS12015 107-108,35	NUS12017 53,13-55	NUS12019 38-40	NUS12019 48-50	NUS12014 68-70	
Y	mg/kg	19,7	18,4	19,1	15,9	16,7	15,3	37,3	20,3	14,8	29,2	19,4	22,8	16,2	30	15,6	12,6	26,1	17,6	20
Zn	mg/kg	38	44	60	6,12	52	58	8	3	26	7	2	9	68	7	8	24	0	24	32
Zr	mg/kg	65,8	51	36,6	84	63,4	48,8	126	63,7	51,2	68,7	107,5	92	39	57,6	30,4	37,7	80,7	78,7	15

Tabell 6: Resultat från totalhaltsanalysen för doleritgången och malm (GCA, 2019) jämfört med medelhalten i morän från Norrbotten (SGU, 2018). Gul markering där moränhalten överskrids 5 gånger.

Borrhål ID	Enhet	Gång (Dyke)						Malm (Sgr)								Morän Norrbotten
		NUS12001 42,25-44	NUS12001 53-55	NUS12006 38,5-40,5	NUS12006 40,5-42,85	NUS12018 79,68-81,8	NUS12019 44,3-46	NUS12001 21-23	NUS12002 65-67	NUS12005 54-56	NUS12010 44-46	NUS12014 30,5-32,5	NUS12017 83-85	NUS12018 52-54	NUS12018 60-62	
C	%	0,06	0,09	0,05	0,06	2,98	0,13	26,8	26,7	24,2	32,6	15	19,9	36,9	42,4	
S (IR08)	%	2,19	1,08	0,29	0,47	9,73	1,32	1,19	5,51	8,18	0,68	3,51	3,49	0,23	1,54	
S (ICP)	%	1,68	1,04	0,3	0,45	7,82	0,97	1,22	5,58	8,56	0,61	3,25	3,22	0,23	1,41	0,0031
TIC	%	0,01	2,15	0	0	0	0,22	1,3	0,3	0	1	1,5	0	1,2	0,4	
Ca	%	2,63	10,1	6,11	6,33	2,53	6,4	2,5	2,01	2,66	0,82	2,96	1,11	1,18	1,41	0,59
Mg	%	3,98	2,75	2,58	2,63	4,32	3,69	2,83	1,91	2,28	1,57	4,76	3,54	1,66	2,18	0,43
K	%	1,07	0,43	0,98	0,71	1,19	0,55	0,4	0,65	0,67	0,72	1,2	1,38	0,17	0,18	0,15
Na	%	5,18	4,23	2,58	2,86	2,81	4,56	3,57	3,24	1,93	2,93	2,64	3,44	3,66	2,92	0,04
Fe	%	4,56	5,3	10,6	9,33	16,3	6,04	2,65	10,1	15,3	2,13	7,52	6,37	0,81	2,84	2,5
Al	%	7,15	6,43	7,88	8,01	5,26	7,37	5,17	4,75	4,38	5,51	5,55	6,07	4,68	4,1	1,19

Borrhål ID	Enhet	Gång (Dyke)						Malm (Sgr)								Morän Norrbotten
		NUS12001 42,25-44	NUS12001 53-55	NUS12006 38,5-40,5	NUS12006 40,5-42,85	NUS12018 79,68-81,8	NUS12019 44,3-46	NUS12001 21-23	NUS12002 65-67	NUS12005 54-56	NUS12010 44-46	NUS12014 30,5-32,5	NUS12017 83-85	NUS12018 52-54	NUS12018 60-62	
Si (GLS)	%	24,5	21,1	22,9	22,4	16,6	22,2	17,8	16,9	14,3	20	20,5	18,8	18,6	14,2	
Ti	%	1,02	0,78	1,05	1,05	0,37	0,73	0,45	0,36	0,35	0,21	0,29	0,5	0,36	0,32	0,24
Ag	mg/kg	0	0,02	0,02	0,01	0,02	0,01	0	0	0,03	0,01	0,02	0,01	0,02	0,01	0,039
As	mg/kg	0	0	1,5	1	0,5	0,5	1,6	1,8	10,3	6,1	4,6	2,3	1,6	2,9	2,4
Au	mg/kg	0,003	0,001	0	0	0,004	0	0,002	0,003	0,018	0,004	0,01	0,004	0	0,002	
B (GLS)	mg/kg	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	
Ba	mg/kg	80	50	500	350	60	70	50	90	100	100	290	60	10	10	57
Be	mg/kg	0,88	0,64	1,15	1,08	0,56	0,61	1,09	0,86	1,13	1,1	1,23	1,53	0,64	0,7	
Bi	mg/kg	0,04	0,04	0,01	0,01	0,35	0,01	0,15	0,24	2,19	0,13	0,16	0,25	0,02	0,29	0,1
Cd	mg/kg	0	0	0,02	0,02	0	0	0	0	0	0,02	0,04	0	0	0	0,05
Ce	mg/kg	30	111	62,6	60,5	34	32,9	44,2	52,1	40,6	40,3	35	31,5	12,4	15,9	81
Co	mg/kg	41,6	55,9	38,1	33,6	138	37,3	14,5	63,6	79,3	11,4	47,8	64,9	4,9	21,5	8
Cr	mg/kg	103	85	24	25	176	97	187	170	198	133	179	299	127	176	28
Cs	mg/kg	1,68	1,22	0,55	0,32	2,41	2,59	0,82	1,64	1,16	0,67	1,13	2,61	0,29	0,5	0,8
Cu	mg/kg	309	249	30,2	48	1,72	75,5	131	518	678	62,3	379	439	50,3	203	16
Cu (GLS)	mg/kg	272	215	32,5	46,9	1,41	94,5	122	463	612	89,5	341	397	59,8	160	
F (GLS)	mg/kg	606	282	635	623	779	346	462	404	483	544	749	1,02	465	516	
Ga	mg/kg	20,5	15	24,2	23,8	14,35	17,1	12,35	12,95	10,45	13,7	16,45	17,5	12,8	11,65	5
Ge	mg/kg	0,12	0,15	0,16	0,15	0,13	0,09	0,16	0,19	0,36	0,14	0,11	0,12	0,05	0,06	
Hf	mg/kg	2,7	2,3	3	3,1	1,7	1,7	2	2,3	1,7	2,6	2,3	1,8	1,9	1,8	0,4

Borrhå ID	Enhet	Gång (Dyke)						Malm (Sgr)								Morän Norrbotten
		NUS12001 42,25-44	NUS12001 53-55	NUS12006 38,5-40,5	NUS12006 40,5-42,85	NUS12018 79,68-81,8	NUS12019 44,3-46	NUS12001 21-23	NUS12002 65-67	NUS12005 54-56	NUS12010 44-46	NUS12014 30,5-32,5	NUS12017 83-85	NUS12018 52-54	NUS12018 60-62	
Hg (GLS)	mg/kg	0,007	0,004	0,002	<0,001	<0,001	<0,001	0,008	0,002	0,003	0,002	<0,001	<0,001	0,005	<0,001	
In	mg/kg	0,026	0,039	0,139	0,144	0,032	0,056	0,027	0,021	0,043	0	0,038	0,011	0,01	0,011	
La	mg/kg	14,8	56,7	26,9	27,1	15,7	14,3	21,8	23,8	18,4	20,2	17,3	12,8	8,4	9,7	35
Li	mg/kg	6	3,6	4,6	4,4	8,6	2,1	7,9	4,4	6,4	12,8	11	8,2	2,9	2,5	10
Mn	mg/kg	184	427	1,5	1,38	251	493	174	156	262	125	391	132	100	130	282
Mo	mg/kg	1,67	0,97	0,69	0,68	33,7	0,28	5,74	26,8	23,3	6,32	9,09	3,71	5,71	7,42	0,5
Mo (GLS)	mg/kg	1,18	0,69	0,72	0,65	30,9	0,45	6,06	22,2	23,9	7,88	8,05	3,26	5,64	7,15	
Nb	mg/kg	9,9	8,4	6,2	6,2	2,8	6,7	5,6	7,1	4,7	1,3	1,4	4	5,5	5,3	4,1
Ni	mg/kg	101	83,7	14,6	21,2	543	116	77,8	320	600	72	278	181	24,3	89,7	12
P	mg/kg	780	540	1,78	1,8	380	510	430	210	780	200	370	200	180	360	970
Pb	mg/kg	1,2	1,4	1,2	1,3	3,6	0,3	1,5	3,2	3	1,3	4,1	1,1	0,8	1	7
Pd	mg/kg	0,001	0	0,002	0	0,032	0	0,003	0,018	0,006	0,002	0,009	0,014	0,004	0,004	
Pt	mg/kg	0	0	0	0	0	0	0,012	0,011	0	0,02	0	0,005	0	0,006	
Rb	mg/kg	73,4	19,8	30,3	18,1	99	28,7	27	36,9	26,6	34,1	50	103,5	12	17,1	17
Re	mg/kg	0,007	0,013	0,007	0,008	0,052	0,004	0,05	0,068	0,086	0,059	0,11	0,031	0,034	0,046	
Sb	mg/kg	0	0	0,4	0,38	0	0,06	0,06	0	0,56	0,08	0,25	0,17	0,13	0,16	0,2
Sc	mg/kg	29,5	22,8	46,4	47,7	24,9	27,8	25,8	18,4	20,3	12,8	23,6	31,5	13,4	34,7	5
Se	mg/kg	5	1	1	2	18	2	11	36	89	5	26	34	1	8	13
Se (GLS)	mg/kg	3,21	0,56	0,27	0,53	15,8	1,32	10,5	31,8	75,4	4,75	30,8	35,5	1,5	6,08	
Sn	mg/kg	0,5	1	2,1	2,5	0	0,5	0,4	0,2	0,7	0	0,6	0,2	0	0	1,2

Borrhål ID	Enhet	Gång (Dyke)						Malm (Sgr)								Morän Norrbotten
		NUS12001 42,25-44	NUS12001 53-55	NUS12006 38,5-40,5	NUS12006 40,5-42,85	NUS12018 79,68-81,8	NUS12019 44,3-46	NUS12001 21-23	NUS12002 65-67	NUS12005 54-56	NUS12010 44-46	NUS12014 30,5-32,5	NUS12017 83-85	NUS12018 52-54	NUS12018 60-62	
Sr	mg/kg	97	214	333	322	46,4	196	102	68,3	51,3	50,4	46,8	45,4	14,8	12	27
Ta	mg/kg	0,69	0,57	0,37	0,38	0,21	0,48	0,39	0,53	0,39	0,09	0,16	0,31	0,42	0,36	
Te	mg/kg	0,5	0,26	0	0	2,37	0,28	0,44	1,54	3,14	0,21	1,44	1,27	0,1	0,6	13
Te (GLS)	mg/kg	0,48	0,21	0,05	0,06	2,44	0,38	0,61	1,47	3,41	0,34	2,06	1,57	0,16	0,7	
Th	mg/kg	1,4	1,7	2,9	3	3	0,9	3,8	7,7	5,2	6,4	7	2,5	4,7	5,4	8,1
Tl	mg/kg	0,09	0	0,11	0,07	0,21	0,02	0,23	0,13	0,18	0,07	0,13	0,19	0	0,06	0,1
U	mg/kg	1,1	2,3	0,8	0,7	7,4	0,7	3,9	12,9	6,1	3,3	6,3	3	3,5	3,7	2,1
V	mg/kg	274	200	370	374	163	199	203	186	176	173	241	261	141	225	49
W	mg/kg	2,4	0,4	0,3	0,4	1,8	0,2	0,4	0,3	1	0,1	0,4	0,7	0,4	0,4	0,4
Y	mg/kg	20,2	24,3	37,5	38	12,4	13,9	37,5	23,9	31,6	10,1	31,7	25,4	14,8	17,5	20
Zn	mg/kg	0	3	83	66	9	7	0	0	8	20	20	4	2	2	32
Zr	mg/kg	97,7	89	104	92	60,5	54,9	77,5	89,6	70,4	97,6	80,4	73,5	75,5	74,8	15

Totalhalterna som analyserades på samlingsproverna som användes i fuktkammarförsöket redovisas i Tabell 7. Proverna från äldre upplag i området från provtagningen 2018 redovisas i Tabell 8. Proverna innehåller en betydande andel kol vilket tyder på att grafit förekommer i proverna.

Som i de andra gråbergsproverna visar samlingsproverna förhöjda halter av kobolt, koppar, krom, nickel, molybden och vanadin. I motsats är dock kadmium, bly och zink delvis tydligt förhöjd i samlingsproverna. Orsaken för detta är oklart. Eftersom halterna i proverna från äldre upplag (1-3a & b) också visar högre halter av kadmium, bly och zink får man utgå ifrån att gråberget innehåller en viss andel av de där metallerna.

Tabell 7: Resultat för samlingsproverna som ingick i fuktkammarförsöket (Bergskraft, 2019) jämfört med medelhalten i morän från Norrbotten (SGU, 2018). Gul markering där moränhalten överskrider 5 gånger.

Ämne	Enhet	Hängvägg	Liggvägg	Gång	Malm	Norrbotten morän
SiO ₂	%	47,4	47,3	42	40,5	
Al ₂ O ₃	%	13,3	13,2	12,2	10,8	
Fe ₂ O ₃	%	13,5	16,3	14,3	9,09	
CaO	%	6,02	5,87	13	3,98	
MgO	%	6,8	6,02	6,32	6,25	
Na ₂ O	%	4,87	5,28	4,14	3,88	
K ₂ O	%	0,95	1,02	1,33	1,25	
Cr ₂ O ₃	%	0,041	0,013	0,018	0,033	
TiO ₂	%	0,95	1,66	0,98	0,82	
MnO	%	0,06	0,07	0,11	0,04	
P ₂ O ₅	%	0,12	0,14	0,1	0,05	
SrO	%	<0,01	<0,01	<0,01	<0,01	
BaO	%	0,01	0,01	0,02	0,02	
LOI	%	4,27	3,22	4,16	22,2	
Total	%	98,2	100,1	98,6	98,9	
C	%	1,16	0,14	2,86	18	
S	%	4,84	5,09	3,34	3,47	0,0031
Ag	ppm	<0,5	<0,5	<0,5	<0,5	0,039
As	ppm	3,4	1,5	1	2,2	2,4
Ba	ppm	120	113	154	158	57
Bi	ppm	1,76	0,12	0,12	0,36	0,1
Cd	ppm	0,9	1,9	1,2	1,9	0,05
Ce	ppm	33,5	51,9	28,8	34,9	81
Co	ppm	108	114	74	55	8
Cr	ppm	290	90	110	250	28

Ämne	Enhet	Hängvägg	Liggvägg	Gång	Malm	Norrbottn morän
Cs	ppm	1,73	1,27	2,12	1,72	0,8
Cu	ppm	653	872	450	575	16
Dy	ppm	3,58	4,11	3,94	3,92	3,7
Er	ppm	2,19	2,2	2,63	2,53	2,1
Eu	ppm	0,72	1,7	0,89	0,85	0,9
Ga	ppm	16,2	18,9	13,5	15,6	5
Gd	ppm	3,22	4,73	3,54	3,71	4,5
Ge	ppm	<5	<5	<5	<5	
Hf	ppm	2,1	3,1	1,9	2,2	0,4
Hg	ppm	0,005	0,012	0,012	0,009	
Ho	ppm	0,82	0,88	0,84	0,96	0,7
In	ppm	0,015	0,02	0,018	0,008	
La	ppm	17,4	22,1	14,4	18	35
Li	ppm	10	10	10	10	10
Lu	ppm	0,32	0,28	0,45	0,33	0,3
Mo	ppm	7	7	5	10	0,5
Nb	ppm	6,3	10,9	3,8	7	4,1
Nd	ppm	15,4	26,5	14,3	17,1	30
Ni	ppm	313	352	202	192	12
Pb	ppm	7	419	8	36	7
Pr	ppm	3,73	6,45	3,19	4,14	8,2
Rb	ppm	36,8	41,4	69,2	70,1	17
Re	ppm	0,027	0,019	0,013	0,05	
Sb	ppm	0,14	0,11	0,05	0,08	0,2
Sc	ppm	31	26	34	26	5
Se	ppm	20,9	5,6	6,4	21,8	
Sm	ppm	3,03	5,39	3,12	3,46	5,5
Sn	ppm	1	2	1	1	1,2
Sr	ppm	82,6	118	123	68,7	27
Ta	ppm	0,2	0,5	<0,1	0,2	
Tb	ppm	0,56	0,74	0,64	0,6	0,7

Ämne	Enhet	Hängvägg	Liggvägg	Gång	Malm	Norrbotten morän
Te	ppm	3,33	0,76	1,01	1,6	13
Th	ppm	2,73	1,95	0,83	4,67	8,1
Tl	ppm	0,13	0,08	0,17	0,28	0,1
Tm	ppm	0,37	0,33	0,48	0,38	0,3
U	ppm	4,23	2,19	1,44	6,18	2,1
V	ppm	268	268	273	270	49
W	ppm	3	1	2	2	0,4
Y	ppm	20,8	21,5	23,4	24,8	20
Yb	ppm	2,15	2,03	2,87	2,61	1,9
Zn	ppm	21	416	28	529	32
Zr	ppm	85	126	60	88	15

Proverna som togs från upplag från den äldre provbrytningen visar främst förhöjda halter av kadmium, koppar, molybden, nickel, bly, vanadin och zink. Förutom för nickel är det ingen större haltskillnad mellan ovittrade prover (a) och fint material (b). Prover som togs i norra delen av det planerade verksamhetsområdet uppvisar höga halter av krom, koppar och molybden. Några prover har höga halter av nickel och kadmium. De höga halterna av kol indikerar att proverna från norra upplaget innehåller en del malm.

Tabell 8: Resultat från totalhaltsanalysen på prover från äldre upplag från området. Halterna jämförs med genomsnittlig morän i Norrbotten (SGU, 2018). Gul markering där halten överskrider 5x moränens halt.

Ämne	Enhet	1a	1b	2a	2b	3a	3b	Vittrat grafit	North chip	North Vittrat	Chip 1	Chip 2	Morän
SiO ₂	%	50,2	44,4	50,3	44,2	49,2	39,9	39,6	34,5	37,5	40,3	34,4	
Al ₂ O ₃	%	13,6	11,4	13,9	12,2	13,9	11,2	9,79	7,84	8,14	9,08	7,84	
Fe ₂ O ₃	%	6,65	11,2	8	15,8	7,47	13	9,73	12,2	7,56	2,96	7,17	
CaO	%	3,38	2,38	4,47	3,84	5,12	2,64	1,03	3,75	4,23	3,86	3,65	
MgO	%	4,22	4,61	4,93	4,52	4,4	4,52	3,36	2,04	3,61	2,31	3,59	
Na ₂ O	%	4,86	3,63	5,32	4,59	5,24	3,41	3,05	3,06	3,14	3,56	2,4	
K ₂ O	%	1,07	1,31	1,27	1,06	0,97	1,15	0,74	0,39	0,91	1,07	2,07	
Cr ₂ O ₃	%	0,019	0,017	0,015	0,013	0,012	0,028	0,023	0,023	0,034	0,028	0,028	
TiO ₂	%	1,36	1,21	1,47	1,45	1,71	1,05	0,65	0,6	0,71	0,78	0,73	
MnO	%	0,04	0,04	0,06	0,07	0,05	0,06	0,04	0,02	0,03	0,02	0,03	
P ₂ O ₅	%	0,19	0,2	0,1	0,2	0,27	0,13	0,12	0,05	0,03	0,02	0,04	
SrO	%	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	<0,01	

Ämne	Enhet	1a	1b	2a	2b	3a	3b	Vittrat grafit	North chip	North Vittrat	Chip 1	Chip 2	Morän
BaO	%	0,02	0,02	0,02	0,02	0,02	0,02	0,01	<0,01	0,01	0,02	0,04	
LOI	%	15,35	18,1	11,9	12	11,5	22,2	30,5	35,6	33,7	35,1	37,4	
Total	%	100,9	98,5	102	99,8	99,9	99,3	98,6	100	99,6	99,1	99,4	
C	%	11,8	8,14	8,69	3,06	8,45	13,4	21,5	26,2	27,2	30,5	31,4	
S	%	1,78	1,29	0,72	0,71	0,61	0,65	0,75	5,18	1,61	0,09	2,35	0,003
Ag	ppm	<0,5	0,7	<0,5	<0,5	<0,5	<0,5	1,5	<0,5	<0,5	<0,5	<0,5	0,039
As	ppm	2,1	14,4	2	3	2,3	5,2	7,5	3	3	1,6	2,1	2,4
Ba	ppm	154	211	154	175	142	204	103	23	119	118	317	57
Bi	ppm	0,27	0,24	0,07	0,14	0,06	0,32	0,29	1,08	0,95	0,25	0,94	0,1
Ce	ppm	53,3	65,3	41,3	38,2	88,3	34,5	48,8	27,8	18,1	20,4	33,6	81
Cd	ppm	4,1	5	0,7	1,8	1,6	2	<0,5	0,6	0,6	<0,5	<0,5	0,05
Co	ppm	28	11	28	15	18	14	7	55	7	3	27	8
Cr	ppm	130	120	100	80	80	200	170	160	240	180	200	28
Cs	ppm	0,64	0,59	1,1	0,87	0,64	1	0,91	0,26	0,79	0,74	1,64	0,8
Cu	ppm	169	247	237	279	126	243	341	477	246	59	190	16
Dy	ppm	4,44	4,55	3,53	3,19	6,5	3,16	2,76	2,96	1,87	2,13	3,39	3,7
Er	ppm	2,39	2,48	1,9	1,54	3,63	1,87	1,68	1,66	1,16	1,17	1,98	2,1
Eu	ppm	1,38	1,16	1,25	1,07	2,48	0,75	0,6	0,83	0,58	0,73	0,93	0,9
Ga	ppm	18,7	18,6	19,6	18,1	21,7	17,6	15,1	10	11,6	11,6	12	5
Gd	ppm	4,57	4,64	3,93	3,54	7,75	2,76	3,2	3,06	1,9	2,04	3,19	4,5
Ge	ppm	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Hf	ppm	3,7	3	3,3	3,2	4,5	3,2	1,7	2	1,9	2,1	2,1	0,4
Hg	ppm	0,016	0,018	0,007	0,009	0,008	0,011	0,015	0,012	0,013	0,019	0,013	
Ho	ppm	1	0,98	0,73	0,67	1,54	0,66	0,6	0,69	0,45	0,52	0,81	0,7
In	ppm	0,008	0,014	0,015	0,018	0,023	0,012	0,005	<0,005	<0,005	<0,005	<0,005	
La	ppm	25,8	35,4	20,1	19,4	41,5	17,6	24,6	15,7	9,7	10,4	18,3	35
Li	ppm	10	20	10	10	10	10	20	<10	<10	<10	<10	10
Lu	ppm	0,34	0,34	0,22	0,22	0,58	0,25	0,25	0,22	0,18	0,17	0,28	0,3
Mo	ppm	4	29	3	3	5	8	3	12	9	8	8	0,5
Nb	ppm	7,8	7,9	10,3	8,4	8,8	8,4	6,1	5,5	6,9	6,4	6,8	4,1

Ämne	Enhet	1a	1b	2a	2b	3a	3b	Vittrat grafit	North chip	North Vittrat	Chip 1	Chip 2	Morän
Nd	ppm	25,4	28,9	21,3	17,4	43,2	15,5	21,7	13,9	9,2	10,2	16,2	30
Ni	ppm	177	26	66	40	59	47	41	280	20	10	144	12
Pb	ppm	581	7 260	88	996	233	1 550	7 230	4	5	26	18	7
Pr	ppm	6,42	7,29	4,94	4,24	10,5	3,97	5,65	3,31	2,19	2,43	3,95	8,2
Rb	ppm	35,6	41,8	51,6	37,5	29	40,6	27,2	5,7	16,2	19,5	49,4	17
Re	ppm	0,036	0,065	0,012	0,013	0,016	0,02	0,01	0,055	0,029	0,024	0,084	
Sb	ppm	0,08	0,47	0,06	0,17	0,06	0,22	1,15	0,09	0,08	0,06	0,09	0,2
Sc	ppm	25	26	22	25	24	27	23	14	25	19	18	5
Se	ppm	8,4	15,9	2,6	12,6	2,3	18,7	15,7	59,1	39,6	7,4	28,1	
Sm	ppm	5,34	5,87	4,37	3,7	8,92	3,33	3,44	3,21	1,99	2,22	3,56	5,5
Sn	ppm	1	1	1	1	2	1	<1	<1	1	1	<1	1,2
Sr	ppm	131	92,2	127	111	172	78,8	49,1	52,3	50,4	49,6	40,2	27
Ta	ppm	0,2	0,1	0,4	0,1	0,2	<0,1	<0,1	0,2	0,1	0,2	0,2	
Tb	ppm	0,72	0,75	0,58	0,5	1,18	0,53	0,4	0,48	0,32	0,33	0,56	0,7
Te	ppm	0,48	1,05	0,26	0,97	0,22	1,04	1,02	3,83	2,14	0,56	1,6	13
Th	ppm	5,42	4,54	3,32	2,47	4,07	3,56	6,63	3,98	2,95	3,68	4,48	8,1
Tl	ppm	0,06	0,11	0,08	0,11	0,05	0,14	0,14	0,05	0,09	0,02	0,09	0,1
Tm	ppm	0,4	0,37	0,27	0,25	0,52	0,24	0,24	0,24	0,15	0,19	0,33	0,3
U	ppm	3,78	2,93	2,32	2,29	4,71	3,98	3,59	5,78	3,19	5,26	6,46	2,1
V	ppm	237	255	246	270	277	268	178	157	238	166	213	49
W	ppm	<1	1	3	2	2	7	1	<1	5	1	2	0,4
Y	ppm	24,7	25,3	18,1	15,3	36,5	17,2	17,3	17,6	11,4	12,4	20,4	20
Yb	ppm	2,49	2,28	1,59	1,58	3,37	1,65	1,69	1,62	1,07	1,06	1,87	1,9
Zn	ppm	1 100	1 770	182	435	194	517	684	9	13	12	9	32
Zr	ppm	148	134	131	126	183	110	91	78	79	82	84	15

5.1.4 ABA-test och NAG-test

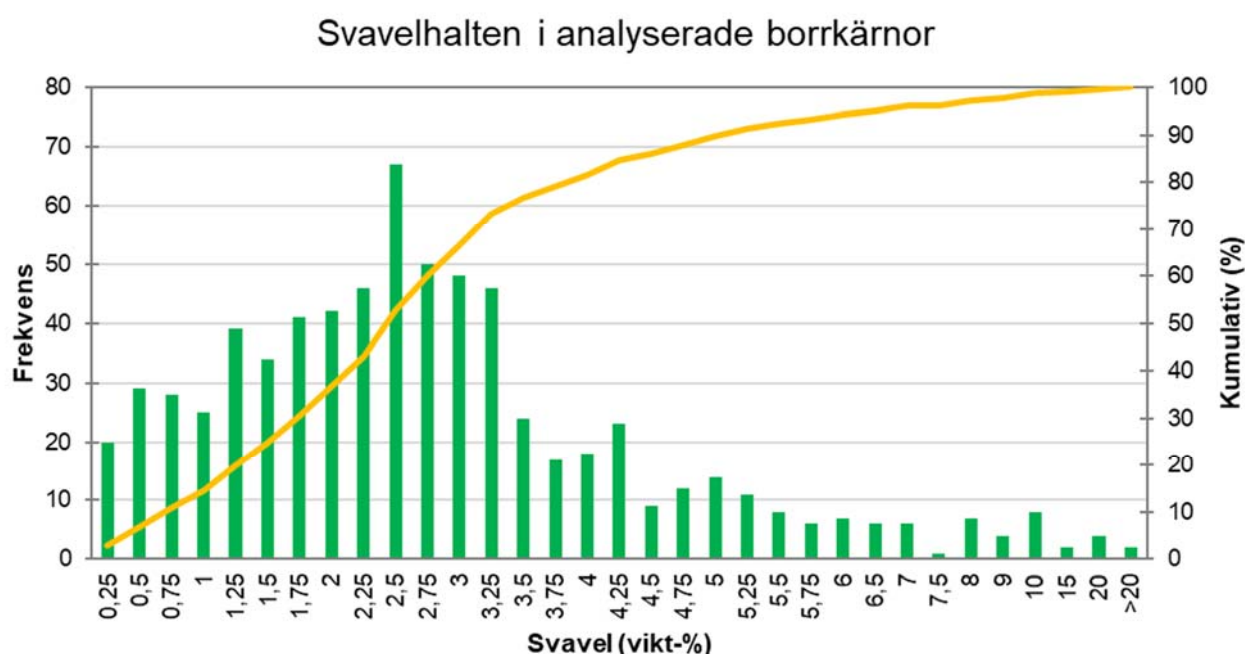
Undersökning av gråbergets syrabildande potential har genomförts genom NAG- och ABA-test (utfört enligt SS:EN 15875:2011). En del av testerna har utförts på enskilda gråbergsprover av ALS år 2012 såsom bestämning av svavel- och kolhalter. Analyserna gjordes om år 2019 av GLS och kompletterades med ytterligare analyser av Graeme Campbell. Resultaten från ABA-test presenteras i Tabell 9 och från NAG-test i Tabell 10. Analysrapporter ingår i BILAGA A.

Tabell 9: Resultat från ABA-test (GCA, 2018). ANC (acid neutralisation capacity) har beräknats enligt AMIRA guideboken (2002). AP har beräknats utifrån sulfidsvavelhalten och NP utifrån totalkolhalten (GLS). Grön markering – inte potentiellt syrabildande, gul – osäkert, röd – potentiellt syrabildande.

Borrhål ID	Intervall	Bergart	Total-S	Total-C	Oorg-C	Sulfid-S	ANC	AP	NP	NNP	NPR
	m		%	%	%	%	kg H ₂ SO ₄ /t	kg CaCO ₃ /t	kg CaCO ₃ /t	NP-AP	NP/AP
NUS12002	46-48	Vrf (Hängvägg)	0,26	0,73	<0,01	0,25	10	7,81	9,79	1,98	1,25
NUS12006	16-18		0,54	3,1	1,08	0,4	103	12,5	101	88,3	8,07
NUS12008	40-47		0,25	2,5	0,89	0,17	97	5,31	95,0	89,7	17,9
NUS12008	73,25-75		9,52	0,2	<0,01	≤ 9,52	9	298	8,81	-289	0,030
NUS12011	12-14		1,64	0,06	<0,01	≤ 1,64	11	51,3	10,8	-40,5	0,21
NUS12016	31,4-33,4		4,47	0,06	<0,01	≤ 4,47	14	140	13,7	-126	0,098
NUS12016	33,4-35,4		2,85	0,37	<0,01	≤ 2,85	8	89,1	7,83	-81,2	0,088
NUS12019	66,17-68,		1,03	0,21	<0,01	0,67	19	20,9	18,6	-2,34	0,89
NUS12019	74-76		0,41	0,22	<0,01	0,3	12	9,38	11,7	2,37	1,25
NUS12014	59,9-61,18		3,34	5,71	0,18	≤ 3,34	12	104	11,7	-92,6	0,11
NUS12003	38,3-40	Pgb (Liggvägg)	3	0,61	<0,01	≤ 3,00	13	93,8	12,7	-81,0	0,14
NUS12005	78,7-81		1,68	0,05	<0,01	≤ 1,68	10	52,5	9,79	-42,7	0,19
NUS12007	104-106		0,1	1,41	0,97	0,09	95	2,81	93,0	90,2	33,1
NUS12015	107-108,35		2,09	0,33	<0,01	≤ 2,09	10	65,3	9,79	-55,5	0,15
NUS12017	53,13-55		20,18	1,38	1,31	≤ 20,18	128	631	125	-505	0,20
NUS12019	38-40		0,15	0,16	0,03	0,11	15	3,44	14,7	11,25	4,27
NUS12019	48-50		9,79	0,18	<0,01	≤ 9,79	7	306	6,85	-299	0,022
NUS12014	68-70		1,47	0,05	<0,01	≤ 1,48	12	46,3	11,7	-34,5	0,25
NUS12001	42,25-44	Dyke (Doleritgång)	1,87	0,05	<0,01	≤ 1,87	15	58,4	14,7	-43,8	0,25
NUS12001	53-55		1,09	2,25	2,17	0,74	217	23,1	212	189	9,19
NUS12006	38,5-40,5		0,25	0,03		0,1	8	3,13	7,83	4,71	2,51
NUS12006	40,5-42,85		0,45	0,02		0,15	6	4,69	5,87	1,19	1,25
NUS12018	79,68-81,8		9,06	2,29	<0,01	≤ 9,06	16	283	15,7	-267	0,055
NUS12019	44,3-46		1,71	0,34	0,2	≤ 1,71	26	53,4	25,5	-28,0	0,48
NUS12001	21-23	Sgr (Malm)	1,24	25,1	<0,01	≤ 1,24	5	38,8	4,90	-33,9	0,13
NUS12002	65-67		5,17	25,9	0,04	≤ 5,17	15	162	14,7	-147	0,091
NUS12005	54-56		8,52	24,0	0,63	≤ 8,52	20	266	19,6	-247	0,074
NUS12010	44-46		0,93	33,4	<0,01	0,52	13	16,3	12,7	-3,52	0,78

Borrhål ID	Intervall	Bergart	Total-S	Total-C	Oorg-C	Sulfid-S	ANC	AP	NP	NNP	NPR
	m		%	%	%	%	kg H ₂ SO ₄ /t	kg CaCO ₃ /t	kg CaCO ₃ /t	NP-AP	NP/AP
NUS12017	83-85		3,98	18,5	<0,01	≤ 3,98	17	124	16,6	-108	0,13
NUS12018	52-54		0,27	38,2	0,16	0,2	10	6,25	9,79	3,54	1,57
NUS12018	60-62		1,21	44,8	<0,01	≤ 1,21	10	37,8	9,79	-28,0	0,26
NUS12014	30,5-32,5		4,75	15,4	0,43	≤ 4,75	13	148	12,7	-136	0,086

I Figur 10 visas ett histogram över frekvensfördelning av svavelinnehåll hos alla gråbergsanalyser från borrhåll. Som framgår av figuren har merparten av gråberget en svavelhalt mellan 1 och 3,25 vikt-% (medianhalt 2,75 vikt-%).

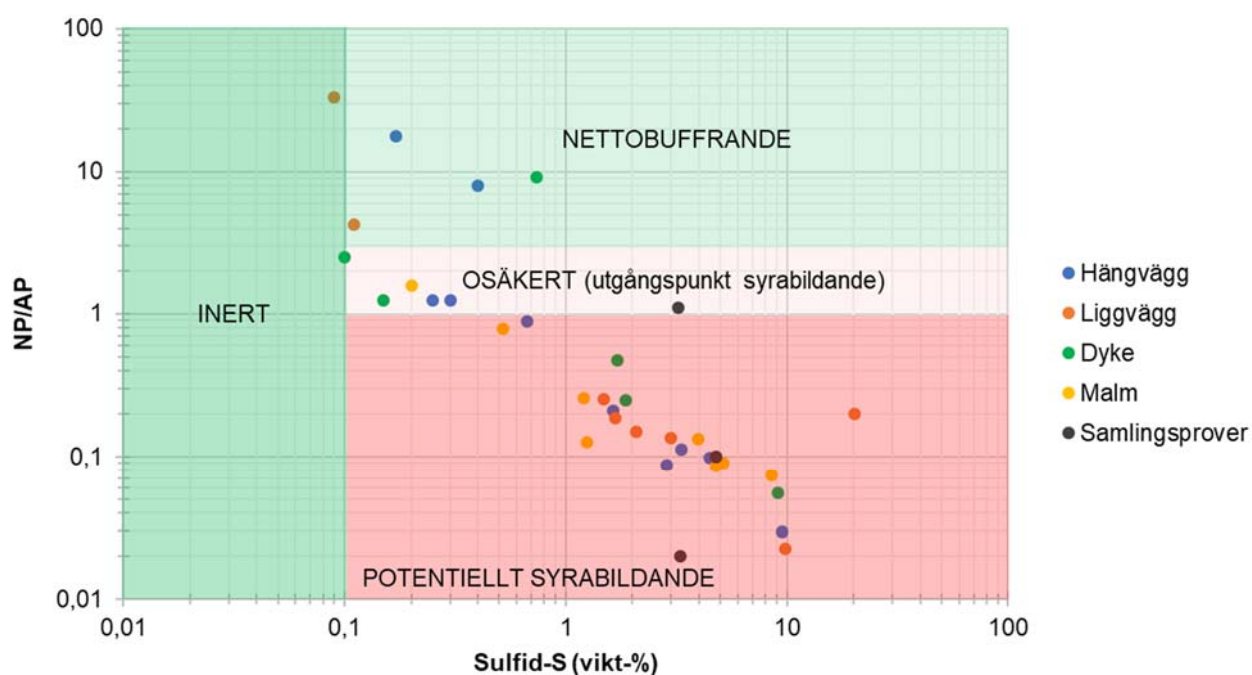


Figur 10: Frekvensfördelning av svavelhalter hos alla med ALS metoden S-IR08 analyserade borrhållprover från Nunasvaara Södra.

ABA-testet visade att de flesta gråbergsprover hade en låg neutraliseringspotential. Eftersom inte alla prover hade ett resultat för andel sulfidsvavel antogs att sulfidsvavelhalten är lika med totalsvavelhalten. På så sätt överskattas syrabildande potentialen (AP) och NPR förskjuts mer till "potentiellt syrabildande". Svavelhalten i proverna är dock generellt så högt att även om bara 50 % av svavelhalten skulle vara sulfidsvavel skulle proverna fortfarande bedömas som potentiellt syrabildande.

Resultat från ABA-test (NPR och sulfidsvavelhalt) har plottats mot varandra för att visualisera syrabildande potential. I Figur 11 ingår både prover från enskilda prover och samlingsprover. Det är tydligt att de flesta prover bedöms vara potentiellt syrabildande på grund av sin höga sulfidsvavelandel med samtidig låg neutraliserande förmåga.

NAG-testet (Tabell 10) bekräftar resultaten från ABA-testet.



Figur 11: Neutraliseringspotentialkvoten mot sulfidsvavelinnehåll för alla analyserade prover och samlingsprover.

Tabell 10: Resultat på NAG-test utförd av GCA, 2019. Grön markering indikerar att materialet inte är potentiellt syrabildande, röd markering anger potentiellt syrabildande.

Borrhål ID	Intervall (m)	Bergart	pH (1:2)	EC-(1:2) mS/m	NAG- pH4,5	NAG- pH7,0	NAG-pH
NUS12002	46-48	Vtf (Hängvägg)	7,1	0,35	<0,5	<0,5	6,1
NUS12006	16-18		7,3	0,61	<0,5	<0,5	10,1
NUS12008	40-47		7,6	0,56	<0,5	<0,5	10,9
NUS12008	73,25-75		4	4	100	134	2,4
NUS12011	12-14		3	4,6	8,7	14	2,9
NUS12016	31,4-33,4		4,5	0,92	35	46	2,5
NUS12016	33,4-35,4		4,7	0,84	33	40	2,4
NUS12019	66,17-68,		6,8	0,97	5,3	11	3,1
NUS12019	74-76		7,3	0,46	<0,5	3	4
NUS12014	59,9-61,18		5,4	1,3	43	53	2,3
NUS12003	38,3-40	Pgb (Liggvägg)	3,1	2,7	26	34	2,5
NUS12005	78,7-81		5,8	0,66	24	29	2,5
NUS12007	104-106		8,1	0,2	<0,5	<0,5	11,2
NUS12015	107-108,35		5	0,82	30	34	2,4
NUS12017	53,13-55		6,3	3	195	208	2,4

Borrhål ID	Intervall (m)	Bergart	pH (1:2)	EC-(1:2) mS/m	NAG- pH4,5	NAG- pH7,0	NAG-pH
NUS12019	38-40		8,3	0,19	<0,5	<0,5	6,9
NUS12019	48-50		4,2	2,3	143	159	2,3
NUS12014	68-70		7,6	0,32	22	28	2,6
NUS12001	42,25-44	Dyke (Dolerit-gång)	4,3	0,85	18	26	2,7
NUS12001	53-55		7,2	1,3	<0,5	<0,5	9,3
NUS12006	38,5-40,5		3,4	1,7	<0,5	<0,5	5,6
NUS12006	40,5-42,85		3,1	1,8	<0,5	1,5	4,9
NUS12018	79,68-81,8		3,6	1,5	127	139	2,3
NUS12019	44,3-46		7,1	0,91	20	25	2,9
NUS12001	21-23	Sgr (Malm)	5,2	0,95	20	26	2,6
NUS12002	65-67		5,6	2,2	61	75	2,4
NUS12005	54-56		5,4	1,6	157	176	2,2
NUS12010	44-46		6,6	0,39	13	17	2,9
NUS12017	83-85		4,4	1,5	39	43	2,4
NUS12018	52-54		7,8	0,19	<0,5	1,8	3,9
NUS12018	60-62		7,1	0,24	17	21	2,6
NUS12014	30,5-32,5		5,3	0,84	61	70	2,2

På samlingsproverna utfördes bara ABA-test (Bergskraft, 2019). Resultaten från analysen visas i Tabell 11.

Mer detaljerad information återfinns i BILAGA B. Svavelhalten utgörs nästan helt av sulfidsvavel.

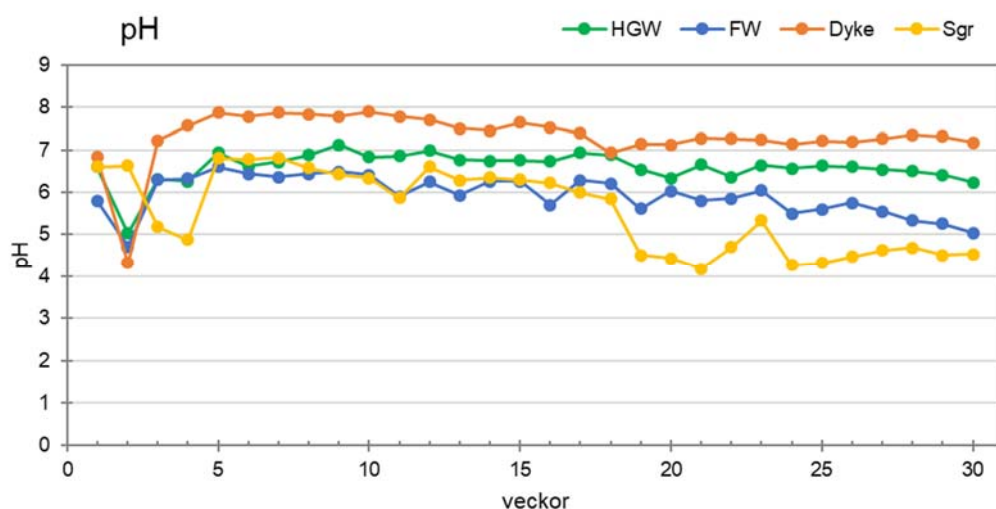
(Svavelhalten i malmprovet är lägre än i de genomsnittliga tidigare analyserade proverna eftersom materialet med höga svavelhalter hade redan använts i andra analyser.) Syrabildande potentialen är hög samtidigt som neutraliserande potentialen är låg. Materialet bedöms i stort sett vara potentiellt syrabildande, gråberg från doleritgången bedöms vara osäkert.

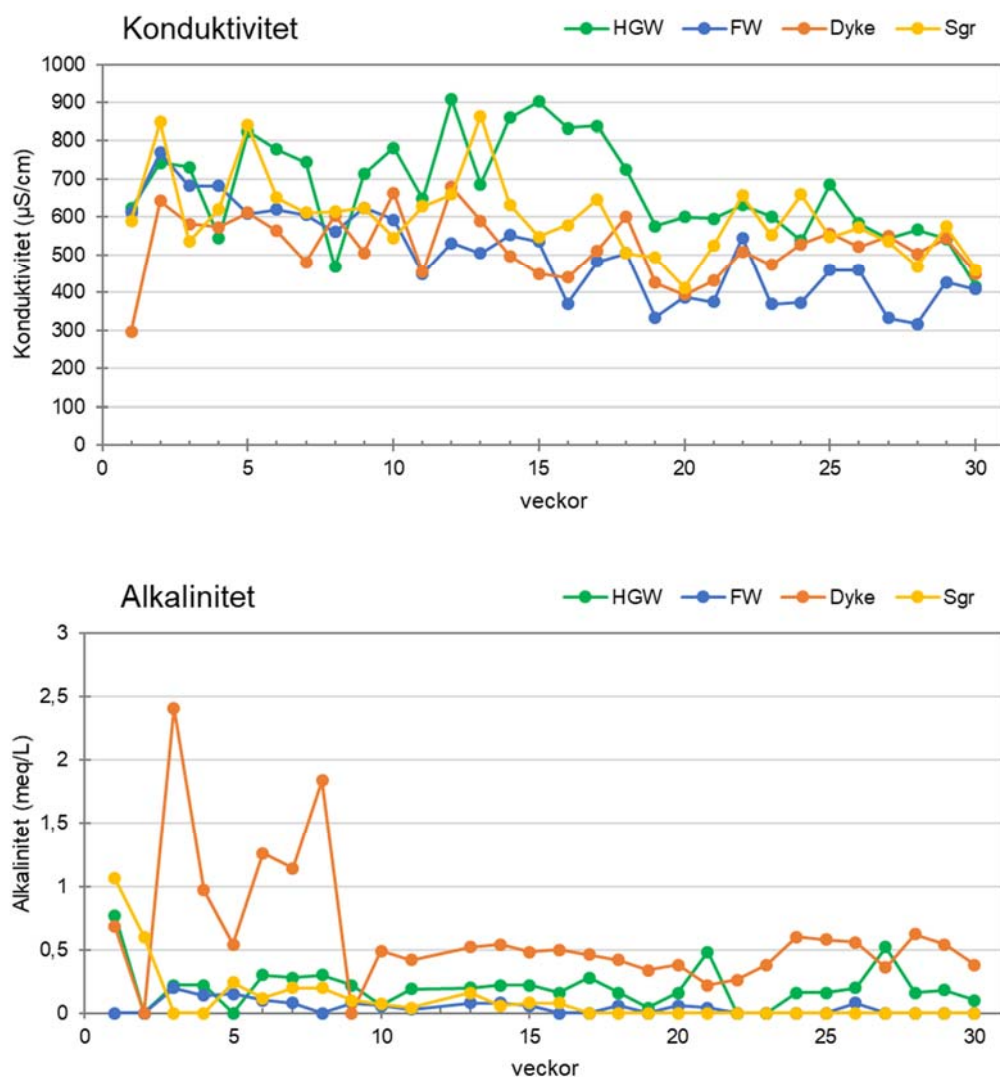
Tabell 11: Resultat från ABA-test för de fyra samlingsproverna som ingick i fuktkammarförsöket (Bergskraft, 2019). Grön markering – inte potentiellt syrabildande, gul – osäkert, röd – potentiellt syrabildande.

Parameter	Enhet	Liggvägg	Hängvägg	Gång (Dyke)	Malm
Total-S	%	4,9	4,85	3,29	3,4
Sulfat-S	%	0,1	0,08	0,07	0,1
Sulfid-S	%	4,8	4,77	3,22	3,3
Total-C	%	0,16	1,19	2,87	18,4
C-org.	%	0,05	0,98	1,47	18,3
C-oorg.	%	0,11	0,21	1,4	0,1
NP	kg CaCO ₃ /t	10	14	110	2
AP	kg CaCO ₃ /t	150	149	100,5	103
NPR		0,1	0,1	1,1	0,02
NNP	kg CaCO ₃ /t	-140	-136	9	-101

5.1.5 Fuktkammarförsök

Fuktkammarförsök har utförts på samlingsprover av material från hängväggen, liggväggen, gång och malm av Bergskraft (2019). Malmprovets sulfidandel är dock mindre jämfört andra malmprover eftersom borrhärdarna med högre sulfidhalt hade redan använts för andra analyser. Fuktkammarförsöket pågick i 30 veckor under 2019. Resultaten redovisas i Figur 12 till Figur 15 och i Tabell 15 och Tabell 16. En utförlig diskussion om resultaten finns i BILAGA B.





Figur 12: Resultat för pH, konduktivitet och alkalinitet från fuktkammarförsöket.

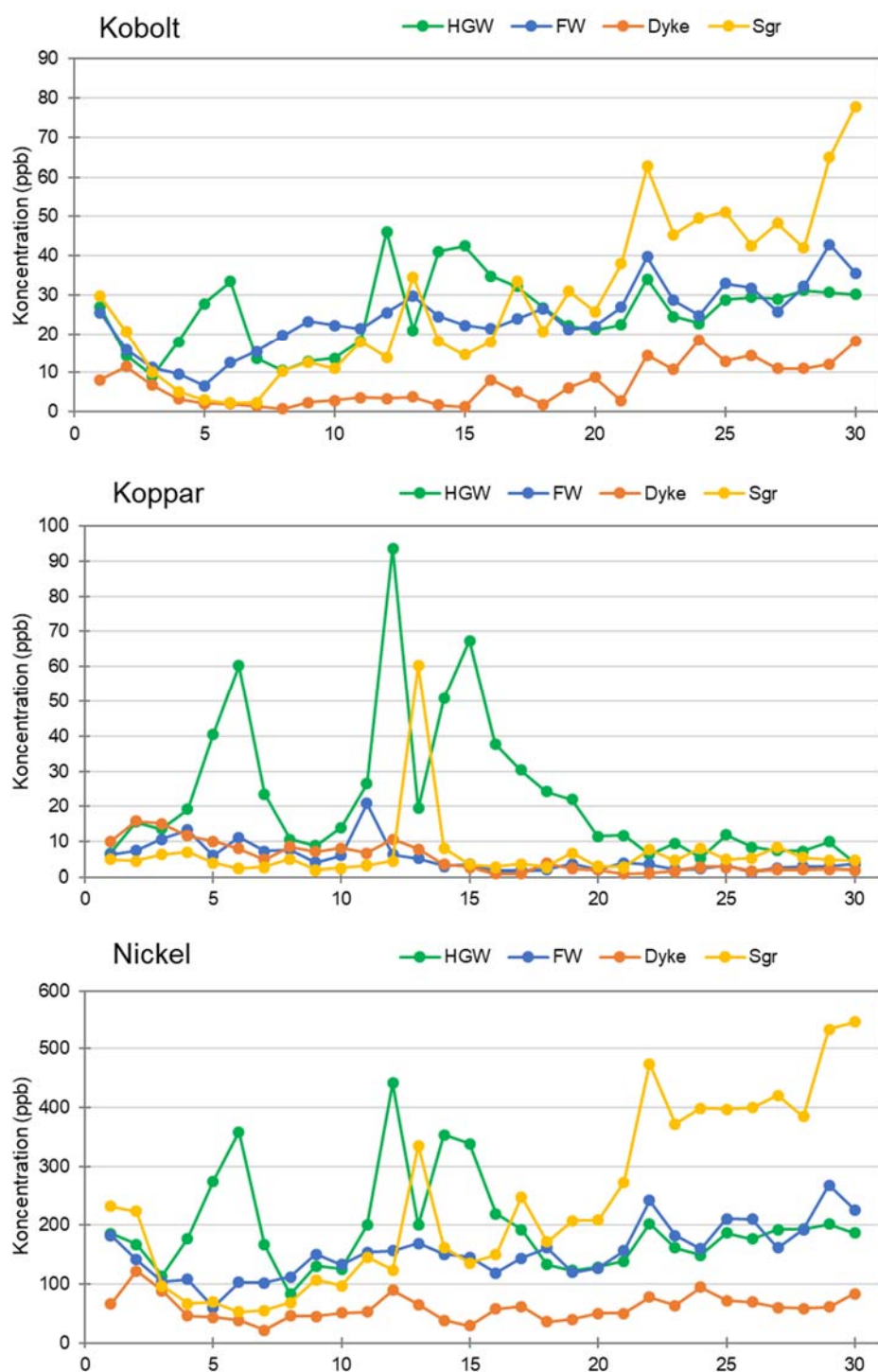
Efter en initial minskning ligger pH-värdet relativt stabilt mellan 8 och 6,5 (Figur 12). Efter vecka 15 börjar pH-värdet avta i alla prover. Gången ligger relativt stabilt över pH 7 och hängväggen mellan pH 7 och 6. Liggväggen faller dock under pH 6 och malmen under pH 5. Tendensen i liggväggen är fallande och den kommer som malmprovet vara syrabildande inom några veckor. Alkalinitet i malm- och liggväggproverna är i princip förbrukat efter 15 veckor försök. Bara gången verkar producera en viss, men rätt låg, alkalinitet. Sulfathalten (som har beräknats från svavelhalten) är relativt hög från början i alla prover. Halten visar en minskande trend under försökets gång men ligger fortfarande över 1000 mg/L vid slutet av försöket (se BILAGA B).

Tabell 12: Resultat för pH, konduktivitet och alkalinitet från fuktkammarförsöket på samlingsprover från Nunasvaara Södra.

	Hängvägg (HGW)			Liggvägg (FW)			Gång (Dyke)			Malm (Sgr)		
Vecka	Kond.	pH	Alk.	Kond.	pH	Alk.	Kond.	pH	Alk.	Kond.	pH	Alk.
Enhet	uS/cm		meq/L	uS/cm		meq/L	uS/cm		meq/L	uS/cm		meq/L
1	623	6,61	0,77	611	5,81	0	297	6,83	0,68	591	6,61	1,06
2	743	5,03	0	769	4,71	0	643	4,32	0	848	6,63	0,6
3	731	6,31	0,22	682	6,3	0,2	582	7,23	2,41	536	5,18	0
4	545	6,26	0,22	682	6,33	0,14	573	7,57	0,97	621	4,88	0
5	824	6,94	0	609	6,61	0,15	611	7,87	0,54	840	6,81	0,24
6	778	6,62	0,3	620	6,44	0,1	564	7,79	1,26	651	6,78	0,12
7	744	6,72	0,28	606	6,36	0,08	481	7,88	1,14	612	6,82	0,2
8	468	6,89	0,3	561	6,44	0	605	7,83	1,84	615	6,58	0,2
9	713	7,13	0,22	625	6,49	0,08	506	7,79	0	625	6,43	0,1
10	782	6,83	0,06	594	6,42	0,06	664	7,9	0,49	546	6,34	0,07
11	649	6,86	0,19	450	5,91	0,03	454	7,79	0,42	629	5,87	0,04
12	908	6,99		531	6,25		680	7,71		660	6,61	
13	687	6,77	0,2	505	5,93	0,08	591	7,51	0,52	864	6,29	0,16
14	860	6,75	0,22	553	6,26	0,08	497	7,45	0,54	633	6,35	0,06
15	902	6,76	0,22	535	6,26	0,06	450	7,65	0,48	548	6,3	0,08
16	833	6,73	0,16	370	5,7	0	440	7,53	0,5	579	6,23	0,08
17	839	6,94	0,28	482	6,29	0	512	7,39	0,46	647	5,99	0
18	725	6,89	0,16	504	6,21	0,06	602	6,94	0,42	504	5,84	0
19	576	6,54	0,04	334	5,62	0	425	7,14	0,34	493	4,51	0
20	601	6,34	0,16	388	6,03	0,06	395	7,12	0,38	413	4,44	0
21	596	6,65	0,48	375	5,81	0,04	431	7,28	0,22	524	4,18	0
22	632	6,36	0	545	5,85	0	509	7,27	0,26	657	4,7	0
23	602	6,64	0	369	6,05	0	474	7,24	0,38	552	5,34	0
24	538	6,57	0,16	374	5,5	0	528	7,14	0,6	659	4,27	0
25	687	6,63	0,16	460	5,6	0	556	7,21	0,58	547	4,32	0
26	583	6,61	0,2	460	5,76	0,08	522	7,19	0,56	572	4,47	0
27	544	6,54	0,52	332	5,55	0	550	7,26	0,36	535	4,62	0

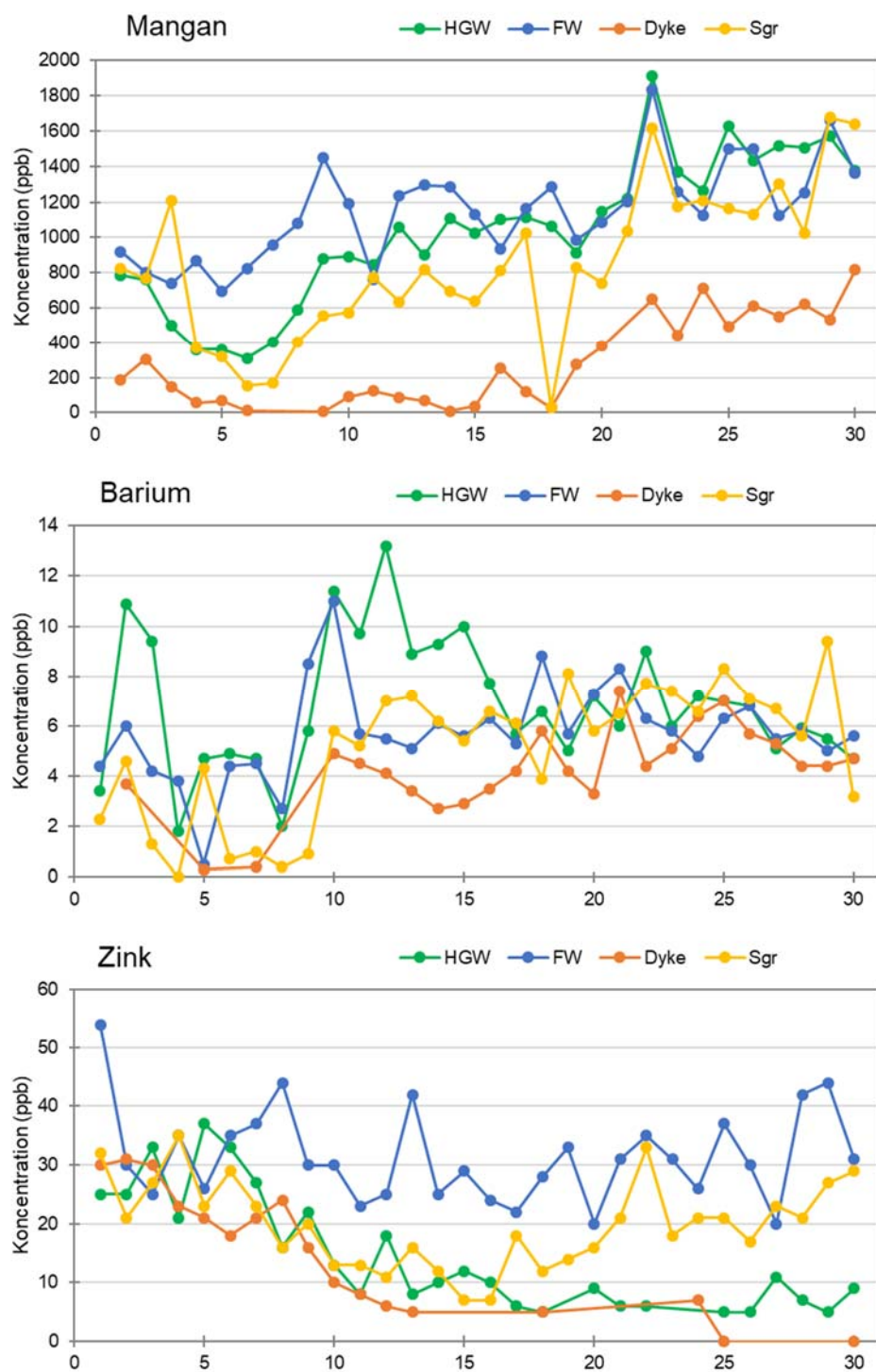
	Hängvägg (HGW)			Liggvägg (FW)			Gång (Dyke)			Malm (Sgr)		
Vecka	Kond.	pH	Alk.	Kond.	pH	Alk.	Kond.	pH	Alk.	Kond.	pH	Alk.
28	566	6,5	0,16	317	5,34	0	503	7,36	0,62	469	4,69	0
29	543	6,42	0,18	427	5,26	0	544	7,31	0,54	575	4,51	0
30	416	6,24	0,1	408	5,05	0	450	7,18	0,38	461	4,54	0

Lakvattnet från fuktkammarförsöket har även analyserats för metaller. Resultaten redovisas i Tabell 13 till Tabell 16 och i sin helhet i BILAGA B. Utvalda metaller presenteras i Figur 13 till Figur 15. Ur totalhaltsanalysen går fram att det är främst, kobolt, krom, koppar, nickel, molybden och vanadin som förekommer i högre halter. Haltutvecklingen i lakvattnet för kobolt, koppar och nickel visas i Figur 13. Krom, vanadin och molybden ligger generellt under rapporteringsgränsen eller strax över. Andra ämnen som ligger under eller strax över rapporteringsgränsen är aluminium, kadmium, bly, fosfor, antimon och uran. Selen ligger något i malmprovet. Järn börjar laka efter vecka 20, när pH börja sjunka, i malmprovet i större omfattning. Även i hängväggen kan man se en utlakning av järn mot slutet av försöket, dock i mindre omfattning.



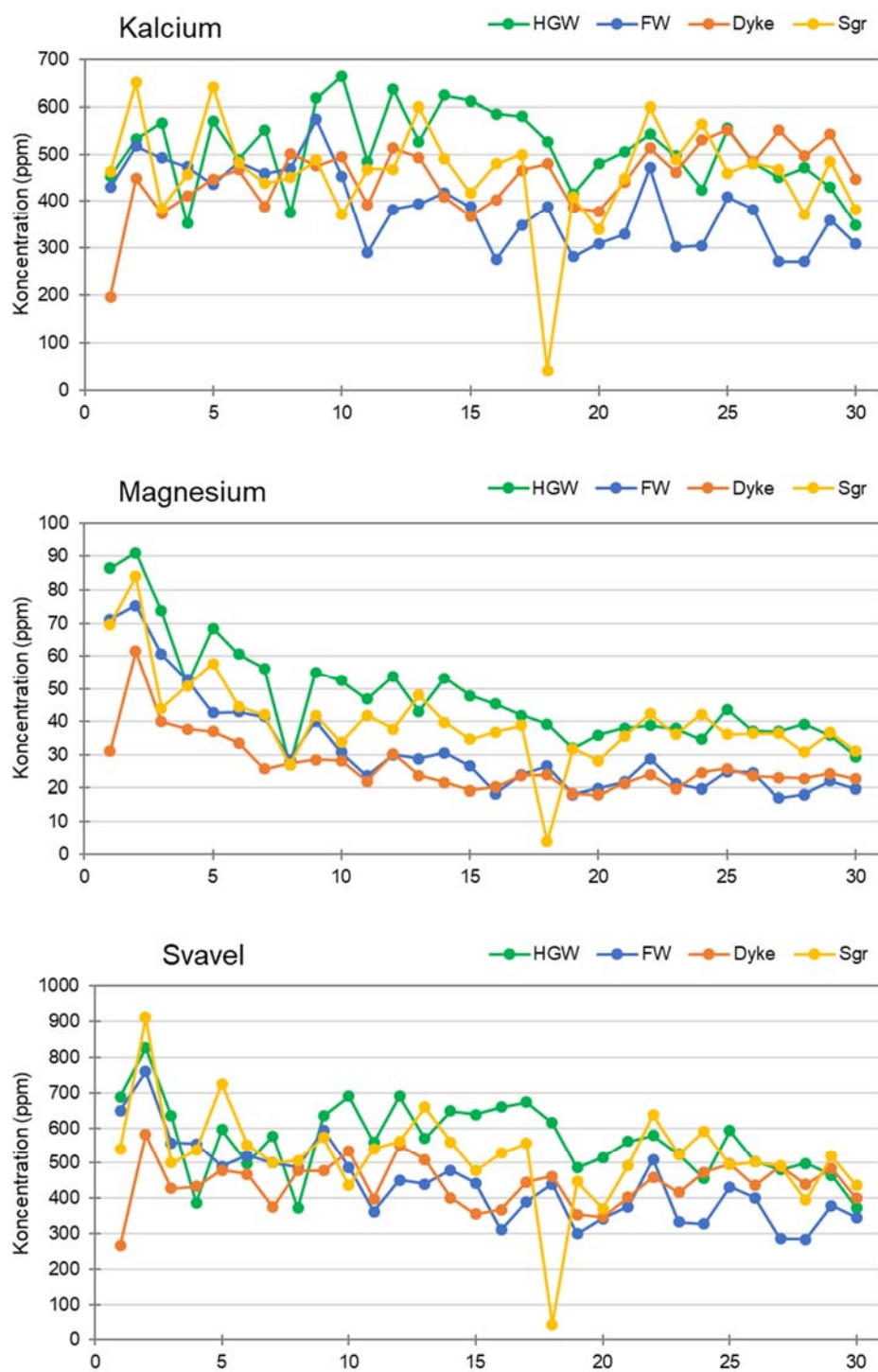
Figur 13: Resultat för utlakade halter av kobolt, koppär och nickel från fuktkammarförsöket. Försöket har pågått i 30 veckor.

Kobolthalten börja öka i alla prover efter vecka 20, som mest i malmprovet. Koppärhalterna är i princip låga i alla prover förutom hängväggen där halten varierar en del. Mot slutet av fuktkammarförsöket har dock koppärhalten stabiliserat sig även i hängväggsprovet. Nickelhalterna är relativt höga redan från början. Häng- och liggväggsproverna ökar nickelutlakningen något mot slutet. Ökningen är tydligare i malmprovet. Gången visar en stabil, lägre halt i lakvattnet.



Figur 14: Resultat för utlakade halter av mangan, barium och zink från fuktkammarförsöket. Försöket har pågått i 30 veckor.

Andra metaller, som hade halter ovanför rapporteringsgränsen redovisas i Figur 14. Manganhalten ökar i lakvattnet från alla prover. Bariumhalten ligger hyfsat stabilt efter de första veckorna. Zinkhalten minskar i liggvägg, gång och malm och faller till och med under rapporteringsgränsen. I malmprovet ökar dock halten igen i sambanden med sjunkande pH. I hängväggen minskar inte zinkhalten utan är relativt stabil.



Figur 15: Resultat för utlakade halter av kalcium, magnesium och svavel från fuktkammarförsöket. Försöket har pågått i 30 veckor.

I Figur 15 presenteras halter i lakvatten för kalcium, magnesium och svavel. Kalcium ligger på samma nivå genom hela försöket, förutom i liggväggen, där halten minskar något. Magnesium- och svavelhalten minskar i alla prover.

Tabell 13: Resultat från veckovis analys av lakvatten från fuktkammarförsök på gråberg från hängväggen. (Bergskraft, 2019)

		HGW 2018- 07-24	HGW 2018- 07-31	HGW 2018- 08-07	HGW 2018- 08-14	HGW 2018- 08-21	HGW 2018- 08-28	HGW 2018- 09-04	HGW 2018- 09-18	HGW 2018- 09-25	HGW 2018- 10-02	HGW 2018- 10-09	HGW 2018- 10-17	HGW 2018- 10-24	HGW 2018- 10-31	HGW 2018- 11-06	HGW 2018- 11-13	HGW 2018- 11-21	HGW 2018- 11-29	HGW 2018- 12-06	HGW 2019- 03-01	HGW 2019- 03-09	HGW 2019- 03-15	HGW 2019- 03-22
Ag	ppb	0,3	0,2	<0,1	<0,1	<0,1	0,6	0,2	0,1	<0,1	0,4	0,2	<0,1	<0,1	<0,1	0,4	<0,1	<0,1	<0,1	0,6	<0,1	0,1	<0,1	<0,1
Al	ppb	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
As	ppb	<0,5	2,2	<0,5	0,9	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,7	<0,5	<0,5	<0,5	<0,5	<0,5	1,1	<0,5	0,6	1	<0,5
Au	ppb	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
B	ppb	108	107	<100	<100	132	139	116	<100	<100	<100	<100	132	<100	141	267	357	171	205	<100	137	113	<100	<100
Ba	ppb	3,4	10,9	9,4	1,8	4,7	4,9	4,7	2	5,8	11,4	9,7	13,2	8,9	9,3	10	7,7	5,7	6,6	5	5,1	5,9	5,5	4,7
Be	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Bi	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ca	ppm	452	532	566	352	570	489	552	375	617	664	483	637	527	624	612	586	580	526	415	450	471	429	349
Cd	ppb	<0,1	<0,1	0,2	<0,1	0,2	0,3	<0,1	<0,1	0,2	<0,1	<0,1	0,2	<0,1	<0,1	0,2	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ce	ppb	0,2	0,2	0,2	0,2	0,2	<0,1	<0,1	<0,1	<0,1	0,1	0,2	0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Co	ppb	26,9	14,5	9,1	17,9	27,7	33,4	13,7	10,6	12,9	13,7	18,2	46,1	21	41,1	42,5	34,8	32,2	26,7	22,1	29	31,2	30,6	30,2
Cr	ppb	<0,5	0,5	0,5	0,6	0,9	0,8	<0,5	<0,5	<0,5	<0,5	<0,5	0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Cs	ppb	0,1	0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Cu	ppb	6,6	15,5	13,6	19,2	40,6	60,2	23,5	10,7	8,8	14	26,5	93,6	19,5	50,8	67,4	37,7	30,4	24,2	22	7,4	7,3	10	3,9
Dy	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Er	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Eu	ppb	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	1,1	1,1	0,1	0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	0,1	<0,1	0,2	<0,1	<0,1
Fe	ppb	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	310	<300	<300	3160
Ga	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Gd	ppb	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1

		HGW 2018- 07-24	HGW 2018- 07-31	HGW 2018- 08-07	HGW 2018- 08-14	HGW 2018- 08-21	HGW 2018- 08-28	HGW 2018- 09-04	HGW 2018- 09-18	HGW 2018- 09-25	HGW 2018- 10-02	HGW 2018- 10-09	HGW 2018- 10-17	HGW 2018- 10-24	HGW 2018- 10-31	HGW 2018- 11-06	HGW 2018- 11-13	HGW 2018- 11-21	HGW 2018- 11-29	HGW 2018- 12-06	HGW 2019- 03-01	HGW 2019- 03-09	HGW 2019- 03-15	HGW 2019- 03-22
Ge	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Hf	ppb	<0,1	0,1	0,1	<0,1	0,2	0,3	0,2	<0,1	<0,1	0,1	0,1	0,5	<0,1	0,1	0,4	0,2	0,2	<0,1	0,3	<0,1	0,2	<0,1	<0,1
Hg	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ho	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
In	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
K	ppm	75	98	92	74	109	114	95	59	92	106	113	168	108	141	151	189	177	155	118	74	74	77	60
La	ppb	0,2	0,1	0,2	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Li	ppb	13	<10	53	12	<10	<10	74	<10	16	12	<10	<10	<10	11	<10	<10	<10	<10	<10	<10	<10	<10	<10
Lu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Mg	ppm	86,4	91,2	73,6	51,3	68,5	60,5	56,3	26,8	55,0	52,5	46,9	53,8	43,1	53,2	47,9	45,3	41,9	39,3	31,9	37,1	39,3	35,8	29,4
Mn	ppb	786	762	497	362	362	312	402	589	881	893	845	1059	900	1106	1026	1103	1116	1064	916	1519	1508	1570	1379
Mo	ppb	0,7	0,6	0,8	0,8	0,8	1,4	0,7	0,5	0,5	<0,5	0,7	0,9	0,5	<0,5	0,8	1,2	0,9	0,5	0,9	<0,5	<0,5	<0,5	<0,5
Na	ppm	57	112	94	112	173	203	125	45	103	110	177	313	170	283	300	307	281	240	167	86	85	97	61
Nb	ppb	1,5	1,2	0,7	0,5	0,5	0,7	0,3	0,2	0,2	0,5	<0,1	0,1	<0,1	<0,1	0,3	<0,1	<0,1	<0,1	0,6	<0,1	0,3	0,2	0,1
Nd	ppb	0,2	0,2	0,2	0,1	<0,1	0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ni	ppb	186	168	114	178	275	359	167	83	131	126	200	442	200	354	339	220	193	133	123	193	194	202	187
P	ppb	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	1067	<1000	<1000
Pb	ppb	12	8	10	11	9	10	10	<5	11	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	7	5	<5
Pd	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Pr	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Pt	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Rb	ppb	17	17,5	17,4	13	16,7	18,7	18,6	10,4	15,5	20,2	14	16,1	13,7	14,5	17,4	18,4	14,3	10,8	14,2	10,8	11,9	11	9,1

		HGW 2018- 07-24	HGW 2018- 07-31	HGW 2018- 08-07	HGW 2018- 08-14	HGW 2018- 08-21	HGW 2018- 08-28	HGW 2018- 09-04	HGW 2018- 09-18	HGW 2018- 09-25	HGW 2018- 10-02	HGW 2018- 10-09	HGW 2018- 10-17	HGW 2018- 10-24	HGW 2018- 10-31	HGW 2018- 11-06	HGW 2018- 11-13	HGW 2018- 11-21	HGW 2018- 11-29	HGW 2018- 12-06	HGW 2019- 03-01	HGW 2019- 03-09	HGW 2019- 03-15	HGW 2019- 03-22
Re	ppb	0,42	0,18	0,12	0,09	0,09	0,08	0,09	<0,04	0,05	0,05	0,05	0,05	<0,04	<0,04	<0,04	<0,04	<0,04	0,05	<0,04	<0,04	<0,04	<0,04	<0,04
S	ppm	688	827	635	388	596	499	577	372	635	690	559	690	570	649	638	659	673	615	486	480	499	465	374
Sb	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	0,9	<0,5	<0,5	<0,5	0,5	<0,5	<0,5	<0,5	<0,5	0,6	<0,5	<0,5	<0,5	0,9	<0,5	<0,5	<0,5	<0,5
Sc	ppb	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Se	ppb	9,6	10,1	5,4	<5	6,3	5,2	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5,2	<5	<5
Si	ppb	574	775	637	432	592	599	512	308	480	411	367	423	358	447	418	396	394	394	299	362	368	398	347
Sm	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Sn	ppb	0,5	<0,1	3,2	14,3	<0,1	1,4	0,5	<0,1	1,9	<0,1	1,3	0,3	<0,1	<0,1	1,1	0,1	<0,1	<0,1	0,2	0,6	0,2	0,5	0,1
Sr	ppb	36,1	43,3	41,3	24,9	44,1	42,2	42,1	26,1	41	41,2	33,7	48,3	36,4	44,6	41,2	43,3	40,9	29,5	29,1	28,8	26,9	26,7	20,6
Ta	ppb	0,2	0,3	0,2	0,2	0,2	0,2	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1
Tb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Te	ppb	<0,5	<0,5	0,8	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,8	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,7	<0,5
Th	ppb	0,4	0,3	<0,1	<0,1	<0,1	0,5	0,2	<0,1	<0,1	0,5	0,3	0,1	<0,1	<0,1	0,6	0,3	0,1	<0,1	0,5	<0,1	0,3	0,1	<0,1
Tl	ppb	<0,1	<0,1	0,1	<0,1	<0,1	0,1	<0,1	<0,1	0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	0,1	0,2	<0,1	<0,1	0,1	0,1	<0,1
Tm	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
U	ppb	0,4	1	0,2	0,1	0,3	0,3	0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
V	ppb	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
W	ppb	0,4	<0,1	0,3	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	0,7	0,4	0,3	0,1	0,2	0,6	0,2	0,2	0,1	0,6	<0,1	0,3	<0,1	<0,1
Y	ppb	0,1	0,2	0,1	0,3	0,5	0,5	<0,1	<0,1	<0,1	<0,1	<0,1	0,3	<0,1	0,3	0,4	0,2	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Yb	ppb	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Zn	ppb	25	25	33	21	37	33	27	16	22	13	8	18	8	10	12	10	6	5	<5	11	7	5	9
Zr	ppb	0,3	0,3	0,4	0,3	0,4	0,5	<0,2	<0,2	<0,2	<0,2	<0,2	0,3	<0,2	0,2	0,4	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2

Tabell 14: Resultat för analys på lakvatten från liggväggen. Bergskraft, 2019.

		FW 2018- 07-24	FW 2018- 07-31	FW 2018- 08-07	FW 2018- 08-14	FW 2018- 08-21	FW 2018- 08-28	FW 2018- 09-04	FW 2018- 09-18	FW 2018- 09-25	FW 2018- 10-02	FW 2018- 10-09	FW 2018- 10-17	FW 2018- 10-24	FW 2018- 10-31	FW 2018- 11-06	FW 2018- 11-13	FW 2018- 11-21	FW 2018- 11-29	FW 2018- 12-06	FW 2019- 03-01	FW 2019- 03-09	FW 2019- 03-15	FW 2019- 03-22
Ag	ppb	0,1	<0,1	<0,1	<0,1	0,7	0,3	0,1	0,1	0,7	0,2	0,2	<0,1	<0,1	0,6	0,2	<0,1	<0,1	0,9	0,2	0,4	<0,1	<0,1	<0,1
Al	ppb	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
As	ppb	0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,6	<0,5	0,5	<0,5	1,4	<0,5	<0,5	<0,5	<0,5	1,2	0,9	<0,5	<0,5	<0,5	<0,5
Au	ppb	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
B	ppb	227	136	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Ba	ppb	4,4	6	4,2	3,8	0,5	4,4	4,5	2,7	8,5	11	5,7	5,5	5,1	6,1	5,6	6,3	5,3	8,8	5,7	5,5	5,8	5	5,6
Be	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Bi	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ca	ppm	429	517	492	474	436	483	459	471	573	453	291	383	395	418	388	275	349	388	282	271	272	360	308
Cd	ppb	<0,1	0,2	0,1	<0,1	0,1	0,2	0,3	<0,1	<0,1	0,4	<0,1	0,2	<0,1	0,2	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	0,2
Ce	ppb	0,2	0,3	0,2	0,1	0,1	<0,1	<0,1	<0,1	0,2	0,1	0,1	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	0,1
Co	ppb	25,5	15,9	11,3	9,7	6,6	12,5	15,4	19,6	23,2	22,2	21,3	25,5	29,7	24,5	22,2	21,4	23,9	26,5	21,1	25,7	32,1	42,9	35,6
Cr	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Cs	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Cu	ppb	6,3	7,5	10,7	13,3	6,1	11,3	7,3	7,7	4,1	6,1	20,9	6,3	5,2	3,2	3,5	1,7	1,9	2,1	3,7	2,6	3	3	3,7
Dy	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Er	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Eu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	0,2	0,1	0,1	0,1	<0,1	<0,1	<0,1	0,1	0,3	11	<0,1	<0,1	<0,1	<0,1
Fe	ppb	420	<300	<300	<300	<300	<300	<300	10830	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	3500	5920	8070	7380
Ga	ppb	0,2	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Gd	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1

		FW 2018- 07-24	FW 2018- 07-31	FW 2018- 08-07	FW 2018- 08-14	FW 2018- 08-21	FW 2018- 08-28	FW 2018- 09-04	FW 2018- 09-18	FW 2018- 09-25	FW 2018- 10-02	FW 2018- 10-09	FW 2018- 10-17	FW 2018- 10-24	FW 2018- 10-31	FW 2018- 11-06	FW 2018- 11-13	FW 2018- 11-21	FW 2018- 11-29	FW 2018- 12-06	FW 2019- 03-01	FW 2019- 03-09	FW 2019- 03-15	FW 2019- 03-22
Ge	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	
Hf	ppb	<0,1	0,1	0,2	0,2	0,1	<0,1	0,2	0,2	0,1	<0,1	0,2	<0,1	<0,1	0,2	0,3	<0,1	0,1	0,2	0,1	0,3	0,1	<0,1	<0,1
Hg	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ho	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
In	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	2,9	<0,1	<0,1
K	ppm	79	116	98	105	90	89	93	72	94	86	95	97	80	93	91	65	74	83	60	45	42	55	67
La	ppb	0,1	0,1	0,2	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	0,1
Li	ppb	117	36	24	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Lu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Mg	ppm	71	75	61	53	43	43	41	28	40	31	24	30	29	31	27	18	24	27	18	17	18	22	20
Mn	ppb	921	802	738	868	694	824	959	1079	1449	1191	762	1240	1296	1290	1133	938	1162	1286	986	1124	1255	1662	1364
Mo	ppb	0,5	<0,5	0,6	0,5	0,8	0,8	0,6	0,6	0,7	0,7	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Na	ppm	77	158	111	137	101	83	85	62	79	83	129	128	99	113	108	64	88	94	53	38	34	44	68
Nb	ppb	1,1	0,8	0,6	0,6	0,7	0,3	0,3	0,2	0,4	0,2	<0,1	<0,1	<0,1	0,3	0,1	<0,1	<0,1	0,8	0,4	0,5	0,2	0,1	<0,1
Nd	ppb	0,1	0,2	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ni	ppb	183	142	104	108	60	103	102	112	151	133	154	157	169	151	146	119	144	162	120	162	193	268	226
P	ppb	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	1064	<1000	<1000	<1000	<1000
Pb	ppb	12	9	10	7	<5	14	<5	<5	9	<5	<5	<5	<5	<5	<5	<5	<5	5	6	10	9	12	<5
Pd	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Pr	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Pt	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Rb	ppb	14,7	14,9	14	13,3	11,2	15	15,3	10,6	20,3	14,3	8,8	11,8	11,4	13,9	12,5	9,9	9,2	13,8	10	8,4	7,2	9,1	8,6

		FW 2018- 07-24	FW 2018- 07-31	FW 2018- 08-07	FW 2018- 08-14	FW 2018- 08-21	FW 2018- 08-28	FW 2018- 09-04	FW 2018- 09-18	FW 2018- 09-25	FW 2018- 10-02	FW 2018- 10-09	FW 2018- 10-17	FW 2018- 10-24	FW 2018- 10-31	FW 2018- 11-06	FW 2018- 11-13	FW 2018- 11-21	FW 2018- 11-29	FW 2018- 12-06	FW 2019- 03-01	FW 2019- 03-09	FW 2019- 03-15	FW 2019- 03-22
Re	ppb	0,11	0,18	0,05	0,1	<0,04	0,05	<0,04	<0,04	0,05	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04
S	ppm	650	760	557	554	490	521	501	488	594	487	362	451	441	480	443	310	389	441	299	286	283	378	346
Sb	ppb	<0,5	<0,5	<0,5	<0,5	1	<0,5	<0,5	<0,5	0,8	<0,5	<0,5	<0,5	<0,5	0,6	<0,5	<0,5	<0,5	1,2	<0,5	0,8	<0,5	<0,5	<0,5
Sc	ppb	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Se	ppb	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Si	ppb	683	830	709	668	631	542	531	595	695	496	307	498	470	557	510	368	438	501	392	398	398	549	481
Sm	ppb	<0,1	0,1	0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Sn	ppb	1,1	1,1	11,8	<0,1	0,6	0,4	0,5	<0,1	0,3	0,4	<0,1	0,2	<0,1	0,1	0,3	<0,1	<0,1	0,4	0,8	0,4	1,4	<0,1	<0,1
Sr	ppb	50,1	58,9	57,2	51,4	34,4	54,5	49,3	49,6	49,3	42,3	31,1	37	40,2	40,2	37,3	24,5	32,1	35,8	23,8	19,1	21,8	29,9	27,6
Ta	ppb	0,3	0,2	0,2	0,2	0,2	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Tb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Te	ppb	0,7	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	1	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,6	1	<0,5	<0,5	<0,5	<0,5
Th	ppb	0,2	0,2	<0,1	<0,1	0,8	0,3	0,1	<0,1	0,6	0,4	0,2	<0,1	<0,1	1	0,4	0,2	0,2	0,9	0,4	0,6	0,3	<0,1	<0,1
Tl	ppb	<0,1	0,2	<0,1	0,1	0,1	<0,1	<0,1	0,2	0,2	<0,1	<0,1	<0,1	<0,1	0,1	0,2	0,2	0,1	<0,1	<0,1	0,2	<0,1	0,2	<0,1
Tm	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
U	ppb	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
V	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
W	ppb	0,6	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	0,7	0,3	0,2	0,3	0,1	0,6	0,2	0,1	<0,1	0,7	0,3	0,6	0,1	0,2	0,2
Y	ppb	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Yb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Zn	ppb	54	30	25	35	26	35	37	44	30	30	23	25	42	25	29	24	22	28	33	20	42	44	31
Zr	ppb	0,2	0,3	0,3	0,3	0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2

Tabell 15: Resultat för lakvattenanalys från fuktkammarförsök på gråberg från gången (dyke). Bergskraft, 2019.

		Dyke 2018- 07-24	Dyke 2018- 07-31	Dyke 2018- 08-07	Dyke 2018- 08-14	Dyke 2018- 08-21	Dyke 2018- 08-28	Dyke 2018- 09-04	Dyke 2018- 09-18	Dyke 2018- 09-25	Dyke 2018- 10-02	Dyke 2018- 10-09	Dyke 2018- 10-17	Dyke 2018- 10-24	Dyke 2018- 10-31	Dyke 2018- 11-06	Dyke 2018- 11-13	Dyke 2018- 11-21	Dyke 2018- 11-29	Dyke 2018- 12-06	Dyke 2019- 03-01	Dyke 2019- 03-09	Dyke 2019- 03-15	Dyke 2019- 03-22
Ag	ppb	0,1	0,1	<0,1	<0,1	1	0,4	0,2	0,2	<0,1	0,2	<0,1	<0,1	<0,1	1	0,2	<0,1	<0,1	1,7	0,4	0,7	0,1	<0,1	<0,1
Al	ppb	750	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
As	ppb	0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	1,2	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	2,1	1,1	0,5	<0,5	<0,5	<0,5
Au	ppb	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
B	ppb	180	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Ba	ppb	<0,1	3,7	<0,1	<0,1	0,3	<0,1	0,4	<0,1	<0,1	4,9	4,5	4,1	3,4	2,7	2,9	3,5	4,2	5,8	4,2	5,3	4,4	4,4	4,7
Be	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Bi	ppb	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ca	ppm	197	449	374	411	447	467	388	502	475	494	392	513	494	409	368	403	466	480	385	550	496	542	447
Cd	ppb	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1
Ce	ppb	0,3	0,2	0,2	0,1	0,2	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Co	ppb	8,2	11,6	6,8	3,2	2,1	2	1,5	0,7	2,4	2,9	3,6	3,4	3,8	1,8	1,2	8,1	5	1,9	6,2	11	11	12,2	18,1
Cr	ppb	<0,5	0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Cs	ppb	0,1	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Cu	ppb	10	15,8	15,1	11,7	10,1	8	4,9	8,6	7,2	8,2	6,7	10,7	7,9	3,6	2,9	1,1	1	3,8	2,5	2,2	2,1	2,3	2
Dy	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Er	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Eu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	0,1	<0,1	<0,1	<0,1	0,1	0,6	3,7	0,2	<0,1	<0,1	<0,1	<0,1
Fe	ppb	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Ga	ppb	0,2	0,2	0,2	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Gd	ppb	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1

		Dyke 2018- 07-24	Dyke 2018- 07-31	Dyke 2018- 08-07	Dyke 2018- 08-14	Dyke 2018- 08-21	Dyke 2018- 08-28	Dyke 2018- 09-04	Dyke 2018- 09-18	Dyke 2018- 09-25	Dyke 2018- 10-02	Dyke 2018- 10-09	Dyke 2018- 10-17	Dyke 2018- 10-24	Dyke 2018- 10-31	Dyke 2018- 11-06	Dyke 2018- 11-13	Dyke 2018- 11-21	Dyke 2018- 11-29	Dyke 2018- 12-06	Dyke 2019- 03-01	Dyke 2019- 03-09	Dyke 2019- 03-15	Dyke 2019- 03-22
Ge	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Hf	ppb	<0,1	<0,1	0,3	<0,1	0,2	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	0,2	0,2	0,2	<0,1	<0,1	0,3	0,2	0,3	0,1	<0,1	<0,1
Hg	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ho	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
In	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
K	ppm	35	89	92	81	90	83	70	84	79	98	63	108	92	67	56	48	64	62	46	44	45	46	37
La	ppb	0,2	0,1	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Li	ppb	28	<10	<10	32	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11
Lu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Mg	ppm	31	61	40	38	37	34	26	27	29	28	22	30	24	22	19	20	24	24	18	23	23	24	23
Mn	ppb	187	305	150	56,3	69	12,5	<0,5	<0,5	6,3	90	125	87,2	68,3	8,8	36,7	256,2	122	29,5	273,9	551,3	621	533,5	816,5
Mo	ppb	<0,5	0,5	1	0,8	0,9	1	0,6	0,7	0,5	0,7	0,8	0,6	0,5	0,6	0,6	<0,5	<0,5	0,8	<0,5	0,9	<0,5	<0,5	<0,5
Na	ppm	35	126	150	112	115	96	71	85	90	143	87	161	122	78	68	50	71	73	47	39	34	41	34
Nb	ppb	1,2	0,9	0,6	0,7	0,9	0,5	0,3	0,2	<0,1	0,3	0,1	<0,1	<0,1	0,6	0,2	<0,1	<0,1	1,1	0,4	0,5	0,1	0,1	<0,1
Nd	ppb	0,1	0,2	0,2	0,2	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ni	ppb	66	122	89	46	44	39	22	46	45	51	53	90	65	39	29	58	62	36	40	60	59	61	84
P	ppb	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	1369	<1000	<1000	<1000
Pb	ppb	11	10	11	10	10	6	10	<5	<5	<5	6	<5	<5	<5	<5	<5	<5	<5	7	8	11	9	<5
Pd	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Pr	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Pt	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	0,2	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Rb	ppb	8,6	13,5	12,9	12,1	15,5	13,9	12,6	11,3	10,3	9,9	10	13	11,8	13,2	9,4	9,6	10,4	16,8	10	11,2	10,3	9,5	8,2

		Dyke 2018- 07-24	Dyke 2018- 07-31	Dyke 2018- 08-07	Dyke 2018- 08-14	Dyke 2018- 08-21	Dyke 2018- 08-28	Dyke 2018- 09-04	Dyke 2018- 09-18	Dyke 2018- 09-25	Dyke 2018- 10-02	Dyke 2018- 10-09	Dyke 2018- 10-17	Dyke 2018- 10-24	Dyke 2018- 10-31	Dyke 2018- 11-06	Dyke 2018- 11-13	Dyke 2018- 11-21	Dyke 2018- 11-29	Dyke 2018- 12-06	Dyke 2019- 03-01	Dyke 2019- 03-09	Dyke 2019- 03-15	Dyke 2019- 03-22
Re	ppb	0,05	0,14	0,06	0,06	0,1	0,05	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	0,06	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04
S	ppm	265	581	428	433	479	468	374	477	477	534	399	551	509	402	355	368	446	462	354	491	439	486	399
Sb	ppb	<0,5	<0,5	<0,5	<0,5	1,2	0,6	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	1,3	<0,5	<0,5	<0,5	2	<0,5	1,2	<0,5	<0,5	<0,5
Sc	ppb	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Se	ppb	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Si	ppb	393	801	589	590	566	530	532	516	520	359	242	424	378	336	265	223	267	303	208	222	263	233	217
Sm	ppb	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Sn	ppb	0,8	<0,1	<0,1	<0,1	0,5	1,5	0,3	<0,1	1,4	0,6	<0,1	<0,1	<0,1	1,5	<0,1	<0,1	<0,1	0,8	0,8	13,3	<0,1	0,4	0,3
Sr	ppb	28,9	66,5	58	55,1	56	57	46,6	57,8	50,1	39,5	42,6	60,6	52,5	43,9	39,1	44,5	46,2	42	36,2	48,7	43,9	50,9	41
Ta	ppb	0,3	0,3	0,2	0,2	0,2	0,1	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Tb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Te	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,6	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,6	<0,5	<0,5	1	<0,5	<0,5
Th	ppb	0,3	0,3	0,2	<0,1	0,7	0,4	0,2	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	1,2	0,5	0,2	0,1	1,1	0,4	0,7	0,3	<0,1	0,1
Tl	ppb	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	0,2	<0,1	0,2	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	0,1	<0,1	<0,1	<0,1
Tm	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
U	ppb	0,1	0,3	<0,1	<0,1	0,2	0,1	0,2	0,3	0,2	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	0,2	0,2	0,2	0,2	0,2
V	ppb	<1	1	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
W	ppb	0,4	<0,1	<0,1	0,3	0,5	<0,1	<0,1	<0,1	<0,1	0,2	0,2	0,3	0,1	0,8	0,4	0,2	0,2	1	0,4	0,5	0,2	<0,1	<0,1
Y	ppb	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Yb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Zn	ppb	30	31	30	23	21	18	21	24	16	10	8	6	5	<5	<5	<5	<5	5	<5	<5	<5	<5	<5
Zr	ppb	0,2	0,4	0,5	0,4	0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2

Tabell 16: Resultat från lakvattenanalys från fuktkammarförsök på malmhaltigt material från Nunasvaara Södra. (Bergskraft, 2019)

		Sgr 2018- 07-24	Sgr 2018- 07-31	Sgr 2018- 08-07	Sgr 2018- 08-14	Sgr 2018- 08-21	Sgr 2018- 08-28	Sgr 2018- 09-04	Sgr 2018- 09-18	Sgr 2018- 09-25	Sgr 2018- 10-02	Sgr 2018- 10-09	Sgr 2018- 10-17	Sgr 2018- 10-24	Sgr 2018- 10-31	Sgr 2018- 11-06	Sgr 2018- 11-13	Sgr 2018- 11-21	Sgr 2018- 11-29	Sgr 2018- 12-06	Sgr 2019- 03-01	Sgr 2019- 03-09	Sgr 2019- 03-15	Sgr 2019- 03-22
Ag	ppb	0,3	<0,1	<0,1	<0,1	1,8	0,4	0,2	<0,1	0,1	0,2	0,1	<0,1	<0,1	1,7	0,2	<0,1	<0,1	<0,1	0,5	0,9	<0,1	<0,1	<0,1
Al	ppb	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
As	ppb	<0,5	0,9	0,7	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,7	<0,5	<0,5	0,7	<0,5	<0,5	<0,5	<0,5	0,7	1	2	<0,5	<0,5
Au	ppb	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
B	ppb	118	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	271	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Ba	ppb	2,3	4,6	1,3	<0,1	4,3	0,7	1	0,4	0,9	5,8	5,2	7	7,2	6,2	5,4	6,6	6,1	3,9	8,1	6,7	5,6	9,4	3,2
Be	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Bi	ppb	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1
Ca	ppm	463	651	384	457	642	482	438	451	488	372	468	468	599	491	417	480	499	43	409	469	371	485	382
Cd	ppb	0,2	0,2	<0,1	<0,1	0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	0,4	0,2	0,1	<0,1	0,1	<0,1	<0,1	0,2	<0,1	<0,1	0,1
Ce	ppb	0,2	0,1	0,2	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	0,2	0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	0,1
Co	ppb	29,7	20,6	10,2	5,1	3	2,2	2,4	10,4	12,7	11,1	17,9	13,9	34,5	18,1	14,6	17,9	33,6	20,6	30,9	48,3	42	64,8	77,8
Cr	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Cs	ppb	0,1	0,2	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Cu	ppb	4,9	4,5	6,3	7	4	2,5	2,8	5,1	2	2,6	3,3	4,5	60,2	8,2	3,6	2,8	3,7	2,8	6,8	8,4	5,5	4,8	4,7
Dy	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Er	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Eu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,9	0,1	<0,1	0,1	<0,1	<0,1	0,4	2	0,9	0,1	<0,1	0,1	<0,1	<0,1	<0,1
Fe	ppb	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	3370	<300	520	7490	15290	24520	34320
Ga	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1

		Sgr 2018- 07-24	Sgr 2018- 07-31	Sgr 2018- 08-07	Sgr 2018- 08-14	Sgr 2018- 08-21	Sgr 2018- 08-28	Sgr 2018- 09-04	Sgr 2018- 09-18	Sgr 2018- 09-25	Sgr 2018- 10-02	Sgr 2018- 10-09	Sgr 2018- 10-17	Sgr 2018- 10-24	Sgr 2018- 10-31	Sgr 2018- 11-06	Sgr 2018- 11-13	Sgr 2018- 11-21	Sgr 2018- 11-29	Sgr 2018- 12-06	Sgr 2019- 03-01	Sgr 2019- 03-09	Sgr 2019- 03-15	Sgr 2019- 03-22
Gd	ppb	0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ge	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Hf	ppb	0,2	0,2	<0,1	0,1	0,1	0,1	<0,1	<0,1	<0,1	0,1	0,1	<0,1	0,1	0,2	0,2	<0,1	<0,1	<0,1	<0,1	0,1	0,2	0,1	<0,1
Hg	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ho	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
In	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
K	ppm	52	94	62	71	125	103	97	102	108	85	86	119	158	114	98	98	86	7	73	65	52	63	51
La	ppb	0,1	<0,1	<0,1	0,1	0,1	<0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	0,1	<0,1
Li	ppb	21	<10	54	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	12	<10	<10
Lu	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Mg	ppm	70	84	44	51	58	45	42	27	42	34	42	38	48	40	35	37	39	4	32	36	31	37	31
Mn	ppb	826	766	1208	370	321	155	170	405	554	574	772	634	816	693	639	811	1025	32	832	1305	1026	1678	1640
Mo	ppb	0,6	0,6	<0,5	0,7	1	1,3	0,5	0,7	0,5	<0,5	<0,5	0,6	0,6	0,7	0,6	<0,5	<0,5	<0,5	0,5	0,5	<0,5	<0,5	<0,5
Na	ppm	40	147	85	99	164	128	119	118	141	104	142	168	298	156	123	119	117	8	81	57	40	51	40
Nb	ppb	1,4	1	0,8	0,6	1,2	0,6	0,4	0,1	<0,1	0,4	0,2	<0,1	<0,1	1	0,2	<0,1	<0,1	<0,1	0,6	0,7	0,2	0,2	<0,1
Nd	ppb	0,2	0,2	<0,1	<0,1	0,2	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Ni	ppb	232	224	97	67	70	53	55	69	107	97	146	124	335	163	136	150	248	172	208	421	385	535	547
P	ppb	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Pb	ppb	10	<5	10	9	9	7	7	6	12	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	8	7	11	<5
Pd	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Pr	ppb	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Pt	ppb	<0,1	0,1	0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1

		Sgr 2018- 07-24	Sgr 2018- 07-31	Sgr 2018- 08-07	Sgr 2018- 08-14	Sgr 2018- 08-21	Sgr 2018- 08-28	Sgr 2018- 09-04	Sgr 2018- 09-18	Sgr 2018- 09-25	Sgr 2018- 10-02	Sgr 2018- 10-09	Sgr 2018- 10-17	Sgr 2018- 10-24	Sgr 2018- 10-31	Sgr 2018- 11-06	Sgr 2018- 11-13	Sgr 2018- 11-21	Sgr 2018- 11-29	Sgr 2018- 12-06	Sgr 2019- 03-01	Sgr 2019- 03-09	Sgr 2019- 03-15	Sgr 2019- 03-22
Rb	ppb	13	15,7	12,4	12,2	24,5	15,8	14,5	9,1	13,9	15,1	13,3	14,1	17,7	23,1	14,5	14,7	13,6	11,2	13,9	16,1	12	13,1	10,8
Re	ppb	0,24	0,23	0,09	0,07	0,08	0,05	0,05	<0,04	0,07	0,07	0,08	<0,04	0,09	<0,04	0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	0,05
S	ppm	540	911	500	536	724	551	501	507	574	437	540	562	660	561	478	528	557	44	448	492	395	519	436
Sb	ppb	<0,5	<0,5	<0,5	<0,5	1,8	0,6	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	2	0,5	<0,5	<0,5	<0,5	0,6	1,4	<0,5	<0,5	<0,5
Sc	ppb	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Se	ppb	9,6	10,7	8,3	9,5	10,6	8,9	6,8	<5	8,2	7,2	7,4	8	6,8	<5	7,1	8,6	5,8	<5	5,4	11,1	10,6	9,5	9,4
Si	ppb	501	737	469	533	639	598	557	395	513	458	427	506	533	569	478	532	488	435	442	608	503	704	621
Sm	ppb	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Sn	ppb	0,3	<0,1	<0,1	<0,1	0,5	0,2	<0,1	<0,1	0,1	11,9	0,3	0,9	17	0,7	0,5	0,2	<0,1	<0,1	0,7	0,6	<0,1	1,1	0,4
Sr	ppb	38,8	48,3	34,8	34,7	52,5	37	29,7	30,9	32,9	30,2	34,5	35,4	46,3	35,2	27,1	29,9	35	28,8	25,9	28,5	26,4	32,3	25,1
Ta	ppb	0,2	0,3	0,2	0,2	0,2	0,1	0,1	0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	0,2	<0,1
Tb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Te	ppb	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,9	<0,5	<0,5	0,6
Th	ppb	0,4	0,3	0,2	<0,1	1,1	0,5	0,2	0,1	<0,1	0,5	0,3	0,3	<0,1	1,4	0,7	0,3	0,1	0,1	0,5	0,9	0,3	<0,1	<0,1
Tl	ppb	<0,1	<0,1	0,1	<0,1	0,2	0,2	<0,1	<0,1	0,1	0,3	0,1	0,1	0,2	0,2	0,2	<0,1	0,1	<0,1	0,2	0,2	0,2	0,1	0,1
Tm	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
U	ppb	0,1	0,2	0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2	0,3	0,2	0,2	0,2
V	ppb	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
W	ppb	0,6	0,1	0,1	0,2	0,9	0,2	0,4	<0,1	0,6	0,4	0,2	0,1	<0,1	1,3	0,5	0,2	0,2	0,1	0,5	0,9	0,4	0,1	<0,1
Y	ppb	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Yb	ppb	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
Zn	ppb	32	21	27	35	23	29	23	16	20	13	13	11	16	12	7	7	18	12	14	23	21	27	29

		Sgr 2018- 07-24	Sgr 2018- 07-31	Sgr 2018- 08-07	Sgr 2018- 08-14	Sgr 2018- 08-21	Sgr 2018- 08-28	Sgr 2018- 09-04	Sgr 2018- 09-18	Sgr 2018- 09-25	Sgr 2018- 10-02	Sgr 2018- 10-09	Sgr 2018- 10-17	Sgr 2018- 10-24	Sgr 2018- 10-31	Sgr 2018- 11-06	Sgr 2018- 11-13	Sgr 2018- 11-21	Sgr 2018- 11-29	Sgr 2018- 12-06	Sgr 2019- 03-01	Sgr 2019- 03-09	Sgr 2019- 03-15	Sgr 2019- 03-22
Zr	ppb	0,2	0,2	0,4	0,3	0,3	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2

5.1.6 Lakvatten

Ett rullförsök har utförts på utvalda prover av Graeme Campbell (2019), se också BILAGA A. Rullförsöket utfördes enligt MEND report 1.20.1 (2009) "Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials" kapitel 11. Gråberget har blandats med vatten i förhållande 1:2 och under försökets gång rullas provbehållaren för att uppnå en jämn blandning. Efter testet har vattnet analyserats. Resultaten redovisas i Tabell 17.

