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Grafiittitutkimukset Rautalammin Käpysuolla vuosina 2016–2019

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Geologian tutkimuskeskus | Geologiska forskningscentralen | Geological Survey of Finland
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GEOLOGIAN TUTKIMUSKESKUS **KUVAILULEHTI**

Päivämäärä / Dnro

Tekijät Timo Ahtola, Jouni Lerssi, Thair Al-Ani Timo Ahtola, Jouni Lerssi, Thair Al-Ani	Raportin laji GTK:n työraportti Toimeksiantaja Geologian tutkimuskeskus
Otsikko Grafiittitutkimukset Rautalammin Käpysuolla vuosina 2016–2019	
Tiivistelmä Geologian tutkimuskeskus tutki vuosina 2016–2019 Rautalammilla sijaitsevaa Käpysuon suomugrafiittiesiintymää. Kohteeseen kairattiin 14 reikää (yhteensä 2017 m), sekä analysoitiin Outokumpu Oy:n 1980-luvun vaiheessa alueelle kairaamien reikien grafiittipitoiset sydännäytteet. Grafiittipitoisten kivilajikerrosten paksuus vaihtelee kymmenistä senteistä kymmeniin metreihin. Grafiittipitoisuus on analyysien perusteella enimmillään 38 %. Alueelle tehtiin geofysiikan maastomittauksia vuosina 2018–2019 tavoitteena testata suomugrafiitin etsintään soveltuvia geofysiikan etsintämenetelmiä (MaxMin, GEM-2, ERT). Kairasydännäytteistä teetettiin seitsemästä näytteestä rikastuskokeet GTK Mintecin laboratoriossa Outokummussa. Vaahdotuksen, alkalipaahdon ja happoliuotuksen jälkeen päästiin rikasteessa yli 99 % grafiittipitoisuuteen.	
Asiasanat (kohde, menetelmät jne.) Käpysuo, suomugrafiitti, geofysiikan maastomittaus, timanttikairaus, rikastuskoe	
Maantieteellinen alue (maa, lääni, kunta, kylä, esiintymä) Suomi, Pohjois-Savo, Rautalampi, Käpysuo	
Karttalehdet N4444	
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Sisällysluettelo

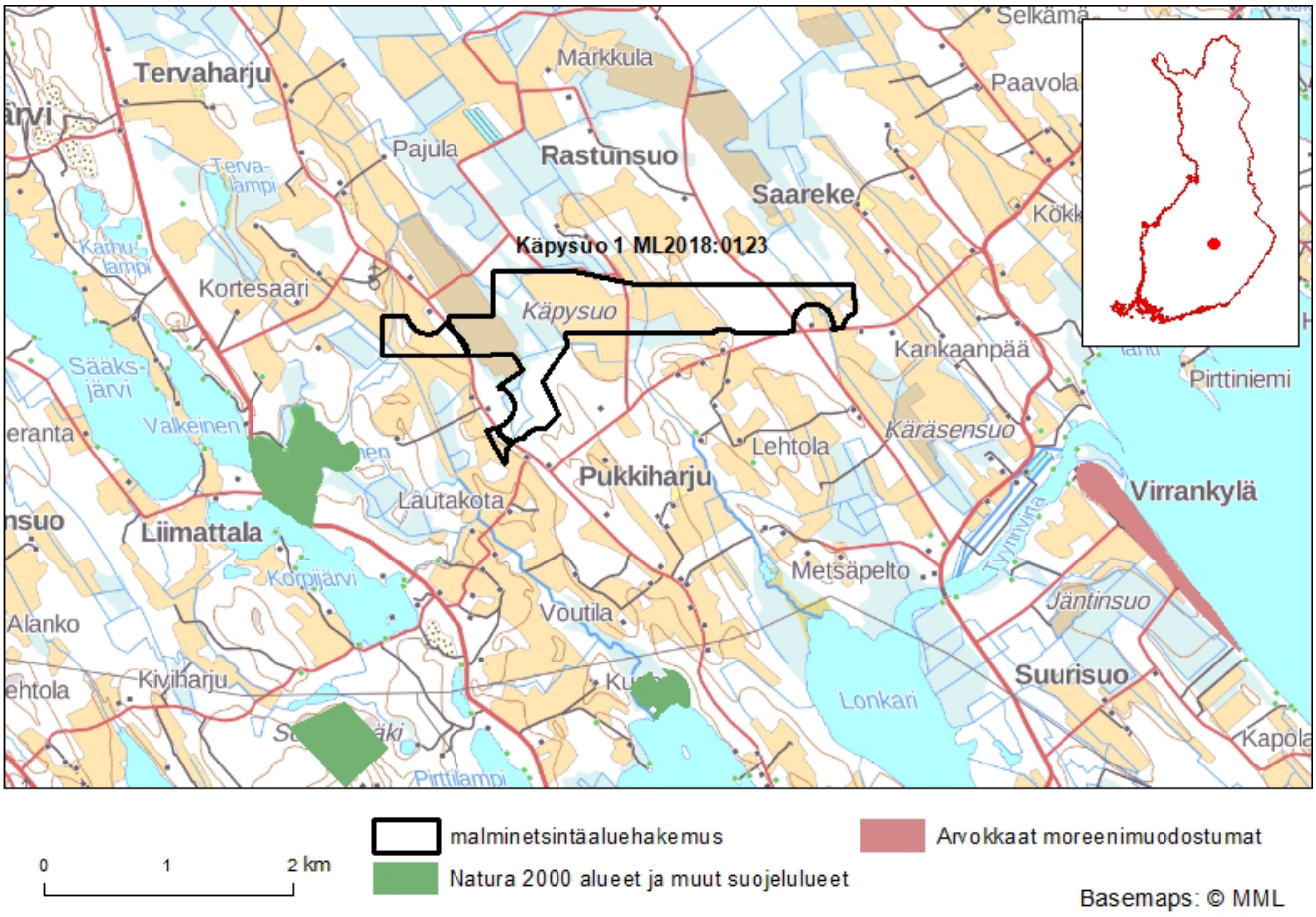
Kuvailulehti

1 JOHDANTO

Geologian tutkimuskeskus (GTK) tutki Käpysuon alueen suomugrafiittipotentiaalia Akkumineraalit projektissa vuosina 2016–2018. Tutkimukset saivat alkunsa, kun Käpysuon alueelle (silloin myös nimellä Pukkiharju) 1980 luvun vaihteessa kairatuissa kairasydämissä havaittiin Lopen kairasydänarkistossa tehdyissä kairasydäntarkistuksissa huomattavia määriä suomugrafiittia sisältäviä kivilajikerroksia.

2 TUTKIMUSALUE

Käpysuon tutkimusalue sijaitsee Pohjois-Savon maakunnassa, Rautalammin kunnassa noin 8 km sen kirkonkylältä pohjoisluoteeseen UTM karttalehdellä N4444. Tutkimusalueella eikä sen välittömässä läheisyydessä ole Natura 2000 eikä muita luonnonsuojelualueita. Tutkimusalue sijoittuu osin metsämaalle, metsää kasvavalle suoalueelle ja pelloille, joista osa on viljelysmaaksi muutettuja entisiä turvetuotantoalueita. Alueelle jätettiin malminetsintäaluehakemus 21.12.2018 (kuva 1).



Kuva 1. Tutkimusalueen sijainti peruskartalla sekä läheisyydessä sijaitsevat Natura 2000 alueet, muut suojelualueet sekä arvokkaat moreenimuodostumat.

3 AIKAISEMMAT TUTKIMUKSET

Käpysuo (Pukkiharju) oli 1970 ja 1980 lukujen vaihteessa Outokumpu Oy:n Zn-Cu malminetsintä kohde (Koistinen, 1984). Alueella tehtiin tuolloin kallioperäkartoitusta, tutkimuskaivantoja, systemaattisia geofysikaalisia maastomittauksia (sähkömagneettinen slingram, painovoima ja magneettinen) maastomittauksia. Slingram mittausten kelaväli oli 60 m ja käytetty taajuus 1775 Hz. Lisäksi kairattiin 17 kairareikää (yhteensä 3701 m), joista 13 lävisti paksuudeltaan ja pitoisuudeltaan vaihtelevia grafiittikerroksia. Grafiittipitoisuuksia eikä sen laatua tuolloin systemaattisesti tutkittu. Alueen grafiittipitoiset kivilajit on kuitenkin esitetty karttana Lahtisen pro-gradu -tutkielmassa (1985) ja lisensiaattityössä (1988). Niistä kallioperäkarttaliite on lähes sellaisenaan siirretty nykyiselle GTK:n DigiKP – kallioperäkartalle.

4 SUORITETUT TUTKIMUKSET

4.1 Geofysiikan mittaukset

Tutkimusalueen geofysikaaliset matalalentomittaukset on lennetty GTK:n toimesta itä-länsi suuntaisena vuonna 1992. GTK mittasi Green Minerals projektissa Käpysuolla vuosina 2018–2019 17 sähkömagneettista MaxMin ja matalan induktion GEM-2 profiilia. Lisäksi kahdelle 1600 metrin profiilille tehtiin sähköinen monielektrodiluotaus (ERT) ABEM Terrameter LS -laitteistolla. Yhden levityksen pituus 5 metrin elektrodivälillä oli 600 m.

4.2 Kallioperäkairaukset

GTK kairasi Käpysuon alueelle kahdessa eri vaiheessa 14 kairareikää, yhteensä 2116,55 m (Taulukko 1). Vuonna 2017 kairattiin kahdeksan reikää (1200 m) ja vuonna 2018 kuusi reikää (916,55 m). Molemmat kairaukset suorittivat Arctic Drilling Company (ADC) teräkalustolla NQ2, jossa sydämen halkaisija on 50,7 mm. Reikien kaltevuudet ja kairaussuunnat mitattiin 2017 kairauksessa tasaisesti 4 m välein ja 2018 kairauksessa aina näyteajon päätteeksi, jos se oli teknisesti mahdollista.

Taulukko 1. GTK:n kairareikien koordinaatit, suunta, kaade, maakairauksen syvyys ja reiän pituus.

Reikätunnus	**vuosi**	**X** (Euref-Fin)	**Y** (Euref-Fin)	**Z**	**Suunta**	**Kaade**	**Maata**	**Pituus** (m)
N4442017R1	2017	6950982.98	487604.03	101.10	180°	45.00	54.4	149.6
N4442017R2	2017	6950887.93	487663.03	100.14	360°	44.74	42.1	148.4
N4442017R3	2017	6950847.77	487662.91	100.24	360°	46.59	35.9	148.6
N4442017R4	2017	6950634.18	487854.88	99.51	360°	45.48	23.9	128.1
N4442017R5	2017	6950601.83	487597.51	101.57	360°	45.79	23.1	107.3
N4442017R6	2017	6950566.51	487597.67	101.71	360°	44.82	25.5	131.2
N4442017R7	2017	6950373.39	487325.04	99.16	360°	44.31	17.3	197.6
N4442017R8	2017	6950480.67	487325.03	98.78	360°	43.94	18.4	189.2
N4442018R25	2018	6950425.53	487036.03	102.05	360°	45.0	41.8	155.6
N4442018R26	2018	6950490.06	487036.13	102.13	360°	46.3	40.9	168.6
N4442018R27	2018	6950157.68	487510.86	101.73	180°	45.0	50.3	191.5
N4442018R28	2018	6950396.22	486631.89	98.17	360°	45.0	12.2	200.7
N4442018R29	2018	6950972.87	488213.79	100.37	180°	45.0	37.8	90.2
N4442018R30	2018	6950842.31	488321.75	99.69	360°	45.0	16.7	110.0
							Yhteensä	2116.6

4.3 Geokemialliset analyysit

Käpysuon kairasydännäytteiden kemialliset analyysit teki Labtium Oy. Outokumpu Oy:n 1980-luvun vaihteessa kairaamat grafiittipitoiset sydämet analysoitiin 2016–2017. GTK:n kairaamat sydämet analysoitiin 2017–2018. Kaikki näytteet hienomurskattiin, ositettiin rännijakolaitteella sekä jauhettiin volframikarbidijauhinastiassa. Monialkuainemääritykset tehtiin briketistä XRF-tekniikalla (menetelmä 176X). Hiilimääritys tehtiin hiilianalysaattorilla käyttäen menetelmää 811L. Lisäksi määritettiin hiilianalysaattorilla karbonaattiin- ja ei karbonaattiin sitoutunut hiili (grafiittinen hiili = Cg) menetelmällä 816L. Vuonna 2016 läpikäydyt Outokumpu Oy:n kairasydämet RTL-PH-7, RTL-PH-16 ja RTL-PH-17 (yhteensä 28 näytettä) analysoitiin myös kuningasvesiliuotuksen jälkeen ICP-MS tekniikalla menetelmällä 511M sekä ICP-OES-tekniikalla menetelmällä 511P.

4.4 Mineralogiset tutkimukset

Käpysuon kairasydännäytteiden mineralogiaa tutkittiin sydännäytteistä teetetyistä kiillotetuista ohuthieistä polarisaatiomikroskoopilla. Lisäksi mineraalien koostumusta ja kivien rakennetta tutkittiin pyyhkäisyelektronimikroskoopilla (SEM) GTK:n tutkimuslaboratoriossa Espoossa. Grafiitin kiteytymisaste ja lämpötila määritettiin Raman mikroskoopilla GTK Mintecin laboratoriossa Outokummussa.

4.5 Rikastuskokeet

Sarja laboratoriomittakaavan bench scale -rikastuskokeita tehtiin seitsemälle Käpysuon grafiittipitoiselle kairasydännäytteelle GTK Mintecin laboratoriossa Outokummussa vuosina 2017–2019. Kokeet pitivät sisällään murskauksen, jauhatuksen ja sarjan vaahdotuksia. Osa grafiitti-rikasteista puhdistettiin lisäksi happoliuotuksella ja alkalipaahdolla (alkali roasting) maksimi puhtausasteen selvittämiseksi.

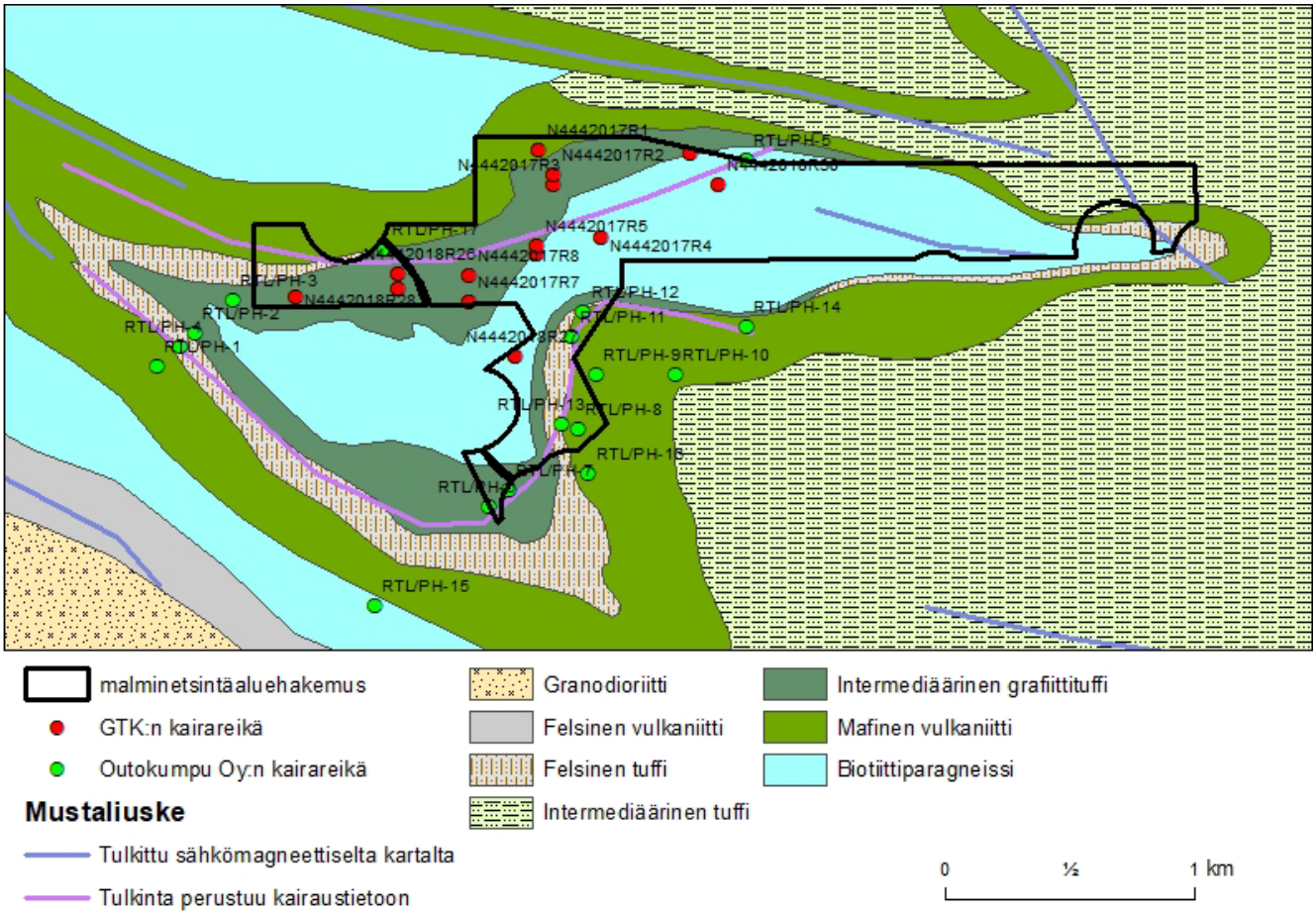
5 TULOKSET

5.1 Tutkimusalueen geologiset pääpiirteet

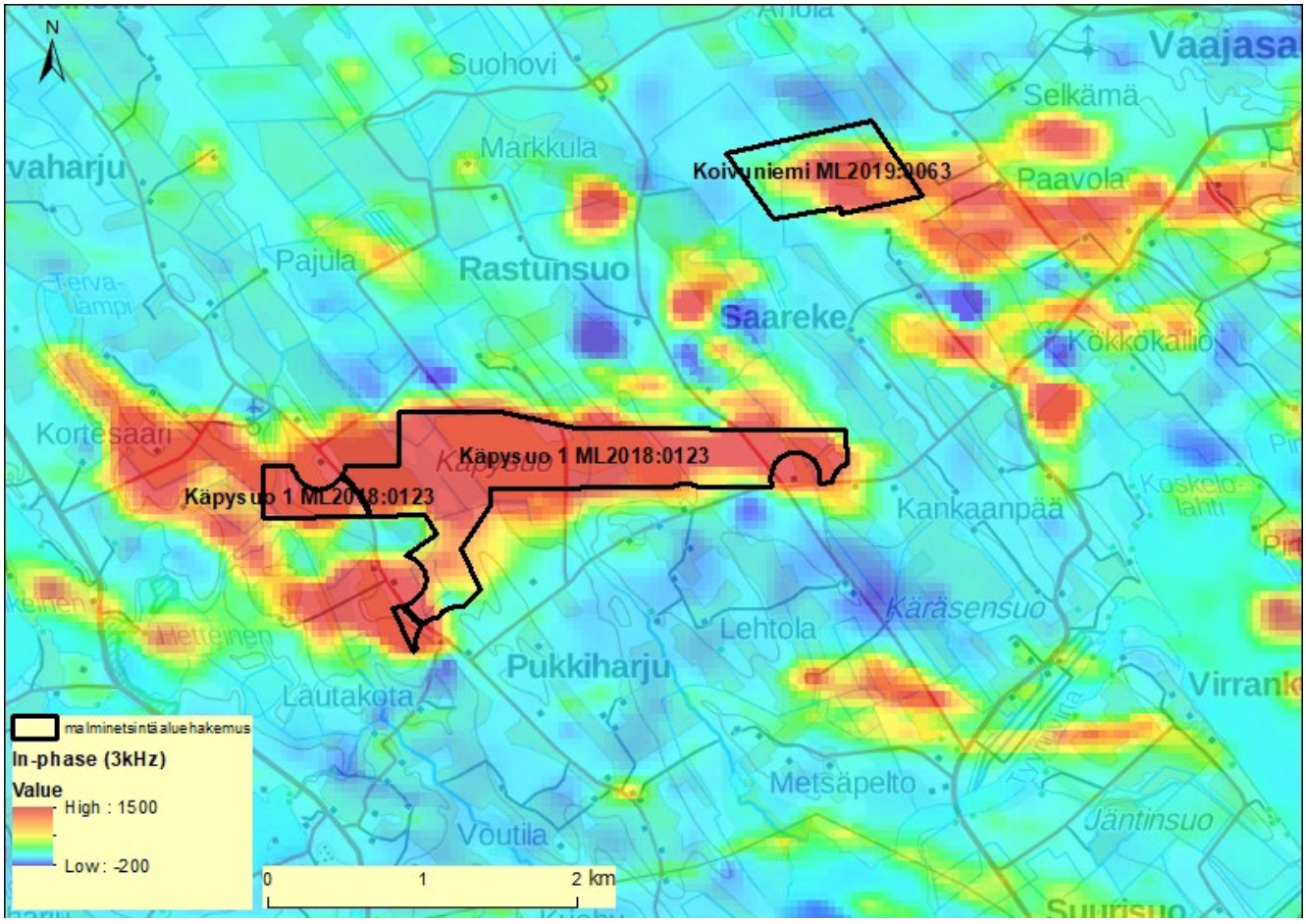
Käpysuon tutkimusalue sijaitsee Svekofennisella Savon liuskejaksolla, joka rajoittuu lännessä Keski-Suomen granitoidikompleksiin ja koillisessa siirroskontaktein karjalaisiin liuskeisiin ja arkeeiseen kallioperään. Savon liuskealueen yleisimpiä kivilajeja ovat turbidiittisyntyiset kiilleliuskeet, gneissit ja migmatiitit. Metavulkaniitteja on melko runsaasti esim. Rautalammin seudulla. Lisäksi tavataan grafiittipitoisia liuskeita, mustaliuskeita, dolomiittisia karbonaattikiviä, uraani-fosfori-metasedimenttejä, kordieriitti-antofylliitti (-granaatti) -gneissejä, sulfidimalmiesiintymiä sekä metaserttejä ja kvartsiraitaisia rautamuodostumia (Lehtinen et al., 1998).

Käpysuon alueen vallitsevia kivilajeja ovat vulkanogeeniset amfiboliitit, felsiset gneissit, kalkkisilikaattipitoiset kivet, kiillegneissit, granaatti-sillimaniitti-gneissit ja grafiittipitoiset kivet. Paikallisesti esiintyy myös kordieriitti-sillimaniitti gneissejä ja granaatti-kordieriitti-ortoamfiboli-/ortopyrokseenikiviä ja -gneissejä (Lahtinen, 1988). Kivien ikä on Lahtisen (1994) mukaan 1.91–1,96 Ga. Alueen vallitseva metamorfoosiaste on granuliittifasies (Hölttä ja Heilimo 2017). Tutkimusalueen tärkeimmän metallogeenisen alueen muodostaa Pukkiharjun Zn-Cu-etsintäkohde (Lahtinen, 1988 & Vaasjoki et al. 2005). Käpysuon tutkimusalueen kallioperä (GigiKP) on esitetty kuvassa 2.

Kaksi kilometriä Käpysuon koillispuolella sijaitsee toinen GTK:n tutkima grafiittikohde Vaajasalmi (Kuusela et al. 2021). Ne ovat erottaneet toisistaan vasenkätinen siirros, joka voidaan havaita lentogeofysiikan sähköisen anomalian katkeamisena ja siirtymisenä (kuva 3).



Kuva 2. Käpysuon tutkimusalueen sijainti geologisella kartalla (Suomen kallioperä – DigiKP, versio 2.2 10.04.2024).

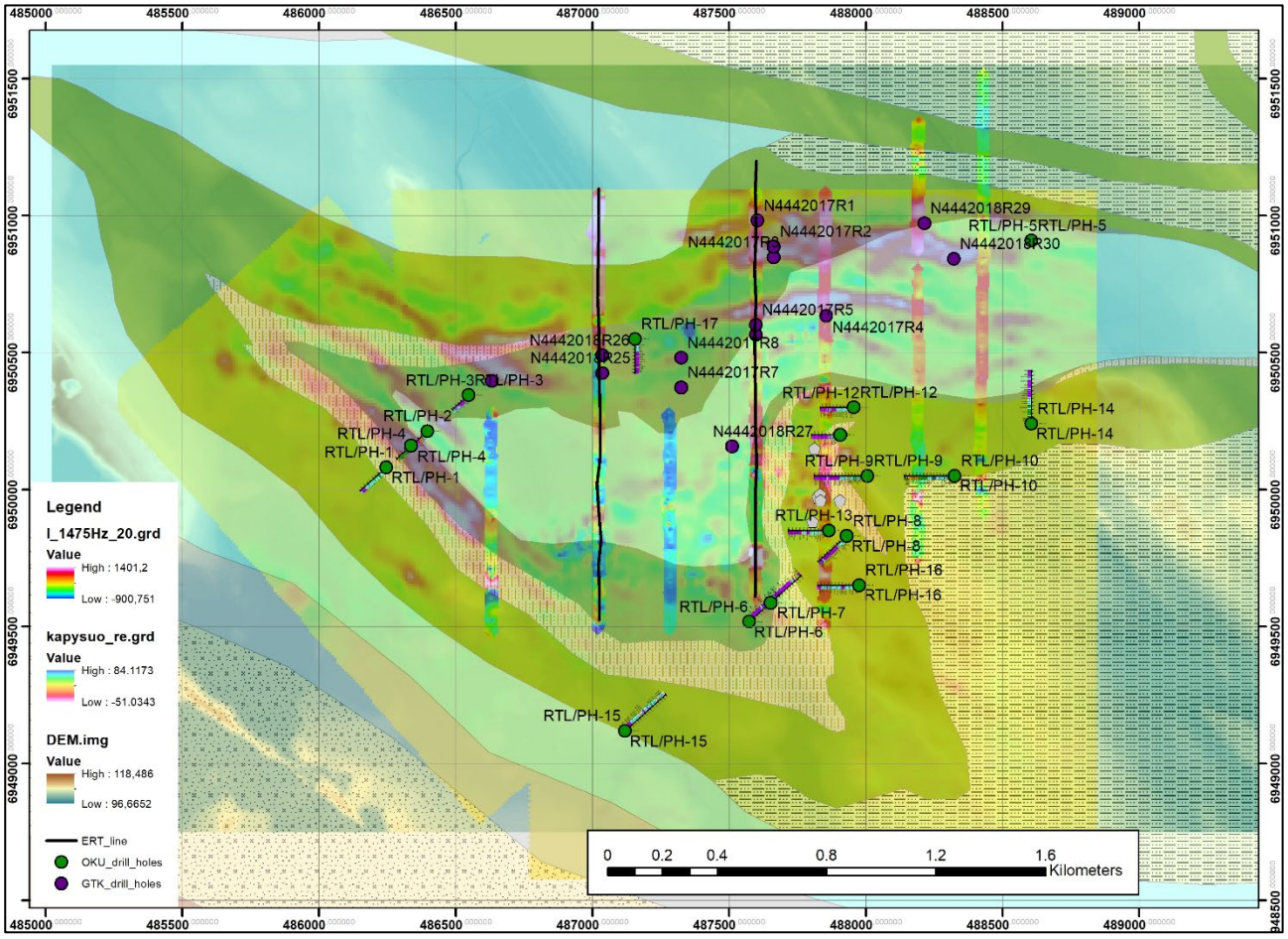


Kuva 3. Käpysuon ja Vaajasalmen tutkimusalueet matalalentogeofysiikan sähkömagneettisella reaalikomponenttikartalla (3 kHz). Pohjakartta © Maanmittauslaitos.

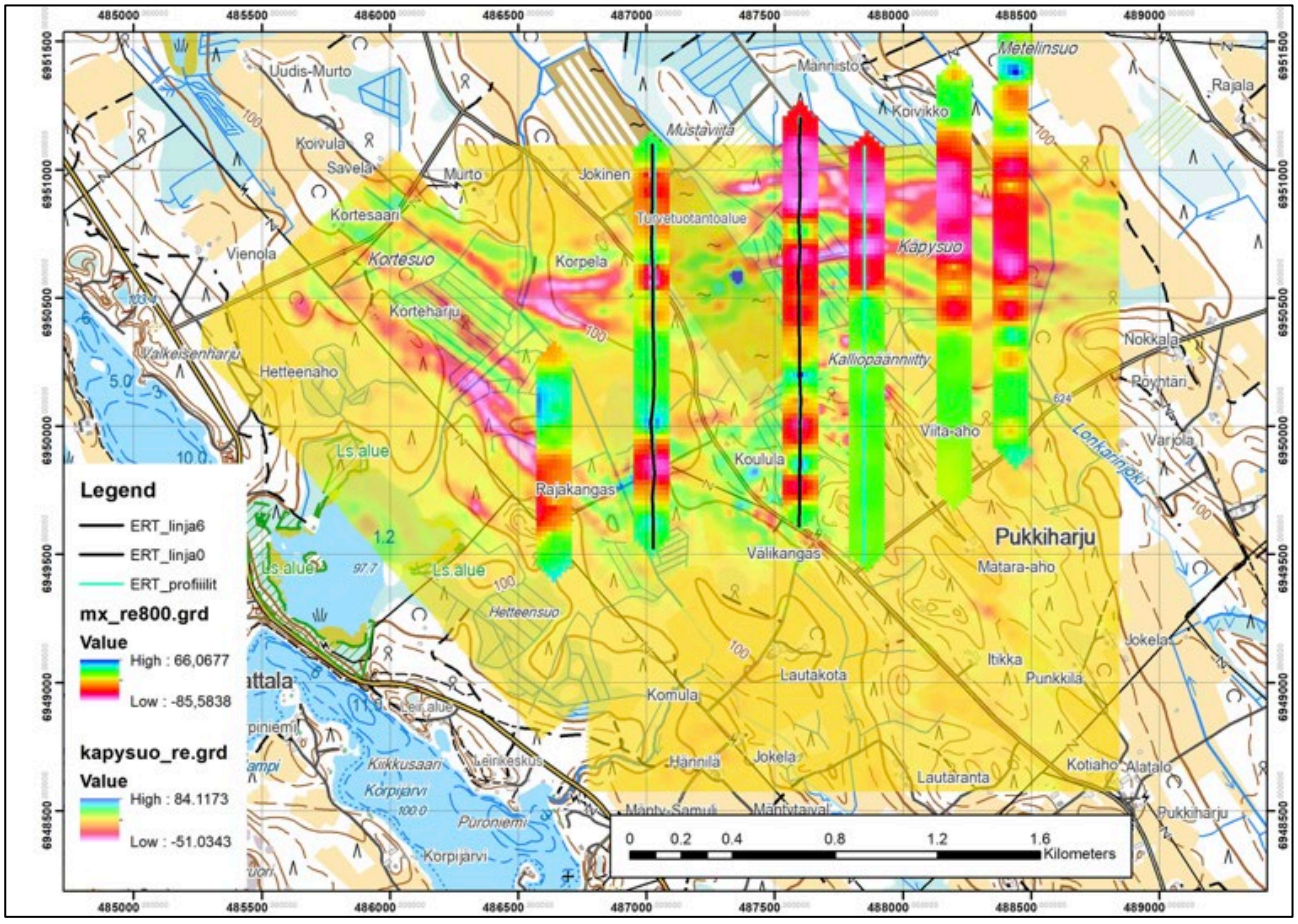
5.2 Geofysikaaliset maastomittaukset

GTK teki Käpysuon alueella Green Minerals projektin puitteissa (Leinonen & Lerssi, 2019) geofysikaalisia maastomittauksia vuosina 2018–2019 tavoitteena testata suomugrafiitin etsintään soveltuvia geofysiikan etsintämenetelmiä (Leinonen, Lerssi & Jokinen, 2019a, 2019b). Grafiitti ja sen isäntäkivet (esim. mustaliuske) ovat yleisesti ottaen erittäin hyviä sähkönjohteita. Tämän vuoksi sähkömagneettiset maanpintamittaukset ovat parhaiten soveltuvia geofysiikan menetelmiä niiden paikantamiseen ja kartoittamiseen.

Käpysuon alueella mitattiin sähkömagneettisia MaxMin sekä matalan induktion minislingram (GEM-2) profiileja. MaxMin -mittauksissa kelaväli oli 100 m ja käytetyt taajuudet 800, 3600, 14000 ja 28000 Hz. GEM-2:ssa käytetyt mittaustaajuudet olivat 1475, 5825, 22225 ja 75525 Hz. MaxMin- ja GEM-2 mittausten matalien taajuuksien tuloksia (800 ja 1475 Hz) on esitetty kuvissa 4 ja 5.



Kuva 4. GEM-2 tulokset (reaalikomponentti 1475 Hz), GTK:n ja Outokumpu Oy:n kairareiät sekä ERT-profiilit. Tausta: slingram reaalikomponentti (Outokumpu Oy), GEM-2 reaalikomponentti (1475 Hz), LiDAR aineisto (© Maanmittauslaitos 2016) ja kallioperäkartta (DigiKP, 2019).

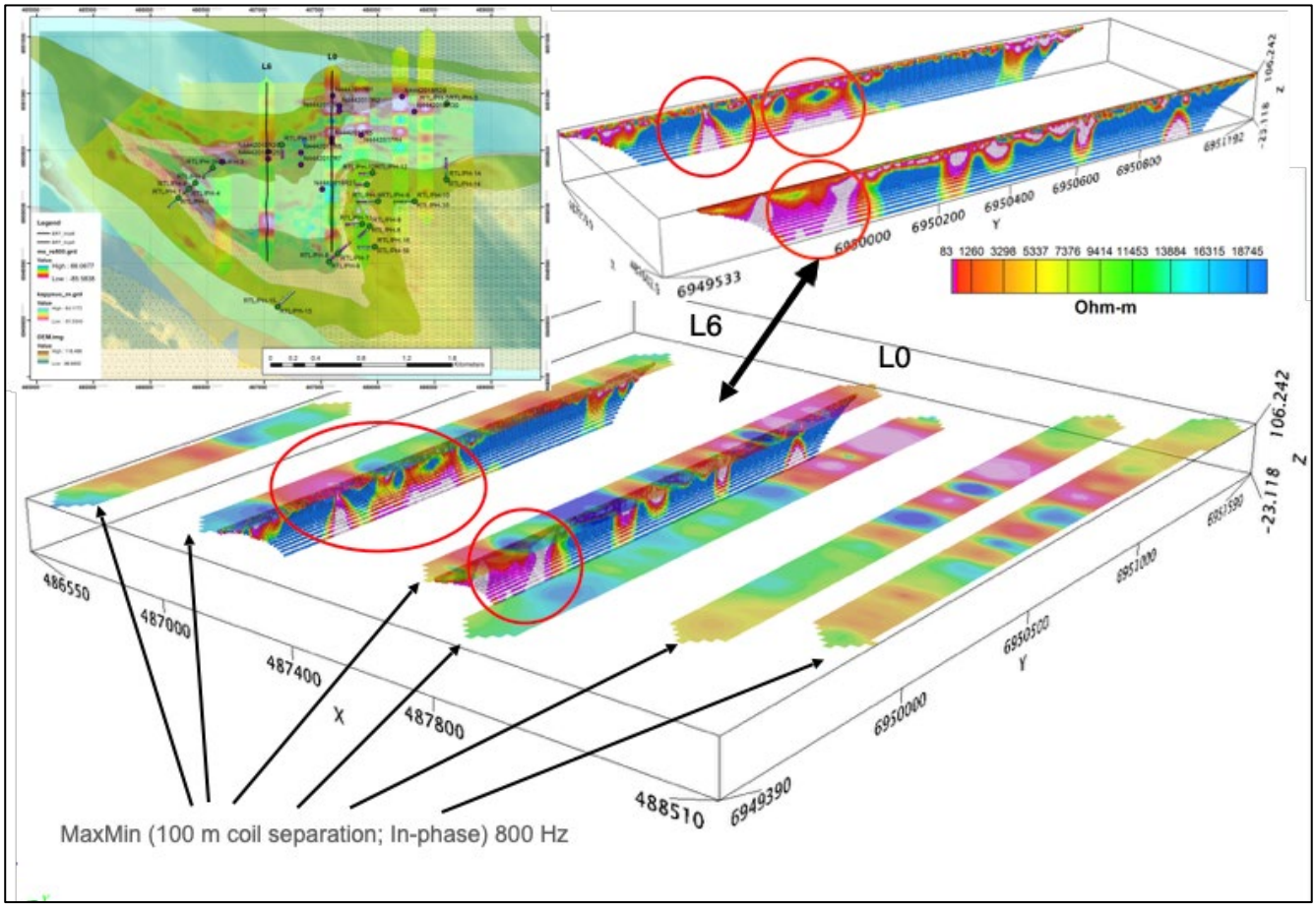


Kuva 5. MaxMin profiilit (reaalikomponentti 800 Hz) ja ERT profiilit. Tausta: slingram reaalikomponentti (Outokumpu Oy). Peruskartta: © Maanmittauslaitos, 2018.

GEM-2 tuloksista havaitaan lähellä pintaa (< 20 m) olevat johteet. MaxMin tuloksista (matalimmilla taajuuksilla) nähdään syvemmälle ulottuvat (≈ 30–50 m) johteet. Käpysuon alueella vaihteleva ja osin paksu maapeite (5–60 m) ja voimakas magneettinen anomalia alueen keskellä vaikeuttavat sähkömagneettisten mittausten tulkintaa.

Edellisten menetelmien lisäksi kahdelle 1600 metrin profiilille tehtiin sähköinen monielektrodiluotaus (ERT) ABEM Terrameter LS -laitteistolla. Yhden levityksen pituus 5 metrin elektrodivälillä oli 600 m (6 kaapelia, 121 elektrodia). Tällä mittauskonfiguraatiolla saavutetaan noin 120 metrin syvyysulottuvuus.

ERT tulosten tulkinta tehtiin res2Dinv inversio-ohjelmistolla (Loke et al., 1996). Ohjelmalla saadaan sähkönjohtavuus jakauma syvyyssuunnassa profiilin kohdalla. ERT-tuloksista havaitaan useita mielenkiintoisia syvälle ulottuvia sähkönjohtavuusanomalioita, jotka on merkitty tulkintakuvaan 6. ERT-tulokset sopivat kohtuullisen hyvin yhteen slingram ja MaxMin -tulosten kanssa, joskin ristiriitaisuuksiakin löytyy.



Kuva 6. ERT-profiilien inversiotulos (sähkönjohtavuusjakauma) yhdistettynä MaxMin-tulosten reaalikomponenttiin (800 Hz). Sijaintikuvan tausta: slingram reaalikomponentti, GEM-2 reaalikomponentti (1475 Hz), LiDAR aineisto (© Maanmittauslaitos 2016) ja kallioperäkartta (DigiKP, 2019).

5.3 Kallioperäkairaus

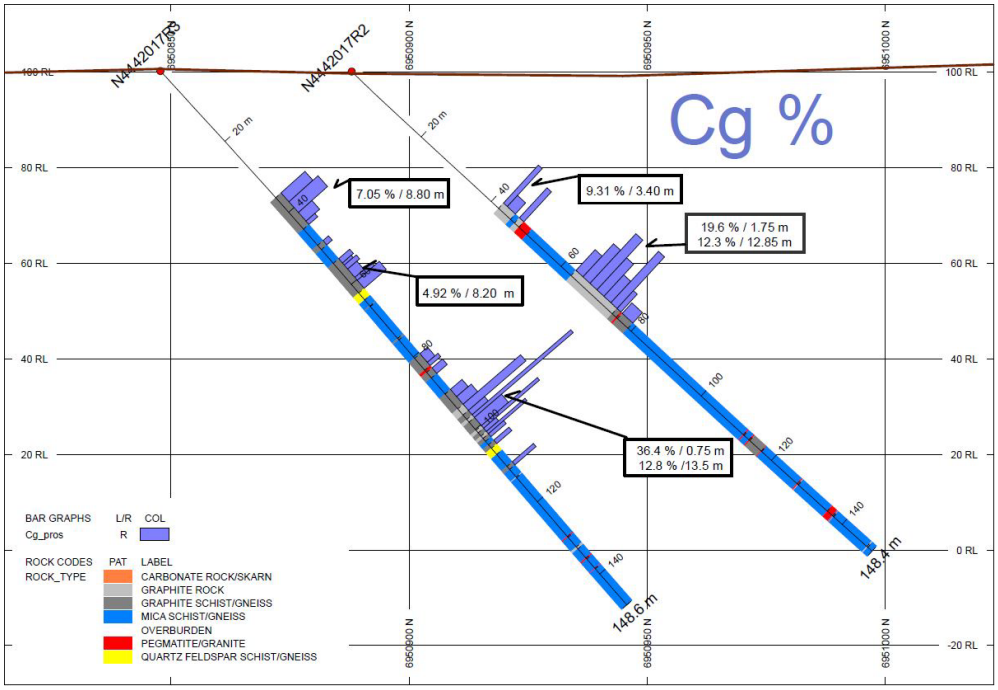
Outokumpu Oy kairasi vuosina 1977–1982 Käpysuolle yhteensä 17 (3701 m) kairareikää, joista 13 lävisti paksuudeltaan ja pitoisuudeltaan vaihtelevia grafiittipitoisia kivilajikerroksia. Koska grafiittipitoisuuksia ei tuolloin määritetty, kävi GTK kairasydämet uudelleen läpi ja analysoi kaikki grafiittipitoiset sydämet vuosina 2016–2017. Parhaat näytepituudella painotetut yhtenäiset grafiittilävistykset olivat 11,8 % Cg @ 20,9 m (reikä RTL/PH-6), 10,7 % Cg @ 96,95 m (reikä RTL/PH-7), 7,5 % Cg @ 37,55 m (reikä RTL/PH-9), 10,9 % Cg @ 33,55 m (reikä RTL/PH-11) ja 9,0 % Cg @ 17,3 m (reikä RTL/PH-17). Yhteenveto valikoiduista grafiittilävistyksistä on esitetty taulukossa 2. Yhteensä analysoitiin 217 grafiittipitoista kairasydännäytettä, joiden yhteispituus oli 493 m.

Taulukko 2. Valikoituja yhtenäisiä grafiittilävistyksiä ja niiden näytepituudella painotetut p-% Cg.

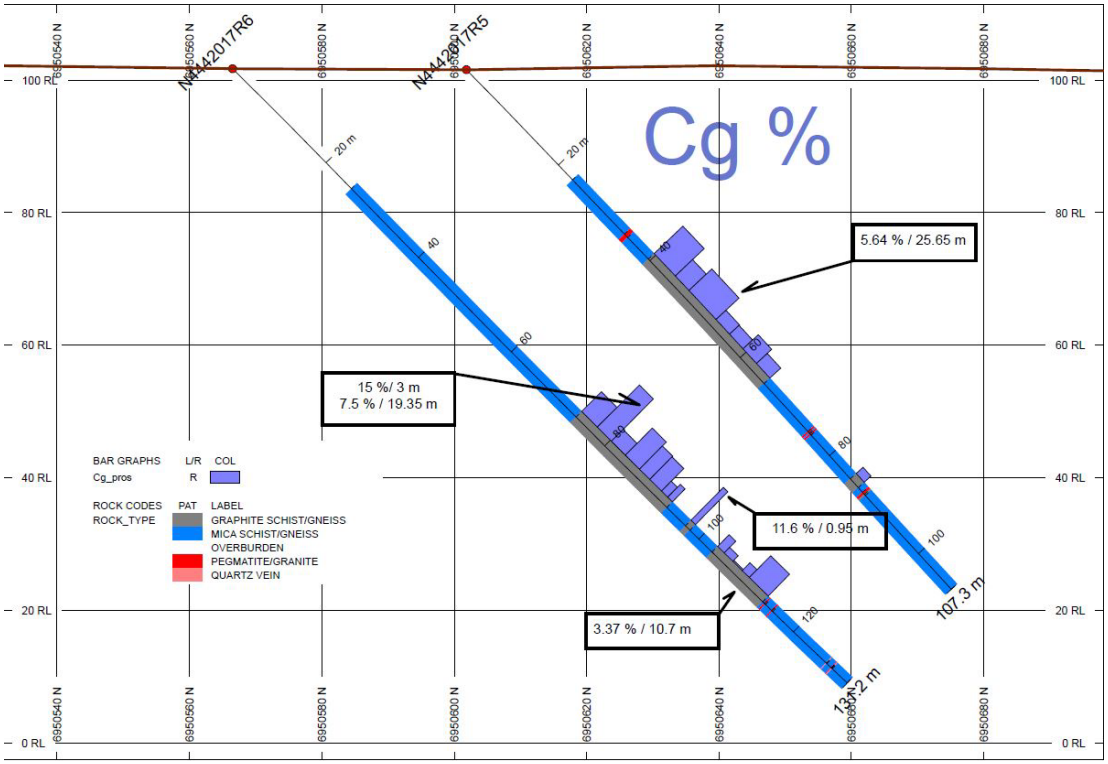
Näytetunnus	Alkaa (m)	Päättyy (m)	Cg %	Lävistyksen pituus (m)
GTK				
N4442017R2	62.85	75.7	12.5	12.85
N4442017R3	90.25	103.3	11.1	13.05
N4442017R6	73.85	93.2	8.1	19.35
N4442018R26	106	126.2	12.1	20.2
N4442018R27	108.3	127.55	19.3	19.25
N4442018R29	37.8	52.5	9.9	14.7
N4442018R30	28.9	42.35	8.06	13.45
Outokumpu Oy				
RTL/PH-6	60.3	81.2	11.799	20.9
RTL/PH-7	16	112.95	10.684	96.95
RTL/PH-9	210.45	248	7.468	37.55
RTL/PH-11	90.75	124.3	10.86	33.55
RTL/PH-17	174.25	191.55	9.0348	17.3

GTK kairasi Käpysuolla Outokumpu Oy:n mittaamiin hyvin sähköä johtaviin anomalioihin vuosina 2017–2018 14 kairareikää, yhteensä 2117 metriä. Kalliopaljastumia ei GTK:n kairauskohteilta eikä niiden läheisyydestä löydy. Kohteiden valinta perustui yksinomaan Outokumpu Oy:n 1980-luvun vaihteessa mittaamaan maastogeofysiikkaan ja kohdistui pääosin slingram mittausten voimakkaasti sähköä johtaviin itä-länsi suuntaisiin anomalioihin. Parhaat näytepituudella painotetut yhtenäiset grafiittilävistykset olivat 12,5 Cg % @ 12,85 m (reikä R2), 11,1 % Cg % @ 13,05 m (reikä R3), 8,1 Cg % @ 19,35 m (reikä R6), 12,1 Cg % @ 20,2 m (reikä R26), 19,3 Cg % @ 19,25 m (reikä R27) ja 8,1 Cg % @ 13,45 m (reikä R30). Yhteenveto valikoiduista GTK:n kairaamista grafiittilävistyksistä on esitetty taulukossa 2. Esimerkki R2:n grafiittilävistyksestä näkyy kairasydänvalokuvassa 7. Valikoidut kairasydänprofiilit R2–R3, R5-R6, R7-R8 sekä R25-R26 on esitetty kuvissa 8, 9, 10 ja 11. Yhteensä analysoitiin 298 grafiittipitoista kairasydännäytettä, joiden yhteispituus oli 615,45 metriä.

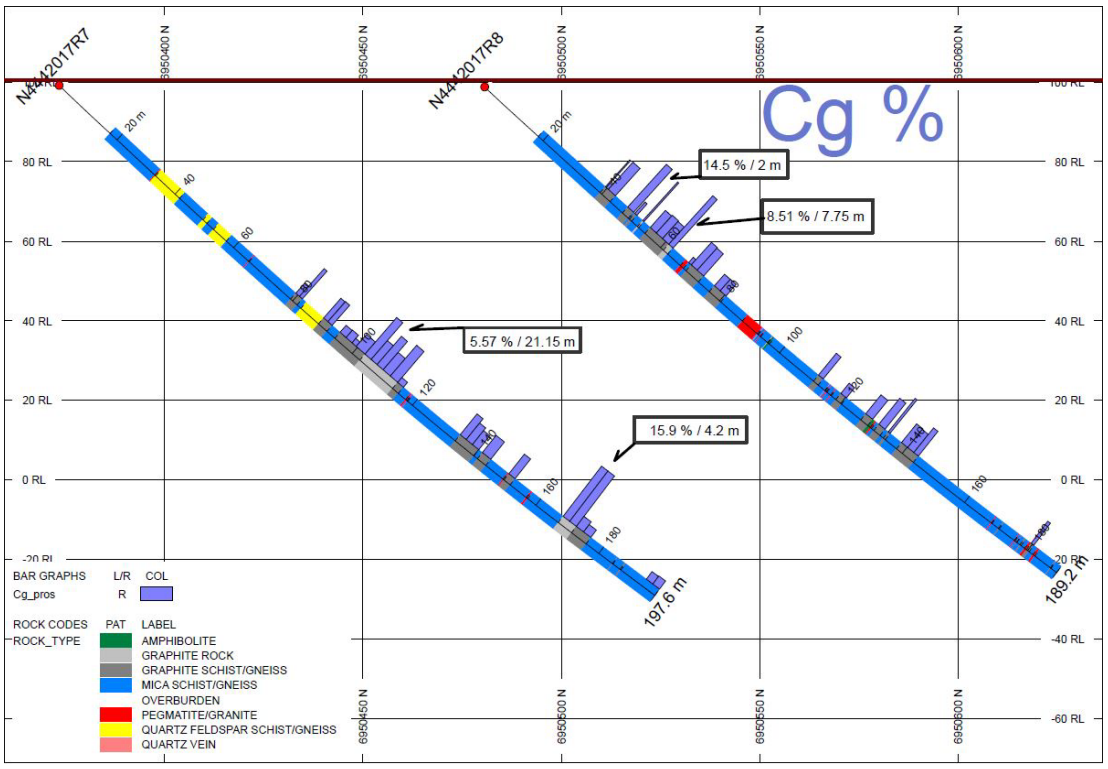
Kuva 7. Kairasydänvalokuva reiän N4442017R2 grafiittilävistyksestä syvyydeltä 66,85–75,70 m. Koko yhtenäisen grafiittilävistyksen näytepituudella painotettu Cg keskiarvo alkaen syvyydeltä 62,85 m on 12,5 %.



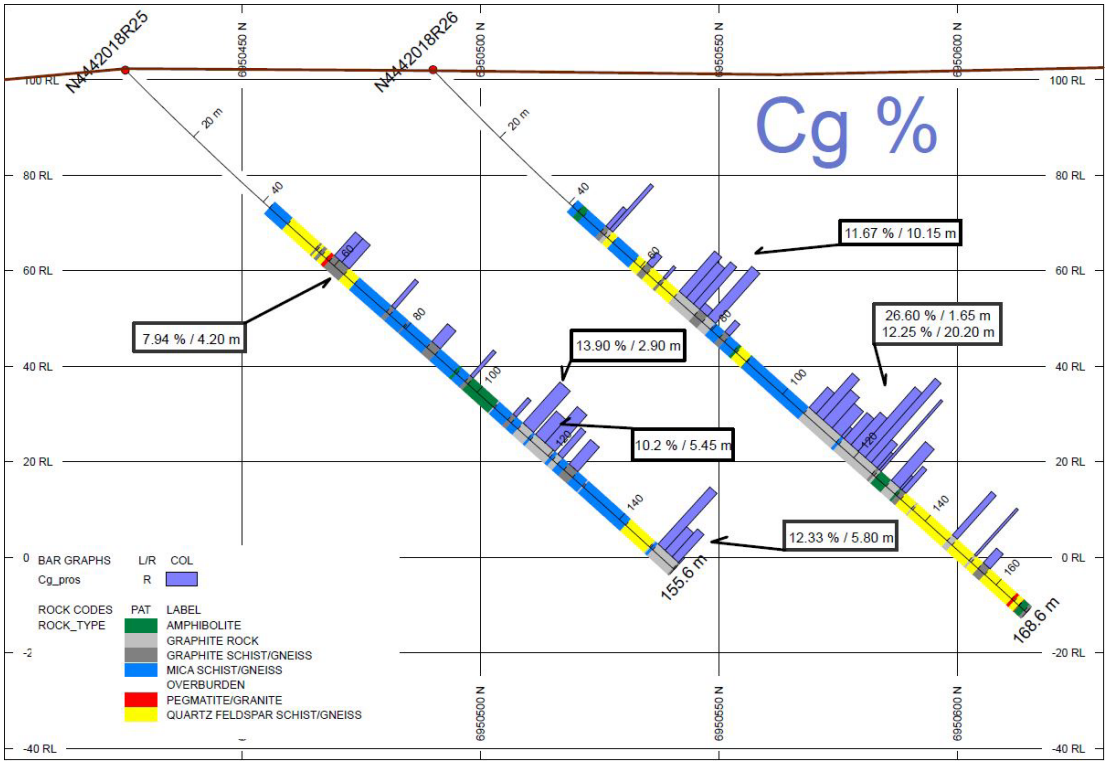
Kuva 8. Kairasydänprofiili N4442017R2-N4442017R3.



