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MINERALOGICAL DESCRIPTION AND PRELIMINARY PROCESSING OF THE VITTAJÄNKÄ KAOLIN DEPOSIT SALLA, NORTHEASTERN FINLAND

GTK

Mineralogical Description and Preliminary Processing of the Vittajänkä Kaolin Deposit Salla, northeastern Finland

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ABSTRACT

The Vittajänkä kaolin deposit is located in the northeastern Finland, in a flat area with abundant wet swamps. The kaolin deposit is covered by a 10-25 m thick glacial overburden and has been investigated by gravity and drilling methods. The deposit is lenticular in shape, 2 Km long, 500 m wide and according to borehole data 20-50 m thick. Geologically the Vittajänkä deposit is located in the southeastern extension of the volcanic serisitic and arcosic quartzite of the meta-sedimentary Matovaara formation.

The Vittajänkä kaolin is of primary or residual origin, formed in situ by weathering of silicate minerals (mainly feldspar and mica) of parent rocks in a warm and humid climate to kaolinite and other clay minerals.

Particle size distributions of the feed materials show that the amounts of the <2 µm fractions vary between 8.7 - 25.7 % with an average of 16 %, and that of the <20 µm fraction 27.7 - 73.0 % with an average of 49 %. According to the XRD analyses, the <2 µm fractions of the final products contain 85 – 95 % kaolinite, 5 – 10 % quartz and <5 % mica, while the main chemical constituents are SiO_2 (50 %), Al_2O_3 (31 %), Fe_2O_3 (1.5 %) and TiO_2 (0.4 %). Comparing the chemical composition of the investigated kaolin with the typical compositions of kaolin filler and coating, it appears that the Vittajänkä kaolin has higher contents of SiO_2 and Fe_2O_3, but lower contents of Al_2O_3 and TiO_2. This indicates that the desilication was not complete.

The brightness values of the final fractions vary between 74 – 84 %, with an average of 79.5 %. The yellowness values vary between 3.5 – 9.6 % with an average of 4.3 %. The low brightness and high yellowness values mainly depend on the occurrence of iron oxides.

The chemical and physical properties of the Vittajänkä kaolin were compared with the typical specifications for kaolin filler and coating grades. It appears that some kaolin properties meet the requirements of paper industry, while some do not meet such requirements. Therefore it is proposed to study other process techniques like froth flotation in addition to high gradient magnetic separation aiming for a purified product suitable for paper coating application.

CONTENTS

1. INTRODUCTION

1.1 Aim of the present investigation

The aim of this report is to discuss and outline some of the basic tests for evaluation of the Vittajänkä kaolin deposit at Salla particularly for use in paper industry and other applications. The processing tests of the kaolin samples were done at the VTT Mineral Processing Laboratory at Outokumpu and the laboratory analyses at GTK-Espoo.

1.2 Background

Kaolin is an important industrial mineral including applications in paper, ceramics, paint, plastics, rubber, ink, fiberglass, cracking catalysts etc. (Murray, 1991).

Kaolin products are composed totally or substantially of the aluminum silicate clay mineral kaolinite. Air-classified grades of raw kaolin normally still contain small amounts of mica, illite, chlorite, smectite and quartz. Kaolin used for the paper coating is water-washed and refined in order to remove these mineral impurities. Both weathering and hydrothermal alteration of aluminosilicate minerals forms kaolinite. Thus, rocks rich in feldspar commonly weather to kaolinite. In order to form, ions like Na, K, Ca, Mg and Fe must first be leached away by the weathering or alteration process. This leaching is favored by acidic water. Granite, gneiss and arkosic rocks, because they are rich in feldspar, are a common source for kaolinite.

According to Combs and Bardossy (1994), Patterson et al. (1986), the formation of kaolin deposits is possible on the following conditions:

- The bedrocks (granites, gneisses, andesites etc.) must have the right primary petrographic composition for forming kaolinite and other clay minerals.
- There must be a tectonic or thermal fissuring, which produce a sufficient permeability allowing a circulation of solutions.
- The pH values of this solution must be acidic ($\cong 5$), low Eh value, and the climate must be tropical or subtropical.
- The kaolin layers must be protected by sedimentary overburden or tectonically by structures, such as sinkholes, faults, fractures, etc.

In northern Finland, there are several small kaolin occurrences that have been known for a long time (Pekkala and Sarapää, 1989).

1.3 Structure of Kaolinite

The kaolin minerals: kaolinite, halloysite, dickite and nacrite have essentially similar chemical compositions but there are important structural and stacking differences. The most common kaolin mineral, and the most important industrially, is kaolinite. The theoretical formula of kaolinite is $Al_2Si_2O_5\ (OH)_4$, giving a theoretical chemical composition of 46.3% SiO_2, 39.8% Al_2O_3 and 13.9% H_2O, but because of the formation process, real kaolinites only approach this formula. Kaolinite is formed out of feldspar and/or mica, two very common minerals in granites and gneisses. Under acidic conditions, the crystal structure of these minerals breaks down and a recrystallization process starts, forming the kaolin crystal, which consists of layers of a SiO_4 tetrahedral and an Al $(O, OH)_6$ octahedral (TO-layer). This layer is bound on one side (as in kaolin) or both sides (as in talc, mica and pyrophyllite) by a continuous silica layer see Fig. 1.

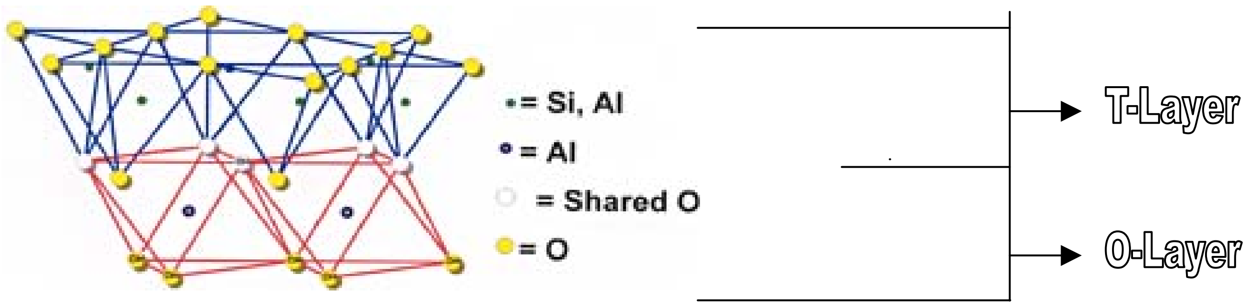


Figure 1. Kaolinite structure

In the water surrounding the crystallisation process, iron is always solved; it can be included in the process and replace Al-ions. Another replacement ion may be Ti. This is the reason why even in pure kaolinite, produced in laboratory-scale size, the above formula is only approached. The range of variation of the chemical composition of kaolinite is as follows:

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	All in %
45-48	38-40	0-0,2	0-0,3	

A kaolinite crystal consists of several (stacked) TO-layers and because it does not absorb water, it does not expand when it comes in contact with water. Thus, kaolinite is the preferred type of clay for the paper and ceramic industries. The continuous sheet structure produces thin particles, which are often found in nature as overlapping flakes. These are informally called “books” because of their resemblance under magnification to stacks of paper. Kaolin books are bound via hydrogen bonding of the octahedral layer hydroxyl face of one flake to the tetrahedral layer oxygen face of the adjacent flake. Separation of books into individual clay flakes is therefore difficult, see Fig. 2.

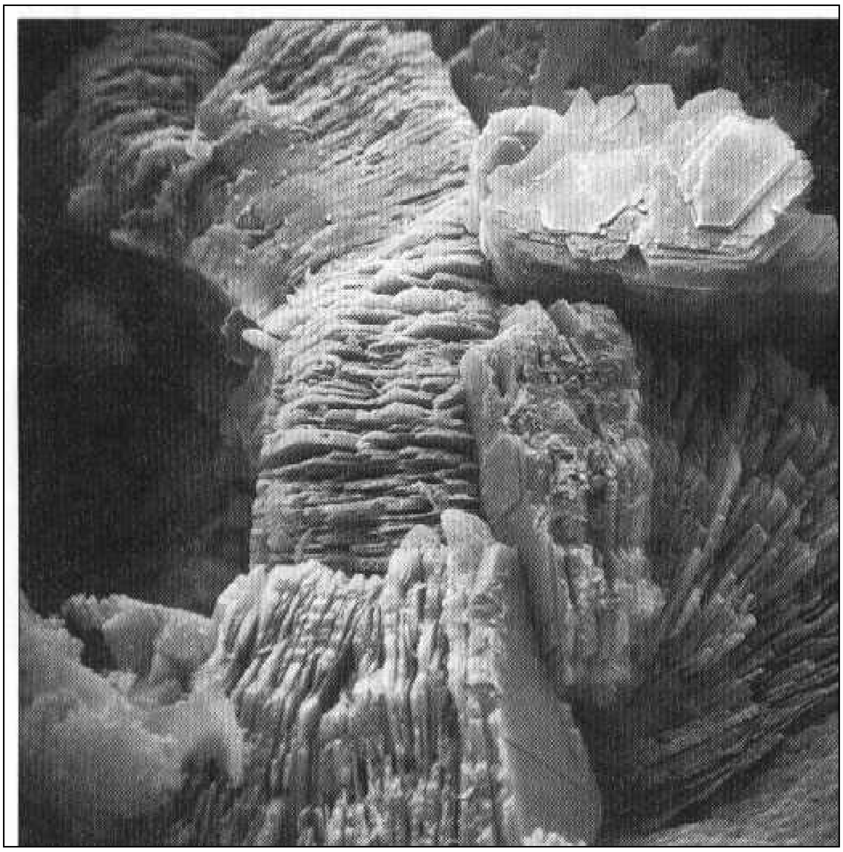


Figure 2. Typical book kaolinite “ Books” crystal x 1000 (www.cfr.edu)

Kaolinite shows a varying degree in crystal order, due to defect structures and translations in unit cells of the crystal lattice. Thus X-ray diffraction patterns of kaolinites may vary considerably. On the surface of the crystals, other ions are adsorbed, bringing Ca, Na and other elements into a chemical analysis of "pure" kaolinite. To make it even more complicated, free iron, titanium and other metal oxides as well as carbonates can crystallize in the surroundings of the kaolinite's forming process. Depending on the pH and temperature, in addition or instead of kaolinite, other clay minerals like illite or smectite can be formed.

2. GEOGRAPHICAL AND GEOLOGICAL SETTING

2.1 Geographical location of the studied area

The Vittajänkä deposit is situated in the Salla municipality, eastern Lapland (map sheet 4621 09) in a flat area. The glacial overburden is thick (10 – 25 m) and the bedrock is not outcropped.

2.2 Previous geological work

The first geological map covering the whole Salla area is the classical work of Hackman & Wilkman (1925) in the scale 1:400 000. In 1967 a geological map in the scale 1:100 000 covering the map sheets 4621 and 4623 was published by Lauerma (1967). This map was made before the low-altitude airborne geophysical data was available, so today the map is out of date. Mapping of the Lapland Volcanite Project in 1980´s, covered also the Vittajänkä area (Manninen, 1991). This mapping together with low altitude airborne geophysical data made it possible to make relatively accurate geological map of the area. The nomenclature of geological units and formations in this text are from Manninen´s (1991) report.

2.3 Geological setting

The Vittajänkä deposit is situated in the southeastern extension of the volcanic-sedimentary Paleoproterozoic Central Lapland Greenstone Belt (CLGB), see Fig. 3. CLGB is compressed between the Central Lapland Granite Complex in the south and southwest, and the Archean rocks of eastern Lapland in the north. On the eastern side of Vittajänkä lies the Salla Greenstone Area (SGA), which is separated from CLGB tectonically by fault. Majority of SGA is situated on the Russian side of the border. Together, the southeastern part of CLGB and SGA is referred as “Salla Schist Belt“. Host rock of Vittajänkä kaolin is arkosic and/or sericitic quartzite belonging to metasedimentary Matovaara Formation (see Fig. 4, bright yellow). This formation is surrounded by underlying metavolcanic Tahkoselkä Formation, which consists of tholeitic metabasalts. Another thick and widespread quarzitic unit, the Kelloselkä Formation (Pale yellow on Fig. 4), underlies the Tahkoselkä volcanics. Thus, the geological structure of Vittajänkä area is as a basin, where older volcanic rocks surround the younger sediments.

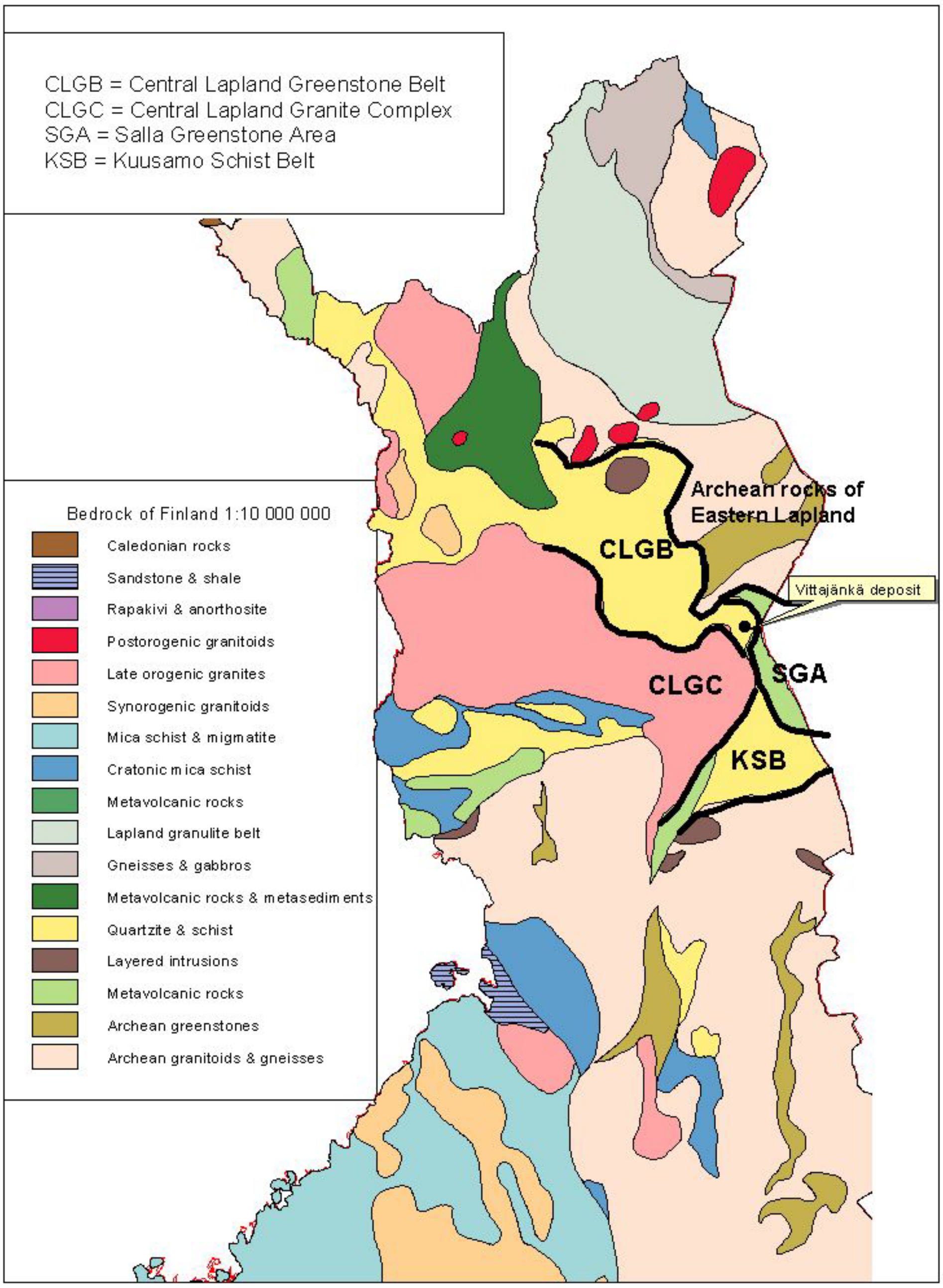


Figure 3. Location of Vittanjänkä deposit on bedrock map of Finland (1:10 000 000) with major geotectonic units bordering the studied area

As mentioned earlier, the Vittajänkä area and its surrounding is very poorly exposed. Additionally, the exposure of the rocks is very selective. This means that the Orthoquartzites of Matovaara Formation and some of the Tahkoselkä volcanics are quite well exposed but the more Al-rich sediments are poorly exposed and in many parts they have been deeply weathered by kaolinization processes.

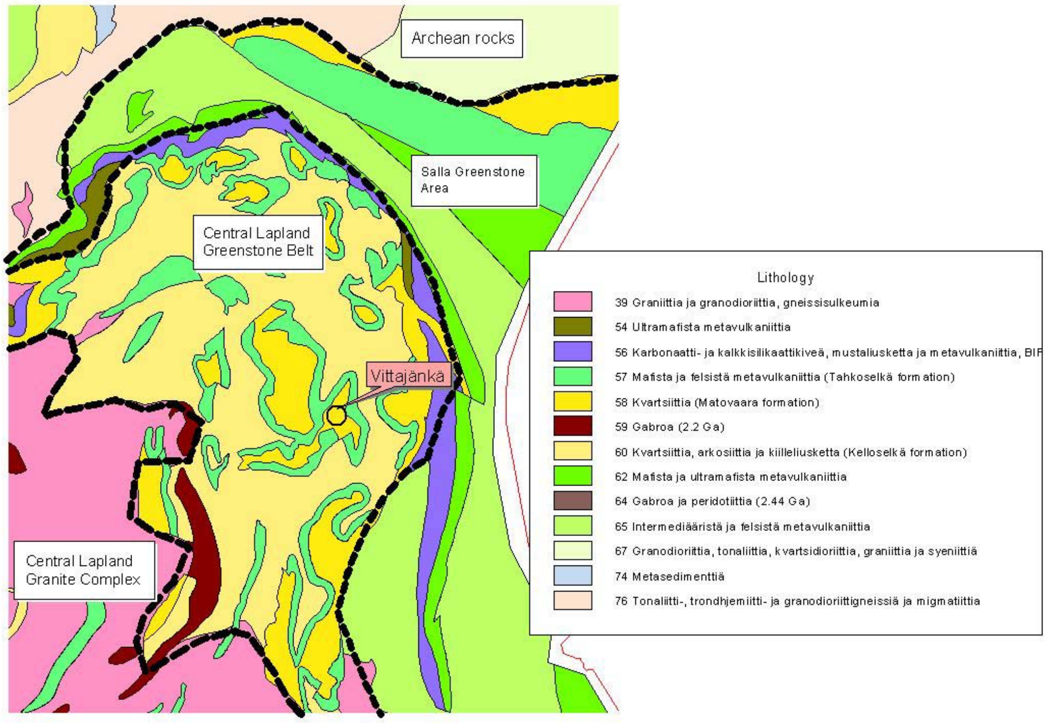


Figure 4. Location of Vittajänkä deposit on Geological Map of Finland (1:1 000 000)

2.4 Kaolinization of Vittajänkä deposit

The Vittajänkä kaolin is completely covered by 10 – 25 m thick glacial overburden, and thus drill core samples have been used in this study. A total of 17 boreholes were drilled in two E – W trending profiles. The northern profile in the X-coordinate 7428.500 and the southern profile in the X-coordinate 7427.800 are shown in Figs. 5 and 6. According to systematic gravimetric and electromagnetic geophysical measurements, the deposit is lenticular in shape, 2 km long, 500 m wide and, according to borehole data, 20 – 50 m deep. It must be noticed that only small section of the geophysical anomaly has been drilled systematically. The deposit consists of boulder-rich sandy till at the uppermost part of sections, fine-grained kaolin in the middle part of sections and slightly to moderately weathered bedrocks in the lower part of the sections. The photos in the figure 7 show a typical drill core of Vittajänkä kaolin deposit. Drill holes R337, R338, R340 and R345 lie in the central part of deposit (Fig. 6), penetrates the thick beds of white kaolin and thin beds of colored kaolin followed by unaltered beds with the depth. From this observations it can be concluded, that the kaolin has a gradual contact with the underlying rocks, which suggests an *in situ* origin for kaolin. Based on paleomagnetic studies, the Fennoscandian Shield was at low or moderate latitudes throughout most of Proterozoic and the Paleozoic, at least until the Permian (Pesonen et al., 1989). Tectonic features have controlled the genesis of Vittajänkä kaolin. Fractures and faults opened cracks in the parent rocks allowing the circulation of meteoric water within the parent rocks to change and alter the feldspar and mica to kaolinite. The free silica released by this kaolinization moved out of the parent rock either to form quartz veins, or perhaps, to fill in the permeability in the parent rocks.

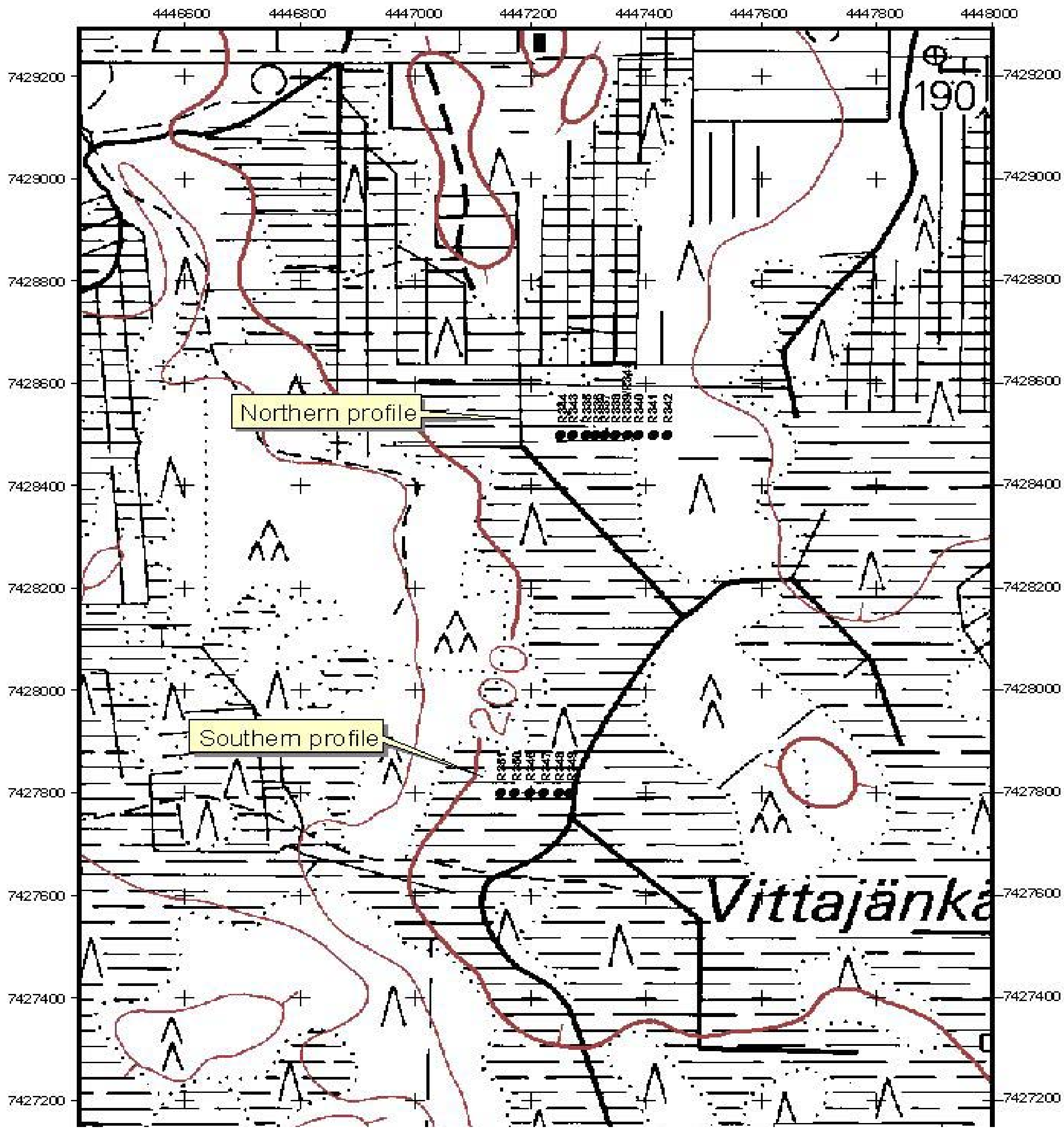


Figure 5. Locations of drill holes in studied area.

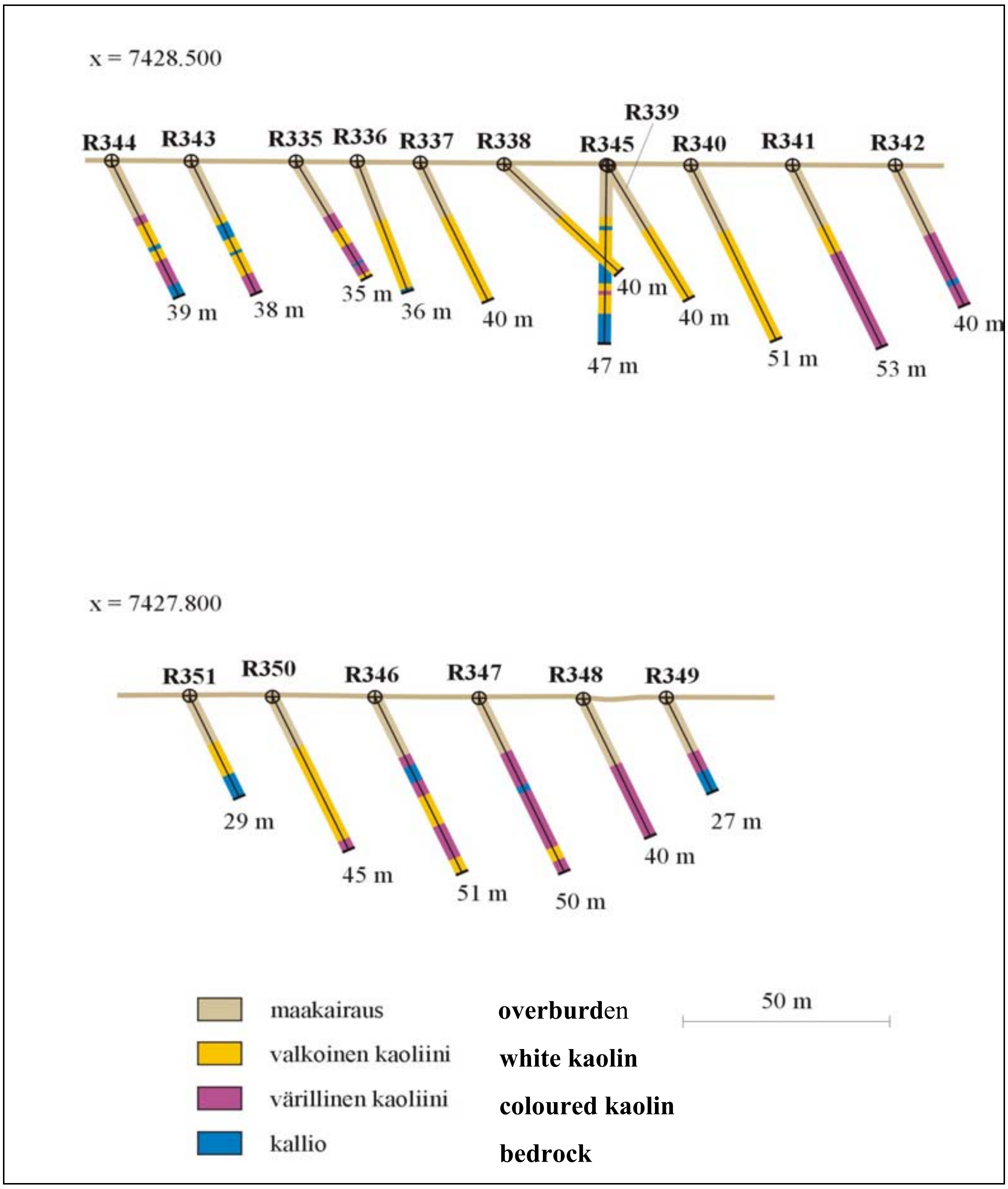


Figure 6. Cross-sections of drill holes in Vittajänkä kaolin deposit.