Ett prov från hängväggen sticker ut med väldigt höga halter av kadmium, bly, uran och zink. Det är sannolikt att provet har påverkats av lagringen. Generellt visar alla prover som har ett lägre pH högre halter av kobolt och nickel. Selen är särskild hög i malmproverna.

Tabell 17: Resultat från analys av lakvatten från rullförsök (GCA, 2019).

Parameter	Enhet	Hängvägg					Liggvägg					Gång			Malm			
		NUS12002 46-48	NUS12019 66, 17-68	NUS12008 73, 25-75	NUS12011 12-14	NUS12016 33, 4-35, 4	NUS12005 78, 7-81	NUS12017 53, 13-55	NUS12015 107-18, 35	NUS12003 38, 3-40	NUS12019 48-50	NUS12001 53-55	NUS12001 42, 25-44	NUS12018 79, 68-81, 8	NUS12005 54-56	NUS12014 30, 5-32, 5	NUS12002 65-67	NUS12017 83-85
Aciditet	mg CaCO ₃ /l	2,9	7,1	1234	1154	16,6	3,8	19	8,3	345	179	5,7	51,8	264	40,9	6,9	27,1	21,4
Tot Alk	mg CaCO ₃ /l	28	50	<2	<2	<2	24	170	6	<2	<2	30	<2	<2	20	12	151	<2
EC	mS/cm	0,27	1,16	4,94	5,05	1,2	0,77	3,07	0,97	3,27	2,79	1,4	0,99	2,02	1,91	0,94	2,77	1,65
pH		7,1	7,4	3,9	3,6	4,8	6,9	7,7	5,9	3,8	4,1	7,8	4,5	3,7	6,1	6,3	8,1	4,6
Ag	µg/l	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	0,1	<0,1	0,1	<0,1	0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1
Al	mg/l	0,13	0,01	6,92	179	0,31	0,01	0,12	<0,01	12,8	3,61	0,04	0,58	2,61	0,07	<0,01	0,15	1,02
As	µg/l	15	6	5	9	4	4	5	4	5	4	3	4	17	3	3	8	3
B	mg/l	0,08	0,03	<0,01	<0,01	0,06	0,05	<0,01	0,07	<0,01	<0,01	0,04	0,07	0,03	0,03	0,05	0,03	0,05
Ba	µg/l	31,1	13,3	1,9	14,3	44,9	32,7	8,9	54	9,5	6,2	16	63,7	5,3	61,8	72,7	19	31,9
Bi	µg/l	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	0,99	<0,05	<0,05	<0,05	<0,05	<0,05
Ca	mg/l	21,4	191	246	397	12	108	656	91	32	579	303	71,7	145	421	129	793	126
Cd	µg/l	<0,2	<0,2	352	2	0,7	<0,2	<0,2	<0,2	<0,2	0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
Cl	mg/l	5	8	5	5	6	10	12	14	11	3	10	6	4	17	6	8	3
Co	µg/l	<1	6	5097	7414	2712	44	63	234	2894	3022	<1	922	5927	315	688	297	760
Cr	mg/l	0,01	<0,01	<0,01	0,15	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	<0,01
Cu	mg/l	<0,01	<0,01	0,01	0,25	0,03	0,01	0,02	<0,01	0,06	0,09	<0,01	<0,01	0,83	<0,01	<0,01	0,03	0,03
F	mg/l	<0,1	<0,1	<0,1	<0,1	<0,1	0,7	<0,1	0,1	0,2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,2
Fe	mg/l	<0,01	<0,01	672	32	2,72	<0,01	0,57	1,3	110	68,8	0,01	20,8	99,3	11,8	0,91	0,44	2,87
Hg	µg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
K	mg/l	14,6	23,6	21,3	20	28,5	18,3	26,7	38,5	77	4,1	27,8	50,8	25,8	25,8	28,4	6,3	46,3

Parameter	Enhet	Hängvägg					Liggvägg					Gång			Malm			
		NUS12002 46-48	NUS12019 66,17-68	NUS12008 73,25-75	NUS12011 12-14	NUS12016 33,4-35,4	NUS12005 78,7-81	NUS12017 53,13-55	NUS12015 107-18,35	NUS12003 38,3-40	NUS12019 48-50	NUS12001 53-55	NUS12001 42,25-44	NUS12018 79,68-81,8	NUS12005 54-56	NUS12014 30,5-32,5	NUS12002 65-67	NUS12017 83-85
Mg	mg/l	7,36	35,9	639	579	72,2	21,14	187	42,6	279	124	14,07	45,36	150	43,9	32,1	26	149
Mn	mg/l	0,004	0,086	16,2	3,36	2,5	0,2	0,89	0,53	2,47	0,67	0,02	0,36	2,89	1,46	1,54	0,84	0,3
Mo	µg/l	1,2	1	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	1,8	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5
Na	mg/l	8,5	14,3	13,3	62,7	16	12,8	3,6	16,2	10,3	15,2	16,8	19,2	12	7,3	8,3	11,4	15,7
Ni	mg/l	<0,01	0,18	28,4	25,24	4,87	0,43	1,16	2,2	11,44	9,29	0,03	2,71	19,7	6,62	5,21	8,36	3,94
P	mg/l	<0,05	<0,05	0,61	<0,05	<0,05	<0,05	0,24	0,07	0,1	<0,05	<0,05	<0,05	0,08	<0,05	<0,05	<0,05	<0,05
Pb	µg/l	<5	<5	2584	20	<5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5	<5	<5
S	mg/l	30,7	192	1482	1385	220	128	664	169	719	637	272	175	402	434	163	614	321
Sb	µg/l	0,3	0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1
Se	µg/l	<5	23	14	31	13	7	10	18	12	8	<5	10	14	133	39	149	72
Si	mg/l	2,01	2,54	13,28	15,29	6,56	2,75	1,48	3,09	9,49	5,22	1,61	4,64	6,9	2,53	2,91	3,04	4,43
Sn	µg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sr	µg/l	52,9	226	51,8	46,5	69,9	59,6	314	160	62,5	207	294	60,3	43,9	107	49,9	268	52,8
Te	µg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Th	µg/l	<0,05	<0,05	<0,05	0,36	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	0,1	<0,05	<0,05	<0,05	<0,05
Tl	µg/l	<0,1	<0,1	<0,1	0,5	0,1	<0,1	<0,1	<0,1	0,1	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1
U	µg/l	0,24	0,47	92,4	13,6	1,19	<0,05	0,53	0,07	2,56	37,4	2,88	0,8	89,2	0,48	1,58	19,2	4,51
V	mg/l	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Zn	mg/l	<0,01	<0,01	23,8	0,42	0,13	<0,01	0,02	0,02	0,11	0,07	<0,01	0,05	0,05	0,02	0,03	0,02	0,04

5.2 Anrikningssand

5.2.1 Fysikaliska och geotekniska egenskaper

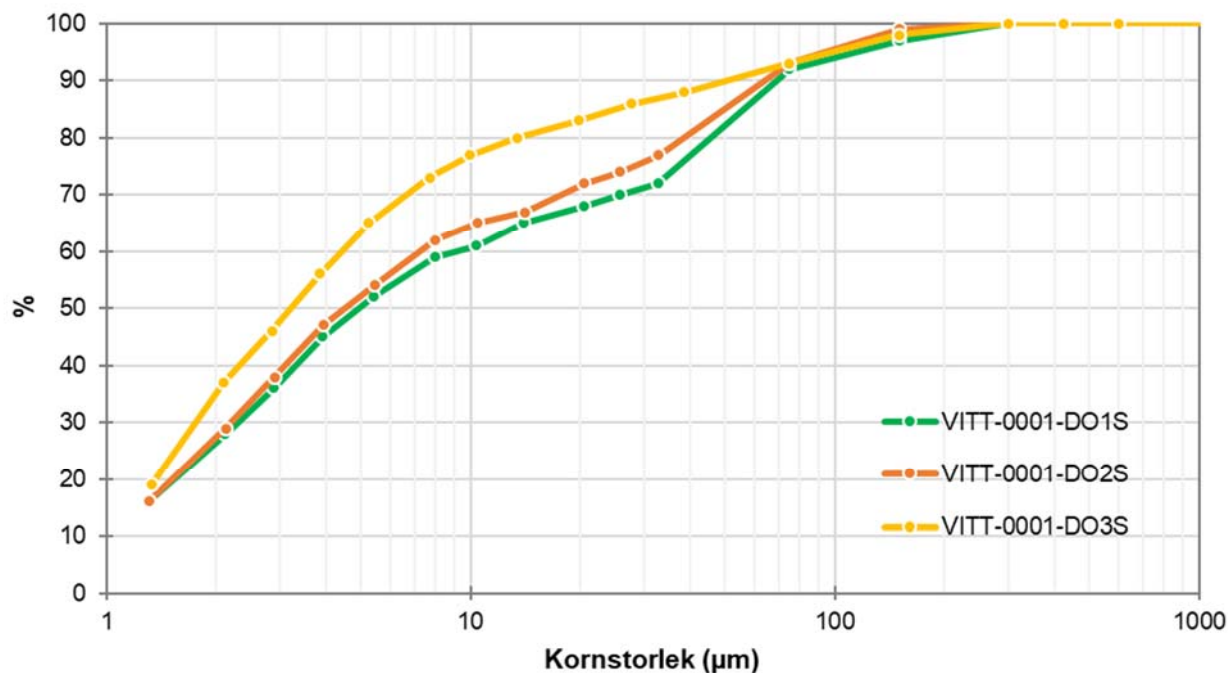
Anrikningssand är den restprodukt som uppstår när grafiten har utvunnits ur den krossade och malda malmen och utgörs av ett fint sandliknande material. Eftersom utvinningsprocessen planeras utföras i två steg uppkommer anrikningssand i två kornstorlekar där anrikningssanden från steg två är något finare. Tre prover av anrikningssand har analyserats av GTI Perth (2019) varav två av proverna kommer från primärflotationen (VITT-0001-DO1S och -DO2S) och ett kommer från sekundärflotationen (VITT-0001-DO3S). Kornstorleksfördelningen presenteras i Figur 16. En sammanfattning av resultaten från klassifikations- och konsolideringstester redovisas i Tabell 18 och Tabell 19. Resultaten återfinns i sin helhet i BILAGA C.

Tabell 18: Resultat för geotekniska egenskaper av anrikningssand (GTI, 2019). När bara ett värde redovisas för proverna från primärflotationen har de samma värde.

Parameter	Anrikningssand från steg ett (VITT-0001-DO1S och -DO2S)	Anrikningssand från steg två (VITT-0001-DO3S)
Vattenkvot	35,2 – 36,4 %	42,8 %
Kompaktdensitet	2,86 – 2,87 ton/m ³	2,79 ton/m ³
Flytgräns (Atterbergs konsistensgränser)	39 – 42 %	46 %
Plasticitetsgräns (Atterbergs konsistensgränser)	25 – 26 %	30 %
Plasticitetstal (Atterbergs konsistensgränser)	13 - 17	16
Krympgräns (linear)	4 %	4,5 %
Emerson klass	6	-
Krymp- & svällindex	1,9	-
pH	5,8	6,0

¹ LINEAR SHRINKAGE TEST OF SOIL (IS-2720-PART-20-1966)

² Shrink-swell index - https://www.newcastle.edu.au/_data/assets/pdf_file/0014/22820/12_The-shrink-swell-test.pdf



Figur 16: Kornstorleksfördelning i de tre analyserade prover anrikningssand från pilotanrikningen.

Tabell 19: Resultat för analys med ödometer och Rowe-cell för prov VITT-0001-DO1S (GTI, 2019).

Parameter	Ödometer (vertikaltryck 6 – 1600 kPa)	Rowe cell (vertikaltryck 10 – 650 kPa)
Portal	0,924 – 0,754	1,144 – 0,869
Konsolideringskoefficient	14,5 – 215,3 m ² /år	89,0 – 246,8 m ² /år
Kompression	2,03*10 ⁻³ – 2,47*10 ⁻⁵ m ² /kN	2,7*10 ⁻³ – 6,2*10 ⁻⁵ m ² /kN
Hydraulisk konduktivitet, mätt	9,16*10 ⁻⁹ – 1,65*10 ⁻⁹ m/s	2,5*10 ⁻⁸ – 1,2*10 ⁻⁸ m/s
Hydraulisk konduktivitet, beräknad	-	7,5*10 ⁻⁸ – 4,7*10 ⁻⁹ m/s
Kompressionsindex	0,108	-

5.2.2 Mineralogisk undersökning

Liksom gråbergsproverna har anrikningssanden undersökts med XRD (röntgendiffraktion) avseende mineralsammansättning. Undersökningen i sin helhet presenteras i Core metallurgy's rapport från 2019 (BILAGA D). Anrikningssand från första flotationssteget (primärflotation) har beteckningen "rougher tail" och anrikningssand från andra flotationssteget (sekundärflotation) betecknas med "cleaner tail".

Anrikningssanden från sekundärflotationen har blivit kontaminerat med zirkonium under malningen. Cirka en tredjedel av materialet i detta prov utgörs av kvarnmaterial (ceria-zirconia) som ackumulerades i provet under malningsprocessen. Den egentliga andelen av de andra mineralen blir då utspädd och är egentligen en cirka 30 % högre. Det påverkar dock inte indelningen i Tabell 20. De dominerade mineralen är plagioklas och biotit i sanden från första flotationssteget. I andra flotationssteget är det plagioklas, biotit, tremolit och kvarts (om man inte tar föroreningen med i beaktande). Typiska sulfidmineral är pyrit och magnetkis och i mindre omfattning kopparkis och zinkblände.

Tabell 20: Resultat av mineralogisk undersökning med XRD på anrikningssand från de två flotationsstegen. Indelningen för Cleaner Tail ändras inte om man räknar bort kontamineringen med ceria-zirconia.

Prov	Dominerande (>10 %)	Sparsam (1-10 %)	Påvisbar (<1 %)
Rougher tail	Biotit (33 %), plagioklas (23 %)	Pyrit, magnetkis, järnhydroxid, tremolit, albit, klorit, kvarts	Kopparkis, zinkblände, baryt, gips, brannerit, rutil, apatit, kaolinit, K-fältspat, titanit
Cleaner tail	Tremolit (13 %), biotit (17 %), plagioklas (18 %), kvarts (14 %), ceria-zirconia (35 %)	Magnetkis	Kopparkis, pyrit, zinkblände, gips, aluminiumhydroxid, järnhydroxid, rutil, apatit, albit, klorit, kaolinit, K-fältspat, titanit

5.2.3 Totalhalter

Totalhalterna analyserades bara på anrikningssand från primärflotationen 2019 av ALS. Analysrapporten bifogas i BILAGA E. Resultaten presenteras i Tabell 21 och jämförs med medelhalten i morän i Norrbotten (SGU, 2018). Jämförelse med halterna i moränen ger bara en indikation på möjligtvis förhöjda halter. Eftersom moränen analyserades med en annan metod är det möjligt att halterna i anrikningssanden överskattas jämförd med morän. Tydligt förhöjda är krom, koppar och nickel.

Tabell 21: Resultat för totalhaltsanalyser på anrikningssand från primärflotationen som uppkom under pilotanrikningen. Halterna jämförs med genomsnittliga halter i morän från Norrbotten (SGU, 2018). Gul markering när halten överskrider 5x morän.

Element	Enhet	Rougher tail	Morän	Element	Enhet	Rougher tail	Morän
Ag	ppm	0,03	0,039	Na	%	2,57	0,04
Al	%	6,64	1,19	Nb	ppm	5,8	4,1
As	ppm	7,2	2,4	Ni	ppm	258	12
Ba	ppm	540	57	P	ppm	390	970
Be	ppm	1,69		Pb	ppm	5,1	7
Bi	ppm	0,47	0,1	Rb	ppm	80,7	17
Ca	%	1,24	0,59	Re	ppm	0,035	0,0031
Cd	ppm	0,05	0,05	S	%	2,06	
Ce	ppm	79,9	81	Sb	ppm	0,28	0,2
Co	ppm	45	8	Sc	ppm	29,7	5
Cr	ppm	1620	28	Se	ppm	31	13
Cs	ppm	2,16	0,8	Sn	ppm	0,5	1,2
Cu	ppm	176	16	Sr	ppm	53,6	27
Fe	%	6,82	2,5	Ta	ppm	0,31	
Ga	ppm	19,8	5	Te	ppm	1,58	13
Ge	ppm	0,37		Th	ppm	7,29	8,1
Hf	ppm	7,7	0,4	Ti	%	0,52	0,24
Hg	ppm	0,012		Tl	ppm	0,47	0,1
In	ppm	0,023		U	ppm	6,4	2,1
K	%	1,86	0,15	V	ppm	295	49
La	ppm	32,5	35	W	ppm	0,7	0,4
Li	ppm	16,5	10	Y	ppm	21,2	20
Mg	%	3,13	0,43	Zn	ppm	38	32
Mn	ppm	254	282	Zr	ppm	300	15
Mo	ppm	3,73	0,5				

5.2.4 ABA-test

ABA-testet utfördes enbart på anrikningssand från primärflotationen på grund av kontamineringen av sanden vid malningsprocessen inför andra flotationssteget. Analysen utfördes i samband med totalhaltsanalysen 2019 av ALS. Resultaten presenteras i Tabell 22. Analysrapporten bifogas i BILAGA E.

Den höga andelen sulfidsvavel och den låga förmågan att neutralisera syra gör att anrikningssanden anses vara potentiellt syrabildande.

Tabell 22: Resultat för ABA-test utförd på anrikningssand från primärflotationen i testanrikning av Nunasvaaramalm.

Parameter	Enhet	Rougher tail	Parameter	Enhet	Rougher tail
total S	%	2,41	C oorg.	%	0,15
Sulfat-S	%	0,75	NP	kg CaCO ₃ /t	-5
Sulfid-S	%	1,66	AP	kg CaCO ₃ /t	51,9
total C	%	2,32	NPR		-0,1
C org.	%	2,17	NNP	kg CaCO ₃ /t	-57

5.2.5 Laktest – SS-EN 12457-3

En laktest enligt standard SS-EN 124578-3 har utförts på anrikningssanden av ALS 2019. Original analysrapporten finns i BILAGA E. Resultaten redovisas i Tabell 23 där de jämföras med mottagningskriterierna för utlakning från sådant avfall som deponeras på deponi för inert avfall (Naturvårdsverkets föreskrifter (NFS 2010:04) om deponering, kriterier och förfaranden för mottagning av avfall vid anläggningar för deponering av avfall).

Resultaten visar att de flesta ämnen lakar i begränsad omfattning vid en första kontakt med vatten. Det är dock oklart i vilken omfattning As, Cd, Pb och Sb lakar eftersom deras rapporteringsgräns ligger över kriteriet för inert avfall. Nickel och sulfat överskrider halterna för mottagning på inert deponi. Nickel lakar i en sådan omfattning att det inte klara kriteriet för mottagning på deponi för farligt avfall som ligger vid 40 mg/kg TS.

Tabell 23: Resultat från skakförsök på anrikningssand enligt SS-EN 12457-3. På grund av en förhöjd rapporteringsgräns är det oklart på vilken nivå vissa ämnen ligger. Resultaten jämförs med haltgränser för mottagning av inert avfall på deponi (NFS 2010:04). Gul markering där gränsen överskrids.

Parameter	Enhet	Rougher Tail		Enhet	Rougher Tail		NFS 2010:04
		L/S 2	L/S 10		L/S 2	L/S 10	
Ca	mg/l	97,5	9,86	mg/kg TS	195	226	
Fe	mg/l	42,2	5,68	mg/kg TS	84,4	110	
K	mg/l	90,6	19,6	mg/kg TS	181	299	
Mg	mg/l	94,5	9,26	mg/kg TS	189	217	
Na	mg/l	114	11,1	mg/kg TS	228	261	
Al	µg/l	4530	251	mg/kg TS	9,06	8,75	

Parameter	Enhet	Rougher Tail		Enhet	Rougher Tail		NFS 2010:04
		L/S 2	L/S 10		L/S 2	L/S 10	
As	µg/l	<1	<100	mg/kg TS	<0,002	<0,9	0,5
Ba	µg/l	78,4	68,3	mg/kg TS	0,16	0,7	20
Cd	µg/l	5,2	<20	mg/kg TS	0,01	<0,2	0,04
Co	µg/l	2820	326	mg/kg TS	5,64	6,89	
Cr	µg/l	23,2	<20	mg/kg TS	0,046	<0,2	0,5
Cu	µg/l	79,3	15,4	mg/kg TS	0,16	0,25	2
Hg	µg/l	<0,02	<0,02	mg/kg TS	<0,00004	<0,0002	0,01
Mn	µg/l	5590	541	mg/kg TS	11,2	12,8	
Mo	µg/l	<1	<20	mg/kg TS	<0,002	<0,2	0,5
Ni	µg/l	20300	2310	mg/kg TS	40,6	49,3	0,4
Pb	µg/l	0,71	<100	mg/kg TS	0,0014	<0,9	0,5
Sb	µg/l	<0,2	<100	mg/kg TS	<0,0004	<0,9	0,06
Se	µg/l	223	-	mg/kg TS	0,446	-	0,1
Zn	µg/l	973	120	mg/kg TS	1,95	2,44	4
pH		5	6,1				
Kond.	mS/m	204	30,6				
DOC	mg/l	6,94	1	mg/kg TS	13,9	18,7	500
Cl	mg/l	12,6	1,13	mg/kg TS	25,2	28	800
F	mg/l	1,65	<0,2	mg/kg TS	3,3	<4	10
SO ₄	mg/l	992	101	mg/kg TS	1980	2310	1000

5.2.6 Processvatten

Vid provanrikningen togs prover av processvattnet efter varje flotationssteg (Core, 2019). Resultaten från analyserade processvatten redovisas tillsammans med halter i ingående kranvatten i Tabell 24. Mer detaljerad beskrivs resultaten i BILAGA D. Vid anrikningsförsöken återcirkulerades i princip inget vatten varför det kan förväntas att halterna kan bli högre vid verklig drift.

Tabell 24: Resultat från processvattenanalysen för de två flotationsstegen i jämförelse med ingående kranvatten (Core, 2019).

Element	Enhet	Brisbane kranvatten	Rougher Tail	Cleaner Tail	Element	Enhet	Brisbane kranvatten	Rougher Tail	Cleaner Tail
Ag	mg/L	<0,1	0,9	1,4	Mo	mg/L	<0,3	2,7	4,1
Al	mg/L	<2,5	22,6	34,5	Na	mg/L	35,8	267	724

Element	Enhet	Brisbane kranvatten	Rougher Tail	Cleaner Tail	Element	Enhet	Brisbane kranvatten	Rougher Tail	Cleaner Tail
As	mg/L	<2,5	22,6	34,5	Ni	mg/L	<0,5	4,5	6,9
B	mg/L	<0,5	4,5	6,9	P	mg/L	<2,5	22,6	34,5
Ba	mg/L	<0,1	0,9	1,4	Pb	mg/L	<2,5	22,6	34,5
Be	mg/L	<0,1	0,9	1,4	S	mg/L	8,98	334	423
Bi	mg/L	<1	9	13,8	Sb	mg/L	<1	9	13,8
Ca	mg/L	23,1	176	326	Sc	mg/L	<0,1	0,9	1,4
Cd	mg/L	<0,1	0,9	1,4	Se	mg/L	<2,5	22,6	34,5
Co	mg/L	<0,1	0,9	1,4	Si	mg/L	<2,5	41,1	333
Cr	mg/L	<0,1	0,9	1,4	Sn	mg/L	<1	9	13,8
Cu	mg/L	<0,3	2,7	4,1	Sr	mg/L	<0,3	2,7	4,1
Fe	mg/L	<0,5	4,5	21	Te	mg/L	<2,5	22,6	34,5
Ga	mg/L	<2,5	22,6	34,5	Th	mg/L	<0,5	4,5	6,9
Ge	mg/L	<2,5	22,6	34,5	Ti	mg/L	<0,1	0,9	1,4
Hg	mg/L	<0,5	4,5	6,9	Tl	mg/L	<2,5	22,6	34,5
K	mg/L	3,9	145	128	U	mg/L	<2,5	22,6	34,5
La	mg/L	<0,1	0,9	1,4	V	mg/L	<2,5	22,6	34,5
Li	mg/L	5	45,1	69,1	W	mg/L	<1	9	13,8
Mg	mg/L	12,9	116	185	Zn	mg/L	<0,5	4,5	6,9
Mn	mg/L	<1	22,3	13,8	Zr	mg/L	<0,5	4,5	13,4

Processvattnet kommer att passera ett reningsverk innan vattnet släpps ut till recipienten. Vattnet behandlas med släckt kalk för att höja pH-värdet (upp till cirka pH 12). I

Tabell 25 jämförs processvattnet från de två flotationsstegen med behandlat processvatten och gränsvärden för dricksvatten. Sulfathalten i processvattnet från första flotationssteget är fortfarande något förhöjd efter reningen jämfört med gränsvärden för dricksvatten. De flesta lösta metaller svarar bra på behandlingen och det neutraliserade processvattnet har betydligt lägre halter. Halten av mangan, nickel, krom, järn, aluminium, arsenik, kobolt och koppar minskade särskilt.

Tabell 25: Resultat från analys av processvatten före och efter reningen (Core, 2019). Som jämförelse är gränsvärdena för dricksvatten med i tabellen. Gul markering där gränsvärdet överskrids.

Parameter	Enhet	Processvatten steg 1	Renat processvatten steg 1	Processvatten steg 2	Renat processvatten steg 2	Gränsvärde för dricksvatten (SLVF 2017:2)
pH		6,74	7,68	7,98	11,8	6,5-10,5
Kond.	µS/cm	462	446	565	1490	2500
Tot. Alk.	mg/L CaCO ₃	25	20	79	334	
Ca	mg/L	21	83	26	57	100
Mg	mg/L	15	<1	16	<1	30
Na	mg/L	35	39	61	63	100
K	mg/L	15	15	8	9	
Fe	mg/L	0,09	<0,05	2,4	<0,05	0,2
Al	mg/L	<0,01	0,01	1,28	<0,01	0,1
As	mg/L	<0,001	<0,001	0,005	<0,001	0,01
Cd	mg/L	<0,0001	<0,0001	0,0004	<0,0001	0,005
Cr	mg/L	0,014	<0,001	0,004	0,002	0,05
Cu	mg/L	0,004	0,009	0,019	0,006	0,2-2
Co	mg/L	0,005	<0,001	0,003	<0,001	
Ni	mg/L	0,056	<0,001	0,02	<0,001	0,02
Pb	mg/L	<0,001	<0,001	0,006	0,004	0,01
Zn	mg/L	0,04	<0,005	0,017	<0,005	
Mn	mg/L	2,57	0,003	0,085	<0,001	0,05
Mo	mg/L	<0,001	<0,001	0,002	0,004	
Se	mg/L	<0,01	<0,01	<0,01	<0,01	0,01
Te	mg/L	<0,005	<0,005	<0,005	<0,005	
Tl	mg/L	<0,001	<0,001	<0,001	<0,001	
U	mg/L	<0,001	<0,001	<0,001	<0,001	
Hg	mg/L	<0,0001	<0,0001	<0,0001	<0,0001	0,001
Cl	mg/L	42	30	57	39	100
SO ₄	mg/L	105	106	88	94	100
P	mg/L	<0,01	<0,01	0,04	0,02	

5.3 Slam från vattenrening

För vattenreningen används släckt kalk och en mindre mängd metallsulfat för att justera pH-värdet och för att fälla ut metaller. I Tabell 26 redovisas totalhalterna för utfällningsprodukten som bildas i samband med reningen jämfört med genomsnittliga halter i morän i Norrbotten (SGU, 2018). Här har de två typen anrikningssand testats separat (Core, 2019). Under produktionen kommer dock slammet härstamma från en reningsanläggning där processvatten från båda flotationsstegen kommer att sambehandlas och halterna kommer troligen ligga emellan de här presenterade halterna. Resultaten i sin helhet presenteras i BILAGA D.

Tabell 26: Resultat för totalhalter av slammet som uppkom under testreningen av vattnet som uppkom under provanrikningen från de två flotationsstegen och för kalken som användes i processen (Core, 2019). Halterna jämförs med morän (medelvärde för Norrbotten, SGU, 2018). Gul markering där 5x moränhalt överskrids. Rödmarkerade värden överskrider analysens övre rapporteringsgräns och de förhöjda halterna kommer från kontaminering vid malningsprocessen.

Parameter	Enhet	Rougher Tails slam	Cleaner Tails slam	Tillsatt kalk	Medelhalt morän
Ag	ppm	0,28	0,02		0,039
Al	ppm	2100	5600	958	11907
As	ppm	29,8	5,6		2,4
Ba	ppm	30	30		57
Be	ppm	0,11	0,28		
Bi	ppm	1,29	0,4		0,1
Ca	ppm	301000	289000	499600	5903
Cd	ppm	1,27	0,79		0,05
Ce	ppm	8,79	>500		81
Co	ppm	16,9	14		8
Cr	ppm	12	16	8,28	28
Cs	ppm	0,14	0,18		0,8
Cu	ppm	639	98,8		16
Fe	ppm	5400	8200	850	24996
Ga	ppm	0,55	3,05		5
Ge	ppm	<0,05	<0,05		
Hf	ppm	0,5	84,1		0,4
In	ppm	0,024	0,006		
K	ppm	500	700	307	1497
La	ppm	3,5	4,9	7,87	35
Li	ppm	2,7	2,9		10
Mg	ppm	46300	34900	2394	4326

Parameter	Enhet	Rougher Tails slam	Cleaner Tails slam	Tillsatt kalk	Medelhalt morän
Mn	ppm	4020	570	224	282
Mo	ppm	1,37	0,49		0,5
Na	ppm	400	2000		399
Nb	ppm	0,6	0,8		4,1
Ni	ppm	95,7	45,4		12
P	ppm	690	530	380	970
Pb	ppm	22,5	17,9		7
Rb	ppm	1,4	2,2		17
Re	ppm	0,002	<0,002		
S	ppm	2200	1000		31
Sb	ppm	2,83	0,67		0,2
Sc	ppm	0,7	1,2		5
Se	ppm	2	3		
Sn	ppm	0,4	<0,2		1,2
Sr	ppm	145	138	193	27
Ta	ppm	0,07	0,05		
Te	ppm	0,09	0,25		13
Th	ppm	0,32	0,73		8,1
Ti	ppm	190	370	7,48	2369
Tl	ppm	0,12	0,04		0,1
U	ppm	0,7	2		2,1
V	ppm	5	12		49
W	ppm	0,8	0,2		0,4
Y	ppm	9,3	10,2		20
Zn	ppm	140	82		32
Zr	ppm	22,4	>500		15

5.4 Avrymningsmassor (morän)

Avrymningsmassorna betraktas inte som utvinningsavfall. Eftersom materialet kommer att användas för olika ändamål (t.ex. anläggningsarbeten och efterbehandling) har en karakterisering utförts. En utförlig beskrivning om moränprovtagning finns i rapporten *Moränkartläggning - Nunasvaara* (Golder, 2019) som är en bilaga till miljökonsekvensbeskrivningen i ansökan (Bilaga B2).

2018 grävdes tre provgropar med grävmaskin där material för geotekniska och geokemiska analyser togs ut. Tre samlingsprover från provgroparna analyserades. Utöver analyserades också två moränprover från området av ett äldre gråbergssupplag.

Moränjorden klassas dels som sandig-siltig dels som siltig-sandig. Det förekommer även sandig-grusig jord. Permeabiliteten av den testade moränen ligger mellan $3,0 \times 10^{-8}$ och $1,2 \times 10^{-7}$ m/s i genomsnitt. Resultaten från kemiska analyser presenteras nedan, totalhalter för 5 prover i Tabell 27, resultat från ABA-test i Tabell 28 och resultat från lakttest enligt SS-EN 12457-3 i Tabell 29.

Resultaten visar att halterna i moränen är delvis förhöjda jämfört med genomsnittlig morän i Norrbotten (SGU, 2018). Vid en första kontakt med vatten lakar moränen bara obetydligt. Moränens sulfidsvavelandel är mycket låg. I ABA-testet användes därför istället för sulfidsvavelhalten den totala svavelhalten för att beräkna syrabildande potential och resultaten överskatta då den verkliga syrabildande potentialen. Den låga sulfidsvavelhalten (<0,01 vikt-%) gör att materialet kan betraktas som inert.

Tabell 27: Resultat från totalhaltsanalysen på jordprover från det planerade verksamhetsområdet. Gul markering där halten överskrider 5 gånger halten av halten i genomsnittlig morän i Norrbotten (SGU, 2018).

Element	Enhet	18GA01TP Sammanlag- ning 4-8	18GA02TP Sammanlag- ning 2-4	18GA02TP Sammanlag- ning 5-7	Ytjord Provbrytning 0-5 cm	Äldre provbrytning 5-20 cm	Medel- halt morän
Ag	ppm	0,069	0,012	<0,002	0,15	0,01	0,039
Al	%	7,31	7,95	7,68	5,28	6,72	1,19
As	ppm	0,11	1,09	1,06	3,33	0,76	2,4
Ba	ppm	291	680	690	134	194	57
Be	ppm	0,94	1,56	1,54	0,51	0,79	
Bi	ppm	0,044	0,045	0,066	0,12	0,038	0,1
Ca	%	3,18	3,57	3,07	2,88	4,54	0,59
Cd	ppm	0,61	0,038	0,04	0,13	0,037	0,05
Ce	ppm	52,5	66,4	63,7	25,2	30,4	81
Co	ppm	138	22,8	20,5	21,6	25,1	8
Cr	ppm	58,1	84,3	82,2	117	81,8	28
Cs	ppm	3,45	0,66	0,56	1,99	1,28	0,8
Cu	ppm	623	77,2	49,7	257	53,2	16
Fe	%	7,22	5,39	5,7	10,9	8,64	2,5
Ga	ppm	18,1	18,2	17	13,6	19,3	5

Element	Enhet	18GA01TP Sammanlag- ning 4-8	18GA02TP Sammanlag- ning 2-4	18GA02TP Sammanlag- ning 5-7	Ytjord Provbrytning 0-5 cm	Äldre provbrytning 5-20 cm	Medel- halt morän
Ge	ppm	0,11	0,13	0,12	0,13	0,09	
Hf	ppm	2,63	2,42	2,36	1,32	1,94	0,4
In	ppm	0,078	0,057	0,056	0,041	0,076	
K	%	1,76	1,91	1,94	0,5	0,69	0,15
La	ppm	26,5	32,3	31,8	10,4	14,1	35
Li	ppm	16,9	8,2	7,6	4,3	3,2	10
Mg	%	3,69	2,09	1,96	2,83	3,37	0,43
Mn	ppm	943	801	666	1000	728	282
Mo	ppm	3,8	0,59	0,54	0,78	0,76	0,5
Na	%	2,97	3,18	3,34	2,35	3,64	0,04
Nb	ppm	9,45	7,86	7,71	5,49	8,12	4,1
Ni	ppm	165	44,1	47,9	39,9	42,1	12
P	%	0,064	0,081	0,081	0,083	0,041	0,097
Pb	ppm	6,88	6,88	5,19	12,2	15,1	7
Rb	ppm	72	61,6	58,8	26,4	30,5	17
Re	ppm	0,003	<0,002	<0,002	0,01	<0,002	
S	%	0,01	0,01	0,01	0,33	0,15	0,0031
Sb	ppm	0,1	0,12	0,14	0,19	0,09	0,2
Sc	ppm	28,9	21	20,5	28,7	30,3	5
Se	ppm	1,2	<0,2	<0,2	17,8	3,4	
Sn	ppm	0,92	1,2	1,23	0,74	1,11	1,2
Sr	ppm	125	262	289	92,2	155	27
Ta	ppm	0,61	0,52	0,5	0,34	0,5	
Te	ppm	1,24	0,06	<0,04	0,28	0,06	13
Th	ppm	1,8	4,54	5,76	7,48	2,5	8,1
Ti	%	0,92	0,49	0,46	0,58	0,79	0,24
Tl	ppm	0,49	0,19	0,16	0,079	0,055	0,1
U	ppm	1,95	1,31	1,37	2,85	0,86	2,1
V	ppm	223	140	144	207	218	49

Element	Enhet	18GA01TP Sammanlag- ning 4-8	18GA02TP Sammanlag- ning 2-4	18GA02TP Sammanlag- ning 5-7	Ytjord Provbrytning 0-5 cm	Äldre provbrytning 5-20 cm	Medel- halt morän
W	ppm	0,71	0,55	0,56	0,21	0,28	0,4
Y	ppm	38,5	23,8	23,3	17,3	15,8	20
Zn	ppm	185	37	35,4	54	36	32
Zr	ppm	96,6	87,2	87,4	40,8	71,4	15

Tabell 28: Resultat från ABA-test på jordprover.

Parameter	Enhet	18GA01TP sammanlag- ning 4-8	18GA02TP sammanlag- ning 2-4	18GA02TP sammanlag- ning 5-7	Ytjord Provbrytning 0-5cm	Äldre Provbrytning 5-20cm
total S	%	0,01	0,01	0,01	0,3	0,13
Sulfat-S	%	0,04	<0,01	<0,01	0,34	0,14
Sulfid-S	%	<0,01	0,01	0,01	<0,01	<0,01
total C	%	0,12	0,13	0,11	9,54	1,25
C org.	%	0,05	0,07	0,02	9,25	1,12
C oorg.	%	0,07	0,06	0,09	0,29	0,13
NP	kg CaCO ₃ /t	1	0	4	-30	-12
AP	kg CaCO ₃ /t	<0,3	<0,3	<0,3	<0,3	<0,3
AP Max ¹	kg CaCO ₃ /t	0,3	0,3	0,3	9,4	4,1
NPR		3,3	0	13,3	-3,2	-2,9
NNP	kg CaCO ₃ /t	0,7	-0,3	3,7	-39,4	-16,1

¹ baserat på total S

Tabell 29: Resultat för laktest enligt SS-EN 12457-3 för tre moränprover jämfört med haltgränser för mottagning på deponier (NFS 2010:04).

	Enhet	18GA01TP sammanslagning 4-8	18GA02TP sammanslagning 2-4	18GA02TP sammanslagning 5-7	NFS 2010:04	
					Inert	Icke-FA
As	mg/kg TS	<0,005	<0,005	<0,005	0,5	2
Ba	mg/kg TS	0,028	0,057	0,11	20	100
Cd	mg/kg TS	<0,0005	<0,0005	<0,0005	0,04	1
Cr	mg/kg TS	0,023	0,014	0,017	0,5	10
Cu	mg/kg TS	0,55	0,1	0,14	2	50
Hg	mg/kg TS	<0,0002	<0,0002	<0,0002	0,01	0,2
Mo	mg/kg TS	0,0156	<0,005	<0,005	0,5	10
Ni	mg/kg TS	0,19	0,023	0,037	0,4	10
Pb	mg/kg TS	0,0039	0,0035	0,0072	0,5	10
Sb	mg/kg TS	<0,001	<0,001	<0,001	0,06	0,7
Se	mg/kg TS	<0,03	<0,03	<0,03	0,1	0,5
Zn	mg/kg TS	0,1	<0,02	0,022	4	50
DOC	mg/kg TS	21,2	24,6	15,6	500	800
Cl	mg/kg TS	<10	<10	<10	800	15000
F	mg/kg TS	<2	<2	<2	10	
SO ₄	mg/kg TS	<50	<50	<50	1000	20000
pH	-	8,4	8,2	8,1	-	-
Kond.	mS/m	<1	<1	<1	-	-

6.0 KLASSIFICERING AV UTVINNINGSAVFALL

Utvinningsavfallsförordningen (SFS 2013:319) föreskriver att allt utvinningsavfall skall klassificeras i enlighet med bilaga 4 till avfallsförordning (SFS 2011:927). Vid klassificeringen skall särskild hänsyn tas till avfallets eventuellt farliga egenskaper. Vid bedömningen har förordning 1357/2014 och 2017/997 tillämpats för att bedöma om utvinningsavfallens innehåll av farliga ämnen är sådana att avfallen ska betraktas som farligt avfall. Bedömningen har gjorts med stöd av Avfall Sveriges rapport 2019:01 *"Uppdaterade bedömningsgrunder för förorenade massor"*. I förordningarna anges vilka egenskaper (HP1 till HP15) och koncentrationsgränser som gör att avfall skall betraktas som farligt avfall.

6.1 Klassificering av gråberg

Gråberg från brytning av icke-metallhaltig malm klassificeras alltid som

- "01 01 02 - avfall från brytning av icke-metallhaltiga mineral"

Ovanstående klassning av gråberg gäller oaktat om gråberget är potentiellt syrabildande eller inte samt oaktat gråbergets innehåll av olika ämnen, t.ex. metaller. Orsaken till detta är att gråberg har en fast ingång som icke farligt avfall i avfallslistan.

I Tabell 30 redovisas totalhalter av metaller i gråberg. Metallerna som redovisas har valts på grund av att de finns listade som farliga ämnen i Avfall Sveriges rapport 2019:01 och bedöms vara viktiga för klassificeringen.

Tabell 30: Klassning av gråberg från Nunasvaara Södra baserat på totalhalter enligt förordningen 1357/2014. Halterna är i mg/kg TS. Högsta värdet för varje ämne är markerat med gul. Halterna jämförs med gränsvärdet för farligt avfall (1357/2014).

Parameter	Faroklass	Farangivelse kod	NUS12002 46,00-48,00	NUS12006 16,00-18,00	NUS12008 45,00-47,00	NUS12008 73,25-75,00	NUS12011 12,00-14,00	NUS12016 31,40-33,40	NUS12016 33,40-35,40	NUS12019 66,17-68,00	NUS12019 74,00-76,00	NUS12014 59,90-61,18	NUS12003 38,30-40,00	NUS12005 78,70-81,00	NUS12007 104,00-106,00	NUS12015 107,00-108,35	NUS12017 53,13-55,00	NUS12019 38,00-40,00	NUS12019 48,00-50,00	NUS12014 68,00-70,00	NUS12001 42,25-44,00	NUS12001 53,00-55,00	NUS12006 38,50-40,50	NUS12006 40,50-42,85	NUS12018 79,68-81,80	NUS12019 44,30-46,00	FA
As	HP6 HP7 HP8 HP14	H300 H350 H314 H400 H410	0	6	0	1,7	1,6	6,6	181	0,6	0,5	2,6	0,9	0,6	6	1,2	2,8	0,2	1,2	0,8	0	0	1,5	1	0,5	0,5	1000
Cd	HP5 HP6 HP7 HP11 HP14	H372 H302 H312 H332 H350 H340 H400 H410	0	0,02	0	18,8	0,03	0,12	0	0	0	0	0	0,02	0,04	0	0	0	0	0	0	0,02	0,02	0	0	0	1000
Co	HP6 HP7 HP10 HP11 HP13 HP14	H302 H350 H360F H341 H317 H334 H400 H410	50,9	49,5	50,9	153	48,3	227	255	31,1	55,6	48,5	41,5	39,6	40,3	37,5	378	41,4	255	43,9	41,6	55,9	38,1	33,6	137,5	37,3	1000
Cr	HP7 HP13 HP14	H350 H317 H400 H410	268	221	209	98	180	237	210	187	173	127	103	42	235	123	158	96	88	68	103	85	24	25	176	97	10000
Cu	HP4 HP6 HP14	H318 H302 H330 H400 H410	90,5	194	112	1,6	125	1,56	1,18	327	153	380	274	385	67,6	354	5,91	68,6	1,68	175	309	249	30,2	48	1,72	75,5	2500
Hg	HP5 HP6 HP14	H373 H300 H310 H330 H400 H410	0,004	0,003	0,001	0,001	<0,001	<0,001	<0,001	0,002	0,003	0,003	0,009	0,005	0,002	0,002	<0,001	0,002	<0,001	0,006	0,007	0,004	0,002	<0,001	<0,001	<0,001	50
Mo	HP4 HP5 HP7	H319 H335 H351	0,34	0,73	0,55	38	0,15	2,15	12,6	5,72	0,83	2	0,98	3,14	0,83	0,84	1,68	0,99	38,6	0,67	1,67	0,97	0,69	0,68	33,7	0,28	10000

Parameter	Farklass	Faraangivelse kod	NUS12002 46,00-48,00	NUS12006 16,00-18,00	NUS12008 45,00-47,00	NUS12008 73,25-75,00	NUS12011 12,00-14,00	NUS12016 31,40-33,40	NUS12016 33,40-35,40	NUS12019 66,17-68,00	NUS12019 74,00-76,00	NUS12014 59,90-61,18	NUS12003 38,30-40,00	NUS12005 78,70-81,00	NUS12007 104,00-106,00	NUS12015 107,00-108,35	NUS12017 53,13-55,00	NUS12019 38,00-40,00	NUS12019 48,00-50,00	NUS12014 68,00-70,00	NUS12001 42,25-44,00	NUS12001 53,00-55,00	NUS12006 38,50-40,50	NUS12006 40,50-42,85	NUS12018 79,68-81,80	NUS12019 44,30-46,00	FA
Ni	HP4 HP5 HP6 HP7 HP10 HP11 HP13 HP14	H315 H372 H302 H332 H350i H360D H341 H317 H334 H400 H410	166	164	127	668	130	335	232	112	116	174	103	79,9	145	159	1,16	84,3	414	69,8	100,5	83,7	14,6	21,2	543	115,5	1000
Pb	HP5 HP6 HP10 HP14	H373 H332 H302 H360D H400 H410	0,7	1,2	0,7	3,04	6,4	8,4	5	0,9	0,3	1,5	0,6	3,1	1,1	0,9	1,7	0,8	2,7	0,7	1,2	1,4	1,2	1,3	3,6	0,3	2500
Sb	HP7	H351	0	0,22	0,06	0,18	0,08	0,37	0,25	0	0,05	0,19	0	0,16	0,12	0,17	0,13	0,1	0	0,24	0	0	0,4	0,38	0	0,06	10000
Zn	HP14	H400 H410	38	44	60	6,12	52	58	8	3	26	7	2	9	68	7	8	24	0	24	0	3	83	66	9	7	2500

I Tabell 30 står även metallernas egenskaper (HP1 till HP15) och faroangivelsekoder som finns listade i rapport 2019:01 samt gränsen för farligt avfall enligt förordning 1357/2014.

Metallhalterna i gråberget är generellt låga och inga värden överskrider gränsen för farligt avfall.

För vissa farliga egenskaper (HP4, HP5 (faroangivelsekod H304), HP6, HP8, HP10 och HP14) krävs en summering av alla förekommande ämnen som har klassats i samma faroklass (faroangivelsekod). Summeringen innebär att ett avfall innehållande flera olika ämnen kan klassificeras som farligt avfall trots att halten av varje enskilt ämne underskrider respektive gräns för farligt avfall. Vid summeringen ska endast de ämnen vars enskilda koncentration överskrider gränsvärde för beaktande tas med i beräkningen. Koncentrationsgränserna och gränsvärde för beaktande vid summering varierar beroende på faroangivelsekod enligt Tabell 31.

Inget ämne i gråberget överskrider gränsvärdet för beaktande och en summering av ämnen i samma faroklass behöver då inte göras.

Tabell 31: Farliga egenskaper som kräver summering av förekommande ämnen i samma faroklass.

Egenskap	Faroangivelsekod	Koncentrationsgräns (%)	Summering av flera ämnen	Gränsvärde för beaktande (%)
HP 4 Irriterande - hudirritation och ögonskador	H314	1	Ja	1
	H315	20	Ja	1
	H319			1
	H318	10	Ja	1
HP 5 Aspirationstoxicitet	H304	10	Ja	Nej
HP 6 Akut toxicitet	H300	0,1	Ja	0,1
	H300	0,25	Ja	0,1
	H301	5	Ja	0,1
	H302	25	Ja	1
	H310	0,25	Ja	0,1
	H310	2,5	Ja	0,1
	H311	15	Ja	0,1
	H312	55	Ja	1
	H330	0,1	Ja	0,1
	H330	0,5	Ja	0,1
	H331	3,5	Ja	0,1
	H332	22,5	Ja	1
HP 8 Frätande	H314	5	Ja	1
HP 14 Ekotoxiskt	H400	25	Ja	0,1
	H410	0,25		0,1

Egenskap	Faroangivelse-kod	Koncentrations-gräns (%)	Summering av flera ämnen	Gränsvärde för beaktande (%)
	H411	2,5	Ja. Summering över olika faroklass kategorier	1
	H412	25		1
	H413	25		1
	H420	0,1	Nej	

6.2 Klassificering av anrikningssand och slam

Genomförda karakteriseringar av anrikningssand och utvärderingen av dess egenskaper visar att anrikningssanden enligt avfallsförordningen skall klassas i kapitel "Avfall från prospektering, ovan- och underjordsbrytning samt fysikalisk och kemisk behandling av mineral " och underkapitel "Avfall från fysikalisk och kemisk behandling av icke-metallhaltiga mineral" som:

- "01 04 99 annat avfall än det som anges i 01 04 07* -01 04 13"

Inga halter i anrikningssanden överskrider gränsvärdet för farligt avfall (Tabell 32). Inte heller överskrider gränsvärdena för beaktande och en summering av ämnen i samma faroklass enligt Tabell 31 behöver då inte göras.

Slammet som uppkommer vid vattenreningen är ett avfall som klassas som:

- "01 03 06 annat gruvavfall än det som anges i 01 03 04 och 01 03 05. (Förordning 2015:27)"

Ingången i avfallsförordningen (2011:927) för slammet som har valts här grundas på att det finns en viss andel metallhaltiga mineral (även om det handlar om ett avfall som indirekt har sitt ursprung i utvinning av icke-metallhaltiga mineral).

Ingen halt i slammet överskrider gränsen för farligt avfall. Inte heller överskrider gränsvärdena för beaktande och en summering behöver då inte göras.

Tabell 32: Klassning av anrikningssand och slam

Parameter	Faroklass	Faroangivelsekod	Rougher tail	Slam 1	Slam 2	FA-gräns
As	HP6 HP7 HP8 HP14	H300 H350 H314 H400 H410	7,2	16,5	4,4	1000
Ba	HP6	H301 H332	540	<10	10	50000
Cd	HP5 HP6 HP7 HP11 HP14	H372 H302 H312 H332 H350 H340 H400 H410	0,05	1,63	0,43	1000

Parameter	Faroklass	Faroangivelsekod	Rougher tail	Slam 1	Slam 2	FA-gräns
Co	HP6 HP7 HP10 HP11 HP13 HP14	H302 H350i H360F H341 H317 H334 H400 H410	45	50,9	2,6	1000
Cr	HP7 HP13 HP14	H350i H317 H400 H410	1620	104	27	10000
Cu	HP4 HP6 HP14	H318 H302 H330 H400 H410	176	805	40,6	2500
Hg	HP5 HP6 HP14	H373 H300 H310 H330 H400 H410	0,012	0,022	0,031	50
Mo	HP4 HP5 HP7	H319 H335 H351	3,73	29,6	1,45	10000
Ni	HP4 HP5 HP6 HP7 HP10 HP11 HP13 HP14	H315 H372 H302 H332 H350i H360D H341 H317 H334 H400 H410	258	25,2	269	1000
Pb	HP5 HP6 HP10 HP14	H373 H332 H302 H360D H400 H410	5,1	11,8	66,9	2500
Sb	HP7	H351	0,28	0,94	0,48	10000
V	HP5 HP6 HP10 HP11 HP14	H372 H335 H302 H332 H361d H341 H411	295	11	81	10000
Zn	HP14	H400 H410	38	89	514	2500

6.3 Inert avfall – bedömning enligt utvinningsavfallsförordningen

Utöver klassificeringen enligt avfallsförordningen har gjorts en bedömning i enlighet med 6 § utvinningsavfallsförordningen (2013:319) huruvida gråberget, anrikningssanden och slammet som uppkommer vid brytning och anrikning samt vattenrening i Nunasvaara Södra går att betrakta som inert avfall.

Med inert avfall enligt utvinningsförordningen anses vara avfall som bland annat

- Inte i någon betydande grad kan sönderfalla eller lösas upp eller annars förändras på något betydande sätt som kan orsaka skada på människors hälsa eller miljön,
- Inte innehåller mer än 0,1 vikt-% sulfidsvavel eller 1 vikt-% sulfidsvavel om neutraliseringspotentialkvoten (NRP) är större än 3.

Resultaten från fuktkammarförsöket på gråbergsmaterial antyder att materialet kommer vara syrabildande och som en följd av detta laka ut metaller. Skakförsök på anrikningssanden visade att materialet lakar nickel i högre omfattning. Slammet innehåller hydroxider som kunde lösas upp och frigöra metaller om pH sjunker. I sin helhet uppfylla utvinningsavfallet inte kriteriet för inert utvinningsavfall enligt 6 § p. 1 utvinningsavfallsförordningen.

Sulfidsvavelinnehållet ligger i nästan alla gråbergsprover över 0,1 vikt-% och de flesta gråbergsprover överstiger till och med 1 vikt-% och kan därmed inte betraktas som inert avfall. Anrikningssandens sulfidsvavelhalt överstiger också 1 vikt-% och är därmed inte att betrakta som inert avfall. Slammets sulfidsvavelhalt har inte bestämts. I sin helhet uppfylla utvinningsavfallet inte kriteriet för inert utvinningsavfall enligt 6 § p. 2 utvinningsavfallsförordningen.

I sin helhet uppfylla utvinningsavfallet kriteriet för inert utvinningsavfall enligt 6 § p. 3 utvinningsavfallsförordningen att den riskera självantända eller kan brinna.

Några metaller överstiger genomsnittliga halten i morän i Norrbotten mer än fem gånger som kan tydas som att materialet kunde utgöra en risk för människors hälsa och miljön. Medelhalten av ämnen i morän från Norrbotten skiljer sig inte väsentligt från nationella bakgrundshalten i morän. För många ämnen är halten i morän från Norrbotten något lägre. Ämnen i fråga är främst koppar, kadmium, kobolt, krom, bly, zink, molybden och vanadin. Samma ämnen är delvis förhöjda i anrikningssanden och i slammet. I sin helhet uppfylla utvinningsavfallet inte kriteriet för inert utvinningsavfall enligt 6 § p. 4 utvinningsavfallsförordningen.

I sin helhet uppfylla utvinningsavfallet kriteriet för inert utvinningsavfall enligt 6 § p. 3 utvinningsavfallsförordningen eftersom det är i allt väsentligt fritt av sådana ämnen som används vid utvinning eller bearbetning och kan skada människors hälsa eller miljön enligt 6 § p. 5.

Således går varken gråberg, anrikningssand eller slam att betrakta som ett inert avfall enligt utvinningsavfallsförordningen.

7.0 REFERENSER

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BILAGA A

**Nunasvaara South Deposit:
Geochemical assessment of mine
waste and ore samples –
Implications for mine waste
management**

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1716

COMPANY: Talga Resources Ltd
ATTENTION: Peter French
FROM: Graeme Campbell
SUBJECT: Nunasvaara South Deposit: Geochemical Assessment of
Mine-Waste and Ore Samples – Implications for Mine-
Waste Management
NO. PAGES (including this page): 82 DATE: 12th January 2018

Peter,

Testwork results are presented in **Tables 1-4**, and shown on **Figures 1-2**.

Photographs of the samples submitted for testing, and various testing procedures, are shown on **Plates 1-9**.

Details of the samples selected for testing, as well as background information for the Project, are presented in **Attachment I**.

Copies of the laboratory-reports are presented in **Attachment II**.

1.0 SAMPLES AND TESTING

1.1 History

The 32 samples provided for testing correspond to:

- 10 samples of Mafic-Tuff (Vtf) waste from the Hangingwall
- 8 samples Gabbro/Dolerite-Mafic (Pgb) waste from the Footwall
- 6 samples of Dolerite-Dyke (Dyke) waste from the Intrusive Dyke

-
- 8 samples of Ore (Sgr)

It is understood that all samples are derived from the coarse-rejects (nominal -10 mm) originally generated by ALS Global (Sweden) in 2012, and subsequently forwarded to, and stored at, Nagrom (Kewdale).

During retrieval of the stored coarse-rejects for this study it became evident that some of the samples had gained moisture whilst in storage, and thus has implications for varying degree of weathering prior to testing herein.

The samples typically correspond to downhole-intervals of *ca.* 2 m.

Not all of the samples indicated in Attachment I were able to be sourced for testing herein.

1.2 Preparation for This Study

All samples were forwarded from Nagrom to GLS Intertek (Maddington) where they were oven-dried at 80 °C, and the gravimetric-water content (GWC) from weight loss determined. The resulting GWC values of the 'as-received' coarse-rejects were within the range 0.09-7.67 % (w/w).

Given the storage time and history of the original coarse-rejects, the following sample-preparation steps were undertaken by GLS, viz.

- (a) passing the coarse-rejects through a crusher with clearance set to nominal 10 mm;
- (b) sub-sampling *ca.* 1 kgs of the resulting 'freshened-up' coarse-rejects and crushing these to -2 mm corresponding to fine-crushings; and,
- (c) sub-sampling *ca.* 200 gms of the fine-crushings and pulverising to -75 µm.

Sufficient amounts of the fine-crushings and pulps were retained by GLS for testing, and all of the remaining coarse-rejects, fine-crushings, and pulps were forwarded to the GCA Testing Laboratory (Bridgetown).

The reasoning behind the step in (a) was to 'freshen-up' any aged surfaces of the clasts (up to pea-gravel sizing), and so better approximate the ex-pit state during mining. The coarse-crushing and fine-crushing steps in (a) and (b), respectively, would also dislodge any adhering deposits of secondary-weathering products on grain / clast surfaces.

1.3 Testing

Testing was performed by GLS, SGS (Newburn), and GCA.

All testing in the GCA Testing Laboratory was carried out personally by Dr. GD Campbell.

The mineralogical assessment was undertaken by Dr. Roger Townend of Townend Mineralogical Laboratory (Malaga).

2.0 TESTWORK RESULTS FOR MINE-WASTE SAMPLES

In practical terms the testwork results indicate essentially no distinction between the Vtf, Pgb and Dyke lithologies.

2.1 Acid-Forming Characteristics

The Total-S values of all samples were typically within the %-range, and the CO₃-C values were typically less than the detection-limit of 0.01 % (**Table 1**). Sample GCA11764 (Gabbro/Dolerite-Mafic, Pgb) had a Total-S value of 20.18 % corresponding to 'massive-sulphides'.

The majority of the samples are classified as Potentially-Acid Forming (PAF), and may be further classified as PAF-[SL], where SL = Short-Lag.

Determination of Oxygen-Consumption Rates (OCRs) for selected samples with CO₃-C values less than 0.01 %, but which are nonetheless circum-neutral (viz. pH 5+), indicate that the sulphide-mineral suite is moderately reactive (viz. under unsaturated conditions at 20 °C the Sulphide-Oxidation Rate (SOR) would likely be 'of-the-order' 10-100 mg SO₄/kg/week).

The actual OCR values were:	<u>kg O₂/kg/s</u>
• GCA11773, Vtf, 0.41%S, CO ₃ -C < 0.01 %	2.26E-11
• GCA11749, Pgb, 1.68%S, CO ₃ -C < 0.01 %	1.20E-10
• GCA11760, Pgb, 1.47%S, CO ₃ -C < 0.01 %	1.91E-11
• GCA11770, Dyke, 1.71%S, CO ₃ -C = 0.20 %	3.66E-11

(The above OCR values correspond to circum-neutral conditions [viz. pH 6-8]).

A number of samples were acidic (i.e. pH-(1:2) values within the range 3-5). For at least some samples, such acidification may have developed during storage.

The occurrence of calcites (i.e. reactive carbonates) in selected samples is inferred from the shapes of the pH-buffering curves shown on **Figure 1**. The occurrence of 'accessory-calcite' in sample GCA11764 (Pgb) was shown in the mineralogical study (**Table 3**). However, as indicated above, carbonate-mineral occurrences are generally the exception to the rule for the Nunasvaara South Deposit.

Selected circum-neutral samples with CO₃-C values less than 0.01 % (detection-limit) were reacted at 20 °C with dilute acetic-acid solutions buffered at pH 5 using an in-house method developed for 'zero-carbonate' samples of mine-wastes. This testing showed that it took less than 1 kg H₂SO₄/tonne for the pH to drop to 5 (i.e. essentially negligible capacity to buffer at circum-neutral-pH during weathering).

2.2 Multi-Element Composition and Mineralogy

Use was made of the comprehensive assays within the Project's geological data-base as part of this study.

However, check assays for Se, Te, Mo, and Cu were performed with a detection-limit of 0.01 mg/kg (cf. 1 mg/kg) for Se. In addition, assays for B, F, Hg and Si were undertaken to supplement the element suite for the samples.

The multi-element assays (**Table 2**) indicate a sizeable enrichment environmentally for Se and Te, and this is fairly consistent across all samples.

Selected samples also exhibit a varying enrichment in Mo and Cu. The enrichment in Cu is chiefly associated with 'trace-chalcopyrite'.

The samples subjected to mineralogical assessment typically had a groundmass comprising plagioclases, marialites, and tremolites (**Table 3**).¹ Accessory amounts of micas also occurred. The sulphide-mineral suite comprised pyrites and pyrrhotites with sub-ordinate chalcopyrites.

2.3 Water-Extraction Testwork

Selected samples have been subjected to water-extraction testwork employing slurries with a solid:solution ratio of 1:2 (w/w), and the bottle-roll technique. This testing was undertaken on both circum-neutral and acidic samples.

The testwork results (**Table 4**) may be summarised as follows:

- (a) generally low minor-element concentrations for circum-neutral samples, though with varying SO₄-dominated salinity; and,
- (b) elevated Fe, Al and Mn concentrations for acidic samples, as expected, with Ni and Co concentrations within the multi-mg/L range typically.

It is not known as to what degree the recorded solubility above reflects sample weathering during storage.

3.0 TESTWORK RESULTS FOR ORE SAMPLES

3.1 Acid-Forming Characteristics

All samples, but one, are classified as PAF-[SL] (**Table 1**).

This reflects Total-S values within the multi-% range, and CO₃-C values typically less than 0.01 %.

Importantly, the two samples with CO₃-C values of *ca.* 0.5 % likely contain siderites – ineffective for circum-neutral buffering under unsaturated conditions – as inferred from the shapes of their pH-buffering curves (**Figure 2**). All tested ore samples therefore had a very limited capacity to consume acid and buffer at pH 5-6 and above.

In terms of intrinsic sulphide reactivity, the OCR value of 8.93E-09 kg O₂/kg/s measured for sample GCA11746 is marked. This sample has a Total-S value of 5.51 %, and a CO₃-C value of 0.03 %, and is circum-neutral (viz. pH-(1:2) value of 5.6). This OCR value corresponds to an Acid-Production Rate (APR) value 'of-the-order' 1 kg H₂SO₄/tonne/week. Generation of acid-producing soluble thiosalts by this sample is shown on **Plate 9**, consistent with the OCR determination.

3.2 Multi-Element Composition and Mineralogy

The available assays indicate that the minor-element contents of the ore samples (**Table**

¹ Marialite is a Ca-aluminosilicatechloride mineral.

2) are similar to those for the mine-waste samples, though the degree of Se enrichment is greater in the ores (e.g. Se contents up to 30-80 mg/kg range).

Save for graphite being a major component, the mineralogy of ore sample GCA11746 was similar to that for the mine-waste samples above (**Table 3**).

3.3 Water-Extraction Testwork

The circum-neutral ore samples had water-extract-Se concentrations ranging up to *ca.* 150 µg/L, and water-extract-Ni concentrations within the multi-mg/L range (**Table 4**).

The indications are, therefore, that prior to acidifying, the ores are likely to be a stronger source of soluble-Se and soluble-Ni forms (cf. mine-wastes).

However, as for the mine-waste samples, it is not known as to what degree the recorded solubility reflects sample weathering during storage.

4.0 MANAGEMENT IMPLICATIONS

It is understood that the mining and processing methods to be employed in the Project are currently being assessed in light the end-commodity produced for sale (e.g. micron-sized graphite particles for battery manufacture, graphene production for a range of highly specialised applications, etc.).

The former end-commodity would likely require conventional drilling, blasting, excavation and dumping techniques during the mining operation, as well as flotation and possible other milling operations during processing.

Production of graphene, however, would probably involve a mining process in which blasting activities will either be tightly constrained and 'light', or non-existent. Instead, cutting with mechanised saws and lifting of ore and waste blocks via cranes, etc., will likely be employed.²

4.1 Mine-Wastes

The clear message from this study is that the [mine-waste streams to be produced from the Nunasvaara South Deposit should be predominantly acid-forming, and possess a groundmass typically devoid of reactive carbonate-minerals \(e.g. calcites\).](#)

The lag-phase associated with the PAF-[SL] variants that are circum-neutral *in situ*, may be no longer than weeks during the peak summer months at the site.³

This projection, though preliminary, applies to mine-wastes where appreciable 'rock-fines' (viz. up to pea-gravel grading) in the ex-pit streams (e.g. as produced from conventional drill, blast and excavation mining methods).

² It is understood that field trials and other assessments are on-going with the aim of developing mining methods which are efficient in producing ore-blocks/slabs suitable for graphene production.

³ The lag-phase is the period during which sulphide-oxidation occurs, but acidification does not develop, due to circum-neutral buffering by groundmass components.

4.1.1 Mining with Conventional Drill and Blast Techniques

The [hyper-reactive ore sample GCA11746](#) points to the possibilities of:

- (a) 'reactive-ground' issues associated with premature-detonation during blasting activities;
- (b) spontaneous combustion of graphitic rock where convective O₂-supply is non-limiting; and,
- (c) occupational-health concerns in terms of air quality (e.g. depressed O₂ levels, elevated SO_{2(g)} emissions, etc.).

Although recorded for ore sample GCA11746, these characteristics have implications for both ore and mine-waste production.

The design of the waste-rock dumps (WRDs) therefore needs to accommodate storage of PAF rock characterised by a short lag-phase.

In terms of engineering design of the WRDs, [it is recommended that advice is sought from professionals experienced in the management of reactive mine-wastes at sites in cold climates](#).

4.1.2 Mining without Conventional Drill and Blast Techniques

The relatively modest rate of mining, and the low surface area of the mine-waste and ore streams (i.e. removed as intact blocks / slabs, etc.), stand to greatly assist achieving geochemical control (cf. Section 4.1.1).

Nonetheless, a waste stream enrich in rock-fines will be produced from the sawing activities, though this should be limited in volume.

4.1.3 Sourcing Construction Materials

Irrespective of the mining method(s) to be employed, rock that is both geochemically benign and physically durable will be required during both the construction / operation of the waste dumps, and decommissioning. Sourcing rock of this kind from the pit footprint may be limited (i.e. need to source from outside of pit).

Likewise, sourcing rock with a calcareous groundmass for *inter alia* buffering 'contact-waters' with bicarbonate alkalinity will likely be limited from the pit.

[The potential need to source construction materials from areas removed from the pit footprint has obvious implications for mining costs for the Project.](#)

4.2 Ores

The geochemical character of the ores should be similar to those of the mine-wastes with related management implications as above.

5.0 CLOSURE

Mining of the Nunasvaara South Deposit will need to control weathering reactions (viz. rock-water-air interactions), and to prevent discharges of Acid-Rock Drainage (ARD) to the mine-site environs.

To guide engineering design for mine-waste and ore management, a comprehensive programme of geochemical testing should be implemented at the earliest opportunity.

Measures for tight geochemical control underpin engineering strategies for the management of the mine-waste and ore streams to be produced during this Project – both for operations, and post-closure.

I trust the above is useful to your current needs.

Regards,

Dr GD Campbell
Director

encl. Tables 1-4 (some formatted for A3-sized paper)
 Figures 1-2
 Plates 1-9
 Attachments I-II

TABLES

Table 1: Results for Acid-Base-Analysis (ABA) and Net-Acid-Generation (NAG) Testing

GCA SAMPLE NO.	SITE SAMPLE NO.	DRILLHOLE ID	DOWNHOLE- INTERVAL (m)	LITHOLOGY	LITHO- CODE	GWC (%, w/w)	pH-(1:2)	EC-(1:2) [mS/cm]	TOTAL-S (%)	TOTAL-S (%)	Cr(II)- RED.-S (%)	SULPHIDE- S (%)	TOTAL-C (%)	TOTAL-C (%)	CO3-C (%)	CO3-C (%)	BULK-ANC			CALCITE- ANC (calc'd)	NAG- pH4.5	NAG- pH7.0	NAG-pH	AFP CATEGORY	
						GLS	GCA	GCA	ALS	GLS	SGS		ALS	GLS	ALS	GLS	AMIRA (2002)	EN 15875	pH- [5-6]		GCA	GCA			
																	GLS	GCA	GCA			kg H2SO4/tonne			kg H2SO4/tonne
MINE-WASTE SAMPLES																									
Hangingwall																									
GCA11745	0022	NUS12002	46.00-48.00	Mafic-Tuff	Vtf	0.79	7.1	0.35	0.22	0.26	0.25	0.25	0.73	0.73	0.04	<0.01	10	8	<1		<0.5	<0.5	6.1	NAF	
GCA11750	0129	NUS12006	16.00-18.00	Mafic-Tuff	Vtf	5.76	7.3	0.61	0.55	0.54	0.40	0.40	3.00	3.10	1.16	1.08	103			88	<0.5	<0.5	10.1	NAF	
GCA11754	0187	NUS12008	45.00-47.00	Mafic-Tuff	Vtf	0.51	7.6	0.56	0.17	0.25	0.17	0.17	0.04	2.50	<0.01	0.89	97			73	<0.5	<0.5	10.9	NAF	
GCA11755	0204	NUS12008	73.25-75.00	Mafic-Tuff	Vtf	7.67	4.0	4.0	9.72	9.52		≤ 9.52	0.37	0.20	<0.01	<0.01	9				100	134	2.4	PAF-[SL]	
GCA11757	0245	NUS12011	12.00-14.00	Mafic-Tuff	Vtf	6.75	3.0	4.6	2.15	1.64		≤ 1.64	0.07	0.06	<0.01	<0.01	11				8.7	14	2.9	PAF-[SL]	
GCA11762	0420	NUS12016	31.40-33.40	Mafic-Tuff	Vtf	0.37	4.5	0.92	4.16	4.47		≤ 4.47	0.10	0.06	<0.01	<0.01	14				35	46	2.5	PAF-[SL]	
GCA11763	0421	NUS12016	33.40-35.40	Mafic-Tuff	Vtf	0.26	4.7	0.84	2.77	2.85		≤ 2.85	0.41	0.37	0.05	<0.01	8				33	40	2.4	PAF-[SL]	
GCA11772	0544	NUS12019	66.17-68.00	Mafic-Tuff	Vtf	0.19	6.8	0.97	1.19	1.03	0.67	0.67	0.29	0.21	0.11	<0.01	19				5.3	11	3.1	PAF-[SL]	
GCA11773	0546	NUS12019	74.00-76.00	Mafic-Tuff	Vtf	0.90	7.3 (7.2)	0.46 (0.42)	0.35	0.41	0.30	0.30	0.30	0.22	0.08	<0.01	12	7 (7)			<0.5 (<0.5)	3.0 (1.7)	4.0 (4.0)	PAF-[SL]	
GCA11759	0381	NUS12014	59.90-61.18	Mafic-Tuff	Vtf	0.09	5.4	1.3	2.74	3.34		≤ 3.34	6.51	5.71	0.40	0.18	12	5		15	43 (42)	53 (54)	2.3 (2.3)	PAF	
Footwall																									
GCA11747	0067	NUS12003	38.30-40.00	Gabbro/Dolerite-Mafic	Pgb	4.21	3.1	2.7	3.19	3.00		≤ 3.00	0.61	0.61	0.04	<0.01	13				26	34	2.5	PAF-[SL]	
GCA11749	0122	NUS12005	78.70-81.00	Gabbro/Dolerite-Mafic	Pgb	7.56	5.8	0.66	1.75	1.68		≤ 1.68	0.09	0.05	<0.01	<0.01	10	6			24	29	2.5	PAF-[SL]	
GCA11753	0158	NUS12007	104.00-106.00	Gabbro/Dolerite-Mafic	Pgb	0.52	8.1	0.20	0.11	0.10	0.09	0.09	1.42	1.41	1.02	0.97	95			79	<0.5	<0.5	11.2	PAF	
GCA11761	0414	NUS12015	107.00-108.35	Gabbro/Dolerite-Mafic	Pgb	0.77	5.0 (5.0)	0.82 (0.82)	2.47	2.09		≤ 2.09	0.45	0.33	<0.01	<0.01	10	6			30	34	2.4	PAF-[SL]	
GCA11764	0442	NUS12017	53.13-55.00	Gabbro/Dolerite-Mafic	Pgb	0.70	6.3	3.0	24.1	20.18		≤ 20.18	1.67	1.38	1.62	1.31	128			107	195	208	2.4	PAF	
GCA11769	0530	NUS12019	38.00-40.00	Gabbro/Dolerite-Mafic	Pgb	0.91	8.3	0.19	0.15	0.15	0.11	0.11	0.17	0.16	0.06	0.03	15	10	1		<0.5	<0.5	6.9	PAF-[SL]	
GCA11771	0534	NUS12019	48.00-50.00	Gabbro/Dolerite-Mafic	Pgb	1.68	4.2	2.3	9.16	9.79		≤ 9.79	0.29	0.18	0.08	<0.01	7				143	159	2.3	PAF-[SL]	
GCA11760	0384	NUS12014	68.00-70.00	Gabbro/Dolerite-Mafic	Pgb	3.93	7.6	0.32	1.63	1.47 (1.48)		≤ 1.48	0.09	0.05 (0.07)	0.05	<0.01	12 (12)	10	<1		22	28	2.6	PAF-[SL]	
Intrusive Dyke																									
GCA11743	0017	NUS12001	42.25-44.00	Dolerite-Dyke	Dyke	1.00	4.3	0.85	2.19	1.87		≤ 1.87	0.07	0.05	0.01	<0.01	15				18	26	2.7	PAF-[SL]	
GCA11744	0019	NUS12001	53.00-55.00	Dolerite-Dyke	Dyke	1.66	7.2	1.3	1.08	1.09	0.74	0.74	2.24	2.25	2.15	2.17	217			177	<0.5	<0.5	9.3	NAF	
GCA11751	0141	NUS12006	38.50-40.50	Dolerite-Dyke	Dyke	2.60	3.4 (3.3)	1.7 (1.6)	0.29	0.25	0.10	0.10	0.05	0.03	<0.01		8				<0.5	<0.5	5.6	PAF-[SL]	
GCA11752	0142	NUS12006	40.50-42.85	Dolerite-Dyke	Dyke	2.73	3.1	1.8	0.47	0.45	0.15	0.15	0.06	0.02	<0.01		6				<0.5	1.5	4.9	PAF	
GCA11768	0494	NUS12018	79.68-81.80	Dolerite-Dyke	Dyke	1.64	3.6	1.5	9.73	9.06		≤ 9.06	2.98	2.29	<0.01	<0.01	16				127	139	2.3	PAF-[SL]	
GCA11770	0532	NUS12019	44.30-46.00	Dolerite-Dyke	Dyke	0.16	7.1	0.91	1.32	1.71		≤ 1.71	0.35	0.34	0.22	0.20	26	19		16	20	25	2.9	PAF	
ORE SAMPLES																									
GCA11742	0006	NUS12001	21.00-23.00	Graphite-Ore	Sgr	0.16	5.2	0.95	1.19	1.24		≤ 1.24	28.10	25.05	1.30	<0.01	5	2			20	26	2.6	PAF-[SL]	
GCA11746	0031	NUS12002	65.00-67.00	Graphite-Ore	Sgr	0.94	5.6	2.2	5.51	5.17		≤ 5.17	27.00	25.86	0.30	0.04	15	5	<1		61	75	2.4	PAF-[SL]	
GCA11748	0109	NUS12005	54.00-56.00	Graphite-Ore	Sgr	1.45	5.4	1.6	8.18	8.52		≤ 8.52	24.20	24.03	<0.01	0.63	20			51	157	176	2.2	PAF-[SL]	
GCA11756	0236	NUS12010	44.00-46.00	Graphite-Ore	Sgr	0.78	6.6	0.39	0.68	0.93	0.52	0.52	33.60	33.35	1.00	<0.01	13	3			13	17	2.9	PAF-[SL]	
GCA11765	0461	NUS12017	83.00-85.00	Graphite-Ore	Sgr	0.78	4.4	1.5	3.49	3.98		≤ 3.98	19.90	18.53	<0.01	<0.01	17				39	43	2.4	PAF-[SL]	
GCA11766	0480	NUS12018	52.00-54.00	Graphite-Ore	Sgr	1.14	7.8	0.19	0.23	0.27	0.20	0.20	38.10	38.19 (38.72)	1.20	0.16	10			13	<0.5	1.8	3.9	PAF	
GCA11767	0484	NUS12018	60-62	Graphite-Ore	Sgr	0.83	7.1	0.24	1.54	1.21		≤ 1.21	42.80	44.80	0.40	<0.01	10	2 (2)	<1		17	21	2.6	PAF-[SL]	
GCA11758	0363	NUS12014	30.50-32.50	LG-Graphite-Ore	Sgr	0.62	5.3	0.84	3.51	4.75		≤ 4.75	16.50	15.44	1.50	0.43	13			35	61	70	2.2	PAF-[SL]	

Notes:
EC = Electrical-Conductivity; ANC = Acid-Neutralisation Capacity; NAG = Net-Acid Generation; AFP = Acid-Formation Potential; NAF = Non-Acid Forming; PAF = Potentially-Acid Forming; PAF-[SL] = PAF-[Short-Lag].
pH-(1:2) and EC-(1:2) values correspond to pH and EC measured on sample slurries prepared with deionised-water, and a solid:solution ratio of *ca.* 1:2 (w/w).
All results expressed on a dry-weight basis, except for pH-(1:2), EC-(1:2), and NAG-pH.
Values in parentheses represent duplicates.

Table 2: Multi-Element-Analysis Results

SITE	GCA	DRILLHOLE	DOWNHOLE-			Graph-	S	S	TIC	Ca	Mg	K	Na	Fe	Al	Si	Ti	Cu	Cu	Zn	Cd	Pb	Hg	Mn	Ni	Cr	Co	As	Sb	Mo	Mo	Se	Se	Te	Te	F	B	P
SAMPLE	SAMPLE	ID	INTERVAL	LITHOLOGY	LITHO-	C	(IR08)	(ICP)								GLS			GLS				GLS								GLS		GLS		GLS	GLS	GLS	
NO.	NO.		(m)		CODE	%	%		%									mg/kg										mg/kg										
MINE-WASTE SAMPLES																																						
Hangingwall																																						
0022	GCA11745	NUS12002	46.00-48.00	Mafic-Tuff	Vtf	0.69	0.22	0.21	0.04	3.84	5.98	0.49	2.37	9.41	7.68	25.4	0.665	90.5	99.7	38	0.00	0.7	0.004	1,270	166.0	268	50.9	0.0	0.00	0.34	0.37	2	1.27	0.72	0.83	347	<20	360
0129	GCA11750	NUS12006	16.00-18.00	Mafic-Tuff	Vtf	1.84	0.55	0.60	1.16	11.00	3.67	0.78	1.92	7.92	7.44	20.9	0.536	193.5	168.9	44	0.02	1.2	0.003	1,280	163.5	221	49.5	6.0	0.22	0.73	0.68	5	3.53	2.36	2.65	384	<20	390
0187	GCA11754	NUS12008	45.00-47.00	Mafic-Tuff	Vtf	0.04	0.17	0.15	0.00	5.00	4.76	0.25	2.87	9.37	7.89	19.3	0.609	112.0	161.0	60	0.00	0.7	0.001	1,600	126.5	209	50.9	0.0	0.06	0.55	0.62	1	1.91	0.27	1.70	306	<20	330
0204	GCA11755	NUS12008	73.25-75.00	Mafic-Tuff	Vtf	0.37	9.72	7.66	0.00	1.51	4.38	0.57	2.04	16.25	5.70	18.0	0.301	1,600	1,492	6,120	18.80	3,040	0.001	554	668.0	98	153.0	1.7	0.18	38.00	38.87	10	8.54	0.99	1.15	504	<20	650
0245	GCA11757	NUS12011	12.00-14.00	Mafic-Tuff	Vtf	0.07	2.15	1.60	0.00	3.08	6.30	0.68	1.89	9.20	7.32	21.3	0.661	124.5	113.0	52	0.03	6.4	<0.001	1,300	130.0	180	48.3	1.6	0.08	0.15	0.20	10	6.74	0.52	0.59	375	<20	390
0420	GCA11762	NUS12016	31.40-33.40	Mafic-Tuff	Vtf	0.10	4.16	3.63	0.00	3.67	6.84	1.22	3.23	7.39	7.37	18.8	0.442	1,560	1,446	58	0.12	8.4	<0.001	737	335.0	237	227.0	6.6	0.37	2.15	1.85	7	6.21	1.25	0.73	751	<20	360
0421	GCA11763	NUS12016	33.40-35.40	Mafic-Tuff	Vtf	0.36	2.77	2.66	0.05	2.86	3.95	0.23	4.92	4.59	7.33	26.1	0.260	1,180	1,060	8	0.00	5.0	<0.001	272	232.0	210	255.0	181.0	0.25	12.55	11.91	16	15.43	0.88	0.48	571	<20	320
0544	GCA11772	NUS12019	66.17-68.00	Mafic-Tuff	Vtf	0.18	1.19	1.13	0.11	5.19	4.99	0.83	3.93	3.56	7.44	22.3	0.588	327.0	255.8	3	0.00	0.9	0.002	246	112.0	187	31.1	0.6	0.00	5.72	4.49	5	3.47	0.56	0.75	646	<20	410
0546	GCA11773	NUS12019	74.00-76.00	Mafic-Tuff	Vtf	0.22	0.35	0.34	0.08	5.52	4.84	0.41	3.06	8.38	7.14	24.6	0.548	153.0	132.7	26	0.00	0.3	0.003	1,240	115.5	173	55.6	0.5	0.05	0.83	0.12	3	1.74	0.56	0.25	273	<20	310
0381	GCA11759	NUS12014	59.90-61.18	Mafic-Tuff	Vtf	6.11	2.74	2.70	0.40	4.52	3.56	1.06	3.47	6.08	7.70	22.8	0.513	380.0	458.9	7	0.00	1.5	0.003	329	174.0	127	48.5	2.6	0.19	2.00	2.34	11	12.20	0.62	0.85	465	<20	590
Footwall																																						
0067	GCA11747	NUS12003	38.30-40.00	Gabbro/Dolerite-Mafic	Pgb	0.57	3.19	2.67	0.04	1.55	4.27	2.43	3.68	6.89	7.50	23.9	0.838	274.0	233.7	2	0.00	0.6	0.009	174	102.5	103	41.5	0.9	0.00	0.98	0.64	9	7.31	0.24	0.31	732	<20	780
0122	GCA11749	NUS12005	78.70-81.00	Gabbro/Dolerite-Mafic	Pgb	0.09	1.75	1.41	0.00	5.15	4.00	0.50	4.49	4.51	7.79	26.2	0.999	385.0	327.3	9	0.02	3.1	0.005	492	79.9	42	39.6	0.6	0.16	3.14	3.89	4	3.29	0.18	0.22	408	<20	740
0158	GCA11753	NUS12007	104.00-106.00	Gabbro/Dolerite-Mafic	Pgb	0.40	0.11	0.09	1.02	10.80	3.53	0.67	1.55	7.67	7.09	21.7	0.508	67.6	75.6	68	0.04	1.1	0.002	1,450	144.5	235	40.3	6.0	0.12	0.83	0.70	2	1.03	1.11	1.14	490	<20	320
0414	GCA11761	NUS12015	107.00-108.35	Gabbro/Dolerite-Mafic	Pgb	0.45	2.47	2.01	0.00	3.25	3.77	1.64	4.36	4.59	7.85	23.7	0.341	354.0	274.2	7	0.00	0.9	0.002	184	159.0	123	37.5	1.2	0.17	0.84	0.53	7	5.61	0.43	0.52	222	<20	480
0442	GCA11764	NUS12017	53.13-55.00	Gabbro/Dolerite-Mafic	Pgb	0.05	24.10	0.00	1.62	5.81	2.72	0.37	0.87	34.70	2.20	6.4	0.155	5,910	4,610	8	0.00	1.7	<0.001	337	1,160	158	378.0	2.8	0.13	1.68	1.28	14	11.52	6.82	8.37	899	<20	810
0530	GCA11769	NUS12019	38.00-40.00	Gabbro/Dolerite-Mafic	Pgb	0.11	0.15	0.11	0.06	5.40	3.79	1.09	4.20	7.35	7.25	22.2	0.772	68.6	76.3	24	0.00	0.8	0.002	1,020	84.3	96	41.4	0.2	0.10	0.99	1.18	1	0.26	0.00	<0.05	257	<20	570
0534	GCA11771	NUS12019	48.00-50.00	Gabbro/Dolerite-Mafic	Pgb	0.21	9.16	6.76	0.08	5.48	2.34	0.29	4.03	14.40	6.00	17.8	0.413	1,680	1,388	0	0.00	2.7	<0.001	61	414.0	88	255.0	1.2	0.00	38.60	51.52	19	17.08	1.71	1.86	184	<20	960
0384	GCA11760	NUS12014	68.00-70.00	Gabbro/Dolerite-Mafic	Pgb	0.04	1.63	1.30	0.05	3.78	3.36	1.19	4.33	8.15	8.00	24.6	1.040	174.5	165.8	24	0.00	0.7	0.006	822	69.8	68	43.9	0.8	0.24	0.67	0.47	3	1.71	0.19	0.21	420	<20	760
Intrusive Dyke																																						
0017	GCA11743	NUS12001	42.25-44.00	Dolerite-Dyke	Dyke	0.06	2.19	1.68	0.01	2.63	3.98	1.07	5.18	4.56	7.15	24.5	1.015	309.0	272.4	0	0.00	1.2	0.007	184	100.5	103	41.6	0.0	0.00	1.67	1.18	5	3.21	0.50	0.48	606	<20	780
0019	GCA11744	NUS12001	53.00-55.00	Dolerite-Dyke	Dyke	0.09	1.08	1.04	2.15	10.10	2.75	0.43	4.23	5.30	6.43	21.1	0.782	249.0	215.4	3	0.00	1.4	0.004	427	83.7	85	55.9	0.0	0.00	0.97	0.69	1	0.56	0.26	0.21	282	<20	540
0141	GCA11751	NUS12006	38.50-40.50	Dolerite-Dyke	Dyke	0.05	0.29	0.30	0.00	6.11	2.58	0.98	2.58	10.55	7.88	22.9	1.050	30.2	32.5	83	0.02	1.2	0.002	1,500	14.6	24	38.1	1.5	0.40	0.69	0.72	1	0.27	0.00	0.05	635	<20	1,780
0142	GCA11752	NUS12006	40.50-42.85	Dolerite-Dyke	Dyke	0.06	0.47	0.45	0.00	6.33	2.63	0.71	2.86	9.33	8.01	22.4	1.050	48.0	46.9	66	0.02	1.3	<0.001	1,380	21.2	25	33.6	1.0	0.38	0.68	0.65	2	0.53	0.00	0.06	623	<20	1,800
0494	GCA11768	NUS12018	79.68-81.80	Dolerite-Dyke	Dyke	2.98	9.73	7.82	0.00	2.53	4.32	1.19	2.81	16.25	5.26	16.6	0.368	1,720	1,405	9	0.00	3.6	<0.001	251	543.0	176	137.5	0.5	0.00	33.70	30.87	18	15.79	2.37	2.44	779	<20	380
0532	GCA11770	NUS12019	44.30-46.00	Dolerite-Dyke	Dyke	0.13	1.32	0.97	0.22	6.40	3.69	0.55	4.56	6.04	7.37	22.2	0.732	75.5	94.5	7	0.00	0.3	<0.001	493	115.5	97	37.3	0.5	0.06	0.28	0.45	2	1.32	0.28	0.38	346	<20	510
ORE SAMPLES																																						
0006	GCA11742	NUS12001	21.00-23.00	Graphite-Ore	Sgr	26.80	1.19	1.22	1.30	2.50	2.83	0.40	3.57	2.65	5.17	17.8	0.450	130.5	121.6	0	0.00	1.5	0.008	174	77.8	187	14.5	1.6	0.06	5.74	6.06	11	10.52	0.44	0.61	462	<20	430
0031	GCA11746	NUS12002	65.00-67.00	Graphite-Ore	Sgr	26.70	5.51	5.58	0.30	2.01	1.91	0.65	3.24	10.05	4.7.																							