Kuva 9. Kairasydänprofiili N4442017R5-N4442017R6.



Kuva 10. Kairasydänprofiili N4442017R2-N4442017R3.



Kuva 11. Kairasydänprofiili N4442018R25-N4442018R26.

5.4 Kemialliset analyysit

Grafiittipitoiset näytteet valittiin analysoitavaksi silmämääräisesti kairasydänraportoinnin yhteydessä, noudattaen kivilaji- ja grafiittipitoisuuden vaihteluun perustuvia rajoja. Kairasydännäytteistä tehtyjen analyysien mukaan, grafiittipitoisuudet vaihtelevat lähes nollasta 38 p-%:iin. GTK:n kairaamien näytteiden maksimigrafiittipitoisuus 36,4 % löytyy reiästä R3. Koko tutkimusalueen korkein grafiittipitoisuus 38 % löytyy Outokummun kairaamasta reiästä RTL/PH-7. Yhteenveto kemiallisista analyyseistä valikoitujen alkuaineiden osalta on esitetty taulukoissa 3 ja 4. Huomionarvoista on korkein analysoitu sinkkipitoisuus 0,91 % reiässä R3, josta löytyy näytepituudella painotettu kairasydänlävistys: 0,26 % Zn @ 10,25 m. Outokummun aineistosta vastaava korkein sinkki pitoisuus 0,44 % osuu reikään RTL/PH-11 syvyysvälille 104,80-105,85 m.

Taulukko 3. Yhteenveto GTK:n kairaamien kairasydänten kemiallisista analyysituloksista (p-%) valikoitujen alkuaineiden osalta (C non carb = grafiittinen hiili).

	näyteväli	Cu	Fe2O3	MgO	S	TiO2	Zn	C non carb
	m	%	%	%	%	%	%	%
maksimi	6.00	0.09	48.81	9.67	19.26	0.98	0.91	36.4
minimi	0.30	0.00	2.16	0.97	0.09	0.17	0.01	0.05
keskiarvo	2.07	0.02	7.81	2.86	2.63	0.52	0.05	7.49
mediaani	3.90	0.06	28.95	6.73	11.14	0.84	0.46	23.6
näytemäärä kpl	298							
analysoitu yhteensä (m)	615.45							
maksimiarvon näytetunnus		N4442017R3 101.85-102.50	N4442018R28 118.60-120.20	N4442018R28 116.75-118.60	N4442018R28 118.60-120.20	N4442018R28 92.70-95.00	N4442017R3 101.85-102.50	N4442017R3 97.25-98.00

Taulukko 4. Yhteenveto Outokumpu Oy:n kairaamien grafiittipitoisten kairasydänten kemiallisista analyysituloksista (p-%) valikoitujen alkuaineiden osalta (C non carb = grafiittinen hiili).

	näyteväli	Cu	Fe2O3	MgO	S	TiO2	Zn	C non carb
	m	%	%	%	%	%	%	%
maksimi	4.75	0.07	28.80	8.20	11.80	1.45	0.44	38.00
minimi	0.60	0.00	3.60	1.07	0.24	0.26	0.01	0.21
keskiarvo	2.27	0.02	8.45	3.12	3.05	0.54	0.06	9.70
mediaani	2.00	0.02	8.10	2.86	2.95	0.53	0.03	8.81
näytemäärä kpl	217							
analysoitu yhteensä (m)	493.00							
maksimiarvon näytetunnus		RTL/PH-011 113.65-115.70	RTL/PH-013 177.05-177.65	RTL/PH/8 155.15-157.2	RTL/PH-013 177.05-177.65	RTL/PH-014 268.95-271.65	RTL/PH-011 104.80-105.85	RTL/PH-007 158.10-158.85

5.5 Rikastuskokeet

Käpysuon suomugrafiitin rikastettavuutta testattiin GTK Mintecin laboratoriossa Outokummussa seitsemästä (taulukko 5) eri GTK:n ja Outokumpu Oy:n kairareiästä. Näytemateriaalina käytettiin kemiallisista analyyseistä jäljelle jääneitä murskeita. Kukin näyte oli yhdistetty useammasta näytteestä riittävän ison näytemäärän saavuttamiseksi. Näytteiden (syöte) grafiittipitoisuus vaihteli 10–12 % välillä.

Näytteet murskattiin ja jauhettiin, jonka jälkeen tehtiin kullekin näytteelle sarja vaahdotuskokeita. Osa vaahdotusrikasteista jatko puhdistettiin alkalipaahdolla (25 p.-% NaOH, 250°C) ja sitä seuranneella happoliotuksella (10 p.-% H_2SO_4) grafiitin maksimipuhtausasteen selvittämiseksi.

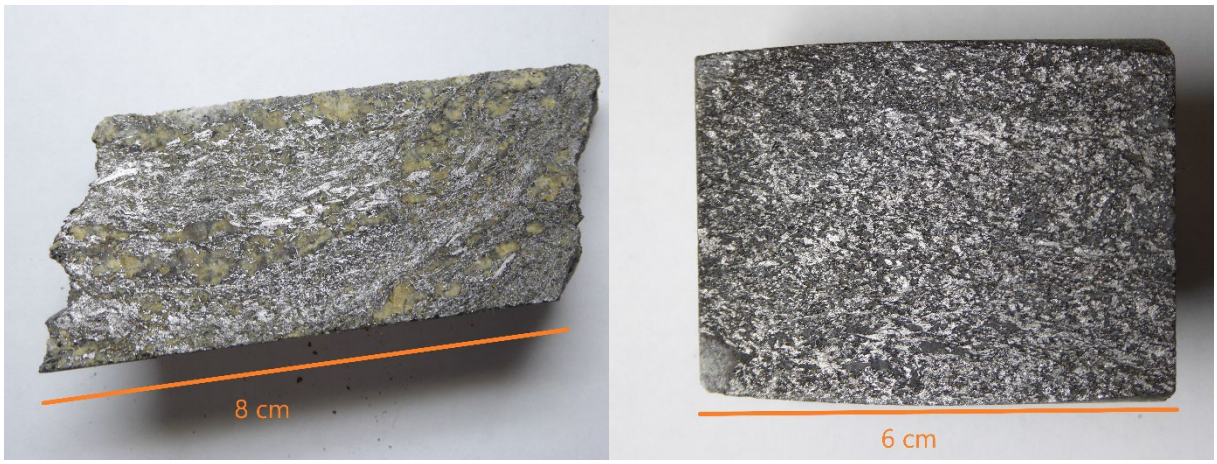
Pelkällä vaahdotuksella päästiin rikasteen osalta parhaimmillaan n. 90 % (86–90%) grafiittipitoisuuteen. Saanti vaihteli välillä 31–85 %. Alkalipaahdolla ja sitä seuranneella happoliuotuksella päästiin yli 99 % grafiittipitoisuuksiin (maksimi 99,4 %). Käpysuon rikastuskokeiden menetelmät ja tulokset on esitetty yksityiskohtaisemmin liitteen yksi työraporteissa ja GTK:n raportissa Al-Ani et al. 2024 sekä julkaisussa Al-Ani et al. 2020.

Taulukko 5. Käpysuon rikastustestien näytteet.

reikätunnus ja näyteväli	reikätunnus ja näyteväli
RTL/PH-016 229.1-231.85	N4442018R25 58.60-60.70
RTL/PH-016 231.85-234.65	N4442018R25 60.70-62.80
RTL/PH-016 234.65-237.4	N4442018R25 74.60-75.55
RTL/PH-016 237.4-240.05	N4442018R25 85.85-88.20
yhteensä 10.95 m	N4442018R25 96.60-97.40
RTL/PH-17 159.55-161.55	N4442018R25 108.65-109.60
RTL/PH-17 161.55-163.55	N4442018R25 111.50-114.40
RTL/PH-17 163.55-165.55	N4442018R25 115.00-117.70
RTL/PH-17 165.55-167.95	N4442018R25 117.70-120.45
yhteensä 8.4 m	N4442018R25 121.25-122.60
N4442017R2 62.85-64.85	N4442018R25 124.40-126.85
N4442017R2 64.85-66.85	N4442018R25 149.45-151.45
N4442017R2 66.85-68.85	N4442018R25 151.45-153.45
N4442017R2 68.85-70.85	N4442018R25 153.45-155.25
N4442017R2 70.85-72.85	**yhteensä 27.2 m**
N4442017R2 72.85-74.60	N4442018R26 69.5-71.5
N4442017R2 74.60-75.70	N4442018R26 71.5-73.5
yhteensä 12.85 m	N4442018R26 73.5-75.2
N4442017R7 102.55-104.60	N4442018R26 75.2-77.4
N4442017R7 104.60-106.60	N4442018R26 77.4-79.65
N4442017R7 106.60-108.60	N4442018R26 129.05-131.5
N4442017R7 108.60-111.00	N4442018R26 131.5-132
N4442017R7 111.00-113.45	N4442018R26 132-133.15
yhteensä 10.90 m	N4442018R26 146.2-147.55
N4442018R27 94.30-95.80	N4442018R26 152.4-152.95
N4442018R27 95.80-97.70	N4442018R26 154.9-156.8
N4442018R27 97.70-99.40	**yhteensä 18.05 m**
N4442018R27 99.40-102.30	
N4442018R27 102.30-104.70	
yhteensä 10.4 m	

6 KÄPYSUON GRAFIITTIESIINTYMÄ

Tämä raportti keskittyy grafiittia sisältäviin kiviin ja niiden potentiaaliin. Grafiittia sisältävät kivilajikerrokset: grafiittiliuskeet, grafiittigneissit ja mustaliuskeet (kairasydänraportoinnissa käytetty grafiittikivi) liittyvät Käpysuon tutkimuskohteessa pääasiassa granaatti- ja sillimaniitti-kiillegneisseihin. Yksittäiset grafiittisuomut ovat suuntautuneet vallitsevan liuskeisuuden mukaisesti ja ne esiintyvät paikoin myös kasaumina (kuva 12). Tasaisesti grafiittia sisältävien kerrosten paksuus vaihtelee kymmenistä senteistä kymmeniin metreihin. Myös Cg-pitoisuus vaihtelee ja on Käpysuolla enimmillään 38 % (RTL/PH-007).



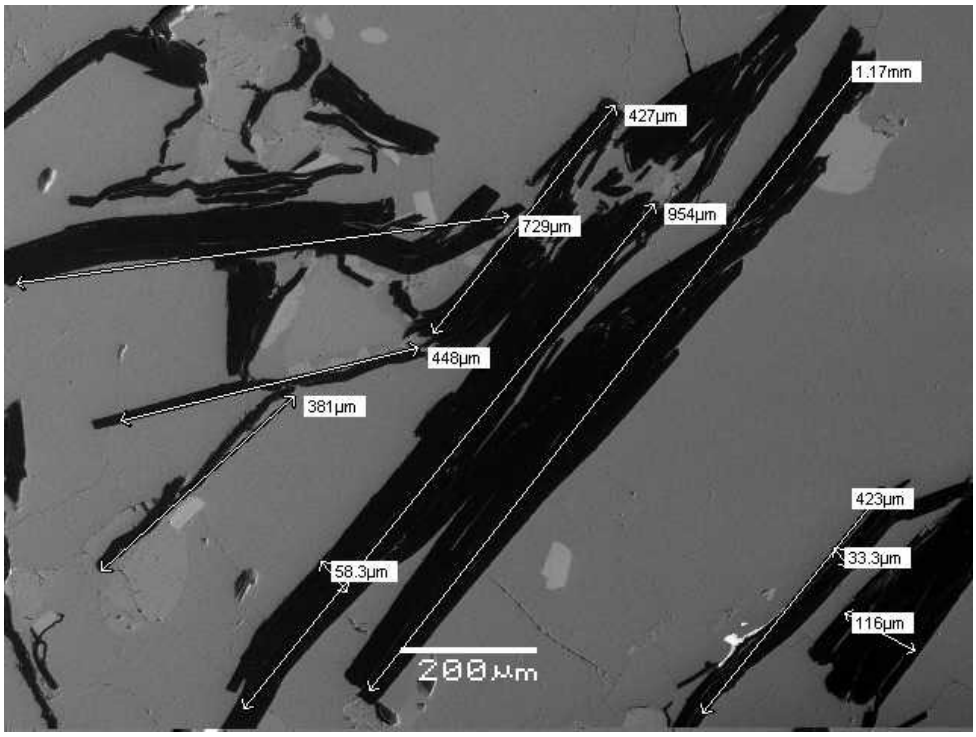
Kuva 12. Käpysuon suomugrafiittigrafiittinäytteitä GTK:n kairasydämistä. (vasemmalla: R8 47,90 m ja oikealla: R27 119,05 m). Grafiittisuomut ja -suomukasaumat voidaan tunnistaa kuvasta niiden metallisen kiillon perusteella. Kuvat T. Ahtola

Grafiittipitoisten kivien (grafiittiliuske- ja gneissi sekä mustaliuske) pääminerаalit ovat grafiitin lisäksi plagioklaasi, kvartsi ja biotiitti (±kalimaasälpä). Paikoin ja erityisesti mustaliuskeessa esiintyy sulfidimineraaleina rikkikiisua ja magneettikiisua. Maasälvät ovat paikoin muuttuneet serisiitiksi ja biotiitti kloriitiksi (taulukko 6).

Taulukko 6. Käpysuon grafiittia sisältävissä kivissä tavatut pää- ja aksessoriset mineraalit.

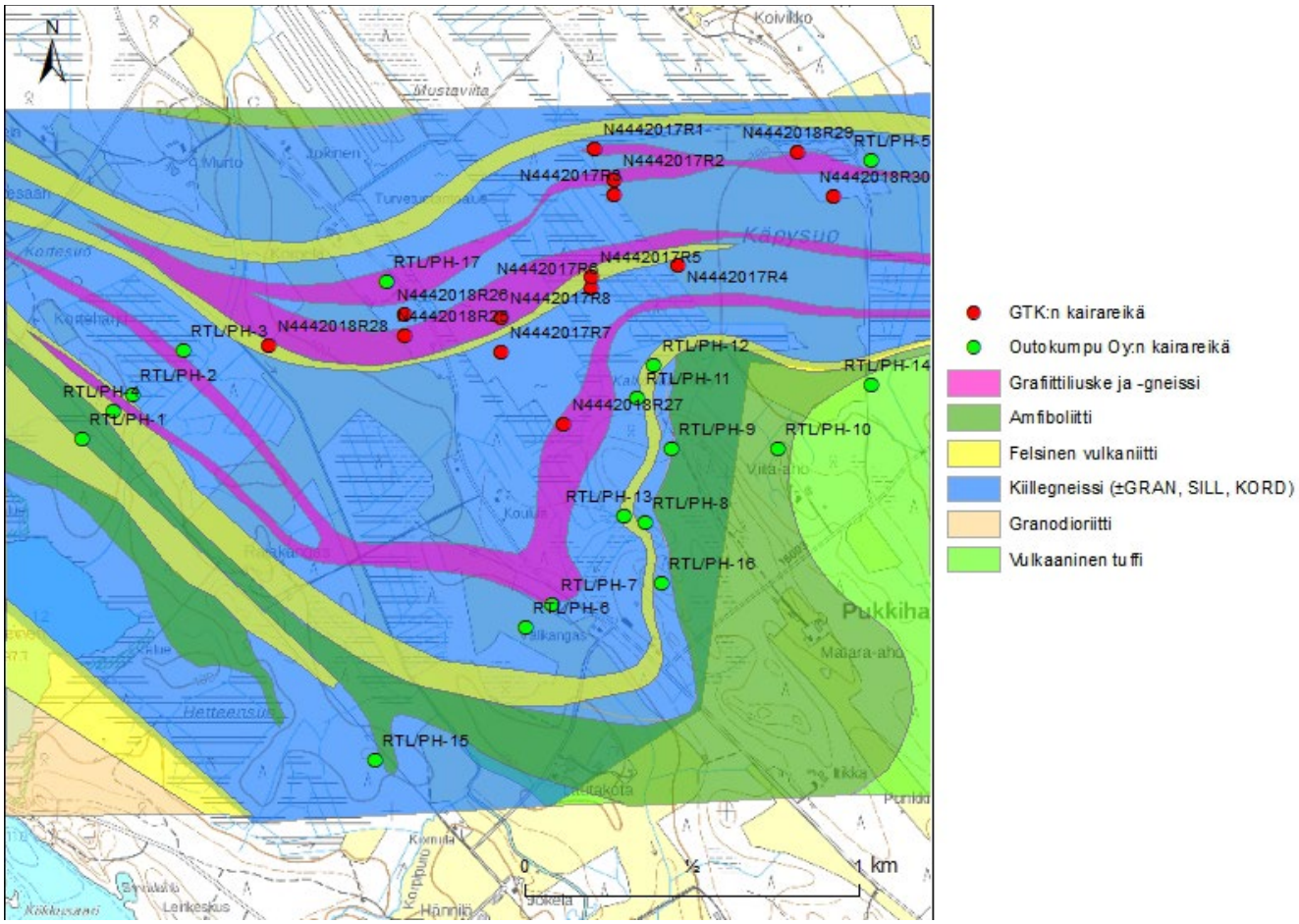
Päämineraali	Aksessorinen mineraali	
plagioklaasi	aktinoliitti	magnettikiisu
kvartsi	antofylliitti	monatsiitti
biotiitti	apatiitti	muskoviitti
grafiitti	goethiitti	pigeoniitti
± kalimaasälpä	kalsiitti	rikkikiisu
	kaoliniitti	rutiili
	kloriitti	sarvivälke
	kordieriitti	sinkkivälke
	ksenotiimi	titaniitti
	kuparikiisu	zoisiitti

Grafiittisuomujen raekoko vaihtelee ja on suurimmillaan 1,2 mm. Noin 70 % suomuista on kuitenkin 100–500 µm kokoisia (kuva 13). Grafiittisuomut ovat pääosin täydellisesti kiteytyneitä perustuen Raman spektroskooppitutkimuksiin (Al-Ani et al., 2020).



Kuva 13. SEM:llä otettu BSE-kuva Käpysuon suomugrafiittinäytteestä R30 41,40 m. Mustina pitkänomaisina liistakkeina näkyvien grafiittisuomujen pituudet on mitattu c-akselin suuntaisesti. Muut mineraalit (kvartsi, plagioklaasi, ja biotiitti) näkyvät kuvassa harmaan eri sävyinä.

GTK:n ja Outokummun kairareikien perusteella tehtiin Leapfrog mallinnusohjelmalla Käpysuon tutkimusalueelta yksinkertaistettu 3D-malli, josta kivilajit pintaan projisoimalla saatiin tutkimusalueelle uusi kallioperäkartta (kuva 14). Grafiittirikkaat kivilajikerrokset muodostavat alueella vaihtelevan levyisiä (n. 20–150 m) vyöhykkeitä, jotka pohjoisosassa kulkevat lähes itä-länsi suuntaisina sekä etelässä muodostavat luoteeseen aukeavan poimurakenteen. Grafiitin mineraalivarantoarviota ei tutkimuskohteesta tehty, koska kairasydänaineisto on siihen liian harva.



Kuva 14. Käpysuon 3D mallista kivilajit pintaan projisoimalla tehty uusi kallioperäkartta sekä kairareikien sijainti. *Maastotietokanta @ Maanmittauslaitos, 2024.*

6.1 Suositellut jatkotutkimukset

Kairaamalla tulisi varmistaa grafiittipitoisten kivilajikerrosten jatkuminen malminetsintäalue-hakemuksessa rajatun alueen itäosaan. Kerrosten jatkumista indikoi sähköinen matalalentoanomalia (kuva 3).

Mineraalivarantoarvion tekeminen Käpysuon grafiittiesiintymästä vaatii kairaustiheyden kasvattamisen eri arviointimenetelmien vaatimalle tasolle.

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8 LIITTYY AINEISTO

Analyysitilausnumerot GTK:n ja Outokumpu Oy:n kairasydämistä. Osa tilauksista sisältää myös muita kuin Käpysuon kairasydämiä. Analyysit ovat saatavilla GTK:n tietokannasta voimassa olevan hinnoitteluperusteen mukaisesti.

kairasydän	analyysitilaus
GTK	
N4442017R1, R2 & R7	40265
N4442017R3, R4, R5, R6, R8	40269
N4442018R25, R26, R27 ,R28, R29 & R30	40299
Outokumpu Oy	
RTL_PH-3, 12 & 13,	40225
RTL_PH-6, 7, 11, 14, 16 & 17	40233
RTL_PH-8 & 9	40240
RTL_PH-7, 16 & 17	40190
RTL_PH-7	40195

Näytelista Käpysuon kairasydämistä, joista on mitattu petrofysiikka. Tulokset ovat saatavilla GTK:n tietokannasta (näytetunnuksella) voimassa olevan hinnoitteluperusteen mukaisesti.

reikätunnus	syvyys (m)	reikätunnus	syvyys (m)	reikätunnus	syvyys (m)
N4442018R25	45.2	N4442018R27	82.5	N4442018R28	92.4
N4442018R25	49.75	N4442018R27	89.2	N4442018R28	97.55
N4442018R25	59.3	N4442018R27	92	N4442018R28	110.2
N4442018R25	65.15	N4442018R27	97.25	N4442018R28	114.9
N4442018R25	72.1	N4442018R27	102.35	N4442018R28	119
N4442018R25	86.7	N4442018R27	111.2	N4442018R28	123.25
N4442018R25	94.8	N4442018R27	119.05	N4442018R28	128.15
N4442018R25	113.55	N4442018R27	124.35	N4442018R28	135.3
N4442018R25	122.1	N4442018R27	128.65	N4442018R28	149.6
N4442018R25	132.2	N4442018R27	143.3	N4442018R28	155.9
N4442018R25	151.25	N4442018R27	152.65	N4442018R28	162.3
N4442018R26	42.15	N4442018R27	159.2	N4442018R28	173.75
N4442018R26	49.15	N4442018R27	180.65	N4442018R28	192.1
N4442018R26	61.05	N4442018R28	15.55	N4442018R29	39.1
N4442018R26	66.75	N4442018R28	23.75	N4442018R29	47.2
N4442018R26	71.35	N4442018R28	28.9	N4442018R29	58.7
N4442018R26	77.9	N4442018R28	31.5	N4442018R29	78.15
N4442018R26	83.45	N4442018R28	37.15	N4442018R29	81.6
N4442018R26	87.9	N4442018R28	39.15	N4442018R29	83.7
N4442018R26	99.25	N4442018R28	42.15	N4442018R30	22.1
N4442018R26	109.35	N4442018R28	45.4	N4442018R30	30.55
N4442018R26	114.7	N4442018R28	47.15	N4442018R30	41.4
N4442018R26	120.5	N4442018R28	53.4	N4442018R30	48.2
N4442018R26	131.4	N4442018R28	58.55	N4442018R30	54.05
N4442018R26	167	N4442018R28	70.3	N4442018R30	60.5
N4442018R27	51.9	N4442018R28	74.9	N4442018R30	69.4
N4442018R27	62.8	N4442018R28	81.55	N4442018R30	77.9
N4442018R27	66.95	N4442018R28	85.8	N4442018R30	90
				N4442018R30	103.85

Maastogeofysiikka: MaxMin -mittausdata (tiedosto: 18mx3224_07.xyz) on saatavilla GTK:n tietokannasta voimassa olevan hinnoitteluperusteen mukaisesti.

9 LIITTEET

Liite 1. Rikastustestien työraportit: Koistinen (2018 & 2019) sekä Salvador (2019).

GEOLOGICAL SURVEY OF FINLAND
Mineral Processing and Material Research
Outokumpu
21.5.2018 C/MT/2018/12

Laboratory Beneficiation Testwork on Rautalampi Graphite Ore

Krista Koistinen

GEOLOGICAL SURVEY OF FINLAND DOCUMENTATION PAGE

21.5.2018 / Dnro

Authors
Krista Koistinen

Type of report
Research report

Comission by
GTK Industrial minerals unit, Panu Lintinen

Title of report
Laboratory Beneficiation Testwork on Rautalampi Graphite Ore

Abstract
Bench scale testwork on two graphite ore samples was performed. The samples were from Rautalampi deposit in eastern Finland. The test work was ordered by GTK Industrial minerals unit and was conducted at GTK Mintec during winter 2017–2018.

The main objective of the work was to find favorable process conditions for graphite beneficiation. Totally, 14 flotation tests which included both a rougher and a cleaner flotation were performed; seven tests on both graphite ores. A magnetic separation and slime separation were tested in some experiments prior to the flotation. In the flotation tests, the 80 % passing size of the feed material varied between 42 µm and 104 µm. In few tests regrinding were performed after rougher flotation. Primary Flotanol 7026 was used as frother. All flotation tests were carried out at natural pH. The flotation time varied from 24 to 40 minutes. Sodium silicate depressant, MIBC frother or kerosene, were tested in a few tests.

The head grades in the sample PH16 were 12 % C, 52 % SiO_2, 12 % Al_2O_3, 3.6 % MgO and 5.9 % Fe. The PH16, graphite gneiss, the main mineral phases were plagioclase, graphite, biotite and quartz. For this sample, rougher concentrates grading 34–50 % C were obtained at recoveries 82–95 %. The highest graphite grade 86 % with 65 % recovery, was obtained with 44 µm grinding fineness, sodium silicate depressant and regrinding of rougher concentrate, after four cleaner flotation step.

The sample PH17 contained mainly 10 % C, 60 % SiO_2, 12 % Al_2O_3, 2.3 % MgO and 4.3 % Fe. The PH17, graphite schist, the main mineral phases were biotate, plagioclase, quartz, K feldspar. The best results, 98 % recovery with 54 % graphite grade in the rougher flotation achieved with 42 µm grinding fineness. The cleaner flotation produced 4–85 % graphite recovery the grade in the concentrate being 81–91 %. The regrinding of rougher concentrates produced the highest 91 % grade while the recovery was 54 %. The best result 88 % graphite grade with 85 % recovery was reached with 42 µm grinding fineness, Flotanol 7026 frother and sodium silicate depressant.

Keywords
Graphite, flotation

Geographical area
Rautalampi, Finland

Map sheet

Other information

Report serial

Archive code
C/MT/2018/12

Total pages
10

Language
English

Price

Confidentiality

Unit and section
407/ISY

Project code
50402-20048 Mineraalipotentiaalin kartoitus akkumineraalit

Siganture/name

Asse Marjasvaara, Chief of Laboratories

Signature/name

Krista Koistinen, Research Scientist

Contents

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LIST OF APPENDIXES

1 INTRODUCTION

Panu Lintinen (GTK Industrial minerals unit) ordered a preliminary bench scale beneficiation testwork on two Rautalampi graphite ore samples. This testwork was related to GTK`s own “Mineraalipotentiaalin kartoitus akkumineraalit” project. The main purpose was to find out favorable process conditions for flotation. The test work consisted of grinding tests and both rougher and cleaner flotation tests.

2 LABORATORY TEST WORK

These bench scale tests and mineralogical characterization were carried out at GTK Mintec of the Geological Survey of Finland (GTK) in Outokumpu.

Mineralogical characterization was conducted with MLA, which is a scanning electron microscope fitted with two energy-dispersive spectrometers for rapid elemental analysis and special software to automatically perform a range of quantitative mineralogical measurements and calculations.

Chemical analysis was mainly performed by X-ray fluorescence (XRF) and combustion technique (Eltra) by Lamtium Oy in Outokumpu. A few total and carbonate carbon analyses were done with combustion technique (Eltra, Kuopio) by Labtium Oy in Kuopio.

2.1 Sample preparation and feed analyses

The test work was accomplished with the Rautalampi graphite ore samples RTL_PH-016 (PH16) and RTL_PH-017 (PH17). PH16 was combined from four drill cores (229.1–240.05) totally 7.5 kg. Sample PH17 was the respectively collected sample from four drill cores (159.55–161.55). At first material was crushed to < 1.4 mm particle size with a roller crusher. Then the crushed material was homogenized by mixing and divided into 0.7 kg sub samples for the bench scale tests.

The crushed feed material was analysed by XRF for overall composition and by Eltra for total carbon content. The assayed analyses and the calculated average feed analyses from the flotation tests are presented in Table I. The main elements were SiO_2, Al_2O_3 and C. The complete feed analyses are presented in Appendix 1.

Table I The feed analyses by XRF and total carbon with Eltra.

Sample	C (%)	SiO_2 (%)	Al_2O_3 (%)	MgO (%)	Fe (%)	Ca (%)	Ti (%)	S (%)
PH16	11.9	51.9	12.3	3.55	5.90	3.02	0.342	2.48
PH16 Calc feed*	11.3	52.4	12.0	3.44	6.46	3.01	0.342	2.68
PH17	10.1	59.7	12.3	2.23	4.25	1.65	0.321	2.60
PH17 Calc feed*	9.12	59.5	12.1	2.05	5.19	1.56	0.314	2.68

*Average values calculated from seven of PH16/PH17 flotation tests.

The total carbon (C_{tot}) and carbonate carbon (C_{carb}) was analysed separately with combustion technique. Determination given the value of non carbonate carbon which can assume to be the same as graphite carbon (C_g). The analysis results are represented in Table II and Appendix 1. The result shows that both samples included ~10 % C_g. The sample PH16 contained a little amount of C_{carb} but the sample PH17 not contained any of C_{carb}.

Table II The feed samples carbon analyses by combustion technique (Eltra, Kuopio) by Labtium Oy in Kuopio.

Sample	C_{tot} (%)	C_{carb} (%)	C_g(%)
PH16	11.5	1.23	10.3
PH17	9.57	<0.05	9.57

The feed samples mineralogy was studied from polished thin sections. Sample PH16 the polished thin section was taken from drill core position 232.95 and sample PH17 from position 161.80. The mineralogy study does not represent the whole feed sample, just the position where the thin section was taken.

Based on the results of the modal mineralogy the graphite gneiss, PH16, the main phases were plagioclase (45 %), graphite (23 %), biotite (19 %) and quartz (7 %). The graphite schist, PH17, the main phases were biotate (24 %), plagioclase (22 %), quartz (20 %), K feldspar (16 %). Other notable phases were clay (7 %), pyrrhotite (7 %) and graphite (2 %). This low graphite content is probably the consequence of flake graphite orientation.

The grinding fineness for both samples should be below 50 µm in order to liberate graphite and gangue minerals. The complete mineralogy analyses are presented in Appendix 3.

2.2 Grinding tests

The grinding tests were done with a mild steel laboratory ball mill. The used slurry density was 50 %, ore sample 0.7 kg, water 0.7 L and balls 8 kg. 15, 30, 45 and 60 minutes grinding time was used for the PH16 sample. 45 and 75 minutes grinding time was performed to PH17 sample. The exception were Test 10, 11, 13 and 14 where ground 45 minutes and after the rougher flotation reground extra 15–30 minutes in one or two part.

In the laboratory testwork a particle size distribution was determined by wet and dry sieving. At first, wet sieving with 20 µm screen was done and after this the overflow of the wet sieving phase was sieved as dry by Ro-Tap sieve shaker. The particle size distributions are shown in Figure 1 and Table III.

Crushed feed materials 80 % passing size (P_{80}) was 845 µm for PH16 and 913 µm for PH17. The PH16 sample seemed to be little softer than the PH17 sample. After 45 minutes grinding the PH16 P_{80} was 51 µm and PH17 was 64 µm.

Table III The 80 % passing size (P_{80}) for ore samples Rautalampi PH16 and PH17.

Sample	Grinding time (min)	P_{80} (µm)
PH16 (crushed feed -1.4 mm)	0	845
PH16	15	104
PH16	30	69
PH16	45	51
PH16	60	44
PH16 (regrinding RC1-3 15 min)	45+15	51/71
PH17 (crushed feed -1.4 mm)	0	914
PH17	45	64
PH17	75	42
PH17 (regrinding RC1-3 30 min)	45+30	64/60
PH17 (regrinding RC1-3 15 min + CC2 15 min)	45+15+15	64/-/89

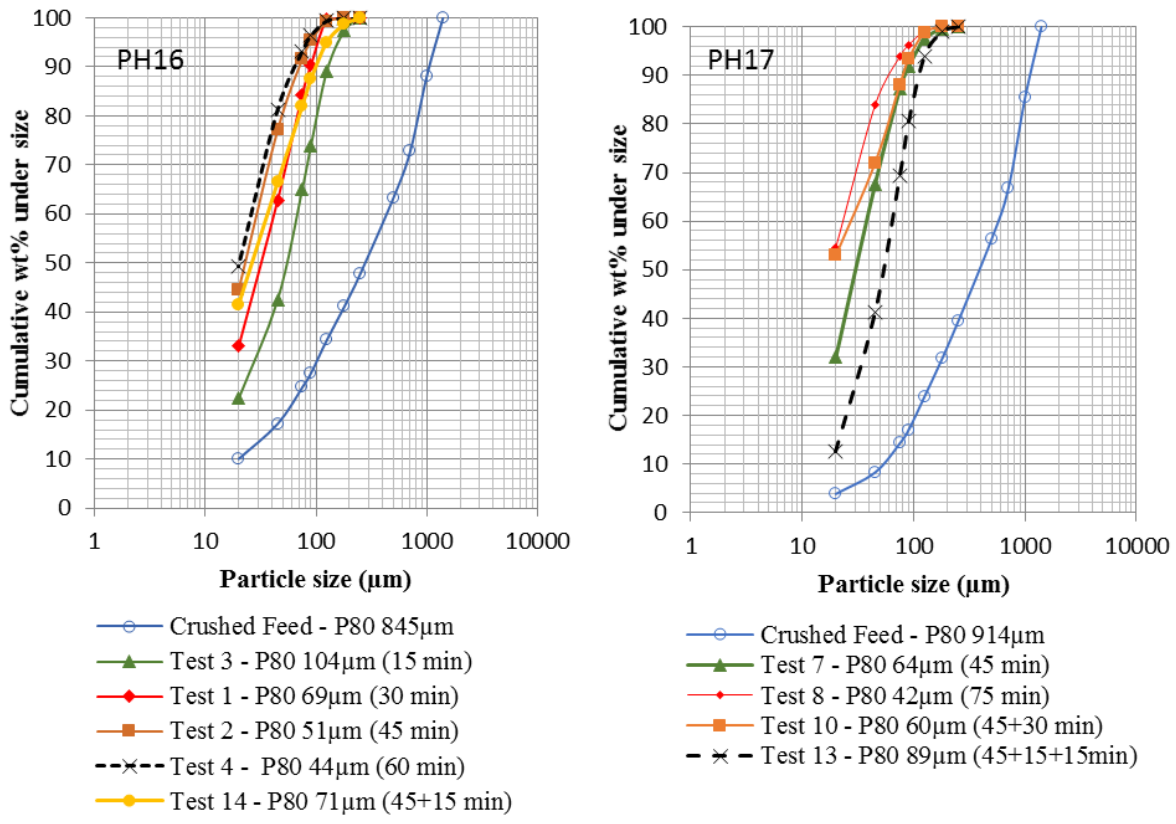

Figure 1. Particle size distribution for the Rautalampi PH16 (left) and PH17 (right) samples.

2.3 Flotation tests

The flotation test conditions are shown in Table IV. All the tests were done in natural pH ~8. The flotation products were analysed by XRF and Eltra. The complete flotation conditions are presented in Appendix 2. Flotation chemicals are shown in Table V.

Sample PH16 was accomplished seven flotation test; one rougher flotation baseline test with 4 step (Test 1) and six experiment which included both rougher and cleaner flotation (Test 2–6, 14). Sample PH16 principle beneficiation flowsheet is shown in Figure 2. The 0.7 kg feed was ground with mild steel ball mill and three rougher concentrates step RC1–3 were performed to reach a high graphite recovery. Then four (Test 2, 3, 5, 6, 14) or five (Test 4) cleaner flotation stages were done in order to upgrade the quality of the graphite concentrates. The magnetic separation with the magnetic field 0.07 T and 0.3 T (Test 1) and the slime separation with the separation limit <10 µm and <15 µm (Test 5) performed prior to the flotation. In the Test 14, 15 minutes regrinding accomplished after the rougher flotation for RC1–3.

Ore sample, PH17, was carried out seven flotation tests which all included 3 rougher flotation step and 5 cleaner flotation steps. The principle beneficiation flowsheet is shown in Figure 2. In Tests 10 and 11 were performed regrinding. Three rougher concentrates RC1–3 were reground 30 minutes before cleaned five times. An exceptional case was Test 13 where regrinding was carried out in two stages; at first 15 minutes after the rougher flotation (RC1 – 3) and then 15 minutes after second cleaner flotation step (CC2).

Table IV The flotation test variables. Rougher flotation and first cleaner flotation step; 2.5 L flotation cell, 1500 rpm rotor speed, 2 L/min air flow. Second to fifth cleaner flotation; 1.5 L flotation cell; rotor speed 1100 rpm, 1.5 L/min air flow.

Test	Sample	Main variable	Grinding time (min)	Rougher flotation	Cleaner flotation	Reagents dosages (g/t)	
						Flotanol 7026	Other
1	PH-16	Magnetic sep.	30	x4	-	180	
2	PH-16	Grinding size	45	x3	x4	155	
3	PH-16	Grinding size	15	x3	x4	155	
4	PH-16	Grinding size	60	x3	x5	155	
5	PH-16	Slime sep.	45	x3	x4	155	
6	PH-16	Frother	45	x3	x4	-	MIBC, 175
7	PH-17	Grinding size	45	x3	x5	174	
8	PH-17	Grinding size	75	x3	x5	204	
9	PH-17	Depressant	75	x3	x5	204	Na_2SiO_3, 1500
10	PH-17	Regrinding	45+30	x3	x5	234	
11	PH-17	Regrinding	45+30	x3	x5	338	
12	PH-17	Collector	75	x3	x5	204	Kerosene, 90
13	PH-17	Regrinding/depressant	45+15+15	x3	x5	394	Na_2SiO_3, 2500
14	PH-16	Regrinding/depressant	45+15	x3	x5	308	Na_2SiO_3, 1500

Table V Flotation chemicals.

Trade Name	Chemical composition	Concentration	Purpose of Use
Zeopol 33	Sodium silicate, Na_2SiO_3	5 %	depressant
Flotanol 7026	Fraction of terpene alcohols	100 %	frother
MIBC	4-metyl-2-pentanol	100 %	frother
Kerosene		100 %	collector

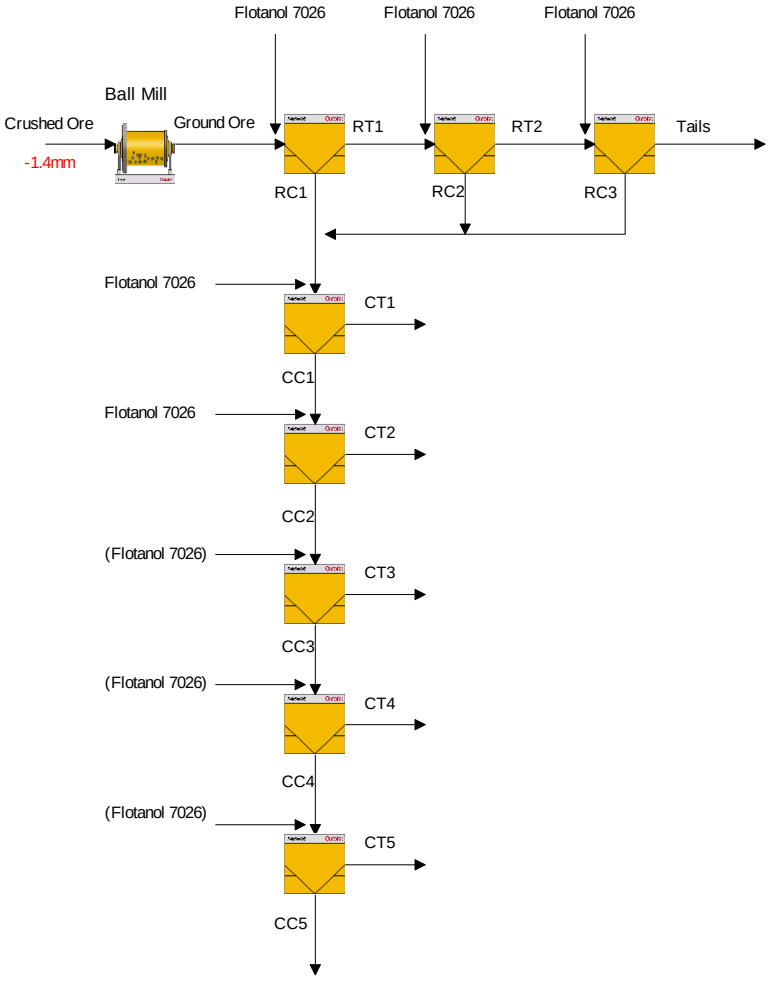

Figure 2. Principle beneficiation flowsheet for PH16 and PH17; grinding, rougher and cleaner flotation.

3 TEST RESULTS

The main test results for the test material, PH16, are shown in Table VI and Figure 3 (Appendix 2). In all seven tests, the graphite recovery to rougher concentrate was 93–95 % and the concentrate grade was 34–44 %. An exceptional case was the Test 5 carried out with slime separation where the C recovery to rougher concentrate was lower level, 80 %, but the C grade

was higher, 50 % after rougher flotation than in other tests. The magnetic separation in the Test 1 has not clear effect to the rougher flotation. The frother MIBC has a promising result after rougher flotation, 94 % recovery and 44 % grade in the Test 6. In this test the MIBC dose was too low level and so even better results could be expected with higher chemical doses.

From the grinding fineness 44, 51, 69 and 104 µm, the 44 µm grinding fineness, gives the highest 81 % graphite grade with 65 % recovery after fourth cleaner flotation. The highest graphite grade 86 % with 65 % recovery was achieved in the Test 14, accomplished with the sodium silicate depressant, Flotanol 7026 frother and rougher concentrate RC1–3 regrinding.

Table VI The graphite sample PH16 beneficiation test results.

Test	Main variable	P(80)	Magnetic/slime separation		RC1-3		CC4		CC5	
		µm	C %	Rec %	C %	Rec %	C %	Rec %	C %	Rec %
1	Magnetic sep.	69	5	2	38	93				
2	Grinding size	51			38	95	80	69		
3	Grinding size	104			34	95	61	62		
4	Grinding size	44			39	95	81	65	82	42
5	Slime sep.	51	9	14	50	82	80	60		
6	MIBC frother	51			44	94	79	47		
14	Regrinding/depressant	51/60			41	95	86	65	86	44

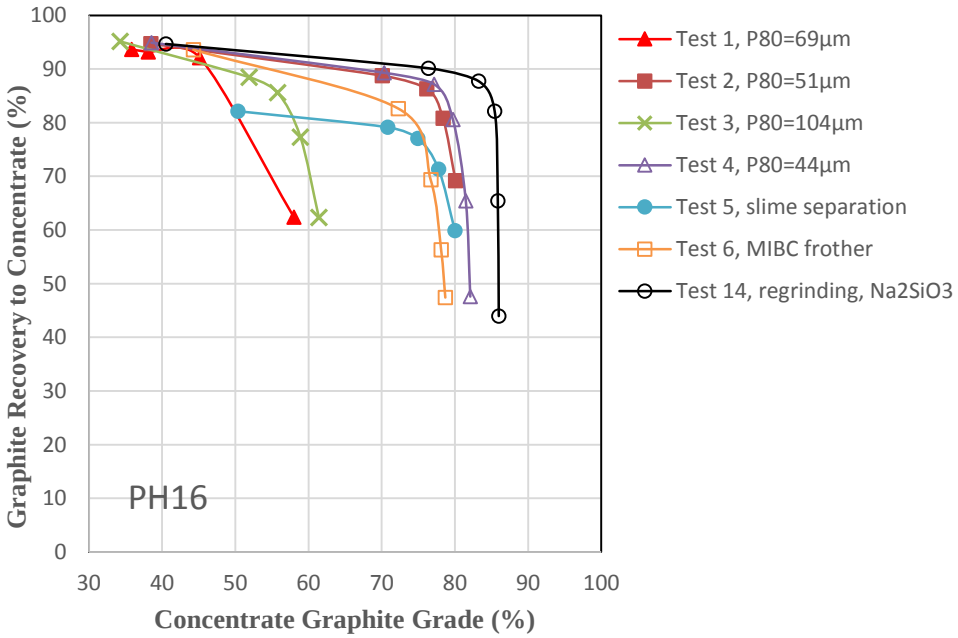

Figure 3. Flotation test results for Rautalampi PH16 ore sample. Test 1 rougher flotation and Test 2–6 and 14 rougher and cleaner flotation.

Rautalampi PH17, ore sample flotation test results are shown in Table VII and Figure 4 (Appendix 2). In these tests, the graphite recovery was between 98–99 % and grade 46–54 % after the rougher flotation. The best results in the rougher flotation, 98 % graphite recovery and 54 % grade, were achieved in the Test 8 with 42 µm grinding fineness and Test 9 with the same fineness and sodium silicate depressant.

After the cleaner flotation in the regrinding Test 10 and 11 the graphite grade was the highest 91 % and at the same time the recovery was at lower level 4–54 %. The 4 % recovery in Test 10 was a consequence of the low frother dose. The good test results, 88 % grade and 85 % recovery, was achieved in Test 9 with 42 µm grinding fineness, sodium silicate depressant and Flotanol 7026 frother.

Table VII The graphite sample PH17 beneficiation test results.

Test	Main variable	P(80) µm	RC1-3		CC5	
			C %	Rec %	C %	Rec %
7	Grinding size	64	50	98	81	49
8	Grinding size	42	54	98	85	82
9	Depressant	42	54	98	88	85
10	Regrinding	64/71	47	98	91	4
11	Regrinding	64/71	46	99	91	54
12	Kerosene collector	42	44	99	83	85
13	Regrinding/depressant	64/71/123	49	98	88	54

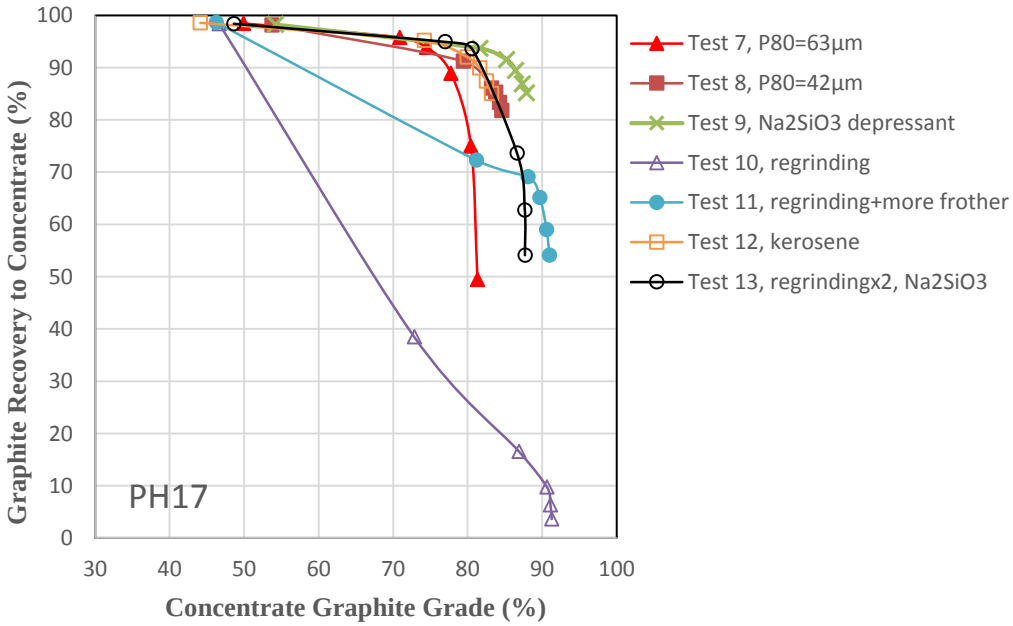

Figure 4. Flotation test results for Rautalampi PH17 ore sample. Both rougher and cleaner flotation.

The modal mineralogy of concentrates from Test 4 and Test 9 are shown in Table VIII. The main phases were pure graphite (~60 %) and graphite with silicates (~35 %). Gangue phases were biotite (~2 %), kaolinite (~1 %), quartz (~1 %) and plagioclase. The complete mineralogical analyses are presented in Appendix 3. The figure 5 shown that free silicates grains could be separated with the flotation optimization. For the phase, graphite with silicates, is probable needed the chemical or pyrometallurgical method to reach higher purity.

Table VIII The modal mineralogy of graphite concentrates.

Mineral	Test4 CC5 - Wt%	Test9 CC5 - Wt%
Quartz	1.19	0.85
Plagioclase	0.14	0.81
K_feldspar	0.00	0.00
Almandine	0.24	0.00
Muscovite	0.53	0.08
Chlorite	0.21	0.00
Kaolinite	0.55	1.68
Biotite	1.76	2.10
Calcite	0.86	0.00
Pyrite	0.61	0.00
Pyrrhotite	0.00	0.00
Pure graphite	60.13	57.86
Graphite with silicates	33.23	36.28
Unknown	0.54	0.35
Total	100.00	100.00
Number of measured points	7045	6805

The graphite concentrate flake size in Test 4, 9, 11 and 14 were 0 % jumpo, ~1 % large, ~14 % medium and ~85 % fine (Table IX). In the future beneficiation test should be aiming at the coarser flake size of graphite concentrate. The graphite concentrate value is highly dependent on the flake size, the bigger the flake size the higher the value.

Table IX Cleaner graphite concentrates CC5 from Test 4, 9, 11 and 14. Graphite flake size distribution and total carbon concentrations.

