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Investigation of talc from 1997 drill-cores from the Nakkan deposit, Altermark, northern Norway

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

Geological Survey of Norway
P.O.Box 3006 - Lade
N-7002 Trondheim, Norway
Tel.: 47 73 90 40 11
Telefax 47 73 92 16 20

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Title:
Investigation of talc from 1997-drillcores from the Nakkan deposit, Altermark, northern Norway

Authors: Tor Arne Karlsen		Client: Norwegian Talc Altermark AS	
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Summary:
As a part of the development of the Nakkan deposit in Altermark a study focused on mineralogy has been carried out. Detailed field inspections of drill cores from 1997 and 1998 are described. The inspection shows that zones contaminated by amphibole are very few and small. XRD, XRF and microscopic analyses were carried out from selected samples from the 1997-drill cores. Microprobe analyses have been carried out on selected samples from the talc mine, Store Esjeklumpen and the Nakkan deposits, with specific attention to the Ni-content in the talc-lattice. From this study it seems clear that there are large variations in the Ni-content of talc, both within samples and between samples. Image analyses have been carried out on a considerable number of samples, in order to achieve more accurate data on the content of magnetite. It seems quite clear that the magnetite content is much lower than previously indicated by the method based on removal of magnetic matter. From the XRF-chemical analyses, a method is described and used to estimate the mineral content of the samples. No clear differences are found regarding the content of talc, breunnerite and chlorite. But unfortunately, very few samples from the mine have been investigated, and more samples are urgently needed in order to make reliable conclusions.

Keywords: Industrimineraler	Hvithet	Røntgenfluorescens
Talk	Røntgendiffraksjon	Kvalitetsundersøkelse
Karbonat	Ultramafisk bergart	Fagrapport

Contents

1. INTRODUCTION

As a part of the development of the Nakkan deposit, the major talc zones from the 1997- and 1998-drilling have been investigated by detailed drill core inspection. The samples from 1997 have been analyses chemically and mineralogically. 21 samples from central parts of the ore have been studied chemically and mineralogically. A major concern, due to environmental rules, is the possible existence of fibrous/asbestiform minerals. Another concern is the mineralogical composition of the ore, as this is of primary importance when discussing possible products. Chemical analyses have been performed in order to add knowledge to the composition of the crude ore.
From the present work it is suggested that more effort should be made to 1) characterise the mineralogy of the crude ore and processed material, and 2) to develop possible products by further processing tests. In addition to the 21 samples from the 1997 –drilling, older samples from 1990,1991,1992 and 1996 have been studied to solve specific tasks.

2. PREVIOUS WORK

The mineralogy and/or geochemistry of the talc deposits in Altermark has been investigated by Karlsen (1995, 1996, 1997, 1998 and 1999). The previous studies have shown that the talc-carbonate ore has the following approximate content: talc (45-60 vol%) + carbonates (40-50 vol%) + chlorite (1-3 vol%) + magnetite/ferrit-chromite (0-3 vol%) ± sulphide (0-0.5 vol%). Tremolite and anthophyllite are usually absent in the ore, but occur locally in distinct zones in the talc-carbonate rock. Antigorite is present close to serpentinitic cores. Sulphides are present in very small amounts (<0.5%) and are dominated by pyrite, pyrrhotite and pentlandite. The carbonates are commonly chemically zoned breunnerites with an increasing $FeCO_3$ - content from core towards rim (up to about 21 mole%). Sometimes, the $FeCO_3$-content in the core is less than 5 mole% (~2.1 wt% FeO) and the carbonate may be termed magnesite. Dolomite is present locally in subordinate amounts. Microprobe analyses (Karlsen 1995) indicate that the talc crystals carry 0-4 wt% FeO (total) and 0-0.3 wt% NiO in their lattices. Two types of magnetite occur: a) chemically zoned large grains with cores of chromites or altered chromites; and b) small unzoned pure magnetite grains. Chlorite occurs with a wide range of compositions, the most common being clinochlore. The chlorite in the talc-carbonate rock may carry up to about 3 wt% Cr_2O_3 and 0.15 wt% NiO in the lattice.
Measurements carried out by Norwegian Talc AS show that the ore has a rather high whiteness after magnetic separation (see for example Karlsen 1997). A problem has been that quite a lot of magnetic matter has been removed. The content of magnetic portion indicate that the magnetite content is highest in samples from Nakkan, lower in samples from the mine and lowest in samples from Store Esjeklumpen. In some cases very high values have been achieved from the Nakkan deposit.
Processing tests have been done by Tavakkoli (1998, 1999) on samples from Store Esjeklumpen, from Nakkan, and from the Altermark talc mine, respectively. The tests have proved that high quality talc-concentrates can be produced from the Altermarc talc. Also, one flotation test was carried out by Finnminerals Oy. Chemical studies of beneficiation material from Nakkan and from the mine have been performed by Karlsen (1998) and Karlsen (1999), respectively.
In the development of the Nakkan deposit, it is important to understand the mineralogy of the deposits, and its variations. Differences in mineralogy between and within the deposits could lead to different talc-products, or to different beneficiation properties of the ore.

3. SCOPE OF INVESTIGATION

In the present work, six mineralogical aspects are discussed:

1. Content of amphibole
   - the presence of amphibole is in general negative for the ore, and because of its often fibrous habitus, its occurrence needs to be mapped. Thin section studies are made to ensure that the conclusions made by visual drill core inspection are correct.
   - Method: careful drill-core inspection, thin section studies, XRD.

2. Content of serpentine
   - the talc-carbonate-veins that cross-cut the serpentinite core often carry serpentine, and in some cases it is difficult from visual inspection of drill cores alone to classify the rock, i.e. whether it can be termed "ore" or not.
   - Method: thin section studies, XRD.

3. Content of Fe-chromite/magnetite
   - Measurment of magnetic matter (see e.g. Karlsen 1995, 1997) generally gives highest values for the Nakkan-deposit, lower for the mine, and lowest for the Store Esjeklumpen-deposit. It is easy to regard the magnetic matter as being synonymous with content of magnetite. Too high values of magnetite will lead to lower recovery of the ore. It is therefore of critical importance to check (1) the content of Fe-chromite/magnetite, and 2) if the content measured by removal of the magnetic portions gives approximately the same results.
   - Method: thin section studies, digital image analyses.

4. Contents and types of sulphides
   - Mondo talc, Finland, makes a Ni-product out of the sulphides from the talc-carbonate-ore. The type of ore is different, as the Finnish talc rock is sulphide-rich and magnetite poor, while the Altermark talc rock is sulphide-poor and magnetite rich. A study of the sulphides has been made to get more insight into the content of such minerals.
   - Method: thin section studies, microprobe analyses.

5. Ni in the talc lattice
   - Analyses of products from beneficiation tests indicate some differences in the Ni-content in the final products between those from Altermark talc mine and those from the Nakkan deposit (Karlsen 1999). A preliminary microprobe study has been made on samples from the two deposits, as well as the Store Esjeklumpen deposit, to get more insight into the Ni-content in the crystal lattice of talc.
   - Method: Microprobe analyses.

6. Calculation of mineralogical content from chemical data
   - Since the amount of the different minerals present in the samples is time-consuming to estimate, a method that calculate the mineralogical content from chemical data was developed by Karlsen (1998). All chemical data collected from Altermark have been included in the present calculation. The reliability of such a method is however not always good; this is discussed.

4. GEOLOGICAL SETTING

The Altermark area is situated about 20 km west of Mo i Rana, Northern Norway (Fig. 1). The rocks belong to the Rödingsfjället Nappe Complex (Gustavson & Gjelle 1991) of the Uppermost Allochthon (Roberts & Gee 1985), which lies upon Precambrian basement visible in the Høgtuva window just west of Altermark. All the nappes in the area have been folded by a major fold structure termed the Sletteffjellet Fold. This structure is, in addition to the schistosity, the most distinct geological structures in the area.
In Altermark, the Rödingsfjället Nappe Complex consists of three units: the Tjørnrasta Nappe, the Straumbotn Nappe (Søvegjarto et al. 1988) and the Slettefjellet Unit (Karlsen 1995). The Tjørnrasta Nappe is dominated by quartzofeldspatic gneisses and quartz-rich mica schists while the Straumbotn Nappe is dominated by kyanite-staurolite bearing garnet-mica schists, marbles, amphibolites, and lenses of ultramafites. Geothermobarometric investigations indicate that all the rocks were metamorphosed at around 640°C at 7-10 Kb pressure (Karlsen 1995).
The ultramafic lenses (Fig. 2) are compositionally zoned. The compositional zoning is a result of two kinds of alteration-processes (Fig. 3): 1) Serpentinisation, 2) Talc-carbonate formation (or "steatitisation").

During serpentinisation original rocks like dunite, peridotite and harzburgite are altered to serpentinite. In Altermark, the serpentinite contains the serpentine species antigorite as the primary mineral. Magnetite is also a product of serpentinisation and occurs widespread within the serpentinite. During the process of talc-carbonate formation, antigorite is broken down and talc and carbonate are formed. Also magnetite is broken down and consumed by the carbonates and talc, but this breakdown takes place much slower than the antigorite breakdown. This has consequences for the content of magnetite in the ore, and will be further treated in this report. During the processes described above, several other rocks that are monomineralic (including talc-schist) are formed at the contact between the ultramafites and the surrounding country rocks.

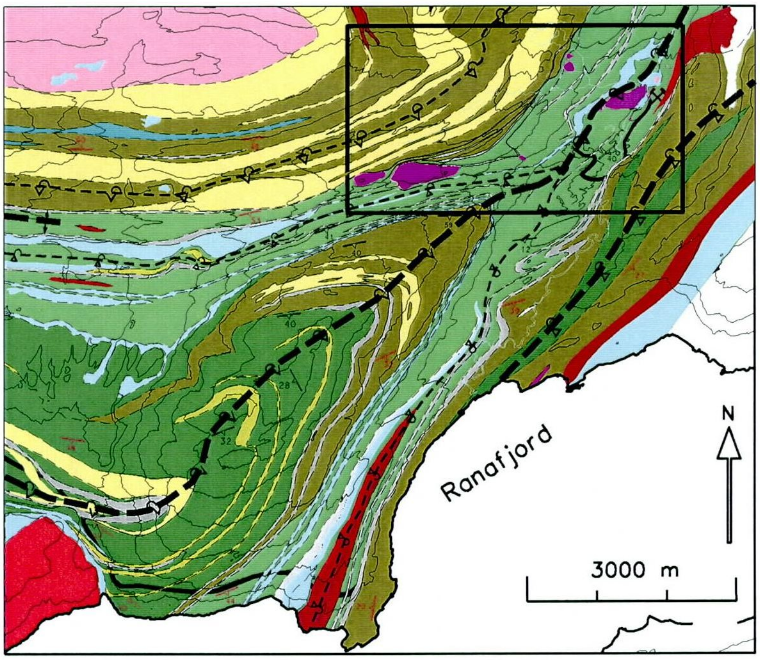

Figure 1: Geological map showing the general geological settings with the Slettefjellet fold (axial trace is shown with black streak from lower left to upper right). The ultramafites (violet colours uccur as lenses in the Straumbotn Nappe (light green coloured). The whole sequence of nappes lie on to of Precambrian basement (light read in the upper left). The boxed area is shown in Fig. 2.

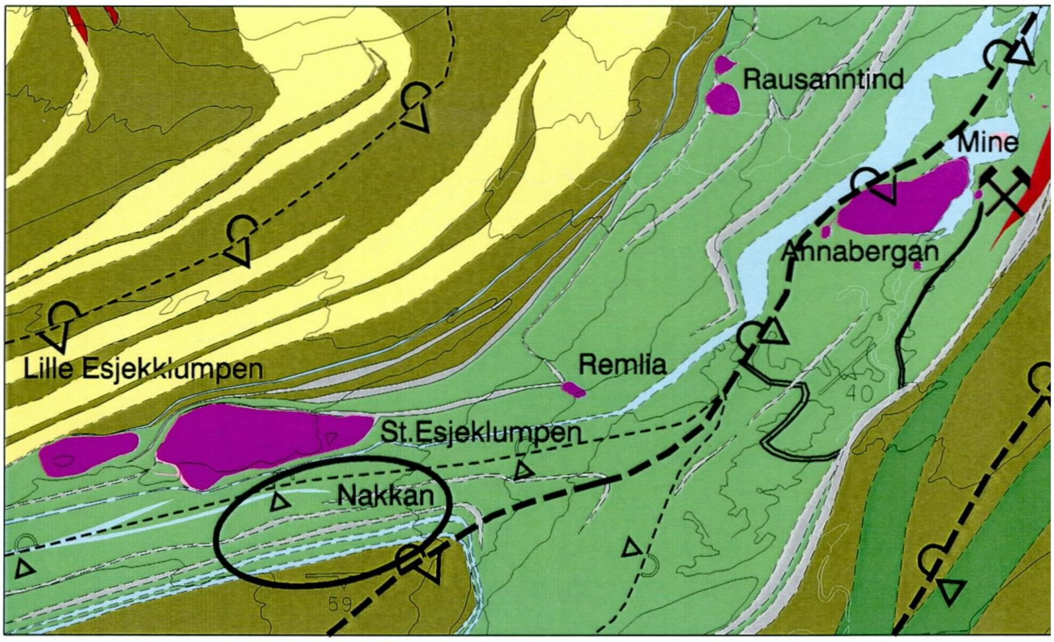

Figure 2: Names and occurrences of the ultramafic lenses in Altermark.

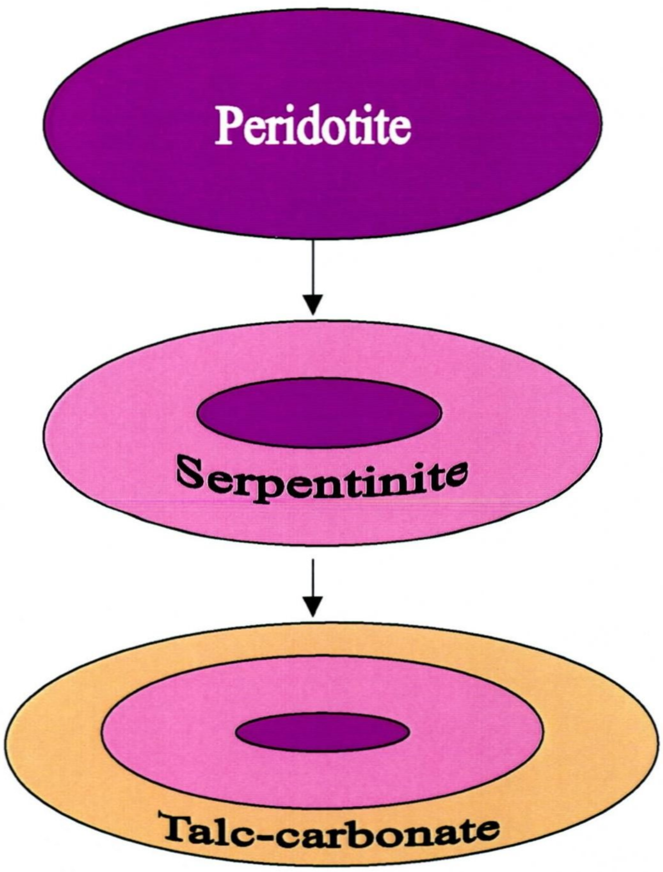

Figure 3: The ultramafites in Altermark are compositionally zoned due to the processes of serpentinisation and talc-carbonate formation.

5. DRILL CORE FIELD-INSPECTION

In order to ensure if the quality of the talc-carbonate in the Nakkan deposit is good enough for economic exploitation, drill core inspection has been carried out on the drill cores from 1997 and 1998.

Drill-cores from 1997:
The quality seemed to be good and no amphibole was encountered in the talc-carbonate ore intersections (Fig. 4, Appendix 1). The purity of the ore has been confirmed by thin section analyses, XRD and/or XRF analyses (presented later in the report). Also, the thin section analyses of talc-carbonate-serpentine rocks termed "possible ore" during drill core inspection, indicate that the serpentine content is rather low (0 - 10%) and that they might be defined as "ore" if a low content of serpentine is accepted in the product or if it proves possible to remove the serpentine during processing.

Drill-cores from 1998:
The good impression from the 1997-drill-cores was followed up by the 1998 drill-cores (Fig. 5, Appendix 2); in general the ore seems to be of good quality. However, one 2.3 m thick zone in drill-hole NAK9812 contains 5 – 20 vol% fibrous amphibole within the 276.00 – 278.30 m interval. The amphibole-type is anthophyllite, and is weakly reddish in colour.

6. INVESTIGATED SAMPLES

Samples studied in details have been taken primarily from the drill cores drilled in 1997 (Table 1). The samples have been studied by microscopy, XRD, XRF, and/or image analyses. In addition, samples from 1991/1992 (Nakkan, Store Esjeklumpen & Altermark talc mine) and 1996 (Nakkan) have been investigated to achieve more data on the content of magnetite in the ore and Ni in the lattice of talc-crystals.

7. XRD-ANALYSES

The XRD analyses (Table 2) first of all give an indication on the main minerals presented in the sample, and these are of little use in detailed investigation. However, the analyses show that talc, carbonate (magnesite/breunnerite) and chlorite (mostly clinochlore) are the main constituents of the ore, as expected. The following conclusions can be drawn from the XRD-analyses:

1. Talc and carbonate are the main constituents of the samples, followed by chlorite.
2. Chlorite is usually of the type clinochlore.
3. The carbonate is in most cases magnesite/breunnerite.
4. dolomite is present in sample 7 & 8.
5. serpentine might be present in samples 1, 2, 3, 4, 6, 11.
6. magnetite is hard to detect due to low concentrations, but is indicated in samples 2, 3 & 4.
7. Amphiboles have not been detected in registerable amounts.