Table 2 (Cont'd): Multi-Element-Analysis Results

SITE SAMPLE NO.	GCA SAMPLE NO.	DRILLHOLE ID	DOWNHOLE- INTERVAL (m)	LITHOLOGY	LITHO- CODE	Tl	Sr	Ba	Be	Bi	Ce	Ga	Ge	Hf	In	La	Li	Rb	Cs	Nb	Re	Sc	Sn	Ta	Th	U	V	W	Y	Zr	Ag	Au	Pt	Pd	
						mg/kg																													
MINE-WASTE SAMPLES																																			
Hangingwall																																			
0022	GCA11745	NUS12002	46.00-48.00	Mafic-Tuff	Vtf	0.05	59.6	110	0.56	0.08	15.10	17.30	0.09	1.7	0.065	6.4	12.2	22.3	0.87	4.3	0.006	41.2	0.5	0.29	1.3	0.6	277	0.2	19.7	65.8	0.00	0.004	0.011	0.003	
0129	GCA11750	NUS12006	16.00-18.00	Mafic-Tuff	Vtf	0.12	55.1	160	0.50	0.26	15.60	15.15	0.09	1.4	0.073	6.7	9.8	31.4	1.04	5.4	0.009	38.0	0.7	0.37	1.3	1.0	236	0.5	18.4	51.0	0.01	0.000	0.010	0.007	
0187	GCA11754	NUS12008	45.00-47.00	Mafic-Tuff	Vtf	0.00	62.0	70	0.33	0.05	9.27	16.85	0.09	1.2	0.062	3.5	13.3	8.9	0.37	3.3	0.002	46.5	0.3	0.21	0.3	0.1	297	0.2	19.1	36.6	0.02	0.000	0.009	0.011	
0204	GCA11755	NUS12008	73.25-75.00	Mafic-Tuff	Vtf	0.04	43.8	90	1.09	0.13	30.30	12.95	0.10	2.3	0.023	10.3	61.7	14.9	0.60	2.6	0.102	25.3	0.0	0.25	3.0	6.0	194	0.9	15.9	84.0	0.81	0.004	0.000	0.026	
0245	GCA11757	NUS12011	12.00-14.00	Mafic-Tuff	Vtf	0.11	51.6	180	0.38	0.15	11.05	17.30	0.10	1.7	0.040	4.3	18.9	24.4	0.87	4.1	0.005	45.8	0.0	0.26	0.6	0.2	297	0.0	16.7	63.4	0.06	0.000	0.010	0.005	
0420	GCA11762	NUS12016	31.40-33.40	Mafic-Tuff	Vtf	0.30	73.5	160	0.76	1.16	15.30	15.35	0.08	1.4	0.106	8.8	24.3	45.9	2.71	2.1	0.007	38.1	1.7	0.18	0.6	0.9	278	0.7	15.3	48.8	0.18	0.020	0.000	0.009	
0421	GCA11763	NUS12016	33.40-35.40	Mafic-Tuff	Vtf	0.00	54.4	40	1.36	0.27	54.30	16.40	0.10	3.4	0.038	24.7	10.2	6.9	0.37	3.3	0.035	35.7	0.5	0.33	5.1	5.4	201	1.2	37.3	126.0	0.10	0.014	0.006	0.027	
0544	GCA11772	NUS12019	66.17-68.00	Mafic-Tuff	Vtf	0.09	175.5	70	0.78	0.08	37.50	16.65	0.12	2.0	0.027	16.8	7.0	61.3	4.00	4.5	0.006	44.5	0.0	0.35	1.3	1.6	272	0.3	20.3	63.7	0.00	0.011	0.012	0.005	
0546	GCA11773	NUS12019	74.00-76.00	Mafic-Tuff	Vtf	0.05	57.9	70	0.45	0.07	11.30	16.05	0.07	1.6	0.088	6.0	3.5	17.3	0.60	3.1	0.003	42.5	0.5	0.23	0.6	1.1	239	0.2	14.8	51.2	0.00	0.012	0.012	0.008	
0381	GCA11759	NUS12014	59.90-61.18	Mafic-Tuff	Vtf	0.05	86.1	240	1.16	0.17	32.00	17.90	0.07	1.9	0.039	14.1	9.9	32.4	0.53	2.3	0.018	45.0	1.4	0.19	2.2	1.5	297	0.7	29.2	68.7	0.02	0.000	0.011	0.022	
Footwall																																			
0067	GCA11747	NUS12003	38.30-40.00	Gabbro/Dolerite-Mafic	Pgb	0.27	78.1	210	1.10	0.04	32.00	20.70	0.11	2.9	0.010	13.3	11.3	98.0	3.03	4.4	0.002	30.6	0.0	0.35	1.3	0.5	273	0.4	19.4	107.5	0.00	0.000	0.000	0.000	
0122	GCA11749	NUS12005	78.70-81.00	Gabbro/Dolerite-Mafic	Pgb	0.02	109.5	70	0.76	0.01	34.90	20.00	0.14	3.0	0.045	14.1	2.5	18.6	0.36	10.3	0.007	31.0	2.9	0.70	1.4	0.9	230	1.1	22.8	92.0	0.02	0.000	0.000	0.001	
0158	GCA11753	NUS12007	104.00-106.00	Gabbro/Dolerite-Mafic	Pgb	0.09	49.3	210	0.59	0.17	12.20	14.80	0.06	1.2	0.065	5.1	11.1	27.6	0.70	3.9	0.000	38.0	0.6	0.26	0.6	0.5	240	0.7	16.2	39.0	0.01	0.000	0.000	0.006	
0414	GCA11761	NUS12015	107.00-108.35	Gabbro/Dolerite-Mafic	Pgb	0.13	153.5	190	1.25	0.12	11.75	20.60	0.05	1.6	0.017	4.5	10.7	30.6	1.11	0.7	0.006	53.2	0.3	0.06	0.2	0.4	390	0.6	30.0	57.6	0.02	0.052	0.017	0.027	
0442	GCA11764	NUS12017	53.13-55.00	Gabbro/Dolerite-Mafic	Pgb	0.17	33.0	20	0.23	0.29	14.80	7.29	0.11	0.9	0.033	7.3	3.9	23.1	0.63	1.2	0.012	14.7	0.2	0.10	2.1	1.1	524	4.6	15.6	30.4	0.06	0.005	0.000	0.034	
0530	GCA11769	NUS12019	38.00-40.00	Gabbro/Dolerite-Mafic	Pgb	0.14	197.5	250	0.57	0.02	22.90	17.40	0.09	1.3	0.062	9.3	3.5	40.4	1.43	7.0	0.005	28.1	0.5	0.50	0.9	0.4	203	0.4	12.6	37.7	0.02	0.000	0.000	0.000	
0534	GCA11771	NUS12019	48.00-50.00	Gabbro/Dolerite-Mafic	Pgb	0.02	124.5	20	1.02	0.07	75.00	12.50	0.15	2.4	0.011	30.2	2.6	6.6	1.02	4.5	0.092	20.0	0.0	0.42	3.3	7.6	150	1.5	26.1	80.7	0.01	0.011	0.000	0.012	
0384	GCA11760	NUS12014	68.00-70.00	Gabbro/Dolerite-Mafic	Pgb	0.12	109.5	150	0.94	0.08	37.10	20.70	0.07	2.1	0.057	14.8	8.0	52.8	0.90	9.8	0.002	28.0	0.5	0.74	1.6	0.4	259	0.5	17.6	78.7	0.02	0.000	0.000	0.000	
Intrusive Dyke																																			
0017	GCA11743	NUS12001	42.25-44.00	Dolerite-Dyke	Dyke	0.09	97.0	80	0.88	0.04	30.00	20.50	0.12	2.7	0.026	14.8	6.0	73.4	1.68	9.9	0.007	29.5	0.5	0.69	1.4	1.1	274	2.4	20.2	97.7	0.00	0.003	0.000	0.001	
0019	GCA11744	NUS12001	53.00-55.00	Dolerite-Dyke	Dyke	0.00	214.0	50	0.64	0.04	110.50	15.00	0.15	2.3	0.039	56.7	3.6	19.8	1.22	8.4	0.013	22.8	1.0	0.57	1.7	2.3	200	0.4	24.3	89.0	0.02	0.001	0.000	0.000	
0141	GCA11751	NUS12006	38.50-40.50	Dolerite-Dyke	Dyke	0.11	333.0	500	1.15	0.01	62.60	24.20	0.16	3.0	0.139	26.9	4.6	30.3	0.55	6.2	0.007	46.4	2.1	0.37	2.9	0.8	370	0.3	37.5	103.5	0.02	0.000	0.000	0.002	
0142	GCA11752	NUS12006	40.50-42.85	Dolerite-Dyke	Dyke	0.07	322.0	350	1.08	0.01	60.50	23.80	0.15	3.1	0.144	27.1	4.4	18.1	0.32	6.2	0.008	47.7	2.5	0.38	3.0	0.7	374	0.4	38.0	92.0	0.01	0.000	0.000	0.000	
0494	GCA11768	NUS12018	79.68-81.80	Dolerite-Dyke	Dyke	0.21	46.4	60	0.56	0.35	34.00	14.35	0.13	1.7	0.032	15.7	8.6	99.0	2.41	2.8	0.052	24.9	0.0	0.21	3.0	7.4	163	1.8	12.4	60.5	0.02	0.004	0.000	0.032	
0532	GCA11770	NUS12019	44.30-46.00	Dolerite-Dyke	Dyke	0.02	195.5	70	0.61	0.01	32.90	17.10	0.09	1.7	0.056	14.3	2.1	28.7	2.59	6.7	0.004	27.8	0.5	0.48	0.9	0.7	199	0.2	13.9	54.9	0.01	0.000	0.000	0.000	
ORE SAMPLES																																			
0006	GCA11742	NUS12001	21.00-23.00	Graphite-Ore	Sgr	0.23	101.5	50	1.09	0.15	44.20	12.35	0.16	2.0	0.027	21.8	7.9	27.0	0.82	5.6	0.050	25.8	0.4	0.39	3.8	3.9	203	0.4	37.5	77.5	0.00	0.002	0.012	0.003	
0031	GCA11746	NUS12002	65.00-67.00	Graphite-Ore	Sgr	0.13	68.3	90	0.86	0.24	52.10	12.95	0.19	2.3	0.021	23.8	4.4	36.9	1.64	7.1	0.068	18.4	0.2	0.53	7.7	12.9	186	0.3	23.9	89.6	0.00	0.003	0.011	0.018	
0109	GCA11748	NUS12005	54.00-56.00	Graphite-Ore	Sgr	0.18	51.3	100	1.13	2.19	40.60	10.45	0.36	1.7	0.043	18.4	6.4	26.6	1.16	4.7	0.086	20.3	0.7	0.39	5.2	6.1	176	1.0	31.6	70.4	0.03	0.018	0.000	0.006	
0236	GCA11756	NUS12010	44.00-46.00	Graphite-Ore	Sgr	0.07	50.4	100	1.10	0.13	40.30	13.70	0.14	2.6	0.000	20.2	12.8	34.1	0.67	1.3	0.059	12.8	0.0	0.09	6.4	3.3	173	0.1	10.1	97.6	0.01	0.004	0.020	0.002	
0363	GCA11758	NUS12014	30.50-32.50	Graphite-Ore	Sgr	0.13	46.8	290	1.23	0.16	35.00	16.45	0.11	2.3	0.038	17.3	11.0	50.0	1.13	1.4	0.106	23.6	0.6	0.16	7.0	6.3	241	0.4	31.7	80.4	0.02	0.010	0.000	0.009	
0461	GCA11765	NUS12017	83.00-85.00	Graphite-Ore	Sgr	0.19	45.4	60	1.53	0.25	31.50	17.50	0.12	1.8	0.011	12.8	8.2	103.5	2.61	4.0	0.031	31.5	0.2	0.31	2.5	3.0	261	0.7	25.4	73.5	0.01	0.004	0.005	0.014	
0480	GCA11766	NUS12018	52.00-54.00	Graphite-Ore	Sgr	0.00	14.8	10	0.64	0.02	12.40	12.80	0.05	1.9	0.010	8.4	2.9	12.0	0.29	5.5	0.034	13.4	0.0	0.42	4.7	3.5	141	0.4	14.8	75.5	0.02	0.000	0.000	0.004	
0484	GCA11767	NUS12018	60.00-62.00	Graphite-Ore	Sgr	0.06	12.0	10	0.70	0.29	15.90	11.65	0.06	1.8	0.011	9.7	2.5	17.1	0.50	5.3	0.046	34.7	0.0	0.36	5.4	3.7	225	0.4	17.5	74.8	0.01	0.002	0.006	0.004	

Table 3: Mineralogical Results

MINE-WASTE SAMPLES						ORE SAMPLE	
<u>Hangingwall</u> Mafic-Tuff, Vtf NUS12016, 33.40-35.40 m 2.85%S, CO3-C < 0.01 %		<u>Footwall</u> Gabbro/Dolerite-Mafic, Pgb NUS12017, 53.13-55.00 m 20.18%S, CO3-C = 1.31 %		<u>Intrusive-Dyke</u> Dolerite-Dyke, Dyke NUS12018, 79.68-81.80 m 2.29%S, CO3-C < 0.01 %		Graphite-Ore, Sgr NUS12002, 65.00-67.00 m 5.17%S, CO3-C = 0.04 %	
PAF-[SL] (GCA11763)		PAF (GCA11764)		PAF-[SL] (GCA11768)		PAF-[SL] (GCA11746)	
plagioclase marialite	20-50 %	pyrrhotite tremolite	20-50 %	plagioclase marialite	20-50 %	plagioclase tremolite graphite	20-50 %
tremolite chlorite	10-20 %	marcasite marialite goethite	10-20 %	tremolite biotite	10-20 %		
pyrite pyrrhotite graphite biotite	1-10 %	calcite gypsum biotite quartz	1-10 %	pyrite pyrrhotite jarosite graphite chlorite goethite	1-10 %	pyrite pyrrhotite chlorite K-feldspar goethite	1-10 %
chalcopyrite rutile	< 1 %	pyrite chalcopyrite violarite	< 1 %	chalcopyrite rutile	< 1 %		
						chalcopyrite	<< 1 %

Notes:

major = 20-50 %; minor = 10-20 %; accessory = 1-10 %; trace is less than 1 %

Table 4: Water-Extraction-Testwork Results

GCA SAMPLE NO.	SITE SAMPLE NO.	DRILLHOLE ID	DOWNHOLE- INTERVAL (m)	LITHO- CODE	pH	pH (GCA)	EC mS/cm	EC (GCA, µS/cm)	HCO3 (mg/L CaCO3)	Acidity (mg/L CaCO3)	SO4	Cl	Ca	Mg	Na	K	Al	Fe	Si	Mn	As	Sb	Se	Te	B	Mo	P	F	Ni	Co	Cu	Zn	Cd	Pb	Cr	Ag	Hg	Bi	Sn	V	Tl	U	Th	Sr	Ba								
											mg/L		mg/L								µg/L								µg/L																								
MINE-WASTE SAMPLES																																																					
Intrusive Dyke																																																					
GCA11744	0019	NUS12001	53.00-55.00	Dyke	7.8	7.68+	1,400	1,340	30	5.7	817	10	302.9	14.07	16.8	27.8	0.04	0.01	1.61	0.020	3	<0.1	<5	<1	40	1.8	<50	<100	30	<1	<10	<10	<10	<0.2	<5	<10	0.1	<1	<0.05	<1	<10	<0.1	2.88	<0.05	293.7	16.0							
GCA11743	0017	NUS12001	42.25-44.00	Dyke	4.5	4.54-	990	976	3	51.8	524	6	71.69	45.36	19.2	50.8	0.58	20.82	4.64	0.357	4	<0.1	10	<1	70	<0.5	<50	<100	2,710	922	<10	50	<0.2	<5	<10	<0.1	<1	0.99	<1	<10	<0.1	0.8	<0.05	60.3	63.7								
GCA11768	0494	NUS12018	79.68-81.80	Dyke	3.7	3.72-	2,020	1,920	<2	264.1	1,206	4	145.1	150.3	12.0	25.8	2.61	99.28	6.90	2.885	17	<0.1	14	<1	30	<0.5	80	<100	19,720	5,927	830	50	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	0.2	89.21	0.10	43.9	5.3								
Hangingwall																																																					
GCA11745	0022	NUS12002	46.00-48.00	Vtf	7.1	7.38+	270	307	28	2.8	92	5	21.42	7.36	8.5	14.6	0.13	<0.01	2.01	0.004	15	0.3	<5	<1	80	1.2	<50	<100	<10	<1	<10	<10	<0.2	<5	10	<0.1	<1	<0.05	<1	<10	<0.1	0.24	<0.05	52.9	31.1								
GCA11772	0544	NUS12019	66.17-68.00	Vtf	7.4	7.56+	1,160	1,180	50	7.1	561	8	192.4	36.65	14.3	23.5	0.04	<0.01	2.52	0.085	6	<0.1	24	<1	40	1.1	<50	<100	180	6	<10	<10	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	0.1	0.53	<0.05	227.3	14.0								
GCA11755	0204	NUS12008	73.25-75.00	Vtf	3.9	4.53-	4,940	5,180	<2	1,234	4,446	5	245.9	638.6	13.3	21.3	6.92	671.98	13.28	16.25	5	<0.1	14	<1	<10	<0.5	610	<100	28,400	5,097	10	23,790	352.2	####	<10	<0.1	<1	<0.05	<1	<10	<0.1	92.38	<0.05	51.8	1.9								
GCA11757	0245	NUS12011	12.00-14.00	Vtf	3.6	3.56-	5,050	5,180	<2	1,154	4,154	5	396.6	579.4	62.7	20.0	178.6	32.03	15.29	3,364	9	<0.1	31	<1	<10	<0.5	<50	<100	25,240	7,414	250	420	2	20	150	0.1	<1	<0.05	<1	<10	0.5	13.58	0.36	46.5	14.3								
GCA11762	0420	NUS12016	33.40-35.40	Vtf	4.8	5.15-	1,200	1,210	3	16.6	661	6	121.1	72.20	16.0	28.5	0.31	2.72	6.56	2,502	4	<0.1	13	<1	60	<0.5	<50	<100	4,870	2,712	30	130	0.7	<5	<10	<0.1	<1	<0.05	<1	<10	0.1	1.19	<0.05	69.9	44.9								
Footwall																																																					
GCA11749	0122	NUS12005	78.70-81.00	Pgb	6.9	6.76+	770	732	24	3.8	385	10	108.3	21.14	12.8	18.3	0.01	<0.01	2.75	0.204	4	<0.1	7	<1	50	<0.5	<50	700	430	44	10	<10	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	<0.05	<0.05	59.6	32.7								
GCA11764	0442	NUS12017	53.13-55.00	Pgb	7.7	7.04+	3,070	3,260	170	19.0	1,992	12	656.2	187.4	3.6	26.7	0.12	0.57	1.48	0.886	5	<0.1	10	<1	<10	<0.5	240	<100	1,160	63	20	20	<0.2	<5	<10	0.1	<1	<0.05	<1	<10	<0.1	0.53	<0.05	314.1	8.9								
GCA11761	0414	NUS12015	107.00-108.35	Pgb	5.9	5.61-	970	990	6	8.3	506	14	91.63	42.63	16.2	38.5	<0.01	1.30	3.09	0.533	4	<0.1	18	<1	70	<0.5	70	100	2,200	234	<10	20	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	0.07	<0.05	159.9	54.0								
GCA11747	0067	NUS12003	38.30-40.00	Pgb	3.8	3.71-	3,270	3,220	<2	344.9	2,158	11	320.2	279.2	10.3	77.0	12.75	110.22	9.49	2,467	5	<0.1	12	<1	<10	<0.5	100	200	11,440	2,894	60	110	<0.2	5	<10	0.1	<1	<0.05	<1	<10	0.1	2.56	<0.05	62.5	9.5								
GCA11771	0534	NUS12019	48.00-50.00	Pgb	4.1	4.22-	2,790	2,740	<2	178.6	1,911	3	579.1	123.8	15.2	4.1	3.61	68.79	5.22	0.673	4	<0.1	8	<1	<10	<0.5	<50	<100	9,290	3,022	90	70	0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	37.43	<0.05	206.5	6.2								
ORE SAMPLES																																																					
GCA11748	0109	NUS12005	54.00-56.00	Sgr	6.1	5.92+	1,910	1,900	20	40.8	1,301	17	421.1	43.85	7.3	25.8	0.07	11.77	2.53	1,460	3	0.1	133	<1	30	<0.5	<50	<100	6,620	315	<10	20	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	0.48	<0.05	107.3	61.8								
GCA11758	0363	NUS12014	30.50-32.50	Sgr	6.3	6.00+	940	872	12	6.9	490	6	129.3	32.07	8.3	28.4	<0.01	0.91	2.91	1,535	3	<0.1	39	<1	50	<0.5	<50	<100	5,210	688	<10	30	<0.2	<5	<10	0.2	<1	<0.05	<1	<10	<0.1	1.58	<0.05	49.9	72.7								
GCA11746	0031	NUS12002	65.00-67.00	Sgr	7.1	6.56+	2,770	2,920	151	27.1	1,843	8	792.6	26.01	11.4	6.3	0.15	0.44	3.04	0.839	8	<0.1	149	<1	30	<0.5	<50	<100	8,360	297	30	20	<0.2	<5	10	<0.1	<1	<0.05	<1	<10	<0.1	19.22	<0.05	268	19.0								
GCA11765	0461	NUS12017	83.00-85.00	Sgr	4.6	5.09-	1,650	1,640	3	21.4	962	3	126.1	148.9	15.7	46.3	1.02	2.87	4.43	0.308	3	<0.1	72	<1	50	<0.5	<50	200	3,940	760	30	40	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	4.51	<0.05	52.8	31.9								
Blank					5.2	5.38+	<10	27	3	1.9	1	<2	0.08	<0.01	<0.01	<0.2	0.01	0.02	0.06	<0.001	2	<0.1	<5	<1	70	<0.5	<50	<100	<10	<1	<10	0.02	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	<0.05	<0.05	0.3	0.6								
HPDW					5.6		<10		3	1.7	1	<2	0.05	<0.01	<0.01	0.2	<0.01	<0.01	<0.05	<0.001	<1	<0.1	<5	<1	40	<0.5	<50	<100	<10	<1	<10	<10	<0.2	<5	<10	<0.1	<1	<0.05	<1	<10	<0.1	<0.05	<0.05	<0.2	<0.5								

Notes:

EC = Electrical-Conductivity

Water-Extraction Testwork employed a solid:solution ratio of 1:2 (w/w) with the test-slurries prepared from pulps and high-purity-deionised-water (HPDW).

Test-slurries were bottle-rolled for ca. 1 day before being left to 'still-stand' for ca. 1 day to allow 'fines' to settle-out.

Supernatants then decanted and vacuum-filtered (0.45µm-membrane) with 'raw-filtrates' and 'HNO3-dosed-filtrates' submitted for specific analyses, as appropriate.

pH and EC values of the water-extracts also determined in the GCA Testing Laboratory.

FIGURES

Figure 1

pH-Buffering Curves for Mine-Waste Samples

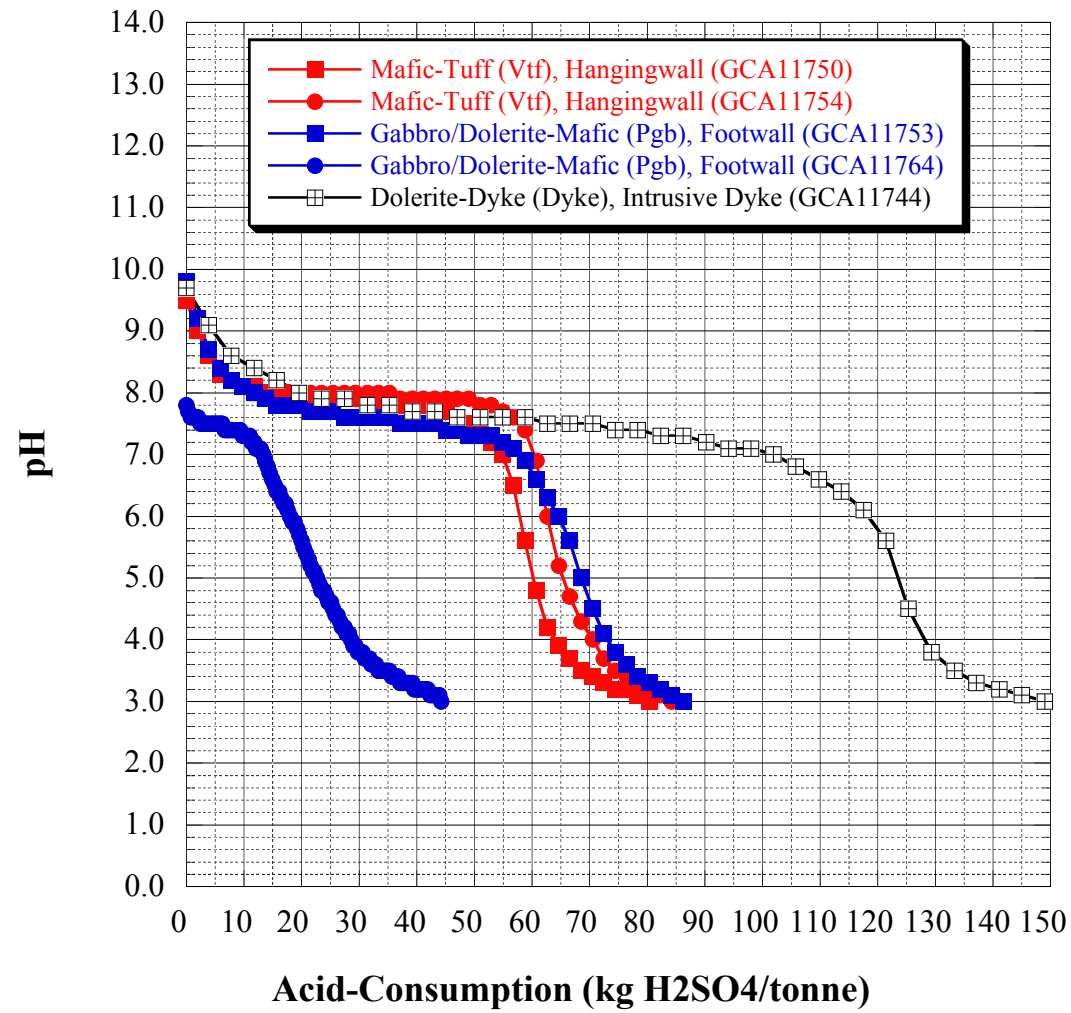
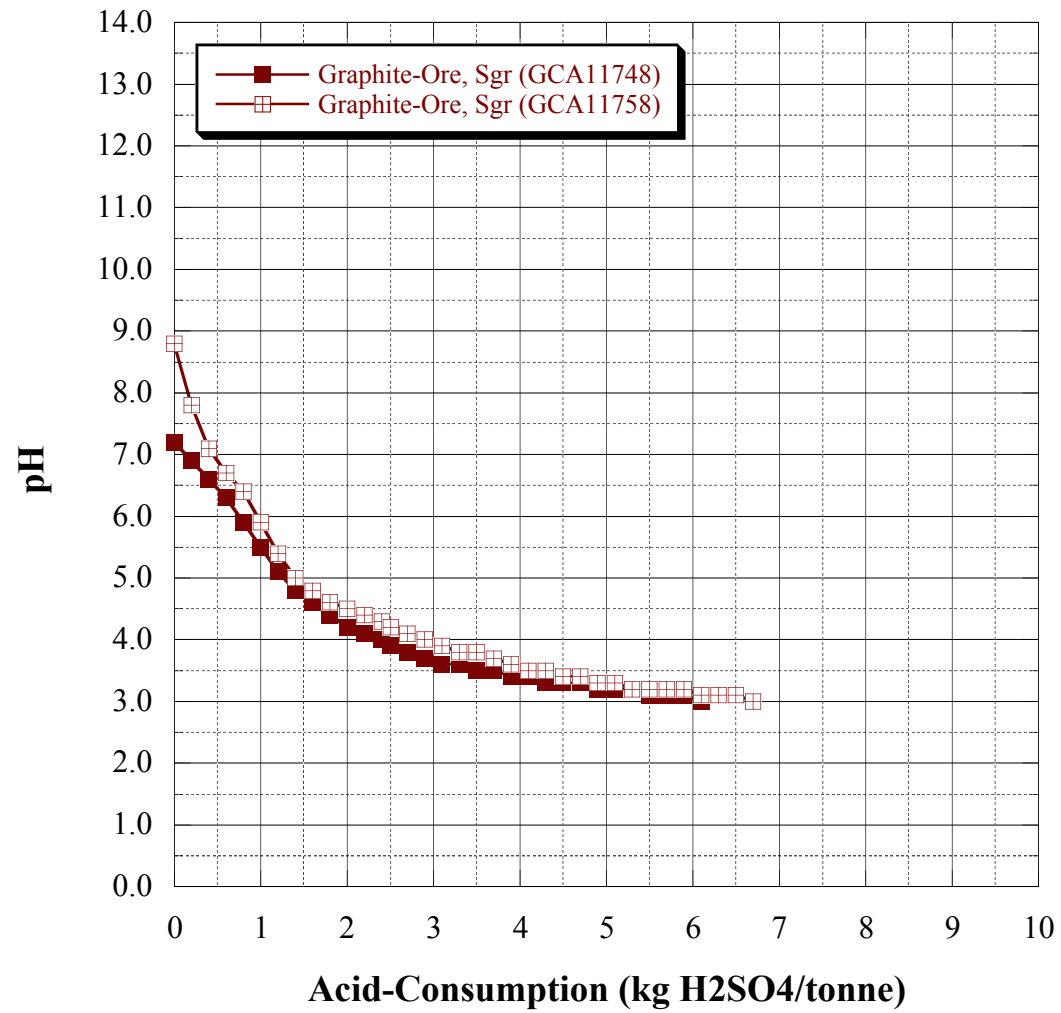


Figure 2

pH-Buffering Curves for Ore Samples



PLATES



PLATE 1: Samples 'As-Received' at GCA Testing Laboratory (Bridgetown) following preparation at GLS Intertek (Maddington).



PLATE 2: Determination of [pH-\(1:2\)](#) and [EC-\(1:2\)](#) values (EC = Electrical-Conductivity). Crushed (-2mm nominal) samples aged in contact with air at room-temperature (20-22 °C) for *ca.* 24 hrs prior to measuring pH and EC. Supernatant-water initially decanted for EC determinations, and following return to container slurry-pH measured.



PLATE 3: **Net-Acid-Generation (NAG)** testing with 15 % (v/v) H_2O_2 . High-S samples housed in larger beakers due to vigour of peak reaction rate. Testing on pulps (-75 μm nominal).

Bottom pair of photographs show peaking ('boiling') of reaction at slightly different times for the tested High-S samples. Reaction for these samples peaked within *ca.* 1 hr.



PLATE 4: Auto-titration testing using 0.1 N-H₂SO₄ to determined pH-buffering properties of selected samples with CO₃-C values above 0.2 %. Testing on pulps (-75 µm nominal).



PLATE 5: Determination of Neutralisation-Potential (NP) [= Acid-Neutralisation Capacity, ANC) values for selected samples with CO₃-C < 0.01 % using the BS EN 15875:2011 method (cf. AMIRA (2002) method) and a shaker-waterbath. Bottom photograph shows bottle-lids with a small hole for gas exchange as specified in BS EN 15875:2001.



PLATE 6: [Water-extraction testing](#) utilising bottle-roll technique and slurries with a solid:solution ratio of 1:2 (w/w). Bottle-rolling overnight followed by 'still-standing' for *ca.* 24 hrs to allows 'suspended-fines' to settle, prior to decanting and vacuum-filtration (0.45 μ m-membrane) for generation of water-extracts for analysis. Testing on crushed (nominal -2mm) samples.



Dry Waste Sample



Moistened Waste Sample



Dry Ore Sample



Moistened Ore Sample



PLATE 7: Moisture-conditioning coarse-crushed (nominal -10 mm) samples for measurement of [Oxygen-Consumption Rates \(OCRs\)](#).

Gravimetric-water content (GWC) adjusted using high-purity-deionised-water (HPDW) via misting from a spay-bottle and homogenising via hand-mixing. GWC values within range 2-4 % (w/w) as governed by sample texture.

Ore samples took more effort to moisten uniformly, due to their hydrophobic ('non-wetting') nature.



PLATE 8: Packed [Oxygen-Consumption Cells \(OCCs\)](#) for selected waste and ore samples, and housed in an incubator at **20.0 (+/- 0.1) °C**.

Samples tested were 'non-acidic' samples (i.e. pH-(1:2) values > 5).

Testing on pre-moistened -10 mm (nominal) fraction that were aged for 2 days in plastic-bags in a CT-room at *ca.* 20 °C prior to packing the OCCs.



Initial Leachate-pH = 6-7



'Spot-Test' for Thiosalts Using Dilute HgCl_2 ('Corrosive Sublimate') Solution



Leachate-pH = 2-3 and formation of characteristic canary-yellow ppt.



PLATE 9: Follow-up testing on leachate chemistry for **hyper-reactive ore (Sgr) sample GCA11746** after completion of OCR testing (Plate 8).

This sample is characterised by 5.51%S, and a $\text{CO}_3\text{-C}$ value of 0.04 %, and is circum-neutral (i.e. pH-(1:2) value greater than 5). It's OCR value was 8.93E-09 kg $\text{O}_2/\text{kg/s}$, corresponding to an **Acid-Production Rate (APR) 'of-the-order' 1 kg $\text{H}_2\text{SO}_4/\text{tonne/week}$** . These results indicate hyper-reactivity, especially given the %S value and circum-neutral state.

Approx. 0.40 kg of the moist solids from the OCC were leached with high-purity-deionised-water (HPDW) to generate *ca.* 100 mL of leachate which was then vacuum-filtered (0.45 μm -membrane). The resulting Leachate-pH was 6.3. This is shown in the top pair of photographs.

The Leachate-pH dropped to 2.7 almost immediately upon addition of 5 mL of 2 % (w/v) HgCl_2 solution with the formation of a canary-yellow precipitate – see bottom pair of photographs.

This 'spot-testing' with the HgCl_2 solutions shows the presence of **thiosalts (e.g. thiosulphate, and polythionates)** in the leachate, **consistent with the hyper-reactivity indicated by the OCR value above.**

ATTACHMENT I

DETAILS OF SAMPLING PROGRAMME

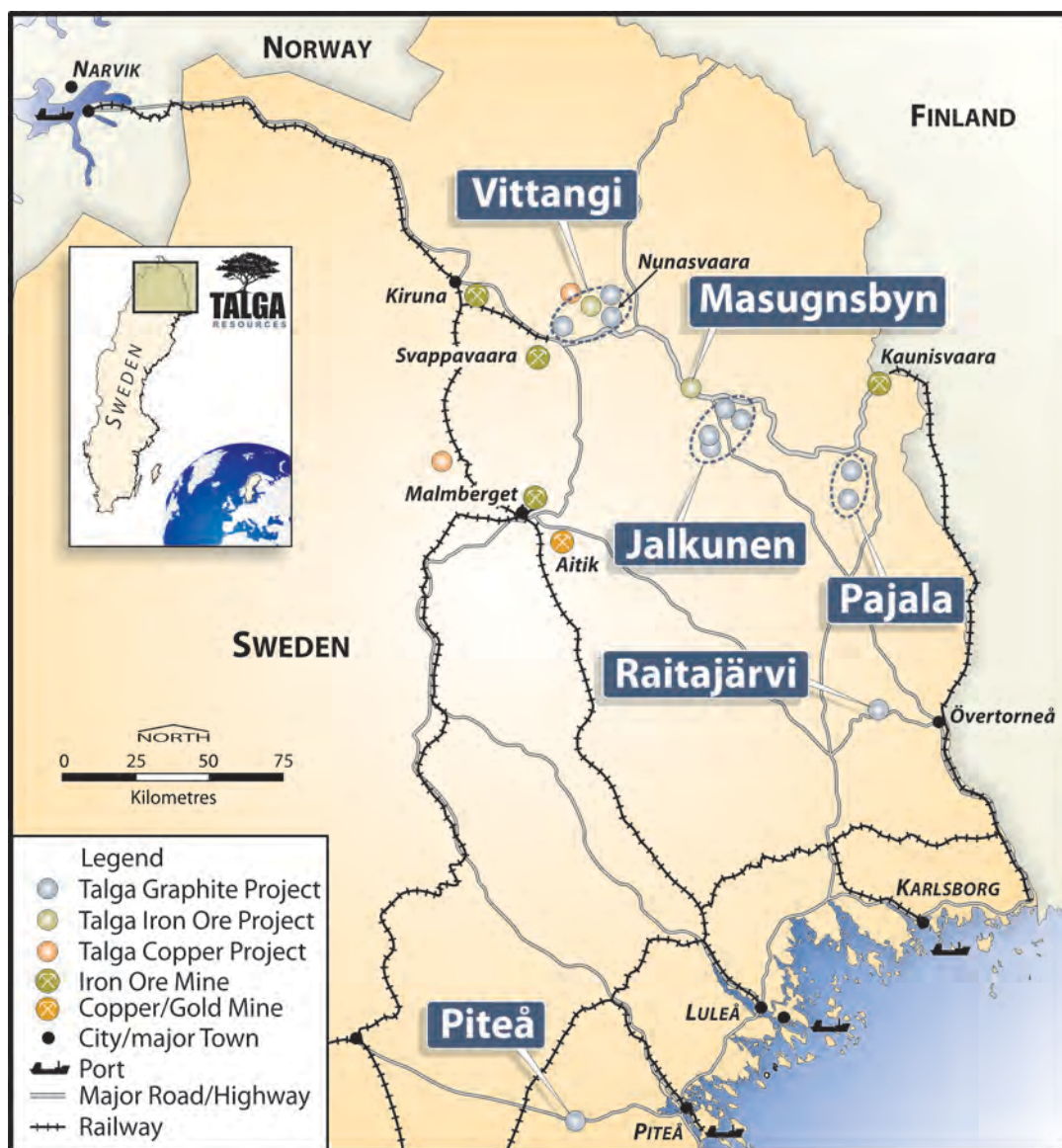
Memorandum

BY:	Peter French
TO:	Graeme Campbell and Associates
DATE:	11 September 2017
SUBJECT:	Nunasvaara South Mine Waste Overview

Purpose of this memo is to provide an overview of the geology and the indicative mine plan as context for interpretation of the initial mine waste rock characterisation testwork being undertaken during 2017. Testwork is being undertaken by Graeme Campbell & Associates on ore and waste drill core samples from storage.

Project Location

Talga's Nunasvaara Graphite deposit is located in the north of Sweden, in the Vittangi region.



West Perth WA 6005
PO Box 720, West Perth WA 6872

T +61 8 9481 6667

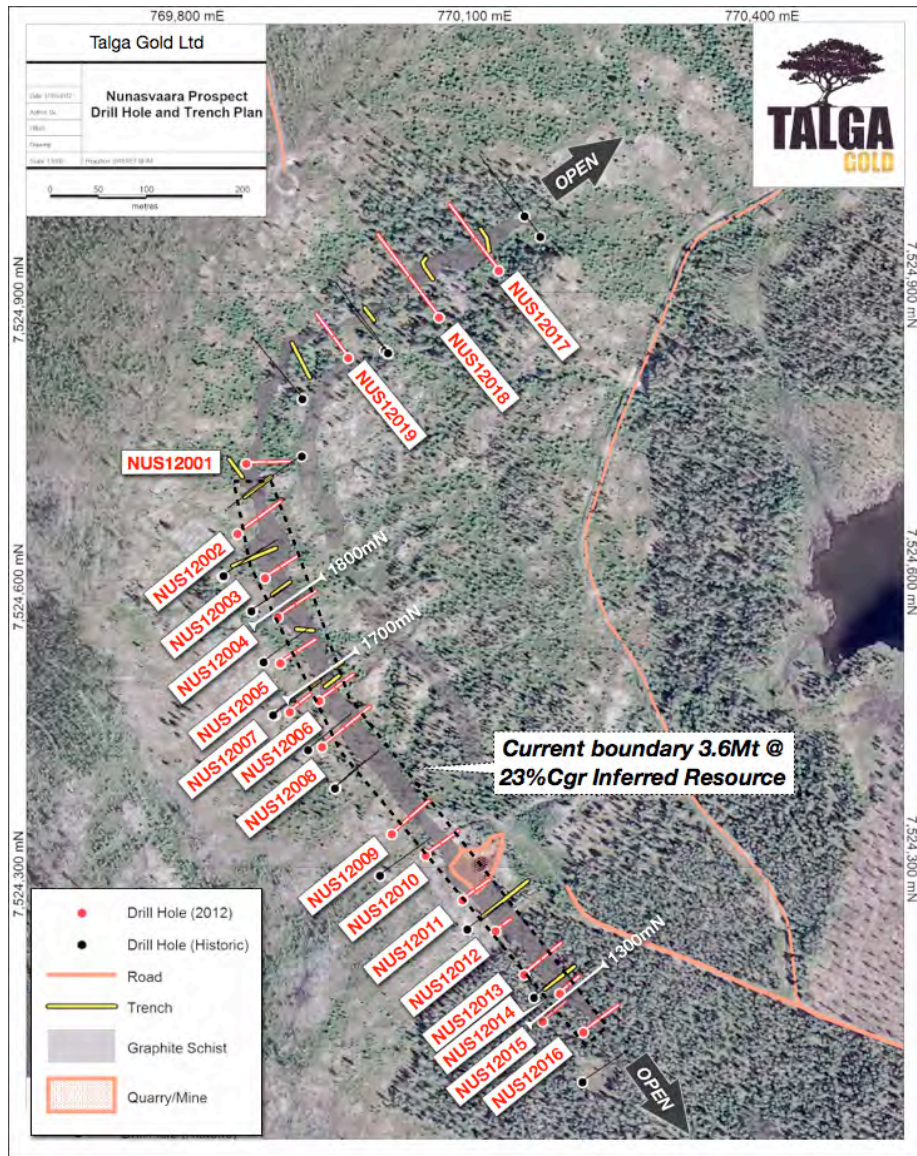
F +61 8 9322 1935

admin@talgaresources.com

talgaresources.com

Exploration Drilling

During 2012 a drilling campaign was undertaken substantially adding to the historic drill data. It is the 2012 drill holes samples that were available for 2017 characterisation test work.



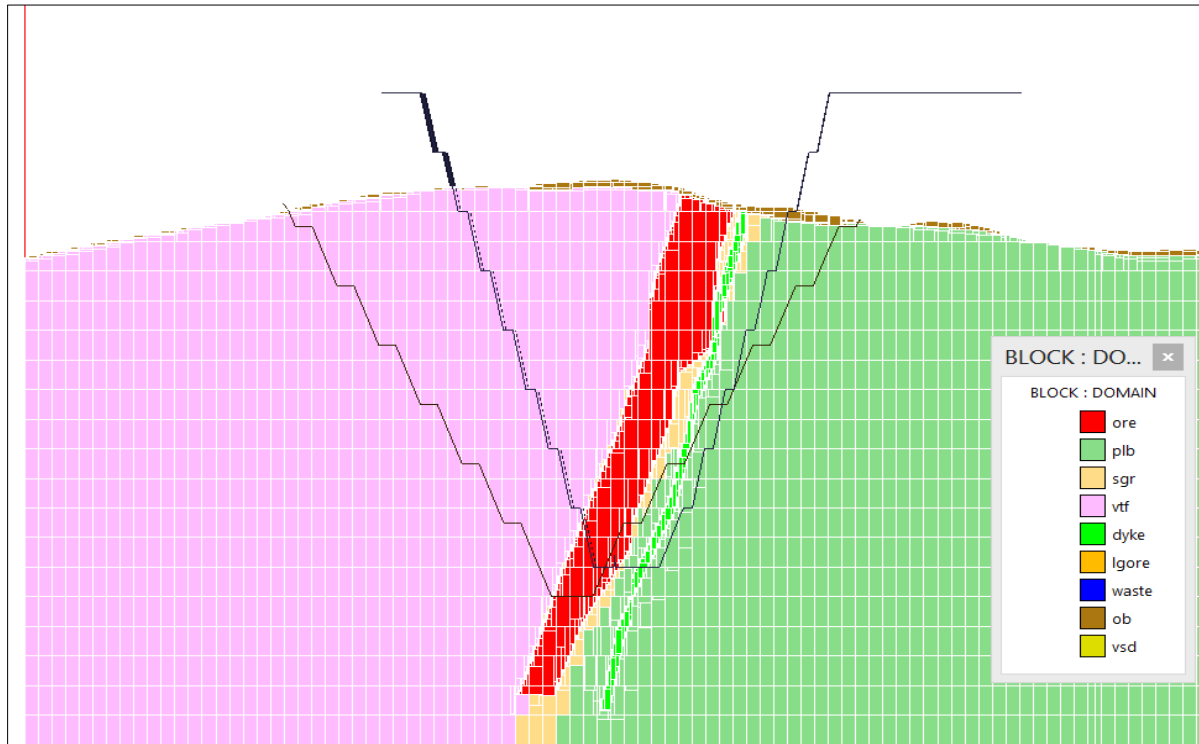
Waste Quantities

Based on the 2017 mine plan, the following waste volumes are expected to come from the 2 pits proposed for Nunasvaara South.

Material Type	Domain	Nunn Sth Pit 1		Nunn Sth Pit 2	
Indicated & Inferred	ore	1,522,000	26%	672,000	41%
Waste	Dyke	188,000	3%	245,000	15%
	OB	105,000	2%	28,000	2%
	Pgb	670,000	11%	270,000	16%
	Sgr	150,000	3%	7,000	0%
	Vtf	3,220,000	55%	434,000	26%
	Total	4,332,000	74%	983,000	59%

An indicative cross section showing the location of the various waste types is show in Figure 1 (Note Plb should be Pgb)

Figure 1. Nunasvaara South Pit 1 Section showing Pit Design Shells and domains. Note: Smaller steeper sided pit is currently considered most favourable mine design.



Existing characterisation

Some analysis of ore and wastes has been undertaken, specifically total sulphur and assays for selected elements. This data was reviewed and the following observations made.

Elemental characterisation:

Average concentrations of metals within each of the four main domains were compared against the Swedish Environmental Protection Agency's general pollutant values, for 'sensitive land use' (SLU) and 'less sensitive land use' (LSLU). These values are not binding levels, but are indicators of the concentrations at which these metals are typically aimed to be reduced to in contaminated site management.

The summary data presented in the table below shows that copper, chromium, cobalt, nickel and vanadium, and to a lesser extent, lead, zinc and barium, are naturally enriched in the rock at site and are at risk of being mobilised into waterways through weathering, especially should acidic conditions develop through oxidation of pyrite, etc.

The data also shows that average sulphur values for all materials are higher than 1%.

	Count of Assays	As ppm	Ba ppm	Cd ppm	Co ppm	Cr ppm	Cu Ppm	Mo ppm	Ni Ppm	Pb ppm	V ppm	Zn ppm	S_%
SEPA gpv - SLU		10	200	0.8	15	80	80	40	40	50	100	250	
SEPA gpv - LSLU		25	300	12	35	150	200	100	120	400	200	500	
Dyke	38	3.2	173.8	0.1	42.7	121.6	234.1	4.2	117.6	17.2	236.0	37.9	1.5
Pgb	104	1.7	115.2	0.1	101.6	103.3	854.3	2.8	229.9	16.7	254.3	64.2	3.3
Sgr	473	7.6	154.2	0.4	49.1	185.8	401.0	8.0	210.4	68.1	199.1	86.3	2.9
Vtf	111	9.8	150.0	0.6	67.2	216.4	397.1	2.9	198.5	63.8	262.5	252.5	2.3
Total / Average	726	6.6	149.8	0.4	57.9	176.3	450.3	6.4	207.9	54.8	214.6	94.7	2.8

Proposed Waste Rock Sampling Plan

No samples of Ob (overburden/moraine) were retained during exploration drilling and will be obtained for testing in a separate program of testwork.

Samples were proposed to be collected for each of the following domains:

- Dyke Dolerite Dyke (7 samples)
- Pgb Gabbro/dolerite mafic footwall (10 samples)
- Sgr Graphite ore (high or low grade). (10 samples)
- Vtf Mafic tuff hanging wall (10 samples)

For each domains samples were targeted to capture the range of %S values present within the domain and the physical spread of samples within the waste zone of the resource.

When the samples were retrieved from storage a portion of samples were unidentifiable. As a result only 32 samples of the targeted 40 samples were retrieved, as outlined below.

- Dyke Dolerite Dyke (6 samples)
- Pgb Gabbro/dolerite mafic footwall (7 samples)
- Sgr Graphite ore (high or low grade). (8 samples)
- Vtf Mafic tuff hanging wall (9 samples)

Targetted Samples						Samples Retrieved and Characterised
Material	Drill Hole ID	mFrom	mTo	Sample_ID	S_%_S-IR08	
Dyke	NUS12001	42.25	44	0017	2.19	Y
Dyke	NUS12001	53	55	0019	1.08	Y
Dyke	NUS12006	38.5	41	0141	0.29	Y
Dyke	NUS12006	40.5	43	0142	0.47	Y
Dyke	NUS12018	79.68	82	0494	9.73	Y
Dyke	NUS12019	44.3	46	0532	1.32	Y
Pgb	NUS12003	38.3	40	0067	3.19	Y
Pgb	NUS12005	78.7	81	0122	1.75	Y
Pgb	NUS12007	104	106	0158	0.11	Y
Pgb	NUS12015	107	108	0414	2.47	Y
Pgb	NUS12017	53.13	55	0442	24.1	Y
Pgb	NUS12019	38	40	0530	0.15	Y
Pgb	NUS12019	48	50	0534	9.16	Y
Sgr	NUS12001	21	23	0006	1.19	Y
Sgr	NUS12002	65	67	0031	5.51	Y
Sgr	NUS12005	54	56	0109	8.18	Y
Sgr	NUS12010	44	46	0236	0.68	Y
Sgr	NUS12014	30.5	33	0363	3.51	Y
Sgr	NUS12017	83	85	0461	3.49	Y
Sgr	NUS12018	52	54	0480	0.23	Y
Sgr	NUS12018	60	62	0484	1.54	Y
Vtf	NUS12002	46	48	0022	0.22	Y
Vtf	NUS12006	16	18	0129	0.55	Y
Vtf	NUS12008	45	47	0187	0.17	Y

Targetted Samples						Samples Retrieved and Characterised
Material	Drill Hole ID	mFrom	mTo	Sample_ID	S_%_S-IR08	
Vtf	NUS12008	73.25	75	0204	9.72	Y
Vtf	NUS12011	12	14	0245	2.15	Y
Vtf	NUS12016	31.4	33	0420	4.16	Y
Vtf	NUS12016	33.4	35	0421	2.77	Y
Vtf	NUS12019	66.17	68	0544	1.19	Y
Vtf	NUS12019	74	76	0546	0.35	Y
Dyke	NUS12006	36.72	39	0140	0.83	N
Pgb	NUS12009	59.04	61	0217	2.48	N
Pgb	NUS12012	98.26	100	0326	19.05	N
Pgb	NUS12014	68	70	0384	1.63	N
Sgr	NUS12006	24	26	0133	2.94	N
Sgr	NUS12013	41	43	0342	1.51	N
Vtf	NUS12014	59.9	61	0381	2.74	N

Reference Documentation:

- European Standard EN 15875 “Characterization of waste - Static test for determination of acid potential and neutralisation potential of sulfidic waste”.
- ARD assessment and management to be of a standard consistent with The International Network for Acid Prevention’s (INAP) Global Acid Rock Drainage (GARD) Guide.

ATTACHMENT II

LABORATORY REPORTS



GRAEME CAMPBELL AND ASSOCIATES

21-12-2017

PO BOX 247

BRIDGETOWN

WESTERN AUSTRALIA 6255

Our reference 24208

Your reference 1716

PLM/XRD ANALYSIS OF FOUR ROCK POWDERS / CHIPS

Roger Townend

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RESULTS

POLISHED SECTIONS/XRD

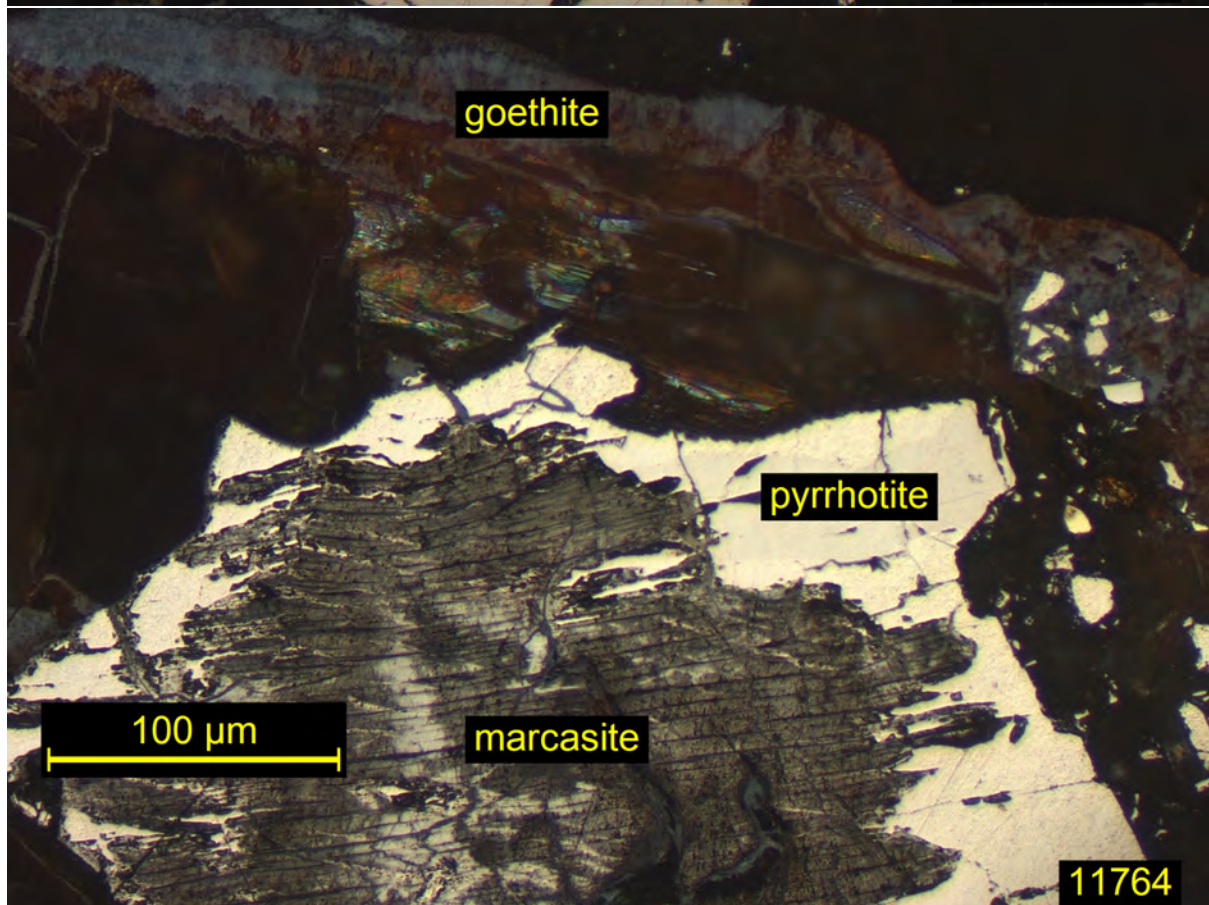
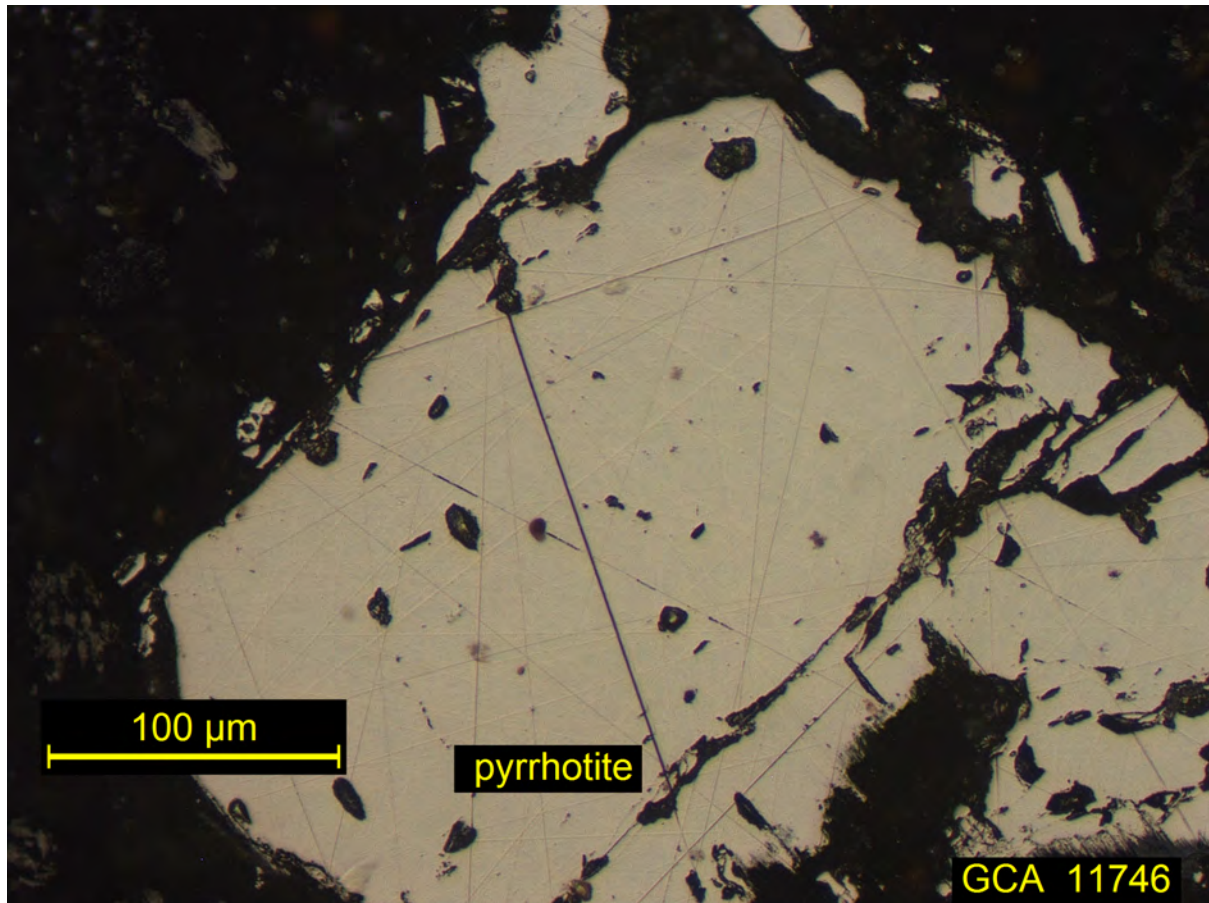
GCA	11746	11763`	11764	11768
TREMOLITE	MAJOR	MINOR	MAJOR	MINOR
PLAGIOCLASE	MAJOR	MAJOR		MAJOR
CHLORITE	ACCESSORY	MINOR		ACCESSORY
K FELDSPAR	ACCESSORY			
MARIALITE		MAJOR	MINOR	MAJOR
BIOTITE		ACCESSORY	ACCESSORY	MINOR
QUARTZ			ACCESSORY	
CALCITE			ACCESSORY	
GRAPHITE	MAJOR	ACCESSORY		ACCESSORY
PYRRHOTITE	ACCESSORY	ACCESSORY	MAJOR	ACCESSORY
MARCASITE			MINOR	
PYRITE	ACCESSORY	ACCESSORY	TRACE	ACCESSORY
CHALCOPYRITE	TRACE	TRACE	TRACE	TRACE
VIOLARITE			TRACE	
GOETHITE	ACCESSORY		MINOR	ACCESSORY
RUTILE		TRACE		TRACE
GYPSUM			ACCESSORY	
JAROSITE				ACCESSORY

MAJOR 20-50 %; MINOR 10-20 %; ACCESSORY 1-10 %; TRACE < 1 %

NOTE

Contrary to what was expected, the pyrrhotite within sample GCA 11746 is often very coarse-grained, with single crystals in excess of 0.5 mm. Curiously, these may be flanked by goethite, with evidence of some leaching of the sulphide between goethite rim and sulphide nucleus. Surprisingly, there is almost no evidence of a marginal marcasite on the pyrrhotite rims, a complete contrast with 11764. See optical images.

Very coarse euhedral pyrite is also present separately, containing chalcopyrite.





Accredited for compliance with ISO/IEC 17025

Dr G Campbell
 CAMPBELL, GRAEME and ASSOCIATES PTY LTD
 PO Box 247
 BRIDGETOWN WA 6255

JOB INFORMATION

JOB CODE	143/1712653
No. of SAMPLES	32
CLIENT O/N	GCA 1716
PROJECT	Nunasvaara
STATE	Mine waste
DATE RECEIVED	4/09/2017
DATE COMPLETED	28/09/2017
DATE AMENDED	25/10/2017

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method

This report has been amended in which the Fizz rate was redone. This report replaces the original report dated 28/09/2017.

The samples were received as ex job 1712451

The samples were received as coarse rejects from historic drill core preparation by ALSGlobal in Sweden.

Sample preparation by Intertek GLS as follows:

The samples were oven-dried in a forced-fan-oven set at 80°C as per the protocol for acid-sulphate-soil samples. Each sample was passed through 'jaw-crusher' with clearance set to nominal 10 mm. This is the coarse-crushing step.

Following the above coarse-crushing a 1kg sub-sample was representatively split-off, and all of this fine-crushed to nominal -2mm.

200g of the fine - crushings were representatively sub-sampled and pulverised to nominal -75µm to generate the pulps, using zirconia-bowl.

Results of analysis on:

Element	C	C-Acinsol	C-CO3	S
Method	/CSA	C71/CSA	/CALC	/CSA
Detection	0.01	0.01	0.01	0.01
Units	%	%	%	%
Sample Name				
Control Blank	X			X
0006 GCA11742	25.05	25.5	X	1.24
0017 GCA11743	0.05	0.1	X	1.87
0019 GCA11744	2.25	0.08	2.17	1.09
0022 GCA11745	0.73	0.73	X	0.26
0031 GCA11746	25.86	25.82	0.04	5.17
0067 GCA11747	0.61	0.66	X	3

Element	C	C-Acinsol	C-CO3	S
Method	/CSA	C71/CSA	/CALC	/CSA
Detection	0.01	0.01	0.01	0.01
Units	%	%	%	%
Sample Name				
0109 GCA11748	24.03	23.4	0.63	8.52
0122 GCA11749	0.05	0.07	X	1.68
0129 GCA11750	3.1	2.02	1.08	0.54
0141 GCA11751	0.03			0.25
0142 GCA11752	0.02			0.45
0158 GCA11753	1.41	0.44	0.97	0.1
0187 GCA11754	2.5	1.61	0.89	0.25
0204 GCA11755	0.2	0.23	X	9.52
0236 GCA11756	33.35	31.09	X	0.93
0245 GCA11757	0.06	0.09	X	1.64
0363 GCA11758	15.44	15.01	0.43	4.75
0381 GCA11759	5.71	5.53	0.18	3.34
0384 GCA11760	0.05	0.05	X	1.47
0384 GCA11760	0.07			1.48
0414 GCA11761	0.33	0.35	X	2.09
0420 GCA11762	0.06	0.1	X	4.47
0421 GCA11763	0.37	0.4	X	2.85
0442 GCA11764	1.38	0.07	1.31	20.18
0461 GCA11765	18.53	18.61	X	3.98
0480 GCA11766	38.19	38.03	0.16	0.27
CH :481 GCA11766	38.72			
0484 GCA11767	44.8	42.98	X	1.21
0494 GCA11768	2.29	2.37	X	9.06
0530 GCA11769	0.16	0.13	0.03	0.15
0532 GCA11770	0.34	0.14	0.2	1.71
0534 GCA11771	0.18	0.19	X	9.79
0544 GCA11772	0.21	0.21	X	1.03
0546 GCA11773	0.22	0.22	X	0.41
OREAS 623	0.33			9.09
GGC-01	26.45			0.05

Notes

1. Total-C and Total-S were determined on -75um samples using an induction furnace according to Genalysis method number MPL_W043. The samples are ignited in oxygen ~1700°C and the CO₂ and SO₂ measured by infrared detectors
2. C-Acinsol (acid insoluble carbon) was determined on -75um samples by a C&S analyser after removal of carbonates and soluble organic carbon using hot hydrochloric acid according to Genalysis method number MPL_W046.

Results of analysis on:

sample	Fizz	volume	HCl	NaOH	pH	ANC soln	ANC
name	Rate	ml	M	M	Drop	final pH	(kgH ₂ SO ₄ /t)
0006 GCA11742	0	10	0.53	0.50	3.0	1.5	5
0017 GCA11743	0	10	0.53	0.50	3.5	1.8	15
0019 GCA11744	2	50	0.53	1.01	3.1	1.6	217
0022 GCA11745	0	10	0.53	0.50	2.7	1.6	10
0031 GCA11746	0	10	0.53	0.50	3.2	2.3	15
0067 GCA11747	0	10	0.53	0.50	3.0	1.9	13
0109 GCA11748	0	20	0.53	0.50	2.5	1.7	20
0122 GCA11749	0	10	0.53	0.50	3.3	1.7	10
0129 GCA11750	1	50	0.53	1.01	3.2	0.9	103

sample	Fizz	volume	HCl	NaOH	pH	ANC soln	ANC
name	Rate	ml	M	M	Drop	final pH	(kgH ₂ SO ₄ /t)
0141 GCA11751	0	10	0.53	0.50	3.7	1.6	8
0142 GCA11752	0	10	0.53	0.50	2.8	1.6	6
0158 GCA11753	1	50	0.53	1.01	3.5	0.8	95
0187 GCA11754	1	50	0.53	1.01	3.4	0.9	97
0204 GCA11755	0	10	0.53	0.50	3.2	2.6	9
0236 GCA11756	0	10	0.53	0.50	3.9	1.7	13
0245 GCA11757	0	10	0.53	0.50	2.9	2.1	11
0363 GCA11758	0	20	0.53	0.50	2.8	1.2	13
0381 GCA11759	0	10	0.53	0.50	3.0	1.8	12
0384 GCA11760	0	10	0.53	0.50	3.1	2.1	12
CH:0384 GCA11760	0	10	0.53	0.50	3.1	1.8	12
0414 GCA11761	0	10	0.53	0.50	3.1	1.6	10
0420 GCA11762	0	10	0.53	0.50	3.1	1.9	14
0421 GCA11763	0	10	0.53	0.50	3.1	1.7	8
0442 GCA11764	1	50	0.53	1.01	2.4	1.8	128
0461 GCA11765	0	10	0.53	0.50	3.1	1.9	17
0480 GCA11766	0	10	0.53	0.50	3.7	1.5	10
0484 GCA11767	0	10	0.53	0.50	3.1	1.6	10
0494 GCA11768	0	10	0.53	0.50	3.1	2.0	16
0530 GCA11769	0	10	0.53	0.50	3.3	1.9	15
0532 GCA11770	1	10	0.53	0.50	3.1	2.1	26
0534 GCA11771	0	10	0.53	0.50	2.9	2.0	7
0544 GCA11772	0	10	0.53	0.50	3.3	2.1	19
0546 GCA11773	0	10	0.53	0.50	3.4	1.7	12

Notes:

1. ANC was determined on 5g -2mm fraction obtained by sieving 'fine-crushings' (nominal -2mm) Acid concentrations are as stated. -75um fine pulverised sample used to measure fizz rating
 2. Two drops of 30 % hydrogen peroxide are added to each sample at pH~ 5 to oxidise any ferrous iron. pH drop: Result reported when the pH drops to a value below 4 on addition of peroxide.
 Titration with NaOH uses an auto titration unit which allows a slow approach to pH 7 endpoint. For samples with low ANC values up to 5 minutes may be required for stabilisation at pH 7.
 3. This "Bulk-ANC" static-testing procedure is based on AMIRA (1002), Genalysis method number: ENV_W035. The samples are heated for 1 hour on a temperature controlled hotplate, temperature of the solution 80-90°C.

4. Selection of the volume and strength of HCl is based on corresponding CO₃-C values, as advised by GCA

The above variations to the AMIRA (2002) procedure reflect specifications by GCA for ANC test work.

NATA ENDORSED DOCUMENT**Company Accreditation Number 3244**

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Intertek Genalysis Signatory: Huong Pham

Huong Pham

Date: 25/10/2017



ANALYTICAL REPORT



Accreditation No. 2562

CLIENT DETAILS

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WA 6255

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Project **GCA Job No. 1716**
Order Number **GCA Job No. 1716**
Samples 17

LABORATORY DETAILS

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SGS Reference **PE119910 R0**
Date Received 03 Oct 2017
Date Reported 18 Oct 2017

COMMENTS

Accredited for compliance with ISO/IEC 17025- Testing. NATA accredited laboratory 2562(898/20210).

SIGNATORIES

Michael McKay
Inorganics and ARD Supervisor



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.001	PE119910.002
			Sample Matrix	Soil	Soil
			Sample Name	GCA11744	GCA11751
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.74	0.099
Chromium Reducible Sulphur (Scr)	moles H+/T	5	460	62
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	23	3.0

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	2.9	0.03
Total Organic Carbon (TOC)	%w/w	0.02	0.02	0.02
Inorganic Carbon (calculated)*	%w/w	0.02	2.9	<0.02



ANALYTICAL REPORT

PE119910 R0

		Sample Number	PE119910.003	PE119910.004
		Sample Matrix	Soil	Soil
		Sample Name	GCA11752	GCA11770
Parameter	Units	LOR		

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.15	1.2
Chromium Reducible Sulphur (Scr)	moles H+/T	5	92	750
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	4.5	37

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	<0.02	0.33
Total Organic Carbon (TOC)	%w/w	0.02	0.03	0.11
Inorganic Carbon (calculated)*	%w/w	0.02	<0.02	0.21



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.005	PE119910.006
			Sample Matrix	Soil	Soil
			Sample Name	GCA11753	GCA11764
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.086	2.0
Chromium Reducible Sulphur (Scr)	moles H+/T	5	54	1200
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	2.6	61

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	1.5	1.1
Total Organic Carbon (TOC)	%w/w	0.02	0.38	0.05
Inorganic Carbon (calculated)*	%w/w	0.02	1.2	1.1



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.007	PE119910.008
			Sample Matrix	Soil	Soil
			Sample Name	GCA11769	GCA11745
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.11	0.25
Chromium Reducible Sulphur (Scr)	moles H+/T	5	69	150
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	3.4	7.5

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	0.10	0.78
Total Organic Carbon (TOC)	%w/w	0.02	0.09	0.67
Inorganic Carbon (calculated)*	%w/w	0.02	<0.02	0.11



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.009	PE119910.010
			Sample Matrix	Soil	Soil
			Sample Name	GCA11750	GCA11754
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.40	0.17
Chromium Reducible Sulphur (Scr)	moles H+/T	5	250	110
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	12	5.2

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	3.5	3.1
Total Organic Carbon (TOC)	%w/w	0.02	2.0	1.5
Inorganic Carbon (calculated)*	%w/w	0.02	1.5	1.5



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.011	PE119910.012
			Sample Matrix	Soil	Soil
			Sample Name	GCA11772	GCA11773
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.67	0.30
Chromium Reducible Sulphur (Scr)	moles H+/T	5	420	180
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	21	9.0

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	0.19	0.21
Total Organic Carbon (TOC)	%w/w	0.02	0.13	0.17
Inorganic Carbon (calculated)*	%w/w	0.02	0.06	0.04



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.013	PE119910.014
			Sample Matrix	Soil	Soil
			Sample Name	GCA11759	GCA11748
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	1.9	2.7
Chromium Reducible Sulphur (Scr)	moles H+/T	5	1200	1700
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	59	83

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	5.3	19
Total Organic Carbon (TOC)	%w/w	0.02	5.3	18
Inorganic Carbon (calculated)*	%w/w	0.02	0.06	1.5



ANALYTICAL REPORT

PE119910 R0

			Sample Number	PE119910.015	PE119910.016
			Sample Matrix	Soil	Soil
			Sample Name	GCA11756	GCA11758
Parameter	Units	LOR			

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.52	3.2
Chromium Reducible Sulphur (Scr)	moles H+/T	5	320	2000
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	16	98

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	23	12
Total Organic Carbon (TOC)	%w/w	0.02	23	12
Inorganic Carbon (calculated)*	%w/w	0.02	0.60	0.10



ANALYTICAL REPORT

PE119910 R0

		Sample Number	PE119910.017
		Sample Matrix	Soil
		Sample Name	GCA11766
Parameter	Units	LOR	

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/10/2017

Chromium Reducible Sulphur (Scr)	%	0.005	0.20
Chromium Reducible Sulphur (Scr)	moles H+/T	5	120
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	6.0

Total Carbon and TOC by LECO Furnace Method: AN203 Tested: 9/10/2017

Total Carbon	%w/w	0.02	1.2
Total Organic Carbon (TOC)	%w/w	0.02	1.6
Inorganic Carbon (calculated)*	%w/w	0.02	<0.02



QC SUMMARY

PE119910 R0

MB blank results are compared to the Limit of Reporting

LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.

DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Chromium Reducible Sulphur (CRS) Method: ME-(AU)-[ENV]AN217

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chromium Reducible Sulphur (Scr)	LB137517	%	0.005	<0.005	4 - 11%	103 - 107%
Chromium Reducible Sulphur (Scr)	LB137517	moles H+/T	5	<5		
Chromium Reducible Sulphur (Scr)	LB137517	kg H2SO4/T	0.25	<0.25		

Total Carbon and TOC by LECO Furnace Method: ME-(AU)-[ENV]AN203

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Carbon	LB137347	%w/w	0.02	<0.02	1 - 9%	97 - 106%
Total Organic Carbon (TOC)	LB137347	%w/w	0.02	<0.02	1 - 6%	105 - 111%
Inorganic Carbon (calculated)*	LB137347	%w/w	0.02	<0.02		

METHOD

METHODOLOGY SUMMARY

AN203	The carbon in the sample is oxidised to carbon dioxide gas in a tube furnace using oxygen to aid the oxidation process. The evolved carbon dioxide is measure by an infra red cell. The infra red cell output is calibrated against the value of a known standard sample to provide the total carbon value of the unknown sample.
AN203	The sample is pre-treated with hydrochloric acid to remove inorganic carbon/carbonate. The residual non-carbonate carbon is oxidised to carbon dioxide gas in a tube furnace using oxygen to aid the oxidation process. The evolved carbon dioxide is measure by an infra red cell. The infra red cell output is calibrated against the value of a known standard sample to provide the total organic carbon value of the unknown sample.
AN217	Dried pulped sample is mixed with acid and chromium metal in a rapid distillation unit to produce hydrogen sulfide (H ₂ S) which is collected and titrated with iodine (I ₂ (aq)) to measure SCR.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calculated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the "Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.

Note that in terms of units of radioactivity:

- 1 Bq is equivalent to 27 pCi
- 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : <http://www.sgs.com.au/~media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf>

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MINERALS TEST REPORT

CLIENT

CAMPBELL, GRAEME and ASSOCIATES
PO Box 247
BRIDGETOWN, W.A. 6255
AUSTRALIA

JOB INFORMATION

JOB CODE : 143.0/1712451
NO. SAMPLES : 32
NO. ELEMENTS : 3
CLIENT ORDER NO. : GCA1716 (Job 1 of 0)
SAMPLE SUBMISSION NO. :
PROJECT : Nunasvaara Project
DATE RECEIVED : 29/08/2017
DATE REPORTED : 15/09/2017
DATE PRINTED : 15/09/2017

REPORT NOTES

1. The following samples were marked Sample Not Received
0133

TESTED BY

Intertek
15 Davison Street, Maddington 6109, Western Australia
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Tel: +61 8 9251 8100
Email: min.aus.per@intertek.com

This report relates specifically to the sample(s) tested that were drawn and/or provided by the client or their nominated third party to Intertek. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report. The results provided are not intended for commercial settlement purposes.

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SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at \$4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at \$150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice for return or collection is received.

LEGEND	X	= Less than Detection Limit	NA	= Not Analysed
	SNR	= Sample Not Received	UA	= Unable to Assay
	*	= Result Checked	>	= Value beyond Limit of Method
	DTF	= Result still to come	+	= Extra Sample Received Not Listed
	IS	= Insufficient Sample for Analysis		



ELEMENTS	LOD	WTDRY	WTTOT
UNITS	%	g	g
DETECTION LIMIT	0.01	0.01	0.01
DIGEST			
ANALYTICAL FINISH	/GRAV	WT02	WT01
SAMPLE NUMBERS			
0001 0006 GCA11742	0.16	4857.10	4865.00
0002 0017 GCA11743	1.00	3902.00	3941.00
0003 0019 GCA11744	1.66	5150.50	5236.00
0004 0022 GCA11745	0.79	4437.00	4472.00
0005 0031 GCA11746	0.94	4867.10	4913.00
0006 0067 GCA11747	4.21	4341.30	4524.00
0007 0109 GCA11748	1.45	3841.40	3897.00
0008 0122 GCA11749	7.56	4326.10	4653.00
0009 0129 GCA11750	5.76	3472.00	3672.00
0010 0141 GCA11751	2.60	5307.10	5445.00
0011 0142 GCA11752	2.73	6598.70	6779.00
0012 0158 GCA11753	0.52	4544.20	4568.00
0013 0187 GCA11754	0.51	4966.70	4992.00
0014 0204 GCA11755	7.67	4147.80	4466.00
0015 0236 GCA11756	0.78	3080.00	3104.00
0016 0245 GCA11757	6.75	5385.40	5749.00
0017 0363 GCA11758	0.62	4272.40	4299.00
0018 0381 GCA11759	0.09	3007.40	3010.00
0019 0384 GCA11760	3.93	4803.30	4992.00
0020 0414 GCA11761	0.77	3203.30	3228.00
0021 0420 GCA11762	0.37	4869.10	4887.00
0022 0421 GCA11763	0.26	4793.60	4806.00
0023 0442 GCA11764	0.70	5769.80	5810.00
0024 0461 GCA11765	0.78	4614.20	4650.00
0025 0480 GCA11766	1.14	2710.00	2741.00
0026 0484 GCA11767	0.83	2826.40	2850.00
0027 0494 GCA11768	1.64	6001.40	6100.00
0028 0530 GCA11769	0.91	5067.70	5114.00
0029 0532 GCA11770	0.16	4245.20	4252.00
0030 0534 GCA11771	1.68	5675.90	5771.00
0031 0544 GCA11772	0.19	4208.90	4217.00
0032 0546 GCA11773	0.90	5201.00	5248.00

MISSING SAMPLES: 0133



METHOD CODE DESCRIPTION

Method Code

Analysing Laboratory

/GRAV

Intertek Genalysis Perth

No digestion or other pre-treatment undertaken. Analysed by Gravimetric Technique

WT01

Intertek Genalysis Perth

Reporting weights of samples

WT02

Intertek Genalysis Perth

Reporting weights of Dry Sample

NEUTRALISATION-POTENTIAL (NP) TESTWORK BASED ON BS EN 15875:2011

SAMPLE		Slurry-pH after HPDW Addition	HCl Vol. at t = 0 hr (mL)	Slurry-pH at t < 2 mins	Slurry-pH at t = 22 hrs	HCl Vol. at t = 22 hrs	Slurry-pH at t < 2 mins	Slurry-pH at t = 24 hrs	milli moles H+ Added	NaOH Titre Vol. (mL)	milli moles OH- Added	pH after H2O2 Added	NP (kg H2SO4/tonne)
ID	WT (g)												
GCA11769	2.03	9.76+	2.00	2.27	3.01	2.00	2.11	2.28	1.964	31.30	1.537	3.7	10
GCA11760	2.03	9.78+	2.00	2.22	3.05	2.00	2.08	2.25	1.964	31.60	1.552	3.5	10
GCA11770	2.00	9.61+	2.00	2.79	4.38	2.00	2.15	2.43	1.964	24.10	1.183	3.8	19
GCA11742	2.02	7.68+	1.00	2.39	2.85	1.00	2.23	2.37	0.982	18.60	0.913	>4.0	2
GCA11746	2.02	8.54+	2.00	2.23	2.85	2.00	2.06	2.24	1.964	35.70	1.753	3.5	5
GCA11756	2.04	9.01+	1.00	2.47	3.03	2.00	2.08	2.27	1.473	27.50	1.350	>4.0	3
GCA11767	1.98	8.97+	1.00	2.37	2.66	1.00	2.19	2.28	0.982	18.20	0.894	>4.0	2
GCA11767 d	2.02	8.91+	1.00	2.38	2.67	1.00	2.20	2.32	0.982	18.30	0.899	>4.0	2
Blank 1			1.00			2.00			1.471	30.70	1.507	102.5%	
Blank 2			1.00			2.00			1.473	30.90	1.517	103.0%	

Notes:

1. Testing performed on pulp (-75 μm) samples. Screw-cap lids of 250 mL glass jars had a 1-mm diameter hole in the middle of lid to allow test-slurries to 'breathe' during testing, especially for CO₂ to degas, etc.
2. *ca.* 90 mL of high-purity-deionised-water (HPDW) added to all samples initially with agitation for *ca.* 10-15 minutes prior to measurement of slurry-pH.
3. Temperature of shaker waterbath 20 (+/- 1-2) °C.
4. HCl concentration = 0.491 M (standardised using sodium tetraborate and bromothymol blue indicator).
5. NaOH concentration = 0.0491 M (standardised using potassium hydrogen phthalate and phenolphthalein indicator).
6. HCl manually added in 1.00 (+/- 0.005) mL aliquots by means of an auto-pipette.
7. Titration with NaOH performed manually with 50 mL glass burette with test-slurry stirred using magnetic stirrer-bar. Fast titration with stopcock fully open until slurry-pH within approximate range 4.0-4.5 when titration stops for H₂O₂ addition.
8. Three drops of 30 % H₂O₂ (v/v) [adjusted to pH 4.5] added to test-slurry to oxidise **soluble-Fe(II)** forms ('latent-acidity') and precipitation of Fe(III)-oxyhydroxides, etc. Minimum slurry-pH attained following H₂O₂ addition recorded.
9. Following completion of H₂O₂ addition, titration with NaOH continues to a **pH=8.3** end-point. Slurry-pH prone to drifting as pH=8.3 end-point is approached, and chiefly associated with reactions at phase surfaces (e.g. deprotonation of hydroxyl groups on Fe/Al-oxyhydroxides, etc.) the majority of which are 'freshly-formed' (and thereby reactive) during course of NaOH-titration. For manual titration (cf. auto-titration) it was more practical to add NaOH dropwise past pH 8.3 (but below 9.0), and thereby 'condition' reactive-phase surfaces near pH=8, until the gradual downward-drift in slurry-pH was deemed slow enough to stop titration. Adding NaOH in this way underestimates the exact amount of HCl consumed during the acid-digestion step. However, under the testwork conditions employed, each 0.10 mL of the NaOH solution added corresponds to *ca.* 0.12 kg H₂SO₄/tonne. Underestimation of the resulting NP value is therefore no more than 1 kg H₂SO₄/tonne.
10. The Blanks correspond to the HPDW and HCl solution added without any test-solid sample.

Variations to BS EN 15875:2011:

1. A check on test-slurry-pH is made within 2 minutes following addition of the HCl aliquots in order to reduce the frequency of repeat determinations should the test-slurry-pH value at 24 hrs exceed 2.5.
2. H₂O₂ is added, as described, to correct for any soluble-Fe(II) forms (i.e. so-called 'siderite correction').

Dr GD Campbell
27th September 2017

NEUTRALISATION-POTENTIAL (NP) TESTWORK BASED ON BS EN 15875:2011

SAMPLE		Slurry-pH after HPDW Addition	HCl Vol. at t = 0 hr (mL)	Slurry-pH at t < 2 mins	Slurry-pH at t = 22 hrs	HCl Vol. at t = 22 hrs	Slurry-pH at t < 2 mins	Slurry-pH at t = 24 hrs	milli moles H ⁺ Added	NaOH Titre Vol. (mL)	milli moles OH ⁻ Added	pH after H ₂ O ₂ Added	NP (kg H ₂ SO ₄ /tonne)
ID	WT (g)												
GCA11745	1.99	9.74+	2.00	2.65	3.01	1.00	2.21	2.37	1.473	23.30	1.144	3.9	8
GCA11749	2.02	9.43+	2.00	2.49	3.05	1.00	2.13	2.39	1.473	25.20	1.237	3.6	6
GCA11759	2.03	8.87+	2.00	2.70	4.38	1.00	2.21	2.42	1.473	25.50	1.252	3.5	5
GCA11761	2.05	8.66+	2.00	2.54	2.85	1.00	2.14	2.34	1.473	24.80	1.218	3.7	6
GCA11773	2.03	9.61+	2.00	2.59	2.85	1.00	2.15	2.33	1.473	23.90	1.173	3.7	7
GCA11773 d	2.01	9.62+	2.00	2.59	3.03	1.00	2.16	2.40	1.473	23.90	1.173	3.8	7
Blank 1			2.00			1.00			1.473	30.60	1.502	102.0%	
Blank 2			2.00			1.00			1.473	30.70	1.507	102.3%	

Notes:

1. Testing performed on pulp (-75 μm) samples. Screw-cap lids of 250 mL glass jars had a 1-mm diameter hole in the middle of lid to allow test-slurries to 'breathe' during testing, especially for CO₂ to degas, etc.
2. *ca.* 90 mL of high-purity-deionised-water (HPDW) added to all samples initially with agitation for *ca.* 10-15 minutes prior to measurement of slurry-pH.
3. Temperature of shaker waterbath 20 (+/- 1-2) oC.
4. HCl concentration = 0.491 M (standardised using sodium tetraborate and bromothymol blue indicator).
5. NaOH concentration = 0.0491 M (standardised using potassium hydrogen phthalate and phenolphthalein indicator).
6. HCl manually added in 1.00 (+/- 0.005) mL aliquots by means of an auto-pipette.
7. Titration with NaOH performed manually with 50 mL glass burette with test-slurry stirred using magnetic stirrer-bar. Fast titration with stopcock fully open until slurry-pH within approximate range 4.0-4.5 when titration stops for H₂O₂ addition.
8. Three drops of 30 % H₂O₂ (v/v) [adjusted to pH 4.5] added to test-slurry to oxidise **soluble-Fe(II)** forms ('latent-acidity') and precipitation of Fe(III)-oxyhydroxides, etc. Minimum slurry-pH attained following H₂O₂ addition recorded.
9. Following completion of H₂O₂ addition, titration with NaOH continues to a **pH=8.3** end-point. Slurry-pH prone to drifting as pH=8.3 end-point is approached, and chiefly associated with reactions at phase surfaces (e.g. deprotonation of hydroxyl groups on Fe/Al-oxyhydroxides, etc.) the majority of which are 'freshly-formed' (and thereby reactive) during course of NaOH-titration. For manual titration (cf. auto-titration) it was more practical to add NaOH dropwise past pH 8.3 (but below 9.0), and thereby 'condition' reactive-phase surfaces near pH=8, until the gradual downward-drift in slurry-pH was deemed slow enough to stop titration. Adding NaOH in this way underestimates the exact amount of HCl consumed during the acid-digestion step. However, under the testwork conditions employed, each 0.10 mL of the NaOH solution added corresponds to *ca.* 0.12 kg H₂SO₄/tonne. Underestimation of the resulting NP value is therefore no more than 1 kg H₂SO₄/tonne.
10. The Blanks correspond to the HPDW and HCl solution added without any test-solid sample.

Variations to BS EN 15875:2011:

1. A check on test-slurry-pH is made within 2 minutes following addition of the HCl aliquots in order to reduce the frequency of repeat determinations should the test-slurry-pH value at 24 hrs exceed 2.5.
2. H₂O₂ is added, as described, to correct for any soluble-Fe(II) forms (i.e. so-called 'siderite correction').

Dr GD Campbell
20th October 2017

ANC-[pH5-6] TESTWORK

In-House Method Based on Reaction with Dilute Acetic-Acid (HAc) Solution Adjusted to pH 5.0 with NaOH

SAMPLE		Slurry-pH at t < 2 mins	Final Filtrate- pH	Titration with NaOH to pH=7.0 Endpoint (Hach Digital Titrator)			Acidity- [pH7.0/ H2O2] (mg H2SO4/L)	Loss of Acidity- [pH7.0/H2O2] (mg H2SO4/L)	ANC-[pH5-6] (kg H2SO4/ tonne)
ID	WT (g)			Vol. (mL)	Titration Reading	pH Drop with H2O2			
GCA11745	10.00	5.08	5.14	25.0	292	none	116	23	< 1
GCA11746	9.98	5.12	5.24	25.0	262	none	104	34	< 1
GCA11760	9.99	5.09	5.30	25.0	237	none	94	44	< 1
GCA11767	9.98	5.06	5.10	25.0	315	none	125	13	< 1
GCA11769	9.99	5.14	5.40	25.0	198	none	79	60	1
Feed-Soln			5.03	25.0	350	none	139		
Feed-Soln d			5.02	25.0	347	none	138		

Notes:

1. Testing performed on **-2mm** samples obtained by sieving 'fine-crushings' (nominal -2mm).
2. **200 mL** pH5-Feed Solution added using a glass measuring cylinder.
3. Temperature of shaker waterbath **20 (+/- 2) °C**. Reaction occurred overnight (approx. **16 hrs**).
4. Dilute **HAc/NaAc** solution prepared using AR HAc and NaOH.
5. **NaOH** concentration = **0.1600 M** [Hach cartridge] (standardised using potassium hydrogen phthalate and pH meter).
6. Following reaction period and allowing settling of 'fines' approx. 30 mL of supernatant decanted and vacuum-filtered (0.45µm-membrane).
7. Three drops of **30 % H2O2 (v/v)** [adjusted to pH 4.5] added during titration to oxidise **soluble-Fe(II)** forms ('latent-acidity') and precipitation of Fe(III)-oxyhydroxides, etc. Minimum slurry-pH attained following H2O2 addition recorded.
H2O2 added as pH 6.0 approached during titration with NaOH.

Dr GD Campbell
Director
10th October 2017

Laboratory Report

pH-(1:2) & EC-(1:2) TESTWORK

SAMPLE NO.	SAMPLE WEIGHT (g)	HPDW WEIGHT (g)	pH-(1:2)	EC-(1:2) (μS/cm)
GCA11742	30.1	60.0	5.2	946
GCA11743	30.0	60.0	4.3	842
GCA11744	30.1	60.0	7.2	1,260
GCA11745	30.1	60.0	7.1	345
GCA11746	30.0	60.0	5.6	2,160
GCA11747	30.1	60.0	3.1	2,640
GCA11748	30.0	60.0	5.4	1,530
GCA11749	30.0	60.0	5.8	660
GCA11750	30.0	60.0	7.3	610
GCA11751	30.0	60.0	3.4	1,650
GCA11751 (d)	30.1	60.0	3.3	1,580
GCA11752	29.9	60.0	3.1	1,800
GCA11753	29.9	60.0	8.1	196
GCA11754	30.0	60.0	7.6	556
GCA11755	30.0	60.0	4.0	3,980
GCA11756	30.1	60.0	6.6	390
GCA11757	30.0	60.0	3.0	4,540
GCA11758	30.0	60.0	5.3	831
GCA11759	30.1	60.0	5.4	1,230
GCA11760	30.0	60.0	7.6	311
GCA11761	30.0	60.0	5.0	816
GCA11761 (d)	30.0	60.0	5.0	815
GCA11762	30.0	60.0	4.5	915
GCA11763	30.0	60.0	4.7	832
GCA11764	30.1	60.0	6.3	2,980
GCA11765	30.0	60.0	4.4	1430
GCA11766	30.0	60.0	7.8	190
GCA11767	30.1	60.0	7.1	240
GCA11768	30.0	60.0	3.6	1,430
GCA11769	30.1	60.0	8.3	188
GCA11770	29.9	60.0	7.1	905
GCA11771	30.0	60.0	4.2	2,240
GCA11772	30.0	60.0	6.8	969
GCA11773	30.0	60.0	7.3	452
GCA11773 (d)	30.0	60.0	7.2	412

Notes: EC = Electrical-Conductivity. Testwork performed on the -2mm (nominal) crushings. pH-(1:2) and EC-(1:2) values correspond to pH and EC values of slurries with a solid:solution ratio of *ca.* 1:2 (w/w) prepared using deionised-water. Test-slurries allowed to age in contact with air for *ca.* 1 day. Testwork performed in a constant-temperature room (*viz.* 20 +/- 2 °C).

Dr GD Campbell
12th September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11744)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H₂SO₄/tonne)	pH
0.00	0.0	9.7
0.40	3.9	9.1
0.80	7.8	8.6
1.20	11.8	8.4
1.60	15.7	8.2
2.00	19.6	8.0
2.40	23.5	7.9
2.80	27.4	7.9
3.20	31.4	7.8
3.60	35.3	7.8
4.00	39.2	7.7
4.40	43.1	7.7
4.80	47.0	7.6
5.20	51.0	7.6
5.60	54.9	7.6
6.00	58.8	7.6
6.40	62.7	7.5
6.80	66.6	7.5
7.20	70.6	7.5
7.60	74.5	7.4
8.00	78.4	7.4
8.40	82.3	7.3
8.80	86.2	7.3
9.20	90.2	7.2
9.60	94.1	7.1
10.00	98.0	7.1
10.40	101.9	7.0
10.80	105.8	6.8
11.20	109.8	6.6
11.60	113.7	6.4
12.00	117.6	6.1
12.40	121.5	5.6
12.80	125.4	4.5
13.20	129.4	3.8
13.60	133.3	3.5
14.00	137.2	3.3
14.40	141.1	3.2
14.80	145.0	3.1
15.20	149.0	3.0

Note: Titration performed using a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 0.50 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = 1 mV (pH=7.00); slope-point = 171 mV (pH=4.00); 95.7 % of Nernstian response for 25 °C.

Dr GD Campbell

24th September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11748)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H₂SO₄/tonne)	pH
0.00	0.0	7.2
0.40	0.2	6.9
0.80	0.4	6.6
1.20	0.6	6.3
1.60	0.8	5.9
2.00	1.0	5.5
2.40	1.2	5.1
2.80	1.4	4.8
3.20	1.6	4.6
3.60	1.8	4.4
4.00	2.0	4.2
4.40	2.2	4.1
4.80	2.4	4.0
5.20	2.5	3.9
5.60	2.7	3.8
6.00	2.9	3.7
6.40	3.1	3.6
6.80	3.3	3.6
7.20	3.5	3.5
7.60	3.7	3.5
8.00	3.9	3.4
8.40	4.1	3.4
8.80	4.3	3.3
9.20	4.5	3.3
9.60	4.7	3.3
10.00	4.9	3.2
10.40	5.1	3.2
10.80	5.3	3.2
11.20	5.5	3.1
11.60	5.7	3.1
12.00	5.9	3.1
12.40	6.1	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 10.0 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -1 mV (pH=7.00); slope-point = 169 mV (pH=4.00); 95.8 % of Nernstian response for 25 °C.

Dr GD Campbell
29th September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11750)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH
0.00	0.0	9.5	15.60	76.4	3.2
0.40	2.0	9.0	16.00	78.4	3.1
0.80	3.9	8.6	16.40	80.4	3.0
1.20	5.9	8.3			
1.60	7.8	8.2			
2.00	9.8	8.1			
2.40	11.8	8.1			
2.80	13.7	8.0			
3.20	15.7	8.0			
3.60	17.6	8.0			
4.00	19.6	7.9			
4.40	21.6	7.9			
4.80	23.5	7.9			
5.20	25.5	7.9			
5.60	27.4	7.9			
6.00	29.4	7.9			
6.40	31.4	7.8			
6.80	33.3	7.8			
7.20	35.3	7.8			
7.60	37.2	7.8			
8.00	39.2	7.8			
8.40	41.2	7.8			
8.80	43.1	7.7			
9.20	45.1	7.7			
9.60	47.0	7.6			
10.00	49.0	7.5			
10.40	51.0	7.4			
10.80	52.9	7.2			
11.20	54.9	7.0			
11.60	56.8	6.5			
12.00	58.8	5.6			
12.40	60.8	4.8			
12.80	62.7	4.2			
13.20	64.7	3.9			
13.60	66.6	3.7			
14.00	68.6	3.5			
14.40	70.6	3.4			
14.80	72.5	3.3			
15.20	74.5	3.2			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 1.00 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = 4 mV (pH=7.00); slope-point = 174 mV (pH=4.00); 96.2 % of Nernstian response for 25 °C.

Dr GD Campbell

19th September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11753)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH
0.00	0.0	9.8	15.60	76.4	3.6
0.40	2.0	9.2	16.00	78.4	3.4
0.80	3.9	8.7	16.40	80.4	3.3
1.20	5.9	8.4	16.80	82.3	3.2
1.60	7.8	8.2	17.20	84.3	3.1
2.00	9.8	8.1	17.60	86.2	3.0
2.40	11.8	8.0			
2.80	13.7	7.9			
3.20	15.7	7.8			
3.60	17.6	7.8			
4.00	19.6	7.8			
4.40	21.6	7.7			
4.80	23.5	7.7			
5.20	25.5	7.7			
5.60	27.4	7.6			
6.00	29.4	7.6			
6.40	31.4	7.6			
6.80	33.3	7.6			
7.20	35.3	7.6			
7.60	37.2	7.5			
8.00	39.2	7.5			
8.40	41.2	7.5			
8.80	43.1	7.5			
9.20	45.1	7.4			
9.60	47.0	7.4			
10.00	49.0	7.3			
10.40	51.0	7.3			
10.80	52.9	7.3			
11.20	54.9	7.2			
11.60	56.8	7.1			
12.00	58.8	6.9			
12.40	60.8	6.6			
12.80	62.7	6.3			
13.20	64.7	6.0			
13.60	66.6	5.6			
14.00	68.6	5.0			
14.40	70.6	4.5			
14.80	72.5	4.1			
15.20	74.5	3.8			

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 1.00 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = 2 mV (pH=7.00); slope-point = 171 mV (pH=4.00); 95.2 % of Nernstian response for 25 °C.

Dr GD Campbell
22nd September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11754)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH
0.00	0.0	9.6	15.60	76.4	3.4
0.40	2.0	9.0	16.00	78.4	3.3
0.80	3.9	8.7	16.40	80.4	3.2
1.20	5.9	8.4	16.80	82.3	3.1
1.60	7.8	8.2	17.20	84.3	3.0
2.00	9.8	8.1			
2.40	11.8	8.1			
2.80	13.7	8.0			
3.20	15.7	8.0			
3.60	17.6	8.0			
4.00	19.6	8.0			
4.40	21.6	8.0			
4.80	23.5	8.0			
5.20	25.5	8.0			
5.60	27.4	8.0			
6.00	29.4	8.0			
6.40	31.4	8.0			
6.80	33.3	8.0			
7.20	35.3	8.0			
7.60	37.2	7.9			
8.00	39.2	7.9			
8.40	41.2	7.9			
8.80	43.1	7.9			
9.20	45.1	7.9			
9.60	47.0	7.9			
10.00	49.0	7.9			
10.40	51.0	7.8			
10.80	52.9	7.8			
11.20	54.9	7.7			
11.60	56.8	7.6			
12.00	58.8	7.4			
12.40	60.8	6.9			
12.80	62.7	6.0			
13.20	64.7	5.2			
13.60	66.6	4.7			
14.00	68.6	4.3			
14.40	70.6	4.0			
14.80	72.5	3.7			
15.20	74.5	3.5			

Note: Titration performed using a Metrohm[®] 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 1.00 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = 1 mV (pH=7.00); slope-point = 171 mV (pH=4.00); 95.6 % of Nernstian response for 25 °C.

Dr GD Campbell

23rd September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11758)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H₂SO₄/tonne)	pH
0.00	0.0	8.8
0.40	0.2	7.8
0.80	0.4	7.1
1.20	0.6	6.7
1.60	0.8	6.4
2.00	1.0	5.9
2.40	1.2	5.4
2.80	1.4	5.0
3.20	1.6	4.8
3.60	1.8	4.6
4.00	2.0	4.5
4.40	2.2	4.4
4.80	2.4	4.3
5.20	2.5	4.2
5.60	2.7	4.1
6.00	2.9	4.0
6.40	3.1	3.9
6.80	3.3	3.8
7.20	3.5	3.8
7.60	3.7	3.7
8.00	3.9	3.6
8.40	4.1	3.5
8.80	4.3	3.5
9.20	4.5	3.4
9.60	4.7	3.4
10.00	4.9	3.3
10.40	5.1	3.3
10.80	5.3	3.2
11.20	5.5	3.2
11.60	5.7	3.2
12.00	5.9	3.2
12.40	6.1	3.1
12.80	6.3	3.1
13.20	6.5	3.1
13.60	6.7	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 10.0 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -1 mV (pH=7.00); slope-point = 169 mV (pH=4.00); 95.5 % of Nernstian response for 25 °C.

Dr GD Campbell
30th September 2017

Graeme Campbell & Associates Pty Ltd

Laboratory Report

pH-BUFFERING TESTWORK (GCA11764)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H2SO4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H2SO4/tonne)	pH
0.00	0.0	7.8	15.60	15.3	6.5
0.40	0.4	7.7	16.00	15.7	6.4
0.80	0.8	7.6	16.40	16.1	6.4
1.20	1.2	7.6	16.80	16.5	6.3
1.60	1.6	7.6	17.20	16.9	6.2
2.00	2.0	7.6	17.60	17.2	6.2
2.40	2.4	7.5	18.00	17.6	6.1
2.80	2.7	7.5	18.40	18.0	6.0
3.20	3.1	7.5	18.80	18.4	5.9
3.60	3.5	7.5	19.20	18.8	5.9
4.00	3.9	7.5	19.60	19.2	5.8
4.40	4.3	7.5	20.00	19.6	5.7
4.80	4.7	7.5	20.40	20.0	5.6
5.20	5.1	7.5	20.80	20.4	5.5
5.60	5.5	7.5	21.20	20.8	5.4
6.00	5.9	7.5	21.60	21.2	5.3
6.40	6.3	7.5	22.00	21.6	5.2
6.80	6.7	7.4	22.40	22.0	5.1
7.20	7.1	7.4	22.80	22.3	5.1
7.60	7.4	7.4	23.20	22.7	5.0
8.00	7.8	7.4	23.60	23.1	4.9
8.40	8.2	7.4	24.00	23.5	4.8
8.80	8.6	7.4	24.40	23.9	4.8
9.20	9.0	7.4	24.80	24.3	4.7
9.60	9.4	7.4	25.20	24.7	4.6
10.00	9.8	7.3	25.60	25.1	4.6
10.40	10.2	7.3	26.00	25.5	4.5
10.80	10.6	7.3	26.40	25.9	4.4
11.20	11.0	7.3	26.80	26.3	4.4
11.60	11.4	7.2	27.20	26.7	4.3
12.00	11.8	7.2	27.60	27.0	4.2
12.40	12.2	7.1	28.00	27.4	4.2
12.80	12.5	7.1	28.40	27.8	4.1
13.20	12.9	7.1	28.80	28.2	4.1
13.60	13.3	7.0	29.20	28.6	4.0
14.00	13.7	6.9	29.60	29.0	3.9
14.40	14.1	6.8	30.00	29.4	3.9
14.80	14.5	6.7	30.40	29.8	3.8
15.20	14.9	6.6	30.80	30.2	3.8

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H ₂ SO ₄ /tonne)	pH
31.20	30.6	3.8
31.60	31.0	3.7
32.00	31.4	3.7
32.40	31.8	3.7
32.80	32.1	3.6
33.20	32.5	3.6
33.60	32.9	3.6
34.00	33.3	3.5
34.40	33.7	3.5
34.80	34.1	3.5
35.20	34.5	3.5
35.60	34.9	3.5
36.00	35.3	3.5
36.40	35.7	3.4
36.80	36.1	3.4
37.20	36.5	3.4
37.60	36.8	3.4
38.00	37.2	3.3
38.40	37.6	3.3
38.80	38.0	3.3
39.20	38.4	3.3
39.60	38.8	3.3
40.00	39.2	3.3
40.40	39.6	3.2
40.80	40.0	3.2
41.20	40.4	3.2
41.60	40.8	3.2
42.00	41.2	3.2
42.40	41.6	3.2
42.80	41.9	3.2
43.20	42.3	3.1
43.60	42.7	3.1
44.00	43.1	3.1
44.40	43.5	3.1
44.80	43.9	3.1
45.20	44.3	3.0

Note: Titration performed using a Metrohm® 736 Titrino auto-titrator, and 0.05 M-H₂SO₄. Equilibration time between titrant additions was 15 minutes. 5.00 g of pulped sample initially dispersed in 150 mL of deionised-water. Test mixture in contact with air, at ambient temperature, and continuously stirred.

Calibration of pH-Glass Electrode:

Immediately prior to titration: asymmetry potential = -1 mV (pH=7.00); slope-point = 170 mV (pH=4.00); 95.9 % of Nernstian response for 25 °C.