		Test 4		**Test 14**		**Test 9**		**Test 11**	
Flake size	**Size µm**	**w-%**	**C %**	**w-%**	**C %**	**w-%**	**C %**	**w-%**	**C %**
Jumbo	>315	0.0		0.0		0.0		0.0	
Large	180–315	1.1	88	0.9	90	1.2	85	0.3	87
Medium	150–180	3.3	85	2.8	87	3.8	87	2.4	87
Medium	106–150	11.3	86	9.5	84	13.7	87	9.7	87
Fine	75–106	19.1	84	15.8	83	22.9	86	18.3	86
Fine	<75	65.2	76	71.0	83	58.3	80	69.3	88
Combined concentrate			82		86		88		91

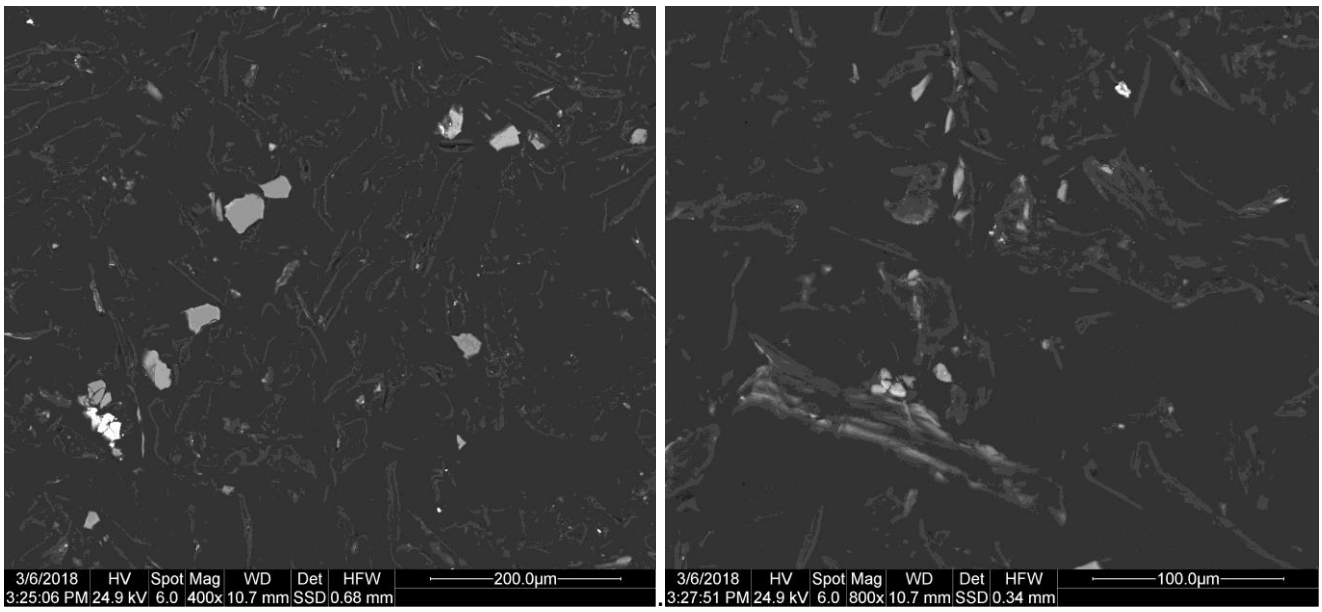

Figure 5. Graphite concentrate; Test 9 CC5. Pure graphite and free silicates grains (left). Graphite with silicates (right). Dark grey pure graphite, grey silicates, white pyrite, base epoxy.

4 CONCLUSIONS

Bench scale testwork on two Rautalampi graphite ore samples was performed. According to the feed analyses the main elements in Rautalampi PH16 ore sample were C 12 %, SiO_2 52 %, Al_2O_3 12 % and in Rautalampi PH17 were C 10 %, SiO_2 60 %, Al_2O_3 12 %. Both ore samples included also minor amounts of MgO, Fe, Ca, S and Ti.

The main objective of the work was to maximize the grade and recovery of graphite in flotation. Totally seven flotation tests were accomplished with the PH16 sample; one rougher flotation and six cleaner flotation. Seven flotation tests were done with PH17 ore, both rougher and cleaner flotation. In these tests, the effects of grinding size, MIBC frother, the kerosene collector, sodium silicate depressant and regrinding on graphite flotation were studied. In one test, magnetic separation and in one test slime separation was carried out before flotation.

In the flotation tests, the 80 % passing size of the feed material varied between 42 µm and 104 µm. The fine grinding produced the high C grade and recovery for both samples. For the PH16 sample, 81 % grade with 65 % recovery was obtained in the test where the grinding fineness was 42 µm and the frother dose was 155 g/t Flotanol 7026. Using 204 g/t Flotanol 7026, 1500 g/t Zeopol 33 and grinding fineness 42 µm for the flotation of the PH 17 sample, 88 % C grade with 85 % recovery was achieved.

The highest graphite grade was obtained by regrinding rougher concentrates. For the PH16 sample, the highest 86 % grade and 65 % recovery was achieved in the test where the grinding fineness of the flotation feed was 51 µm and the chemical dosages were 308 g/t Flotanol 7026 and 1500 g/t sodium silicate. Respectively for the sample PH17, 91 % grade with 54 % recovery was reached with 64 µm grinding fineness and 338 g/t Flotanol 7026 dose.

The frother MIBC (175 g/t) produced the higher C grade after rougher flotation than Flotanol 7026 (155 g/t) and both seemed to work equally in the cleaner flotation. It would be worthwhile to study the behaviour of MIBC with higher dosages because it is the weaker frother than Flotanol 7026. Magnetic separation prior to the flotation gave poor results for the sample PH16. This could be the consequence of sample mineralogy which shown that the sample did not include magnetic iron. Magnetic separation should be tested in future if the test material included magnetic minerals. Slime separation before flotation gave more promising results for the sample PH16. Using a separation limit <15 µm, ~15 % of gangue minerals were removed. The selectivity was poor and the graphite loss was 14 % in the slime separation step. A dispersing agent could be used in slime separation to achieve higher selectivity against graphite.

In future testwork it would be worthwhile to study the different grinding methods and graphite beneficiation process which produce more course graphite concentrate. These preliminary flotation tests were batch tests in the open flotation circuit. The higher mass recoveries can be expected in the continuous process.

Appendix 1 – Chemical analyses

Laboratory Beneficiation Testwork on Rautalampi Graphite Ore

Feed material: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

Element	RTL/PH-16	RTL/PH-17
SiO2	51.9	59.7
TiO2	0.57	0.54
Al2O3	12.3	12.3
Cr2O3	0.023	0.019
V2O3	0.097	0.068
FeO	7.58	5.60
MnO	0.073	0.038
MgO	3.55	2.23
CaO	4.23	2.31
Rb2O	0.0053	0.0054
SrO	0.026	0.022
BaO	0.044	0.069
Na2O	1.70	2.38
K2O	1.89	2.41
ZrO2	0.018	0.026
P2O5	0.292	0.168
OxSumm	97.50	99.50
Cu	0.015	0.010
Ni	0.024	0.019
Co	0.009	0.018
Zn	0.027	0.024
Pb	0.009	0.010
Ag	0.001	0.001
S	2.48	2.60
As	0.000	0.000
Sb	0.011	0.009
Bi	0.002	0.002
Nb	0.0019	0.0024
Mo	0.0053	0.0033
Sn	0.003	0.003
W	0.001	0.000
Cl	0.005	0.005
Th	0.0008	0.0010
U	0.0000	0.0000
Cs	0.003	0.000
La	0.005	0.007
Ce	0.006	0.007
Si	24.2	27.9
Ti	0.342	0.321
Cr	0.016	0.013
V	0.066	0.046
Fe	5.90	4.35
Mn	0.056	0.030
Mg	2.14	1.35
Ca	3.02	1.65
Ba	0.039	0.062
Eltra C	11.9	10.1

Flotation test 1, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1
Element	**M1**	**M2**	**RC1**	**RC2**	**RC3**	**RC4**	**Tails**
SiO2	25.2	30.1	19.9	38.3	58.5	56.7	62.9
TiO2	0.214	0.361	0.300	0.57	0.68	0.72	0.65
Al2O3	6.07	8.00	5.87	10.1	13.8	14.0	13.5
Cr2O3	0.041	0.047	0.014	0.024	0.029	0.032	0.025
V2O3	0.041	0.067	0.082	0.132	0.128	0.151	0.098
FeO	43.6	34.6	4.40	6.22	7.59	8.56	6.80
MnO	0.327	0.320	0.043	0.063	0.080	0.087	0.076
MgO	1.71	2.65	1.84	3.35	4.17	4.46	3.72
CaO	2.37	3.95	2.76	3.81	4.96	5.29	4.62
Rb2O	0.0086	0.0092	0.0000	0.0034	0.0067	0.0080	0.0049
SrO	0.0084	0.016	0.013	0.021	0.030	0.031	0.031
BaO	0.021	0.026	0.021	0.038	0.052	0.051	0.052
Na2O	0.97	1.15	0.56	1.13	1.93	1.85	2.15
K2O	0.77	1.06	0.95	1.69	2.17	2.22	2.13
ZrO2	0.008	0.010	0.008	0.014	0.020	0.019	0.022
P2O5	0.123	0.123	0.116	0.216	0.321	0.322	0.327
OxSumm	95.40	96.30	95.50	97.40	98.40	99.00	99.20
Cu	0.042	0.066	0.009	0.015	0.048	0.106	0.012
Ni	0.168	0.170	0.012	0.016	0.023	0.025	0.021
Co	0.025	0.025	0.002	0.010	0.017	0.018	0.015
Zn	0.024	0.039	0.014	0.024	0.034	0.050	0.028
Pb	0.003	0.008	0.009	0.009	0.007	0.009	0.009
Ag	0.002	0.003	0.001	0.001	0.002	0.001	0.001
S	17.6	14.0	1.05	1.61	2.28	2.60	2.14
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.013	0.002	0.008	0.011	0.011	0.009
Bi	0.002	0.003	0.002	0.002	0.002	0.002	0.002
Nb	0.0000	0.0000	0.0023	0.0022	0.0015	0.0012	0.0025
Mo	0.0008	0.0011	0.021	0.017	0.010	0.0092	0.0013
Sn	0.002	0.004	0.000	0.002	0.003	0.003	0.002
W	0.000	0.000	0.001	0.000	0.000	0.000	0.001
Cl	0.003	0.004	0.003	0.002	0.005	0.003	0.007
Th	0.0024	0.0018	0.0000	0.0000	0.0016	0.0013	0.0015
U	0.0037	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.003	0.001	0.001	0.001	0.001	0.001
La	0.004	0.006	0.003	0.004	0.006	0.005	0.005
Ce	0.003	0.002	0.003	0.005	0.007	0.006	0.007
Si	11.8	14.1	9.30	17.9	27.3	26.5	29.4
Ti	0.128	0.217	0.180	0.342	0.407	0.429	0.387
Cr	0.028	0.032	0.0096	0.017	0.020	0.022	0.017
V	0.028	0.045	0.056	0.090	0.087	0.102	0.067
Fe	33.9	26.9	3.42	4.84	5.90	6.65	5.29
Mn	0.253	0.248	0.033	0.049	0.062	0.067	0.059
Mg	1.03	1.60	1.11	2.02	2.51	2.69	2.24
Ca	1.69	2.82	1.97	2.72	3.54	3.78	3.30
Ba	0.018	0.024	0.018	0.034	0.047	0.045	0.047
C	4.71	6.40	58.0	30.8	2.62	2.83	0.79

Flotation test 2, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CC4**
SiO2	60.5	56.1	44.2	20.0	10.8	6.49
TiO2	0.63	0.62	0.59	0.427	0.259	0.146
Al2O3	13.1	13.1	12.1	6.89	4.09	2.63
Cr2O3	0.027	0.026	0.029	0.022	0.014	0.0077
V2O3	0.099	0.115	0.136	0.131	0.087	0.054
FeO	9.26	9.20	9.07	6.09	3.89	2.61
MnO	0.094	0.094	0.092	0.055	0.034	0.023
MgO	3.66	3.82	3.81	2.56	1.55	0.92
CaO	4.50	4.92	4.92	3.15	1.95	1.45
Rb2O	0.0053	0.0058	0.0059	0.0003	0.0000	0.0000
SrO	0.029	0.029	0.026	0.014	0.0084	0.0028
BaO	0.050	0.049	0.041	0.022	0.013	0.008
Na2O	2.04	1.87	1.39	0.54	0.25	0.14
K2O	2.03	2.03	1.89	1.18	0.70	0.424
ZrO2	0.022	0.019	0.015	0.007	0.004	0.003
P2O5	0.304	0.313	0.269	0.123	0.064	0.034
OxSumm	98.90	98.90	98.30	95.80	93.70	95.40
Cu	0.035	0.025	0.022	0.011	0.006	0.004
Ni	0.030	0.028	0.025	0.016	0.010	0.007
Co	0.022	0.017	0.018	0.007	0.008	0.006
Zn	0.029	0.030	0.027	0.017	0.011	0.007
Pb	0.009	0.009	0.008	0.009	0.010	0.010
Ag	0.002	0.002	0.002	0.001	0.000	0.001
S	3.13	2.81	2.42	1.38	0.80	0.475
As	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.012	0.010	0.003	0.002	0.001
Bi	0.003	0.003	0.003	0.003	0.002	0.002
Nb	0.0024	0.0025	0.0020	0.0026	0.0023	0.0015
Mo	0.0018	0.011	0.029	0.038	0.026	0.014
Sn	0.003	0.003	0.003	0.001	0.002	0.001
W	0.001	0.000	0.000	0.000	0.000	0.001
Cl	0.005	0.002	0.004	0.002	0.004	0.003
Th	0.0012	0.0013	0.0009	0.0004	0.0011	0.0011
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.001	0.003	0.003	0.000	0.002	0.001
La	0.006	0.005	0.005	0.003	0.002	0.001
Ce	0.006	0.006	0.005	0.003	0.002	0.001
Si	28.3	26.2	20.7	9.37	5.04	3.04
Ti	0.377	0.373	0.357	0.256	0.155	0.088
Cr	0.018	0.018	0.020	0.015	0.0093	0.0053
V	0.067	0.078	0.092	0.089	0.059	0.036
Fe	7.20	7.15	7.05	4.74	3.02	2.03
Mn	0.073	0.073	0.071	0.043	0.026	0.018
Mg	2.21	2.30	2.30	1.54	0.93	0.56
Ca	3.21	3.51	3.52	2.25	1.39	1.04
Ba	0.045	0.043	0.037	0.020	0.012	0.007
C	0.83	4.98	18.2	53.7	69.5	80.1

Flotation test 2, cleaner concentrate 4 (CC4) sieve fractions. Chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	CC4	CC4	CC4	CC4	CC4	CC4	CC4
Element	**-20µm**	**20µm**	**45µm**	**75µm**	**90µm**	**125µm**	**180µm**
SiO2	9.14	7.45	8.21	5.84	5.50	3.57	1.69
TiO2	0.152	0.112	0.170	0.167	0.193	0.123	0.042
Al2O3	3.26	2.87	3.31	2.45	2.36	1.53	0.72
Cr2O3	0.013	0.0064	0.0095	0.0096	0.010	0.0066	0.0026
V2O3	0.043	0.045	0.068	0.062	0.064	0.038	0.012
FeO	3.88	3.07	3.02	2.24	2.14	1.45	0.43
MnO	0.033	0.025	0.026	0.021	0.021	0.015	0.005
MgO	1.06	0.91	1.15	0.96	0.96	0.62	0.27
CaO	2.09	1.73	1.62	1.17	1.12	0.85	0.51
Rb2O	0.0000	0.0000	0.0000	0.0000	0.0018	0.0010	0.0003
SrO	0.0072	0.0066	0.0066	0.0019	0.0013	0.0004	0.0000
BaO	0.010	0.009	0.011	0.008	0.008	0.005	0.003
Na2O	0.22	0.18	0.19	0.11	0.09	0.05	0.02
K2O	0.461	0.429	0.53	0.430	0.437	0.277	0.112
ZrO2	0.006	0.003	0.003	0.003	0.002	0.002	0.001
P2O5	0.071	0.052	0.040	0.021	0.019	0.011	0.006
OxSumm	97.70	95.40	92.40	98.20	96.80	93.40	96.80
Cu	0.070	0.006	0.006	0.003	0.004	0.004	0.001
Ni	0.019	0.009	0.009	0.006	0.006	0.004	0.002
Co	0.003	0.005	0.006	0.006	0.004	0.007	0.015
Zn	0.012	0.008	0.007	0.006	0.006	0.005	0.001
Pb	0.150	0.013	0.012	0.010	0.011	0.010	0.006
Ag	0.001	0.000	0.000	0.000	0.000	0.000	0.000
S	1.01	0.73	0.56	0.297	0.253	0.151	0.092
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.002	0.001	0.001	0.000	0.000	0.000	0.000
Bi	0.002	0.003	0.002	0.002	0.002	0.002	0.001
Nb	0.0029	0.0017	0.0014	0.0015	0.0013	0.0012	0.0007
Mo	0.025	0.020	0.016	0.0099	0.0070	0.0042	0.0012
Sn	0.003	0.001	0.001	0.001	0.000	0.001	0.000
W	0.000	0.001	0.000	0.001	0.001	0.001	0.001
Cl	0.002	0.004	0.003	0.004	0.003	0.003	0.003
Th	0.0014	0.0010	0.0014	0.0013	0.0018	0.0012	0.0004
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.000	0.001	0.001	0.000	0.000	0.001	0.001
La	0.002	0.002	0.002	0.002	0.002	0.001	0.001
Ce	0.002	0.001	0.002	0.001	0.001	0.001	0.001
Si	4.27	3.48	3.84	2.73	2.57	1.67	0.79
Ti	0.091	0.067	0.102	0.100	0.116	0.074	0.025
Cr	0.0089	0.0044	0.0065	0.0066	0.0070	0.0045	0.0018
V	0.029	0.030	0.046	0.042	0.044	0.026	0.0083
Fe	3.01	2.39	2.35	1.74	1.66	1.13	0.33
Mn	0.025	0.020	0.020	0.016	0.016	0.011	0.004
Mg	0.64	0.55	0.69	0.58	0.58	0.38	0.16
Ca	1.49	1.24	1.16	0.83	0.80	0.61	0.365
Ba	0.009	0.008	0.010	0.007	0.007	0.004	0.003
C	76.4	78.0	73.7	84.5	83.7	84.7	92.9

Flotation test 3, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CC4**
SiO2	61.6	53.5	43.7	30.3	21.5	13.9
TiO2	0.62	0.67	0.66	0.56	0.460	0.298
Al2O3	13.1	13.6	12.9	9.84	7.37	5.06
Cr2O3	0.024	0.029	0.033	0.029	0.023	0.015
V2O3	0.087	0.142	0.173	0.173	0.149	0.099
FeO	8.52	9.18	9.50	7.69	6.02	4.34
MnO	0.089	0.095	0.084	0.060	0.047	0.036
MgO	3.49	4.32	4.48	3.68	2.82	1.86
CaO	4.43	5.18	5.00	3.73	2.94	2.44
Rb2O	0.0061	0.0068	0.0067	0.0039	0.0003	0.0000
SrO	0.028	0.030	0.026	0.020	0.014	0.0099
BaO	0.049	0.048	0.039	0.031	0.024	0.016
Na2O	2.10	1.75	1.36	0.88	0.58	0.35
K2O	2.02	2.14	2.05	1.65	1.29	0.85
ZrO2	0.022	0.018	0.014	0.009	0.008	0.006
P2O5	0.310	0.321	0.291	0.200	0.143	0.080
OxSumm	99.00	98.90	98.90	97.40	94.60	91.30
Cu	0.017	0.025	0.021	0.012	0.010	0.006
Ni	0.028	0.029	0.029	0.022	0.017	0.012
Co	0.024	0.021	0.017	0.014	0.014	0.008
Zn	0.028	0.033	0.032	0.024	0.018	0.013
Pb	0.010	0.010	0.009	0.010	0.010	0.011
Ag	0.002	0.001	0.002	0.002	0.001	0.001
S	3.08	2.87	2.93	2.14	1.53	0.96
As	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.011	0.010	0.008	0.003	0.002
Bi	0.002	0.003	0.003	0.003	0.003	0.003
Nb	0.0026	0.0022	0.0015	0.0023	0.0027	0.0026
Mo	0.0015	0.012	0.023	0.024	0.020	0.015
Sn	0.003	0.003	0.002	0.002	0.001	0.002
W	0.001	0.000	0.001	0.001	0.001	0.000
Cl	0.003	0.005	0.005	0.004	0.004	0.003
Th	0.0022	0.0009	0.0001	0.0000	0.0000	0.0000
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.001	0.000	0.002	0.000	0.001	0.001
La	0.005	0.005	0.004	0.004	0.004	0.003
Ce	0.008	0.005	0.006	0.004	0.002	0.002
Si	28.8	25.0	20.4	14.2	10.0	6.48
Ti	0.370	0.401	0.398	0.338	0.276	0.178
Cr	0.017	0.020	0.023	0.020	0.016	0.010
V	0.059	0.096	0.118	0.118	0.101	0.067
Fe	6.62	7.14	7.39	5.98	4.68	3.38
Mn	0.069	0.073	0.065	0.046	0.036	0.028
Mg	2.11	2.60	2.70	2.22	1.70	1.12
Ca	3.17	3.70	3.57	2.67	2.10	1.74
Ba	0.044	0.043	0.035	0.028	0.021	0.014
C	0.76	6.23	16.9	37.3	50.3	61.4

Flotation test 3, flotation feed sieve fractions. Chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3
Element	**-20µm**	**20µm**	**45µm**	**75µm**	**90µm**	**+125µm**
SiO2	48.9	53.3	57.2	56.9	55.3	48.5
TiO2	0.56	0.493	0.55	0.59	0.67	0.75
Al2O3	13.4	10.7	11.5	12.3	13.1	13.0
Cr2O3	0.028	0.019	0.020	0.023	0.026	0.031
V2O3	0.093	0.083	0.085	0.098	0.114	0.138
FeO	10.4	9.02	7.50	6.56	6.19	6.06
MnO	0.131	0.068	0.063	0.067	0.068	0.066
MgO	3.58	2.88	3.04	3.38	3.98	4.50
CaO	6.25	4.12	3.68	3.55	3.59	3.29
Rb2O	0.0056	0.0031	0.0049	0.0048	0.0048	0.0069
SrO	0.030	0.024	0.027	0.026	0.027	0.026
BaO	0.047	0.041	0.046	0.051	0.049	0.050
Na2O	1.66	1.66	1.83	1.92	1.89	1.70
K2O	1.98	1.57	1.75	1.94	2.16	2.18
ZrO2	0.024	0.032	0.018	0.011	0.010	0.011
P2O5	0.410	0.405	0.268	0.184	0.155	0.134
OxSumm	96.20	99.00	99.10	99.20	99.00	98.90
Cu	0.039	0.018	0.016	0.012	0.010	0.008
Ni	0.042	0.031	0.024	0.019	0.016	0.014
Co	0.019	0.018	0.022	0.026	0.019	0.016
Zn	0.043	0.026	0.022	0.019	0.020	0.021
Pb	0.032	0.008	0.008	0.008	0.011	0.008
Ag	0.001	0.001	0.002	0.001	0.001	0.001
S	3.24	3.98	3.05	2.11	1.45	0.95
As	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.013	0.010	0.012	0.009	0.007	0.011
Bi	0.003	0.003	0.002	0.002	0.003	0.002
Nb	0.0018	0.0017	0.0022	0.0020	0.0029	0.0019
Mo	0.0086	0.0064	0.0038	0.0046	0.0046	0.0051
Sn	0.004	0.003	0.003	0.003	0.001	0.003
W	0.000	0.001	0.001	0.001	0.001	0.001
Cl	0.003	0.004	0.003	0.003	0.004	0.006
Th	0.0014	0.0022	0.0009	0.0009	0.0000	0.0010
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.000	0.002	0.001	0.001	0.002	0.001
La	0.006	0.007	0.005	0.007	0.005	0.005
Ce	0.006	0.010	0.006	0.004	0.003	0.005
Si	22.8	24.9	26.7	26.6	25.9	22.7
Ti	0.333	0.296	0.328	0.354	0.399	0.447
Cr	0.019	0.013	0.014	0.016	0.018	0.021
V	0.063	0.056	0.058	0.067	0.077	0.094
Fe	8.08	7.01	5.83	5.10	4.81	4.71
Mn	0.101	0.052	0.049	0.052	0.053	0.051
Mg	2.16	1.74	1.83	2.04	2.40	2.71
Ca	4.46	2.94	2.63	2.54	2.56	2.35
Ba	0.042	0.037	0.041	0.046	0.044	0.045
C	6.89	12.4	9.76	10.4	10.8	17.9

Flotation test 4, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 4	Test 4	Test 4	Test 4	Test 4	Test 4	Test 4
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	58.5	56.2	45.1	17.5	7.93	5.59	4.87
TiO2	0.63	0.61	0.57	0.372	0.197	0.136	0.109
Al2O3	13.3	13.2	12.1	6.19	3.11	2.32	2.13
Cr2O3	0.026	0.028	0.027	0.020	0.011	0.0080	0.0064
V2O3	0.101	0.109	0.124	0.114	0.066	0.049	0.041
FeO	8.98	9.36	9.07	5.50	3.11	2.38	2.15
MnO	0.092	0.096	0.090	0.050	0.028	0.021	0.020
MgO	3.91	3.75	3.71	2.26	1.10	0.78	0.72
CaO	4.47	4.89	4.88	2.86	1.58	1.24	1.23
Rb2O	0.0070	0.0068	0.0045	0.0014	0.0000	0.0000	0.0000
SrO	0.029	0.029	0.026	0.012	0.0031	0.0021	0.0020
BaO	0.050	0.048	0.042	0.019	0.012	0.008	0.006
Na2O	1.91	1.86	1.42	0.45	0.17	0.11	0.09
K2O	2.06	2.01	1.84	1.03	0.53	0.383	0.331
ZrO2	0.022	0.019	0.014	0.006	0.003	0.002	0.003
P2O5	0.330	0.304	0.267	0.106	0.047	0.033	0.025
OxSumm	96.80	98.90	96.00	92.70	91.20	93.20	94.10
Cu	0.016	0.023	0.023	0.010	0.005	0.004	0.003
Ni	0.027	0.029	0.026	0.014	0.008	0.006	0.006
Co	0.011	0.017	0.018	0.008	0.005	0.006	0.006
Zn	0.027	0.031	0.028	0.014	0.008	0.006	0.005
Pb	0.007	0.008	0.009	0.009	0.012	0.010	0.009
Ag	0.001	0.002	0.002	0.001	0.000	0.000	0.000
S	2.81	2.85	2.45	1.16	0.55	0.400	0.338
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.012	0.011	0.011	0.006	0.001	0.001	0.001
Bi	0.002	0.003	0.003	0.003	0.002	0.002	0.002
Nb	0.0016	0.0017	0.0014	0.0018	0.0019	0.0013	0.0016
Mo	0.0013	0.011	0.029	0.039	0.016	0.014	0.011
Sn	0.003	0.004	0.003	0.001	0.001	0.001	0.001
W	0.001	0.001	0.001	0.001	0.001	0.000	0.001
Cl	0.007	0.006	0.005	0.003	0.004	0.003	0.002
Th	0.0015	0.0013	0.0006	0.0000	0.0018	0.0013	0.0012
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.003	0.002	0.002	0.002	0.001	0.002	0.001
La	0.006	0.006	0.004	0.002	0.001	0.002	0.002
Ce	0.007	0.006	0.005	0.003	0.002	0.001	0.001
Si	27.4	26.3	21.1	8.20	3.71	2.61	2.28
Ti	0.376	0.364	0.341	0.223	0.118	0.082	0.065
Cr	0.018	0.019	0.019	0.014	0.0075	0.0055	0.0044
V	0.069	0.074	0.084	0.077	0.045	0.033	0.028
Fe	6.98	7.28	7.05	4.28	2.42	1.85	1.67
Mn	0.071	0.075	0.070	0.039	0.022	0.016	0.015
Mg	2.36	2.26	2.24	1.36	0.66	0.47	0.44
Ca	3.19	3.49	3.48	2.04	1.13	0.88	0.88
Ba	0.045	0.043	0.037	0.017	0.011	0.007	0.005
C	0.78	4.70	15.3	55.4	72.9	79.9	82.1

Flotation test 4, flotation feed sieve fractions. Chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 4	Test 4	Test 4	Test 4	Test 4	Test 4
Element	**-20µm**	**20µm**	**45µm**	**75µm**	**90µm**	**+125µm**
SiO2	56.0	56.5	41.5	25.8	19.7	No XRFanal.
TiO2	0.465	0.56	0.94	1.11	1.09	
Al2O3	12.5	12.2	12.1	9.44	8.02	
Cr2O3	0.020	0.024	0.038	0.044	0.045	
V2O3	0.071	0.100	0.178	0.197	0.182	
FeO	10.6	6.65	6.85	6.99	6.49	
MnO	0.100	0.064	0.089	0.106	0.117	
MgO	2.75	3.28	5.53	6.09	5.82	
CaO	5.33	3.91	2.34	1.20	0.85	
Rb2O	0.0047	0.0046	0.0043	0.0021	0.0000	
SrO	0.030	0.027	0.018	0.0091	0.0063	
BaO	0.047	0.044	0.052	0.041	0.040	
Na2O	1.97	1.88	1.13	0.46	0.25	
K2O	1.73	1.84	2.36	2.29	2.21	
ZrO2	0.025	0.021	0.007	0.004	0.004	
P2O5	0.351	0.306	0.100	0.034	0.023	
OxSumm	98.50	99.20	96.40	91.90	89.10	
Cu	0.027	0.011	0.005	0.004	0.003	
Ni	0.038	0.018	0.012	0.009	0.008	
Co	0.029	0.018	0.010	0.021	0.022	
Zn	0.035	0.019	0.018	0.017	0.016	
Pb	0.009	0.007	0.013	0.015	0.017	
Ag	0.001	0.001	0.001	0.000	0.001	
S	3.83	2.20	0.64	0.295	0.212	
As	0.000	0.000	0.000	0.000	0.000	
Sb	0.013	0.011	0.003	0.001	0.002	
Bi	0.003	0.002	0.003	0.003	0.004	
Nb	0.0018	0.0015	0.0038	0.0039	0.0041	
Mo	0.0051	0.0058	0.0075	0.0066	0.0055	
Sn	0.003	0.003	0.001	0.000	0.002	
W	0.001	0.001	0.000	0.001	0.001	
Cl	0.004	0.004	0.004	0.003	0.003	
Th	0.0010	0.0011	0.0000	0.0000	0.0023	
U	0.0000	0.0000	0.0000	0.0000	0.0000	
Cs	0.000	0.003	0.000	0.001	0.001	
La	0.005	0.006	0.004	0.003	0.003	
Ce	0.008	0.005	0.002	0.001	0.002	
Si	26.2	26.4	19.4	12.1	9.22	
Ti	0.279	0.333	0.56	0.66	0.65	
Cr	0.014	0.016	0.026	0.030	0.031	
V	0.049	0.068	0.121	0.134	0.123	
Fe	8.23	5.17	5.33	5.43	5.05	
Mn	0.077	0.050	0.069	0.082	0.091	
Mg	1.66	1.98	3.33	3.67	3.51	
Ca	3.81	2.79	1.67	0.86	0.61	
Ba	0.042	0.040	0.047	0.037	0.036	
C	4.37	10.5	22.7	37.8	44.0	66.9

Flotation test 5, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 5	Test 5	Test 5	Test 5	Test 5	Test 5	Test 5	Test 5
Element	**-10µm**	**-15µm**	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CC4**
SiO2	58.7	55.3	59.8	52.2	35.6	18.5	10.1	6.25
TiO2	0.54	0.495	0.67	0.70	0.69	0.466	0.257	0.147
Al2O3	15.2	13.2	13.4	13.7	12.0	6.91	3.95	2.66
Cr2O3	0.023	0.022	0.026	0.033	0.034	0.024	0.014	0.0079
V2O3	0.079	0.086	0.103	0.154	0.202	0.151	0.089	0.054
FeO	6.50	7.04	9.49	10.1	9.78	5.97	3.69	2.57
MnO	0.081	0.088	0.093	0.107	0.096	0.053	0.032	0.023
MgO	2.67	3.13	3.92	4.37	4.69	2.72	1.45	0.93
CaO	5.11	5.47	4.23	5.26	4.71	3.01	1.90	1.49
Rb2O	0.0027	0.0049	0.0063	0.0072	0.0074	0.0030	0.0000	0.0000
SrO	0.037	0.031	0.028	0.028	0.022	0.013	0.0082	0.0056
BaO	0.060	0.049	0.052	0.048	0.034	0.024	0.013	0.008
Na2O	2.62	1.88	2.04	1.66	1.02	0.46	0.22	0.13
K2O	2.12	1.93	2.09	2.11	1.93	1.22	0.69	0.428
ZrO2	0.014	0.014	0.024	0.019	0.013	0.007	0.005	0.003
P2O5	0.181	0.299	0.326	0.341	0.247	0.119	0.060	0.033
OxSumm	99.30	98.90	98.90	98.50	96.30	92.00	90.80	95.00
Cu	0.020	0.022	0.013	0.073	0.048	0.014	0.006	0.003
Ni	0.023	0.024	0.031	0.033	0.026	0.015	0.010	0.006
Co	0.027	0.020	0.015	0.017	0.011	0.005	0.003	0.003
Zn	0.040	0.032	0.028	0.040	0.030	0.017	0.010	0.007
Pb	0.012	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Ag	0.000	0.001	0.001	0.001	0.002	0.001	0.001	0.001
S	1.54	1.80	3.43	3.04	2.56	1.30	0.71	0.431
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.005	0.011	0.010	0.011	0.012	0.008	0.004	0.003
Bi	0.004	0.003	0.003	0.002	0.003	0.002	0.002	0.002
Nb	0.0032	0.0014	0.0010	0.0013	0.0012	0.0017	0.0016	0.0020
Mo	0.0041	0.0060	0.0008	0.018	0.043	0.036	0.026	0.018
Sn	0.002	0.003	0.003	0.003	0.003	0.002	0.001	0.002
W	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
Cl	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003
Th	0.0000	0.0000	0.0012	0.0013	0.0012	0.0000	0.0000	0.0007
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.003	0.000	0.002	0.003	0.003	0.001	0.001	0.001
La	0.004	0.006	0.008	0.004	0.003	0.003	0.002	0.001
Ce	0.004	0.005	0.007	0.006	0.004	0.002	0.002	0.001
Si	27.4	25.8	28.0	24.4	16.7	8.67	4.72	2.92
Ti	0.324	0.297	0.403	0.417	0.416	0.279	0.154	0.088
Cr	0.016	0.015	0.018	0.022	0.023	0.017	0.0094	0.0054
V	0.054	0.058	0.070	0.105	0.138	0.103	0.060	0.037
Fe	5.05	5.48	7.38	7.87	7.60	4.65	2.87	2.00
Mn	0.063	0.068	0.072	0.083	0.074	0.041	0.025	0.018
Mg	1.61	1.89	2.37	2.63	2.83	1.64	0.87	0.56
Ca	3.65	3.91	3.02	3.75	3.37	2.15	1.36	1.06
Ba	0.053	0.044	0.046	0.043	0.031	0.021	0.012	0.008
C	4.35	8.85	0.66	5.84	23.6	51.5	67.9	80.0

Flotation test 6, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 6	Test 6	Test 6	Test 6	Test 6	Test 6
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CC4**
SiO2	59.6	50.1	18.4	9.37	7.66	5.79
TiO2	0.65	0.58	0.363	0.222	0.181	0.137
Al2O3	13.6	12.6	6.16	3.76	3.18	2.54
Cr2O3	0.026	0.026	0.018	0.013	0.0099	0.0073
V2O3	0.104	0.110	0.101	0.074	0.064	0.050
FeO	9.10	8.63	5.22	3.50	3.03	2.45
MnO	0.093	0.090	0.053	0.032	0.027	0.022
MgO	3.85	3.75	2.11	1.33	1.12	0.89
CaO	4.61	4.74	2.78	1.87	1.62	1.48
Rb2O	0.0075	0.0058	0.0011	0.0000	0.0000	0.0000
SrO	0.028	0.027	0.013	0.0076	0.0065	0.0060
BaO	0.053	0.045	0.019	0.013	0.010	0.008
Na2O	2.04	1.61	0.48	0.21	0.16	0.11
K2O	2.08	1.92	1.02	0.62	0.52	0.402
ZrO2	0.023	0.017	0.008	0.004	0.004	0.004
P2O5	0.328	0.291	0.109	0.054	0.044	0.028
OxSumm	98.80	97.30	93.00	92.60	93.20	92.90
Cu	0.018	0.018	0.009	0.005	0.004	0.004
Ni	0.028	0.026	0.014	0.009	0.009	0.006
Co	0.015	0.012	0.008	0.005	0.004	0.004
Zn	0.028	0.028	0.015	0.010	0.008	0.006
Pb	0.007	0.007	0.007	0.007	0.008	0.007
Ag	0.001	0.001	0.001	0.001	0.001	0.001
S	3.01	2.44	1.09	0.62	0.52	0.364
As	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.013	0.008	0.003	0.003	0.003
Bi	0.002	0.002	0.002	0.002	0.002	0.001
Nb	0.0013	0.0011	0.0014	0.0016	0.0020	0.0020
Mo	0.0019	0.014	0.028	0.023	0.021	0.014
Sn	0.003	0.003	0.002	0.001	0.003	0.002
W	0.000	0.001	0.001	0.001	0.001	0.001
Cl	0.005	0.003	0.003	0.003	0.004	0.003
Th	0.0017	0.0010	0.0000	0.0000	0.0012	0.0013
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.002	0.001	0.001	0.001	0.001
La	0.005	0.005	0.002	0.002	0.002	0.002
Ce	0.008	0.006	0.002	0.001	0.002	0.001
Si	27.9	23.4	8.61	4.38	3.58	2.71
Ti	0.388	0.349	0.218	0.133	0.109	0.082
Cr	0.018	0.018	0.012	0.0086	0.0068	0.0050
V	0.071	0.074	0.069	0.050	0.043	0.034
Fe	7.07	6.71	4.06	2.72	2.35	1.91
Mn	0.072	0.070	0.041	0.025	0.021	0.017
Mg	2.32	2.26	1.27	0.80	0.67	0.53
Ca	3.30	3.38	1.98	1.34	1.16	1.05
Ba	0.048	0.040	0.017	0.011	0.009	0.007
C	0.93	11.3	55.5	71.1	75.2	78.7

Flotation test 7, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 7	Test 7	Test 7	Test 7	Test 7	Test 7	Test 7
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	66.7	62.3	45.9	28.7	13.3	7.85	6.16
TiO2	0.58	0.54	0.61	0.456	0.210	0.120	0.083
Al2O3	13.1	13.9	13.6	10.1	5.06	3.22	2.76
Cr2O3	0.017	0.021	0.033	0.032	0.015	0.0091	0.0067
V2O3	0.064	0.079	0.141	0.138	0.069	0.042	0.032
FeO	6.80	6.55	6.54	4.67	2.75	1.93	1.54
MnO	0.044	0.049	0.072	0.057	0.027	0.017	0.014
MgO	2.19	2.15	3.26	2.79	1.17	0.66	0.50
CaO	2.39	2.71	2.23	1.45	0.66	0.343	0.233
Rb2O	0.0072	0.0063	0.0092	0.0067	0.0014	0.0000	0.0000
SrO	0.025	0.024	0.018	0.012	0.0062	0.0038	0.0012
BaO	0.075	0.070	0.049	0.030	0.013	0.007	0.006
Na2O	2.69	2.48	1.75	1.01	0.41	0.21	0.13
K2O	2.50	2.49	2.58	2.05	1.00	0.63	0.54
ZrO2	0.029	0.028	0.027	0.018	0.010	0.007	0.006
P2O5	0.175	0.194	0.164	0.107	0.049	0.026	0.016
OxSumm	99.20	99.30	99.50	94.80	91.20	94.20	93.60
Cu	0.011	0.029	0.023	0.009	0.005	0.005	0.005
Ni	0.020	0.018	0.018	0.012	0.007	0.006	0.004
Co	0.020	0.017	0.015	0.007	0.004	0.003	0.002
Zn	0.028	0.034	0.030	0.020	0.011	0.008	0.007
Pb	0.008	0.009	0.010	0.009	0.008	0.007	0.007
Ag	0.000	0.001	0.002	0.002	0.001	0.001	0.001
S	2.99	2.39	2.05	1.42	0.84	0.57	0.434
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.011	0.011	0.009	0.005	0.003	0.002
Bi	0.002	0.002	0.003	0.003	0.002	0.001	0.001
Nb	0.0015	0.0014	0.0015	0.0012	0.0017	0.0020	0.0012
Mo	0.0003	0.0098	0.029	0.027	0.017	0.013	0.010
Sn	0.003	0.003	0.004	0.002	0.003	0.002	0.001
W	0.001	0.000	0.001	0.000	0.001	0.001	0.000
Cl	0.004	0.003	0.005	0.005	0.004	0.003	0.004
Th	0.0022	0.0013	0.0015	0.0003	0.0000	0.0013	0.0010
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.001	0.001	0.001	0.000	0.001	0.001
La	0.007	0.005	0.005	0.004	0.002	0.001	0.002
Ce	0.009	0.008	0.009	0.004	0.003	0.002	0.001
Si	31.2	29.1	21.5	13.4	6.24	3.67	2.88
Ti	0.350	0.324	0.363	0.274	0.126	0.072	0.050
Cr	0.012	0.014	0.022	0.022	0.010	0.0062	0.0046
V	0.044	0.053	0.096	0.094	0.047	0.029	0.022
Fe	5.29	5.10	5.08	3.64	2.14	1.50	1.20
Mn	0.034	0.038	0.056	0.044	0.021	0.013	0.011
Mg	1.32	1.30	1.97	1.68	0.71	0.40	0.30
Ca	1.71	1.93	1.59	1.04	0.473	0.245	0.166
Ba	0.067	0.063	0.044	0.027	0.012	0.006	0.005
C	0.175	4.29	21.2	42.4	65.9	78.8	81.3

Flotation test 8, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 8	Test 8	Test 8	Test 8	Test 8	Test 8	Test 8
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	66.0	58.7	32.5	27.3	15.6	13.9	5.10
TiO2	0.59	0.487	0.352	0.323	0.227	0.202	0.070
Al2O3	13.1	12.8	8.82	8.29	5.62	5.06	2.12
Cr2O3	0.020	0.019	0.018	0.019	0.015	0.013	0.0058
V2O3	0.069	0.070	0.076	0.074	0.066	0.060	0.025
FeO	7.30	6.51	5.25	5.35	3.64	3.27	1.55
MnO	0.050	0.045	0.041	0.041	0.028	0.028	0.012
MgO	2.24	1.90	1.60	1.46	1.16	1.03	0.38
CaO	2.41	2.44	1.51	1.39	0.84	0.73	0.197
Rb2O	0.0067	0.0045	0.0012	0.0000	0.0000	0.0035	0.0014
SrO	0.025	0.022	0.012	0.0038	0.0021	0.0013	0.0000
BaO	0.072	0.064	0.033	0.029	0.014	0.013	0.005
Na2O	2.63	2.32	1.13	0.94	0.47	0.43	0.10
K2O	2.51	2.27	1.58	1.38	0.99	0.90	0.413
ZrO2	0.029	0.025	0.016	0.009	0.008	0.006	0.002
P2O5	0.196	0.173	0.113	0.110	0.067	0.060	0.018
OxSumm	99.10	99.40	99.10	95.80	96.40	96.20	94.90
Cu	0.013	0.019	0.014	0.016	0.008	0.008	0.004
Ni	0.020	0.018	0.014	0.014	0.010	0.009	0.005
Co	0.030	0.016	0.019	0.037	0.010	0.013	0.003
Zn	0.029	0.029	0.024	0.026	0.016	0.014	0.006
Pb	0.009	0.010	0.013	0.025	0.015	0.015	0.009
Ag	0.000	0.002	0.001	0.001	0.000	0.000	0.000
S	2.95	2.29	1.62	1.63	1.07	1.01	0.468
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.010	0.003	0.000	0.001	0.000	0.000
Bi	0.003	0.003	0.002	0.004	0.002	0.003	0.002
Nb	0.0020	0.0017	0.0029	0.0029	0.0022	0.0020	0.0011
Mo	0.0015	0.012	0.022	0.013	0.015	0.011	0.0052
Sn	0.003	0.002	0.001	0.001	0.001	0.001	0.000
W	0.000	0.001	0.001	0.000	0.001	0.001	0.001
Cl	0.004	0.002	0.003	0.005	0.002	0.004	0.002
Th	0.0011	0.0008	0.0000	0.0029	0.0022	0.0017	0.0009
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.000	0.000	0.000	0.001	0.001	0.001	0.001
La	0.006	0.004	0.004	0.003	0.003	0.002	0.001
Ce	0.009	0.007	0.005	0.005	0.003	0.003	0.001
Si	30.9	27.5	15.2	12.8	7.30	6.50	2.38
Ti	0.355	0.292	0.211	0.194	0.136	0.121	0.042
Cr	0.014	0.013	0.012	0.013	0.011	0.0092	0.0040
V	0.047	0.047	0.052	0.050	0.045	0.041	0.017
Fe	5.68	5.06	4.08	4.16	2.83	2.54	1.20
Mn	0.039	0.035	0.032	0.032	0.022	0.021	0.009
Mg	1.35	1.14	0.96	0.88	0.70	0.62	0.23
Ca	1.72	1.74	1.08	0.99	0.60	0.52	0.141
Ba	0.065	0.058	0.030	0.026	0.013	0.012	0.005
C	0.204	10.2	45.1	48.1	67.0	69.9	84.6

Flotation test 9, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 9	Test 9	Test 9	Test 9	Test 9	Test 9	Test 9
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	65.9	61.2	39.6	23.8	15.7	14.1	4.82
TiO2	0.57	0.51	0.436	0.320	0.233	0.213	0.065
Al2O3	13.1	13.3	11.0	7.86	5.68	5.19	2.01
Cr2O3	0.018	0.021	0.023	0.019	0.015	0.014	0.0057
V2O3	0.065	0.073	0.095	0.088	0.070	0.065	0.023
FeO	7.38	6.44	6.18	4.94	3.78	3.55	1.49
MnO	0.052	0.050	0.050	0.040	0.032	0.028	0.011
MgO	2.28	2.02	2.15	1.66	1.20	1.09	0.35
CaO	2.43	2.53	1.85	1.26	0.85	0.76	0.181
Rb2O	0.0065	0.0050	0.0051	0.0003	0.0000	0.0000	0.0014
SrO	0.024	0.022	0.014	0.0088	0.0058	0.0024	0.0001
BaO	0.070	0.069	0.041	0.022	0.015	0.013	0.004
Na2O	2.63	2.40	1.37	0.78	0.47	0.42	0.09
K2O	2.50	2.37	1.94	1.38	1.03	0.93	0.390
ZrO2	0.029	0.026	0.021	0.015	0.010	0.008	0.003
P2O5	0.178	0.173	0.132	0.094	0.065	0.063	0.016
OxSumm	99.10	99.30	95.40	96.50	94.10	93.20	97.60
Cu	0.012	0.018	0.016	0.011	0.007	0.008	0.004
Ni	0.022	0.017	0.016	0.012	0.010	0.010	0.004
Co	0.019	0.020	0.018	0.010	0.008	0.017	0.004
Zn	0.029	0.031	0.026	0.018	0.014	0.014	0.008
Pb	0.009	0.011	0.011	0.013	0.013	0.015	0.009
Ag	0.000	0.001	0.000	0.000	0.000	0.000	0.000
S	2.96	2.19	1.88	1.58	1.21	1.13	0.449
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.011	0.009	0.001	0.001	0.000	0.000
Bi	0.003	0.003	0.003	0.003	0.003	0.002	0.002
Nb	0.0024	0.0025	0.0023	0.0034	0.0032	0.0025	0.0012
Mo	0.0007	0.011	0.030	0.028	0.020	0.015	0.0055
Sn	0.003	0.003	0.002	0.001	0.001	0.001	0.000
W	0.000	0.001	0.001	0.000	0.000	0.000	0.001
Cl	0.005	0.003	0.003	0.003	0.003	0.004	0.003
Th	0.0017	0.0010	0.0005	0.0000	0.0016	0.0021	0.0009
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.003	0.002	0.001	0.000	0.000	0.001
La	0.005	0.006	0.004	0.002	0.003	0.001	0.001
Ce	0.008	0.007	0.005	0.004	0.002	0.003	0.001
Si	30.8	28.6	18.5	11.1	7.36	6.59	2.25
Ti	0.341	0.307	0.262	0.192	0.140	0.128	0.039
Cr	0.012	0.015	0.016	0.013	0.011	0.0093	0.0039
V	0.044	0.049	0.065	0.059	0.048	0.044	0.016
Fe	5.74	5.01	4.80	3.84	2.94	2.76	1.15
Mn	0.041	0.039	0.039	0.031	0.025	0.022	0.009
Mg	1.38	1.22	1.30	1.00	0.72	0.66	0.21
Ca	1.73	1.81	1.32	0.90	0.60	0.54	0.129
Ba	0.063	0.062	0.037	0.020	0.014	0.012	0.004
C	0.199	6.84	29.4	53.2	64.2	66.1	87.9

Flotation test 10, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 10	Test 10	Test 10	Test 10	Test 10	Test 10	Test 10
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	66.6	34.0	19.1	7.77	4.06	3.39	3.08
TiO2	0.59	0.345	0.202	0.097	0.059	0.049	0.042
Al2O3	13.1	8.82	5.16	2.55	1.60	1.40	1.29
Cr2O3	0.018	0.020	0.013	0.0069	0.0044	0.0042	0.0039
V2O3	0.065	0.070	0.044	0.025	0.019	0.016	0.015
FeO	6.91	6.38	4.34	2.68	1.96	1.57	1.52
MnO	0.042	0.054	0.036	0.021	0.015	0.012	0.012
MgO	2.14	1.72	0.90	0.40	0.25	0.22	0.20
CaO	2.39	1.45	0.82	0.343	0.182	0.143	0.120
Rb2O	0.0050	0.0028	0.0000	0.0021	0.0011	0.0007	0.0010
SrO	0.024	0.013	0.0072	0.0011	0.0000	0.0000	0.0000
BaO	0.074	0.037	0.021	0.010	0.006	0.004	0.004
Na2O	2.72	1.20	0.62	0.20	0.07	0.06	0.05
K2O	2.48	1.64	0.96	0.450	0.285	0.248	0.232
ZrO2	0.028	0.017	0.010	0.004	0.002	0.001	0.001
P2O5	0.175	0.098	0.058	0.030	0.020	0.018	0.014
OxSumm	99.20	94.60	97.80	97.00	98.60	98.40	98.20
Cu	0.011	0.016	0.011	0.008	0.006	0.007	0.006
Ni	0.021	0.014	0.009	0.006	0.004	0.004	0.004
Co	0.020	0.012	0.013	0.010	0.011	0.016	0.016
Zn	0.028	0.020	0.014	0.010	0.008	0.008	0.008
Pb	0.010	0.011	0.012	0.012	0.010	0.009	0.009
Ag	0.001	0.000	0.000	0.000	0.000	0.000	0.000
S	3.03	1.49	0.97	0.65	0.487	0.494	0.475
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.007	0.002	0.000	0.000	0.000	0.000
Bi	0.003	0.002	0.003	0.002	0.002	0.002	0.002
Nb	0.0022	0.0024	0.0030	0.0019	0.0014	0.0015	0.0011
Mo	0.0006	0.013	0.0099	0.0075	0.0050	0.0035	0.0030
Sn	0.003	0.002	0.001	0.001	0.000	0.000	0.000
W	0.000	0.001	0.000	0.001	0.001	0.001	0.001
Cl	0.005	0.002	0.003	0.003	0.002	0.003	0.003
Th	0.0016	0.0000	0.0000	0.0012	0.0011	0.0010	0.0007
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.001	0.001	0.001	0.001	0.001	0.001
La	0.007	0.004	0.003	0.002	0.001	0.002	0.002
Ce	0.009	0.005	0.003	0.002	0.001	0.002	0.001
Si	31.1	15.9	8.94	3.63	1.90	1.58	1.44
Ti	0.352	0.207	0.121	0.058	0.035	0.029	0.025
Cr	0.012	0.014	0.0092	0.0047	0.0030	0.0029	0.0027
V	0.044	0.048	0.030	0.017	0.013	0.011	0.0099
Fe	5.38	4.96	3.37	2.09	1.52	1.22	1.18
Mn	0.033	0.042	0.028	0.017	0.012	0.009	0.009
Mg	1.29	1.03	0.54	0.24	0.15	0.13	0.12
Ca	1.71	1.03	0.58	0.245	0.130	0.102	0.086
Ba	0.066	0.033	0.019	0.009	0.005	0.004	0.004
Eltra C	0.184	37.9	64.9	82.0	89.8	90.9	91.3