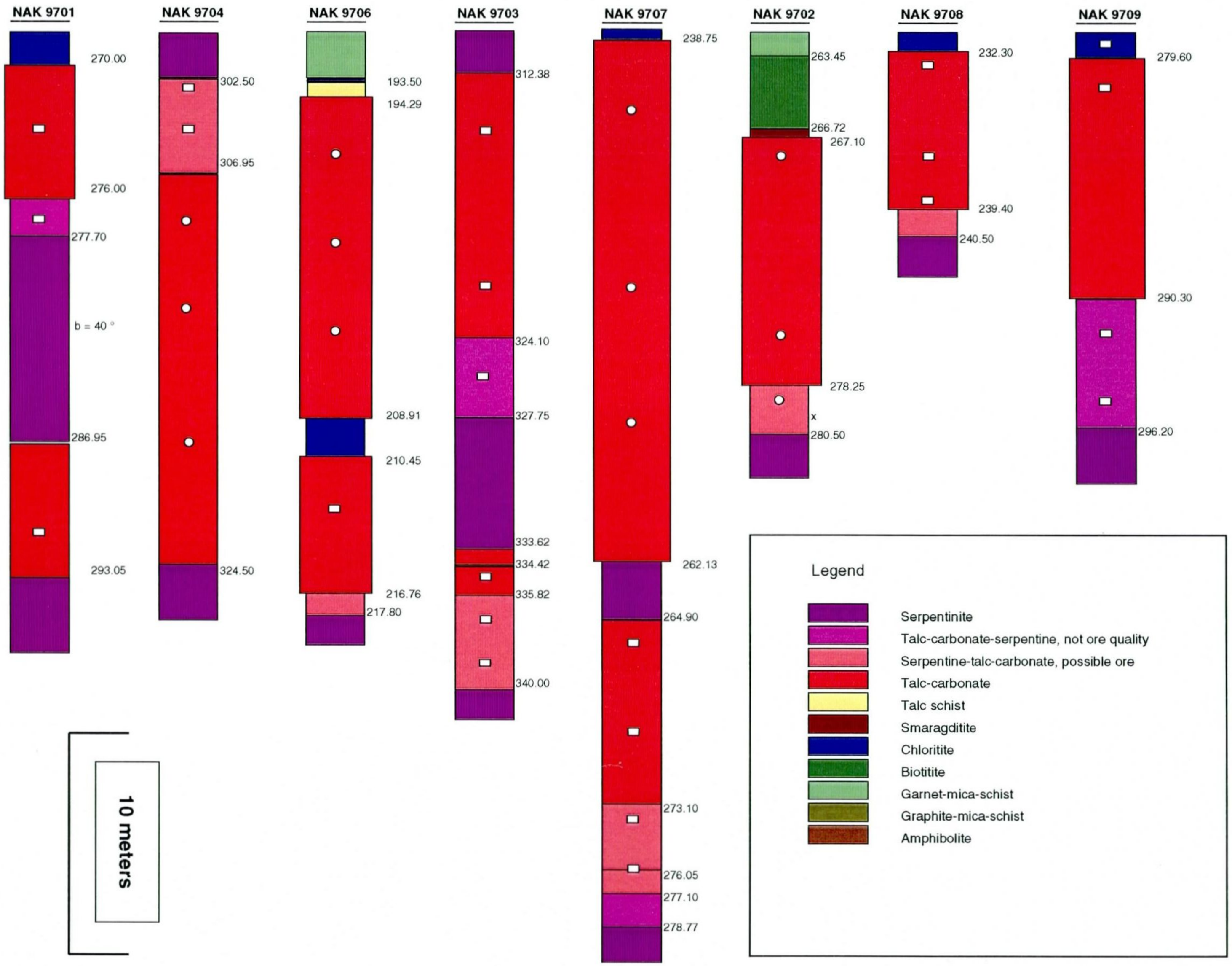

Figure 4: Drill core logs from the 1997 –drilling at Nakkan.

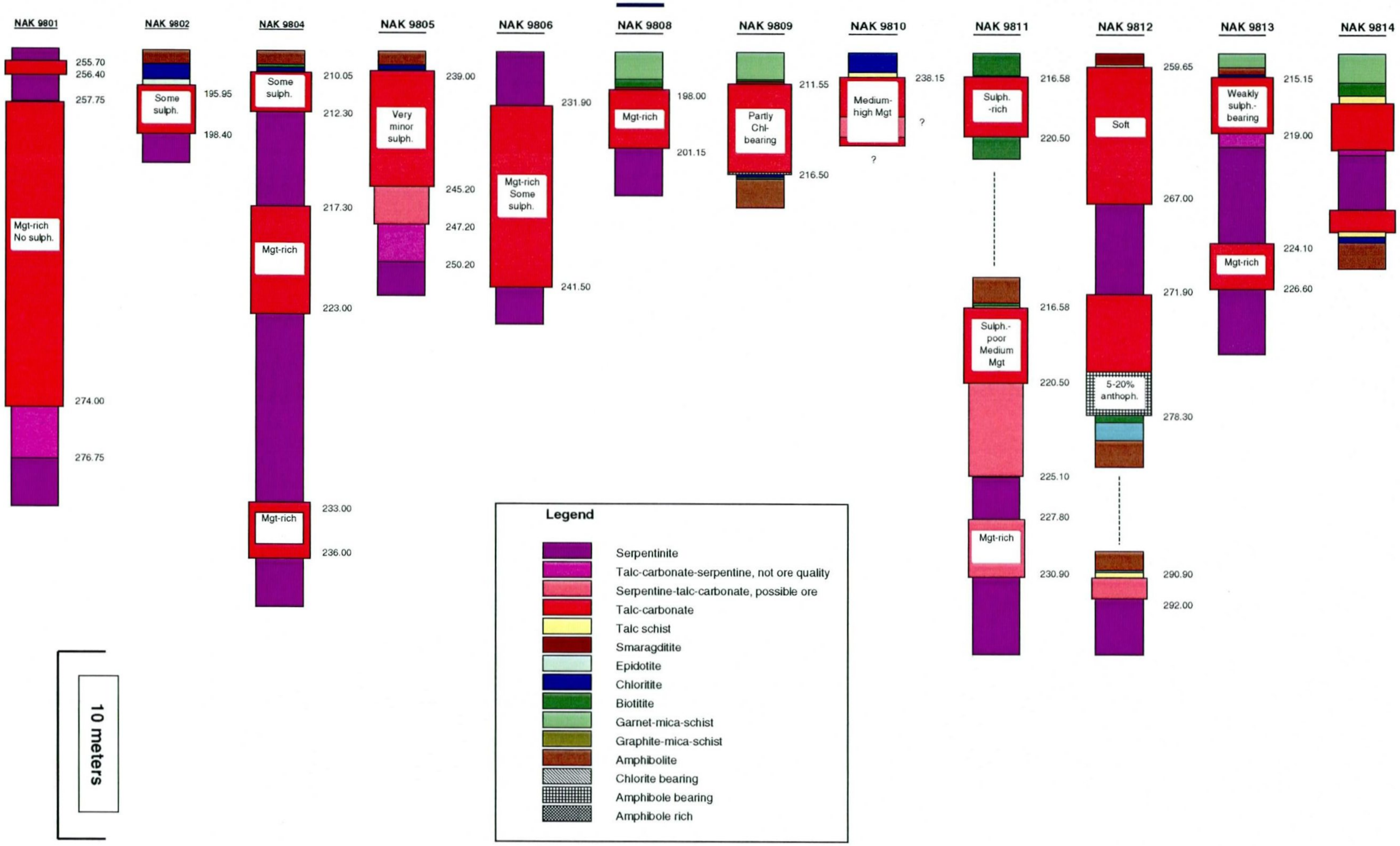

Figure 5: Drill core logs from the 1998-drilling at Nakkan.

<u>**Table 1:**</u> **Overview of studied samples from Nakkan.**

Sample		Description	Thin Section '=polished	XRD	XRF	Micro-probe	Image analyses	Insol. rest
NAK 9701, 273 m	13	Tc-carb, ext. ore	X'		X		X	
NAK 9701, 277 m	14	Tc-carb-serp, int. not ore	X				X	
NAK 9701, 291 m	15	Tc-carb, int. ore	X'		X		X	
NAK 9703, 315 m	16	Tc-carb, int. ore	X'		X		X	
NAK 9703, 322 m	17	Tc-carb, int. ore	X'		X		X	
NAK 9703, 326 m	18	Tc-carb-serp, int. not ore	X				X	
NAK 9703, 327 m	19		X					
NAK 9703, 335 m	20	Tc-carb, int. ore	X				X	
NAK 9703, 337 m		Tc-carb-serp, int. ore	X				X	
NAK 9703, 339 m	21	Tc-carb-serp, int. ore	X'		X		X	
NAK 9704, 303 m								
NAK 9704, 305 m	23	Tc-carb-serp, int. ore	X				X	
NAK 9704, 303 m	22	Tc-carb-serp, int. ore	X				X	
NAK 9706, 213 m	24	Tc-carb-serp, ext. ore	X				X	
NAK 9706, 217 m	25							
NAK 9707, 266 m	26	Tc-carb, int. ore	X'		X		X	
NAK 9707, 270 m	27	Tc-carb, int. ore	X				X	
NAK 9707, 274 m	28	Tc-carb-serp, int. ore	X				X	
NAK 9707, 276 m	29	Tc-carb-serp, int. ore	X'		X		X	
NAK 9708, 233 m	30	Tc-carb, ext. ore	X				X	
NAK 9708, 239 m	32	Tc-carb, ext. ore	X				X	
NAK 9708, 237 m	31	Tc-carb, ext. ore	X'		X		X	
NAK 9709, 279 m	33	Blackwall rim	X					
NAK 9709, 281 m	34	Tc-carb, ext. ore	X'		X		X	
NAK 9709, 292 m	35	Tc-carb-serp, int. not ore	X				X	
NAK 9709, 295 m	36	Tc-carb-serp, int. not ore	X				X	
NAK 9702, 268 m	1		X	X	X			
NAK 9702, 276 m	2		X	X	X			
NAK 9702, 279 m	3		X	X	X			
NAK 9704, 309 m	4		X	X	X			
NAK 9704, 313 m	5		X	X	X			
NAK 9704, 319 m	6		X	X	X			
NAK 9706, 197 m	7		X	X	X			
NAK 9706, 201 m	8		X	X	X			
NAK 9706, 205 m	9		X	X	X			
NAK 9707, 242 m	10		X	X	X			
NAK 9707, 250 m	11		X	X	X			
NAK 9707, 256 m	12		X	X	X			

Table 2: Results from XRD-analyses.

Sample id	File name	Ref. no. On XRF (Table 9 & 10)	Probable main minerals / minerals	Other possible minerals
1 NAK 9702, 268 m	9816001	**1**	**Talc, magnesite, *clinochlore***	Serpentine,
2 NAK 9702, 276 m	9816002	**2**	**Talc, magnesite, *clinochlore***	Serpentine, magnetite
3 NAK 9702, 279 m	9816003	**3**	**Talc, magnesite**	Serpentine, magnetite
4 NAK 9704, 309 m	9816004	**4**	**Magnesite, talc, *clinochlore***	Serpentine, magnetite
5 NAK 9704, 313 m	9816005	**5**	**Magnesite, talc, *clinochlore***	Enstatite grp. (ex. Enstatite)
6 NAK 9704, 319 m	9816006	**6**	**Magnesite, talc, clinochlore**	Serpentine, Pyroxene (ex. diopside)
7 NAK 9706, 197 m	9816007	**7**	**Dolomite, magnesite, talc, *clinochlore/ sudoite***	
8 NAK 9706, 201 m	9816008	**8**	**Talc, *magnesite, dolomite, clinochlore/ sudoite***	
9 NAK 9706, 205 m	9816009	**9**	**Magnesite, talc, *clinochlore/sudoite***	
10 NAK 9707, 242 m	9816010	**10**	**Magnesite, talc, *clinochlore***	
11 NAK 9707, 250 m	9816011	**11**	**Talc, magnesite, *clinochlore/ sudoite***	Serpentine
12 NAK 9707, 256 m	9816012	**12**	**Magnesite, talc, *clinochlore***	Zeolite (ex. Edingtonite)

8. MICROSCOPY

In general, the microscopic analyses (Table 3) support the interpretations made by drill core inspection concerning the definition of ore, and also the general lack of amphibole in the samples. However, the microscopic analyses show that the rock termed talc-carbonate-serpentine-rock by the drill core inspection contain lower serpentine than expected. The rock might therefore be of interest for future mining.

An interesting result that might reflect compositional variations in the talc-carbonate zones is that external parts of the ore, i.e. those parts situated far from the serpentinic core of the ultramafic lens, seem to have higher talc/carbonate ratio than internal parts. If this trend proves to be correct by further analyses, it means that a higher recovery will be obtained in the rim zone and far from the serpentinite, if the ore is going to be beneficiated to a pure talc-product. This difference in talc content related to the position in the ore, is also slightly visible from Table 12.

Distribution of magnetite in the ore

Previous studies on magnetite-content has been done by two different methods: 1) by removal of magnetic matter in connection with whiteness measurements, and 2) microscopy. Especially the first mentioned method indicate that there are large variations in the content of magnetite, with highest contents in the Nakkan deposit and lowest in the Store Esjeklumpen deposit.
The general trend with higher amounts of magnetite in Nakkan compared to Store Esjeklumpen is also indicated by microscopic studies, but at a lower level. From the mine, too few samples exists to make any conclusions.

In the present report, the magnetite content has been estimated for a lot of samples by image analyses. The goal is to 1) add knowledge to the distribution of magnetite, and 2) compare the deposits.

By the procedure followed in the image analyses, the areal distribution (vol%) of the opaque minerals are measured (Table 4). In parallel light on the microscope, opaque minerals are black-coloured while all other minerals are transparent. Since both magnetite and sulphides are opaque, the numbers given in this estimation include a small content of sulphide in some of the samples.
Since the estimation by image analyses gives the areal distribution of the magnetite in vol-%, it is not directly comparable to the contents achieved by for example magnetic separation, where the wt-% is measured. The density of magnetite is around 1.8 times the other major minerals in the ore, which means that a content of 1 vol-% magnetite deduced from image analyses calculates to around 1.8 wt-% magnetite.

The results of the image analyses indicate that the content of opaques (i.e. mostly magnetite) in most samples from Nakkan is below 1 vol.% and less than 0.5 vol.% for the Store Esjeklumpen samples (Table 4, Fig. 6). For the Altermark talc mine too few analyses have been carried out to make any conclusion.
The results give similar trends as the previous results by removal of magnetic matter; The Store Esjeklumpen samples contain very low amounts of magnetite, while the Nakkan samples contain more. The difference is, however much smaller than anticipated earlier. The reason for this can only be that the removal of magnetic matter also removes a lot of other minerals. This probably has to do with the grain size and effective liberation by grinding; In the procedure followed by Norwegian Talc AS, the grain size of the powder is probably to coarse to liberate all magnetite from its surrounding minerals, resulting in removal of much talc, carbonate and chlorite in addition to the magnetite.

The reason for the difference in magnetite content between the Store Esjeklumpen deposit and the Nakkan deposit can be explained as follows:
Previous analyses have proven that magnetite show some distinct distribution pattern in the talc-carbonate rock related to the degree of alteration. In zones that are proximal to the serpentinitic core the amount is high, while in more distal parts from the serpentinic core the magnetite is broken down (Fig. 7; Karlsen 1995; Karlsen & Olesen 1996). The investigated part of the Store Esjeklumpen is mostly the distal parts, while both proximal and distal parts of the Nakkan deposit have been investigated.

Although no detailed grain size distribution analyses are made in this report, some general comments and examples are given:
In the talc-carbonate rocks in Altermark, magnetite has a somewhat bimodal distribution with one group containing relatively coarse grains (~ 0.5 - 3 mm) and the other group containing very fine grains (< ~ 200 µm) (Fig. 8). The grains in the last mentioned group often define "clouds" of magnetite dispersed in the rock.

Geological model that accounts for the distribution of magnetite

During the process of serpentinisation magnetite is formed by the release of iron during the breakdown of preexisting olivines and pyroxenes. Two kinds of magnetite are produced: small grains that appear as dust in the rock, and magnetite that occurs in the rim around preexisting grains of chromite. During the process of talc-carbonate formation from serpentinite, the serpentine is easily broken down and carbonate and talc are formed. Also magnetite is broken down in such a process, but at a slower rate. This implies that the talc-carbonate ore may or may not contain magnetite depending on the maturity of the talc-carbonate forming process.
In the talc-carbonate ore a distinct zoning pattern of magnetite has been documented by magnetic susceptibility measurments (Karlsen 1995, Karlsen & Olesen 1996); in the inner parts of the talc-carbonate zone, the magnetite content is high, while in the outer parts it is low. This trend is also indicated by the % magnetic matter removed by magnetic separation measured by Norwegian Talc AS. In this sense, the innermost parts represent immatured alteration, while the outermost parts represent matured alteration.
What actually happens with the magnetite content is that the small grains (the "dust") are consumed by the silicates and carbonates during progressive deformation, while the bigger grains remain in the rock. This progressive breakdown of magnetite is the primary cause of the zoning pattern in the carbonates with Mg-rich cores and Fe-rich rims, and also the reason for the Fe-content in talc.

The model can explain the differences in magnetite content in the Altermark ores;
Samples from the Store Esjeklumpen deposit contain very low amounts of magnetite, simply because the talc-carbonate ore is situated in a thick pocket of talc where the average distance from the serpentinic core is big. The process of talc-carbonate alteration has reached an advanced stage.
On the average samples from the Nakkan deposit contain more magnetite than samples from Store Esjeklumpen. This is quite what could be expected from the above mentioned model: many of the talc-carbonate zones studied so far, are thinner than the big pocket at Store Esjeklumpen, and occur closer to the serpentinite than does the Store Esjeklumpen ore. This implies that the process of talc-carbonate formation has reached a less advanced stage and the content of magnetite remains higher. If thicker pockets of talc-carbonate ore are found by the future exploration one should expect to find lower content of magnetite.
In the mine, several kinds of ore are present. Some of them occur far from serpentinite (for example much of the "A-deposit"), representing "matured" talc-carbonate alteration, and some of them occur close to serpentinite (for example parts of the "I-deposit"), representing "immatured" talc-carbonate alteration. The variation in magnetite content is therefore assumed to be highly variable. However, more samples from the mine need to be studied to confirm this.

Table 3: Mineralogical content estimated from thin section study by microscope. Except for the contents of opaques which are estimated by image analyses, the amounts are estimated visually, and are only approximate. Abbrevations: Tc = talc, carb = carbonate, Br = breunnerite, dol = dolomite, serp = serpentinite, Tr =trace, i = inclusion, e = external (matrix), ext. ore = external ore (rim around serpentinite), int. ore = veins of talc-carbonate crosscutting the serpentinite, bi =biotite.