Dr GD Campbell
21st September 2017

Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK

Sample Number	Sample Weight (g)	Comments	pH of Test Mixture Before Boiling Step	Test Mixture After Boiling Step		Titre (mL) (0.1 M-NaOH)		NAG (kg H ₂ SO ₄ /tonne)		
				pH	EC (µS/cm)	To pH 4.5	pH 4.5 to pH 7.0	To pH 4.5	pH 4.5 to pH 7.0	To pH 7.0
GCA11742	2.98	reaction peaked (boiled) in <i>ca.</i> 2 hrs	2.5	2.6	1,370	12.20	3.40	20.1	5.6	25.7
GCA11743	3.01	reaction peaked (boiled) in <i>ca.</i> 2 hrs	2.5	2.7	1,520	11.00	5.10	17.9	8.3	26.2
GCA11744	3.00	reaction peaked overnight	7.5	9.3	410	-	-	<0.5	<0.5	<0.5
GCA11745	2.99	reaction peaked overnight	4.8	6.1	192	-	0.10	<0.5	<0.5	<0.5
GCA11746	3.00	reaction peaked (boiled) in <i>ca.</i> 30 mins	2.2	2.4	2,640	37.40	8.30	61.1	13.6	74.7
GCA11747	3.01	reaction peaked (boiled) in <i>ca.</i> 2 hrs	2.3	2.5	2,030	15.70	5.00	25.7	8.2	33.9
GCA11748	1.08	reaction peaked (boiled) in <i>ca.</i> 1 hr	2.3	2.2	2,720	32.00	3.90	156.8	19.1	176
GCA11749	2.98	reaction peaked (boiled) in <i>ca.</i> 3 hrs	2.4	2.5	1,660	14.90	2.90	24.4	4.8	29.2
GCA11750	3.00	reaction peaked overnight (slight only)	7.5	10.1	390	-	-	<0.5	<0.5	<0.5
GCA11751	3.01	reaction peaked overnight	4.2	5.6	197	-	0.30	<0.5	<0.5	<0.5
GCA11752	3.01	reaction peaked overnight	3.9	4.9	240	-	0.90	<0.5	1.5	1.5
GCA11753	2.99	reaction peaked overnight (slight only)	7.3	11.2	577	-	-	<0.5	<0.5	<0.5
GCA11754	3.01	reaction peaked overnight	7.4	10.9	411	-	-	<0.5	<0.5	<0.5
GCA11755	1.00	reaction peaked (boiled) in <i>ca.</i> 40 mins	2.4	2.4	2,080	20.30	7.00	99.5	34.3	134
GCA11756	3.00	reaction peaked (boiled) in <i>ca.</i> 4 hrs	2.7	2.9	894	7.90	2.60	12.9	4.3	17.2
GCA11757	3.02	reaction peaked (boiled) in <i>ca.</i> 7 hrs	3.0	2.9	952	5.30	3.10	8.7	5.1	13.8
GCA11758	2.99	reaction peaked (boiled) in <i>ca.</i> 45 mins	2.2	2.2	3,090	37.10	5.50	60.6	9.0	69.6
GCA11759	3.01	reaction peaked (boiled) in <i>ca.</i> 1 hr	2.2	2.3	2,560	26.20	6.10	42.8	10.0	52.8
GCA11759 (d)	3.02	reaction peaked (boiled) in <i>ca.</i> 1 hr	2.2	2.3	2,510	25.70	7.50	42.0	12.3	54.3
Blank	3.01	no apparent reaction overnight	5.8	6.8	41	-	-	<0.5	<0.5	<0.5

Notes: If needed, the pH of the 15 % (v/v) H₂O₂ solution is adjusted to pH 4.5 using dilute NaOH solution prior to commencing the NAG Tests. 250 mL of peroxide solution used. Following an overnight-reaction period the test mixtures were boiled for *ac.* 1-2 hours. Then, after allowing the test-mixtures to cool, *ca.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *ca.* 1-2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted-H₂O₂ in the test-mixtures (AS 4969.12-2009). K-Feldspar was employed as the Blank. All testing performed on pulps. 0.0976 M-NaOH used in NaOH-titration (standardised with potassium hydrogen phthalate and phenolphthalein indicator).

NET-ACID-GENERATION (NAG) TESTWORK

Sample Number	Sample Weight (g)	Comments	pH of Test Mixture Before Boiling Step	Test Mixture After Boiling Step		Titre (mL) (0.1 M-NaOH)		NAG (kg H ₂ SO ₄ /tonne)		
				pH	EC (µS/cm)	To pH 4.5	pH 4.5 to pH 7.0	To pH 4.5	pH 4.5 to pH 7.0	To pH 7.0
GCA11760	2.98	reaction peaked (boiled) in <i>ca.</i> 5 hrs	2.6	2.6	1,670	13.30	4.00	21.8	6.6	28.4
GCA11761	3.01	reaction peaked (boiled) in <i>ca.</i> 4 hrs	2.3	2.4	2,370	18.20	2.70	29.8	4.4	34.2
GCA11762	3.00	reaction peaked (boiled) in <i>ca.</i> 2.5 hrs	2.3	2.5	1,940	21.50	6.90	35.2	11.3	46.5
GCA11763	2.98	reaction peaked (boiled) in <i>ca.</i> 2.5 hrs	2.3	2.4	2,110	19.90	4.70	32.6	7.7	40.3
GCA11764	0.99	reaction peaked (boiled) in <i>ca.</i> 30 mins	2.3	2.4	2,820	39.80	2.70	195.0	13.2	208.2
GCA11765	2.99	reaction peaked (boiled) in <i>ca.</i> 3 hrs	2.2	2.4	2,120	23.80	2.30	38.9	3.8	42.7
GCA11766	3.00	reaction peaked (boiled) in <i>ca.</i> 6 hrs	3.4	3.9	341	0.20	1.10	-	1.8	1.8
GCA11767	3.01	reaction peaked (boiled) in <i>ca.</i> 4 hrs	2.5	2.6	1,260	10.20	2.50	16.7	4.1	20.8
GCA11768	1.02	reaction peaked (boiled) in <i>ca.</i> 1 hr	2.3	2.3	2,300	25.90	2.40	126.9	11.9	138.7
GCA11769	2.98	no apparent reaction overnight	6.4	6.9	227	-	-	<0.5	<0.5	<0.5
GCA11770	3.01	reaction peaked (boiled) in <i>ca.</i> 7 hrs	2.7	2.9	1,065	11.90	3.10	19.5	5.6	25.1
GCA11771	1.01	reaction peaked (boiled) in <i>ca.</i> 1 hr	2.3	2.3	2,470	29.10	3.30	142.6	16.2	158.8
GCA11772	3.02	reaction peaked (boiled) in <i>ca.</i> 7 hrs	3.0	3.1	885	3.20	3.60	5.3	5.9	11.2
GCA11773	2.98	reaction peaked overnight	3.9	4.0	334	0.10	1.80	-	3.0	3.0
GCA11773 (d)	3.00	reaction peaked overnight	3.9	4.0	287	0.10	1.00	-	1.7	1.7
Blank	2.99	no apparent reaction overnight	6.0	7.0	42	-	-	<0.5	<0.5	<0.5

Notes: If needed, the pH of the 15 % (v/v) H₂O₂ solution is adjusted to pH 4.5 using dilute NaOH solution prior to commencing the NAG Tests. 250 mL of peroxide solution used. Following an overnight-reaction period, the test-mixtures were boiled for *ac.* 1-2 hours. Then, after allowing the test-mixtures to cool, *ca.* 1.0 mL of 0.016 M-CuSO₄ solution was added, and the test-mixtures again boiled for *ca.* 1-2 hours. The addition of Cu(II) catalyses the decomposition of any residual, unreacted-H₂O₂ in the test-mixtures (AS 4969.12-2009) . K-Feldspar was employed as the Blank. All testing performed on pulps. 0.0976 M-NaOH used in NaOH-titration (standardised with potassium hydrogen phthalate and phenolphthalein indicator).

Dr GD Campbell
28th September 2017

Determination of Oxygen-Consumption Rates (OCRs) in Oxygen-Consumption-Cells (OCCs)

Sample Details	GCA11770	GCA11773	GCA11749	GCA11760	GCA11746	GCA11767
	Dyke	Vtf	Pgb	Pgb	Sgr	Sgr
	1.71%S	0.41%S	1.68%S	1.47%S	5.17%S	1.21%S
	CO ₃ -C = 0.20%	CO ₃ -C < 0.01%	CO ₃ -C < 0.01%	CO ₃ -C < 0.01%	CO ₃ -C = 0.04%	CO ₃ -C < 0.01%
	pH-(1:2) = 7.1	pH-(1:2) = 7.2	pH-(1:2) = 5.8	pH-(1:2) = 7.6	pH-(1:2) = 5.6	pH-(1:2) = 7.1
<u>Test Specifications and Conditions</u>						
Moist-Solids (kg)	0.918	0.956	0.926	0.942	0.882	0.840
GWC (%)	3.0	4.0	4.0	4.0	4.0	2.0
Dry-Solids [DS] (kg)	0.89	0.92	0.89	0.91	0.85	0.82
Solids-SG	2.80	2.80	2.80	2.80	2.60	2.60
Dry-Solids Volume (L)	0.32	0.33	0.32	0.32	0.33	0.32
Pore-Fluid Volume (L)	0.03	0.04	0.04	0.04	0.03	0.02
Cell Volume (L)	0.61	0.61	0.61	0.61	0.61	0.61
Gas Volume [GV] (L)	0.26	0.24	0.26	0.25	0.25	0.28
GV/DS Ratio (L/kg)	0.30	0.27	0.29	0.28	0.29	0.34
Temperature (oC) [+/- 0.1]	20.0	20.0	20.0	20.0	20.0	20.0
<u>Measurement with Quantek 901</u>						
Reaction-Time (days)	2.0	2.0	2.0	2.0	0.021	2.0
Reaction-Time (hrs)	48.0	48.0	48.0	48.0	0.50	48.0
Measured O ₂ -Conc. (%) [+/- 0.1]	19.3	19.8	15.5	20.0	16.8	16.7
O ₂ -Consumption (%) [+/- 0.2]	1.6	1.1	5.4	0.9	4.1	4.2
O ₂ -Consumption (mg O ₂)	5.6	3.6	18.4	3.0	13.6	15.5
OCR (kg O ₂ /kg/s)	3.66E-11	2.26E-11	1.20E-10	1.91E-11	8.93E-09	1.09E-10

Notes:

GWC = Gravimetric-Water Content; SG = Specific-Gravity.

SG for the mine-waste samples is estimated. The SG values for the ore samples is based on information provided by Talga.

Testing performed on 'coarse-crushings' of nominal -10 mm. After oven-drying at 80 oC as part of sample preparation for testing, a 1.0 kg sub-sample was moistened with high-purity-deionised-water (HPDW) via misting using a spray-bottle, and then left to age for *ca.* 2 days in a plastic-bag in a CT-room at 20 oC.

The GWC achieved was within the range 2-4 % (w/w). Effort was required in terms of mixing by hand in order to 'moisture-condition' the samples, especially the highly hydrophobic (non-wetting) ore samples.

Following packing of the OCCs they were store din an incubator at 20.0 (+/- 0.1) oC for the reaction period.

The relative-error for the OCR values is estimated to be *ca.* 10-20 %.

[N.B. Ore sample GCA11746 was so reactive that several runs \(with repacking OCCs for each run\) were required in order to obtain a meaningful measurement of the OCR. When left to age for 48 hrs - as for the other tested samples - the headspace-O₂ concentration for GCA11746 was 0.1 % \(v/v\) \[!\].](#)

Dr GD Campbell

30th September 2017

MINERALS TEST REPORT

CLIENT

CAMPBELL, GRAEME and ASSOCIATES

PO Box 247

BRIDGETOWN, W.A. 6255

AUSTRALIA

JOB INFORMATION

JOB CODE	: 143.0/1715008
NO. SAMPLES	: 32
NO. ELEMENTS	: 8
CLIENT ORDER NO.	: GCA1716 (Job 1 of 0)
SAMPLE SUBMISSION NO.	:
PROJECT	: SOUTH-NUNASVAARA
SAMPLE TYPE	: Ex-Pulp
DATE RECEIVED	: 28/09/2017
DATE REPORTED	: 03/11/2017
DATE PRINTED	: 03/11/2017

REPORT NOTES

TESTED BY

Intertek

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Accredited for compliance with ISO/IEC 17025.

Company Accreditation Number 3244



This report relates specifically to the sample(s) tested that were drawn and/or provided by the client or their nominated third party to Intertek. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report. The results provided are not intended for commercial settlement purposes.

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JOB NO : 143.0/1715008

CLIENT REF : GCA1716

NOTES

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

Analysing Laboratory: Intertek Genalysis Perth

The contents of this report have been prepared in accordance with the terms of NATA accreditation and as such should only be reproduced in full.

The analysis results reported herein have been obtained using the following methods and conditions:

The samples as listed were received as being pulps ex job 143.0/1712451 and 143/1712653 which had been pulverise zirconia bowl.

The results have been determined according to Genalysis methods codes:

Digestions: GL_W009 (AR005/), GL_W013 (AR01/), MPL_W002 (4A/), MPL_W005 (SE1/), ENV_W012 (FC7/SIE) and MI (FP1/).

Analytical Finishes: ICP_W004 (/OE), ICP_W003 (/MS) and AAS_W004 (/CV).

The results included the assay of blanks and international reference standards:

AMIS0342, OREAS 45d, OREAS 920, OREAS H1OREAS 98, WGB-1, SY-4, SARM3, MP-1b and OREAS 45e.

and Genalysis in-house standards:

OREAS 97.01, MPL-5 and HgSTD-7

The results are expressed as parts per million or parts per billion or percent by mass in the dried and prepared material.

Intertek Genalysis signatory

Huong ICP PHAM

ICP Chemist



Date: 02-Nov-2017

This report relates specifically to the sample(s) tested that were drawn and/or provided by the client or their nominated third party to Intertek. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report. The results provided are not intended for commercial settlement purposes.

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JOB NO : 143.0/1715008

CLIENT REF : GCA1716



SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at \$4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at \$150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice for return or collection is received.

LEGEND	X	= Less than Detection Limit	NA	= Not Analysed
	SNR	= Sample Not Received	UA	= Unable to Assay
	*	= Result Checked	>	= Value beyond Limit of Method
	DTF	= Result still to come	+	= Extra Sample Received Not Listed
	IS	= Insufficient Sample for Analysis		



ELEMENTS	B	B	Cu	Cu	F	Hg	Hg	Mo	Mo	Se
UNITS	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm
DETECTION LIMIT	50	20	0.5	0.2	50	1	0.01	0.1	0.02	0.1
DIGEST	FP1/	AR005/	4A/	AR005/	FC7/	AR01/	AR005/	4A/	AR005/	AR005/
ANALYTICAL FINISH	OE	MS	MS	MS	SIE	CV	MS	MS	MS	MS
SAMPLE NUMBERS										
0001 0006 GCA11742	X	X	121.6	121.6	462	8	0.01	5.7	6.06	11.1
0002 0017 GCA11743	X	X	272.4	270.7	606	7	X	1.6	1.18	4.2
0003 0019 GCA11744	X	X	214.0	215.4	282	4	X	0.8	0.69	0.7
0004 0022 GCA11745	X	X	101.8	99.7	347	4	X	0.6	0.37	1.5
0005 0031 GCA11746	X	X	481.2	462.9	404	2	X	25.6	22.15	34.3
0006 0067 GCA11747	X	X	228.7	233.7	732	9	X	0.7	0.64	7.7
0007 0109 GCA11748	X	X	612.4	609.5	483	3	X	25.2	23.87	78.3
0008 0122 GCA11749	X	X	314.6	327.3	408	5	X	4.2	3.89	2.8
0009 0129 GCA11750	X	X	168.9	168.8	384	3	X	0.8	0.68	4.0
0010 0141 GCA11751	X	X	32.5	31.3	635	2	X	0.6	0.72	0.5
0011 0142 GCA11752	X	X	46.7	46.9	623	X	X	0.8	0.65	0.7
0012 0158 GCA11753	X	X	75.6	72.3	490	2	X	1.0	0.70	1.2
0013 0187 GCA11754	X	X	161.0	156.1	306	1	X	0.7	0.62	2.2
0014 0204 GCA11755	X	X	1491.7	1465.4	504	1	X	42.2	38.87	9.2
0015 0236 GCA11756	X	X	89.5	89.1	544	2	X	7.3	7.88	5.1
0016 0245 GCA11757	X	X	113.0	109.7	375	X	X	0.3	0.20	7.4
0017 0363 GCA11758	X	X	339.8	340.7	749	X	X	9.9	8.05	31.9
0018 0381 GCA11759	X	X	434.9	458.9	465	3	X	2.4	2.34	13.0
0019 0384 GCA11760	X	X	165.8	163.3	420	6	X	0.6	0.47	1.9
0020 0414 GCA11761	X	X	274.2	271.7	899	2	X	0.6	0.53	6.1
0021 0420 GCA11762	X	X	1445.9	1426.5	751	X	X	2.5	1.85	6.7
0022 0421 GCA11763	X	X	1020.8	1059.8	571	X	X	12.9	11.91	16.2
0023 0442 GCA11764	X	X	4606.5	4669.4	222	X	X	1.6	1.28	12.7
0024 0461 GCA11765	X	X	396.7	386.7	1017	X	X	3.5	3.26	37.9
0025 0480 GCA11766	X	X	59.5	59.8	465	5	X	5.5	5.64	1.9
0026 0484 GCA11767	X	X	159.5	156.4	516	X	X	6.0	7.15	6.8
0027 0494 GCA11768	X	X	1404.1	1398.7	779	X	X	30.4	30.87	16.3
0028 0530 GCA11769	X	X	76.3	72.1	257	2	X	1.6	1.18	0.4
0029 0532 GCA11770	X	X	94.5	90.1	346	X	X	0.5	0.45	1.5
0030 0534 GCA11771	X	X	1349.5	1387.4	184	X	X	52.6	51.52	18.9
0031 0544 GCA11772	X	X	255.8	254.3	646	2	X	4.6	4.49	3.9
0032 0546 GCA11773	X	X	141.1	132.7	273	3	X	1.4	0.12	0.1

CHECKS										
0001 0381 GCA11759		X		461.8		1	X		2.41	12.8
0002 0022 GCA11745					357					
0003 0480 GCA11766	X		60.8					5.2		



ELEMENTS	Se	Si	Te	Te
UNITS	ppm	%	ppm	ppm
DETECTION LIMIT	0.01	0.1	0.2	0.05
DIGEST	SE1/	FP1/	4A/	AR005/
ANALYTICAL FINISH	MS	OE	MS	MS
SAMPLE NUMBERS				
0001 0006 GCA11742	10.52	17.8	0.5	0.61
0002 0017 GCA11743	3.21	24.5	0.4	0.48
0003 0019 GCA11744	0.56	21.1	X	0.21
0004 0022 GCA11745	1.27	25.4	1.0	0.83
0005 0031 GCA11746	31.75	16.9	1.5	1.47
0006 0067 GCA11747	7.31	23.9	0.3	0.31
0007 0109 GCA11748	75.39	14.3	3.4	3.41
0008 0122 GCA11749	3.29	26.2	X	0.22
0009 0129 GCA11750	3.53	20.9	2.6	2.65
0010 0141 GCA11751	0.27	22.9	X	0.05
0011 0142 GCA11752	0.53	22.4	X	0.06
0012 0158 GCA11753	1.03	21.7	1.3	1.14
0013 0187 GCA11754	1.91	19.3	1.7	1.70
0014 0204 GCA11755	8.54	18.0	1.0	1.15
0015 0236 GCA11756	4.75	20.0	0.3	0.34
0016 0245 GCA11757	6.74	21.3	0.6	0.59
0017 0363 GCA11758	30.83	20.5	1.8	2.06
0018 0381 GCA11759	12.20	22.8	0.9	0.85
0019 0384 GCA11760	1.71	24.6	0.2	0.21
0020 0414 GCA11761	5.61	23.7	0.4	0.52
0021 0420 GCA11762	6.21	18.8	0.9	0.73
0022 0421 GCA11763	15.43	26.1	0.5	0.48
0023 0442 GCA11764	11.52	6.4	6.5	8.37
0024 0461 GCA11765	35.52	18.8	1.6	1.57
0025 0480 GCA11766	1.50	18.6	X	0.16
0026 0484 GCA11767	6.08	14.2	0.6	0.70
0027 0494 GCA11768	15.79	16.6	2.5	2.44
0028 0530 GCA11769	0.26	22.2	X	X
0029 0532 GCA11770	1.32	22.2	0.3	0.38
0030 0534 GCA11771	17.08	17.8	2.0	1.86
0031 0544 GCA11772	3.47	22.3	0.8	0.75
0032 0546 GCA11773	1.74	24.6	0.8	0.25
CHECKS				
0001 0381 GCA11759				0.87
0002 0022 GCA11745	1.38			
0003 0480 GCA11766		16.2	X	



ELEMENTS	B	B	Cu	Cu	F	Hg	Hg	Mo	Mo	Se
UNITS	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm
DETECTION LIMIT	50	20	0.5	0.2	50	1	0.01	0.1	0.02	0.1
DIGEST	FP1/	AR005/	4A/	AR005/	FC7/	AR01/	AR005/	4A/	AR005/	AR005/
ANALYTICAL FINISH	OE	MS	MS	MS	SIE	CV	MS	MS	MS	MS
STANDARDS										
0001 OREAS 45d	X									
0002 OREAS 920			108.5					0.4		
0003 AMIS0342					1087					
0004 OREAS 97.01										
0005 HgSTD-7						1631				
0006 OREAS H1		X		27.9			0.15		4.04	2.0
BLANKS										
0001 Control Blank					X					
0002 Control Blank	X		X					X		
0003 Control Blank		X		X		X	X		X	X



ELEMENTS	Se	Si	Te	Te
UNITS	ppm	%	ppm	ppm
DETECTION LIMIT	0.01	0.1	0.2	0.05
DIGEST	SE1/	FP1/	4A/	AR005/
ANALYTICAL FINISH	MS	OE	MS	MS
STANDARDS				
0001 OREAS 45d		23.1		
0002 OREAS 920			X	
0003 AMIS0342				
0004 OREAS 97.01	0.64			
0005 HgSTD-7				
0006 OREAS H1				2.68
BLANKS				
0001 Control Blank	X			
0002 Control Blank		X	X	
0003 Control Blank				X



METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
4A/MS	Intertek Genalysis Perth 3244 3237 Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.	4A/ : MPL_W002, MS : ICP_W003
AR005/MS	Intertek Genalysis Perth 3244 3237 0.5 gram mini Aqua-Regia digest. Analysed by Inductively Coupled Plasma Mass Spectrometry.	
AR01/CV	Intertek Genalysis Perth 3244 3237 Aqua-Regia digest. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.	
FC7/SIE	Intertek Genalysis Perth 3244 3237 Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.	ENV_W012, SIE : ENV_W012
FP1/OE	Intertek Genalysis Perth 3244 3237 Sodium peroxide fusion (Zirconia crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.	FP1/ : MPL_W011, OE : ICP_W004
SE1/MS	Intertek Genalysis Perth 3244 3237 Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled Plasma Mass Spectrometry.	



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Dr G Campbell

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JOB INFORMATION

JOB CODE	143/1714208
No. of SAMPLES	38
CLIENT O/N	GCA 1716
PROJECT	SOUTH-NUNASVAARA
STATE	Solution
DATE RECEIVED	28/09/2017
DATE COMPLETED	09/10/2017

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
()	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method

A range of solutions were received to be analysed. The pH, EC, F, Cl and alkalinity of requested raw-solutions were measured. (Alkalinity: APHA method code 2320B).

Genalysis method codes: ENV_W001, (pH) ENV_W002, (EC), ENV_W011, (Cl), and ENV_W013 (F)

APHA code refers to "Standard methods for the examination of water and wastewater", 22nd Edition 2012

The HNO₃ dosed filtered solutions were analysed for the requested element suite by ICPOES and ICPMS

Genalysis method codes: ICP_W004 (ICPOES) and ICP_W003 (ICPMS)

Results of analysis on:

Element		Acidy	Cl	CO ₃	HCO ₃	OH
Method		/VOL	/COL	/VOL	/VOL	/VOL
Detection		0.2	2	1	2	1
Units		mgCaCO ₃ /L	mg/l	mgCaCO ₃ /L	mgCaCO ₃ /L	mgCaCO ₃ /L
Sample Name						
Control Blank		1.1	X	X	3	X
GCA11744 RAW		5.7	10	X	30	X
GCA11744 RAW	check	5.2	11	X	33	X
GCA11772 RAW		7.1	8	X	50	X
GCA11757 RAW		1154.3	5	X	X	X
GCA11747 RAW		344.9	11	X	X	X
GCA11761 RAW		8.3	14	X	6	X
GCA11745 RAW		2.9	5	X	28	X
GCA11768 RAW		264.1	4	X	X	X
GCA11748 RAW		40.9	17	X	20	X
GCA11758 RAW		6.9	6	X	12	X
GCA11746 RAW		27.1	8	X	151	X
GCA11762 RAW		16.6	6	X	3	X

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GCA11749 RAW		3.8	10	X	24	X
GCA11771 RAW		178.6	3	X	X	X
GCA11743 RAW		51.8	6	X	3	X
GCA11764 RAW		19	12	X	170	X
GCA11765 RAW		21.4	3	X	3	X
GCA11755 RAW		1234.1	5	X	X	X
Blank RAW		1.9	X	X	3	X
HPDW RAW		1.7	X	X	3	X
GWS-1			34			

Element		TotAlk	F	EC	pH
Method		/CALC	/SIE	/MTR	/MTR
Detection		5	0.1	0.01	0.1
Units		mgCaCO3/L	mg/l	mS/cm	NONE
Sample Name					
Control Blank		X	X	X	5.2
GCA11744 RAW		30	X	1.4	7.8
GCA11744 RAW	check	33	X	1.38	7.8
GCA11772 RAW		50	X	1.16	7.4
GCA11757 RAW		X	X	5.05	3.6
GCA11747 RAW		X	0.2	3.27	3.8
GCA11761 RAW		6	0.1	0.97	5.9
GCA11745 RAW		28	X	0.27	7.1
GCA11768 RAW		X	X	2.02	3.7
GCA11748 RAW		20	X	1.91	6.1
GCA11758 RAW		12	X	0.94	6.3
GCA11746 RAW		151	X	2.77	8.1
GCA11762 RAW		X	X	1.2	4.8
GCA11749 RAW		24	0.7	0.77	6.9
GCA11771 RAW		X	X	2.79	4.1
GCA11743 RAW		X	X	0.99	4.5
GCA11764 RAW		170	X	3.07	7.7
GCA11765 RAW		X	0.2	1.65	4.6
GCA11755 RAW		X	X	4.94	3.9
Blank RAW		X	X	X	5.2
HPDW RAW		X	X	X	5.6
GWS-1					

Element		Ag	As	Ba	Bi	Cd	Co	Hg
Method		/MS	/MS	/MS	/MS	/MS	/MS	/MS
Detection		0.1	1	0.5	0.05	0.2	1	1
Units		ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
Sample Name								
Control Blank		X	X	X	X	X	X	X
GCA11744 HNO3		0.1	3	16	X	X	X	X
GCA11772 HNO3		X	6	14	X	X	6	X
GCA11772 HNO3	check	X	6	13.3	X	X	6	X
GCA11757 HNO3		0.1	9	14.3	X	2	7414	X

GCA11747 HNO3		0.1	5	9.5	X	X	2894	X
GCA11761 HNO3		X	4	54	X	X	234	X
GCA11745 HNO3		X	15	31.1	X	X	X	X
GCA11768 HNO3		X	17	5.3	X	X	5927	X
GCA11748 HNO3		X	3	61.8	X	X	315	X
GCA11758 HNO3		0.2	3	72.7	X	X	688	X
GCA11746 HNO3		X	8	19	X	X	297	X
GCA11762 HNO3		X	4	44.9	X	0.7	2712	X
GCA11749 HNO3		X	4	32.7	X	X	44	X
GCA11771 HNO3		X	4	6.2	X	0.2	3022	X
GCA11743 HNO3		X	4	63.7	0.99	X	922	X
GCA11764 HNO3		0.1	5	8.9	X	X	63	X
GCA11765 HNO3		X	3	31.9	X	X	760	X
GCA11755 HNO3		X	5	1.9	X	352.2	5097	X
Blank HNO3		X	2	0.6	X	X	X	X
HPDW HNO3		X	X	X	X	X	X	X
TMDW		1.8	84	51.8	10.28	10.6	26	X

Element		Mo	Pb	Sb	Se	Sn	Sr	Te
Method		/MS	/MS	/MS	/MS	/MS	/MS	/MS
Detection		0.5	5	0.1	5	1	0.2	1
Units		ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
Sample Name								
Control Blank		X	X	X	X	X	X	X
GCA11744 HNO3		1.8	X	X	X	X	293.7	X
GCA11772 HNO3		1.1	X	X	24	X	227.3	X
GCA11772 HNO3	check	1	X	0.1	23	X	225.9	X
GCA11757 HNO3		X	20	X	31	X	46.5	X
GCA11747 HNO3		X	5	X	12	X	62.5	X
GCA11761 HNO3		X	X	X	18	X	159.9	X
GCA11745 HNO3		1.2	X	0.3	X	X	52.9	X
GCA11768 HNO3		X	X	X	14	X	43.9	X
GCA11748 HNO3		X	X	0.1	133	X	107.3	X
GCA11758 HNO3		X	X	X	39	X	49.9	X
GCA11746 HNO3		X	X	X	149	X	268	X
GCA11762 HNO3		X	X	X	13	X	69.9	X
GCA11749 HNO3		X	X	X	7	X	59.6	X
GCA11771 HNO3		X	X	X	8	X	206.5	X
GCA11743 HNO3		X	X	X	10	X	60.3	X
GCA11764 HNO3		X	X	X	10	X	314.1	X
GCA11765 HNO3		X	X	X	72	X	52.8	X
GCA11755 HNO3		X	2584	X	14	X	51.8	X
Blank HNO3		X	X	X	X	X	0.3	X
HPDW HNO3		X	X	X	X	X	X	X
TMDW		100.4	41	10.4	11	X	264.9	3

Element		Th	Tl	U	Al	B	Ca	Cr
Method		/MS	/MS	/MS	/OE	/OE	/OE	/OE
Detection		0.05	0.1	0.05	0.01	0.01	0.01	0.01
Units		ug/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l
Sample Name								
Control Blank		X	X	X	X	X	X	X
GCA11744 HNO3		X	X	2.88	0.04	0.04	302.86	X
GCA11772 HNO3		X	0.1	0.53	0.04	0.04	192.41	X
GCA11772 HNO3	check	X	X	0.47	0.01	0.03	190.56	X
GCA11757 HNO3		0.36	0.5	13.58	178.63	X	396.58	0.15
GCA11747 HNO3		X	0.1	2.56	12.75	X	320.23	X
GCA11761 HNO3		X	X	0.07	X	0.07	91.63	X
GCA11745 HNO3		X	X	0.24	0.13	0.08	21.42	0.01
GCA11768 HNO3		0.1	0.2	89.21	2.61	0.03	145.1	X
GCA11748 HNO3		X	X	0.48	0.07	0.03	421.06	X
GCA11758 HNO3		X	X	1.58	X	0.05	129.31	X
GCA11746 HNO3		X	X	19.22	0.15	0.03	792.64	0.01
GCA11762 HNO3		X	0.1	1.19	0.31	0.06	121.05	X
GCA11749 HNO3		X	X	X	0.01	0.05	108.26	X
GCA11771 HNO3		X	X	37.43	3.61	X	579.12	X
GCA11743 HNO3		X	X	0.8	0.58	0.07	71.69	X
GCA11764 HNO3		X	X	0.53	0.12	X	656.18	X
GCA11765 HNO3		X	X	4.51	1.02	0.05	126.08	X
GCA11755 HNO3		X	X	92.38	6.92	X	245.89	X
Blank HNO3		X	X	X	0.01	0.07	0.08	X
HPDW HNO3		X	X	X	X	0.04	0.05	X
TMDW		X	10.6	10.34				
UNI 1					24.74	5.24	25.12	24.33

Element		Cu	Fe-Sol	K	Mg	Mn	Na	Ni
Method		/OE	/OE	/OE	/OE	/OE	/OE	/OE
Detection		0.01	0.01	0.1	0.01	0.001	0.1	0.01
Units		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Sample Name								
Control Blank		X	X	X	X	X	X	X
GCA11744 HNO3		X	0.01	27.8	14.07	0.02	16.8	0.03
GCA11772 HNO3		X	X	23.5	36.65	0.085	14.3	0.18
GCA11772 HNO3	check	X	X	23.6	35.86	0.086	14.3	0.18
GCA11757 HNO3		0.25	32.03	20	579.36	3.364	62.7	25.24
GCA11747 HNO3		0.06	110.22	77	279.2	2.467	10.3	11.44
GCA11761 HNO3		X	1.3	38.5	42.63	0.533	16.2	2.2
GCA11745 HNO3		X	X	14.6	7.36	0.004	8.5	X
GCA11768 HNO3		0.83	99.28	25.8	150.28	2.885	12	19.72
GCA11748 HNO3		X	11.77	25.8	43.85	1.46	7.3	6.62
GCA11758 HNO3		X	0.91	28.4	32.07	1.535	8.3	5.21
GCA11746 HNO3		0.03	0.44	6.3	26.01	0.839	11.4	8.36
GCA11762 HNO3		0.03	2.72	28.5	72.2	2.502	16	4.87

GCA11749 HNO3		0.01	X	18.3	21.14	0.204	12.8	0.43
GCA11771 HNO3		0.09	68.79	4.1	123.83	0.673	15.2	9.29
GCA11743 HNO3		X	20.82	50.8	45.36	0.357	19.2	2.71
GCA11764 HNO3		0.02	0.57	26.7	187.37	0.886	3.6	1.16
GCA11765 HNO3		0.03	2.87	46.3	148.87	0.308	15.7	3.94
GCA11755 HNO3		0.01	671.98	21.3	638.55	16.247	13.3	28.4
Blank HNO3		X	0.02	X	X	X	X	X
HPDW HNO3		X	X	0.2	X	X	X	X
UNI 1		9.83	240.66	25	24.23	9.624	25.3	10.12

Element		P	S	Si	V	Zn
Method		/OE	/OE	/OE	/OE	/OE
Detection		0.05	0.05	0.05	0.01	0.01
Units		mg/l	mg/l	mg/l	mg/l	mg/l
Sample Name						
Control Blank		X	X	X	X	X
GCA11744 HNO3		X	272.35	1.61	X	X
GCA11772 HNO3		X	186.87	2.52	X	X
GCA11772 HNO3	check	X	192.22	2.54	X	X
GCA11757 HNO3		X	1384.8	15.29	X	0.42
GCA11747 HNO3		0.1	719.36	9.49	X	0.11
GCA11761 HNO3		0.07	168.56	3.09	X	0.02
GCA11745 HNO3		X	30.69	2.01	X	X
GCA11768 HNO3		0.08	402.15	6.9	X	0.05
GCA11748 HNO3		X	433.77	2.53	X	0.02
GCA11758 HNO3		X	163.42	2.91	X	0.03
GCA11746 HNO3		X	614.24	3.04	X	0.02
GCA11762 HNO3		X	220.46	6.56	X	0.13
GCA11749 HNO3		X	128.4	2.75	X	X
GCA11771 HNO3		X	636.87	5.22	X	0.07
GCA11743 HNO3		X	174.63	4.64	X	0.05
GCA11764 HNO3		0.24	664.12	1.48	X	0.02
GCA11765 HNO3		X	320.58	4.43	X	0.04
GCA11755 HNO3		0.61	1482.08	13.28	X	23.79
Blank HNO3		X	0.34	0.06	X	0.02
HPDW HNO3		X	0.29	X	X	X
UNI 1		24.02	25.03	46.98	9.43	9.93

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

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Intertek Genalysis Signatory: Huong Pham

Huong Pham

Date: 16/10/2017

BILAGA B

Assessment of the future leachate quality from waste rock at Nunasvaara South



BERGSKRAFT

Bergslagen AB

Report

Assessment of the future leachate quality from waste rock at
Nunasvaara South



Mattias Backstrom
Lotta Sartz

BKBAB 18-107 Rep

rev. 2020-01-11

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APPENDIX 1 – SELECTED SAMPLES

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APPENDIX 7 – PRIMARY DATA – ELEMENTS, LEACHATE SOLUTIONS

EXECUTIVE SUMMARY

Waste rock from Nunasvaara South will eventually generate acid rock drainage. Acid-base-accounting indicate a significant acid generating potential and the samples from the old waste deposit was acid. It is, however, hard to predict exactly when the acid will form. Large kinetic tests show acid generation starting to form after around 17 weeks from the Sgr sample and later also from the FW sample. There is still no acid generation from the Dyke and HGW samples. It must, however, be noted that 30 weeks are to be considered a relatively short time period in order to determine when acid will be formed. This study, however, indicate that the evolution of acid drainage might not be as fast as has been indicated by earlier laboratory studies. There is thus no need for immediate action to prevent acid formation from the waste rock during the mining operation. It should be possible to handle the waste during the end of the season even though it should be noted that waste with higher sulfide concentrations than the tested samples will also be present at the site.

Cobalt and nickel are the trace elements of greatest concern at the site. It is possible that leachate with pH 3 will form if no measures are taken in order to avoid acid generation from the mining waste. This will lead to cobalt and nickel concentrations around 5 and 19 mg/L, respectively, in the pore water from the dump. Increased copper and zinc concentrations can not be excluded if the waste rock is significantly oxidized. This scenario is, however, not very likely as weathering showed to be rather slow and no major leachates was formed prior to 30 weeks.

Leachate quality from the waste rock and the pit walls have been estimated from the leaching tests.

Sulfate analysis indicate a sulfide oxidation rate (SOR) of between 90 and 160 mg SO_4^{2-} /kg/week. Elemental analysis of the leachates indicate that cobalt, nickel and copper to some degree are possible problematic elements, also at circum neutral pH. Sulfate concentrations will be around 1 200-1 400 mg/L due to possible gypsum equilibrium.

There is a risk that, at least the ore samples (Sgr), can react spontaneously with added explosives prior to ignition. This means that there is a risk for premature detonation during blasting. It also means that there is a risk for spontaneous combustion of waste rock containing high concentrations of graphite. Waste piles allowing for convective flow of air should therefore be avoided.

INTRODUCTION

Talga Resources is planning to apply for a concession for graphite in area around Nunasvaara (Nunasvaara South). This report summarizes the results from performed field work and small scale pilot kinetic tests with respect to acid generation and waste rock leachate quality.

DESCRIPTION OF THE AREA

Topography

On a regional scale the area is mainly consisting of lowland where heights vary between 350-450 meter above sea level (masl) with areas with moors and small lakes between the heights. The landscape at Nunasvaara is hilly with two dominating peaks; Hosiorinta and Nunasvaara. Major part of the planned mining area is on the eastern slope of Hosiorinta towards the lake Hosiojärvi.

Geology

Soil depth is generally very thin in the entire area.

The geology of the project area comprises greenstones (basalt to andesite), metasediments (quartzite, slate, marble) and metadolerites that form part of the Vittangi greenstone group and belongs to the Paleoproterozoic volcanic sedimentary domain in northern Sweden.

Earlier studies have found that most of the material is potentially acid forming with low or no carbonates present.

Planned mining operation

According to Talga graphite ore is planned to be mined up to 100 000 tonnes/year from the Nunasvaara South deposit. Over a 25-year life of mine up to 2.5 million tonnes of ore is expected to be mined. Approximately 7.5 million tonnes of waste rock is expected to be generated.

Conventional drill and blast mining will be utilised for mining waste rock and for mining most ore to feed the concentrator. Each blast will be subject to its own design to minimise fly rock generation and fracture of non-target in situ ore. Rock and ore will be mined via conventional excavator and truck operations, with ore placed at a run of mine stockpile and waste rock placed at the waste management facility.

The block mining method employs cutting devices to cut the in-situ ore into blocks producing up to 10 000 tonnes/year of ore blocks. Mined ore blocks will be delivered to a block store facility for cutting.

Two methods are being considered for block mining: a wet wire-cut method; and a dry chainsaw cut method.

Waste rock generation

According to Talga waste rock and low-grade ore generated will be removed and stockpiled initially outside of the mine pit. As the mine develops and sufficient operational space is available within the pit, waste rock will be placed within a waste management facility within the pit enabling progressive rehabilitation as mining progresses.

Waste rock tonnages to be produced are estimated to be around 100 000-500 000 tonnes/year, up to approximately 7.5 million tonnes in total over the 25 year life of mine. As the waste rock is known to become acid generating over time it will be placed in a lined, engineered facility from which drainage water can be collected and treated. Waste rock mineral consists mainly of silicates (including plagioclases, marialites, and tremolites) and non-recoverable graphite.

FIELD WORK

Performed field work

Field work was performed June 8-10 2018 by Mattias Bäckström. Peter French and Tom Kearney from Talga Resources were present during part of the field work.

The main objective with the field work was to study the waste rock deposit found some hundred meters east of the trial mining area. It was assumed that the waste deposit was a result of trial mining performed by LKAB during the 1970s. Waste materials in the deposit should then have been exposed to air and water for approximately 40 years. This material can therefore be assumed to represent some sort of worst-case scenario when it comes to weathering of the generated waste rock.

Three test pits were dug by hand in the waste deposit down to around 70 cm. From each test pit two composite samples were collected; one representing relatively unweathered material and one consisting of mainly fine material.

Simple shake tests were also performed in the field using the solid material (around 2 kg material and 4 liters of water) to obtain an indication about the already generated acidity. pH and electrical conductivity were measured using a hand-held field instrument after 24 hours.

In addition to the samples from the waste deposit at the trial mining area some composite samples (as chip samples) were also sampled from waste piles in the northern part of the concession area Nunasvaara South. These historical waste piles have a visibly higher content of sulfides and possible also copper. Both unweathered and weathered samples were collected. Samples from the field work was analyzed for total elemental content by ALS. Coordinates for all samples can be found in Appendix 1.



Figure 1: Typical composition of material from the old waste deposit close to the trial mining area.

Results

During sampling of the old waste deposit close to the trial mining it was noted that the material contained a significant amount of fine material (Figure 1). It is therefore likely that the waste deposit consists of a mixture between waste rock from the trial mining performed during the 1970s and overburden (probably till).

From the shake tests performed on the material from the old waste deposit acid production is either ongoing or has ceased with an average pH around 4. pH is also generally lower in the fine material indicating the presence of secondary weathering products from the original waste rock and not only overburden. Electrical conductivity is rather low, indicating that the current acid generation has peaked or is rather low or even has stopped.

Table 1: pH and electrical conductivity in the performed shake tests (L/S 2) on the material from the old waste deposit.

	pH	Electrical conductivity (µS/cm)
1a, unweathered	3.71	170
1b, fine material	3.49	210
2a, unweathered	4.22	90
2b, fine material	4.04	100
3a, unweathered	4.34	80
3b, fine material	3.94	130
Weathered graphite	4.83	50

Concentrations of carbon (Table 2) indicate a significant portion of graphite in the samples, even though the concentrations are not as high as in the ore samples.

Table 2: Element concentrations in samples from the old waste deposit. Reported concentrations in the corresponding oxides should not be interpreted as presence of oxide minerals; this is just a reporting convention for whole rock analysis. Concentrations in yellow exceed the 99th percentile for Swedish tills (SGU, 2018). See Appendix 2 for all data.

		1a	1b	2a	2b	3a	3b	Weathered graphite
SiO ₂	%	50.2	44.4	50.3	44.2	49.2	39.9	39.6
Al ₂ O ₃	%	13.55	11.4	13.9	12.15	13.9	11.2	9.79
Fe ₂ O ₃	%	6.65	11.2	8	15.75	7.47	12.95	9.73
CaO	%	3.38	2.38	4.47	3.84	5.12	2.64	1.03
MgO	%	4.22	4.61	4.93	4.52	4.4	4.52	3.36
Na ₂ O	%	4.86	3.63	5.32	4.59	5.24	3.41	3.05
K ₂ O	%	1.07	1.31	1.27	1.06	0.97	1.15	0.74
Cr ₂ O ₃	%	0.019	0.017	0.015	0.013	0.012	0.028	0.023
TiO ₂	%	1.36	1.21	1.47	1.45	1.71	1.05	0.65
MnO	%	0.04	0.04	0.06	0.07	0.05	0.06	0.04
P ₂ O ₅	%	0.19	0.2	0.1	0.2	0.27	0.13	0.12
SrO	%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BaO	%	0.02	0.02	0.02	0.02	0.02	0.02	0.01
LOI	%	15.35	18.1	11.9	11.95	11.5	22.2	30.5

		1a	1b	2a	2b	3a	3b	Weathered graphite
Total	%	100.91	98.52	101.76	99.81	99.86	99.26	98.64
C	%	11.8	8.14	8.69	3.06	8.45	13.35	21.5
S	%	1.78	1.29	0.72	0.71	0.61	0.65	0.75
Ba	ppm	154	211	153.5	174.5	141.5	204	103
Ce	ppm	53.3	65.3	41.3	38.2	88.3	34.5	48.8
Cr	ppm	130	120	100	80	80	200	170
Cs	ppm	0.64	0.59	1.1	0.87	0.64	1	0.91
Dy	ppm	4.44	4.55	3.53	3.19	6.5	3.16	2.76
Er	ppm	2.39	2.48	1.9	1.54	3.63	1.87	1.68
Eu	ppm	1.38	1.16	1.25	1.07	2.48	0.75	0.6
Ga	ppm	18.7	18.6	19.6	18.1	21.7	17.6	15.1
Gd	ppm	4.57	4.64	3.93	3.54	7.75	2.76	3.2
Ge	ppm	<5	<5	<5	<5	<5	<5	<5
Hf	ppm	3.7	3	3.3	3.2	4.5	3.2	1.7
Ho	ppm	1	0.98	0.73	0.67	1.54	0.66	0.6
La	ppm	25.8	35.4	20.1	19.4	41.5	17.6	24.6
Lu	ppm	0.34	0.34	0.22	0.22	0.58	0.25	0.25
Nb	ppm	7.8	7.9	10.3	8.4	8.8	8.4	6.1
Nd	ppm	25.4	28.9	21.3	17.4	43.2	15.5	21.7
Pr	ppm	6.42	7.29	4.94	4.24	10.45	3.97	5.65
Rb	ppm	35.6	41.8	51.6	37.5	29	40.6	27.2
Sm	ppm	5.34	5.87	4.37	3.7	8.92	3.33	3.44
Sn	ppm	1	1	1	1	2	1	<1
Sr	ppm	131	92.2	127	111	172	78.8	49.1
Ta	ppm	0.2	0.1	0.4	0.1	0.2	<0.1	<0.1
Tb	ppm	0.72	0.75	0.58	0.5	1.18	0.53	0.4
Th	ppm	5.42	4.54	3.32	2.47	4.07	3.56	6.63
Tm	ppm	0.4	0.37	0.27	0.25	0.52	0.24	0.24
U	ppm	3.78	2.93	2.32	2.29	4.71	3.98	3.59
V	ppm	237	255	246	270	277	268	178
W	ppm	<1	1	3	2	2	7	1
Y	ppm	24.7	25.3	18.1	15.3	36.5	17.2	17.3
Yb	ppm	2.49	2.28	1.59	1.58	3.37	1.65	1.69
Zr	ppm	148	134	131	126	183	110	91
As	ppm	2.1	14.4	2	3	2.3	5.2	7.5
Bi	ppm	0.27	0.24	0.07	0.14	0.06	0.32	0.29
Hg	ppm	0.016	0.018	0.007	0.009	0.008	0.011	0.015
In	ppm	0.008	0.014	0.015	0.018	0.023	0.012	0.005
Re	ppm	0.036	0.065	0.012	0.013	0.016	0.02	0.01
Sb	ppm	0.08	0.47	0.06	0.17	0.06	0.22	1.15
Se	ppm	8.4	15.9	2.6	12.6	2.3	18.7	15.7
Te	ppm	0.48	1.05	0.26	0.97	0.22	1.04	1.02
Tl	ppm	0.06	0.11	0.08	0.11	0.05	0.14	0.14

		1a	1b	2a	2b	3a	3b	Weathered graphite
Ag	ppm	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	1.5
Cd	ppm	4.1	5	0.7	1.8	1.6	2	<0.5
Co	ppm	28	11	28	15	18	14	7
Cu	ppm	169	247	237	279	126	243	341
Li	ppm	10	20	10	10	10	10	20
Mo	ppm	4	29	3	3	5	8	3
Ni	ppm	177	26	66	40	59	47	41
Pb	ppm	581	7 260	88	996	233	1 550	7 230
Sc	ppm	25	26	22	25	24	27	23
Zn	ppm	1 100	1 770	182	435	194	517	684

Also in samples from the northern part the concentrations of carbon are high (Table 3), indicating a clear presence of graphite also in this part of the area.

Table 3: Element concentrations in samples from the waste deposit in the northern part of the concession area Nunasvaara South. Reported concentrations in the corresponding oxides should not be interpreted as presence of oxide minerals; this is just a reporting convention for whole rock analysis. Concentrations in yellow exceed the 99th percentile for Swedish tills (SGU, 2018). See appendix 2 for all data.

		North chip	North weathered	Chip 1	Chip 2
SiO ₂	%	34.5	37.5	40.3	34.4
Al ₂ O ₃	%	7.84	8.14	9.08	7.84
Fe ₂ O ₃	%	12.15	7.56	2.96	7.17
CaO	%	3.75	4.23	3.86	3.65
MgO	%	2.04	3.61	2.31	3.59
Na ₂ O	%	3.06	3.14	3.56	2.4
K ₂ O	%	0.39	0.91	1.07	2.07
Cr ₂ O ₃	%	0.023	0.034	0.028	0.028
TiO ₂	%	0.6	0.71	0.78	0.73
MnO	%	0.02	0.03	0.02	0.03
P ₂ O ₅	%	0.05	0.03	0.02	0.04
SrO	%	<0.01	<0.01	0.01	<0.01
BaO	%	<0.01	0.01	0.02	0.04
LOI	%	35.6	33.7	35.1	37.4
Total	%	100.02	99.6	99.12	99.39
C	%	26.2	27.2	30.5	31.4
S	%	5.18	1.61	0.09	2.35
Ba	ppm	23	119	117.5	317
Ce	ppm	27.8	18.1	20.4	33.6
Cr	ppm	160	240	180	200
Cs	ppm	0.26	0.79	0.74	1.64
Dy	ppm	2.96	1.87	2.13	3.39
Er	ppm	1.66	1.16	1.17	1.98
Eu	ppm	0.83	0.58	0.73	0.93

		North chip	North weathered	Chip 1	Chip 2
Ga	ppm	10	11.6	11.6	12
Gd	ppm	3.06	1.9	2.04	3.19
Ge	ppm	<5	<5	<5	<5
Hf	ppm	2	1.9	2.1	2.1
Ho	ppm	0.69	0.45	0.52	0.81
La	ppm	15.7	9.7	10.4	18.3
Lu	ppm	0.22	0.18	0.17	0.28
Nb	ppm	5.5	6.9	6.4	6.8
Nd	ppm	13.9	9.2	10.2	16.2
Pr	ppm	3.31	2.19	2.43	3.95
Rb	ppm	5.7	16.2	19.5	49.4
Sm	ppm	3.21	1.99	2.22	3.56
Sn	ppm	<1	1	1	<1
Sr	ppm	52.3	50.4	49.6	40.2
Ta	ppm	0.2	0.1	0.2	0.2
Tb	ppm	0.48	0.32	0.33	0.56
Th	ppm	3.98	2.95	3.68	4.48
Tm	ppm	0.24	0.15	0.19	0.33
U	ppm	5.78	3.19	5.26	6.46
V	ppm	157	238	166	213
W	ppm	<1	5	1	2
Y	ppm	17.6	11.4	12.4	20.4
Yb	ppm	1.62	1.07	1.06	1.87
Zr	ppm	78	79	82	84
As	ppm	3	3	1.6	2.1
Bi	ppm	1.08	0.95	0.25	0.94
Hg	ppm	0.012	0.013	0.019	0.013
In	ppm	<0.005	<0.005	<0.005	<0.005
Re	ppm	0.055	0.029	0.024	0.084
Sb	ppm	0.09	0.08	0.06	0.09
Se	ppm	59.1	39.6	7.4	28.1
Te	ppm	3.83	2.14	0.56	1.6
Tl	ppm	0.05	0.09	0.02	0.09
Ag	ppm	<0.5	<0.5	<0.5	<0.5
Cd	ppm	0.6	0.6	<0.5	<0.5
Co	ppm	55	7	3	27
Cu	ppm	477	246	59	190
Li	ppm	<10	<10	<10	<10
Mo	ppm	12	9	8	8
Ni	ppm	280	20	10	144
Pb	ppm	4	5	26	18
Sc	ppm	14	25	19	18
Zn	ppm	9	13	12	9

LARGE KINETIC TESTS AND CHEMICAL ANALYSIS

Experimental methods

Selection of samples for the large kinetic tests was made together with Talga geologist Tom Kearney. From earlier categories of rock from drill cores in the area it was decided that the following categories should be used for kinetic testing; Dyke, Sgr (ore), FW (foot wall) and HGW (hanging wall). Since a lot of the cores from the ore zone were missing lower sulfide content than expected were obtained for the sample Sgr (Figure 3). Selected samples in each category can be found in Appendix 1.

Composite samples from each category was created by crushing the cores in a jaw crusher until a reasonable size distribution was obtained (Figure 2). For categories Sgr, FW and HGW 20 kg was obtained while for category Dyke only 10 kg was obtained due to lack of samples.

Each category was placed in a geo textile within a large plastic container. To increase the weathering of the present sulfides the samples were exposed to dry air for $\frac{1}{2}$ week followed by moist conditions for $\frac{1}{2}$ week. Plastic hoses were installed at the bottom of the plastic container in order to add dry and water saturated air, respectively. Due to the large sample size distilled water was also added directly to the samples corresponding to L/S 0.025 every week to ensure fully moist conditions in the entire sample volume during the last part of the week prior to sampling. Sampling was performed by adding distilled water corresponding to L/S 0.1 each week. After 1 hour added water was drained and collected for chemical analysis.



Figure 2: Used size fraction for the large kinetic tests.

Chemical analysis

Composite samples from the large kinetic tests were sent for analysis with respect to acid-base-accounting (ABA) (Appendix 3), total element concentrations (Appendix 2) and mineralogy (MLA) (Appendix 4). It was not possible to identify graphite during MLA analysis due to mounting with epoxy resin.

Leachates from the large kinetic tests were analyzed for pH, electrical conductivity and alkalinity by Bergskraft using standard electrodes and titration (end point pH 5.4), respectively (Appendix 6). Sulfate (calculated from dissolved sulfur) and element concentrations (Appendix 7) were analyzed by MS Analytical, Vancouver, using ICP-MS.

In order to determine the worst case scenario with regards to sulfide oxidation and the resulting leachate quality a fine fraction of the solid phases after 30 weeks were leached with water and hydrogen peroxide, respectively, in order to fully oxidize the sulfides present in the samples.

Sample Sgr (ore sample) was also analyzed for reactivity towards ammonium nitrate according to AEISG by Orica (Appendix 5).

Multivariate calculations

Principal component analysis (PCA) was performed in order to determine if different samples are associated with each other.

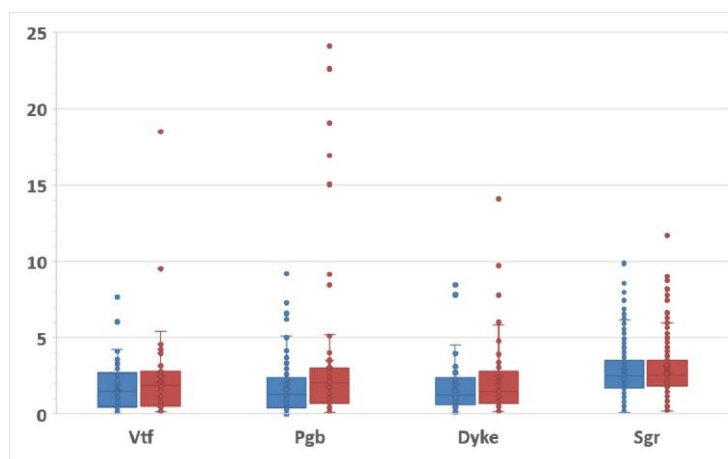
Geochemical analysis

Geochemical calculations were performed using PHREEQC in order to determine if any dissolved concentrations are governed by a solid mineral phase.

Results – solid phase

From the results of the acid-base-accounting FW, HGW and Sgr are potentially acid generating while Dyke is not clearly potentially acid generating (Table 4). A clear acid generation was determined in earlier work by Campbell (2018). It should, however, be noted that sulfide concentrations in the Sgr sample is lower compared to the worst samples Campbell (2018) used for his studies. This is since the richer segments in the core boxes had already been sent for analysis of the mineral of interest. As a comparison, it can be noted that the highest total sulfur concentrations in samples from the earlier study was as high as 20.18% (Campbell, 2018).

Figure 3: Sulfur concentrations in all analysed samples at the site. Vtf; mafic tuff hanging wall (HGW) and Pgb gabbro/diorite mafic footwall (FW). Average sulfur concentrations for the different categories are; Vtf (HGW) 1.74% (n 111), Pgb (FW) 1.85% (n 104), Dyke 1.31% (n 38) and Sgr 2.75% (n 473).



In Figure 3 all sulfur data for the entire deposit is presented for the different categories. It is clear that the selected samples (Table 4) have sulfur concentrations within the normal range (towards

the upper quartile) of all analysed samples. Selected samples are thereby representative for the entire data set, even though it is important to remember that much higher sulfur concentrations is also not uncommon.

Table 4: Results from acid-base-accounting for the categories in the large kinetic tests. All data in Appendix 3.

		FW	HGW	Dyke	Sgr
S – total	%	4.9	4.85	3.29	3.4
S – sulfate	%	0.1	0.08	0.07	0.1
S – sulfide	%	4.8	4.77	3.22	3.3
C – total	%	0.16	1.19	2.87	18.35
C – organic	%	0.05	0.98	1.47	18.25
C - inorganic	%	0.11	0.21	1.4	0.1
NP ^a	tCaCO ₃ /1Kt	10	14	110	2
AP ^b	tCaCO ₃ /1Kt	150	149	100.5	103
NPR ^c		0.1	0.1	1.1	0
NNP ^d	tCaCO ₃ /1Kt	-140	-136	9	-101

^a NP; neutralizing potential

^b AP; acid generating potential

^c NPR; ratio between acid generating and neutralizing potential

^d NNP; net neutralizing potential

Element concentrations were also analyzed and it was found that elevated concentrations were primarily found for chromium, cobalt, copper, nickel, zinc and vanadium (Table 5). Selenium is found at fairly low concentrations in all sample types. It can not be excluded that the chromium concentrations are an artefact from milling prior to analysis.

Table 5: Element concentrations in the four categories used in the large kinetic tests. Reported concentrations in the corresponding oxides should not be interpreted as presence of oxide minerals; this is just a reporting convention for whole rock analysis. Concentrations in yellow exceed the 99th percentile for Swedish tills (SGU, 2018). All data in Appendix 2.

		FW	HGW	Dyke	Sgr
SiO ₂	%	47.3	47.4	42	40.5
Al ₂ O ₃	%	13.15	13.25	12.2	10.75
Fe ₂ O ₃	%	16.3	13.45	14.3	9.09
CaO	%	5.87	6.02	12.95	3.98
MgO	%	6.02	6.8	6.32	6.25
Na ₂ O	%	5.28	4.87	4.14	3.88
K ₂ O	%	1.02	0.95	1.33	1.25
Cr ₂ O ₃	%	0.013	0.041	0.018	0.033
TiO ₂	%	1.66	0.95	0.98	0.82
MnO	%	0.07	0.06	0.11	0.04
P ₂ O ₅	%	0.14	0.12	0.1	0.05
SrO	%	<0.01	<0.01	<0.01	<0.01
BaO	%	0.01	0.01	0.02	0.02
LOI	%	3.22	4.27	4.16	22.2
Total	%	100.05	98.19	98.63	98.86
C	%	0.14	1.16	2.86	18
S	%	5.09	4.84	3.34	3.47

		FW	HGW	Dyke	Sgr
Ba	ppm	112.5	120	154	158
Ce	ppm	51.9	33.5	28.8	34.9
Cr	ppm	90	290	110	250
Cs	ppm	1.27	1.73	2.12	1.72
Dy	ppm	4.11	3.58	3.94	3.92
Er	ppm	2.2	2.19	2.63	2.53
Eu	ppm	1.7	0.72	0.89	0.85
Ga	ppm	18.9	16.2	13.5	15.6
Gd	ppm	4.73	3.22	3.54	3.71
Ge	ppm	<5	<5	<5	<5
Hf	ppm	3.1	2.1	1.9	2.2
Ho	ppm	0.88	0.82	0.84	0.96
La	ppm	22.1	17.4	14.4	18
Lu	ppm	0.28	0.32	0.45	0.33
Nb	ppm	10.9	6.3	3.8	7
Nd	ppm	26.5	15.4	14.3	17.1
Pr	ppm	6.45	3.73	3.19	4.14
Rb	ppm	41.4	36.8	69.2	70.1
Sm	ppm	5.39	3.03	3.12	3.46
Sn	ppm	2	1	1	1
Sr	ppm	118	82.6	123	68.7
Ta	ppm	0.5	0.2	<0.1	0.2
Tb	ppm	0.74	0.56	0.64	0.6
Th	ppm	1.95	2.73	0.83	4.67
Tm	ppm	0.33	0.37	0.48	0.38
U	ppm	2.19	4.23	1.44	6.18
V	ppm	268	268	273	270
W	ppm	1	3	2	2
Y	ppm	21.5	20.8	23.4	24.8
Yb	ppm	2.03	2.15	2.87	2.61
Zr	ppm	126	85	60	88
As	ppm	1.5	3.4	1	2.2
Bi	ppm	0.12	1.76	0.12	0.36
Hg	ppm	0.012	0.005	0.012	0.009
In	ppm	0.02	0.015	0.018	0.008
Re	ppm	0.019	0.027	0.013	0.05
Sb	ppm	0.11	0.14	0.05	0.08
Se	ppm	5.6	20.9	6.4	21.8
Te	ppm	0.76	3.33	1.01	1.6
Tl	ppm	0.08	0.13	0.17	0.28
Ag	ppm	<0.5	<0.5	<0.5	<0.5
Cd	ppm	1.9	0.9	1.2	1.9
Co	ppm	114	108	74	55
Cu	ppm	872	653	450	575

		FW	HGW	Dyke	Sgr
Li	ppm	10	10	10	10
Mo	ppm	7	7	5	10
Ni	ppm	352	313	202	192
Pb	ppm	419	7	8	36
Sc	ppm	26	31	34	26
Zn	ppm	416	21	28	529

Results from the principal component analysis (PCA) of log transformed element data is presented in Figure 4 (scores) and Figure 5 (loadings). Selenium is strongly associated with carbon and LOI, indicating an association with the graphite mineralization and not the sulfides.

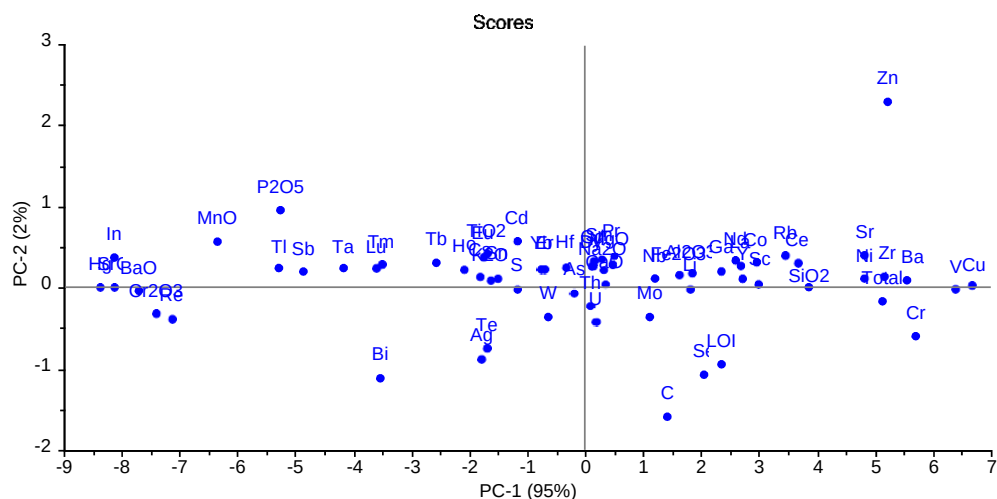


Figure 4: Scores plot based on all elemental concentrations. Lead has been excluded from the calculations. All concentrations were log transformed prior to calculations.

From Figure 5 it is clear that the composition of the samples from the northern part are different compared to the samples from the waste pile and the samples from the mineralization (FW, HGW, Sgr and Dyke).

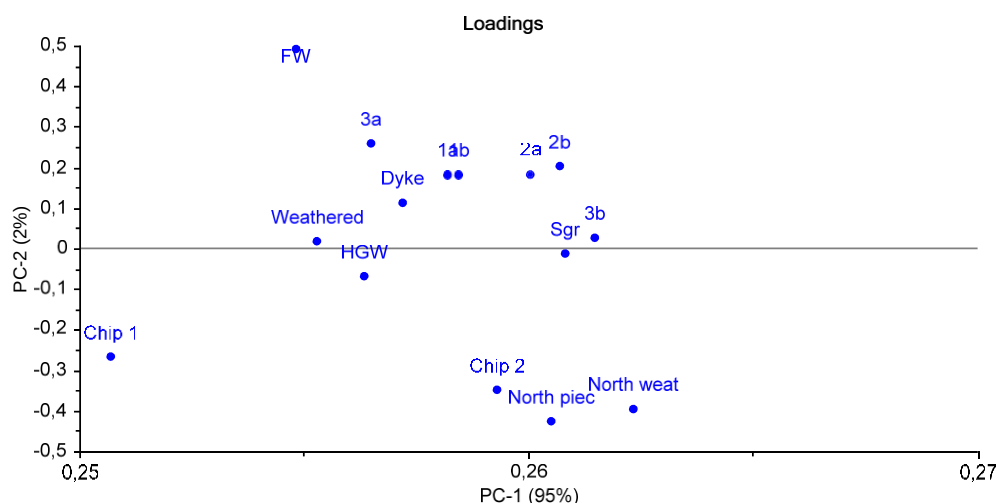


Figure 5: Loading plot based on all elemental concentrations. Lead has been excluded from the calculations. All concentrations were log transformed prior to calculations.

Results from the MLA analysis indicate that major sulfide minerals are pyrite and pyrrhotite, with only minor concentrations of other sulfide minerals (chalcopyrite, galena and sphalerite). MLA indicate that cobalt and nickel primarily are associated with pentlandite while copper and zinc are most likely found in chalcopyrite and sphalerite. Pentlandite is commonly found together with pyrrhotite and may even be intergrown together with it, making pentlandite more easily weathered compared to the other sulfide minerals.

When comparing acid producing potential (AP) and neutralization potential (NP) (Table 4) it is clear that only 14-40% of the neutralization potential is accounted by calcite in samples FW, HGW and Dyke. For Sgr the neutralization potential is low.

For acid producing potential 15-20% is accounted for by pyrite in FW, HGW and Dyke, indicating that pyrrhotite also contribute to acid production. For Sgr the fraction of AP accounted for by pyrite is higher (70%), indicating a lower contribution from pyrrhotite. It should be noted that the potential acid production from pyrrhotite is depending on the specific composition of pyrrhotite (from almost no acid production from FeS to maximum acid production from Fe₇S₈) (Robinson, 1996). After subtracting the acid producing potential from the pyrite, the remaining acid producing potential indicate that the pyrrhotite composition in Sgr differs (lower acid generating potential) from the pyrrhotite in the other samples (FW, HGW and Dyke).

Table 6: Ungrouped mineral abundances (wt%) in the four categories used in the large kinetic tests. Corrections for the presence of graphite in Sgr have been made by assuming that the organic carbon content in Table 4 are graphite (18.0%). All data in Appendix 4.

Mineral		FW Wt%	HGW Wt%	Dyke Wt%	Sgr Wt%
Chalcopyrite	CuFeS ₂	0.20	0.13	0.11	0.18
Galena	PbS	0.05	0.00	0.00	0.01
Molybdenite	MoS ₂	0.00	0.00	0.00	0.00
Pentlandite	(Fe,Ni,Co) ₉ S ₈	0.00	0.00	0.00	0.01
Pyrite	FeS ₂	1.49	1.46	1.20	3.57
Pyrrhotite	Fe ₇ S ₈	17.73	17.82	11.04	8.31

Mineral		FW Wt%	HGW Wt%	Dyke Wt%	Sgr Wt%
Sphalerite	(Zn,Fe)S	0.05	0.00	0.00	0.09
Ilmenite	(Fe,Mn)TiO ₃	0.64	0.06	0.25	0.01
Iron-oxide	Fe ₃ O ₄	0.89	0.03	0.02	0.02
Rutile	TiO ₂	0.07	0.27	0.06	0.16
Ankerite	Ca(Mg,Fe,Mn)(CO ₃) ₂	0.00	0.02	0.00	0.00
Calcite	(Ca,Mg,Fe)CO ₃	0.14	0.36	4.35	0.25
Dolomite	Ca(Mg,Fe,Mn)(CO ₃) ₂	0.00	0.08	0.00	0.00
Siderite	(Fe,Ca,Mn)CO ₃	0.03	0.02	0.06	0.06
Apatite	Ca ₅ (PO ₄) ₃ (F,Cl,OH)	0.28	0.31	0.18	0.17
Xenotime	(Y,Yb,Dy,Gd,Ho,Er,Tb)PO ₄	0.00	0.00	0.00	0.00
Albite	(Na,Ca)(Al,Fe)Si ₃ O ₈	25.39	18.89	4.57	22.85
Allanite	Ca(Ce,La,Nd,Pr)[(Al,Ti) ₂ (Fe,Mg)](Si ₂ O ₇)(SiO ₄)O(OH)	0.01	0.01	0.01	0.01
Amphibole	(Na,K)Ca ₂ [Mg ₄ (Fe,Mn,Ti)]Si ₆ Al ₂ O ₂₂ (OH,Cl) ₂	9.94	6.77	22.45	1.06
Biotite	K(Mg,Fe) ₃ (Al,Fe,Ti)Si ₃ O ₁₀ (OH,Cl) ₂	3.24	0.78	3.22	0.71
Chamosite	(Fe,Mg,Ca) ₅ (Al,Fe)(Si ₃ Al)O ₁₀ (OH) ₈	0.12	0.04	0.13	0.31
Chlorite	(Fe,Mg,Mn,Ca,K) ₅ (Al,Ti,Fe)(Si ₃ Al)O ₁₀ (OH) ₈	1.52	0.90	0.92	2.10
Cumingtonite	(Mg,Fe,Ca,Mn,Al) ₇ Si ₈ O ₂₂ (OH) ₂	0.01	2.32	0.00	0.01
Diopside	(Ca,Na)(Mg,Fe,Mn,Al)Si ₂ O ₆	3.55	3.41	4.20	1.94
K-feldspar	(K,Na)(Al,Fe)Si ₃ O ₆	0.48	0.56	0.95	2.16
Muscovite	(K,Na)(Al,Fe,Ti) ₂ Si ₃ AlO ₁₀ (OH,Cl) ₂	0.02	0.03	0.10	0.03
Phlogopite	K(Mg,Fe,Ti,Cr) ₃ AlSi ₃ O ₁₀ (OH,Cl) ₂	3.17	7.33	4.72	9.05
Plagioclase	(Na,Ca)(Al,Fe) ₁₋₂ [Si] ₃₋₂ O ₈	0.13	0.46	2.77	0.13
Prehnite	(Ca,Mg) ₂ (Al,Fe) ₂ Si ₃ O ₁₀ (OH) ₂	0.01	0.01	0.05	0.13
Quartz	SiO ₂	1.03	2.80	0.23	2.06
Scapolite	(Na,Ca,K) ₄ Al ₃ Si ₉ O ₂₄ (Cl,CO ₃)	18.33	23.67	29.51	8.45
Talc	(Mg,Fe) ₃ (Si,Al) ₄ O ₁₀ (OH) ₂	0.00	0.14	0.00	0.00
Titanite	Ca(Ti,Al,Fe)SiO ₅	2.49	1.10	1.08	1.75
Tourmaline	(Na,Ca)(Mg,Fe) ₃ (Al,Cr,V,Ti) ₆ (Si ₆ O ₁₈)(BO ₃) ₃ (OH) ₃ (OH)	0.04	0.05	0.01	0.00
Tremolite	([],Na,K)Ca ₂ (Mg,Fe,Mn,Ti,Al) ₅ Si ₈ O ₂₂ (OH) ₂	8.93	10.17	7.77	16.38
Zircon	(Zr,Hf,Al,Fe,Ca)SiO ₄	0.02	0.01	0.01	0.02
Total		100.0	100.0	100.0	82.0

It was found that when Sgr (ore sample) was reacted with ammonium nitrate temperature increased with more than 8°C (Figure 6), indicating that the sample is reactive towards explosives. A temperature increase in excess of 2°C is considered a risk. This means that there is a risk for premature detonation during blasting. It also means that there is a risk for spontaneous combustion of waste rock containing high concentrations of graphite. Waste piles allowing for convective air flow should therefore be avoided. See Appendix 5 for further details.

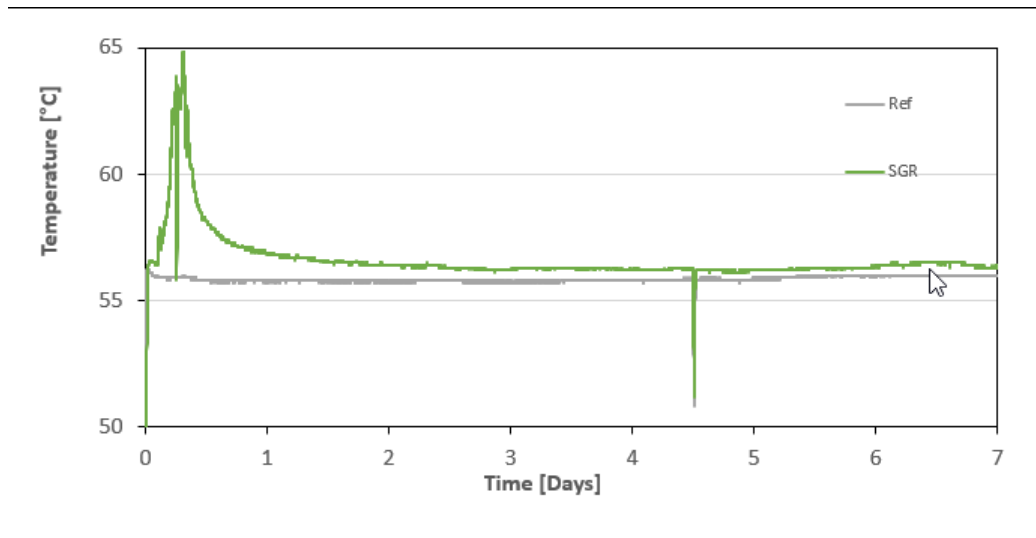


Figure 6: Sgr reactivity towards ammonium nitrate.

Results – kinetic tests

During the 30 weeks of the large kinetic tests no acidity has been formed from HGW and Dyke. There is initially a tendency to lower pH (Figure 7), which probably is a result from surface weathering in the core boxes during storage. When these acid weathering products has been washed out pH is fairly stable at around 6-7 for HGW, while it for Dyke is just below 8. However, for Sgr and FW pH has started to drop after around 17 cycles. pH close to 4 has been observed for Sgr and close to pH 5 for FW. Sgr has a much higher pyrite content compared to the other samples and thereby more prone to acid generation and also has almost no neutralization potential.

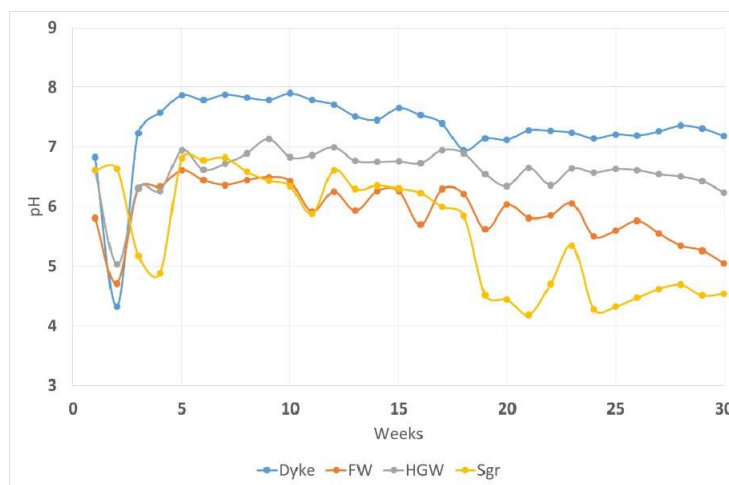
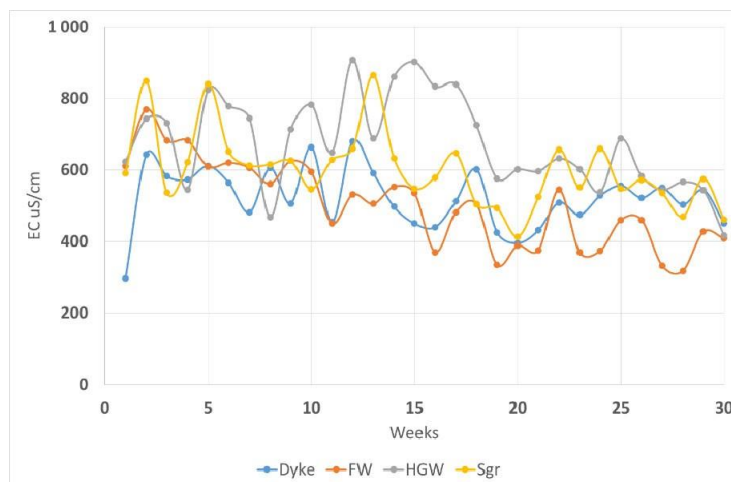


Figure 7: pH during the 30 weeks of the large kinetic tests.

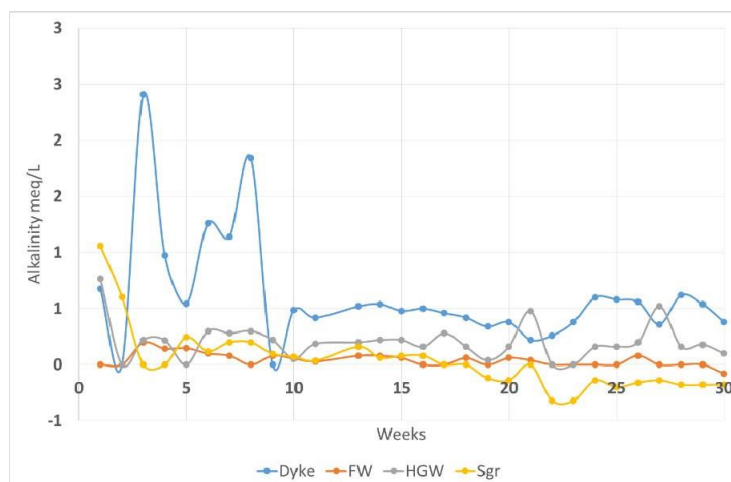
Electrical conductivity (Figure 9) during the 30 weeks indicate a moderate leaching of weathering products with values between 400 and 800 $\mu\text{S}/\text{cm}$ for all samples. Electrical conductivity is stable or slowly declining during the 30 weeks and there is no obvious indication for significantly increased weathering. Dyke and FW have slightly lower electrical conductivity compared with HGW and Sgr. However, this difference is very small.

Figure 9: Electrical conductivity ($\mu\text{S}/\text{cm}$) during the 30 weeks of the large kinetic tests.



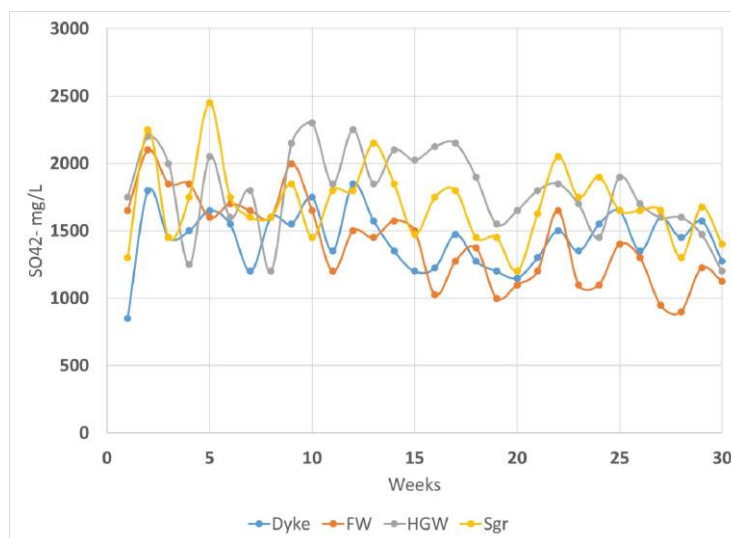
Alkalinity (Figure 10) was initially high in the leachates, probably due to early weathering that had triggered the neutralizing reactions from the present carbonate minerals. This is very clear for Dyke, where the alkalinity was initially high and then decreased during the following weeks. Alkalinity was, however, remaining fairly high in the Dyke compared to the other samples with low alkalinity. This is most likely due to the significantly higher content of calcite in Dyke compared to the other samples (Table 6).

Figure 10: Alkalinity (meq/L) during the 30 weeks in the large kinetic tests. Negative values represents acidity.



Sulfate leaching (Figure 11) is roughly the same for all samples. The sulfate leaching corresponds to a sulfide oxidation rate (SOR) of about 90-160 $\text{mg SO}_4^{2-}/\text{kg}/\text{week}$. This corresponds well with earlier estimates from small laboratory experiments of about 10-100 $\text{mg SO}_4^{2-}/\text{kg}/\text{week}$ (Campbell, 2018) ($\text{OCR } 1.91 \cdot 10^{-11}$ to $1.20 \cdot 10^{-10} \text{ kg O}_2/\text{kg/s}$). In total between 850 and 1 500 mg/kg sulfur has been leached during the 30 weeks. This corresponds to 2.3-4% of the total content of sulfur in the samples prior to the start of leaching. It can not be excluded that sulfate concentrations in all samples are governed by gypsum (CaSO_4) equilibrium, thus underestimating the sulfide oxidation rate. Geochemical calculations indicate that gypsum is likely present as a secondary mineral in all samples (saturation index between -0.3 to -0.2 in all systems after 30 weeks).

Figure 11: Sulfate (mg/L) during the 30 weeks in the large kinetic tests. Sulfate concentrations calculated from sulfur concentrations.



Analysis of metals in the leachates have also been performed. With no obvious sign of evolution of acidic drainage from HGW and Dyke, the concentrations are, in general fairly low. Element concentrations will be presented as averages in Table 8 below as well as in Figures for selected elements. At neutral pH there is no leaching of anionic elements such as vanadium, molybdenum, arsenic and selenium. In general, the only elements that are found in significantly enhanced levels are cobalt, nickel and copper. Leaching of cobalt, nickel and copper was also noted during simple water leaching tests (ratio 1:2 shaking 24 hours) during earlier studies (Campbell, 2018). However, Campbell (2018) also noted some selenium leaching at circum neutral conditions from some samples. There is some indication that selenium is correlated with sulfate, indicating that selenium is interchanged with sulfur in the sulfide minerals. This is, however, not confirmed by the mineralogical analysis.

Iron concentrations (Figure 12) increase significantly (close to 35 mg/L for Sgr) towards the end of the experiment in samples Sgr and FW, indicating an increased weathering of iron sulfides. This is also consistent with decreasing pH. Increased iron concentrations are not followed by increased sulfate concentrations, thus supporting the idea that sulfate leaching is governed by the presence of gypsum.

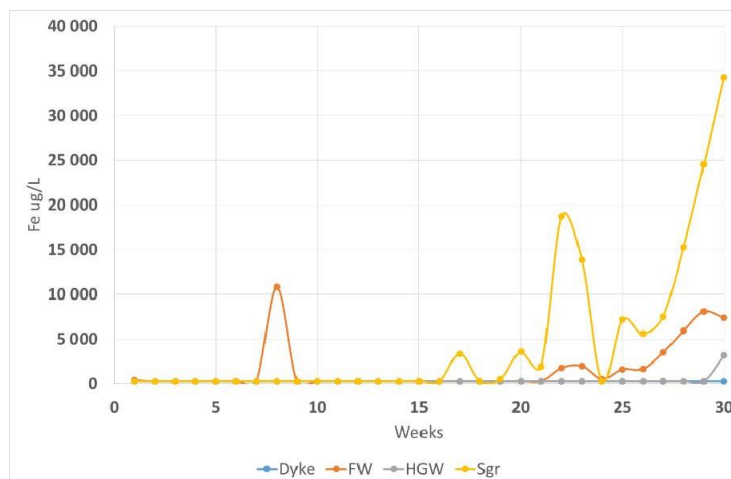


Figure 12: Iron (µg/L) during the 30 weeks in the large kinetic tests.

Calcium concentrations are fairly stable in all systems (Figure 13), with only a small decrease with time. It is likely that calcium concentrations are constrained by equilibrium with a solid phase (possibly calcite (CaCO_3) or secondary gypsum (CaSO_4)). Despite the fact that Dyke is the only sample with significant concentrations of calcite leached calcium concentrations are similar to the other systems, confirming the hypothesis that the calcium concentrations are governed by equilibrium with gypsum. The fact that a decrease in pH does not increase the leachability supports the fact that gypsum is the more likely candidate instead of calcite that is more affected by lower pH.

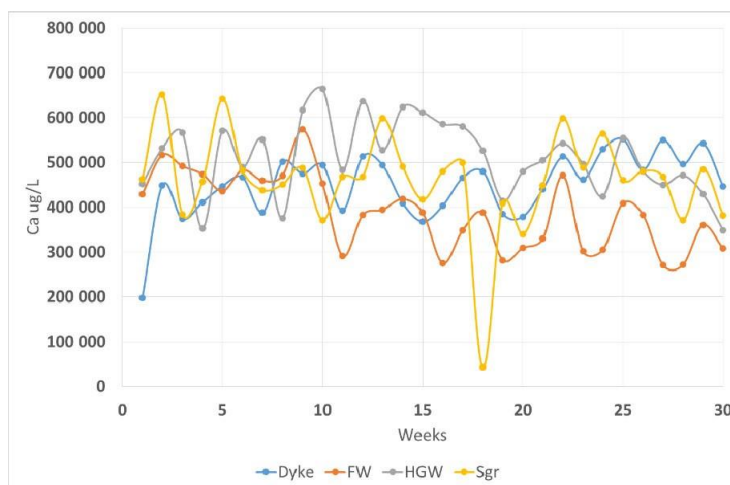


Figure 13: Calcium ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Potassium concentrations (Figure 14) decrease somewhat in all systems during the experiments.

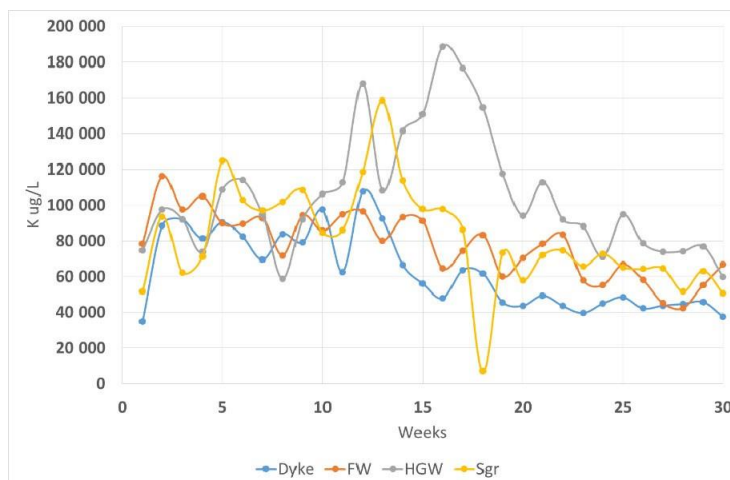


Figure 14: Potassium ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Magnesium concentrations (Figure 15) decrease significantly during the first 10 weeks of the experiment, indicating an initial first flush of weathering products. Magnesium behaves not as calcium, indicating that the source of magnesium is not entirely the same as for calcium.

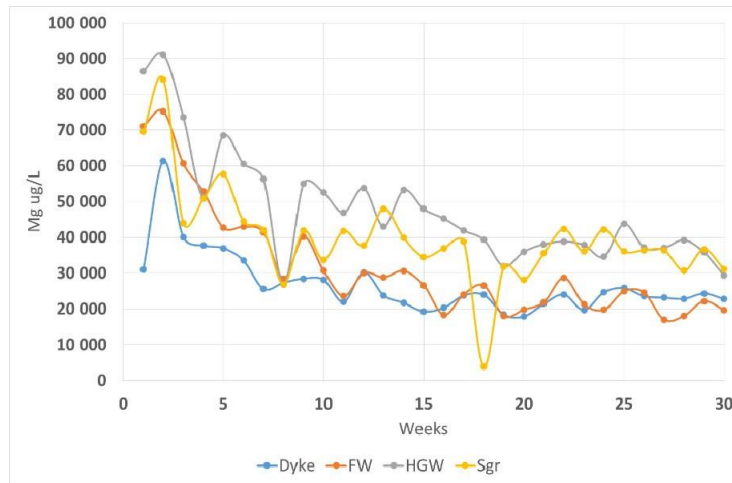


Figure 15: Magnesium ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Sodium has a behavior similar to potassium, indicating a similar source.

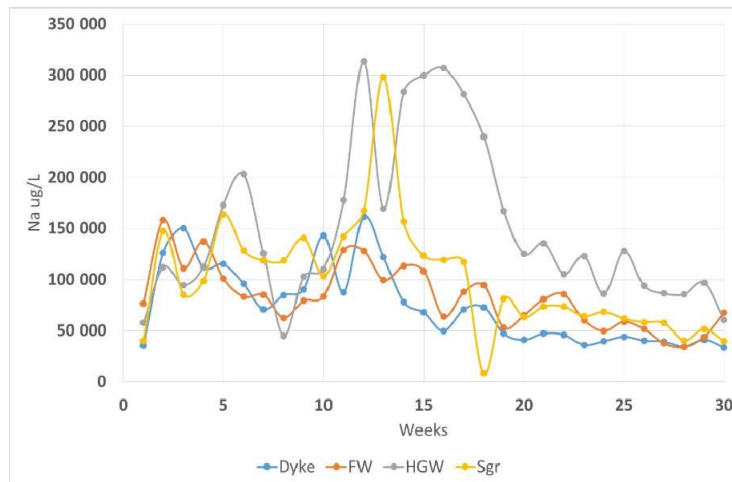


Figure 16: Sodium ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Zinc concentrations (Figure 17) decrease initially for Dyke, HGW and Sgr. FW has roughly the same zinc concentrations throughout the entire experiment. For Dyke and HGW the concentrations seem to have levelled off at very low concentrations (around $5 \mu\text{g/L}$) while in the Sgr system the concentrations has started to increase again as pH decreased. The concentrations are still fairly low.

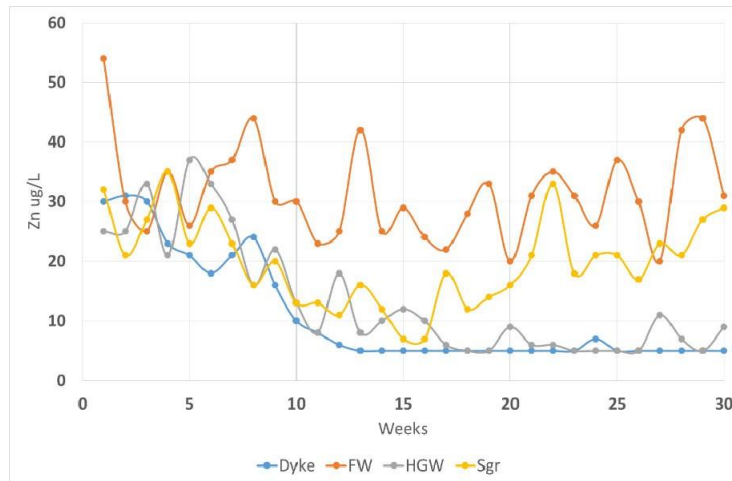


Figure 17: Zinc ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Cobalt concentrations (Figure 18) have increased throughout the entire experiment with a final concentration around 40-80 $\mu\text{g/L}$. The highest cobalt concentrations were found from the ore sample (Sgr). Cobalt concentrations increase in all systems regardless of change in pH, indicating a release through weathering as the primary mechanism.

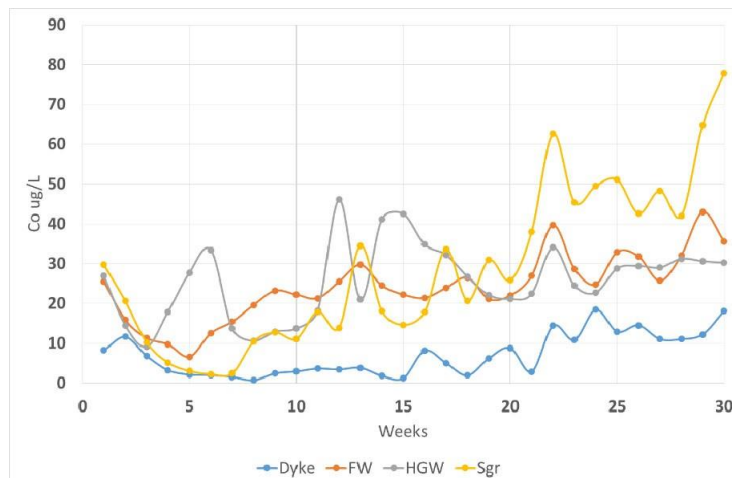


Figure 19: Cobalt ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Nickel has a behavior similar to cobalt (Figure 19), indicating a similar source. This source is most likely pentlandite even if it was barely detected in the solid phase (Table 6). Leaching is highest from the ore sample (Sgr) followed by FW and HGW. Leaching is similar from FW and HGW despite a significant difference in pH (one pH unit lower in FW), indicating that weathering of the primary mineral is more important when it comes to leaching than the pH. In total between 0.104 mg/kg (Dyke) and 0.561 mg/kg (Sgr) has been leached during 30 weeks, corresponding to between 0.051 and 0.29% of the total nickel concentrations. However, nickel leaching from Sgr has increased roughly one order of magnitude comparing week 5 and week 30 reaching rates of around 2.3 mg/kg/year. With a total concentration at 192 mg/kg nickel will, in theory, be leached within 80 years. With a further drop in pH it is not hard to imagine nickel reaching leaching rates around 20 mg/kg/year cutting the leaching time to around 10 years. For the other systems, the leaching rate is, however, lower.

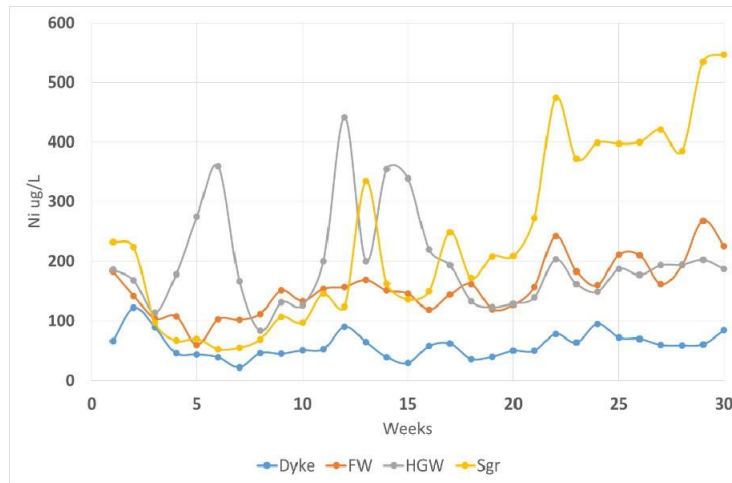


Figure 19: Nickel ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Copper concentrations from all systems (Figure 20) are roughly the same (around $5 \mu\text{g/L}$) throughout the entire experiment.

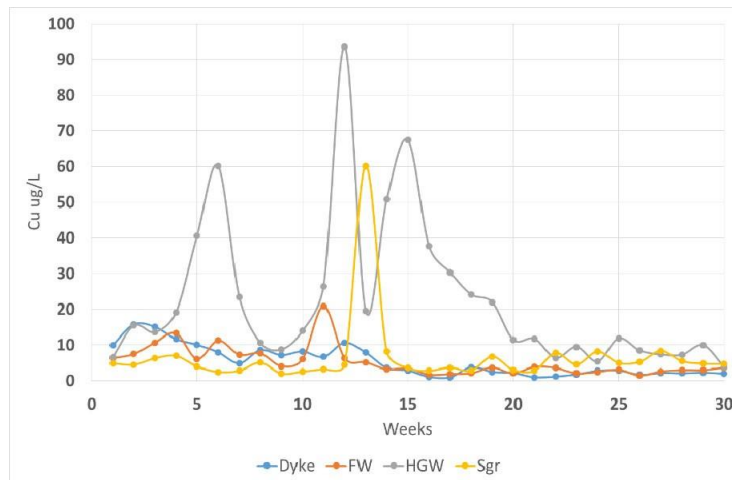


Figure 20: Copper ($\mu\text{g/L}$) during the 30 weeks in the large kinetic tests.

Despite being found at fairly high total concentrations chromium and vanadium leaching were not leached above detection limit. Selenium concentrations were found just above detection limit ($5 \mu\text{g/L}$) in the ore sample only. Molybdenum leaching (Figure 21) is also low in all systems at all times.

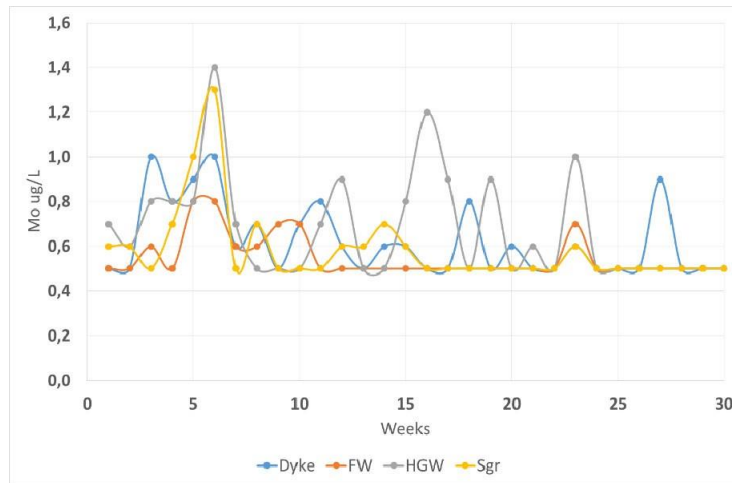


Figure 21: Molybdenum (µg/L) during the 30 weeks in the large kinetic tests.