Flotation test 11, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 11	Test 11	Test 11	Test 11	Test 11	Test 11	Test 11
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	66.5	46.1	39.3	14.7	5.86	4.33	3.09
TiO2	0.58	0.437	0.361	0.173	0.080	0.064	0.039
Al2O3	13.1	11.6	10.5	4.63	2.20	1.70	1.25
Cr2O3	0.017	0.025	0.021	0.012	0.0061	0.0045	0.0038
V2O3	0.064	0.087	0.073	0.043	0.025	0.020	0.014
FeO	6.94	8.10	8.49	4.74	2.40	1.81	1.39
MnO	0.044	0.075	0.073	0.040	0.020	0.015	0.012
MgO	2.16	2.37	1.84	0.74	0.37	0.28	0.20
CaO	2.41	1.91	1.64	0.69	0.276	0.198	0.118
Rb2O	0.0066	0.0066	0.0045	0.0000	0.0015	0.0011	0.0010
SrO	0.024	0.017	0.015	0.0059	0.0002	0.0000	0.0000
BaO	0.072	0.051	0.039	0.015	0.008	0.005	0.004
Na2O	2.70	1.73	1.42	0.42	0.12	0.08	0.05
K2O	2.49	2.10	1.74	0.80	0.392	0.309	0.229
ZrO2	0.029	0.023	0.020	0.009	0.003	0.002	0.002
P2O5	0.172	0.148	0.135	0.057	0.026	0.021	0.013
OxSumm	99.20	97.10	96.70	95.90	94.00	95.70	97.70
Cu	0.011	0.025	0.022	0.012	0.006	0.004	0.003
Ni	0.021	0.017	0.018	0.010	0.006	0.005	0.004
Co	0.018	0.022	0.021	0.010	0.007	0.011	0.008
Zn	0.029	0.032	0.032	0.017	0.009	0.006	0.005
Pb	0.009	0.013	0.015	0.014	0.012	0.010	0.009
Ag	0.002	0.002	0.001	0.001	0.000	0.000	0.000
S	3.07	1.87	1.77	0.95	0.58	0.481	0.381
As	0.000	0.001	0.001	0.000	0.000	0.000	0.000
Sb	0.012	0.010	0.009	0.003	0.000	0.000	0.000
Bi	0.003	0.003	0.003	0.003	0.002	0.002	0.002
Nb	0.0018	0.0025	0.0033	0.0031	0.0015	0.0011	0.0010
Mo	0.0005	0.013	0.018	0.018	0.0086	0.0055	0.0052
Sn	0.004	0.003	0.002	0.002	0.001	0.000	0.000
W	0.000	0.001	0.000	0.001	0.000	0.000	0.001
Cl	0.006	0.003	0.004	0.003	0.003	0.003	0.003
Th	0.0013	0.0003	0.0003	0.0014	0.0014	0.0010	0.0006
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.001	0.002	0.002	0.001	0.002	0.001	0.001
La	0.006	0.004	0.005	0.002	0.002	0.002	0.002
Ce	0.009	0.004	0.005	0.003	0.002	0.001	0.001
Si	31.1	21.5	18.4	6.89	2.74	2.02	1.44
Ti	0.349	0.262	0.217	0.104	0.048	0.039	0.023
Cr	0.012	0.017	0.014	0.0085	0.0042	0.0031	0.0026
V	0.044	0.059	0.050	0.029	0.017	0.013	0.0092
Fe	5.40	6.30	6.60	3.68	1.87	1.41	1.08
Mn	0.034	0.058	0.057	0.031	0.015	0.012	0.009
Mg	1.30	1.43	1.11	0.45	0.22	0.17	0.12
Ca	1.72	1.36	1.17	0.493	0.197	0.142	0.084
Ba	0.065	0.045	0.035	0.014	0.007	0.005	0.004
Eltra C	0.163	21.2	30.0	68.2	81.8	86.5	91.0

Flotation test 12, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 12	Test 12	Test 12	Test 12	Test 12	Test 12	Test 12
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	66.1	63.4	46.4	31.3	20.0	16.5	5.41
TiO2	0.58	0.50	0.447	0.383	0.290	0.249	0.075
Al2O3	13.1	13.3	11.7	9.51	6.99	5.99	2.23
Cr2O3	0.019	0.018	0.021	0.022	0.018	0.017	0.0060
V2O3	0.068	0.066	0.086	0.095	0.084	0.076	0.027
FeO	7.31	7.12	6.70	6.03	4.37	3.88	1.73
MnO	0.052	0.049	0.053	0.050	0.038	0.033	0.014
MgO	2.27	1.95	2.12	1.93	1.54	1.31	0.40
CaO	2.38	2.51	2.03	1.58	1.09	0.89	0.210
Rb2O	0.0069	0.0065	0.0047	0.0035	0.0002	0.0000	0.0000
SrO	0.024	0.024	0.017	0.012	0.0078	0.0064	0.0011
BaO	0.070	0.070	0.047	0.032	0.020	0.016	0.005
Na2O	2.65	2.52	1.71	1.08	0.64	0.52	0.11
K2O	2.51	2.35	2.05	1.67	1.25	1.08	0.438
ZrO2	0.029	0.027	0.024	0.019	0.013	0.011	0.005
P2O5	0.170	0.180	0.150	0.118	0.081	0.069	0.018
OxSumm	99.20	99.20	99.00	97.00	96.50	95.20	94.20
Cu	0.011	0.019	0.016	0.014	0.009	0.008	0.004
Ni	0.020	0.019	0.017	0.015	0.011	0.010	0.005
Co	0.017	0.020	0.022	0.017	0.010	0.009	0.003
Zn	0.028	0.031	0.028	0.025	0.017	0.016	0.007
Pb	0.008	0.009	0.010	0.012	0.011	0.012	0.008
Ag	0.001	0.001	0.001	0.001	0.001	0.001	0.001
S	2.95	2.60	2.11	1.77	1.33	1.26	0.53
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.011	0.010	0.008	0.002	0.003	0.002
Bi	0.002	0.003	0.002	0.003	0.003	0.002	0.001
Nb	0.0018	0.0017	0.0017	0.0029	0.0032	0.0033	0.0013
Mo	0.0001	0.0080	0.025	0.029	0.024	0.021	0.011
Sn	0.003	0.004	0.003	0.001	0.000	0.002	0.002
W	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Cl	0.005	0.002	0.003	0.004	0.004	0.004	0.003
Th	0.0016	0.0018	0.0009	0.0003	0.0000	0.0016	0.0010
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.005	0.003	0.002	0.001	0.001	0.001	0.002
La	0.007	0.003	0.005	0.003	0.003	0.003	0.002
Ce	0.007	0.007	0.006	0.004	0.004	0.003	0.001
Si	30.9	29.7	21.7	14.6	9.37	7.70	2.53
Ti	0.348	0.300	0.268	0.230	0.174	0.149	0.045
Cr	0.013	0.012	0.014	0.015	0.012	0.012	0.0041
V	0.046	0.045	0.059	0.065	0.057	0.051	0.018
Fe	5.68	5.54	5.21	4.69	3.40	3.02	1.34
Mn	0.041	0.038	0.041	0.039	0.029	0.026	0.011
Mg	1.37	1.17	1.28	1.17	0.93	0.79	0.24
Ca	1.70	1.79	1.45	1.13	0.78	0.64	0.150
Ba	0.063	0.063	0.042	0.029	0.018	0.014	0.004
Eltra C	0.161	3.56	24.1	42.1	59.2	63.8	83.2

Flotation test 13, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 13	Test 13	Test 13	Test 13	Test 13	Test 13	Test 13
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	66.6	57.5	46.1	12.6	6.32	3.06	2.08
TiO2	0.59	0.54	0.481	0.203	0.099	0.048	0.027
Al2O3	13.1	14.4	13.0	4.90	2.56	1.32	0.94
Cr2O3	0.018	0.028	0.027	0.015	0.0076	0.0042	0.0023
V2O3	0.067	0.109	0.110	0.069	0.034	0.018	0.012
FeO	6.96	8.69	8.84	5.71	3.37	1.68	1.20
MnO	0.044	0.080	0.080	0.059	0.032	0.015	0.011
MgO	2.21	2.86	2.65	1.27	0.53	0.24	0.15
CaO	2.40	2.47	2.15	0.56	0.293	0.134	0.071
Rb2O	0.0053	0.0091	0.0070	0.0000	0.0000	0.0010	0.0005
SrO	0.024	0.021	0.017	0.0052	0.0006	0.0000	0.0000
BaO	0.068	0.057	0.043	0.012	0.007	0.004	0.002
Na2O	2.68	2.33	1.70	0.28	0.12	0.04	0.02
K2O	2.50	2.57	2.21	1.01	0.498	0.256	0.187
ZrO2	0.027	0.027	0.024	0.008	0.004	0.002	0.001
P2O5	0.174	0.172	0.156	0.038	0.021	0.012	0.007
OxSumm	99.20	97.50	97.50	91.30	95.40	94.70	92.60
Cu	0.011	0.022	0.021	0.009	0.005	0.003	0.002
Ni	0.021	0.019	0.019	0.009	0.006	0.004	0.003
Co	0.022	0.025	0.025	0.011	0.005	0.007	0.007
Zn	0.029	0.032	0.032	0.013	0.008	0.005	0.005
Pb	0.011	0.009	0.012	0.014	0.011	0.009	0.008
Ag	0.001	0.001	0.001	0.000	0.000	0.000	0.000
S	2.99	2.22	2.18	0.81	0.54	0.361	0.273
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.010	0.010	0.002	0.000	0.000	0.000
Bi	0.003	0.003	0.003	0.004	0.002	0.002	0.002
Nb	0.0026	0.0018	0.0020	0.0038	0.0019	0.0010	0.0008
Mo	0.0016	0.010	0.030	0.018	0.013	0.0077	0.0044
Sn	0.002	0.002	0.003	0.001	0.001	0.000	0.000
W	0.001	0.001	0.001	0.000	0.001	0.000	0.001
Cl	0.004	0.005	0.003	0.003	0.003	0.003	0.003
Th	0.0014	0.0015	0.0009	0.0022	0.0011	0.0010	0.0010
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.000	0.002	0.001	0.001	0.001	0.001	0.001
La	0.006	0.007	0.006	0.002	0.002	0.001	0.001
Ce	0.009	0.007	0.006	0.002	0.002	0.001	0.000
Si	31.1	26.9	21.6	5.88	2.96	1.43	0.97
Ti	0.354	0.327	0.288	0.122	0.059	0.029	0.016
Cr	0.012	0.019	0.018	0.011	0.0052	0.0029	0.0016
V	0.045	0.074	0.075	0.047	0.023	0.012	0.0081
Fe	5.41	6.75	6.87	4.44	2.62	1.31	0.93
Mn	0.034	0.062	0.062	0.045	0.025	0.012	0.009
Mg	1.33	1.73	1.60	0.77	0.32	0.14	0.09
Ca	1.72	1.77	1.53	0.401	0.209	0.096	0.051
Ba	0.061	0.051	0.038	0.011	0.006	0.004	0.002
Eltra C	0.167	4.39	18.6	64.1	81.1	87.6	87.7

Flotation test 14, chemical analysis: C content by Eltra (%), other element contents by XRF (%) method 180X-O.

	Test 14	Test 14	Test 14	Test 14	Test 14	Test 14	Test 14
Element	**Tails**	**CT1**	**CT2**	**CT3**	**CT4**	**CT5**	**CC5**
SiO2	60.1	52.9	41.6	16.1	5.43	4.09	3.59
TiO2	0.64	0.64	0.58	0.321	0.137	0.100	0.082
Al2O3	13.3	13.3	11.8	5.40	2.19	1.75	1.62
Cr2O3	0.028	0.029	0.029	0.016	0.0077	0.0053	0.0047
V2O3	0.099	0.135	0.137	0.094	0.046	0.036	0.031
FeO	9.29	11.0	10.7	5.47	2.35	1.88	1.76
MnO	0.096	0.107	0.105	0.054	0.021	0.017	0.016
MgO	3.72	4.12	3.77	1.82	0.78	0.61	0.54
CaO	4.55	4.98	4.77	2.51	1.08	0.90	0.93
Rb2O	0.0061	0.0056	0.0055	0.0000	0.0000	0.0013	0.0013
SrO	0.029	0.028	0.024	0.011	0.0022	0.0009	0.0012
BaO	0.049	0.048	0.040	0.021	0.008	0.007	0.006
Na2O	2.03	1.70	1.28	0.40	0.10	0.07	0.06
K2O	2.06	2.04	1.78	0.89	0.364	0.280	0.251
ZrO2	0.023	0.019	0.015	0.006	0.002	0.002	0.002
P2O5	0.315	0.289	0.235	0.089	0.028	0.021	0.018
OxSumm	98.90	96.80	97.30	94.20	96.60	95.60	95.10
Cu	0.040	0.029	0.025	0.011	0.004	0.003	0.003
Ni	0.029	0.030	0.027	0.013	0.006	0.005	0.005
Co	0.024	0.025	0.022	0.010	0.007	0.008	0.006
Zn	0.030	0.032	0.030	0.015	0.006	0.005	0.005
Pb	0.009	0.010	0.008	0.011	0.010	0.009	0.009
Ag	0.001	0.001	0.002	0.001	0.000	0.000	0.000
S	3.08	2.75	2.53	1.01	0.382	0.296	0.246
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.013	0.012	0.012	0.001	0.001	0.000	0.000
Bi	0.003	0.003	0.002	0.003	0.002	0.001	0.002
Nb	0.0019	0.0023	0.0015	0.0024	0.0013	0.0014	0.0013
Mo	0.0009	0.0093	0.034	0.042	0.020	0.014	0.012
Sn	0.004	0.005	0.005	0.001	0.001	0.000	0.000
W	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cl	0.004	0.005	0.004	0.003	0.003	0.002	0.003
Th	0.0006	0.0007	0.0016	0.0000	0.0010	0.0010	0.0008
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.003	0.002	0.002	0.002	0.000	0.001	0.002
La	0.005	0.006	0.004	0.003	0.001	0.001	0.001
Ce	0.007	0.007	0.005	0.003	0.002	0.001	0.001
Si	28.1	24.7	19.4	7.52	2.54	1.91	1.68
Ti	0.381	0.385	0.346	0.192	0.082	0.060	0.049
Cr	0.019	0.020	0.020	0.011	0.0053	0.0036	0.0032
V	0.067	0.092	0.093	0.064	0.031	0.025	0.021
Fe	7.22	8.52	8.29	4.25	1.83	1.46	1.37
Mn	0.074	0.083	0.081	0.042	0.017	0.013	0.013
Mg	2.24	2.48	2.28	1.10	0.47	0.37	0.33
Ca	3.25	3.56	3.41	1.79	0.77	0.64	0.66
Ba	0.044	0.043	0.036	0.018	0.007	0.006	0.005
Eltra C	0.81	3.91	19.0	60.4	83.8	85.6	86.0

Report No.: 029446 7.3.2018

GTK MMA Laboratoriot 5040300093
Krista Koistinen
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83500 OUTOKUMPU

Request: S18-08403
Customer referral number:
Order number: S18-08403
Received on: 1.3.2018

Results

Analytical method: 811L
Analytical method description: Analysis of C by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	811L *
Parameter	C *
Unit	%
Detection Limit	0.05
Sample id	
RTL / PH-16	11.5
RTL / PH-16 (2)	11.5
RTL / PH-17	9.57

Analytical method: 816L
Analytical method description: Determination of C carb and C non carb by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	816L	816L
Parameter	C carb	C non carb
Unit	%	%
Detection Limit	0.05	0.05
Sample id		
RTL / PH-16	1.23	10.3
RTL / PH-16 (2)	1.28	10.3
RTL / PH-17	<0.05	9.57

Quality control samples

Analytical method: 811L
Analytical method description: Analysis of C by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	811L *
Parameter	C *
Unit	%
Detection Limit	0.05
QC-Sample id / Description	
18007293 / QCGS310-7	4.11

* Accredited

7.3.2018 Timo Myöhänen
Kemisti / Chemist

Distribution Koistinen, Krista / GTK MMA Laboratoriot 5040300093
Korhonen, Tero / GTK MMA Laboratoriot 5040300093

Report No.: 031294 10.4.2018

GTK MMA Laboratoriot 5040300093
Krista Koistinen
Tutkijankatu 1
83500 OUTOKUMPU

Request: S18-08894
Customer referral number: 50402-20048
Order number: S18-08894
Received on: 28.3.2018

Results

Analytical method: 811L
Analytical method description: Analysis of C by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	811L *
Parameter	C *
Unit	%
Detection Limit	0.05
Sample id	
Test 4 CC5	84.7
Test 4 CC5 (2)	84.9
Test 9 CC5	87.0
Test 11 CC5	92.3
Test 14 CC5	88.3

Analytical method: 816L
Analytical method description: Determination of C carb and C non carb by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	816L	816L
Parameter	C carb	C non carb
Unit	%	%
Detection Limit	0.05	0.05
Sample id		
Test 4 CC5	1.25	83.5
Test 4 CC5 (2)	1.30	83.6
Test 9 CC5	<0.05	87.1
Test 11 CC5	0.53	91.8
Test 14 CC5	1.28	87.1

Quality control samples

Analytical method: 811L
Analytical method description: Analysis of C by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	811L *
Parameter	C *
Unit	%
Detection Limit	0.05
QC-Sample id / Description	
18011039 / QC309E	13.0

Analytical method: 816L
Analytical method description: Determination of C carb and C non carb by combustion technique
Analyzed in laboratory: Kuopio

Analytical method code	816L
Parameter	C non carb
Unit	%
Detection Limit	0.05
QC-Sample id / Description	
18010199 / QCSK1	0.74
18010200 / QCUUTTOSOKEA	<0.05

* Accredited

10.4.2018 Susanna Arvilommi
Laboratoriopäällikkö/Laboratory manager

Distribution Koistinen, Krista / GTK MMA Laboratoriot 5040300093
Korhonen, Tero / GTK MMA Laboratoriot 5040300093

Appendix 2 – Flotation test report

Laboratory Beneficiation Testwork on Rautalampi Graphite Ore

FLOTATION TEST REPORT

Sample:	Rautalampi PH-16	**Grind:**	Mill:	Mild steel	**Remarks:** RC3: vaahdon muodostus huonoa, hiili alkaa loppua
Project:	Kriittiset Mineraalit		Charge:	8 kg balls	
Date:	31.10.2017		Water:	0.7 l	
Author:	Kpu	**Feed**		0.7019 kg	
Test no.:	1	**Screen anal:**			

			Reagents (g/t)/mL											Grades and Recoveries													
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (Eltra)	
	min	**min**	100 %	100 %	100 %	100 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	30																														
	0,07T												M1	22.8	3.3	5	1.32	25.20	1.57	6.07	1.68	1.7	1.7	33.9	17.8	1.69	1.84	0.13	1.21	17.60	22.16
NM1	0,3T												M2	8.6	1.2	6.40	0.68	30.10	0.71	8.00	0.84	2.7	1.0	26.9	5.3	2.82	1.16	0.22	0.78	14.00	6.65
													M1-2	31.5	4.5	5.17	1.99	26.54	2.28	6.60	2.52	1.97		31.98		2.00		0.15		16.61	
							2.5		1500				NM2	662.7	95.5	12.07	98.01	53.93	97.72	12.11	97.48	3.5	97.4	5.0	76.9	3.08	97.01	0.36	98.01	1.95	71.19
NM2		2	45						"	8.43																					
			0.032					2	"		6	6	RC1	87.8	12.6	58.0	62.37	19.90	4.77	5.87	6.26	1.8	6.8	3.4	6.9	1.97	8.23	0.18	6.56	1.05	5.08
									"	8.29			RT1	575.0	82.8	5.06	35.64	59.13	92.94	13.06	91.22	3.7	90.5	5.3	70.0	3.25	88.78	0.38	91.45	2.09	66.11
									"																						
RT1		2	45						"	8.33																					
			0.032					2	"		6	12	RC2	78.9	11.4	30.80	29.76	38.30	8.26	10.10	9.67	3.4	11.2	4.8	8.8	2.72	10.20	0.34	11.20	1.61	7.00
									"	8.28			RC1-2	166.6	24.0	45.13	92.12	28.61	13.03	7.87	15.93	2.6	18.1	4.1	15.7	2.32	18.43	0.26	17.76	1.32	12.08
									"				RT2	496.1	71.5	0.97	5.88	62.44	84.69	13.53	81.55	3.8	79.3	5.4	61.2	3.33	78.58	0.39	80.25	2.16	59.12
									"																						
RT2		2	45						"	8.32																					
			0.032					2	"		6	18	RC3	32.9	4.7	2.62	1.06	58.50	5.27	13.80	5.52	4.2	5.8	5.9	4.5	3.54	5.55	0.41	5.57	2.28	4.14
									"	8.29			RC1-3	199.6	28.7	38.11	93.18	33.54	18.30	8.85	21.45	2.8	23.9	4.4	20.1	2.53	23.98	0.28	23.33	1.47	16.22
									"				RT3	463.2	66.7	0.85	4.83	62.72	79.42	13.51	76.03	3.7	73.5	5.3	56.7	3.31	73.03	0.39	74.68	2.15	54.98
									"																						
RT3		2	45						"	8.29																					
			0.032					2	"		6	24	RC4	13.7	2.0	2.83	0.48	56.70	2.13	14.00	2.33	4.5	2.6	6.7	2.1	3.78	2.47	0.43	2.45	2.60	1.97
									"	8.24			RC1-4	213.3	30.7	35.8	93.7	35.0	20.4	9.2	23.8	2.9	26.5	4.5	22.2	2.61	26.45	0.29	25.77	1.55	18.18
													Tails	449.4	64.7	0.8	4.4	62.9	77.3	13.5	73.7	3.7	70.9	5.3	54.6	3.30	70.56	0.39	72.24	2.14	53.01
Total	30	8	1.80	0	0	0				Total	24		Calc Feed	694.2	100.0	11.8	100.0	52.7	100.0	11.9	100.0	3.4	100.0	6.3	100.0	3.0	100.0	0.3	100.0	2.6	100.0

FLOTATION TEST REPORT

Sample:	Rautalampi PH-16	**Grind:**	Mill:	Mild steel	**Remarks:** taukoaika 1.5s
Project:	Kriittiset Mineraalit		Charge:	8 kg balls	RC1 isokuplainen melko huono vaahto
Date:	2.11.2017		Water:	0.7 l	RC2 pieni kuplainen tod. Hyvä vaahto
Author:	KJP	**Feed**		0.702 kg	RC3 2 min kohdalla loppuu tavara
Test no.:	2	**Screen anal:**			

Feed	Grind	Cond	Reagents (g/t)/mL				Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		Grades and Recoveries													
																C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	min	Flotanol 7026 100 %	MIBC 100 %	CMC 100 %	Na2SiO2 100 %	l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																													
							2.5		1500	8.72																				
		2	45						"	8.74																				
			0.032					2	"	8.39	6	6	RC1																	
									"	8.3																				
RT1		2	45						"	8.39																				
			0.032					2	"	8.39	6	12	RC2																	
									"	8.4																				
RT2		2	45						"																					
			0.032					2	"	8.38	6	18	RC3																	
									"	8.36			RC1-3	194.5	27.8	38.44	94.69	33.48	17.58	8.50	20.01	2.60	21.46	4.97	21.00	2.45	22.71	0.25	22.40	1.77	17.92
									"				Tails	504.7	72.2	0.83	5.31	60.50	82.42	13.10	79.99	3.66	78.54	7.20	79.00	3.21	77.29	0.34	77.60	3.13	82.08
									"																					
							2.5		1500	8.55																				
RC1-3		3	10					2	"	8.43	6	24	CC1	100.0	14.3	70.05	88.73	12.12	3.27	4.16	5.04	1.44	6.12	2.91	6.32	1.44	6.89	0.14	6.33	0.80	4.13
			0.007						"				CT1	94.5	13.5	5.0	5.96	56.1	14.30	13.1	14.97	3.8	15.34	7.2	14.68	3.5	15.82	0.4	16.07	2.8	13.79
							15		1100	8.57																				
CC1		2	10					15	"	8.4	5	29	CC2	89.5	12.8	76.16	86.31	8.34	2.01	3.23	3.50	1.16	4.42	2.42	4.71	1.20	5.12	0.11	4.61	0.60	2.81
			0.007						"				CT2	10.5	1.5	18.2	2.43	44.2	1.26	12.1	1.54	3.8	1.71	7.1	1.61	3.5	1.77	0.4	1.71	2.4	1.32
									"																					
									"																					
CC2								15	"	8.53	4	33	CC3	81.4	11.6	78.38	80.83	7.19	1.58	2.87	2.82	1.02	3.54	2.19	3.88	1.10	4.26	0.10	3.67	0.53	2.23
									"	8.42			CT3	8.1	1.2	53.7	5.48	20.0	0.43	6.9	0.67	2.6	0.88	4.7	0.83	2.3	0.86	0.3	0.94	1.4	0.58
									"																					
									"																					
CC3								15	"	8.55	3	36	CC4	68.2	9.8	80.1	69.18	6.5	1.19	2.6	2.17	0.9	2.67	2.0	3.01	1.0	3.38	0.1	2.74	0.5	1.68
									"	8.46			CT4	13.2	1.9	69.5	11.66	10.8	0.39	4.1	0.66	1.6	0.87	3.0	0.87	1.4	0.88	0.2	0.94	0.8	0.55
Total	45	11	155	0	0	0				Total	36	36	Calc Feed	699.2	100.0	11.3	100.0	53.0	100.0	11.8	100.0	3.4	100.0	6.6	100.0	3.0	100.0	0.3	100.0	2.8	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-16	**Grind:** Mill:		Mild steel	**Remarks:** **taukoaika 1.5s**
Project:	Kriittiset Mineraalit	Charge:		8 kg balls	RC1 hyvä vaahto, kesto n. 3 min
Date:	7.11.2017	Water:		0.7 l	RC2 pieni kuplainen tood. Hyvä vaahto, kesto n. 3min
Author:	Kpu	**Feed**		0.702 kg	RC3 mieto vaahto, hyvin vähän hiiltä jäljellä
Test no.:	3	**Screen anal:**			

			Reagents (g/t)/mL												**Grades and Recoveries**													
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	100 %	**l**	**l/min**	**rpm**		**min**	**min**		**g**	**%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**
-14mm	15																														
							2.5		1500	8.41																					
		2	45						"	8.43																					
			0.032					2	"	8.35	6	6	RC1																		
									"	8.4																					
RT1		2	45						"	8.4																					
			0.032					2	"	8.42	6	12	RC2																		
									"	8.42																					
RT2		2	45						"	8.42																					
			0.032					2	"	8.44	6	18	RC3																		
									"				RC1-3	211.2	30.2	34.27	95.13	33.13	18.91	9.47	23.86	3.22	28.56	5.42	26.21	2.72	27.13	0.30	26.06	197	21.74
									"				Tails	487.0	69.8	0.76	4.87	61.60	81.09	13.10	76.14	3.49	71.44	6.62	73.79	3.17	72.87	0.37	73.94	3.08	78.26
									"																						
							2.5		1500	8.51																					
RC1-3		2	10					2	"	8.44	6	24	CC1	129.7	18.6	51.88	88.46	20.34	7.13	6.87	10.64	2.53	13.78	4.35	12.90	2.11	12.90	0.24	12.66	1.41	9.54
			0.007						"				CT1	81.4	11.7	6.2	6.67	53.5	11.78	13.6	13.22	4.3	14.79	7.1	13.31	3.7	14.22	0.4	13.40	2.9	12.20
							15		1100	8.56																					
CC1		2	10					15	"	8.59	5	29	CC2	116.7	16.7	55.77	85.58	17.74	5.60	6.20	8.64	2.31	11.33	4.01	10.71	1.94	10.71	0.22	10.54	1.24	7.56
			0.007						"	8.45			CT2	13.0	1.9	16.9	2.89	43.7	1.53	12.9	2.00	4.5	2.45	7.4	2.20	3.6	2.19	0.4	2.12	2.9	1.99
									"																						
									"																						
CC2								15	"	8.51	4	33	CC3	99.9	14.3	58.88	77.33	15.63	4.22	5.59	6.66	2.08	8.73	3.68	8.40	1.82	8.59	0.20	8.21	1.09	5.68
									"	8.43			CT3	16.8	2.4	37.3	8.25	30.3	1.38	9.8	1.98	3.7	2.60	6.0	2.30	2.7	2.12	0.3	2.33	2.1	1.88
									"																						
									"																						
CC3								15	"	8.58	3	36	CC4	77.2	11.1	61.4	62.31	13.9	2.90	5.1	4.66	1.9	6.04	3.4	5.97	1.7	6.34	0.2	5.64	1.0	3.87
									"				CT4	22.7	3.3	50.3	15.02	21.5	1.32	7.4	2.00	2.8	2.69	4.7	2.43	2.1	2.25	0.3	2.57	1.5	1.81

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-16	**Grind:** Mill:	Mild steel	**Remarks:**	taukoaika 1.5s PH-16 229.10-240.05
Project:	Kriittiset Mineraalit	Charge:	8 kg balls		RC1 iso kupla, liian vähän vaahdotetta?
Date:	03.01.2018	Water:	0.7 l		RC2 pieni kupla, korkea vaahtopatja
Author:	KJP	**Feed**	0.703 kg		RC3 kohtalainen vaahto, alkaa loppua 2 min kohdalla
Test no.:	Test 4	**Screen anal:**			CC2 ei välttämättä tarvitse vaahdotetta

			Reagents (g/t)/mL												Grades and Recoveries													
Feed	Grind	Cond	Flotanol 7026	MIBC	CMC	Na2SiO2	Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	min	100 %	100 %	100 %	100 %	l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	60																													
							2.5		1500	8.98																				
		2	45						"	9.03																				
			0.032					2	"	8.86	6	6	RC1																	
									"	8.54																				
RT1		2	45						"	8.51																				
			0.032					2	"	8.52	6	12	RC2																	
									"	8.5																				
RT2		2	45						"																					
			0.032					2	"	8.49	6	18	RC3																	
									"				RC1-3	192.5	27.3	38.55	94.90	32.95	17.49	8.36	19.12	2.47	19.21	4.90	20.90	2.37	21.85	0.24	19.32	1.74	18.88
									"				Tails	511.5	72.7	0.78	5.10	58.50	82.51	13.30	80.88	3.91	80.79	6.98	79.10	3.19	78.15	0.38	80.68	2.81	81.12
									"																					
							2.5		1500	8.58																				
RC1-3		2	10					2	"		6	24	CC1	99.3	14.1	70.32	89.29	11.13	3.05	3.81	4.49	1.27	5.08	2.66	5.86	1.32	6.26	0.12	5.08	0.69	3.89
			0.007						"	8.5			CT1	93.2	13.2	4.7	5.60	56.2	14.45	13.2	14.63	3.8	14.12	7.3	15.04	3.5	15.59	0.4	14.24	2.9	15.00
							15		1100	8.68																				
CC1		2	10					15	"		5	29	CC2	88.3	12.5	77.17	87.14	6.90	1.68	2.77	2.91	0.96	3.44	2.12	4.14	1.05	4.43	0.09	3.51	0.48	2.37
			0.007						"	8.55			CT2	11.0	1.6	15.3	2.15	45.1	1.37	12.1	1.58	3.7	1.65	7.1	1.72	3.5	1.83	0.3	1.57	2.5	1.52
									"																					
									"	8.72																				
CC2								15	"		4	33	CC3	79.1	11.2	79.72	80.59	5.66	1.23	2.37	2.23	0.81	2.59	1.86	3.27	0.93	3.53	0.08	2.64	0.40	1.76
									"				CT3	9.3	1.3	55.4	6.55	17.5	0.45	6.2	0.68	2.3	0.84	4.3	0.88	2.0	0.90	0.2	0.87	1.2	0.61
									"																					
									"	8.66																				
CC3								15	"		3	36	CC4	62.8	8.9	81.49	65.42	5.07	0.88	2.18	1.63	0.74	1.87	1.72	2.39	0.88	2.65	0.07	1.84	0.36	1.26
									"	8.57			CT4	16.3	2.3	72.9	15.17	7.9	0.36	3.1	0.60	1.1	0.72	2.4	0.87	1.1	0.88	0.1	0.81	0.6	0.51
CC4								15	"		3	39	CC5	45.3	6.4	82.1	47.59	4.9	0.61	2.1	1.15	0.7	1.32	1.7	1.68	0.9	1.91	0.1	1.24	0.3	0.86
									"	8.57			CT5	17.5	2.5	79.9	17.83	5.6	0.27	2.3	0.48	0.8	0.55	1.9	0.72	0.9	0.74	0.1	0.60	0.4	0.39
Total	60	10	155	0	0	0				Total	39	39	Calc Feed	704.0	100.0	11.1	100.0	51.5	100.0	11.9	100.0	3.5	100.0	6.4	100.0	3.0	100.0	0.3	100.0	2.5	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-16	**Grind:**	Mill:	Mild steel	**Remarks:** taukoaika 1.5s
Project:	Kriittiset Mineraalit		Charge:	8 kg balls	Näytteen tiheys 2.71
Date:	23.1.2018		Water:	0.7 l	
Author:	KJP, Arvo, Dandara	**Feed**		0.7 kg	
Test no.:	5	**Screen anal:**			

Feed	Grind	Cond	Reagents (g/t)/mL				Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		Grades and Recoveries											
			Flotanol 7026	MIBC	CMC	Na2SiO2										C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	min	100 %	100 %	100 %	100 %	l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																													
		Slime separation					4	0.142					-10µm	3.4	0.5	4	0.19	59	0.55	15.200	0.61	2.67	0.38	5.1	0.38	3.65	0.59	0.32	0.45	15	0.27
+10µm		Slime separation					4	0.32					-15µm	125.8	18.1	9	14.03	55	19.20	13.200	19.63	3.13	16.28	5.5	15.35	3.91	23.47	0.30	15.34	18	11.84
													<15µm	129.2	18.6	8.73	14.21														
													+15µm	564.7	81.4	12.06	85.79	51.49	80.25	11.95	79.76	3.57	83.35	6.70	84.27	2.82	75.94	0.36	84.21	2.98	87.89
							2.5		1500	8.7																				
+15µm		2	45						"	8.7																				
			0.032					2	"	8.4	6	6	RC1																	
									"	8.4																				
RT1		2	45						"	8.4																				
			0.032					2	"	8.4	6	12	RC2																	
									"	8.4																				
RT2		2	45						"	8.4																				
			0.032					2	"	8.4	6	18	RC3																	
									"				RC1-3	129.5	18.7	50.35	82.17	23.57	8.42	7.07	10.83	2.40	12.82	4.43	12.76	2.14	13.22	0.23	12.20	1.46	9.87
									"				Tails	435.2	62.7	0.66	3.62	59.80	71.83	13.40	68.93	3.92	70.52	7.38	71.51	3.02	62.72	0.40	72.01	3.43	78.02
									"																					
							2.5		1500	8.4																				
RC1-3		2	10					2	"	8.5	6	24	CC1	88.7	12.8	70.83	79.16	10.40	2.55	4.02	4.22	1.49	5.45	2.84	5.61	1.40	5.92	0.14	5.21	0.73	3.38
			0.007						"	8.5			CT1	40.8	5.9	5.8	3.00	52.2	5.88	13.7	6.61	4.4	7.37	7.9	7.15	3.8	7.30	0.4	6.99	3.0	6.48
							15		1100	8.6																				
CC1		2	10					15	"	8.4	5	29	CC2	81.6	11.8	74.94	77.05	8.20	1.85	3.33	3.21	1.21	4.08	2.43	4.41	1.23	4.78	0.12	4.00	0.57	2.43
			0.007						"				CT2	7.1	1.0	23.6	2.11	35.6	0.70	12.0	1.01	4.7	1.38	7.6	1.20	3.4	1.14	0.4	1.21	2.6	0.95
									"																					
									"	0.5																				
CC2								15	"	8.4	4	33	CC3	72.8	10.5	77.77	71.34	6.96	1.40	2.90	2.49	1.03	3.09	2.16	3.50	1.12	3.87	0.10	2.99	0.48	1.84
									"				CT3	8.8	1.3	5.15	5.71	18.5	0.45	6.9	0.72	2.7	0.99	4.7	0.91	2.2	0.90	0.3	1.01	1.3	0.60
									"																					
									"	8.5																				
CC3								15	"	8.5	3	36	CC4	59.4	8.6	80.00	59.88	6.25	1.02	2.66	1.87	0.93	2.28	2.00	2.64	1.06	3.00	0.09	2.15	0.43	1.34
									"				CT4	13.4	1.9	67.9	11.46	10.1	0.37	4.0	0.63	1.5	0.80	2.9	0.86	1.4	0.87	0.2	0.85	0.7	0.50
Total	45	10	155	0	0	0				Total	36	36	Calc Feed	693.9	100.0	11.4	100.0	52.2	100.0	12.2	100.0	3.5	100.0	6.5	100.0	3.0	100.0	0.4	100.0	2.8	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-16	**Grind:** Mill:	Mild steel	**Remarks:**	**taukoaika 1.5s**
Project:	Kriittiset Mineraalit	Charge:	8 kg balls		RC1 hyvä vaahto, pienempi kupla kuin Flotanol 7026
Date:	25.1.2017	Water:	0.7 l		RC2 hyvä vaahto
Author:	KJP	**Feed**	0.7 kg		RC3 Malko vaalea vaahto
Test no.:	6	**Screen anal:**			CC3 vaahto ei nouse, annosteltu MIBC (MIBC tarvitsee suuremmat annostukset kuin Flotanol)

			Reagents (g/t)/mL												Grades and Recoveries													
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	100 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																														
							2.5		1500	8.8																					
		2		45					"	8.8																					
				0.032				2	"	8.6	6	6	RC1																		
									"																						
RT1		2		45					"	8.6																					
				0.032				2	"	8.6	6	12	RC2																		
									"																						
RT2		2		45					"	8.5																					
				0.032				2	"	8.5	6	18	RC3																		
									"				RC1-3	164.5	23.5	44.28	93.60	27.97	12.59	7.71	14.82	2.39	16.02	4.45	16.20	2.26	17.35	0.23	15.16	1.43	12.73
									"				Tails	535.6	76.5	0.93	6.40	59.60	87.41	13.60	85.18	3.85	83.98	7.07	83.80	3.30	82.65	0.39	84.84	3.01	87.27
									"																						
							2.5		1500	8.6																					
RC1-3		2		10				2	"	8.6	6	24	CC1	89.0	12.7	72.26	82.64	9.20	2.24	3.56	3.70	1.24	4.49	2.54	4.99	1.30	5.42	0.12	4.41	0.57	2.76
				0.007					"				CT1	75.5	10.8	11.3	10.96	50.1	10.35	12.6	11.12	3.8	11.53	6.7	11.21	3.4	11.93	0.3	10.75	2.4	9.97
							1.5		1100	8.7																					
CC1		2		10				1.5	"	8.6	5	29	CC2	70.4	10.1	76.70	69.36	6.76	1.30	2.87	2.36	1.01	2.89	2.13	3.32	1.12	3.70	0.10	2.75	0.44	1.66
				0.007					"				CT2	18.6	2.7	55.5	13.28	18.4	0.94	6.2	1.34	2.1	1.60	4.1	1.67	2.0	1.72	0.2	1.66	1.1	1.10
									"																						
									"																						
CC2				10				1.5	"	8.6	4	33	CC3	56.1	8.0	78.12	56.33	6.10	0.94	2.65	1.74	0.93	2.12	1.98	2.46	1.07	2.80	0.09	1.98	0.39	1.18
				0.007					"				CT3	14.3	2.0	7.11	13.02	9.4	0.37	3.8	0.63	1.3	0.77	2.7	0.86	1.3	0.89	0.1	0.77	0.6	0.48
									"																						
									"																						
CC3				10				1.5	"	8.7	3	36	CC4	46.9	6.7	78.7	47.41	5.8	0.74	2.5	1.39	0.9	1.70	1.9	1.98	1.1	2.30	0.1	1.57	0.4	0.92
				0.007					"				CT4	9.2	1.3	75.2	8.93	7.7	0.19	3.2	0.34	1.1	0.42	2.4	0.48	1.2	0.50	0.1	0.41	0.5	0.26
Total	45	10	0	175	0	0				Total	36	36	Calc Feed	700.1	100.0	111	100.0	52.2	100.0	12.2	100.0	3.5	100.0	6.5	100.0	3.1	100.0	0.3	100.0	2.6	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:**	Mill:	Mild steel	**Remarks:** **taukoaika 1.5s**
Project:	Kriittiset Mineraalit		Charge:	8 kg balls	RC1 hyvä vaahto, 6 min kohdalla enää vähän hiiltä
Date:	6.2.2018		Water:	0.7 l	RC2 & RC3 grafiitti jo melko lopussa, vaal. Harm vaahto
Author:	KJP	**Feed**		0.7 kg	CC3-CC5 mieto vaahto, vaahdotteen lisäys tarpeen
Test no.:	7	**Screen anal:**			

Feed	Grind	Cond	Reagents (g/t)/mL				Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		Grades and Recoveries													
																C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	min	Flotanol 7026 100 %	MIBC 100 %	CMC 100 %	Na2SiO2 100 %	l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																													
							2.5		1500	8.5																				
		2	64						"	8.6																				
			0.045					2	"	8.5	6	6	RC1																	
									"																					
RT1		2	45						"	7.9																				
			0.032					2	"	7.8	3	9	RC2																	
									"																					
RT2		2	45						"																					
			0.032					2	"	7.8	2	11	RC3																	
									"				RC1-3	125.4	18.0	49.90	98.42	28.06	8.44	7.53	11.18	1.38	12.13	2.90	10.73	0.90	10.30	0.18	9.91	1.25	8.38
									"				Tails	572.8	82.0	0.18	1.58	66.70	91.56	13.10	88.82	2.19	87.87	5.29	89.27	1.71	89.70	0.35	90.09	2.99	91.62
									"																					
							2.5		1500																					
RC1-3		2	10					2	"	8.1	7	18	CC1	85.9	12.3	70.88	95.76	12.31	2.53	4.59	4.67	1.03	6.18	1.89	4.79	0.42	3.31	0.11	4.15	0.72	3.33
			0.007						"				CT1	39.5	5.7	4.3	2.67	62.3	5.90	13.9	6.50	2.2	5.95	5.1	5.94	1.9	6.99	0.3	5.76	2.4	5.05
							15		1100	8.2																				
CC1		2	10					15	"	8	6	24	CC2	80.1	11.5	74.48	93.83	9.88	1.90	3.94	3.74	0.87	4.86	1.66	3.92	0.34	2.47	0.09	3.21	0.63	2.69
			0.007						"				CT2	5.8	0.8	21.2	1.93	45.9	0.64	13.6	0.93	3.3	1.32	5.1	0.87	1.6	0.84	0.4	0.94	2.1	0.64
									"																					
									"	8																				
CC2								15	"		6	30	CC3	72.7	10.4	77.75	88.87	7.95	1.39	3.31	2.85	0.67	3.41	1.46	3.12	0.26	1.76	0.07	2.29	0.55	2.13
									"				CT3	7.4	1.1	42.4	4.95	28.7	0.51	10.1	0.89	2.8	1.45	3.6	0.80	1.0	0.71	0.3	0.91	1.4	0.56
									"																					
									"																					
CC3								15	"	7.9	5	35	CC4	59.3	8.5	80.43	75.00	6.75	0.96	2.92	2.05	0.56	2.31	1.30	2.28	0.22	1.18	0.06	1.54	0.48	1.53
									"				CT4	13.4	1.9	65.9	13.88	13.3	0.43	5.1	0.80	1.2	1.10	2.1	0.84	0.5	0.58	0.1	0.76	0.8	0.60
CC4								15	"	7.9	5	40	CC5	38.7	5.5	81.3	49.45	6.2	0.57	2.8	1.26	0.5	1.35	1.2	1.37	0.2	0.87	0.1	0.87	0.4	0.90
									"				CT5	20.6	3.0	78.8	25.55	7.9	0.39	3.2	0.79	0.7	0.95	1.5	0.91	0.2	0.31	0.1	0.67	0.6	0.63
Total	45	10	174	0	0	0				Total	40	40	Calc Feed	698.2	100.0	9.1	100.0	59.8	100.0	12.1	100.0	2.0	100.0	4.9	100.0	1.6	100.0	0.3	100.0	2.7	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:** Mill:		Mild steel	**Remarks:** Kone 1, pH-mittari 1, taukoaika 1.5s
Project:	Kriittiset Mineraalit	Charge:		8 kg balls	
Date:	12.02.2018	Water:		0.7 l	
Author:	MKP, KJP	**Feed**		0.7 kg	
Test no.:	8	**Screen anal:**			

			Reagents (g/t)/mL												Grades and Recoveries													
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	100 %	**l**	**l/min**	**rpm**		**min**	**min**		**g**	**%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**	**%**	**Rec%**
-14mm	75																														
							2.5		1500	9.1																					
		2	64						"																					
			0.045					2	"	9.1	6	6	RC1																	
RT1		2	45						"	8.4																					
			0.032					2	"		3	3	RC2																	
RT2		2	45						"																					
			0.032					2	"	8.2	2	8	RC3																	
									"	7.9			RC1-3	117.1	16.6	53.72	98.13	27.19	7.59	6.65	9.20	105	8.55	2.88	8.93	0.81	8.61	0.15	8.16	1.24	7.75
									"				Tails	587.1	83.4	0.20	1.87	66.00	92.41	13.10	90.80	2.24	91.45	5.86	91.07	1.72	91.39	0.34	91.84	2.95	92.25
									"																					
							2.5		1500																					
RC1-3		2	10					2	"	8.2	7	15	CC1	73.6	10.5	79.44	91.21	8.56	1.50	3.02	2.62	0.55	2.81	1.59	3.11	0.26	1.76	0.06	2.23	0.62	2.45
			0.007						"	8.2			CT1	43.5	6.2	10.2	6.92	58.7	6.09	12.8	6.57	1.9	5.75	5.1	5.83	1.7	6.85	0.3	5.93	2.3	5.31
							1.5		1100																					
CC1		2	10					1.5	"	8.2	6	21	CC2	66.3	9.4	83.22	86.08	5.93	0.94	2.38	1.86	0.43	1.99	1.32	2.32	0.18	1.05	0.05	1.51	0.51	1.82
			0.007						"				CT2	7.3	1.0	45.1	5.14	32.5	0.57	8.8	0.76	1.6	0.81	4.1	0.79	1.1	0.71	0.2	0.72	1.6	0.63
									"																					
									"																					
CC2		2	10					1.5	"		6	27	CC3	65.3	9.3	83.78	85.30	5.59	0.87	2.28	1.76	0.42	1.89	1.28	2.20	0.16	0.96	0.05	1.41	0.50	1.73
			0.007						"	8.2			CT3	1.0	0.1	48.1	0.77	27.3	0.07	8.3	0.10	1.5	0.10	4.2	0.11	1.0	0.09	0.2	0.09	1.6	0.09
									"																					
									"																					
CC3		2	10					1.5	"	8	5	32	CC4	63.4	9.0	84.28	83.34	5.29	0.80	2.18	1.64	0.39	1.74	1.23	2.06	0.15	0.86	0.04	1.30	0.48	1.62
			0.007						"	8			CT4	1.9	0.3	67.0	1.96	15.6	0.07	5.6	0.12	1.2	0.15	2.8	0.14	0.6	0.10	0.1	0.12	1.1	0.11
CC4		2	10					1.5	"	8	5	37	CC5	62.0	8.8	84.6	81.81	5.1	0.75	2.1	1.55	0.4	1.64	1.2	1.97	0.1	0.79	0.0	1.22	0.5	1.55
			0.007						"				CT5	1.4	0.2	69.9	1.53	13.9	0.05	5.1	0.08	1.0	0.10	2.5	0.09	0.5	0.07	0.1	0.08	1.0	0.08
Total	75	1.6	204	0	0	0				Total	40	37	Calc Feed	704.2	100.0	9.1	100.0	59.5	100.0	12.0	100.0	2.0	100.0	5.4	100.0	1.6	100.0	0.3	100.0	2.7	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:** Mill:	Mild steel	**Remarks:**	**taukoaika 1.5s**
Project:	Kriittiset Mineraalit	Charge:	8 kg balls		Vaahdotuskone 1
Date:	20.2.2018	Water:	0.7 l		Titraattori 1
Author:	MKP, KJP	**Feed**	0.702 kg		
Test no.:	9	**Screen anal:**			

			Reagents (g/t)/mL												**Grades and Recoveries**															
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	5 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	75																														
							2.5		1500	9																					
		5				1500																									
						21.059				9.5																					
		2	64						"																						
			0.045					2	"	8.9	6	6	RC1																		
RT1		2	45						"																						
			0.032					2	"	8.4	3	9	RC2																		
RT2		2	45						"	8.3																					
			0.032					2	"	8.4	2	11	RC3																		
									"				RC1-3	119.7	17.0	54.19	98.24	27.71	7.93	6.77	9.57	109	8.94	2.84	9.19	0.83	8.92	0.15	8.43	120	7.65
									"				Tails	584.4	83.0	0.20	176	65.90	92.07	13.10	90.43	2.28	91.06	5.74	90.81	173	91.08	0.34	91.57	2.96	92.35
							2.5		1500	8.4																					
RC1-3		2	10					2	"		7	18	CC1	75.8	10.8	81.64	93.69	8.29	1.50	2.99	2.67	0.56	2.88	1.57	3.23	0.26	1.76	0.06	2.23	0.62	2.51
			0.007						"				CT1	43.9	6.2	6.8	4.55	61.2	6.43	13.3	6.90	2.0	6.06	5.0	5.96	1.8	7.16	0.3	6.20	2.2	5.14
							1.5		1100	8.1																					
CC1		2	10					1.5	"		6	24	CC2	70.9	10.1	85.25	91.51	6.13	1.04	2.43	2.04	0.45	2.16	1.35	2.59	0.18	1.18	0.05	1.64	0.53	2.02
			0.007						"	8			CT2	4.9	0.7	29.4	2.18	39.6	0.46	11.0	0.64	2.2	0.72	4.8	0.64	1.3	0.58	0.3	0.59	1.9	0.49
									"	7.9																					
CC2		2	10					1.5	"	7.8	6	30	CC3	68.3	9.7	86.43	89.47	5.48	0.89	2.23	1.80	0.40	1.87	1.26	2.33	0.16	0.97	0.05	1.42	0.50	1.81
			0.007						"	7.8			CT3	2.5	0.4	53.2	2.04	23.8	0.14	7.9	0.23	1.7	0.29	3.8	0.26	0.9	0.21	0.2	0.22	1.6	0.21
									"																						
CC3		2	10					1.5	"		5	35	CC4	65.6	9.3	87.35	86.85	5.06	0.79	2.09	1.62	0.37	1.65	1.19	2.12	0.14	0.82	0.04	1.24	0.47	1.63
			0.007						"	7.8			CT4	2.7	0.4	64.2	2.62	15.7	0.10	5.7	0.18	1.2	0.22	2.9	0.21	0.6	0.15	0.1	0.17	1.2	0.17
										7.6																					
CC4		2	10					1.5	"		5	40	CC5	64.0	9.1	87.9	85.18	4.8	0.74	2.0	1.52	0.4	1.53	1.2	1.99	0.1	0.74	0.0	1.15	0.4	1.53
			0.007						"	7.3			CT5	1.7	0.2	66.1	1.67	14.1	0.06	5.2	0.10	1.1	0.12	2.8	0.12	0.5	0.08	0.1	0.10	1.1	0.10
										7.6																					
Total	75	21	204	0	0	1500				Total	40	40	Calc Feed	704.1	100.0	9.4	100.0	59.4	100.0	12.0	100.0	2.1	100.0	5.2	100.0	1.6	100.0	0.3	100.0	2.7	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:** Mill:	Mild steel	**Remarks:**	**taukoaika 1.5 s**
Project:	Kriittiset Mineraalit	Charge:	8 kg balls		vaahdotuskone 1, titraattori 1
Date:	22.2.2018	Water:	0.7 l		Toinen jauhatus: RC1-3 suodatetaan, muttei kuivata + 240 mL vettä
Author:	MKP	**Feed**	0.7 kg		CC1 ensin 7µl Flotanolia, ei vaahtoa (kerätty 4 min). Lisätty 21µl Flotanolia ja vaahdotettu 10 min.
Test no.:	10	**Screen anal:**			Grafiittia jäi jätteeseen, Flotanolin annostus liian alhainen lisäjauhatuksen jälkeen.