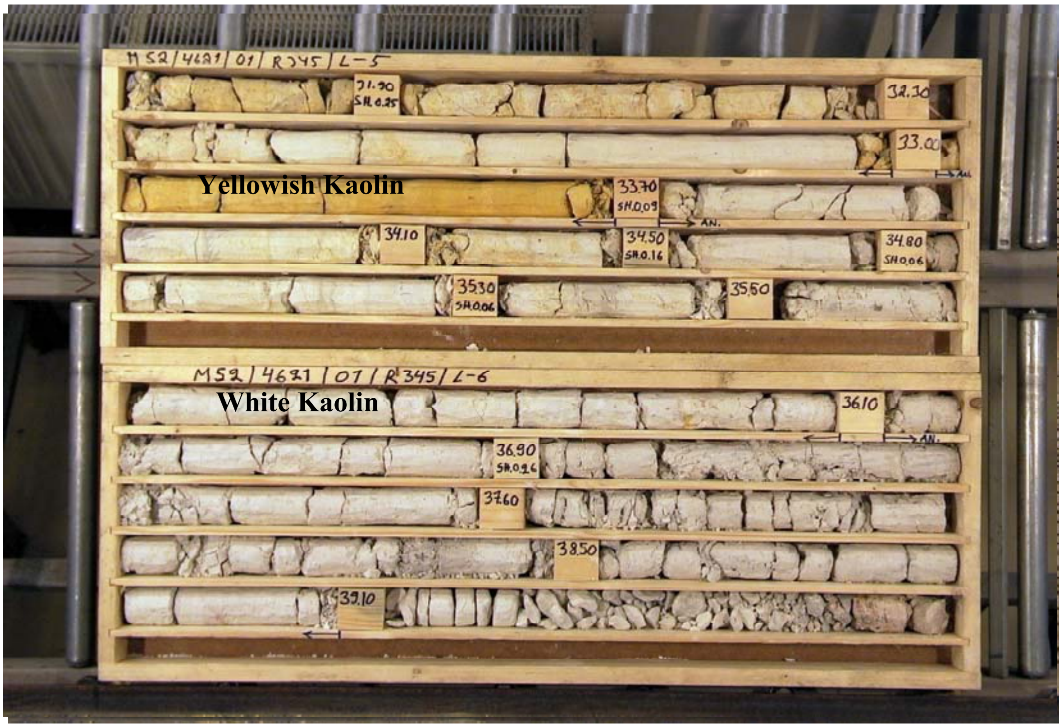


Figure 7. Drill core of borehole R345 showing the till overburden, white and yellowish kaolin as well as the weathered bedrocks.

3. MATERIALS AND METHODS

The methods, which have been used, are summarized in the Fig. 8 and Appendix 1/5 (VTT 2003). The primary step in kaolin processing is the removing of the waste minerals like quartz and mica by sieving and cyclone separation. The separation of kaolin from primary deposits as in the Vittajänkä deposit is more difficult due to the presence of a high proportion of abrasive minerals that have survived the alteration process. High gradient magnetic separation (HGMS) was used to remove titanium and iron oxides.

Further mineralogical investigation was carried out with (Philips-XRD) on powders of bulk samples and processed samples of different size fractions by high magnetic separation and final product. The major and minor elements were determined by XRF-analytical technique. Micro morphological characteristics of kaolinite and other minerals were studied with Scanning Electron Microscope (SEM).

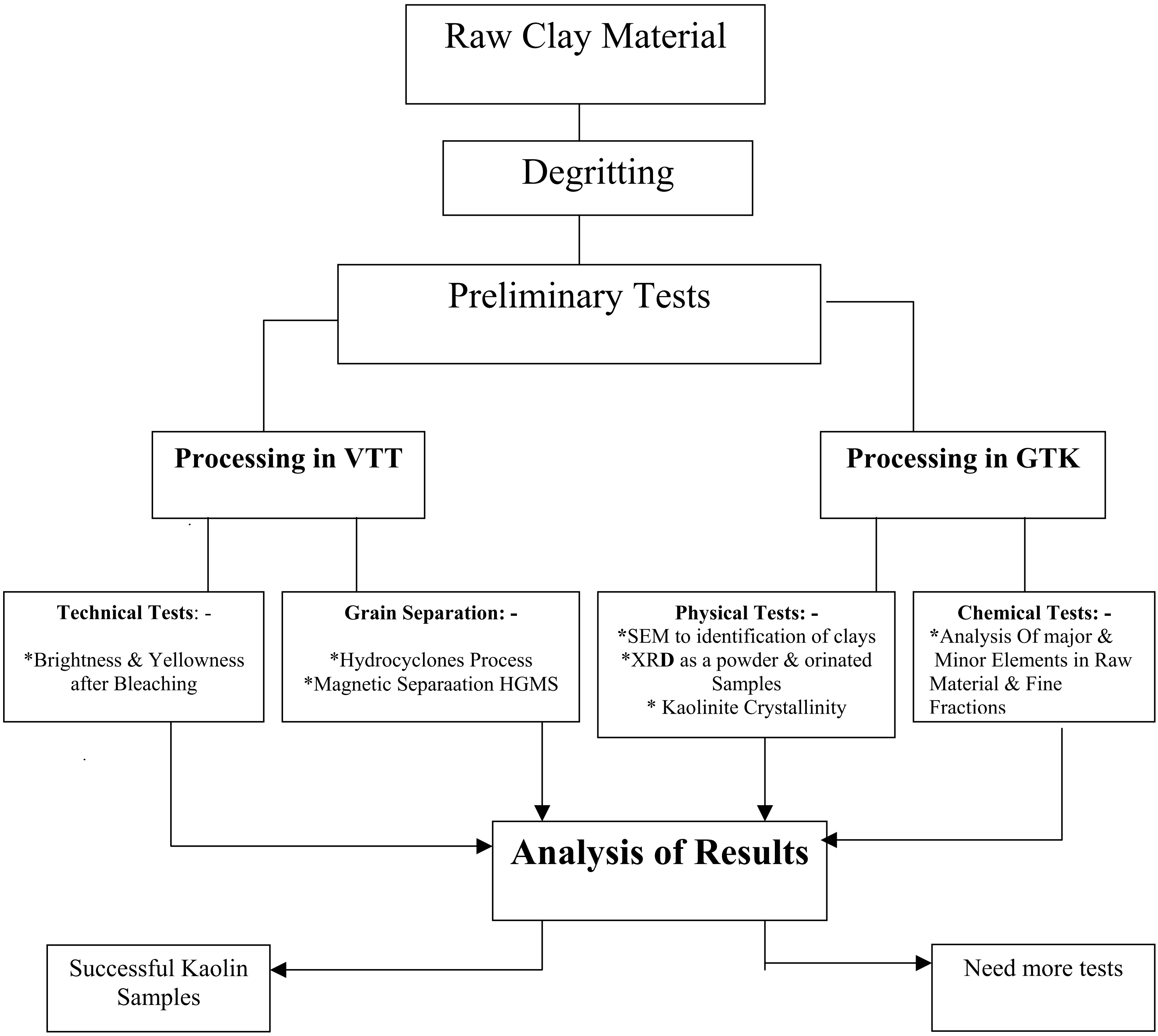


Figure 8. Schematic Diagram Showing the Processing on Studied Kaolin

4. MINERALOGY, CHEMISTRY AND KAOLIN PROCESSING

4.1 Particle size distribution

Particle size distribution is one of the most important properties of kaolin as it affects viscosity, brightness and many other properties. Before further studies kaolins should be processed by sieving and hydro cyclone separation. The results of Sedigraph particle size distribution done at GTK are summarized in Table 1. The percentage of particles < 2 μ m in the feed samples are between 8.7 – 25.7% with an average of 15.3% and that of < 20 μm between 27.7 – 73.0% with average of 49%. More information about grain size analysis of studied samples is found in Appendix 2.

Table 1. Summary of sieving and sedigraph of 96 feed samples.

Salla / Vittajänkä, KL 4621 09					
Cumulative permeability percentage					
	2 μm	**6 μm**	**20 μm**	**60 μm**	**200 μm**
The results	**%**	**%**	**%**	**%**	**%**
Range	**8.7-25.7**	**14.8-40.5**	**27.7-73.0**	**35.7-91.1**	**60.2-99.6**
Average	**15.3**	**26.5**	**49.0**	**61.2**	**93.2**

4.2 Mineralogy

The mineral content of kaolin is very important in assessing the applications and the result of many tests for determining the physical properties. XRD of the whole samples give us the mineral composition (see Appendix 3), but in many cases minor quantities of some minerals such as illite will not be detected. Table 2 shows the statistical summary of mineral composition for final product of < 2 μm, < 20 μm and raw kaolin. It's indicated that the kaolinite will concentrate in finer fraction and the other alkaline minerals will be decreased or/and removed in separation processes.

Kaolinite content of raw material ranges between 10 – 70% with an average of 39%. Additional constituents are quartz ranging between

5 – 70% with an average of 43% (more than kaolin content), muscovite between 0 – 15% with an average of 8% and plagioclase between 0–10% with average of 6%. Small amount of goethite, pyroxene and talc are found in some samples. Although the final production fraction is composed almost entirely of kaolinite with an average of more than 92%, the contents of quartz is still between <5 – 10% with an average of 6% and muscovite about 4%.

Table 2. Statistical summary of mineral composition for final products (<2 μm), <20 μm fractions and raw material samples

Minerals	Raw materials		< 20μm Fractions		Final Products (<2 μm)	
	Range	Average	Range	Average	Range	Average
Quartz	**5 - 70**	**43**	**0 - 45**	**12**	**<5 - 10**	**6**
Plag.	**0 - 10**	**6**	**0 - 55**	**13**	**0**	**0**
Muscovite	**0 -15**	**8**	**0 - 50**	**11**	**0 -<5**	**4**
Kaolinite	**10 - 70**	**39**	**5 - 95**	**62**	**85 - 95**	**92**
Hematite	**0 - 20**	**2**	**0 - 35**	**3**	**0**	**0**
Pyr.	**0 - 20**	**3**	**0**	**0**	**0**	**0**
Talc	**< 5**	**Trace**	**0 - 15**	**0.3**	<5 Talc (one sample)	

Oriented slides of the < 2 μm fraction were used for enhancing the basal reflections *00l* of the studied clay samples and diminishing or even suppressing the *hko* & *hkl* reflections (Brown, 1961). The advantage of using oriented clay slides will give us a better identification of clay minerals found in minor content such as illite, and also we can heat the slides directly to 350°C and 500°C.

The examination of selected samples of Vittajänkä deposits indicates that kaolinite is the main clay mineral with traces of illite or mixed layer clay of illite – smectite found in the studied samples, such as in the sample R342 (19.6 – 20.6) see Fig (9). The high concentration of Fe_2O_3 (4.6%) in the <20 μm fraction of this sample may be due to contamination of the kaolinite with illite, also it shows reduction in brightness to 50%. XRD analysis of oriented clay in Fig. 9 shows that untreated sample has a broad reflection (10Å to 10.5Å). In glycolated sample the illite peak reflection shifted towards the (9.0Å – 9.5Å) and shows a broad reflection in 17.7 Å of expanded layers (montmorillonite). When the sample is heated to 550 °C, the expanded layers of smectite and the non-expanded layers of kaolinite will collapse and increase the intensity of the peak of

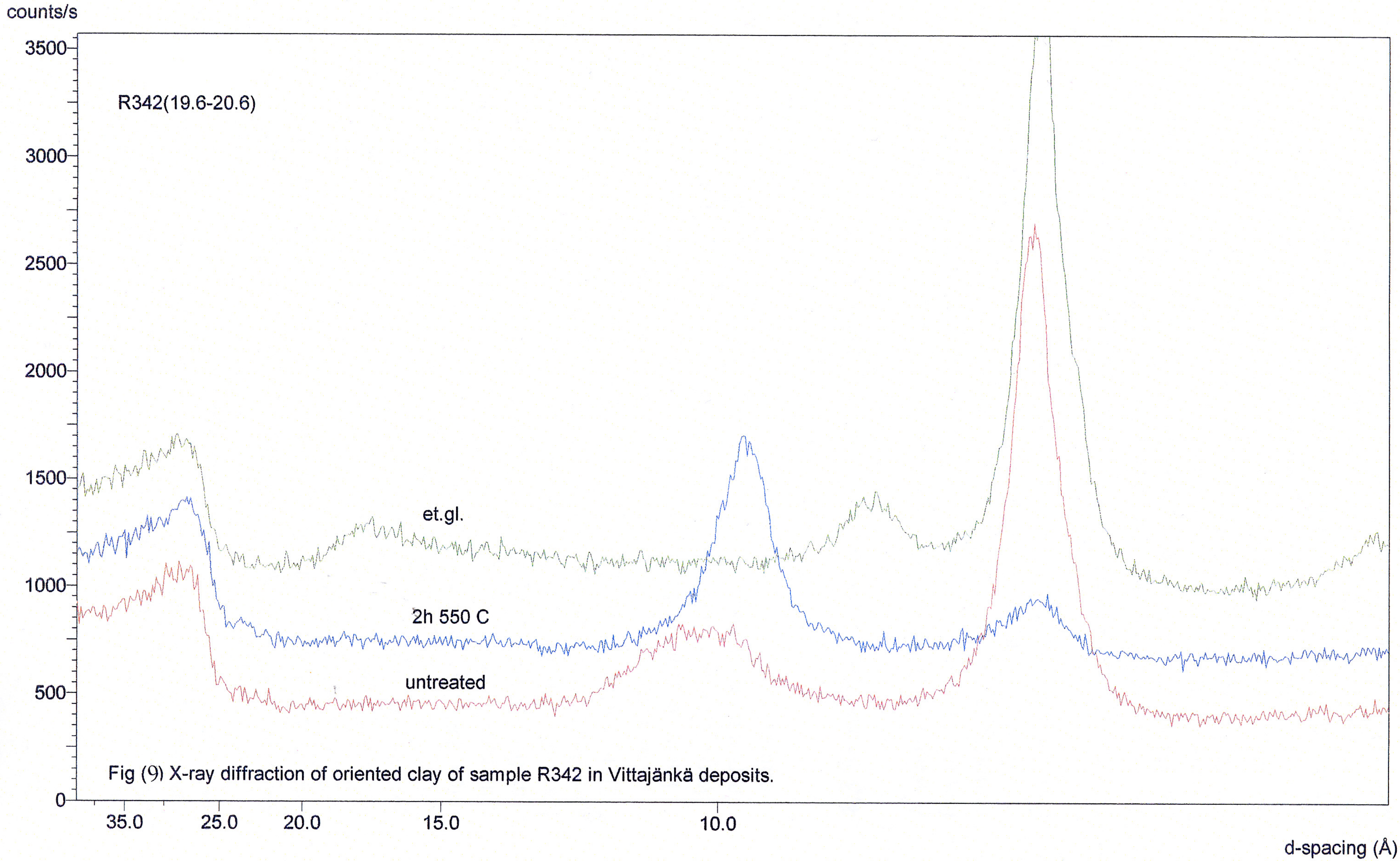


Fig (9) X-ray diffraction of oriented clay of sample R342 in Vittajänkä deposits.

Illite in 10 Å (i.e. the peak of kaolinite will be removed due to heat, but the peak of illite will become more intensive). For more information about clay minerals see Figures in Appendix 4.

Determination of kaolinite crystallinity index were made from (*hkl*) reflections of X-ray diffract grams using the methods of Hinckley (1963), Patricia and Emilio (1999). The “well crystallized kaolinite“ in some studied samples has values ranging between (0.7 – 0.88); especially the samples R337 (25.7 – 33.8), R340 (28.2 – 36.6), R345 (28.6 – 37.1) and R350 (14.6 – 27.7). These samples contain small amounts of quartz and mica. This shows that in Salla the most intensive chemical weathering generated Vittajänkä kaolin deposits and the well-crystallized kaolinite was formed by the removal of alkalines and silica to produce authigenic kaolinite. On the other hand the “moderately crystallized kaolinite” samples have values between (0.59 – 0.7), such as in samples R342 (19.6 – 20.6) and R339 (30.2 – 30.65), which reflect the presence of free silica, mica and small amounts of iron oxide minerals that effected crystallinity of kaolinite (Landa and Gast, 1973). The peak of kaolinite shows an inverse relationship with a mica peak; on the other hand the recorded sharp and high intensity mica peak indicates lower crystallinity of kaolinite.

4.3 Scanning Electron Microscope (SEM)

A scanning electron microscope was used to investigate the surface features, size and shape of individual crystal grains of the studied samples. Photographs published by others especially Keller (1976,1977,1978) of kaolinite were used for better identification and comparison.

The micro texture of Vittajänkä kaolin, shown in the figures 10 and 11, is characterized by euhedral to subhedral crystals in flat plates, loosely packed, in general uniform in size and with not much intergrowth of crystals. In some cases kaolin shows sharp crystalline outlines that exhibits a pseudo-hexagonal form with individual crystals (Fig 10 A, B). It signifies the environment where there is abundant available space for kaolin crystals to grow and produce high crystallinty of kaolin. These texture characteristics indicate that the studied kaolin is product of *in situ* weathering of primary silicate rocks. The common forms of studied kaolin are a flaky shape with high aspect ratio (ratio of mean diameter to thickness). Many of the so-called coarse flakes are in effect stacks of fine and ultra-fine particles (Fig 11A,B). Often the kaolinite plates are stacked

together by cohesive forces, but in our case SEM does not show high quantity of kaolin stack, i.e. delaminating process is not necessary to apply to remove the coarse fractions and kaolin stacks.
Some edge of hexagonal platelets are at time rounded and the EDX spectra reveals the presence of K, which could be probably be indicative of illite (Fig 12 A, B). Also the XRD tests indicates that illite found as a trace amount in the studied samples, such as in the sample R342 (19.6 – 20.6) see Fig (9). Illite and kaolin did not show appreciable variation in the crystal chemistry parameter upon treatment. This shows that illite is neoformed due digenetic process such as dissolution of smectite or/and alteration of muscovite to crystallization of illite. The SEM studies indicate that Vittajänkä kaolins consist of ultra-fine and thin platy to flaky particles and lack of kaolinite books (Fig 12B).

The micaceous material is partly composed of degraded primary mica, but there is also illitic mica. The mica is deficient in potassium, due to replacement of K by OH to form illite. A big amount of coarse mica and quartz particles of waste samples shown on Fig (13 A, B), indicates a well performed magnetic and hydrocyclone separation process.

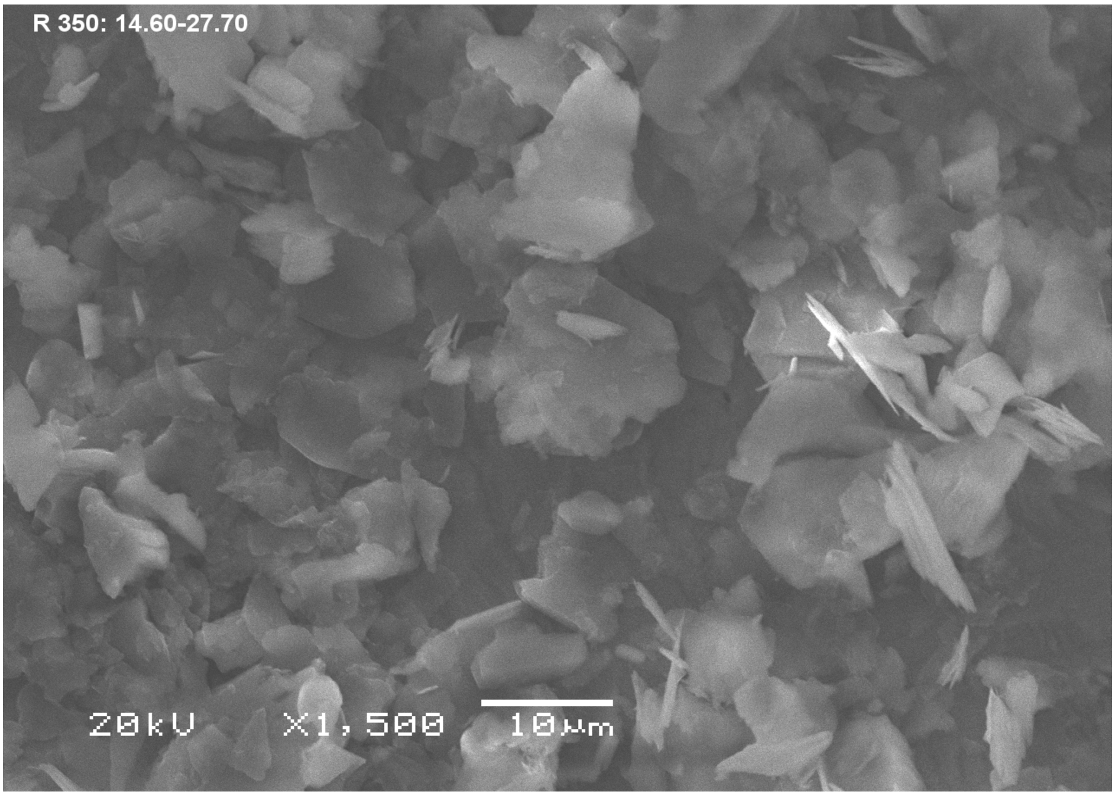
4.4 Chemical analysis

Chemical analysis provided by XRF is summarized in Table 3. The analysis was determined from raw material, for < 20 µm fraction of raw material and from final products (Appendix 5). The main constituents of the white samples are as follows: In raw material the main constituents are SiO_2 (50.3 – 90.3)% with an average of 73.7%, Al_2O_3 (5.5 – 27.6)% with an average of 13.9%, Fe_2O_3 (0.5 – 12.1)% with an average of 2.94%, TiO_2 (0.08 – 1.38)% with an average of 0.32% and LOI between (1.2 – 10.6)% with an average of 4.5%, as well as small contents of other elements such as MgO, Na_2O, K_2O, CaO, and MnO.

In the < 20 µm fraction the main constituents are SiO_2 (45.8 – 6.0)% with an average of 51.6%, Al_2O_3 (23.1 – 35.7)% with an average of 27.9%, Fe_2O_3 (1.4 – 4.5)% with an average of 2.9% and TiO_2 (0.2 – 1.1)% with an average of 0.6%.

In the final fraction (< 2 µm) the main constituents are SiO_2 (46.9 – 55.3)% with an average of 50.06 %, Al_2O_3 (28.9 – 36.4)% with an average of 31.3%, Fe_2O_3 (0.8 – 2.6)% with an average of 1.51%, TiO_2 (0.2 – 0.7)% with an average of 0.4%. This shows that the amount of SiO_2, Fe_2O_3, TiO_2 and alkaline elements in the final products decreased

A



B

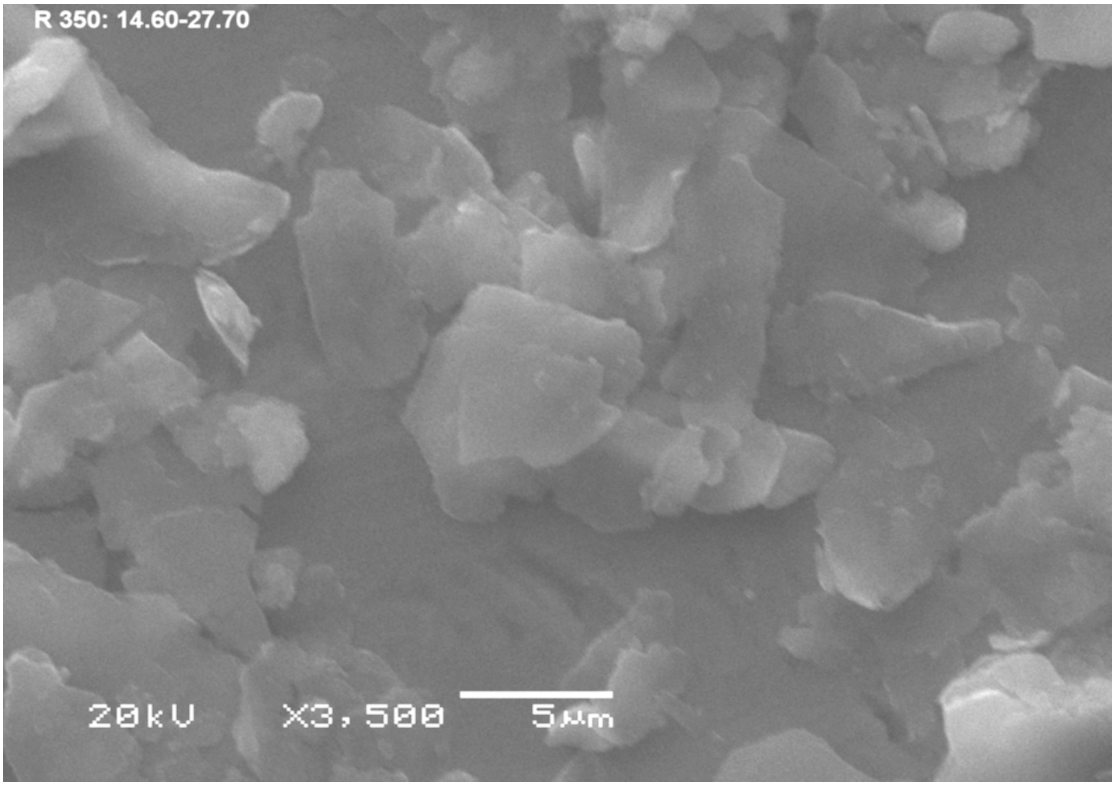
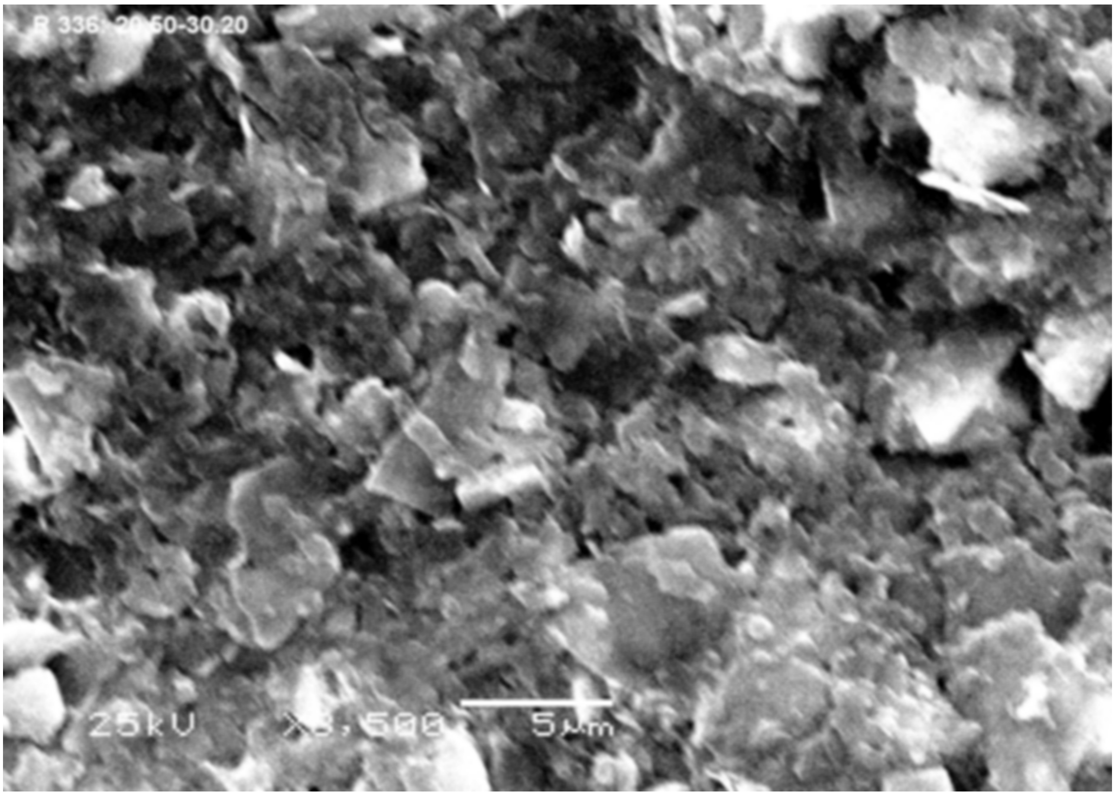


Fig (10) SEM images showing kaolinite stacking of Vittajänkä deposit as sharp crystalline outlines that exhibits (A) a pseudo-hexagonal form and (B) individual crystals