Sulfide oxidation – addition of hydrogen peroxide

After leaching of the fine fraction remaining after 30 weeks using both water and hydrogen peroxide, respectively, pH and elements were analysed (Table 7). A difference in pH between water and hydrogen peroxide indicate that oxidizable sulfides (primarily pyrite and pyrrhotite) was still present in the samples. Lower pH in the hydrogen peroxide leachate indicate that a further lowering of pH in the systems are expected assuming continuing contact with air and water.

It should be noted that there is a very good agreement between the trace element concentrations after 30 weeks in the large scale kinetic tests (Table 8) and the water leaching (Table 7). This indicates that the water and the hydrogen peroxide leaching can be used in order to estimate final leachate composition.

During the oxidizing leaching test a significant change in colour was noted for Dyke, FW and HGW (to a more red colour) indicating transformation of iron sulfides into iron(hydr)oxides.

It is clear that FW, HGW and Sgr behave similar to each other when it comes to acid generation generating a pH around 2.4-2.5 when hydrogen peroxide is added. Dyke do not generate acidity. This is a confirmation of the acid-base properties presented in Table 4, which clearly state FW, HGW and Sgr as acid generating while Dyke is not. This means that the pH in Sgr, FW and HGW will eventually drop to below 3 if contact with air and water is not prevented. This is also confirmed by the fact that the lowest pH found in contact with solid material from the site was below 3.5 (Table 1). It is thus entirely possible that waste rock from the mining operation can create a leachate with a pH between 3 and 3.5.

As pH decreases significantly during the addition of hydrogen peroxide trace element concentrations also increase (Table 7). There is an increase in cobalt and nickel concentrations as expected but there is also a drastic increase in copper and zinc concentrations. Copper and zinc have not been noticed in the large scale kinetic tests.

Table 7: Comparison between water leaching and oxidizing leaching with respect to pH and elements. pH for hydrogen peroxide around 3.86. Generated $[H^+]$ indicate extra generated protons (mM) from the material itself due to primarily oxidation of iron sulfides.

		Dyke		FW		HGW		Sgr	
		Water	H ₂ O ₂	Water	H ₂ O ₂	Water	H ₂ O ₂	Water	H ₂ O ₂
pH		7.50	4.50	6.96	2.41	6.96	2.45	6.21	2.40
$[H^+]$			-0.11		3.75		3.41		3.84

		Dyke		FW		HGW		Sgr	
Na	mg/L	2.37	6.34	3.44	15.9	4.60	11.2	2.04	11.7
Mg	mg/L	3.89	28.8	1.80	31.7	4.57	94.2	2.33	33.4
K	mg/L	8.23	45.2	8.43	43.1	9.65	52.2	6.22	73.0
Ca	mg/L	52.7	580	30.9	322	39.1	363	31.1	180
Fe	mg/L	4.64	4.73	2.14	855	3.68	463	1.50	793
Mn	mg/L	0.04	2.23	0.16	4.71	0.12	3.35	0.15	2.28
Co	µg/L	10.3	1 680	25.3	5 240	26.4	3 530	57.1	3 410
Ni	µg/L	58.2	5 220	135	18 900	152	12 400	386	14 400
Cu	µg/L	13.5	218	10.5	9 720	17.1	6 710	19.8	13 200
Zn	µg/L	39.1	312	48.1	21 000	39.1	868	55.8	4 420
Pb	µg/L	2.7	1.0	2.1	19.6	11.1	159	9.4	402
Mo	µg/L	3.3	6.8	1.9	2.8	5.0	2.9	2.7	2.3
As	µg/L	2.6	0.5	1.5	7.5	1.5	7.1	0.8	4.8
Cr	µg/L	11.0	2.0	18.1	29.3	1.3	14.7	6.2	33.7
U	µg/L	0.7	0.2	0.8	81.1	0.3	52.0	0.3	291
Cd	µg/L	0.1	1.5	0.5	2.2	0.3	48.9	0.1	10.7
Hg	µg/L	<1	<1	<1	<1	<1	<1	<1	<1

Assessment of future leachate quality from the waste rock

In Table 8 below, average and final (after 30 weeks) concentrations can be found for all relevant elements. Even if the concentrations change with time for some of the elements in some of the systems the average concentrations are still useful for comparisons and to determine leachate quality.

It is obvious that Dyke will not generate acidity and leachate with low quality. The amount of Dyke is also much smaller compared to the other waste rock fractions. The following assessment will therefore only be based on the leachate from FW, HGW and Sgr.

Table 8: Final (30 weeks) and average (n 30) element concentrations in the leachates from the large kinetic tests.

		Dyke		FW		HGW		Sgr	
		Average	30 wks	Average	30 wks	Average	30 wks	Average	30 wks
pH		7.3	7.18	5.9	5.05	6.6	6.24	5.6	4.54
SO ₄ ²⁻	mg/L	1 450	1 280	1 400	1 130	1 800	1 200	1 700	1 400
Fe	mg/L	<0.30	<0.30	1.65	7.38	<0.30	3.16	4.73	34.3
Mn	mg/L	0.29	0.82	1.15	1.36	1.03	1.38	0.84	1.64
Ca	mg/L	450	447	389	308	512	349	460	382
K	mg/L	63.0	37.5	78.0	66.8	105	59.9	81.4	50.7
Mg	mg/L	27.0	22.8	32.0	19.8	48.0	29.4	40.0	31.1
Na	mg/L	74.0	33.7	83.0	67.6	150	69.6	100	39.8
Zn	µg/L	17	<5	31	31	15	9.0	20	29
Co	µg/L	7.0	18	24	35.6	26	30.2	29	77.8
Ni	µg/L	60	84	155	226	197	187	239	547
Cu	µg/L	5.4	<2.0	5.3	3.7	23	4.70	6.6	3.90
Pb	µg/L	<9.08	<5.0	<9.36	<5.0	<9.3	<5.0	<8.07	<5.0
Mo	µg/L	0.6	<0.50	0.6	<0.50	0.7	<0.50	0.6	<0.50

		Dyke		FW		HGW		Sgr	
As	µg/L	<0.97	<0.5	<0.84	<0.5	<0.95	<0.5	<1.02	<0.5
Cr	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U	µg/L	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2
Cd	µg/L	<0.1	0.1	<0.3	0.2	<0.2	<0.1	<0.2	0.1
Hg	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Nickel is the only element with distinct increase in leachability due to increased weathering as well as lowered pH. pH is able to drop around 1.5 units compared to the final pH in Sgr. Cobalt and nickel concentrations will increase roughly 25 times compared to at pH 4.54 resulting in a maximum concentration of around 5 and 19 mg/L for cobalt and nickel, respectively. Cobalt and nickel are most likely found in pentlandite and are thus easily weathered. Copper and zinc concentrations will also increase significantly during oxidizing conditions, even if they have not leached significantly during earlier tests. Copper and zinc are likely found in harder to oxidize minerals like chalcopyrite and sphalerite. As they require longer exposure to air and water to oxidize compared to pentlandite, copper and zinc will take longer time before they appear in the leachate. Remaining trace elements are only affected to a low degree and are found at relatively low concentrations. Sulfate concentrations will probably not be affected by increased oxidation due to equilibrium with gypsum.

An assessment of the future leachate quality from waste rock can be found in Table 9 below. Best case concentrations are based on the large scale kinetic tests assuming that oxygen and water are kept from the waste rock (qualified waste management). It should be noted that sulfate concentrations exceeding 2 000 mg/L has occasionally been noted in the large kinetic tests. Worst case concentrations are based on the data from hydrogen peroxide leaching (fully oxidized) while the best estimate is based on some management of the waste rock, but with some contact with air and water. Some immobilization processes are also likely to be found in the field (buffering from kinetically constrained minerals, sorption and precipitation). An average pH of around 4 in the waste rock found at the site (Table 1) supports the assumption of pH 3.5 as conservative best estimate. It has been assumed that sulfate is being controlled by equilibrium with gypsum.

Table 9: Assessment of the leachate quality from the waste rock dump. Best case based on the large scale pilot tests, worst case from leaching with hydrogen peroxide. Best estimate considers slower reacting buffering minerals and sorption/precipitation mechanisms.

		Best case	Worst case	Best estimate
pH		5.0	2.5	3.5
SO ₄ ²⁻	mg/L	1 250	2 600	1 350
Fe	mg/L	10	800	80
Mn	mg/L	1.4	4.0	2.0
Ca	mg/L	350	350	350
K	mg/L	60	60	60
Mg	mg/L	30	60	30
Na	mg/L	70	15	70
Zn	µg/L	30	20 000	2 000
Co	µg/L	40	4 000	400
Ni	µg/L	200	17 000	1 700
Cu	µg/L	10	10 000	1 000
Pb	µg/L	<5.0	400	50

Mo	µg/L	<0.50	3	3
As	µg/L	<0.5	7	2.5
Cr	µg/L	<0.5	30	10
U	µg/L	<0.2	250	100
Cd	µg/L	<0.2	50	5
Hg	µg/L	<1	<1	<1

Assessment of future leachate quality from the pit walls

Performed leaching tests were originally designed to determine the leachate quality from waste rock. Pit walls have a lower effective area but the mineral composition can be assumed to be similar to the waste rock. An assessment of the future leachate quality from the pit walls can be found in Table 10 below. Best case concentrations are based on the large scale kinetic tests assuming contact with air and water during a period equivalent to L/S 3. This corresponds roughly to a couple of years. Prolonged exposure will lead to more oxidizing conditions. Worst case concentrations are based on the data from hydrogen peroxide leaching (fully oxidized) corrected for the lower surface area for the pit walls compared to the waste rock (estimated to 25%) while the best estimate is based on some management of the pit walls, but with some contact with air and water. The applied correction factor for the pit walls is in reality probably lower, but a conservative approach has been used. It has been assumed that sulfate is controlled by gypsum equilibrium. It is important to note that the uncertainties in the assessment of the leachate from the pit walls are greater than the assessment of the leachate from the waste rock as the performed tests more closely simulate waste rock leaching.

Table 10: Assessment of the leachate quality from the pit walls. Best case based on the large scale pilot tests, worst case from leaching with hydrogen peroxide. Best estimate considers slower reacting buffering minerals and sorption/precipitation mechanisms. In order to correct for the lower effective surface area of the pit walls compared to the waste rock a correction factor of 25% has been applied.

		Best case	Worst case	Best estimate
pH		5.0	3.0	4.0
SO ₄ ²⁻	mg/L	1 250	1 620	1 220
Fe	mg/L	10	200	20
Mn	mg/L	1.4	2.0	1.5
Ca	mg/L	350	350	350
K	mg/L	60	60	60
Mg	mg/L	30	30	30
Na	mg/L	70	70	70
Zn	µg/L	30	5 000	500
Co	µg/L	40	500	100
Ni	µg/L	200	4 000	400
Cu	µg/L	10	2 500	250
Pb	µg/L	<5.0	100	10
Mo	µg/L	<0.50	3	3
As	µg/L	<0.5	5	2.5
Cr	µg/L	<0.5	10	10
U	µg/L	<0.2	70	30
Cd	µg/L	<0.2	15	2
Hg	µg/L	<1	<1	<1

SUMMARY

Altogether, it is clear that waste rock from Nunasvaara South will eventually generate acid rock drainage. Acid-base-accounting indicate a significant acid generating potential and the samples from the old waste deposit was acid. It is, however, hard to predict exactly when the acid will form. The large kinetic tests show acid generation starting to form after around 17 weeks from the Sgr sample and later also from the FW sample. There is still no acid generation from the Dyke and HGW samples. It must, however, be noted that 30 weeks are to be considered a relatively short time period in order to determine when acid will be formed. This study, however, indicate that the evolution of acid drainage might not be as fast as has been indicated by earlier laboratory studies. There is thus no need for immediate action to prevent acid formation from the waste rock during the mining operation. It should be possible to handle the waste during the end of the season even though it should be noted that waste with higher sulfide concentrations than the tested samples will also be present at the site.

Cobalt and nickel are the trace elements of greatest concern at the site. It is possible that leachate with pH 3 will form if no measures are taken in order to avoid acid generation from the mining waste. This will lead to cobalt and nickel concentrations around 5 and 19 mg/L, respectively, in the pore water from the dump. Increased copper and zinc concentrations can not be excluded if the waste rock is significantly oxidized. This scenario is, however, not very likely for the waste rock as weathering showed to be rather slow and no major leachates was formed prior to 30 weeks.

Leachate quality from the waste rock and the pit walls have been estimated from the leaching tests.

Sulfate analysis indicate a sulfide oxidation rate (SOR) of between 90 and 160 mg SO_4^{2-} /kg/week. Elemental analysis of the leachates indicate that cobalt, nickel and copper to some degree are possible problematic elements, also at circum neutral pH. Sulfate concentrations will be around 1 200-1 400 mg/L due to possible gypsum equilibrium.

There is a risk that, at least the ore samples (Sgr), can react spontaneously with added explosives prior to ignition. This means that there is a risk for premature detonation during blasting. It also means that there is a risk for spontaneous combustion of waste rock containing high concentrations of graphite. Waste piles allowing for convective flow of air should therefore be avoided.

IMPLICATIONS

Several of the tested samples (FW, HGW and Sgr) will eventually generate acid rock drainage and increased concentrations of primarily cobalt and nickel. Acid generation is, however, not very quick, providing the operator of the mine ample time to manage the area. It is possible that pH 3 will be reached with pore water concentrations of cobalt and nickel at 5 and 19 mg/L, respectively. This is, however, not the base case. Pore water concentration exceeding 1 mg/L nickel should rarely occur if the waste rock is treated properly within 4-6 months.

Waste piles containing sulfides and graphite should be treated with care since there is a possibility for spontaneous combustion. Waste piles allowing for convective flow of air should therefore be avoided.

REFERENCES

Campbell, G. (2018) Nunasvaara South Deposit: Geochemical Assessment of Mine-Waste and Ore Samples – Implications for Mine Waste Management

- Robinson, C. (1996) Pyrrhotite composition and its relationship to acid drainage potential in the Halifax formation, Meguma group, Nova Scotia. Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia
- SGU (2018) Geochemical Atlas of Sweden. Geological Survey of Sweden



Selection of samples, Nuunasvaara

Appendix 1

Lith Start (m) Stop (m) Sample Length S (%)

Dyke	NUS12001	42,25	44	1,75	2,1
	NUS12001	44	46	2	3,08
	NUS12018	79,68	81,8	2,12	9,73
HGW	NUS12015	56	58	2	2,9
	NUS12017	47,2	49,3	2,1	9,28
	NUS12018	44	45,91	1,91	5,11
	NUS12019	48	50	2	9,16
	NUS12019	50	52,16	2,16	3,57
	NUS12012	19	21	2	4,52
	NUS12012	23	24,82	1,82	4,07
	NUS12012	36,5	38,5	2	4,26
	NUS12015	62	64	2	4,07
	NUS12015	68,6	70,6	2	4,53
	NUS12015	70,6	72,72	2,12	5,44
	NUS12016	31,4	33,4	2	4,16
FW	NUS12003	39,2	41,2	2	3,19
	NUS12006	55	57	2	4,01
	NUS12010	54	56	2	3,2
	NUS12012	98,4	100	1,6	19,05
	NUS12012	100	102	2	15,05
	NUS12012	102	104	2	4,12
	NUS12014	63	65	2	3,36
	NUS12008	73,25	75	1,75	9,72
Sgr	NUS12002	69,00	71,00	2	5,98
	NUS12018	78,00	79,68	1,68	5,79
	NUS12002	65,00	67,00	2	5,51
	NUS12002	67,00	69,00	2	5,50
	NUS12002	61,00	63,00	2	5,30
	NUS12009	49,28	51,30	2,02	5,19
	NUS12018	114,65	116	1,35	6,81



Coordinates samples, Nuunasvaara

Sample		North	East
1a		7524341	770175
1b		7524341	770175
2a		7524351	770185
2b		7524351	770185
3a		7524358	770171
3b		7524358	770171
Weathered graphite		7524360	770179
North chip		7524894	770075
North weathered		7524894	770075
Chip 1		7524894	770075
Chip 2		7524916	770052



Appendix 2

			FW	HGW	Dyke	Sgr	North pieces	North weathered	Chip 1	Chip 2
ME-ICP06	SiO2	%	47,3	47,4	42	40,5	34,5	37,5	40,3	34,4
ME-ICP06	Al2O3	%	13,15	13,25	12,2	10,75	7,84	8,14	9,08	7,84
ME-ICP06	Fe2O3	%	16,3	13,45	14,3	9,09	12,15	7,56	2,96	7,17
ME-ICP06	CaO	%	5,87	6,02	12,95	3,98	3,75	4,23	3,86	3,65
ME-ICP06	MgO	%	6,02	6,8	6,32	6,25	2,04	3,61	2,31	3,59
ME-ICP06	Na2O	%	5,28	4,87	4,14	3,88	3,06	3,14	3,56	2,4
ME-ICP06	K2O	%	1,02	0,95	1,33	1,25	0,39	0,91	1,07	2,07
ME-ICP06	Cr2O3	%	0,013	0,041	0,018	0,033	0,023	0,034	0,028	0,028
ME-ICP06	TiO2	%	1,66	0,95	0,98	0,82	0,6	0,71	0,78	0,73
ME-ICP06	MnO	%	0,07	0,06	0,11	0,04	0,02	0,03	0,02	0,03
ME-ICP06	P2O5	%	0,14	0,12	0,1	0,05	0,05	0,03	0,02	0,04
ME-ICP06	SrO	%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0,01	<0.01
ME-ICP06	BaO	%	0,01	0,01	0,02	0,02	<0.01	0,01	0,02	0,04
OA-GRA05	LOI	%	3,22	4,27	4,16	22,2	35,6	33,7	35,1	37,4
TOT-ICP06	Total	%	100,05	98,19	98,63	98,86	100,02	99,6	99,12	99,39
C-IR07	C	%	0,14	1,16	2,86	18	26,2	27,2	30,5	31,4
S-IR08	S	%	5,09	4,84	3,34	3,47	5,18	1,61	0,09	2,35
ME-MS81	Ba	ppm	112,5	120	154	158	23	119	117,5	317
ME-MS81	Ce	ppm	51,9	33,5	28,8	34,9	27,8	18,1	20,4	33,6
ME-MS81	Cr	ppm	90	290	110	250	160	240	180	200
ME-MS81	Cs	ppm	1,27	1,73	2,12	1,72	0,26	0,79	0,74	1,64
ME-MS81	Dy	ppm	4,11	3,58	3,94	3,92	2,96	1,87	2,13	3,39
ME-MS81	Er	ppm	2,2	2,19	2,63	2,53	1,66	1,16	1,17	1,98
ME-MS81	Eu	ppm	1,7	0,72	0,89	0,85	0,83	0,58	0,73	0,93
ME-MS81	Ga	ppm	18,9	16,2	13,5	15,6	10	11,6	11,6	12
ME-MS81	Gd	ppm	4,73	3,22	3,54	3,71	3,06	1,9	2,04	3,19
ME-MS81	Ge	ppm	<5	<5	<5	<5	<5	<5	<5	<5
ME-MS81	Hf	ppm	3,1	2,1	1,9	2,2	2	1,9	2,1	2,1
ME-MS81	Ho	ppm	0,88	0,82	0,84	0,96	0,69	0,45	0,52	0,81
ME-MS81	La	ppm	22,1	17,4	14,4	18	15,7	9,7	10,4	18,3
ME-MS81	Lu	ppm	0,28	0,32	0,45	0,33	0,22	0,18	0,17	0,28
ME-MS81	Nb	ppm	10,9	6,3	3,8	7	5,5	6,9	6,4	6,8
ME-MS81	Nd	ppm	26,5	15,4	14,3	17,1	13,9	9,2	10,2	16,2
ME-MS81	Pr	ppm	6,45	3,73	3,19	4,14	3,31	2,19	2,43	3,95
ME-MS81	Rb	ppm	41,4	36,8	69,2	70,1	5,7	16,2	19,5	49,4
ME-MS81	Sm	ppm	5,39	3,03	3,12	3,46	3,21	1,99	2,22	3,56
ME-MS81	Sn	ppm	2	1	1	1	<1	1	1	<1
ME-MS81	Sr	ppm	118	82,6	123	68,7	52,3	50,4	49,6	40,2
ME-MS81	Ta	ppm	0,5	0,2	<0.1	0,2	0,2	0,1	0,2	0,2
ME-MS81	Tb	ppm	0,74	0,56	0,64	0,6	0,48	0,32	0,33	0,56
ME-MS81	Th	ppm	1,95	2,73	0,83	4,67	3,98	2,95	3,68	4,48
ME-MS81	Tm	ppm	0,33	0,37	0,48	0,38	0,24	0,15	0,19	0,33
ME-MS81	U	ppm	2,19	4,23	1,44	6,18	5,78	3,19	5,26	6,46
ME-MS81	V	ppm	268	268	273	270	157	238	166	213
ME-MS81	W	ppm	1	3	2	2	<1	5	1	2
ME-MS81	Y	ppm	21,5	20,8	23,4	24,8	17,6	11,4	12,4	20,4
ME-MS81	Yb	ppm	2,03	2,15	2,87	2,61	1,62	1,07	1,06	1,87
ME-MS81	Zr	ppm	126	85	60	88	78	79	82	84
ME-MS42	As	ppm	1,5	3,4	1	2,2	3	3	1,6	2,1
ME-MS42	Bi	ppm	0,12	1,76	0,12	0,36	1,08	0,95	0,25	0,94
ME-MS42	Hg	ppm	0,012	0,005	0,012	0,009	0,012	0,013	0,019	0,013
ME-MS42	In	ppm	0,02	0,015	0,018	0,008	<0.005	<0.005	<0.005	<0.005
ME-MS42	Re	ppm	0,019	0,027	0,013	0,05	0,055	0,029	0,024	0,084
ME-MS42	Sb	ppm	0,11	0,14	0,05	0,08	0,09	0,08	0,06	0,09
ME-MS42	Se	ppm	5,6	20,9	6,4	21,8	59,1	39,6	7,4	28,1
ME-MS42	Te	ppm	0,76	3,33	1,01	1,6	3,83	2,14	0,56	1,6
ME-MS42	Tl	ppm	0,08	0,13	0,17	0,28	0,05	0,09	0,02	0,09
ME-4ACD81	Ag	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
ME-4ACD81	Cd	ppm	1,9	0,9	1,2	1,9	0,6	0,6	<0.5	<0.5
ME-4ACD81	Co	ppm	114	108	74	55	55	7	3	27
ME-4ACD81	Cu	ppm	872	653	450	575	477	246	59	190
ME-4ACD81	Li	ppm	10	10	10	10	<10	<10	<10	<10
ME-4ACD81	Mo	ppm	7	7	5	10	12	9	8	8
ME-4ACD81	Ni	ppm	352	313	202	192	280	20	10	144
ME-4ACD81	Pb	ppm	419	7	8	36	4	5	26	18
ME-4ACD81	Sc	ppm	26	31	34	26	14	25	19	18
ME-4ACD81	Zn	ppm	416	21	28	529	9	13	12	9

			1a	1b	2a	2b	3a	3b	Weathered graphite
ME-ICP06	SiO2	%	50,2	44,4	50,3	44,2	49,2	39,9	39,6
ME-ICP06	Al2O3	%	13,55	11,4	13,9	12,15	13,9	11,2	9,79
ME-ICP06	Fe2O3	%	6,65	11,2	8	15,75	7,47	12,95	9,73
ME-ICP06	CaO	%	3,38	2,38	4,47	3,84	5,12	2,64	1,03
ME-ICP06	MgO	%	4,22	4,61	4,93	4,52	4,4	4,52	3,36
ME-ICP06	Na2O	%	4,86	3,63	5,32	4,59	5,24	3,41	3,05
ME-ICP06	K2O	%	1,07	1,31	1,27	1,06	0,97	1,15	0,74
ME-ICP06	Cr2O3	%	0,019	0,017	0,015	0,013	0,012	0,028	0,023
ME-ICP06	TiO2	%	1,36	1,21	1,47	1,45	1,71	1,05	0,65
ME-ICP06	MnO	%	0,04	0,04	0,06	0,07	0,05	0,06	0,04
ME-ICP06	P2O5	%	0,19	0,2	0,1	0,2	0,27	0,13	0,12
ME-ICP06	SiO	%	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
ME-ICP06	BaO	%	0,02	0,02	0,02	0,02	0,02	0,02	0,01
OA-GRA05	LOI	%	15,35	18,1	11,9	11,95	11,5	22,2	30,5
TOT-ICP06	Total	%	100,91	98,52	101,76	99,81	99,86	99,26	98,64
C-IR07	C	%	11,8	8,14	8,69	3,06	8,45	13,35	21,5
S-IR08	S	%	1,78	1,29	0,72	0,71	0,61	0,65	0,75
ME-MS81	Ba	ppm	154	211	153,5	174,5	141,5	204	103
ME-MS81	Ce	ppm	53,3	65,3	41,3	38,2	88,3	34,5	48,8
ME-MS81	Cr	ppm	130	120	100	80	80	200	170
ME-MS81	Cs	ppm	0,64	0,59	1,1	0,87	0,64	1	0,91
ME-MS81	Dy	ppm	4,44	4,55	3,53	3,19	6,5	3,16	2,76
ME-MS81	Er	ppm	2,39	2,48	1,9	1,54	3,63	1,87	1,68
ME-MS81	Eu	ppm	1,38	1,16	1,25	1,07	2,48	0,75	0,6
ME-MS81	Ga	ppm	18,7	18,6	19,6	18,1	21,7	17,6	15,1
ME-MS81	Gd	ppm	4,57	4,64	3,93	3,54	7,75	2,76	3,2
ME-MS81	Ge	ppm	<5	<5	<5	<5	<5	<5	<5
ME-MS81	Hf	ppm	3,7	3	3,3	3,2	4,5	3,2	1,7
ME-MS81	Ho	ppm	1	0,98	0,73	0,67	1,54	0,66	0,6
ME-MS81	La	ppm	25,8	35,4	20,1	19,4	41,5	17,6	24,6
ME-MS81	Lu	ppm	0,34	0,34	0,22	0,22	0,58	0,25	0,25
ME-MS81	Nb	ppm	7,8	7,9	10,3	8,4	8,8	8,4	6,1
ME-MS81	Nd	ppm	25,4	28,9	21,3	17,4	43,2	15,5	21,7
ME-MS81	Pr	ppm	6,42	7,29	4,94	4,24	10,45	3,97	5,65
ME-MS81	Rb	ppm	35,6	41,8	51,6	37,5	29	40,6	27,2
ME-MS81	Sm	ppm	5,34	5,87	4,37	3,7	8,92	3,33	3,44
ME-MS81	Sn	ppm	1	1	1	1	2	1	<1
ME-MS81	Sr	ppm	131	92,2	127	111	172	78,8	49,1
ME-MS81	Ta	ppm	0,2	0,1	0,4	0,1	0,2	<0,1	<0,1
ME-MS81	Tb	ppm	0,72	0,75	0,58	0,5	1,18	0,53	0,4
ME-MS81	Th	ppm	5,42	4,54	3,32	2,47	4,07	3,56	6,63
ME-MS81	Tm	ppm	0,4	0,37	0,27	0,25	0,52	0,24	0,24
ME-MS81	U	ppm	3,78	2,93	2,32	2,29	4,71	3,98	3,59
ME-MS81	V	ppm	237	255	246	270	277	268	178
ME-MS81	W	ppm	<1	1	3	2	2	7	1
ME-MS81	Y	ppm	24,7	25,3	18,1	15,3	36,5	17,2	17,3
ME-MS81	Yb	ppm	2,49	2,28	1,59	1,58	3,37	1,65	1,69
ME-MS81	Zr	ppm	148	134	131	126	183	110	91
ME-MS42	As	ppm	2,1	14,4	2	3	2,3	5,2	7,5
ME-MS42	Bi	ppm	0,27	0,24	0,07	0,14	0,06	0,32	0,29
ME-MS42	Hg	ppm	0,016	0,018	0,007	0,009	0,008	0,011	0,015
ME-MS42	In	ppm	0,008	0,014	0,015	0,018	0,023	0,012	0,005
ME-MS42	Re	ppm	0,036	0,065	0,012	0,013	0,016	0,02	0,01
ME-MS42	Sb	ppm	0,08	0,47	0,06	0,17	0,06	0,22	1,15
ME-MS42	Se	ppm	8,4	15,9	2,6	12,6	2,3	18,7	15,7
ME-MS42	Te	ppm	0,48	1,05	0,26	0,97	0,22	1,04	1,02
ME-MS42	Tl	ppm	0,06	0,11	0,08	0,11	0,05	0,14	0,14
ME-4ACD81	Ag	ppm	<0,5	0,7	<0,5	<0,5	<0,5	<0,5	1,5
ME-4ACD81	Cd	ppm	4,1	5	0,7	1,8	1,6	2	<0,5
ME-4ACD81	Co	ppm	28	11	28	15	18	14	7
ME-4ACD81	Cu	ppm	169	247	237	279	126	243	341
ME-4ACD81	Li	ppm	10	20	10	10	10	10	20
ME-4ACD81	Mo	ppm	4	29	3	3	5	8	3
ME-4ACD81	Ni	ppm	177	26	66	40	59	47	41
ME-4ACD81	Pb	ppm	581	7260	88	996	233	1550	7230
ME-4ACD81	Sc	ppm	25	26	22	25	24	27	23
ME-4ACD81	Zn	ppm	1100	1770	182	435	194	517	684

Metod	Parameter	Enhet	FW	HGW	Dyke	Sgr
S-IR08	total S	%	4,9	4,85	3,29	3,4
S-ICP19	sulfat-S	%	0,1	0,08	0,07	0,1
S-CAL19	sulfid-S	%	4,8	4,77	3,22	3,3
C-IR07	total C	%	0,16	1,19	2,87	18,35
C-IR06	org. C	%	0,05	0,98	1,47	18,25
C-CAL04	oorg. C	%	0,11	0,21	1,4	0,1
OA-VOL08EU	NP	kg CaCO ₃ /t	10	14	110	2
OA-VOL08EU	AP	kg CaCO ₃ /t	150	149	100,5	103
OA-VOL08EU	NPR		0,1	0,1	1,1	0
OA-VOL08EU	NNP	kg CaCO ₃ /t	-140	-136	9	-101



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7-November-2018

Mattias Backstrom
Bergskraft Bergslagen AB

Re: Report – ALS Job No J0714.

Dear Mattias;

Please find enclosed a copy of a report by the undersigned titled 'J0714 MLA Analysis of Bergskraft Bergslagen Waste Rock Samples – Final Report'.

If you have any queries about the report please do not hesitate to contact me.

Regards

Alexander Grist
Laboratory Manager – *ALS Mineralogy*

ALS Mineralogy

J0714
MLA Analysis of Bergskraft
Bergslagen Waste Rock
Samples
– Final Report

Alexander Grist

Submitted to

Bergskraft Bergslagen AB

ALS Job No. J0714 - November-2018

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1. INTRODUCTION

Bergskraft Bergslagen AB via ALS Geochemistry Nordic, Sweden requested the Australian Laboratory Services Pty. Ltd. (ALS) Mineralogy section to perform quantitative mineral analysis on 4 waste rock samples. The samples were labelled FW, HGW, Dyke, and Sgr.

The analysed samples were supplied as pulverized material.

The objective of the analysis was to characterise the bulk mineralogy of the tailings samples for environmental assessment. The results reported are based on ALS Mineralogy Proposal 18/048 dated 24th of September, 2018.

The samples were analysed using the Mineral Liberation Analyser (MLA). The MLA is a scanning-electron microscope fitted with energy dispersive detectors and customised software for providing quantitative mineralogical data.

2. METHODOLOGY

ALS Mineralogy section prepared a single polished mount for each sample. The polished mounts were analysed using the MLA XMOD analysis to report the bulk mineral abundances.

The XMOD analysis supplied bulk mineralogy data only and thus mineral occurrences of less than 0.1-0.2 Wt% may not be reliably quantified. The XMOD analysis does not provide textural data (grain size and locking and liberation).

3. RESULTS

3.1 Assay Data

The MLA calculated assay data is reported in Table 1

Table 1 **MLA Calculated Assay (%)**

Element	FW - Wt%	HGW - Wt%	Dyke - Wt%	Sgr - Wt%
Al	6.35	6.29	6.62	6.17
B	0.00	0.00	0.00	0.00
C	0.04	0.08	0.56	0.05
Ca	4.18	4.08	7.36	3.84
Ce	0.00	0.00	0.00	0.00
Cl	0.66	0.82	1.06	0.37
Co	0.00	0.00	0.00	0.00
Cr	0.01	0.01	0.01	0.02
Cu	0.07	0.05	0.04	0.07
Dy	0.00	0.00	0.00	0.00
Er	0.00	0.00	0.00	0.00
F	0.01	0.01	0.00	0.00
Fe	15.15	13.87	11.70	11.00
Gd	0.00	0.00	0.00	0.00
H	0.07	0.07	0.08	0.10
Hf	0.00	0.00	0.00	0.00
Ho	0.00	0.00	0.00	0.00
K	0.68	0.83	0.96	1.38
La	0.00	0.00	0.00	0.00
Mg	2.79	3.39	3.77	4.37
Mn	0.03	0.03	0.03	0.03
Mo	0.00	0.00	0.00	0.00
Na	3.95	3.83	3.50	3.37
Nd	0.00	0.00	0.00	0.00
Ni	0.00	0.00	0.00	0.00
O	36.21	36.67	38.65	39.06
P	0.05	0.05	0.03	0.04
Pb	0.04	0.00	0.00	0.01
Pr	0.00	0.00	0.00	0.00
S	8.25	8.22	5.26	6.65
Si	20.39	21.06	19.62	22.57
Tb	0.00	0.00	0.00	0.00
Ti	1.03	0.62	0.72	0.81
V	0.00	0.00	0.00	0.00
Y	0.00	0.00	0.00	0.00
Yb	0.00	0.00	0.00	0.00
Zn	0.03	0.00	0.00	0.06
Zr	0.01	0.01	0.00	0.01
Total	100.00	100.00	100.00	100.00

3.2 Mineral Reference File

The list of detected minerals including formulae and density are displayed in Table 2.

It should be noted that the assigned composition is an average and that minerals that are part of a solid solution series or mineral mixes may have a highly variable composition.

The complete list including the assigned elemental concentrations are displayed in Appendix 1.

Table 2 Mineral List

Mineral	Density	Formula
Chalcopyrite	4.19	CuFeS ₂
Galena	7.54	PbS
Molybdenite	5.50	MoS ₂
Pentlandite	4.80	(Fe,Ni,Co) ₉ S ₈
Pyrite	4.90	FeS ₂
Pyrrhotite	4.65	Fe ₇ S ₈
Sphalerite	4.05	(Zn,Fe)S
Ilmenite	4.73	(Fe,Mn)TiO ₃
Iron-oxide	5.19	Fe ₃ O ₄
Rutile	4.25	TiO ₂
Ankerite	2.97	Ca(Mg,Fe,Mn)(CO ₃) ₂
Calcite	2.79	(Ca,Mg,Fe)CO ₃
Dolomite	2.84	Ca(Mg,Fe,Mn)(CO ₃) ₂
Siderite	3.96	(Fe,Ca,Mn)CO ₃
Apatite	3.35	Ca ₅ (PO ₄) ₃ (F,Cl,OH)
Xenotime	4.66	(Y,Yb,Dy,Gd,Ho,Er,Tb)PO ₄
Albite	2.62	(Na,Ca)(Al,Fe)Si ₃ O ₈
Allanite	4.11	Ca(Ce,La,Nd,Pr)[(Al,Ti) ₂ (Fe,Mg)](Si ₂ O ₇)(SiO ₄)O(OH)
Amphibole	3.20	(Na,K)Ca ₂ [Mg ₄ (Fe,Mn,Ti)]Si ₆ Al ₂ O ₂₂ (OH,Cl) ₂
Biotite	3.01	K(Mg,Fe) ₃ (Al,Fe,Ti)Si ₃ O ₁₀ (OH,Cl) ₂
Chamosite	3.12	(Fe,Mg,Ca) ₅ (Al,Fe)(Si ₃ Al)O ₁₀ (OH) ₈
Chlorite	3.12	(Fe,Mg,Mn,Ca,K) ₅ (Al,Ti,Fe)(Si ₃ Al)O ₁₀ (OH) ₈
Cummingtonite	3.18	(Mg,Fe,Ca,Mn,Al) ₇ Si ₈ O ₂₂ (OH) ₂
Diopside	3.33	(Ca,Na)(Mg,Fe,Mn,Al)Si ₂ O ₆
K-feldspar	2.56	(K,Na)(Al,Fe)Si ₃ O ₆
Muscovite	2.86	(K,Na)(Al,Fe,Ti) ₂ Si ₃ AlO ₁₀ (OH,Cl) ₂
Phlogopite	2.91	K(Mg,Fe,Ti,Cr) ₃ AlSi ₃ O ₁₀ (OH,Cl) ₂
Plagioclase	2.70	(Na,Ca)(Al,Fe) ₁₋₂ [Si] ₃₋₂ O ₈
Prehnite	2.92	(Ca,Mg) ₂ (Al,Fe) ₂ Si ₃ O ₁₀ (OH) ₂
Quartz	2.62	SiO ₂
Scapolite	2.63	(Na,Ca,K) ₄ Al ₃ Si ₉ O ₂₄ (Cl,CO ₃)
Talc	2.69	(Mg,Fe) ₃ (Si,Al) ₄ O ₁₀ (OH) ₂
Titanite	3.50	Ca(Ti,Al,Fe)SiO ₅
Tourmaline	3.10	(Na,Ca)(Mg,Fe) ₃ (Al,Cr,V,Ti) ₆ (Si ₆ O ₁₈)(BO ₃) ₃ (OH) ₃ (OH)
Tremolite	2.96	([],Na,K)Ca ₂ (Mg,Fe,Mn,Ti,Al) ₅ Si ₈ O ₂₂ (OH) ₂
Zircon	4.54	(Zr,Hf,Al,Fe,Ca)SiO ₄

3.3 Mineral Abundances and Grouping

The ungrouped mineral abundances and grain count data are reported in Table 3 Table 4. The grouped mineral abundances are displayed in Table 5 and in Figure 2. The grouping list used to determine the grouped mineral abundances are displayed in Figure 1.

Table 3 Ungrouped Mineral Abundances (Wt%)

Mineral	FW - Wt%	HGW - Wt%	Dyke - Wt%	Sgr - Wt%
Chalcopyrite	0.20	0.13	0.11	0.22
Galena	0.05	0.00	0.00	0.01
Molybdenite	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.01
Pyrite	1.49	1.46	1.20	4.35
Pyrrhotite	17.73	17.82	11.04	10.13
Sphalerite	0.05	0.00	0.00	0.11
Ilmenite	0.64	0.06	0.25	0.01
Iron-oxide	0.89	0.03	0.02	0.03
Rutile	0.07	0.27	0.06	0.19
Ankerite	0.00	0.02	0.00	0.00
Calcite	0.14	0.36	4.35	0.30
Dolomite	0.00	0.08	0.00	0.00
Siderite	0.03	0.02	0.06	0.07
Apatite	0.28	0.31	0.18	0.21
Xenotime	0.00	0.00	0.00	0.00
Albite	25.39	18.89	4.57	27.86
Allanite	0.01	0.01	0.01	0.01
Amphibole	9.94	6.77	22.45	1.29
Biotite	3.24	0.78	3.22	0.87
Chamosite	0.12	0.04	0.13	0.38
Chlorite	1.52	0.90	0.92	2.56
Cumingtonite	0.01	2.32	0.00	0.01
Diopside	3.55	3.41	4.20	2.36
K-feldspar	0.48	0.56	0.95	2.64
Muscovite	0.02	0.03	0.10	0.04
Phlogopite	3.17	7.33	4.72	11.04
Plagioclase	0.13	0.46	2.77	0.16
Prehnite	0.01	0.01	0.05	0.16
Quartz	1.03	2.80	0.23	2.51
Scapolite	18.33	23.67	29.51	10.31
Talc	0.00	0.14	0.00	0.00
Titanite	2.49	1.10	1.08	2.14
Tourmaline	0.04	0.05	0.01	0.00
Tremolite	8.93	10.17	7.77	19.97
Zircon	0.02	0.01	0.01	0.02
Total	100.00	100.00	100.00	100.00

Table 4 Grain Count Data

Mineral	FW - Grain Count	HGW - Grain Count	Dyke - Grain Count	Sgr - Grain Count
Chalcopyrite	226	144	111	169
Galena	29	0	0	6
Molybdenite	4	3	2	1
Pentlandite	0	4	2	4
Pyrite	1410	1383	1019	2910
Pyrrhotite	17633	17729	9859	7134
Sphalerite	62	0	0	86
Ilmenite	624	60	218	10
Iron-oxide	792	25	19	20
Rutile	79	290	57	143
Ankerite	0	24	2	0
Calcite	228	589	6479	354
Dolomite	0	137	7	0
Siderite	37	29	67	62
Apatite	392	423	219	206
Xenotime	0	1	0	0
Albite	44818	33367	7241	34828
Allanite	7	11	13	6
Amphibole	14368	9791	29138	1325
Biotite	4976	1197	4445	945
Chamosite	178	53	170	395
Chlorite	2251	1329	1223	2692
Cumingtonite	11	3369	2	15
Diopside	4927	4734	5235	2323
K-feldspar	864	1018	1545	3371
Muscovite	33	46	149	48
Phlogopite	5030	11649	6735	12424
Plagioclase	227	785	4260	192
Prehnite	12	13	70	182
Quartz	1812	4952	369	3139
Scapolite	32224	41651	46590	12838
Talc	1	238	0	3
Titanite	3285	1456	1287	2004
Tourmaline	55	76	17	0
Tremolite	13945	15894	10904	22094
Zircon	20	14	5	17
Total	150560	152484	137459	109946

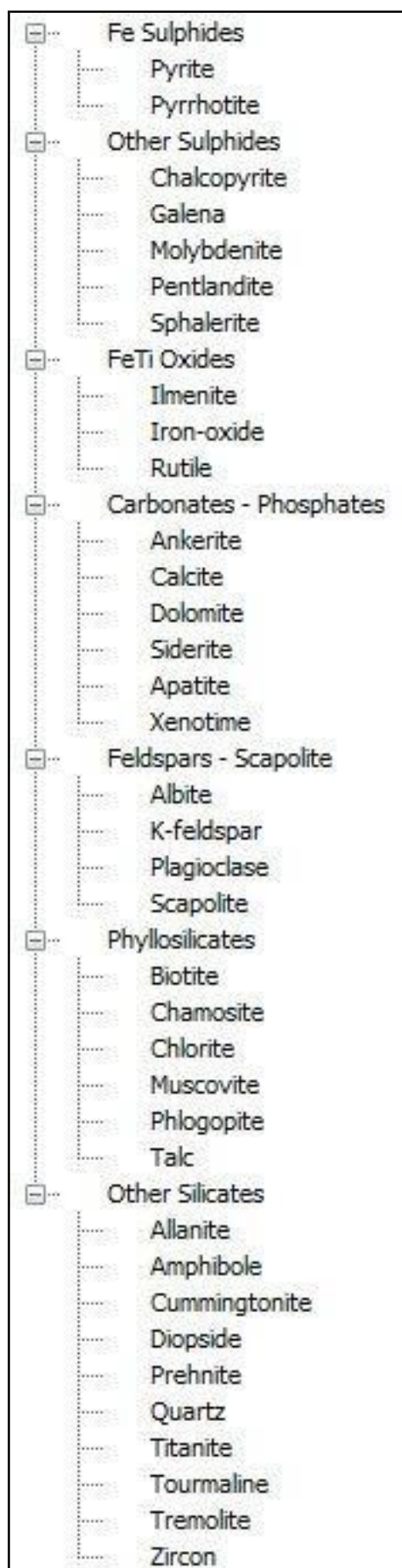
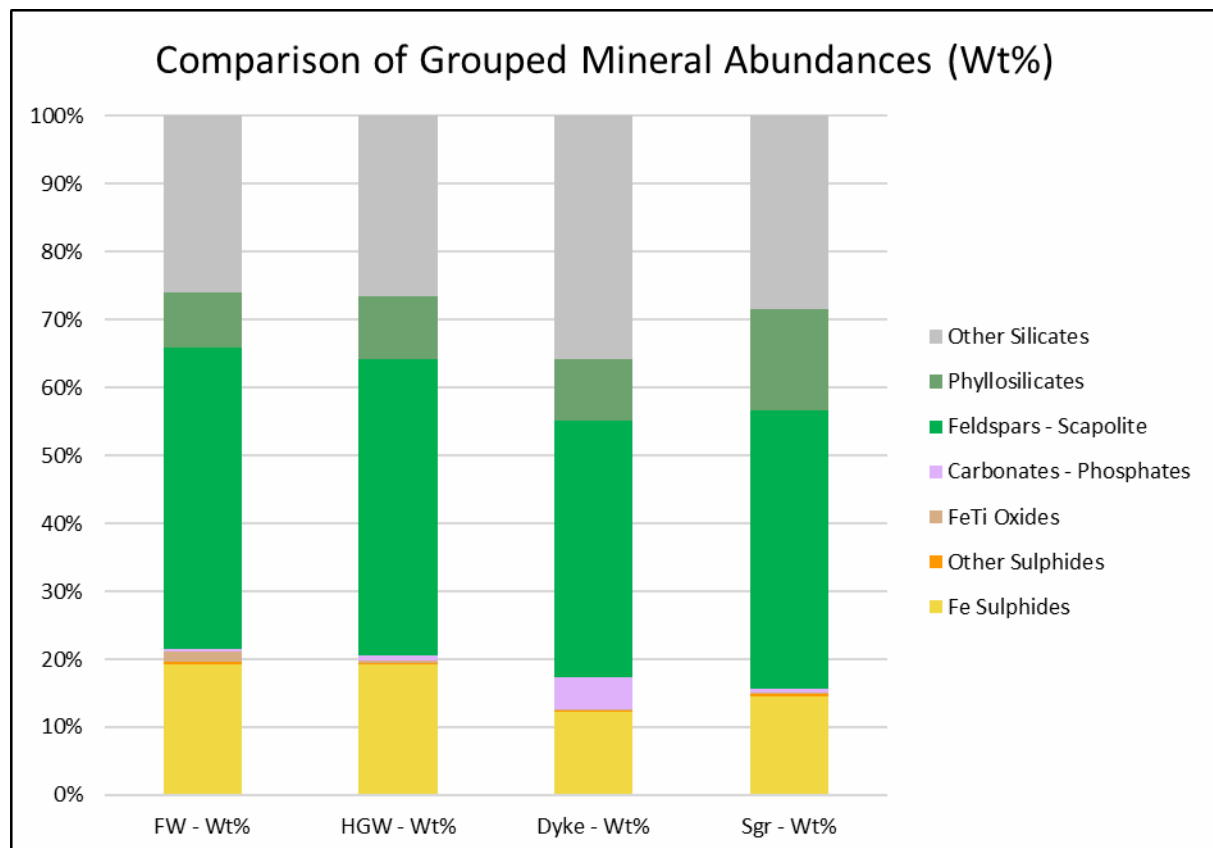


Figure 1 Grouping List

Table 5 **Grouped Mineral Abundances (Wt%)**

Mineral	FW - Wt%	HGW - Wt%	Dyke - Wt%	Sgr - Wt%
Fe Sulphides	19.23	19.28	12.24	14.48
Other Sulphides	0.31	0.14	0.12	0.34
FeTi Oxides	1.60	0.36	0.33	0.23
Carbonates - Phosphates	0.45	0.79	4.60	0.59
Feldspars - Scapolite	44.33	43.59	37.80	40.97
Phyllosilicates	8.06	9.20	9.09	14.89
Other Silicates	26.01	26.65	35.82	28.49
Total	100.00	100.00	100.00	100.00

**Figure 2** **Grouped Mineral Abundances (Wt%)**

3.4 Elemental Distributions

The elemental distributions of elements to grouped minerals are displayed in Table 6. The ungrouped elemental distributions are shown in Appendix 2.

Table 6 Grouped Elemental Distributions (%)

Mineral	FW - Al (%)	HGW - Al (%)	Dyke - Al (%)	Sgr - Al (%)	FW - B (%)	HGW - B (%)	Dyke - B (%)	Sgr - B (%)	FW - C (%)	HGW - C (%)	Dyke - C (%)	Sgr - C (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.01	71.02	94.73	81.06
Feldspars - Scapolite	78.99	79.67	68.91	73.54	0.00	0.00	0.00	0.00	47.99	28.98	5.27	18.94
Phyllosilicates	10.24	11.84	11.21	19.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Silicates	10.77	8.49	19.89	6.59	100.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - Ca (%)	HGW - Ca (%)	Dyke - Ca (%)	Sgr - Ca (%)	FW - Ce (%)	HGW - Ce (%)	Dyke - Ce (%)	Sgr - Ce (%)	FW - Cl (%)	HGW - Cl (%)	Dyke - Cl (%)	Sgr - Cl (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	4.05	6.98	24.26	5.38	0.00	0.00	0.00	0.00	0.27	0.23	0.10	0.35
Feldspars - Scapolite	24.87	32.21	23.66	16.70	0.00	0.00	0.00	0.00	91.21	95.37	91.49	91.49
Phyllosilicates	0.08	0.04	0.03	0.16	0.00	0.00	0.00	0.00	4.93	2.41	3.35	7.33
Other Silicates	71.00	60.78	52.05	77.76	100.00	100.00	100.00	100.00	3.60	1.98	5.06	0.84
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Co (%)	HGW - Co (%)	Dyke - Co (%)	Sgr - Co (%)	FW - Cr (%)	HGW - Cr (%)	Dyke - Cr (%)	Sgr - Cr (%)	FW - Cu (%)	HGW - Cu (%)	Dyke - Cu (%)	Sgr - Cu (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	94.44	96.61	98.66	100.00	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	0.00	0.00	5.56	3.39	1.34	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Dy (%)	HGW - Dy (%)	Dyke - Dy (%)	Sgr - Dy (%)	FW - Er (%)	HGW - Er (%)	Dyke - Er (%)	Sgr - Er (%)	FW - F (%)	HGW - F (%)	Dyke - F (%)	Sgr - F (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - Fe (%)	HGW - Fe (%)	Dyke - Fe (%)	Sgr - Fe (%)	FW - Gd (%)	HGW - Gd (%)	Dyke - Gd (%)	Sgr - Gd (%)	FW - H (%)	HGW - H (%)	Dyke - H (%)	Sgr - H (%)
Fe Sulphides	73.09	80.08	60.00	72.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.45	0.29	0.30	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	5.75	0.30	0.91	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.09	0.10	0.36	0.30	0.00	100.00	0.00	0.00	0.21	0.23	0.11	0.10
Feldspars - Scapolite	0.28	0.24	0.15	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	7.76	5.24	9.65	12.72	0.00	0.00	0.00	0.00	49.26	43.85	35.29	59.67
Other Silicates	12.57	13.75	28.64	13.24	0.00	0.00	0.00	0.00	50.53	55.91	64.60	40.23
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - Hf (%)	HGW - Hf (%)	Dyke - Hf (%)	Sgr - Hf (%)	FW - Ho (%)	HGW - Ho (%)	Dyke - Ho (%)	Sgr - Ho (%)	FW - K (%)	HGW - K (%)	Dyke - K (%)	Sgr - K (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.74	13.65	18.09	26.79
Phyllosilicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	76.43	80.42	67.45	71.35
Other Silicates	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	9.83	5.93	14.47	1.86
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - La (%)	HGW - La (%)	Dyke - La (%)	Sgr - La (%)	FW - Mg (%)	HGW - Mg (%)	Dyke - Mg (%)	Sgr - Mg (%)	FW - Mn (%)	HGW - Mn (%)	Dyke - Mn (%)	Sgr - Mn (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.27	2.24	9.44	0.57
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.02	0.38	0.40	0.02	0.54	1.12	1.11	1.28
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	26.28	32.92	23.28	40.01	4.22	2.30	2.45	7.12
Other Silicates	100.00	100.00	100.00	100.00	73.70	66.70	76.32	59.97	69.97	94.33	87.00	91.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Mo (%)	HGW - Mo (%)	Dyke - Mo (%)	Sgr - Mo (%)	FW - Na (%)	HGW - Na (%)	Dyke - Na (%)	Sgr - Na (%)	FW - Nd (%)	HGW - Nd (%)	Dyke - Nd (%)	Sgr - Nd (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	93.74	94.94	86.28	95.88	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	0.00	0.00	6.25	5.06	13.70	4.11	100.00	100.00	100.00	100.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Ni (%)	HGW - Ni (%)	Dyke - Ni (%)	Sgr - Ni (%)	FW - O (%)	HGW - O (%)	Dyke - O (%)	Sgr - O (%)	FW - P (%)	HGW - P (%)	Dyke - P (%)	Sgr - P (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	1.32	0.36	0.28	0.22	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.53	0.96	5.66	0.66	100.00	100.00	100.00	100.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	57.82	55.57	44.78	49.98	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	9.33	10.86	9.86	16.55	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	0.00	0.00	31.01	32.25	39.41	32.59	0.00	0.00	0.00	0.00
Total	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Pb (%)	HGW - Pb (%)	Dyke - Pb (%)	Sgr - Pb (%)	FW - Pr (%)	HGW - Pr (%)	Dyke - Pr (%)	Sgr - Pr (%)	FW - S (%)	HGW - S (%)	Dyke - S (%)	Sgr - S (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	98.81	99.41	99.22	98.26
Other Sulphides	100.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	1.19	0.59	0.78	1.74
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Total	100.00	0.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Si (%)	HGW - Si (%)	Dyke - Si (%)	Sgr - Si (%)	FW - Tb (%)	HGW - Tb (%)	Dyke - Tb (%)	Sgr - Tb (%)	FW - Ti (%)	HGW - Ti (%)	Dyke - Ti (%)	Sgr - Ti (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.63	28.89	15.77	14.28
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Feldspars - Scapolite	63.17	58.38	50.80	54.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	6.97	8.54	8.54	12.40	0.00	0.00	0.00	0.00	10.92	17.21	17.84	19.75
Other Silicates	29.86	33.08	40.66	33.27	0.00	0.00	0.00	0.00	65.46	53.90	66.40	65.97
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - V (%)	HGW - V (%)	Dyke - V (%)	Sgr - V (%)	FW - Y (%)	HGW - Y (%)	Dyke - Y (%)	Sgr - Y (%)	FW - Yb (%)	HGW - Yb (%)	Dyke - Yb (%)	Sgr - Yb (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Silicates	100.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	0.00	0.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00

Mineral	FW - Zn (%)	HGW - Zn (%)	Dyke - Zn (%)	Sgr - Zn (%)	FW - Zr (%)	HGW - Zr (%)	Dyke - Zr (%)	Sgr - Zr (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	100.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
FeTi Oxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbonates - Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feldspars - Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
Total	100.00	0.00	0.00	100.00	100.00	100.00	100.00	100.00

4. TERMS & CONDITIONS

1. General

- a) ALS will provide the Services described in the accompanying tender, quotation, letter, fax or email to the Client, which together with these terms and conditions will hereafter be called the 'Agreement'.
- b) This Agreement will be binding on the Client from the date the Agreement is accepted by the Client in the Acceptance section below. However, the placement of an order for or receipt of samples for analysis based on this Agreement will constitute acceptance of the Agreement by the Client.
- c) This Agreement is valid for acceptance by the Client for ninety (90) days from the issue date unless specifically indicated otherwise.

2. Provision of Services

- a) ALS will provide the Services by exercising the same degree of skill, care and diligence that would be exercised by professional service providers in similar circumstances.
- b) The Client acknowledges that it is the Client's sole responsibility to make its own assessment of the suitability for any purpose of the Service, the ALS Report and its contents.
- c) If the Client requires the Services to be performed by specific test method, or requires detection limits and/or confidence intervals different to those inherent in ALS's standard testing methodology, then the Client must instruct ALS of such a variation prior to ALS performing the Services.
- d) ALS may delegate the performance of all or part of the Service to an agent or subcontractor and the Client consents to ALS disclosing all information (including Confidential Information) of the Client to that agent or subcontractor necessary for the performance of the Service by the agent or subcontractor.

3. Fees and Payment

- a) ALS reserves the right to review prices at any time if significant changes to ALS's costs are incurred that are beyond ALS's control, such changes may include, but are not limited to, changes in legislative requirements, Client variations to sample numbers, turnaround required, or reporting requirements.
- b) Invoices will also be delivered on work order approval to the nominated Client representative via email in a secure PDF format, unless otherwise requested. This is the official invoice and should be used for payment purposes. Hard copies can be printed from this file if required.
- c) Payment terms are 30 days from the date of invoice (Due Date), unless negotiated otherwise prior to the placement of an order or submission of samples. Any such variance from the standard payment terms must be stipulated separately in writing in the Agreement.
- d) All prices quoted by ALS are exclusive of GST (or other value added tax if relevant) unless stated otherwise.
- e) All fees due and payable after the Due Date (Outstanding Amount) will be subject to the payment of interest at a rate of 1.5% per month of the Outstanding Amount from the Due Date up to and including the date of payment, unless ALS and the Client otherwise agree in writing.
- f) The Client will indemnify ALS for any fees incurred by ALS to recover the Outstanding Amount, including any solicitor fees, or collection agency fees.

4. Limitation of Liability

- a) To the full extent permitted by law, ALS excludes all warranties, terms, conditions or undertakings (Terms), whether expressed or implied, in relation to the Services, the ALS Report, or its contents. Where any legislation implies any Terms in this Agreement that cannot be modified or excluded then, such Terms shall deem to be included. However, to the full extent permitted by law, ALS's liability to the Client for any breach of any Terms that cannot be excluded by law is limited at ALS's option to the re-performance of the Service or the refund of the fee for the Service.
- b) The Client hereby releases and indemnifies and shall continue to release and indemnify ALS, its officers, employees and agents from and against all actions, claims (actual or threatened), proceedings or demands (including any costs and expenses in defending or servicing same) which may be brought against it or them, in respect of any loss (including Consequential Loss), death, injury, illness or damage to persons or property, and whether direct or indirect and in respect of any breach of any industrial or intellectual property rights, howsoever arising out of the use of, reliance on, or benefit of, the Services or any ALS Report, except to the extent that the loss, death, injury, illness or damage to persons or property was directly caused by the negligence, wilful acts or omissions of ALS or its employees.
- c) Notwithstanding any other provision in this Agreement, the cumulative liability of ALS under this Agreement to the Client and any third party is limited for any claim for loss or damage whatsoever, whether arising in tort or contract or any other cause of action, to the value of the Services provided by ALS to the Client.
- d) Without limiting the generality of clauses 4.a) and 4.b), it is agreed that, to the full extent permitted by any applicable laws having jurisdiction, ALS will not be liable to the Client or any other person for any special, indirect or Consequential Loss arising from the Client's use of, reliance on, or benefit of, the Services or any ALS Report.

e) The Client acknowledges that during the performance of the Services, any samples supplied by, or on behalf of, the Client or parts thereof may be altered, lost, damaged or destroyed. ALS will not be liable whatsoever to the Client or any third party for any samples so altered, lost, damaged or destroyed.

5. Client's Obligations

a) The Client will ensure that all personnel, information, samples, access, assistance, records, documentation and facilities needed by ALS to perform the Service, are available when reasonably required by ALS.

b) The Client will give written notice to ALS of all known safety or health hazards and special procedures applicable to the performance of the Service, and the safe handling, testing, storage, transport and disposal of samples submitted to ALS. ALS may in its absolute discretion, refuse to provide part or all of the Services where it determines that the provision of part or all of the Services may pose a health or safety hazard.

c) The Client must take all necessary steps to remove or remedy any known safety or health hazards, or any obstacles to or anything that is likely to interrupt the performance of the Services by ALS.

6. Termination

a) ALS may suspend or terminate its obligations under this Agreement if (a) monies payable to ALS by the client are outstanding 60 days or more (unless otherwise agreed) after the date of invoice, (b) other substantial breach by the Client of their obligations under the Agreement, which breach is not remedied within 30 days of written notice from ALS requiring the breach to be remedied, (c) by giving the Client 60 days written notice of ALS's intention to terminate.

b) The Client may terminate its obligations under this Agreement in the event of a substantial breach by ALS of its obligations under the Agreement, which breach has not been remedied within 30 days of written notice from the Client to ALS requiring the breach to be remedied.

c) If ALS, acting reasonably, suspects that the Client is insolvent or is having difficulties paying its debts as and when they become due, or the Client is insolvent, ALS may give written notice to the Client of ALS's intention to immediately suspend or terminate its obligations under this Agreement.

d) In the event of termination, ALS is entitled to be paid for all work performed before the date of termination and for any unavoidable commitments entered into by ALS before the date of termination.

7. Intellectual Property

a) All ALS Intellectual Property will remain the property of ALS.

b) ALS grants to the Client a world-wide, non-exclusive, royalty free licence to use ALS Intellectual Property for the purpose agreed to between the Client and ALS to the extent that it is needed for the enjoyment and benefit of the Services.

8. Confidential Information

a) Neither ALS nor the Client will disclose Confidential Information of the other party to any third party without the prior written consent of the other party, unless required by law or the rules of a relevant stock exchange.

b) ALS and the Client will only use Confidential Information of the other party for the purpose of the supply of the Services.

9. Reports

a) Any report, findings, results, statement, certification issued by ALS (ALS Report) is issued on the basis of testing of samples or materials, information, or documents provided by, or on behalf of, the Client. The Client will indemnify and hold harmless ALS, its officers, employees, agents and subcontractors for any claim whatsoever in relation to any ALS Report arising from unclear, erroneous, incomplete, misleading or false information provided to ALS; or arising from any incorrect or defective materials or samples provided to ALS.

b) Each ALS Report is

i. issued on the testing of samples or specific materials using detection limits and confidence intervals inherent in ALS's testing methodology; and

ii. contains ALS's results and opinions (if provided) on those samples or specific materials only.

c) Each ALS Report is solely for the benefit of the Client, its officers and employees. The Client will not disclose any ALS Report to any third party without the prior written consent of ALS, unless required by law, and subject to the following terms:

i. the ALS Report has been commissioned by the Client on the terms and conditions contained in this Agreement;

ii. copyright in the ALS Report and all information and data contained in it, save for any information supplied by the Client, are owned by ALS;

iii. moral rights in the ALS Report are owned by ALS;

iv. the ALS Report has been prepared at the request of the Client for the purpose agreed between the Client and ALS. The Client may disclose the report to a third party for that purpose only, but ALS does not accept any responsibility or liability (including, without limitation, liability for negligence) to that third party. Any disclosure to a third party must be of the whole of the ALS Report, including ALS's disclaimer notice which is substantially the same as the terms outlined in this clause 9.b);

v. while ALS has taken all due care to ensure that the information contained in the ALS Report is true and correct and is not misleading or deceptive, neither ALS, nor any of its officers, employees or agents make any representations or warranties, express or implied, other than to the Client, as to the accuracy of the information

contained therein. Except insofar as liability under any law cannot be excluded, and subject to clause 4, ALS accepts no responsibility arising in respect of the information contained in the ALS Report for errors or omissions (including responsibility to any person by reason of negligence); and

vi ALS reserves its right to review, update or supplement any ALS Report. Any further information will be provided subject to the terms of this Agreement.

d) The Client will not reproduce or publish extracts of any ALS Report without the prior written consent of ALS, and subject to terms outlined in clause 9.b).

e) The Client indemnifies ALS, its directors, employees, agents, consultants, contractors, successors in title and assigns against any claim made against any or all of them by third parties arising out of either the disclosure of any ALS Report, whether directly or indirectly by the Client, to a third party; or any reproduction or publication of an extract of any ALS Report.

f) The Client acknowledges and agrees that any action, inaction, or decision of the Client in response to the ALS Report will be determined by the Client. Neither ALS nor any of its officers, employees, agents, or subcontractors will be liable to the Client or any third party for any action or inaction of the Client in response to any ALS Report.

h) ALS will retain Client data and Confidential Information for 3 years from date of the final ALS Report.

10. Samples

a) Unless otherwise agreed, sample disposal is the responsibility of the Client. Samples may be collected within 90 days of receiving the ALS Report. Uncollected samples may incur a storage or disposal charge.

b) For samples, pulps and rejects that are in storage at an ALS facility, warehouse, or at a third party storage facility sub-contracted by ALS, the Client should obtain coverage for fire and theft. The responsibility of ALS for client's goods is strictly limited to exercising the reasonable care and diligence as required by statute. All of ALS other obligations, undertakings, covenants, representations, warranties and conditions, are excluded, unless they are expressly agreed to in writing by an authorized representative of ALS.

c) Except as provided in clause 2.b) above, the Client's goods are stored at the Client's exclusive risk of loss, damage or delay in delivery whatsoever, including, without limitation, loss, damage or delay caused through (a) any action or failure to act beyond the reasonable control of ALS, (b) ordinary wear and tear in handling, (c) natural deterioration of packing material over time, (d) theft, (e) sprinkler or other water damage, (f) fire.

11. Force Majeure

a) If ALS is prevented in whole or in part from performing its obligations by a Force Majeure Event, ALS may suspend performance of those obligations by giving written notice to the Client. Any non-performance or delay in performance resulting from the Force Majeure Event will not be deemed to be a breach of this Agreement.

b) If a suspension under this clause 3 exceeds 90 days, ALS may immediately terminate the Agreement by written notice to the Client. In the event of termination, ALS is entitled to be paid for all work performed before the date of termination and for any unavoidable commitments entered into by ALS before the date of termination.

12. Definitions

a) In this Agreement:

i ALS means ALS Mineralogy Pty Ltd ACN 009 936 029 and each of its related bodies corporate (as defined in the Corporations Act 2001 (Cth)).

ii ALS Intellectual Property means all intellectual property and proprietary rights (whether registered or unregistered) owned by ALS prior to performance of the Services, developed by ALS in performance of the Services, or developed by ALS outside of, or after, performance of the Services, and without limitation includes business names, trade or service marks, any right to have information (including confidential information) kept confidential, patents, patent applications, drawings, discoveries, inventions, improvements, trade secrets, technical data, formulae, databases, know-how, logos, designs, design rights, copyright and similar industrial or intellectual property rights.

iii ALS Report has the meaning given to it in clause 9.a).

iv Client means the entity to which the accompanying tender, quotation, letter, fax or email is addressed.

v Confidential Information means all information in relation to a disclosing party, its business, operations, products, processes, customers, suppliers or contractors which is or might reasonably be considered by the disclosing party to be confidential, including all technical data, formulae, specifications, diagrams, plans, drawings, sketches, designs, business plans and reports, business methods and systems, business records, production information, unpublished financial accounts and reports, discount and supply agreements, subcontractor lists, customer lists, except to the extent that such information is lawfully in the public domain.

vi Consequential Loss means loss or damage from a breach of contract, tort (including negligence), under statute or any other basis in law or equity including, but without limitation loss of profits, loss of revenue, loss of production, loss or denial of opportunity, loss of access to markets, loss of goodwill, loss of business reputation, future reputation or publicity, damage to credit rating, loss of use, and indirect, remote, abnormal or unforeseeable loss, or any similar loss whether or not in the reasonable contemplation of the parties at the time of this Agreement.

vii Force Majeure Event means any event or circumstance beyond the reasonable control of ALS, including without limitation any act of God, strike, boycott, lockout or other industrial disturbance, default of suppliers or sub-contractors, lightning, fire, storm, flood, earthquake, inclement weather, act of war (declared or undeclared), blockade, insurrection, riot or other civil disturbance, inability to obtain equipment, labour or essential materials,

act of any government or authority, including refusal or delay in obtaining any necessary consent, approval or licence, or accident, explosion or breakage.

vi. Services means the services described in the accompanying tender, quotation, letter, fax or email.

13. Miscellaneous

a) ALS may assign or subcontract the storage and handling of samples under this Agreement without prior written approval of the Client, excluding transport.

b) Any provision of this Agreement that is illegal, invalid or unenforceable will be severed to the extent that it is illegal, invalid or unenforceable, with the remainder of the Agreement continuing in full force.

c) This Agreement is governed by the law of the state or territory in which the Services are provided, and each party irrevocably and unconditionally submits to the non-exclusive jurisdiction of the courts of that place.

Appendix 1 Mineral List

Mineral	Density	Formula	Al (%)	B (%)
Chalcopyrite	4.19	CuFeS ₂	0.00	0.00
Galena	7.54	PbS	0.00	0.00
Molybdenite	5.50	MoS ₂	0.00	0.00
Pentlandite	4.80	(Fe,Ni,Co) ₉ S ₈	0.00	0.00
Pyrite	4.90	FeS ₂	0.00	0.00
Pyrrhotite	4.65	Fe ₇ S ₈	0.00	0.00
Sphalerite	4.05	(Zn,Fe)S	0.00	0.00
Ilmenite	4.73	(Fe,Mn)TiO ₃	0.00	0.00
Iron-oxide	5.19	Fe ₃ O ₄	0.00	0.00
Rutile	4.25	TiO ₂	0.00	0.00
Ankerite	2.97	Ca(Mg,Fe,Mn)(CO ₃) ₂	0.00	0.00
Calcite	2.79	(Ca,Mg,Fe)CO ₃	0.00	0.00
Dolomite	2.84	Ca(Mg,Fe,Mn)(CO ₃) ₂	0.00	0.00
Siderite	3.96	(Fe,Ca,Mn)CO ₃	0.00	0.00
Apatite	3.35	Ca ₅ (PO ₄) ₃ (F,Cl,OH)	0.00	0.00
Xenotime	4.66	(Y,Yb,Dy,Gd,Ho,Er,Tb)PO ₄	0.00	0.00
Albite	2.62	(Na,Ca)(Al,Fe)Si ₃ O ₈	10.79	0.00
Allanite	4.11	Ca(Ce,La,Nd,Pr)[(Al,Ti) ₂ (Fe,Mg)](Si ₂ O ₇)(SiO ₄)O(OH)	7.45	0.00
Amphibole	3.20	(Na,K)Ca ₂ [Mg ₄ (Fe,Mn,Ti)]Si ₆ Al ₂ O ₂₂ (OH,Cl) ₂	5.23	0.00
Biotite	3.01	K(Mg,Fe) ₃ (Al,Fe,Ti)Si ₃ O ₁₀ (OH,Cl) ₂	7.66	0.00
Chamosite	3.12	(Fe,Mg,Ca) ₅ (Al,Fe)(Si ₃ Al)O ₁₀ (OH) ₈	8.10	0.00
Chlorite	3.12	(Fe,Mg,Mn,Ca,K) ₅ (Al,Ti,Fe)(Si ₃ Al)O ₁₀ (OH) ₈	8.49	0.00
Cummingtonite	3.18	(Mg,Fe,Ca,Mn,Al) ₇ Si ₈ O ₂₂ (OH) ₂	0.11	0.00
Diopside	3.33	(Ca,Na)(Mg,Fe,Mn,Al)Si ₂ O ₆	0.24	0.00
K-feldspar	2.56	(K,Na)(Al,Fe)Si ₃ O ₆	10.11	0.00
Muscovite	2.86	(K,Na)(Al,Fe,Ti) ₂ Si ₃ AlO ₁₀ (OH,Cl) ₂	20.15	0.00
Phlogopite	2.91	K(Mg,Fe,Ti,Cr) ₃ AlSi ₃ O ₁₀ (OH,Cl) ₂	8.18	0.00
Plagioclase	2.70	(Na,Ca)(Al,Fe) ₁₋₂ [Si] ₃₋₂ O ₈	15.25	0.00
Prehnite	2.92	(Ca,Mg) ₂ (Al,Fe) ₂ Si ₃ O ₁₀ (OH) ₂	11.99	0.00
Quartz	2.62	SiO ₂	0.00	0.00
Scapolite	2.63	(Na,Ca,K) ₄ Al ₃ Si ₉ O ₂₄ (Cl,CO ₃)	12.03	0.00
Talc	2.69	(Mg,Fe) ₃ (Si,Al) ₄ O ₁₀ (OH) ₂	0.81	0.00
Titanite	3.50	Ca(Ti,Al,Fe)SiO ₅	0.53	0.00
Tourmaline	3.10	(Na,Ca)(Mg,Fe) ₃ (Al,Cr,V,Ti) ₆ (Si ₆ O ₁₈)(BO ₃) ₃ (OH) ₃ (OH)	16.13	3.28
Tremolite	2.96	(□,Na,K)Ca ₂ (Mg,Fe,Mn,Ti,Al) ₅ Si ₈ O ₂₂ (OH) ₂	1.51	0.00
Zircon	4.54	(Zr,Hf,Al,Fe,Ca)SiO ₄	0.21	0.00

Mineral	C (%)	Ca (%)	Ce (%)	Cl (%)	Co (%)	Cr (%)	Cu (%)	Dy (%)	Er (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	34.63	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	3.26	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	12.14	20.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	12.01	39.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	12.94	21.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	10.54	4.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	40.17	0.00	0.62	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.56	3.22
Albite	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	8.28	13.24	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	9.20	0.00	0.24	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	18.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.18	0.00	0.18	0.00	0.00	0.00
Plagioclase	0.00	7.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	17.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.10	5.12	0.00	3.30	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	21.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.86	0.00	0.00	0.00	0.91	0.00	0.00	0.00
Tremolite	0.00	9.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	1.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Mineral	F (%)	Fe (%)	Gd (%)	H (%)	Hf (%)	Ho (%)	K (%)	La (%)	Mg (%)
Chalcopyrite	0.00	30.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	27.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	46.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	58.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	10.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	35.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	72.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	11.16	0.00	0.00	0.00	0.00	0.00	0.00	7.01
Calcite	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Dolomite	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	12.60
Siderite	0.00	42.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	2.27	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.54	1.62	0.00	0.00	1.01	0.00	0.00	0.00
Albite	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	12.81	0.00	0.27	0.00	0.00	0.00	3.91	0.33
Amphibole	0.00	11.83	0.00	0.17	0.00	0.00	0.59	0.00	7.25
Biotite	0.00	20.31	0.00	0.19	0.00	0.00	7.88	0.00	5.16
Chamosite	0.00	37.17	0.00	1.14	0.00	0.00	0.00	0.00	0.42
Chlorite	0.00	20.75	0.00	1.27	0.00	0.00	0.12	0.00	9.76
Cummingtonite	0.00	13.78	0.00	0.24	0.00	0.00	0.00	0.00	13.06
Diopside	0.00	5.69	0.00	0.00	0.00	0.00	0.00	0.00	8.05
K-feldspar	0.00	0.28	0.00	0.00	0.00	0.00	13.35	0.00	0.00
Muscovite	0.00	0.84	0.00	0.40	0.00	0.00	7.54	0.00	0.00
Phlogopite	0.00	4.99	0.00	0.20	0.00	0.00	8.21	0.00	13.16
Plagioclase	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	4.33	0.00	0.48	0.00	0.00	0.00	0.00	0.22
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00
Talc	0.00	2.18	0.00	0.52	0.00	0.00	0.00	0.00	17.05
Titanite	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	2.72	0.00	0.41	0.00	0.00	0.00	0.00	5.53
Tremolite	0.00	5.77	0.00	0.19	0.00	0.00	0.09	0.00	11.70
Zircon	0.00	0.84	0.00	0.00	1.65	0.00	0.00	0.00	0.00

Mineral	Mn (%)	Mo (%)	Na (%)	Nd (%)	Ni (%)	O (%)	P (%)	Pb (%)	Pr (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.60	0.00
Molybdenite	0.00	59.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	36.61	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	1.14	0.00	0.00	0.00	0.00	31.61	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	27.64	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	40.05	0.00	0.00	0.00
Ankerite	0.94	0.00	0.00	0.00	0.00	48.50	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	48.01	0.00	0.00	0.00
Dolomite	0.10	0.00	0.00	0.00	0.00	51.72	0.00	0.00	0.00
Siderite	0.49	0.00	0.00	0.00	0.00	42.13	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	39.07	17.82	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	31.50	14.14	0.00	0.00
Albite	0.00	0.00	8.40	0.00	0.00	48.71	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	1.77	0.00	36.07	0.00	0.00	1.06
Amphibole	0.05	0.00	1.90	0.00	0.00	41.80	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	38.74	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	40.84	0.00	0.00	0.00
Chlorite	0.08	0.00	0.00	0.00	0.00	45.55	0.00	0.00	0.00
Cummingtonite	0.42	0.00	0.00	0.00	0.00	45.11	0.00	0.00	0.00
Diopside	0.15	0.00	0.27	0.00	0.00	42.67	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.24	0.00	0.00	46.06	0.00	0.00	0.00
Muscovite	0.00	0.00	0.46	0.00	0.00	46.82	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	43.33	0.00	0.00	0.00
Plagioclase	0.00	0.00	4.13	0.00	0.00	47.19	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	45.78	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	53.26	0.00	0.00	0.00
Scapolite	0.00	0.00	8.55	0.00	0.00	45.20	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	49.94	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	40.64	0.00	0.00	0.00
Tourmaline	0.00	0.00	1.63	0.00	0.00	50.18	0.00	0.00	0.00
Tremolite	0.11	0.00	0.54	0.00	0.00	44.46	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	35.73	0.00	0.00	0.00

Mineral	S (%)	Si (%)	Tb (%)	Ti (%)	V (%)	Y (%)	Yb (%)	Zn (%)	Zr (%)
Chalcopyrite	34.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	13.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	40.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	32.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	53.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	41.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	33.47	0.00	0.00	0.00	0.00	0.00	0.00	56.36	0.00
Ilmenite	0.00	0.00	0.00	31.45	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	59.95	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.52	0.00	0.00	41.59	2.30	0.00	0.00
Albite	0.00	31.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	14.43	0.00	0.38	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	20.78	0.00	0.96	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	17.12	0.00	2.11	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	11.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	13.31	0.00	0.49	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	26.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	24.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	29.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	23.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	20.40	0.00	1.17	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	25.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	19.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	46.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	25.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	29.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	14.27	0.00	22.72	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	17.14	0.00	0.64	0.57	0.00	0.00	0.00	0.00
Tremolite	0.00	25.73	0.00	0.18	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	15.68	0.00	0.00	0.00	0.00	0.00	0.00	44.21

Appendix 2 Ungrouped Elemental Distribution

Mineral	FW - Al (%)	HGW - Al (%)	Dyke - Al (%)	Sgr - Al (%)	FW - B (%)	HGW - B (%)	Dyke - B (%)	Sgr - B (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	43.17	32.40	7.45	48.73	0.00	0.00	0.00	0.00
Allanite	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Amphibole	8.19	5.63	17.74	1.10	0.00	0.00	0.00	0.00
Biotite	3.91	0.95	3.73	1.08	0.00	0.00	0.00	0.00
Chamosite	0.15	0.05	0.16	0.49	0.00	0.00	0.00	0.00
Chlorite	2.03	1.21	1.18	3.53	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.13	0.13	0.15	0.09	0.00	0.00	0.00	0.00
K-feldspar	0.76	0.90	1.45	4.32	0.00	0.00	0.00	0.00
Muscovite	0.06	0.09	0.31	0.14	0.00	0.00	0.00	0.00
Phlogopite	4.08	9.52	5.83	14.64	0.00	0.00	0.00	0.00
Plagioclase	0.32	1.11	6.38	0.39	0.00	0.00	0.00	0.00
Prehnite	0.01	0.02	0.09	0.32	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	34.74	45.26	53.62	20.10	0.00	0.00	0.00	0.00
Talc	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.21	0.09	0.09	0.18	0.00	0.00	0.00	0.00
Tourmaline	0.09	0.13	0.03	0.00	100.00	100.00	100.00	0.00
Tremolite	2.12	2.44	1.77	4.89	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00

Mineral	FW - C (%)	HGW - C (%)	Dyke - C (%)	Sgr - C (%)	FW - Ca (%)	HGW - Ca (%)	Dyke - Ca (%)	Sgr - Ca (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	2.29	0.03	0.00	0.00	0.08	0.00	0.00
Calcite	43.26	52.21	93.38	66.54	1.29	3.42	23.24	3.09
Dolomite	0.00	13.32	0.11	0.00	0.00	0.44	0.01	0.00
Siderite	8.75	3.20	1.20	14.52	0.03	0.03	0.04	0.08
Apatite	0.00	0.00	0.00	0.00	2.73	3.01	0.96	2.21
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	2.19	1.67	0.22	2.62
Allanite	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02
Amphibole	0.00	0.00	0.00	0.00	21.88	15.25	28.06	3.11
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.04
Chlorite	0.00	0.00	0.00	0.00	0.07	0.04	0.02	0.12
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	15.50	15.24	10.42	11.25
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.25	0.87	2.91	0.32
Prehnite	0.00	0.00	0.00	0.00	0.03	0.04	0.12	0.74
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	47.99	28.98	5.27	18.94	22.44	29.67	20.52	13.76
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	12.80	5.80	3.17	12.02
Tourmaline	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	20.75	24.19	10.26	50.61
Zircon	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Ce (%)	HGW - Ce (%)	Dyke - Ce (%)	Sgr - Ce (%)	FW - Cl (%)	HGW - Cl (%)	Dyke - Cl (%)	Sgr - Cl (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.27	0.23	0.10	0.35
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	3.60	1.98	5.06	0.84
Biotite	0.00	0.00	0.00	0.00	4.05	0.79	2.51	1.94
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.04
Phlogopite	0.00	0.00	0.00	0.00	0.86	1.61	0.80	5.34
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	91.21	95.37	91.49	91.49
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Co (%)	HGW - Co (%)	Dyke - Co (%)	Sgr - Co (%)	FW - Cr (%)	HGW - Cr (%)	Dyke - Cr (%)	Sgr - Cr (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	94.44	96.61	98.66	100.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	5.56	3.39	1.34	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Cu (%)	HGW - Cu (%)	Dyke - Cu (%)	Sgr - Cu (%)	FW - Dy (%)	HGW - Dy (%)	Dyke - Dy (%)	Sgr - Dy (%)
Chalcopyrite	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	0.00

Mineral	FW - Er (%)	HGW - Er (%)	Dyke - Er (%)	Sgr - Er (%)	FW - F (%)	HGW - F (%)	Dyke - F (%)	Sgr - F (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
Xenotime	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - Fe (%)	HGW - Fe (%)	Dyke - Fe (%)	Sgr - Fe (%)	FW - Gd (%)	HGW - Gd (%)	Dyke - Gd (%)	Sgr - Gd (%)
Chalcopyrite	0.41	0.29	0.29	0.60	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Pyrite	4.59	4.91	4.78	18.42	0.00	0.00	0.00	0.00
Pyrrhotite	68.50	75.16	55.21	53.88	0.00	0.00	0.00	0.00
Sphalerite	0.04	0.00	0.00	0.10	0.00	0.00	0.00	0.00
Ilmenite	1.51	0.16	0.76	0.05	0.00	0.00	0.00	0.00
Iron-oxide	4.25	0.15	0.15	0.21	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.01	0.13	0.01	0.00	0.00	0.00	0.00
Dolomite	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.09	0.08	0.23	0.29	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Albite	0.27	0.22	0.06	0.41	0.00	0.00	0.00	0.00
Allanite	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Amphibole	7.77	5.77	22.70	1.39	0.00	0.00	0.00	0.00
Biotite	4.34	1.14	5.59	1.60	0.00	0.00	0.00	0.00
Chamosite	0.29	0.10	0.41	1.27	0.00	0.00	0.00	0.00
Chlorite	2.08	1.34	1.63	4.84	0.00	0.00	0.00	0.00
Cummingtonite	0.01	2.30	0.00	0.02	0.00	0.00	0.00	0.00
Diopside	1.33	1.40	2.04	1.22	0.00	0.00	0.00	0.00
K-feldspar	0.01	0.01	0.02	0.07	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Phlogopite	1.04	2.64	2.01	5.01	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.01	0.06	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.02	0.06	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.05	0.02	0.03	0.06	0.00	0.00	0.00	0.00
Tourmaline	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	3.40	4.23	3.83	10.47	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	0.00

Mineral	FW - H (%)	HGW - H (%)	Dyke - H (%)	Sgr - H (%)	FW - Hf (%)	HGW - Hf (%)	Dyke - Hf (%)	Sgr - Hf (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.21	0.23	0.11	0.10	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.02	0.04	0.04	0.02	0.00	0.00	0.00	0.00
Amphibole	25.06	17.56	46.30	2.16	0.00	0.00	0.00	0.00
Biotite	9.12	2.26	7.42	1.62	0.00	0.00	0.00	0.00
Chamosite	2.03	0.62	1.77	4.21	0.00	0.00	0.00	0.00
Chlorite	28.59	17.36	14.15	31.98	0.00	0.00	0.00	0.00
Cummingtonite	0.03	8.48	0.00	0.03	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.12	0.17	0.50	0.16	0.00	0.00	0.00	0.00
Phlogopite	9.39	22.35	11.45	21.68	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.05	0.06	0.29	0.76	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	1.10	0.00	0.01	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.22	0.32	0.06	0.00	0.00	0.00	0.00	0.00
Tremolite	25.14	29.46	17.91	37.25	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Ho (%)	HGW - Ho (%)	Dyke - Ho (%)	Sgr - Ho (%)	FW - K (%)	HGW - K (%)	Dyke - K (%)	Sgr - K (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	8.65	4.82	13.74	0.56
Biotite	0.00	0.00	0.00	0.00	37.63	7.41	26.34	4.98
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.27	0.13	0.11	0.22
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	9.41	9.08	13.19	25.59
Muscovite	0.00	0.00	0.00	0.00	0.23	0.26	0.80	0.23
Phlogopite	0.00	0.00	0.00	0.00	38.31	72.62	40.19	65.92
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	4.32	4.57	4.90	1.20
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	1.18	1.10	0.73	1.31
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	0.00	0.00	100.00	100.00	100.00	100.00

Mineral	FW - La (%)	HGW - La (%)	Dyke - La (%)	Sgr - La (%)	FW - Mg (%)	HGW - Mg (%)	Dyke - Mg (%)	Sgr - Mg (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.02	0.03	0.38	0.02
Dolomite	0.00	0.00	0.00	0.00	0.00	0.31	0.02	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	25.87	14.49	43.19	2.15
Biotite	0.00	0.00	0.00	0.00	6.00	1.19	4.41	1.02
Chamosite	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.04
Chlorite	0.00	0.00	0.00	0.00	5.32	2.58	2.38	5.72
Cummingtonite	0.00	0.00	0.00	0.00	0.04	8.92	0.01	0.04
Diopside	0.00	0.00	0.00	0.00	10.25	8.09	8.97	4.35
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	14.95	28.45	16.48	33.22
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.01
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.07	0.08	0.02	0.00
Tremolite	0.00	0.00	0.00	0.00	37.47	35.11	24.13	53.42
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Mn (%)	HGW - Mn (%)	Dyke - Mn (%)	Sgr - Mn (%)	FW - Mo (%)	HGW - Mo (%)	Dyke - Mo (%)	Sgr - Mo (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	25.27	2.24	9.44	0.57	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.46	0.04	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.27	0.02	0.00	0.00	0.00	0.00	0.00
Siderite	0.54	0.39	1.04	1.28	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	17.27	10.86	37.45	2.25	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	4.22	2.30	2.45	7.12	0.00	0.00	0.00	0.00
Cummingtonite	0.11	31.20	0.02	0.21	0.00	0.00	0.00	0.00
Diopside	18.49	16.39	21.01	12.30	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	34.10	35.88	28.52	76.27	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Na (%)	HGW - Na (%)	Dyke - Na (%)	Sgr - Na (%)	FW - Nd (%)	HGW - Nd (%)	Dyke - Nd (%)	Sgr - Nd (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	53.95	41.49	10.95	69.37	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
Amphibole	4.78	3.36	12.18	0.73	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.24	0.24	0.32	0.19	0.00	0.00	0.00	0.00
K-feldspar	0.03	0.04	0.07	0.19	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.14	0.49	3.26	0.19	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	39.63	52.92	72.00	26.13	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Tremolite	1.22	1.44	1.20	3.20	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Ni (%)	HGW - Ni (%)	Dyke - Ni (%)	Sgr - Ni (%)	FW - O (%)	HGW - O (%)	Dyke - O (%)	Sgr - O (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.56	0.05	0.20	0.01
Iron-oxide	0.00	0.00	0.00	0.00	0.68	0.02	0.02	0.02
Rutile	0.00	0.00	0.00	0.00	0.08	0.29	0.06	0.19
Ankerite	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.18	0.46	5.41	0.37
Dolomite	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.00
Siderite	0.00	0.00	0.00	0.00	0.04	0.03	0.07	0.08
Apatite	0.00	0.00	0.00	0.00	0.31	0.33	0.18	0.21
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	34.16	25.09	5.76	34.75
Allanite	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Amphibole	0.00	0.00	0.00	0.00	11.48	7.72	24.28	1.39
Biotite	0.00	0.00	0.00	0.00	3.47	0.82	3.23	0.86
Chamosite	0.00	0.00	0.00	0.00	0.14	0.04	0.13	0.39
Chlorite	0.00	0.00	0.00	0.00	1.91	1.11	1.08	2.99
Cummingtonite	0.00	0.00	0.00	0.00	0.01	2.85	0.00	0.02
Diopside	0.00	0.00	0.00	0.00	4.18	3.96	4.63	2.58
K-feldspar	0.00	0.00	0.00	0.00	0.61	0.71	1.14	3.11
Muscovite	0.00	0.00	0.00	0.00	0.03	0.04	0.12	0.05
Phlogopite	0.00	0.00	0.00	0.00	3.79	8.66	5.29	12.25
Plagioclase	0.00	0.00	0.00	0.00	0.17	0.59	3.38	0.19
Prehnite	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.19
Quartz	0.00	0.00	0.00	0.00	1.51	4.07	0.32	3.42
Scapolite	0.00	0.00	0.00	0.00	22.88	29.18	34.51	11.93
Talc	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	2.79	1.22	1.14	2.23
Tourmaline	0.00	0.00	0.00	0.00	0.05	0.07	0.02	0.00
Tremolite	0.00	0.00	0.00	0.00	10.96	12.33	8.94	22.73
Zircon	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.02
Total	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - P (%)	HGW - P (%)	Dyke - P (%)	Sgr - P (%)	FW - Pb (%)	HGW - Pb (%)	Dyke - Pb (%)	Sgr - Pb (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	100.00	0.00	0.00	100.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	100.00	99.74	100.00	100.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	0.00	0.00	100.00

Mineral	FW - Pr (%)	HGW - Pr (%)	Dyke - Pr (%)	Sgr - Pr (%)	FW - S (%)	HGW - S (%)	Dyke - S (%)	Sgr - S (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.87	0.55	0.74	1.14
Galena	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.03
Molybdenite	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.01
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03
Pyrite	0.00	0.00	0.00	0.00	9.68	9.52	12.21	35.03
Pyrrhotite	0.00	0.00	0.00	0.00	89.13	89.89	87.01	63.24
Sphalerite	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.54
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	FW - Si (%)	HGW - Si (%)	Dyke - Si (%)	Sgr - Si (%)	FW - Tb (%)	HGW - Tb (%)	Dyke - Tb (%)	Sgr - Tb (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Albite	39.34	28.32	7.35	38.99	0.00	0.00	0.00	0.00
Allanite	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Amphibole	10.14	6.68	23.78	1.19	0.00	0.00	0.00	0.00
Biotite	2.72	0.63	2.81	0.66	0.00	0.00	0.00	0.00
Chamosite	0.07	0.02	0.08	0.20	0.00	0.00	0.00	0.00
Chlorite	0.99	0.57	0.62	1.51	0.00	0.00	0.00	0.00
Cummingtonite	0.01	2.96	0.00	0.02	0.00	0.00	0.00	0.00
Diopside	4.29	3.99	5.28	2.58	0.00	0.00	0.00	0.00
K-feldspar	0.70	0.80	1.45	3.50	0.00	0.00	0.00	0.00
Muscovite	0.02	0.03	0.12	0.04	0.00	0.00	0.00	0.00
Phlogopite	3.17	7.09	4.91	9.98	0.00	0.00	0.00	0.00
Plagioclase	0.17	0.55	3.59	0.18	0.00	0.00	0.00	0.00
Prehnite	0.01	0.01	0.05	0.14	0.00	0.00	0.00	0.00
Quartz	2.35	6.22	0.55	5.20	0.00	0.00	0.00	0.00
Scapolite	22.96	28.70	38.40	11.67	0.00	0.00	0.00	0.00
Talc	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	1.74	0.75	0.79	1.35	0.00	0.00	0.00	0.00
Tourmaline	0.03	0.04	0.01	0.00	0.00	0.00	0.00	0.00
Tremolite	11.27	12.42	10.19	22.77	0.00	0.00	0.00	0.00
Zircon	0.02	0.01	0.00	0.02	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	0.00

Mineral	FW - Ti (%)	HGW - Ti (%)	Dyke - Ti (%)	Sgr - Ti (%)	FW - V (%)	HGW - V (%)	Dyke - V (%)	Sgr - V (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	19.42	3.11	10.89	0.56	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	4.21	25.78	4.88	13.72	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Amphibole	9.23	10.49	30.06	1.53	0.00	0.00	0.00	0.00
Biotite	6.61	2.65	9.48	2.26	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.72	0.71	0.63	1.55	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.01	0.03	0.01	0.00	0.00	0.00	0.00
Phlogopite	3.58	13.84	7.70	15.93	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	54.64	40.39	34.37	60.00	0.00	0.00	0.00	0.00
Tourmaline	0.02	0.05	0.01	0.00	100.00	100.00	100.00	0.00
Tremolite	1.55	2.95	1.95	4.43	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00

Mineral	FW - Y (%)	HGW - Y (%)	Dyke - Y (%)	Sgr - Y (%)	FW - Yb (%)	HGW - Yb (%)	Dyke - Yb (%)	Sgr - Yb (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cumingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00

Mineral	FW - Zn (%)	HGW - Zn (%)	Dyke - Zn (%)	Sgr - Zn (%)	FW - Zr (%)	HGW - Zr (%)	Dyke - Zr (%)	Sgr - Zr (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Galena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentlandite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	100.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Ilmenite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron-oxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ankerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolomite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siderite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xenotime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphibole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chamosite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cummingtonite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscovite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlogopite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prehnite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scapolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tremolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zircon	0.00	0.00	0.00	0.00	100.00	100.00	100.00	100.00
Total	100.00	0.00	0.00	100.00	100.00	100.00	100.00	100.00

Unknown Mine

Reactive Ground Testing

Report Nr: RG1902

2019-02-04

Niklas Sandberg

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1. Summary

A rock sample (ID SGR) was sent from an unknown site to Orica Gyttorp for reactive ground testing. The sample underwent a 7-day screening test with ammonium nitrate at 55°C. The sample was found to be reactive.

2. Conclusions

The rock sample (ID SGR) from an unknown site was found to be reactive according to AEISG – code of practice, Elevated temperature and Reactive ground.

3. Recommendation

Based on the testing performed on sample (ID SGR), it is recommended to do further testing with inhibited formulations to ensure that no potential reactions will arise during operations.

In the event that mining operations progress into new geology known to contain sulphides, it is recommended to conduct further sampling and testing every 12 months to assess the potential for reactivity.

Note that this recommendation is based solely on the results of the samples provided for testing. It is possible that none of these samples represent the most reactive ground in the specific region or area covered by the sampling. It is also possible that weathering of the ground after sampling and prior to loading with explosive product could render the ground more reactive than indicated by the samples provided for testing.

4. Results

4.1 Isothermal screening test

Figure 1 show the temperature log from the screening tests. The sample was tested for 7 days at 55°C with ammonium nitrate. A reaction between nitrate (from the ammonium nitrate) and sulphide (from the rock sample) is characterized by an exothermic peak in the graphs. If an exotherm exceeds 2°C, the sample is considered to be reactive.

The sample SGR was found to be reactive with an exothermic peak of 8.3°C.

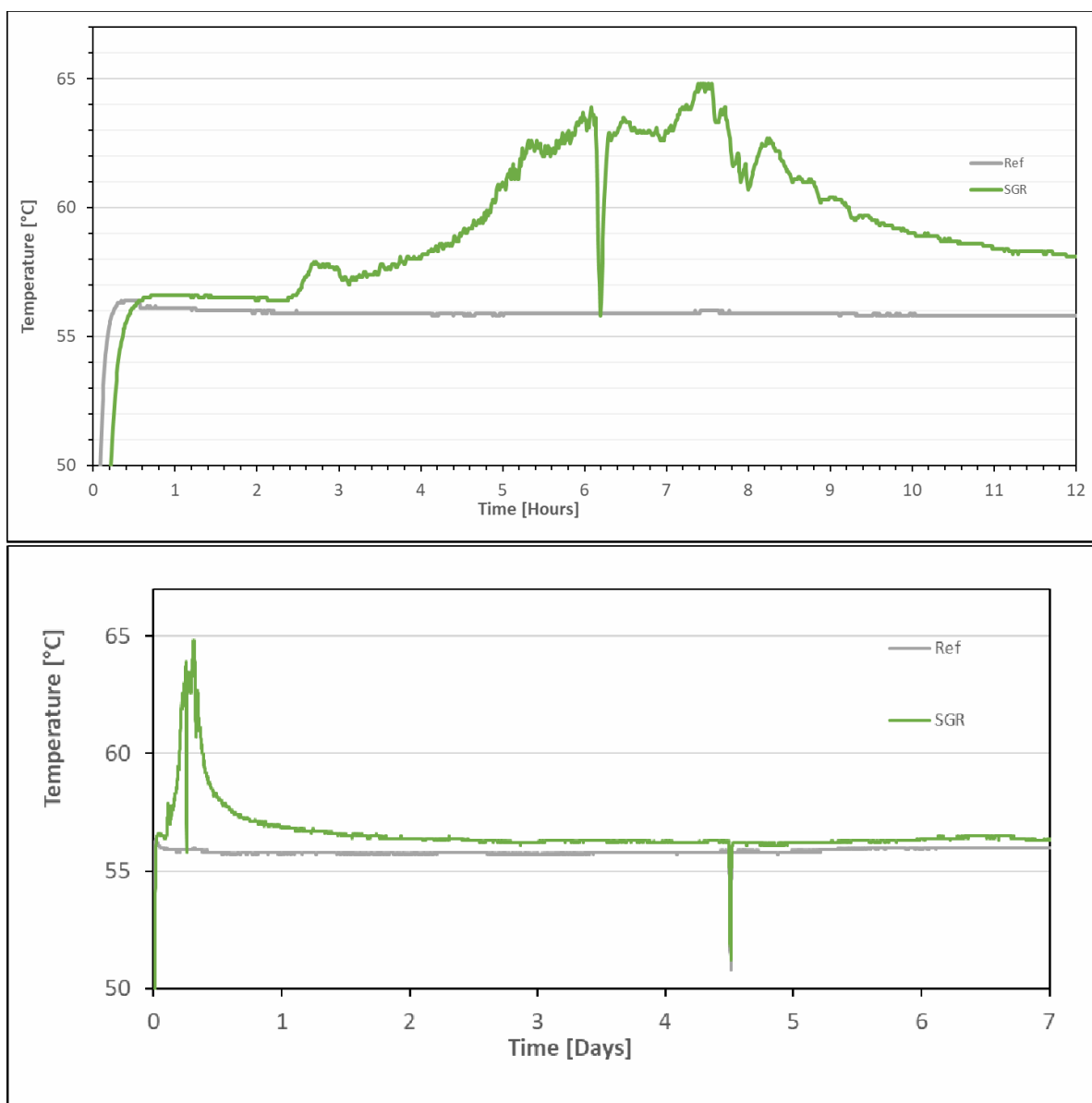


Figure 1: Temperature log of sample SGR tested at 55°C for 7 days. The first graph shows the first 12 hours of the test and the second graph shows the entire 7 days. Sample SGR created an exothermic peak of 8.3°C and thus is characterized as reactive.