Sample	Description from drill core inspection	Ref. no. on XRF (Table 9, 10)	Talc	Carbonate	Chlorite	Serpentine	Amphibole	Opaques	Fe-chromite /magnetite	Sulphide	Others
NAK 9701, 273 m	Tc-carb, ext. ore	13	62	31 Br & dol	6	-	-	0.29	Tr	Obs.	
NAK 9708, 233 m	Tc-carb, ext. ore		55	40 Br	4	I	-	0.46	1	-	
NAK 9708, 239 m	Tc-carb, ext. ore		48	48 Br	< 1	< 1	-	2.74	1.5	-	
NAK 9708, 237 m	Tc-carb, ext. ore	31	93	4 Br	2	-	-	0.2	1	Obs.	
NAK 9709, 281 m	Tc-carb, ext. ore	34	55	44 Br	Tr	-	-	0.38	< 1	Tr	
Average			*63*	*33*	*2.6*	*0.2*	*0*	*0.81*			
NAK 9701, 291 m	Tc-carb, int. ore	15	55	43 Br	1	-	-	1.29	< 1	Tr	
NAK 9703, 315 m	Tc-carb, int. ore	16	49	48 Br & dol	2	< 1	-	0.52	0.5	0.5	
NAK 9703, 322 m	Tc-carb, int. ore	17	50	43 Br	2	4	-	1.01	1-2	0.5	
NAK 9703, 335 m	Tc-carb, int. ore		41	54 Br	2	2	1	0.86	2		
NAK 9707, 266 m	Tc-carb, int. ore	26	49	49 Br	1	Tr	-	0.97	1	Tr	
NAK 9707, 270 m	Tc-carb, int. ore		58	40 Br	1	I	-	0.76	< 1	Obs.	
Average			*50*	*46*	*1.5*	*1.2*	*0.2*	*0.9*			
NAK 9706, 213 m	Tc-carb-serp, ext. ore		50	49 Br	Tr (i,e)	-	-	0.93	2-3		
NAK 9703, 337 m	Tc-carb-serp, int. ore		50	49 Br	Tr	Tr (i)	-	0.25			
NAK 9703, 339 m	Tc-carb-serp, int. ore	21	54	41 Br	Tr	3 ie	-	1.53	2	Tr	
NAK 9704, 305 m	Tc-carb-serp, int. ore		50	40 Br	-	8	-	2.71	3	-	
NAK 9704, 303 m	Tc-carb-serp, int. ore		40	52 Br	-	7	-	0.69			
NAK 9707, 274 m	Tc-carb-serp, int. ore		55	44 Br	Itr	Tr	-	0.32	< 1	-	
NAK 9707, 276 m	Tc-carb-serp, int. ore	29	45	40 Br	4	10	-	0.63	3	Obs.	
Average			*49*	*45*	*0.6*	*4*	*0*	*1.0*			
NAK 9701, 277 m	Tc-carb-serp, int. not ore		32	32 Br	-	32	-	0.89	2		
NAK 9703, 326 m	Tc-carb-serp, int. not ore		33	33 Br & dol	-	33	-	0.37	1		
NAK 9709, 292 m	Tc-carb-serp, int. not ore		33	33 Br	-	33	-	0.57	< 1	-	
NAK 9709, 295 m	Tc-carb-serp, int. not ore		37	60 Br		3	-	0.63	1	-	
Average			*34*	*40*	*0*	*25*	*0*	*0.6*			
NAK 9709, 279 m	Blackwall rim		10	25 Br & dol	1	-	38	0.42	tr	-	Bi 25 %

Table 4: Content of magnetite estimated from digital image analyses of micro-photos.

Drill-core	m	Avg.(vol%)	No.	Drill-core	m	Avg.(vol%)	No.
NAK9708	239	2.74		NAK9612	190.5	0.48	
NAK9708	233	0.46		NAK9612	200.5	0.59	
NAK9703	315	0.52	118	NAK9207	211	3.58	336
NAK9703	337	0.25		NAK9203	271	0.70	61
NAK9703	335	0.86		NAK9204	172	2.31	48
NAK9703	322	1.01		NAK9207	140	1.77	64
NAK9703	339	1.53		NAK9201	311	1.28	53
NAK9703	326	0.37		NAK9207	137	1.04	32
NAK9707	276	0.63		NAK9204	182	0.10	8
NAK9707	274	0.32		NAK9204	247	0.06	10
NAK9707	270	0.76		***Average, Nakkan***		***1.00***	***77***
NAK9707	266	0.97					
NAK9707	295	0.63					
NAK9709	292	0.57					
NAK9709	281	0.38		ESK9008A	151.3	0.06	16
NAK9704	303	0.69		ESK9008A	180.3	0.33	24
NAK9701	201	0.74		ESK9102	56.55	0.08	14
NAK9701	273	0.29		ESK9106	110	0.40	41
NAK9704	305	2.71		ESK9108A	92	0.32	19
NAK9706	213	0.93		ESK9003A	92	0.26	8
NAK9708	237	0.41	45	ESK9003C	178	0.01	1
NAK9709	279	0.42		ESK9108A	72	0.07	19
NAK9613	169	0.92		ESK9108A	67	0.16	20
NAK9613	170	0.27		ESK9106	120.12	0.10	24
NAK9613	181	0.46		ESK9003C	127	0.23	35
NAK9613	189	1.20		ESK9003A	87	0.15	30
NAK9613	175	0.64		ESK9106	85.06	0.17	14
NAK9603	216	4.41		***Average, St. Esjeklumpen***		***0.18***	***20***
NAK9603	200	1.79					
NAK9603	202	0.94					
NAK9603	192	2.33		GR2		0.42	74
NAK9603	210	1.03		GR1		0.63	61
NAK9604	196	0.19		A, Etg.5		1.56	55
NAK9604	194	0.71		ABG9102, H1	98	2.01	13
NAK9604	204	1.85		ABG9101A	127	0.48	65
NAK9604	335	0.21		ABG9101A	125	0.33	15
NAK9604	339	0.02		***Average, mine***		***0.90***	***47***

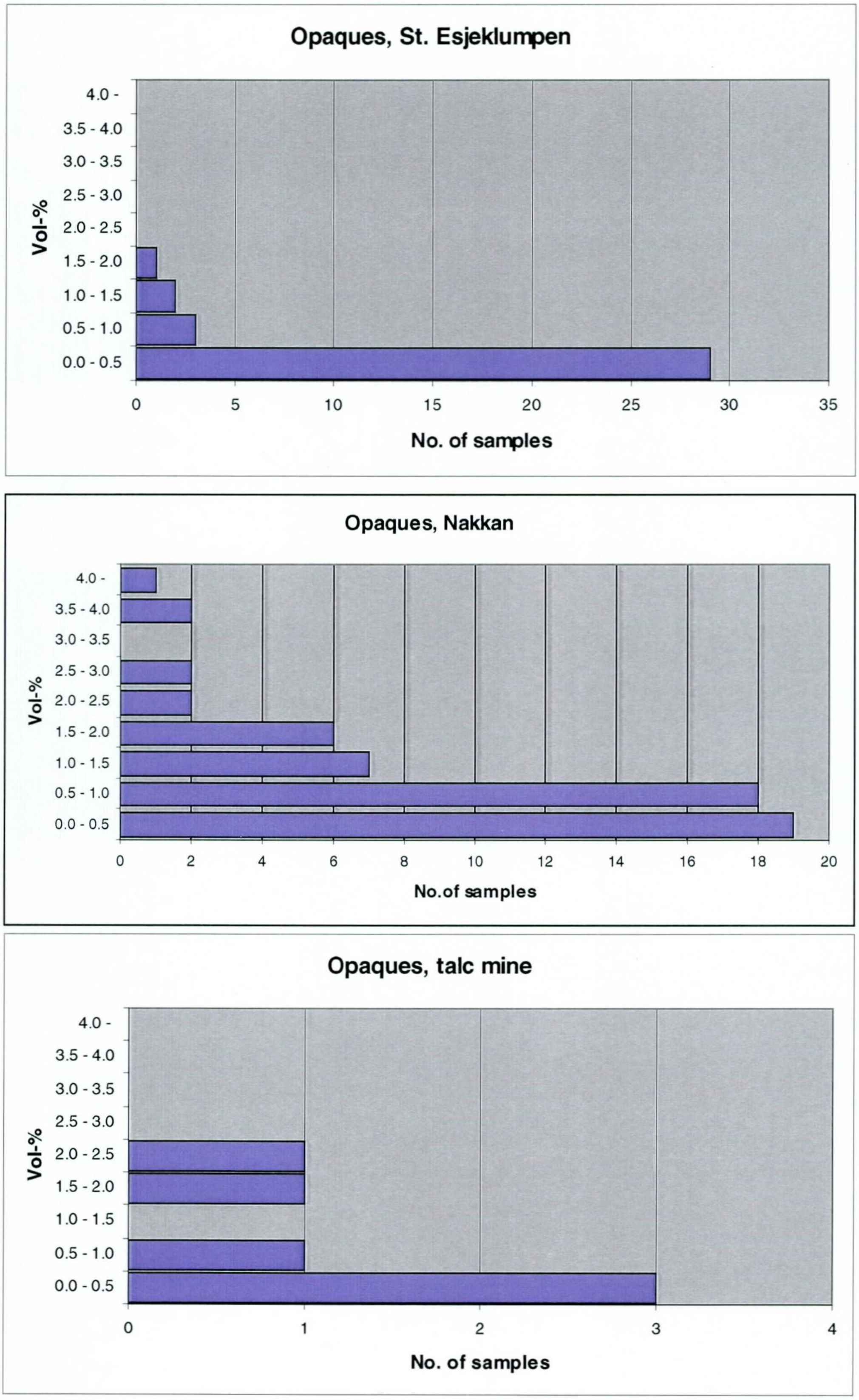

Figure 6: Graphs of the content of opaques calculated by image analyses. More details are given in Table 4.

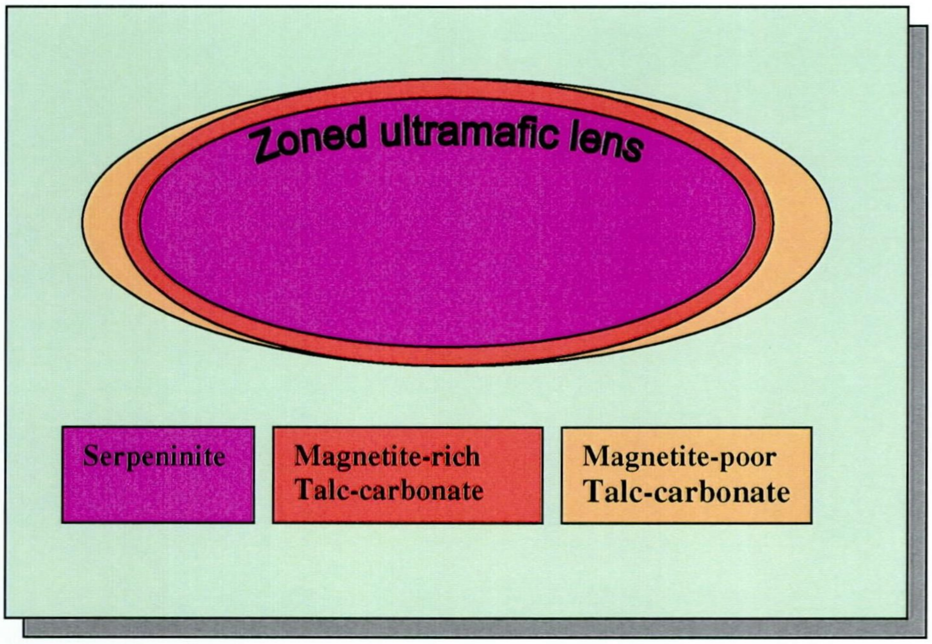

Figure 7: Schematic model illustrating the general distribution pattern of magnetite in the talc-carbonate ore.

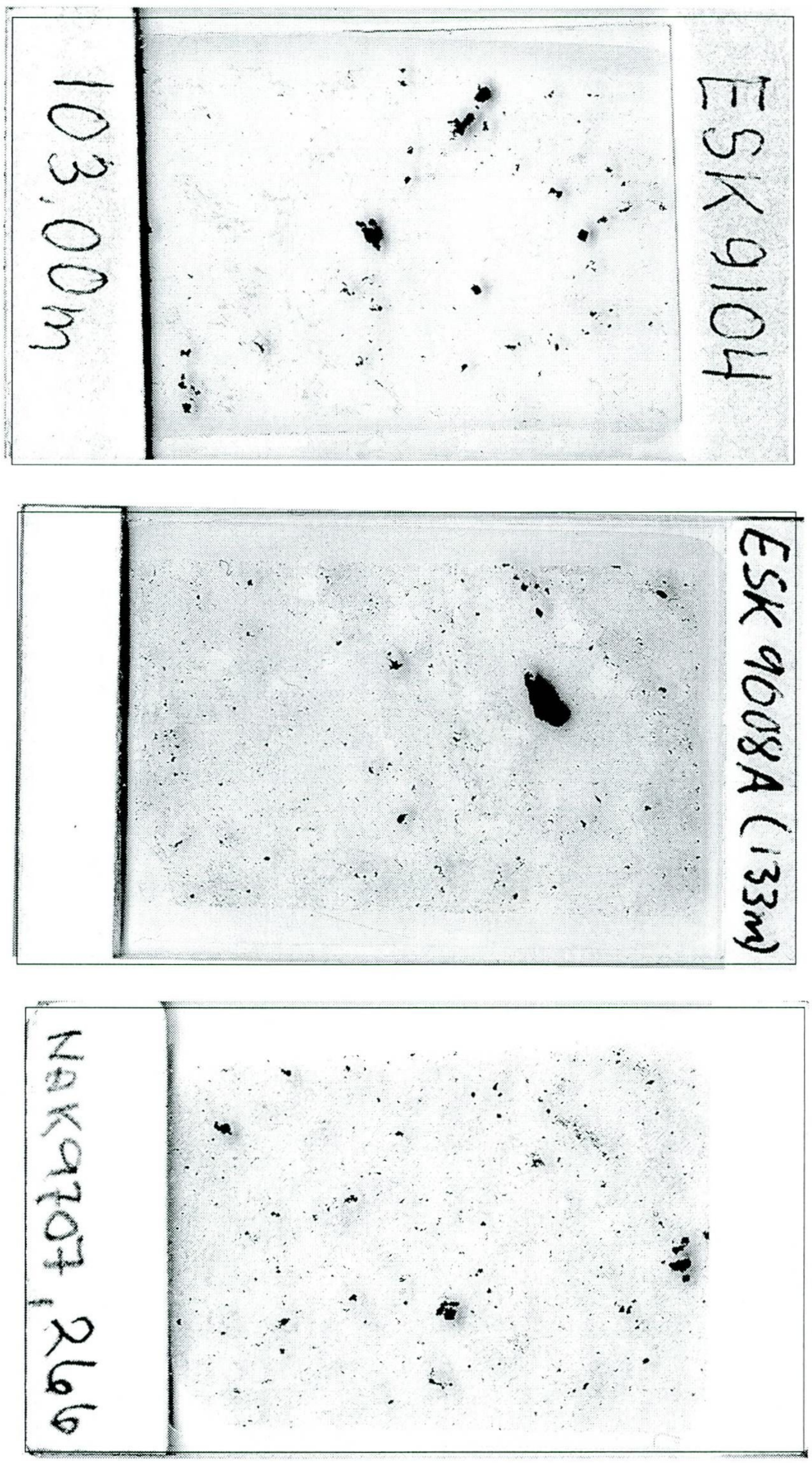

Figure 8: Thin sections that have been scanned directly in order to illustrate the bi-modal distribution of Fe-chromite/magnetite (black spots) in the talc-carbonate. The width of the sections are 2.2 cm. The very fine grained magnetite dust is probably difficult to liberate during grinding.

9. MICROPROBE ANALYSES

Microprobe analyses have been carried out on nine samples from the deposits of Store Esjeklumpen, Nakkan and the mine.

The goal for this investigation is to get more insight into:
1. content of accessory minerals, especially sulphides
2. the composition of the talc crystals with focus on the Ni-content
3. achieve a better understanding of mineralogy of the ore

Microprobe analyses have been carried out by two different methods, EDS (Energy dispersible system) and to a limited amount, WDS (wavelength dispersible system); EDS analyses are less accurate but less time-consuming to perform than WDS. By using the EDS method a great number of analyses can be sampled in a short period of time and at lower cost. A drawback is, however, that the accuracy is lower than WDS, especially when trace elements are studied. The EDS-method is quite useful for 1) identification and quantification of minerals, and 2) to analyse compositional trends in individual mineral phases. The present study has failed to obtain good mineral-chemical data by the EDS. This is probably caused by a combination of the limitations of the system, but also the settings of the system during the analyses.

In this report, the results of the EDS-analyses are presented. Because of the great importance of the Ni-content and the inaccurancy encountered by the EDS-method, the samples had to be re-analysed for Ni by WDS. The WDS-analyses were carried out automatically in a profile across the thin section.

<u>Content of accessory minerals</u>

Sulphides in the talc-carbonate ore might be of economic interest, but only if they contain useful elements and if they occur in large enough amounts. Previous studies (Karlsen 1995) have indicated a very low content of sulphides and that the primary types are pyrite, pyrrhotite and pentlandite.

In the present study, where nine thin sections were analysed, the following sulphides, and associated minerals, have been detected:
Pyrrhotite
Cu-sulphide
Pentlandite
Sphalerite
Heazlewoodite
Native copper
Awaruite
Bornite
Pyrite

The content of sulphide varies between 0% to ~ 1.1 vol% in the samples. Sulphides are represented primarily by pyrrhotite, followed by pentlandite. Copper-bearing phases include native copper, heazlewoodite and awaruite. Pyrite is present only in a single sample from the rim-zone of Store Esjeklumpen.

Sphalerite (Zn,Fe)S, which is the dominant carrier of Zn, is observed sporadically. Zn is also present in the lattice of carbonate. Magnetite/chromite carries, in addition to Fe and Cr, small amounts of Ti and Mn. The major Ti – carrier imenite is observed in one sample. Trace amounts of Mn are present in the carbonates.

Chemistry of talc

Previous investigations (Karlsen 1995) have shown that Ni and Fe occurs in the crystal lattice of talc from Altermark. This is typical for talc of ultramafic origin. However, in some ultramafic talc deposits, such as those mined in Finland, Ni is present foremost as sulphides such as pentlandite and only to a lesser extent in talc. In the Altermark deposits pentlandite occurs only in trace amounts and the vast majority of Ni is present in the talc lattice.

In the present work microprobe analyses have been carried out in order to find if there are variations in especially the Ni-content, but also the Fe and Cr-contents, within 1) individual samples, 2) individual deposits, and 3) between the deposits.
As earlier mentioned, the EDS-analyses proved to be inaccurate, and accurate contents are only avaliable for the Ni.

The general formula for the mineral talc is:

$Mg_6[Si_8O_{20}](OH)_4$

Substitutions:
For Mg: Fe^{2+}, Fe^{3+}, Ni^{2+}, Mn^{2+}, Al
For Si: Al, Ti

In addition Ca and alkalis may substitute for Mg, but are more common between the layers in the sheet structure (Deer et al. 1962).