			Reagents (g/t)/mL												**Grades and Recoveries**															
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	5 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																														
							2.5		1500																						
		2	64						"																						
			0.045					2	"		6	6	RC1																		
RT1		2	45						"																						
			0.032					2	"		3	9	RC2																		
RT2		2	45						"																						
			0.032					2	"		2	11	RC3																		
									"				RC1-3	137.0	19.4	46.65	98.39	29.03	9.51	7.61	12.29	1.46	14.13	4.41	16.49	0.88	11.04	0.18	10.88	1.32	9.52
									"				Tails	568.2	80.6	0.18	1.61	66.60	90.49	13.10	87.71	2.14	85.87	5.38	83.51	1.71	88.96	0.35	89.12	3.03	90.48
RC1-3	30																														
							2.5		1500																						
RC1-3		2	40					2	"		10	21	CC1	34.3	4.9	72.85	38.47	14.14	1.16	3.99	1.61	0.68	1.65	2.75	2.58	0.43	1.35	0.09	1.41	0.82	1.48
			0.028						"				CT1	102.7	14.6	37.9	59.92	34.0	8.35	8.8	10.67	1.7	12.47	5.0	13.92	1.0	9.69	0.21	9.47	1.5	8.04
							1.5		1100																						
CC1		2	10					1.5	"		6	27	CC2	12.4	1.8	86.89	16.59	5.37	0.16	1.92	0.28	0.30	0.26	1.65	0.56	0.17	0.19	0.04	0.23	0.56	0.36
			0.007						"				CT2	21.9	3.1	64.9	21.88	19.1	1.00	5.2	1.33	0.9	1.39	3.4	2.02	0.6	1.16	0.12	1.18	1.0	1.12
									"																						
CC2		2	10					1.5	"		6	33	CC3	7.0	1.0	90.66	9.77	3.51	0.06	1.43	0.12	0.22	0.11	1.31	0.25	0.11	0.07	0.03	0.09	0.48	0.18
			0.007						"				CT3	5.4	0.8	82.0	6.82	7.8	0.10	2.6	0.16	0.4	0.15	2.1	0.31	0.2	0.12	0.06	0.14	0.7	0.18
									"																						
CC3		2	10					1.5	"		5	38	CC4	4.5	0.6	91.13	6.31	3.21	0.03	1.34	0.07	0.21	0.07	1.20	0.15	0.09	0.04	0.03	0.05	0.48	0.11
			0.007						"				CT4	2.5	0.4	89.8	3.46	4.1	0.02	1.6	0.05	0.3	0.04	1.5	0.10	0.1	0.03	0.04	0.04	0.5	0.06
CC4		2	10					1.5	"		5	43	CC5	2.6	0.4	91.3	3.65	3.1	0.02	1.3	0.04	0.2	0.04	1.2	0.08	0.1	0.02	0.03	0.03	0.5	0.06
			0.007						"				CT5	1.9	0.3	90.9	2.66	3.4	0.02	1.4	0.03	0.2	0.03	1.2	0.06	0.1	0.02	0.03	0.02	0.5	0.05
Total	75	16	234	0	0	#REF!				Total	43	43	Calc Feed	705.2	100.0	9.2	100.0	59.3	100.0	12.0	100.0	2.0	100.0	5.2	100.0	1.5	100.0	0.32	100.0	2.7	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:**	Mill:	Mild steel	**Remarks:** **taukoaika 1.5 s**
Project:	Kriittiset Mineraalit		Charge:	8 kg balls	vaahdotuskone 1, titraattori 1
Date:	27.2.2018		Water:	0.7 l	RC2-3 vaalea vaahto, ei enää grafiittia
Author:	MKP	**Feed**		0.7 kg 702.3g	Toinen jauhatus: RC1-3 suodatetaan, muttei kuivata + 240 mL vettä
Test no.:	11	**Screen anal:**			Saanti alhainen, vaatisiko pitemmän vaahdotusajan, kun partikkelit pienempiä?

			Reagents (g/t)/mL													**Grades and Recoveries**													
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	5 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																														
							2.5		1500	8.4																					
		2	64						"																						
			0.045					2	"	8.3	6	6	RC1																		
RT1		2	45						"	7.7																					
			0.032					2	"		3	9	RC2																		
RT2		2	45						"																						
			0.032					2	"	7.7	2	11	RC3																		
									"				RC1-3	139.6	20.0	46.25	98.61	30.39	10.25	7.88	13.07	1.57	15.36	4.50	17.25	0.90	11.54	0.18	11.16	1.34	9.86
									"				Tails	558.51	80.0	0.16	1.39	66.50	89.75	13.10	86.93	2.16	84.64	5.40	82.75	1.72	88.46	0.35	88.84	3.07	90.14
RC1-3	30									8.4			jätettä kaatui muutama gramma pöydälle																		
							2.5		1500																						
RC1-3		2	109					2	"		7	18	CC1	58.3	8.4	81.18	72.28	8.47	1.19	2.68	1.86	0.45	1.84	2.00	3.19	0.25	1.36	0.05	1.45	0.61	1.86
			0.076						"	8.3			CT1	81.33	11.6	21.2	26.33	46.1	9.06	11.6	11.21	2.4	13.52	6.3	14.06	1.4	10.18	0.26	9.71	1.9	8.00
							15		1100																						
CC1		2	45					15	"	8.2	6	24	CC2	51.4	7.4	88.10	69.10	4.31	0.53	1.62	0.99	0.26	0.95	1.37	1.94	0.13	0.61	0.03	0.76	0.45	1.21
			0.032						"				CT2	6.94	1.0	30.0	3.18	39.3	0.66	10.5	0.87	1.8	0.90	6.6	1.26	1.2	0.75	0.22	0.69	1.8	0.65
									"																						
CC2		2	10					15	"	8.1	6	30	CC3	47.5	6.8	89.70	65.12	3.47	0.40	1.38	0.78	0.22	0.75	1.19	1.55	0.10	0.44	0.03	0.58	0.41	1.02
			0.007						"				CT3	3.83	0.5	68.2	3.99	14.7	0.14	4.6	0.21	0.7	0.20	3.7	0.39	0.5	0.17	0.10	0.18	1.0	0.19
									"	7.7																					
CC3		2	10					15	"	8	5	35	CC4	42.6	6.1	90.61	58.99	3.20	0.33	1.29	0.65	0.21	0.62	1.11	1.30	0.09	0.35	0.02	0.47	0.39	0.87
			0.007						"	7.7			CT4	4.9	0.7	81.8	6.12	5.9	0.07	2.2	0.13	0.4	0.13	1.9	0.25	0.2	0.09	0.05	0.11	0.6	0.15
										7.7																					
CC4		2	10					15	"	7.8	5	40	CC5	38.95	5.6	91.0	54.12	3.1	0.29	1.3	0.58	0.2	0.55	1.1	1.15	0.1	0.30	0.02	0.41	0.4	0.78
			0.007						"				CT5	3.69	0.5	86.5	4.87	4.3	0.04	1.7	0.07	0.3	0.07	1.4	0.14	0.1	0.05	0.04	0.07	0.5	0.09
										7.5																					
Total	75	16	338	0	0	0				Total	40	40	Calc Feed	698.2	100.0	9.4	100.0	59.3	100.0	12.1	100.0	2.0	100.0	5.2	100.0	1.6	100.0	0.31	100.0	2.7	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:**	Mill:	Mild steel	**Remarks:**	**taukoaika 1.5 s**
Project:	Kriittiset Mineraalit		Charge:	8 kg balls		vaahdotuskone 1, titraattori 1
Date:	6.3.2018		Water:	0.7 l		RC1 heikompi vaahto kuin normaalisti
Author:	MKP	**Feed**		0.7 kg		RC2 hyvin vähän hiiltä jäljellä
Test no.:	12	**Screen anal:**				CC1 vahva vaahto — CC2 3 min kohdalla vähenee grafiitti

			Reagents (g/t)/mL												Grades and Recoveries													
															C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	Kerosene	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**																
	min	**min**	100 %	100 %	100 %	5 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	75																													
							2.5		1500	9.3																				
		2+2	64		25				"																					
			0.045		0.018			2	"	9.3	6	6	RC1																	
RT1		2+2	45		10				"	7.9																				
			0.032		0.007			2	"	8.1	3	9	RC2																	
RT2		2+2	45		10				"	7.8																				
			0.032		0.007			2	"	7.9	2	11	RC3																	
									"	7.7			RC1-3	143.3	20.3	44.10	98.58	33.56	11.43	7.82	13.17	1.23	12.13	3.50	13.54	0.97	12.63	0.18	11.34	1.56	11.85
									"				Tails	563.61	79.7	0.16	1.42	66.10	88.57	13.10	86.83	2.27	87.87	5.68	86.46	1.70	87.37	0.35	88.66	2.95	88.15
							2.5		1500	8.1																				
RC1-3		2+2	10		25			2	"		7	18	CC1	82.3	11.6	74.17	95.20	11.44	2.24	3.75	3.63	0.70	3.96	1.98	4.41	0.36	2.68	0.08	3.06	0.79	3.44
			0.007		0.018				"	8.2			CT1	61	8.6	3.6	3.39	63.4	9.19	13.3	9.54	2.0	8.17	5.5	9.13	1.8	9.96	0.30	8.27	2.6	8.41
							15		1100	7.9																				
CC1		2+2	10		10			15	"		6	24	CC2	73.8	10.4	79.95	91.99	7.40	1.30	2.84	2.46	0.54	2.72	1.61	3.21	0.23	1.55	0.06	2.03	0.64	2.49
			0.007		0.007				"	8.1			CT2	8.52	1.2	24.1	3.20	46.4	0.94	11.7	1.17	2.1	1.24	5.2	1.20	1.5	1.13	0.27	1.03	2.1	0.95
									"	8																				
CC2		2+2	10		10			15	"	8	6	30	CC3	70.7	10.0	81.61	89.96	6.35	1.07	2.54	2.11	0.48	2.31	1.48	2.82	0.19	1.23	0.05	1.71	0.59	2.19
			0.007		0.007				"	7.7			CT3	3.1	0.4	42.1	2.04	31.3	0.23	9.5	0.35	1.9	0.41	4.7	0.39	1.1	0.32	0.23	0.32	1.8	0.29
									"																					
CC3		2	10					15	"		5	35	CC4	67.9	9.6	82.52	87.42	5.80	0.94	2.36	1.89	0.43	2.01	1.40	2.57	0.17	1.04	0.05	1.49	0.56	2.00
			0.007						"	7.4			CT4	2.75	0.4	59.2	2.54	20.0	0.13	7.0	0.23	1.5	0.29	3.4	0.25	0.8	0.20	0.17	0.22	1.3	0.19
CC4		2	10					15	"	7.8	5	40	CC5	65.51	9.3	83.2	85.04	5.4	0.84	2.2	1.72	0.4	1.80	1.3	2.37	0.2	0.90	0.05	1.33	0.5	1.84
			0.007						"	7.5			CT5	2.39	0.3	63.8	2.38	16.5	0.09	6.0	0.17	1.3	0.22	3.0	0.19	0.6	0.14	0.15	0.16	1.3	0.16
Total	75	4	204	0	90	0				Total	40	40	Calc Feed	706.9	100.0	9.1	100.0	59.5	100.0	12.0	100.0	2.1	100.0	5.2	100.0	1.6	100.0	0.31	100.0	2.7	100.0

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-17	**Grind:** Mill:	Mild steel	**Remarks:**	**taukoaika 1.5 s** vaahdotuskone 1, titraattori 1
Project:	Kriittiset Mineraalit	Charge:	8 kg balls		Toinen jauhatus: RC1-3 suodatetaan, muttei kuivata + 250 mL vettä
Date:	12.3.2018	Water:	0.7 l		Kolmas jauhatus: CC2 suodatetaan, muttei kuivata + 140 mL
Author:	MKP	**Feed**	0.7 kg		RC2-3 Vaalea vaahto, grafiitti lopussa
Test no.:	13	**Screen anal:**			

			Reagents (g/t)/mL												Grades and Recoveries															
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	5 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																														
							2.5		1500	8.3																					
		5				1500																									
						21.000																									
		2	64						"	8.8																					
			0.045					2	"	8	6	6	RC1																		
RT1		2	45						"																						
			0.032					2	"	7.9	3	9	RC2																		
RT2		2	45						"	8																					
			0.032					2	"	7.9	2	11	RC3																		
									"				RC1-3	122.58	17.46	48.60	98.40	27.26	7.97	7.37	10.63	1.50	12.55	4.09	13.78	0.84	9.38	0.17	9.07	1.21	7.86
									"				Tails	579.64	82.54	0.17	1.60	66.60	92.03	13.10	89.37	2.21	87.45	5.41	86.22	1.72	90.62	0.35	90.93	2.99	92.14
RC1-3	15									8.2																					
							2.5		1500																						
		5				500				8.8																					
						7.000																									
RC1-3		2	109					2	"	8.5	7	18	CC1	74.68	10.63	76.96	94.93	7.86	1.40	2.85	2.51	0.63	3.20	2.38	4.89	0.25	1.68	0.06	2.13	0.56	2.21
			0.076						"	7.9			CT1	47.90	6.82	4.39	3.47	57.50	6.57	14.40	8.12	2.86	9.35	6.75	8.89	1.77	7.71	0.33	6.94	2.22	5.65
							15		1100	8.2																					
CC1		2	45					15	"		6	24	CC2	70.30	10.01	80.60	93.58	5.48	0.92	2.22	1.84	0.50	2.41	2.10	4.06	0.17	1.07	0.05	1.57	0.46	1.70
			0.032						"				CT2	4.38	0.62	18.60	1.35	46.10	0.48	13.00	0.67	2.65	0.79	6.87	0.83	1.53	0.61	0.29	0.56	2.18	0.51
CC2	15																														
		5				500																									
						7.000			"	8.5																					
CC2		2	64					15	"		6	30	CC3	5.44	7.33	86.65	73.62	2.86	0.35	1.24	0.75	0.22	0.77	1.24	1.76	0.08	0.38	0.02	0.55	0.33	0.89
			0.045						"				CT3	18.86	2.69	64.10	19.97	12.60	0.57	4.90	1.09	1.27	1.64	4.44	2.30	0.40	0.69	0.12	1.02	0.81	0.81
									"	8.2																					
CC3		2	10					15	"	8.4	6	36	CC4	43.32	6.17	87.69	62.74	2.22	0.23	0.99	0.51	0.16	0.48	0.98	1.17	0.06	0.23	0.02	0.34	0.29	0.66
			0.007						"	7.4			CT4	8.12	1.16	81.10	10.88	6.32	0.12	2.56	0.24	0.53	0.29	2.62	0.58	0.21	0.15	0.06	0.21	0.54	0.23
CC4		2	10					15	"	7.4	6	42	CC5	37.35	5.32	87.70	54.10	2.08	0.19	0.94	0.41	0.15	0.38	0.93	0.96	0.05	0.17	0.02	0.26	0.27	0.54
			0.007						"				CT5	5.97	0.85	87.60	8.64	3.06	0.04	1.32	0.09	0.24	0.10	1.31	0.22	0.10	0.05	0.03	0.08	0.36	0.11
										7																					
Total	75	31	392	0	0	2500				Total	42	42	Calc Feed	702.22	100.00	8.62	100.00	59.73	100.00	12.10	100.00	2.09	100.00	5.18	100.00	1.57	100.00	0.32	100.00	2.68	100.00

FLOTATION TEST REPORT

GTK

Sample:	Rautalampi PH-16	**Grind:** Mill:	Mild steel	**Remarks:**	**taukoaika 1.5 s**
Project:	Kriittiset Mineraalit	Charge:	8 kg balls		vaahdotuskone 1, titraattori 1
Date:	19.3.2018	Water:	0.7 l		Toinen jauhatus: RC1-3 suodatetaan, muttei kuivata + 320 mL vettä
Author:	MKP	**Feed**	0.702 kg		RC1 melko isoja kuplia / CC1 ja CC2 pienempi määrä vaahdotetta olisi riittänyt
Test no.:	14	**Screen anal:**			RC2 pienempää kuplaa kuin RC1 / RC3 ei paljon vaahtoa, vaalenee 1 min kohdalla

			Reagents (g/t)/mL												**Grades and Recoveries**															
Feed	**Grind**	**Cond**	Flotanol 7026	MIBC	CMC	Na2SiO2	**Cell**	**Air**	**Rotor**	**pH**	**Flot**	**Cum Flot**	**Product**	**Weight**		C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)		Ti (XRF)		S (XRF)	
	min	**min**	100 %	100 %	100 %	5 %	**l**	**l/min**	**rpm**		**min**	**min**		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-14mm	45																														
							2.5		1500	8.8																					
		5				1500																									
						21.053				9.3																					
		2	64						"	8.7																					
			0.045					2	"	8.7	6	6	RC1																		
RT1		2	45						"																						
			0.032					2	"	8.6	6	12	RC2																		
RT2		2	45						"																						
			0.032					2	"	8.5	6	18	RC3																		
									"	8.5			RC1-3	184.60	26.20	40.50	94.67	30.76	15.38	8.16	17.90	2.57	19.67	5.45	21.13	2.30	20.05	0.24	18.34	1.66	16.03
									"				Tails	519.85	73.80	0.81	5.33	60.10	84.62	13.30	82.10	3.72	80.33	7.22	78.87	3.25	79.95	0.38	81.66	3.08	83.97
RC1-3	15																														
							2.5		1500	8.5																					
RC1-3		2	109					2	"	8.3	6	24	CC1	93.21	13.23	76.38	90.14	9.04	2.28	3.13	3.46	1.04	4.03	2.43	4.76	1.06	4.66	0.10	3.84	0.58	2.85
			0.076						"				CT1	91.39	12.97	3.91	4.52	52.90	13.09	13.30	14.43	4.12	15.64	8.52	16.36	3.56	15.40	0.39	14.51	2.75	13.18
							1.5		1100																						
CC1		2	45					1.5	"	8.4	5	29	CC2	83.27	11.82	83.23	87.75	5.16	1.16	2.09	2.07	0.71	2.47	1.73	3.03	0.78	3.06	0.07	2.42	0.35	1.53
			0.032						"	8			CT2	9.94	1.41	19.00	2.39	41.60	1.12	11.80	1.39	3.77	1.56	8.29	1.73	3.41	1.60	0.35	1.42	2.53	1.32
CC2		2						1.5	"	8.3	4	33	CC3	75.94	10.78	85.44	82.15	4.10	0.84	1.77	1.60	0.61	1.92	1.49	2.38	0.68	2.43	0.06	1.84	0.29	1.14
			0.000						"	8.2			CT3	7.33	1.04	60.40	5.61	16.10	0.32	5.40	0.47	1.82	0.55	4.25	0.65	1.79	0.62	0.19	0.58	1.01	0.39
									"																						
CC3		2						1.5	"	8.3	3	36	CC4	60.17	8.54	85.87	65.42	3.75	0.61	1.66	1.19	0.56	1.41	1.40	1.77	0.65	1.86	0.05	1.31	0.26	0.83
			0.000						"	8.2			CT4	15.77	2.24	83.80	16.73	5.43	0.23	2.19	0.41	0.78	0.51	1.83	0.61	0.77	0.57	0.08	0.53	0.38	0.32
CC4		2						1.5	"	8.3	3	39	CC5	40.39	5.73	86.00	43.98	3.59	0.39	1.62	0.78	0.54	0.91	1.37	1.16	0.66	1.26	0.05	0.82	0.25	0.52
			0.000						"	8.4			CT5	19.78	2.81	85.60	21.44	4.09	0.22	1.75	0.41	0.61	0.50	1.46	0.61	0.64	0.60	0.06	0.49	0.30	0.31
Total	60	21	308	0	0	1500				Total	39	39	Calc Feed	704.45	100.00	11.21	100.00	52.41	100.00	11.95	100.00	3.42	100.00	6.76	100.00	3.00	100.00	0.34	100.00	2.71	100.00

Appendix 3 – Mineralogy

Laboratory Beneficiation Testwork on Rautalampi Graphite Ore

GTK MMA

8.12.2017

Jukka Laukkanen

Kahden grafiittinäytteen mineraalipitoisuudet ja jauhatusasteen arviointia

Tutkittavina näytteinä olivat taulukossa 1 esitetyt kiillotetut ohuthieet. Hieet mitattiin Quanta 600 SEM:llä käyttäen MLA-ohjelmaa. Mittausmenetelmänä oli XMOD_std.

Jauhatusasteen arvioimiseksi näytteistä otettiin BSE-kuvia.

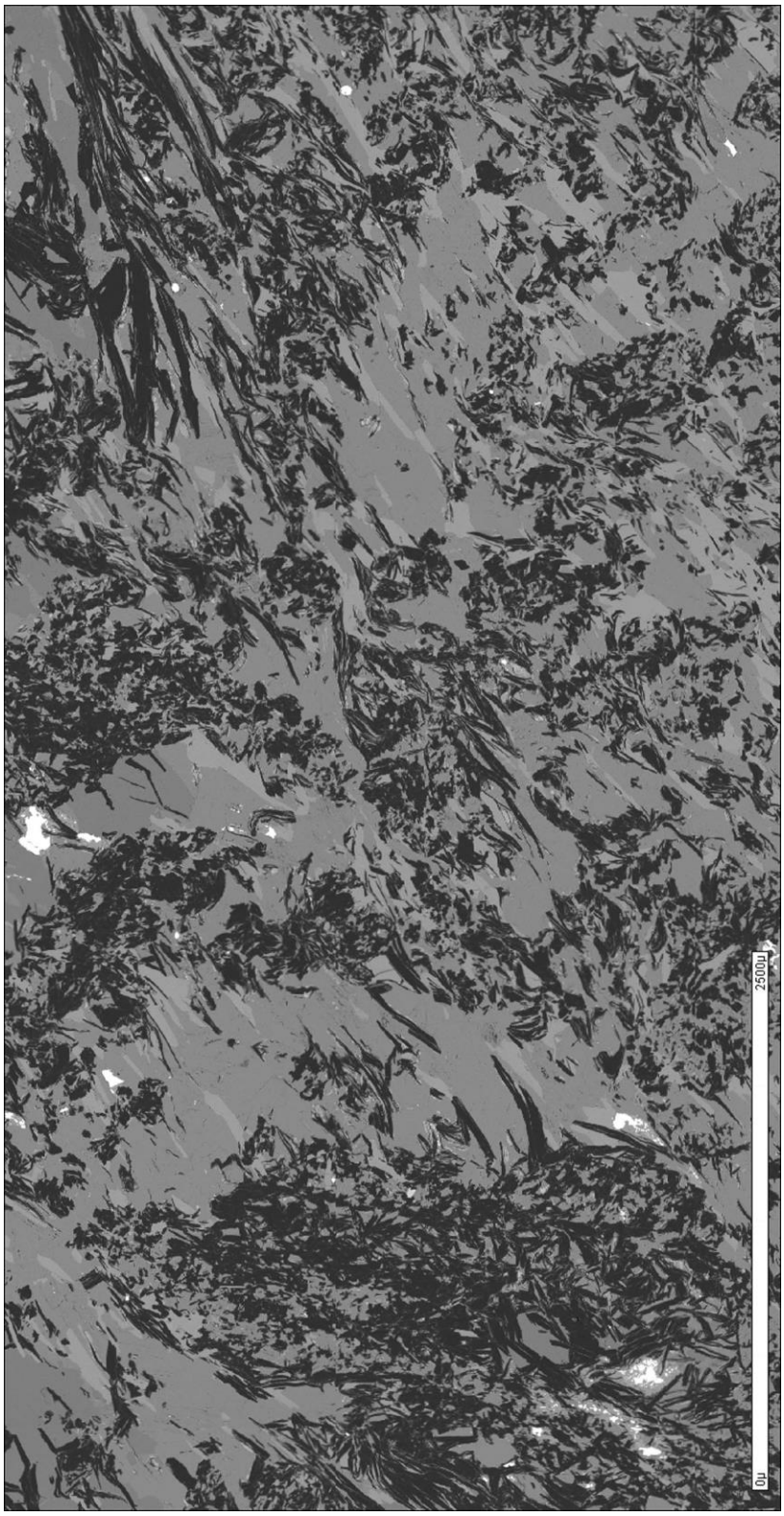
Taulukko 1. Mineraalipitoisuudet XMOD-std menetelmällä.

Mineral	160391_graphite_gneiss - Wt%	160397_graphite_schist - Wt%
Plagioclase	45.38	22.41
K_feldspar	0.01	15.55
Quartz	7.34	20.23
Biotite	19.26	23.77
Chlorite	0.51	0.08
Kaolinite	0.03	0.42
Clay	0.07	7.22
Apatite	1.16	0.22
Monazite	0.01	0.01
Calcite	0.67	0.00
Pyrite	0.27	0.00
Pyrrhotite	0.60	7.18
Sphalerite	0.00	0.02
Chalcopyrite	0.00	0.00
Rutile	0.10	0.35
Graphite	23.31	2.45
Unknown	1.29	0.10
Total	100.00	100.00

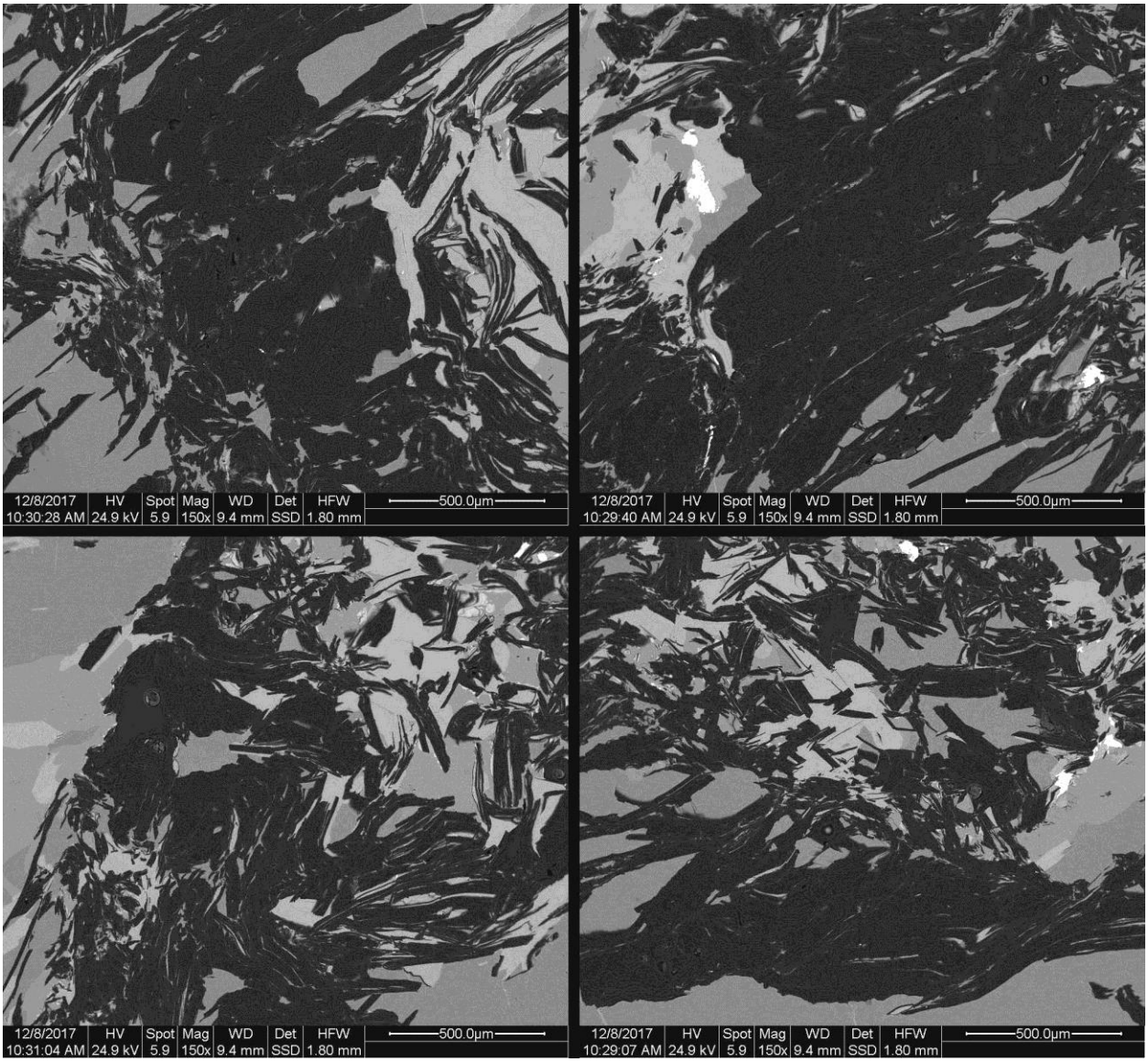
Number of measured points	15048	15048

Hieessä 160397 (RTL_PH-017) grafiitin määrä jäänyt varsin alhaiseksi, mikä saattaa johtua grafiittisuomujen orientaatiosta (suomuja mitattu vain yhdestä suunnasta, koska kivi on voimakkaasti suuntautunut). Tämän näytteen Labtiumin analysoima hiilipitoisuus on 9.6 %. Hieen 160391 (RTL_PH-016) grafiittigneissin analysoitu hiilipitoisuus on 17.9 %.

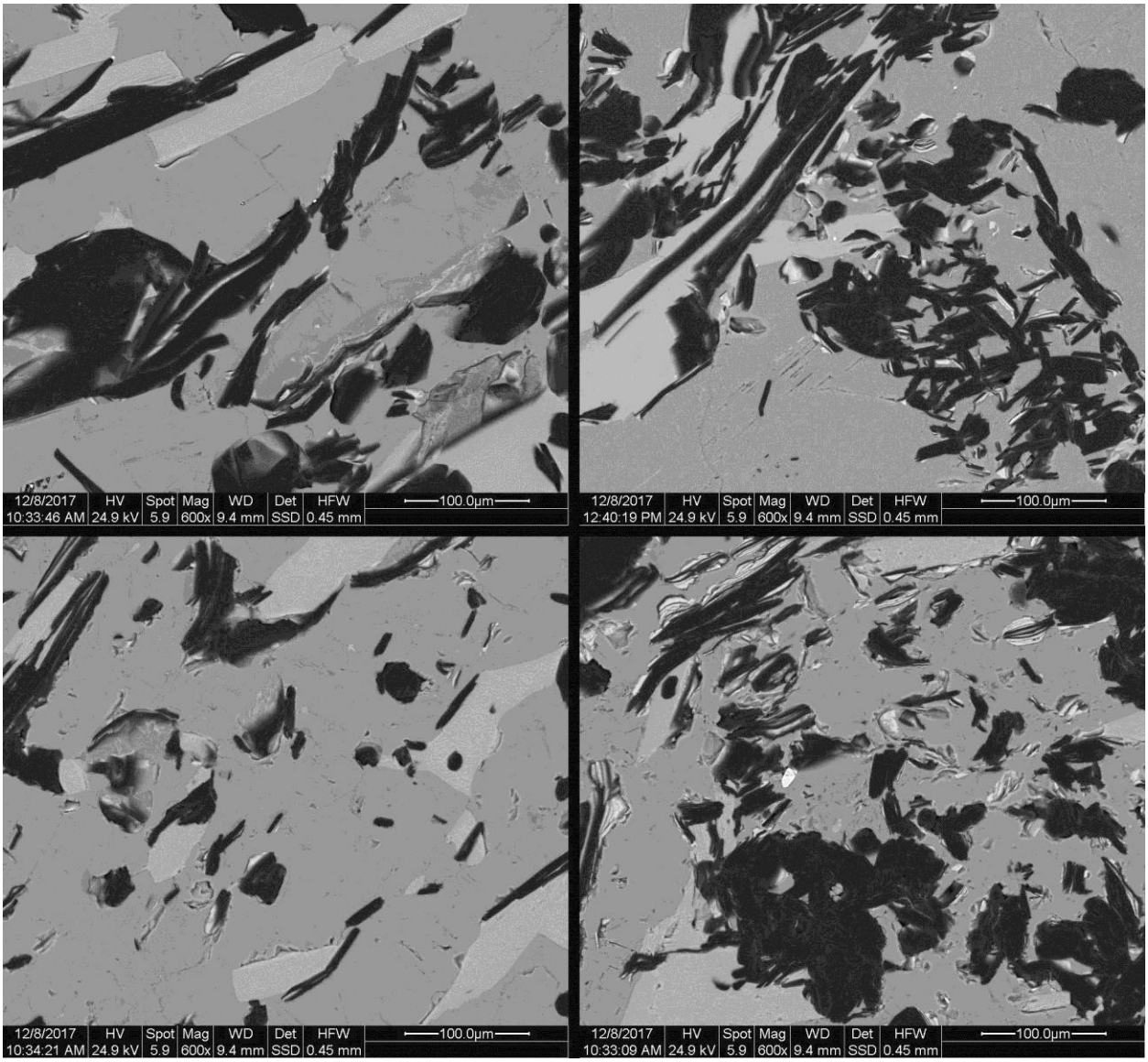
Jauhatusasteen arviointi: mikäli grafiittigneissinäytteessä pienetkin grafiittisuomut halutaan jauhaa vapaiksi partikkeleiksi, niin raekoon tulisi olla alle 50 µm. Grafiittiliukenäytteessä jauhatusasteen tulisi olla ainakin sama. Todennäköisesti raekoon tulisi olla selvästi alle 50 µm, jotta kapeat suomut vapautuisivat silikaateista.



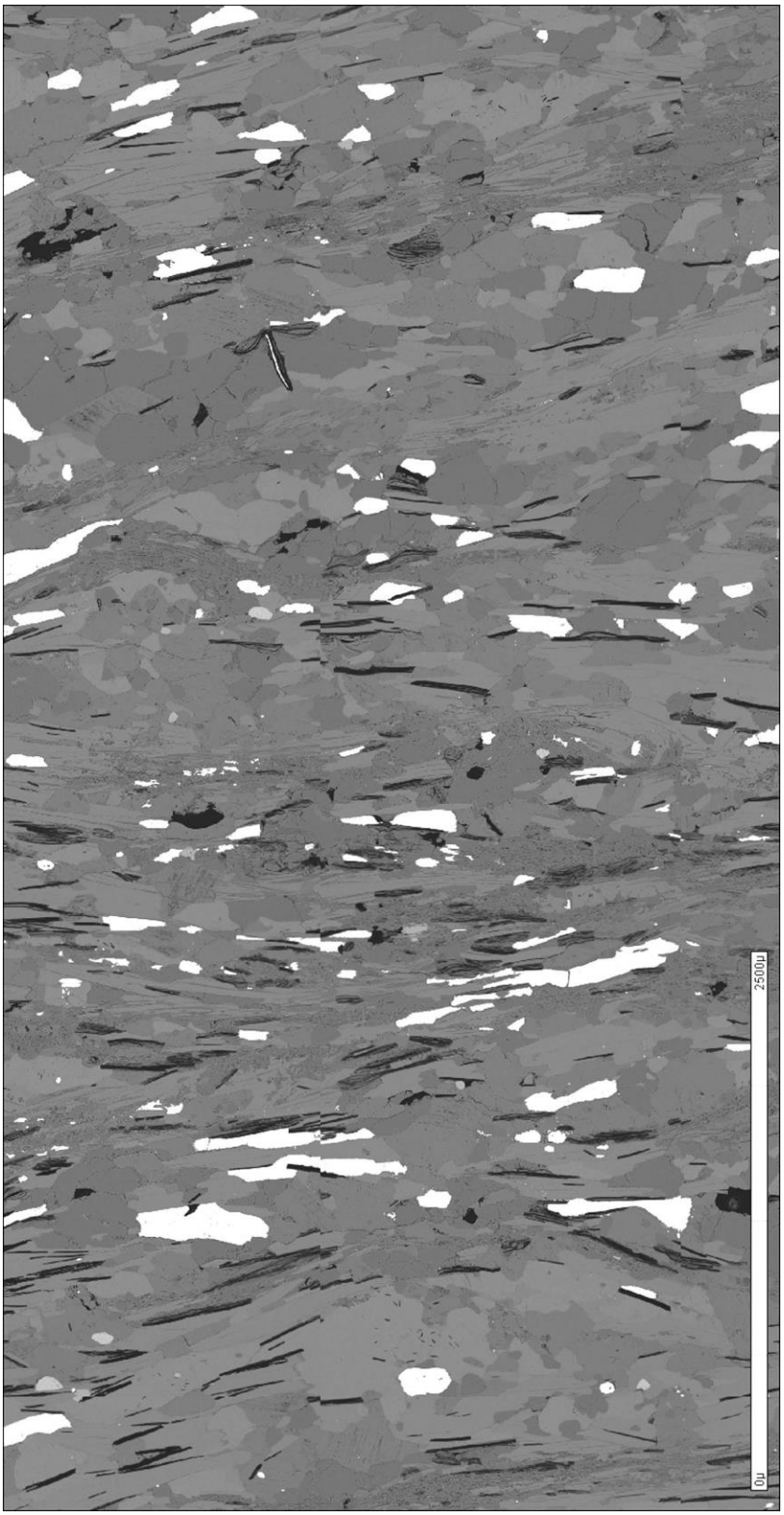
Kuva 1. Hie 160391 grafiittigneissi. Musta on grafiittia. Valkoiset alueet ovat pääosin sulfideja ja muu aines on silikaatteja.



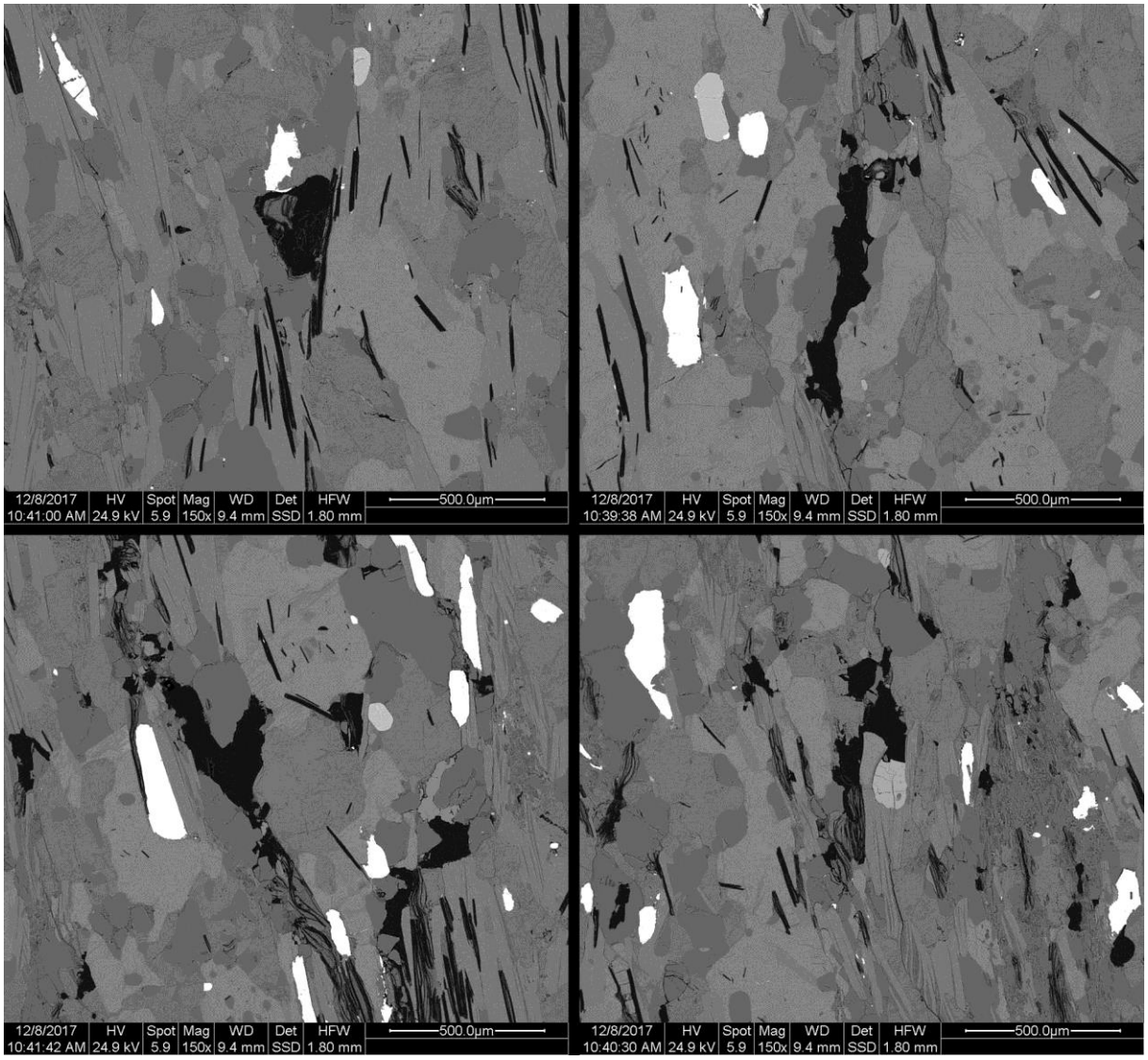
Kuva 2. Hie 160391 grafiittigneissi. Musta on grafiittia. Kuvat on otettu kohteista, joissa on isoja grafiittisuomuja.



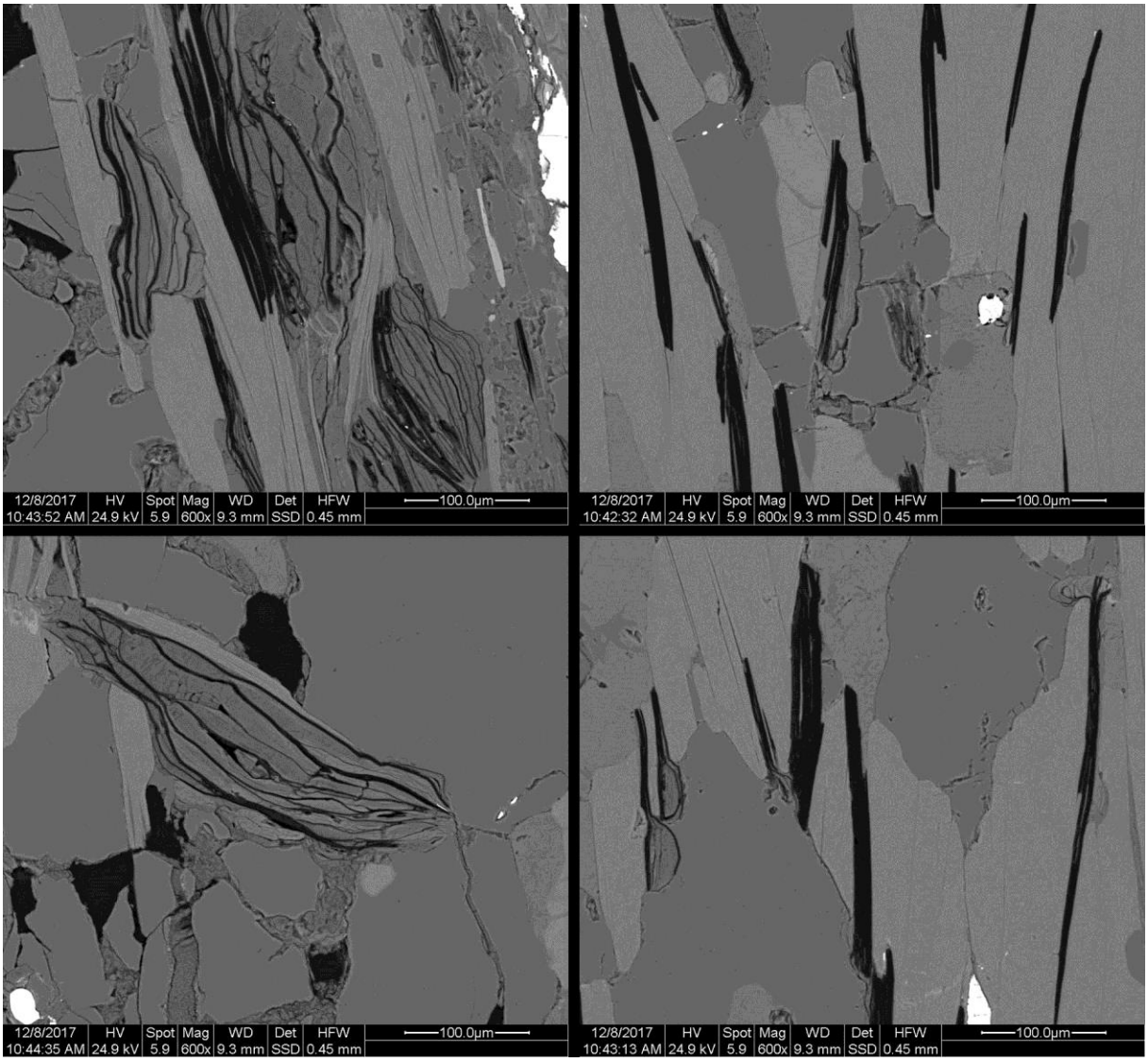
Kuva 3. Hie 160391 grafiittigneissi. Musta on grafiittia. Kuvat on otettu kohteista, joissa on pieniä grafiittisuomuja.



Kuva 4. Hie 160397 grafiittiliuske. Musta on grafiittia. Valkoiset alueet ovat pääosin sulfideja ja muu aines on silikaatteja.



Kuva 5. Hie 160397 grafiittiliuske. Musta on grafiittia. Kuvat on otettu kohdista, joissa on mahdollisimman isoa grafiittia.



Kuva 6. Hie 160397 grafiittiliuske. Musta on grafiittia. Kuvat on otettu kohdista, joissa on hyvin kapeita grafiittisuomuja.

GTK MMA

6.3.2018

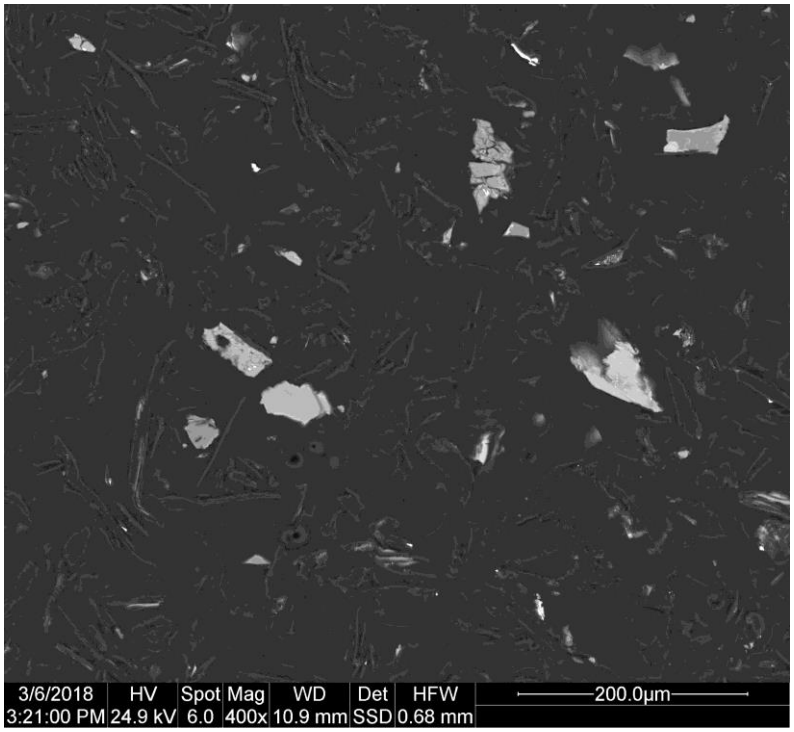
Jukka Laukkanen

Grafiittirikasteiden mineraalipitoisuudet

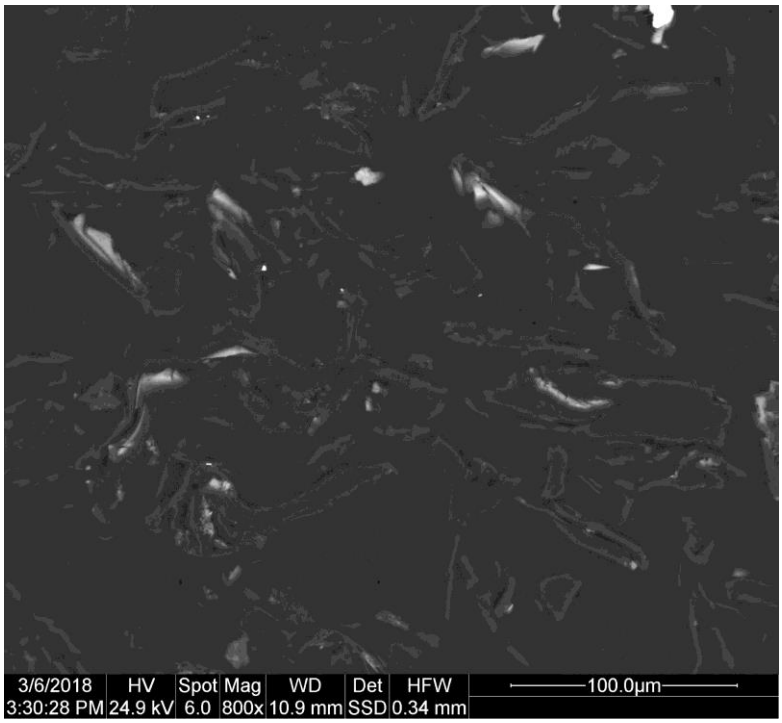
Taulukko 1. Mineraalipitoisuudet

Mineral	Test4 CC5 - Wt%	Test9 CC5 - Wt%
Quartz	1.19	0.85
Plagioclase	0.14	0.81
K_feldspar	0.00	0.00
Almandine	0.24	0.00
Muscovite	0.53	0.08
Chlorite	0.21	0.00
Kaolinite	0.55	1.68
Biotite	1.76	2.10
Calcite	0.86	0.00
Pyrite	0.61	0.00
Pyrrhotite	0.00	0.00
Pure graphite	60.13	57.86
Graphite with silicates	33.23	36.28
Unknown	0.54	0.35
Total	100.00	100.00

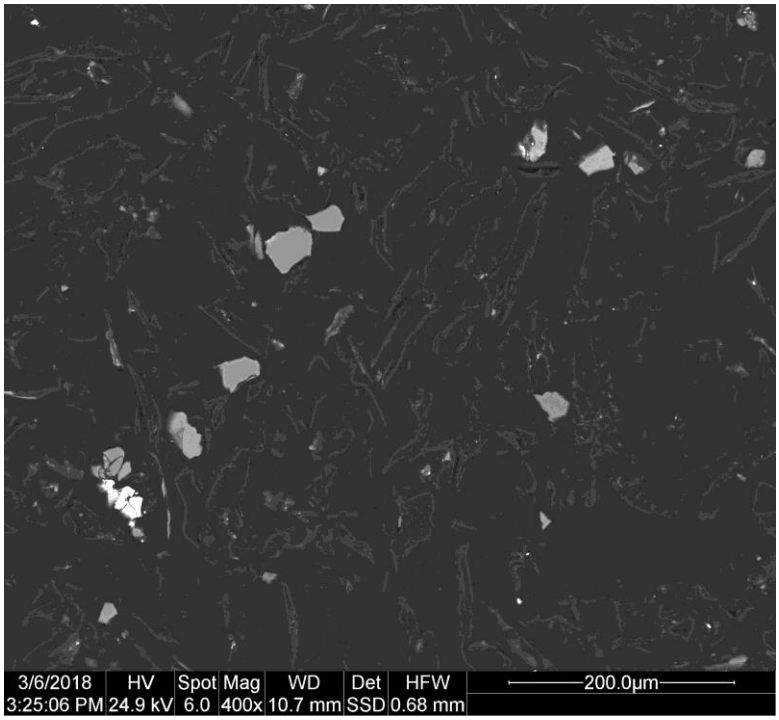
Number of measured points	7045	6805



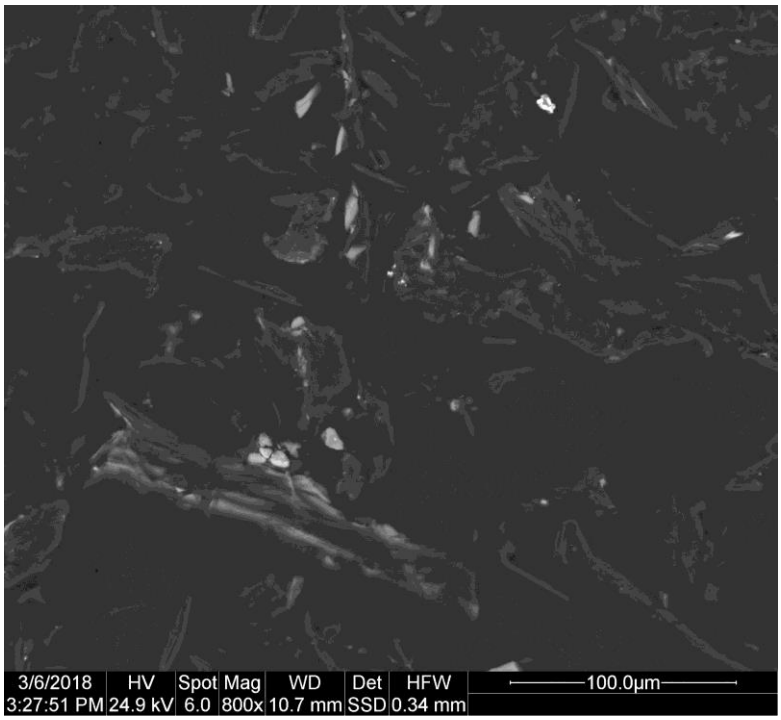
Kuva 1. Test 4 CC5. Tummanharmaat rakeet ovat grafiittia ja niiden välitilassa on epoksia. Vaalea aines on silikaattia. Osa silikaatista on vapaata.