A



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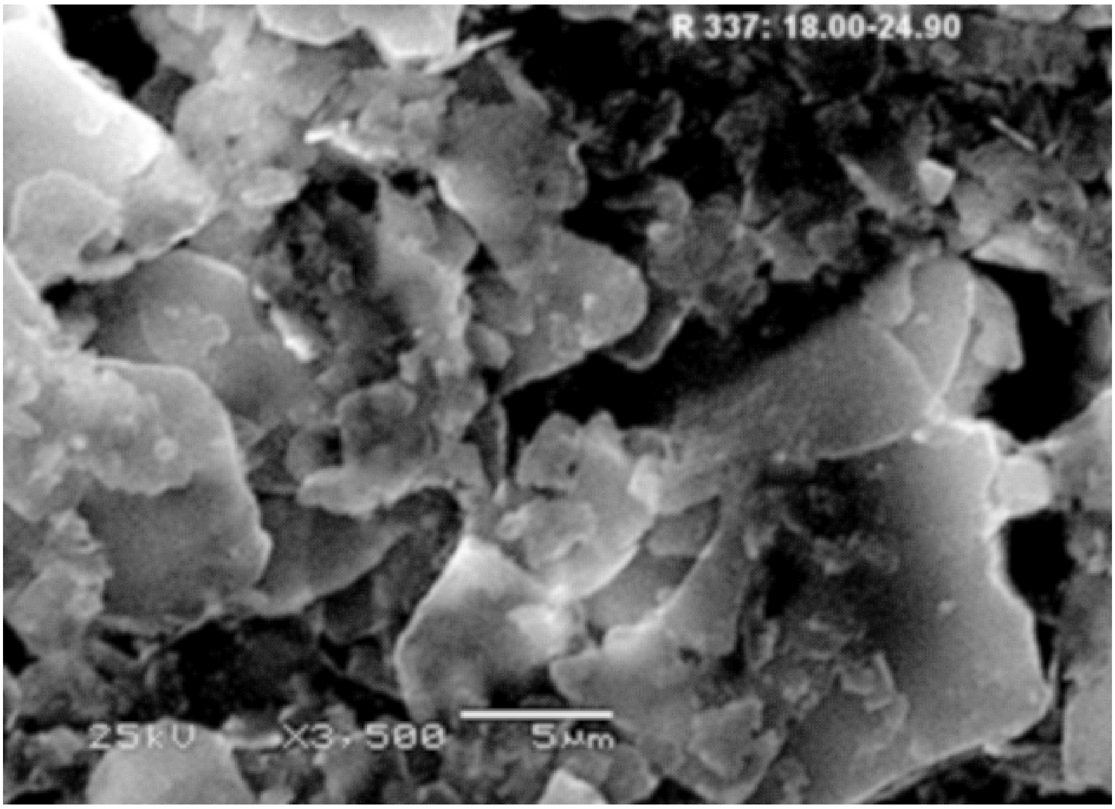
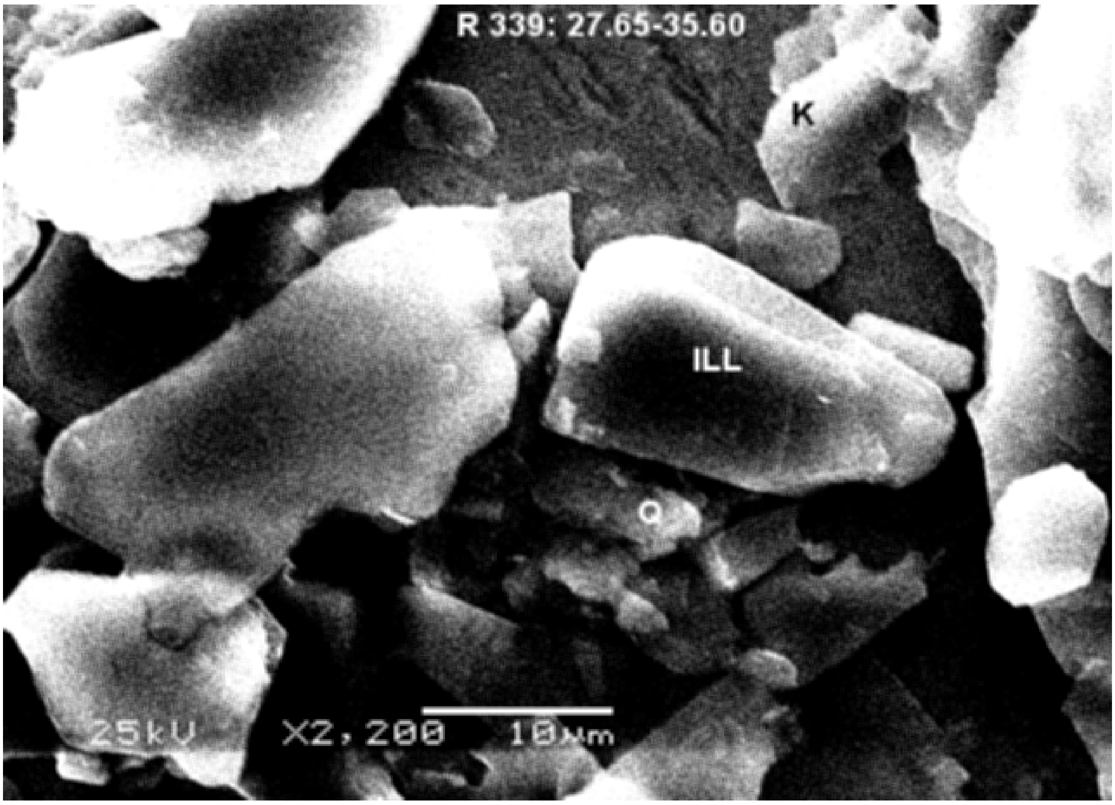


Fig (11) SEM images of coarse flakes of kaolinite that stacks the fine particles in two studied samples of Vittajänkä kaolin (A) R336 and (B) R337.

A



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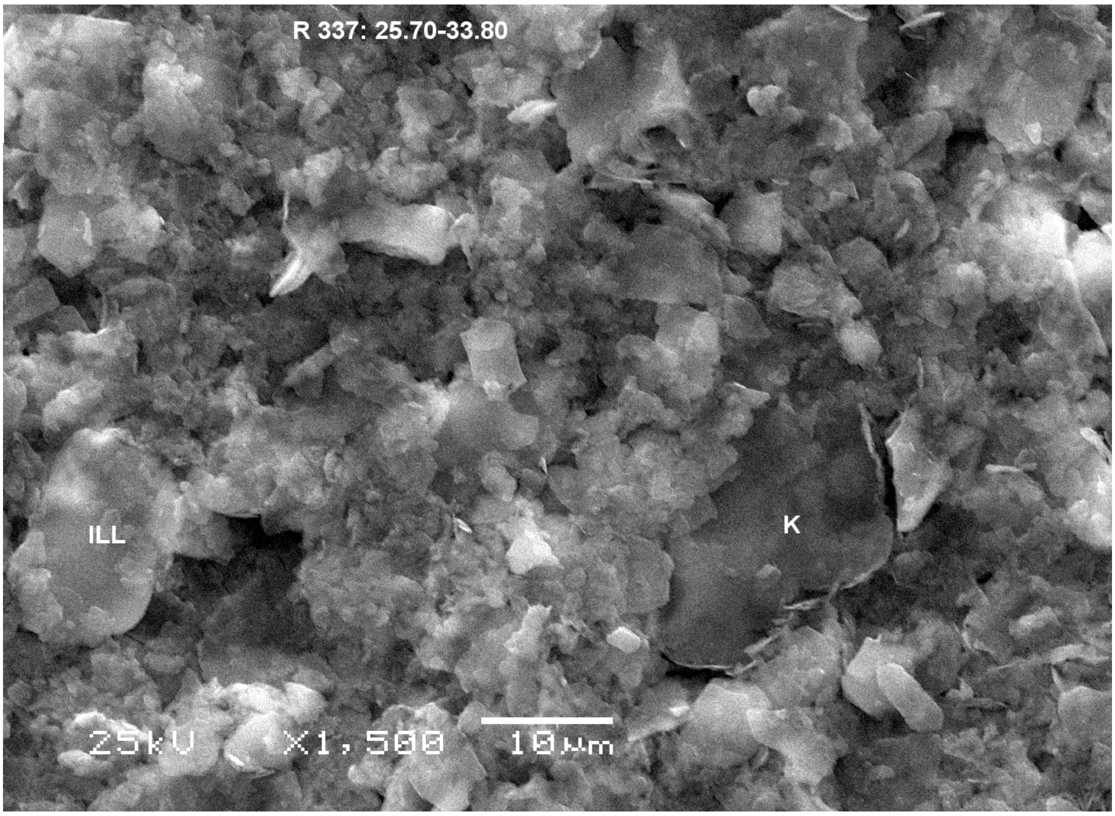
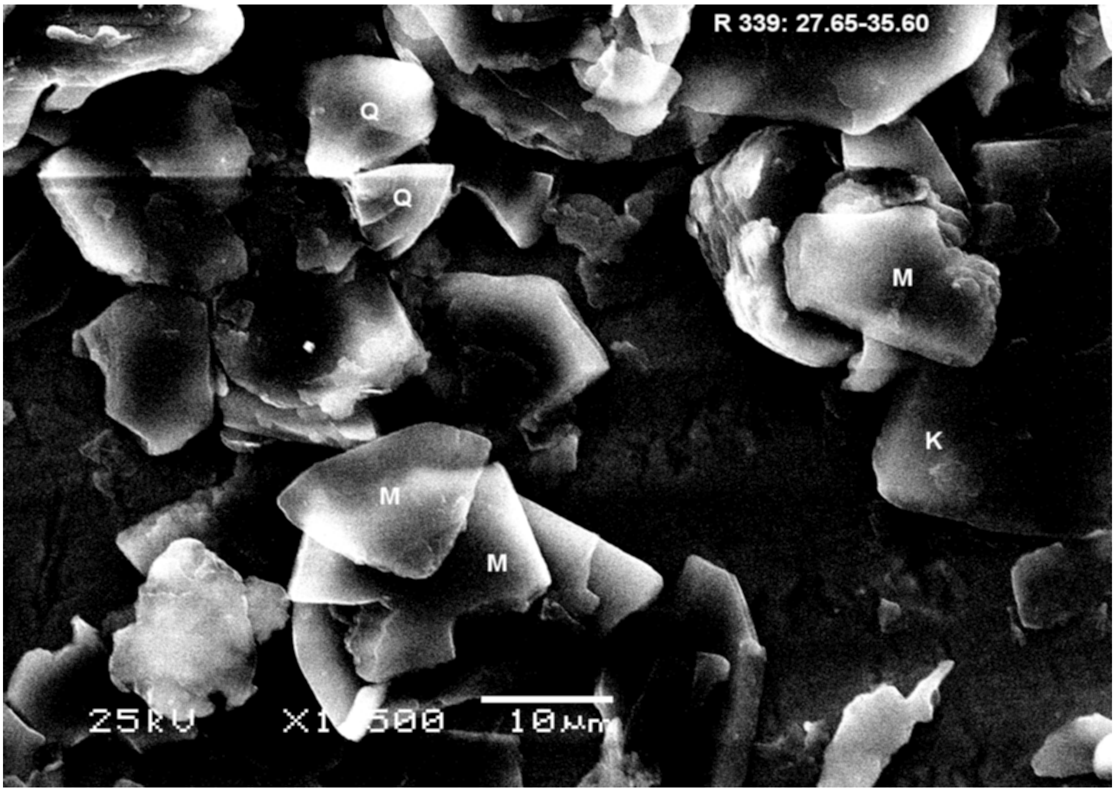


Fig (12) SEM images showing at (A) coarse kaolinite particles with rare illite particles in sample R339 (B) ultra-fine and thin platy to flaky particles of kaolinite with rare illite particles Sample R337.



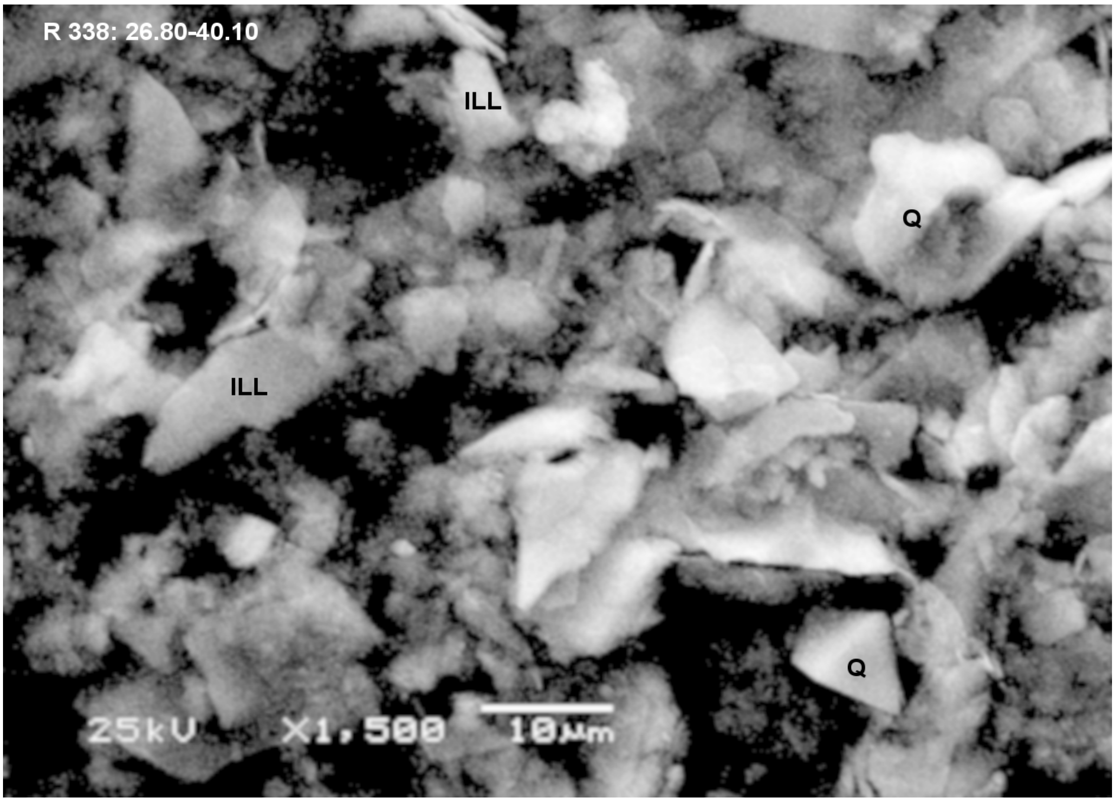


Fig (13) SEM of waste samples after magnetic separation showing higher content of coarse mica and quartz particles with illite particles (A) sample R339 and (B) sample R338.

due to the separation process, whereas the percentage of Al_2O_3 increased. The content of Fe_2O_3 is still high in the < 2 μm fractions, which is due to presence of iron oxide and hydroxide minerals. The content of TiO_2 is also high and the titanium impurities usually occur in the form of ultra-fine particles (< 2 μm). A separate flotation process is required to remove these impurities from the kaolin. The high content of K_2O in the final production is due to the presence of muscovite and illite.
The SiO_2, and Fe_2O_3 contents of the Vittajänkä kaolin is higher than the typical chemical percentages of kaolin filler and coating grades. This implies that the desilication was not complete. This can be explained by higher silica content of the parent rocks and less perfect drainage conditions and/or by secondary resilication. The presence of silica will increase the abrasiveness of kaolin slurries and shorten the life of coating equipment as well as affect the quality of coated paper.

Table 3. **Statistical summary of chemical analysis results of various fractions**
.

Elements	Raw materials		<20 micron fractions		Final Products		Typical Kaolin *	
	Range%	Average%	Range %	Average%	Range%	Average%	Coating %	filler%
SiO_2	52.5 - 87.7	**76.2**	45.8 - 61.0	**51.6**	46.9 - 55.3	**50.0**	45 - 47	46 - 48
Al_2O_3	7.6 - 26.8	**13.9**	23.1 - 35.70	**27.9**	28.9 - 36.4	**32.3**	37 - 38	37 - 38
TiO_2	0.08 - 1.40	**0.32**	0.23 - 1.16	**0.6**	0.18 - 0.68	**0.4**	0.5 - 1.03	0.04- 1.5
Fe_2O_3	0.51 - 5.5	**1.7**	1.40 – 4.5	**2.9**	0.83 - 2.36	**1.5**	0:5 - 1.0	0.5 - 1.0
MnO	0.008 - 0.02	**0.02**	0.01 - 0.05	**0.02**	0.004 - 0.02	**0.005**		
MgO	0.42 - 6.09	**1.2**	0.98 – 5.3	**1.8**	0.48 - 1.32	**0.5**		
CaO	0.013 - 0.1	**0.03**	0.0 - 0.36	**0.01**	0.016 - 0.046	**0.03**		
Na_2O	0.07 - 1.27	**0.05**	0.08 – 0.64	**0.2**	0.0 - 0.05	**0.02**		
K_2O	0.06 - 5.34	**3.2**	0.03 - 9.11	**6.2**	0.07 - 4.97	**2.7**		

* Specification of kaolins for coating and filler grades (after Prasad et al., 1991).

4.5 Brightness and Yellowness

Whiteness or brightness is the most important quality criterion for commercial kaolin. Brightness is a very important parameter in the paper industry. The brighter the paper is, the better is the kaolin. Pure kaolin is white. A loss in brightness originates from small amounts of iron oxides, titanium oxides or organic substances, depending on the origin of the impurities.

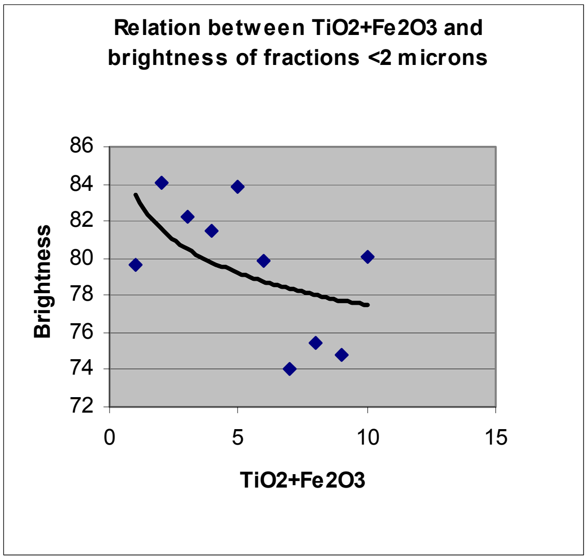
These properties were determined from the <20 μm fractions and from

the final products (< 2 μm). The results are shown in the Tables 4, 5 and Appendix 6
. The brightness of the < 2 μm fraction is higher than that of < 20 μm fraction, because the < 2 μm fraction has been processed. The < 20 μm fraction has only been fractioned by grain size, but not cleaned by magnetic separator, nor bleached. However, the brightness still needs to be improved by removing the impurities by other separation techniques, like flotation separation.
The residual kaolins have higher brightness values ranging between (74.0 – 84.1)% with an average of 79.5%. However, the yellowness ranges between (3.5 – 9.6) percent with an average of 4.3%. In fact, the whiteness and yellowness values depend on the occurrence of impurities such as titanium and iron oxides, as shown in the Figure 14, where there is a negative relation between brightness and $TiO_2+Fe_2O_3$, whereas a positive relation exists between yellowness and $TiO_2+Fe_2O_3$.

The ranges of brightness and yellowness of the < 20 μm fractions vary more than that of the < 2 μm fractions. The brightness values vary between (51.5 – 84.6) percent with an average of 69.6% (this represents the value of white clay samples only). The yellowness values vary between
(5.2 – 35.3)% with an average of 13.7%. The relation between brightness and impurities is also negative but not so strong, see Figure 15.

Table 4. The content of $TiO_2+Fe_2O_3$ and brightness and yellowness of < 2 μm fractions.

Sample No.	TiO2 + Fe2O3	Brightness	Yellowness
R336 (20.50-30.20)	**1.81**	**79.6**	**4.8**
R337 (18.00-24.90)	**1.29**	**84.1**	**4.3**
R337 (25.70 - 33.80)	**1.18**	**82.2**	**5.1**
R338 (26.8 - 40.10)	**2.23**	**81.5**	**4.2**
R339 (27.65- 35.60)	**2.82**	**83.8**	**3.5**
R340 (28.20-36.60)	**2.83**	**79.9**	**4.7**
R341 (17.50-25.35)	**1.97**	**74**	**9.6**
R343 (15.95-25.80)	**1.24**	**75.4**	**9.4**
R346 (28.60-37.10)	**1.51**	**74.8**	**7.2**
R350 (14.60 - 27.70)	**2.15**	**80.1**	**5.9**
Average	**1.87**	**79.54**	**5.87**
Min	**1.18**	**74**	**3.5**
Max	**2.83**	**84.1**	**9.6**



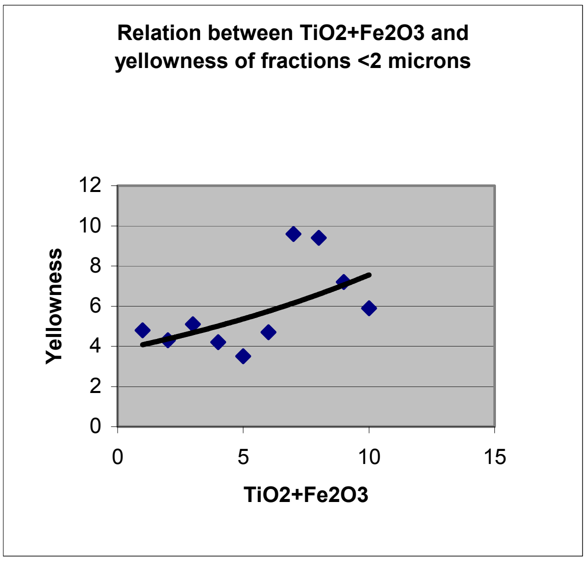


Figure 14. Relation between TiO_2+Fe_2O_3 and brightness and yellowness of < 2 µm fractions

Table 5. The content of TiO_2+Fe_2O_3 and brightness and yellowness of < 20 µm fractions

Sample No.	TiO_2 + Fe_2O_3	Brightness	Yellowness
R335 (16.40-20.70)	**4.82**	**51.5**	**35.3**
R335 (20.70-23.55)	**3.2**	**63.3**	**25.1**
R335 (23.55-25.25)	**2**	**80.2**	**8.6**
R335 (30.70-33.80)	**4.72**	**59.3**	**26.8**
R336 (20.50-25.10)	**3.58**	**75.5**	**11.0**
R337 (23.10-28.15)	**2.15**	**81.9**	**7.7**
R337 (36.30-40.00)	**3**	**81.8**	**7.1**
R342 (21.95-26.60)	**3.39**	**45.7**	**21.7**
R343 (29.20-32.30)	**1.88**	**60.7**	**25.1**
R344 (25.60-28.70)	**2.06**	**69.0**	**18.5**
R345 (16.7-20.60)	**4.75**	**70.3**	**16.1**
R345 (33.70-36.10)	**2**	**81.2**	**8.1**
R345 (36.10-39.10)	**1.63**	**84.6**	**5.2**
Average	2.82	**69.6**	13.6
Min	**1.63**	51.5	**5.2**
Max	**4.82**	84.6	**35.3**

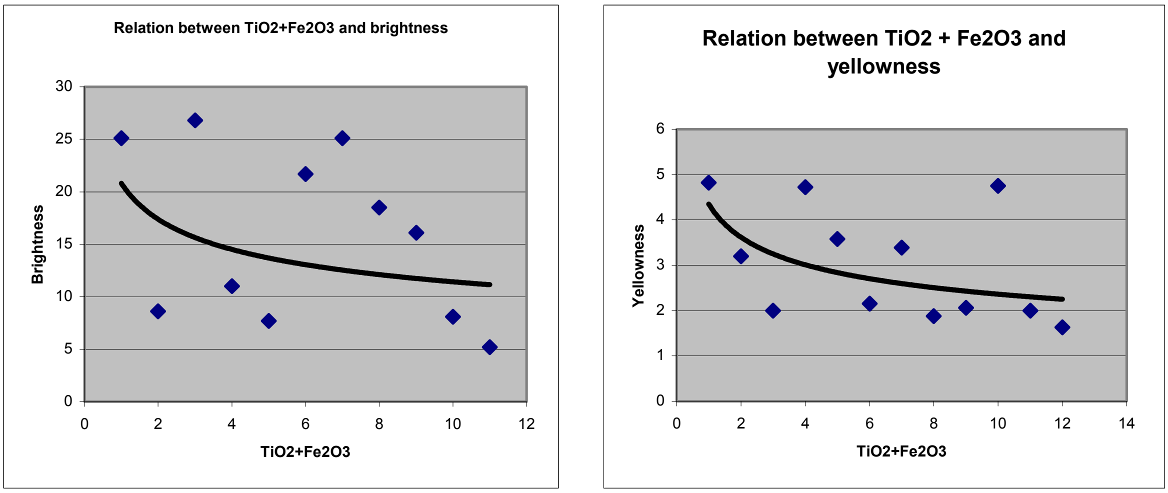


Figure 15. Relation between TiO_2+Fe_2O_3 and brightness and yellowish of <20 μm fractions

5. CONCLUSIONS

1. The Vittajänkä kaolins greatly depend on the mineralogy of the parent rocks. The white kaolin is most likely formed from arkosic to sericitic quartzites and in places albitized rocks due to high concentration of Na_2O, for example in borehole R342. The kaolin deposits of Vittajänkä formed due to alteration of primary minerals such as feldspar and mica in parent rocks of the metasedimentary Matovaara Formation. On the other hand the high content of elements such as MgO, Fe_2O_3, and MnO in coloured kaolin samples indicates that the parent rocks of coloured kaolins are rich in mafic minerals, possibly originating from the tholeitic metabasalts of Tahkoselkä Formation underlying the Matovaara Formation.

2. The mineralogical and geochemical evidences, and particle size distribution along the kaolin profiles indicate that Vittajänkä kaolin was formed *in situ* by a chemical weathering process. The kaolinite content changes towards the depth, but it shows high content in the middle parts of the studied boreholes as shown in R336, R337, R338, and R339. This strongly suggests that they were formed in the region of high intensity leaching during stages of kaolinization.

3. The comparison of the chemical and physical tests of the samples from the Vittajänkä kaolin deposit with the typical specifications for kaolin filler and coating grades listed by Prasad et al. (1991) is shown in Table 6. It seems that some kaolin properties meets the requirement of paper industry, while others do not meet such requirements. Therefore it is suggested to utilize other process techniques for removing the impurities such as froth flotation in addition to conventional magnetic separation technique. It has been found that the magnetic separation does not remove all impurities from the Vittajänkä kaolin. According to Table 7 listed by Norrgan & Orlich (1988) showing the relative susceptibility of various ferro- and paramagnetic minerals, the magnetic separation was successful for removal of iron oxide impurities (strong susceptibility) from kaolin. However, the separation was not successful for removing of muscovite and free silica (weak susceptibility). In particular the froth flotation increases the brightness and decreases the yellowness to an appreciable degree.

4. By utilizing the flotation process, the mica and silica particles can be separated from the kaolinite and the purified concentrates are suitable starting materials for several commercial grades. This separation technique has been used in the processing of kaolin deposits at Cornwall in UK and Georgia in USA. For example titanium impurities has been removed and separated from kaolin at acidic pH levels. Micaceous impurities have been removed by forth flotation at alkaline pH levels in the presence of a collector such as the Phosphate ester (Yang, 1974).

5. The Vittajänkä kaolin is primary in origin. The separation of impurities from primary kaolins is more difficult than from secondary kaolins, as they contain a higher proportion of abrasive minerals (quartz and mica). For these reasons the studied kaolin material needs more physical purification (such as froth flotation) besides magnetic separation in order to reduce the content of impurities and thus increase the brightness of kaolin. As the standard magnetic separation tests at VTT Mineral Processing Laboratory did not produce brightness levels approved for paper pigment, it was decided to continue the test work at VTT Mineral Processing Laboratory aiming for flotation separation of excess silica, mica and iron/titanium oxides.

Table 6. Comparison of studied kaolin samples with specification of kaolins for coating and filler grades (after Prasad et al., 1991)

Properties			Coating	Filler	Examined Samples
					Final products
Mineral compounds (%)					
Kaolinit			93 - 99	95 - 90	**85 - 95**
Mica			7 - 10	5 - 10	**0 - 5**
Quartz			-	-	**5 - 25**
Other			Trace	3 - Trace	**Traces**
Chemical composition (%)					
SiO_2			45 - 47	46 - 48	**46.9 - 55.3**
Al_2O_3			37 - 38	37 - 38	**28.9 - 36.4**
Fe_2O_3			0.5 - 1.0	0.5 - 1.0	**0.83 - 2.36**
TiO_2			0.5 - 1.3	0.04 - 1.5	**0.20- 0.68**
LOI			13.9 - 14.3	12.3 - 13.7	
Physical properties					
Particle size					
Less than 10 μm			100	85 - 87	
Less than 2 μm			89 - 92	60 - 80	
Brightness (%)			90 – 92*	82 - 85	**74.0 - 84.1**
Viscosity (cps)			74	-	

* The typical brightness level of kaolin in Georgia and Cornwall varies between 87-90%

Table 7.