5. Experimental

The reactive ground test performed is based on the procedure recommended in the AEISG Code of Practice [1]. The setup of the equipment can be seen in figures 7-8.

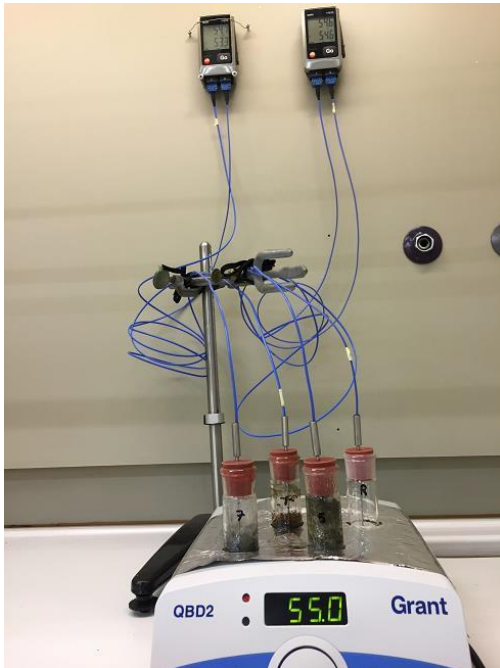


Figure 7: Setup of the reactive ground test.

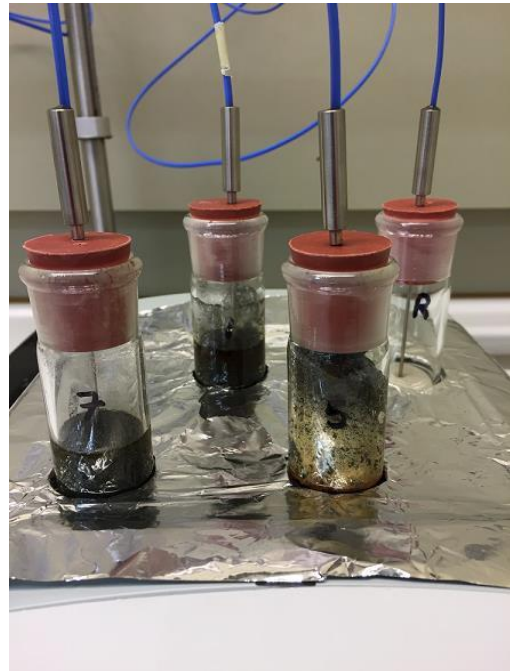


Figure 8: Setup of the test tubes with thermocouples inside to log temperature.

6. References

[1] *AEISG Code of Practice: Elevated temperature and reactive ground. Edition 3. June 2012. Pages 30-35.*

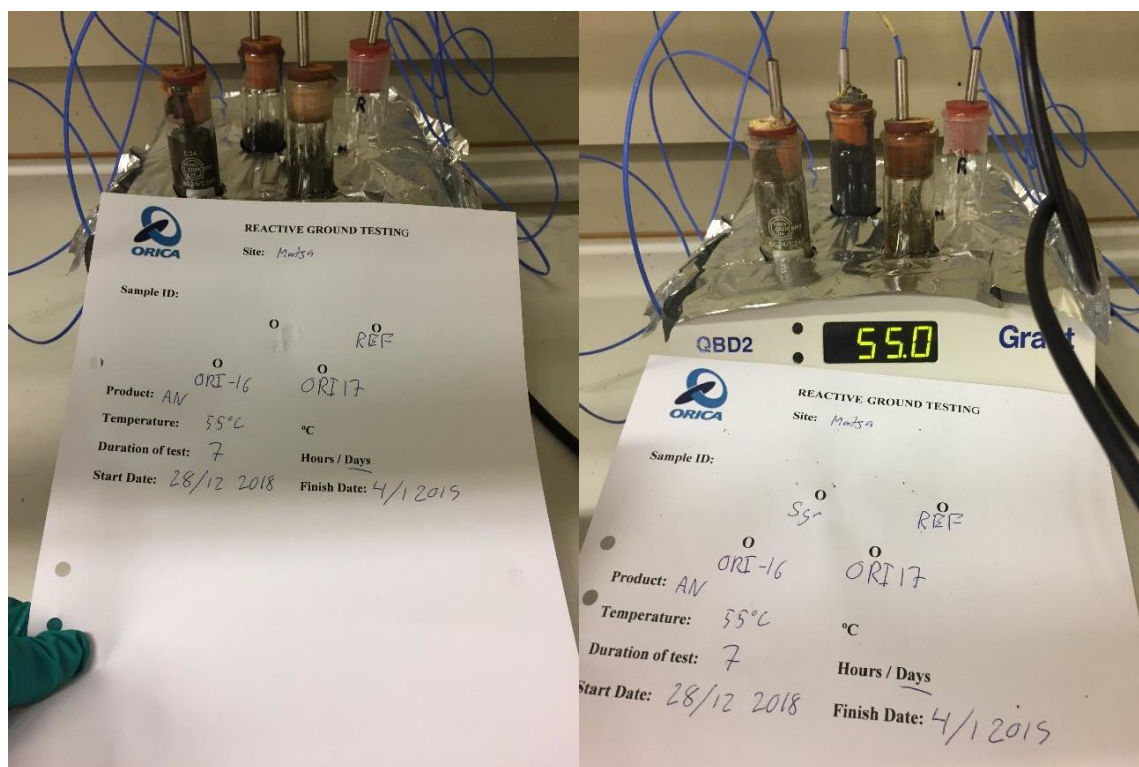
7. Authorisation

Niklas P Sandberg
PPIS Technologist

Margarita Nikolova
PPIS Team Leader EMET

Appendix 1: Before and After-test pictures

Pictures of setup before test on the left and after test on the right.



Enhanced picture of SGR sample before test on the left and after test on the right.



Lechate data Dyke

	El. cond.	pH	Alkalinity
	(uS/cm)		(meq/L)
Dyke 2018-07-24	297	6,83	0,68
Dyke 2018-07-31	643	4,32	0,00
Dyke 2018-08-07	582	7,23	2,41
Dyke 2018-08-14	573	7,57	0,97
Dyke 2018-08-21	611	7,87	0,54
Dyke 2018-08-28	564	7,79	1,26
Dyke 2018-09-04	481	7,88	1,14
Dyke 2018-09-18	605	7,83	1,84
Dyke 2018-09-25	506	7,79	0,00
Dyke 2018-10-02	664	7,9	0,49
Dyke 2018-10-09	454	7,79	0,42
Dyke 2018-10-17	680	7,71	
Dyke 2018-10-24	591	7,51	0,52
Dyke 2018-10-31	497	7,45	0,54
Dyke 2018-11-06	450	7,65	0,48
Dyke 2018-11-13	440	7,53	0,50
Dyke 2018-11-21	512	7,39	0,46
Dyke 2018-11-29	602	6,94	0,42
Dyke 2018-12-06	425	7,14	0,34
Dyke 2018-12-13	395	7,12	0,38
Dyke 2018-12-21	431	7,28	0,22
Dyke 2019-01-24	509	7,27	0,26
Dyke 2019-01-31	474	7,24	0,38
Dyke 2019-02-08	528	7,14	0,60
Dyke 2019-02-15	556	7,21	0,58
Dyke 2019-02-22	522	7,19	0,56
Dyke 2019-03-01	550	7,26	0,36
Dyke 2019-03-09	503	7,36	0,62
Dyke 2019-03-15	544	7,31	0,54
Dyke 2019-03-22	450	7,18	0,38



Lechate data Footwall (FW)

	El. cond.	pH	Alkalinity
	(uS/cm)		(meq/L)
FW 2018-07-24	611	5,81	0,00
FW 2018-07-31	769	4,71	0,00
FW 2018-08-07	682	6,3	0,20
FW 2018-08-14	682	6,33	0,14
FW 2018-08-21	609	6,61	0,15
FW 2018-08-28	620	6,44	0,10
FW 2018-09-04	606	6,36	0,08
FW 2018-09-18	561	6,44	0,00
FW 2018-09-25	625	6,49	0,08
FW 2018-10-02	594	6,42	0,06
FW 2018-10-09	450	5,91	0,03
FW 2018-10-17	531	6,25	
FW 2018-10-24	505	5,93	0,08
FW 2018-10-31	553	6,26	0,08
FW 2018-11-06	535	6,26	0,06
FW 2018-11-13	370	5,7	0,00
FW 2018-11-21	482	6,29	0,00
FW 2018-11-29	504	6,21	0,06
FW 2018-12-06	334	5,62	0,00
FW 2018-12-13	388	6,03	0,06
FW 2018-12-21	375	5,81	0,04
FW 2019-01-24	545	5,85	0,00
FW 2019-01-31	369	6,05	0,00
FW 2019-02-08	374	5,5	0,00
FW 2019-02-15	460	5,6	0,00
FW 2019-02-22	460	5,76	0,08
FW 2019-03-01	332	5,55	0,00
FW 2019-03-09	317	5,34	0,00
FW 2019-03-15	427	5,26	0,00
FW 2019-03-22	408	5,05	-0,08



Lechate data Hanging Wall (HGW)

	El. cond.	pH	Alkalinity
	(uS/cm)		(meq/L)
HGW 2018-07-24	623	6,61	0,77
HGW 2018-07-31	743	5,03	0,00
HGW 2018-08-07	731	6,31	0,22
HGW 2018-08-14	545	6,26	0,22
HGW 2018-08-21	824	6,94	0,00
HGW 2018-08-28	778	6,62	0,30
HGW 2018-09-04	744	6,72	0,28
HGW 2018-09-18	468	6,89	0,30
HGW 2018-09-25	713	7,13	0,22
HGW 2018-10-02	782	6,83	0,06
HGW 2018-10-09	649	6,86	0,19
HGW 2018-10-17	908	6,99	
HGW 2018-10-24	687	6,77	0,20
HGW 2018-10-31	860	6,75	0,22
HGW 2018-11-06	902	6,76	0,22
HGW 2018-11-13	833	6,73	0,16
HGW 2018-11-21	839	6,94	0,28
HGW 2018-11-29	725	6,89	0,16
HGW 2018-12-06	576	6,54	0,04
HGW 2018-12-13	601	6,34	0,16
HGW 2018-12-21	596	6,65	0,48
HGW 2019-01-24	632	6,36	0,00
HGW 2019-01-31	602	6,64	0,00
HGW 2019-02-08	538	6,57	0,16
HGW 2019-02-15	687	6,63	0,16
HGW 2019-02-22	583	6,61	0,20
HGW 2019-03-01	544	6,54	0,52
HGW 2019-03-09	566	6,5	0,16
HGW 2019-03-15	543	6,42	0,18
HGW 2019-03-22	416	6,24	0,10



Lechate data Ore samples (Sgr)

	El. cond.	pH	Alkalinity
	(uS/cm)		(meq/L)
Sgr 2018-07-24	591	6,61	1,06
Sgr 2018-07-31	848	6,63	0,60
Sgr 2018-08-07	536	5,18	0,00
Sgr 2018-08-14	621	4,88	0,00
Sgr 2018-08-21	840	6,81	0,24
Sgr 2018-08-28	651	6,78	0,12
Sgr 2018-09-04	612	6,82	0,20
Sgr 2018-09-18	615	6,58	0,20
Sgr 2018-09-25	625	6,43	0,10
Sgr 2018-10-02	546	6,34	0,07
Sgr 2018-10-09	629	5,87	0,04
Sgr 2018-10-17	660	6,61	
Sgr 2018-10-24	864	6,29	0,16
Sgr 2018-10-31	633	6,35	0,06
Sgr 2018-11-06	548	6,3	0,08
Sgr 2018-11-13	579	6,23	0,08
Sgr 2018-11-21	647	5,99	0,00
Sgr 2018-11-29	504	5,84	0,00
Sgr 2018-12-06	493	4,51	-0,12
Sgr 2018-12-13	413	4,44	-0,14
Sgr 2018-12-21	524	4,18	0,00
Sgr 2019-01-24	657	4,7	-0,32
Sgr 2019-01-31	552	5,34	-0,32
Sgr 2019-02-08	659	4,27	-0,14
Sgr 2019-02-15	547	4,32	-0,20
Sgr 2019-02-22	572	4,47	-0,16
Sgr 2019-03-01	535	4,62	-0,14
Sgr 2019-03-09	469	4,69	-0,18
Sgr 2019-03-15	575	4,51	-0,18
Sgr 2019-03-22	461	4,54	-0,18



Appendix 7

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS
	Ag ppb	Al ppb	As ppb	Au ppb	B ppb	Ba ppb	Be ppb	Bi ppb	Ca ppb	Cd ppb	Ce ppb	Co ppb	Cr ppb
Dyke 2018-07-24	0,10	750,00	0,50	<0,2	180,00	<0,1	<0,5	<0,1	197 180,00	<0,1	0,30	8,20	<0,5
Dyke 2018-07-31	0,10	<200	<0,5	<0,2	<100	3,70	<0,5	<0,1	448 710,00	0,20	0,20	11,60	0,50
Dyke 2018-08-07	<0,1	<200	<0,5	<0,2	<100	<0,1	<0,5	<0,1	373 910,00	<0,1	0,20	6,80	<0,5
Dyke 2018-08-14	<0,1	<200	<0,5	<0,2	<100	<0,1	<0,5	<0,1	410 780,00	<0,1	0,10	3,20	<0,5
Dyke 2018-08-21	1,00	<200	<0,5	<0,2	<100	0,30	<0,5	0,10	446 960,00	<0,1	0,20	2,10	<0,5
Dyke 2018-08-28	0,40	<200	<0,5	<0,2	<100	<0,1	<0,5	<0,1	466 830,00	<0,1	<0,1	2,00	<0,5
Dyke 2018-09-04	0,20	<200	<0,5	<0,2	<100	0,40	<0,5	<0,1	388 430,00	<0,1	<0,1	1,50	<0,5
Dyke 2018-09-18	0,20	<200	<0,5	<0,2	<100	<0,1	<0,5	<0,1	501 760,00	<0,1	<0,1	0,70	<0,5
Dyke 2018-09-25	<0,1	<200	<0,5	<0,2	<100	<0,1	<0,5	<0,1	475 020,00	<0,1	<0,1	2,40	<0,5
Dyke 2018-10-02	0,20	<200	1,20	<0,2	<100	4,90	<0,5	<0,1	494 450,00	<0,1	0,10	2,90	<0,5
Dyke 2018-10-09	<0,1	<200	<0,5	<0,2	<100	4,50	<0,5	<0,1	392 230,00	<0,1	<0,1	3,60	<0,5
Dyke 2018-10-17	<0,1	<200	<0,5	<0,2	<100	4,10	<0,5	<0,1	513 030,00	<0,1	<0,1	3,40	<0,5
Dyke 2018-10-24	<0,1	<200	<0,5	<0,2	<100	3,40	<0,5	<0,1	493 780,00	<0,1	<0,1	3,80	<0,5
Dyke 2018-10-31	1,00	<200	<0,5	<0,2	<100	2,70	<0,5	0,10	409 170,00	<0,1	<0,1	1,80	<0,5
Dyke 2018-11-06	0,20	<200	<0,5	<0,2	<100	2,90	<0,5	<0,1	368 020,00	<0,1	<0,1	1,20	<0,5
Dyke 2018-11-13	<0,1	<200	<0,5	<0,2	<100	3,50	<0,5	<0,1	403 280,00	0,20	<0,1	8,10	<0,5
Dyke 2018-11-21	<0,1	<200	<0,5	<0,2	<100	4,20	<0,5	<0,1	465 950,00	<0,1	<0,1	5,00	<0,5
Dyke 2018-11-29	1,70	<200	2,10	<0,2	<100	5,80	<0,5	<0,1	479 740,00	<0,1	0,10	1,90	<0,5
Dyke 2018-12-06	0,40	<200	1,10	<0,2	<100	4,20	<0,5	<0,1	385 400,00	<0,1	<0,1	6,20	<0,5
Dyke 2018-12-13	<0,1	<200	0,60	<0,2	<100	3,30	<0,5	<0,1	379 030,00	<0,1	<0,1	8,80	<0,5
Dyke 2018-12-21	<0,1	<200	0,70	<0,2	<100	7,40	<0,5	<0,1	440 500,00	<0,1	<0,1	2,80	<0,5
Dyke 2019-01-24	<0,1	<200	0,90	<0,2	<100	4,40	<0,5	<0,1	512 940,00	<0,1	<0,1	14,40	<0,5
Dyke 2019-01-31	0,70	<200	1,10	<0,2	<100	5,10	<0,5	<0,1	461 760,00	<0,1	<0,1	10,80	<0,5
Dyke 2019-02-08	<0,1	<200	<0,5	<0,2	<100	6,40	<0,5	<0,1	529 670,00	<0,1	<0,1	18,40	<0,5
Dyke 2019-02-15	<0,1	<200	<0,5	<0,2	<100	7,00	<0,5	<0,1	552 020,00	<0,1	<0,1	12,90	<0,5
Dyke 2019-02-22	<0,1	<200	<0,5	<0,2	<100	5,70	<0,5	<0,1	483 500,00	<0,1	<0,1	14,50	<0,5
Dyke 2019-03-01	0,70	<200	0,50	<0,2	<100	5,30	<0,5	<0,1	550 310,00	<0,1	<0,1	11,00	<0,5
Dyke 2019-03-09	0,10	<200	<0,5	<0,2	<100	4,40	<0,5	<0,1	496 150,00	<0,1	<0,1	11,00	<0,5
Dyke 2019-03-15	<0,1	<200	<0,5	<0,2	<100	4,40	<0,5	<0,1	542 150,00	<0,1	<0,1	12,20	<0,5
Dyke 2019-03-22	<0,1	<200	<0,5	<0,2	<100	4,70	<0,5	<0,1	446 950,00	0,10	<0,1	18,10	<0,5
FW 2018-07-24	0,10	<200	0,50	<0,2	227,00	4,40	<0,5	<0,1	429 210,00	<0,1	0,20	25,50	<0,5
FW 2018-07-31	<0,1	<200	<0,5	<0,2	136,00	6,00	<0,5	<0,1	516 780,00	0,20	0,30	15,90	<0,5
FW 2018-08-07	<0,1	<200	<0,5	<0,2	<100	4,20	<0,5	<0,1	491 710,00	0,10	0,20	11,30	<0,5
FW 2018-08-14	<0,1	<200	<0,5	<0,2	<100	3,80	<0,5	<0,1	473 890,00	<0,1	0,10	9,70	<0,5
FW 2018-08-21	0,70	<200	<0,5	<0,2	<100	0,50	<0,5	<0,1	435 870,00	0,10	0,10	6,60	<0,5
FW 2018-08-28	0,30	<200	<0,5	<0,2	<100	4,40	<0,5	<0,1	483 050,00	0,20	<0,1	12,50	<0,5
FW 2018-09-04	0,10	<200	<0,5	<0,2	<100	4,50	<0,5	<0,1	459 330,00	0,30	<0,1	15,40	<0,5
FW 2018-09-18	0,10	<200	<0,5	<0,2	<100	2,70	<0,5	<0,1	470 660,00	<0,1	<0,1	19,60	<0,5
FW 2018-09-25	0,70	<200	0,60	<0,2	<100	8,50	<0,5	<0,1	573 410,00	<0,1	0,20	23,20	<0,5
FW 2018-10-02	0,20	<200	<0,5	<0,2	<100	11,00	<0,5	<0,1	452 560,00	0,40	0,10	22,20	<0,5
FW 2018-10-09	0,20	<200	0,50	<0,2	<100	5,70	<0,5	<0,1	291 080,00	<0,1	0,10	21,30	<0,5
FW 2018-10-17	<0,1	<200	<0,5	<0,2	<100	5,50	<0,5	<0,1	382 590,00	0,20	0,10	25,50	<0,5
FW 2018-10-24	<0,1	<200	1,40	<0,2	<100	5,10	<0,5	<0,1	394 560,00	<0,1	0,10	29,70	<0,5
FW 2018-10-31	0,60	<200	<0,5	<0,2	<100	6,10	<0,5	<0,1	418 300,00	0,20	<0,1	24,50	<0,5
FW 2018-11-06	0,20	<200	<0,5	<0,2	<100	5,60	<0,5	<0,1	387 960,00	0,20	<0,1	22,20	<0,5
FW 2018-11-13	<0,1	<200	<0,5	<0,2	<100	6,30	<0,5	<0,1	275 040,00	<0,1	<0,1	21,40	<0,5
FW 2018-11-21	<0,1	<200	<0,5	<0,2	<100	5,30	<0,5	<0,1	348 840,00	<0,1	<0,1	23,90	<0,5
FW 2018-11-29	0,90	<200	1,20	<0,2	<100	8,80	<0,5	<0,1	388 340,00	<0,1	<0,1	26,50	<0,5
FW 2018-12-06	0,20	<200	0,90	<0,2	<100	5,70	<0,5	<0,1	281 790,00	<0,1	<0,1	21,10	<0,5
FW 2018-12-13	<0,1	<200	<0,5	<0,2	<100	7,30	<0,5	<0,1	309 470,00	<0,1	<0,1	22,00	<0,5
FW 2018-12-21	<0,1	<200	0,90	<0,2	<100	8,30	<0,5	<0,1	329 770,00	<0,1	<0,1	26,90	<0,5
FW 2019-01-24	<0,1	<200	0,60	<0,2	<100	6,30	<0,5	<0,1	471 050,00	0,20	<0,1	39,70	<0,5
FW 2019-01-31	0,40	<200	1,10	<0,2	<100	5,80	<0,5	<0,1	302 010,00	0,30	<0,1	28,70	<0,5
FW 2019-02-08	<0,1	<200	<0,5	<0,2	<100	4,80	<0,5	<0,1	305 170,00	<0,1	<0,1	24,80	<0,5
FW 2019-02-15	0,10	<200	<0,5	<0,2	<100	6,30	<0,5	<0,1	409 280,00	<0,1	<0,1	32,90	<0,5
FW 2019-02-22	<0,1	<200	0,70	<0,2	<100	6,80	<0,5	<0,1	383 180,00	0,30	<0,1	31,80	<0,5
FW 2019-03-01	0,40	<200	<0,5	<0,2	<100	5,50	<0,5	<0,1	271 170,00	<0,1	<0,1	25,70	<0,5
FW 2019-03-09	<0,1	<200	<0,5	<0,2	<100	5,80	<0,5	<0,1	271 580,00	<0,1	<0,1	32,10	<0,5
FW 2019-03-15	<0,1	<200	<0,5	<0,2	<100	5,00	<0,5	<0,1	360 110,00	0,20	0,10	42,90	<0,5
FW 2019-03-22	<0,1	<200	<0,5	<0,2	<100	5,60	<0,5	<0,1	308 160,00	0,20	0,10	35,60	<0,5

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS
	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
HGW 2018-07-24	0,30	<200	<0,5	<0,2	108,00	3,40	<0,5	<0,1	452 400,00	<0,1	0,20	26,90	<0,5
HGW 2018-07-31	0,20	<200	2,20	<0,2	107,00	10,90	<0,5	<0,1	531 500,00	<0,1	0,20	14,50	0,50
HGW 2018-08-07	<0,1	<200	<0,5	<0,2	<100	9,40	<0,5	<0,1	566 010,00	0,20	0,20	9,10	0,50
HGW 2018-08-14	<0,1	<200	0,90	<0,2	<100	1,80	<0,5	<0,1	352 220,00	<0,1	0,20	17,90	0,60
HGW 2018-08-21	<0,1	<200	<0,5	<0,2	132,00	4,70	<0,5	<0,1	570 310,00	0,20	0,20	27,70	0,90
HGW 2018-08-28	0,60	<200	<0,5	<0,2	139,00	4,90	<0,5	0,10	489 260,00	0,30	<0,1	33,40	0,80
HGW 2018-09-04	0,20	<200	<0,5	<0,2	116,00	4,70	<0,5	<0,1	551 500,00	<0,1	<0,1	13,70	<0,5
HGW 2018-09-18	0,10	<200	<0,5	<0,2	<100	2,00	<0,5	<0,1	375 040,00	<0,1	<0,1	10,60	<0,5
HGW 2018-09-25	<0,1	<200	<0,5	<0,2	<100	5,80	<0,5	<0,1	617 390,00	0,20	<0,1	12,90	<0,5
HGW 2018-10-02	0,40	<200	<0,5	<0,2	<100	11,40	<0,5	<0,1	664 330,00	<0,1	0,10	13,70	<0,5
HGW 2018-10-09	0,20	<200	<0,5	<0,2	<100	9,70	<0,5	<0,1	483 410,00	<0,1	0,20	18,20	<0,5
HGW 2018-10-17	<0,1	<200	<0,5	<0,2	132,00	13,20	<0,5	<0,1	636 660,00	0,20	0,10	46,10	0,50
HGW 2018-10-24	<0,1	<200	0,70	<0,2	<100	8,90	<0,5	<0,1	527 010,00	<0,1	<0,1	21,00	<0,5
HGW 2018-10-31	<0,1	<200	<0,5	<0,2	141,00	9,30	<0,5	<0,1	623 700,00	<0,1	<0,1	41,10	<0,5
HGW 2018-11-06	0,40	<200	<0,5	<0,2	267,00	10,00	<0,5	<0,1	611 900,00	0,20	0,10	42,50	<0,5
HGW 2018-11-13	<0,1	<200	<0,5	<0,2	357,00	7,70	<0,5	<0,1	585 540,00	<0,1	<0,1	34,80	<0,5
HGW 2018-11-21	<0,1	<200	<0,5	<0,2	171,00	5,70	<0,5	<0,1	580 080,00	0,20	<0,1	32,20	<0,5
HGW 2018-11-29	<0,1	<200	<0,5	<0,2	205,00	6,60	<0,5	<0,1	526 150,00	<0,1	<0,1	26,70	<0,5
HGW 2018-12-06	0,60	<200	1,10	<0,2	<100	5,00	<0,5	<0,1	414 710,00	<0,1	<0,1	22,10	<0,5
HGW 2018-12-13	<0,1	<200	<0,5	<0,2	140,00	7,20	<0,5	<0,1	479 650,00	<0,1	<0,1	21,10	<0,5
HGW 2018-12-21	<0,1	<200	0,60	<0,2	<100	6,00	<0,5	<0,1	504 930,00	<0,1	<0,1	22,40	<0,5
HGW 2019-01-24	<0,1	<200	0,90	<0,2	<100	9,00	<0,5	<0,1	542 580,00	<0,1	<0,1	34,10	<0,5
HGW 2019-01-31	1,60	<200	0,90	<0,2	144,00	6,00	<0,5	0,10	496 300,00	<0,1	<0,1	24,50	<0,5
HGW 2019-02-08	0,30	<200	<0,5	<0,2	<100	7,20	<0,5	<0,1	424 140,00	<0,1	<0,1	22,70	<0,5
HGW 2019-02-15	<0,1	<200	0,60	<0,2	155,00	7,00	<0,5	<0,1	554 790,00	<0,1	<0,1	28,80	<0,5
HGW 2019-02-22	<0,1	<200	<0,5	<0,2	193,00	6,80	<0,5	<0,1	480 420,00	<0,1	<0,1	29,40	<0,5
HGW 2019-03-01	<0,1	<200	<0,5	<0,2	137,00	5,10	<0,5	<0,1	450 060,00	<0,1	<0,1	29,00	<0,5
HGW 2019-03-09	0,10	<200	0,60	<0,2	113,00	5,90	<0,5	<0,1	471 370,00	<0,1	<0,1	31,20	<0,5
HGW 2019-03-15	<0,1	<200	1,00	<0,2	<100	5,50	<0,5	<0,1	429 360,00	<0,1	<0,1	30,60	<0,5
HGW 2019-03-22	<0,1	<200	<0,5	<0,2	<100	4,70	<0,5	<0,1	348 860,00	<0,1	<0,1	30,20	<0,5
Sgr 2018-07-24	0,30	<200	<0,5	<0,2	118,00	2,30	<0,5	<0,1	462 580,00	0,20	0,20	29,70	<0,5
Sgr 2018-07-31	<0,1	<200	0,90	<0,2	<100	4,60	<0,5	<0,1	650 980,00	0,20	0,10	20,60	<0,5
Sgr 2018-08-07	<0,1	<200	0,70	<0,2	<100	1,30	<0,5	<0,1	384 450,00	<0,1	0,20	10,20	<0,5
Sgr 2018-08-14	<0,1	<200	<0,5	<0,2	<100	<0,1	<0,5	<0,1	456 910,00	<0,1	<0,1	5,10	<0,5
Sgr 2018-08-21	1,80	<200	<0,5	<0,2	<100	4,30	<0,5	0,20	641 840,00	0,10	0,20	3,00	<0,5
Sgr 2018-08-28	0,40	<200	<0,5	<0,2	<100	0,70	<0,5	<0,1	482 090,00	<0,1	<0,1	2,20	<0,5
Sgr 2018-09-04	0,20	<200	<0,5	<0,2	<100	1,00	<0,5	<0,1	438 410,00	<0,1	<0,1	2,40	<0,5
Sgr 2018-09-18	<0,1	<200	<0,5	<0,2	<100	0,40	<0,5	<0,1	450 790,00	0,20	<0,1	10,40	<0,5
Sgr 2018-09-25	0,10	<200	<0,5	<0,2	<100	0,90	<0,5	<0,1	487 890,00	<0,1	<0,1	12,70	<0,5
Sgr 2018-10-02	0,20	<200	<0,5	<0,2	<100	5,80	<0,5	<0,1	371 560,00	<0,1	0,20	11,10	<0,5
Sgr 2018-10-09	0,10	<200	0,70	<0,2	<100	5,20	<0,5	<0,1	468 070,00	<0,1	0,10	17,90	<0,5
Sgr 2018-10-17	<0,1	<200	<0,5	<0,2	<100	7,00	<0,5	<0,1	468 380,00	<0,1	<0,1	13,90	<0,5
Sgr 2018-10-24	<0,1	<200	<0,5	<0,2	271,00	7,20	<0,5	<0,1	598 640,00	0,40	<0,1	34,50	<0,5
Sgr 2018-10-31	1,70	<200	0,70	<0,2	<100	6,20	<0,5	0,20	491 280,00	0,20	0,20	18,10	<0,5
Sgr 2018-11-06	0,20	<200	<0,5	<0,2	<100	5,40	<0,5	<0,1	417 460,00	0,10	<0,1	14,60	<0,5
Sgr 2018-11-13	<0,1	<200	<0,5	<0,2	<100	6,60	<0,5	<0,1	479 640,00	<0,1	<0,1	17,90	<0,5
Sgr 2018-11-21	<0,1	<200	<0,5	<0,2	<100	6,10	<0,5	<0,1	499 450,00	0,10	<0,1	33,60	<0,5
Sgr 2018-11-29	<0,1	<200	<0,5	<0,2	<100	3,90	<0,5	<0,1	43 080,00	<0,1	<0,1	20,60	<0,5
Sgr 2018-12-06	0,50	<200	0,70	<0,2	<100	8,10	<0,5	<0,1	409 090,00	<0,1	<0,1	30,90	<0,5
Sgr 2018-12-13	0,10	<200	<0,5	<0,2	<100	5,80	<0,5	<0,1	339 600,00	<0,1	<0,1	25,80	<0,5
Sgr 2018-12-21	<0,1	<200	0,60	<0,2	<100	6,50	<0,5	<0,1	449 030,00	<0,1	0,10	38,00	<0,5
Sgr 2019-01-24	<0,1	<200	<0,5	<0,2	<100	7,70	<0,5	<0,1	598 270,00	<0,1	0,20	62,60	<0,5
Sgr 2019-01-31	0,90	<200	1,60	<0,2	<100	7,40	<0,5	0,10	489 090,00	<0,1	0,10	45,40	<0,5
Sgr 2019-02-08	0,20	<200	1,10	<0,2	<100	6,60	<0,5	<0,1	564 590,00	<0,1	0,10	49,50	<0,5
Sgr 2019-02-15	<0,1	<200	1,20	<0,2	<100	8,30	<0,5	<0,1	460 120,00	0,20	<0,1	51,10	<0,5
Sgr 2019-02-22	<0,1	<200	<0,5	<0,2	<100	7,10	<0,5	<0,1	480 870,00	<0,1	<0,1	42,60	<0,5
Sgr 2019-03-01	0,90	<200	1,00	<0,2	<100	6,70	<0,5	0,10	468 560,00	0,20	0,10	48,30	<0,5
Sgr 2019-03-09	<0,1	<200	2,00	<0,2	<100	5,60	<0,5	<0,1	371 490,00	<0,1	<0,1	42,00	<0,5
Sgr 2019-03-15	<0,1	<200	<0,5	<0,2	<100	9,40	<0,5	<0,1	484 860,00	<0,1	<0,1	64,80	<0,5
Sgr 2019-03-22	<0,1	<200	<0,5	<0,2	<100	3,20	<0,5	<0,1	382 040,00	0,10	0,10	77,80	<0,5

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS
	Cs	Cu	Dy	Er	Eu	Fe	Ga	Gd	Ge	Hf	Hg	Ho	In
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Dyke 2018-07-24	0,10	10,00	<0,1	<0,1	<0,1	<300	0,20	0,10	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-07-31	0,10	15,80	<0,1	<0,1	<0,1	<300	0,20	0,10	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-08-07	0,10	15,10	<0,1	<0,1	<0,1	<300	0,20	<0,1	<0,5	0,30	<1	<0,1	<0,1
Dyke 2018-08-14	<0,1	11,70	<0,1	<0,1	<0,1	<300	0,20	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-08-21	<0,1	10,10	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Dyke 2018-08-28	<0,1	8,00	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-09-04	<0,1	4,90	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-09-18	<0,1	8,60	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Dyke 2018-09-25	<0,1	7,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-10-02	<0,1	8,20	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-10-09	<0,1	6,70	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-10-17	<0,1	10,70	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-10-24	<0,1	7,90	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Dyke 2018-10-31	<0,1	3,60	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Dyke 2018-11-06	<0,1	2,90	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Dyke 2018-11-13	<0,1	1,10	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-11-21	<0,1	1,00	<0,1	<0,1	0,60	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-11-29	<0,1	3,80	<0,1	<0,1	3,70	<300	<0,1	0,10	<0,5	0,30	<1	<0,1	<0,1
Dyke 2018-12-06	<0,1	2,50	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Dyke 2018-12-13	<0,1	2,20	<0,1	<0,1	0,10	<300	0,20	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2018-12-21	<0,1	1,00	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2019-01-24	<0,1	1,20	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2019-01-31	<0,1	1,80	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Dyke 2019-02-08	<0,1	2,80	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2019-02-15	<0,1	2,90	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2019-02-22	<0,1	1,70	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2019-03-01	<0,1	2,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,30	<1	<0,1	<0,1
Dyke 2019-03-09	<0,1	2,10	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Dyke 2019-03-15	<0,1	2,30	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Dyke 2019-03-22	<0,1	2,00	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-07-24	<0,1	6,30	<0,1	<0,1	<0,1	420,00	0,20	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-07-31	<0,1	7,50	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
FW 2018-08-07	<0,1	10,70	<0,1	<0,1	<0,1	<300	0,20	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-08-14	<0,1	13,30	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-08-21	<0,1	6,10	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
FW 2018-08-28	<0,1	11,30	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-09-04	<0,1	7,30	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-09-18	<0,1	7,70	<0,1	<0,1	<0,1	10 830,00	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-09-25	<0,1	4,10	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
FW 2018-10-02	<0,1	6,10	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-10-09	<0,1	20,90	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-10-17	<0,1	6,30	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-10-24	<0,1	5,20	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-10-31	<0,1	3,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-11-06	<0,1	3,50	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,30	<1	<0,1	<0,1
FW 2018-11-13	<0,1	1,70	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-11-21	<0,1	1,90	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
FW 2018-11-29	<0,1	2,10	<0,1	<0,1	0,30	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2018-12-06	<0,1	3,70	<0,1	<0,1	11,00	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
FW 2018-12-13	<0,1	2,10	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2018-12-21	<0,1	3,90	<0,1	<0,1	2,80	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2019-01-24	<0,1	3,60	<0,1	<0,1	<0,1	1 780,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2019-01-31	<0,1	2,10	<0,1	<0,1	<0,1	2 010,00	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
FW 2019-02-08	<0,1	2,50	<0,1	<0,1	<0,1	550,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2019-02-15	<0,1	3,10	<0,1	<0,1	0,10	1 640,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2019-02-22	<0,1	1,50	<0,1	<0,1	0,10	1 670,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
FW 2019-03-01	<0,1	2,60	<0,1	<0,1	<0,1	3 500,00	<0,1	<0,1	<0,5	0,30	<1	<0,1	<0,1
FW 2019-03-09	<0,1	3,00	<0,1	<0,1	<0,1	5 920,00	<0,1	<0,1	<0,5	0,10	<1	<0,1	2,90
FW 2019-03-15	<0,1	3,00	<0,1	<0,1	<0,1	8 070,00	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
FW 2019-03-22	<0,1	3,70	<0,1	<0,1	<0,1	7 380,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS
	Cs	Cu	Dy	Er	Eu	Fe	Ga	Gd	Ge	Hf	Hg	Ho	In
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
HGW 2018-07-24	0,10	6,60	<0,1	<0,1	<0,1	<300	<0,1	0,10	<0,5	<0,1	<1	<0,1	<0,1
HGW 2018-07-31	0,10	15,50	<0,1	<0,1	0,20	<300	<0,1	0,10	<0,5	0,10	<1	<0,1	<0,1
HGW 2018-08-07	<0,1	13,60	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2018-08-14	<0,1	19,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2018-08-21	0,10	40,60	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
HGW 2018-08-28	<0,1	60,20	0,10	0,10	<0,1	<300	<0,1	<0,1	<0,5	0,30	<1	<0,1	<0,1
HGW 2018-09-04	<0,1	23,50	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
HGW 2018-09-18	<0,1	10,70	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2018-09-25	<0,1	8,80	<0,1	<0,1	1,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2018-10-02	<0,1	14,00	<0,1	<0,1	1,10	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2018-10-09	<0,1	26,50	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2018-10-17	<0,1	93,60	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,50	<1	<0,1	<0,1
HGW 2018-10-24	<0,1	19,50	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2018-10-31	<0,1	50,80	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2018-11-06	<0,1	67,40	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,40	<1	<0,1	<0,1
HGW 2018-11-13	<0,1	37,70	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
HGW 2018-11-21	<0,1	30,40	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
HGW 2018-11-29	<0,1	24,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2018-12-06	<0,1	22,00	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,30	<1	<0,1	<0,1
HGW 2018-12-13	<0,1	11,50	<0,1	<0,1	44,50	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2018-12-21	<0,1	11,80	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2019-01-24	<0,1	6,40	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2019-01-31	<0,1	9,50	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,50	<1	<0,1	<0,1
HGW 2019-02-08	<0,1	5,40	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2019-02-15	<0,1	11,90	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
HGW 2019-02-22	<0,1	8,50	<0,1	<0,1	2,00	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2019-03-01	<0,1	7,40	<0,1	<0,1	<0,1	310,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2019-03-09	<0,1	7,30	<0,1	<0,1	0,20	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
HGW 2019-03-15	<0,1	10,00	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
HGW 2019-03-22	<0,1	3,90	<0,1	<0,1	<0,1	3 160,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-07-24	0,10	4,90	<0,1	<0,1	<0,1	<300	<0,1	0,10	<0,5	0,20	<1	<0,1	<0,1
Sgr 2018-07-31	0,20	4,50	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Sgr 2018-08-07	0,10	6,30	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-08-14	0,10	7,00	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2018-08-21	<0,1	4,00	<0,1	<0,1	<0,1	<300	<0,1	0,20	<0,5	0,10	<1	<0,1	<0,1
Sgr 2018-08-28	<0,1	2,50	<0,1	<0,1	<0,1	<300	0,20	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2018-09-04	<0,1	2,80	<0,1	<0,1	<0,1	<300	0,20	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-09-18	<0,1	5,10	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-09-25	<0,1	2,00	<0,1	<0,1	0,90	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-10-02	<0,1	2,60	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2018-10-09	<0,1	3,30	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2018-10-17	0,10	4,50	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-10-24	<0,1	60,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2018-10-31	<0,1	8,20	<0,1	<0,1	<0,1	<300	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Sgr 2018-11-06	<0,1	3,60	<0,1	<0,1	0,40	<300	0,20	<0,1	<0,5	0,20	<1	<0,1	<0,1
Sgr 2018-11-13	<0,1	2,80	<0,1	<0,1	2,00	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-11-21	<0,1	3,70	<0,1	<0,1	0,90	3 370,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-11-29	<0,1	2,80	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-12-06	<0,1	6,80	<0,1	<0,1	<0,1	520,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-12-13	<0,1	3,00	<0,1	<0,1	0,30	3 590,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2018-12-21	<0,1	2,80	<0,1	<0,1	0,10	1 920,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2019-01-24	0,10	7,80	<0,1	<0,1	<0,1	18 720,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2019-01-31	<0,1	4,60	<0,1	<0,1	<0,1	13 860,00	0,20	<0,1	<0,5	0,30	<1	<0,1	<0,1
Sgr 2019-02-08	<0,1	8,20	<0,1	<0,1	0,10	<300	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2019-02-15	0,10	5,00	<0,1	<0,1	1,30	7 160,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2019-02-22	<0,1	5,30	<0,1	<0,1	<0,1	5 620,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1
Sgr 2019-03-01	<0,1	8,40	<0,1	<0,1	0,10	7 490,00	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2019-03-09	<0,1	5,50	<0,1	<0,1	<0,1	15 290,00	<0,1	<0,1	<0,5	0,20	<1	<0,1	<0,1
Sgr 2019-03-15	<0,1	4,80	<0,1	<0,1	<0,1	24 520,00	<0,1	<0,1	<0,5	0,10	<1	<0,1	<0,1
Sgr 2019-03-22	<0,1	4,70	<0,1	<0,1	<0,1	34 320,00	<0,1	<0,1	<0,5	<0,1	<1	<0,1	<0,1

	DIR-IMS K ppb	DIR-IMS La ppb	DIR-IMS Li ppb	DIR-IMS Lu ppb	DIR-IMS Mg ppb	DIR-IMS Mn ppb	DIR-IMS Mo ppb	DIR-IMS Na ppb	DIR-IMS Nb ppb	DIR-IMS Nd ppb	DIR-IMS Ni ppb	DIR-IMS P ppb
Dyke 2018-07-24	34 680,00	0,20	28,00	<0,1	30 990,00	187,40	<0,5	35 490,00	1,20	0,10	66,00	<1000
Dyke 2018-07-31	88 590,00	0,10	<10	<0,1	61 400,00	304,60	0,50	126 220,00	0,90	0,20	122,00	<1000
Dyke 2018-08-07	91 960,00	0,10	<10	<0,1	40 040,00	149,80	1,00	150 080,00	0,60	0,20	89,00	<1000
Dyke 2018-08-14	81 460,00	0,10	32,00	<0,1	37 710,00	56,30	0,80	111 820,00	0,70	0,20	46,00	<1000
Dyke 2018-08-21	90 370,00	<0,1	<10	<0,1	37 000,00	69,00	0,90	114 950,00	0,90	0,20	44,00	<1000
Dyke 2018-08-28	82 540,00	<0,1	<10	<0,1	33 530,00	12,50	1,00	95 900,00	0,50	<0,1	39,00	<1000
Dyke 2018-09-04	69 570,00	<0,1	<10	<0,1	25 620,00	<0,5	0,60	70 960,00	0,30	<0,1	22,00	<1000
Dyke 2018-09-18	83 930,00	<0,1	<10	<0,1	27 360,00	<0,5	0,70	84 700,00	0,20	<0,1	46,00	<1000
Dyke 2018-09-25	79 160,00	<0,1	<10	<0,1	28 500,00	6,30	0,50	90 270,00	<0,1	<0,1	45,00	<1000
Dyke 2018-10-02	97 540,00	<0,1	<10	<0,1	28 180,00	90,00	0,70	143 200,00	0,30	<0,1	51,00	<1000
Dyke 2018-10-09	62 650,00	<0,1	<10	<0,1	21 940,00	124,80	0,80	87 470,00	0,10	<0,1	53,00	<1000
Dyke 2018-10-17	107 540,00	<0,1	<10	<0,1	30 240,00	87,20	0,60	161 390,00	<0,1	<0,1	90,00	<1000
Dyke 2018-10-24	92 470,00	<0,1	<10	<0,1	23 800,00	68,30	0,50	121 720,00	<0,1	<0,1	65,00	<1000
Dyke 2018-10-31	66 640,00	<0,1	<10	<0,1	21 680,00	8,80	0,60	78 030,00	0,60	<0,1	39,00	<1000
Dyke 2018-11-06	56 160,00	<0,1	<10	<0,1	19 320,00	36,70	0,60	67 750,00	0,20	<0,1	29,00	<1000
Dyke 2018-11-13	47 930,00	<0,1	<10	<0,1	20 310,00	256,20	<0,5	49 500,00	<0,1	<0,1	58,00	<1000
Dyke 2018-11-21	63 780,00	<0,1	<10	<0,1	23 770,00	122,00	<0,5	70 780,00	<0,1	<0,1	62,00	<1000
Dyke 2018-11-29	61 740,00	<0,1	<10	<0,1	23 940,00	29,50	0,80	72 900,00	1,10	0,10	36,00	<1000
Dyke 2018-12-06	45 650,00	<0,1	<10	<0,1	18 420,00	273,90	<0,5	47 150,00	0,40	<0,1	40,00	<1000
Dyke 2018-12-13	43 710,00	<0,1	<10	<0,1	17 910,00	380,60	0,60	40 860,00	0,40	<0,1	50,00	<1000
Dyke 2018-12-21	49 340,00	<0,1	<10	<0,1	21 390,00	<0,5	0,50	47 220,00	0,20	<0,1	50,00	<1000
Dyke 2019-01-24	43 580,00	<0,1	<10	<0,1	24 050,00	649,70	<0,5	45 840,00	0,20	<0,1	78,00	<1000
Dyke 2019-01-31	39 560,00	<0,1	<10	<0,1	19 690,00	441,90	0,60	36 090,00	0,50	<0,1	64,00	<1000
Dyke 2019-02-08	44 920,00	<0,1	<10	<0,1	24 640,00	714,40	<0,5	39 610,00	0,30	<0,1	95,00	<1000
Dyke 2019-02-15	48 540,00	<0,1	<10	<0,1	25 840,00	492,60	<0,5	44 010,00	0,20	<0,1	72,00	<1000
Dyke 2019-02-22	42 260,00	<0,1	<10	<0,1	23 570,00	611,90	<0,5	40 270,00	<0,1	<0,1	70,00	<1000
Dyke 2019-03-01	43 820,00	<0,1	<10	<0,1	23 150,00	551,30	0,90	39 220,00	0,50	<0,1	60,00	1 369,00
Dyke 2019-03-09	44 800,00	<0,1	<10	<0,1	22 850,00	621,00	<0,5	34 480,00	0,10	<0,1	59,00	<1000
Dyke 2019-03-15	45 810,00	<0,1	<10	<0,1	24 310,00	533,50	<0,5	41 040,00	0,10	<0,1	61,00	<1000
Dyke 2019-03-22	37 470,00	<0,1	11,00	<0,1	22 770,00	816,50	<0,5	33 700,00	<0,1	<0,1	84,00	<1000
FW 2018-07-24	78 530,00	0,10	117,00	<0,1	71 070,00	920,70	0,50	76 580,00	1,10	0,10	183,00	<1000
FW 2018-07-31	116 180,00	0,10	36,00	<0,1	75 260,00	801,70	<0,5	158 070,00	0,80	0,20	142,00	<1000
FW 2018-08-07	97 510,00	0,20	24,00	<0,1	60 620,00	737,80	0,60	111 130,00	0,60	<0,1	104,00	<1000
FW 2018-08-14	105 020,00	<0,1	<10	<0,1	52 820,00	868,40	0,50	137 220,00	0,60	0,10	108,00	<1000
FW 2018-08-21	89 700,00	<0,1	<10	<0,1	42 710,00	693,70	0,80	101 180,00	0,70	<0,1	60,00	<1000
FW 2018-08-28	89 430,00	<0,1	<10	<0,1	42 970,00	823,80	0,80	82 980,00	0,30	<0,1	103,00	<1000
FW 2018-09-04	92 830,00	<0,1	<10	<0,1	41 450,00	958,80	0,60	84 740,00	0,30	<0,1	102,00	<1000
FW 2018-09-18	71 730,00	0,10	<10	<0,1	28 470,00	1 078,90	0,60	62 470,00	0,20	<0,1	112,00	<1000
FW 2018-09-25	94 260,00	<0,1	<10	<0,1	40 140,00	1 449,30	0,70	79 100,00	0,40	<0,1	151,00	<1000
FW 2018-10-02	85 640,00	<0,1	<10	<0,1	30 710,00	1 190,60	0,70	83 160,00	0,20	<0,1	133,00	<1000
FW 2018-10-09	94 920,00	<0,1	<10	<0,1	23 540,00	762,00	<0,5	128 630,00	<0,1	<0,1	154,00	<1000
FW 2018-10-17	96 610,00	<0,1	<10	<0,1	30 020,00	1 239,70	<0,5	128 050,00	<0,1	<0,1	157,00	<1000
FW 2018-10-24	80 130,00	<0,1	<10	<0,1	28 830,00	1 296,30	<0,5	99 440,00	<0,1	<0,1	169,00	<1000
FW 2018-10-31	93 200,00	<0,1	<10	<0,1	30 650,00	1 289,90	<0,5	113 170,00	0,30	<0,1	151,00	<1000
FW 2018-11-06	91 080,00	<0,1	<10	<0,1	26 610,00	1 133,40	<0,5	108 250,00	0,10	<0,1	146,00	<1000
FW 2018-11-13	64 610,00	<0,1	<10	<0,1	18 360,00	937,90	<0,5	63 570,00	<0,1	<0,1	119,00	<1000
FW 2018-11-21	74 460,00	<0,1	<10	<0,1	24 050,00	1 162,10	<0,5	87 610,00	<0,1	<0,1	144,00	<1000
FW 2018-11-29	83 460,00	<0,1	<10	<0,1	26 570,00	1 285,60	0,50	94 220,00	0,80	<0,1	162,00	<1000
FW 2018-12-06	60 130,00	<0,1	<10	<0,1	18 040,00	985,90	<0,5	52 800,00	0,40	<0,1	120,00	1 064,00
FW 2018-12-13	70 460,00	<0,1	<10	<0,1	19 820,00	1 087,80	<0,5	65 060,00	0,30	<0,1	127,00	<1000
FW 2018-12-21	78 410,00	<0,1	18,00	<0,1	21 890,00	1 204,80	<0,5	80 740,00	0,20	<0,1	157,00	<1000
FW 2019-01-24	83 650,00	<0,1	<10	<0,1	28 760,00	1 836,40	<0,5	85 550,00	0,10	<0,1	242,00	<1000
FW 2019-01-31	58 080,00	<0,1	<10	<0,1	21 300,00	1 259,80	0,70	60 080,00	0,50	<0,1	183,00	<1000
FW 2019-02-08	55 230,00	<0,1	11,00	<0,1	19 770,00	1 128,20	<0,5	49 730,00	0,30	<0,1	160,00	<1000
FW 2019-02-15	66 860,00	<0,1	<10	<0,1	24 940,00	1 498,30	<0,5	58 720,00	0,10	<0,1	211,00	<1000
FW 2019-02-22	58 180,00	<0,1	19,00	<0,1	24 610,00	1 500,40	<0,5	51 440,00	0,10	<0,1	210,00	<1000
FW 2019-03-01	45 210,00	<0,1	<10	<0,1	16 990,00	1 124,30	<0,5	37 640,00	0,50	<0,1	162,00	<1000
FW 2019-03-09	42 390,00	<0,1	<10	<0,1	18 090,00	1 255,00	<0,5	33 840,00	0,20	<0,1	193,00	<1000
FW 2019-03-15	55 230,00	0,10	<10	<0,1	22 160,00	1 662,10	<0,5	43 990,00	0,10	<0,1	268,00	<1000
FW 2019-03-22	66 760,00	0,10	<10	<0,1	19 750,00	1 364,20	<0,5	67 640,00	<0,1	<0,1	226,00	<1000

	DIR-IMS K ppb	DIR-IMS La ppb	DIR-IMS Li ppb	DIR-IMS Lu ppb	DIR-IMS Mg ppb	DIR-IMS Mn ppb	DIR-IMS Mo ppb	DIR-IMS Na ppb	DIR-IMS Nb ppb	DIR-IMS Nd ppb	DIR-IMS Ni ppb	DIR-IMS P ppb
HGW 2018-07-24	74 710,00	0,20	13,00	<0,1	86 440,00	786,10	0,70	57 410,00	1,50	0,20	186,00	<1000
HGW 2018-07-31	97 500,00	0,10	<10	<0,1	91 160,00	762,00	0,60	112 040,00	1,20	0,20	168,00	<1000
HGW 2018-08-07	92 050,00	0,20	53,00	<0,1	73 640,00	497,00	0,80	94 320,00	0,70	0,20	114,00	<1000
HGW 2018-08-14	73 920,00	<0,1	12,00	<0,1	51 290,00	362,10	0,80	112 160,00	0,50	0,10	178,00	<1000
HGW 2018-08-21	108 560,00	0,10	<10	<0,1	68 470,00	361,50	0,80	172 560,00	0,50	<0,1	275,00	<1000
HGW 2018-08-28	114 070,00	<0,1	<10	<0,1	60 490,00	312,10	1,40	203 220,00	0,70	0,10	359,00	<1000
HGW 2018-09-04	94 790,00	<0,1	74,00	<0,1	56 310,00	402,30	0,70	125 440,00	0,30	<0,1	167,00	<1000
HGW 2018-09-18	58 710,00	<0,1	<10	<0,1	26 840,00	589,10	0,50	44 760,00	0,20	0,10	83,00	<1000
HGW 2018-09-25	92 010,00	<0,1	16,00	<0,1	55 010,00	880,60	0,50	102 920,00	0,20	<0,1	131,00	<1000
HGW 2018-10-02	106 220,00	<0,1	12,00	<0,1	52 540,00	893,00	<0,5	110 160,00	0,50	<0,1	126,00	<1000
HGW 2018-10-09	112 590,00	<0,1	<10	<0,1	46 900,00	844,60	0,70	177 370,00	<0,1	<0,1	200,00	<1000
HGW 2018-10-17	168 010,00	<0,1	<10	<0,1	53 780,00	1 058,90	0,90	313 190,00	0,10	<0,1	442,00	<1000
HGW 2018-10-24	108 250,00	<0,1	<10	<0,1	43 060,00	899,70	0,50	169 630,00	<0,1	<0,1	200,00	<1000
HGW 2018-10-31	141 490,00	<0,1	11,00	<0,1	53 210,00	1 106,00	<0,5	283 430,00	<0,1	<0,1	354,00	<1000
HGW 2018-11-06	151 090,00	<0,1	<10	<0,1	47 940,00	1 026,00	0,80	299 790,00	0,30	<0,1	339,00	<1000
HGW 2018-11-13	188 840,00	<0,1	<10	<0,1	45 290,00	1 103,00	1,20	306 690,00	<0,1	<0,1	220,00	<1000
HGW 2018-11-21	176 650,00	<0,1	<10	<0,1	41 900,00	1 115,80	0,90	281 220,00	<0,1	<0,1	193,00	<1000
HGW 2018-11-29	154 790,00	<0,1	<10	<0,1	39 320,00	1 064,10	0,50	239 780,00	<0,1	<0,1	133,00	<1000
HGW 2018-12-06	117 590,00	<0,1	<10	<0,1	31 910,00	915,90	0,90	167 290,00	0,60	<0,1	123,00	<1000
HGW 2018-12-13	94 170,00	<0,1	<10	<0,1	36 010,00	1 148,10	0,50	125 000,00	0,40	<0,1	129,00	<1000
HGW 2018-12-21	112 730,00	<0,1	<10	<0,1	38 090,00	1 221,20	0,60	135 430,00	0,30	<0,1	139,00	<1000
HGW 2019-01-24	91 960,00	<0,1	<10	<0,1	38 810,00	1 913,10	<0,5	105 300,00	0,10	<0,1	203,00	<1000
HGW 2019-01-31	88 190,00	<0,1	<10	<0,1	37 900,00	1 372,10	1,00	122 860,00	0,90	<0,1	162,00	<1000
HGW 2019-02-08	71 000,00	<0,1	<10	<0,1	34 610,00	1 266,20	<0,5	85 930,00	0,40	<0,1	149,00	<1000
HGW 2019-02-15	94 810,00	<0,1	31,00	<0,1	43 790,00	1 628,20	<0,5	127 710,00	0,10	<0,1	187,00	<1000
HGW 2019-02-22	78 660,00	<0,1	<10	<0,1	37 160,00	1 433,10	<0,5	93 820,00	<0,1	<0,1	177,00	<1000
HGW 2019-03-01	73 840,00	<0,1	<10	<0,1	37 070,00	1 519,30	<0,5	86 220,00	<0,1	<0,1	193,00	<1000
HGW 2019-03-09	74 300,00	<0,1	<10	<0,1	39 250,00	1 507,90	<0,5	85 370,00	0,30	<0,1	194,00	1 067,00
HGW 2019-03-15	76 970,00	<0,1	<10	<0,1	35 830,00	1 570,30	<0,5	96 750,00	0,20	<0,1	202,00	<1000
HGW 2019-03-22	59 860,00	<0,1	<10	<0,1	29 350,00	1 379,40	<0,5	60 590,00	0,10	<0,1	187,00	<1000
Sgr 2018-07-24	51 670,00	0,10	21,00	<0,1	69 610,00	826,40	0,60	40 340,00	1,40	0,20	232,00	<1000
Sgr 2018-07-31	93 660,00	<0,1	<10	<0,1	84 160,00	766,10	0,60	147 240,00	1,00	0,20	224,00	<1000
Sgr 2018-08-07	62 220,00	<0,1	54,00	<0,1	43 970,00	1 207,90	<0,5	85 100,00	0,80	<0,1	97,00	<1000
Sgr 2018-08-14	71 270,00	0,10	<10	<0,1	50 830,00	370,20	0,70	98 830,00	0,60	<0,1	67,00	<1000
Sgr 2018-08-21	124 800,00	0,10	<10	<0,1	57 660,00	321,00	1,00	163 530,00	1,20	0,20	70,00	<1000
Sgr 2018-08-28	103 080,00	<0,1	<10	<0,1	44 540,00	154,50	1,30	128 370,00	0,60	0,10	53,00	<1000
Sgr 2018-09-04	97 030,00	<0,1	<10	<0,1	42 130,00	169,80	0,50	118 600,00	0,40	<0,1	55,00	<1000
Sgr 2018-09-18	101 930,00	<0,1	<10	<0,1	26 870,00	404,90	0,70	118 310,00	0,10	<0,1	69,00	<1000
Sgr 2018-09-25	108 490,00	<0,1	<10	<0,1	41 900,00	554,10	0,50	140 830,00	<0,1	<0,1	107,00	<1000
Sgr 2018-10-02	84 720,00	0,20	<10	<0,1	33 770,00	573,80	<0,5	103 570,00	0,40	<0,1	97,00	<1000
Sgr 2018-10-09	86 000,00	<0,1	<10	<0,1	41 860,00	772,40	<0,5	142 240,00	0,20	<0,1	146,00	<1000
Sgr 2018-10-17	118 620,00	<0,1	<10	<0,1	37 770,00	633,90	0,60	167 730,00	<0,1	<0,1	124,00	<1000
Sgr 2018-10-24	158 440,00	<0,1	<10	<0,1	48 060,00	816,40	0,60	298 400,00	<0,1	<0,1	335,00	<1000
Sgr 2018-10-31	113 710,00	0,10	<10	<0,1	39 880,00	693,10	0,70	156 490,00	1,00	0,10	163,00	<1000
Sgr 2018-11-06	97 840,00	<0,1	<10	<0,1	34 580,00	638,90	0,60	123 260,00	0,20	<0,1	136,00	<1000
Sgr 2018-11-13	97 840,00	<0,1	<10	<0,1	36 940,00	811,10	<0,5	119 030,00	<0,1	<0,1	150,00	<1000
Sgr 2018-11-21	86 390,00	<0,1	<10	<0,1	38 810,00	1 024,50	<0,5	117 010,00	<0,1	<0,1	248,00	<1000
Sgr 2018-11-29	7 250,00	<0,1	<10	<0,1	3 920,00	31,60	<0,5	8 480,00	<0,1	<0,1	172,00	<1000
Sgr 2018-12-06	73 280,00	<0,1	<10	<0,1	31 780,00	831,90	0,50	81 090,00	0,60	<0,1	208,00	<1000
Sgr 2018-12-13	57 910,00	<0,1	<10	<0,1	28 190,00	740,50	<0,5	63 030,00	0,30	<0,1	209,00	<1000
Sgr 2018-12-21	72 140,00	<0,1	<10	<0,1	35 550,00	1 034,60	<0,5	73 660,00	0,30	<0,1	273,00	<1000
Sgr 2019-01-24	74 650,00	0,20	<10	<0,1	42 350,00	1 617,90	<0,5	73 430,00	0,10	<0,1	474,00	<1000
Sgr 2019-01-31	65 740,00	0,20	15,00	<0,1	36 110,00	1 176,30	0,60	64 230,00	0,80	<0,1	372,00	<1000
Sgr 2019-02-08	72 730,00	0,10	<10	<0,1	42 250,00	1 209,40	<0,5	68 380,00	0,40	<0,1	399,00	<1000
Sgr 2019-02-15	65 240,00	<0,1	<10	<0,1	36 120,00	1 162,90	<0,5	61 720,00	0,20	<0,1	397,00	<1000
Sgr 2019-02-22	64 340,00	<0,1	<10	<0,1	36 450,00	1 131,50	<0,5	58 220,00	0,20	<0,1	400,00	<1000
Sgr 2019-03-01	64 770,00	<0,1	<10	<0,1	36 460,00	1 305,00	0,50	57 460,00	0,70	<0,1	421,00	<1000
Sgr 2019-03-09	51 760,00	0,10	12,00	<0,1	30 700,00	1 025,80	<0,5	40 170,00	0,20	<0,1	385,00	<1000
Sgr 2019-03-15	63 240,00	0,10	<10	<0,1	36 730,00	1 677,50	<0,5	51 350,00	0,20	<0,1	535,00	<1000
Sgr 2019-03-22	50 650,00	<0,1	<10	<0,1	31 120,00	1 640,00	<0,5	39 760,00	<0,1	<0,1	547,00	<1000

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS
	Pb	Pd	Pr	Pt	Rb	Re	S	Sb	Sc	Se	Si	Sm	Sn
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Dyke 2018-07-24	11,00	<0,5	<0,1	<0,1	8,60	0,05	265 400,00	<0,5	<40	<5	393,00	0,10	0,80
Dyke 2018-07-31	10,00	<0,5	<0,1	<0,1	13,50	0,14	581 120,00	<0,5	<40	<5	801,00	<0,1	<0,1
Dyke 2018-08-07	11,00	<0,5	<0,1	<0,1	12,90	0,06	427 690,00	<0,5	<40	<5	589,00	<0,1	<0,1
Dyke 2018-08-14	10,00	<0,5	<0,1	<0,1	12,10	0,06	432 850,00	<0,5	<40	<5	590,00	<0,1	<0,1
Dyke 2018-08-21	10,00	<0,5	<0,1	<0,1	15,50	0,10	478 720,00	1,20	<40	<5	566,00	<0,1	0,50
Dyke 2018-08-28	6,00	<0,5	<0,1	<0,1	13,90	0,05	467 570,00	0,60	<40	<5	530,00	<0,1	1,50
Dyke 2018-09-04	10,00	<0,5	<0,1	0,20	12,60	<0,04	374 260,00	<0,5	<40	<5	532,00	<0,1	0,30
Dyke 2018-09-18	<5	<0,5	<0,1	<0,1	11,30	<0,04	477 290,00	<0,5	<40	<5	516,00	<0,1	<0,1
Dyke 2018-09-25	<5	<0,5	<0,1	<0,1	10,30	<0,04	477 300,00	<0,5	<40	<5	520,00	<0,1	1,40
Dyke 2018-10-02	<5	<0,5	<0,1	<0,1	9,90	<0,04	534 120,00	<0,5	<40	<5	359,00	<0,1	0,60
Dyke 2018-10-09	6,00	<0,5	<0,1	0,20	10,00	<0,04	398 870,00	<0,5	<40	<5	242,00	<0,1	<0,1
Dyke 2018-10-17	<5	<0,5	<0,1	0,10	13,00	<0,04	551 210,00	<0,5	<40	<5	424,00	<0,1	<0,1
Dyke 2018-10-24	<5	<0,5	<0,1	<0,1	11,80	<0,04	509 460,00	<0,5	<40	<5	378,00	<0,1	<0,1
Dyke 2018-10-31	<5	<0,5	<0,1	<0,1	13,20	<0,04	401 580,00	1,30	<40	<5	336,00	<0,1	1,50
Dyke 2018-11-06	<5	<0,5	<0,1	<0,1	9,40	<0,04	355 190,00	<0,5	<40	<5	265,00	<0,1	<0,1
Dyke 2018-11-13	<5	<0,5	<0,1	<0,1	9,60	<0,04	367 610,00	<0,5	<40	<5	223,00	<0,1	<0,1
Dyke 2018-11-21	<5	<0,5	<0,1	<0,1	10,40	0,06	446 030,00	<0,5	<40	<5	267,00	<0,1	<0,1
Dyke 2018-11-29	<5	<0,5	<0,1	<0,1	16,80	<0,04	462 030,00	2,00	<40	<5	303,00	<0,1	0,80
Dyke 2018-12-06	7,00	<0,5	<0,1	<0,1	10,00	<0,04	353 770,00	<0,5	<40	<5	208,00	<0,1	0,80
Dyke 2018-12-13	<5	<0,5	<0,1	<0,1	9,40	<0,04	347 080,00	<0,5	<40	<5	224,00	<0,1	<0,1
Dyke 2018-12-21	<5	<0,5	<0,1	<0,1	10,70	<0,04	403 120,00	<0,5	<40	<5	291,00	<0,1	3,00
Dyke 2019-01-24	<5	<0,5	<0,1	<0,1	8,70	<0,04	459 120,00	<0,5	<40	<5	233,00	<0,1	0,30
Dyke 2019-01-31	<5	<0,5	<0,1	<0,1	10,00	0,04	415 900,00	1,10	<40	<5	215,00	<0,1	0,60
Dyke 2019-02-08	<5	<0,5	<0,1	<0,1	10,40	<0,04	473 320,00	<0,5	<40	<5	262,00	<0,1	<0,1
Dyke 2019-02-15	<5	<0,5	<0,1	<0,1	10,50	<0,04	497 150,00	<0,5	<40	<5	252,00	<0,1	<0,1
Dyke 2019-02-22	<5	<0,5	<0,1	<0,1	9,20	<0,04	436 620,00	<0,5	<40	<5	207,00	<0,1	<0,1
Dyke 2019-03-01	8,00	<0,5	<0,1	<0,1	11,20	<0,04	490 860,00	1,20	<40	<5	222,00	<0,1	13,30
Dyke 2019-03-09	11,00	<0,5	<0,1	<0,1	10,30	<0,04	439 480,00	<0,5	<40	<5	263,00	<0,1	<0,1
Dyke 2019-03-15	9,00	<0,5	<0,1	<0,1	9,50	<0,04	485 550,00	<0,5	<40	<5	233,00	<0,1	0,40
Dyke 2019-03-22	<5	<0,5	<0,1	<0,1	8,20	<0,04	399 130,00	<0,5	<40	<5	217,00	<0,1	0,30
FW 2018-07-24	12,00	<0,5	<0,1	<0,1	14,70	0,11	649 770,00	<0,5	<40	<5	683,00	<0,1	1,10
FW 2018-07-31	9,00	<0,5	<0,1	<0,1	14,90	0,18	759 920,00	<0,5	<40	<5	830,00	0,10	1,10
FW 2018-08-07	10,00	<0,5	<0,1	<0,1	14,00	0,05	557 270,00	<0,5	<40	<5	709,00	0,10	11,80
FW 2018-08-14	7,00	<0,5	<0,1	<0,1	13,30	0,10	554 030,00	<0,5	<40	<5	668,00	<0,1	<0,1
FW 2018-08-21	<5	<0,5	<0,1	<0,1	11,20	<0,04	490 450,00	1,00	<40	<5	631,00	0,10	0,60
FW 2018-08-28	14,00	<0,5	<0,1	<0,1	15,00	0,05	520 600,00	<0,5	<40	<5	542,00	<0,1	0,40
FW 2018-09-04	<5	<0,5	<0,1	0,10	15,30	<0,04	500 790,00	<0,5	<40	<5	531,00	<0,1	0,50
FW 2018-09-18	<5	<0,5	<0,1	<0,1	10,60	<0,04	488 000,00	<0,5	<40	<5	595,00	<0,1	<0,1
FW 2018-09-25	9,00	<0,5	<0,1	<0,1	20,30	0,05	593 640,00	0,80	<40	<5	695,00	<0,1	0,30
FW 2018-10-02	<5	<0,5	<0,1	<0,1	14,30	<0,04	487 060,00	<0,5	<40	<5	496,00	<0,1	0,40
FW 2018-10-09	<5	<0,5	<0,1	<0,1	8,80	<0,04	361 890,00	<0,5	<40	<5	307,00	<0,1	<0,1
FW 2018-10-17	<5	<0,5	<0,1	0,10	11,80	<0,04	451 300,00	<0,5	<40	<5	498,00	<0,1	0,20
FW 2018-10-24	<5	<0,5	<0,1	<0,1	11,40	<0,04	440 830,00	<0,5	<40	<5	470,00	<0,1	<0,1
FW 2018-10-31	<5	<0,5	<0,1	<0,1	13,90	<0,04	479 980,00	0,60	<40	<5	557,00	<0,1	0,10
FW 2018-11-06	<5	<0,5	<0,1	<0,1	12,50	<0,04	442 930,00	<0,5	<40	<5	510,00	<0,1	0,30
FW 2018-11-13	<5	<0,5	<0,1	<0,1	9,90	<0,04	310 010,00	<0,5	<40	<5	368,00	<0,1	<0,1
FW 2018-11-21	<5	<0,5	<0,1	<0,1	9,20	<0,04	389 420,00	<0,5	<40	<5	438,00	<0,1	<0,1
FW 2018-11-29	5,00	<0,5	<0,1	<0,1	13,80	<0,04	440 830,00	1,20	<40	<5	501,00	<0,1	0,40
FW 2018-12-06	6,00	<0,5	<0,1	<0,1	10,00	<0,04	299 370,00	<0,5	<40	<5	392,00	<0,1	0,80
FW 2018-12-13	<5	<0,5	<0,1	<0,1	10,20	<0,04	342 250,00	<0,5	<40	<5	452,00	<0,1	0,40
FW 2018-12-21	<5	<0,5	<0,1	<0,1	11,00	<0,04	375 470,00	<0,5	<40	<5	459,00	<0,1	0,40
FW 2019-01-24	<5	<0,5	<0,1	<0,1	11,10	<0,04	510 460,00	<0,5	<40	<5	550,00	<0,1	2,80
FW 2019-01-31	<5	<0,5	<0,1	<0,1	9,70	<0,04	333 190,00	0,50	<40	<5	415,00	<0,1	4,20
FW 2019-02-08	<5	<0,5	<0,1	<0,1	8,20	<0,04	326 960,00	<0,5	<40	<5	413,00	<0,1	<0,1
FW 2019-02-15	<5	<0,5	<0,1	<0,1	9,60	<0,04	431 670,00	<0,5	<40	<5	505,00	<0,1	<0,1
FW 2019-02-22	<5	<0,5	<0,1	<0,1	8,60	<0,04	400 520,00	<0,5	<40	<5	485,00	<0,1	<0,1
FW 2019-03-01	10,00	<0,5	<0,1	<0,1	8,40	<0,04	285 810,00	0,80	<40	<5	398,00	<0,1	0,40
FW 2019-03-09	9,00	<0,5	<0,1	<0,1	7,20	<0,04	283 260,00	<0,5	<40	<5	398,00	<0,1	1,40
FW 2019-03-15	12,00	<0,5	<0,1	<0,1	9,10	<0,04	378 110,00	<0,5	<40	<5	549,00	<0,1	<0,1
FW 2019-03-22	<5	<0,5	<0,1	<0,1	8,60	<0,04	345 900,00	<0,5	<40	<5	481,00	<0,1	<0,1

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS
	Pb	Pd	Pr	Pt	Rb	Re	S	Sb	Sc	Se	Si	Sm	Sn
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
HGW 2018-07-24	12,00	<0,5	<0,1	<0,1	17,00	0,42	688 320,00	<0,5	<40	9,60	574,00	<0,1	0,50
HGW 2018-07-31	8,00	<0,5	<0,1	<0,1	17,50	0,18	827 200,00	<0,5	<40	10,10	775,00	<0,1	<0,1
HGW 2018-08-07	10,00	<0,5	<0,1	<0,1	17,40	0,12	634 500,00	<0,5	<40	5,40	637,00	<0,1	3,20
HGW 2018-08-14	11,00	<0,5	<0,1	<0,1	13,00	0,09	387 530,00	<0,5	<40	<5	432,00	<0,1	14,30
HGW 2018-08-21	9,00	<0,5	<0,1	<0,1	16,70	0,09	595 600,00	<0,5	<40	6,30	592,00	<0,1	<0,1
HGW 2018-08-28	10,00	<0,5	<0,1	0,10	18,70	0,08	498 830,00	0,90	<40	5,20	599,00	<0,1	1,40
HGW 2018-09-04	10,00	<0,5	<0,1	<0,1	18,60	0,09	577 390,00	<0,5	<40	<5	512,00	<0,1	0,50
HGW 2018-09-18	<5	<0,5	<0,1	0,10	10,40	<0,04	371 730,00	<0,5	<40	<5	308,00	<0,1	<0,1
HGW 2018-09-25	11,00	<0,5	<0,1	<0,1	15,50	0,05	634 780,00	<0,5	<40	<5	480,00	<0,1	1,90
HGW 2018-10-02	<5	<0,5	<0,1	<0,1	20,20	0,05	689 950,00	0,50	<40	<5	411,00	<0,1	<0,1
HGW 2018-10-09	<5	<0,5	<0,1	<0,1	14,00	0,05	559 320,00	<0,5	<40	<5	367,00	<0,1	1,30
HGW 2018-10-17	<5	<0,5	<0,1	<0,1	16,10	0,05	689 920,00	<0,5	<40	<5	423,00	<0,1	0,30
HGW 2018-10-24	<5	<0,5	<0,1	<0,1	13,70	<0,04	570 320,00	<0,5	<40	<5	358,00	<0,1	<0,1
HGW 2018-10-31	<5	<0,5	<0,1	<0,1	14,50	<0,04	648 700,00	<0,5	<40	<5	447,00	<0,1	<0,1
HGW 2018-11-06	<5	<0,5	<0,1	<0,1	17,40	<0,04	638 140,00	0,60	<40	<5	418,00	<0,1	1,10
HGW 2018-11-13	<5	<0,5	<0,1	<0,1	18,40	<0,04	658 850,00	<0,5	<40	<5	396,00	<0,1	0,10
HGW 2018-11-21	<5	<0,5	<0,1	<0,1	14,30	<0,04	672 950,00	<0,5	<40	<5	394,00	<0,1	<0,1
HGW 2018-11-29	<5	<0,5	<0,1	<0,1	10,80	0,05	615 290,00	<0,5	<40	<5	394,00	<0,1	<0,1
HGW 2018-12-06	<5	<0,5	<0,1	<0,1	14,20	<0,04	485 840,00	0,90	<40	<5	299,00	<0,1	0,20
HGW 2018-12-13	<5	<0,5	<0,1	<0,1	13,70	<0,04	516 050,00	<0,5	<40	<5	349,00	<0,1	0,10
HGW 2018-12-21	<5	<0,5	<0,1	<0,1	13,90	<0,04	561 310,00	<0,5	<40	<5	366,00	<0,1	0,40
HGW 2019-01-24	<5	<0,5	<0,1	<0,1	11,80	<0,04	579 000,00	<0,5	<40	<5	356,00	<0,1	<0,1
HGW 2019-01-31	<5	<0,5	<0,1	<0,1	17,60	<0,04	526 010,00	2,10	<40	<5	373,00	<0,1	0,90
HGW 2019-02-08	<5	<0,5	<0,1	<0,1	10,60	<0,04	455 000,00	0,70	<40	<5	333,00	<0,1	0,40
HGW 2019-02-15	<5	<0,5	<0,1	<0,1	11,40	<0,04	593 090,00	<0,5	<40	<5	423,00	<0,1	0,10
HGW 2019-02-22	<5	<0,5	<0,1	<0,1	10,40	<0,04	505 070,00	<0,5	<40	<5	377,00	<0,1	<0,1
HGW 2019-03-01	<5	<0,5	<0,1	<0,1	10,80	<0,04	480 010,00	<0,5	<40	<5	362,00	<0,1	0,60
HGW 2019-03-09	7,00	<0,5	<0,1	<0,1	11,90	<0,04	498 580,00	<0,5	<40	5,20	368,00	<0,1	0,20
HGW 2019-03-15	5,00	<0,5	<0,1	<0,1	11,00	<0,04	465 200,00	<0,5	<40	<5	398,00	<0,1	0,50
HGW 2019-03-22	<5	<0,5	<0,1	<0,1	9,10	<0,04	373 760,00	<0,5	<40	<5	347,00	<0,1	0,10
Sgr 2018-07-24	10,00	<0,5	<0,1	<0,1	13,00	0,24	540 160,00	<0,5	<40	9,60	501,00	<0,1	0,30
Sgr 2018-07-31	<5	<0,5	<0,1	0,10	15,70	0,23	910 750,00	<0,5	<40	10,70	737,00	<0,1	<0,1
Sgr 2018-08-07	10,00	<0,5	<0,1	0,10	12,40	0,09	499 600,00	<0,5	<40	8,30	469,00	0,10	<0,1
Sgr 2018-08-14	9,00	<0,5	<0,1	<0,1	12,20	0,07	536 380,00	<0,5	<40	9,50	533,00	<0,1	<0,1
Sgr 2018-08-21	9,00	<0,5	0,10	<0,1	24,50	0,08	724 490,00	1,80	<40	10,60	639,00	<0,1	0,50
Sgr 2018-08-28	7,00	<0,5	<0,1	<0,1	15,80	0,05	551 340,00	0,60	<40	8,90	598,00	<0,1	0,20
Sgr 2018-09-04	7,00	<0,5	<0,1	0,10	14,50	0,05	500 880,00	<0,5	<40	6,80	557,00	<0,1	<0,1
Sgr 2018-09-18	6,00	<0,5	<0,1	<0,1	9,10	<0,04	506 530,00	<0,5	<40	<5	395,00	<0,1	<0,1
Sgr 2018-09-25	12,00	<0,5	<0,1	<0,1	13,90	0,07	573 530,00	<0,5	<40	8,20	513,00	<0,1	0,10
Sgr 2018-10-02	<5	<0,5	<0,1	<0,1	15,10	0,07	436 620,00	<0,5	<40	7,20	458,00	<0,1	11,90
Sgr 2018-10-09	<5	<0,5	<0,1	<0,1	13,30	0,08	540 410,00	<0,5	<40	7,40	427,00	0,10	0,30
Sgr 2018-10-17	<5	<0,5	<0,1	<0,1	14,10	<0,04	561 700,00	<0,5	<40	8,00	506,00	<0,1	0,90
Sgr 2018-10-24	<5	<0,5	<0,1	<0,1	17,70	0,09	659 910,00	<0,5	<40	6,80	533,00	<0,1	17,00
Sgr 2018-10-31	<5	<0,5	0,10	<0,1	23,10	<0,04	560 720,00	2,00	<40	<5	569,00	<0,1	0,70
Sgr 2018-11-06	<5	<0,5	<0,1	<0,1	14,50	0,04	478 080,00	0,50	<40	7,10	478,00	<0,1	0,50
Sgr 2018-11-13	<5	<0,5	<0,1	<0,1	14,70	<0,04	527 690,00	<0,5	<40	8,60	532,00	<0,1	0,20
Sgr 2018-11-21	<5	<0,5	<0,1	<0,1	13,60	<0,04	556 740,00	<0,5	<40	5,80	488,00	<0,1	<0,1
Sgr 2018-11-29	<5	<0,5	<0,1	0,10	11,20	<0,04	43 620,00	<0,5	<40	<5	435,00	<0,1	<0,1
Sgr 2018-12-06	<5	<0,5	<0,1	<0,1	13,90	<0,04	447 760,00	0,60	<40	5,40	442,00	<0,1	0,70
Sgr 2018-12-13	6,00	<0,5	<0,1	<0,1	11,00	<0,04	370 420,00	<0,5	<40	8,00	381,00	<0,1	0,10
Sgr 2018-12-21	<5	<0,5	<0,1	<0,1	13,40	<0,04	493 730,00	<0,5	<40	8,90	548,00	<0,1	1,60
Sgr 2019-01-24	5,00	<0,5	<0,1	<0,1	15,00	0,05	637 420,00	<0,5	<40	8,20	617,00	<0,1	<0,1
Sgr 2019-01-31	<5	<0,5	<0,1	<0,1	14,50	<0,04	523 320,00	1,30	<40	7,70	520,00	<0,1	0,50
Sgr 2019-02-08	7,00	<0,5	<0,1	<0,1	15,60	0,11	590 530,00	0,50	<40	10,10	635,00	<0,1	2,70
Sgr 2019-02-15	7,00	<0,5	<0,1	<0,1	13,20	0,05	495 010,00	<0,5	<40	8,70	580,00	<0,1	0,20
Sgr 2019-02-22	<5	<0,5	<0,1	<0,1	13,20	<0,04	502 560,00	<0,5	<40	10,30	569,00	<0,1	<0,1
Sgr 2019-03-01	8,00	<0,5	<0,1	<0,1	16,10	<0,04	492 350,00	1,40	<40	11,10	608,00	<0,1	0,60
Sgr 2019-03-09	7,00	<0,5	<0,1	<0,1	12,00	<0,04	394 790,00	<0,5	<40	10,60	503,00	<0,1	<0,1
Sgr 2019-03-15	11,00	<0,5	<0,1	<0,1	13,10	<0,04	519 390,00	<0,5	<40	9,50	704,00	<0,1	1,10
Sgr 2019-03-22	<5	<0,5	<0,1	<0,1	10,80	0,05	435 850,00	<0,5	<40	9,40	621,00	<0,1	0,40

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	
	Sr	Ta	Tb	Te	Th	Tl	Tm	U	V	W	Y	Yb	Zn
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Dyke 2018-07-24	28,90	0,30	<0,1	<0,5	0,30	<0,1	<0,1	0,10	<1	0,40	<0,1	<0,1	30,00
Dyke 2018-07-31	66,50	0,30	<0,1	<0,5	0,30	<0,1	<0,1	0,30	1,00	<0,1	0,10	<0,1	31,00
Dyke 2018-08-07	58,00	0,20	<0,1	<0,5	0,20	<0,1	<0,1	<0,1	1,00	<0,1	<0,1	<0,1	30,00
Dyke 2018-08-14	55,10	0,20	<0,1	<0,5	<0,1	0,20	<0,1	<0,1	1,00	0,30	<0,1	<0,1	23,00
Dyke 2018-08-21	56,00	0,20	<0,1	<0,5	0,70	<0,1	<0,1	0,20	<1	0,50	<0,1	<0,1	21,00
Dyke 2018-08-28	57,00	0,10	<0,1	<0,5	0,40	<0,1	<0,1	0,10	<1	<0,1	<0,1	<0,1	18,00
Dyke 2018-09-04	46,60	0,10	<0,1	0,60	0,20	0,20	<0,1	0,20	<1	<0,1	<0,1	<0,1	21,00
Dyke 2018-09-18	57,80	0,10	<0,1	<0,5	<0,1	<0,1	<0,1	0,30	<1	<0,1	<0,1	<0,1	24,00
Dyke 2018-09-25	50,10	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	0,20	<1	<0,1	<0,1	<0,1	16,00
Dyke 2018-10-02	39,50	<0,1	<0,1	<0,5	0,20	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	10,00
Dyke 2018-10-09	42,60	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	8,00
Dyke 2018-10-17	60,60	<0,1	<0,1	<0,5	<0,1	0,10	<0,1	0,10	<1	0,30	<0,1	<0,1	6,00
Dyke 2018-10-24	52,50	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	5,00
Dyke 2018-10-31	43,90	<0,1	<0,1	<0,5	1,20	<0,1	<0,1	<0,1	<1	0,80	<0,1	<0,1	<5
Dyke 2018-11-06	39,10	<0,1	<0,1	<0,5	0,50	<0,1	<0,1	<0,1	<1	0,40	<0,1	<0,1	<5
Dyke 2018-11-13	44,50	<0,1	<0,1	<0,5	0,20	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	<5
Dyke 2018-11-21	46,20	<0,1	<0,1	<0,5	0,10	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	<5
Dyke 2018-11-29	42,00	<0,1	<0,1	0,60	1,10	0,20	<0,1	0,10	<1	1,00	<0,1	<0,1	5,00
Dyke 2018-12-06	36,20	<0,1	<0,1	<0,5	0,40	<0,1	<0,1	0,20	<1	0,40	<0,1	<0,1	<5
Dyke 2018-12-13	34,80	<0,1	<0,1	<0,5	0,30	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	<5
Dyke 2018-12-21	40,60	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	0,10	<1	<0,1	<0,1	<0,1	<5
Dyke 2019-01-24	45,40	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	0,20	<1	0,20	<0,1	<0,1	<5
Dyke 2019-01-31	43,70	<0,1	<0,1	<0,5	0,90	<0,1	<0,1	0,10	<1	0,40	<0,1	<0,1	<5
Dyke 2019-02-08	50,70	<0,1	<0,1	0,60	0,20	<0,1	<0,1	0,20	<1	0,40	<0,1	<0,1	7,00
Dyke 2019-02-15	48,50	<0,1	<0,1	<0,5	0,10	<0,1	<0,1	0,20	<1	0,20	<0,1	<0,1	<5
Dyke 2019-02-22	41,70	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	0,20	<1	<0,1	<0,1	<0,1	<5
Dyke 2019-03-01	48,70	<0,1	<0,1	<0,5	0,70	0,10	<0,1	0,20	<1	0,50	<0,1	<0,1	<5
Dyke 2019-03-09	43,90	<0,1	<0,1	1,00	0,30	<0,1	<0,1	0,20	<1	0,20	<0,1	<0,1	<5
Dyke 2019-03-15	50,90	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	0,20	<1	<0,1	<0,1	<0,1	<5
Dyke 2019-03-22	41,00	<0,1	<0,1	<0,5	0,10	<0,1	<0,1	0,20	<1	<0,1	<0,1	<0,1	<5
FW 2018-07-24	50,10	0,30	<0,1	0,70	0,20	<0,1	<0,1	0,10	<1	0,60	0,10	<0,1	54,00
FW 2018-07-31	58,90	0,20	<0,1	<0,5	0,20	0,20	<0,1	0,10	<1	<0,1	0,10	<0,1	30,00
FW 2018-08-07	57,20	0,20	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	25,00
FW 2018-08-14	51,40	0,20	<0,1	<0,5	<0,1	0,10	<0,1	<0,1	<1	<0,1	<0,1	<0,1	35,00
FW 2018-08-21	34,40	0,20	<0,1	<0,5	0,80	0,10	<0,1	<0,1	<1	0,20	<0,1	<0,1	26,00
FW 2018-08-28	54,50	0,10	<0,1	<0,5	0,30	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	35,00
FW 2018-09-04	49,30	<0,1	<0,1	<0,5	0,10	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	37,00
FW 2018-09-18	49,60	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	<0,1	<1	<0,1	<0,1	<0,1	44,00
FW 2018-09-25	49,30	<0,1	<0,1	<0,5	0,60	0,20	<0,1	<0,1	<1	0,70	<0,1	<0,1	30,00
FW 2018-10-02	42,30	<0,1	<0,1	<0,5	0,40	<0,1	<0,1	<0,1	<1	0,30	<0,1	<0,1	30,00
FW 2018-10-09	31,10	<0,1	<0,1	1,00	0,20	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	23,00
FW 2018-10-17	37,00	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,30	<0,1	<0,1	25,00
FW 2018-10-24	40,20	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	42,00
FW 2018-10-31	40,20	<0,1	<0,1	<0,5	1,00	0,10	<0,1	<0,1	<1	0,60	<0,1	<0,1	25,00
FW 2018-11-06	37,30	<0,1	<0,1	<0,5	0,40	0,20	<0,1	<0,1	<1	0,20	<0,1	<0,1	29,00
FW 2018-11-13	24,50	<0,1	<0,1	<0,5	0,20	0,20	<0,1	<0,1	<1	0,10	<0,1	<0,1	24,00
FW 2018-11-21	32,10	<0,1	<0,1	<0,5	0,20	0,10	<0,1	<0,1	<1	<0,1	<0,1	<0,1	22,00
FW 2018-11-29	35,80	<0,1	<0,1	0,60	0,90	<0,1	<0,1	<0,1	<1	0,70	<0,1	<0,1	28,00
FW 2018-12-06	23,80	<0,1	<0,1	1,00	0,40	<0,1	<0,1	<0,1	<1	0,30	<0,1	<0,1	33,00
FW 2018-12-13	26,70	<0,1	<0,1	<0,5	0,30	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	20,00
FW 2018-12-21	29,20	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	31,00
FW 2019-01-24	45,00	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	35,00
FW 2019-01-31	25,60	<0,1	<0,1	<0,5	0,70	<0,1	<0,1	<0,1	<1	1,30	<0,1	<0,1	31,00
FW 2019-02-08	25,40	<0,1	<0,1	<0,5	0,10	0,10	<0,1	<0,1	<1	8,30	<0,1	<0,1	26,00
FW 2019-02-15	32,50	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	37,00
FW 2019-02-22	31,50	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	30,00
FW 2019-03-01	19,10	<0,1	<0,1	<0,5	0,60	0,20	<0,1	<0,1	<1	0,60	<0,1	<0,1	20,00
FW 2019-03-09	21,80	<0,1	<0,1	<0,5	0,30	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	42,00
FW 2019-03-15	29,90	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	<0,1	<1	0,20	<0,1	<0,1	44,00
FW 2019-03-22	27,60	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	31,00

	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	DIR-IMS	
	Sr	Ta	Tb	Te	Th	Tl	Tm	U	V	W	Y	Yb	Zn
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
HGW 2018-07-24	36,10	0,20	<0,1	<0,5	0,40	<0,1	<0,1	0,40	<1	0,40	0,10	<0,1	25,00
HGW 2018-07-31	43,30	0,30	<0,1	<0,5	0,30	<0,1	<0,1	1,00	1,00	<0,1	0,20	<0,1	25,00
HGW 2018-08-07	41,30	0,20	<0,1	0,80	<0,1	0,10	<0,1	0,20	<1	0,30	0,10	<0,1	33,00
HGW 2018-08-14	24,90	0,20	<0,1	<0,5	<0,1	<0,1	<0,1	0,10	<1	<0,1	0,30	<0,1	21,00
HGW 2018-08-21	44,10	0,20	<0,1	<0,5	<0,1	<0,1	<0,1	0,30	<1	<0,1	0,50	0,10	37,00
HGW 2018-08-28	42,20	0,20	<0,1	<0,5	0,50	0,10	<0,1	0,30	<1	0,20	0,50	<0,1	33,00
HGW 2018-09-04	42,10	0,10	<0,1	<0,5	0,20	<0,1	<0,1	0,10	<1	<0,1	<0,1	<0,1	27,00
HGW 2018-09-18	26,10	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	16,00
HGW 2018-09-25	41,00	<0,1	<0,1	<0,5	<0,1	0,10	<0,1	<0,1	<1	<0,1	<0,1	<0,1	22,00
HGW 2018-10-02	41,20	<0,1	<0,1	<0,5	0,50	0,20	<0,1	<0,1	<1	0,70	<0,1	<0,1	13,00
HGW 2018-10-09	33,70	<0,1	<0,1	<0,5	0,30	<0,1	<0,1	<0,1	<1	0,40	<0,1	<0,1	8,00
HGW 2018-10-17	48,30	<0,1	<0,1	0,80	0,10	<0,1	<0,1	0,10	<1	0,30	0,30	<0,1	18,00
HGW 2018-10-24	36,40	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	8,00
HGW 2018-10-31	44,60	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,20	0,30	<0,1	10,00
HGW 2018-11-06	41,20	<0,1	<0,1	<0,5	0,60	<0,1	<0,1	<0,1	<1	0,60	0,40	0,10	12,00
HGW 2018-11-13	43,30	<0,1	<0,1	<0,5	0,30	0,20	<0,1	<0,1	<1	0,20	0,20	<0,1	10,00
HGW 2018-11-21	40,90	<0,1	<0,1	<0,5	0,10	0,10	<0,1	<0,1	<1	0,20	0,10	<0,1	6,00
HGW 2018-11-29	29,50	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	<0,1	<1	0,10	0,10	<0,1	5,00
HGW 2018-12-06	29,10	<0,1	<0,1	<0,5	0,50	<0,1	<0,1	<0,1	<1	0,60	<0,1	<0,1	<5
HGW 2018-12-13	30,10	<0,1	<0,1	<0,5	0,30	0,20	<0,1	<0,1	<1	0,40	<0,1	<0,1	9,00
HGW 2018-12-21	34,50	<0,1	<0,1	<0,5	0,20	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	6,00
HGW 2019-01-24	30,90	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	<0,1	<1	<0,1	<0,1	<0,1	6,00
HGW 2019-01-31	30,40	<0,1	<0,1	<0,5	1,20	0,30	<0,1	<0,1	<1	1,10	<0,1	<0,1	<5
HGW 2019-02-08	23,20	<0,1	<0,1	1,00	0,60	<0,1	<0,1	<0,1	<1	0,40	<0,1	<0,1	<5
HGW 2019-02-15	31,10	<0,1	<0,1	<0,5	0,10	0,10	<0,1	<0,1	<1	0,30	<0,1	<0,1	5,00
HGW 2019-02-22	27,50	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	5,00
HGW 2019-03-01	28,80	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	11,00
HGW 2019-03-09	26,90	0,10	<0,1	<0,5	0,30	0,10	<0,1	<0,1	<1	0,30	<0,1	<0,1	7,00
HGW 2019-03-15	26,70	<0,1	<0,1	0,70	0,10	0,10	<0,1	<0,1	<1	<0,1	<0,1	<0,1	5,00
HGW 2019-03-22	20,60	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	9,00
Sgr 2018-07-24	38,80	0,20	<0,1	<0,5	0,40	<0,1	<0,1	0,10	<1	0,60	<0,1	<0,1	32,00
Sgr 2018-07-31	48,30	0,30	<0,1	<0,5	0,30	<0,1	<0,1	0,20	1,00	0,10	<0,1	<0,1	21,00
Sgr 2018-08-07	34,80	0,20	<0,1	<0,5	0,20	0,10	<0,1	0,10	<1	0,10	0,10	<0,1	27,00
Sgr 2018-08-14	34,70	0,20	<0,1	<0,5	<0,1	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	35,00
Sgr 2018-08-21	52,50	0,20	<0,1	<0,5	1,10	0,20	<0,1	0,10	<1	0,90	<0,1	<0,1	23,00
Sgr 2018-08-28	37,00	0,10	<0,1	<0,5	0,50	0,20	<0,1	<0,1	<1	0,20	<0,1	<0,1	29,00
Sgr 2018-09-04	29,70	0,10	<0,1	<0,5	0,20	<0,1	<0,1	<0,1	<1	0,40	<0,1	<0,1	23,00
Sgr 2018-09-18	30,90	0,10	<0,1	<0,5	0,10	<0,1	<0,1	<0,1	<1	<0,1	<0,1	<0,1	16,00
Sgr 2018-09-25	32,90	0,10	<0,1	<0,5	<0,1	0,10	<0,1	<0,1	<1	0,60	<0,1	<0,1	20,00
Sgr 2018-10-02	30,20	<0,1	<0,1	<0,5	0,50	0,30	<0,1	<0,1	<1	0,40	<0,1	<0,1	13,00
Sgr 2018-10-09	34,50	<0,1	<0,1	<0,5	0,30	0,10	<0,1	<0,1	<1	0,20	<0,1	<0,1	13,00
Sgr 2018-10-17	35,40	<0,1	<0,1	<0,5	0,30	0,10	<0,1	<0,1	<1	0,10	<0,1	<0,1	11,00
Sgr 2018-10-24	46,30	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	<0,1	<1	<0,1	<0,1	<0,1	16,00
Sgr 2018-10-31	35,20	<0,1	<0,1	<0,5	1,40	0,20	<0,1	<0,1	<1	1,30	<0,1	<0,1	12,00
Sgr 2018-11-06	27,10	<0,1	<0,1	<0,5	0,70	0,20	<0,1	<0,1	<1	0,50	<0,1	<0,1	7,00
Sgr 2018-11-13	29,90	<0,1	<0,1	<0,5	0,30	<0,1	<0,1	<0,1	<1	0,20	<0,1	<0,1	7,00
Sgr 2018-11-21	35,00	<0,1	<0,1	<0,5	0,10	0,10	<0,1	<0,1	<1	0,20	<0,1	<0,1	18,00
Sgr 2018-11-29	28,80	<0,1	<0,1	<0,5	0,10	<0,1	<0,1	<0,1	<1	0,10	<0,1	<0,1	12,00
Sgr 2018-12-06	25,90	<0,1	<0,1	<0,5	0,50	0,20	<0,1	0,20	<1	0,50	<0,1	<0,1	14,00
Sgr 2018-12-13	23,10	<0,1	<0,1	<0,5	0,20	0,20	<0,1	<0,1	<1	0,20	<0,1	<0,1	16,00
Sgr 2018-12-21	27,70	<0,1	<0,1	<0,5	0,40	0,10	<0,1	0,20	<1	0,20	<0,1	<0,1	21,00
Sgr 2019-01-24	37,40	<0,1	<0,1	<0,5	<0,1	0,20	<0,1	0,30	<1	<0,1	<0,1	<0,1	33,00
Sgr 2019-01-31	31,40	<0,1	<0,1	<0,5	1,10	0,20	<0,1	0,20	<1	0,60	<0,1	<0,1	18,00
Sgr 2019-02-08	33,50	<0,1	<0,1	<0,5	0,40	0,20	<0,1	0,40	<1	0,30	<0,1	<0,1	21,00
Sgr 2019-02-15	28,40	<0,1	<0,1	<0,5	0,20	<0,1	<0,1	0,30	<1	0,30	<0,1	<0,1	21,00
Sgr 2019-02-22	30,80	<0,1	<0,1	<0,5	<0,1	<0,1	<0,1	0,20	<1	<0,1	<0,1	<0,1	17,00
Sgr 2019-03-01	28,50	0,10	<0,1	0,90	0,90	0,20	<0,1	0,30	<1	0,90	<0,1	<0,1	23,00
Sgr 2019-03-09	26,40	<0,1	<0,1	<0,5	0,30	0,20	<0,1	0,20	<1	0,40	<0,1	<0,1	21,00
Sgr 2019-03-15	32,30	0,20	<0,1	<0,5	<0,1	0,10	<0,1	0,20	<1	0,10	<0,1	<0,1	27,00
Sgr 2019-03-22	25,10	<0,1	<0,1	0,60	<0,1	0,10	<0,1	0,20	<1	<0,1	<0,1	<0,1	29,00

DIR-IMS

Zr

ppb

Dyke 2018-07-24	0,20
Dyke 2018-07-31	0,20
Dyke 2018-08-07	0,40
Dyke 2018-08-14	0,50
Dyke 2018-08-21	0,40
Dyke 2018-08-28	0,20
Dyke 2018-09-04	<0,2
Dyke 2018-09-18	<0,2
Dyke 2018-09-25	<0,2
Dyke 2018-10-02	<0,2
Dyke 2018-10-09	<0,2
Dyke 2018-10-17	<0,2
Dyke 2018-10-24	<0,2
Dyke 2018-10-31	<0,2
Dyke 2018-11-06	<0,2
Dyke 2018-11-13	<0,2
Dyke 2018-11-21	<0,2
Dyke 2018-11-29	<0,2
Dyke 2018-12-06	<0,2
Dyke 2018-12-13	<0,2
Dyke 2018-12-21	<0,2
Dyke 2019-01-24	<0,2
Dyke 2019-01-31	<0,2
Dyke 2019-02-08	<0,2
Dyke 2019-02-15	<0,2
Dyke 2019-02-22	<0,2
Dyke 2019-03-01	<0,2
Dyke 2019-03-09	<0,2
Dyke 2019-03-15	<0,2
Dyke 2019-03-22	<0,2
FW 2018-07-24	0,20
FW 2018-07-31	0,30
FW 2018-08-07	0,30
FW 2018-08-14	0,30
FW 2018-08-21	0,20
FW 2018-08-28	<0,2
FW 2018-09-04	<0,2
FW 2018-09-18	<0,2
FW 2018-09-25	<0,2
FW 2018-10-02	<0,2
FW 2018-10-09	<0,2
FW 2018-10-17	<0,2
FW 2018-10-24	<0,2
FW 2018-10-31	<0,2
FW 2018-11-06	<0,2
FW 2018-11-13	<0,2
FW 2018-11-21	<0,2
FW 2018-11-29	<0,2
FW 2018-12-06	<0,2
FW 2018-12-13	<0,2
FW 2018-12-21	<0,2
FW 2019-01-24	<0,2
FW 2019-01-31	<0,2
FW 2019-02-08	<0,2
FW 2019-02-15	<0,2
FW 2019-02-22	<0,2
FW 2019-03-01	<0,2
FW 2019-03-09	<0,2
FW 2019-03-15	<0,2
FW 2019-03-22	<0,2

DIR-IMS

Zr

ppb

HGW 2018-07-24	0,30
HGW 2018-07-31	0,30
HGW 2018-08-07	0,40
HGW 2018-08-14	0,30
HGW 2018-08-21	0,40
HGW 2018-08-28	0,50
HGW 2018-09-04	<0,2
HGW 2018-09-18	<0,2
HGW 2018-09-25	<0,2
HGW 2018-10-02	<0,2
HGW 2018-10-09	<0,2
HGW 2018-10-17	0,30
HGW 2018-10-24	<0,2
HGW 2018-10-31	0,20
HGW 2018-11-06	0,40
HGW 2018-11-13	<0,2
HGW 2018-11-21	<0,2
HGW 2018-11-29	<0,2
HGW 2018-12-06	<0,2
HGW 2018-12-13	<0,2
HGW 2018-12-21	<0,2
HGW 2019-01-24	<0,2
HGW 2019-01-31	<0,2
HGW 2019-02-08	<0,2
HGW 2019-02-15	<0,2
HGW 2019-02-22	<0,2
HGW 2019-03-01	<0,2
HGW 2019-03-09	<0,2
HGW 2019-03-15	<0,2
HGW 2019-03-22	<0,2

Sgr 2018-07-24	0,20
Sgr 2018-07-31	0,20
Sgr 2018-08-07	0,40
Sgr 2018-08-14	0,30
Sgr 2018-08-21	0,30
Sgr 2018-08-28	<0,2
Sgr 2018-09-04	<0,2
Sgr 2018-09-18	<0,2
Sgr 2018-09-25	<0,2
Sgr 2018-10-02	<0,2
Sgr 2018-10-09	<0,2
Sgr 2018-10-17	<0,2
Sgr 2018-10-24	<0,2
Sgr 2018-10-31	0,20
Sgr 2018-11-06	<0,2
Sgr 2018-11-13	<0,2
Sgr 2018-11-21	<0,2
Sgr 2018-11-29	<0,2
Sgr 2018-12-06	<0,2
Sgr 2018-12-13	<0,2
Sgr 2018-12-21	<0,2
Sgr 2019-01-24	<0,2
Sgr 2019-01-31	<0,2
Sgr 2019-02-08	<0,2
Sgr 2019-02-15	<0,2
Sgr 2019-02-22	<0,2
Sgr 2019-03-01	<0,2
Sgr 2019-03-09	<0,2
Sgr 2019-03-15	<0,2
Sgr 2019-03-22	<0,2

BILAGA C

Talga Resources Vittangi Project Tailings Feasibility Study - Laboratory Testing

FACTUAL REPORT

Client Details:	
Name:	GHD
PO No.:	6138474
Client Reference:	6138474
Project Name:	Talga Resources Vittanga Project Tailings Feasibility Study
Contact:	Mr Jiri Herza Email: Jiri.Herza@ghd.com
GTI Perth Details:	
Reference No:	C16-P01-T01
Job No.:	20-003
Address:	16 Glory Road, Gnangara, WA 6077
Contact:	Mr Francis Lee Telephone: (08) 9303 4042 Email: flee@gtiperth.com.au

TALGA RESOURCES VITTANGA PROJECT TAILINGS FEASIBILITY STUDY – LABORATORY TESTING

GTI Perth Pty Ltd (GTI Perth) was contracted by GHD to provide laboratory testing services for the Talga Resources Vittanga project.