Kuva 2. Test 4 CC5. Grafiittiin sitoutunutta silikaattiainesta (vaalea faasi).



Kuva 3. Test 9 CC5. Tummanharmaat rakeet ovat grafiittia ja niiden välitilassa on epoksia. Vaalea aines on silikaattia. Osa silikaatista on vapaata. Valkoinen faasi on rikkikiisua.



Kuva 4. Test 9 CC5. Grafiittiin sitoutunutta silikaattiainesta (vaalea faasi).

Geological Survey of Finland
Mineral Processing and Materials Research
Outokumpu

17.10.2019 C/MT/2019/22

Production of high-purity graphite from Käpysuo graphite ore by flotation and alkali roasting

Krista Koistinen

GEOLOGICAL SURVEY OF FINLAND **DOCUMENTATION PAGE**

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Type of report
Research report

Commission by
Seppo Leinonen, GTK

Title of report
Production of high-purity graphite from Käpysuo graphite ore by flotation and alkali roasting

Abstract
Bench scale testwork on three graphite ore samples was performed. The samples were from Rautalampi deposit in eastern Finland. The test work was ordered by GTK and was conducted at GTK Mintec during autumn 2019.

The head grades in the sample R25, R26 and R27 were 10–11 % C, 52–56 % SiO_2, 13–15 % Al_2O_3. The main mineral phases were plagioclase, quartz and graphite. Secondary abundant minerals were biotite, K-feldspar and pyrite. Comparing the samples between each other, samples R25 and R26 were very similar in bulk mineralogy, but sample R27 was defer in accessory mineralogy. It was valuably elevated content of muscovite and chlorite and almost totally free from zoesite.

The one objective of the work was to find favorable process conditions for graphite beneficiation. Totally, 7 flotation tests which included both a rougher and a cleaner flotation were performed; at least one tests on each graphite ores. In few tests regrinding were performed after rougher flotation. The flotation time varied from 36 to 76 minutes. Sodium silicate and Raisamyl 008-50 depressant, MIBC frother and kerosene collector were used in all tests.

The high graphite grade 84–85 % with 86 % recovery, were obtained with ore type R25 and R26. The R27 produced 31 % graphite recovery the grade in the concentrate being 87–89 %. Blend 2, composite of sample R25 and R26, and regrinding after rougher flotation produced the highest 95 % grade while the recovery was 78 %.

The highest 98.2 % graphite purity was achieved in alkaline roasting with 25 w–% NaOH at 250 °C for 2 h followed by water wash and acidic leaching by 10 w–% H_2SO_4 at room temperature. The feed material graphite concentration was 86 %.

Keywords
graphite, flotation, alkali roasting

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Contents

Documentation page

1 INTRODUCTION

Seppo Leinonen ordered a bench scale beneficiation testwork on Käpysuo graphite ore sample. The main purpose was to produce high-purity graphite by flotation and alkali roasting. The flotation testwork was related to GTK`s own Battery Minerals project and graphite purification by alkali roasting related to co-funded Green Minerals project. The purpose was to find out favorable process conditions for flotation and purification and produce high-purity graphite for following battery tests.

2 LABORATORY TEST WORK

These bench scale tests and mineralogical characterization were carried out at GTK Mintec of the Geological Survey of Finland (GTK) in Outokumpu.

Mineralogical characterization was conducted with MLA, which is a scanning electron microscope fitted with two energy-dispersive spectrometers for rapid elemental analysis and special software to automatically perform a range of quantitative mineralogical measurements and calculations.

Chemical analysis was performed by X-ray fluorescence (XRF) by Eurofins Oy in Outokumpu. The total carbon and carbonate carbon analyses were done with combustion technique (Eltra, Kuopio) by Eurofins Oy in Kuopio. After alkali roasting high-purity graphite analysis was performed by "gravimetric method (not standard method)" in Eurofins Oy, Outokumpu.

2.1 Sample preparation and feed analyses

The study was accomplished with the Käpysuo graphite ore samples N4442018R25 (R25), N4442018R26 (R26) and N4442018R27 (R27). R25 was combined from 14 drill cores (58.60–155.25) totally 46.5 kg. Sample R26 was the respectively collected sample from 11 drill cores (159.55–161.55) totally 28 kg. R27 was combined from five drill cores (94.30–104.70) totally 10.4 kg. At first material was crushed to < 1.5 mm particle size with a jaw and roller crusher. Then each crushed sample was homogenized by mixing and divided into three 1.0 kg sub samples for the bench scale tests.

After that sample R25 and R26 was homogenized by mixing to one composite sample (Blend 2). Then sample was divided into 1.0 kg and 5.0 kg sub samples for the bench scale tests.

The crushed feed materials were analysed by XRF for overall composition and by Eltra for total carbon content. The assayed analyses are presented in Table I. The main elements were SiO_2, Al_2O_3 and C. The complete feed analyses are presented in Appendix 1.

Table I The Käpysuo graphite ore feed analyses by XRF and total carbon by Eltra.

Sample	C (%)	SiO_2 (%)	Al_2O_3 (%)	MgO (%)	Fe (%)	Ca (%)
R25	9,57	52,2	14,2	3,65	6,12	2,62
R25	9,88	52,4	14,0	3,6	6,19	2,63
R25	9,71	52,7	14,1	3,58	6,22	2,62
R26	10,8	55,5	13,3	2,87	5,29	1,98
R26	10,2	55,4	13,4	2,86	5,29	1,98
R26	10,6	55,6	13,2	2,89	5,28	1,97
R27	9,47	53,9	14,6	3,48	6,16	1,18
R27	10,2	53,9	14,6	3,54	6,11	1,17
R27	9,66	54,2	14,6	3,45	6,04	1,17
Blend 2	10,3	53,8	13,8	3,38	5,77	2,39
Blend 2	10,2	53,7	13,9	3,41	5,75	2,4
Blend 2	10,1	53,5	13,8	3,43	5,92	2,41

The total carbon (C_{tot}) and carbonate carbon (C_{carb}) was analysed separately with combustion technique. Determination given the value of non-carbonate carbon which can assume to be the same as graphite carbon (C_g). The analysis results are represented in Table II. The result shows that all samples included ~10 % C_g. The sample R26 contained a little amount of C_{carb} but the sample R25 not contained any of C_{carb}.

Table II The feed samples carbon analyses by combustion technique (Eltra, Kuopio).

Sample	C_{tot} (%)	C_{carb} (%)	C_g(%)
R25	9.57	<0.05	9.81
R25	9.88	<0.05	9.99
R25	10.8	<0.05	9.80
R26	10.8	0.36	10.4
R26	10.2	0.43	9.73
R26	10.6	0.13	10.4
R27	9.47	<0.05	9.62
R27	10.2	1.59	8.58
R27	9.66	0.12	9.54
Blend 2	9.92	<0.05	9.87
Blend 2	9.95	<0.05	10.1
Blend 2	9.95	0.65	9.3

Modal mineralogy of the samples R25, R26 and R27 are present in Table III. According to the table, main minerals in all samples were quartz and plagioclase. Secondary abundant minerals were biotite, K-feldspar and pyrite. Graphite content varied from 10.1 w–% in R25 sample to 11.3 w–% in R27. Comparing the samples between each other, samples R25 and R26 were very similar in bulk mineralogy, but sample R27 was defer in accessory mineralogy. It was valuably elevated content of muscovite and chlorite and almost totally free from zoesite. The complete mineralogy analyses are presented in Appendix 2.

Table III Modal Mineralogy.

Mineral	R25	R26	R27
Graphite	10.10	10.65	11.26
Quartz	21.98	24.86	24.29
Plagioclase	32.75	31.90	25.26
K-feldspar	6.55	5.52	3.82
Pigeonite	0.15	0.01	0.04
Actinolite	2.02	0.72	0.04
Anthophyllite	0.43	0.52	0.92
Hornblende	0.47	0.14	0.05
Biotite	10.10	6.47	10.36
Muscovite	1.71	1.18	8.96
Chlorite	2.70	2.68	6.69
Sekaninaite	1.05	1.41	1.04
Zoisite	3.24	2.10	0.11
Cordierite	0.01	0.04	0.01
Titanite	0.18	0.16	0.03
Calcite	0.24	0.07	0.13
Apatite	0.32	0.83	0.41
Xenotime	0.02	0.00	0.00
Rutile	0.12	0.17	0.13
Goethite	0.16	1.34	1.76
Pyrite	5.28	8.80	4.16
Chalcopyrite	0.06	0.02	0.01
Sphalerite	0.13	0.08	0.01
Unclassified	0.22	0.33	0.49
Total	100.00	100.00	100.00
Nr of measured perticles	29086	30130	29781

2.2 Grinding

The grinding was done with a mild steel laboratory ball mill in tests T10–T15. The used slurry density was 50 %, ore sample 1.0 kg, water 1.0 L and balls 8 kg. 90 minutes grinding time were used for the R25, R26 and R27 sample. The exception was test T15 where ground 60 minutes and after the rougher flotation reground extra 30 minutes in one part. The regrinding was done with a stainless steel laboratory ball mill with 5 kg different size ceramic and steel balls.

In test T16 grinding was done with a Mergan rod mill. The slurry density was 50 %, ore sample 5.0 kg, water 5.0 L and 22 kg rods. 75 minutes grinding time was used for the Blend 2. After the rougher flotation, RC1–8 was split in two part and both were reground extra 45 minutes with a stainless steel laboratory ball mill with 5 kg different size ceramic and steel balls.

In the laboratory testwork a particle size distribution was determined by wet and dry sieving. At first, wet sieving with 20 µm screen was done and after this the overflow of the wet sieving phase was sieved as dry by Ro-Tap sieve shaker. The particle size distributions are shown in Figure 1.

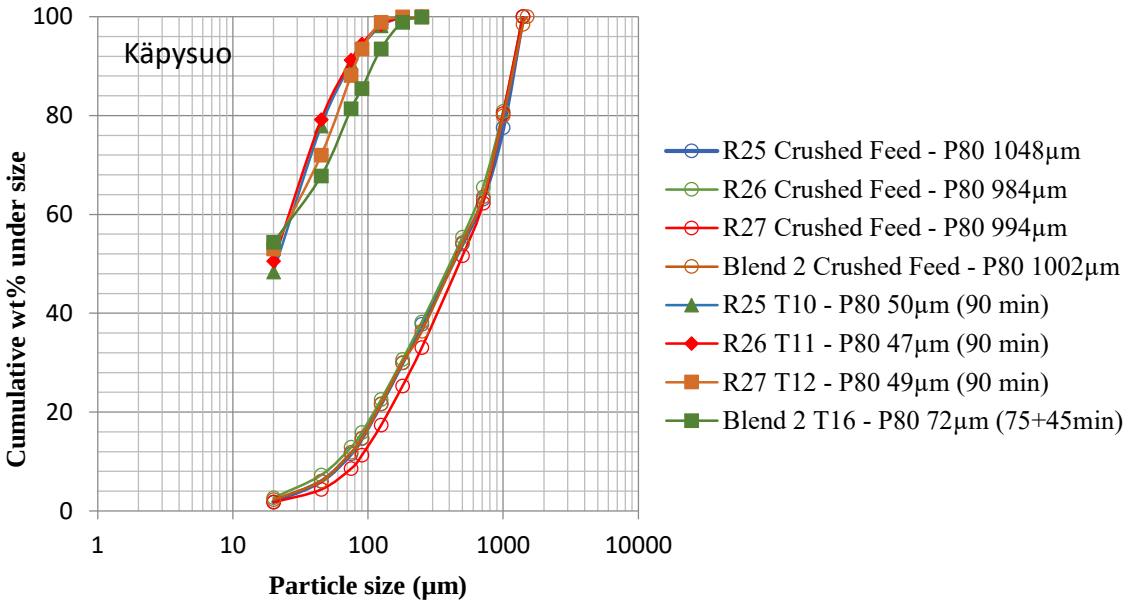

Figure 1. Particle size distribution for the Käpysuo samples.

2.3 Flotation

Totally 7 seven flotation test were accomplished (T10–T16) in GTK Mintec (Figure 3.). Graphite beneficiation included three rougher flotation stages to reach a high graphite recovery. Followed by five cleaner flotation stages, which were done in order to upgrade the quality of the graphite concentrates. Sodium silicate and starch were used as depressant, kerosene as collector and MIBC as frother. The principle beneficiation flowsheet is shown in Figure 2. The flotation test conditions are shown in Table IV. The flotation products were analysed by XRF and Eltra (Kuopio). The complete flotation conditions are presented in Appendix 3. Flotation chemicals are shown in Table V.

Table IV The flotation test variables.

Test	Sample	Main variable	Grinding time (min)	Rougher flotation	Cleaner flotation	Frother (g/t) MIBC
10	R25	Ore type	90	x3	x5	180
11	R26	Ore type	90	x3	x5	180
12	R27	Ore type	90	x3	x5	180
13	R27	pH	90	x3	x5	180
14	R25	slurry density	90	x3	x5	180
15	Blend 2	Regrinding	60+30	x3	x5	344
16	Blend 2	Concentration production	75+2*45	x8	x5	988

Flotation test T10, T11 and T12 the studied variable were the Käpysuo ore type (R25, R26, R27). These three tests were done in natural pH 6.5–8.5. In test T13 (ore type R27) pH was adjusted to 8.0 with calcium hydroxide before flotation. Laboratory tests were done with 1 kg feed sample. Rougher flotation

cell size was 4 L, 1st cleaner flotation 2.5 L and 2nd to 5th cleaner flotation 1.5 L. Exceptional case were test T14 (ore type R25), where the flotation was done more dilute solid content and flotation cell size was 4 L both rougher and cleaner flotation stages.

Käpysuo Blend 2 composite sample was accomplished two graphite beneficiation test. In these two test pH were adjusted to 8.5 with sodium hydroxide. Rougher graphite concentrate was reground 30 minutes before cleaned five times (T15). Test T16 was performed 5 kg feed sample and aim was graphite concentrate production for battery tests. Rougher flotation cell size was 13 L, 1st cleaner flotation 7 L and 2nd to 5th cleaner flotation 4 L. There was also performed regrinding before cleaner flotation.

Table V Flotation chemicals.

Trade Name	Chemical composition	Concentration	Purpose of Use
Zeopol 33	Sodium silicate, Na_2SiO_3	5 %	depressant
Raisamyl 088-50	Starch	1 %	depressant
MIBC	4-metyl-2-pentanol	100 %	frother
Kerosene		100 %	collector
NaOH	sodium hydroxide	5 %	pH
Ca(OH)2	calcium hydroxide	100 %	pH

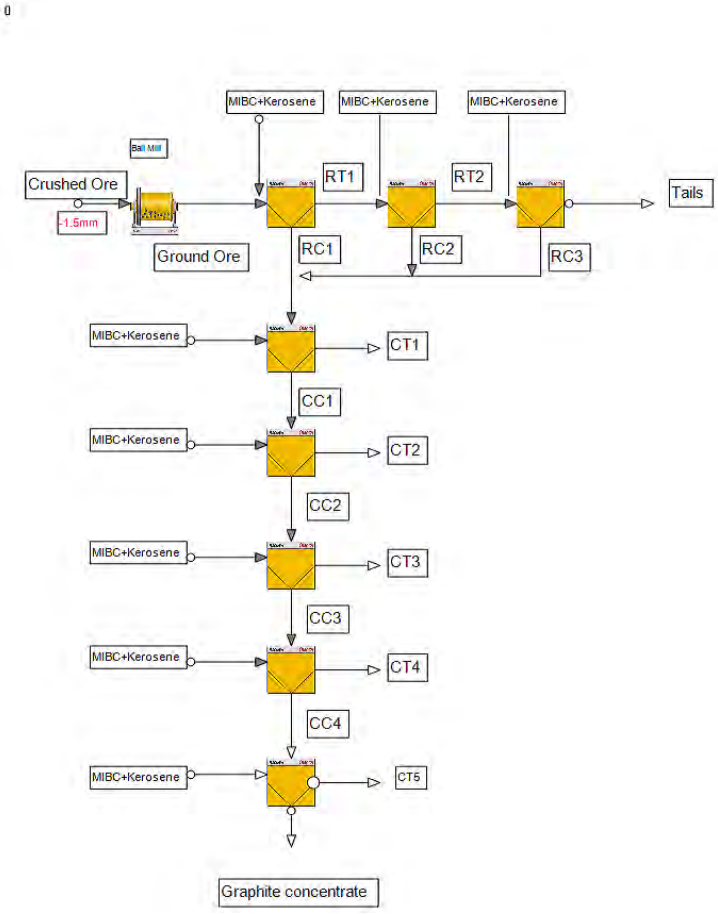

Figure 2. Principle beneficiation flowsheet for Käpysuo graphite; grinding, rougher and cleaner flotation.

Figure 3. Graphite flotation test in GTK Mintec laboratory in Outokumpu.

2.4 Alkaline roasting

The graphite purification method included three step; an alkaline roasting, a water wash and a sulfuric acid leaching (Figure 5. and Figure 6.). At the first was carried out alkaline roasting with sodium hydroxide at 250 °C, in this stage impurities were converted to soluble form. Next the graphite was washed with water to dilute soluble impurities and extra alkali. Last stage was acidic leaching with sulfuric acid at room temperature, where removed acid soluble impurities.

Seven purification test (LT15–LT21) were performed for graphite flotation concentrate. The effect of alkali concentration, roasting temperature and time was investigated (Table VI). Liquid–solid ratio was 2/1 (w/w) in alkaline roasting and 5/1 (w/w) in acidic leaching. The raw material was combined from flotation test T10–T14 concentrates CC5 and this material was used in all tests (Figure 4.).

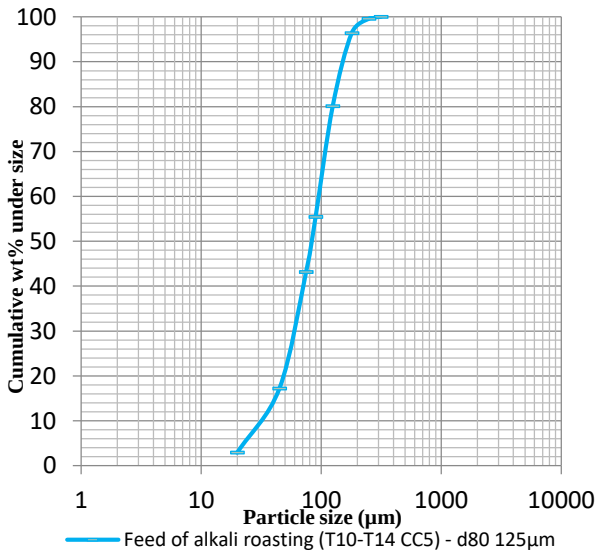

Figure 4. Particle size distribution for the alkali roasting feed material (T10–T14 CC5).

Figure 5. Graphite concentrate and sodium hydroxide before (left) and after (right) alkaline roasting at 150–350 °C in a chamber furnace in GTK Mintec Laboratory in Outokumpu.

Figure 6. Water wash of alkaline roasted graphite concentrate in the beaker (left). Filtration with the vacuum filter (middle). Final graphite concentrate (right).

3 TEST RESULTS

The main beneficiation results for the test material, Käpysuo, are shown in Table VI and Figure 6 (Appendix 3). In two ore type R25 (T10) and R26 (T11), the graphite recovery to rougher concentrate were 95–96 % and the concentrate grade were 53–58 %. An exceptional case was the test T12 carried out with R27 ore type where the C recovery to rougher concentrate was lower level, 51 % and C grade was also lower 45 %. Rougher flotation pH was naturally low 6.5 in test T12. In the test T13 the pH was adjusted to 8 before rougher flotation and the C recovery raised to 67 % and at the same time the C grade was 50 % after rougher flotation stage. After 5th cleaner flotation both Käpysuo ore types R25 (T10) and

R26 (T11) gives 86 % C recovery and 84–85 % C grade. Ore type R27 (T12, T13) beneficiation study resulted lower 31–55 % C recovery and higher 87–89 % C grade.

Lower solid content was used in T14 (R25). Flotation cell size was 4 L in all flotation stages. Compere to T10 which was accomplished with same R25 ore type the C recovery was significantly lower, 38 %, respectively the C grade was 10 % higher, 94 %.

The highest graphite grade 95.4 % with 78 % recovery was achieved in the T15, accomplished with rougher concentrate RC1–3 regrinding at pH 8.5. Bigger scale test, T16, resulted high 95 % C grade but the C recovery was low, 58 %. Especially in rougher flotation stage was used MIBC frother four time more than usually and still the recovery was only 78 %.

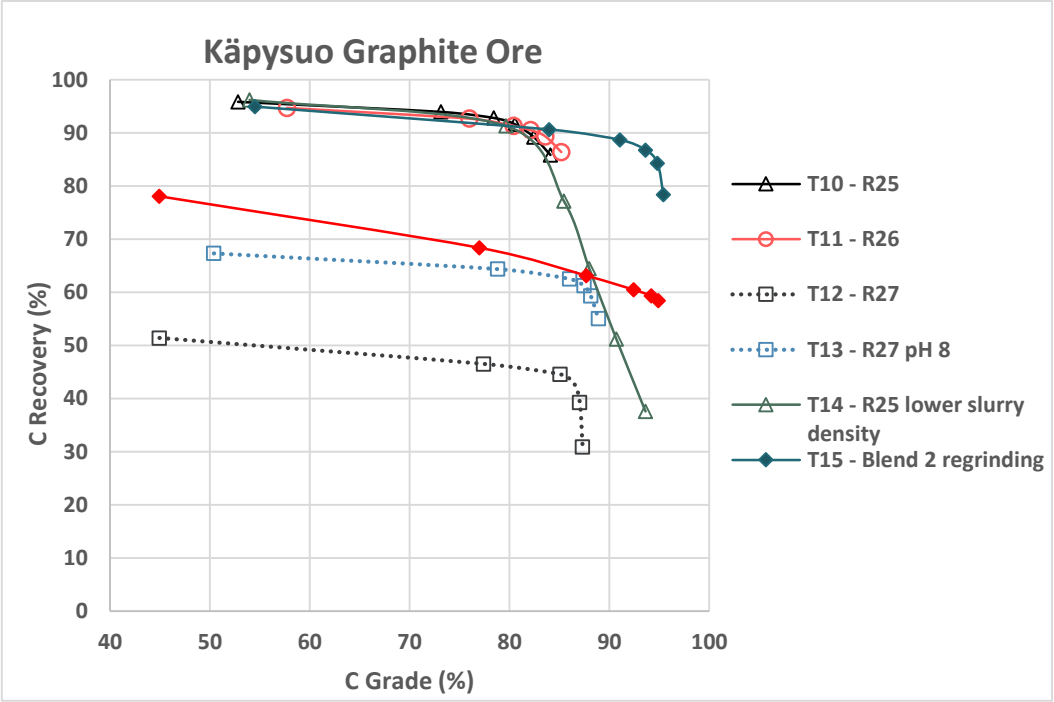

Figure 6. Flotation test results for Käpysuo ore sample; rougher and cleaner flotation.

The Käpysuo graphite concentrate alkali roasting results are shown in Table VII. The raw material C concentration was 86 %. The highest 98.2 % graphite purity was achieved in alkaline roasting with 25 –% NaOH at 250 °C for 2 h followed by water wash and acidic leaching with 10 w–% sulfuric acid at room temperature.

The results (Figure 7.) shown that the material can be effectively purified on 2–3 hours. The effect of roasting temperatures was also investigate and the results indicates that for this material the best product purity can be achieved at 250–350 °C. The highest sulfur removal reached at 350 °C, the sulfur content in the product can be reduced from 0.5 % to below 0,07 %.

Table VI The Käpysuo graphite sample beneficiation test results. C analysis by Eltra, Kuopio.

	Test 10 (R25)			Test 11 (R26)			Test 12 (R27)			Test 13 (R27)			Test 14 (R25)			Test 15 (Blend 2)			Test 16 (Blend 2)		
	Mass (g)	% C	% C Distr.	Mass (g)	% C	% C Distr.	Mass (g)	% C	% C Distr.	Mass (g)	% C	% C Distr.	Mass (g)	% C	% C Distr.	Mass (g)	% C	% C Distr.	Mass (g)	% C	% C Distr.
RC	177,52	52,8	95,9	174,68	57,7	94,7	110,63	44,9	51,4	132,08	50,4	67,3	178,23	54,0	96,2	173,96	54,5	94,9	874,7	44,9	78,1
Rtails	823,5	0,49	4,1	825,66	0,68	5,3	887,48	5,3	48,6	867,76	3,72	32,7	821,39	0,46	3,8	828	0,61	5,1	4106,6	2,69	21,9
CC1	125,62	73,1	94,0	129,9	76,0	92,7	58,12	77,4	46,5	80,71	78,8	64,4	114,66	79,6	91,3	107,83	84,0	90,6	447	77,0	68,4
CT1	51,9	3,6	1,9	44,78	4,8	2,0	52,51	9	4,9	51,37	5,7	3,0	63,57	7,7	4,9	66,13	6,5	4,3	427,7	11,4	9,7
CC2	115,76	78,4	92,8	120,91	80,4	91,3	50,67	85,1	44,5	71,82	86,0	62,5	90,29	85,4	77,2	97,3	91,1	88,7	362,3	87,7	63,1
CT2	9,86	11,3	1,1	8,99	16,2	1,4	7,45	25,3	1,9	8,89	20,6	1,9	24,37	58,1	14,2	10,53	18,5	1,9	84,7	31,2	5,2
CC3	111,29	80,5	91,6	117,38	82,1	90,5	48,08	86,4	42,9	69,18	87,5	61,2	73,21	88,0	64,4	92,6	93,6	86,8	329,5	92,4	60,5
CT3	4,47	25,8	1,2	3,53	24,1	0,8	2,59	60,1	1,6	2,64	47,9	1,3	17,08	74,5	12,7	4,7	40,6	1,9	32,8	40,3	2,6
CC4	105,83	82,4	89,2	113,83	83,6	89,4	43,64	87,0	39,3	66,49	88,1	59,3	56,44	90,7	51,2	88,78	94,8	84,3	317,3	94,2	59,4
CT4	5,46	43,6	2,4	3,55	34,9	1,2	4,44	80,3	3,7	2,69	70,7	1,9	16,77	78,9	13,2	3,82	66	2,5	12,2	46,6	1,1
CC5	99,81	84,1	85,8	107,97	85,2	86,4	34,2	87,3	30,9	61,23	88,9	55,1	40,14	93,6	37,6	82,08	95,4	78,4	310	94,9	58,4
CT5	6,02	54,8	3,4	5,86	53,9	3,0	9,44	86	8,4	5,26	79,4	4,2	16,3	83,5	13,6	6,7	87,6	5,9	7,3	63,6	0,9
Feed	1001,02	9,8		1000,34	10,6		998,11	9,7		999,84	9,9		999,62	10,0		1001,96	10,0		4981,3	10,1	

Table VII The Käpysuo flotation concentrate purification tests variable and results. SiO_2 and Fe analysis by XRF, S by Eltra and C by gravimetric, no standard, method.

Leaching Test	Feed	Alkaline Roasting				Acid Leaching		Feed	Residue	Upgrade	Leaching Test	SiO2 Feed	SiO2 residue	S Feed	S residue	Fe Feed	Fe residue
		Base	%	ToC	Time	Acid	%	C (%)	C (%)	%		%	%	%	%	%	%
LT15	T10-14 CC5		15	250	2		10	86,0	95,1	10,6	LT15	5,73	1,96	0,480	0,174	1,4	0,27
LT16	T10-14 CC5		25	250	2		10	86,0	98,2	14,2	LT16	5,73	0,69	0,480	0,110	1,4	0,06
LT17	T10-14 CC5		35	250	2		10	86,0	97,3	13,1	LT17	5,73	1,11	0,480	0,133	1,4	0,15
LT18	T10-14 CC5	NaOH	25	250	1	H2SO4	10	86,0	95,8	11,4	LT18	5,73	1,69	0,480	0,170	1,4	0,22
LT19	T10-14 CC5		25	250	3		10	86,0	98,0	14,0	LT19	5,73	0,89	0,480	0,116	1,4	0,13
LT20	T10-14 CC5		25	150	2		10	86,0	93,5	8,7	LT20	5,73	2,77	0,480	0,121	1,4	0,39
LT21	T10-14 CC5		25	350	2		10	86,0	97,3	13,1	LT21	5,73	0,67	0,480	0,069	1,4	0,06

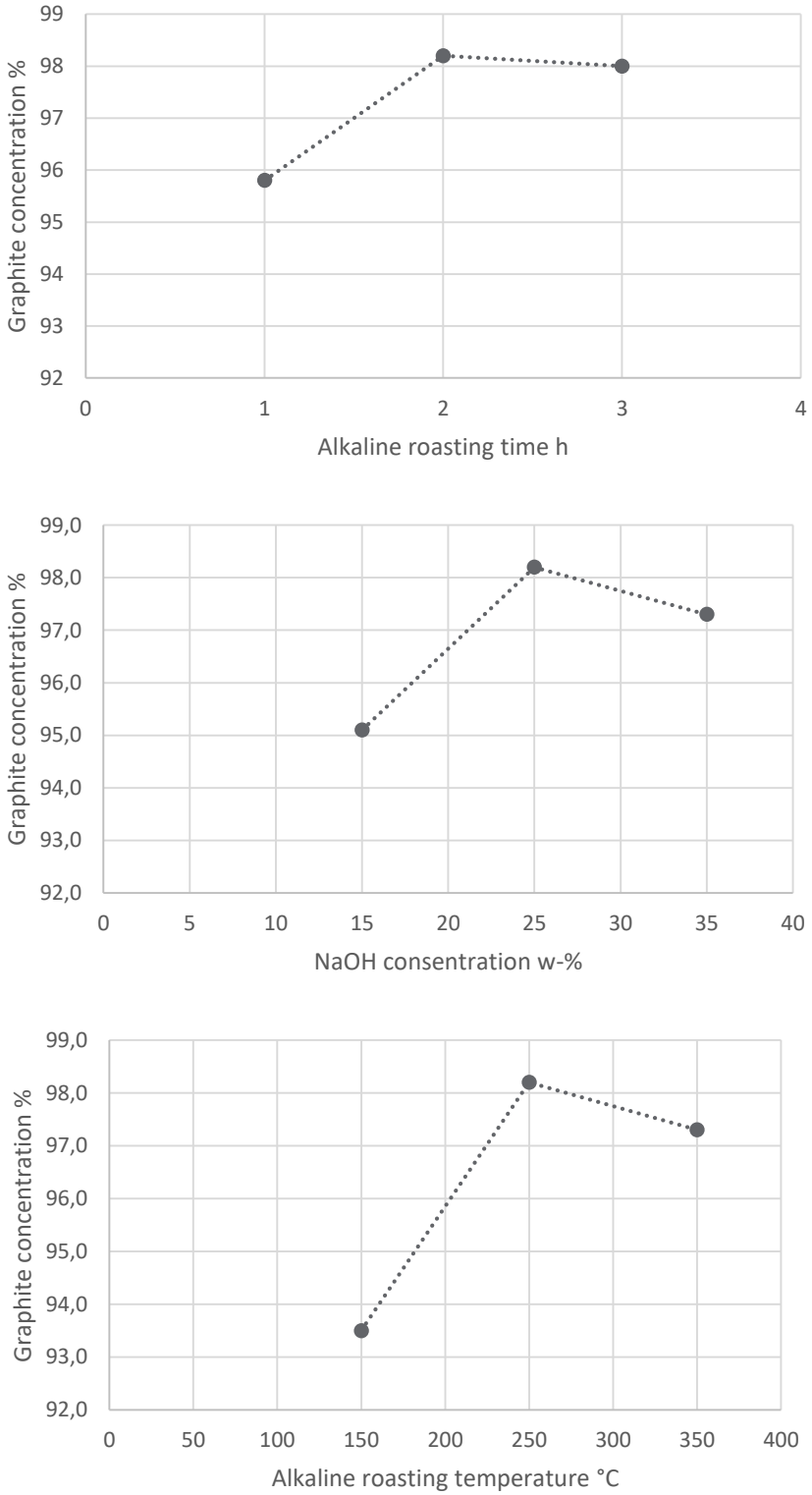

Figure 7. Alkaline roasting of graphite concentrate. Raw material C concentrate was 86 %.

4 CONCLUSIONS

The highest graphite grade was obtained by regrinding rougher concentrates. For the Blend 2 composite sample, the highest 95 % graphite grade and 78 % C recovery was achieved in the test where the pH was 8.5 and the chemical dosages were 344 g/t MIBC, 181 g/t kerosene 1500 g/t sodium silicate 300 g/t Raisamyl 088-50. Above mentioned test procedure in bigger scale produced 95 % graphite grade but only 58 % C recovery. In future testwork it would be worthwhile to study the depressant dose effect to graphite recovery in bigger scale.

The highest 98.2 % graphite purity was achieved in alkaline roasting with 25 –% NaOH at 250 °C for 2 h followed by water wash and acidic leaching with 10 w–% sulfuric acid at room temperature. The raw material C concentration was only 86 %, which could be decreasing the final graphite purity.

Appendix 1
Chemical analysis

Feed material: C content by Eltra (%), other element contents by XRF (%)												
	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo
Element	**R25_1**	**R25_2**	**R25_3**	**R26_1**	**R26_2**	**R26_3**	**R27_1**	**R27_2**	**R27_3**	**Blend 2_1**	**Blend 2_2**	**Blend 2_3**
SiO2	52.2	52.4	52.7	55.5	55.4	55.6	53.9	53.9	54.2	53.8	53.7	53.5
TiO2	0.59	0.59	0.60	0.54	0.53	0.54	0.67	0.68	0.67	0.59	0.57	0.56
Al2O3	14.2	14.0	14.1	13.3	13.4	13.2	14.6	14.6	14.6	13.8	13.9	13.8
Cr2O3	0.020	0.019	0.019	0.020	0.020	0.018	0.018	0.017	0.016	0.020	0.019	0.021
V2O3	0.094	0.093	0.096	0.099	0.096	0.098	0.080	0.080	0.080	0.095	0.096	0.096
FeO	7.87	7.96	8.00	6.80	6.81	6.79	7.92	7.85	7.77	7.42	7.40	7.61
MnO	0.073	0.073	0.071	0.061	0.060	0.061	0.048	0.047	0.047	0.069	0.071	0.070
MgO	3.65	3.60	3.58	2.87	2.86	2.89	3.48	3.54	3.45	3.38	3.41	3.43
CaO	3.66	3.68	3.66	2.77	2.78	2.75	1.65	1.64	1.64	3.35	3.35	3.37
Rb2O	0.0062	0.0069	0.0072	0.0058	0.0061	0.0058	0.0095	0.0090	0.0093	0.0065	0.0059	0.0066
SrO	0.024	0.024	0.023	0.018	0.018	0.019	0.022	0.021	0.021	0.022	0.022	0.022
BaO	0.052	0.048	0.046	0.049	0.048	0.049	0.055	0.056	0.055	0.046	0.049	0.047
Na2O	2.25	2.27	2.30	2.09	2.11	2.09	2.05	2.00	2.06	2.23	2.22	2.23
K2O	2.07	2.07	2.06	1.99	2.05	2.02	2.56	2.60	2.57	2.07	2.09	2.04
ZrO2	0.016	0.016	0.016	0.019	0.019	0.019	0.015	0.015	0.015	0.016	0.017	0.017
P2O5	0.206	0.190	0.195	0.223	0.230	0.226	0.204	0.210	0.207	0.206	0.208	0.218
CO2	37.8	37.0	36.4	40.5	40.0	40.3	38.1	38.1	38.1	37.8	37.4	37.0
OxSumm	99.20	99.20	99.40	99.30	99.30	99.40	99.20	99.10	99.20	99.40	99.20	99.20
Cu	0.016	0.017	0.015	0.014	0.016	0.015	0.009	0.011	0.011	0.016	0.015	0.015
Ni	0.027	0.025	0.027	0.029	0.029	0.028	0.027	0.027	0.026	0.028	0.027	0.027
Co	0.012	0.021	0.005	0.023	0.023	0.026	0.020	0.018	0.006	0.011	0.007	0.007
Zn	0.050	0.053	0.054	0.049	0.050	0.051	0.027	0.031	0.027	0.053	0.052	0.048
Pb	0.006	0.007	0.007	0.007	0.007	0.007	0.006	0.007	0.006	0.007	0.008	0.007
Ag	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
S	3.53	3.63	3.70	3.41	3.47	3.45	2.65	2.54	2.62	3.43	3.46	3.62
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.009	0.010	0.010	0.012	0.011	0.010	0.010	0.010	0.011	0.011	0.010	0.010
Bi	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Te	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.001	0.000
Y	0.0040	0.0042	0.0039	0.0038	0.0041	0.0034	0.0036	0.0036	0.0034	0.0041	0.0042	0.0040
Nb	0.0012	0.0014	0.0010	0.0016	0.0019	0.0011	0.0012	0.0015	0.0013	0.0014	0.0011	0.0015
Mo	0.0056	0.0055	0.0054	0.0052	0.0055	0.0058	0.0036	0.0027	0.0035	0.0059	0.0060	0.0062
Sn	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.003
W	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.001
Cl	0.007	0.005	0.005	0.006	0.007	0.007	0.008	0.007	0.006	0.004	0.004	0.005
Th	0.0015	0.0013	0.0011	0.0016	0.0015	0.0015	0.0013	0.0011	0.0014	0.0015	0.0012	0.0012
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.001	0.002	0.002	0.001	0.000	0.002	0.002	0.002	0.002	0.000	0.002
La	0.004	0.007	0.004	0.006	0.005	0.005	0.004	0.006	0.005	0.003	0.006	0.004
Ce	0.006	0.007	0.004	0.007	0.007	0.006	0.007	0.006	0.006	0.005	0.005	0.007
Ta	0.001	0.001	0.001	0.000	0.002	0.000	0.002	0.001	0.000	0.001	0.000	0.001
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0018	0.0018	0.0018	0.0015	0.0012	0.0014	0.0015	0.0022	0.0015	0.0015	0.0016	0.0017
Si	24.4	24.5	24.6	25.9	25.9	26.0	25.2	25.2	25.3	25.2	25.1	25.0
Ti	0.352	0.352	0.360	0.322	0.318	0.322	0.403	0.407	0.399	0.353	0.342	0.336
Cr	0.014	0.013	0.013	0.014	0.014	0.012	0.012	0.012	0.011	0.014	0.013	0.014
V	0.064	0.063	0.065	0.067	0.065	0.067	0.054	0.055	0.054	0.065	0.066	0.065
Fe	6.12	6.19	6.22	5.29	5.29	5.28	6.16	6.11	6.04	5.77	5.75	5.92
Mn	0.057	0.056	0.055	0.047	0.046	0.047	0.037	0.037	0.036	0.054	0.055	0.054
Mg	2.20	2.17	2.16	1.73	1.73	1.74	2.10	2.13	2.08	2.04	2.05	2.07
Ca	2.62	2.63	2.62	1.98	1.98	1.97	1.18	1.17	1.17	2.39	2.40	2.41
Ba	0.047	0.043	0.042	0.044	0.043	0.043	0.049	0.050	0.049	0.041	0.043	0.042
Eltra C	10.3	10.1	9.93	11.0	10.9	11.0	10.4	10.4	10.4	10.3	10.2	10.1

Flotation test T10: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T10 Tails**	**T10 CT1**	**T10 CT2**	**T10 CT3**	**T10 CT4**	**T10 CT5**	**T10 CC5**
SiO2	57.9	57.2	50.9	37.9	25.0	21.5	6.26
TiO2	0.65	0.56	0.53	0.462	0.410	0.361	0.104
Al2O3	15.0	15.2	14.4	12.2	9.07	7.99	2.62
Cr2O3	0.021	0.019	0.019	0.022	0.021	0.018	0.0063
V2O3	0.101	0.089	0.099	0.106	0.110	0.100	0.031
FeO	9.59	8.36	7.92	6.58	4.51	4.02	1.70
MnO	0.081	0.081	0.081	0.078	0.070	0.063	0.021
MgO	3.76	3.17	3.35	3.19	2.89	2.52	0.69
CaO	3.98	4.14	3.84	3.16	2.20	1.93	0.52
Rb2O	0.0077	0.0061	0.0067	0.0018	0.0033	0.0027	0.0000
SrO	0.026	0.028	0.025	0.018	0.013	0.012	0.0043
BaO	0.053	0.055	0.049	0.041	0.032	0.028	0.009
Na2O	2.54	2.51	2.17	1.61	0.99	0.87	0.20
K2O	2.19	2.00	1.97	1.76	1.56	1.37	0.416
ZrO2	0.022	0.017	0.016	0.014	0.011	0.011	0.004
P2O5	0.214	0.205	0.191	0.126	0.070	0.060	0.016
CO2	1.80	13.0	41.4	94.6	159.9	201.0	308.4
OxSumm	98.90	99.00	98.60	94.40	91.40	96.40	97.00
Cu	0.018	0.022	0.024	0.025	0.013	0.010	0.006
Ni	0.030	0.027	0.025	0.021	0.013	0.011	0.006
Co	0.004	0.008	0.011	0.012	0.005	0.003	0.002
Zn	0.060	0.059	0.053	0.042	0.025	0.023	0.009
Pb	0.007	0.008	0.008	0.013	0.009	0.008	0.007
Ag	0.001	0.002	0.001	0.000	0.001	0.001	0.000
S	4.09	3.15	2.87	2.23	1.36	1.19	0.51
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.012	0.011	0.010	0.006	0.005	0.002	0.000
Bi	0.002	0.002	0.002	0.003	0.003	0.002	0.001
Te	0.001	0.000	0.001	0.006	0.004	0.004	0.001
Y	0.0049	0.0041	0.0050	0.0037	0.0028	0.0028	0.0019
Nb	0.0037	0.0012	0.0015	0.0041	0.0023	0.0022	0.0012
Mo	0.0021	0.010	0.025	0.034	0.035	0.035	0.014
Sn	0.003	0.003	0.003	0.000	0.001	0.001	0.001
W	0.000	0.001	0.000	0.000	0.001	0.001	0.001
Cl	0.002	0.002	0.004	0.004	0.003	0.002	0.003
Th	0.0023	0.0014	0.0018	0.0012	0.0004	0.0006	0.0015
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.003	0.003	0.002	0.000	0.002	0.000	0.001
La	0.006	0.006	0.006	0.003	0.003	0.005	0.001
Ce	0.009	0.006	0.006	0.005	0.003	0.003	0.001
Ta	0.000	0.001	0.002	0.000	0.001	0.001	0.001
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0024	0.0014	0.0020	0.0021	0.0019	0.0016	0.0006
Si	27.1	26.8	23.8	17.7	11.7	10.1	2.93
Ti	0.390	0.333	0.319	0.277	0.246	0.217	0.062
Cr	0.015	0.013	0.013	0.015	0.015	0.012	0.0043
V	0.069	0.060	0.067	0.072	0.075	0.068	0.021
Fe	7.46	6.50	6.16	5.12	3.51	3.13	1.32
Mn	0.063	0.063	0.063	0.061	0.054	0.049	0.017
Mg	2.27	1.91	2.02	1.92	1.74	1.52	0.42
Ca	2.85	2.96	2.75	2.26	1.57	1.38	0.369
Ba	0.048	0.049	0.043	0.036	0.029	0.025	0.008
Eltra C	0.490	3.55	11.3	25.8	43.6	54.8	84.1

Flotation test T11: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T11 Tails**	**T11 CT1**	**T11 CT2**	**T11 CT3**	**T11 CT4**	**T11 CT5**	**T11 CC5**
SiO2	61.9	58.9	47.1	35.6	29.0	21.3	6.14
TiO2	0.60	0.472	0.404	0.374	0.406	0.318	0.088
Al2O3	14.3	14.5	12.8	11.0	10.2	7.85	2.45
Cr2O3	0.022	0.016	0.017	0.019	0.024	0.021	0.0057
V2O3	0.108	0.088	0.094	0.106	0.139	0.115	0.036
FeO	8.19	8.11	6.95	6.12	5.09	3.95	1.62
MnO	0.072	0.066	0.066	0.066	0.073	0.061	0.021
MgO	3.11	2.47	2.52	2.46	3.11	2.55	0.62
CaO	3.01	3.23	2.84	2.51	2.09	1.57	0.413
Rb2O	0.0071	0.0056	0.0044	0.0000	0.0013	0.0008	0.0000
SrO	0.020	0.021	0.017	0.012	0.011	0.0090	0.0013
BaO	0.054	0.053	0.039	0.037	0.033	0.026	0.009
Na2O	2.32	2.21	1.72	1.32	1.09	0.81	0.19
K2O	2.21	1.93	1.70	1.50	1.59	1.24	0.359
ZrO2	0.020	0.019	0.016	0.013	0.012	0.011	0.005
P2O5	0.250	0.226	0.177	0.129	0.096	0.069	0.018
CO2	2.49	17.6	59.4	88.4	128.0	197.7	312.4
OxSumm	99.00	99.00	94.30	86.70	88.80	94.50	97.50
Cu	0.017	0.022	0.020	0.017	0.012	0.008	0.007
Ni	0.031	0.034	0.028	0.024	0.018	0.014	0.007
Co	0.013	0.009	0.008	0.015	0.012	0.005	0.001
Zn	0.059	0.057	0.046	0.039	0.029	0.022	0.009
Pb	0.007	0.008	0.008	0.015	0.011	0.008	0.007
Ag	0.001	0.001	0.002	0.000	0.000	0.001	0.000
S	3.77	3.46	2.71	2.23	1.71	1.23	0.50
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.011	0.009	0.002	0.004	0.002	0.001
Bi	0.003	0.002	0.003	0.004	0.003	0.003	0.001
Te	0.002	0.001	0.001	0.007	0.005	0.004	0.001
Y	0.0046	0.0038	0.0034	0.0026	0.0034	0.0026	0.0021
Nb	0.0015	0.0007	0.0019	0.0038	0.0028	0.0019	0.0011
Mo	0.0029	0.012	0.022	0.022	0.025	0.026	0.015
Sn	0.003	0.003	0.003	0.000	0.000	0.001	0.001
W	0.000	0.001	0.001	0.001	0.000	0.001	0.001
Cl	0.002	0.003	0.003	0.003	0.003	0.005	0.003
Th	0.0014	0.0009	0.0013	0.0005	0.0004	0.0004	0.0016
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.003	0.000	0.002	0.000	0.001	0.001	0.001
La	0.005	0.005	0.003	0.006	0.005	0.004	0.003
Ce	0.006	0.005	0.006	0.004	0.005	0.004	0.001
Ta	0.001	0.002	0.000	0.002	0.001	0.000	0.000
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0022	0.0015	0.0018	0.0013	0.0018	0.0014	0.0007
Si	29.0	27.5	22.0	16.6	13.5	9.96	2.87
Ti	0.361	0.283	0.242	0.224	0.243	0.191	0.053
Cr	0.015	0.011	0.012	0.013	0.017	0.014	0.0039
V	0.073	0.060	0.064	0.072	0.095	0.078	0.024
Fe	6.37	6.31	5.40	4.76	3.96	3.07	1.26
Mn	0.056	0.051	0.051	0.051	0.057	0.047	0.017
Mg	1.88	1.49	1.52	1.48	1.88	1.54	0.37
Ca	2.15	2.30	2.03	1.79	1.49	1.12	0.295
Ba	0.049	0.048	0.035	0.033	0.030	0.023	0.009
Eltra C	0.68	4.81	16.2	24.1	34.9	53.9	85.2

Flotation test T12: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T12 Tails**	**T12 CT1**	**T12 CT2**	**T12 CT3**	**T12 CT4**	**T12 CT5**	**T12 CC5**
SiO2	56.8	54.0	41.6	17.0	7.58	5.04	3.79
TiO2	0.71	0.63	0.52	0.280	0.159	0.113	0.090
Al2O3	15.1	14.7	12.0	5.63	2.93	2.05	1.65
Cr2O3	0.017	0.017	0.014	0.0099	0.0075	0.0047	0.0037
V2O3	0.084	0.075	0.065	0.042	0.029	0.023	0.019
FeO	8.82	9.02	8.40	6.11	3.92	2.68	2.04
MnO	0.053	0.050	0.042	0.022	0.014	0.010	0.008
MgO	3.65	3.24	2.76	1.42	0.84	0.59	0.54
CaO	1.66	1.57	1.18	0.477	0.196	0.123	0.082
Rb2O	0.010	0.0092	0.0063	0.0000	0.0000	0.0000	0.0012
SrO	0.022	0.021	0.017	0.0065	0.0040	0.0007	0.0001
BaO	0.058	0.053	0.041	0.021	0.010	0.007	0.005
Na2O	2.12	2.01	1.49	0.56	0.22	0.12	0.07
K2O	2.68	2.47	1.96	0.87	0.446	0.319	0.255
ZrO2	0.016	0.017	0.016	0.008	0.006	0.005	0.004
P2O5	0.216	0.206	0.154	0.057	0.025	0.013	0.009
CO2	19.4	33.0	92.8	220.4	294.5	315.4	320.1
OxSumm	98.80	98.50	96.70	93.20	97.00	97.30	96.00
Cu	0.012	0.015	0.014	0.012	0.006	0.005	0.004
Ni	0.029	0.029	0.026	0.016	0.009	0.006	0.005
Co	0.011	0.009	0.009	0.005	0.002	0.002	0.002
Zn	0.029	0.031	0.029	0.019	0.011	0.008	0.006
Pb	0.007	0.006	0.007	0.012	0.009	0.008	0.008
Ag	0.001	0.001	0.001	0.000	0.001	0.000	0.000
S	2.66	2.43	1.92	0.95	0.438	0.294	0.219
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.012	0.011	0.000	0.001	0.002	0.000
Bi	0.002	0.002	0.003	0.004	0.003	0.001	0.001
Te	0.001	0.001	0.002	0.006	0.001	0.001	0.001
Y	0.0037	0.0037	0.0035	0.0008	0.0001	0.0018	0.0013
Nb	0.0014	0.0014	0.0017	0.0032	0.0024	0.0012	0.0009
Mo	0.0032	0.0049	0.0076	0.0085	0.0087	0.0070	0.0064
Sn	0.003	0.003	0.003	0.000	0.001	0.001	0.001
W	0.000	0.000	0.001	0.001	0.000	0.001	0.000
Cl	0.004	0.002	0.004	0.003	0.004	0.003	0.003
Th	0.0021	0.0016	0.0012	0.0001	0.0015	0.0015	0.0011
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.002	0.002	0.001	0.001	0.001	0.001
La	0.004	0.004	0.004	0.002	0.003	0.002	0.001
Ce	0.006	0.007	0.005	0.003	0.002	0.001	0.001
Ta	0.000	0.001	0.001	0.001	0.001	0.000	0.000
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0013	0.0021	0.0015	0.0013	0.0004	0.0005	0.0003
Si	26.5	25.3	19.4	7.94	3.54	2.36	1.77
Ti	0.427	0.379	0.314	0.168	0.095	0.068	0.054
Cr	0.012	0.012	0.0097	0.0068	0.0051	0.0032	0.0025
V	0.057	0.051	0.044	0.029	0.020	0.015	0.013
Fe	6.86	7.02	6.53	4.75	3.05	2.08	1.58
Mn	0.041	0.039	0.032	0.017	0.011	0.008	0.006
Mg	2.20	1.96	1.67	0.86	0.51	0.36	0.33
Ca	1.18	1.12	0.84	0.341	0.140	0.088	0.059
Ba	0.052	0.048	0.036	0.019	0.009	0.007	0.005
Eltra C	5.30	8.99	25.3	60.1	80.3	86.0	87.3