Relative attractability of various ferro and paramagnetic minerals (Norrgran and Orlich, 1988)

Mineral	Magnetic intensity (Gauss)	Attractability
Iron	500	Strong
Magnetite	1000	Strong
Pyrrhotite	1000	Strong
Franklinite	5000	Strong
Ilmenite	5000	Moderate
Chromite	5000	Moderate
Siderite	10,000	Moderate
Hematite	10,000	Moderate
Serpentine	10,000	Moderate
Olivine	10,000	Weak
Biotite	10,000	Weak
Bastinite	10,000	Weak
Garnet	10,000	Weak
Pyrolusite	15,000	Weak
Monazite	15,000	Weak
Goethite	15,000	Weak
Pyroxene	15,000	Feeble
Amphibole	18,000 and over	Feeble

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APPENDICES

APPENDIX 1	Processing tests of kaolin samples – a research report by VTT PROSESSIT, in Finnish. "Kaoliinimalminäytteiden prosessointikokeet". VTT Prosessit / Mineraalitekniikka, TUTKIMUSSELOSTUS NRO PRO5/4006/03. 5 s.
APPENDIX 2	Cumulative permeability percentages of raw kaolin samples.
APPENDIX 3	Mineralogical analysis (XRD) 3.1 Mineralogical composition of processed kaolin samples, <2 microns 3.2 Mineralogical composition of <20 microns fractions 3.3 Mineralogical composition of raw kaolin samples
APPENDIX 4	X-ray diffractograms of oriented clays from processed, <2 microns kaolin samples.
APPENDIX 5	Chemical analysis (XRF) 5.1 Chemical composition of processed kaolin samples, <2 microns 5.2 Chemical composition of <20 microns fractions 5.3 Chemical composition of raw kaolin samples
APPENDIX 6	Brightness and yellowness values of <20 microns kaolin samples

Appendix 1

Kaoliinimalminäytteiden prosessointikokeet

Tilaaja: Geologinen tutkimuskeskus

VTT PROSESSIT

Tilaaja	Geologinen tutkimuskeskus
Tilaus	R42/46/2003
Käsittelijät	Markku Klemetti
Tehtävä	Kaoliinimalminäytteiden prosessointikokeet

Outokumpu 3. huhtikuuta 2003

Ryhmäpäällikkö	Kauko Ingerttilä
Erikoistutkija	Markku Klemetti

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JAKELU	GTK VTT / arkisto

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1 JOHDANTO

VTT Prosessit / Mineraalitekniikassa suoritettiin helmi-huhtikuussa 2003 prosessointikokeita Geologisen tutkimuskeskuksen (GTK) Rovaniemen yksikön lähettämillä kaoliinimalminäytteillä.

Näytteille, joita oli yhteensä kymmenen, suoritettiin seuraavat osaprosessit :

1. Luokitus seulalla ja syklonilla
2. HGMS-puhdistus
3. Valkaisu
4. Vaaleusmittaukset

Lopulliset kaoliinirikasteet lähetettiin GTK:n Espoon yksikön tutkimuslaboratorioon jatkokokeita varten.

2 NÄYTTEET

Kokeisiin lähetetyt kaoliinimalminäytteet ja näytemäärät olivat seuraavat:

1	M52/4621/R336/20,50-30,30	5,20 kg
2	M52/4621/R337/18,00-24,90	4,80 kg
3	M52/4621/R337/25,70-33,80	4,70 kg
4	M52/4621/R338/26,80-41,10	4,75 kg
5	M52/4621/R339/27,65-35,60	4,70 kg
6	M52/4621/R340/28,20-36,60	4,90 kg
7	M52/4621/R341/17,50-25,35	4,80 kg
8	M52/4621/R343/15,95-25,80	5,35 kg
9	M52/4621/R346/28,60-37,10	4,75 kg
10	M52/4621/R350/14,60-27,70	5,15 kg

3 PROSESSOINTIKOKEET JA TULOKSET

Aluksi saapuneet näytteet kahtioitiin ja puolet näytteistä käytettiin ensivaiheessa prosessointikokeisiin. Toinen puoli säilytettiin mahdollisia täydennyskokeita varten.

3.1 Seulonta ja syklonointi

Syötenäytteet lietettin veteen ja seulottiin märkänä Sweco-täryseulalla, jossa seulaverkon aukkokoko oli 30 µm. Seulan ylitteet suodatettiin ja kuivattiin, ja alitteet syklonoitiin AKW:n 10 mm:n syklonilla, jossa yliteaukon halkaisija oli 1,5 mm ja aliteaukon halkaisija 3,0 mm. Ylitteet kerrattiin samoin parametrein. Syklonipumppuna oli Ahström LPSN-32 pystykeskipakopumppu ja ajopaine oli 2,0 bar. Lietetiheys syklonoinnin alussa oli noin 10 % ja lietteeseen lisättiin dispergantiksi Na-heksametafosfaattia 500 g/t.

Luokituksen massataseet on esitetty taulukossa 1 ja prosessointikaavio kuvassa 1.

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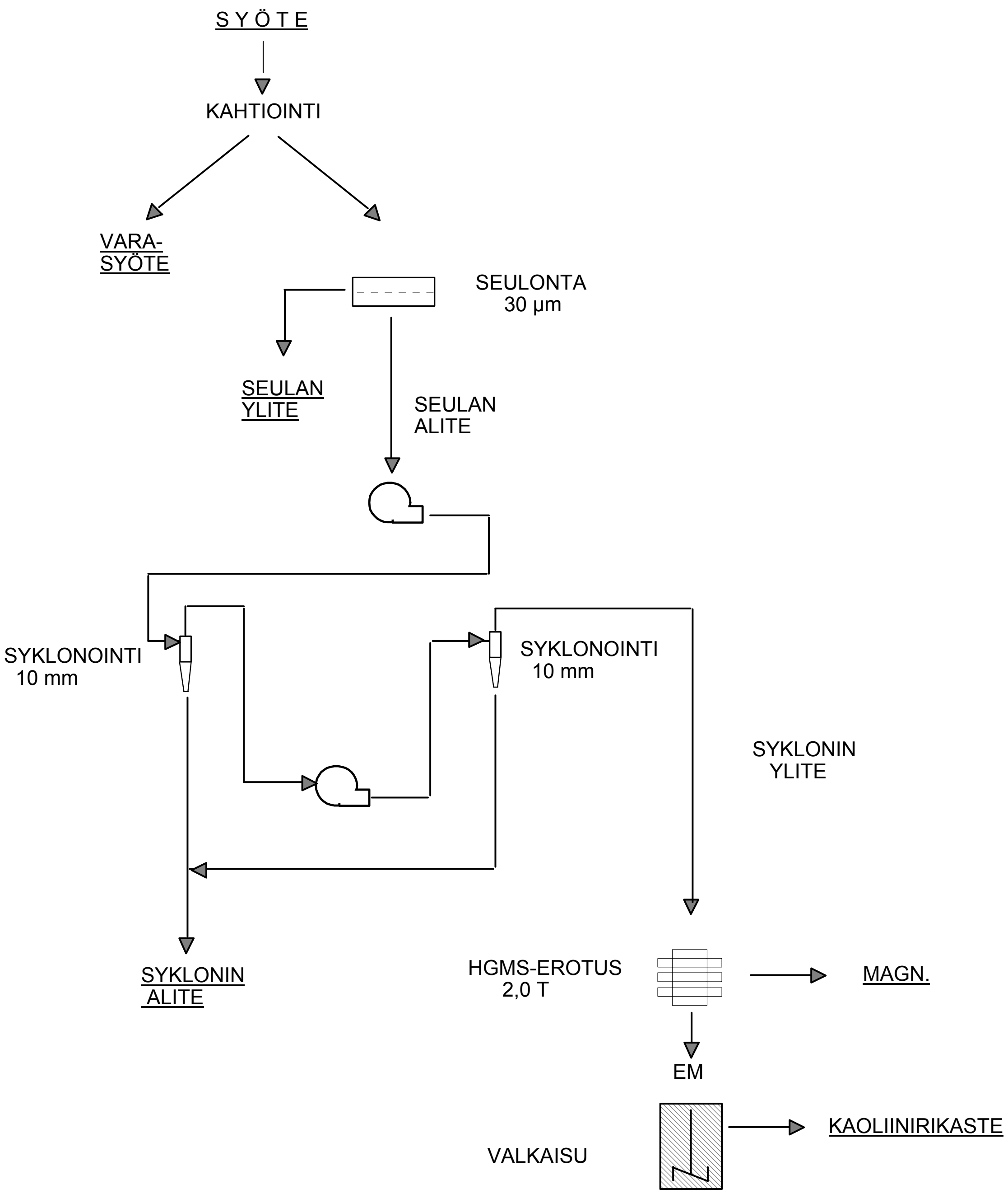

Kuva 1. Kaoliinimalminäytteiden prosessointikaavio.

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3.2 HGMS-puhdistus

Luokituksen hienotuotteille, syklonin ylitteille, tehtiin seuraavaksi vahvamagneettinen puhdistus Salan HGMS (High Gradient Magnetic Separation) -erottimella.

HGMS-erotuksessa käytetty matriiisi oli teräsvillamatriisi 3.5 WC ja magneettinen kenttävoimakkuus erotuksessa oli laitteen maksimi 2,0 teslaa (T). Lietetiheys erotuksessa oli noin 5 %.

HGMS-ajossa matriisissa virtausnopeus oli 0,4 l/s, syklien määrä kolme, syöttöaika 8 s, sekä matriisin huuhteluaika 7 s.

HGMS-erotuksen tuotteet olivat magneettinen fraktio ja ei-magneettinen, puhdistettu fraktio. Massajakaumat HGMS-erotuksessa on esitetty taulukossa 1.

Taulukko 1. Prosessointikokeiden massajakaumat

Näyte	Syöte g	Seulan ylite µm g	Seulan alite µm g	Syklonin alite Sa g	Syklonin ylite Sy g	Syklonin ylite Sy p-%	HGMS Ei-magn. g	HGMS Magn. g
R336/20,50-30,20	2499,3	1444,3	1055,0	820,6	234,4	9,4	119,1	115,3
R337/18,00-24,90	2450,0	1527,5	922,5	725,1	197,4	8,1	128,6	68,8
R337/25,70-33,80	2340,0	1468,8	871,2	670,8	200,4	8,6	131,7	68,7
R338/26,80-40,10	2329,3	1221,2	1108,1	908,1	200,0	8,6	91,5	108,5
R339/27,65-35,60	2340,0	1208,8	1131,2	889,4	241,8	10,3	120,2	121,6
R340/28,20-36,60	2363,9	1401,8	962,1	814,4	147,7	6,2	64,2	83,5
R341/17,50-25,35	2360,0	1302,3	1057,7	862,2	195,5	8,3	124,1	71,4
R343/15,95-25,80	2430,0	1549,0	881,0	729,9	151,1	6,2	88,0	63,1
R346/28,60-37,10	2340,0	632,2	1707,8	1312,8	395,0	16,9	356,6	38,4
R350/14,60-27,70	2590,0	1508,4	1081,6	919,0	162,6	6,3	82,7	79,9

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3.3 Valkaisu ja vaaleusmittaukset

HGMS-erotuksella puhdistetuille kaoliinirikasteille suoritettiin prosessointikokeiden lopuksi valkaisu natriumditioniitilla. Na-ditioniittipitoisuus valkaisulietteessä oli 0,75 % ja pH, joka säädettiin rikkihapolla, oli 4,0. Lietetiheys oli 22 % ka. ja reaktioaika oli 20 min.

Valkaistut tuotteet suodatettiin, kuivattiin ja niistä mitattiin ISOR457-vaaleus Elerepho 2000-vaaleusmittarilla.

Taulukossa 2 on esitetty lopullisten kaoliinirikasteiden vaaleusmittaustulokset ja valkaisun rikkihappokulutukset (laskettu valkaisusyötettä kohti) kunkin näytteen osalta.

Rikasteet toimitettiin GTK:n Espoon yksikköön jatkokokeita varten.

Taulukko 2. Valkaisukokeiden tulokset

Näyte	Vaaleus ISOR457	Keltaisuus R570-R457	Rikkihappo-kulutus kg/t	Rikasteen määrä %
R336/20,50-30,20	79,6	4,8	4,2	4,8
R337/18,00-24,90	84,1	4,3	3,0	5,2
R337/25,70-33,80	82,2	5,1	4,1	5,6
R338/26,80-40,10	81,5	4,2	3,3	3,9
R339/27,65-35,60	83,8	3,5	3,6	5,1
R340/28,20-36,60	79,9	4,7	5,0	2,7
R341/17,50-25,35	74,0	9,6	5,3	5,3
R343/15,95-25,80	75,4	9,4	6,4	3,6
R346/28,60-37,10	74,8	7,2	4,6	15,2
R350/14,60-27,70	80,1	5,9	3,4	3,2

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Appendix 2. Cumulative permeability percentages of raw kaolin samples.

	Cumulative permeability percentage				
	2 µm	6 µm	20 µm	60 µm	200 µm
Sample	%	%	%	%	%
R 335 (16,40 – 20,70)	16.1	29.8	57.4	70	98.3
R 335 (20,70 – 23,55)	17.8	32.1	54.7	63.6	96.1
R 335 (23,55 – 25,25)	15.6	26.2	43.4	52.9	98.8
R 335 (25,25 – 30,10)	17.4	31.1	61.8	72.3	96.5
R 335 (30,70 – 33,80)	16.2	32.1	63.4	75.5	97.3
R 335 (33,80 – 35,00)	18.6	30.7	56.5	68.9	98.9
R 336 (16,00 – 20,50)	15.5	30.4	58	67.5	98.8
R 336 (20,50 – 25,10)	18.1	31.8	55.7	64.8	99.2
R 336 (25,10 – 30,20)	13.5	25.2	49.6	57.3	95.8
R 336 (30,20 – 35,20)	12.4	25.8	60.4	70.7	98.7
R 337 (15,50 – 18,00)	16.5	31.2	60	68.6	98.5
R 337 (18,00 – 23,10)	13.6	26.8	42.4	49.6	98.4
R 337 (23,10 – 28,15)	13.6	26.6	42.9	50.2	97.2
R 337 (28,15 – 33,80)	16.3	29.6	45.1	53.4	98
R 337 (33,80 – 36,30)	11.3	22.5	40.2	49	97.4
R 337 (36,30 – 40,00)	14.6	29.2	52.1	59.6	97.4
R 338 (19,85 – 21,80)	14.1	24.6	40.3	46.9	94.6
R 338 (21,80 – 26,80)	15.1	30.1	59.3	68.5	97.3
R 338 (26,80 – 31,10)	16.1	29.3	56.9	65.8	98.6
R 338 (31,10 – 35,10)	16	29.5	57	65.5	99.3
R 338 (35,10 – 40,10)	16.2	29.6	56.9	67.3	97.3
R 339 (19,40 – 23,60)	14.8	27.6	53.9	64.2	95
R 339 (23,60 – 27,65)	14.6	26.4	53.3	62	94.6
R 339 (27,65 – 31,65)	18.4	33	59.8	68	99.3
R 339 (31,65 – 35,60)	17.2	31.7	59.9	68.9	99.6
R 339 (35,60 – 40,50)	14.1	27.5	56.7	65.5	98.2
R 340 (18,90 – 24,10)	18.4	32.6	59.6	70.9	99
R 340 (24,10 – 28,20)	12	21.3	45.9	56	86.2
R 340 (28,20 – 31,60)	15.3	28.6	58.7	68.2	98.3
R 340 (31,60 – 36,60)	10.8	19.8	44.5	52.7	93.6
R 340 (36,60 – 40,60)	9.3	16.8	40.9	48.7	75.8
R 340 (40,60 – 44,60)	14.7	25.7	51.1	59.8	94.6
R 340 (44,60 – 50,60)	11.7	20.2	44.7	53.2	90.7

Appendix 2 continued

	Cumulative permeability percentage				
	2 µm	6 µm	20 µm	60 µm	200 µm
Sample	**%**	**%**	**%**	**%**	**%**
R 341 (17,50 – 21,60)	14.4	24	45.7	56.4	86.8
R 341 (21,60 – 25,35)	16.9	28	51.1	61.6	97
R 341 (25,35 – 29,80)	18.5	31.5	58.6	68.5	97.8
R 341 (29,80 – 35,60)	17.8	31.6	55.4	65.9	99.3
R 342 (35,60 – 41,60)	19.8	30.7	43.2	55.8	81
R 341 (41,60 – 48,60)	25.7	37.4	50.6	61.3	83.8
R 341 (48,60 – 52,60)	18.7	35.2	55.9	64.6	97.3
R 342 (19,60 – 21,95)	22.7	31.7	60.3	85.6	98.6
R 342 (21,95 – 26,60)	16.4	21.3	48	76.2	91.9
R 342 (26,60 – 32,50)	16.7	23.1	48.8	75.7	93.4
R 342 (34,10 – 40,10)	21.1	36.9	73	87.9	98
R 343 (15,95 – 18,70)	13.1	21.3	39.2	50.2	79
R 343 (22,10 – 25,80)	12.1	20.8	41.5	53.9	84.3
R 343 (26,30 – 29,20)	11.2	19.4	39	51	88.1
R 343 (29,20 – 32,30)	13.7	23.4	45.9	57	95.4
R 343 (32,30 – 35,60)	16.3	27	50.7	61.4	94.1
R 343 (35,60 – 38,10)	13.1	20.6	38.3	48.5	85.6
R 344 (15,75 – 18,10)	9.7	16.8	29.5	37.3	72.3
R 344 (18,10 – 21,10)	10.8	21.2	42	51.2	94
R 344 (21,10 – 24,60)	10.3	18.3	37.3	48.1	86.8
R 344 (25,60 – 28,70)	14.1	25.2	43.7	51.4	81.1
R 344 (28,70 – 32,00)	13.7	23.5	39.1	47.1	76.6
R 344 (32,00 – 35,30)	8.7	14.8	27.7	35.7	60.2
R 345 (13,60 – 16,20)	12.9	28.3	56	62.9	97.7
R 345 (16,70 – 20,60)	11.5	22.7	51.2	62.1	95.7
R 345 (20,60 – 24,00)	12.7	25.1	54.7	63.6	97.7
R 345 (24,00 – 25,35)	14.7	33.5	65.5	73.6	99.2
R 345 (31,10 – 33,00)	13.9	28.1	49	55.7	99
R 345 (33,00 – 33,70)	14.9	30.3	49	55.1	98.7
R 345 (33,70 – 36,10)	12.3	23.3	42.8	51.2	96.9
R 345 (36,10 – 39,10)	9.4	16.8	31.3	40.1	95.2

Appendix 2 continued

	Cumulative permeability percentage				
	2 µm	6 µm	20 µm	60 µm	200 µm
Sample	%	%	%	%	%
R 346 (17,15 – 20,25)	18.6	32.6	57.5	77.7	95.6
R 346 (24,40 – 28,60)	22.7	38.2	69.8	88.9	96.9
R 346 (28,60 – 33,10)	19	34.5	64.7	86.3	94.5
R 346 (33,10 – 37,10)	22	38.1	65.2	78.6	89.6
R 346 (37,10 – 41,60)	22.8	40.5	70.1	91.1	98.5
R 346 (41,60 – 46,60)	20.1	36.1	56.2	70.7	95.1
R 346 (46,60 – 50,60)	17.3	31	56	66.7	99.2
R 347 (16,60 – 20,90)	12.4	20.8	35	49.6	88.1
R 347 (20,90 – 25,10)	15.7	25.1	38.7	52.3	94.5
R 347 (27,10 – 31,00)	16.3	25.9	38.4	50.8	96.7
R 347 (31,00 – 34,10)	22.2	31.7	42.7	54.7	96
R 347 (34,10 – 38,80)	19	28.5	46.9	67.9	95.2
R 347 (38,80 – 42,80)	17.1	28.4	49.9	72.8	95.5
R 347 (42,80 – 46,60)	16.3	28.6	50.7	72.4	98.3
R 347 (46,60 – 50,00)	14.8	25.5	40.3	60.6	97.7
R 348 (19,00 – 23,70)	13.1	17.4	32.9	54.4	94.8
R 348 (23,70 – 26,80)	11.8	15.3	28.1	50.1	96
R 348 (26,80 – 30,80)	12.3	16.4	29.8	54.7	93.8
R 348 (30,80 – 35,30)	12.2	15.8	28.2	55.3	95.3
R 348 (35,30 – 40,00)	18.6	26.6	36.9	44.7	80.6
R 349 (15,30 – 18,60)	15	21.6	46.6	69.6	96.1
R 349 (18,60 – 21,10)	15	22.4	48.2	69.9	95.2
R 350 (14,60 – 19,60)	11.7	20.2	40.2	49.9	76.6
R 350 (19,60 – 23,20)	10.8	19.8	40.4	49	81
R 350 (23,20 – 27,70)	12.3	22.2	44.9	54.8	86.5
R 350 (27,70 – 32,10)	13.5	24.1	48.1	58.7	91.2
R 350 (32,10 – 36,80)	15.1	25.9	48.2	60.2	94.1
R 350 (36,80 – 41,30)	14.1	22.7	46.6	57.5	90.4
R 350 (41,30 – 44,80)	17.2	29.3	58.9	73.2	95.3
R 351 (13,70 – 17,10)	14.5	25.9	47	60.3	93.4
R 351 (17,10 – 20,20)	13.1	21.4	42.5	53.4	88.7
R 351 (20,20 – 23,20)	15.2	25.7	48.4	59.7	91.9

Appendix 3.1. Mineralogical composition of processed kaolin samples, <2 microns

Sample	Quartz	Muscovite	Kaolinite	Talc	Hematite	
R 336 / 20,50 - 30,20 / **LT**	10	<5	85	0	0	
R 336 / 20,50 - 30,20 / **M**	5	35	60	0	0	
R 336 / 20,50 - 30,20 / **SA**	20	25	55	0	0	
R 337 / 18,00 - 24,90 / **LT**	<5	<5	95	0	0	
R 337 / 18,00 - 24,90 / **M**	<5	10	90	0	0	
R 337 / 18,00 - 24,90 / **SA**	5	5	90	0	0	
R 337 / 25,70 - 33,80 / **LT**	5	<5	95	0	0	
R 337 / 25,70 - 33,80 / **M**	0	15	85	0	0	
R 337 / 25,70 - 33,80 / **SA**	10	5	85	0	0	
R 338 / 26,80 - 40,10 / **LT**	5	5	90	0	0	
R 338 / 26,80 - 40,10 / **M**	0	30	65	0	5	
R 338 / 26,80 - 40,10 / **SA**	10	20	70	0	0	
R 339 / 27,65 - 35,60 / **LT**	5	5	90	0	0	
R 339 / 27,65 - 35,60 / **M**	0	30	70	0	0	
R 339 / 27,65 - 35,60 / **SA**	10	25	65	0	0	
R 340 / 28,20 - 36,60 / **LT**	<5	<5	95	0	0	
R 340 / 28,20 - 36,60 / **M**	0	30	70	0	0	
R 340 / 28,20 - 36,60 / **SA**	5	30	65	0	0	
R 341 / 17,50 - 25,35 / **LT**	<5	<5	95	0	0	
R 341 / 17,50 - 25,35 / **M**	0	20	80	0	<5	
R 341 / 17,50 - 25,35 / **SA**	10	15	75	0	0	
R 343 / 15,95 - 25,80 / **LT**	25	<5	70	0	0	
R 343 / 15,95 - 25,80 / **M**	0	35	65	0	0	
R 343 / 15,95 - 25,80 / **SA**	30	20	50	0	0	
R 346 / 28,60 - 37,10 / **LT**	<5	0	95	<5	0	Contains ruti
R 346 / 28,60 - 37,10 / **M**	0	<5	35	<5	60	Contains ruti
R 346 / 28,60 - 37,10 / **SA**	5	<5	65	<5	30	Contains ruti
R 350 / 14,60 - 27,70 / **LT**	5	<5	95	0	0	
R 350 / 14,60 - 27,70 / **M**	0	20	80	0	0	
R 350 / 14,60 - 27,70 / **SA**	10	20	70	0	0	

LT (lopputuote) = Final product - Cycloned, magnetically separated and bleached
M = Magnetic fraction
SA (syklonin alite) = <2 micron fraction after cycloning

Appendix 3.2. Mineralogical composition of <20 microns fractions.

Sample	qtz	plag	kfsp	musc	kaol	smec	talc	hemat	chl	Tot.
R 335 (16,40 – 20,70)	25	20	0	40	20	0	0	0	0	100
R 335 (20,70 – 23,55)	10	10	0	15	65	0	0	0	0	100
R 335 (23,55 – 25,25)	10	5	0	5	80	0	0	0	0	100
R 335 (25,25 – 30,10)	35	25	0	25	15	0	0	0	0	100
R 335 (30,70 – 33,80)	15	15	0	35	35	0	0	0	0	100
R 335 (33,80 – 35,00)	20	10	0	15	55	0	0	0	0	100
R 336 (16,00 – 20,50)	15	15	0	20	45	0	0	0	0	100
R 336 (20,50 – 25,10)	15	10	0	10	60	0	0	0	0	100
R 336 (25,10 – 30,20)	10	15	0	15	60	0	0	0	0	100
R 336 (30,20 – 35,20)	15	15	0	40	35	0	0	0	0	100
R 337 (15,50 – 18,00)	25	25	0	25	30	0	0	0	0	100
R 337 (18,00 – 23,10)	5	<5	0	<5	90	0	0	0	0	100
R 337 (23,10 – 28,15)	5	5	0	5	85	0	0	0	0	100
R 337 (28,15 – 33,80)	5	5	0	5	85	0	0	0	0	100
R 337 (33,80 – 36,30)	5	<5	0	5	85	0	0	0	0	100
R 337 (36,30 – 40,00)	5	5	0	<5	85	0	0	0	0	100
R 338 (19,85 – 21,80)	10	5	0	10	75	0	0	0	0	100
R 338 (21,80 – 26,80)	15	10	0	35	35	0	0	5	0	100
R 338 (26,80 – 31,10)	5	15	0	10	70	0	0	0	0	100
R 338 (31,10 – 35,10)	5	10	0	10	75	0	0	0	0	100
R 338 (35,10 – 40,10)	5	10	0	10	75	0	0	0	0	100
R 339 (19,40 – 23,60)	5	10	0	20	65	0	0	0	0	100
R 339 (23,60 – 27,65)	5	10	0	20	65	0	0	0	0	100
R 339 (27,65 – 31,65)	5	10	0	10	75	0	0	0	0	100
R 339 (31,65 – 35,60)	10	10	0	15	65	0	0	0	0	100
R 339 (35,60 – 40,50)	5	20	0	10	65	0	0	0	0	100
R 340 (18,90 – 24,10)	5	10	0	10	75	0	0	0	0	100
R 340 (24,10 – 28,20)	5	10	0	25	60	0	0	0	0	100
R 340 (28,20 – 31,60)	<5	10	0	15	75	0	0	0	0	100
R 340 (31,60 – 36,60)	<5	10	0	20	70	0	0	0	0	100
R 340 (36,60 – 40,60)	<5	10	0	10	75	0	0	0	0	100
R 340 (40,60 – 44,60)	<5	5	0	15	75	0	0	0	0	100
R 340 (44,60 – 50,60)	<5	5	0	25	65	0	0	0	0	100
R 341 (17,50 – 21,60)	<5	30	0	10	55	0	0	0	0	100
R 341 (21,60 – 25,35)	5	5	0	5	85	0	0	0	0	100
R 341 (25,35 – 29,80)	5	5	0	10	80	0	0	0	0	100
R 341 (29,80 – 35,60)	<5	5	0	5	85	0	0	0	0	100
R 342 (35,60 – 41,60)	5	<5	0	<5	90	0	0	0	0	100
R 341 (41,60 – 48,60)	0	<5	0	<5	95	0	0	0	0	100
R 341 (48,60 – 52,60)	10	5	0	5	80	0	0	0	0	100
R 342 (19,60 – 21,95)	5	45	0	0	25	10	0	10	0	100
R 342 (21,95 – 26,60)	<5	55	0	0	30	0	0	10	0	100
R 342 (26,60 – 32,50)	5	50	0	0	20	5	0	20	0	100
R 342 (34,10 – 40,10)	5	20	0	<5	15	25	0	35	0	100
R 343 (15,95 – 18,70)	30	15	0	10	45	0	0	0	0	100
R 343 (22,10 – 25,80)	25	15	0	15	45	0	0	0	0	100
R 343 (26,30 – 29,20)	20	15	0	15	50	0	0	0	0	100
R 343 (29,20 – 32,30)	25	20	0	10	45	0	0	0	0	100
R 343 (32,30 – 35,60)	30	25	0	10	35	0	0	0	0	100
R 343 (35,60 – 38,10)	45	15	0	10	30	0	0	0	0	100
R 344 (15,75 – 18,10)	10	10	0	5	75	0	0	0	0	100
R 344 (18,10 – 21,10)	5	10	0	10	75	0	0	0	0	100
R 344 (21,10 – 24,60)	15	15	0	10	60	0	0	0	0	100
R 344 (25,60 – 28,70)	20	10	0	10	60	0	0	0	0	100
R 344 (28,70 – 32,00)	20	10	0	5	65	0	0	0	0	100
R 344 (32,00 – 35,30)	40	10	0	5	45	0	0	0	0	100