Ni-content in talc

By using the EDS-method, the Ni-content ranged from 0 to more than 5 % in individual analyses (Table 5). Such high amounts were not considered believable, so the samples were re-analysed using the more accurate WDS-method (Table 6, Fig. 9). However, despite the large unrealistic range of the EDS-analyses, the general trends within and between the samples are considered to be correct.

The more accurate WDS-analyses gave data with less spread and lower averages (Table 6).

The results can be summarised as follows:

1. There are large variations in the Ni-content of talc, both within samples and between samples.
2. The average Ni-content is calculated to be around 0.2 % in the investigated samples.
3. The variations of Ni-content in talc between the samples is probably related to the grade of talc-carbonate alteration. However, a more detailed study is necessary to confirm this.

<u>Table 6:</u> **Summary statistics of microprobe analyses carried out by EDS equipment and measured automatically in a grid. In the NiO- and Fe_2O_3-statistics only analyses containing 62-69% SiO_2 is included. In the calculation of talc-content analyses with 60 – 74 % SiO_2 are included, giving a minimum content. NB! Note that the analyses give too high values and are considered to be misleading when it comes to the chemistry of the minerals. Excact analyses on Ni have been carried out by WDS and are given in Table 7. In the table below, the Ni and Fe_2O_3-contents in talc have been adjusted for a LOI content in talc of 5 %.**

Sample	Deposit	Occurrence	No. of EDS - analyses	Talc content (%)	Ni – range (%) in talc	Ni – average (%) in talc	% below detection level (0.1% NiO)	Fe_2O_3-range (%) in talc	Fe_2O_3-average (%) in talc	% below detection level (0.1% Fe2O3)	Cr-range (%) in talc	Cr-average (%) in talc	% below detection level (0.xx% Cr_2O_3)
NAK9709, 281 m	Nakkan	External	2309	> 63	0 – 1.16	0.32 x	44	0 - 8.1	3.92	0	0-1.81	0.16 x	52
NAK9703, 339 m	Nakkan	Internal	3000	> 48	0 – 3.36	0.66 x	24	0 - 7.4	2.53	2.8	0-1.56	0.16 x	54.3
NAK9703, 315 m	Nakkan	Internal	2628	> 58	0 – 1.23	0.22 x	33	1.1 - 9.5	3.02	0	0-0.74	0.08 x	51
ESK9102, 56.66 m	St. Esjekl.	External	2715	> 65	0 – 3.12	0.57 x	32	5.9 - 15	10.07	0	0-1.05	0.14 x	49
ESK9106, 120.12 m	St. Esjekl.	Ext/int	1754	> 93	0 – 0.93	0.22 x	43	1.4 – 7.0	3.81	0	0-0.90	0.10 x	43
ABG9101a, 127 m	Mine	External	2970	> 56	0 – 1.31	0.25 x	27	0.3 - 7.9	4.22	0	0-1.65	0.08 x	47
Gr.1	Mine	External	3000	> 39	0 – 3.44	0.82 x	22	3.5 - 11.9	6.95	0	0-1.51	0.16 x	48
Gr.2	Mine	External	3000	> 47	0 – 3.94	0.53 x	30.1	3.2 - 13.4	7.84	0	0-2.27	0.16 x	50.1
Etg.5	Mine	External	3000	> 62	0 – 5.16	0.80 x	24	0.5 -11.6	5.02	0	0-1.15	0.14 x	52

X = Clearly too high values, Ni –values have been re-calculated by WDS and are shown in Table 7.

Table 7: WDS microprobe analyses of Ni in talc. These numbers are more correct than the EDS-analyses of Ni shown in Table 6. Ni-metal has been used as a standard.

Sample	Deposit	No. of WDS - analyses	Ni – range (%) in talc	Ni – average (%) in talc
NAK9709, 281 m	Nakkan	204	0.00 - 0.56	0.24
NAK9703, 339 m	Nakkan	242	0.10 - 0.78	0.35
NAK9703, 315 m	Nakkan	231	0.00 - 0.31	0.13
ESK9102, 56.66 m	St.Esjekl.	496	0.01 - 0.30	0.11
ESK9106, 120.12 m	St.Esjekl.	358	0.00 - 0.94	0.19
ABG9101a, 127 m	Mine	308	0.00 - 0.47	0.10
Gr.1	Mine	115	0.00 - 1.06	0.35
Gr.2	Mine	147	0.00 - 0.77	0.20
Total average				***0.21***

Fe_2O_3-content in talc

The EDS analyses of talc indicate variable amounts of Fe_2O_3 present in talc (Table 6). The amounts range from around 2.5 wt% to more than 10 wt% Fe_2O_3. Compared to the content in beneficiated pure talc-products (2.6 – 3.2 wt%) this is considerably higher.

Although the less accurate EDS method does not give the exact composition, the general trends are considered to be correct. Fe, here expressed as Fe_2O_3, is almost always present in talc, but in different amounts (Table 7). From the few samples investigated in this report, and those investigated by Karlsen (1995), a trend is indicated where talc from the ore situated close to serpentinite has low Fe-content, while talc close to the country rocks have high Fe-contents. This trend is probably related to the distribution pattern of magnetite in the talc-carbonate zone (Fig. 7) and the maturity of talc-carbonate formation; in the outer part of the ore, magnetite has been broken down and the Fe has entered talc as well as carbonates, giving Fe-rich talc and chemically zoned carbonates with Fe-rich rims. If this assumption is correct, then there should be a negative correlation between the content of magnetite in the rock and the Fe-content in talc. This is in fact indicated (Table 8), though more analyses are needed to confirm this.

Table 8: A weak negative correlation seems to exist between the Fe-content (here expreseed as Fe_2O_3) in the talc lattice and the content of magnetite.

Sample	Wt-% Fe_2O_3 in the talc lattice - deduced from Microprobe EDS	Content of magnetite (vol-%) - estimated by image analyses
NAK9709, 281 m	3.92	0.38
NAK9703, 339 m	2.53	1.53
NAK9703, 315 m	3.02	0.52
ESK9102, 56.66 m	10.07	0.08
ESK9106, 120.12 m	3.81	0.10
ABG9101a, 127 m	4.22	0.48
Gr.1	6.95	0.63
Gr.2	7.84	0.42
A, Etg.5	5.02	1.56

The consequence of such a trend is as follows:

1. Large parts of the Store Esjeklumpen deposit contain low amounts of magnetite, indicating a high Fe-content in the talc lattice
2. Many parts of the Nakkan deposit contain somewhat higher amounts of magnetite, and the Fe-content in the talc lattice is probably lower than in the Store Esjeklumpen.

Although this has not been investigated, it might be that whiteness of the ore is reduced if the Fe-content in the talc lattice is high. If this is correct it is important to see if there are any differences between and within the deposits in Altermark.

Cr-content in talc

With a detection level of 0.1%, the EDS analyses of Cr in talc from Altermark is not accurate enough. However, the analyses have been carried together with the other analyses in order to pick up any trends. The study gave the following results:

1) Only around 50% of the talc-analyses carried Cr above the detection level of 0.1 vol%.
2) The average values of Cr in talc, although not very realistic, varied between the samples from 0.07% to 0.17%. This is far more than whole-rock XRF-analyses of pure talc-products from Nakkan and the mine (ca. 0.01 – 0.06 wt%, Karlsen 1999).

From the present analyses it seems realistic to believe that some very small amounts of Cr might be present occasionally in talc, but at a lower level than indicated by the EDS analyses. Otherwise, the EDS-analyses proved that chlorite is the major Cr-bearing mineral.

Carbonate chemistry

From the EDS-study on carbonates, the following trends are observed:

- Mg-Fe-carbonates are very dominant, and dolomite is observed only in less amounts in two of the nine investigated sections
- EDS-analyses show some very nice trends with respect to the content of Fe and Mg (see Appendix 3), resulting from the negative correlation of these elements and variable contents. Previous investigations (Karlsen 1995) have shown that the carbonates are chemically zoned, with incresing Fe/Mg ratio from the core to the rim.
- The average MgO/FeO-ratio between the samples is different from sample to sample, probably reflecting different grades of breakdown of magnetite, and its position in the ore
- The MgO-rich variety, which is common in the core of the carbonates is not always present.
- The carbonates also carries small amounts of both Ni and Zn.

Although the trends in the Fe-content are considered to be correct the level of the Fe-content is considered to be too high.

10. XRF WHOLE ROCK CHEMICAL ANALYSES

XRF-whole rock analyses of samples from the 1997-drilling are shown in Tables 9 & 10. The analyses are quite similar to earlier analyses, and supports the impression that the talc-carbonate ore from Altermark is extremely low in harmful elements, except for minor amounts of nickel and chromium. Elements which pose potential risks to health, such as *Cd* and *U/Th* are all either absent or at extremely low concentrations below the respective detection limits (Karlsen 1997). *As* is detected in one sample in very small amounts (Table 10), but is otherwise absent or below detection level.

Correlation analyses

A correlation analysis of the elements normally present in the talc-carbonate rock has been made (Table 11). The interpretation of matrix is not straight-forward, due to the variation in chemical composition of the minerals, and due to the existence of Mg and Fe in both talc and carbonate. The following correlations are most distinct or important:

1. Strong negative correlation between SiO_2 and Loss On Ignition.
    - It simply shows that when the carbonate content is high, the content of silicates are low
2. Positive correlation between Cr and Fe_2O_3
    - Cr occurs together with Fe in Fe-chromite and Cr-magnetite
3. A negative correlation between Cr and SiO_2, and positive between Cr and LOI
    - This is an illustration of what has been mention earlier: Magnetite/Fe-chromite are trapped as inclusions within carbonates, and occur in lesser amounts in the talc-matrix. So, when the content of carbonate is high ($\approx$ LOI) the content of Cr-bearing magnetite is high.
4. Positive correlation between V and Cr & Fe_2O_3
    - Vanadium occurs within magnetite/chromite

5. Positive correlation between Sr and Ca
    - Strontium substitute for Ca in carbonate
6. Weak positive correlation between Ni and Fe_2O_3 & MgO
    - Ni substitute for both Fe and Mg in both talc and carbonate
7. Negative correlation between Ni and SiO_2 and positive correlation between Ni and LOI
    - This correlation suggests that Ni occurs in carbonates and to a lesser degree in talc, which obviously is wrong. Microprobe analyses proves that Ni mostly is present in talc, and to a lesser degree in carbonate.
8. Positive correlation between Cu and CaO & Sr
    - This indicates that Cu occurs in calcic carbonate
9. Positive correlation between Co and Fe_2O_3 & MgO & LOI
    - Indicates that Co substitutes for Fe and Mg in carbonate
10. Strong positive correlation between Mn and LOI and strong negative correlation between Mn and SiO_2
    - Indicates that Mn occurs in carbonate and not in silicates

The microprobe studies carried out in the present report provide some additional knowledge on the chemistry of the ore and mineralogical distribution of elements. As shown on Table 10, small amounts of *Zn* is present in the samples. Zn is a major constituents in sphalerite, which occurs in very small amounts, but is also quite common as a minor constituent in carbonates. Otherwise it occurs occasionally at very low levels in spinel.
Ti occurs within the sparce ilmenite, but also in lower amounts in magnetite.
Mn occurs primarily in spinels, but also in low amounts in carbonate.

Mineralogical content estimated from XRF-data

An attempt has been made to give the general mineralogical content of the carbonate-rich talc products based on the chemistry (Table 12). See Appendix 4 for the mineral compositions used in this approximation.

The method used for the estimation is as follows:
1. Chlorite is estimated based on the Al_2O_3 content
2. Talc is estimated based on the remaining SiO_2 content
3. Carbonate is estimated based on the remaining Loss On Ignition

The error sources for this approximation are as follows:
1. Al_2O_3 occurs primarily within chlorite, but also in low amounts in chromite, serpentine, talc, and in amphibole, when it is present.
2. The LOI in carbonates depends on the type of carbonate present. In the present calculations breunnerite, the dominant carbonate, has been used as a basis. In the breunnerite the LOI value depends on the Fe/Mg relationship, which varies both within individual grains and between samples.

Chlorites have different contents of Al_2O_3 depending on the location in the talc ore; the Al_2O_3 content is, in general, high in the external parts of the ore, and low in internal parts of the ore close to serpeninites. In the present calculation the Al_2O_3-rich type of chlorite has been used.

As Table 12 and Fig. 10 show, the content of *chlorite* is rather low and is generally below 3 wt%, although with a total average around 3.4% including samples with significantly higher contents. From the limited amount of data, it is not possible to conclude that there are differences between the deposits. When thin sections are available for the samples (most of them) the results have been checked by microscopy. The results shows that the method is valid with certain restrictions (see below).

The content of *talc* is estimated to be between 35 and 100 wt%, but with a majority of samples having a content of 50-65 wt%; the total average is around 59 wt%. The modal content of talc also include serpentine found in two of the samples (Table 12). It is not possible to prove any statistical differences between the deposit.

The *carbonate* content is estimated to be in the range 30-50 wt% for most samples with a total average of ~35 wt%. Carbonate and talc show a well-defined negative correlation in the samples (Fig. 10).

As mentioned above, there are certain limitations in the applied method. To show this, samples of other types than pure talc-carbonate have been treated in the same manner (Table 13). The results show that 1) pure talc and chlorite rocks give reasonable results, 2) amphibole is recorded as chlorite and talc, and 3) serpentine is recorded mainly as talc.

11. CONCLUSION

1. Detailed field-inspection of drill cores from Nakkan 1997 and 1998 shows that ore consists of pure talc-carbonate rocks. Only one single 2.3 meters wide zone from the1998-drilling was contaminated by amphibole. The purity of the 1997- drill cores has been confirmed by XRD, XRF and microscopy.
2. Samples of talc-carbonate-serpentine rocks termed "possible ore" from the detailed field inspections have serpentine content between 0-10%, and might be classified as ore if small amounts of serpentine are accepted in the product.
3. Image analyses on microscopic sections show that the content of magnetite is lower than earlier indicated by the removal of the magnetic fraction. It is concluded that the data from magnetic separation are probably suitable to give the general trends, but not absolute measurements of magnetite content.
4. The content of magnetite in samples from Nakkan is generally below 1 vol%, and below 0.5 vol% for Store Esjeklumpen samples. For the Altermark talc mine, too few analyses have been carried out so far, to make any conclusions.
5. It is suggested that fine grain size of magnetite, more than the amounts, is the reason for high content of "magnetic matter" measured by magnetic separation. In such cases the grain size of the grinded material has been too coarse to liberate magnetite by the following magnetic separation.

6. Ni-content in talc show a large variation both within samples, and between nine studied samples. The highest average was recorded to be 0.35 wt-%, while the lowest value was 0.10 wt-%.
7. In almost all studied samples, breunnerite is the dominant carbonate. The breunnerites show some extreme variations in the Mg/Fe ratio. Very high amounts of Fe_2O_3 have been recorded by EDS analyses on microprobe. It is not clear whether these results are artificial or real.
8. The content of sulphides is very low (0-1.1 vol%) in the investigated samples. Pyrrhotite and pentlandite dominate, while several other types are present locally.

12. RECOMMENDATIONS

The present work has touched upon some areas of great importance in the development of the Nakkan deposit, but generally without going into details. A follow-up work should be done that focuses on the mineralogical variations both within and between the deposits. Detailed and accurate microprobe WDS-analyses of 15-20 samples should be carried out to find the exact composition of the minerals and the compositional variations. Image analyses should be carried out to map the grain size distribution of magnetite, as well as other minerals. To be able to compare the deposits, more data is needed from the mine.

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Table 9: Major element distribution analysed by XRF.

	Sample	SiO2 %	Al2O3 %	Fe2O3 %	TiO2 %	MgO %	CaO %	Na2O %	K2O %	MnO %	P2O5 %	LOI %	Sum %
1	NAK9702, 268m	47.72	0.69	5.68	0.01	31.14	0.50	<0.10	<0.01	0.08	<0.01	13.10	98.90
2	NAK9702, 276m	37.27	0.52	6.31	0.01	34.07	0.43	<0.10	<0.01	0.09	<0.01	20.84	99.53
3	NAK9702, 279m	40.83	0.54	5.59	0.01	34.87	0.60	<0.10	<0.01	0.07	<0.01	17.79	100.29
4	NAK9704, 309m	22.53	0.12	9.09	0.02	36.34	0.17	<0.10	<0.01	0.15	<0.01	30.62	99.01
5	NAK9704, 313m	36.66	0.39	6.13	0.01	33.58	0.13	<0.10	<0.01	0.06	<0.01	21.18	98.11
6	NAK9704, 319m	37.38	0.55	5.75	0.01	34.84	1.03	<0.10	<0.01	0.07	<0.01	21.63	101.25
7	NAK9706, 197m	42.87	0.36	4.77	<0.01	27.85	7.35	<0.10	<0.01	0.08	0.03	16.43	99.72
8	NAK9706, 201m	58.41	0.59	4.81	0.01	29.60	1.12	<0.10	<0.01	0.02	<0.01	6.00	100.57
9	NAK9706, 205m	41.51	0.41	5.61	0.01	33.28	1.21	<0.10	<0.01	0.09	<0.01	18.26	100.38
10	NAK9707, 242m	40.10	0.57	5.91	0.02	33.61	0.31	<0.10	<0.01	0.07	<0.01	18.58	99.17
11	NAK9707, 250m	51.92	0.45	4.28	0.02	32.97	0.38	<0.10	<0.01	0.03	<0.01	11.48	101.53
12	NAK9707, 256m	35.35	0.50	6.06	0.01	36.24	0.11	<0.10	<0.01	0.08	<0.01	23.28	101.60
13	NAK9701, 273m	38.67	1.30	4.96	0.03	33.37	2.52	<0.10	<0.01	0.13	0.01	20.41	101.39
15	NAK9701, 291m	34.51	0.28	6.37	<0.01	36.02	0.46	<0.10	<0.01	0.09	<0.01	23.58	101.30
16	NAK9703, 315m	35.68	0.40	6.60	0.01	34.97	0.78	<0.10	<0.01	0.09	<0.01	21.92	100.44
17	NAK9703, 322m	36.32	0.43	7.34	0.01	34.68	1.23	<0.10	<0.01	0.09	<0.01	21.67	101.79
21	NAK9703, 339m	35.47	0.27	6.80	0.01	35.74	0.46	<0.10	<0.01	0.11	<0.01	21.83	100.67
26	NAK9707, 266m	27.70	0.40	7.62	<0.01	36.81	0.14	<0.10	<0.01	0.12	<0.01	27.72	100.48
29	NAK9707, 276m	27.91	0.29	6.59	0.01	37.69	0.20	<0.10	<0.01	0.17	<0.01	28.10	100.96
31	NAK9708, 237m	63.07	0.06	2.25	0.01	31.01	0.01	<0.10	<0.01	<0.01	<0.01	4.80	101.20
34	NAK9709, 295m	32.36	0.09	6.56	0.02	33.86	1.06	<0.10	<0.01	0.16	<0.01	24.92	99.02

Table 10: Trace element distribution analysed by XRF.