Flotation test T13: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T13 Tails**	**T13 CT1**	**T13 CT2**	**T13 CT3**	**T13 CT4**	**T13 CT5**	**T13 CC5**
SiO2	58.0	56.6	44.6	23.9	11.7	8.00	3.94
TiO2	0.73	0.64	0.55	0.362	0.251	0.181	0.096
Al2O3	15.3	15.2	12.9	7.85	4.39	3.10	1.67
Cr2O3	0.019	0.016	0.015	0.012	0.0098	0.0067	0.0045
V2O3	0.086	0.076	0.068	0.053	0.044	0.034	0.019
FeO	8.93	9.33	8.92	7.75	5.38	3.82	2.01
MnO	0.056	0.050	0.046	0.033	0.022	0.016	0.009
MgO	3.65	3.23	2.90	1.97	1.30	0.91	0.51
CaO	1.71	1.66	1.30	0.68	0.312	0.204	0.089
Rb2O	0.011	0.0095	0.0067	0.0000	0.0000	0.0000	0.0000
SrO	0.022	0.022	0.018	0.0095	0.0057	0.0041	0.0006
BaO	0.056	0.054	0.044	0.024	0.014	0.011	0.006
Na2O	2.21	2.17	1.63	0.85	0.38	0.23	0.08
K2O	2.70	2.53	2.06	1.18	0.69	0.492	0.264
ZrO2	0.016	0.017	0.017	0.011	0.007	0.007	0.004
P2O5	0.229	0.220	0.182	0.114	0.041	0.025	0.010
CO2	13.6	20.8	75.5	175.6	259.3	291.2	326.0
OxSumm	99.00	98.90	97.00	93.50	95.70	96.70	97.80
Cu	0.012	0.016	0.015	0.013	0.007	0.005	0.004
Ni	0.029	0.031	0.028	0.019	0.013	0.009	0.006
Co	0.014	0.014	0.010	0.001	0.002	0.002	0.002
Zn	0.029	0.032	0.030	0.024	0.015	0.011	0.006
Pb	0.007	0.008	0.007	0.012	0.011	0.008	0.007
Ag	0.000	0.001	0.001	0.000	0.001	0.001	0.000
S	2.77	2.59	2.05	1.29	0.64	0.443	0.226
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.010	0.013	0.010	0.004	0.002	0.003	0.000
Bi	0.002	0.003	0.003	0.003	0.003	0.003	0.001
Te	0.001	0.001	0.001	0.006	0.002	0.001	0.001
Y	0.0038	0.0043	0.0030	0.0027	0.0005	0.0006	0.0015
Nb	0.0012	0.0014	0.0015	0.0037	0.0024	0.0020	0.0011
Mo	0.0033	0.0044	0.0066	0.0094	0.0095	0.0097	0.0058
Sn	0.003	0.003	0.003	0.000	0.002	0.002	0.001
W	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Cl	0.003	0.003	0.003	0.003	0.004	0.002	0.002
Th	0.0017	0.0014	0.0015	0.0004	0.0022	0.0000	0.0012
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.004	0.003	0.001	0.002	0.001	0.002	0.001
La	0.006	0.004	0.003	0.003	0.003	0.003	0.002
Ce	0.005	0.008	0.006	0.004	0.003	0.002	0.001
Ta	0.000	0.000	0.001	0.000	0.002	0.001	0.001
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0016	0.0019	0.0017	0.0011	0.0008	0.0006	0.0002
Si	27.1	26.4	20.8	11.2	5.49	3.74	1.84
Ti	0.438	0.386	0.330	0.217	0.151	0.108	0.058
Cr	0.013	0.011	0.010	0.0079	0.0067	0.0046	0.0031
V	0.058	0.051	0.046	0.036	0.030	0.023	0.013
Fe	6.94	7.26	6.94	6.03	4.19	2.97	1.57
Mn	0.043	0.039	0.035	0.026	0.017	0.012	0.007
Mg	2.20	1.95	1.75	1.19	0.79	0.55	0.31
Ca	1.22	1.19	0.93	0.488	0.223	0.146	0.064
Ba	0.050	0.048	0.039	0.022	0.013	0.010	0.006
Eltra C	3.72	5.66	20.6	47.9	70.7	79.4	88.9

Flotation test T14: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T14 Tails**	**T14 CT1**	**T14 CT2**	**T14 CT3**	**T14 CT4**	**T14 CT5**	**T14 CC5**
SiO2	58.0	54.3	20.7	12.3	8.50	6.25	4.58
TiO2	0.66	0.54	0.312	0.210	0.150	0.109	0.070
Al2O3	15.1	14.9	7.21	4.66	3.37	2.58	2.10
Cr2O3	0.020	0.018	0.016	0.012	0.0076	0.0064	0.0041
V2O3	0.100	0.089	0.081	0.060	0.044	0.033	0.021
FeO	9.44	8.03	4.18	2.80	2.16	1.75	1.28
MnO	0.085	0.076	0.054	0.038	0.028	0.022	0.015
MgO	3.71	3.21	2.03	1.34	0.96	0.69	0.48
CaO	4.02	3.97	1.82	1.09	0.73	0.51	0.314
Rb2O	0.0074	0.0062	0.0024	0.0000	0.0000	0.0000	0.0018
SrO	0.027	0.027	0.012	0.0075	0.0062	0.0044	0.0011
BaO	0.051	0.049	0.027	0.016	0.011	0.008	0.005
Na2O	2.58	2.39	0.80	0.47	0.31	0.21	0.11
K2O	2.19	1.94	1.17	0.79	0.56	0.420	0.304
ZrO2	0.018	0.017	0.011	0.008	0.006	0.005	0.004
P2O5	0.223	0.203	0.069	0.034	0.022	0.016	0.009
CO2	1.69	28.3	213.1	273.2	289.3	306.2	343.2
OxSumm	99.00	99.20	97.50	98.90	96.20	96.50	103.20
Cu	0.018	0.021	0.012	0.007	0.006	0.006	0.007
Ni	0.031	0.025	0.013	0.009	0.007	0.007	0.005
Co	0.017	0.010	0.006	0.001	0.001	0.001	0.001
Zn	0.059	0.056	0.025	0.015	0.012	0.010	0.008
Pb	0.006	0.007	0.008	0.008	0.008	0.007	0.007
Ag	0.001	0.001	0.001	0.000	0.001	0.000	0.000
S	4.10	3.10	1.35	0.87	0.67	0.53	0.374
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.010	0.008	0.004	0.003	0.002	0.001
Bi	0.002	0.002	0.002	0.002	0.002	0.001	0.001
Te	0.000	0.000	0.003	0.000	0.000	0.001	0.001
Y	0.0048	0.0046	0.0024	0.0015	0.0007	0.0001	0.0012
Nb	0.0009	0.0015	0.0020	0.0017	0.0023	0.0011	0.0011
Mo	0.0021	0.014	0.034	0.025	0.020	0.017	0.011
Sn	0.003	0.003	0.002	0.003	0.002	0.001	0.001
W	0.001	0.000	0.001	0.001	0.001	0.001	0.001
Cl	0.003	0.004	0.003	0.002	0.003	0.003	0.003
Th	0.0017	0.0012	0.0004	0.0002	0.0011	0.0015	0.0013
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.003	0.001	0.001	0.001	0.001	0.001	0.001
La	0.004	0.005	0.003	0.002	0.002	0.002	0.002
Ce	0.006	0.006	0.003	0.002	0.002	0.002	0.002
Ta	0.002	0.002	0.000	0.001	0.001	0.001	0.001
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0022	0.0022	0.0011	0.0010	0.0006	0.0007	0.0004
Si	27.1	25.4	9.70	5.75	3.97	2.92	2.14
Ti	0.394	0.321	0.187	0.126	0.090	0.065	0.042
Cr	0.014	0.013	0.011	0.0083	0.0052	0.0044	0.0028
V	0.068	0.061	0.055	0.041	0.030	0.022	0.014
Fe	7.34	6.24	3.25	2.18	1.68	1.36	1.00
Mn	0.066	0.059	0.042	0.030	0.021	0.017	0.012
Mg	2.24	1.94	1.23	0.81	0.58	0.42	0.29
Ca	2.87	2.83	1.30	0.78	0.52	0.368	0.224
Ba	0.046	0.043	0.024	0.015	0.010	0.007	0.005
Eltra C	0.460	7.72	58.1	74.5	78.9	83.5	93.6

Flotation test T15: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T15 tails**	**T15 CT1**	**T15 CT2**	**T15 CT3**	**T15 CT4**	**T15 CT5**	**T15 CC5**
SiO2	59.4	48.5	41.8	27.7	13.6	4.40	1.70
TiO2	0.64	0.57	0.460	0.327	0.205	0.084	0.027
Al2O3	14.7	15.5	13.5	9.40	4.87	1.78	0.78
Cr2O3	0.020	0.209	0.193	0.140	0.078	0.020	0.0057
V2O3	0.101	0.138	0.110	0.082	0.058	0.028	0.010
FeO	8.91	13.4	12.0	9.11	5.11	1.89	0.86
MnO	0.073	0.119	0.102	0.078	0.048	0.020	0.008
MgO	3.50	3.95	3.11	2.29	1.31	0.54	0.19
CaO	3.66	3.49	3.11	2.11	1.09	0.321	0.095
Rb2O	0.0073	0.0082	0.0066	0.0015	0.0000	0.0011	0.0007
SrO	0.024	0.021	0.019	0.013	0.0060	0.0002	0.0000
BaO	0.054	0.049	0.043	0.031	0.017	0.006	0.003
Na2O	2.50	2.18	1.79	1.07	0.45	0.11	0.03
K2O	2.20	2.19	1.76	1.21	0.71	0.296	0.104
ZrO2	0.019	0.021	0.019	0.014	0.007	0.003	0.002
P2O5	0.257	0.191	0.184	0.133	0.080	0.025	0.010
CO2	2.24	23.7	67.8	148.9	242.0	321.2	349.8
OxSumm	99.00	98.60	98.10	95.30	94.20	97.40	99.40
Cu	0.017	0.034	0.031	0.026	0.016	0.007	0.004
Ni	0.032	0.079	0.072	0.056	0.030	0.010	0.004
Co	0.013	0.025	0.020	0.008	0.001	0.002	0.003
Zn	0.060	0.047	0.043	0.033	0.019	0.008	0.004
Pb	0.008	0.008	0.009	0.012	0.013	0.009	0.006
Ag	0.001	0.001	0.002	0.001	0.000	0.000	0.000
S	4.13	2.36	2.05	1.50	0.90	0.455	0.265
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.011	0.011	0.013	0.007	0.002	0.000	0.000
Bi	0.003	0.003	0.002	0.004	0.003	0.002	0.001
Te	0.003	0.002	0.004	0.005	0.002	0.002	0.002
Y	0.0044	0.0049	0.0038	0.0034	0.0005	0.0013	0.0008
Nb	0.0016	0.0014	0.0022	0.0030	0.0033	0.0014	0.0009
Mo	0.0033	0.024	0.036	0.044	0.034	0.018	0.0094
Sn	0.003	0.004	0.003	0.001	0.002	0.000	0.000
W	0.000	0.001	0.000	0.001	0.001	0.001	0.001
Cl	0.003	0.005	0.003	0.003	0.004	0.003	0.003
Th	0.0017	0.0017	0.0020	0.0007	0.0023	0.0016	0.0009
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.002	0.002	0.000	0.002	0.002	0.001	0.001
La	0.006	0.004	0.005	0.004	0.003	0.002	0.001
Ce	0.008	0.008	0.005	0.004	0.003	0.001	0.001
Ta	0.001	0.002	0.002	0.001	0.001	0.001	0.000
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0019	0.0023	0.0013	0.0013	0.0010	0.0006	0.0002
Si	27.8	22.7	19.5	12.9	6.34	2.06	0.79
Ti	0.386	0.344	0.276	0.196	0.123	0.051	0.016
Cr	0.014	0.143	0.132	0.096	0.053	0.014	0.0039
V	0.069	0.094	0.075	0.056	0.040	0.019	0.0071
Fe	6.93	10.4	9.33	7.08	3.98	1.47	0.67
Mn	0.056	0.092	0.079	0.060	0.037	0.015	0.006
Mg	2.11	2.38	1.88	1.38	0.79	0.33	0.11
Ca	2.61	2.50	2.23	1.50	0.78	0.230	0.068
Ba	0.048	0.044	0.038	0.027	0.015	0.005	0.003
Eltra C	0.61	6.46	18.5	40.6	66.0	87.6	95.4

Flotation test T16: C content by Eltra (%), other element contents by XRF (%)							
	Käpysuo	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**	**Käpysuo**
Element	**T16 Tails**	**T16 CT1**	**T16 CT2**	**T16 CT3**	**T16 CT4**	**T16 CT5**	**T16 CC5**
SiO2	57.8	52.6	40.7	34.6	29.6	17.9	1.88
TiO2	0.63	0.476	0.352	0.315	0.288	0.201	0.027
Al2O3	14.3	15.5	12.3	10.7	9.41	5.99	0.86
Cr2O3	0.082	0.104	0.083	0.085	0.093	0.070	0.0067
V2O3	0.103	0.103	0.073	0.065	0.063	0.048	0.011
FeO	8.87	6.03	5.32	5.14	5.21	3.91	0.70
MnO	0.077	0.087	0.068	0.062	0.061	0.044	0.008
MgO	3.59	3.04	2.10	1.84	1.65	1.19	0.18
CaO	3.51	3.91	3.05	2.60	2.24	1.35	0.101
Rb2O	0.0050	0.0053	0.0030	0.0010	0.0000	0.0000	0.0003
SrO	0.024	0.024	0.019	0.016	0.014	0.0084	0.0000
BaO	0.051	0.054	0.039	0.034	0.030	0.019	0.004
Na2O	2.45	2.10	1.57	1.31	1.08	0.61	0.03
K2O	2.18	2.02	1.48	1.27	1.12	0.75	0.115
ZrO2	0.018	0.018	0.014	0.012	0.011	0.008	0.001
P2O5	0.228	0.180	0.131	0.114	0.095	0.057	0.005
CO2	9.86	41.8	114.4	147.8	170.9	233.2	348.0
OxSumm	99.10	98.80	99.40	99.30	98.50	96.50	99.00
Cu	0.016	0.028	0.030	0.032	0.036	0.030	0.004
Ni	0.051	0.055	0.047	0.048	0.051	0.039	0.005
Co	0.008	0.021	0.021	0.017	0.011	0.008	0.003
Zn	0.057	0.055	0.045	0.044	0.045	0.034	0.005
Pb	0.008	0.010	0.009	0.011	0.013	0.012	0.007
Ag	0.002	0.001	0.001	0.001	0.001	0.001	0.000
S	4.37	1.66	1.34	1.30	1.30	1.06	0.277
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.012	0.010	0.009	0.004	0.003	0.003	0.000
Bi	0.003	0.003	0.002	0.003	0.003	0.003	0.001
Te	0.003	0.003	0.003	0.004	0.005	0.001	0.002
Y	0.0046	0.0051	0.0034	0.0037	0.0026	0.0016	0.0007
Nb	0.0022	0.0018	0.0019	0.0025	0.0032	0.0030	0.0009
Mo	0.0076	0.025	0.026	0.027	0.028	0.027	0.0057
Sn	0.004	0.003	0.002	0.002	0.000	0.003	0.000
W	0.001	0.000	0.001	0.000	0.000	0.001	0.001
Cl	0.004	0.002	0.003	0.004	0.003	0.004	0.003
Th	0.0015	0.0015	0.0009	0.0005	0.0005	0.0000	0.0008
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.000	0.001	0.000	0.002	0.001	0.000	0.001
La	0.006	0.007	0.004	0.005	0.003	0.003	0.001
Ce	0.005	0.004	0.003	0.004	0.003	0.003	0.001
Ta	0.000	0.001	0.002	0.001	0.000	0.001	0.000
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0015	0.0018	0.0019	0.0014	0.0013	0.0010	0.0003
Si	27.0	24.6	19.0	16.2	13.8	8.38	0.88
Ti	0.380	0.286	0.211	0.189	0.173	0.121	0.016
Cr	0.056	0.071	0.057	0.058	0.064	0.048	0.0046
V	0.070	0.070	0.050	0.044	0.043	0.033	0.0073
Fe	6.90	4.69	4.13	4.00	4.05	3.04	0.54
Mn	0.059	0.068	0.052	0.048	0.047	0.034	0.006
Mg	2.16	1.84	1.27	1.11	0.99	0.72	0.11
Ca	2.51	2.79	2.18	1.86	1.60	0.96	0.072
Ba	0.045	0.048	0.035	0.031	0.027	0.017	0.003
Eltra C	2.69	11.4	31.2	40.3	46.6	63.6	94.9

Purification tests: C content by gravimetric, no standard method (%), S by Eltra, other element contents by XRF (%)

	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo	Käpysuo
Element	**Feed, T10-T14 CC5**	**LT15**	**LT16**	**LT17**	**LT18**	**LT19**	**LT20**	**LT21**
SiO2	5.73	1.96	0.69	1.11	1.69	0.89	2.77	0.67
TiO2	0.100	0.063	0.034	0.045	0.056	0.038	0.069	0.026
Al2O3	2.33	0.59	0.18	0.32	0.49	0.22	0.92	0.18
Cr2O3	0.0058	0.0034	0.0016	0.0028	0.0034	0.0025	0.0045	0.0020
V2O3	0.030	0.015	0.0062	0.011	0.014	0.0079	0.021	0.0053
FeO	1.80	0.34	0.08	0.19	0.29	0.16	0.50	0.07
MnO	0.018	0.007	0.002	0.005	0.006	0.004	0.010	0.003
MgO	0.62	0.25	0.09	0.18	0.25	0.11	0.40	0.08
CaO	0.369	0.137	0.054	0.100	0.120	0.079	0.152	0.040
Rb2O	0.0019	0.0007	0.0003	0.0007	0.0005	0.0004	0.0011	0.0004
SrO	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BaO	0.008	0.006	0.004	0.005	0.007	0.005	0.007	0.005
Na2O	0.17	0.07	0.02	0.02	0.05	0.01	0.10	0.03
K2O	0.365	0.163	0.059	0.111	0.149	0.076	0.226	0.058
ZrO2	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P2O5	0.019	0.003	0.003	0.001	0.002	0.002	0.002	0.001
CO2	315.4	348.9	360.2	356.7	351.4	359.2	342.8	356.9
OxSumm	97.90	98.80	99.50	99.40	99.00	99.60	98.70	98.50
Cu	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.006	0.002	0.001	0.002	0.002	0.001	0.002	0.002
Co	0.000	0.001	0.000	0.003	0.004	0.004	0.003	0.004
Zn	0.009	0.002	0.001	0.001	0.001	0.001	0.002	0.001
Pb	0.009	0.006	0.005	0.005	0.005	0.005	0.006	0.004
Ag	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S	0.451	0.102	0.011	0.059	0.090	0.055	0.094	0.007
As	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Te	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Y	0.0014	0.0006	0.0004	0.0005	0.0005	0.0004	0.0005	0.0002
Nb	0.0013	0.0007	0.0007	0.0007	0.0008	0.0006	0.0008	0.0007
Mo	0.0096	0.0030	0.0015	0.0018	0.0020	0.0014	0.0019	0.0010
Sn	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W	0.010	0.001	0.000	0.001	0.001	0.000	0.001	0.001
Cl	0.003	0.003	0.002	0.003	0.003	0.003	0.003	0.003
Th	0.0017	0.0008	0.0007	0.0009	0.0009	0.0007	0.0010	0.0006
U	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cs	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
La	0.003	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Ce	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.001
Ta	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.000
LOI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ga	0.0006	0.0004	0.0003	0.0003	0.0003	0.0002	0.0003	0.0002
Si	2.68	0.92	0.32	0.52	0.79	0.41	1.29	0.31
Ti	0.060	0.038	0.021	0.027	0.034	0.023	0.041	0.015
Cr	0.0040	0.0023	0.0011	0.0019	0.0023	0.0017	0.0031	0.0014
V	0.021	0.010	0.0042	0.0074	0.0096	0.0054	0.014	0.0036
Fe	1.40	0.27	0.06	0.15	0.22	0.13	0.39	0.06
Mn	0.014	0.005	0.002	0.004	0.005	0.003	0.007	0.003
Mg	0.38	0.15	0.05	0.11	0.15	0.07	0.24	0.05
Ca	0.263	0.098	0.039	0.071	0.086	0.057	0.108	0.029
Ba	0.007	0.006	0.004	0.004	0.006	0.005	0.006	0.004
Eltra C	86.0	95.1	98.2	97.3	95.8	98.0	93.5	97.3
Eltra S	0.4796	0.174	0.1098	0.1329	0.1696	0.1159	0.1209	0.0685

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Graphite mineralogy of R25, R26 and R27 samples

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Title of report
Graphite mineralogy of R25, R26 and R27 samples

Abstract

Three Käpysuo feed samples R25, R26 and R27 were submitted for mineralogical characterisation of graphite. Samples were measured by XBSE mode of Mineral Liberation Analyser (MLA 650FEG).

Main minerals in all samples are quartz and plagioclase. Secondary abundant minerals are biotite, K-feldspar and pyrite. Graphite content vary from 10.1 wt% in R25 sample to 11.3 wt% in R27. The main minerals with which graphite associates are quartz, plagioclase and biotite. Graphite association of sample R27 is slightly different from it in samples R25 and R26: one of the main minerals with which graphite is locked in R27 sample is chlorite. P80 of graphite grains are liberated for 20-25 wt%. P80 of graphite grains is about 200µm in sample R25, 180µm in R26 sample and 150µm in R27. Largest grains are 0.7mm, 0.6mm and 0.42mm in samples R25, R26 and R27 correspondingly.

Keywords
Graphite, mineralogy, liberation, association

Geographical area

Map sheet

Other information

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Contents

1 INTRODUCTION

Three Käpysuo feed samples R25, R26 and R27 were submitted for mineralogical characterisation of graphite. The samples were crushed -1.5mm with followed by grinding below 0.5mm. The samples material was moulded with Petropoxy with 12% addition of iodoform. The solution was put on objective glass and has been mixed all the time while hardening. After it was cured, the specimen was polished and coated with the graphite. That kind of sample preparation allows the graphite significantly defer from the epoxy while the measurements.

Samples were measured by Mineral Liberation Analyser (MLA 650FEG). It is an automated mineral analysis system that identify minerals in different kinds of polished sections, as well as quantify a wide range of mineral characteristics, such as mineral abundance, grain size, mineral liberation and association. MLA combines a large specimen chamber automated Scanning Electron Microscope (SEM), multiple Energy Dispersive X-ray spectrometers (EDS) with state-of-the-art automated quantitative mineralogy software. The software controls SEM and EDS hardware to quantitatively analyse minerals and their characteristics.

The present study specimens were measured by the XBSE measurement mode. The mode is an extended liberation analysis method in which each BSE image is collected and segmented to delineate mineral grain boundaries in each particle, then each segment of particles (mineral grain) is analysed with one x-ray analysis. The off-line processing generates particle mineral maps from particle segmentation data and x-ray spectra. Each of the collected spectra is being compared with the standard library spectra and a mineral name is assigned to each of them according to best match procedure. Finally, the numbers of each mineral's spectra are converted into percentage proportions by taking mineral densities into account.

2 RESULTS

2.1 Modal Mineralogy

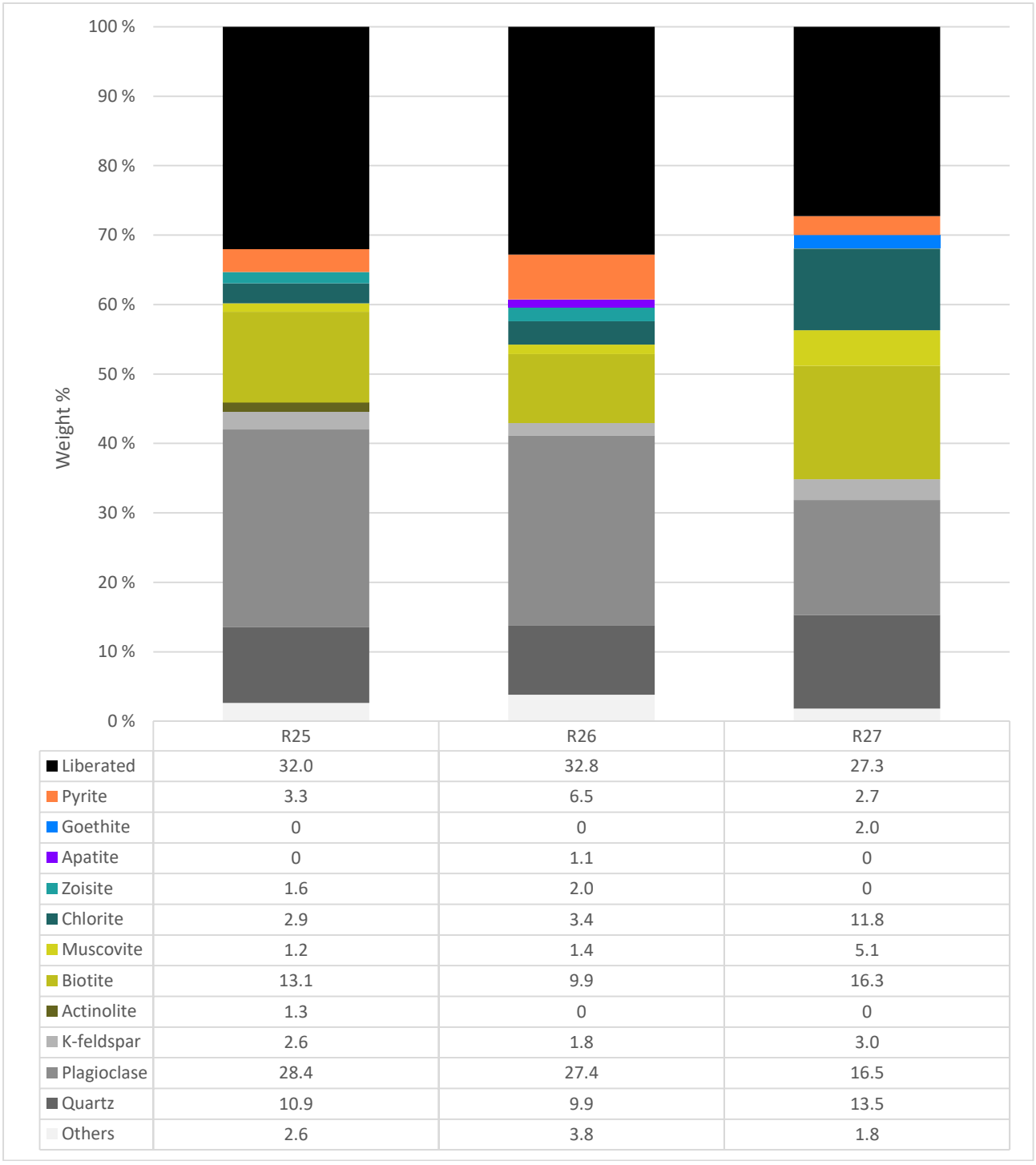
Table 1. Modal mineralogy.

Mineral	R25	R26	R27
Graphite	10.10	10.65	11.26
Quartz	21.98	24.86	24.29
Plagioclase	32.75	31.90	25.26
K-feldspar	6.55	5.52	3.82
Pigeonite	0.15	0.01	0.04
Actinolite	2.02	0.72	0.04
Anthophyllite	0.43	0.52	0.92
Hornblende	0.47	0.14	0.05
Biotite	10.10	6.47	10.36
Muscovite	1.71	1.18	8.96
Chlorite	2.70	2.68	6.69
Sekaninaite	1.05	1.41	1.04
Zoisite	3.24	2.10	0.11
Cordierite	0.01	0.04	0.01
Titanite	0.18	0.16	0.03
Calcite	0.24	0.07	0.13
Apatite	0.32	0.83	0.41
Xenotime	0.02	0.00	0.00
Rutile	0.12	0.17	0.13
Goethite	0.16	1.34	1.76
Pyrite	5.28	8.80	4.16
Chalcopyrite	0.06	0.02	0.01
Sphalerite	0.13	0.08	0.01
Unclassified	0.22	0.33	0.49
Total	100.00	100.00	100.00
Nr of measured perticles	29086	30130	29781

Modal mineralogy of the samples are present in Table 1. According to the table, main minerals in all samples are quartz and plagioclase. Secondary abundant minerals are biotite, K-feldspar and pyrite. Graphite content vary from 10.1 wt% in R25 sample to 11.3 wt% in R27. Comparing the samples between each other, samples R25 and R26 are very similar in bulk mineralogy, but sample R27 defer in accessory mineralogy. It has valuably elevated content of muscovite and chlorite and almost totally free from zoesite.

2.2 Graphite association

Graphite association is shown in Figure 1. As it can be seen from the graph only 27-32 wt% of graphite are totally liberated in the samples. The main minerals with which graphite associates are quartz, plagioclase and biotite. Graphite association of sample R27 is slightly different from it in samples R25 and R26: one of the main minerals with which graphite is locked in R27 sample is chlorite.



	R25	R26	R27
Liberated	32.0	32.8	27.3
Pyrite	3.3	6.5	2.7
Goethite	0	0	2.0
Apatite	0	1.1	0
Zoisite	1.6	2.0	0
Chlorite	2.9	3.4	11.8
Muscovite	1.2	1.4	5.1
Biotite	13.1	9.9	16.3
Actinolite	1.3	0	0
K-feldspar	2.6	1.8	3.0
Plagioclase	28.4	27.4	16.5
Quartz	10.9	9.9	13.5
Others	2.6	3.8	1.8

Figure 1. Graphite association.

2.3 Graphite Liberation

Graphite liberation, calculated by particle compositions, is shown in Figure 2. Reading the graph it become obvious that P80 of graphite grains are liberated for 20-25 wt%. It means that 80% of graphite grains have at least 20-25% of free surface. The liberation curves of all three samples are very similar.

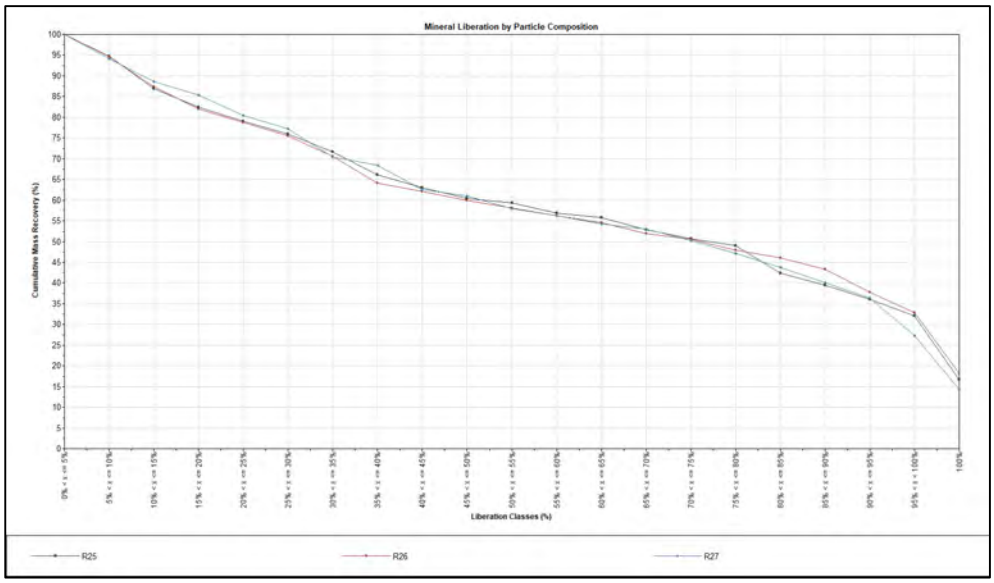


Figure 2. Graphite liberation.

2.4 Graphite Grain Size Distribution

Graphite grain size distribution (GSD), calculated by polygon stereology, is shown in Figure 3. P80 of graphite grains is about 200µm in sample R25, 180µm in R26 sample and 150µm in R27. Largest grains are 0.7mm, 0.6mm and 0.42mm in samples R25, R26 and R27 correspondingly.

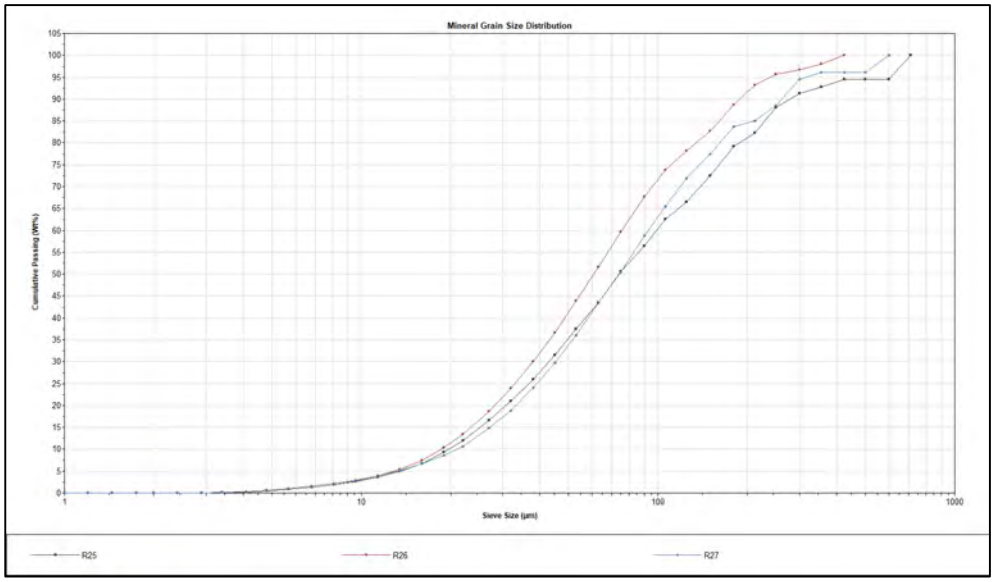


Figure 3. Graphite grain size distribution.

2.5 Overview Images

Legend of false mineral colors, used in overview images are shown in Figure 4. Overview MLA images of samples R25, R26 and R27 are shown in Figures 5, 6 and 7 respectively.

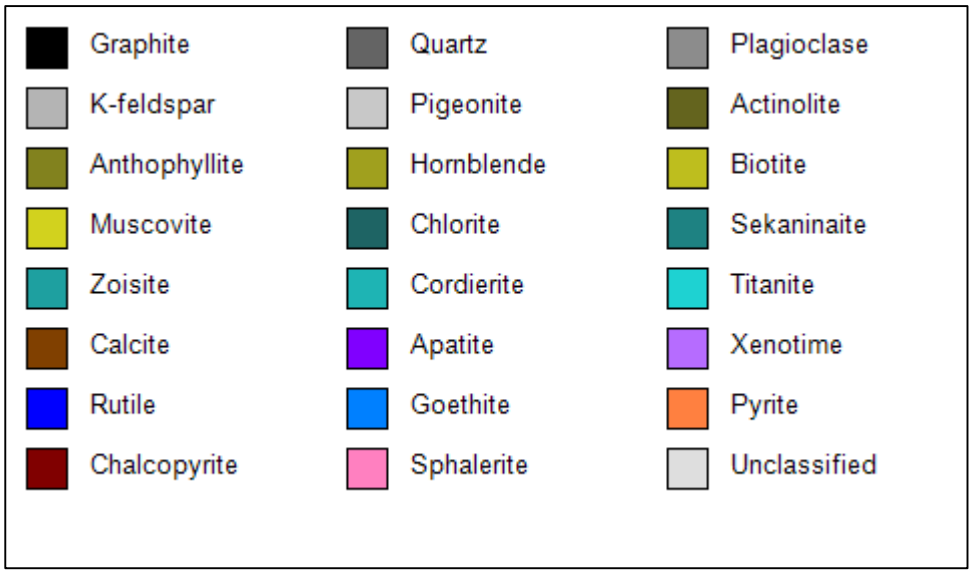


Figure 4. Legend of mineral colors.

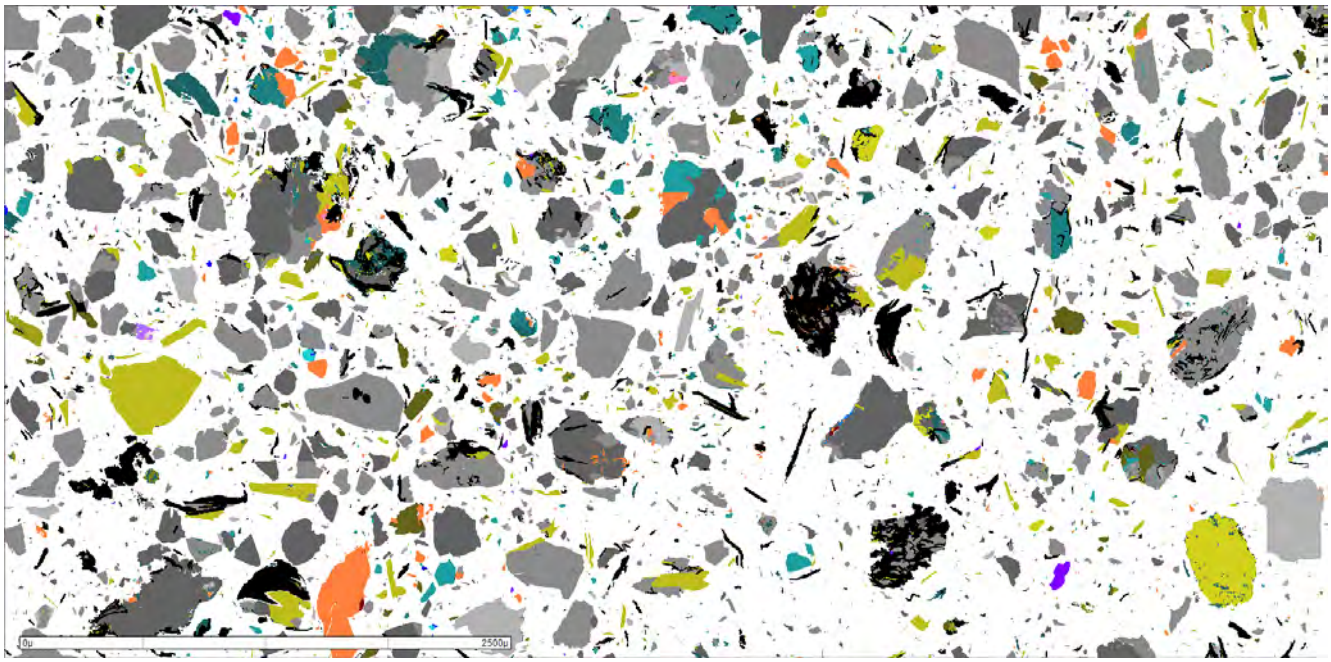


Figure 5. MLA overview image of sample R25.

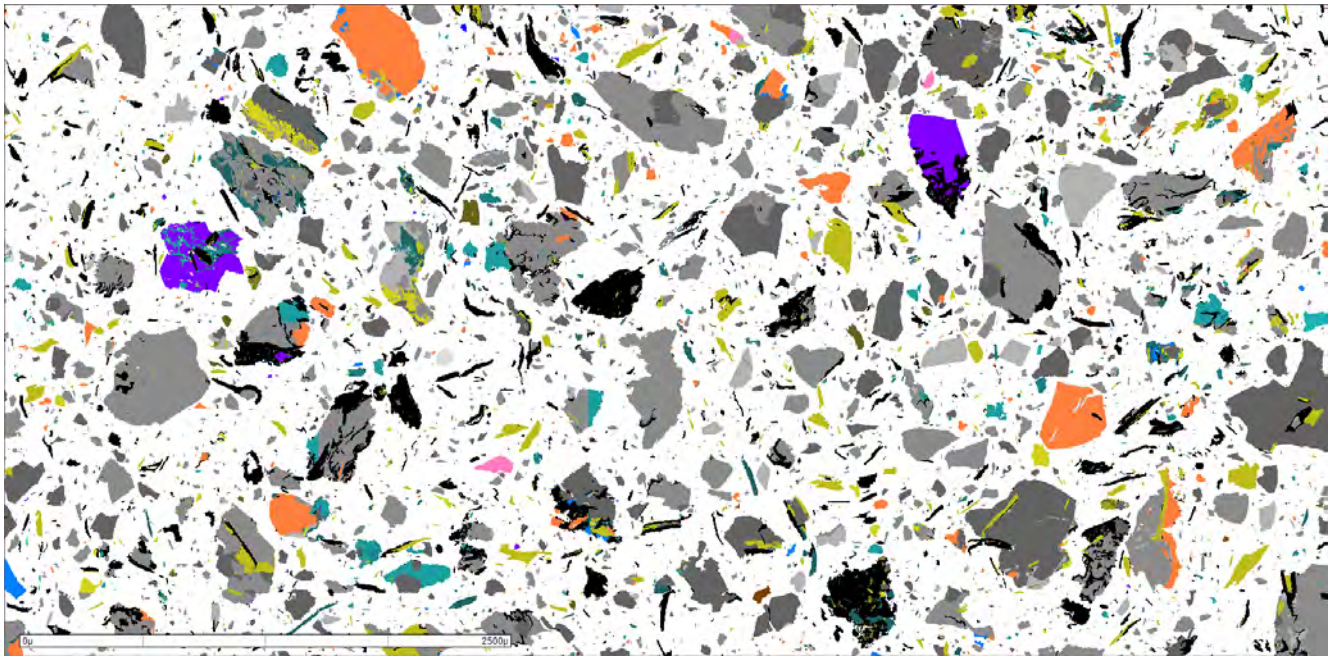


Figure 6. MLA overview image of sample R26.

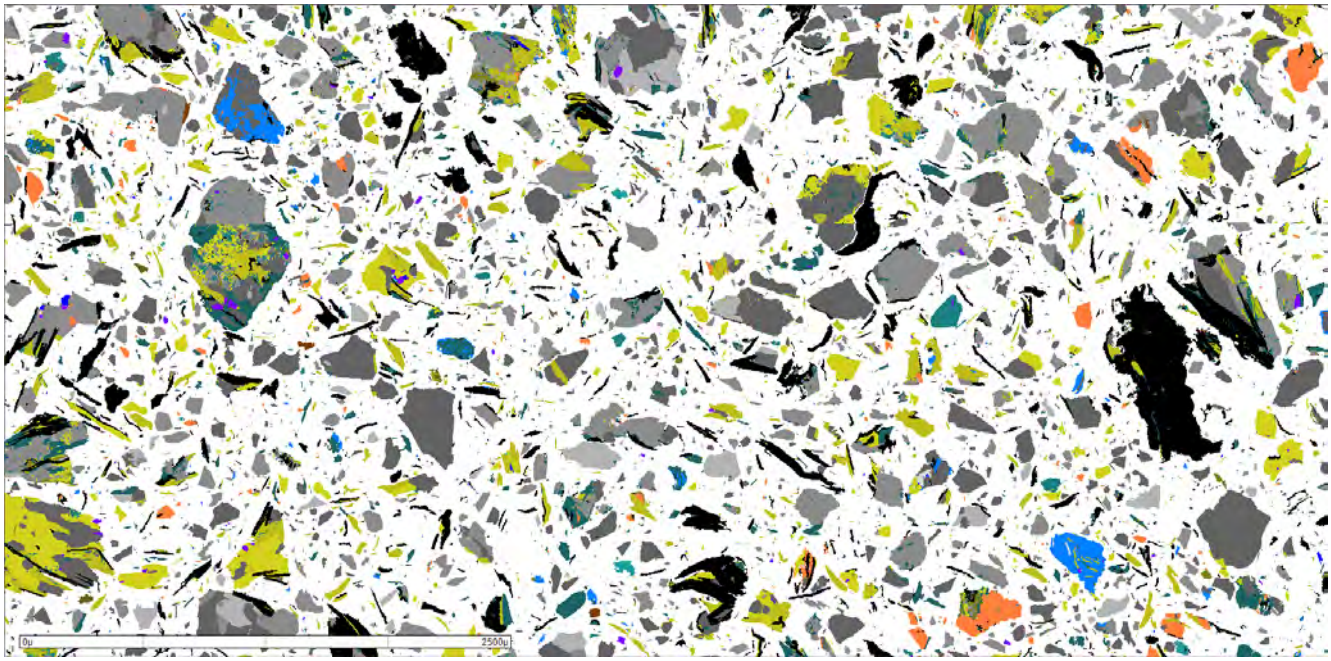


Figure 7. MLA overview image of sample R27.