Appendix 3.2 continued

Sample	qtz	plag	kfsp	musc	kaol	smec	talc	hemat	chl	Tot.
R 345 (13,60 – 16,20)	10	10	0	15	55	0	0	10	0	100
R 345 (16,70 – 20,60)	15	20	0	50	15	0	0	0	0	100
R 345 (20,60 – 24,00)	20	20	0	40	20	0	0	0	0	100
R 345 (24,00 – 25,35)	15	25	0	30	30	0	0	0	0	100
R 345 (31,10 – 33,00)	<5	<5	0	5	90	0	0	0	0	100
R 345 (33,00 – 33,70)	<5	<5	0	10	85	0	0	0	0	100
R 345 (33,70 – 36,10)	10	5	0	10	75	0	0	0	0	100
R 345 (36,10 – 39,10)	20	5	0	10	65	0	0	0	0	100
R 346 (17,15 – 20,25)	<5	0	<5	0	90	0	<5	<5	0	100
R 346 (24,40 – 28,60)	5	0	<5	0	80	0	<5	10	0	100
R 346 (28,60 – 33,10)	5	0	<5	0	90	0	<5	5	0	100
R 346 (33,10 – 37,10)	<5	0	<5	0	90	0	<5	5	0	100
R 346 (37,10 – 41,60)	5	0	<5	0	85	0	<5	10	0	100
R 346 (41,60 – 46,60)	<5	<5	<5	<5	90	0	0	<5	0	100
R 346 (46,60 – 50,60)	5	<5	0	10	85	0	0	0	0	100
R 347 (16,60 – 20,90)	5	<5	5	0	80	0	0	5	0	100
R 347 (20,90 – 25,10)	5	<5	0	<5	90	0	0	<5	0	100
R 347 (27,10 – 31,00)	<5	<5	0	5	90	0	0	<5	0	100
R 347 (31,00 – 34,10)	<5	0	0	5	90	0	0	5	0	100
R 347 (34,10 – 38,80)	5	0	0	<5	85	0	0	10	0	100
R 347 (38,80 – 42,80)	5	<5	0	5	75	0	0	15	0	100
R 347 (42,80 – 46,60)	5	10	0	10	55	0	0	15	<5	100
R 347 (46,60 – 50,00)	15	15	0	10	50	0	0	10	<5	100
R 348 (19,00 – 23,70)	10	40	0	0	15	20	<5	15	0	100
R 348 (23,70 – 26,80)	10	30	0	0	20	25	<5	10	0	100
R 348 (26,80 – 30,80)	10	30	0	0	35	10	5	<5	0	100
R 348 (30,80 – 35,30)	15	25	0	0	55	0	<5	0	0	100
R 348 (35,30 – 40,00)	5	<5	0	0	45	30	<5	10	0	100
R 349 (15,30 – 18,60)	10	35	0	0	5	30	5	15	0	100
R 349 (18,60 – 21,10)	15	20	0	0	10	45	15	0	0	100
R 350 (14,60 – 19,60)	5	5	0	10	80	0	0	0	0	100
R 350 (19,60 – 23,20)	<5	5	0	10	85	0	0	0	0	100
R 350 (23,20 – 27,70)	5	5	0	5	80	0	0	0	0	100
R 350 (27,70 – 32,10)	10	5	0	10	75	0	0	0	0	100
R 350 (32,10 – 36,80)	10	5	<5	10	75	0	0	0	0	100
R 350 (36,80 – 41,30)	5	5	<5	10	75	0	0	<5	0	100
R 350 (41,30 – 44,80)	10	10	0	5	55	0	0	20	0	100
R 351 (13,70 – 17,10)	<5	<5	0	5	85	0	0	<5	0	100
R 351 (17,10 – 20,20)	10	10	0	15	65	0	0	<5	0	100
R 351 (20,20 – 23,20)	10	5	0	5	70	0	0	5	0	100

Appendix 3.3. Mineralogical composition of raw kaolin samples

SAMPLE	qtz	plag	musc	kaol	chlor	talc	hemat	smec	amphib	kfsp	calc	pyrox	Tot
R 335 (16,40 – 20,70)	70	15	10	0	0	0	0	0	0	0	0	0	100
R 335 (20,70 – 23,55)	60	10	5	30	0	0	0	0	0	0	0	0	100
R 335 (23,55 - 25,25)	60	<5	<5	30	0	0	0	0	0	0	0	0	100
R 335 (25,25 – 30,10)	70	15	15	0	0	0	0	0	0	0	0	0	100
R 335 (30,70 – 33,80)	50	10	20	15	0	0	0	0	0	0	0	0	100
R 335 (33,80 – 35,00)	65	10	5	20	0	0	0	0	0	0	0	0	100
R 336 (16,00 – 20,50)	55	10	15	20	0	0	0	0	0	0	0	0	100
R 336 (20,50 – 25,10)	60	10	5	25	0	0	0	0	0	0	0	0	100
R 336 (25,10 – 30,20)	50	5	10	30	0	0	0	0	0	0	0	0	100
R 336 (30,20 – 35,20)	55	10	20	15	0	0	0	0	0	0	0	0	100
R 337 (15,50 – 18,00)	60	10	15	15	0	0	0	0	0	0	0	0	100
R 337 (18,00 – 23,10)	50	<5	<5	45	0	0	0	0	0	0	0	0	100
R 337 (23,10 – 28,15)	45	<5	<5	50	0	0	0	0	0	0	0	0	100
R 337 (28,15 – 33,80)	50	<5	<5	45	0	0	0	0	0	0	0	0	100
R 337 (33,80 – 36,30)	55	<5	<5	40	0	0	0	0	0	0	0	0	100
R 337 (36,30 – 40,00)	45	5	5	45	0	0	0	0	0	0	0	0	100
R 338 (19,85 – 21,80)	65	<5	<5	30	0	0	0	0	0	0	0	0	100
R 338 (21,80 – 26,80)	55	10	15	15	0	0	0	0	0	0	0	0	100
R 338 (26,80 – 31,10)	45	5	10	40	0	0	0	0	0	0	0	0	100
R 338 (31,10 – 35,10)	45	<5	10	45	0	0	0	0	0	0	0	0	100
R 338 (35,10 – 40,10)	40	5	10	45	0	0	0	0	0	0	0	0	100
R 339 (19,40 – 23,60)	50	10	15	30	0	0	0	0	0	0	0	0	100
R 339 (23,60 – 27,65)	50	5	15	30	0	0	0	0	0	0	0	0	100
R 339 (27,65 – 31,65)	40	5	10	45	0	0	0	0	0	0	0	0	100
R 339 (31,65 – 35,60)	40	5	10	40	0	0	0	0	0	0	0	0	100
R 339 (35,60 – 40,50)	40	5	10	40	0	0	0	0	0	0	0	0	100
R 340 (18,90 – 24,10)	40	5	10	45	0	0	0	0	0	0	0	0	100
R 340 (24,10 – 28,20)	50	10	15	25	0	0	0	0	0	0	0	0	100
R 340 (28,20 – 31,60)	35	10	10	45	0	0	0	0	0	0	0	0	100
R 340 (31,60 – 36,60)	50	10	15	25	0	0	0	0	0	0	0	0	100
R 340 (36,60 – 40,60)	40	5	10	40	0	0	0	0	0	0	0	0	100
R 340 (40,60 – 44,60)	55	5	15	25	0	0	0	0	0	0	0	0	100
R 340 (44,60 – 50,60)	60	5	15	20	0	0	0	0	0	0	0	0	100

Appendix 3.3 continued

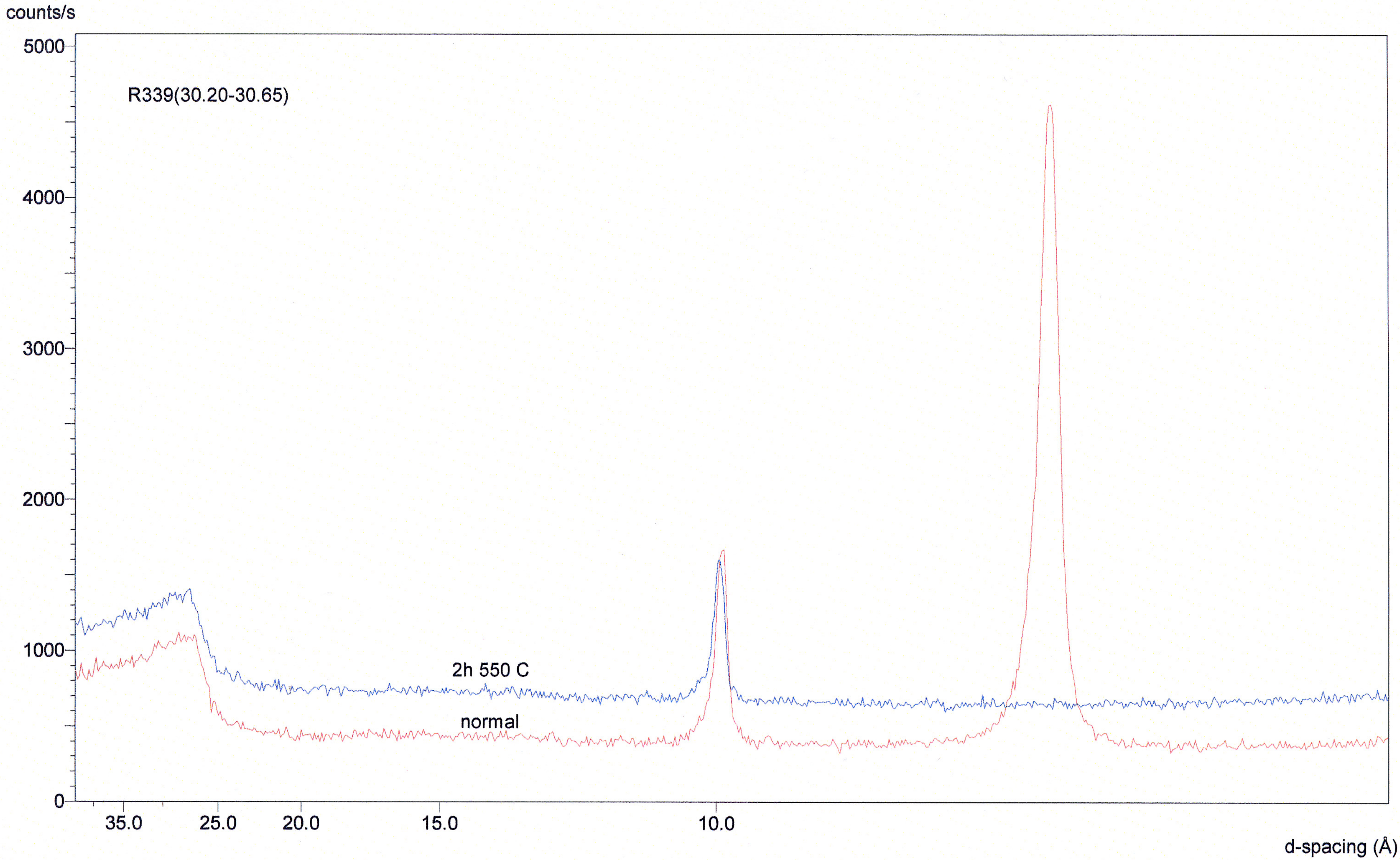
SAMPLE	qtz	plag	musc	kaol	chlor	talc	hemat	smec	amphib	kfsp	calc	pyrox	Tot
R 341 (17,50 – 21,60)	55	<5	10	30	0	0	0	0	0	0	0	0	100
R 341 (21,60 – 25,35)	40	5	5	45	0	0	0	0	0	0	0	0	100
R 341 (25,35 – 29,80)	40	5	5	45	0	0	0	0	0	0	0	0	100
R 341 (29,80 – 35,60)	35	<5	5	55	0	0	0	0	0	0	0	0	100
R 342 (35,60 – 41,60)	45	<5	<5	50	0	0	0	0	0	0	0	0	100
R 341 (41,60 – 48,60)	25	0	<5	70	0	<5	0	0	0	0	0	0	100
R 341 (48,60 – 52,60)	45	<5	<5	50	0	0	0	0	0	0	0	0	100
R 342 (19,60 – 21,95)	20	45	0	15	<5	0	0	20	0	0	0	0	100
R 342 (21,95 – 26,60)	<5	45	0	0	0	0	55	0	0	0	0	0	100
R 342 (26,60 – 32,50)	10	30	0	15	0	0	30	15	0	0	0	0	100
R 342 (34,10 – 40,10)	20	25	<5	10	0	0	30	10	0	0	0	0	100
R 343 (15,95 – 18,70)	70	<5	<5	20	0	0	0	0	0	0	0	0	100
R 343 (22,10 – 25,80)	70	10	10	10	0	0	0	0	0	0	0	0	100
R 343 (26,30 – 29,20)	70	5	10	15	0	0	0	0	0	0	0	0	100
R 343 (29,20 – 32,30)	65	10	10	15	0	0	0	0	0	0	0	0	100
R 343 (32,30 – 35,60)	75	5	5	10	0	0	0	0	0	0	0	0	100
R 343 (35,60 – 38,10)	85	<5	<5	5	0	0	0	0	0	0	0	0	100
R 344 (15,75 – 18,10)	70	<5	<5	20	0	0	0	0	0	0	0	0	100
R 344 (18,10 – 21,10)	60	5	<5	30	0	0	0	0	0	0	0	0	100
R 344 (21,10 – 24,60)	80	5	<5	10	0	0	0	0	0	0	0	0	100
R 344 (25,60 – 28,70)	70	5	5	20	0	0	0	0	0	0	0	0	100
R 344 (28,70 – 32,00)	75	5	<5	15	0	0	0	0	0	0	0	0	100
R 344 (32,00 – 35,30)	85	<5	<5	10	0	0	0	0	0	0	0	0	100
R 345 (13,60 – 16,20)	50	10	15	20	0	0	10	0	0	0	0	0	100
R 345 (16,70 – 20,60)	65	10	20	5	0	0	0	0	0	0	0	0	100
R 345 (20,60 – 24,00)	40	40	15	5	0	0	0	0	0	0	0	0	100
R 345 (24,00 – 25,35)	50	15	20	15	0	0	0	0	0	5	0	0	100
R 345 (31,10 – 33,00)	45	<5	<5	45	0	0	0	0	0	0	0	0	100
R 345 (33,00 – 33,70)	45	<5	<5	45	0	0	0	0	0	0	0	0	100
R 345 (33,70 – 36,10)	60	5	5	30	0	0	0	0	0	0	0	0	100
R 345 (36,10 – 39,10)	80	<5	<5	15	0	0	0	0	0	0	0	0	100
R 346 (17,15 – 20,25)	10	<5	<5	70	0	<5	15	0	0	<5	0	0	100
R 346 (24,40 – 28,60)	<5	0	0	80	0	<5	15	0	0	<5	0	0	100
R 346 (28,60 – 33,10)	5	0	0	70	0	<5	20	0	0	<5	0	0	100
R 346 (33,10 – 37,10)	5	0	0	70	0	<5	20	0	0	<5	0	0	100

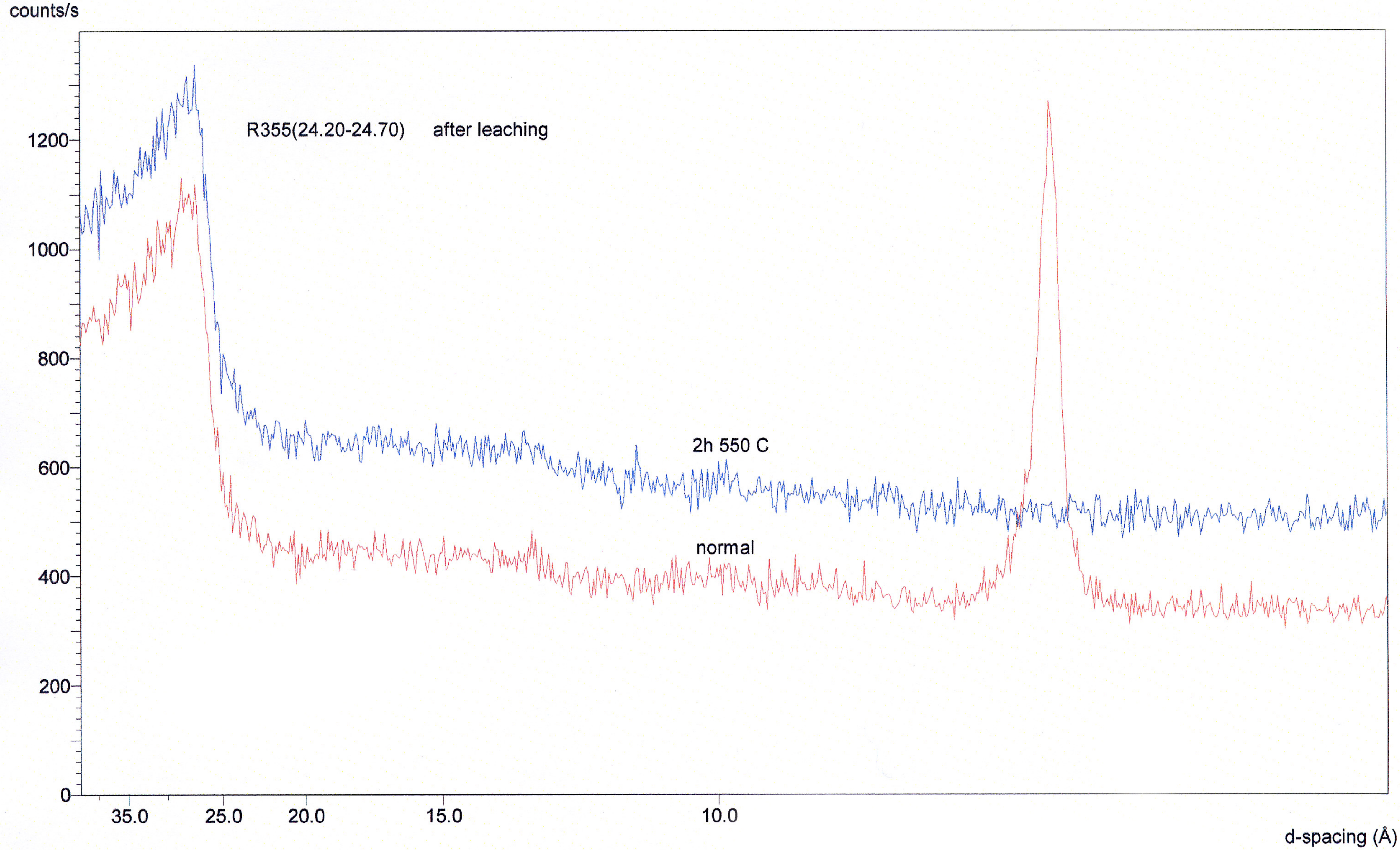
Appendix 3.3 continued

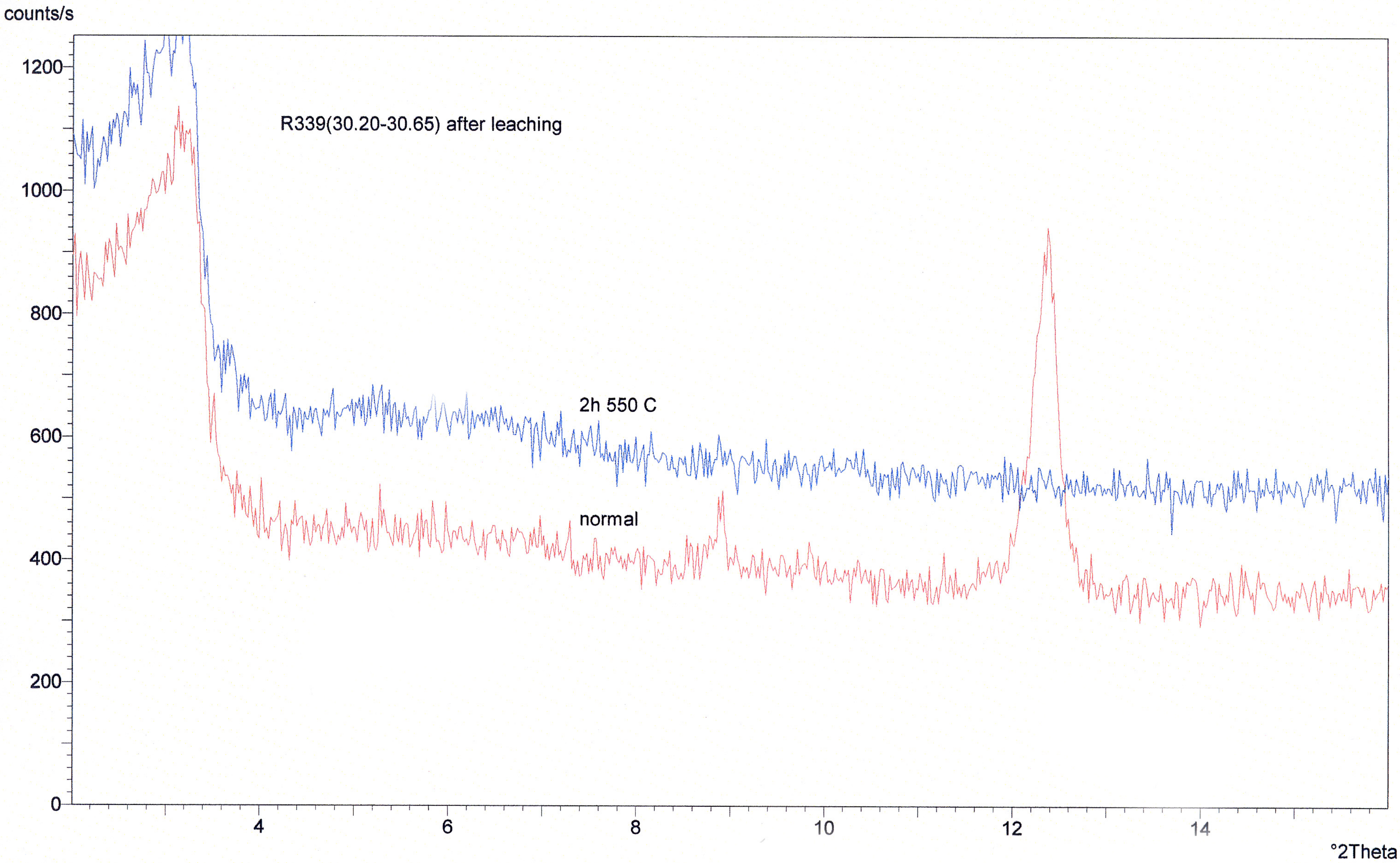
SAMPLE	qtz	plag	musc	kaol	chlor	talc	hemat	smec	amphib	kfsp	calc	pyrox	Tot
R 346 (37,10 – 41,60)	5	0	0	70	0	<5	20	0	0	<5	0	0	100
R 346 (41,60 – 46,60)	25	<5	0	70	0	0	<5	0	0	<5	0	0	100
R 346 (46,60 – 50,60)	45	5	5	40	0	0	0	0	0	0	<5	0	100
R 347 (16,60 – 20,90)	35	<5	15	45	0	0	0	0	0	0	0	5	100
R 347 (20,90 – 25,10)	30	0	10	55	0	0	5	0	0	0	0	0	100
R 347 (27,10 – 31,00)	35	0	10	50	0	0	5	0	0	0	0	0	100
R 347 (31,00 – 34,10)	30	0	5	55	0	0	5	0	0	0	0	0	100
R 347 (34,10 – 38,80)	25	5	5	50	0	0	20	0	0	0	0	0	100
R 347 (38,80 – 42,80)	25	5	10	30	<5	0	30	0	0	0	0	0	100
R 347 (42,80 – 46,60)	35	15	15	10	<5	0	20	0	0	0	0	0	100
R 347 (46,60 – 50,00)	45	25	10	10	<5	0	10	0	0	0	0	0	100
R 348 (19,00 – 23,70)	15	65	0	0	0	<5	5	5	0	0	0	0	100
R 348 (23,70 – 26,80)	25	30	0	0	0	5	25	15	<5	0	0	0	100
R 348 (26,80 – 30,80)	15	70	0	10	0	0	<5	0	0	0	0	0	100
R 348 (30,80 – 35,30)	20	60	0	15	0	5	0	0	0	0	0	0	100
R 348 (35,30 - 40,00)	35	5	0	20	<5	<5	25	0	<5	5	0	0	100
R 349 (15,30 - 18,60)	10	75	0	5	<5	5	10	0	0	0	0	0	100
R 349 (18,60 - 21,10)	10	40	0	0	<5	25	20	0	<5	0	0	0	100
R 350 (14,60 – 19,60)	35	5	5	35	0	0	0	0	0	0	0	20	100
R 350 (19,60 – 23,20)	40	<5	10	30	0	0	0	0	0	0	0	15	100
R 350 (23,20 – 27,70)	35	5	10	30	0	0	0	0	0	0	0	20	100
R 350 (27,70 – 32,10)	40	5	5	30	0	0	0	0	0	<5	0	15	100
R 350 (32,10 – 36,80)	35	<5	5	30	0	0	0	0	0	<5	0	20	100
R 350 (36,80 – 41,30)	40	<5	5	30	0	0	<5	0	0	<5	0	15	100
R 350 (41,30 – 44,80)	30	5	5	30	0	0	0	0	0	5	0	20	100
R 351 (13,70 – 17,10)	40	<5	5	35	0	0	<5	0	0	<5	0	15	100
R 351 (17,10 – 20,20)	40	5	5	25	0	0	<5	0	0	5	0	15	100
R 351 (20,20 – 23,20)	40	10	<5	25	0	0	5	0	0	5	0	10	100

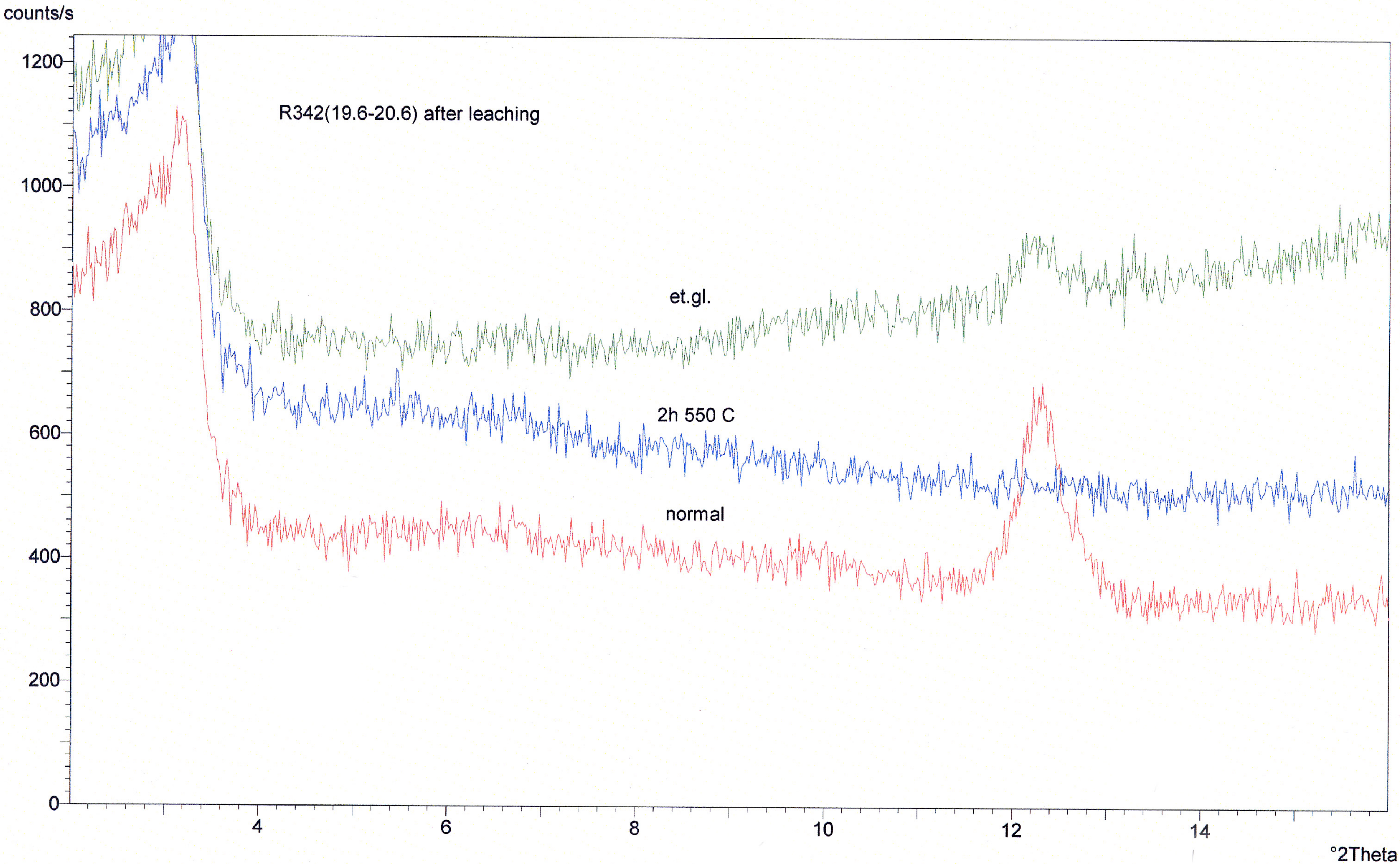
Appendix 4

X-ray Diffractograms of Oriented clay for final production Samples
by: **GTK Lab.**


counts/s
5000
4000
3000
2000
1000
0
R339(30.20-30.65)
2h 550 C
normal
35.0
25.0
20.0
15.0
10.0
d-spacing (Å)


counts/s
1200
1000
800
600
400
200
0
R355(24.20-24.70) after leaching
2h 550 C
normal
35.0
25.0
20.0
15.0
10.0
d-spacing (Å)


counts/s
1200
1000
800
600
400
200
0
R339(30.20-30.65) after leaching
2h 550 C
normal
4
6
8
10
12
14
°2Theta


counts/s
1200
1000
800
600
400
200
0
R342(19.6-20.6) after leaching
et.gl.
2h 550 C
normal
4
6
8
10
12
14
°2Theta