	Sample	Mo	Nb	Zr	Y	Sr	Rb	U	Th	Pb	Cr	V
		%	%	%	%	%	%	%	%	%	%	%
1	NAK9702, 268m	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.2340	0.0017
2	NAK9702, 276m	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1983	0.0015
3	NAK9702, 279m	<0.0005	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1804	0.0012
4	NAK9704, 309m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.4817	0.0021
5	NAK9704, 313m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.2053	0.0015
6	NAK9704, 319m	<0.0005	<0.0005	<0.0005	<0.0005	0.0011	<0.0005	<0.0010	<0.0010	<0.0010	0.1592	0.0013
7	NAK9706, 197m	<0.0005	<0.0005	<0.0005	<0.0005	0.0112	<0.0005	<0.0010	<0.0010	<0.0010	0.0992	0.0011
8	NAK9706, 201m	<0.0005	<0.0005	<0.0005	<0.0005	0.0009	<0.0005	<0.0010	<0.0010	<0.0010	0.1559	0.0011
9	NAK9706, 205m	<0.0005	<0.0005	<0.0005	<0.0005	0.0010	<0.0005	<0.0010	<0.0010	<0.0010	0.1349	0.0010
10	NAK9707, 242m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1729	0.0016
11	NAK9707, 250m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1052	0.0010
12	NAK9707, 256m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1747	0.0011
13	NAK9701, 273m	<0.0005	<0.0005	<0.0005	<0.0005	0.0052	<0.0005	<0.0010	<0.0010	<0.0010	0.1514	0.0020
15	NAK9701, 291m	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1637	0.0013
16	NAK9703, 315m	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.2083	0.0012
17	NAK9703, 322m	<0.0005	<0.0005	<0.0005	<0.0005	0.0013	<0.0005	<0.0010	<0.0010	<0.0010	0.2191	0.0014
21	NAK9703, 339m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1911	0.0015
26	NAK9707, 266m	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1972	0.0012
29	NAK9707, 276m	<0.0005	<0.0005	0.0143	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1278	0.0011
31	NAK9708, 237m	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.0081	<0.0005
34	NAK9709, 295m	<0.0005	<0.0005	<0.0005	<0.0005	0.0014	<0.0005	<0.0010	<0.0010	<0.0010	0.1623	0.0020

	Sample	As	Sc	S	Cl	F	Ba	Sb	Sn	Cd	Ag
		%	%	%	%	%	%	%	%	%	%
1	NAK9702, 268m	0.003	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
2	NAK9702, 276m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
3	NAK9702, 279m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
4	NAK9704, 309m	<0.0010	<0.0010	<0.10	<0.10	<0.10	0.0011	<0.0010	<0.0010	<0.0010	<0.0010
5	NAK9704, 313m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
6	NAK9704, 319m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
7	NAK9706, 197m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
8	NAK9706, 201m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
9	NAK9706, 205m	<0.0010	<0.0010	<0.10	<0.10	<0.10	0.0011	<0.0010	<0.0010	<0.0010	<0.0010
10	NAK9707, 242m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
11	NAK9707, 250m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
12	NAK9707, 256m	<0.0010	<0.0010	<0.10	<0.10	<0.10	0.0014	<0.0010	<0.0010	<0.0010	<0.0010
13	NAK9701, 273m	<0.0010	<0.0010	<0.10	<0.10	<0.10	0.0014	<0.0010	<0.0010	<0.0010	<0.0010
15	NAK9701, 291m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
16	NAK9703, 315m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
17	NAK9703, 322m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
21	NAK9703, 339m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
26	NAK9707, 266m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
29	NAK9707, 276m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
31	NAK9708, 237m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
34	NAK9709, 295m	<0.0010	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010

<u>Table 10 continued:</u> Trace element distribution analysed by XRF.

	Sample	Ga	Zn	Cu	Ni	Yb	Co	Ce	La	Nd	W
		%	%	%	%	%	%	%	%	%	%
1	NAK9702, 268m	<0.0010	0.0105	0.0009	0.1661	<0.0010	0.0072	<0.0010	<0.0010	<0.0010	<0.0030
2	NAK9702, 276m	<0.0010	0.0036	0.0009	0.1530	<0.0010	0.0088	<0.0010	<0.0010	<0.0010	<0.0030
3	NAK9702, 279m	<0.0010	0.0028	<0.0005	0.1497	<0.0010	0.0081	<0.0010	<0.0010	<0.0010	<0.0030
4	NAK9704, 309m	<0.0010	0.0040	0.0008	0.1331	<0.0010	0.0098	0.0023	<0.0010	<0.0010	<0.0030
5	NAK9704, 313m	<0.0010	0.0031	0.0008	0.1333	<0.0010	0.0083	<0.0010	<0.0010	<0.0010	<0.0030
6	NAK9704, 319m	<0.0010	0.0021	0.0006	0.1132	<0.0010	0.0075	<0.0010	<0.0010	<0.0010	<0.0030
7	NAK9706, 197m	<0.0010	0.0023	0.0037	0.0898	<0.0010	0.0060	<0.0010	<0.0010	<0.0010	<0.0030
8	NAK9706, 201m	<0.0010	0.0021	0.0006	0.1165	<0.0010	0.0072	<0.0010	<0.0010	<0.0010	<0.0030
9	NAK9706, 205m	<0.0010	0.0016	0.0015	0.1380	<0.0010	0.0076	<0.0010	<0.0010	<0.0010	<0.0030
10	NAK9707, 242m	<0.0010	0.0031	0.0009	0.1291	<0.0010	0.0080	<0.0010	<0.0010	<0.0010	<0.0030
11	NAK9707, 250m	<0.0010	0.0031	<0.0005	0.1188	<0.0010	0.0065	<0.0010	<0.0010	<0.0010	<0.0030
12	NAK9707, 256m	<0.0010	0.0024	0.0007	0.1275	<0.0010	0.0090	<0.0010	<0.0010	<0.0010	<0.0030
13	NAK9701, 273m	<0.0010	0.0037	<0.0005	0.1512	<0.0010	0.0075	<0.0010	<0.0010	<0.0010	<0.0030
15	NAK9701, 291m	<0.0010	0.0020	<0.0005	0.1701	<0.0010	0.0086	<0.0010	<0.0010	<0.0010	<0.0030
16	NAK9703, 315m	<0.0010	0.0031	0.0012	0.1416	<0.0010	0.0088	<0.0010	<0.0010	<0.0010	<0.0030
17	NAK9703, 322m	<0.0010	0.0024	<0.0005	0.1333	<0.0010	0.0086	<0.0010	<0.0010	<0.0010	<0.0030
21	NAK9703, 339m	<0.0010	0.0015	0.0005	0.2216	<0.0010	0.0074	<0.0010	<0.0010	<0.0010	<0.0030
26	NAK9707, 266m	<0.0010	0.0021	0.0019	0.1424	<0.0010	0.0091	<0.0010	<0.0010	<0.0010	<0.0030
29	NAK9707, 276m	<0.0010	0.0017	<0.0005	0.1489	<0.0010	0.0093	<0.0010	<0.0010	<0.0010	<0.0030
31	NAK9708, 237m	<0.0010	0.0016	<0.0005	0.1042	<0.0010	0.0065	<0.0010	<0.0010	<0.0010	<0.0030
34	NAK9709, 295m	<0.0010	0.0033	<0.0005	0.1613	<0.0010	0.0081	<0.0010	<0.0010	<0.0010	<0.0030

Table 11: Correlation diagram of data from chemical analyses (XRF).

	SiO2	*Al2O3*	*Fe2O3*	*MgO*	*CaO*	*MnO*	*LOI*	*Sum*	*Zr*	*Sr*	*Cr*	*V*	*Ba*	*Zn*	*Cu*	*Ni*	*Co*
SiO2	1.00																
Al2O3	0.27	1.00															
Fe2O3	-0.78	-0.04	1.00														
MgO	-0.81	-0.32	0.60	1.00													
CaO	0.12	0.04	-0.26	-0.55	1.00												
MnO	-0.76	-0.07	0.66	0.50	0.01	1.00											
LOI	-0.99	-0.33	0.72	0.84	-0.14	0.74	1.00										
Sum	0.21	-0.11	-0.28	0.15	0.03	-0.27	-0.15	1.00									
Zr	-0.18	-0.13	0.07	0.29	-0.10	0.34	0.20	0.18	1.00								
Sr	0.10	0.08	-0.27	-0.52	0.98	0.06	-0.11	0.02	-0.09	1.00							
Cr	-0.47	0.14	0.79	0.31	-0.27	0.36	0.40	-0.37	-0.14	-0.27	1.00						
V	-0.32	0.58	0.55	0.06	-0.07	0.44	0.25	-0.46	-0.15	-0.04	0.67	1.00					
Ba	-0.14	0.41	0.11	0.02	-0.04	0.28	0.13	-0.22	-0.17	0.03	0.12	0.32	1.00				
Zn	0.17	0.19	-0.02	-0.31	0.05	0.04	-0.19	-0.31	-0.11	0.04	0.26	0.34	0.07	1.00			
Cu	-0.06	0.13	0.04	-0.36	0.65	0.07	0.02	-0.31	-0.18	0.61	0.02	-0.01	0.04	0.02	1.00		
Ni	-0.47	-0.22	0.39	0.55	-0.35	0.46	0.47	-0.05	0.08	-0.35	0.21	0.26	-0.14	0.07	-0.35	1.00	
Co	-0.79	-0.29	0.72	0.84	-0.47	0.48	0.79	0.00	0.26	-0.46	0.53	0.19	-0.01	-0.17	-0.22	0.40	1.00

<u>Table 12:</u> Main mineralogical content of talc-carbonate ore estimated from XRF-chemical data.

SAMPLE		Chlorite Weight-%	Talc Weight-%	Carbonate Weight-%	Total Weight-%	Rock-type	Location
NAK 9702, 268 m		4.0	74.5	19.7	98.2	Talc-carbonate	external
NAK 9702, 276 m		3.0	58.2	37.2	98.5	Talc-carbonate	external
NAK 9702, 279 m		3.2	63.9	30.4	97.5	Talc-carbonate	external
NAK 9704, 309 m		0.7	35.7	59.8	96.3	Talc-carbonate	proximate
NAK 9704, 313 m		2.3	57.6	38.2	98.1	Talc-carbonate	internal
NAK 9704, 319 m		3.2	58.3	38.8	100.3	Talc-carbonate	internal
NAK 9706, 197 m		2.1	67.6	27.6	97.3	Talc-carbonate	external
NAK 9706, 201 m		3.4	91.9	3.7	99.1	Talc-carbonate	external
NAK 9706, 205 m		2.4	65.3	31.5	99.2	Talc-carbonate	external
NAK 9707, 242 m		3.3	62.6	32.1	98.1	Talc-carbonate	external
NAK 9707, 250 m		2.6	81.9	16.1	100.6	Talc-carbonate	external
NAK 9707, 256 m		2.9	55.2	42.5	100.7	Talc-carbonate	external
NAK 9701, 273 m		7.6	58.2	35.2	101.1	Talc-carbonate	external
NAK 9701, 291 m		1.6	54.5	43.5	99.6	Talc-carbonate	internal
NAK 9703, 315 m		2.3	56.0	39.8	98.2	Talc-carbonate	internal
NAK 9703, 322 m		2.5	57.0	39.2	98.6	Talc-carbonate	internal
NAK 9703, 339 m		1.6	56.0	39.8	97.4	(Serp)-talc-carbonate	internal
NAK 9707, 266 m		2.3	43.2	52.8	98.4	Talc-carbonate	internal
NAK 9707, 276 m		1.7	43.9	53.7	99.3	Serp-talc-carbonate	internal
NAK 9708, 237 m		0.4	100.9	1.3	102.5	Talc-carbonate	external
NAK 9709, 281 m		0.5	51.6	46.8	98.9	Talc-carbonate	external
NAK 9603	191.5	5.9	50.3	42.6	98.8	Talc-carbonate	external
NAK 9603	201.5	1.6	47.0	49.7	98.3	Talc-carbonate	external
NAK 9610	252.5	9.6	86.7	-0.1	96.2	Talc-carbonate	internal
NAK 9610	272.5	2.1	46.8	51.2	100.1	Talc-carbonate	internal
NAK 9610	342.5	2.2	48.4	49.2	99.8	Talc-carbonate	external
NAK 9611	197.5	2.6	43.8	52.9	99.4	Talc-carbonate	external
NAK 9612	190.5	3.6	52.6	42.2	98.3	Talc-carbonate	external
NAK 9612	200.5	8.6	51.0	38.7	98.4	Talc-carbonate	int/prox
NAK 9613	169.9	5.0	66.4	27.3	98.6	Talc-carbonate	external
NAK 9613	174.5	2.2	56.8	40.6	99.7	Talc-carbonate	external
NAK 9613	188.75	1.6	50.8	46.1	98.5	Talc-carbonate	external
NAK 9201	371 m	1.2	54.3	40.1	95.5	Talc-carbonate	external
NAK 9201	321 m	9.2	53.3	28.3	90.8	Talc-carbonate	internal
Average	*Nakkan*	*3.2*	*58.9*	*36.4*	*98.5*		
ESK 9008A	151.3 m	2.2	86.1	4.5	92.9	Tc-Carb	external
ESK 9102	64.34 m	7.0	60.8	26.2	94.0	Tc-carb	external
ESK 9008A		1.9	47.8	45.4	95.2	Tc-Carb	external
ESK 9008A	133 m	2.8	55.1	34.2	92.1	Tc-Carb	external
ESK 9008A	163.2 m	1.2	47.0	48.5	96.7	Tc-Carb	external
ESK 9008A	180.3 m	2.2	46.8	47.7	96.7	Tc-Carb	external
ESK 9106	92.40 m	11.8	88.7	-3.1	97.5	Steatite	external
Average	*St. Esjekl.*	*4.1*	*61.8*	*29.1*	*95.0*		
Gr 1		2.3	45.8	47.0	95.1	Tc-Carb	external
Gr 2		5.7	62.2	26.2	94.2	Tc-Carb	external
A, Etg.5		2.2	50.2	43.7	96.2	Tc-Carb	external
Average	Mine	*3.4*	*52.8*	*39.0*	*95.2*		
Average	**Total**	**3.4**	**58.9**	**35.4**	**97.7**		

Table 13: **Main mineralogical content of non-ore rocks estimated from XRF-chemical data.**

Sample		Rock-type	Chlorite	Talc	Carbonate	Sum
NAK 9207	133 m	Smaragditite	26.7	71.3	-11.2	13.2
NAK 9102	218.3 m	Chloritite	97.6	-8.5	-5.3	16.2
ABG 9101A	48 m	Serpentinite	6.7	62.3	16.4	14.5
St. 57 H	7 m	Anthoph-Tc-Carb	18.5	59.5	9.8	12.2
Gemtalc	Lv5	Steatite	1.2	99.4	-3.7	96.9

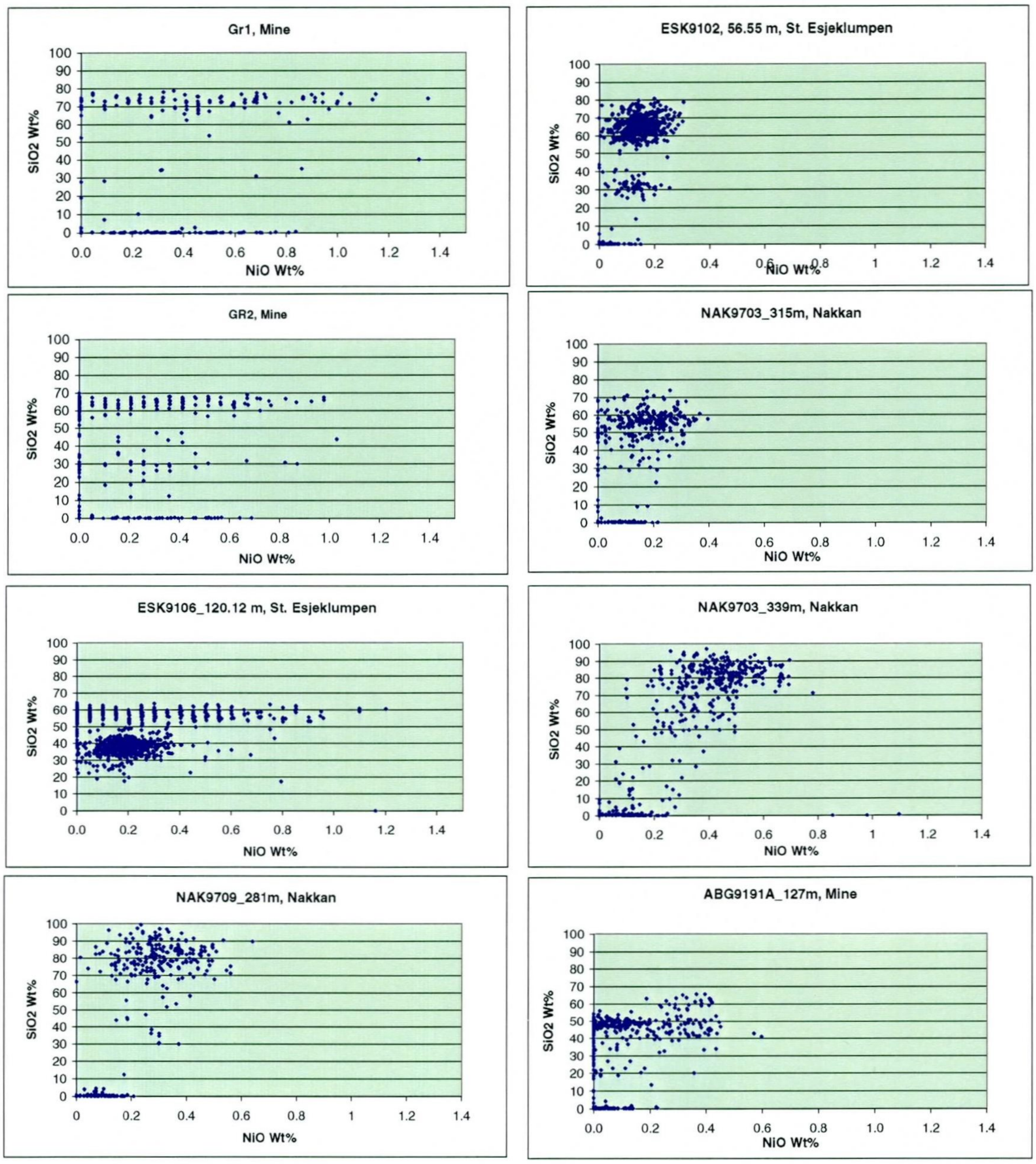


Figure 9: Plots of NiO versus SiO_2, based on microprobe WDS. Explanation: Talc-crystals plot in the uppermost cluster at SiO_2 ~ 40 –100 wt-% (it has not been focused on correct SiO_2-level), while carbonates plot at SiO_2<5 wt-%. In two of the diagrams, for example that to the upper right side, have clusters between talc and carbonate. These clusters represent chlorite. The number of plots in the clusters gives the relative amounts of the mineral species. From the diagrams it is easy to see that Ni in concentrated in talc relative to carbonate and chlorite.