Three bags of bulk samples were provided by the client, and delivered to GTI Perth on 25 July 2019:

- Bag 1: VITT-0001-DO1S
- Bag 2: VITT-0001-DO2S
- Bag 3: VITT-0001-DO3S

The tests to be performed on the as-received samples were specified by GHD (email dated 7 August 2019). The scope of work includes:

- 3 x Classification testing, including moisture content, particle size distribution (PSD), soil particle density (G_s) and Atterberg limits including linear shrinkage
- 1 x Emerson Class
- 1 x Shrink-swell Index
- 1 x Consolidation – Oedometer test
- 1 x Rowe cell consolidation with permeability measurement
- 1 x Triaxial compression test.
- 3 x pH measurement

This laboratory report includes results of all tests. Methodology and standard used are described as required.

TEST RESULTS

1. CLASSIFICATION TESTS

The results of the classification tests are presented in **Appendix A**. The classification tests were performed on samples on all three bags.

Moisture Content

Moisture content was measured following Australian Standards AS1289.2.1.1. Values of 36.4%, 35.2% and 42.8% were obtained for the samples from VITT-0001-DO1S, VITT-0001-DO2S and VITT-0001-DO3S respectively. **Figure A1** presents the results of the moisture content tests.

Soil Particle Density

Soil particle density (G_s) was measured following the Australian Standards AS1289.3.5.1. Values of 2.86, 2.87 and 2.79 were obtained for the samples from VITT-0001-DO1S, VITT-0001-DO2S and VITT-0001-DO3S respectively. **Figure A2** presents the results of the soil particle density tests.

Particle Size Distribution

Particle size distribution (PSD) tests were performed on the samples from VITT-0001-DO1S, VITT-0001-DO2S and VITT-0001-DO3S, following the Australian Standards AS1289.3.6.1 and AS1289.3.6.3. **Figure A3** presents the results of the PSD tests in tabulated and graphical forms. Median particle size (D_{50}) of 0.005 mm, 0.004 mm and 0.003 mm, fines content (<0.075 mm) of 92%, 93% and 93%, and clay size content (<0.002 mm) of 27%, 27% and 35% were obtained from samples VITT-0001-DO1S, VITT-0001-DO2S and VITT-0001-DO3S respectively.

Atterberg Limits

Atterberg limits test comprises measurement of the liquid limit (w_L) and plastic limit (w_P) of the soil sample. The liquid limit test was carried out using the static cone penetrometer method (AS 1289 3.9.1) while the plastic limit test was carried out by mixing the soil sample with water and rolling it until the sediment showed signs of crumbling when the diameter was 3 mm (AS 1289 3.2.1). Linear shrinkage test was carried out following the Australian Standards AS1289.3.4.1.

The plasticity Index (I_p) of the sediment is calculated as:

$$I_p = w_L - w_P \quad (1)$$

Atterberg limit test was performed on samples from all 3 bags, and the results are presented in **Figure A4**. Liquid limit (w_L) of 39%, 42% and 46%, plastic limit (I_p) of 26%, 25% and 30%, plasticity index of 13, 17 and 16, linear shrinkage of 4.0%, 4.0% and 4.5% were obtained from the samples from VITT-0001-DO1S, VITT-0001-DO2S and VITT-0001-DO3S respectively.

Emerson Class

Emerson Class was determined on a sample from VITT-0001-DO1S following the Australian Standards AS1289.3.8.1. The Emerson class was found to be 6. **Figure A5** presents the result of the Emerson class test.

Shrink-swell Index

Shrink-swell Index was determined on a sample from VITT-0001-DO1S following the Australian Standard AS1289.7.1.1. The sample for the swelling test was taken from the bagged bulk material by pushing a cutting ring into the soil sample. For the shrinkage test, the sample was prepared at “as-received” moisture content using tamping method. Five layers were tamped in order to achieve desired density. **Figure B** presents the result of the shrink-swell index test.

pH Determination

The pH tests were performed by Australian Laboratory Services (ALS) on samples from all three bags. The results of the pH tests are presented in **Appendix F**.

2. CONSOLIDATION TESTS

Oedometer

One-dimensional consolidation (oedometer) test was performed on sample VITT-0001-DO1S using a motorised load controlled oedometer machine and following the test method as described in the Australian Standard (AS 1289 6.6.1). The test comprised multi-stage loading from a specified initial vertical stress (σ'_{v-ini}) to a maximum vertical stress (σ'_{v-max}). The sample was then unloaded back to σ'_{v-ini} before removing it from the machine. The loading pattern for each test was is shown in **Figure C**.

The results of oedometer test is presented in **Figure C** in 3 pages:

- In Page 1, the results are shown in tabulated form, including the details of the loading and unloading stages, the applied stress for each stage, and the results in terms of:

- void ratio (e),
- coefficient of consolidation (c_v) for the loading stages; estimated using the square root time method,
- coefficient of volume compressibility (m_v) for all stages:

$$m_v = \frac{\Delta H}{\Delta \sigma} \frac{1}{H} \quad (2)$$

where ΔH is the change in sample height for the stage, $\Delta \sigma$ is the increase in applied vertical stress for the stage and H is the height of the sample at the start of the stage.

- coefficient of permeability (k) for the loading stages:

$$k = \frac{c_v \cdot m_v}{\gamma_w} \quad (3)$$

where γ_w is the unit weight of water.

- On Page 2, plot of void ratio (e) versus applied vertical stress (σ'_v) for each stage is presented. Slopes for determining the compression index (C_c) and swelling index (C_{s-Max}) are shown on the plot and the obtained values are provided in the table below the plot.
- On Page 3, plot of sample height (H) versus the square root of time for each loading stage.

Rowe cell

The Rowe Cell test was performed on a sample from VITT-0001-DO1S following GTI Perth test procedure GTI-STT-P06. Water was added to the sample and mixed thoroughly until the mixture reached the consistency of a thin paste. Initial moisture content of the mixture of about 55% was obtained.

The Rowe Cell test was carried out by applying a seating stress of 10 kPa on the sample and allowed it to consolidate prior to starting the loading stages. Eight loading stages (from 10 kPa to 650 kPa) were applied and final unload stages were undertaken at the maximum stress of 650 kPa, back to 10 kPa.

Permeability tests were carried out at completion of each loading stages. Two pressure head differences (ΔP) of 5kPa and 10 kPa, were used to measure the permeability k of the sample.

Figure D presents the results of the Rowe Cell tests, the results are presented in 3 pages:

- In Page 1, the results are presented in tabulated form, showing:
 - the details of the loading and unloading stages, the applied vertical stress (σ_v) for each stage, and
 - the results in terms of:
 - a) void ratio (e),
 - b) coefficient of consolidation (c_v) for the loading stages; values of c_v obtained using the square root time method and c_v obtained by matching the pore pressure dissipation curve to the theoretical curve (Terzaghi, 1936) are provided.
 - c) coefficient of volume compressibility (m_v) for all stages and
 - d) coefficient of permeability (k); (1) k calculated using c_v and corresponding m_v and (2) measured at the end of each loading stage.
- On Page 2, plot of e versus σ_v for each stage.
- On page 3, plots of c_v , m_v and k versus σ_v . For m_v , the values obtained for the loading, unloading stages are presented.

3. TRIAXIAL TESTS

A multi-stage (3-stage) static triaxial test was carried out following GTI Perth test procedure GTI-ADT-P04. The test was performed on a reconstituted sample, under isotropic consolidation conditions (CIU). The sample was prepared using a mixture of materials from all 3 bag samples. The test details are summarized in **Table 1** and the results are presented in **Appendix E**.

Table 1 Triaxial test – Summary Result

Sample ID	Stage	Consolidation		Loading Rate	Results			
		σ'_v	σ'_h		q_{max}	$q_{stage\ end}$	ϵ_{a-qmax}	ϵ_{a-max}
	No.	(kPa)	(kPa)	(mm/min)	(kPa)	(kPa)	(%)	(%)
Combined – VITT-0001-DO1S, VITT-0001-DO2S VITT-0001-DO3S	1	52	50	0.1	44.2	44.2	1.09	1.09
	2	102	100		109.3	109.2	5.03	5.04
	3	402	400		822.0	822.0	17.7	17.7

Sample Preparation

The test sample was prepared from a mixture of samples from VITT-0001-DO1S, VITT-0001-DO2S and VITT-0001-DO3S. The target dry density of approximately 1.42 g/cm³ was provided by GHD for the sample.

A split mould of 70 mm diameter and 140 mm height was used to prepare the sample. Equal portion of oven-dried material from each of the three samples was taken and mixed thoroughly. The undercompaction method (Ladd 1978) was used to achieve a uniform density across the sample length. The sample was compacted in 7 layers, with a 5% undercompaction was applied to the first layer. A dry density of 1.43 g/cm³ and initial moisture content of 28 % were obtained.

The reconstituted sample is extruded from the split mould and placed on the base pedestal. A flexible membrane is then stretched around the sample and sealed at the top and bottom using “O-rings”.

The sample, caps and membrane are then transferred to the machine, and the base pedestal bolted to the cell. The vertical loading ram is lowered and connected to the top cap. Drainage lines are connected to the caps before closing the cell and filling it with water.

Before starting the test, the sample was flushed with water from bottom to top, in order to de-air the sample, by applying a small confining pressure (about 10 kPa) and isolating the bottom back pressure line from the top back pressure line. A pressure of about 5 kPa was applied at the bottom of the sample, while the top drainage was maintained at atmospheric pressure. The flushing was continued until steady flow of water with no visible air bubble was observed. The inlet and outlet water volume were monitored to determine the initial moisture content of the test sample prior starting of saturation phase. Moisture content of approximately 34 % was obtained after flushing.

Saturation

The cell pressure and back-pressure were ramped up in parallel, with never more than 10 kPa difference between them, until the cell pressure reached 410 kPa and the back pressure 400 kPa.

The sample was then left overnight to ensure full saturation, after which a B-value check was carried out. This consisted of closing the drainage valves and applying a cell pressure

increment ($\Delta\sigma_h$) of 20 kPa, while measuring the corresponding pore pressure change (Δu). A B-value of 0.96 was obtained for the remoulded sample.

Consolidation

The sample was consolidated isotropically, by ramping the cell pressure (σ_h) to the target consolidation pressure, with the drainage valves open. A constant vertical stress of 2 kPa was maintained throughout the consolidation stage to ensure the loading ram is in contact with the sample. After ramping, sufficient time was allowed for the specimen to fully consolidate before shearing. Following the first stage of loading, the vertical stress was released to the initial value (2 kPa) and drainage valves opened to dissipate the excess pore pressure before starting the second stage consolidation. The process was repeated for the third stage consolidation. The test was carried out at consolidation pressures of 50 kPa (Stage 1), 100 kPa (Stage 2) and 400 kPa (Stage 3).

Loading

The compression test was performed at a nominal constant rate of vertical displacement of 0.1 mm/min (equivalent to a nominal constant axial strain rate of about 4.3%/h). For the first two stages, the sample was loaded until the effective stress ratio (σ'_1/σ'_3) reached a peak value. The machine was then stopped and loading was reversed until the vertical stress reached the initial value. For the third (final) stage, the test was terminated after the cumulative axial strain greater than 20% was reached.

Test Result

The result of the static triaxial test is presented in a graphical form with the following plots across 3 pages:

- Page 1: The results of the consolidation for all 3-stages are presented on this page in terms of:
 - consolidation stresses ($\sigma_v = \sigma_h$) versus time
 - cumulative axial strain (ε_a) versus time
 - cumulative volumetric strain (ε_v) versus time and
 - cumulative volumetric (ε_v) strain versus mean stress (p).
- Page 2: The results of the shearing for all 3-stages are presented on this page in terms of:
 - deviator stress ($q = \sigma'_v - \sigma'_h$) versus cumulative axial strain (ε_a)
 - deviator stress (q) versus ε_a obtained for each stage. The inserted plot in this figure shows the close up of the initial part of the loading stages.
 - excess pore pressure (Δu) versus ε_a .
 - Cambridge stress path: deviator stress ($q = \sigma'_v - \sigma'_h$) versus mean effective stress ($p' = (\sigma'_v + 2\sigma'_h)/3$).
- Page 3: Photograph of the sample after testing.

This report presents the factual results of tests performed on the “as received” samples. These results should be used in combination with all available data from the site, by competent Geotechnical Engineers, to derive design parameters, with the knowledge of their limitation.

* * * * *

We trust that the test results provided in this factual report meets your requirements, but should you have any queries then please do not hesitate to contact us.

Yours sincerely

GTI Perth Pty Ltd



Francis Lee
Director

REFERENCES

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- AS 1289 3.2.1 (2009). *"Soil Classification Tests – Determination of the Plastic Limit of a Soil – Standard Method"*.
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- AS 1289 7.1.1 (2003), *"Soil Reactivity Tests – Determination of Shrinkage index of a soil – Shrink-swell index"*.
- GTI-ADT-P04 *"Determination of Shear Strength - Static Triaxial Test"*.
- GTI-STT-P06 *"Measurement of Consolidation and Permeability – Rowe Cell Method"*.
- R. Ladd (1978), *"Preparing Test Specimens Using Undercompaction,"* Geotechnical Testing Journal 1, no. 1: 16-23.

Appendix A

Moisture Content
Test Method: AS1289.2.1.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Project:	Talga Resources Vittanga Project
Client reference:	6138474		Tailings Feasibility Study

Summary Results			
Test No.:	20-003-M-01	20-003-M-02	20-003-M-03
Sample No.:	VITT-0001-DO1S	VITT-0001-DO2S	VITT-0001-DO3S
Moisture Content (%):	36.4	35.2	42.8
Solid Content (%):	73.3	74.0	70.0
Tested By:	BC/GG	BC/GG	BC/GG
Date Tested:	1/08/2019	1/08/2019	1/08/2019
Checked By:	FL	FL	FL
Date Checked:	2/08/2019	2/08/2019	2/08/2019

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GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Classification Test - Moisture Content

Job No.:20-003

Figure A1

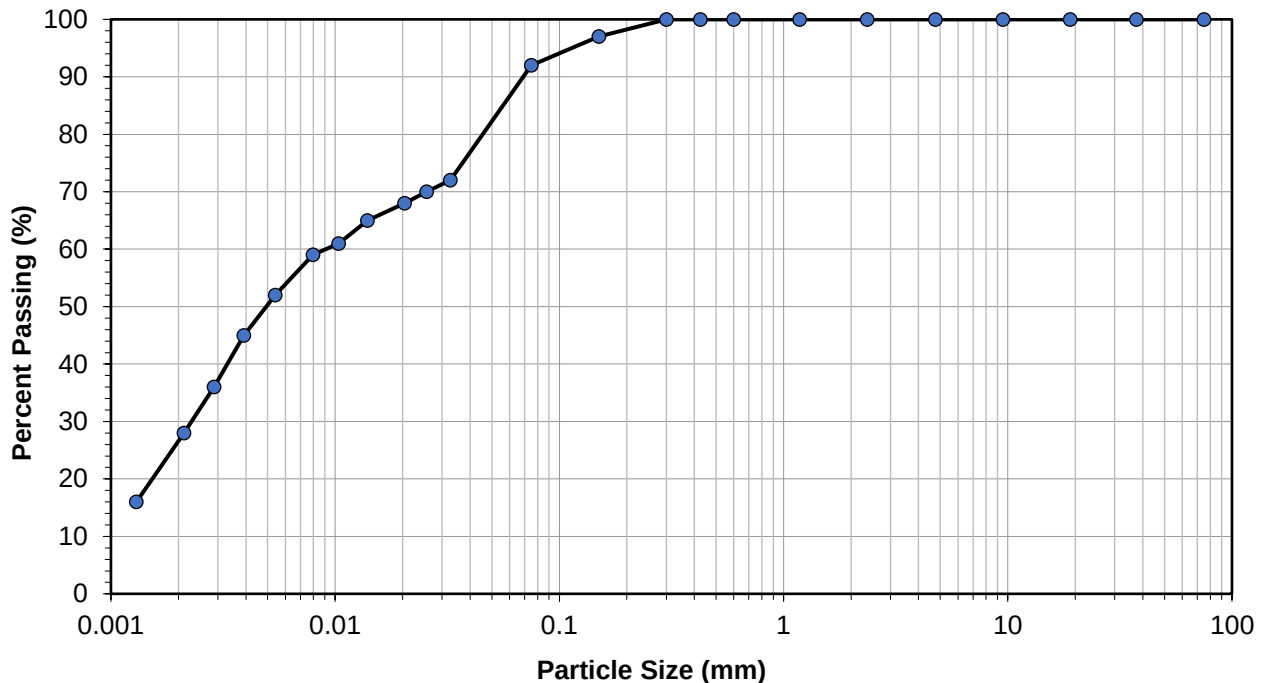
Soil Particle Density
Test Method: AS1289.3.5.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Project:	Talga Resources Vittanga Project
Client reference:	6138474		Tailings Feasibility Study

Summary Results			
Test No. (N):	20-003-GS-01	20-003-GS-02	20-003-GS-03
Sample No.:	VITT-0001-DO1S	VITT-0001-DO2S	VITT-0001-DO3S
Soil Particle Density (g/cm³):	2.86	2.87	2.79
Tested By:	BC	BC	BC
Date Tested:	9/08/2019	9/08/2019	9/08/2019
Checked By:	FL	FL	FL
Date Checked:	21/08/2019	21/08/2019	21/08/2019

Particle Size Distribution
Test Method: AS1289.3.6.1 & AS1289.3.6.3

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003--PSD-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Sample No:	VITT-0001-DO1S
		Hydrometer Type:	ASTM-152H
		Pretreatment :	No
Client reference:	6138474	Dispersion Method:	Dispersion agent - 4g/L
		Loss in Pretreatment:	NA
Tested By:	BC	Checked By:	FL
Date:	8/08/2019	Date:	21/08/2019



Sieving		Hydrometer	
Size	Passing	Size	Passing
mm	%	mm	%
75.0	100	0.0327	72
37.5	100	0.0256	70
19.0	100	0.0204	68
9.5	100	0.0139	65
4.75	100	0.0104	61
2.36	100	0.0080	59
1.18	100	0.0054	52
0.600	100	0.0039	45
0.425	100	0.0029	36
0.300	100	0.0021	28
0.150	97	0.0013	16
0.075	92		

Summary Results	
Average Particle Size, D_{50} (mm)	0.005
Effective Size, D_{10} (mm)	NA
Max Size of the Smallest 30%, D_{30} (mm)	0.002
Max Size of the Smallest 60%, D_{60} (mm)	0.009
Uniformity Coefficient, $C_u = D_{60}/D_{10}$	NA
Coefficient of Gradation, $C_g = D_{30}^2/(D_{60} \times D_{10})$	NA
Fines Content, $<75\mu\text{m}$ (%)	92
Clay size Content, $<2\mu\text{m}$ (%)	27

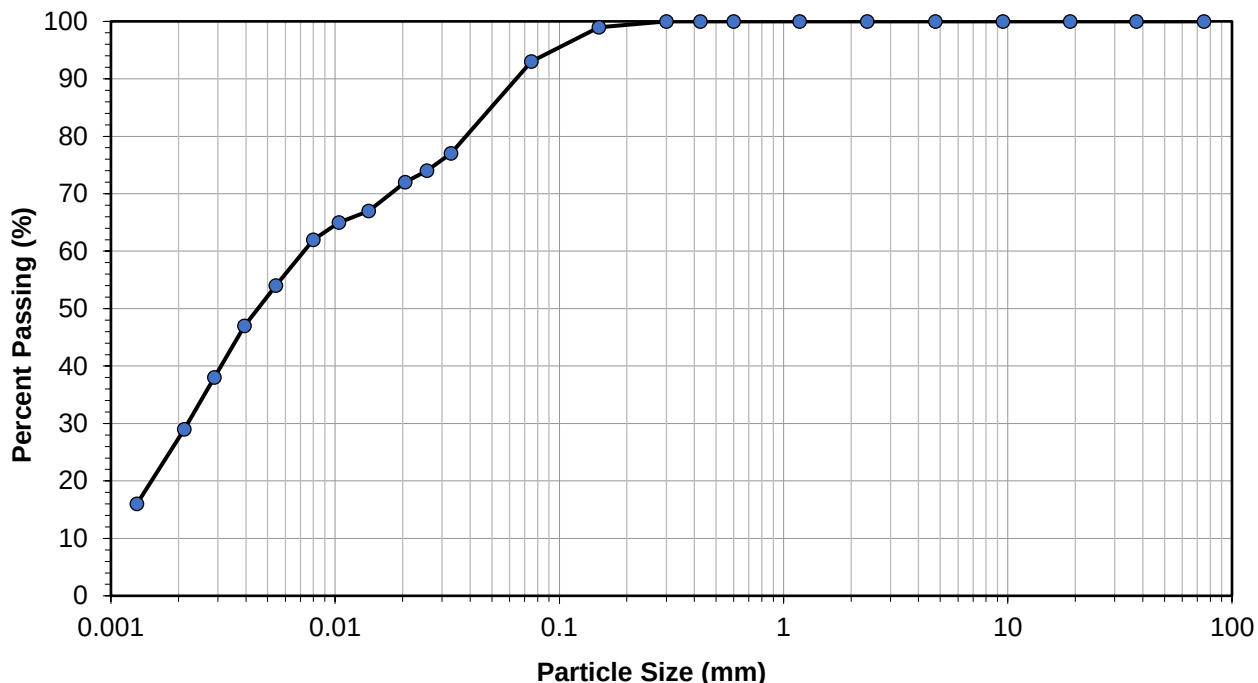
GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Classification Test - Particle Size Distribution

Job No.:20-003

Figure A3 - Page 1

Particle Size Distribution
Test Method: AS1289.3.6.1 & AS1289.3.6.3

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-PSD-02
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Sample No:	VITT-0001-DO2S
		Hydrometer Type:	ASTM-152H
		Pretreatment :	No
Client reference:	6138474	Dispersion Method:	Dispersion agent - 4g/L
		Loss in Pretreatment:	NA
Tested By:	BC	Checked By:	FL
Date:	8/08/2019	Date:	21/08/2019



Sieving		Hydrometer	
Size	Passing	Size	Passing
mm	%	mm	%
75.0	100	0.0328	77
37.5	100	0.0257	74
19.0	100	0.0205	72
9.5	100	0.0141	67
4.75	100	0.0104	65
2.36	100	0.0080	62
1.18	100	0.0054	54
0.600	100	0.0039	47
0.425	100	0.0029	38
0.300	100	0.0021	29
0.150	99	0.0013	16
0.075	93		

Summary Results	
Average Particle Size, D_{50} (mm)	0.004
Effective Size, D_{10} (mm)	NA
Max Size of the Smallest 30%, D_{30} (mm)	0.002
Max Size of the Smallest 60%, D_{60} (mm)	0.007
Uniformity Coefficient, $C_u = D_{60}/D_{10}$	NA
Coefficient of Gradation, $C_g = D_{30}^2/(D_{60} \times D_{10})$	NA
Fines Content, $<75\mu\text{m}$ (%)	93
Clay size Content, $<2\mu\text{m}$ (%)	27

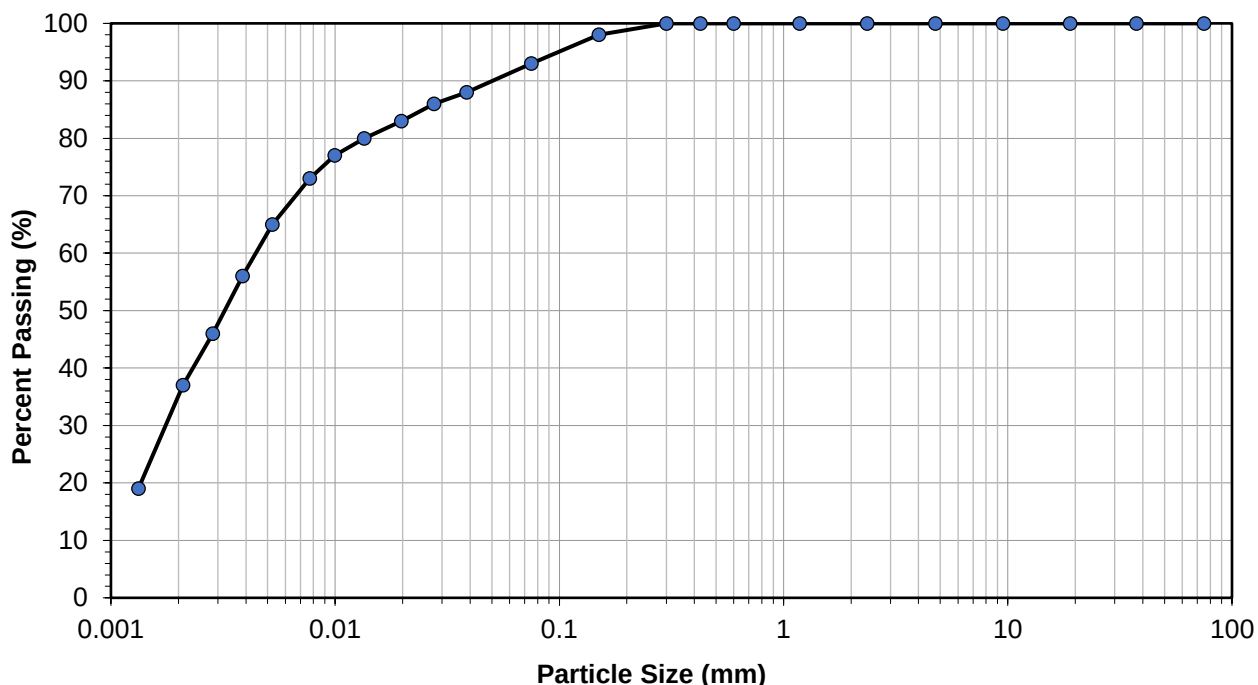
GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Classification Test - Particle Size Distribution

Job No.:20-003

Figure A3 - Page 2

Particle Size Distribution
Test Method: AS1289.3.6.1 & AS1289.3.6.3

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-PSD-03
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Sample No:	VITT-0001-DO3S
		Hydrometer Type:	ASTM-152H
		Pretreatment :	No
Client reference:	6138474	Dispersion Method:	Dispersion agent - 4g/L
		Loss in Pretreatment:	NA
Tested By:	BC	Checked By:	FL
Date:	8/08/2019	Date:	21/08/2019



Sieving		Hydrometer	
Size	Passing	Size	Passing
mm	%	mm	%
75.0	100	0.0386	88
37.5	100	0.0276	86
19.0	100	0.0198	83
9.5	100	0.0135	80
4.75	100	0.0100	77
2.36	100	0.0077	73
1.18	100	0.0053	65
0.600	100	0.0039	56
0.425	100	0.0028	46
0.300	100	0.0021	37
0.150	98	0.0013	19
0.075	93		

Summary Results	
Average Particle Size, D_{50} (mm)	0.003
Effective Size, D_{10} (mm)	NA
Max Size of the Smallest 30%, D_{30} (mm)	0.002
Max Size of the Smallest 60%, D_{60} (mm)	0.004
Uniformity Coefficient, $C_u = D_{60}/D_{10}$	NA
Coefficient of Gradation, $C_g = D_{30}^2/(D_{60} \times D_{10})$	NA
Fines Content, $<75\mu\text{m}$ (%)	93
Clay size Content, $<2\mu\text{m}$ (%)	35

GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Classification Test - Particle Size Distribution

Job No.:20-003

Figure A3 - Page 3

Atterberg Limits**Test Method: AS1289.3.9.1 (Liquid Limit), AS1289.3.2.1 (Plastic Limit),
AS1289.3.3.2 (Plasticity Index) & AS1289.3.4.1 (Linear Shrinkage)**

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Project:	Talga Resources Vittanga Project
Client Reference:	6138474		Tailings Feasibility Study

Summary Results

Test No. (N):	20-003-AL-01	20-003-AL-02	20-003-AL-03
Sample No.:	VITT-0001-DO1S	VITT-0001-DO2S	VITT-0001-DO3S
Liquid Limit (%):	39	42	46
Plastic Limit (%):	26	25	30
Plasticity Index:	13	17	16
Linear Shrinkage (%):	4.0	4.0	4.5
Shrinkage type:	Flat	Flat	Flat
Sample History:	Air dry	Air dry	Air dry
Tested By:	BC	BC	BC
Date Tested:	12/08/2019	9/08/2019	12/08/2019
Checked By:	FL	FL	FL
Date Checked:	14/08/2019	21/08/2019	21/08/2019

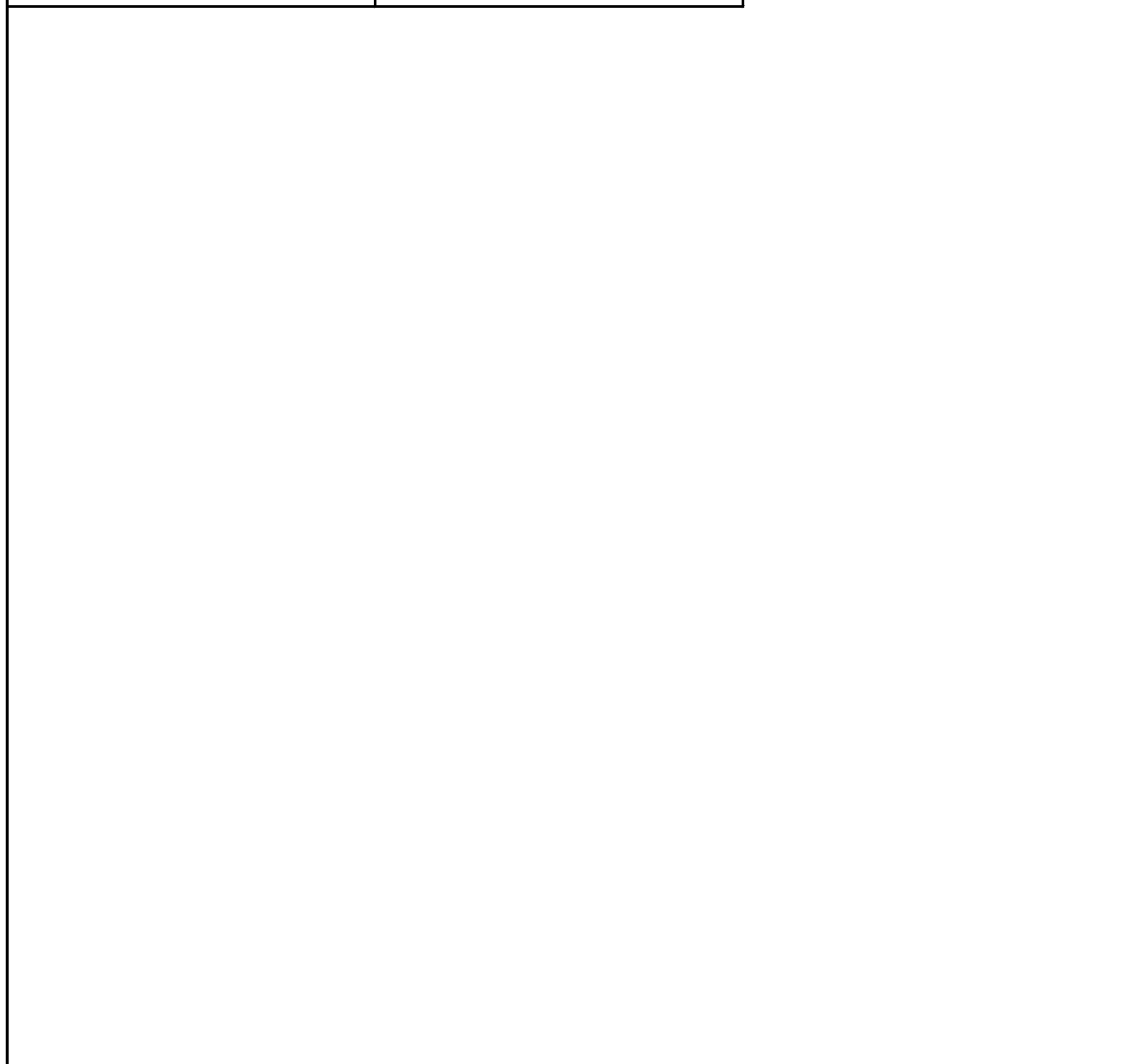
**GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Classification Test - Atterberg Limits****Job No.:20-003****Figure A4**

Emerson Class
Test Method: AS1289.3.8.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Project:	Talga Resources Vittanga Project
Client reference:	6138474		Tailings Feasibility Study

Summary Results

Test No. (N):	20-003-EMER-01
Sample No.:	VITT-0001-DO1S
Emerson Class:	6
Visual Description:	Green Black SILT, GLEY 1, 2.5/10Y
Type of Water Used :	Distilled water
Temperature of Water (°C):	23
Tested By:	FL
Date Tested:	9/08/2019
Checked By:	HJ
Date Checked:	28/08/2019



GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Classification Test - Emerson Class

Job No.:20-003

Figure A5

Appendix B

Shrink-Swell Index
Test Method: AS1289.7.1.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Project:	Talga Resources Vittanga Project
Client reference:	6138474		Tailings Feasibility Study

Summary Results	
Test No.:	20-003-SSI-01
Sample No.:	VITT-0001-DO1S
Tested By:	FL
Date Tested:	21/08/2019
Checked By:	HJ
Date Checked:	28/08/2019
Visual Description:	Greenish Black SILT, GLEY 1 2.5/10Y
Estimated Inert Inclusion (%):	0.0

Swell Test	
Sample Diameter (mm):	63.5
Sample Height (mm):	25.54
Initial Moisture Content (%):	32.8
Initial Dry Density (g/cm³):	1.50
Swell ϵ_{sw} (%):	0.0

Simplified Core Shrinkage Test	
Sample Diameter (mm):	69.0
Sample Height (mm):	106.1
Initial Moisture Content (%):	32.8
Initial Dry Density (g/cm³):	1.42
Shrinkage Strain ϵ_{sh} (%):	3.4
Extent of Crack of Shrinkage sample:	Minor cracks
Sample crumbling during Shrinkage?	No

Shrinkage-Swell Index (I_{ss})	1.9
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Note:

- Swelling test sample taken from bulk bag material using cutting ring.
- Shrinkage test sample remoulded at as received moisture content.

Talga Resources Vittanga Project Tailings Feasibility Study Shrink-Swell Index Figure B	
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20-003

Appendix C

Consolidation Test - Oedometer
Test Method: Australian Standard AS 1289.6.6.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-OED-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Initial	Final
		Sample Diameter (mm):	70.00 70.00
		Sample Height (mm):	16.90 15.19
Client reference:	6138474	Moisture Content (%) :	32.3* 27.1
Sample No:	VITT-0001-DO1S	Dry Density (g/cm³):	1.46 1.59
Sample Status:	Intact	Soil Particle Density (g/cm³):	2.86
Test Condition:	Inundated at stage 1	Initial Void Ratio:	1.002 0.799
		Degree of Saturation (%):	92.3 97.1
Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample			
Tested by:	NC	Checked By:	FL
Date:	8/08/2019	Date:	21/08/2019

Stage		Vertical Stress	Void ratio	Coefficient of		
				Consolidation	Compressibility	Permeability
Type	No.	σ_v kPa	e	c_v m ² /year	m_v m ² /kN	k m/sec
Loading	1	6	0.924	14.5	2.03E-03	9.16E-09
	2	13	0.915	29.2	7.37E-04	6.69E-09
	3	25	0.902	46.1	5.17E-04	7.39E-09
	4	50	0.887	58.3	3.31E-04	5.99E-09
	5	100	0.868	96.1	2.00E-04	5.97E-09
	6	200	0.846	127.7	1.19E-04	4.71E-09
	7	400	0.820	182.0	6.98E-05	3.95E-09
	8	800	0.789	155.2	4.19E-05	2.02E-09
	9	1600	0.754	215.3	2.47E-05	1.65E-09
Unloading	10	400	0.762	-	3.72E-06	-
	11	100	0.770	-	1.65E-05	-
	12	25	0.780	-	7.27E-05	-
	13	6	0.789	-	2.54E-04	-

GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Oedometer

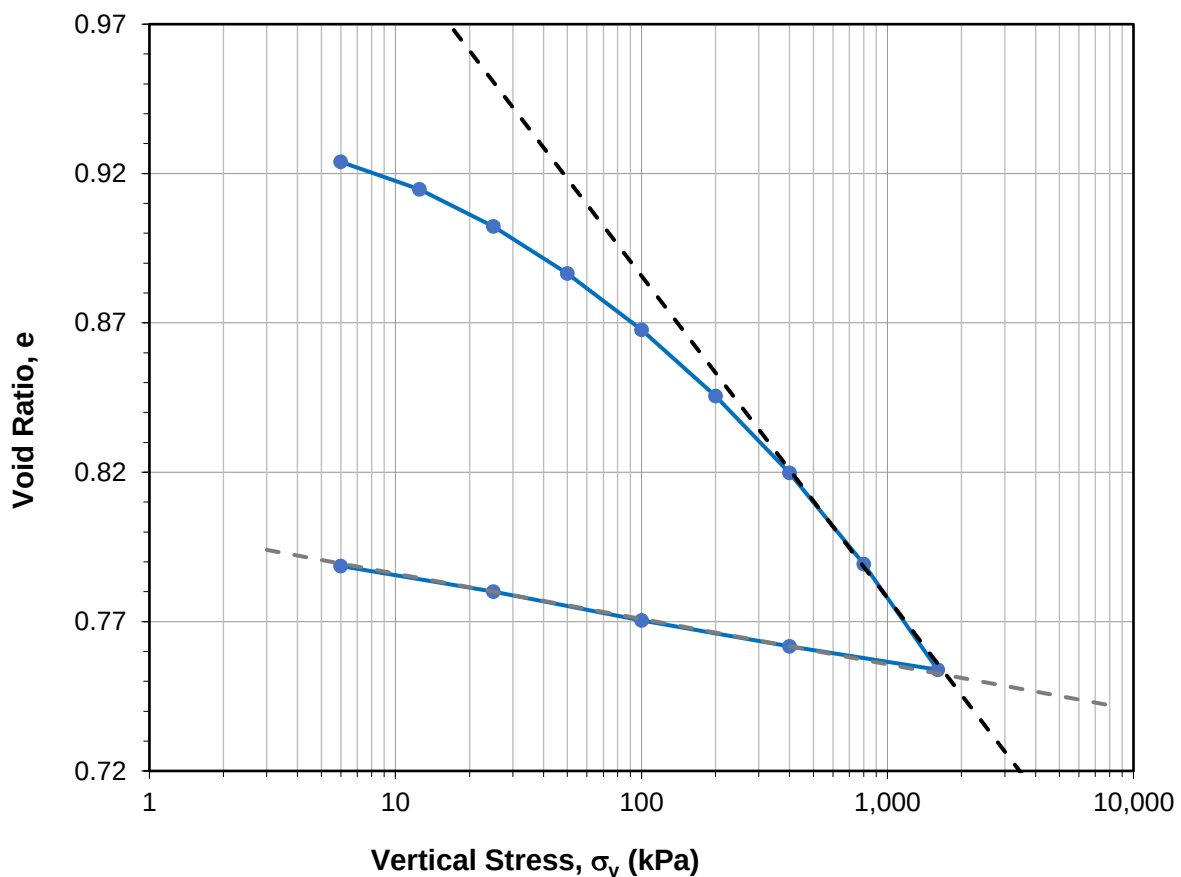
Job No.:20-003

Figure C - Page 1

Consolidation Test - Oedometer
Test Method: Australian Standard AS 1289.6.6.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-OED-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Initial	Final
		Sample Diameter (mm):	70.00 70.00
		Sample Height (mm):	16.90 15.19
Client reference:	6138474	Moisture Content (%) :	32.3* 27.1
Sample No:	VITT-0001-DO1S	Dry Density (g/cm³):	1.46 1.59
Sample Status:	Intact	Soil Particle Density (g/cm³):	2.86
Test Condition:	Inundated at stage 1	Initial Void Ratio:	1.002 0.799
		Degree of Saturation (%):	92.3 97.1
Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample			

Tested by: NC
Date: 8/08/2019
Checked By: FL
Date: 21/08/2019



Interpreted Parameters		
Compression index, C_c	0.108	
Swelling index, C_{s-int}	-	at intermediate unload-reloading stress
Swelling index, C_{s-Max}	0.015	at final loading stage unload-reloading stress

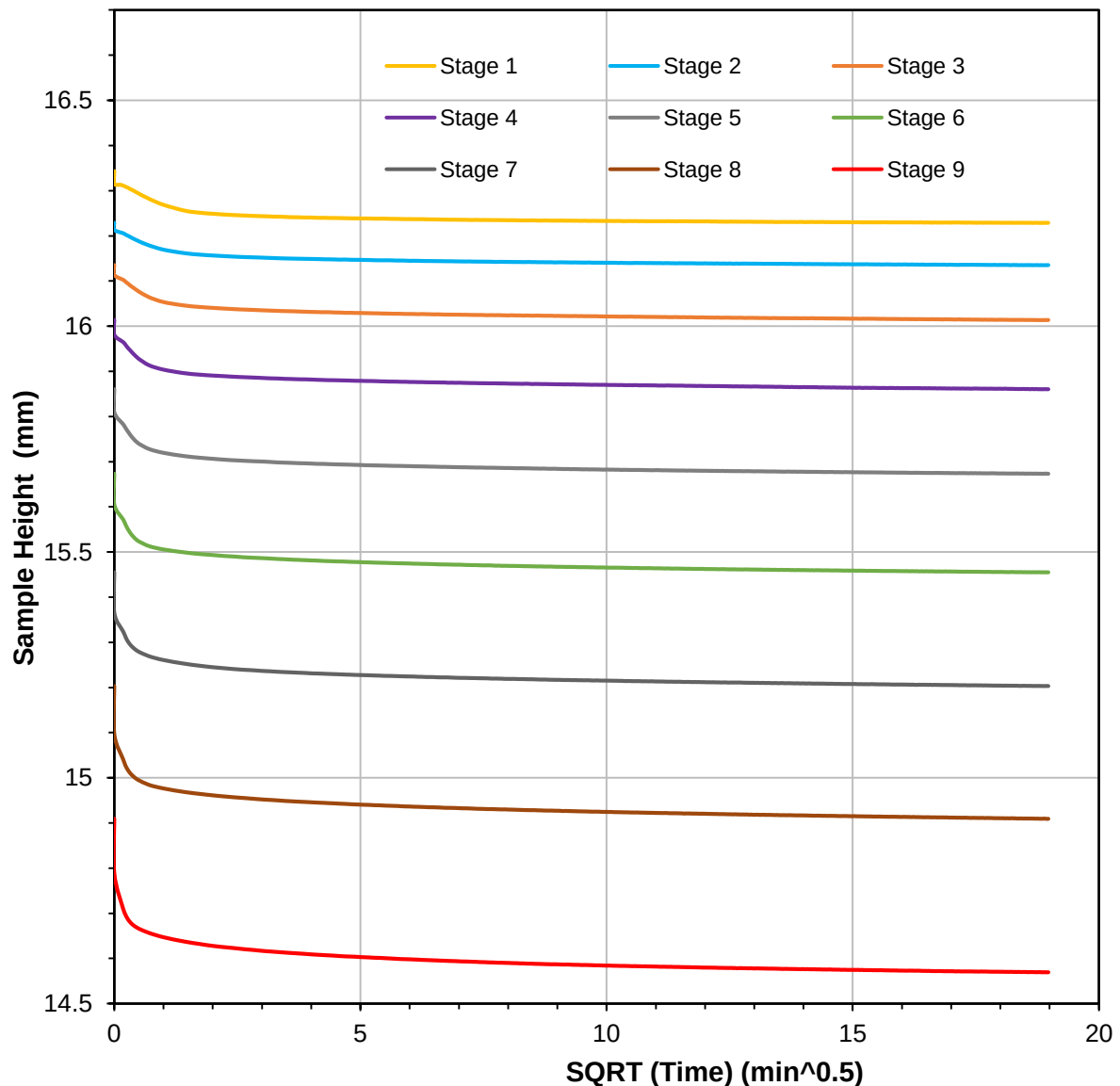
GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Oedometer

Job No.:20-003

Figure C - Page 2

Consolidation Test - Oedometer
Test Method: Australian Standard AS 1289.6.6.1

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-OED-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Initial	Final
		Sample Diameter (mm):	70.00 70.00
		Sample Height (mm):	16.90 15.19
Client reference:	6138474	Moisture Content (%) :	32.3* 27.1
Sample No:	VITT-0001-DO1S	Dry Density (g/cm³):	1.46 1.59
Sample Status:	Intact	Soil Particle Density (g/cm³):	2.86
Test Condition:	Inundated at stage 1	Initial Void Ratio:	1.002 0.799
		Degree of Saturation (%):	92.3 97.1
Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample			
Tested by:	NC	Checked By:	FL
Date:	8/08/2019	Date:	21/08/2019



GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Oedometer

Appendix D

Consolidation Test - Rowe Cell
Test Method: GTI-STT-P06

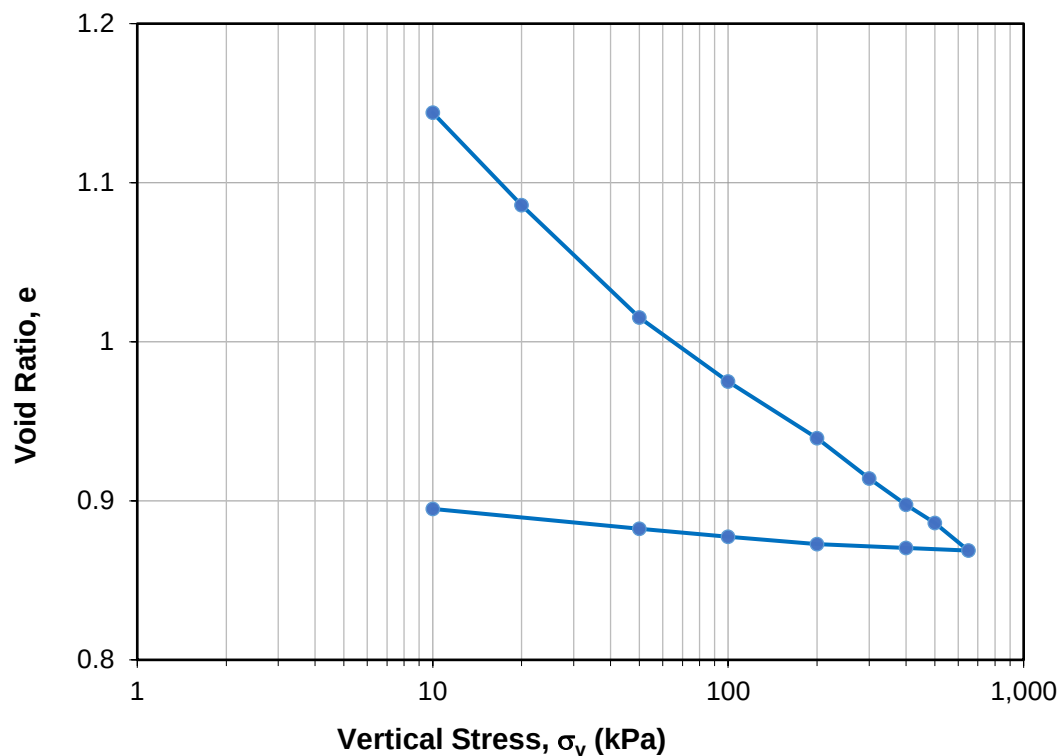
PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-RC-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Initial	Final
		Sample Diameter (mm):	151.40 151.40
		Sample Height (mm):	40.68 30.10
Client Reference:	6138474	Moisture Content (%):	55.02 32.57
Sample No:	VITT-0001-DO1S	Dry Density (t/m³):	1.12 1.51
Sample Status:	Reconstituted	Soil Particle Density (t/m³):	2.86
Test Condition:	Thick Slurry	Initial Void Ratio:	1.564 0.898
		Degree of Saturation (%):	100.6 103.8
Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample			
Tested by:	GG	Checked by:	BB
Date:	4/09/2019	Date:	11/09/2019

Stage		Vertical Stress	Void ratio	Coefficient of			
				Consolidation, c_v	Compressibility, m_v	Permeability, k	
Type	No.	σ_v kPa	e	m ² /year	m ² /kN	Calculated m/sec	Measured m/sec
Loading	1	10	1.144	-	-	-	-
	2	20	1.086	89.0	2.7E-03	7.5E-08	2.5E-08
	3	50	1.015	135.2	1.1E-03	4.7E-08	2.0E-08
	4	100	0.975	137.0	4.0E-04	1.7E-08	1.8E-08
	5	200	0.939	220.9	1.8E-04	1.2E-08	1.6E-08
	6	300	0.914	235.0	1.3E-04	9.5E-09	1.4E-08
	7	400	0.898	237.8	8.6E-05	6.4E-09	1.4E-08
	8	500	0.886	107.4	6.0E-05	2.0E-09	1.3E-08
	9	650	0.869	246.8	6.2E-05	4.7E-09	1.2E-08
Unloading	10	400	0.870	-	3.5E-06	-	-
	11	200	0.873	-	6.6E-06	-	-
	12	100	0.877	-	2.5E-05	-	-
	13	50	0.882	-	5.4E-05	-	-
	14	10	0.895	-	1.7E-04	-	-

GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Rowe Cell
Job No.:20-003 **Figure D - Page 1**

Consolidation Test - Rowe Cell
Test Method: GTI-STT-P06

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-RC-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Initial	Final
		Sample Diameter (mm):	151.40 151.40
		Sample Height (mm):	40.68 30.10
Client Reference:	6138474	Moisture Content (%) :	55.02 32.57
Sample No:	VITT-0001-DO1S	Dry Density (t/m³) :	1.12 1.51
Sample Status:	Reconstituted	Soil Particle Density (t/m³):	2.86
Test Condition:	Thick Slurry	Initial Void Ratio:	1.564 0.898
		Degree of Saturation (%):	100.6 103.8
Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample			
Tested by:	GG	Checked by:	BB
Date:	4/09/2019	Date:	11/09/2019



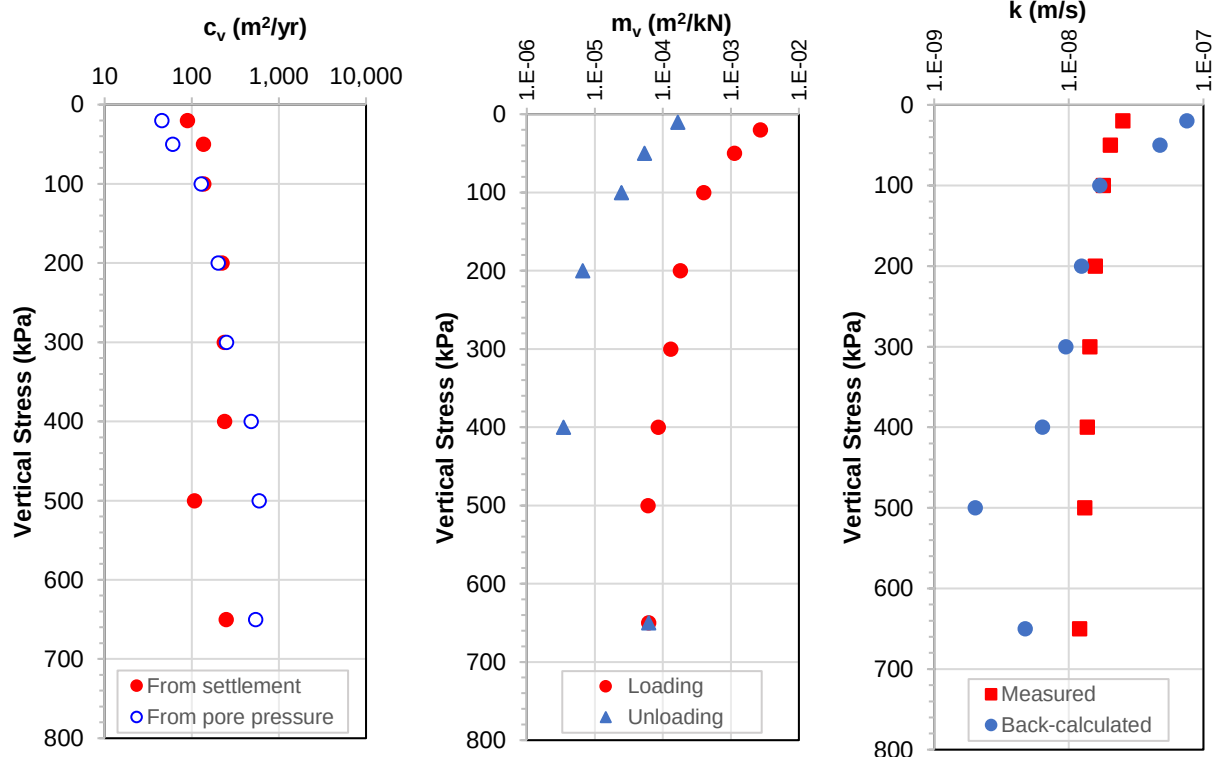
GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Rowe Cell

Job No.:20-003

Figure D - Page 2

Consolidation Test - Rowe Cell
Test Method: GTI-STT-P06

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client:	GHD	Filename:	20-003-RC-01
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Sample Diameter (mm):	Initial 151.40 Final 151.40
		Sample Height (mm):	40.68 30.10
Client Reference:	6138474	Moisture Content (%) :	55.02 32.57
Sample No:	VITT-0001-DO1S	Dry Density (t/m³) :	1.12 1.51
Sample Status:	Reconstituted	Soil Particle Density (t/m³):	2.86
Test Condition:	Thick Slurry	Initial Void Ratio:	1.564 0.898
		Degree of Saturation (%):	100.6 103.8
Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample			
Tested by:	GG	Checked by:	BB
Date:	4/09/2019	Date:	11/09/2019



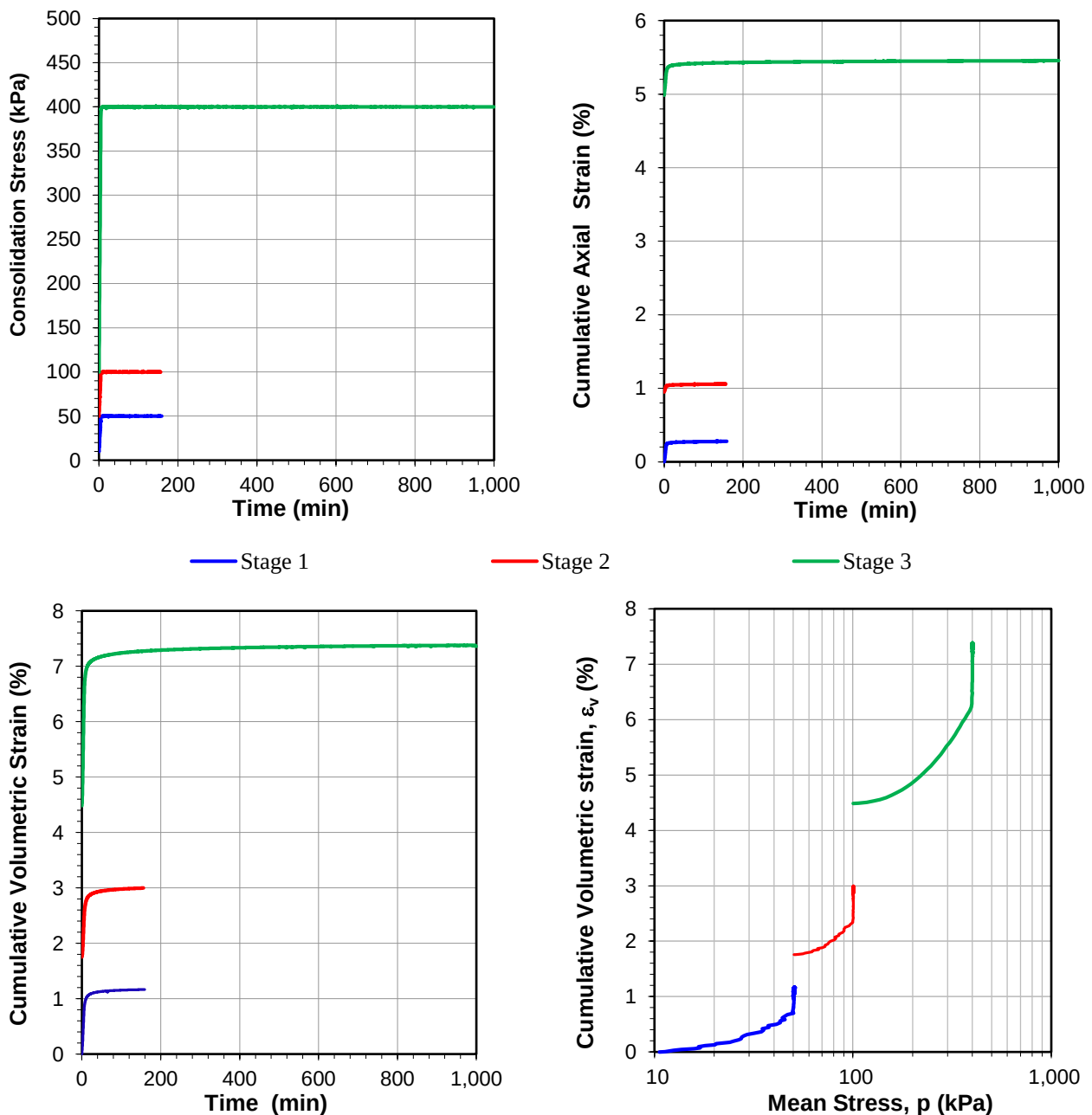
GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Rowe Cell
Job No.:20-003 **Figure D - Page 3**

Appendix E

Multi-Stage Static Triaxial - CIUC
Test Method: GTI-ADT-P04

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client	GHD	Filename:	20-003-TX-01-CIUC
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Test Depth:	-
Client Reference:	6138474	Sample Diameter (mm):	70.0
Sample No:	VIIT-0001- D01S/D02S/D03S	Sample Height (mm):	140.3
Sample Status:	Remoulded	Initial Moisture Content (%):	27.9*
Test Condition:	Moisture Content @28%	Final Moisture Content (%):	31.7
		Initial Dry Density (g/cm³):	1.43
		Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample	
Tested By:	Ting	Checked By:	FL
Date:	6/09/2019	Date:	2/10/2019

CONSOLIDATION STAGE:



GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Multi-Stage Static Triaxial - CIUC - Shearing Rate = 0.1 mm/min

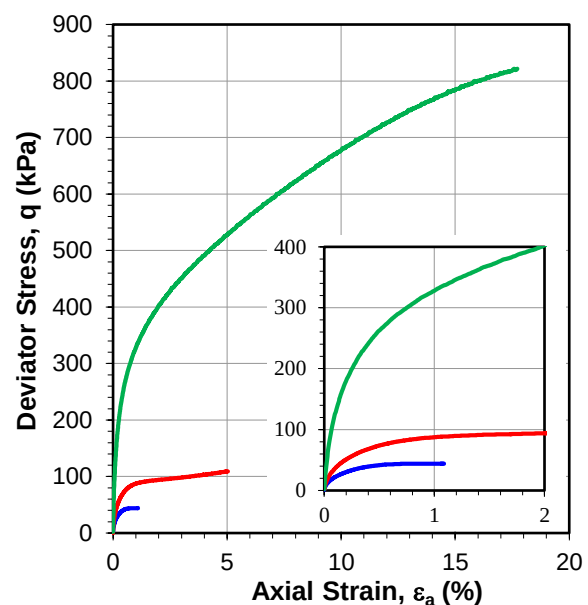
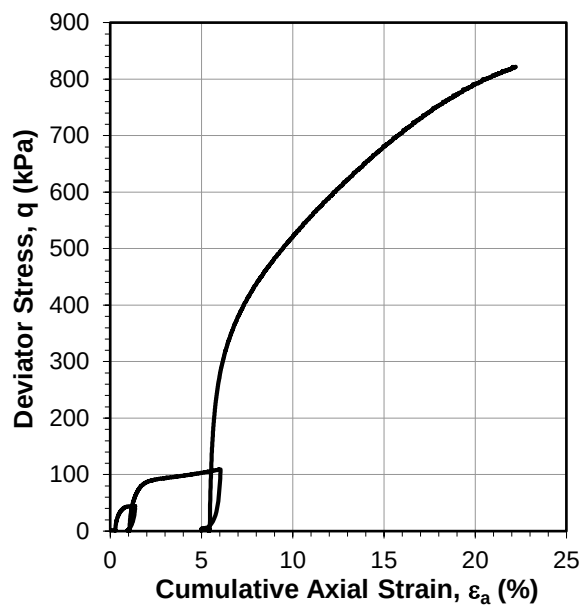
Job No.:20-003

Figure E - Page 1

Multi-Stage Static Triaxial - CIUC
Test Method: GTI-ADT-P04

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client	GHD	Filename:	20-003-TX-01-CIUC
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Test Depth:	-
Client Reference:	6138474	Sample Diameter (mm):	70.0
Sample No:	VIIT-0001- D01S/D02S/D03S	Sample Height (mm):	140.3
Sample Status:	Remoulded	Initial Moisture Content (%):	27.9*
Test Condition:	Moisture Content @28%	Final Moisture Content (%):	31.7
		Initial Dry Density (g/cm³):	1.43
		Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample	
Tested By:	Ting	Checked By:	FL
Date:	6/09/2019	Date:	2/10/2019

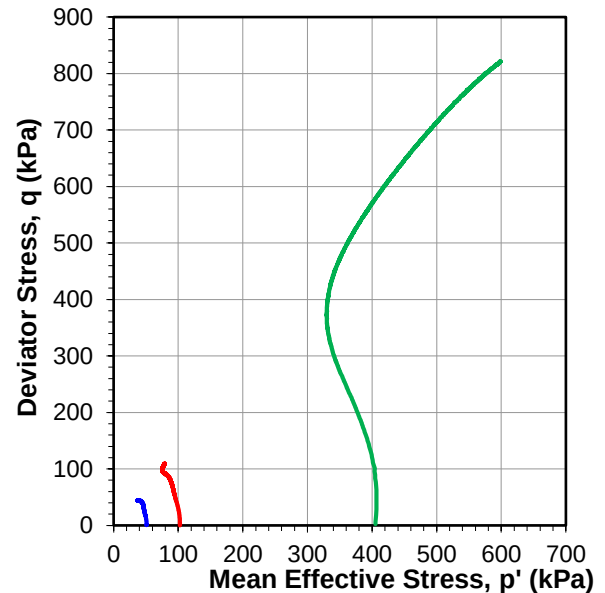
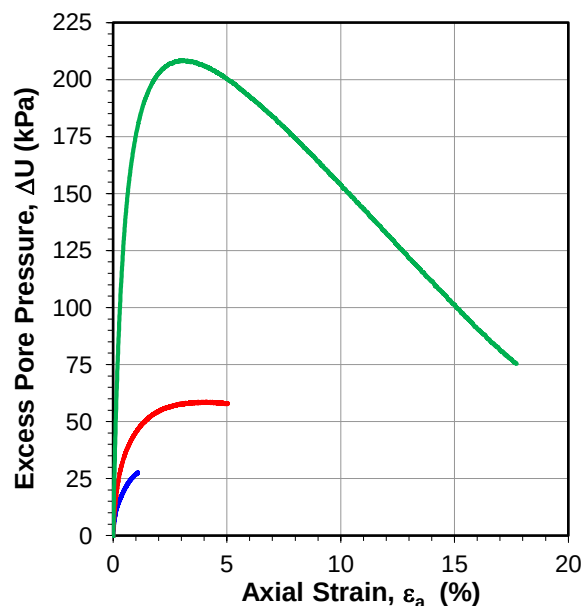
SHEARING STAGE:



— Stage 1

— Stage 2

— Stage 3



GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Multi-Stage Static Triaxial - CIUC - Shearing Rate = 0.1 mm/min

Job No.:20-003

Figure E - Page 2

PO No.:	6138474	GTI Perth Client Reference:	C16-P01-T01
Client	GHD	Filename:	20-003-TX-01-CIUC
Project:	Talga Resources Vittanga Project Tailings Feasibility Study	Test Depth:	-
Client Reference:	6138474	Sample Diameter (mm):	70.0
Sample No:	VIIT-0001- D01S/D02S/D03S	Sample Height (mm):	140.3
Sample Status:	Remoulded	Initial Moisture Content (%):	27.9*
Test Condition:	Moisture Content @28%	Final Moisture Content (%):	31.7
		Initial Dry Density (g/cm³):	1.43
		Notes: *Moisture content calculated using trimmings; may not be representative of the whole sample	
Tested By:	Ting	Checked By:	FL
Date:	6/09/2019	Date:	2/10/2019

SAMPLE AFTER TESTING:



GHD - Talga Resources Vittanga Project Tailings Feasibility Study
Multi-Stage Static Triaxial - CIUC - Shearing Rate = 0.1 mm/min

Appendix F

CERTIFICATE OF ANALYSIS

Work Order	: EP1907496	Page	: 1 of 2
Client	: Geotechnical Testing and Interpretation Perth	Laboratory	: Environmental Division Perth
Contact	: Binaya Bhattana	Contact	: Customer Services EP
Address	: 16 Glory Road Gnangara 6077	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: ----	Telephone	: +61-8-9406 1301
Project	: ----	Date Samples Received	: 29-Jul-2019 16:00
Order number	: GTIPO-20-005	Date Analysis Commenced	: 01-Aug-2019
C-O-C number	: ----	Issue Date	: 01-Aug-2019 13:40
Sampler	: ----		
Site	: ----		
Quote number	: EN/333		
No. of samples received	: 3		
No. of samples analysed	: 3		



Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
 LOR = Limit of reporting
 ^ = This result is computed from individual analyte detections at or above the level of reporting
 ø = ALS is not NATA accredited for these tests.
 ~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				VITT-0001/D01S	VITT-0001/D02S	VITT-0001/D03S	----	----
Client sampling date / time				29-Jul-2019 00:00	29-Jul-2019 00:00	29-Jul-2019 00:00	----	----
Compound	CAS Number	LOR	Unit	EP1907496-001	EP1907496-002	EP1907496-003	-----	-----
				Result	Result	Result	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.8	5.8	6.0	----	----

BILAGA D

Talga Environmental Treatment - Bulk Neutralisation Pilot Plant: Neutralisation of Talga's Rougher Tails and Cleaner Tails Decant Process Water

TECHNICAL FILENOTE

To:	Catherine Hanson, Peter French, Martin Philips, Tom Kearney – Talga
Cc:	Duncan Turner, Kim Ngoviky, David Cavanagh, Peter Rohner, Rob Coleman – Core
FROM:	Rod Ventura - Core
DATE:	5 March 2019
REPORT:	TF 1080R-001
REVISION:	0
SUBJECT:	1080R - Talga Environmental Treatment - Bulk Neutralisation Pilot Plant Neutralisation of Talga's Rougher Tails and Cleaner Tails Decant Process Water



Core Metallurgy Pty Ltd
Part of the Core Group
44 Corunna Street, Albion
Queensland, 4010
AUSTRALIA

Introduction

Core Metallurgy (Core) is assisting Talga Resources Ltd. (TLG) to develop the Vittangi Graphite Project in Vittangi, Sweden. This technical filenote presents the bulk neutralisation results for the environmental treatment of the process water effluents from the rougher and cleaner tails streams of the Talga Vittangi graphite flotation pilot plant.

The results, comments and recommendations below are based on the bulk neutralisation conducted on decanted process water samples from the rougher and cleaner tails streams of the previous Talga graphite flotation pilot plant. Results, discussions, corresponding comments and recommendations are presented in the following sections.

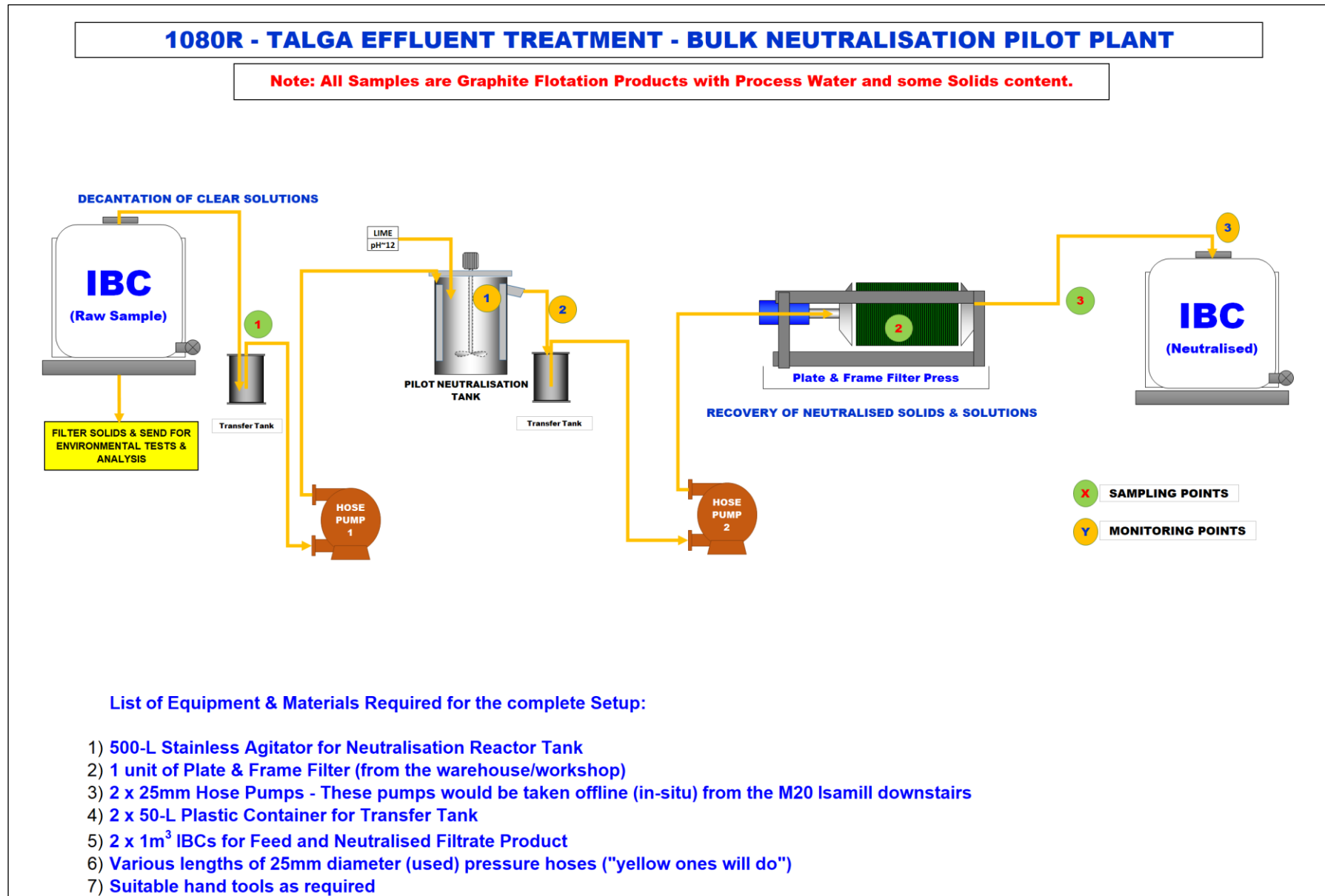
Talga Effluent Treatment - Bulk Neutralisation Pilot Plant

The Talga effluent treatment by neutralising the decanted process water with hydrated lime to pH~12, mixing up to around 60 minutes residence time in an agitated tank equipped with pitched blade flat axial flow impellers with air, is presented in a simplified flowsheet in Figure 1 below.

The rougher tails produced during the Talga graphite flotation pilot plant were stored into four (4) Intermediate Bulk Containers (IBCs), while the cleaner tails produced were stored into twenty-five (25) IBCs. These volumes of rougher and cleaner tails were obviously much more diluted than the expected volumes based on the process design criteria of the Talga graphite flotation concentrator plant. These diluted volumes were due to the manner that the Talga pilot plant was operated with very low % solids in the ultra-fine grinding stage, while “in-series” continuously with multiple cleaning and re-cleaning flotation stages.

The dilution factors, estimated for the above rougher tail and cleaner tail streams based on the rougher feed, mass pull and concentrate recovered, and final tails produced, are presented and summarised in Table 2 below.

Figure 1: Simplified Talga - Rougher and Cleaner Tails Effluent Process Water Treatment - Pilot Plant Flowsheet



Characterisation and Analysis of Decanted Process Water

In Table 1 below, shows the comprehensive analysis of the “as stored” decanted rougher and cleaner tails process water samples, along with the sample of Brisbane tap water as the source of fresh water for the Talga graphite flotation pilot plant.

All of the assay values in Table 1 are artificially low due to too much dilution of Brisbane tap water added in the rougher and cleaner flotation circuits during the pilot plant run.

Table 1: Assays - Decanted “Diluted” Process Water from Rougher Tails, Cleaner Tails and Brisbane Tap Water

LQ-MEICP	Units	Limit of Reporting	Brisbane Tap Water	Pre-Neut Rougher Tail Solution	Pre-Neut Cleaner Tail Solution	LQ-MEICP	Units	Limit of Reporting	Brisbane Tap Water	Pre-Neut Rougher Tail Solution	Pre-Neut Cleaner Tail Solution
Analyte		LOR	Assay	Assay	Assay	Analyte		LOR	Assay	Assay	Assay
Ag	mg/L	0.1	<0.1	<0.1	<0.1	Mo	mg/L	0.3	<0.3	<0.3	<0.3
Al	mg/L	2.5	<2.5	<2.5	<2.5	Na	mg/L	5	35.8	29.6	52.4
As	mg/L	2.5	<2.5	<2.5	<2.5	Ni	mg/L	0.5	<0.5	<0.5	<0.5
B	mg/L	0.5	<0.5	<0.5	<0.5	P	mg/L	2.5	<2.5	<2.5	<2.5
Ba	mg/L	0.1	<0.1	<0.1	<0.1	Pb	mg/L	2.5	<2.5	<2.5	<2.5
Be	mg/L	0.1	<0.1	<0.1	<0.1	S	mg/L	5	8.98	37	30.6
Bi	mg/L	1	<1	<1	<1	Sb	mg/L	1	<1	<1	<1
Ca	mg/L	1	23.1	19.5	23.6	Sc	mg/L	0.1	<0.1	<0.1	<0.1
Cd	mg/L	0.1	<0.1	<0.1	<0.1	Se	mg/L	2.5	<2.5	<2.5	<2.5
Co	mg/L	0.1	<0.1	<0.1	<0.1	Si	mg/L	2.5	<2.5	4.55	24.1
Cr	mg/L	0.1	<0.1	<0.1	<0.1	Sn	mg/L	1	<1	<1	<1
Cu	mg/L	0.3	<0.3	<0.3	<0.3	Sr	mg/L	0.3	<0.3	<0.3	<0.3
Fe	mg/L	0.5	<0.5	<0.5	1.52	Te	mg/L	2.5	<2.5	<2.5	<2.5
Ga	mg/L	2.5	<2.5	<2.5	<2.5	Th	mg/L	0.5	<0.5	<0.5	<0.5
Ge	mg/L	2.5	<2.5	<2.5	<2.5	Ti	mg/L	0.1	<0.1	<0.1	<0.1
Hg	mg/L	0.5	<0.5	<0.5	<0.5	Tl	mg/L	2.5	<2.5	<2.5	<2.5
K	mg/L	0.3	3.9	16.1	9.29	U	mg/L	2.5	<2.5	<2.5	<2.5
La	mg/L	0.1	<0.1	<0.1	<0.1	V	mg/L	2.5	<2.5	<2.5	<2.5
Li	mg/L	5	<5	<5	<5	W	mg/L	1	<1	<1	<1
Mg	mg/L	0.5	12.9	12.9	13.4	Zn	mg/L	0.5	<0.5	<0.5	<0.5
Mn	mg/L	1	<1	2.47	<1	Zr	mg/L	0.5	<0.5	<0.5	0.968

Below, in Table 2, illustrates the designed process flowsheet conditions compared with the “as stored” volumes of rougher and cleaner tails produced in the actual pilot plant run. As estimated, the final “as stored” volume of rougher tail stream product is at least 9.0 times more than the designed process volume. On the other hand, the final “as stored” volume of cleaner tail stream product is at least 13.8 times more than the designed process volume.

Therefore, the normalised assays of the designed process water volume can be estimated by using the dilution factors mentioned above, and presented in Table 2 below.

Table 2: Process Water Estimates – Process Design Volume vs. Actual Diluted Volume

Ideal Process Design Conditions (Based on Designed Process Flowsheet)					Talga - Final Pilot Plant Stream Products (Decanted for Environmental Treatment)			
Stream	Wt., (kg)	% Solids	Wt. Slurry (kg)	Process Water (kg or L)	No. of IBCs	Volume per IBC	Total Volume	Dilution Factor
Rougher Feed	474.8	32	1483.8	1009.0		L	L	
Rougher Tails	189.9	30	633.1	443.1	4	1,000	4,000	9.0
Rougher Con	284.9	35	813.9	529.1				
Cleaner Tails	115.5	6	1924.7	1809.2	25	1,000	25,000	13.8
Cleaner Con	169.4	30	564.7	395.3				
Final Con (1st Production)	56.2	30	187.3	131.1				
Final Tails	305.4		2557.7	2252.3	3	1,000	3,000	7.6

As a result, Table 3 presents the adjusted and normalised assays of the decanted process water from the “dilute” rougher and cleaner tails streams. The dilution factor used to normalise the diluted “as stored” rougher tail process water to the designed process volume is 9.0. Likewise, the dilution factor used to normalise the diluted “as stored” cleaner tail process water to the designed process volume is 13.8. Hence, comprehensive assays of the “as stored” rougher and cleaner tails process water samples were normalised from the diluted assays presented in Table 1, by using their respective calculated dilution factors.

Table 3: Adjusted (Normalised) Assays using the Dilution Factor shown in Table 2

LQ-MEICP	Units	Limit of Reporting	Brisbane Tap Water	Pre-Neut Rougher Tail Solution	Pre-Neut Cleaner Tail Solution	LQ-MEICP	Units	Limit of Reporting	Brisbane Tap Water	Pre-Neut Rougher Tail Solution	Pre-Neut Cleaner Tail Solution
Analyte		LOR	Assay	Assay	Assay	Analyte		LOR	Assay	Assay	Assay
Ag	mg/L	0.1	<0.1	0.9	1.4	Mo	mg/L	0.3	<0.3	2.7	4.1
Al	mg/L	2.5	<2.5	22.6	34.5	Na	mg/L	5	35.8	267.2	724.1
As	mg/L	2.5	<2.5	22.6	34.5	Ni	mg/L	0.5	<0.5	4.5	6.9
B	mg/L	0.5	<0.5	4.5	6.9	P	mg/L	2.5	<2.5	22.6	34.5
Ba	mg/L	0.1	<0.1	0.9	1.4	Pb	mg/L	2.5	<2.5	22.6	34.5
Be	mg/L	0.1	<0.1	0.9	1.4	S	mg/L	5	8.98	334.0	422.8
Bi	mg/L	1	<1	9.0	13.8	Sb	mg/L	1	<1	9.0	13.8
Ca	mg/L	1	23.1	176.0	326.1	Sc	mg/L	0.1	<0.1	0.9	1.4
Cd	mg/L	0.1	<0.1	0.9	1.4	Se	mg/L	2.5	<2.5	22.6	34.5
Co	mg/L	0.1	<0.1	0.9	1.4	Si	mg/L	2.5	<2.5	41.1	333.0
Cr	mg/L	0.1	<0.1	0.9	1.4	Sn	mg/L	1	<1	9.0	13.8
Cu	mg/L	0.3	<0.3	2.7	4.1	Sr	mg/L	0.3	<0.3	2.7	4.1
Fe	mg/L	0.5	<0.5	4.5	21.0	Te	mg/L	2.5	<2.5	22.6	34.5
Ga	mg/L	2.5	<2.5	22.6	34.5	Th	mg/L	0.5	<0.5	4.5	6.9
Ge	mg/L	2.5	<2.5	22.6	34.5	Ti	mg/L	0.1	<0.1	0.9	1.4
Hg	mg/L	0.5	<0.5	4.5	6.9	Tl	mg/L	2.5	<2.5	22.6	34.5
K	mg/L	0.3	3.9	145.3	128.4	U	mg/L	2.5	<2.5	22.6	34.5
La	mg/L	0.1	<0.1	0.9	1.4	V	mg/L	2.5	<2.5	22.6	34.5
Li	mg/L	5	<5	45.1	69.1	W	mg/L	1	<1	9.0	13.8
Mg	mg/L	0.5	12.9	116.4	185.2	Zn	mg/L	0.5	<0.5	4.5	6.9
Mn	mg/L	1	<1	22.3	13.8	Zr	mg/L	0.5	<0.5	4.5	13.4

Neutralisation Treatment Efficiency of Process Water at pH~12 with Lime

Table 4 below summarises the efficiency of precipitating the dissolved metals by neutralising the decanted process water with hydrated lime at pH~12 from both Talga's Rougher Tail and Cleaner Tail streams. Most of the dissolved metals responded well with the use of hydrated lime, especially manganese, nickel, chromium, iron, aluminium, arsenic, cobalt and copper. It is important to note that there was no detectable trace of mercury on both process water streams, even at the detection limit of 0.0001 mg/L.

The neutralisation was carried out in 45 to 60 minutes reaction time in an agitated tank equipped with pitched blade flat impellers generating axial flow with some air injection. The pH was maintained at around 12 to complete the neutralisation reaction.

Table 4: Neutralisation Treatment Efficiency on Dissolved Metals

TALGA PROCESS WATER - ENVIRONMENTAL ANALYSIS		Rougher Tail Process Water	Neutralised Rougher Tail Process Water	Neutralisation Efficiency - Rougher Tail Process Water (%)	Cleaner Tail Process Water	Neutralised Cleaner Tail Process Water	Neutralisation Efficiency - Cleaner Tail Process Water (%)
Analyte	Unit						
Dissolved Metals by ICP-MS							
Aluminium	mg/L	0.01	0.01	<i>BDL</i>	1.28	0.01	99.2
Arsenic	mg/L	0.001	0.001	<i>BDL</i>	0.005	0.001	80.0
Cadmium	mg/L	0.0001	0.0001	<i>BDL</i>	0.0004	0.0001	75.0
Chromium	mg/L	0.014	0.001	92.9	0.004	0.002	50.0
Cobalt	mg/L	0.005	0.001	80.0	0.003	0.001	66.7
Copper	mg/L	0.004	0.009	-	0.019	0.006	68.4
Lead	mg/L	0.001	0.001	<i>BDL</i>	0.006	0.004	33.3
Manganese	mg/L	2.57	0.003	99.9	0.085	0.001	98.8
Molybdenum	mg/L	0.001	0.001	<i>BDL</i>	0.002	0.004	-
Nickel	mg/L	0.056	0.001	98.2	0.020	0.001	95.0
Selenium	mg/L	0.01	0.01	<i>BDL</i>	0.01	0.01	<i>BDL</i>
Tellurium	mg/L	0.005	0.005	<i>BDL</i>	0.005	0.005	<i>BDL</i>
Thallium	mg/L	0.001	0.001	<i>BDL</i>	0.001	0.001	<i>BDL</i>
Uranium	mg/L	0.001	0.001	<i>BDL</i>	0.001	0.001	<i>BDL</i>
Zinc	mg/L	0.040	0.005	87.5	0.017	0.005	70.6
Iron	mg/L	0.09	0.05	44.4	2.40	0.05	97.9
Dissolved Mercury by FIMS							
Mercury	mg/L	0.0001	0.0001	<i>BDL</i>	0.0001	0.0001	<i>BDL</i>
				BDL-Below Detection Limit			BDL-Below Detection Limit

Characterisation of Settled/Filtered Solids from Rougher Tail & Cleaner Tail

The filtered and dried settled solid samples from the rougher and cleaner tails, after decanting the clear process water for effluent treatment, were sent for environmental assessment by mineral liberation analysis (MLA) and X-ray modal (XMOD) analysis at ALS Mineralogy in Stafford, Queensland.

Table 5 illustrates the MLA calculated assays of both rougher and cleaner tails solid samples. The rougher tail contains higher iron sulphides than the cleaner tail sample assaying 12.89% Fe and 5.12% S, while the cleaner tail sample contains higher cerium and zirconium at 6.43% and 18.90% respectively.

Table 5: Mineral Liberation Assay (MLA) Calculated Assay (%)

Element	1080R Rghr Tail	1080R Clr Tail
Al	6.45	3.93
As	0.00	0.00
Ba	0.00	0.00
Ca	1.96	2.31
Ce	0.01	6.43
Cl	0.24	0.12
Co	0.00	0.00
Cr	0.06	0.03
Cu	0.02	0.00
F	0.01	0.00
Fe	12.89	3.96
H	0.15	0.08
Hf	0.00	0.53
K	2.67	1.38
Mg	4.47	3.33
Mn	0.03	0.03
Na	1.75	1.14
Ni	0.00	0.00
O	39.83	37.95
P	0.10	0.00
Pb	0.00	0.00
S	5.12	0.61
Se	0.00	0.00
Si	23.16	18.73
Th	0.00	0.00
Ti	0.95	0.52
U	0.00	0.00
Y	0.01	0.01
Zn	0.06	0.01
Zr	0.02	18.90
Total	100.00	100.00

In regards to the grouped mineral abundances in Table 6 below, the rougher tail solid sample contained 11.86% iron sulphides and 35% phyllosilicates, while the cleaner tail solid sample contained 34.67% ceria-zirconia and 17.67% phyllosilicate minerals. The presence of high ceria-zirconia minerals in the cleaner tail sample confirm the high wear and consumption of ceramic media due to very low % solids (~ 6 to 7% w/w) feeding the M20 IsaMill during the ultra-fine grinding stage.

This ultra-fine grinding at very low % solids was carried out because the M20 IsaMill was run “in series” with the cleaner and re-cleaner circuits without any solid-liquid separation to remove excess water from the concentrates before grinding down to P_{80} ~6 to 7 μ m. Such would result to very high media wear due to high degree of attrition among grinding media particles inside the IsaMill while % solids of mill feed slurry is very low. Hence, very high ceramic media consumption which is evidenced by the very high ceria-zirconia content of the cleaner tail solids sample at 34.67% w/w.

Table 6: Grouped Mineral Abundances (Wt %)

Mineral	1080R Rghr Tail	1080R Clr Tail
Fe Sulphides	11.86	1.40
Other Sulphides	0.14	0.01
Sulphates-Phosphates	0.65	0.40
Oxides-Hydroxides	3.41	0.26
Phyllosilicates	35.02	17.67
Other Silicates	48.90	45.59
Ceria-zirconia	0.03	34.67
Total	100.00	100.00

Table 7 presents the ungrouped mineral abundances, confirming the presence of pyrite, pyrrhotite, biotite, plagioclase and iron-hydroxide on the rougher tail. Likewise, the cleaner tail confirmed the very high content of ceria-zirconia minerals at 34.67% w/w, which clearly shows the presence of excessive amounts of “very fine” worn out ceramic grinding media from the ultra-fine grinding stage.

Table 7: Ungrouped Mineral Abundances (Wt %)

Mineral	1080R Rghr Tail	1080R Clr Tail
Chalcopyrite	0.06	0.01
Clausthalite	0.00	0.00
Cobaltite	0.00	0.00
Pyrite	3.77	0.22
Pyrrhotite	8.09	1.18
Sphalerite	0.07	0.01
Barite	0.01	0.00
Gypsum_mix	0.05	0.38
Natroalunite	0.00	0.00
Al-hydroxide	0.00	0.03
Fe-hydroxide	3.07	0.17
Brannerite	0.01	0.00
Rutile	0.34	0.06
Apatite	0.59	0.02
Actinolite-Tremolite	7.47	13.18
Albite	3.98	0.21
Biotite	32.71	17.11
Chlorite	2.04	0.55
Kaolinite	0.27	0.01
K-feldspar	0.26	0.02
Plagioclase	23.02	17.52
Quartz	13.41	13.93
Titanite	0.75	0.73
Ceria-zirconia	0.03	34.67
Total	100.00	100.00

Solid Precipitates from Neutralised and Treated Process Water

In regards to the treatment and neutralisation of decanted process water, the hydrated lime used was also analysed comprehensively to characterise the alkali reagent used to neutralise the process water, and precipitate most of the dissolved metals and compounds. The comprehensive analysis of the hydrated lime is presented in Table 8 below.

Table 8: Analysis of the Hydrated Lime used to Neutralise the Decanted Effluent Process Water

MEICP	Units	Limit of Reporting	Lime Sample	MEICP	Units	Limit of Reporting	Lime Sample
Analyte		LOR	Assay	Analyte		LOR	Assay
Ag	mg/kg	5	< 5	Na	mg/kg	250	< 250
Al	mg/kg	125	957.6	Ni	mg/kg	25	< 25
As	mg/kg	125	< 125	P	mg/kg	125	379.8
Ba	mg/kg	5	< 5	Pb	mg/kg	125	< 125
Be	mg/kg	2.5	< 2.5	S	mg/kg	250	< 250
Bi	mg/kg	50	< 50	Sb	mg/kg	50	< 50
Ca	mg/kg	50	499600	Sc	mg/kg	3	< 3
Cd	mg/kg	5	< 5	Se	mg/kg	125	< 125
Co	mg/kg	5	< 5	Sn	mg/kg	50	< 50
Cr	mg/kg	5	8.282	Sr	mg/kg	13	192.7
Cu	mg/kg	13	< 13	Te	mg/kg	125	< 125
Fe	mg/kg	25	850.3	Th	mg/kg	25	< 25
Ga	mg/kg	125	< 125	Ti	mg/kg	5	7.484
Ge	mg/kg	125	< 125	Tl	mg/kg	125	< 125
K	mg/kg	13	306.5	U	mg/kg	125	< 125
La	mg/kg	5	7.87	V	mg/kg	50	< 50
Li	mg/kg	250	< 250	W	mg/kg	50	< 50
Mg	mg/kg	5	2394	Zn	mg/kg	25	< 25
Mn	mg/kg	1	224.2	Zr	mg/kg	25	< 25
Mo	mg/kg	13	< 13				

Moreover, the comprehensive analysis of the solids precipitate residue produced in the neutralisation of process water effluent is shown in Table 9 below. The solid precipitate residues from the treatment of rougher and cleaner tails process water were recovered, filtered and dried for further environmental testing. It is evident that the elements of aluminium, cobalt, copper, iron, magnesium, manganese, sodium, nickel, phosphorus, lead, sulphur, strontium, titanium, zinc and zirconium were precipitated by the reaction of lime added (as alkali) to achieve the alkalinity of around pH~12. Such neutralisation was completed by proper mixing with hydrated lime and air for about 60 minutes.

Table 9: Comprehensive Analysis of the Solids Residue from Treatment of Decanted Process Water

MEICP	Units	Limit of Reporting	Neutralised Solids Residue		MEICP	Units	Limit of Reporting	Neutralised Solids Residue	
Analyte		LOR	Rougher Tails Precipitate	Cleaner Tails Precipitate	Analyte		LOR	Rougher Tails Precipitate	Cleaner Tails Precipitate
Ag	ppm	0.01	0.28	0.02	Na	ppm	100	400	2000
Al	ppm	100	2100	5600	Nb	ppm	0.1	0.6	0.8
As	ppm	0.2	29.8	5.6	Ni	ppm	0.2	95.7	45.4
Ba	ppm	10	30	30	P	ppm	10	690	530
Be	ppm	0.05	0.11	0.28	Pb	ppm	0.5	22.5	17.9
Bi	ppm	0.01	1.29	0.4	Rb	ppm	0.1	1.4	2.2
Ca	ppm	100	301000	289000	Re	ppm	0.002	0.002	<0.002
Cd	ppm	0.02	1.27	0.79	S	ppm	100	2200	1000
Ce	ppm	0.01	8.79	>500	Sb	ppm	0.05	2.83	0.67
Co	ppm	0.1	16.9	14	Sc	ppm	0.1	0.7	1.2
Cr	ppm	1	12	16	Se	ppm	1	2	3
Cs	ppm	0.05	0.14	0.18	Sn	ppm	0.2	0.4	<0.2
Cu	ppm	0.2	639	98.8	Sr	ppm	0.2	145	137.5
Fe	ppm	100	5400	8200	Ta	ppm	0.05	0.07	0.05
Ga	ppm	0.05	0.55	3.05	Te	ppm	0.05	0.09	0.25
Ge	ppm	0.05	<0.05	<0.05	Th	ppm	0.01	0.32	0.73
Hf	ppm	0.1	0.5	84.1	Ti	ppm	50	190	370
In	ppm	0.005	0.024	0.006	Tl	ppm	0.02	0.12	0.04
K	ppm	100	500	700	U	ppm	0.1	0.7	2
La	ppm	0.5	3.5	4.9	V	ppm	1	5	12
Li	ppm	0.2	2.7	2.9	W	ppm	0.1	0.8	0.2
Mg	ppm	100	46300	34900	Y	ppm	0.1	9.3	10.2
Mn	ppm	5	4020	570	Zn	ppm	2	140	82
Mo	ppm	0.05	1.37	0.49	Zr	ppm	0.5	22.4	>500

Environmental Analysis of Decanted Process Water - Pre & Post Treatment

Furthermore, the neutralised and treated process water effluents were also sent to ALS for comprehensive environmental analysis. The results of comprehensive environmental analysis are presented in the following Tables 10, 11, 12, 13 and 14.