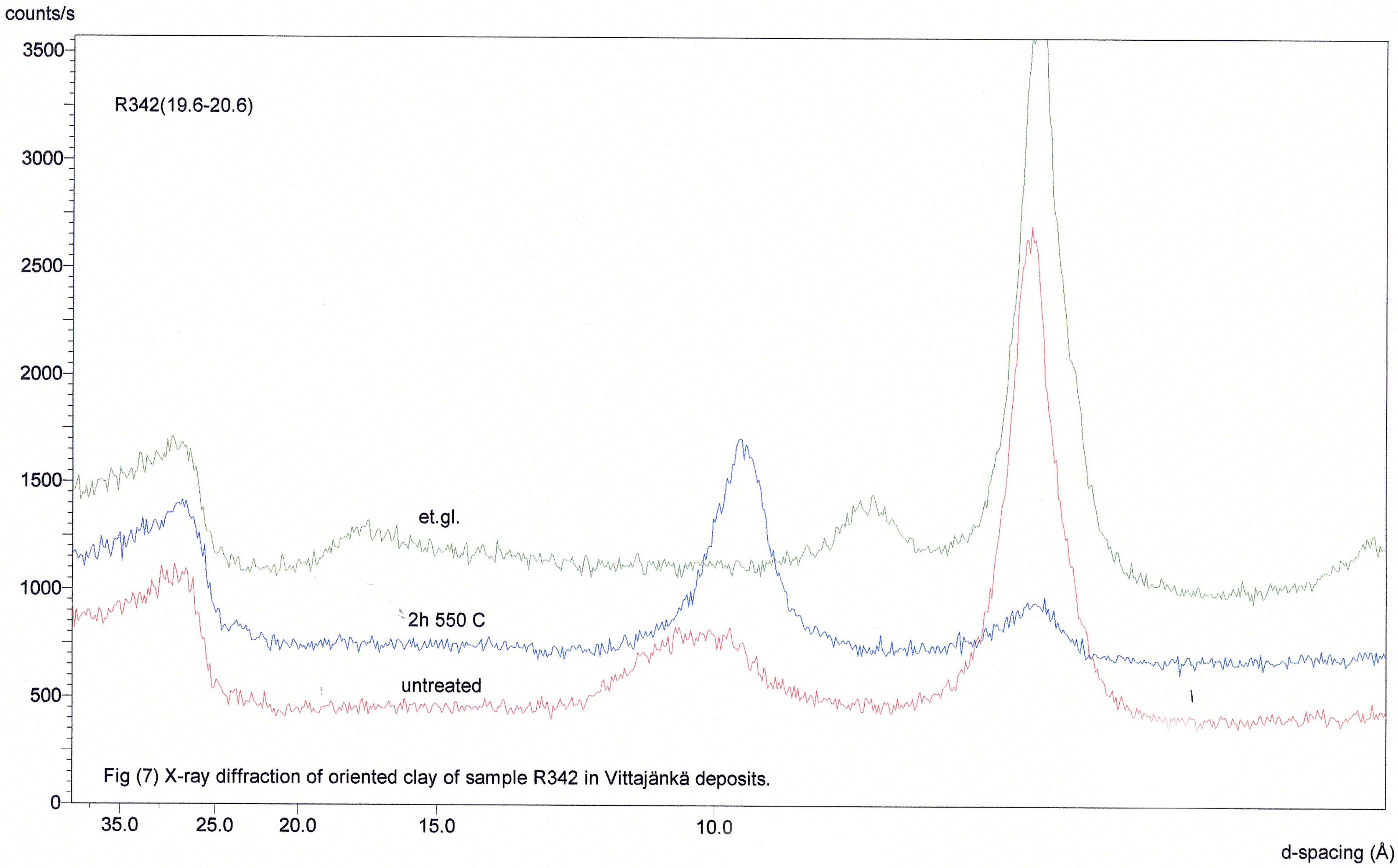


Fig (7) X-ray diffraction of oriented clay of sample R342 in Vittajänkä deposits.

Appendix 5.1. Chemical composition of processed kaolin samples, <2 microns

SAMPLE	Na2O %	MgO %	Al2O3 %	SiO2 %	P2O5 %	K2O %	CaO %	TiO2 %	MnO %	Fe2O3 %	S %	Cl *ppm*	Sc *ppm*	V *ppm*	Cr *ppm*	Ni *ppm*	Cu *ppm*	Zn *ppm*
R 336 / 20,50 - 30,20 / **LT**	0.03	0.74	29.5	55.3	0.09	2.41	0.05	0.35	0.01	1.47	0.06	28	1	50	82	31	73	27
R 336 / 20,50 - 30,20 / **M**	0.10	2.40	28.5	48.3	0.03	9.40	0.03	0.75	0.03	4.23	0	62	11	131	153	25	24	1
R 336 / 20,50 - 30,20 / **SA**	0.08	1.95	24.5	56.8	0.01	7.30	0.01	0.57	0.02	3.32	0	60	4	98	113	14	11	7
R 337 / 18,00 - 24,90 / **LT**	0.01	0.58	33.9	50.6	0.03	2.06	0.03	0.23	0.01	1.06	0.07	28	0	42	78	31	39	17
R 337 / 18,00 - 24,90 / **M**	0.06	1.71	31.7	48.3	0.01	6.62	0.03	0.45	0.01	2.58	0	61	4	87	137	30	20	7
R 337 / 18,00 - 24,90 / **SA**	0.05	1.36	28.3	55.8	0.01	5.11	0.02	0.32	0.01	2.00	0	55	1	69	103	19	9	10
R 337 / 25,70 - 33,80 / **LT**	0	0.48	33.6	51.1	0.06	1.67	0.03	0.21	0.01	0.98	0.08	42	0	44	64	29	37	24
R 337 / 25,70 - 33,80 / **M**	0.07	2.06	30.4	47.9	0.01	8.08	0.02	0.50	0.01	3.25	0	66	3	110	140	28	20	8
R 337 / 25,70 - 33,80 / **SA**	0.05	1.38	27.5	56.4	0	5.24	0.02	0.31	0.01	2.17	0	65	0	61	95	19	15	7
R 338 / 26,80 - 40,10 / **LT**	0.02	1.05	30.0	52.3	0.04	3.70	0.03	0.39	0	1.85	0.06	44	2	58	88	23	36	15
R 338 / 26,80 - 40,10 / **M**	0.10	2.32	29.4	47.9	0.01	9.29	0.02	0.69	0.01	4.09	0	54	7	139	142	15	14	5
R 338 / 26,80 - 40,10 / **SA**	0.09	1.99	26.3	54.1	0.01	7.71	0.01	0.53	0.01	3.39	0	50	8	106	109	12	10	6
R 339 / 27,65 - 35,60 / **LT**	0.04	1.32	28.9	53.3	0.03	4.97	0.02	0.47	0	2.36	0.06	56	0	73	111	25	43	15
R 339 / 27,65 - 35,60 / **M**	0.10	2.31	29.1	47.8	0.01	9.36	0.01	0.67	0.01	4.13	0	68	1	119	144	21	11	10
R 339 / 27,65 - 35,60 / **SA**	0.08	1.96	25.7	54.8	0	7.76	0.01	0.54	0.01	3.43	0	68	5	103	108	16	7	3
R 340 / 28,20 - 36,60 / **LT**	0.03	1.14	31.4	50.3	0.03	3.90	0.03	0.57	0.01	2.27	0.09	30	6	79	104	18	41	14
R 340 / 28,20 - 36,60 / **M**	0.09	2.29	29.1	47.3	0.01	9.20	0.02	0.77	0.01	4.46	0	60	10	137	141	13	12	8
R 340 / 28,20 - 36,60 / **SA**	0.08	2.17	27.3	51.0	0	8.39	0.01	0.63	0.01	4.10	0	72	6	108	126	17	11	11
R 341 / 17,50 - 25,35 / **LT**	0.01	0.55	34.6	48.4	0.05	1.73	0.04	0.40	0.01	1.58	0.04	28	9	77	100	21	39	18
R 341 / 17,50 - 25,35 / **M**	0.07	1.88	30.4	46.9	0.03	7.92	0.05	0.91	0.01	4.21	0	64	12	189	184	13	22	17
R 341 / 17,50 - 25,35 / **SA**	0.07	1.70	28.0	52.5	0.01	6.84	0.02	0.68	0.01	3.67	0	55	8	150	145	14	0	8
R 343 / 15,95 - 25,80 / **LT**	0.05	0.93	23.9	63.2	0.08	3.00	0.04	0.18	0.02	1.06	0.06	37	0	36	57	25	46	15
R 343 / 15,95 - 25,80 / **M**	0.10	2.58	29.0	48.8	0.06	9.47	0.06	0.49	0.06	2.64	0	66	4	96	115	30	36	16
R 343 / 15,95 - 25,80 / **SA**	0.10	1.89	22.5	62.0	0.03	6.86	0.03	0.33	0.04	1.81	0	41	0	63	72	15	6	5
R 346 / 28,60 - 37,10 / **LT**	0	0.78	36.4	46.9	0.06	0.070	0.04	0.69	0	0.83	0.05	49	24	62	63	62	39	15
R 346 / 28,60 - 37,10 / **M**	0.02	1.41	28.7	36.8	0.08	0.777	0.11	4.77	0.01	26.9	0	30	47	635	620	51	121	32
R 346 / 28,60 - 37,10 / **SA**	0.00	2.74	30.6	48.1	0.02	0.445	0.04	1.79	0.01	15.3	0	43	26	285	273	83	11	6
R 350 / 14,60 - 27,70 / **LT**	0.04	0.85	31.6	52.1	0.04	2.69	0.04	0.53	0	1.62	0.07	42	1	79	70	18	34	14
R 350 / 14,60 - 27,70 / **M**	0.09	2.00	29.9	47.1	0.02	8.36	0.03	1.03	0.01	4.03	0	50	8	182	164	17	14	12
R 350 / 14,60 - 27,70 / **SA**	0.09	1.74	27.2	53.5	0.02	6.95	0.02	0.71	0.01	3.45	0	42	7	145	126	16	8	8

LT (Lopputuote / end product) = cycloned, magnetically separated and bleached; **M** = Magnetic fraction**,**
SA (Syklonin alite) = <2 microns fraction after cycloning

Appendix 5.1 continued

SAMPLE	Ga ppm	As ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Sn ppm	Sb ppm	Ba ppm	La ppm	Ce ppm	Pb ppm	Bi ppm	Th ppm	U ppm
R 336 / 20,50 - 30,20 / **LT**	26	7	58	10	11	186	0	4	2	0	0	0	0	1	1	1	0
R 336 / 20,50 - 30,20 / **M**	39	0	215	13	12	74	14	1	0	0	886	23	77	18	0	6	0
R 336 / 20,50 - 30,20 / **SA**	34	0	164	7	10	103	6	1	0	0	647	20	47	13	5	3	0
R 337 / 18,00 - 24,90 / **LT**	29	0	48	4	6	108	0	2	0	1	270	40	98	23	4	9	0
R 337 / 18,00 - 24,90 / **M**	43	0	147	7	9	75	16	0	0	0	487	7	33	15	3	4	0
R 337 / 18,00 - 24,90 / **SA**	35	0	111	6	8	84	13	2	0	0	385	1	20	12	1	1	0
R 337 / 25,70 - 33,80 / **LT**	26	0	36	3	5	122	1	2	0	0	163	16	27	15	8	1	0
R 337 / 25,70 - 33,80 / **M**	41	0	170	8	8	67	11	1	0	0	598	6	29	16	0	0	0
R 337 / 25,70 - 33,80 / **SA**	36	0	111	4	5	89	5	1	0	0	388	0	27	15	1	1	0
R 338 / 26,80 - 40,10 / **LT**	28	0	82	6	28	151	3	2	0	0	296	52	174	21	2	12	0
R 338 / 26,80 - 40,10 / **M**	40	0	208	9	14	67	14	0	0	0	699	10	46	17	1	2	0
R 338 / 26,80 - 40,10 / **SA**	34	0	171	8	11	70	5	1	0	0	578	8	43	14	5	2	1
R 339 / 27,65 - 35,60 / **LT**	27	1	113	4	24	149	3	2	0	0	395	24	76	26	3	7	0
R 339 / 27,65 - 35,60 / **M**	37	4	205	8	14	65	14	1	0	0	689	4	36	15	0	4	3
R 339 / 27,65 - 35,60 / **SA**	35	1	167	8	9	73	9	0	0	0	580	12	27	14	0	2	0
R 340 / 28,20 - 36,60 / **LT**	31	0	92	8	18	188	4	1	0	0	309	28	84	21	2	16	0
R 340 / 28,20 - 36,60 / **M**	34	0	205	7	17	82	8	0	0	0	705	6	51	15	2	4	0
R 340 / 28,20 - 36,60 / **SA**	35	0	188	7	14	71	9	2	0	0	626	11	34	13	2	1	1
R 341 / 17,50 - 25,35 / **LT**	27	0	44	5	21	156	3	2	0	0	120	37	112	19	0	4	0
R 341 / 17,50 - 25,35 / **M**	46	0	170	10	16	113	23	0	0	0	510	18	63	16	2	1	1
R 341 / 17,50 - 25,35 / **SA**	39	0	148	6	10	90	6	2	0	0	445	24	45	13	0	0	0
R 343 / 15,95 - 25,80 / **LT**	21	0	70	11	29	118	1	3	0	0	291	57	167	22	4	7	0
R 343 / 15,95 - 25,80 / **M**	42	0	214	25	38	73	15	0	0	0	841	64	160	17	3	6	2
R 343 / 15,95 - 25,80 / **SA**	29	0	150	11	22	78	1	1	0	0	548	28	66	13	2	0	0
R 346 / 28,60 - 37,10 / **LT**	51	3	4	5	10	132	6	5	0	0	27	0	35	17	6	9	0
R 346 / 28,60 - 37,10 / **M**	40	6	19	12	80	526	71	0	14	0	68	25	110	18	2	10	9
R 346 / 28,60 - 37,10 / **SA**	46	1	10	4	44	250	15	0	0	0	63	9	44	17	0	3	3
R 350 / 14,60 - 27,70 / **LT**	30	0	64	5	13	127	3	4	0	0	188	6	26	19	0	0	0
R 350 / 14,60 - 27,70 / **M**	43	0	184	9	23	113	13	3	0	0	540	15	51	17	5	1	3
R 350 / 14,60 - 27,70 / **SA**	37	0	148	4	19	92	8	1	0	0	440	14	45	14	0	0	0

LT (Lopputuote / end product) = cycloned, magnetically separated and bleached; **M** = Magnetic fraction**,**
SA (Syklonin alite) = <2 microns fraction after cycloning

Appendix 5.2. Chemical compositions of <20 microns fractions.

SAMPLE	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	S	Cl	Sc	V	Cr	Ni	Cu	Zn	Ga	As
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
R 335 (16,40 – 20,70)	0.15	2.18	22.4	55.6	0.04	8.13	0.04	0.62	0.04	4.18	0.00	80	2	100	111	22	52	12	29	1
R 335 (20,70 – 23,55)	0.14	1.70	26.3	53.9	0.06	6.41	0.02	0.47	0.03	2.73	0.00	53	1	90	89	24	45	11	27	4
R 335 (23,55 - 25,25)	0.08	1.06	29.4	53.0	0.07	3.89	0.03	0.28	0.02	1.73	0.00	46	4	53	77	26	51	19	25	3
R 335 (25,25 – 30,10)	0.14	2.13	22.2	56.7	0.04	8.08	0.04	0.67	0.04	4.06	0.00	70	5	113	112	24	51	8	27	0
R 335 (30,70 – 33,80)	0.14	2.22	24.5	52.5	0.04	8.60	0.01	0.96	0.04	4.28	0.00	80	5	126	132	26	48	6	33	0
R 335 (33,80 – 35,00)	0.12	1.75	25.0	55.4	0.07	6.43	0.04	0.46	0.03	3.07	0.00	54	0	77	87	25	54	12	25	1
R 336 (16,00 – 20,50)	0.14	1.98	25.1	53.9	0.04	7.62	0.01	0.66	0.02	3.73	0.02	80	3	111	125	20	48	5	33	3
R 336 (20,50 – 25,10)	0.17	1.71	26.5	53.6	0.08	6.38	0.01	0.55	0.02	3.04	0.00	70	3	95	108	24	42	4	33	0
R 336 (25,10 – 30,20)	0.13	1.88	26.9	51.8	0.05	7.11	0.01	0.60	0.02	3.26	0.00	70	6	107	114	24	48	7	30	0
R 336 (30,20 – 35,20)	0.13	2.23	24.2	53.7	0.03	8.77	0.00	0.86	0.03	4.09	0.00	70	7	132	136	20	41	9	31	2
R 337 (15,50 – 18,00)	0.17	2.05	24.5	54.2	0.06	7.86	0.02	0.62	0.01	3.90	0.00	70	5	95	126	24	41	6	32	3
R 337 (18,00 – 23,10)	0.13	1.14	31.1	50.8	0.07	4.37	0.01	0.32	0.01	1.76	0.00	52	3	63	88	21	39	8	34	4
R 337 (23,10 – 28,15)	0.13	1.16	30.4	51.6	0.07	4.40	0.00	0.32	0.01	1.83	0.00	50	4	71	89	20	35	4	33	1
R 337 (28,15 – 33,80)	0.11	1.13	29.8	52.3	0.05	4.33	0.01	0.29	0.01	1.94	0.00	58	0	58	77	19	37	5	32	0
R 337 (33,80 – 36,30)	0.14	1.22	28.6	53.2	0.07	4.72	0.01	0.35	0.01	2.37	0.00	70	4	76	75	25	41	8	34	0
R 337 (36,30 – 40,00)	0.15	1.36	30.3	50.0	0.06	5.20	0.01	0.49	0.01	2.51	0.00	59	1	78	95	18	39	8	36	0
R 338 (19,85 – 21,80)	0.16	1.64	28.9	51.4	0.03	5.89	0.03	0.40	0.01	2.37	0.00	42	1	123	97	21	43	5	33	2
R 338 (21,80 – 26,80)	0.15	2.18	24.9	52.4	0.08	8.47	0.01	0.81	0.01	4.57	0.00	70	13	132	147	18	42	7	30	7
R 338 (26,80 – 31,10)	0.15	1.79	28.8	50.0	0.07	6.99	0.00	0.54	0.00	3.11	0.00	45	3	108	116	11	42	7	31	1
R 338 (31,10 – 35,10)	0.16	1.74	28.9	49.7	0.08	6.72	0.00	0.53	0.01	3.05	0.00	70	4	106	109	25	35	4	32	0
R 338 (35,10 – 40,10)	0.16	1.78	28.5	49.9	0.06	6.97	0.00	0.62	0.00	3.20	0.00	55	3	112	114	14	47	4	35	3
R 339 (19,40 – 23,60)	0.17	2.02	27.7	50.1	0.06	7.96	0.00	0.59	0.00	3.66	0.00	51	4	135	124	24	43	8	34	1
R 339 (23,60 – 27,65)	0.15	1.97	27.8	49.8	0.05	7.92	0.01	0.60	0.01	3.68	0.00	55	4	131	118	12	43	7	39	1
R 339 (27,65 – 31,65)	0.16	1.77	28.2	50.8	0.08	6.99	0.00	0.56	0.00	3.19	0.00	53	4	102	117	14	44	10	36	0
R 339 (31,65 – 35,60)	0.16	1.85	27.2	51.8	0.06	7.33	0.00	0.56	0.00	3.28	0.00	47	7	103	115	20	50	8	32	1
R 339 (35,60 – 40,50)	0.13	1.95	28.1	50.0	0.05	7.74	0.00	0.59	0.00	3.45	0.00	60	3	108	108	21	46	9	34	4
R 340 (18,90 – 24,10)	0.16	1.73	28.8	50.0	0.05	6.69	0.00	0.58	0.01	3.34	0.00	43	3	102	120	12	47	11	30	0
R 340 (24,10 – 28,20)	0.15	2.03	27.8	48.9	0.06	8.13	0.00	0.65	0.01	4.02	0.00	70	9	123	143	6	46	7	37	0
R 340 (28,20 – 31,60)	0.15	1.83	29.2	48.8	0.06	7.09	0.00	0.66	0.01	3.58	0.00	60	3	121	115	11	50	8	36	0
R 340 (31,60 – 36,60)	0.16	2.12	28.1	48.5	0.06	8.11	0.00	0.63	0.01	4.08	0.00	70	11	118	125	15	47	7	38	4
R 340 (36,60 – 40,60)	0.14	2.07	28.5	48.0	0.07	7.90	0.01	0.91	0.01	4.12	0.00	60	13	157	112	17	33	8	35	2
R 340 (40,60 – 44,60)	0.16	1.78	29.4	47.9	0.06	6.81	0.00	0.70	0.01	3.59	0.00	60	6	130	79	17	49	9	36	2
R 340 (44,60 – 50,60)	0.16	1.95	28.6	48.5	0.06	7.58	0.01	0.69	0.01	3.89	0.00	47	1	137	100	13	40	11	36	2
R 341 (17,50 – 21,60)	0.15	1.58	29.8	48.5	0.06	6.08	0.00	0.64	0.01	3.33	0.00	60	11	131	122	17	44	10	40	0

Appendix 5.2 continued

SAMPLE	Na_2O %	MgO %	Al_2O_3 %	SiO_2 %	P_2O_5 %	K_2O %	CaO %	TiO_2 %	MnO %	Fe_2O_3 %	S %	Cl ppm	Sc ppm	V ppm	Cr ppm	Ni ppm	Cu ppm	Zn ppm	Ga ppm	As ppm
R 341 (21,60 – 25,35)																				
R 341 (25,35 – 29,80)	0.15	1.25	30.3	48.6	0.05	5.19	0.005	0.65	0.01	3.38	0.00	55	7	166	132	8	40	6	35	1
R 341 (29,80 – 35,60)	0.17	1.10	31.4	48.1	0.09	4.46	0.01	0.74	0.01	3.10	0.00	43	11	157	129	27	36	9	34	2
R 342 (35,60 – 41,60)	0.13	0.60	33.4	46.0	0.10	1.50	0.06	0.68	0.02	3.33	0.01	45	12	147	72	34	39	12	35	0
R 341 (41,60 – 48,60)	0.28	0.80	33.5	45.3	0.18	0.75	0.02	0.53	0.01	3.46	0.00	39	4	96	57	36	36	7	38	0
R 341 (48,60 – 52,60)	0.14	1.19	29.9	49.9	0.04	4.86	0.01	0.67	0.01	3.00	0.00	51	5	140	108	13	50	10	37	1
R 342 (19,60 – 21,95)	6.84	1.62	21.2	58.7	0.06	0.36	0.11	0.89	0.01	4.65	0.00	70	14	90	140	132	39	7	29	0
R 342 (21,95 – 26,60)	7.98	0.27	22.9	60.5	0.06	0.34	0.08	0.39	0.01	2.98	0.00	50	0	42	34	46	41	7	27	3
R 342 (26,60 – 32,50)	6.78	1.78	21.5	57.5	0.08	1.25	0.09	0.73	0.01	6.02	0.00	150	10	107	112	84	43	9	31	0
R 342 (34,10 – 40,10)	3.71	6.23	19.3	52.8	0.12	3.54	0.35	1.01	0.01	8.49	0.00	300	19	190	179	123	44	8	33	0
R 343 (15,95 – 18,70)	0.23	1.49	23.1	61.0	0.10	5.04	0.02	0.27	0.03	1.68	0.00	60	0	58	64	18	37	6	29	2
R 343 (22,10 – 25,80)	0.17	1.85	23.8	58.8	0.06	6.78	0.01	0.33	0.05	1.78	0.00	50	1	61	76	24	50	7	28	3
R 343 (26,30 – 29,20)	0.14	1.90	24.3	58.1	0.07	6.87	0.01	0.30	0.04	1.84	0.00	60	1	53	70	18	39	6	26	0
R 343 (29,20 – 32,30)	0.18	1.86	24.7	57.9	0.06	6.69	0.01	0.29	0.05	1.60	0.00	24	0	57	58	18	42	5	34	0
R 343 (32,30 – 35,60)	0.17	1.84	24.3	58.3	0.07	6.68	0.01	0.28	0.04	1.96	0.00	60	0	63	70	16	44	10	27	0
R 343 (35,60 – 38,10)	0.13	1.42	19.0	67.2	0.05	5.11	0.03	0.18	0.03	1.57	0.00	37	0	50	72	27	46	15	27	2
R 344 (15,75 – 18,10)	0.17	1.33	29.1	52.3	0.07	4.71	0.01	0.29	0.01	2.30	0.00	54	0	74	64	19	45	30	34	4
R 344 (18,10 – 21,10)	0.20	1.71	29.8	50.7	0.10	6.36	0.00	0.35	0.01	2.00	0.00	57	0	72	64	12	41	9	34	0
R 344 (21,10 – 24,60)	0.16	1.78	27.1	54.0	0.06	6.51	0.01	0.36	0.01	2.05	0.00	60	0	76	72	23	40	10	32	3
R 344 (25,60 – 28,70)	0.17	1.59	26.0	57.1	0.06	5.61	0.01	0.28	0.01	1.68	0.00	49	0	68	61	16	37	3	32	0
R 344 (28,70 – 32,00)	0.20	1.45	26.2	56.5	0.09	5.07	0.01	0.29	0.02	1.84	0.00	54	1	69	68	13	41	10	34	0
R 344 (32,00 – 35,30)	0.19	1.17	21.3	64.2	0.10	4.13	0.01	0.19	0.01	1.92	0.00	51	0	65	88	25	48	11	28	4
R 345 (13,60 – 16,20)	0.19	1.90	26.1	52.5	0.12	7.08	0.03	0.83	0.01	4.16	0.00	70	5	127	144	27	37	12	33	2
R 345 (16,70 – 20,60)	0.14	2.33	24.6	52.7	0.05	9.11	0.00	0.63	0.01	4.12	0.00	80	5	123	119	19	42	6	33	0
R 345 (20,60 – 24,00)	0.16	2.27	25.2	52.7	0.06	8.72	0.00	0.58	0.01	3.92	0.00	70	0	122	115	22	49	11	28	2
R 345 (24,00 – 25,35)	0.17	2.25	24.3	52.8	0.06	8.62	0.03	1.00	0.01	4.22	0.00	70	2	133	159	19	45	5	33	2
R 345 (31,10 – 33,00)	0.12	1.26	30.3	50.4	0.06	4.73	0.00	0.43	0.01	2.28	0.00	47	0	91	103	18	36	9	27	1
R 345 (33,00 – 33,70)	0.14	1.26	30.1	50.2	0.08	4.82	0.01	0.42	0.01	2.81	0.00	41	0	103	103	18	35	14	35	2
R 345 (33,70 – 36,10)	0.19	1.48	28.3	53.5	0.09	5.25	0.00	0.34	0.01	1.77	0.00	52	1	90	80	19	36	7	29	2
R 345 (36,10 – 39,10)	0.21	1.20	26.6	56.8	0.10	4.19	0.01	0.23	0.01	1.40	0.00	56	0	69	71	22	36	4	27	0
R 346 (17,15 – 20,25)	0.23	1.60	34.4	46.8	0.11	0.83	0.02	1.05	0.00	2.36	0.00	38	14	146	110	78	40	9	42	3
R 346 (24,40 – 28,60)	0.13	2.19	34.4	46.4	0.11	0.03	0.01	1.42	0.00	3.21	0.00	32	20	163	146	81	32	6	50	0
R 346 (28,60 – 33,10)	0.13	1.19	35.3	45.8	0.11	0.04	0.01	1.16	0.00	3.18	0.00	14	23	131	96	49	37	9	44	0
R 346 (33,10 – 37,10)	0.11	0.98	35.7	46.1	0.08	0.11	0.01	1.13	0.00	2.75	0.00	37	32	137	117	89	37	7	52	0