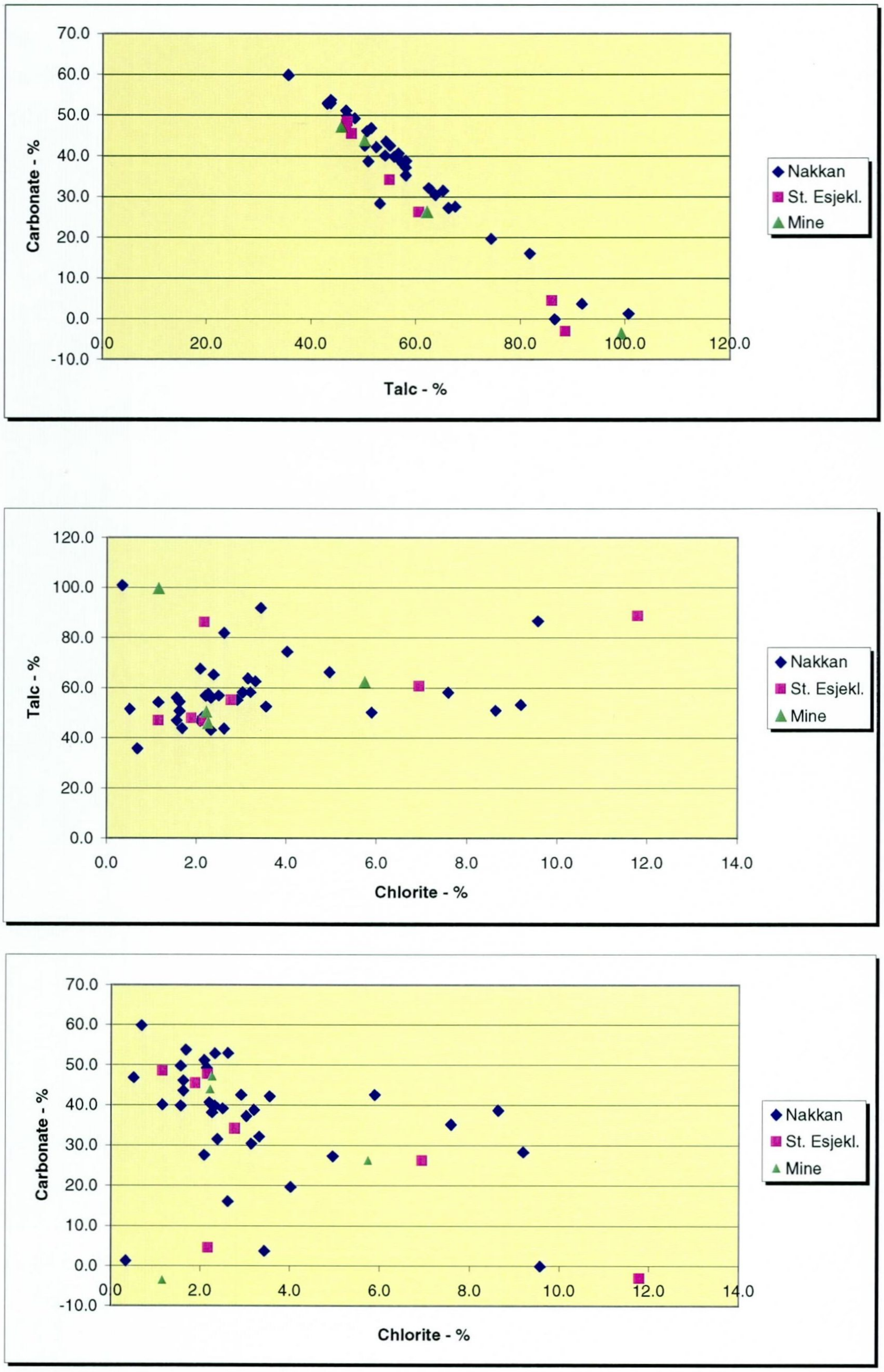


Figure 10: Variation diagrams of mineralogy of the talc-carbonate rocks deduced from chemical data (XRF).

14. APPENDIX

Appendix 1: Drill core logs from the 1997-drilling

DRILL-HOLE	-TO	DESCRIPTION
¨ NAK 9701		
	‧ - 270.0	Chloritite
	‧ - 276.0	Talc-carbonate
		‧ Dark w/augen-texture
		‧ lighter and more fine-grained the last 2 metres
	‧ - 277.7	Talc-carbonate-serpentine
	‧ - 286.95	Serpentinite
		‧ B = 40
	‧ - 293.05	Tc-carb
		‧ Grey, somewhat banded with greenish bands, Mgt-rich
		‧ Medium soft
		‧ No fibres
	‧ - xxxxx	Serpentinite
		‧ Dark with many light greenish veins (dimension stone quality)
NAK 9704		
	‧ - 302.5	Serpentinite
	‧ - 306.95	Serpentine-talc-carbonate
		‧ possibly ore
	‧ - 324.5	Talc-carbonate
		‧ light grey
		‧ magnetite-rich, usually as small grains, but also as a few large grains
		‧ no fiber
		‧ assumed good quality
		‧ Serpentine-bearing the last 3 metres
		‧ B = 30 - 60
	‧ - xxxxx	Serpentinite
¨ NAK 9706		
	‧ - 193.5	Garnet-mica-schist and graphite-schist
	‧ - 193.6	Chloritite
	‧ - 193.75	Smaragdite
	‧ - 194.29	Talc-schist
		‧ dark
	‧ - 208.91	Talc-carbonate
		‧ to 195.5 m: w/carbonate-augen
		‧ to 202.13 m: more banded (white carbonate-bands)
		‧ 200.95-202.13 m: some pure talc-veins
		‧ to 206.62: more massive, a bit darker
		‧ from 206.62: contains some serpentine, darker
		‧ chlorite-bearing the last meter
		‧ B = 45
		‧ the talc-carbonate-zone is in general rather magnetite-rich (increases towards the serpentinite)

· no fiber observed

· - 210.45 Chloritite

· - 216.76 Talc-carbonate
· homogenous to weakly banded
· dark the first meter (assumed chlorite-bearing)
· magnetite-rich
· contains serpentine towards the end

· - 217.80 Serpentine-talc-carbonate
· increased content of serpentine towards the end
· most of it can probably be defined as ore

¨ NAK 9703

· - 312.38 Serpentinite

· - 324.10 Talc-carbonate
· grey, homogenous, magnetite-rich, no fiber

· - 327.75 Talc-carbonate-serpentine
· assumed not ore

· - 333.62 Serpentinite

· - 334.30 Talc-carbonate
· light - medium grey with a weak greenish colour caused by talc-veins
· mgt-rich

· - 334.42 Biotitite

· - 335.82 Talc-carbonate
· as previously

· - 340.0 Talc-carbonate-serpentine
· possibly ore
· greenish
· increased serpentine towards the end

¨ NAK 9707

· - 238.60 Chloritite
· B = 80

· - 238.75 Epidotite

· - 262.13 Talc-carbonate
· partly banded by carbonate
· grey coloured
· magnetite-rich

· - 264.90 Serpentinite
· some talc and carbonate, but not ore quality

· - 273.10 Talc-carbonate
· homogenous
· grey, partly grey-bluish
· somewhat hard
· mgt-rich

· - 276.05 Serpentine-talc-carbonate
· assumed ore

· - 277.10 Serpentine-talc-carbonate
· darker
· possibly ore

· - 278.77 Talc-carbonate-serpentine
- a bit more serpentine, but possibly ore

· - xxxxx Serpentinite
- m/ magnesite and some talc

¨ NAK 9702

· - 263.45 Garnet-mica-schist
- B = 30 - 50

· - 266.72 Biotitite

· - 267.10 Smaragditite

· - 278.25 Talc-carbonate
- greenish to blue-greyish
- homogenous
- dots (mm - 3 cm) of magnesite
- medium magnetite-content, < 5 %

· - 280.50 Talc-carbonate-serpentine
- possibly ore

· - xxxxx Serpentinite

¨ NAK 9708

-232.3 Chloritite, epidot-biotitite m/ garnet
- B = 60

· - 239.4 Talc-carbonate
- some smaragdite the first 10 cm
- magnetite-rich
- more fine-grained and greyish towards 234.12, afterwards more greenish and coarser with carbonate as porphyroblasts 1-2 cm + elongated carbonate-lenses 1-2 dm
- pure talc-veins from 235.5 to the end

· - 240.50 Serpentine-talc-carbonate
- possibly ore

· - xxxxx Serpentinite
- nice, dark w/light gem-serpentine-veins, w/carbonate
- B = 70-80

¨ NAK 9709

· - xxxxx Marble and graphite schist
- B = 70-80, but variable

· - 279.60 Smaragditite, biotitite

· - 290.30 Talc-carbonate
- some amphibole the first 10 cm
- B = 70-90
- to ca. 282.5 m: light , with a weak greenish colour, with carbonates separated as blasts and elongated lenses
- after ca. 282.5 m: more bands of carbonate, a bit darker and more magnetite-rich

· - 296.20 Serpentine-talc-carbonate

· assumed not ore

· - xxxxx Serpentinite

Appendix 2: Drill core logs from the 1998-drilling

DRILL-HOLE	FROM	TO	DESCRIPTION
NAK 9814		256.65	Schist
		257.20	Biotitite w/finegrained smaragditite at the end
		257.60	Talc-schist
		260.10	Talc-carbonate
			- good quality, no fibres
		260.40	Talc-carbonate-serpentine
		263.30	Serpentinite
			- gradual transitions in both ends
		264.50	Talc-carbonate
		264.70	Talc-schist
			- grey, probably chlorite rich
		265.50	Smaragditite (first), then biotitite & smar. alternately
		?	Amphibolite
NAK 9813			
		215.05	Garnet-mica-schist & amphibolite alternately
		215.15	Smaragditite w/some chlorite
		218.20	Talc-carbonate
			- Weakly sulphide bearing
			- Good quality
		219.00	Talc-carbonate-serpentine
		224.10	Serpentine
		226.60	Talc-carbonate
			- incl. some serpentine
			- magnetite rich
		?	Serpentinite
NAK 9812		259.55	Smaragditite
		259.65	Talc-schist
		267.00	Talc-carbonate
			- soft
			- patches (0.5-1cm) and bands of carbonate
		271.90	Serpentinite
			- talc & carbonate bearing
		278.30	Talc-carbonate
			- weakly serpentine bearing 271,90-276,00 m (gradually decreasing)
			- contains reddish anthophyllite (5-20%) in the area 276,00-278,30 m
		278.60	Chloritite
		279.60	Impure marble
		?	Amphibolite
NAK 9812		290.50	Amphibolite and biotitite alternately, and some smaragditite
		290.55	Marble
		290.90	Talc-schist
		292.00	Talc-carbonate-serpentine
			-Probably ore
		?	Serpentinite
			- gradual transition from above

NAK 9804	209.70	Amphibolite
	209.90	Biotitite
	210.05	Chloritite
	212.30	Talc-carbonate - weakly sulphide-bearing - coarse patches (2-3cm) of carbonate rich in magnetite
	217.30	Serpentinite
	223.00	Talc-carbonate - serpentine bearing the last 70 cm - medium quality - magnetite-content a bit higher than usual - relatively high content of talc despite the occurrence as an internal ore
	233.00	Serpentinite
	236.00	Talc-carbonate - magnetite rich - otherwise an OK talc% - some serpentine the last 0.5 m)
	?	Serpentinite
NAK 9806	231.90	Serpentinite - the last 0.5 m: talc-carbonate-rich
	241.50	Talc-carbonate - dark - *rich in chromite/magnetite* - some small amounts of sulphide
	?	Serpentinite - Talc-bearing the first 0.5 m
NAK 9802	194.70	Amphibolite
	195.55	Chloritite w/big garnets and secondary magnetite
	195.95	Epidotite
	198.40	Talc-carbonate - weakly sulphide bearing - gradual transtition to....
	?	Serpentinite
NAK 9808	197.45	Garnet-mica-schist, quartz-rich
	197.90	Biotitite
	198.00	Smaragditite
	201.15	Talc-carbonate - magnetite rich - rather light coloured
	?	Serpentinite
NAK 9809	211.45	Garnet-mica-schist, graphite bearing
	211.49	Biotitite
	211.55	Smaragditite
	216.50	Talc-carbonate - 216.20-216.30: Talc-schist - 216.30-216.50: Chlorite-talc-schist - partly chlorite-bearing
	216.65	Chloritite
	216.70	Biotitite
	?	Amphibolite

NAK 9805	238.70 Amphibolite
	239.00 Chloritite
	245.20 Talc-carbonate
	- greencoloured talc
	- very small amounts of sulphides
	- contains biotite the first 20 cm's
	247.20 Serpentine-talc-carbonate
	250.20 Talc-carbonate-serpentine
	? Serpentinite
NAK 9801	257.75 Serpentinite
	- rich in magnesite veins
	- blue-green
	- Talc-carbonate: 255,70-256,40 m
	274.00 Talc-carbonate
	- serpentine bearing in the area 264,45 ....
	- no sulphide observed
	- magnetite rich
	- greyish-bluish colour
	- rather high talc-content despite being an internal zone
	276.75 Talc-carbonate-serpentine
	- gradually increasing serpentine content
	? Serpentinite
NAK 9810	238.05 Chloritite/smaragditite
	238.15 Talc-schist
	? Talc-carbonate
	- serpentine-bearing: 240.4-241.5 m
	- medium-high magnetite content
	- banded texture the first 2 metres, then serpentinite textured
	- missing core
NAK 9811	80.25 Biotitite
	83.45 Talc-carbonate
	- greenish, relatively sulphide-rich
	? Biotitite w/fragments of garnet-mica-schist
	216.25 Amphibolite
	216.50 Biotitite/smaragditite
	216.58 Smaragditite-talc-schist
	220.50 Talc-carbonate
	- low sulphide
	- Talc-rich
	- medium magnetite-content
	- weakly banded
	- mostly greyish
	225.10 Serpentine-talc-carbonate
	- possible ore
	- greyish-greenish, green serpentine bands, partly serpentinite textured
	227.80 Serpentinite
	230.90 Serpentine-talc-carbonate
	- possible ore
	- magnetite rich
	? Serpentinite

Appendix 3: Variation diagrams from Microprobe EDS analyses

- By using the EDS-system, the analyses are normalised to 100 %, and volatile elements are not included.

Upper diagrams: SiO_2 versus NiO

The diagram illustrates the content of NiO in the minerals. The cluster of plots to the right, at $SiO_2 \approx 60 - 74\%$, represent talc. To the left of the diagram, non-silicate-minerals like carbonate, magnetite and sulphides are seen to plot. When present, chlorite and serpentine plot to the left of talc, at $SiO_2 \approx 30\text{-}40\%$. The diagram also illustrates the general lack of quartz, which should plot to the right side of the diagram at $SiO_2 \approx 90 - 100\%$.
It is important to note that the level of NiO in talc on these diagrams are unrealistically high, and that the samples have been re-analysed by the more excact WDS-system on microprobe.

Middle diagrams: Fe_2O_3 versus MgO

Two clusters of plot are presented in most of the samples, one for the carbonates (uppermost) and one for talc and chlorite (at MgO = 20-30wt). The shape of the carbonate cluster is primarily caused by chemical zoning of the carbonates with Mg rich cores and Fe rich rims. The talc/chlorite cluster shows the variation in Fe-content within talc and chlorite. A precaution to this interpretation must be given: some of the analyses might be affected by nearby magnetite, resulting in too high Fe_2O_3 values.
In case magnetite is present, it plots on the lower right side.
It is important to note that the level of Fe_2O_3 in these diagrams is considered to be too high, and only the trends are correct.

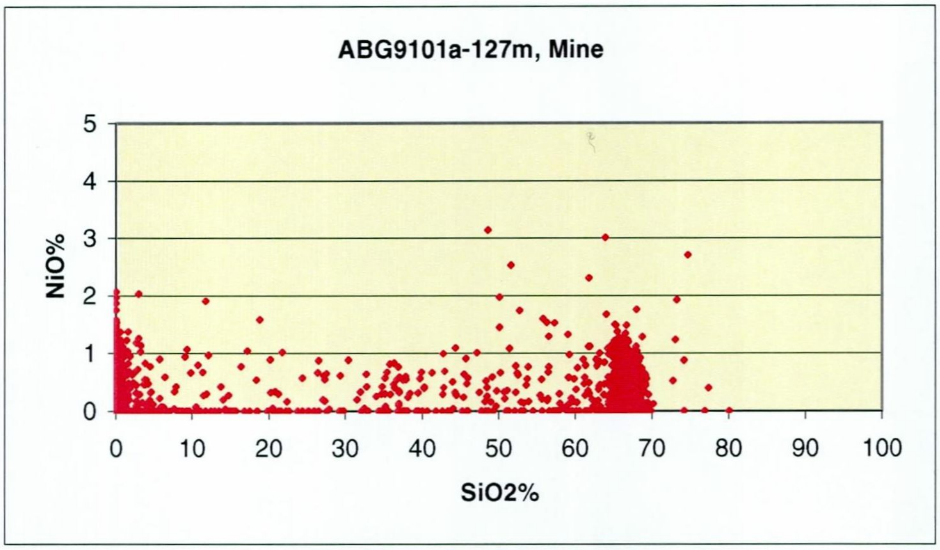
Lower diagrams: SiO_2 versus Cr_2O_3

These diagrams indicate that small amounts of Chromium is present within talc (the cluster to the right) and in carbonate (the cluster to the lower left). When chlorite, which is the dominant Chromium bearing silicate, occurs it plots at $SiO_2 \approx 30 - 40\%$.

In some cases there are many single points between the clusters in the diagram. These points represent analyses that are affected by two or more minerals. The abundance of such points is partly dependent of the grain size and texture of the rock-sample.