The results of analysis like pH, conductivity, alkalinity, sulphate (turbidimetric), chloride, and dissolved major cations are summarised in the following Table 10.

Table 10: Decanted & Treated Process Water – Environmental Analysis & Characterisation (pH, Alkalinity, Conductivity, Sulphate, Chloride and Dissolved Major Cations)

TALGA PROCESS WATER - ENVIRONMENTAL ANALYSIS				Rougher Tail Process Water	Neutralised Rougher Tail Process Water	Cleaner Tail Process Water	Neutralised Cleaner Tail Process Water
Analyte Grouping / Analyte	CAS Number	Unit	Limit of Reporting				
EA005P: pH by PC Titrator							
pH Value		pH Unit	0.01	6.74	7.68	7.98	11.8
EA010P: Conductivity by PC Titrator							
Electrical Conductivity @ 25°C		µS/cm	1	462	446	565	1490
ED037P: Alkalinity by PC Titrator							
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	mg/L	1	<1	<1	<1	295
Carbonate Alkalinity as CaCO ₃	3812-32-6	mg/L	1	<1	<1	<1	78
Bicarbonate Alkalinity as CaCO ₃	71-52-3	mg/L	1	25	20	79	<1
Total Alkalinity as CaCO ₃		mg/L	1	25	20	79	334
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA							
Sulfate as SO ₄ - Turbidimetric	14808-79-8	mg/L	1	105	106	88	94
ED045G: Chloride by Discrete Analyser							
Chloride	16887-00-6	mg/L	1	42	30	57	39
ED093F: Dissolved Major Cations							
Calcium	7440-70-2	mg/L	1	21	83	26	57
Magnesium	7439-95-4	mg/L	1	15	<1	16	<1
Sodium	7440-23-5	mg/L	1	35	39	61	63
Potassium	7440-09-7	mg/L	1	15	15	8	9

In regards to dissolved metals, Table 11 presents the environmental analysis carried out on the rougher and cleaner tails, pre and post-treatment samples. The analysis also includes the dissolved mercury in the process water, both pre and post-neutralisation treatment.

Table 11: Decanted & Treated Process Water Analysis – Dissolved Metals including Mercury

TALGA PROCESS WATER - ENVIRONMENTAL ANALYSIS				Rougher Tail Process Water	Neutralised Rougher Tail Process Water	Cleaner Tail Process Water	Neutralised Cleaner Tail Process Water
Analyte Grouping / Analyte	CAS Number	Unit	Limit of Reporting				
EG020F: Dissolved Metals by ICP-MS							
Aluminium	7429-90-5	mg/L	0.01	<0.01	0.01	1.28	<0.01
Arsenic	7440-38-2	mg/L	0.001	<0.001	<0.001	0.005	<0.001
Cadmium	7440-43-9	mg/L	0.0001	<0.0001	<0.0001	0.0004	<0.0001
Chromium	7440-47-3	mg/L	0.001	0.014	<0.001	0.004	0.002
Cobalt	7440-48-4	mg/L	0.001	0.005	<0.001	0.003	<0.001
Copper	7440-50-8	mg/L	0.001	0.004	0.009	0.019	0.006
Lead	7439-92-1	mg/L	0.001	<0.001	<0.001	0.006	0.004
Manganese	7439-96-5	mg/L	0.001	2.57	0.003	0.085	<0.001
Molybdenum	7439-98-7	mg/L	0.001	<0.001	<0.001	0.002	0.004
Nickel	7440-02-0	mg/L	0.001	0.056	<0.001	0.020	<0.001
Selenium	7782-49-2	mg/L	0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	22541-49-7	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Thallium	7440-28-0	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	mg/L	0.005	0.040	<0.005	0.017	<0.005
Iron	7439-89-6	mg/L	0.05	0.09	<0.05	2.40	<0.05
EG035F: Dissolved Mercury by FIMS							
Mercury	7439-97-6	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001

In regards to nitrogen speciation, the nitrogen analyses on both rougher and cleaner tail samples, pre and post treatment, are presented in Table 12 below. It also includes the total phosphorus and reactive phosphorus, together with their ionic balance on total anions and cations.

Table 12: Decanted & Treated Process Water Analysis – Nitrogen (as Ammonia, Nitrite and Nitrate), Phosphorus Characterisation and Ionic Balance

TALGA PROCESS WATER - ENVIRONMENTAL ANALYSIS				Rougher Tail Process Water	Neutralised Rougher Tail Process Water	Cleaner Tail Process Water	Neutralised Cleaner Tail Process Water
Analyte Grouping / Analyte	CAS Number	Unit	Limit of Reporting				
EK055G: Ammonia as N by Discrete Analyser							
Ammonia as N	7664-41-7	mg/L	0.01	0.01	0.02	0.07	0.45
EK057G: Nitrite as N by Discrete Analyser							
Nitrite as N	14797-65-0	mg/L	0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser							
Nitrate as N	14797-55-8	mg/L	0.01	<0.01	0.02	0.02	0.03
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser							
Nitrite + Nitrate as N		mg/L	0.01	<0.01	0.02	0.02	0.03
EK067G: Total Phosphorus as P by Discrete Analyser							
Total Phosphorus as P		mg/L	0.01	<0.01	<0.01	0.04	0.02
EK071G: Reactive Phosphorus as P by discrete analyser							
Reactive Phosphorus as P	14265-44-2	mg/L	0.01	<0.01	<0.01	<0.01	<0.01
EN055: Ionic Balance							
Total Anions		meq/L	0.01	3.87	3.45	5.02	9.73
Total Cations		meq/L	0.01	4.19	6.22	5.47	5.81
Ionic Balance		%	0.01	3.95	28.6	4.32	25.2

Table 13 shows the analysis of dissolved organic carbon, chemical and biochemical oxygen demands on both untreated and treated process water effluent samples.

Table 13: Decanted & Treated Process Water Analysis – Dissolved Organic Carbon, Chemical and Biochemical Oxygen Demand

TALGA PROCESS WATER - ENVIRONMENTAL ANALYSIS				Rougher Tail Process Water	Neutralised Rougher Tail Process Water	Cleaner Tail Process Water	Neutralised Cleaner Tail Process Water
Analyte Grouping / Analyte	CAS Number	Unit	Limit of Reporting				
EP002: Dissolved Organic Carbon (DOC)							
Dissolved Organic Carbon		mg/L	1	27	18	8	10
EP026SP: Chemical Oxygen Demand (Spectrophotometric)							
Chemical Oxygen Demand		mg/L	10	105	73	33	36
EP030: Biochemical Oxygen Demand (BOD)							
Biochemical Oxygen Demand		mg/L	2	48	5	18	15

For the environmental analyses of hydrocarbons on both untreated and treated process water samples, Table 14 presents all the results. The use of kerosene as collector and methyl isobutyl carbinol (MIBC) as frother reagent for the flotation of graphite minerals would have contributed to the presence of traceable amounts of hydrocarbons in both rougher and cleaner tail process water samples.

Table 14: Decanted & Treated Process Water Analysis – Total Petroleum Hydrocarbons, Total Recoverable Hydrocarbons – NEPM, BTEXN and TPH(V)/BTEX Surrogates

TALGA PROCESS WATER - ENVIRONMENTAL ANALYSIS				Rougher Tail Process Water	Neutralised Rougher Tail Process Water	Cleaner Tail Process Water	Neutralised Cleaner Tail Process Water
Analyte Grouping / Analyte	CAS Number	Unit	Limit of Reporting				
EP080/071: Total Petroleum Hydrocarbons							
C6 - C9 Fraction		µg/L	20	2930	1480	290	140
C10 - C14 Fraction		µg/L	50	150	120	110	470
C15 - C28 Fraction		µg/L	100	210	200	270	250
C29 - C36 Fraction		µg/L	50	<50	<50	<50	<50
C10 - C36 Fraction (sum)		µg/L	50	360	320	380	720
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions							
C6 - C10 Fraction	C6_C10	µg/L	20	2890	1440	290	140
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	µg/L	20	2890	1440	290	140
>C10 - C16 Fraction		µg/L	100	150	110	100	480
>C16 - C34 Fraction		µg/L	100	210	180	260	200
>C34 - C40 Fraction		µg/L	100	<100	<100	<100	<100
>C10 - C40 Fraction (sum)		µg/L	100	360	290	360	680
>C10 - C16 Fraction minus Naphthalene (F2)		µg/L	100	150	110	100	480
EP080: BTEXN							
Benzene	71-43-2	µg/L	1	<1	<1	<1	<1
Toluene	108-88-3	µg/L	2	<2	<2	<2	<2
Ethylbenzene	100-41-4	µg/L	2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	µg/L	2	<2	<2	<2	<2
ortho-Xylene	95-47-6	µg/L	2	<2	<2	<2	<2
Total Xylenes		µg/L	2	<2	<2	<2	<2
Sum of BTEX		µg/L	1	<1	<1	<1	<1
Naphthalene	91-20-3	µg/L	5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates							
1,2-Dichloroethane-D4	17060-07-0	%	2	87.4	90.3	87.8	89.3
Toluene-D8	2037-26-5	%	2	99.1	102	104	102
4-Bromofluorobenzene	460-00-4	%	2	98.7	98.7	101	100

Comments and Recommendations

- 1) The rougher flotation circuit is designed to run at around 35% solids slurry. Even at slightly lower, say 32% solids slurry, the process water from the rougher tail would not be as diluted as the one treated on this bulk neutralisation treatment. Hence, the water balance should be reviewed considering the % moisture of the rougher/scavenger tailings material being rejected and retained on dry-stack tailings storage system. For this, process water bleed-off may not be an issue.
- 2) On the other hand, the cleaner and re-cleaner flotation circuits are designed to run at around 7 to 8% solids slurry. Ultra-fine grinding of the rougher concentrates down to $P_{80} \sim 6$ to $7\mu\text{m}$ grind size should be carried out upfront prior to multiple cleaning and re-cleaning flotation stages at around 30% solids. This is necessary in order to isolate the ultra-fine grinding from the very dilute cleaner/re-cleaner flotation circuits. This way, the ultra-fine grinding efficiency is higher, hence, lower specific power and ceramic media consumptions per ton of rougher concentrates milled, or per kWh of power used.
- 3) The neutralisation treatment of decanted process water can be carried out by an agitated tank reactor with the addition of hydrated lime slurry to around pH~12, measured by a pH controller. The reaction time is between 45 and 60 minutes with air and good mixing.
- 4) The precipitated solids residue formed during the neutralisation treatment of the decanted process water can be efficiently recovered by settling/thickening and then filtering, or by direct in-line filtering.
- 5) The solid-liquid separation of the decant process water and settled solids from the rougher and cleaner tails streams can be carried out by a standard or high-rate Thickener. The settled solids can be filtered to maximise process water recovery for reuse in the flotation concentrator and ultra-fine grinding circuits. The filtered tails solids can be sent to a dry-stacking tailings storage facility.

Appendix A – Environmental Analysis of Rougher and Cleaner Tails Process Water Samples (Pre and Post-Neutralisation) by ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order : **EB1830935**
Client : **HRL TESTING PTY LTD**
Contact : **ROD VENTURA**
Address :
Telephone : ----
Project : **TALGA ENVIRONMETNAL TESTWORK 1080R**
Order number : **HRLC-1080R-617**
C-O-C number : ----
Sampler : ----
Site : ----
Quote number : **EN/333**
No. of samples received : **4**
No. of samples analysed : **4**

Page : 1 of 6
Laboratory : Environmental Division Brisbane
Contact : Customer Services EB
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61-7-3243 7222
Date Samples Received : 17-Dec-2018 16:11
Date Analysis Commenced : 19-Dec-2018
Issue Date : 14-Jan-2019 13:57



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Diana Mesa	2IC Organic Chemist	Brisbane Organics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Sarah Ashworth	Laboratory Manager - Brisbane	Brisbane Organics, Stafford, QLD



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- Ionic Balance out of acceptable limits for some samples due to analytes not quantified in this report.
- ED037-P (Total Alkalinity) - Insufficient sample was provided for repeat analysis.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Client sample ID

				1080R - 617 Process Water	1080R - 618 Neutralised Process Water	1080R - 619 Process Water	1080R - 620 Neutralised Process Water	----
Client sampling date / time				12-Dec-2018 00:00	12-Dec-2018 00:00	12-Dec-2018 00:00	12-Dec-2018 00:00	----
Compound	CAS Number	LOR	Unit	EB1830935-001	EB1830935-002	EB1830935-003	EB1830935-004	-----
				Result	Result	Result	Result	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.74	7.68	7.98	11.8	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	462	446	565	1490	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	295	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	78	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	25	20	79	<1	----
Total Alkalinity as CaCO3	----	1	mg/L	25	20	79	334	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	105	106	88	94	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	42	30	57	39	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	21	83	26	57	----
Magnesium	7439-95-4	1	mg/L	15	<1	16	<1	----
Sodium	7440-23-5	1	mg/L	35	39	61	63	----
Potassium	7440-09-7	1	mg/L	15	15	8	9	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	0.01	1.28	<0.01	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.005	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.0004	<0.0001	----
Chromium	7440-47-3	0.001	mg/L	0.014	<0.001	0.004	0.002	----
Copper	7440-50-8	0.001	mg/L	0.004	0.009	0.019	0.006	----
Cobalt	7440-48-4	0.001	mg/L	0.005	<0.001	0.003	<0.001	----
Nickel	7440-02-0	0.001	mg/L	0.056	<0.001	0.020	<0.001	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.006	0.004	----
Zinc	7440-66-6	0.005	mg/L	0.040	<0.005	0.017	<0.005	----
Manganese	7439-96-5	0.001	mg/L	2.57	0.003	0.085	<0.001	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	0.002	0.004	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Tellurium	22541-49-7	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	----
Thallium	7440-28-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	1080R - 617 Process Water	1080R - 618 Neutralised Process Water	1080R - 619 Process Water	1080R - 620 Neutralised Process Water	----
Client sampling date / time				12-Dec-2018 00:00	12-Dec-2018 00:00	12-Dec-2018 00:00	12-Dec-2018 00:00	----	
Compound	CAS Number	LOR	Unit	EB1830935-001	EB1830935-002	EB1830935-003	EB1830935-004	-----	
				Result	Result	Result	Result	----	
EG020F: Dissolved Metals by ICP-MS - Continued									
Iron	7439-89-6	0.05	mg/L	0.09	<0.05	2.40	<0.05	----	
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----	
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L	0.01	0.02	0.07	0.45	----	
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----	
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	0.02	0.02	0.03	----	
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	0.02	0.02	0.03	----	
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L	<0.01	<0.01	0.04	0.02	----	
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----	
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L	3.87	3.45	5.02	9.73	----	
Total Cations	----	0.01	meq/L	4.19	6.22	5.47	5.81	----	
Ionic Balance	----	0.01	%	3.95	28.6	4.32	25.2	----	
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L	27	18	8	10	----	
EP026SP: Chemical Oxygen Demand (Spectrophotometric)									
Chemical Oxygen Demand	----	10	mg/L	105	73	33	36	----	
EP030: Biochemical Oxygen Demand (BOD)									
Biochemical Oxygen Demand	----	2	mg/L	48	5	18	15	----	
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L	2930	1480	290	140	----	
C10 - C14 Fraction	----	50	µg/L	150	120	110	470	----	
C15 - C28 Fraction	----	100	µg/L	210	200	270	250	----	
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	----	
^ C10 - C36 Fraction (sum)	----	50	µg/L	360	320	380	720	----	
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Client sample ID

				1080R - 617 Process Water	1080R - 618 Neutralised Process Water	1080R - 619 Process Water	1080R - 620 Neutralised Process Water	----
Client sampling date / time				12-Dec-2018 00:00	12-Dec-2018 00:00	12-Dec-2018 00:00	12-Dec-2018 00:00	----
Compound	CAS Number	LOR	Unit	EB1830935-001	EB1830935-002	EB1830935-003	EB1830935-004	-----
				Result	Result	Result	Result	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
C6 - C10 Fraction	C6_C10	20	µg/L	2890	1440	290	140	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	2890	1440	290	140	----
>C10 - C16 Fraction	----	100	µg/L	150	110	100	480	----
>C16 - C34 Fraction	----	100	µg/L	210	180	260	200	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	360	290	360	680	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	150	110	100	480	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	----
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	----
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	----
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	----
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	----
EP080S: TPH(V)/BTEX Surrogates								
1,2-Dichloroethane-D4	17060-07-0	2	%	87.4	90.3	87.8	89.3	----
Toluene-D8	2037-26-5	2	%	99.1	102	104	102	----
4-Bromofluorobenzene	460-00-4	2	%	98.7	98.7	101	100	----



Surrogate Control Limits

Sub-Matrix: **WATER**

		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP080S: TPH(V)/BTEX Surrogates			
1,2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Appendix B – MLA XMOD Analysis on Rougher and Cleaner Tail Solids Samples by ALS Mineralogy



Australian Laboratory Services Pty Ltd
Mineralogy
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Stafford QLD Australia 4053
T: +61 7 3243 7222
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ABN: 84 009 936 029
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30-January-2019

Rod Ventura
Core Group
36 Corunna Street
Albion, Queensland 4010
Australia

Re: Report – ALS Job No J0760.

Dear Rod;

Please find enclosed a copy of a report by Matthew Ng, and reviewed by the undersigned titled “J0760 MLA Analysis of Graphite Tailings Samples for Environmental Assessment – Final Report”.

If you have any queries about the report please do not hesitate to contact me.

Regards

Alexander Grist
Laboratory Manager – *ALS Mineralogy*

ALS Mineralogy

J0760
MLA Analysis of Graphite
Tailing Samples for
Environmental Assessment
– Final Report

Matthew Ng

Submitted to

Core Group

ALS Job No. J0760 - January-2019

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1. INTRODUCTION

The Core Group (on behalf of Talga Resources) requested the Australian Laboratory Services Pty. Ltd. (ALS) Mineralogy section to perform quantitative mineral analysis on two tailings samples. The samples supplied are described as a cleaner tail and rougher tail.

The analysed samples were supplied unsized. Both samples are known to contain naturally occurring graphite that was not included in the analysis. The cleaner tail sample also contained a phase best described as *ceria-zirconia*, ideally $(\text{Zr,Ce})\text{O}_2$. Core Group advised the presence of *ceria-zirconia* is due to the unavoidable contamination of the sample with inert grinding media. The occurrence of *ceria-zirconia* is considered in this report.

The objective of the analysis was to characterise the bulk mineralogy (especially sulfides) of the tailing samples for environmental assessment. The results reported are based on ALS Mineralogy Proposal 18/055 dated 27th of November 2018.

The samples were analysed using the Mineral Liberation Analyser (MLA). The MLA is a scanning-electron microscope fitted with energy dispersive detectors and customised software for providing quantitative mineralogical data.

2. METHODOLOGY

ALS Mineralogy section prepared a single polished mount for each sample. The polished mounts were analysed using the MLA XMOD analysis to report the bulk mineral abundances.

The XMOD analysis supplied bulk mineralogy data only and thus mineral occurrences of less than 0.1-0.2 Wt% may not be reliably quantified. The XMOD analysis does not provide textural data (grain size and locking and liberation).

3. RESULTS

3.1 Assay Data

The MLA calculated assay data is reported in Table 1

Table 1 **MLA Calculated Assay (%)**

Element	1080R Rghr Tail	1080R Clr Tail
Al	6.45	3.93
As	0.00	0.00
Ba	0.00	0.00
Ca	1.96	2.31
Ce	0.01	6.43
Cl	0.24	0.12
Co	0.00	0.00
Cr	0.06	0.03
Cu	0.02	0.00
F	0.01	0.00
Fe	12.89	3.96
H	0.15	0.08
Hf	0.00	0.53
K	2.67	1.38
Mg	4.47	3.33
Mn	0.03	0.03
Na	1.75	1.14
Ni	0.00	0.00
O	39.83	37.95
P	0.10	0.00
Pb	0.00	0.00
S	5.12	0.61
Se	0.00	0.00
Si	23.16	18.73
Th	0.00	0.00
Ti	0.95	0.52
U	0.00	0.00
Y	0.01	0.01
Zn	0.06	0.01
Zr	0.02	18.90
Total	100.00	100.00

3.2 Mineral Reference File

The list of detected minerals including formulae and density are displayed in Table 2.

It should be noted that the assigned composition is an average and that minerals that are part of a solid solution series or mineral mixes may have a highly variable composition.

The complete list including the assigned elemental concentrations are displayed in Appendix 1.

Table 2 Mineral List

Mineral	Density	Formula
Chalcopyrite	4.19	CuFeS ₂
Clausthalite	8.20	PbSe
Cobaltite	6.33	(Co,Fe,Ni)AsS
Pyrite	4.90	FeS ₂
Pyrrhotite	4.69	Fe ₇ S ₈
Sphalerite	4.05	(Zn,Fe)S
Barite	4.50	BaSO ₄
Gypsum_mix	2.65	[CaSO ₄ .2H ₂ O].Na ₂ O.K ₂ O.CaO.MgO.Fe ₂ O ₃ .Al ₂ O ₃ .SiO ₄ .[(Zr,Ce)O ₂]
Natroalunite	2.78	(Na,K)(Al,Fe) ₃ (SO ₄) ₂ (OH) ₆
Al-hydroxide	2.40	Al(OH) ₃
Fe-hydroxide	4.23	FeO(OH).SiO ₂
Brannerite	5.17	(U,Th)Ti ₂ O ₆
Rutile	4.46	TiO ₂
Apatite	3.19	Ca ₅ (PO ₄) ₃ (Cl,F,OH)
Actinolite-Tremolite	2.99	([],Na)Ca ₂ (Mg,Fe,Mn,Ti) ₅ Si ₈ O ₂₂ (OH) ₂
Albite	2.65	(Na,K,Ca)AlSi ₃ O ₈
Biotite	3.01	K(Mg,Fe,Mn) ₃ (Al,Fe,Cr,Ti)Si ₃ O ₁₀ (OH,Cl) ₂
Chlorite	2.82	(Mg,Fe,Ca,Mn,Zn) ₅ (Al,Ti)(Si ₃ Al)O ₁₀ (OH) ₈
Kaolinite	2.34	Al ₂ Si ₂ O ₅ (OH,Cl) ₄ .CaSO ₄ .K ₂ O.Fe ₂ O ₃
K-feldspar	2.58	(K,Na)AlSi ₃ O ₈
Plagioclase	2.67	(Na,Ca)[Al] ₁₋₂ [Si] ₃₋₂ O ₈
Quartz	2.65	SiO ₂
Titanite	3.50	(Ca,Y)(Ti,Fe,Al)SiO ₅
Ceria-zirconia	6.50	(Zr,Hf,Ce,Ca,Fe)O ₂

3.3 Mineral Abundances and Grouping

The ungrouped mineral abundances and grain count data are reported in Table 3 Table 4. The grouped mineral abundances are displayed in Table 5 and in Figure 2. The grouping list used to determine the grouped mineral abundances are displayed in Figure 1.

Table 3 Ungrouped Mineral Abundances (Wt%)

Mineral	1080R Rghr Tail	1080R Clr Tail
Chalcopyrite	0.06	0.01
Clausthalite	0.00	0.00
Cobaltite	0.00	0.00
Pyrite	3.77	0.22
Pyrrhotite	8.09	1.18
Sphalerite	0.07	0.01
Barite	0.01	0.00
Gypsum_mix	0.05	0.38
Natroalunite	0.00	0.00
Al-hydroxide	0.00	0.03
Fe-hydroxide	3.07	0.17
Brannerite	0.01	0.00
Rutile	0.34	0.06
Apatite	0.59	0.02
Actinolite-Tremolite	7.47	13.18
Albite	3.98	0.21
Biotite	32.71	17.11
Chlorite	2.04	0.55
Kaolinite	0.27	0.01
K-feldspar	0.26	0.02
Plagioclase	23.02	17.52
Quartz	13.41	13.93
Titanite	0.75	0.73
Ceria-zirconia	0.03	34.67
Total	100.00	100.00

Table 4 Grain Count Data

Mineral	1080R Rghr Tail	1080R Clr Tail
Chalcopyrite	104	13
Clausthalite	1	0
Cobaltite	2	0
Pyrite	5312	321
Pyrrhotite	11916	1795
Sphalerite	120	9
Barite	8	1
Gypsum_mix	124	1029
Natroalunite	7	0
Al-hydroxide	0	82
Fe-hydroxide	5007	284
Brannerite	8	1
Rutile	526	104
Apatite	1279	37
Actinolite-Tremolite	17267	31486
Albite	10375	563
Biotite	75078	40609
Chlorite	5010	1387
Kaolinite	800	26
K-feldspar	701	42
Plagioclase	59563	46889
Quartz	34964	37561
Titanite	1489	1495
Ceria-zirconia	33	38108
Total	229694	201842

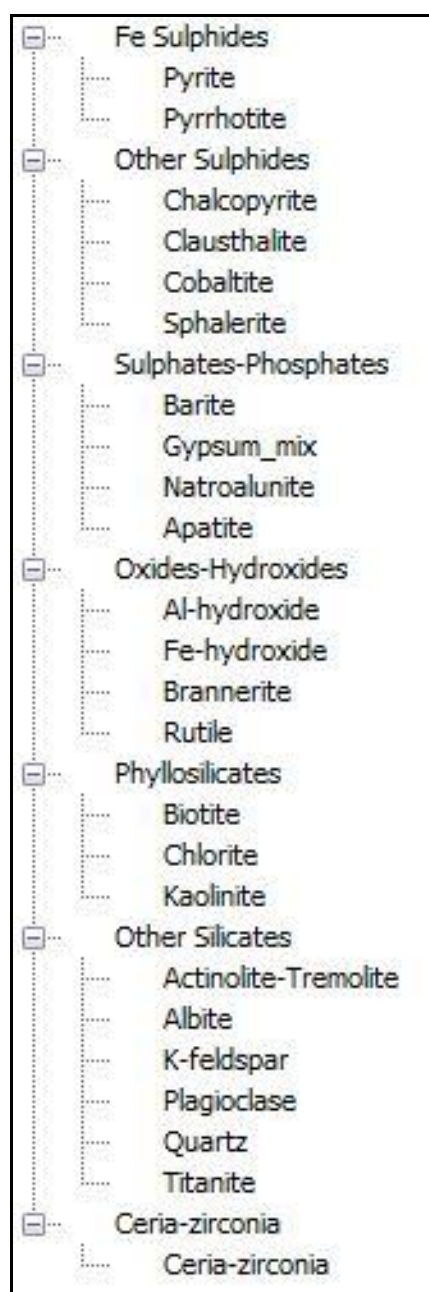


Figure 1 Grouping List

Table 5 Grouped Mineral Abundances (Wt%)

Mineral	1080R Rghr Tail	1080R Clr Tail
Fe Sulphides	11.86	1.40
Other Sulphides	0.14	0.01
Sulphates-Phosphates	0.65	0.40
Oxides-Hydroxides	3.41	0.26
Phyllosilicates	35.02	17.67
Other Silicates	48.90	45.59
Ceria-zirconia	0.03	34.67
Total	100.00	100.00

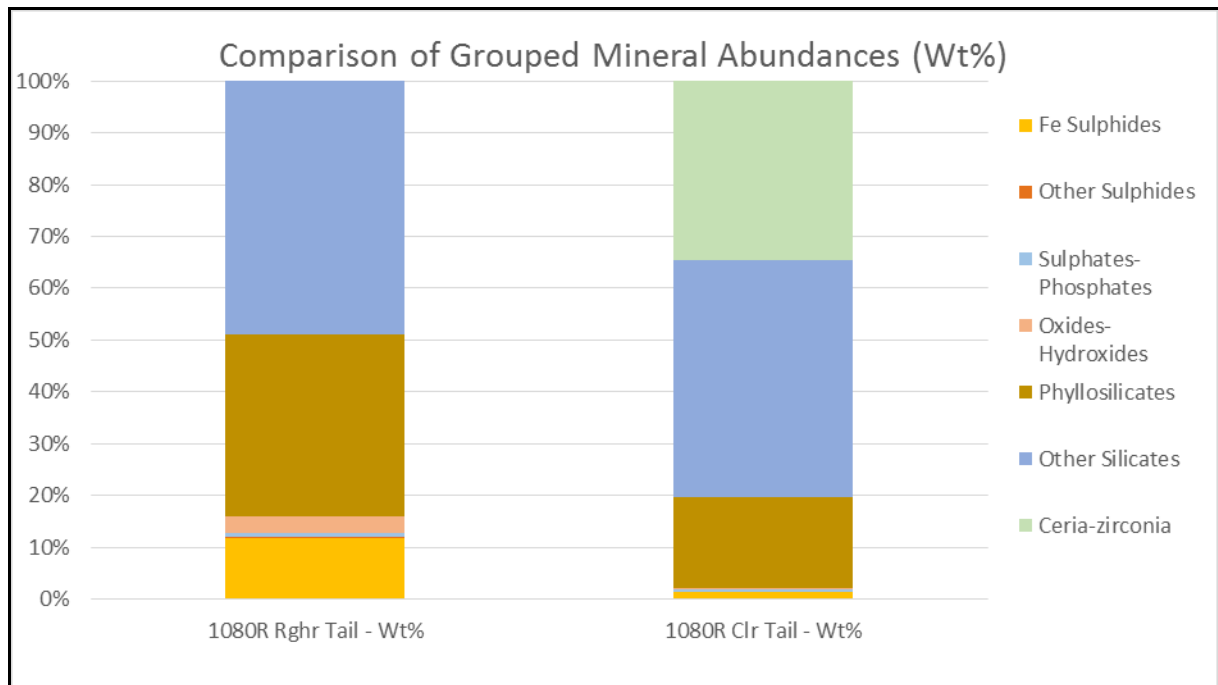


Figure 2 **Grouped Mineral Abundances (Wt%)**

3.4 Elemental Distributions

The elemental distributions of elements to grouped minerals are displayed in Table 6. The ungrouped elemental distributions are shown in Appendix 2.

Table 6 Grouped Elemental Distributions (%)

Mineral	1080R Rghr Tail - Al (%)	1080R Clr Tail - Al (%)	1080R Rghr Tail - As (%)	1080R Clr Tail - As (%)	1080R Rghr Tail - Ba (%)	1080R Clr Tail - Ba (%)	1080R Rghr Tail - Ca (%)	1080R Clr Tail - Ca (%)	1080R Rghr Tail - Ce (%)	1080R Clr Tail - Ce (%)	1080R Rghr Tail - Cl (%)	1080R Clr Tail - Cl (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphates-Phosphates	0.04	0.40	0.00	0.00	100.00	100.00	12.31	2.77	11.74	0.10	4.07	0.23
Oxides-Hydroxides	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	46.06	37.81	0.00	0.00	0.00	0.00	0.16	0.03	0.00	0.00	95.93	99.77
Other Silicates	53.90	61.55	0.00	0.00	0.00	0.00	87.52	90.13	0.00	0.00	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00	0.01	7.07	88.26	99.90	0.00	0.00
Total	100.00	100.00	100.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - Co (%)	1080R Clr Tail - Co (%)	1080R Rghr Tail - Cr (%)	1080R Clr Tail - Cr (%)	1080R Rghr Tail - Cu (%)	1080R Clr Tail - Cu (%)	1080R Rghr Tail - F (%)	1080R Clr Tail - F (%)	1080R Rghr Tail - Fe (%)	1080R Clr Tail - Fe (%)	1080R Rghr Tail - H (%)	1080R Clr Tail - H (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.65	21.11	0.00	0.00
Other Sulphides	100.00	0.00	0.00	0.00	100.00	100.00	0.00	0.00	0.19	0.07	0.00	0.00
Sulphates-Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00	0.01	0.19	0.50	1.46
Oxides-Hydroxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.48	2.59	21.84	3.68
Phyllosilicates	0.00	0.00	100.00	100.00	0.00	0.00	0.00	0.00	28.91	47.21	66.53	56.68
Other Silicates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.76	21.48	11.13	38.18
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.36	0.00	0.00
Total	100.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - Hf (%)	1080R Clr Tail - Hf (%)	1080R Rghr Tail - K (%)	1080R Clr Tail - K (%)	1080R Rghr Tail - Mg (%)	1080R Clr Tail - Mg (%)	1080R Rghr Tail - Mn (%)	1080R Clr Tail - Mn (%)	1080R Rghr Tail - Na (%)	1080R Clr Tail - Na (%)	1080R Rghr Tail - Ni (%)	1080R Clr Tail - Ni (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Sulphates-Phosphates	0.00	0.00	0.01	0.05	0.01	0.06	0.00	0.00	0.08	0.94	0.00	0.00
Oxides-Hydroxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	98.46	99.78	81.00	55.03	71.80	42.13	0.00	0.00	0.00	0.00
Other Silicates	0.00	0.00	1.53	0.17	18.99	44.91	28.20	57.87	99.92	99.06	0.00	0.00
Ceria-zirconia	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00

Mineral	1080R Rghr Tail - O (%)	1080R Clr Tail - O (%)	1080R Rghr Tail - P (%)	1080R Clr Tail - P (%)	1080R Rghr Tail - Pb (%)	1080R Clr Tail - Pb (%)	1080R Rghr Tail - S (%)	1080R Clr Tail - S (%)	1080R Rghr Tail - Se (%)	1080R Clr Tail - Se (%)	1080R Rghr Tail - Si (%)	1080R Clr Tail - Si (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	98.95	92.62	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	100.00	0.00	0.89	0.72	100.00	0.00	0.00	0.00
Sulphates-Phosphates	0.64	0.47	100.00	100.00	0.00	0.00	0.12	6.65	0.00	0.00	0.03	0.28
Oxides-Hydroxides	3.16	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.01
Phyllosilicates	36.15	19.01	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	28.75	18.00
Other Silicates	60.04	58.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.03	81.71
Ceria-zirconia	0.02	22.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	0.00	100.00	100.00	100.00	0.00	100.00	100.00

Mineral	1080R Rghr Tail - Th (%)	1080R Clr Tail - Th (%)	1080R Rghr Tail - Ti (%)	1080R Clr Tail - Ti (%)	1080R Rghr Tail - U (%)	1080R Clr Tail - U (%)	1080R Rghr Tail - Y (%)	1080R Clr Tail - Y (%)	1080R Rghr Tail - Zn (%)	1080R Clr Tail - Zn (%)	1080R Rghr Tail - Zr (%)	1080R Clr Tail - Zr (%)
Fe Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Sulphides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.77	34.23	0.00	0.00
Sulphates-Phosphates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.41	0.09
Oxides-Hydroxides	100.00	100.00	21.50	7.55	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Phyllosilicates	0.00	0.00	59.78	57.51	0.00	0.00	0.00	0.00	34.23	65.77	0.00	0.00
Other Silicates	0.00	0.00	18.71	34.94	0.00	0.00	100.00	100.00	0.00	0.00	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	88.59	99.91
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

4. TERMS & CONDITIONS

1. General

- a) ALS will provide the Services described in the accompanying tender, quotation, letter, fax or email to the Client, which together with these terms and conditions will hereafter be called the 'Agreement'.
- b) This Agreement will be binding on the Client from the date the Agreement is accepted by the Client in the Acceptance section below. However, the placement of an order for or receipt of samples for analysis based on this Agreement will constitute acceptance of the Agreement by the Client.
- c) This Agreement is valid for acceptance by the Client for ninety (90) days from the issue date unless specifically indicated otherwise.

2. Provision of Services

- a) ALS will provide the Services by exercising the same degree of skill, care and diligence that would be exercised by professional service providers in similar circumstances.
- b) The Client acknowledges that it is the Client's sole responsibility to make its own assessment of the suitability for any purpose of the Service, the ALS Report and its contents.
- c) If the Client requires the Services to be performed by specific test method, or requires detection limits and/or confidence intervals different to those inherent in ALS's standard testing methodology, then the Client must instruct ALS of such a variation prior to ALS performing the Services.
- d) ALS may delegate the performance of all or part of the Service to an agent or subcontractor and the Client consents to ALS disclosing all information (including Confidential Information) of the Client to that agent or subcontractor necessary for the performance of the Service by the agent or subcontractor.

3. Fees and Payment

- a) ALS reserves the right to review prices at any time if significant changes to ALS's costs are incurred that are beyond ALS's control, such changes may include, but are not limited to, changes in legislative requirements, Client variations to sample numbers, turnaround required, or reporting requirements.
- b) Invoices will also be delivered on work order approval to the nominated Client representative via email in a secure PDF format, unless otherwise requested. This is the official invoice and should be used for payment purposes. Hard copies can be printed from this file if required.
- c) Payment terms are 30 days from the date of invoice (Due Date), unless negotiated otherwise prior to the placement of an order or submission of samples. Any such variance from the standard payment terms must be stipulated separately in writing in the Agreement.
- d) All prices quoted by ALS are exclusive of GST (or other value added tax if relevant) unless stated otherwise.
- e) All fees due and payable after the Due Date (Outstanding Amount) will be subject to the payment of interest at a rate of 1.5% per month of the Outstanding Amount from the Due Date up to and including the date of payment, unless ALS and the Client otherwise agree in writing.
- f) The Client will indemnify ALS for any fees incurred by ALS to recover the Outstanding Amount, including any solicitor fees, or collection agency fees.

4. Limitation of Liability

- a) To the full extent permitted by law, ALS excludes all warranties, terms, conditions or undertakings (Terms), whether expressed or implied, in relation to the Services, the ALS Report, or its contents. Where any legislation implies any Terms in this Agreement that cannot be modified or excluded then, such Terms shall deem to be included. However, to the full extent permitted by law, ALS's liability to the Client for any breach of any Terms that cannot be excluded by law is limited at ALS's option to the re-performance of the Service or the refund of the fee for the Service.
- b) The Client hereby releases and indemnifies and shall continue to release and indemnify ALS, its officers, employees and agents from and against all actions, claims (actual or threatened), proceedings or demands (including any costs and expenses in defending or servicing same) which may be brought against it or them, in respect of any loss (including Consequential Loss), death, injury, illness or damage to persons or property, and whether direct or indirect and in respect of any breach of any industrial or intellectual property rights, howsoever arising out of the use of, reliance on, or benefit of, the Services or any ALS Report, except to the extent that the loss, death, injury, illness or damage to persons or property was directly caused by the negligence, wilful acts or omissions of ALS or its employees.
- c) Notwithstanding any other provision in this Agreement, the cumulative liability of ALS under this Agreement to the Client and any third party is limited for any claim for loss or damage whatsoever, whether arising in tort or contract or any other cause of action, to the value of the Services provided by ALS to the Client.
- d) Without limiting the generality of clauses 4.a) and 4.b), it is agreed that, to the full extent permitted by any applicable laws having jurisdiction, ALS will not be liable to the Client or any other person for any special, indirect or Consequential Loss arising from the Client's use of, reliance on, or benefit of, the Services or any ALS Report.

e) The Client acknowledges that during the performance of the Services, any samples supplied by, or on behalf of, the Client or parts thereof may be altered, lost, damaged or destroyed. ALS will not be liable whatsoever to the Client or any third party for any samples so altered, lost, damaged or destroyed.

5. Client's Obligations

a) The Client will ensure that all personnel, information, samples, access, assistance, records, documentation and facilities needed by ALS to perform the Service, are available when reasonably required by ALS.

b) The Client will give written notice to ALS of all known safety or health hazards and special procedures applicable to the performance of the Service, and the safe handling, testing, storage, transport and disposal of samples submitted to ALS. ALS may in its absolute discretion, refuse to provide part or all of the Services where it determines that the provision of part or all of the Services may pose a health or safety hazard.

c) The Client must take all necessary steps to remove or remedy any known safety or health hazards, or any obstacles to or anything that is likely to interrupt the performance of the Services by ALS.

6. Termination

a) ALS may suspend or terminate its obligations under this Agreement if (a) monies payable to ALS by the client are outstanding 60 days or more (unless otherwise agreed) after the date of invoice, (b) other substantial breach by the Client of their obligations under the Agreement, which breach is not remedied within 30 days of written notice from ALS requiring the breach to be remedied, (c) by giving the Client 60 days written notice of ALS's intention to terminate.

b) The Client may terminate its obligations under this Agreement in the event of a substantial breach by ALS of its obligations under the Agreement, which breach has not been remedied within 30 days of written notice from the Client to ALS requiring the breach to be remedied.

c) If ALS, acting reasonably, suspects that the Client is insolvent or is having difficulties paying its debts as and when they become due, or the Client is insolvent, ALS may give written notice to the Client of ALS's intention to immediately suspend or terminate its obligations under this Agreement.

d) In the event of termination, ALS is entitled to be paid for all work performed before the date of termination and for any unavoidable commitments entered into by ALS before the date of termination.

7. Intellectual Property

a) All ALS Intellectual Property will remain the property of ALS.

b) ALS grants to the Client a world-wide, non-exclusive, royalty free licence to use ALS Intellectual Property for the purpose agreed to between the Client and ALS to the extent that it is needed for the enjoyment and benefit of the Services.

8. Confidential Information

a) Neither ALS nor the Client will disclose Confidential Information of the other party to any third party without the prior written consent of the other party, unless required by law or the rules of a relevant stock exchange.

b) ALS and the Client will only use Confidential Information of the other party for the purpose of the supply of the Services.

9. Reports

a) Any report, findings, results, statement, certification issued by ALS (ALS Report) is issued on the basis of testing of samples or materials, information, or documents provided by, or on behalf of, the Client. The Client will indemnify and hold harmless ALS, its officers, employees, agents and subcontractors for any claim whatsoever in relation to any ALS Report arising from unclear, erroneous, incomplete, misleading or false information provided to ALS; or arising from any incorrect or defective materials or samples provided to ALS.

b) Each ALS Report is

i. issued on the testing of samples or specific materials using detection limits and confidence intervals inherent in ALS's testing methodology; and

ii. contains ALS's results and opinions (if provided) on those samples or specific materials only.

c) Each ALS Report is solely for the benefit of the Client, its officers and employees. The Client will not disclose any ALS Report to any third party without the prior written consent of ALS, unless required by law, and subject to the following terms:

i. the ALS Report has been commissioned by the Client on the terms and conditions contained in this Agreement;

ii. copyright in the ALS Report and all information and data contained in it, save for any information supplied by the Client, are owned by ALS;

iii. moral rights in the ALS Report are owned by ALS;

iv. the ALS Report has been prepared at the request of the Client for the purpose agreed between the Client and ALS. The Client may disclose the report to a third party for that purpose only, but ALS does not accept any responsibility or liability (including, without limitation, liability for negligence) to that third party. Any disclosure to a third party must be of the whole of the ALS Report, including ALS's disclaimer notice which is substantially the same as the terms outlined in this clause 9.b);

v. while ALS has taken all due care to ensure that the information contained in the ALS Report is true and correct and is not misleading or deceptive, neither ALS, nor any of its officers, employees or agents make any representations or warranties, express or implied, other than to the Client, as to the accuracy of the information

contained therein. Except insofar as liability under any law cannot be excluded, and subject to clause 4, ALS accepts no responsibility arising in respect of the information contained in the ALS Report for errors or omissions (including responsibility to any person by reason of negligence); and

vi. ALS reserves its right to review, update or supplement any ALS Report. Any further information will be provided subject to the terms of this Agreement.

d) The Client will not reproduce or publish extracts of any ALS Report without the prior written consent of ALS, and subject to terms outlined in clause 9.b).

e) The Client indemnifies ALS, its directors, employees, agents, consultants, contractors, successors in title and assigns against any claim made against any or all of them by third parties arising out of either the disclosure of any ALS Report, whether directly or indirectly by the Client, to a third party; or any reproduction or publication of an extract of any ALS Report.

f) The Client acknowledges and agrees that any action, inaction, or decision of the Client in response to the ALS Report will be determined by the Client. Neither ALS nor any of its officers, employees, agents, or subcontractors will be liable to the Client or any third party for any action or inaction of the Client in response to any ALS Report.

h) ALS will retain Client data and Confidential Information for 3 years from date of the final ALS Report.

10. Samples

a) Unless otherwise agreed, sample disposal is the responsibility of the Client. Samples may be collected within 90 days of receiving the ALS Report. Uncollected samples may incur a storage or disposal charge.

b) For samples, pulps and rejects that are in storage at an ALS facility, warehouse, or at a third party storage facility sub-contracted by ALS, the Client should obtain coverage for fire and theft. The responsibility of ALS for client's goods is strictly limited to exercising the reasonable care and diligence as required by statute. All of ALS other obligations, undertakings, covenants, representations, warranties and conditions, are excluded, unless they are expressly agreed to in writing by an authorized representative of ALS.

c) Except as provided in clause 2.b) above, the Client's goods are stored at the Client's exclusive risk of loss, damage or delay in delivery whatsoever, including, without limitation, loss, damage or delay caused through (a) any action or failure to act beyond the reasonable control of ALS, (b) ordinary wear and tear in handling, (c) natural deterioration of packing material over time, (d) theft, (e) sprinkler or other water damage, (f) fire.

11. Force Majeure

a) If ALS is prevented in whole or in part from performing its obligations by a Force Majeure Event, ALS may suspend performance of those obligations by giving written notice to the Client. Any non-performance or delay in performance resulting from the Force Majeure Event will not be deemed to be a breach of this Agreement.

b) If a suspension under this clause 3 exceeds 90 days, ALS may immediately terminate the Agreement by written notice to the Client. In the event of termination, ALS is entitled to be paid for all work performed before the date of termination and for any unavoidable commitments entered into by ALS before the date of termination.

12. Definitions

a) In this Agreement:

i. ALS means ALS Mineralogy Pty Ltd ACN 009 936 029 and each of its related bodies corporate (as defined in the Corporations Act 2001 (Cth)).

ii. ALS Intellectual Property means all intellectual property and proprietary rights (whether registered or unregistered) owned by ALS prior to performance of the Services, developed by ALS in performance of the Services, or developed by ALS outside of, or after, performance of the Services, and without limitation includes business names, trade or service marks, any right to have information (including confidential information) kept confidential, patents, patent applications, drawings, discoveries, inventions, improvements, trade secrets, technical data, formulae, databases, know-how, logos, designs, design rights, copyright and similar industrial or intellectual property rights.

iii. ALS Report has the meaning given to it in clause 9.a).

iv. Client means the entity to which the accompanying tender, quotation, letter, fax or email is addressed.

v. Confidential Information means all information in relation to a disclosing party, its business, operations, products, processes, customers, suppliers or contractors which is or might reasonably be considered by the disclosing party to be confidential, including all technical data, formulae, specifications, diagrams, plans, drawings, sketches, designs, business plans and reports, business methods and systems, business records, production information, unpublished financial accounts and reports, discount and supply agreements, subcontractor lists, customer lists, except to the extent that such information is lawfully in the public domain.

vi. Consequential Loss means loss or damage from a breach of contract, tort (including negligence), under statute or any other basis in law or equity including, but without limitation loss of profits, loss of revenue, loss of production, loss or denial of opportunity, loss of access to markets, loss of goodwill, loss of business reputation, future reputation or publicity, damage to credit rating, loss of use, and indirect, remote, abnormal or unforeseeable loss, or any similar loss whether or not in the reasonable contemplation of the parties at the time of this Agreement.

vii. Force Majeure Event means any event or circumstance beyond the reasonable control of ALS, including without limitation any act of God, strike, boycott, lockout or other industrial disturbance, default of suppliers or sub-contractors, lightning, fire, storm, flood, earthquake, inclement weather, act of war (declared or undeclared), blockade, insurrection, riot or other civil disturbance, inability to obtain equipment, labour or essential materials,

act of any government or authority, including refusal or delay in obtaining any necessary consent, approval or licence, or accident, explosion or breakage.

viii. Services means the services described in the accompanying tender, quotation, letter, fax or email.

13. Miscellaneous

a) ALS may assign or subcontract the storage and handling of samples under this Agreement without prior written approval of the Client, excluding transport.

b) Any provision of this Agreement that is illegal, invalid or unenforceable will be severed to the extent that it is illegal, invalid or unenforceable, with the remainder of the Agreement continuing in full force.

c) This Agreement is governed by the law of the state or territory in which the Services are provided, and each party irrevocably and unconditionally submits to the non-exclusive jurisdiction of the courts of that place.

Appendix 1 Mineral List

Mineral	Density	Formula	Al (%)	As (%)	Ba (%)
Chalcopyrite	4.19	CuFeS ₂	0.00	0.00	0.00
Clausthalite	8.20	PbSe	0.00	0.00	0.00
Cobaltite	6.33	(Co,Fe,Ni)AsS	0.00	43.63	0.00
Pyrite	4.90	FeS ₂	0.00	0.00	0.00
Pyrrhotite	4.69	Fe ₇ S ₈	0.00	0.00	0.00
Sphalerite	4.05	(Zn,Fe)S	0.00	0.00	0.00
Barite	4.50	BaSO ₄	0.00	0.00	58.84
Gypsum_mix	2.65	[CaSO ₄ .2H ₂ O].Na ₂ O.K ₂ O.CaO.MgO.Fe ₂ O ₃ .Al ₂ O ₃ .SiO ₄ .[(Zr,Ce)O ₂]	4.13	0.00	0.00
Natroalunite	2.78	(Na,K)(Al,Fe) ₃ (SO ₄) ₂ (OH) ₆	21.55	0.00	0.00
Al-hydroxide	2.40	Al(OH) ₃	34.59	0.00	0.00
Fe-hydroxide	4.23	FeO(OH).SiO ₂	0.00	0.00	0.00
Brannerite	5.17	(U,Th)Ti ₂ O ₆	0.00	0.00	0.00
Rutile	4.46	TiO ₂	0.00	0.00	0.00
Apatite	3.19	Ca ₅ (PO ₄) ₃ (Cl,F,OH)	0.00	0.00	0.00
Actinolite-Tremolite	2.99	([],Na)Ca ₂ (Mg,Fe,Mn,Ti) ₅ Si ₈ O ₂₂ (OH) ₂	1.22	0.00	0.00
Albite	2.65	(Na,K,Ca)AlSi ₃ O ₈	10.79	0.00	0.00
Biotite	3.01	K(Mg,Fe,Mn) ₃ (Al,Fe,Cr,Ti)Si ₃ O ₁₀ (OH,Cl) ₂	8.39	0.00	0.00
Chlorite	2.82	(Mg,Fe,Ca,Mn,Zn) ₅ (Al,Ti)(Si ₃ Al)O ₁₀ (OH) ₈	8.62	0.00	0.00
Kaolinite	2.34	Al ₂ Si ₂ O ₅ (OH,Cl) ₄ .CaSO ₄ .K ₂ O.Fe ₂ O ₃	18.57	0.00	0.00
K-feldspar	2.58	(K,Na)AlSi ₃ O ₈	10.11	0.00	0.00
Plagioclase	2.67	(Na,Ca)[Al]1-2[Si]3-2O ₈	12.70	0.00	0.00
Quartz	2.65	SiO ₂	0.00	0.00	0.00
Titanite	3.50	(Ca,Y)(Ti,Fe,Al)SiO ₅	0.81	0.00	0.00
Ceria-zirconia	6.50	(Zr,Hf,Ce,Ca,Fe)O ₂	0.00	0.00	0.00

Mineral	Ca (%)	Ce (%)	Cl (%)	Co (%)	Cr (%)	Cu (%)	F (%)	Fe (%)	H (%)	Hf (%)	K (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	34.63	0.00	30.43	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	24.00	0.00	0.00	0.00	7.88	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.55	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	62.21	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.15	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	15.03	1.61	0.00	0.00	0.00	0.00	0.00	1.97	0.30	0.00	0.19
Natroalunite	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.29	1.50	0.00	1.71
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.88	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.86	1.10	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	39.74	0.00	1.68	0.00	0.00	0.00	1.98	0.00	0.10	0.00	0.00
Actinolite-Tremolite	9.89	0.00	0.00	0.00	0.00	0.00	0.00	6.42	0.23	0.00	0.00
Albite	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
Biotite	0.00	0.00	0.71	0.00	0.19	0.00	0.00	10.47	0.22	0.00	8.04
Chlorite	0.10	0.00	0.00	0.00	0.00	0.00	0.00	14.01	1.32	0.00	0.00
Kaolinite	0.44	0.00	0.58	0.00	0.00	0.00	0.00	5.63	1.39	0.00	0.14
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.77
Plagioclase	3.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	20.53	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00
Ceria-zirconia	0.47	18.54	0.00	0.00	0.00	0.00	0.00	0.84	0.00	1.52	0.00

Mineral	Mg (%)	Mn (%)	Na (%)	Ni (%)	O (%)	P (%)	Pb (%)	S (%)	Se (%)	Si (%)	Th (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.94	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00	72.41	0.00	27.59	0.00	0.00
Cobaltite	0.00	0.00	0.00	5.70	0.00	0.00	0.00	18.79	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.45	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.79	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.08	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	27.42	0.00	0.00	13.74	0.00	0.00	0.00
Gypsum_mix	0.50	0.00	2.82	0.00	44.78	0.00	0.00	10.57	0.00	13.52	0.00
Natroalunite	0.00	0.00	2.31	0.00	55.42	0.00	0.00	17.12	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	61.53	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	36.56	0.00	0.00	0.00	0.00	1.48	0.00
Brannerite	0.00	0.00	0.00	0.00	26.75	0.00	0.00	0.00	0.00	0.00	7.95
Rutile	0.00	0.00	0.00	0.00	40.05	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	38.82	17.68	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	11.36	0.13	0.31	0.00	43.95	0.00	0.00	0.00	0.00	26.36	0.00
Albite	0.00	0.00	8.05	0.00	48.89	0.00	0.00	0.00	0.00	31.94	0.00
Biotite	10.36	0.07	0.00	0.00	40.63	0.00	0.00	0.00	0.00	19.18	0.00
Chlorite	11.32	0.09	0.00	0.00	47.14	0.00	0.00	0.00	0.00	16.27	0.00
Kaolinite	0.00	0.00	0.00	0.00	53.22	0.00	0.00	0.70	0.00	19.33	0.00
K-feldspar	0.00	0.00	0.87	0.00	46.17	0.00	0.00	0.00	0.00	30.08	0.00
Plagioclase	0.00	0.00	6.11	0.00	48.28	0.00	0.00	0.00	0.00	29.35	0.00
Quartz	0.00	0.00	0.00	0.00	53.26	0.00	0.00	0.00	0.00	46.74	0.00
Titanite	0.00	0.00	0.00	0.00	40.49	0.00	0.00	0.00	0.00	14.20	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	24.16	0.00	0.00	0.00	0.00	0.00	0.00

Mineral	Ti (%)	U (%)	Y (%)	Zn (%)	Zr (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	59.77	0.00
Barite	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.00	0.00	4.58
Natroalunite	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00
Brannerite	26.78	38.52	0.00	0.00	0.00
Rutile	59.95	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	0.13	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00
Biotite	1.74	0.00	0.00	0.00	0.00
Chlorite	0.06	0.00	0.00	1.07	0.00
Kaolinite	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00
Titanite	22.38	0.00	1.02	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	54.47

Appendix 2 Ungrouped Elemental Distribution

Mineral	1080R Rghr Tail - Al (%)	1080R Clr Tail - Al (%)	1080R Rghr Tail - As (%)	1080R Clr Tail - As (%)	1080R Rghr Tail - Ba (%)	1080R Clr Tail - Ba (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	100.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	100.00	100.00
Gypsum_mix	0.03	0.40	0.00	0.00	0.00	0.00
Natroalunite	0.01	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.24	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	1.41	4.10	0.00	0.00	0.00	0.00
Albite	6.66	0.57	0.00	0.00	0.00	0.00
Biotite	42.55	36.56	0.00	0.00	0.00	0.00
Chlorite	2.73	1.20	0.00	0.00	0.00	0.00
Kaolinite	0.78	0.04	0.00	0.00	0.00	0.00
K-feldspar	0.41	0.04	0.00	0.00	0.00	0.00
Plagioclase	45.32	56.69	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.09	0.15	0.00	0.00	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	0.00	100.00	100.00

Mineral	1080R Rghr Tail - Ca (%)	1080R Clr Tail - Ca (%)	1080R Rghr Tail - Ce (%)	1080R Clr Tail - Ce (%)	1080R Rghr Tail - Cl (%)	1080R Clr Tail - Cl (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.36	2.49	11.74	0.10	0.00	0.00
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	11.95	0.28	0.00	0.00	4.07	0.23
Actinolite-Tremolite	37.63	56.53	0.00	0.00	0.00	0.00
Albite	0.28	0.01	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	95.28	99.73
Chlorite	0.10	0.02	0.00	0.00	0.00	0.00
Kaolinite	0.06	0.00	0.00	0.00	0.64	0.04
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	41.72	27.06	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	7.88	6.52	0.00	0.00	0.00	0.00
Ceria-zirconia	0.01	7.07	88.26	99.90	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - Co (%)	1080R Clr Tail - Co (%)	1080R Rghr Tail - Cr (%)	1080R Clr Tail - Cr (%)	1080R Rghr Tail - Cu (%)	1080R Clr Tail - Cu (%)
Chalcopyrite	0.00	0.00	0.00	0.00	100.00	100.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	100.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.00	0.00	0.00	0.00
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	100.00	100.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00
Kaolinite	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	0.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - F (%)	1080R Clr Tail - F (%)	1080R Rghr Tail - Fe (%)	1080R Clr Tail - Fe (%)	1080R Rghr Tail - H (%)	1080R Clr Tail - H (%)
Chalcopyrite	0.00	0.00	0.15	0.06	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	13.61	2.59	0.00	0.00
Pyrrhotite	0.00	0.00	39.05	18.52	0.00	0.00
Sphalerite	0.00	0.00	0.04	0.01	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.01	0.19	0.09	1.44
Natroalunite	0.00	0.00	0.00	0.00	0.03	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	1.35
Fe-hydroxide	0.00	0.00	14.48	2.59	21.84	2.33
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	100.00	100.00	0.00	0.00	0.38	0.02
Actinolite-Tremolite	0.00	0.00	3.72	21.37	11.13	38.18
Albite	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	26.57	45.26	46.61	47.42
Chlorite	0.00	0.00	2.22	1.94	17.48	9.10
Kaolinite	0.00	0.00	0.12	0.01	2.44	0.15
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.03	0.11	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	7.36	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - Hf (%)	1080R Clr Tail - Hf (%)	1080R Rghr Tail - K (%)	1080R Clr Tail - K (%)	1080R Rghr Tail - Mg (%)	1080R Clr Tail - Mg (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.00	0.05	0.01	0.06
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	0.00	0.00	0.00	0.00	18.99	44.91
Albite	0.00	0.00	0.28	0.03	0.00	0.00
Biotite	0.00	0.00	98.45	99.78	75.82	53.18
Chlorite	0.00	0.00	0.00	0.00	5.18	1.86
Kaolinite	0.00	0.00	0.01	0.00	0.00	0.00
K-feldspar	0.00	0.00	1.25	0.14	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00
Ceria-zirconia	100.00	100.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - Mn (%)	1080R Clr Tail - Mn (%)	1080R Rghr Tail - Na (%)	1080R Clr Tail - Na (%)	1080R Rghr Tail - Ni (%)	1080R Clr Tail - Ni (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	100.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.08	0.94	0.00	0.00
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	28.20	57.87	1.32	3.59	0.00	0.00
Albite	0.00	0.00	18.27	1.48	0.00	0.00
Biotite	66.46	40.46	0.00	0.00	0.00	0.00
Chlorite	5.34	1.66	0.00	0.00	0.00	0.00
Kaolinite	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.13	0.01	0.00	0.00
Plagioclase	0.00	0.00	80.20	93.98	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	0.00	0.00	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	0.00

Mineral	1080R Rghr Tail - O (%)	1080R Clr Tail - O (%)	1080R Rghr Tail - P (%)	1080R Clr Tail - P (%)	1080R Rghr Tail - Pb (%)	1080R Clr Tail - Pb (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	100.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.05	0.45	0.00	0.00	0.00	0.00
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.04	0.00	0.00	0.00	0.00
Fe-hydroxide	2.81	0.16	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.34	0.07	0.00	0.00	0.00	0.00
Apatite	0.58	0.02	100.00	100.00	0.00	0.00
Actinolite-Tremolite	8.25	15.26	0.00	0.00	0.00	0.00
Albite	4.88	0.27	0.00	0.00	0.00	0.00
Biotite	33.37	18.32	0.00	0.00	0.00	0.00
Chlorite	2.42	0.68	0.00	0.00	0.00	0.00
Kaolinite	0.36	0.01	0.00	0.00	0.00	0.00
K-feldspar	0.30	0.02	0.00	0.00	0.00	0.00
Plagioclase	27.90	22.29	0.00	0.00	0.00	0.00
Quartz	17.93	19.55	0.00	0.00	0.00	0.00
Titanite	0.77	0.78	0.00	0.00	0.00	0.00
Ceria-zirconia	0.02	22.07	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	0.00

Mineral	1080R Rghr Tail - S (%)	1080R Clr Tail - S (%)	1080R Rghr Tail - Se (%)	1080R Clr Tail - Se (%)	1080R Rghr Tail - Si (%)	1080R Clr Tail - Si (%)
Chalcopyrite	0.43	0.44	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	100.00	0.00	0.00	0.00
Cobaltite	0.01	0.00	0.00	0.00	0.00	0.00
Pyrite	39.30	19.36	0.00	0.00	0.00	0.00
Pyrrhotite	59.65	73.26	0.00	0.00	0.00	0.00
Sphalerite	0.45	0.28	0.00	0.00	0.00	0.00
Barite	0.01	0.01	0.00	0.00	0.00	0.00
Gypsum_mix	0.10	6.64	0.00	0.00	0.03	0.28
Natroalunite	0.01	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.20	0.01
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	0.00	0.00	0.00	0.00	8.50	18.54
Albite	0.00	0.00	0.00	0.00	5.49	0.36
Biotite	0.00	0.00	0.00	0.00	27.09	17.52
Chlorite	0.00	0.00	0.00	0.00	1.44	0.48
Kaolinite	0.04	0.01	0.00	0.00	0.23	0.01
K-feldspar	0.00	0.00	0.00	0.00	0.34	0.02
Plagioclase	0.00	0.00	0.00	0.00	29.17	27.46
Quartz	0.00	0.00	0.00	0.00	27.07	34.77
Titanite	0.00	0.00	0.00	0.00	0.46	0.56
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	0.00	100.00	100.00

Mineral	1080R Rghr Tail - Th (%)	1080R Clr Tail - Th (%)	1080R Rghr Tail - Ti (%)	1080R Clr Tail - Ti (%)	1080R Rghr Tail - U (%)	1080R Clr Tail - U (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.00	0.00	0.00	0.00
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	100.00	100.00	0.17	0.04	100.00	100.00
Rutile	0.00	0.00	21.34	7.51	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	0.00	0.00	1.02	3.31	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	59.65	57.45	0.00	0.00
Chlorite	0.00	0.00	0.13	0.06	0.00	0.00
Kaolinite	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	0.00	0.00	17.69	31.63	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

Mineral	1080R Rghr Tail - Y (%)	1080R Clr Tail - Y (%)	1080R Rghr Tail - Zn (%)	1080R Clr Tail - Zn (%)	1080R Rghr Tail - Zr (%)	1080R Clr Tail - Zr (%)
Chalcopyrite	0.00	0.00	0.00	0.00	0.00	0.00
Clausthalite	0.00	0.00	0.00	0.00	0.00	0.00
Cobaltite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrite	0.00	0.00	0.00	0.00	0.00	0.00
Pyrrhotite	0.00	0.00	0.00	0.00	0.00	0.00
Sphalerite	0.00	0.00	65.77	34.23	0.00	0.00
Barite	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum_mix	0.00	0.00	0.00	0.00	11.41	0.09
Natroalunite	0.00	0.00	0.00	0.00	0.00	0.00
Al-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Fe-hydroxide	0.00	0.00	0.00	0.00	0.00	0.00
Brannerite	0.00	0.00	0.00	0.00	0.00	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.00	0.00	0.00	0.00	0.00	0.00
Actinolite-Tremolite	0.00	0.00	0.00	0.00	0.00	0.00
Albite	0.00	0.00	0.00	0.00	0.00	0.00
Biotite	0.00	0.00	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	34.23	65.77	0.00	0.00
Kaolinite	0.00	0.00	0.00	0.00	0.00	0.00
K-feldspar	0.00	0.00	0.00	0.00	0.00	0.00
Plagioclase	0.00	0.00	0.00	0.00	0.00	0.00
Quartz	0.00	0.00	0.00	0.00	0.00	0.00
Titanite	100.00	100.00	0.00	0.00	0.00	0.00
Ceria-zirconia	0.00	0.00	0.00	0.00	88.59	99.91
Total	100.00	100.00	100.00	100.00	100.00	100.00

Appendix C – Comprehensive ICP Analysis of Hydrated Lime, Brisbane Tap Water, Rougher Tail and Cleaner Tail Process Water Samples by hrlTesting



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CERTIFICATE OF ANALYSIS

Project Job	1080R-9427
Test Method	
Description	1080R 4 Solution Samples & 1 Solid Sample



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Project Job: 1080R-9427										
Sample ID	Sample Description	Method Analyte units LOR	LQ-MEICP Ag mg/L 0.1	LQ-MEICP Al mg/L 2.5	LQ-MEICP As mg/L 2.5	LQ-MEICP B mg/L 0.5	LQ-MEICP Ba mg/L 0.1	LQ-MEICP Be mg/L 0.1	LQ-MEICP Bi mg/L 1	LQ-MEICP Ca mg/L 1
Lime Sample										
Brisbane Tap Water			< 0.1	< 2.5	< 2.5	< 0.5	< 0.1	< 0.1	< 1	23.1
Pre-Neut. Ro. Tail			< 0.1	< 2.5	< 2.5	< 0.5	< 0.1	< 0.1	< 1	19.5
Pre-Neut. Clr. Tail			< 0.1	< 2.5	< 2.5	< 0.5	< 0.1	< 0.1	< 1	23.6
Pre-Neut. Scav Clr. Con			< 0.1	< 2.5	< 2.5	< 0.5	< 0.1	< 0.1	< 1	21.6



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		Project Job: 1080R-9427								
Sample ID	Sample Description	Method Analyte units LOR	LQ-MEICP Cd mg/L 0.1	LQ-MEICP Co mg/L 0.1	LQ-MEICP Cr mg/L 0.1	LQ-MEICP Cu mg/L 0.3	LQ-MEICP Fe mg/L 0.5	LQ-MEICP Ga mg/L 2.5	LQ-MEICP Ge mg/L 2.5	LQ-MEICP Hg mg/L 0.5
Lime Sample										
Brisbane Tap Water			< 0.1	< 0.1	< 0.1	< 0.3	< 0.5	< 2.5	< 2.5	< 0.5
Pre-Neut. Ro. Tail			< 0.1	< 0.1	< 0.1	< 0.3	< 0.5	< 2.5	< 2.5	< 0.5
Pre-Neut. Clr. Tail			< 0.1	< 0.1	< 0.1	< 0.3	1.52	< 2.5	< 2.5	< 0.5
Pre-Neut. Scav Clr. Con			< 0.1	< 0.1	< 0.1	< 0.3	< 0.5	< 2.5	< 2.5	< 0.5



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Project Job: 1080R-9427										
Sample ID	Sample Description	Method Analyte units LOR	LQ-MEICP K mg/L 0.3	LQ-MEICP La mg/L 0.1	LQ-MEICP Li mg/L 5	LQ-MEICP Mg mg/L 0.5	LQ-MEICP Mn mg/L 1	LQ-MEICP Mo mg/L 0.3	LQ-MEICP Na mg/L 5	LQ-MEICP Ni mg/L 0.5
Lime Sample										
Brisbane Tap Water			3.9	< 0.1	< 5	12.9	< 1	< 0.3	35.8	< 0.5
Pre-Neut. Ro. Tail			16.1	< 0.1	< 5	12.9	2.47	< 0.3	29.6	< 0.5
Pre-Neut. Clr. Tail			9.29	< 0.1	< 5	13.4	< 1	< 0.3	52.4	< 0.5
Pre-Neut. Scav Clr. Con			13.2	< 0.1	< 5	16.6	< 1	< 0.3	54.6	< 0.5



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Project Job: 1080R-9427										
Sample ID	Sample Description	Method Analyte units LOR	LQ-MEICP P mg/L 2.5	LQ-MEICP Pb mg/L 2.5	LQ-MEICP S mg/L 5	LQ-MEICP Sb mg/L 1	LQ-MEICP Sc mg/L 0.1	LQ-MEICP Se mg/L 2.5	LQ-MEICP Si mg/L 2.5	LQ-MEICP Sn mg/L 1
Lime Sample										
Brisbane Tap Water			< 2.5	< 2.5	8.98	< 1	< 0.1	< 2.5	< 2.5	< 1
Pre-Neut. Ro. Tail			< 2.5	< 2.5	37	< 1	< 0.1	< 2.5	4.55	< 1
Pre-Neut. Clr. Tail			< 2.5	< 2.5	30.6	< 1	< 0.1	< 2.5	24.1	< 1
Pre-Neut. Scav Clr. Con			< 2.5	< 2.5	53.5	< 1	< 0.1	< 2.5	16	< 1



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Date Printed: 11 Jan, 2019

		Project Job: 1080R-9427								
Sample ID	Sample Description	Method Analyte units LOR	LQ-MEICP Sr mg/L 0.3	LQ-MEICP Te mg/L 2.5	LQ-MEICP Th mg/L 0.5	LQ-MEICP Ti mg/L 0.1	LQ-MEICP Tl mg/L 2.5	LQ-MEICP U mg/L 2.5	LQ-MEICP V mg/L 2.5	LQ-MEICP W mg/L 1
Lime Sample										
Brisbane Tap Water			< 0.3	< 2.5	< 0.5	< 0.1	< 2.5	< 2.5	< 2.5	< 1
Pre-Neut. Ro. Tail			< 0.3	< 2.5	< 0.5	< 0.1	< 2.5	< 2.5	< 2.5	< 1
Pre-Neut. Clr. Tail			< 0.3	< 2.5	< 0.5	< 0.1	< 2.5	< 2.5	< 2.5	< 1
Pre-Neut. Scav Clr. Con			< 0.3	< 2.5	< 0.5	< 0.1	< 2.5	< 2.5	< 2.5	< 1

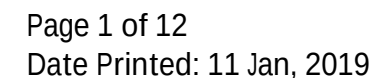


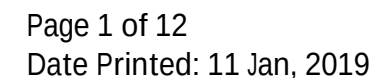
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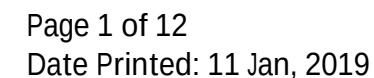
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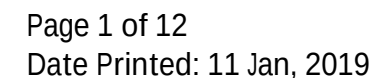
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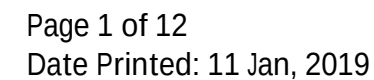
Project Job: 1080R-9427										
Sample ID	Sample Description	Method Analyte units LOR	LQ-MEICP Zn mg/L 0.5	LQ-MEICP Zr mg/L 0.5	SS-2AD- MEICP Ag mg/kg 5	SS-2AD- MEICP Al mg/kg 125	SS-2AD- MEICP As mg/kg 125	SS-2AD- MEICP Ba mg/kg 5	SS-2AD- MEICP Be mg/kg 2.5	SS-2AD- MEICP Bi mg/kg 50
Lime Sample					< 5	957.6	< 125	< 5	< 2.5	< 50
Brisbane Tap Water			< 0.5	< 0.5						
Pre-Neut. Ro. Tail			< 0.5	< 0.5						
Pre-Neut. Clr. Tail			< 0.5	0.968						
Pre-Neut. Scav Clr. Con			< 0.5	< 0.5						

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[illegible]

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Appendix D – Comprehensive ICP Analysis of Neutralised Solid Precipitates from the Treatment of Decanted Rougher and Cleaner Tails Process Water



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An INAB accredited testing laboratory Reg. No. 173T. Accredited methods are listed in the Scope of Accreditation available on request.

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C/O INTERTRUST SWEDEN AB
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103 25 STOCKHOLM

Page: 1
Total # Pages: 2 (A - D)
Plus Appendix Pages
Finalized Date: 18-FEB-2019
Account: NELAAG

CERTIFICATE PI19029030

Project: Not provided

This report is for 2 Tailings samples submitted to our lab in Pitea, Sweden on 4-FEB-2019.

The following have access to data associated with this certificate:

PETER FRENCH

TOM KEARNEY

SAMPLE PREPARATION

ALS CODE	DESCRIPTION
WEI-21	Received Sample Weight
SPLIT-Z	Pulp split for send out
CRU-QC	Crushing QC Test
PUL-QC	Pulverizing QC Test
LOG-22	Sample login - Rcd w/o BarCode
CRU-31	Fine crushing - 70% <2mm
SPL-22Y	Split Sample - Boyd Rotary Splitter
PUL-31	Pulverize split to 85% <75 um

ANALYTICAL PROCEDURES

ALS CODE	DESCRIPTION
ME-MS61	48 element four acid ICP-MS

This is the Final Report and supersedes any preliminary report with this certificate number. Results apply to samples as submitted. All pages of this report have been checked and approved for release.

***** See Appendix Page for comments regarding this certificate *****

Comments: Samples were received on 16-Jan-2019 and the SSF/Request on 4-Feb-2019.

Signature:

Andrey Tairov, Technical Manager, Ireland



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Account: NELAAG

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Project: Not provided

CERTIFICATE OF ANALYSIS PI19029030

Sample Description	Method Analyte Units LOD	WEI-21	CRU-QC	PUL-QC	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
		Recvd Wt.	Pass2mm	Pass75um	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr
		kg	%	%	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
		0.02	0.01	0.01	0.01	0.01	0.2	10	0.05	0.01	0.01	0.02	0.01	0.1	1
1080R Cleaner Tails		1.64	95.7	92.7	0.02	0.56	5.6	30	0.28	0.40	28.9	0.79	>500	14.0	16
1080R Rougher Tails		1.29			0.28	0.21	29.8	30	0.11	1.29	30.1	1.27	8.79	16.9	12

Comments: Samples were received on 16-Jan-2019 and the SSF/Request on 4-Feb-2019.

***** See Appendix Page for comments regarding this certificate *****



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Account: NELAAG

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Project: Not provided

CERTIFICATE OF ANALYSIS PI19029030

Sample Description	Method Analyte Units LOD	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
		Cu	Fe	Ga	Ge	Hf	In	K	La	Li	Mg	Mn	Mo	Na	Nb
		ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm
		0.2	0.01	0.05	0.05	0.1	0.005	0.01	0.5	0.2	0.01	5	0.05	0.01	0.1
1080R Cleaner Tails		98.8	0.82	3.05	<0.05	84.1	0.006	0.07	4.9	2.9	3.49	570	0.49	0.20	0.8
1080R Rougher Tails		639	0.54	0.55	<0.05	0.5	0.024	0.05	3.5	2.7	4.63	4020	1.37	0.04	0.6

Comments: Samples were received on 16-Jan-2019 and the SSF/Request on 4-Feb-2019.

***** See Appendix Page for comments regarding this certificate *****



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Total # Pages: 2 (A - D)

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Finalized Date: 18-FEB-2019

Account: NELAAG

An INAB accredited testing laboratory Reg. No. 173T. Accredited methods are listed in the Scope of Accreditation available on request.

Project: Not provided

CERTIFICATE OF ANALYSIS PI19029030

Sample Description	Method Analyte Units LOD	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
		P	Pb	Rb	Re	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti
		ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%
		10	0.5	0.1	0.002	0.01	0.05	0.1	1	0.2	0.2	0.05	0.05	0.01	0.005
1080R Cleaner Tails		530	17.9	2.2	<0.002	0.10	0.67	1.2	3	<0.2	137.5	0.05	0.25	0.73	0.037
1080R Rougher Tails		690	22.5	1.4	0.002	0.22	2.83	0.7	2	0.4	145.0	0.07	0.09	0.32	0.019

Comments: Samples were received on 16-Jan-2019 and the SSF/Request on 4-Feb-2019.

***** See Appendix Page for comments regarding this certificate *****



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Account: NELAAG

An INAB accredited testing laboratory Reg. No. 173T. Accredited methods are listed in the Scope of Accreditation available on request.

Project: Not provided

CERTIFICATE OF ANALYSIS PI19029030

Sample Description	Method Analyte Units LOD	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
		U	V	W	Y	Zn	Zr
		ppm	ppm	ppm	ppm	ppm	ppm
		0.1	1	0.1	0.1	2	0.5
1080R Cleaner Tails		2.0	12	0.2	10.2	82	>500
1080R Rougher Tails		0.7	5	0.8	9.3	140	22.4

Comments: Samples were received on 16-Jan-2019 and the SSF/Request on 4-Feb-2019.

***** See Appendix Page for comments regarding this certificate *****



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Finalized Date: 18-FEB-2019

Account: NELAAG

An INAB accredited testing laboratory Reg. No. 173T. Accredited methods are listed in the Scope of Accreditation available on request.

Project: Not provided

CERTIFICATE OF ANALYSIS PI19029030

CERTIFICATE COMMENTS

ANALYTICAL COMMENTS

Applies to Method: REE's may not be totally soluble in this method.
ME-MS61

ACCREDITATION COMMENTS

Applies to Method: The methods immediately below this line are ISO 17025:2005 Accredited. INAB Registration No: 173T
ME-MS61



LABORATORY ADDRESSES

Applies to Method: Processed at ALS Pitea located at Hammarvagen 22, SE-943 36, Ojebyn, Sweden.
CRU - 31 CRU-QC LOG-22
PUL-QC SPL-22Y SPLIT-Z

PUL-31
WEI-21

Applies to Method: Processed at ALS Loughrea located at Dublin Road, Loughrea, Co. Galway, Ireland.
ME-MS61

BILAGA E

ALS resultatrapporter

Report

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L1934455

20IYMRXFZIJ



Date received 2019-11-05
Issued 2019-11-13

Talga Graphene AB (TGAB)
Tom Kearney

Storgatan 7E
972 38 Luleå
Sweden

Project Missing

Analysis: LV3A

Your ID	1080Y Tailings L/S 2					
LabID	U11670659					
Analysis	Results	Uncertainty (±)	Unit	Method	Issuer	Sign
Provberedning *	-----			1	1	LIAS
SS-EN 12457-3	Ja	71	ArbMom	2	I	MASB
DW before leaching	98.2	2%	%	3	I	LIAS
Weigh in *	178.2		g	4	I	LIAS
Volume added *	347		ml	4	I	LIAS
Volume after filtration *	255		ml	4	I	LIAS
Ca	97.5	12.4	mg/l	5	R	MATU
Fe	42.2	5.1	mg/l	5	R	MATU
K	90.6	11.1	mg/l	5	R	MATU
Mg	94.5	11.2	mg/l	5	R	MATU
Na	114	14	mg/l	5	R	MATU
Al	4530	703	µg/l	5	R	MATU
As	<1		µg/l	5	H	IDJO
Ba	78.4	15.7	µg/l	5	H	IDJO
Cd	5.20	0.89	µg/l	5	H	IDJO
Co	2820	339	µg/l	5	R	MATU
Cr	23.2	4.8	µg/l	5	H	IDJO
Cu	79.3	12.2	µg/l	5	R	MATU
Hg	<0.02		µg/l	5	F	ELEN
Mn	5590	658	µg/l	5	R	MATU
Mo	<1		µg/l	5	H	IDJO
Ni	20300	2460	µg/l	5	R	MATU
Pb	0.705	0.216	µg/l	5	H	IDJO
Sb	<0.2		µg/l	5	H	IDJO
Se	223	39	µg/l	5	H	IDJO
Zn	973	118	µg/l	5	R	MATU
pH	5.0			6	V	MARH
Conductivity	204		mS/m	7	V	MARH
DOC	6.94	1.39	mg/l	8	2	KRBE
Cl	12.6	1.90	mg/l	9	2	KRBE
F	1.65	0.248	mg/l	9	2	KRBE
SO ₄	992	149	mg/l	9	2	KRBE
Leaching test recalculated mg/kg DW						
Ca	195		mg/kg TS	5	R	MATU
Fe	84.4		mg/kg TS	5	R	MATU

Report

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L1934455

20IYMRXFZIJ



Your ID	1080Y Tailings L/S 2					
LabID	U11670659					
Analysis	Results	Uncertainty ($\pm$)	Unit	Method	Issuer	Sign
K	181		mg/kg TS	5	R	MATU
Mg	189		mg/kg TS	5	R	MATU
Na	228		mg/kg TS	5	R	MATU
Al	9.06		mg/kg TS	5	R	MATU
As	<0.002		mg/kg DW	5	H	IDJO
Ba	0.157		mg/kg DW	5	H	IDJO
Cd	0.0104		mg/kg DW	5	H	IDJO
Co	5.64		mg/kg TS	5	R	MATU
Cr	0.0464		mg/kg DW	5	H	IDJO
Cu	0.159		mg/kg DW	5	R	MATU
Hg	<0.00004		mg/kg DW	5	F	ELEN
Mn	11.2		mg/kg TS	5	R	MATU
Mo	<0.002		mg/kg DW	5	H	IDJO
Ni	40.6		mg/kg DW	5	R	MATU
Pb	0.00141		mg/kg DW	5	H	IDJO
Sb	<0.0004		mg/kg DW	5	H	IDJO
Se	0.446		mg/kg DW	5	H	IDJO
Zn	1.95		mg/kg DW	5	R	MATU
DOC	13.9		mg/kg DW	5	3	KRBE
Cl	25.2		mg/kg DW	5	3	KRBE
F	3.30		mg/kg DW	5	3	KRBE
SO ₄	1980		mg/kg DW	5	3	KRBE
Provberedning utförd av ALS i Öjebyn ej enl standard. Prov torkat och krossat till 70% -2mm						

Report

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L1934455

20IYMRXFZIJ



Your ID		1080Y Tailings				
		L/S 10				
LabID		U11670660				
Analysis	Results	Uncertainty (±)	Unit	Method	Issuer	Sign
SS-EN 12457-3	Ja	71	ArbMom	2	I	MASB
DW before leaching	98.2	2%	%	3	I	LIAS
Weigh in *	178.2		g	4	I	LIAS
Volume added *	1400		ml	4	I	LIAS
Volume after filtration *	-----		ml	4	I	MASB
Ca	9.86	1.24	mg/l	5	R	MATU
Fe	5.68	0.69	mg/l	5	R	MATU
K	19.6	2.4	mg/l	5	R	MATU
Mg	9.26	1.10	mg/l	5	R	MATU
Na	11.1	1.4	mg/l	5	R	MATU
Al	251	40	µg/l	5	R	MATU
As	<0.5		µg/l	5	H	IDJO
Ba	68.3	11.0	µg/l	5	R	MATU
Cd	0.510	0.091	µg/l	5	H	IDJO
Co	326	39	µg/l	5	R	MATU
Cr	1.08	0.34	µg/l	5	H	IDJO
Cu	15.4	2.0	µg/l	5	R	MATU
Hg	<0.02		µg/l	5	F	ELEN
Mn	541	64	µg/l	5	R	MATU
Mo	<0.5		µg/l	5	H	IDJO
Ni	2310	276	µg/l	5	R	MATU
Pb	<0.2		µg/l	5	H	IDJO
Sb	<0.1		µg/l	5	H	IDJO
Se	15.8	2.9	µg/l	5	H	IDJO
Zn	120	15	µg/l	5	R	MATU
pH	6.1			6	V	MARH
Conductivity	30.6		mS/m	7	V	MARH
DOC	1.00	0.20	mg/l	8	2	KRBE
Cl	1.13	0.170	mg/l	9	2	KRBE
F	<0.200		mg/l	9	2	KRBE
SO ₄	101	15.2	mg/l	9	2	KRBE
Leaching test recalculated mg/kg DW						
Ca	226		mg/kg TS	5	R	MATU
Fe	110		mg/kg TS	5	R	MATU
K	299		mg/kg TS	5	R	MATU
Mg	217		mg/kg TS	5	R	MATU
Na	261		mg/kg TS	5	R	MATU
Al	8.75		mg/kg TS	5	R	MATU
As	<0.006		mg/kg DW	5	H	IDJO
Ba	0.698		mg/kg DW	5	R	MATU
Cd	0.0119		mg/kg DW	5	H	IDJO
Co	6.89		mg/kg TS	5	R	MATU
Cr	0.0430		mg/kg DW	5	H	IDJO
Cu	0.247		mg/kg DW	5	R	MATU
Hg	<0.0002		mg/kg DW	5	F	ELEN
Mn	12.8		mg/kg TS	5	R	MATU

Report

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L1934455

20IYMRXFZIJ



Your ID	1080Y Tailings L/S 10					
LabID	U11670660					
Analysis	Results	Uncertainty ($\pm$)	Unit	Method	Issuer	Sign
Mo	<0.006		mg/kg DW	5	H	IDJO
Ni	49.3		mg/kg DW	5	R	MATU
Pb	<0.003		mg/kg DW	5	H	IDJO
Sb	<0.001		mg/kg DW	5	H	IDJO
Se	0.460		mg/kg DW	5	H	IDJO
Zn	2.44		mg/kg DW	5	R	MATU
DOC	18.7		mg/kg DW	5	3	KRBE
Cl	28.0		mg/kg DW	5	3	KRBE
F	<4		mg/kg DW	5	3	KRBE
SO ₄	2310		mg/kg DW	5	3	KRBE

Report

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L1934455

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Method specification	
1	Analysed according to Provberedning utförd av underleverantör.
2	Laktesten har utförts enligt SS-EN 12457-3. Den utvidgade osäkerheten är 71% enligt SS-EN 12457-3. Osäkerheten är beräknad med täckningsfaktor lika med 2 vilket ger en konfidensnivå på ungefär 95%.
3	Analysed according to SS 028113-1.
4	Sample preparation.
5	Analysis of leachate. For determination of metals the sample was acidified with 1 ml of high-purity nitric acid per 100 ml. Determinations of tungsten (W) are however performed on non-acidified samples. For the determination of silver (Ag) the sample is preserved with (excess) hydrochloric acid. The ICP-SFMS analyses were carried out according to SS EN ISO 17294-1, 2 (modified) and US EPA Method 200.8 (modified). The ICP-AES analyses were carried out according to SS EN ISO 11885 (modified) and US EPA Method 200.7 (modified). The AFS analyses for Hg were carried out according to SS EN ISO 17852. Note that limits of reporting may be affected if, e.g. additional dilution was required because of matrix effects, or the sample quantity was limited. If the leaching test has been performed by ALS in Luleå, for recalculated concentrations to mg/kg TS (dry weight) see report or attachment.
6	Samples for measurement of pH should arrive to the laboratory as soon as possible after sampling, since pH is time sensitive analysis. According to SS EN ISO 5667-3 measurement should be done within 24 hours after sampling. Measurement of pH is based on SS EN ISO 10523. The measurement uncertainty for pH is 0.1 pH units.
7	Samples for measurement of conductivity should arrive to the laboratory as soon as possible after sampling, since conductivity is time sensitive analysis. According to SS EN ISO 5667-3 measurement should be done within 24 hours after sampling. Measurement of conductivity is based on SS EN 27888. The measurement uncertainty for conductivity is 8% expressed as relative value.
8	CZ_SOP_D06_02_056 Determination of total organic carbon (TOC), dissolved organic carbon (DOC), total inorganic carbon (TIC) and total carbon (TC) by IR detection (based on CSN EN 1484, CSN EN 16192, SM 5310).
9	CZ_SOP_D06_02_068 (CSN ISO 10304-1, CSN EN 16192) Determination of dissolved fluoride, chloride, nitrite, bromide, nitrate and sulphate by ion liquid chromatography and determination of nitrite nitrogen and nitrate nitrogen and sulfate sulfur by calculation from measured values.

	Approver
ELEN	Elina Engström
IDJO	Ida Jonsson
KRBE	Kristina Berglund
LIAS	Linda Åström
MARH	Maria Hansman
MASB	Marlene Sundberg

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The document is approved and
digitally signed by

Kristina Berglund
ALS Scandinavia AB
Client Service
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2019.11.13 17:13:18

Report

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L1934455

20IYMRXFZIJ



	Approver
MATU	Marcus Turunen

	Issuer ¹
F	AFS
H	ICP-SFMS
I	Man.Inm.
R	ICP-AES
V	Våtkemi
1	The analysis is provided by ALS Chemex, Hammarvägen 22, 943 36 Öjebyn.
2	The analysis is provided by ALS Czech Republic, s.r.o., Na Harfe 336/9, 190 00 Prague 9, Czech Republic, which is a testing laboratory, accredited by the Czech Republic accreditation body CAI (Reg.no. 1163). CAI is a signatory to a MLA within the EA, the same MLA to which the Swedish accreditation body SWEDAC is also a signatory.
3	

* indicates unaccredited analysis.

The uncertainty is given as extended uncertainty (according to the definition in "Guide to the Expression of Uncertainty in Measurement", JCGM 100:2008 Corrected version 2010) calculated with a coverage factor of 2, which gives a confidence level of approximately 95%.

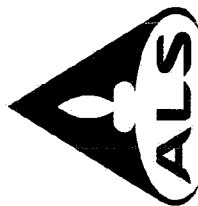
Measurement of uncertainty is reported only for detected substances with levels above the reporting limits.

The uncertainty from subcontractors is often given as extended uncertainty calculated with a coverage factor of 2. Contact the laboratory for further information.

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¹ The technical unit within ALS Scandinavia where the analysis was carried out, alternatively the subcontractor for the analysis.



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Page: 1
Total # Pages: 2 (A - E)
Plus Appendix Pages
Finalized Date: 5-NOV-2019
Account: NELAAG

An INAB accredited testing laboratory Reg. No. 173T. Accredited methods are listed in the Scope of Accreditation available on request.

CERTIFICATE PI19261974

Project: Not provided

This report is for 1 Tailings sample submitted to our lab in Pitea, Sweden on 16-OCT-2019.

The following have access to data associated with this certificate:

ADMIN

PETER FRENCH

TOM KEARNEY

SAMPLE PREPARATION

ALS CODE	DESCRIPTION
WEI-21	Received Sample Weight
LOG-22	Sample login - Rcd w/o BarCode
CRU-31	Fine crushing - 70% <2mm
SPLIT-Z	Pulp split for send out
SPL-22Y	Split Sample - Boyd Rotary Splitter
PUL-31	Pulverize up to 250g 85% <75 um
CRU-QC	Crushing QC Test
PUL-QC	Pulverizing QC Test

ANALYTICAL PROCEDURES

ALS CODE	DESCRIPTION	INSTRUMENT
Hg-MS42	Trace Hg by ICPMS	ICP-MS
S-IR08	Total Sulphur (IR Spectroscopy)	LECO
S-ICP19	Sulphate Sulphur / By ICP-AES	ICP-AES
S-CAL19	Sulphide Sulphur (Calculated)	LECO
C-IR07	Total Carbon (IR Spectroscopy)	LECO
C-IR06	Organic Carbon (IR Spectroscopy)	LECO
C-CAL04	Inorganic Carbon	LECO
OA-VOL08EU	AP & NP of Sulphidic Waste	
ME-MS61	48 element four acid ICP-MS	

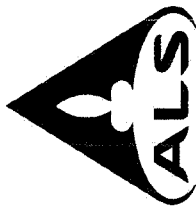
This is the Final Report and supersedes any preliminary report with this certificate number. Results apply to samples as submitted. All pages of this report have been checked and approved for release.

***** See Appendix Page for comments regarding this certificate *****

Comments: Samples were received on 16-Oct-2019 and the SSF/Request on 15-Oct-2019.

Signature:

Andrey Tairov, Technical Manager, Ireland



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Project: Not provided

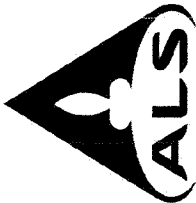
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CERTIFICATE OF ANALYSIS PI19261974

Sample Description	Method Analyte Units LOD	WEI-21 Recvd Wt. kg 0.02	CRU-QC Pass2mm % 0.01	PUL-QC Pass75um % 0.01	ME-MS61 Ag ppm 0.01	ME-MS61 Al % 0.01	ME-MS61 As ppm 0.2	ME-MS61 Ba ppm 10	ME-MS61 Be ppm 0.05	ME-MS61 Bi ppm 0.01	ME-MS61 Ca % 0.01	ME-MS61 Cd ppm 0.02	ME-MS61 Ce ppm 0.01	ME-MS61 Co ppm 0.1	ME-MS61 Cr ppm 1	ME-MS61 Cs ppm 0.05	2.16
1080Y		2.21	90.2	98.0	0.03	6.64	7.2	540	1.69	0.47	1.24	0.05	79.9	45.0	1620		

Comments: Samples were received on 16-Oct-2019 and the SSF/Request on 15-Oct-2019.

***** See Appendix Page for comments regarding this certificate *****



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An INAB accredited testing laboratory Reg. No. 1737. Accredited methods are listed in the Scope of Accreditation available on request.

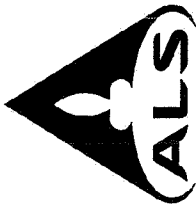
Project: Not provided

CERTIFICATE OF ANALYSIS PI19261974

Sample Description	Method Analyte Units LOD	ME-MS61 Cu ppm 0.2	ME-MS61 Fe %	ME-MS61 Ga ppm 0.05	ME-MS61 Ge ppm 0.05	ME-MS61 Hf ppm 0.1	Hg-MS42 Hg ppm 0.005	ME-MS61 In ppm 0.005	ME-MS61 K %	ME-MS61 La ppm 0.5	ME-MS61 Li ppm 0.2	ME-MS61 Mg %	ME-MS61 Mn ppm 5	ME-MS61 Mo ppm 0.05	ME-MS61 Na %	ME-MS61 Nb ppm 0.1	ME-MS61 Ni ppm 0.1
T080Y		175.5	6.82	19.75	0.37	7.7	0.012	0.023	1.86	32.5	16.5	3.13	254	3.73	2.57	5.8	

Comments: Samples were received on 16-Oct-2019 and the SSF/Request on 15-Oct-2019.

***** See Appendix Page for comments regarding this certificate *****



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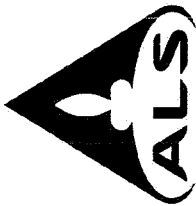
Project: Not provided

CERTIFICATE OF ANALYSIS PI19261974

Method Analyte Units LOD	Sample Description	ME-MS61 Ni ppm 0.2	ME-MS61 P ppm 10	ME-MS61 Pb ppm 0.5	ME-MS61 Rb ppm 0.1	ME-MS61 Re ppm 0.002	ME-MS61 S % 0.01	ME-MS61 Sb ppm 0.05	ME-MS61 Sc ppm 0.1	ME-MS61 Se ppm 1	ME-MS61 Sn ppm 0.2	ME-MS61 Sr ppm 0.2	ME-MS61 Ta ppm 0.05	ME-MS61 Te ppm 0.05	ME-MS61 Th ppm 0.01	ME-MS61 Ti % 0.005
1080Y		258	390	5.1	80.7	0.035	2.06	0.28	29.7	31	0.5	53.6	0.31	1.58	7.29	0.515

Comments: Samples were received on 16-Oct-2019 and the SSF/Request on 15-Oct-2019.

***** See Appendix Page for comments regarding this certificate *****



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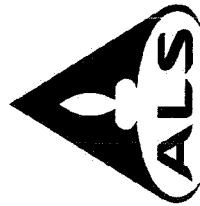
Project: Not provided

CERTIFICATE OF ANALYSIS PI19261974

Method Analyte Units LOD	Sample Description	ME-MS61 Ti ppm 0.02	ME-MS61 U ppm 0.1	ME-MS61 V ppm 1	ME-MS61 W ppm 0.1	ME-MS61 Y ppm 0.1	ME-MS61 Zn ppm 2	ME-MS61 Zr ppm 0.5	S-IR08 S % 0.01	S-ICP19 S % 0.01	S-CAL19 S % 0.01	C-IR07 C % 0.01	C-IR06 C organi % 0.01	C-CAL04 C inorga % 0.01	OA-VOL08EU NP tCaCO3/1Kt 1	OA-VOL08EU AP tCaCO3/1Kt 0.3	OA-VOL08EU 51.9
1080Y		0.47	6.4	295	0.7	21.2	38	300	2.41	0.75	1.66	2.32	2.17	0.15	-5		

Comments: Samples were received on 16-Oct-2019 and the SSF/Request on 15-Oct-2019.

***** See Appendix Page for comments regarding this certificate *****



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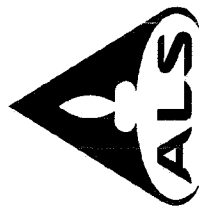
Project: Not provided

CERTIFICATE OF ANALYSIS PI19261974

Sample Description	Method Analyte Units LOD	OA-VOL08EU OA-VOL08EU NPR NNP Unit tCaCO ₃ /1Kt 0.01 1 -0.10 -57
1080Y		

Comments: Samples were received on 16-Oct-2019 and the SSF/Request on 15-Oct-2019.

***** See Appendix Page for comments regarding this certificate *****



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Page: Appendix 1
Total # Appendix Pages: 1
Finalized Date: 5-NOV-2019
Account: NELAAG

An INAB accredited testing laboratory Reg. No. 173T. Accredited methods are listed in the Scope of Accreditation available on request.

Project: Not provided

CERTIFICATE OF ANALYSIS PI19261974

CERTIFICATE COMMENTS	
Applies to Method:	ANALYTICAL COMMENTS REE's may not be totally soluble in this method. ME-MS61 OA-VOL08EU Units: tCaCO3/1 Kt = tCaCO3/1 000t ore OA-VOL08EU The methods immediately below this line are ISO 17025:2005 Accredited. INAB Registration No: 173T C-IR07 ME-MS61 S-IR08
Applies to Method:	
Applies to Method:	
Applies to Method:	LABORATORY ADDRESSES Processed at ALS Pitea located at Hammarvagen 22, SE-943 36, Ojebyn, Sweden. CRU-31 PUL-QC LOG-22 SPLIT-Z Processed at ALS Loughrea located at Dublin Road, Loughrea, Co. Galway, Ireland. C-CAL04 ME-MS61 S-IR08 PUL-31 WEI-21 Hg-MS42 S-ICP19
Applies to Method:	



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