Appendix 5.2 continued

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	S	Cl	Sc	V	Cr	Ni	Cu	Zn	Ga	As
SAMPLE	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
R 346 (37,10 – 41,60)	0.14	1.21	35.4	46.0	0.10	0.04	0.01	1.14	0.00	3.45	0.00	32	20	144	115	68	38	6	46	3
R 346 (41,60 – 46,60)	0.13	0.54	33.9	47.7	0.08	1.47	0.02	0.75	0.01	2.30	0.00	41	25	145	87	29	44	9	44	1
R 346 (46,60 – 50,60)	0.18	1.25	30.2	49.8	0.07	4.94	0.01	0.75	0.00	2.74	0.00	43	1	175	108	23	35	8	38	0
R 347 (16,60 – 20,90)	0.33	2.87	29.7	46.9	0.12	3.49	0.11	0.59	0.03	5.77	0.00	35	15	271	150	155	49	17	37	1
R 347 (20,90 – 25,10)	0.27	4.62	30.3	45.6	0.10	1.76	0.02	0.56	0.02	4.00	0.00	37	11	105	82	127	46	30	33	0
R 347 (27,10 – 31,00)	0.23	6.80	28.2	47.3	0.08	2.88	0.01	0.45	0.02	2.72	0.00	70	6	99	85	65	39	14	33	0
R 347 (31,00 – 34,10)	0.32	5.55	27.6	46.6	0.08	2.01	0.04	0.90	0.02	5.40	0.00	57	7	156	112	115	37	13	33	0
R 347 (34,10 – 38,80)	0.43	4.71	29.8	46.6	0.07	1.87	0.04	0.97	0.01	4.91	0.00	60	22	144	124	123	40	17	39	0
R 347 (38,80 – 42,80)	0.51	5.88	27.8	47.4	0.08	4.67	0.02	0.82	0.01	5.36	0.00	120	25	224	166	105	45	11	38	0
R 347 (42,80 – 46,60)	0.64	5.33	28.0	48.2	0.11	6.26	0.02	0.56	0.01	3.45	0.00	120	14	217	159	67	34	9	33	3
R 347 (46,60 – 50,00)	1.08	4.61	26.7	51.7	0.10	5.19	0.04	0.48	0.01	2.71	0.00	110	11	197	125	63	46	8	32	1
R 348 (19,00 – 23,70)	3.75	7.42	13.9	53.7	0.27	0.86	0.40	0.45	0.03	9.53	0.00	200	9	61	131	155	39	19	24	3
R 348 (23,70 – 26,80)																				
R 348 (26,80 – 30,80)	4.67	8.39	14.7	60.2	0.23	0.16	0.07	0.30	0.01	4.52	0.00	51	15	61	106	153	43	10	23	4
R 348 (30,80 – 35,30)																				
R 348 (35,30 - 40,00)	1.26	7.99	20.6	41.9	0.18	0.26	0.99	0.62	0.04	12.80	0.00	80	11	185	139	437	42	30	27	0
R 349 (15,30 - 18,60)	4.86	12.50	12.4	59.7	0.18	0.29	0.36	0.47	0.01	3.92	0.00	150	11	58	79	76	38	11	23	4
R 349 (18,60 - 21,10)	3.03	19.10	8.5	59.7	0.16	0.17	0.35	0.31	0.01	3.63	0.00	170	1	51	58	65	35	14	17	0
R 350 (14,60 – 19,60)	0.18	1.40	30.2	49.1	0.06	5.37	0.00	0.74	0.01	2.75	0.00	60	10	133	96	11	35	12	35	3
R 350 (19,60 – 23,20)	0.22	1.49	29.1	50.3	0.12	5.77	0.00	0.75	0.01	2.90	0.00	55	7	147	115	17	37	14	38	1
R 350 (23,20 – 27,70)	0.22	1.31	29.7	50.6	0.12	5.24	0.00	0.65	0.00	2.69	0.00	55	6	110	105	18	35	11	36	1
R 350 (27,70 – 32,10)	0.21	1.31	29.9	50.5	0.10	5.21	0.01	0.57	0.00	2.59	0.00	57	0	114	95	22	38	5	32	3
R 350 (32,10 – 36,80)	0.21	1.41	28.7	51.7	0.08	5.55	0.01	0.56	0.00	2.60	0.00	60	2	125	95	19	37	7	34	0
R 350 (36,80 – 41,30)	0.24	2.55	28.4	50.4	0.11	5.27	0.01	0.64	0.01	2.61	0.00	80	1	155	117	37	36	8	33	0
R 350 (41,30 – 44,80)	0.33	4.31	25.3	51.4	0.06	6.38	0.02	0.89	0.01	5.16	0.00	80	17	159	176	70	46	8	36	0
R 351 (13,70 – 17,10)	0.28	2.91	29.3	49.0	0.10	5.09	0.02	0.53	0.01	2.60	0.00	70	6	103	101	29	41	11	33	0
R 351 (17,10 – 20,20)	0.29	3.33	26.3	51.3	0.05	6.40	0.02	0.54	0.01	3.44	0.00	90	3	128	116	48	38	11	32	2
R 351 (20,20 – 23,20)	0.60	4.37	25.3	52.3	0.06	5.07	0.03	0.51	0.01	2.94	0.00	90	2	133	108	61	45	18	36	4

Appendix 5.2 continued

SAMPLE	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Sn ppm	Sb ppm	Ba ppm	La ppm	Ce ppm	Pb ppm	Bi ppm	Th ppm	U ppm	C %	LOI %	LOIX %
R 335 (16,40 – 20,70)	188	7	15	108	6	1	0	0	763	29	80	11	2	3	0	0.04	4.05	1.74
R 335 (20,70 – 23,55)	146	7	14	112	6	3	0	0	619	42	94	13	1	4	0	0.06	6.26	4.57
R 335 (23,55 - 25,25)	91	9	13	114	3	3	0	0	340	41	90	10	1	3	0	0.11	8.68	7.71
R 335 (25,25 – 30,10)	189	10	14	150	5	0	0	0	768	26	75	16	2	8	0	0.05	4.05	1.92
R 335 (30,70 – 33,80)	199	4	19	144	8	0	0	0	839	39	90	13	0	10	2	0.04	4.48	2.08
R 335 (33,80 – 35,00)	152	14	27	129	5	1	0	0	698	68	108	13	2	5	1	0.09	6.08	4.77
R 336 (16,00 – 20,50)	174	6	8	119	7	0	0	0	711	20	64	9	0	4	1	0.03	5.40	3.25
R 336 (20,50 – 25,10)	150	10	7	136	9	1	0	0	614	38	96	11	2	5	1	0.04	6.38	5.11
R 336 (25,10 – 30,20)	167	8	15	120	6	4	0	0	648	26	77	14	0	6	1	0.05	6.07	4.43
R 336 (30,20 – 35,20)	202	9	13	106	7	0	0	0	807	25	28	10	3	7	1	0.02	4.17	1.23
R 337 (15,50 – 18,00)	179	5	10	119	5	1	0	0	666	21	25	10	1	6	3	0.04	4.86	2.78
R 337 (18,00 – 23,10)	100	5	7	96	6	1	0	0	312	5	6	10	0	3	0	0.04	9.01	7.91
R 337 (23,10 – 28,15)	99	1	6	99	4	5	0	0	328	10	6	12	2	0	0	0.04	8.72	7.43
R 337 (28,15 – 33,80)	95	0	4	100	5	3	0	0	315	3	47	14	0	4	0	0.04	8.57	7.82
R 337 (33,80 – 36,30)	105	2	7	117	4	1	0	0	362	8	28	14	4	2	0	0.04	7.88	7.15
R 337 (36,30 – 40,00)	118	3	5	126	4	3	0	0	423	7	35	11	5	4	0	0.06	8.47	7.44
R 338 (19,85 – 21,80)	132	5	16	101	5	0	0	0	431	15	8	15	2	2	1	0.07	7.40	5.44
R 338 (21,80 – 26,80)	191	15	22	112	6	0	0	0	778	70	100	12	5	5	2	0.03	4.61	1.88
R 338 (26,80 – 31,10)	162	4	12	118	5	0	0	0	524	17	45	14	3	6	2	0.03	6.67	5.46
R 338 (31,10 – 35,10)	154	4	29	105	5	0	0	0	499	38	43	16	0	4	0	0.03	6.96	5.99
R 338 (35,10 – 40,10)	160	6	26	125	8	0	0	0	530	16	23	11	1	4	0	0.04	6.82	4.96
R 339 (19,40 – 23,60)	182	5	21	94	9	0	0	0	557	19	3	12	2	5	0	0.03	5.93	3.60
R 339 (23,60 – 27,65)	181	6	29	110	7	0	0	0	580	39	63	11	0	11	0	0.03	6.01	4.51
R 339 (27,65 – 31,65)	163	6	18	113	7	0	0	0	507	24	32	11	0	6	1	0.03	6.66	5.58
R 339 (31,65 – 35,60)	163	3	20	116	5	0	0	0	548	3	12	12	1	3	0	0.03	6.06	4.10
R 339 (35,60 – 40,50)	176	3	19	105	7	1	0	0	580	25	30	13	0	3	1	0.04	6.23	4.61
R 340 (18,90 – 24,10)	160	2	15	115	6	0	0	0	489	9	8	15	0	5	0	0.04	7.08	6.00
R 340 (24,10 – 28,20)	188	6	32	118	7	0	0	0	593	63	146	14	2	13	1	0.04	5.89	4.29
R 340 (28,20 – 31,60)	165	4	15	121	7	1	0	0	538	0	0	15	1	7	3	0.04	7.05	5.89
R 340 (31,60 – 36,60)	184	6	14	114	8	1	0	0	619	10	19	12	1	8	1	0.05	6.11	4.21
R 340 (36,60 – 40,60)	180	6	32	177	10	0	0	0	620	68	127	17	4	19	0	0.03	6.39	4.17
R 340 (40,60 – 44,60)	154	5	25	130	5	1	0	0	524	4	49	13	4	3	1	0.04	7.38	6.15
R 340 (44,60 – 50,60)	174	4	28	158	5	0	0	68	556	19	36	13	4	10	0	0.04	6.59	5.25
R 341 (17,50 – 21,60)	143	3	16	121	6	0	0	0	406	21	31	15	1	4	0	0.04	7.86	6.74

Appendix 5.2 continued

SAMPLE	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Sn ppm	Sb ppm	Ba ppm	La ppm	Ce ppm	Pb ppm	Bi ppm	Th ppm	U ppm	C %	LOI %	LOIX %
R 341 (21,60 – 25,35)																0.05	8.93	7.84
R 341 (25,35 – 29,80)	113	3	12	105	8	6	0	0	346	8	49	10	2	1	0	0.05	8.58	7.64
R 341 (29,80 – 35,60)	94	5	11	123	6	2	0	0	304	9	5	10	0	2	0	0.10	9.50	8.66
R 342 (35,60 – 41,60)	36	4	13	155	0	1	0	0	105	9	2	15	0	3	0	0.15	12.70	12.00
R 341 (41,60 – 48,60)	21	1	18	123	0	2	0	0	54	6	8	16	3	4	0	0.22	13.50	12.80
R 341 (48,60 – 52,60)	107	4	10	123	7	2	0	0	323	7	17	17	2	0	0	0.05	8.52	7.70
R 342 (19,60 – 21,95)	12	8	47	122	3	0	0	0	28	13	16	19	0	2	1	0.11	5.38	4.73
R 342 (21,95 – 26,60)	10	5	36	186	6	2	0	17	23	19	0	10	0	0	0	0.07	4.00	3.72
R 342 (26,60 – 32,50)	33	4	37	145	9	0	0	0	89	18	0	19	3	0	0	0.09	4.77	4.18
R 342 (34,10 – 40,10)	92	9	30	104	8	0	0	51	158	20	4	14	3	2	1	0.08	5.63	4.35
R 343 (15,95 – 18,70)	120	13	27	104	1	2	0	0	490	47	55	11	3	4	0	0.07	5.87	4.57
R 343 (22,10 – 25,80)	155	10	19	112	5	0	0	0	577	35	57	11	3	5	1	0.06	4.91	3.25
R 343 (26,30 – 29,20)	159	13	17	102	4	0	0	0	625	37	48	11	1	4	1	0.06	4.93	3.39
R 343 (29,20 – 32,30)	154	7	13	116	6	0	0	0	540	20	48	12	4	3	3	0.09	5.29	3.50
R 343 (32,30 – 35,60)	156	9	16	97	4	0	0	0	527	21	76	12	5	0	0	0.06	5.17	3.32
R 343 (35,60 – 38,10)	123	7	14	87	3	1	0	0	370	32	49	9	0	0	0	0.10	4.22	3.13
R 344 (15,75 – 18,10)	115	2	19	136	3	8	0	0	281	18	2	8	5	0	0	0.09	8.42	7.50
R 344 (18,10 – 21,10)	149	5	11	100	3	0	0	0	385	25	25	11	0	0	0	0.08	9.69	6.33
R 344 (21,10 – 24,60)	149	12	15	110	4	0	0	0	417	51	40	11	1	4	2	0.06	6.41	4.90
R 344 (25,60 – 28,70)	130	8	18	94	4	0	0	0	347	48	18	8	0	2	0	0.06	6.45	4.81
R 344 (28,70 – 32,00)	119	5	22	99	4	0	0	0	300	22	7	11	3	0	0	0.10	7.03	6.13
R 344 (32,00 – 35,30)	96	4	31	132	0	1	0	0	257	25	34	10	4	0	0	0.13	5.79	5.12
R 345 (13,60 – 16,20)	158	18	24	136	5	0	0	82	705	98	228	12	4	7	0	0.07	5.74	3.83
R 345 (16,70 – 20,60)	206	10	19	112	5	1	0	0	798	58	86	21	0	8	1	0.05	4.23	1.57
R 345 (20,60 – 24,00)	193	6	19	107	6	3	0	131	745	18	24	16	3	6	0	0.05	4.66	2.56
R 345 (24,00 – 25,35)	196	7	17	150	9	0	0	116	756	43	98	15	1	10	2	0.07	4.43	2.59
R 345 (31,10 – 33,00)	104	2	7	123	4	3	0	63	363	14	0	12	1	5	0	0.05	8.67	7.93
R 345 (33,00 – 33,70)	105	3	5	111	6	3	0	52	361	8	0	10	2	3	0	0.06	8.66	7.74
R 345 (33,70 – 36,10)	117	4	10	124	4	3	0	0	383	2	51	14	1	3	0	0.07	7.52	6.55
R 345 (36,10 – 39,10)	93	3	13	118	0	4	0	0	292	24	20	15	2	2	0	0.10	7.67	6.49
R 346 (17,15 – 20,25)	21	4	18	185	6	0	0	1	117	14	18	11	4	2	0	0.08	12.80	12.30
R 346 (24,40 – 28,60)	4	3	19	187	9	0	0	0	13	6	8	13	4	0	0	0.06	13.50	12.70
R 346 (28,60 – 33,10)	0	1	20	201	9	2	0	0	14	5	23	14	4	0	0	0.07	13.60	12.90
R 346 (33,10 – 37,10)	4	1	24	201	10	3	0	2	23	2	0	14	3	1	0	0.07	13.70	13.20

Appendix 5.2 continued

SAMPLE	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Sn ppm	Sb ppm	Ba ppm	La ppm	Ce ppm	Pb ppm	Bi ppm	Th ppm	U ppm	C %	LOI %	LOIX %
R 346 (37,10 – 41,60)	3	3	16	181	9	2	0	121	15	3	0	12	2	0	0	0.07	13.60	13.20
R 346 (41,60 – 46,60)	34	2	16	162	5	3	0	0	124	5	0	12	1	2	0	0.06	12.30	11.60
R 346 (46,60 – 50,60)	105	1	16	127	5	0	0	93	386	3	0	10	2	0	0	0.05	8.55	7.49
R 347 (16,60 – 20,90)	87	4	36	166	3	2	0	106	562	52	69	16	0	14	1	0.09	10.30	8.90
R 347 (20,90 – 25,10)	56	1	42	167	1	0	0	0	222	47	30	12	3	12	0	0.08	12.20	11.20
R 347 (27,10 – 31,00)	87	4	21	157	3	1	0	0	243	13	23	12	2	3	0	0.07	10.60	9.58
R 347 (31,00 – 34,10)	70	4	24	195	5	2	0	108	127	17	12	12	3	4	2	0.11	11.30	10.20
R 347 (34,10 – 38,80)	74	2	43	185	5	1	0	0	79	41	44	12	2	7	0	0.09	11.90	10.90
R 347 (38,80 – 42,80)	127	3	14	157	6	1	0	0	419	4	0	14	5	0	3	0.07	8.72	7.43
R 347 (42,80 – 46,60)	146	3	9	141	2	4	0	80	699	5	0	11	2	3	0	0.07	7.23	5.89
R 347 (46,60 – 50,00)	110	5	13	137	4	1	0	0	561	22	0	8	1	0	1	0.07	6.91	5.32
R 348 (19,00 – 23,70)	49	12	34	233	8	2	0	0	62	33	24	9	1	4	0	0.50	9.46	7.98
R 348 (23,70 – 26,80)																		
R 348 (26,80 – 30,80)	11	10	19	207	4	0	0	0	28	34	26	15	0	7	0	0.10	6.26	4.92
R 348 (30,80 – 35,30)																		
R 348 (35,30 - 40,00)	22	9	56	177	5	0	0	113	73	49	93	9	3	8	0	0.09	13.50	11.60
R 349 (15,30 - 18,60)	15	16	24	190	2	0	0	0	37	107	136	11	4	5	0	0.09	4.91	3.02
R 349 (18,60 - 21,10)	6	5	15	122	1	0	0	117	38	35	12	14	3	0	0	0.07	5.14	2.41
R 350 (14,60 – 19,60)	125	3	22	122	7	2	0	0	344	13	0	9	1	0	0	0.08	8.43	6.91
R 350 (19,60 – 23,20)	135	3	19	154	7	2	0	0	368	11	0	12	2	0	0	0.06	7.72	6.82
R 350 (23,20 – 27,70)	120	0	19	121	7	3	0	1	332	11	0	11	0	3	0	0.07	8.22	7.25
R 350 (27,70 – 32,10)	116	2	18	135	3	0	0	26	316	19	15	10	2	0	0	0.07	8.44	7.55
R 350 (32,10 – 36,80)	123	5	25	132	5	1	0	0	367	21	22	11	1	2	0	0.06	8.01	6.67
R 350 (36,80 – 41,30)	129	4	30	138	4	2	0	100	333	41	62	12	3	4	0	0.07	8.34	6.94
R 350 (41,30 – 44,80)	170	4	26	131	5	0	0	0	407	27	59	9	2	6	1	0.04	6.49	4.87
R 351 (13,70 – 17,10)	129	2	21	135	3	2	0	0	282	25	28	12	2	3	0	0.08	8.85	7.38
R 351 (17,10 – 20,20)	169	3	22	143	6	1	0	0	346	38	57	11	2	3	0	0.07	7.07	4.90
R 351 (20,20 – 23,20)	149	4	23	133	2	1	0	46	248	25	28	11	2	2	0	0.07	7.62	6.37

Appendix 5.3. Chemical compositions of raw kaolin samples.

SAMPLE	Na2O	MgO	Al2O3	SiO2	P2O5	K2O	CaO	TiO2	MnO	Fe2O3	S	Cl	Sc	V	Cr	Ni	Cu	Zn	Ga	As
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
R 335 (16,40 – 20,70)	0.10	1.23	12.5	75.2	0.02	4.50	0.06	0.35	0.02	2.61	0	70	0	50	73	12	8	3	17	0
R 335 (20,70 – 23,55)	0.03	0.91	12.6	77.5	0.01	3.34	0.02	0.24	0.02	1.47	0	53	0	40	52	9	4	0	21	2
R 335 (23,55 – 25,25)	0.00	0.47	10.8	82.8	0.01	1.74	0.02	0.12	0.01	0.77	0	43	0	22	36	7	0	0	16	0
R 335 (25,25 – 30,10)	0.15	1.32	13.0	74.2	0.01	4.70	0.10	0.37	0.02	2.51	0	80	0	51	75	14	10	5	23	0
R 335 (30,70 – 33,80)	0.13	1.35	14.2	72.2	0.01	4.94	0.08	0.53	0.03	2.94	0	70	0	51	78	15	0	5	22	0
R 335 (33,80 – 35,00)	0.05	0.98	12.5	77.3	0.02	3.55	0.04	0.24	0.02	1.71	0	49	0	43	50	8	5	0	17	0
R 336 (16,00 – 20,50)	0.04	1.12	13.8	74.3	0.01	4.19	0.02	0.36	0.01	2.24	0	52	0	61	64	18	0	0	24	1
R 336 (20,50 – 25,10)	0.06	0.93	13.2	76.8	0.02	3.30	0.04	0.28	0.01	1.63	0	57	0	41	58	22	0	0	21	1
R 336 (25,10 – 30,20)	0.11	1.06	13.0	76.2	0.01	3.67	0.10	0.31	0.02	1.81	0	59	0	42	66	15	0	1	20	0
R 336 (30,20 – 35,20)	0.11	1.37	14.2	72.1	0.00	5.09	0.05	0.49	0.02	2.53	0	52	0	53	80	0	0	3	23	2
R 337 (15,50 – 18,00)	0.05	1.19	13.3	74.7	0.01	4.41	0.03	0.34	0.01	2.24	0	59	0	52	70	15	0	2	19	1
R 337 (18,00 – 23,10)	0.00	0.49	11.8	81.3	0.00	1.83	0.01	0.13	0.00	0.73	0	40	0	24	37	12	0	5	16	1
R 337 (23,10 – 28,15)	0.00	0.46	11.6	81.7	0.00	1.68	0.02	0.13	0.00	0.71	0	42	0	28	38	6	0	2	17	0
R 337 (28,15 – 33,80)	0.00	0.45	11.5	81.8	0.00	1.70	0.02	0.12	0.01	0.79	0	36	0	20	37	6	0	2	16	0
R 337 (33,80 – 36,30)	0.01	0.50	10.1	83.1	0.00	1.92	0.02	0.13	0.01	0.97	0	27	0	25	40	6	0	0	13	1
R 337 (36,30 – 40,00)	0.05	0.88	13.9	75.9	0.00	3.13	0.04	0.26	0.01	1.50	0	44	0	35	51	13	0	5	22	0
R 338 (19,85 – 21,80)	0.14	0.67	11.8	80.3	0.01	1.94	0.11	0.16	0.01	0.90	0	44	0	47	42	8	0	2	16	2
R 338 (21,80 – 26,80)	0.07	1.27	13.8	72.8	0.02	4.79	0.03	0.48	0.01	3.41	0	44	0	64	91	15	4	6	22	0
R 338 (26,80 – 31,10)	0.04	1.03	14.8	74.4	0.01	3.75	0.03	0.29	0.00	1.69	0	42	0	51	66	8	0	4	19	0
R 338 (31,10 – 35,10)	0.03	1.02	15.0	73.9	0.01	3.73	0.02	0.28	0.00	1.69	0	46	0	48	63	12	0	1	22	0
R 338 (35,10 – 40,10)	0.04	1.07	14.6	74.1	0.01	3.97	0.02	0.32	0.00	1.81	0	48	0	49	67	9	0	5	23	0
R 339 (19,40 – 23,60)	0.05	1.14	14.3	74.3	0.01	4.17	0.03	0.30	0.01	1.96	0	46	0	54	67	10	0	5	19	2
R 339 (23,60 – 27,65)	0.07	1.17	14.4	74.4	0.02	4.22	0.05	0.32	0.01	2.04	0	44	0	61	68	4	0	0	21	1
R 339 (27,65 – 31,65)	0.04	1.03	14.9	74.7	0.01	3.88	0.04	0.30	0.00	1.78	0	42	0	46	62	12	0	3	23	0
R 339 (31,65 – 35,60)	0.04	1.06	14.6	74.5	0.01	4.07	0.02	0.31	0.00	1.85	0	42	0	45	72	15	0	0	20	0
R 339 (35,60 – 40,50)	0.04	1.13	14.8	73.8	0.01	4.23	0.02	0.32	0.01	1.90	0	60	0	51	64	9	0	2	23	0
R 340 (18,90 – 24,10)	0.04	1.02	15.0	73.9	0.01	3.73	0.02	0.32	0.00	1.86	0	35	0	54	69	7	0	0	21	0
R 340 (24,10 – 28,20)	0.05	1.14	13.2	75.7	0.02	4.08	0.03	0.32	0.00	2.08	0	46	0	48	79	6	0	0	20	0
R 340 (28,20 – 31,60)	0.04	1.19	15.3	72.6	0.00	4.17	0.02	0.36	0.00	2.10	0	50	0	55	71	13	0	0	21	0
R 340 (31,60 – 36,60)	0.03	1.16	12.4	77.2	0.01	3.78	0.03	0.28	0.00	1.95	0	46	0	52	60	6	0	0	21	0
R 340 (36,60 – 40,60)	0.04	1.18	12.5	77.2	0.01	3.71	0.05	0.37	0.01	1.99	0	44	0	64	55	12	0	5	19	0
R 340 (40,60 – 44,60)	0.02	1.10	14.0	74.8	0.01	3.54	0.03	0.33	0.01	1.88	0	48	0	55	42	5	0	0	19	0
R 340 (44,60 – 50,60)	0.04	1.04	12.6	77.2	0.01	3.77	0.04	0.31	0.00	1.95	0	46	0	65	47	7	0	3	19	1
R 341 (17,50 – 21,60)	0.03	0.87	13.7	76.6	0.01	2.97	0.04	0.31	0.01	1.72	0	42	0	63	61	12	0	12	22	2