Appendix 4: Mineral formulas used in the calculation of mineralogical content from chemical data (XRF).

Mineral formulas	*talc*	*breunnerite*	*chlorite*
SiO_2	62.43	-	30.40
TiO_2	0.32	-	0.00
Al_2O_3	0.04	-	17.11
FeO	1.05	11.68	6.30
MnO	0.00	0.12	0.06
MgO	31.63	39.33	31.31
CaO	0.00	0.28	0.03
Na_2O	0.09	-	0.00
K_2O	0.03	-	0.01
Cr_2O_3	0.09	-	2.75
NiO	0.22	-	0.11
Sum	95.90	51.41	88.08
LOI	4.10	48.59	11.92



ABG9101a-127m, Mine
NiO%
SiO2%
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2
3
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10
20
30
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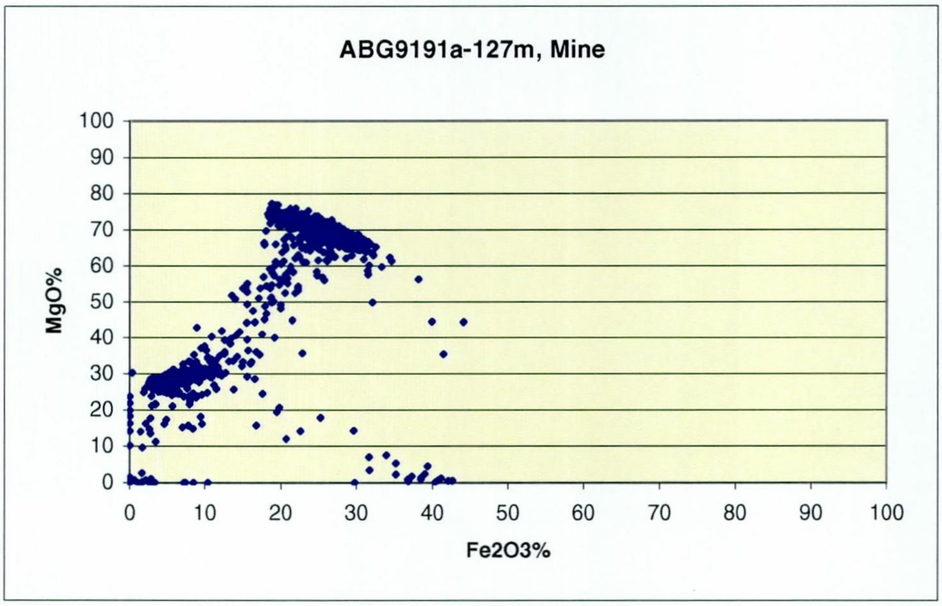
60
70
80
90
100



ABG9191a-127m, Mine
MgO%
Fe2O3%
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90
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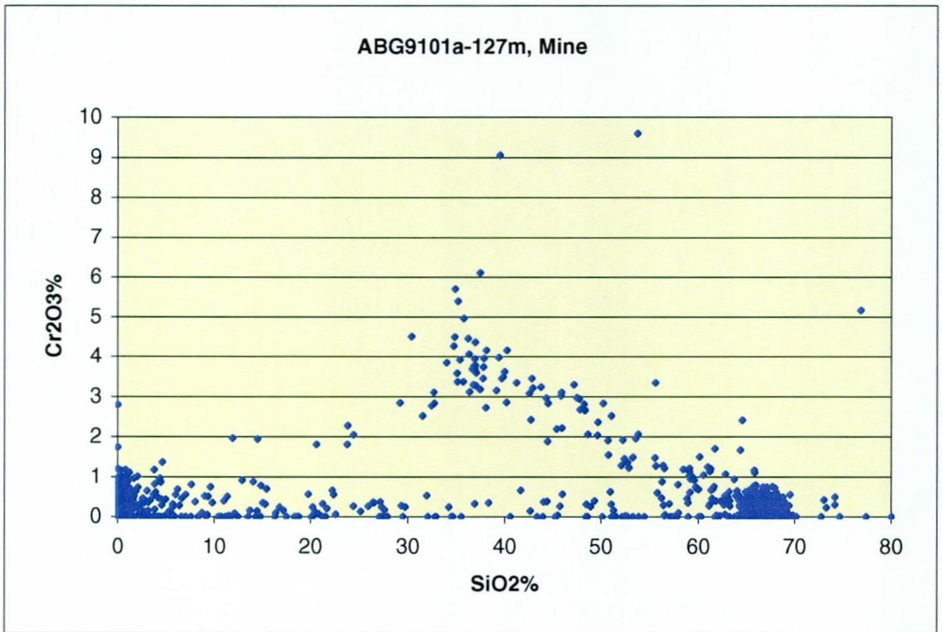