Appendix 3
Flotation test reports

FLOTATION TEST REPORT

GTK

Sample:	Käpysuo 2_R25	**Grind:**	Mill:	Mild steel
Project:	Battery Minerals 50402-2009022		Charge:	8 kg balls
Date:	27.8.2019		Water:	1.0 l
Author:	KMS	**Feed**		1 kg
Test no.:	T10	**Screen anal:**		

Remarks: taukoaika 1.5 s
vaahdotuskone 1, titraattori 1

Feed	Grind min	Cond min	Reagents (g/t) / mL Na2SiO2 5 %	Starch 1%	Flotanol 7026 100 %	MIBC 100 %	Kerosene 100 %	Na2SiO2 5 %	Cell l	Air l/min	Rotor rpm	pH	Flot min	Cum Flot min	Product	Weight g	Weight %	C (Eltra) %	C (Eltra) Rec%	SiO2 (XRF) %	SiO2 (XRF) Rec%	Al2O3 (XRF) %	Al2O3 (XRF) Rec%	MgO (XRF) %	MgO (XRF) Rec%	Fe (XRF) %	Fe (XRF) Rec%	Ca (XRF) %	Ca (XRF) Rec%
-15mm	90																												
									4		1800	8,3																	
		3	1500																										
			30,0																										
		2		300								8,9																	
				30,0																									
		1				80	80				"																		
						0,080	0,080			3	"	8,5	3	3	RC1														
RT1		1				20	20				"																		
						0,020	0,020			3	"		3	6	RC2														
RT2		1				20	20				"	8,2																	
						0,020	0,020			3	"	8,2	3	9	RC3														
											"				RC1-3	177,5	17,7	52,80	95,87	25,52	8,68	7,57	9,81	1,76	9,14	3,33	8,77	1,38	9,44
											"				Tails	823,5	82,3	0,49	4,13	57,90	91,32	15,00	90,19	3,76	90,86	7,46	91,23	2,85	90,56
									2,5		1500	8,2																	
RC1-3		1				20	20			2	"		7	16	CC1	125,6	12,5	73,15	93,99	12,43	2,99	4,42	4,05	1,17	4,32	2,02	3,76	0,72	3,51
						0,020	0,020				"	8,2			CT1	51,9	5,2	3,6	1,88	57,2	5,69	15,2	5,76	3,2	4,83	6,5	5,01	3,0	5,93
									1,5		1100	8																	
CC1		1				17	17			1,5	"		6	22	CC2	115,8	11,6	78,41	92,85	9,16	2,03	3,57	3,02	0,99	3,35	1,66	2,86	0,55	2,46
						0,017	0,017				"	8			CT2	9,86	1,0	11,3	1,14	50,9	0,96	14,4	1,04	3,4	0,97	6,2	0,90	2,8	1,05
									1,5		1100	8																	
CC2		1				12	12			1,5	"	8	5	27	CC3	111,3	11,1	80,53	91,67	8,00	1,71	3,23	2,62	0,90	2,93	1,53	2,52	0,48	2,07
						0,012	0,012				"				CT3	4,47	0,4	25,8	1,18	37,9	0,32	12,1	0,39	3,2	0,42	5,1	0,34	2,3	0,39
									1,5		1100	7,9																	
CC3		1				7	7			1,5	"	7,9	5	32	CC4	105,8	10,6	82,43	89,23	7,13	1,44	2,93	2,26	0,79	2,47	1,42	2,24	0,43	1,74
						0,007	0,007				"				CT4	5,46	0,5	43,6	2,43	25,0	0,26	9,1	0,36	2,9	0,46	3,5	0,28	1,6	0,33
									1,5		1100	8																	
CC4		1				5	5			1,5	"	7,8	4	36	CC5	99,81	10,0	84,1	85,86	6,3	1,20	2,6	1,91	0,7	2,02	1,3	1,96	0,4	1,42
						0,005	0,005				"				CT5	6,02	0,6	54,8	3,37	21,5	0,25	8,0	0,35	2,5	0,45	3,1	0,28	1,4	0,32
Total	90	13	1500	300	0	181	181	0				Total	36	36	Calc Feed	1001,0	100,0	9,8	100,0	52,2	100,0	13,7	100,0	3,4	100,0	6,7	100,0	2,6	100,0
															Assayed Feed	1000,0		###		52,43		14,10		3,61		6,18		2,62	
															Relat. Difference (%)	-0,102		-0,48		0,525		2,96		5,692		-8,91		1,313	

FLOTATION TEST REPORT

GTK

Sample:	Käpysuo 2_R26	**Grind:**	Mill:	Mild steel	**Remarks:** taukoaika 1.5 s
Project:	Battery Minerals 50402-2009022		Charge:	8 kg balls	vaahdotuskone 1, titraattori 1
Date:	28.8.2019		Water:	1.0 l	
Author:	KMS	**Feed**		1 kg	
Test no.:	T11	**Screen anal:**			

Feed	Grind	Cond	Reagents (g/t) / mL						Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		Grades and Recoveries											
			Na2SiO2	Starch	Flotanol 7026	MIBC	Kerosene	Na2SiO2										C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)	
	min	min	5 %	1%	100 %	100 %	100 %	5 %	l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-15mm	90											7,5																	
									4		1800																		
		3	1500									7,9																	
			30,0																										
		2		300								7,9																	
				30,0																									
		1				80	80				"	7,9																	
						0,080	0,080			3	"	7	3	3	RC1														
RT1		1				20	20				"	7,2																	
						0,020	0,020			3	"	7,1	3	6	RC2														
RT2		1				20	20				"																		
						0,020	0,020			3	"		3	9	RC3														
											"				RC1-3	174,7	17,5	57,73	94,73	23,34	7,39	6,58	8,88	1,34	8,38	2,95	8,93	0,98	8,80
											"				Tails	825,66	82,5	0,68	5,27	61,90	92,61	14,30	91,12	3,11	91,62	6,37	91,07	2,15	91,20
									2,5		1500	7																	
RC1-3		1				20	20			2	"		7	16	CC1	129,9	13,0	75,98	92,70	11,08	2,61	3,85	3,86	0,96	4,43	1,80	4,04	0,53	3,51
						0,020	0,020				"	7,3			CT1	44,78	4,5	4,8	2,02	58,9	4,78	14,5	5,01	2,5	3,95	6,3	4,89	2,3	5,29
									1,5		1100																		
CC1		1				17	17			1,5	"	7	6	22	CC2	120,9	12,1	80,42	91,34	8,41	1,84	3,19	2,98	0,84	3,63	1,53	3,20	0,41	2,57
						0,017	0,017				"	7,4			CT2	8,99	0,9	16,2	1,37	47,1	0,77	12,8	0,89	2,5	0,81	5,4	0,84	2,0	0,94
									1,5		1100																		
CC2		1				12	12			1,5	"	7,2	5	27	CC3	117,4	11,7	82,12	90,54	7,59	1,61	2,95	2,68	0,79	3,32	1,43	2,91	0,37	2,25
						0,012	0,012				"	7,6			CT3	3,53	0,4	24,1	0,80	35,6	0,23	11,0	0,30	2,5	0,31	4,8	0,29	1,8	0,32
									1,5		1100	7,4																	
CC3		1				7	7			1,5	"	7,3	5	32	CC4	113,8	11,4	83,59	89,37	6,92	1,43	2,73	2,40	0,72	2,92	1,35	2,67	0,34	1,97
						0,007	0,007				"	7,6			CT4	3,55	0,4	34,9	1,16	29,0	0,19	10,2	0,28	3,1	0,39	4,0	0,24	1,5	0,27
									1,5		1100																		
CC4		1				5	5			1,5	"	7,4	4	36	CC5	107,97	10,8	85,2	86,41	6,1	1,20	2,5	2,04	0,6	2,39	1,3	2,36	0,3	1,64
						0,005	0,005				"	7,6			CT5	5,86	0,6	53,9	2,97	21,3	0,23	7,9	0,36	2,6	0,53	3,1	0,31	1,1	0,34
Total	90	13	1500	300	0	181	181	0				Total	36	36	Calc Feed	1000,3	100,0	10,6	100,0	55,2	100,0	13,0	100,0	2,8	100,0	5,8	100,0	1,9	100,0
															Assayed Feed	1000,0		10,53		55,50		13,30		2,87		5,29		1,98	
															Relat. Difference (%)	-0,034		-1,04		0,6		2,613		2,492		-9,21		1,563	

FLOTATION TEST REPORT

GTK

Sample:	Käpysuo 2_R27	**Grind:** Mill:	Mild steel
Project:	Battery Minerals 50402-2009022	Charge:	8 kg balls
Date:	29.8.2019	Water:	1.0 l
Author:	KMS	**Feed**	1 kg
Test no.:	T12	**Screen anal:**	

Remarks: taukoaika 1.5 s
vaahdotuskone 1, titraattori 1

Feed	Grind min	Cond min	Reagents (g/t) / mL Na2SiO2 5 %	Starch 1%	Flotanol 7026 100 %	MIBC 100 %	Kerosene 100 %	Na2SiO2 5 %	Cell l	Air l/min	Rotor rpm	pH	Flot min	Cum Flot min	Product	Weight g	Weight %	Grades and Recoveries C (Eltra) %	C (Eltra) Rec%	SiO2 (XRF) %	SiO2 (XRF) Rec%	Al2O3 (XRF) %	Al2O3 (XRF) Rec%	MgO (XRF) %	MgO (XRF) Rec%	Fe (XRF) %	Fe (XRF) Rec%	Ca (XRF) %	Ca (XRF) Rec%
-15mm	90											7,0																	
									4		1800																		
		3	1500									7,2																	
			30,0																										
		2		300								7,2																	
				30,0																									
		1				80	80				"																		
						0,080	0,080			3	"	6,4	3	3	RC1														
RT1		1				20	20				"	6,6																	
						0,020	0,020			3	"	6,5	3	6	RC2														
RT2		1				20	20				"	6,6																	
						0,020	0,020			3	"	6,7	3	9	RC3														
											"				RC1-3	110,6	11,1	44,93	51,38	30,74	6,32	8,72	6,72	2,01	6,42	4,67	7,82	0,63	6,22
											"	6,8			Tails	887,48	88,9	5,30	48,62	56,80	93,68	15,10	93,28	3,65	93,58	6,86	92,18	1,18	93,78
									2,5		1500																		
RC1-3		1				20	20			2	"	7,3	7	16	CC1	58,1	5,8	77,39	46,50	9,72	1,05	3,32	1,34	0,90	1,50	2,55	2,24	0,18	0,95
						0,020	0,020				"				CT1	52,51	5,3	9,0	4,88	54,0	5,27	14,7	5,37	3,2	4,92	7,0	5,58	1,1	5,27
									1,5		1100	7,4																	
CC1		1				17	17			1,5	"	7,2	6	22	CC2	50,7	5,1	85,05	44,55	5,03	0,47	2,04	0,72	0,62	0,91	1,96	1,51	0,09	0,39
						0,017	0,017				"	7,6			CT2	7,45	0,7	25,3	1,95	41,6	0,58	12,0	0,62	2,8	0,59	6,5	0,74	0,8	0,56
									1,5		1100	7,5																	
CC2		1				12	12			1,5	"	7,6	5	27	CC3	48,1	4,8	86,40	42,94	4,39	0,39	1,85	0,62	0,58	0,80	1,81	1,32	0,07	0,31
						0,012	0,012				"				CT3	2,59	0,3	60,1	1,61	17,0	0,08	5,6	0,10	1,4	0,11	4,8	0,19	0,3	0,08
									1,5		1100	7,4																	
CC3		1				7	7			1,5	"	7,4	5	32	CC4	43,6	4,4	87,02	39,26	4,06	0,33	1,74	0,53	0,55	0,69	1,69	1,12	0,07	0,26
						0,007	0,007				"	7,6			CT4	4,44	0,4	80,3	3,69	7,6	0,06	2,9	0,09	0,8	0,11	3,1	0,21	0,1	0,06
									1,5		1100																		
CC4		1				5	5			1,5	"	7,7	4	36	CC5	34,2	3,4	87,3	30,86	3,8	0,24	1,7	0,39	0,5	0,53	1,6	0,82	0,1	0,18
						0,005	0,005				"	7,7			CT5	9,44	0,9	86,0	8,39	5,0	0,09	2,1	0,13	0,6	0,16	2,1	0,30	0,1	0,07
Total	90	13	1500	300	0	181	181	0				Total	36	36	Calc Feed	998,1	100,0	9,7	100,0	53,9	100,0	14,4	100,0	3,5	100,0	6,6	100,0	1,1	100,0
															Assayed Feed	1000,0		9,78		54,00		14,60		3,49		6,10		1,17	
															Relat. Difference (%)	0,189		0,864		0,165		1,419		0,63		-8,42		4,651	

FLOTATION TEST REPORT

GTK	Sample: Käpysuo 2_R27	Grind:	Mill:	Mild steel	Remarks: taukoaika 1.5 s
	Project: Battery Minerals 50402-2009022		Charge:	8 kg balls	vaahdotuskone 1, titraattori 1
	Date: 4.9.2019		Water:	1.0 l	
	Author: KMS	Feed		1 kg	
	Test no.: T13	Screen anal:			

Feed	Grind	Cond	Reagents (g/t) / mL						Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		Grades and Recoveries											
			Na2SiO3	Starch	Flotanol 7026	MIBC	Kerosene	Ca(OH)2										C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)	
	min	min	5 %	1%	100 %	100 %	100 %		l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-15mm	90																												
								540	4		1800																		
säädetään pH 8.0								0,54																					
		3	1500									8,3																	
			30,0																										
		2		300								8,26																	
				30,0																									
		1				80	80				"																		
						0,080	0,080			3	"	7,9	2	2	RC1														
RT1		1				20	20				"																		
						0,020	0,020			3	"	7,7	3	5	RC2														
RT2		1				20	20				"																		
						0,020	0,020			3	"	7,6	3	8	RC3														
											"				RC1-3	132,1	13,2	50,36	67,33	27,88	6,82	7,92	7,31	1,79	6,95	4,34	8,70	0,58	6,70
											"				Tails	867,76	86,8	3,72	32,67	58,00	93,18	15,30	92,69	3,65	93,05	6,94	91,30	1,22	93,30
									2,5		1500	7																	
RC1-3		1				20	20			2	"		7	15	CC1	80,7	8,1	78,81	64,38	9,59	1,43	3,29	1,86	0,87	2,07	2,49	3,04	0,18	1,31
						0,020	0,020				"	7,4			CT1	51,37	5,1	5,7	2,94	56,6	5,38	15,2	5,45	3,2	4,87	7,3	5,65	1,2	5,39
									1,5		1100																		
CC1		1				17	17			1,5	"	7,3	6	21	CC2	71,8	7,2	86,02	62,53	5,26	0,70	2,10	1,05	0,62	1,31	1,93	2,11	0,09	0,58
						0,017	0,017				"	7,6			CT2	8,89	0,9	20,6	1,85	44,6	0,73	12,9	0,80	2,9	0,76	6,9	0,94	0,9	0,73
									1,5		1100																		
CC2		1				12	12			1,5	"	7,7	5	26	CC3	69,2	6,9	87,47	61,25	4,55	0,58	1,88	0,91	0,57	1,16	1,78	1,87	0,08	0,47
						0,012	0,012				"				CT3	2,64	0,3	47,9	1,28	23,9	0,12	7,9	0,14	2,0	0,15	6,0	0,24	0,5	0,11
									1,5		1100	7,8																	
CC3		1				7	7			1,5	"	7,7	5	31	CC4	66,5	6,7	88,15	59,32	4,26	0,52	1,78	0,83	0,54	1,06	1,68	1,69	0,07	0,41
						0,007	0,007				"				CT4	2,69	0,3	70,7	1,93	11,7	0,06	4,4	0,08	1,3	0,10	4,2	0,17	0,2	0,05
									1,5		1100																		
CC4		1				5	5			1,5	"	7,8	4,5	35,5	CC5	61,23	6,1	88,9	55,10	3,9	0,45	1,7	0,71	0,5	0,92	1,6	1,46	0,1	0,35
						0,005	0,005				"				CT5	5,26	0,5	79,4	4,23	8,0	0,08	3,1	0,11	0,9	0,14	3,0	0,24	0,1	0,07
Total	90	13	1500	300	0	181	181	0				Total	35,5	35,5	Calc Feed	999,8	100,0	9,9	100,0	54,0	100,0	14,3	100,0	3,4	100,0	6,6	100,0	1,1	100,0
															Assayed Feed	1000,0		9,78		54,00		14,60		3,49		6,10		1,17	
															Relat. Difference (%)	0,016		-1,07		-0,04		1,879		2,456		-8,09		3,282	

FLOTATION TEST REPORT

GTK

Sample:	Käpysuo 2_R25	**Grind:** Mill:	Mild steel
Project:	Battery Minerals 50402-2009022	Charge:	8 kg balls
Date:	10.9.2019	Water:	1.0 l
Author:	KMS	**Feed**	1 kg
Test no.:	T14	**Screen anal:**	

Remarks: taukoaika 1.5 s
vaahdotuskone 1, titraattori 1

Feed	Grind min	Cond min	Reagents (g/t) / mL Na2SiO2 5 %	Starch 1%	Flotanol 7026 100 %	MIBC 100 %	Kerosene 100 %	Ca(OH)2	Cell l	Air l/min	Rotor rpm	pH	Flot min	Cum Flot min	Product	Weight g	Weight %	Grades and Recoveries C (Eltra) %	C Rec%	SiO2 (XRF) %	SiO2 Rec%	Al2O3 (XRF) %	Al2O3 Rec%	MgO (XRF) %	MgO Rec%	Fe (XRF) %	Fe Rec%	Ca (XRF) %	Ca Rec%
-15mm	90																												
									4,0		1800	8,3																	
		3	1500									8,9																	
			30,0									8,8																	
		2		300																									
				30,0								8,8																	
		1				80	80				"	8,8																	
						0,080	0,080			3	"	8,3	3	3	RC1														
RT1		1				20	20				"																		
						0,020	0,020			3	"	8,1	3	6	RC2														
RT2		1				20	20				"																		
						0,020	0,020			3	"	8	3	9	RC3														
											"				RC1-3	178,2	17,8	53,98	96,22	26,00	8,87	7,84	10,12	1,84	9,72	3,43	9,22	1,41	9,66
											"				Tails	821,39	82,2	0,46	3,78	58,00	91,13	15,10	89,88	3,71	90,28	7,34	90,78	2,87	90,34
									4,0		1800																		
RC1-3		1				20	20			3	"		7	16	CC1	114,7	11,5	79,62	91,31	10,31	2,26	3,92	3,26	1,08	3,67	1,88	3,24	0,63	2,76
						0,020	0,020				"	8			CT1	63,57	6,4	7,7	4,91	54,3	6,60	14,9	6,86	3,2	6,05	6,2	5,97	2,8	6,89
									4,0		1800																		
CC1		1				17	17			3	"		6	22	CC2	90,3	9,0	85,43	77,15	7,51	1,30	3,03	1,98	0,83	2,21	1,51	2,05	0,45	1,55
						0,017	0,017				"	7,8			CT2	24,37	2,4	58,1	14,16	20,7	0,97	7,2	1,27	2,0	1,47	3,3	1,19	1,3	1,21
									4,0		1800																		
CC2		1				12	12			3	"		5	27	CC3	73,2	7,3	87,98	64,42	6,39	0,90	2,65	1,41	0,71	1,53	1,35	1,49	0,37	1,04
						0,012	0,012				"	7,7			CT3	17,08	1,7	74,5	12,73	12,3	0,40	4,7	0,58	1,3	0,68	2,2	0,56	0,8	0,51
									4,0		1800																		
CC3		1				7	7			3	"		5	32	CC4	56,4	5,6	90,68	51,19	5,77	0,62	2,44	1,00	0,63	1,05	1,26	1,07	0,33	0,71
						0,007	0,007				"	7,7			CT4	16,77	1,7	78,9	13,23	8,5	0,27	3,4	0,41	1,0	0,48	1,7	0,42	0,5	0,33
									4,0		1800																		
CC4		1				5	5			3	"	7,7	4	36	CC5	40,14	4,0	93,6	37,58	6,3	0,48	2,6	0,75	0,7	0,82	1,4	0,82	0,4	0,57
						0,005	0,005				"	7,7			CT5	16,3	1,6	83,5	13,61	4,6	0,14	2,1	0,25	0,5	0,23	1,0	0,25	0,2	0,14
Total	90	13	1500	300	0	181	181	0				Total	36	36	Calc Feed	999,6	100,0	10,0	100,0	52,3	100,0	13,8	100,0	3,4	100,0	6,6	100,0	2,6	100,0
															Assayed Feed	1000,0		###		52,43		14,10		3,61		6,18		2,62	
															Relat. Difference (%)	0,038		-2,9		0,264		2,092		6,463		-7,56		0,492	

FLOTATION TEST REPORT

Sample:	Käpysuo blend 2	**Grind:**	Mill:	Mild steel	**Remarks:** taukoaika 1.5 s
Project:	Battery Minerals 50402-2009022		Charge:	8 kg balls	vaahdotuskone 1, titraattori 1
Date:	27.9.2019		Water:	1.0 l	
Author:	KMS	**Feed**		1 kg	
Test no.:	T15	**Screen anal:**			

Feed	Grind	Cond	Reagents (g/t)/mL						Cell	Air	Rotor	pH	Flot	Cum Flot	Product	Weight		Grades and Recoveries											
			Na2SiO2	Starch	Flotanol 7026	MIBC	Kerosene	NaOH										C (Eltra)		SiO2 (XRF)		Al2O3 (XRF)		MgO (XRF)		Fe (XRF)		Ca (XRF)	
	min	min	5 %	1%	100 %	100 %	100 %	5 %	l	l/min	rpm		min	min		g	%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%	%	Rec%
-15mm	60																												
									4		1800																		
säädetään pH 8.5								199				8,5																	
		3	1500					3,99				8,7																	
			30,0																										
		2		300								8,5																	
				30,0																									
		2				80	80				"	8,4																	
säädetään ph 8,5						0,080	0,080	85		3	"	7,9	6	6	RC1														
RT1		2				40	20	171			"	8,4																	
						0,040	0,020			3	"	8,3	3	9	RC2														
RT2		2				40	20				"	8,2																	
						0,040	0,020			3	"	8,1	2	11	RC3														
											"				RC1-3	174,0	17,4	54,51	94,94	22,99	7,52	7,51	9,69	1,89	10,19	5,17	13,55	1,23	9,02
											"				Tails	828	82,6	0,61	5,06	59,40	92,48	14,70	90,31	3,50	89,81	6,93	86,45	2,61	90,98
RC1-3	30	`+150 mL vettä		keraamiset+teräs kuulat +HK-mylly																									
säädetään ph								24	2,5		1500	8,5																	
RC1-3		2				100	20	0,48		2	"	8,1	7	18	CC1	107,8	10,8	83,98	90,67	7,34	1,49	2,60	2,08	0,63	2,10	1,96	3,19	0,45	2,06
						0,100	0,020				"				CT1	66,13	6,6	6,5	4,28	48,5	6,03	15,5	7,61	4,0	8,09	10,4	10,36	2,5	6,96
									1,5		1100	8,1																	
CC1		2				60	17			1,5	"	7,9	6	24	CC2	97,3	9,7	91,06	88,71	3,61	0,66	1,43	1,03	0,36	1,08	1,16	1,71	0,26	1,07
						0,060	0,017				"				CT2	10,53	1,1	18,5	1,95	41,8	0,83	13,5	1,05	3,1	1,01	9,3	1,48	2,2	0,99
säädetään ph								6	1,5		1100	8,5																	
CC2		2				12	12	0,12		1,5	"	8,2	5	29	CC3	92,6	9,2	93,62	86,80	2,39	0,42	1,02	0,70	0,26	0,75	0,86	1,21	0,20	0,78
						0,012	0,012				"				CT3	4,7	0,5	40,6	1,91	27,7	0,24	9,4	0,33	2,3	0,33	7,1	0,50	1,5	0,30
säädetään ph								3	1,5		1100	8,5																	
CC3		2				7	7	0,06		1,5	"		5	34	CC4	88,8	8,9	94,81	84,28	1,90	0,32	0,86	0,56	0,22	0,60	0,73	0,98	0,17	0,65
						0,007	0,007				"				CT4	3,82	0,4	66,0	2,52	13,6	0,10	4,9	0,14	1,3	0,16	4,0	0,23	0,8	0,13
säädetään ph								3	1,5		1100	8,5																	
CC4		2				5	5	0,05		1,5	"	8,1	5	39	CC5	82,08	8,2	95,4	78,40	1,7	0,26	0,8	0,48	0,2	0,48	0,7	0,83	0,1	0,23
						0,005	0,005				"				CT5	6,7	0,7	87,6	5,88	4,4	0,06	1,8	0,09	0,5	0,11	1,5	0,15	1,5	0,41
Total	90	21	1500	300	0	344	181	123,42				Total	39	39	Calc Feed	1002,0	100,0	10,0	100,0	53,1	100,0	13,5	100,0	3,2	100,0	6,6	100,0	2,4	100,0
								ml							Assayed Feed	1000,0		10,200		53,67		13,83		3,41		5,81		2,40	
															Relat. Difference (%)	-0,196		2,276		1,097		2,763		5,461		-14		1,221	

F L O T A T I O N T E S T R E P O R T

GTK

Sample:	Käpysuo blend 2	**Grind:**	Mill:	Mergan
Project:	Battery Minerals 50402-2009022		Charge:	22 kg rods
Date:	8.10.2019		Water:	5,0 l
Author:	AEN	**Feed**		5 kg
Test no.:	T16	**Screen anal:**		

Remarks: taukoaika 1.5 s
vaahdotuskone 2, titraattori 2
RC1-8 jauhettu kahdessa erässä, 2*45 min, vettä 2*0.5L
1 kertaus; kemikaalit lisätty kahdessa erässä, vaahdotusaika 5+3 m

Feed	Grind min	Cond min	Reagents (g/t)/mL Na2SiO3 5 %	Starch 1%	NaOH 5 %	MIBC 100 %	Kerosene 100 %	Ca(OH)2	Cell l	Air l/min	Rotor rpm	pH	Flot min	Cum Flot min	Product	Weight g	Weight %	Grades and Recoveries: C (Eltra) %	C (Eltra) Rec%	SiO2 (XRF) %	SiO2 (XRF) Rec%	Al2O3 (XRF) %	Al2O3 (XRF) Rec%	MgO (XRF) %	MgO (XRF) Rec%	Fe (XRF) %	Fe (XRF) Rec%	Ca (XRF) %	Ca (XRF) Rec%
-15mm	75																												
									13		2400	7,1																	
säädetään pH 8.5					24,5							8,5																	
		3	1500																										
			150,0																										
		2		300																									
				150,0																									
		2				100	80				"																		
						0,500	0,400			8	"	8	9	9	RC1														
RT1		2			6,7	60	20				"	8,5																	
						0,300	0,100			8	"	8,3	6	15	RC2														
RT2		2			2,6	40	20				"	8,5																	
						0,200	0,100			8	"	8,3	6	21	RC3														
RT3		2			6	100	80				"	8,5																	
						0,500	0,400			8	"	8,8	5	26	RC4														
RT4		2				100	80				"																		
						0,500	0,400			8	"	8,7	5	31	RC5														
RT5		2				100	80				"																		
						0,500	0,400			8	"	8,5	5	36	RC6														
RT6		2				100	80				"																		
						0,500	0,400			8	"	8,4	5	41	RC7														
RT6		2				100	80				"																		
					1,300	0,500	0,400			8	"	8,4	5	46	RC8														
											"				RC1-8	874,7	17,6	44,92	78,06	32,19	10,60	9,66	12,58	1,86	9,92	3,12	8,78	1,70	12,61
											"				Tails	4106,6	82,4	2,69	21,94	57,80	89,40	14,30	87,42	3,59	90,08	6,90	91,22	2,51	87,39
RC1-8	45*2		`+1L vettä		keraamiset+teräs kuulat 5 kg + HK-mylly																								
säädetään pH 8.5									7		2100	8,1																	
RC1-8		2			1,7	200	60			5	"	8,5	8	54	CC1	447,0	9,0	76,99	68,37	12,65	2,13	4,07	2,71	0,72	1,97	1,61	2,32	0,66	2,50
						1,000	0,300				"				CT1	427,7	8,6	11,4	9,69	52,6	8,47	15,5	9,87	3,0	7,94	4,7	6,46	2,8	10,12
säädetään pH 8.5									4,0		1800	8,3																	
CC1		2			0,2	60	17			3	"	8,5	7	61	CC2	362,3	7,3	87,70	63,12	6,10	0,83	2,14	1,16	0,40	0,89	1,02	1,19	0,30	0,93
						0,300	0,085				"				CT2	84,7	1,7	31,2	5,25	40,7	1,30	12,3	1,55	2,1	1,09	4,1	1,13	2,2	1,57
säädetään pH 8.5									4,0		1800	8,4																	
CC2		2			0,15	12	12			3	"	8,5	6	67	CC3	329,5	6,6	92,42	60,49	3,26	0,40	1,29	0,63	0,26	0,52	0,73	0,77	0,15	0,41
						0,060	0,060				"				CT3	32,8	0,7	40,3	2,63	34,6	0,43	10,7	0,52	1,8	0,37	4,0	0,42	1,9	0,52
säädetään pH 8.5									4,0		1800	8,4																	
CC3		2			0,1	7	7			3	"	8,5	5	72	CC4	317,3	6,4	94,18	59,36	2,25	0,27	0,98	0,46	0,20	0,39	0,60	0,61	0,09	0,25
						0,035	0,035				"				CT4	12,2	0,2	46,6	1,13	29,6	0,14	9,4	0,17	1,7	0,12	4,1	0,16	1,6	0,17
säädetään pH 8.5									4,0		1800	8,3																	
CC4		2			0,15	5	5			3	"	8,4	4	76	CC5	310	6,2	94,9	58,44	1,9	0,22	0,9	0,40	0,2	0,34	0,5	0,54	0,1	0,19
						0,025	0,025				"				CT5	7,3	0,1	63,6	0,92	17,9	0,05	6,0	0,07	1,2	0,05	3,0	0,07	1,0	0,06
					43,4																								
Total	75	31	1650	450		988,92	221	0				Total	76	76	Calc Feed	4981,3	100,0	10,1	100,0	53,3	100,0	13,5	100,0	3,3	100,0	6,2	100,0	2,4	100,0
															Assayed Feed	5000,0		10,2		53,67		13,83		3,41		5,81		2,40	
															Relat. Difference (%)	0,374		0,926		0,679		2,52		3,559		-7,26		1,336	

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT15

Alkaline Roasting

NaOH	15	w-%
Temperature	250	°C
Time	2	h
L/S ratio	2:1	
Sample	20,09	g
NaOH	40,18	g

Water wash

Deionized hot water	1000 ~~200~~	mL
Time	30	min

1 step	≈60° liete	11,72	pH	Suodos pH 12,55 Lappoa vesi pois
2 step	≈60°C liek	11,07	pH	
3 step			pH	Kylmällä vedellä huuhtelu
4 step			pH	

Acid Leaching

H2SO4	10	w-%
Temperature	25	°C
Time	2	h
L/S ratio	5:1	
H2SO4	100.45	g

Loppusakka 17,55 g

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT16

Alkaline Roasting

NaOH	25 w-%		
Temperature	250 °C		
Time	2 h		
L/S ratio	2:1		
Sample	20,90	g	loppusakka
NaOH	41,8	g	

Water wash

Deionized hot water	600 ~~200~~	mL	huuhtelu deikassa magneettisekoituksella 210 rpm
Time	30 min		→ suodatus ja runsas huuhtelu vedellä

600ml	1 step	>+60°C Liek	12,56	pH	suodos pH 13.10 (+22°C)
~3 l	2 step	kylmä vesi	10.78	pH	huuhdottu n. 3 litralla kylmää vettä
400ml	3 step	>60°C	10.43 Liek	pH	suodoksen pH 10.77 (4 tippaa 10 w-% H_2SO_4 tiputtaa pH:n < 8,6
	4 step			pH	

↓ happopesuun

Acid Leaching

H2SO4	10 w-%		
Temperature	25 °C		
Time	2 h		
L/S ratio	5:1		
H2SO4	104.5	g	huuhteluun käytetty > 2 Litraa vettä → pH < 7,8

Loppusakka 17,54 g

Vähän pyöreämpi pohja haihdutusmaljassa
maljaa laitettiin kylmään uuniin, kello päälle kun uuni 250 °C.
Laptiumin muhveliuuni lämpeni vielä >40 °C yli 250 °C.
Seuraavan kerran kannattaa uuni lämmittää ensin ja odottaa,
että lämpö tasoittuu → 250°C (n. 1h)

- Näyte 1. huuhteluvedestä
- näyte happosuodoksesta

2.10.2019

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT17

Alkaline Roasting

NaOH	35 w-%	
Temperature	250 °C	
Time	2 h	
L/S ratio	2:1	
Sample	20.83	g
NaOH	41.66	g ≈ 33 ml

Uunin lämpö pysyi tasaisena +245-255°C

Water wash

Deionized hot water	~~200 ml~~	1000 ml
Time	30 min	

kokeile onnistuuko huuhtelujen välillä veden poisto lappoamalla.

1 step ~60°C 1000ml	12.63 l	pH liete
2 step ~60°C 1000ml	11.52 liet	pH
3 step kylmä vesi		pH
4 step		pH

Ensin lappoaminen → liuoksen suodatus → suodos pH 12.82

→ Suodatus → pesu kylmällä vedellä suppilossa

Acid Leaching

H2SO4	10 w-%	
Temperature	25 °C	
Time	2 h	
L/S ratio	5:1	
H2SO4	104,15	g

310rpm, 250 ml kapea dekka

loppusakka 18,03 g

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT18

Alkaline Roasting

NaOH	25	w-%
Temperature	250	°C
Time	1	h
L/S ratio	2:1	
Sample	20,68	g
NaOH	41,36	g

Water wash

Deionized hot water	1000 ~~200~~	mL
Time	30	min

1 step	kuma Liete	11,96	pH
2 step	kuma liete	10,90	pH
3 step			pH Suodattuu hitaasti
4 step			pH

Acid Leaching

H2SO4	10	w-%
Temperature	25	°C
Time	2	h
L/S ratio	5:1	
H2SO4	103,4	g

loppusakka 18,08g

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT19

Alkaline Roasting

NaOH	25	w-%
Temperature	250	°C
Time	3	h
L/S ratio	2:1	
Sample	20,01	g
NaOH	40.02	g

Water wash

Deionized hot water	200	mL
Time	30	min

1 step	kuuma liete	~~11,07~~ 12,33	pH
2 step	-"-	11,07	pH
3 step	kylmä huuhtelu		pH Suodattuu todella hitaasti
4 step			pH

Acid Leaching

H2SO4	10	w-%
Temperature	25	°C
Time	2	h
L/S ratio	5:1	
H2SO4	100,5	g

loppusakka 17,15 g

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT20

Alkaline Roasting

NaOH	25	w-%
Temperature	150	°C
Time	2	h
L/S ratio	2:1	
Sample	20,02	g
NaOH	40,07	g

Water wash

Deionized hot water	200	mL
Time	30	min

1 step kuuma liete	~~12,13~~ 12,93	pH
2 step -"-	11,76	pH Tähän jäi lapotessa enemmän ekaa liuosta
3 step		pH
4 step		pH

Acid Leaching

H2SO4	10	w-%
Temperature	25	°C
Time	2	h
L/S ratio	5:1	
H2SO4	100,1	g

loppusakka 18,04g

GRAPHITE PURIFICATION TEST REPORT

Sample: Käpysuo graphite concentrate blend
Project: Green Minerals 50404-40137
Date:
Author:
Test no.: LT21

Alkaline Roasting

NaOH	25	w-%
Temperature	350	°C
Time	2	h
L/S ratio	2:1	
Sample	20,85	g
NaOH	41,70	g

Water wash

Deionized hot water	1000 ~~200~~	mL
Time	30	min

1 step	kuuma liete	11.98	pH	Lapottu neste pois → Lapottu liuos suodatettu ja paperit huuhdeltu
2 step	"	10.96	pH	Seuraavaan vaiheeseen ~~[illegible]~~
3 step	kylmä huuhtelu		pH	suodattuu melko nopeasti
4 step			pH	

Acid Leaching

H2SO4	10	w-%
Temperature	25	°C
Time	2	h
L/S ratio	5:1	
H2SO4	104,25	g

Loppusakkea 16.98 g

Geological Survey of Finland
Mineral Processing and Materials Research
Outokumpu

5.12.2019 C/MT/2019/

Production of High-Purity Flake Graphite Concentrate from Graphite Occurrences in Rautalampi, Finland

Dandara Ataide Salvador

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Production of High-Purity Flake Graphite Concentrate from Graphite Occurrences in Rautalampi, Finland.</td></tr>
<tr><td colspan="5">Abstract
High-purity flake graphite concentrate from Rautalampi area, referred as Käpysuo, were produced to be tested as anode material in Li-Ion battery. The raw material was obtained from drill cores. The test-work involved sample preparation, graphite concentration by flotation, and purification by alkaline roasting and acid leaching.
The beneficiation test-work included crushing to -1.4 mm, grinding by rod mill and separation by flotation with roughing and five cleaning stages. The 5th cleaner concentrates C grade was ca. 90% C, at C recoveries between 67 to 83%.
The purification scheme by alkaline roasting followed by acid leaching proved to be efficient, producing high-purity graphite concentrates, with over 99% C purity.</td></tr>
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1 INTRODUCTION

A test-work was developed during April and May of 2019 at GTK Mintec in Outokumpu to produce high-purity graphite concentrate. The raw material was drill cores from Rautalampi area in Finland. The test-work involved crushing, grinding, graphite concentration by flotation and purification by alkaline roasting and acid leaching.

Six samples with C grade varying from 90 to 99% C were requested. The objective was to investigate the battery performance considering different graphite purity grades in the anode. The d50 target was approximately 20 microns.

1.1 Analytical Methods

Chemical analyses of process products were carried out by Eurofins Labtium Oy, located in the same premises as GTK Mintec in Outokumpu. The chemical analytical methods were X-ray fluorescence (XRF) for the oxides and other elements, and Eltra for C. In addition, for the purified graphite concentrates, a different method was formulated. The samples were first weighted and analyzed by XRF. After that, the samples were burnt at 950°C for two hours and then dissolved by HF for SiO_2 determination. A second burn was done at 950°C for one hour. The remaining sample was weighted, and the C was calculated based on the burnt mass.

1.2 Sample Preparation

Rautalampi Käpysuo samples R7 (ca. 6 kg), R26 (ca. 11 kg) and R27 (ca. 11 kg), previously crushed to -1.6mm were blended to generate enough feed material for the test, the blend sample was called ''Käpysuo Blend''. A feed sample from the Käpysuo Blend was sent to C Eltra and XRF analysis. Table 1 details the results. The C grade was 14.4%, SiO_2 51.3%, and S 3.2%.

Table 1: Eltra and XRF analyses results for the Käpysuo Blend feed sample.

Analysis Method	Eltra	XRF								
Oxides/Elements	C	SiO2	Al2O3	FeO	MgO	CaO	Na2O	K2O	S	C
(%)	14.4	51.3	13.3	7.21	3.3	2.4	1.8	2.2	3.2	14.4

2 MATERIALS AND METHODS

The drill cores samples from Käpysuo were combined, crushed, ground and the graphite was concentrated by flotation. The graphite flotation concentrate was milled to reach the target d50. The sample was then purified by alkaline roasting and acid leaching. Figure 1 shows the flotation process (A), concentrate after alkaline roasting (B) and leaching procedure (C).

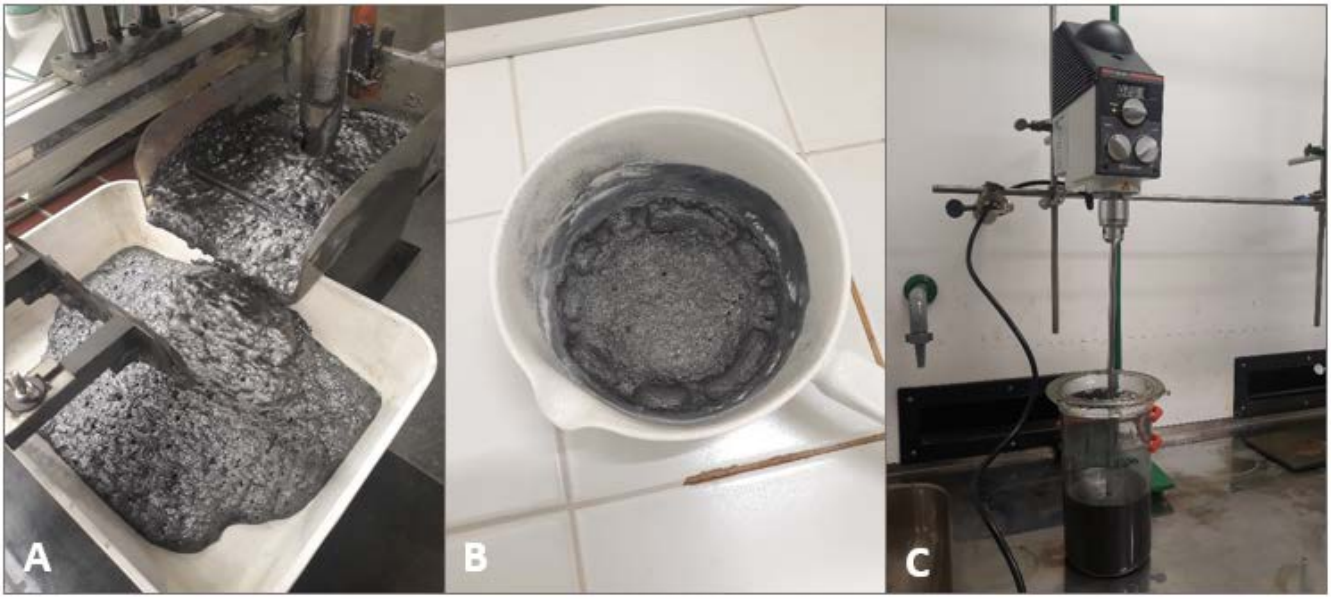

Figure 1: Graphite concentrate production procedures. A: Graphite concentration by flotation. B: Graphite concentrate after alkaline roasting. C: Acid leaching procedure.

2.1 Flotation

The crushed feed to 100% -1.4 mm was used for flotation tests and concentrate production. The first four flotation tests were performed to obtain information about the Käpysuo Blend sample behavior in flotation.

The tests were done with 1 kg samples. Test 1, 2 and 4 were done by one-stage rod mill grinding for 75 minutes. On the other hand, in Test 3, first the feed was ground by rod mill for 30 minutes, and later a second-stage grinding for 30 minutes with ball mill. The inner dimensions of the mill were Ø190 × 220 mm and it was charged with 8.0 kg of Fe rods. Grinding was performed wet, using tap water (0.9 L) at room temperature.

Flotation experiments were performed in Outokumpu type flotation machine in 2.5 or 4 liters flotation cells. In all tests, Kerosene and MIBC were used. In addition, Na_2SiO_3 and Starch were used as depressants in roughing stage. Table 2 details the reagents dosages.

Tests 5, 6 and 7 were done using Test 4 conditions to produce the graphite concentration. For these, 5 kg samples were used. The objective was to produce concentrate for the purification tests, and consequently for the battery tests. Reagent dosages needed to be increased in Tests 6 and 7.

Table 2: Flotation Test reagent dosages.

		Dosage (g/t)			
Test	**Sample (kg)**	**Kerosene**	**MIBC**	**Na2SiO3**	**Starch**
1	1	116	187	1500	300
2	1	95	95	-	-
3	1	89	89	-	-
4	1	181	181	1500	300
5	5	181	181	1500	300
6	5	221	221	1500	300
7	5	201	201	1500	300

2.2 Graphite Flake Size Reduction

Different grindings options were tried to reach the target d50 of approximately 20 µm: Laboratory ball mill, Mergan ball mill, swing/ring mill, and attritor mill. Union Process – Model 1S Attritor mill was used with 3 to 4 mm diameter ceramic balls, 564 rpm, 3.8 L balls, and about 20% solids.

2.3 Purification Tests

The purification tests were based on Lu and Forssberg (2002). The test consisted in a first alkaline roasting followed by acid leaching. In total, fourteen purification tests were done. Table 5 details each test's parameters. LT6 to LT14 were done to produce concentrate.

Table 3: Purification tests feed samples and parameters applied in alkaline roasting and acid leaching.

Purification Test	Feed	Alkaline Roasting				Acid Leaching		Feed
		Base	%	T(°C)	Time	Acid	%	C (%)
LT1	Test 1 CC5	NaOH	25	220	1.5	H_2SO_4	10	92.7
LT2	Test 1 CC5			220	2.5		10	92.7
LT3	Test 4 CC5 +90 µm			220	2.5		10	94.9
LT4	Test 4 CC5 90-45 µm			220	2.5		10	90.8
LT5	Test 4 CC5 -45 µm			220	2.5		10	83.3
LT6	Test 8 CC7			220	2.5		10	86.2
LT7	Test 8 CC7			220	1		10	86.2
LT8	Test 9 CC8-1			200	2.5		10	93.3
LT9	Test 9 CC8-1			200	2.5		10	93.3
LT10	Test 9 CC8-2			200	3		20	93.3
LT11	Test 9 CC8-2			200	3	HCl	20	93.3
LT12	LT8 Residue			200	3	H_2SO_4	20	97.7
LT13	LT9 Residue			200	3		20	97.5
LT14	LT10 Residue			200	3		20	97.9

2.3.1 Alkaline Roasting

The graphite concentrate was placed in a ceramic bowl with NaOH solution with 25% concentration for all tests. The ratio liquid/solid (L/S) by weight percentage was 2/1. In Lu and Forssberg (2002), the optimal temperature found was 250°C. However, the oven used at GTK Mintec could only reach to about 220-180°C. From LT8 onwards the maximum temperature that could be reached was 200°C. The roasting time was between 1 to 3 hours. After the roasting, the samples were washed twice with distilled water.

2.3.2 Acid leaching

Acid leaching was performed using sulfuric acid (H_2SO_4) in all tests, except on LT 11 which was done with Hydrochloric acid (HCl). The acid concentration was 10 to 20%.

3 RESULTS

3.1 Flotation

Figure 2 presents the C grade and recovery curve for the tests. The first point in the curves represent the rougher flotation concentrate and the following ones the cleaner concentrates, from 1st to 5th. Rougher concentrate grades varied from 62.6% C in Test 3, to 73.3% C in Test 1, while the 5th cleaner concentrate grade was the highest in Test 1, 92.7% C, and the lowest in Test 3 (88.4% C).

In Test 2 and 3 no depressants were added. As a result, C recoveries were higher. Test 1 and 4 were very similar, with comparable results. The mass pull in Test 4, was slightly lower, resulting in smaller recoveries.

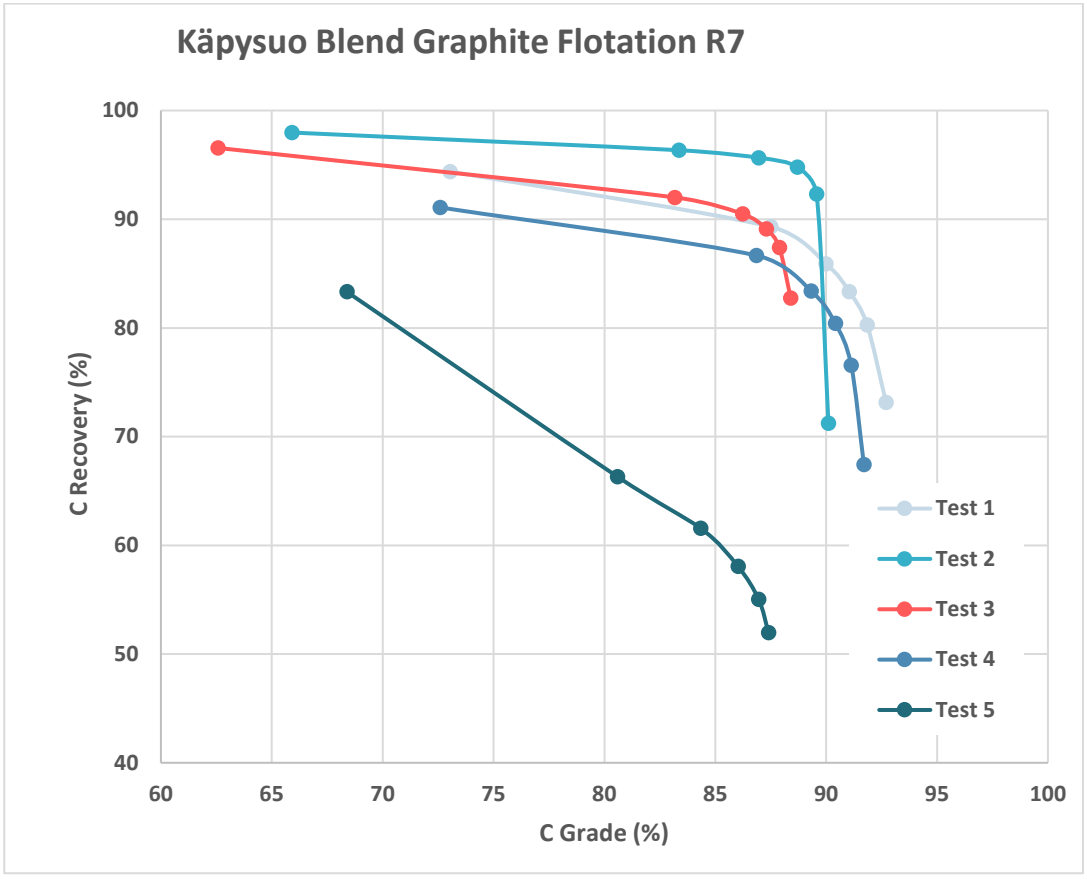

Figure 2: Käpysuo Blend Graphite Flotation tests.

The flotation tests 5, 6, and 7 with 5 kg presented different flotation performance than the tests with 1 kg samples. Even using the same collector dosages and conditions, the C grade and recovery was considerable lower, as it can be seen in Figure 2. The highest C grade obtained in the 5th cleaner concentrate was 87.4%, at 52% recovery, in Test 5.

The concentrate from these three tests were combined. The mass was 1569.7 g, and C grade 82.5%. Since the concentrate C grade was lower than expected, comparing with the preliminary tests, two additional cleanings were done (6th and 7th). The 7th cleaner concentrate mass was 1280.3 g at 86.2% C.

3.2 Graphite Flake Size Reduction

After 75 minutes grinding, the d80 of the sample was 50 µm, although the d80 of the 5th cleaner concentrate was much coarser, 108 µm, as shown in Table 4. It was also pointed that in the concentrate, the coarser fractions have higher C content. The + 125 µm fraction C grade was 96.9%, 90.7% for the 75-45 µm, and 82.6% in the – 20 µm. Therefore, impurities such as SiO_2, FeO and S present higher grade in the finer particle sizes.

Table 4: Test 1 Bulk sample and 5th cleaner concentrate sieve analyses.

Käpysuo Blend - Test 1 (75 min. grinding)					
Sieve-opening (µm)	**Bulk**		**5th Cleaner Concentrate**		
	Passing (%)	**Retained (%)**	**Passing (%)**	**Retained (%)**	**C (%)**
250	100		100		
180	99.9	0.1	99.8	0.2	
125	98.9	1.0	91.1	8.7	96.9
90	94.5	4.4	68.4	22.7	95.0
75	91.0	3.5	53.6	14.8	93.6
45	77.8	13.3	23.0	30.6	90.7
20	41.7	36.1	3.0	20.0	84.1
		41.7		3.0	82.6
d80 (µm)	*50*		*108*		

3.2.1 Milling

The flotation concentrate d50 after 360 minutes milling in the attritor mill was 24 µm. The effect of milling by attritor mill on the graphite flakes can be seen in Figure 3. In A - before attritor milling, the graphite flakes have rounded borders. In B - after attritor milling, the flakes' borders are mostly irregular, with sharp edges.

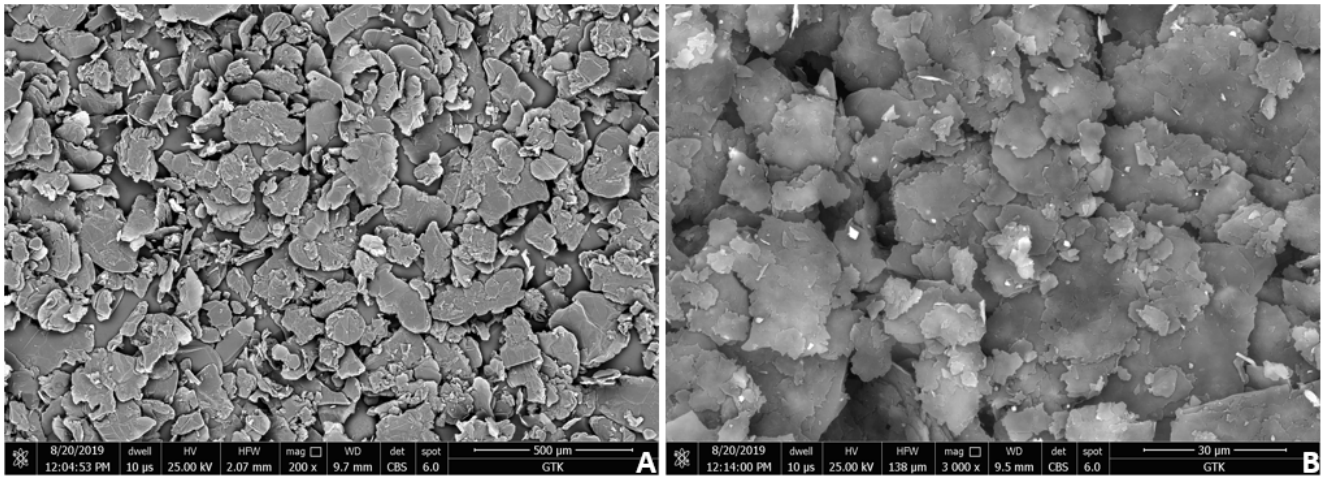

Figure 3: Comparison of graphite flakes of non-attritor mill ground sample (A) and attritor mill ground (B).

In addition, after the milling, it was noticed that the slurry had a brownish color. Due to the long milling time, process Fe was passed to the sample, decreasing the C grade. Therefore, additional flotation cleanings were performed to decrease the impurities content in the concentrate.

3.3 Purification tests

Table 5 details the purification tests done with the feed samples and the parameters applied. LT1 and LT2 were done same with the same to investigate the roasting time effect. LT2 had one hour more roasting time, but the difference in upgrade was little, just 0.1%.

In LT3, LT4 and LT5, the three different size fractions, + 90 µm, 90-45 µm, -45 µm, presented different C feed grades. The coarser fraction had the highest C feed grade, and also presented the highest C grade in the residue. Although, the C upgrade was the highest for the finest fraction which was the most impure one.

Table 5: Purification tests feed samples and parameters applied in alkaline roasting and acid leaching. The samples highlighted in blue were the ones sent to the battery tests.

Purification Test	Alkaline Roasting				Acid Leaching		Feed	Residue	Upgrade
	Base	%	T(°C)	Time	Acid	%	C (%)	C (%)	(%)
LT1	NaOH	25	220	1.5	H_2SO_4	10	92.7	98.9	6.7
LT2			220	2.5		10	92.7	99.0	6.8
LT3			220	2.5		10	94.9	99.3	4.7
LT4			220	2.5		10	90.8	99.0	9.1
LT5			220	2.5		10	83.3	98.5	18.3
LT6			220	2.5		10	86.2	95.2	10.4
LT7			220	1		10	86.2	92.0	6.7
LT8			200	2.5		10	93.3	97.7	4.7
LT9			200	2.5		10	93.3	97.5	4.5
LT10			200	3		20	93.3	97.9	4.9
LT11			200	3	HCl	20	93.3	97.7	4.7
LT12			200	3	H_2SO_4	20	97.7	99.4	1.7
LT13			200	3		20	97.5	99.2	1.7
LT14			200	3		20	97.9	99.4	1.5

The removal of impurities are detailed in Table 6. Most of the remaining impurities (>75%) in the high C grade concentrates is SiO_2. The Fe content is about 0.06%, and S 0.03%.

Table 6: SiO_2, S and Fe removal after purification tests. The samples highlighted in blue were the ones sent to the battery tests.

Purification Test	SiO_2 Feed	SiO_2 Residue	S Feed	S Residue	Fe Feed	Fe Residue
	%	%	%	%	%	%
LT1	3.99	0.40	0.25	0.069	1.01	0.10
LT2	3.99	0.38	0.25	0.068	1.01	0.10
LT3	2.10	0.25	0.17	0.026	0.56	0.05
LT4	3.73	0.39	0.23	0.041	0.96	0.07
LT5	7.13	0.53	0.53	0.139	1.70	0.18
LT6	4.32	2.74	0.21	0.068	1.07	0.68
LT7	4.32	3.38	0.21	0.161	1.07	1.35
LT8	2.18	1.17	0.16	0.045	2.26	0.34
LT9	2.18	1.26	0.16	0.049	2.26	0.37
LT10	2.18	1.26	0.16	0.029	2.26	0.13
LT11	2.18	1.58	0.16	0.021	2.26	0.07
LT12	1.17	0.36	0.05	0.031	0.34	0.06
LT13	1.26	0.39	0.05	0.032	0.37	0.07
LT14	1.26	0.32	0.03	0.031	0.13	0.05

When comparing LT2 with LT5, the condition were the same. The feed grade in LT5 was almost 10% lower than in LT2. Despite that, the C grade in the residue was just 0.5% higher in LT2. This fact suggests that even lower grade samples could be treated, or also that reagents could be reduced.

4 CONCLUSIONS AND RECOMMENDATIONS

Graphite occurrences from Rautalampi area presented ca. 14% C feed grade. The beneficiation test-work included crushing to -1.4 mm, grinding by rod mill, and separation by flotation with roughing and five cleaning stages. The C grade in the flotation concentrates was ca. 90% C, at C recoveries between 67 to 83%.

Graphite flake size reduction by milling with attritor grinding showed to be efficient; however, graphite flake edges were deteriorated, and milling time was long. Different milling techniques and grinding medias should be tried to find alternative that do not compromise the flake shape.

The purification scheme by alkaline roasting followed by acid leaching proved to be capable of producing high-purity graphite concentrates, with over 99% purity. The highest C grade obtained was 99.4% in LT14. The process seems to be efficient even for lower feed grades, as 83.3% C feed grade in LT 5, reaching 98.5% C after the purification process.

The results pointed that there is C purity limitation that can be reached by this method. This limit is probably close to 99.4% C, since this value was also the highest one obtained by the Lu and Forssberg (2002) with the Woxna graphite.

REFERENCE

Lu, X. & Forssberg, E. (2002). Preparation of high-purity and low-sulphur graphite from Woxna fine graphite concentrate by alkali roasting. Minerals Engineering - MINER ENG. 15. 755-757. 10.1016/S0892-6875(02)00172-3.