Appendix 5.3 continued

SAMPLE	Na2O %	MgO %	Al2O3 %	SiO2 %	P2O5 %	K2O %	CaO %	TiO2 %	MnO %	Fe2O3 %	S %	Cl ppm	Sc ppm	V ppm	Cr ppm	Ni ppm	Cu ppm	Zn ppm	Ga ppm	As ppm
R 341 (21,60 – 25,35)	0.03	0.71	14.8	75.4	0.01	2.78	0.03	0.35	0.00	1.73	0	46	0	76	75	1	0	5	20	0
R 341 (25,35 – 29,80)	0.03	0.77	16.2	72.7	0.02	3.05	0.02	0.39	0.01	2.22	0	50	0	89	77	9	0	4	24	1
R 341 (29,80 – 35,60)	0.02	0.68	15.5	74.4	0.01	2.75	0.02	0.39	0.01	2.22	0	44	0	75	69	19	0	0	24	1
R 342 (35,60 – 41,60)	0.00	0.40	15.4	74.2	0.03	0.99	0.07	0.46	0.01	3.87	0	28	0	84	67	23	0	0	21	2
R 341 (41,60 – 48,60)	0.00	4.66	17.3	66.8	0.02	0.61	0.06	0.45	0.01	4.49	0	30	1	80	59	44	0	0	26	1
R 341 (48,60 – 52,60)	0.03	0.76	15.4	74.3	0.01	2.64	0.04	0.39	0.01	2.14	0	53	0	71	62	8	0	2	23	1
R 342 (19,60 – 21,95)	7.18	1.06	18.0	61.7	0.01	0.22	0.18	0.96	0.02	9.65	0	70	13	118	136	102	0	3	26	1
R 342 (21,95 – 26,60)	9.65	0.12	18.5	58.3	0.01	0.24	0.10	0.83	0.01	12.10	0	180	0	123	68	17	0	2	22	9
R 342 (26,60 – 32,50)	7.43	2.17	17.8	58.9	0.02	1.04	0.15	1.01	0.01	11.20	0	280	6	129	124	62	6	7	25	0
R 342 (34,10 – 40,10)	3.12	5.21	15.8	59.4	0.02	2.72	0.35	0.93	0.01	9.67	0	260	14	152	165	118	0	4	26	2
R 343 (15,95 – 18,70)	0.04	0.61	8.9	85.5	0.02	2.18	0.03	0.12	0.02	0.70	0	41	0	19	30	7	0	0	18	0
R 343 (22,10 – 25,80)	0.05	0.83	9.9	82.9	0.01	2.97	0.04	0.15	0.02	0.84	0	45	0	23	36	6	0	0	18	2
R 343 (26,30 – 29,20)	0.03	0.82	10.0	82.4	0.03	2.97	0.01	0.13	0.02	0.86	0	43	0	22	30	13	0	0	17	2
R 343 (29,20 – 32,30)	0.04	0.87	10.9	81.5	0.01	3.09	0.01	0.14	0.02	0.74	0	38	0	28	28	9	0	0	15	0
R 343 (32,30 – 35,60)	0.04	0.86	10.3	82.2	0.02	3.02	0.02	0.13	0.02	0.90	0	47	0	24	39	11	1	1	18	0
R 343 (35,60 – 38,10)	0.05	0.65	7.4	87.0	0.01	2.10	0.11	0.09	0.02	0.86	0	70	0	26	36	14	2	2	14	0
R 344 (15,75 – 18,10)	0.01	0.44	8.4	86.5	0.01	1.47	0.02	0.10	0.01	0.77	0	41	0	26	28	7	3	11	18	0
R 344 (18,10 – 21,10)	0.02	0.79	12.0	80.1	0.01	2.84	0.02	0.15	0.01	0.87	0	33	0	25	25	7	0	0	16	0
R 344 (21,10 – 24,60)	0.02	0.69	9.8	83.5	0.01	2.52	0.02	0.14	0.01	0.81	0	36	0	28	30	4	0	0	13	1
R 344 (25,60 – 28,70)	0.01	0.66	10.3	83.3	0.01	2.27	0.03	0.12	0.01	0.71	0	59	0	22	31	4	0	2	13	0
R 344 (28,70 – 32,00)	0.01	0.56	10.1	83.7	0.01	1.87	0.03	0.12	0.01	0.76	0	60	0	22	31	7	0	3	20	0
R 344 (32,00 – 35,30)	0.01	0.39	5.5	90.5	0.01	1.31	0.03	0.06	0.01	0.56	0	51	0	13	31	8	2	0	13	2
R 345 (13,60 – 16,20)	0.07	1.16	14.1	73.7	0.03	4.16	0.05	0.49	0.01	3.24	0	59	0	62	84	14	0	12	22	0
R 345 (16,70 – 20,60)	0.05	1.24	12.5	76.3	0.01	4.60	0.02	0.32	0.01	2.13	0	55	0	62	68	11	0	24	16	1
R 345 (20,60 – 24,00)	0.05	1.23	12.9	75.7	0.01	4.55	0.02	0.30	0.01	2.07	0	57	0	54	63	11	20	0	18	1
R 345 (24,00 – 25,35)	0.11	1.46	14.9	71.2	0.01	5.34	0.06	0.58	0.01	2.76	0	52	4	59	104	20	2	6	23	3
R 345 (31,10 – 33,00)	0.01	0.65	13.7	78.2	0.01	2.32	0.02	0.19	0.01	1.11	0	49	0	34	45	7	0	1	16	0
R 345 (33,00 – 33,70)	0.01	0.64	13.9	77.5	0.01	2.34	0.02	0.20	0.01	1.47	0	42	0	41	50	6	0	8	18	0
R 345 (33,70 – 36,10)	0.01	0.66	11.3	81.7	0.00	2.33	0.02	0.15	0.01	0.78	0	38	0	36	37	12	0	1	16	0
R 345 (36,10 – 39,10)	0.00	0.42	7.7	87.7	0.00	1.49	0.02	0.08	0.00	0.51	0	39	0	18	27	5	0	4	14	0
R 346 (17,15 – 20,25)	0.04	4.11	23.1	57.9	0.02	0.62	0.06	1.14	0.01	7.85	0	53	14	180	169	89	0	13	32	3
R 346 (24,40 – 28,60)	0.00	7.75	27.6	50.3	0.04	0.03	0.04	1.37	0.00	7.75	0	42	22	183	201	151	0	11	39	4
R 346 (28,60 – 33,10)	0.00	5.21	26.1	52.5	0.03	0.06	0.04	1.35	0.01	12.10	0	38	27	202	212	106	0	7	37	3
R 346 (33,10 – 37,10)	0.00	2.68	26.8	53.6	0.03	0.16	0.04	1.38	0.00	10.30	0	33	23	197	176	97	6	2	40	1

Appendix 5.3 continued

SAMPLE	Na2O %	MgO %	Al2O3 %	SiO2 %	P2O5 %	K2O %	CaO %	TiO2 %	MnO %	Fe2O3 %	S %	Cl ppm	Sc ppm	V ppm	Cr ppm	Ni ppm	Cu ppm	Zn ppm	Ga ppm	As ppm
R 346 (37,10 – 41,60)	0.00	4.47	27.4	50.5	0.02	0.03	0.05	1.42	0.00	11.10	0	33	28	228	202	97	0	0	40	0
R 346 (41,60 – 46,60)	0.00	0.42	18.7	70.9	0.02	1.16	0.04	0.57	0.00	2.76	0	30	7	98	79	21	0	3	30	1
R 346 (46,60 – 50,60)	0.02	0.73	15.6	74.7	0.01	2.81	0.03	0.39	0.00	1.55	0	50	0	86	63	12	1	0	22	1
R 347 (16,60 – 20,90)	0.07	5.49	14.3	67.2	0.03	2.78	1.22	0.65	0.05	4.86	0	60	5	114	105	122	4	11	20	2
R 347 (20,90 – 25,10)	0.00	6.28	15.0	68.4	0.01	2.37	0.14	0.48	0.03	2.46	0	58	0	68	65	88	9	19	20	2
R 347 (27,10 – 31,00)	0.00	5.69	13.4	72.2	0.01	2.24	0.07	0.31	0.01	1.83	0	52	0	64	59	38	0	2	21	0
R 347 (31,00 – 34,10)	0.00	5.74	14.6	67.7	0.02	2.10	0.14	0.55	0.02	4.34	0	49	5	109	89	99	0	10	25	1
R 347 (34,10 – 38,80)	0.41	5.09	17.6	62.9	0.01	1.87	0.16	0.82	0.01	7.38	0	53	12	116	138	96	0	0	28	3
R 347 (38,80 – 42,80)	0.47	6.83	16.1	60.6	0.01	3.21	0.11	0.87	0.01	9.96	0	130	7	132	151	97	0	14	27	5
R 347 (42,80 – 46,60)	1.27	6.09	15.3	65.6	0.01	4.01	0.09	0.71	0.01	5.50	0	130	3	120	125	68	0	2	24	0
R 347 (46,60 – 50,00)	1.99	3.82	13.5	73.1	0.01	2.66	0.10	0.41	0.01	2.57	0	120	0	83	76	42	0	8	19	0
R 348 (19,00 – 23,70)	5.67	4.66	11.8	70.6	0.03	0.38	0.55	0.31	0.01	3.84	0	120	0	31	67	40	0	7	13	0
R 348 (23,70 – 26,80)	6.39	4.89	12.5	69.8	0.04	0.24	0.57	0.32	0.01	3.46	0	110	0	32	57	48	2	5	19	0
R 348 (26,80 – 30,80)	6.41	4.85	12.5	69.8	0.03	0.24	0.57	0.33	0.01	3.46	0	42	0	37	57	68	4	5	21	1
R 348 (30,80 – 35,30)	6.58	5.79	12.6	70.8	0.01	0.07	0.11	0.31	0.01	1.79	0	80	0	40	57	74	0	3	26	0
R 348 (35,30 – 40,00)	0.30	8.05	9.5	67.2	0.03	0.13	2.28	0.31	0.03	6.11	0	60	7	86	75	210	0	12	14	3
R 349 (15,30 – 18,60)	6.31	8.30	12.4	67.2	0.06	0.18	0.44	0.36	0.01	2.76	0	130	0	35	53	43	0	5	23	1
R 349 (18,60 – 21,10)	5.23	13.90	11.1	62.8	0.11	0.09	0.43	0.34	0.01	3.64	0	200	1	41	63	36	0	6	15	4
R 350 (14,60 – 19,60)	0.03	0.77	13.2	78.0	0.01	2.82	0.03	0.33	0.01	1.49	0	42	0	52	44	5	3	0	22	0
R 350 (19,60 – 23,20)	0.03	0.85	12.9	78.3	0.01	3.11	0.03	0.35	0.01	1.60	0	53	0	61	65	9	1	5	21	2
R 350 (23,20 – 27,70)	0.03	0.80	14.1	76.4	0.01	3.17	0.03	0.33	0.01	1.60	0	55	0	55	63	12	0	5	19	1
R 350 (27,70 – 32,10)	0.04	0.80	14.4	75.9	0.01	3.29	0.03	0.30	0.00	1.54	0	35	0	54	54	7	0	6	19	3
R 350 (32,10 – 36,80)	0.03	0.77	14.3	76.1	0.01	3.44	0.03	0.28	0.00	1.38	0	49	0	61	56	12	0	0	21	1
R 350 (36,80 – 41,30)	0.04	1.66	14.1	75.0	0.01	3.68	0.04	0.37	0.01	1.48	0	46	0	71	70	25	0	0	25	3
R 350 (41,30 – 44,80)	0.28	3.40	15.6	67.4	0.01	4.87	0.05	0.66	0.01	4.90	0	70	1	82	123	55	0	2	21	0
R 351 (13,70 – 17,10)	0.13	2.05	13.9	74.5	0.01	3.77	0.07	0.29	0.01	1.50	0	60	0	53	50	17	0	7	23	1
R 351 (17,10 – 20,20)	0.08	1.90	13.1	75.4	0.01	4.09	0.06	0.28	0.01	1.93	0	60	0	62	62	25	0	2	21	3
R 351 (20,20 – 23,20)	0.58	2.39	13.4	74.4	0.01	3.49	0.09	0.30	0.01	2.31	0	70	0	69	68	29	1	4	21	0

Appendix 5.3 continued

SAMPLE	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Sn ppm	Sb ppm	Ba ppm	Su ppm	Ce ppm	Pb ppm	Bi ppm	Th ppm	U ppm	C %	LOI %	LOIX %
R 335 (16,40 – 20,70)	110	6	11	208	4	0	0	0	438	21	56	10	0	4	4	0.03	2.24	1.03
R 335 (20,70 – 23,55)	77	7	11	222	3	1	0	0	336	25	52	7	0	4	2	0.02	2.77	2.11
R 335 (23,55 – 25,25)	38	4	7	198	0	3	0	0	156	17	31	6	0	1	1	0.02	2.87	2.43
R 335 (25,25 – 30,10)	110	9	13	220	4	2	0	0	450	11	44	9	0	2	2	0.03	2.25	1.03
R 335 (30,70 – 33,80)	112	11	16	265	7	3	0	0	481	28	59	5	0	5	1	0.02	2.43	1.10
R 335 (33,80 – 35,00)	82	7	18	201	2	1	0	0	373	33	58	9	0	2	1	0.03	2.68	1.69
R 336 (16,00 – 20,50)	95	3	9	229	4	2	0	0	386	14	53	6	0	1	2	0.02	2.76	1.52
R 336 (20,50 – 25,10)	79	6	6	262	6	4	0	1	325	18	52	9	0	4	1	0.02	2.97	2.28
R 336 (25,10 – 30,20)	88	6	12	263	2	1	0	0	356	13	44	9	0	4	1	0.03	2.65	1.90
R 336 (30,20 – 35,20)	115	11	12	211	5	0	0	0	477	14	37	7	0	6	0	0.03	2.35	0.92
R 337 (15,50 – 18,00)	105	4	11	220	3	4	0	0	382	19	33	6	0	4	0	0.03	2.45	1.38
R 337 (18,00 – 23,10)	38	1	8	196	1	3	0	0	146	9	16	4	1	1	0	0.02	3.17	2.81
R 337 (23,10 – 28,15)	35	2	8	182	1	1	0	0	128	8	16	8	0	0	0	0.02	3.21	2.84
R 337 (28,15 – 33,80)	41	0	5	152	1	3	0	0	139	4	34	8	0	0	0	0.03	3.13	2.74
R 337 (33,80 – 36,30)	45	3	5	217	1	3	0	0	147	11	27	9	0	1	0	0.03	2.53	2.05
R 337 (36,30 – 40,00)	73	7	5	210	2	2	0	0	264	10	37	4	0	2	0	0.03	3.30	2.37
R 338 (19,85 – 21,80)	41	3	19	242	1	1	0	0	154	6	24	10	0	3	1	0.03	3.04	2.38
R 338 (21,80 – 26,80)	105	6	24	217	5	0	0	0	441	35	85	7	0	3	0	0.03	2.46	0.95
R 338 (26,80 – 31,10)	84	2	21	270	3	0	0	0	286	21	56	5	0	4	3	0.03	3.26	2.66
R 338 (31,10 – 35,10)	83	3	30	237	4	1	0	0	284	25	95	7	0	4	1	0.02	3.36	2.84
R 338 (35,10 – 40,10)	88	2	27	283	4	2	0	0	296	18	64	10	0	5	0	0.03	3.12	2.44
R 339 (19,40 – 23,60)	92	6	18	244	1	1	0	0	299	14	48	7	0	3	0	0.04	2.84	2.15
R 339 (23,60 – 27,65)	96	6	24	274	1	0	0	0	309	56	124	9	0	8	2	0.03	2.87	2.03
R 339 (27,65 – 31,65)	91	4	21	251	3	0	0	0	293	30	67	12	0	4	2	0.03	3.24	2.56
R 339 (31,65 – 35,60)	90	2	21	266	2	1	0	0	312	13	36	8	0	4	1	0.03	3.09	2.34
R 339 (35,60 – 40,50)	96	2	28	275	4	2	0	0	318	21	69	7	0	5	1	0.03	3.02	2.14
R 340 (18,90 – 24,10)	87	1	20	263	3	2	0	0	273	14	30	11	0	4	0	0.02	3.30	2.32
R 340 (24,10 – 28,20)	94	6	30	232	2	1	0	0	294	51	151	9	0	8	0	0.03	2.71	1.92
R 340 (28,20 – 31,60)	98	3	14	274	4	2	0	0	318	10	24	8	0	4	0	0.03	3.71	2.88
R 340 (31,60 – 36,60)	86	3	15	193	1	1	0	0	295	14	39	10	0	4	0	0.03	2.68	1.89
R 340 (36,60 – 40,60)	82	6	22	274	0	1	0	0	305	24	83	10	0	7	1	0.04	2.65	2.00
R 340 (40,60 – 44,60)	81	5	17	256	0	4	0	0	280	16	32	12	0	4	0	0.03	3.32	2.57
R 340 (44,60 – 50,60)	87	3	17	257	4	4	0	0	291	13	37	12	0	5	0	0.04	2.65	1.84
R 341 (17,50 – 21,60)	65	4	23	234	2	5	0	0	198	38	78	11	0	3	2	0.03	3.50	2.67

Appendix 5.3 continued

SAMPLE	Rb	Sr	Y	Zr	Nb	Mo	Sn	Sb	Ba	Su	Ce	Pb	Bi	Th	U	C	LOI	LOIX
	ppm	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*%*	*%*	*%*
R 341 (21,60 – 25,35)	57	1	20	266	0	0	0	0	190	29	68	9	0	4	0	0.02	3.86	3.21
R 341 (25,35 – 29,80)	64	3	18	264	0	5	0	4	207	20	72	15	0	4	0	0.02	4.23	3.04
R 341 (29,80 – 35,60)	62	5	19	270	0	5	0	0	178	17	65	8	0	5	0	0.02	4.28	3.17
R 341 (35,60 – 41,60)	21	0	25	292	5	6	0	0	77	21	69	12	1	4	0	0.03	5.29	4.97
R 341 (41,60 – 48,60)	18	0	22	283	2	3	0	0	47	14	50	14	4	3	0	0.03	6.71	5.87
R 341 (48,60 – 52,60)	53	3	20	276	1	5	0	0	192	17	68	10	0	5	0	0.02	4.23	3.85
R 342 (19,60 – 21,95)	12	9	54	214	6	0	0	0	39	27	75	16	2	1	1	0.02	3.45	3.21
R 342 (21,95 – 26,60)	8	3	22	196	5	2	0	0	17	26	47	6	5	3	0	0.02	1.08	1.03
R 342 (26,60 – 32,50)	31	4	35	197	8	1	0	0	58	28	49	16	4	5	2	0.02	2.70	2.28
R 342 (34,10 – 40,10)	76	10	44	193	6	1	0	0	139	42	59	16	4	4	0	0.03	4.49	3.38
R 343 (15,95 – 18,70)	47	8	11	161	0	5	0	3	208	16	42	11	0	1	0	0.03	1.98	1.65
R 343 (22,10 – 25,80)	70	7	14	222	2	2	0	0	270	19	46	6	0	4	1	0.03	1.84	0.97
R 343 (26,30 – 29,20)	70	6	13	185	0	4	0	0	289	26	43	8	0	2	1	0.02	1.87	0.94
R 343 (29,20 – 32,30)	71	5	7	219	0	1	0	0	270	15	34	4	0	4	0	0.03	2.13	1.43
R 343 (32,30 – 35,60)	70	2	12	177	0	5	0	0	238	9	66	8	0	3	0	0.02	2.01	1.29
R 343 (35,60 – 38,10)	48	6	7	122	0	4	0	0	158	14	41	4	0	1	2	0.04	1.44	1.06
R 344 (15,75 – 18,10)	35	2	15	137	0	3	0	0	101	23	45	6	0	0	0	0.03	2.20	1.91
R 344 (18,10 – 21,10)	66	3	15	174	0	2	0	0	167	24	39	5	0	1	0	0.02	2.63	2.12
R 344 (21,10 – 24,60)	58	6	11	181	0	7	0	0	163	28	45	7	0	2	0	0.03	2.06	1.61
R 344 (25,60 – 28,70)	53	3	16	173	1	2	0	0	141	27	34	8	0	1	1	0.03	2.37	1.94
R 344 (28,70 – 32,00)	42	1	20	179	1	3	0	0	121	24	50	7	0	1	1	0.02	2.55	2.07
R 344 (32,00 – 35,30)	30	4	12	88	0	0	0	0	82	28	51	1	0	4	0	0.02	1.18	0.97
R 345 (13,60 – 16,20)	98	11	25	231	4	1	0	0	441	57	110	10	0	3	2	0.03	2.75	2.04
R 345 (16,70 – 20,60)	100	5	22	220	2	0	0	0	397	35	88	11	0	4	0	0.02	2.01	1.18
R 345 (20,60 – 24,00)	105	3	19	196	4	1	0	0	384	22	52	4	0	3	2	0.03	2.24	1.52
R 345 (24,00 – 25,35)	124	8	16	211	5	1	0	0	484	28	84	12	0	9	1	0.03	2.47	1.65
R 345 (31,10 – 33,00)	53	2	11	254	2	0	0	0	187	13	37	9	0	5	0	0.03	3.65	3.47
R 345 (33,00 – 33,70)	53	1	11	167	4	3	0	0	185	10	24	11	0	1	1	0.03	3.45	3.05
R 345 (33,70 – 36,10)	52	1	10	219	1	1	0	0	180	15	30	12	0	2	0	0.02	2.51	2.04
R 345 (36,10 – 39,10)	32	0	8	120	0	2	0	0	117	12	32	8	0	2	0	0.03	1.80	1.51
R 346 (17,15 – 20,25)	20	2	25	323	7	2	0	0	77	34	91	11	0	8	0	0.05	8.12	6.97
R 346 (24,40 – 28,60)	4	2	50	300	12	0	0	0	19	108	235	13	0	16	1	0.02	10.60	9.09
R 346 (28,60 – 33,10)	3	2	49	284	9	0	0	0	18	52	136	11	4	8	1	0.03	9.38	8.36
R 346 (33,10 – 37,10)	6	1	44	316	14	0	0	0	18	48	103	10	0	7	3	0.02	9.45	8.73

Appendix 5.3 continued

SAMPLE	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Sn ppm	Sb ppm	Ba ppm	Su ppm	Ce ppm	Pb ppm	Bi ppm	Th ppm	U ppm	C %	LOI %	LOIX %
R 346 (37,10 – 41,60)	5	2	37	299	13	0	0	0	19	64	121	13	0	12	4	0.02	10.00	9.26
R 346 (41,60 – 46,60)	28	3	31	314	4	5	0	0	103	46	97	11	1	7	1	0.02	6.28	6.00
R 346 (46,60 – 50,60)	59	2	23	260	1	3	0	1	222	8	56	8	0	7	0	0.02	4.00	3.57
R 347 (16,60 – 20,90)	88	17	24	197	1	4	0	0	248	34	79	11	1	7	0	0.05	3.98	3.39
R 347 (20,90 – 25,10)	69	4	21	255	0	5	0	0	222	28	55	9	0	5	0	0.02	5.07	4.34
R 347 (27,10 – 31,00)	67	2	19	201	0	0	0	0	171	15	38	11	0	2	1	0.03	4.39	3.82
R 347 (31,00 – 34,10)	72	1	17	197	1	1	0	0	126	22	42	10	2	4	3	0.02	5.38	4.68
R 347 (34,10 – 38,80)	71	5	30	188	2	2	0	0	72	15	69	8	5	4	2	0.02	6.22	5.50
R 347 (38,80 – 42,80)	99	3	26	207	3	4	0	0	205	28	67	4	9	5	0	0.02	4.61	3.73
R 347 (42,80 – 46,60)	104	4	9	173	0	5	0	0	302	11	57	14	4	4	0	0.02	3.07	2.21
R 347 (46,60 – 50,00)	67	7	14	210	1	3	0	0	228	39	87	10	3	2	0	0.02	2.54	1.95
R 348 (19,00 – 23,70)	23	13	21	194	0	4	0	0	29	29	42	12	3	3	0	0.02	2.29	1.59
R 348 (23,70 – 26,80)	17	10	20	198	2	1	0	0	18	14	41	12	0	5	1	0.03	1.93	1.23
R 348 (26,80 – 30,80)	5	10	10	188	4	3	0	0	16	23	48	12	3	4	0	0.02	1.79	0.93
R 348 (30,80 – 35,30)	8	10	9	234	0	1	0	0	20	20	36	14	1	4	0	0.02	1.57	0.99
R 348 (35,30 – 40,00)	12	6	31	135	0	4	0	0	40	17	78	3	0	4	0	0.03	6.27	5.28
R 349 (15,30 – 18,60)	11	13	28	193	3	6	0	0	28	46	102	10	3	2	0	0.02	2.27	0.95
R 349 (18,60 – 21,10)	3	8	30	178	1	1	0	0	25	62	115	8	3	4	0	0.02	3.47	1.30
R 350 (14,60 – 19,60)	64	5	29	255	3	2	0	0	192	27	54	9	0	3	1	0.04	3.13	2.59
R 350 (19,60 – 23,20)	66	5	26	274	3	4	0	0	223	40	84	11	0	3	0	0.04	2.88	2.26
R 350 (23,20 – 27,70)	75	2	20	259	3	3	0	0	214	25	48	8	0	4	0	0.03	3.30	2.69
R 350 (27,70 – 32,10)	71	6	26	238	0	1	0	0	228	31	62	10	0	3	0	0.02	3.35	2.74
R 350 (32,10 – 36,80)	76	5	27	271	3	0	0	0	259	19	61	7	0	4	0	0.02	3.37	2.87
R 350 (36,80 – 41,30)	80	5	31	237	0	0	0	0	284	21	67	6	0	2	1	0.03	3.33	2.68
R 350 (41,30 – 44,80)	118	7	27	219	3	0	0	0	376	25	67	6	0	1	0	0.02	3.27	2.36
R 351 (13,70 – 17,10)	88	6	31	243	2	1	0	0	257	25	53	9	0	2	0	0.02	3.18	2.43
R 351 (17,10 – 20,20)	98	9	29	265	2	3	0	0	286	19	64	7	0	0	0	0.02	2.92	2.13
R 351 (20,20 – 23,20)	88	5	29	229	2	6	0	0	216	22	64	9	0	2	0	0.02	3.10	2.57

Appendix 6. Brightness and yellowness values of <20 microns kaolin samples.

SAMPLE	brightness %	yellowness %
R 335 (16,40 – 20,70)	51.5	35.3
R 335 (20,70 – 23,55)	63.3	25.1
R 335 (23,55 – 25,25)	80.2	8.6
R 335 (25,25 – 30,10)	59.3	26.8
R 335 (30,70 – 33,80)	59.2	24
R 335 (33,80 – 35,00)	71.9	14.8
R 336 (16,00 – 20,50)	69.7	14.4
R 336 (20,50 – 25,10)	75.5	11
R 336 (25,10 – 30,20)	75.8	10
R 336 (30,20 – 35,20)	67.3	15.7
R 337 (15,50 – 18,00)	60.8	25
R 337 (18,00 – 23,10)	82.4	7.3
R 337 (23,10 – 28,15)	81.9	7.7
R 337 (28,15 – 33,80)	82.7	7.3
R 337 (33,80 – 36,30)	73.7	14.7
R 337 (36,30 – 40,00)	81.8	7.1
R 338 (19,85 – 21,80)	78.1	8.2
R 338 (21,80 – 26,80)	62.8	16.6
R 338 (26,80 – 31,10)	80.1	7.5
R 338 (31,10 – 35,10)	80.7	7.4
R 338 (35,10 – 40,10)	80	8.3
R 339 (19,40 – 23,60)	77	9.8
R 339 (23,60 – 27,65)	74	11.6
R 339 (27,65 – 31,65)	80.3	7.8
R 339 (31,65 – 35,60)	80.4	7.3
R 339 (35,60 – 40,50)	77.7	9.2
R 340 (18,90 – 24,10)	77.3	10.3
R 340 (24,10 – 28,20)	72.1	14.4
R 340 (28,20 – 31,60)	75.6	11.8
R 340 (31,60 – 36,60)	73.5	13.4
R 340 (36,60 – 40,60)	64.8	22.7
R 340 (40,60 – 44,60)	73.2	13.6
R 340 (44,60 – 50,60)	71.8	14.6
R 341 (17,50 – 21,60)	69	16
R 341 (21,60 – 25,35)	63.5	21.8
R 341 (25,35 – 29,80)	54.4	34
R 341 (29,80 – 35,60)	58.7	27.4
R 341 (35,60 – 41,60)	45.7	42.2
R 341 (41,60 – 48,60)	43.7	44.1
R 341 (48,60 – 52,60)	59.9	25.5
R 342 (19,60 – 21,95)	51	21.9
R 342 (21,95 – 26,60)	45.7	21.7
R 342 (26,60 – 32,50)	37.3	31.7
R 342 (34,10 – 40,10)	35.9	26
R 343 (15,95 – 18,70)	65.4	20.4
R 343 (22,10 – 25,80)	63.7	21.8
R 343 (26,30 – 29,20)	60	26.9
R 343 (29,20 – 32,30)	60.7	25.1
R 343 (32,30 – 35,60)	53.2	36.3
R 343 (35,60 – 38,10)	58.5	28.9

SAMPLE	brightness %	yellowness %
R 344 (15,75 – 18,10)	52.3	36.6
R 344 (18,10 – 21,10)	68.3	19
R 344 (21,10 – 24,60)	68.9	18.6
R 344 (25,60 – 28,70)	69	18.5
R 344 (28,70 – 32,00)	56.8	28.3
R 344 (32,00 – 35,30)	55.8	30.8
R 345 (13,60 – 16,20)	60.6	16.3
R 345 (16,70 – 20,60)	70.3	16.1
R 345 (20,60 – 24,00)	76.9	9.5
R 345 (24,00 – 25,35)	68.1	13.7
R 345 (31,10 – 33,00)	75.5	13.9
R 345 (33,00 – 33,70)	51.3	40.3
R 345 (33,70 – 36,10)	81.2	8.1
R 345 (36,10 – 39,10)	84.6	5.2
R 346 (17,15 – 20,25)	59.4	13.1
R 346 (24,40 – 28,60)	58.6	8
R 346 (28,60 – 33,10)	61	7.7
R 346 (33,10 – 37,10)	61.9	9.1
R 346 (37,10 – 41,60)	59.6	9.8
R 346 (41,60 – 46,60)	58.7	23.7
R 346 (46,60 – 50,60)	70.9	17.5
R 347 (16,60 – 20,90)	36.9	43.8
R 347 (20,90 – 25,10)	45.2	36.9
R 347 (27,10 – 31,00)	51.8	34.7
R 347 (31,00 – 34,10)	42.8	38.3
R 347 (34,10 – 38,80)	53.4	20.4
R 347 (38,80 – 42,80)	53.3	16.2
R 347 (42,80 – 46,60)	63.9	10.5
R 347 (46,60 – 50,00)	58.4	18.7
R 348 (19,00 – 23,70)	34.3	37
R 348 (23,70 – 26,80)	----	----
R 348 (26,80 – 30,80)	49.5	29.9
R 348 (30,80 – 35,30)	46.9	35.3
R 348 (35,30 – 40,00)	21.7	71.4
R 349 (15,30 – 18,60)	42.5	33.8
R 349 (18,60 – 21,10)	47	26.7
R 350 (14,60 – 19,60)	76.9	10.5
R 350 (19,60 – 23,20)	78.5	8.5
R 350 (23,20 – 27,70)	75.3	11.9
R 350 (27,70 – 32,10)	76.5	10.5
R 350 (32,10 – 36,80)	73	13.1
R 350 (36,80 – 41,30)	72.6	12
R 350 (41,30 – 44,80)	53.9	17.4
R 351 (13,70 – 17,10)	74.8	10.7
R 351 (17,10 – 20,20)	63.6	17.6
R 351 (20,20 – 23,20)	60.3	18.1