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Cr2O3%
SiO2%
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3
4
5
6
7
8
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10
20
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50
60
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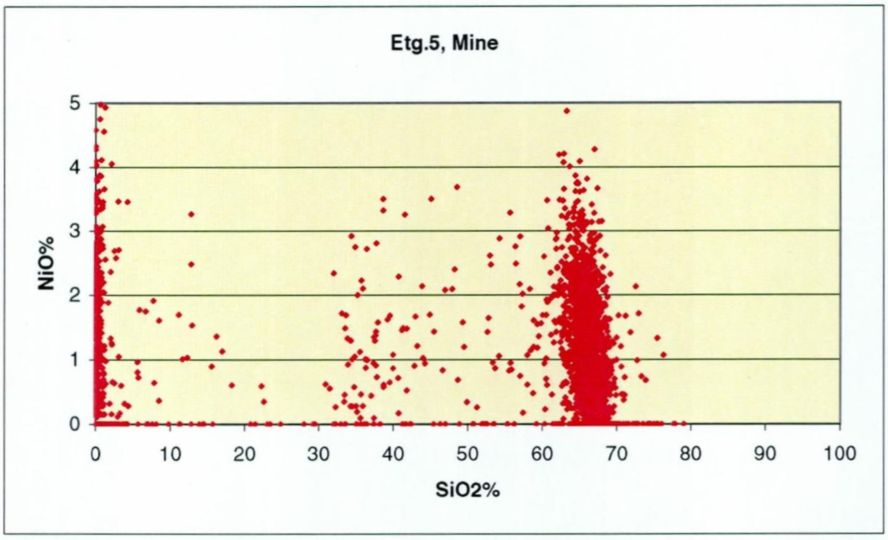
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SiO2%
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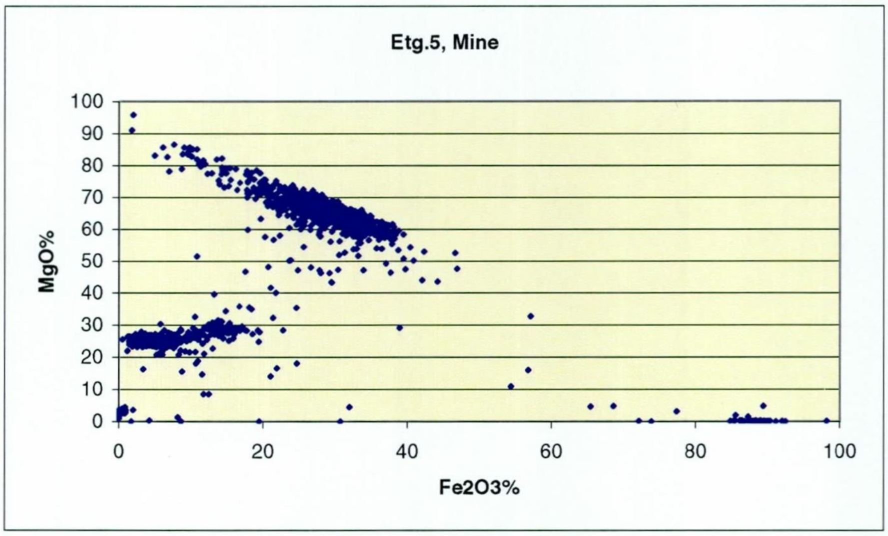
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Fe2O3%
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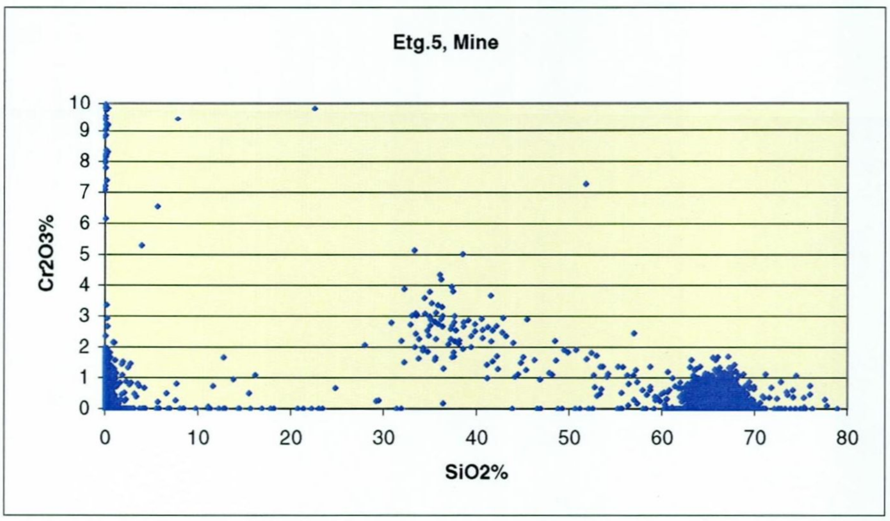
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SiO2%
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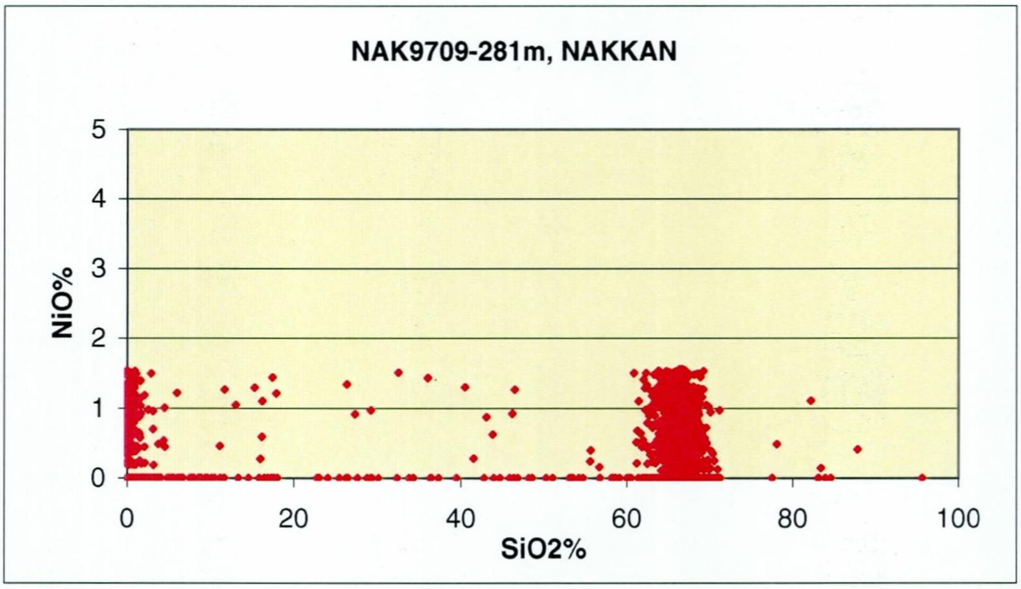
40
50
60
70
80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SiO2%
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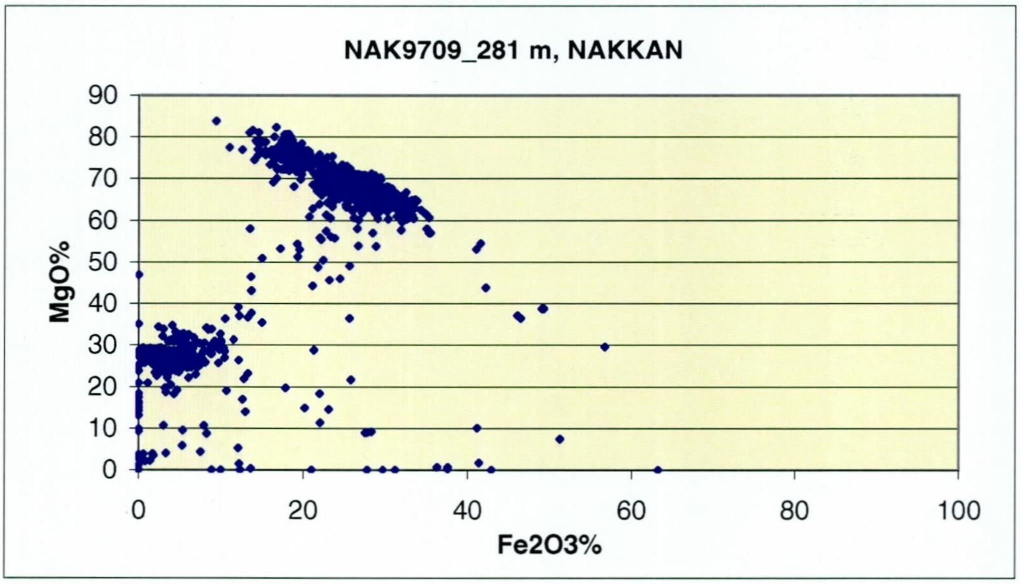
100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MgO%
Fe2O3%
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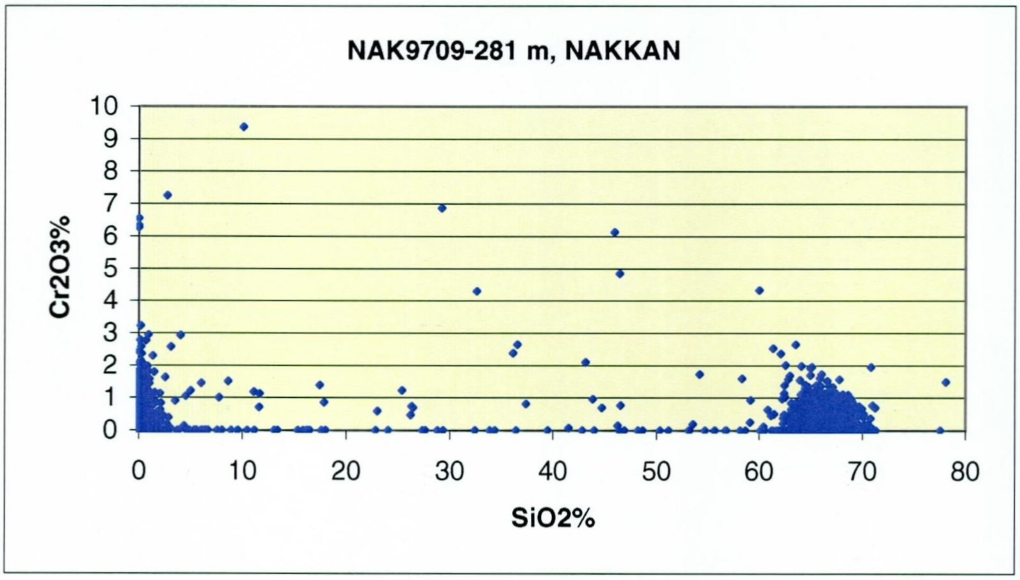
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Cr2O3%
SiO2%
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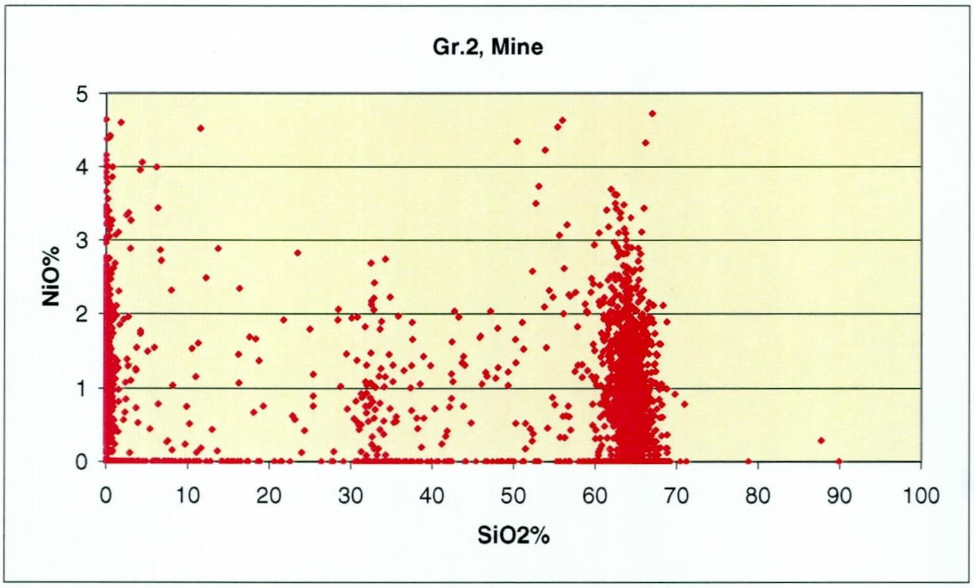
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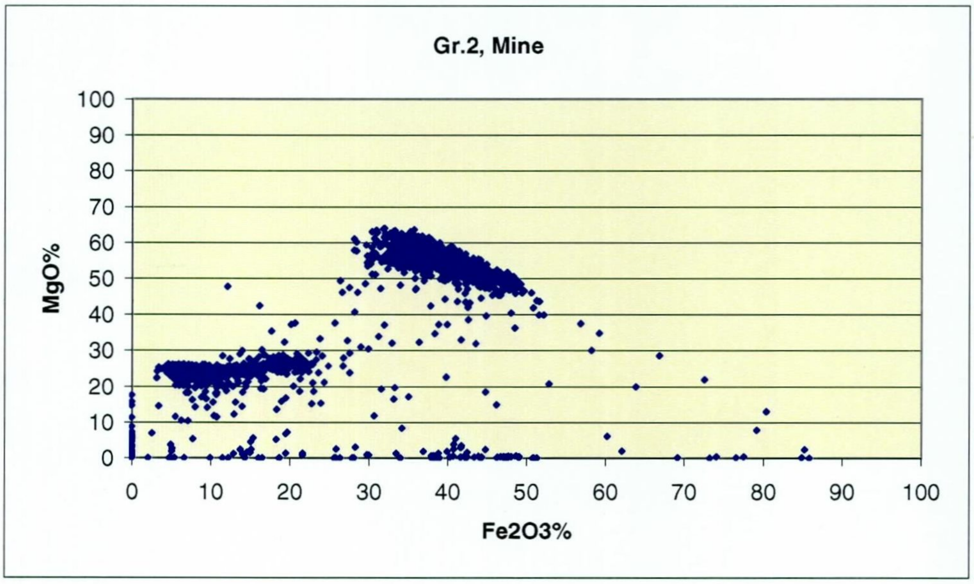
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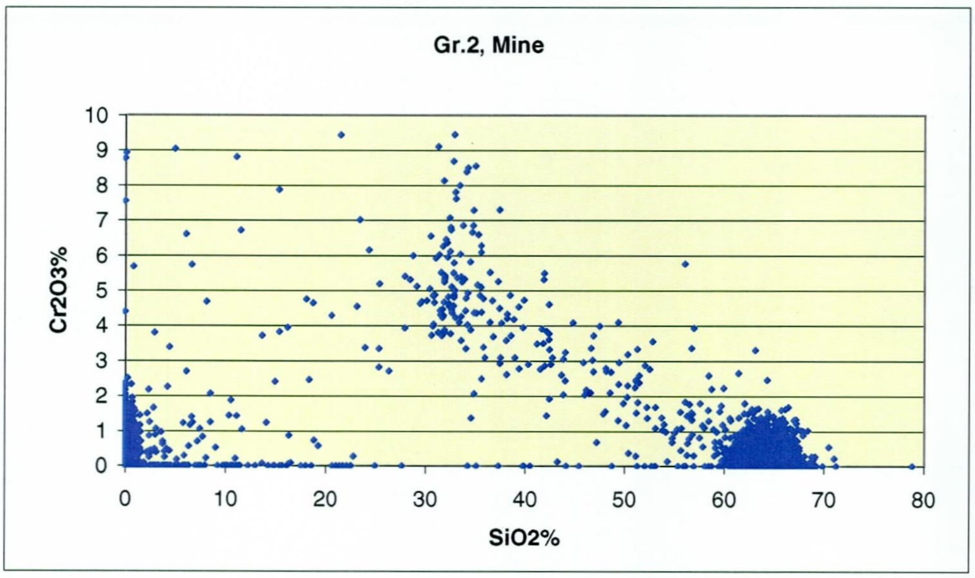
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Cr2O3%
SiO2%
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3
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7
8
9
10
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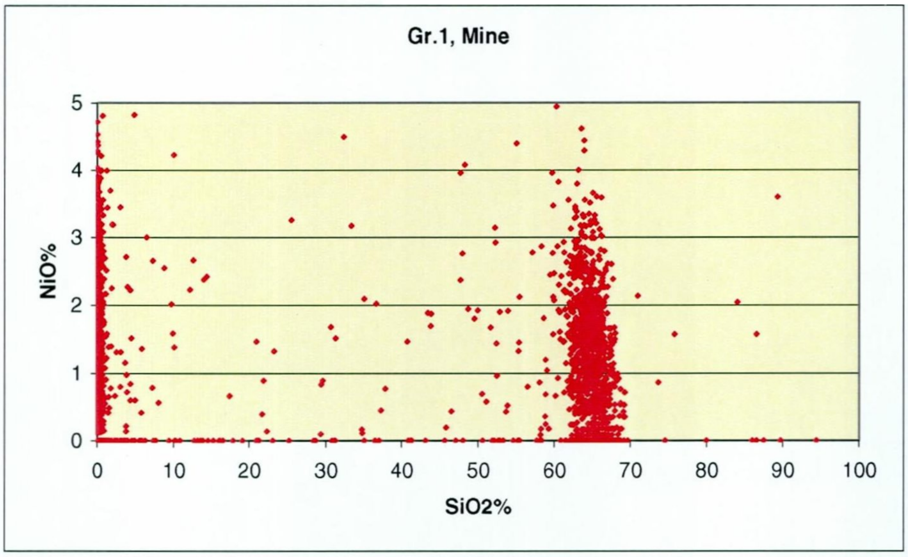
80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SiO2%
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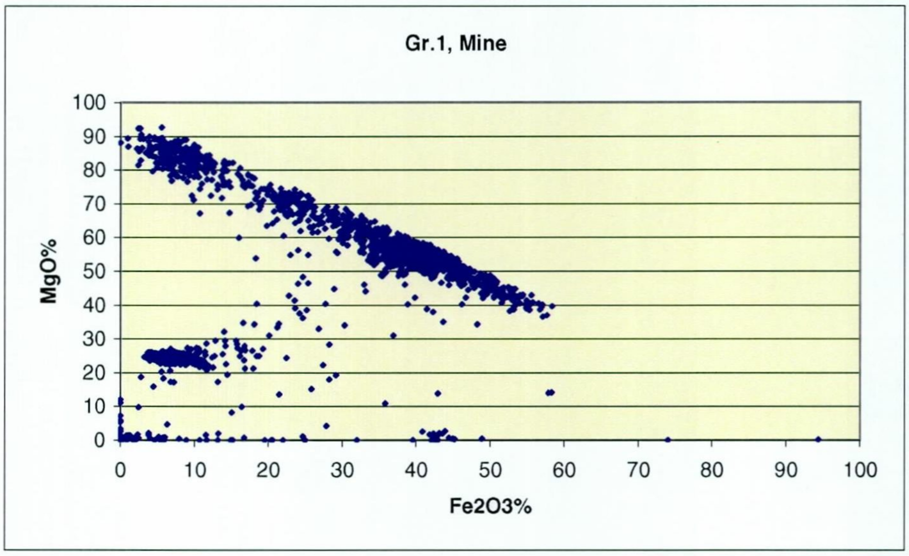
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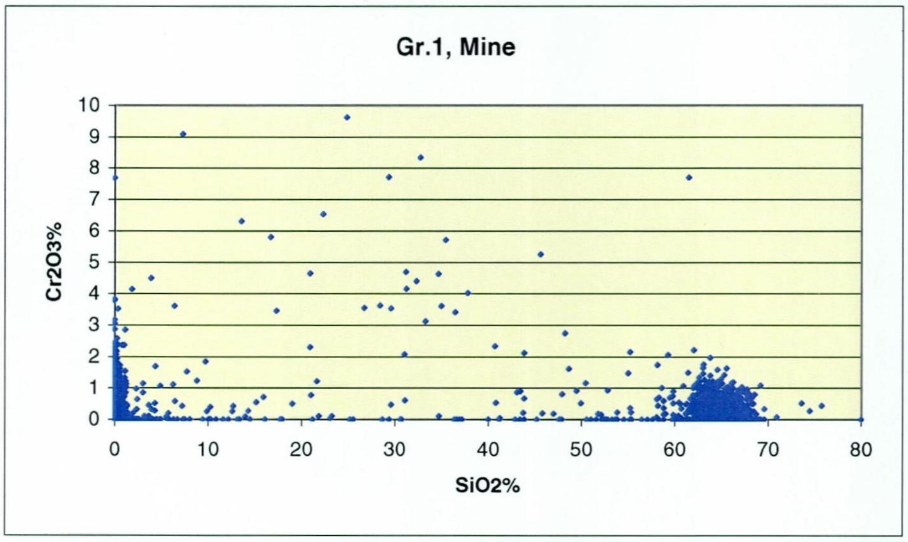
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SiO2%
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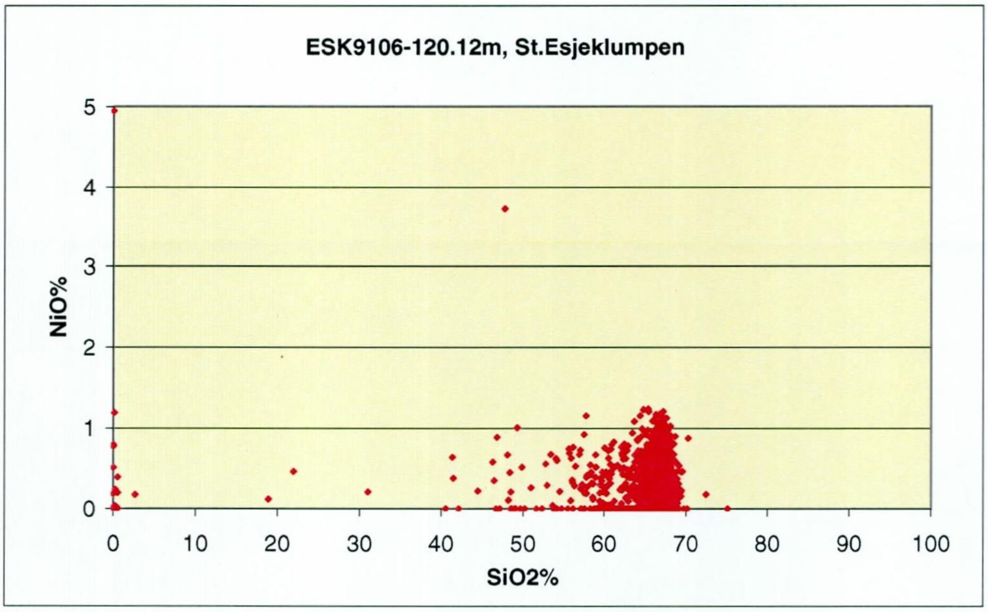
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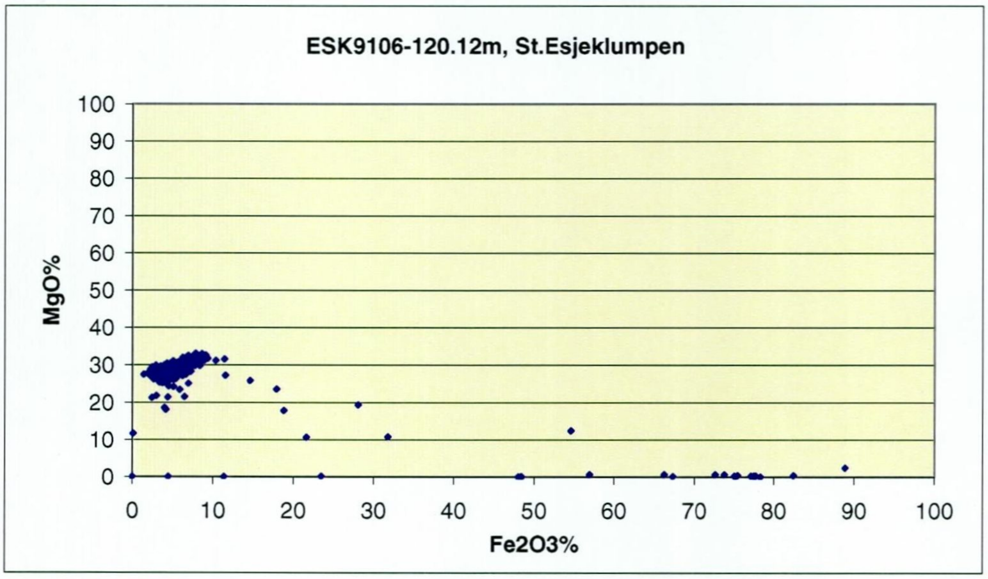
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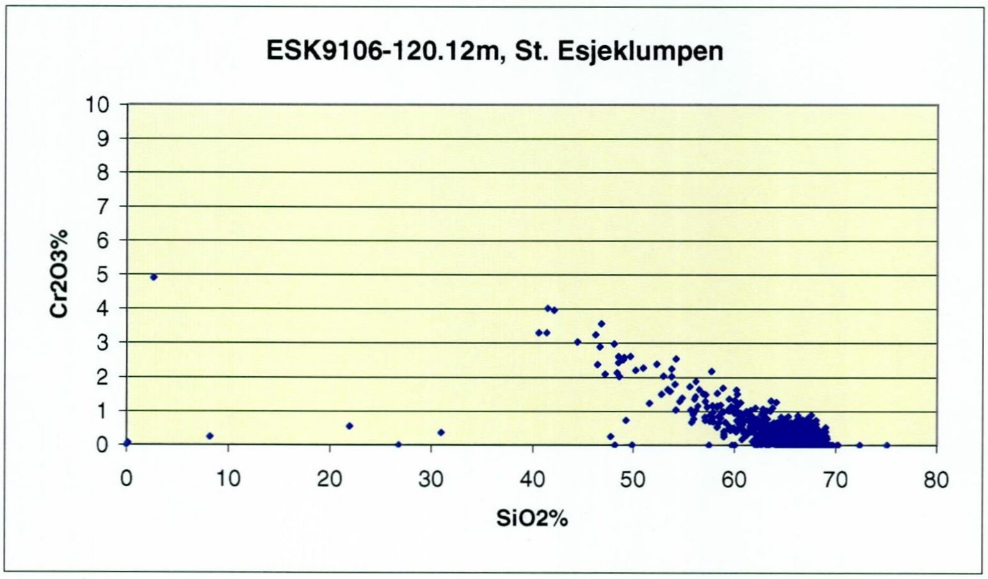
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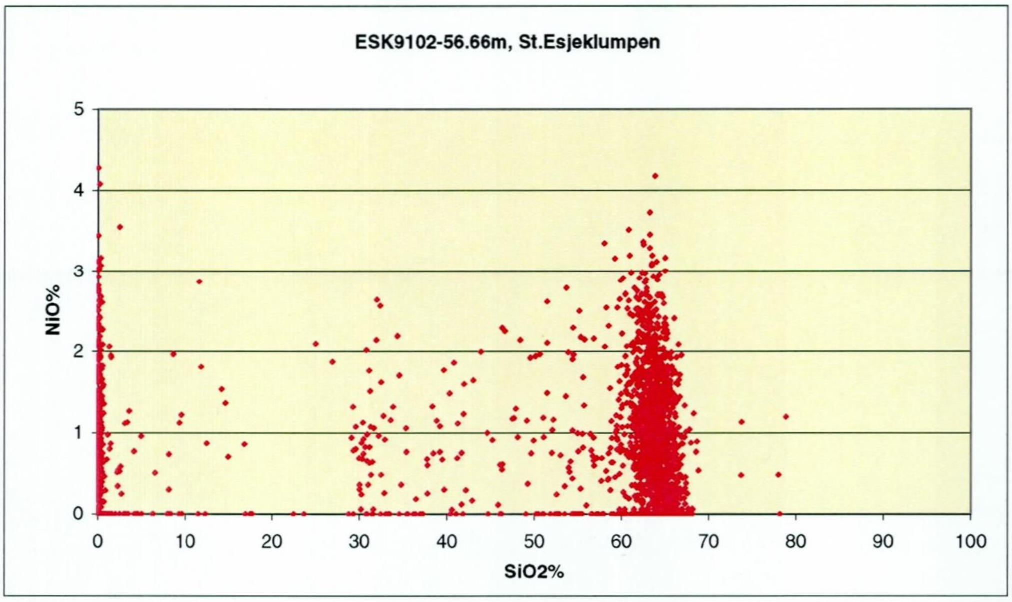
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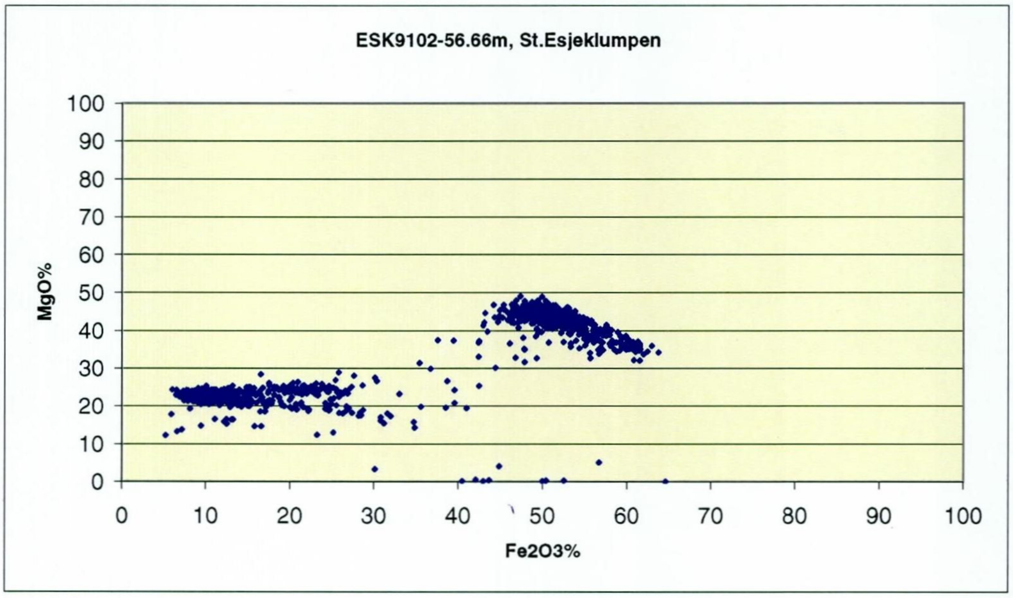
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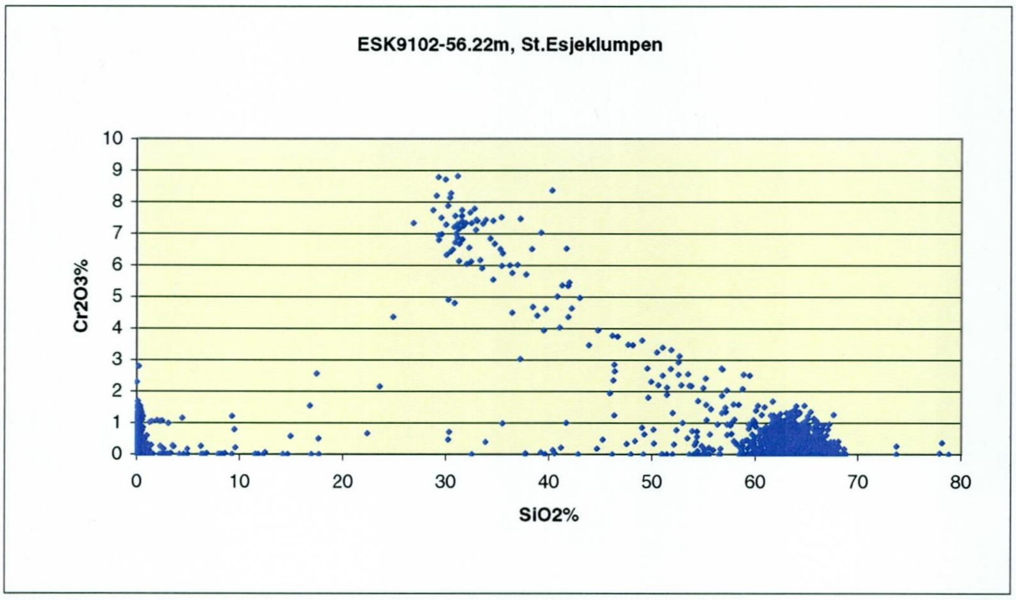
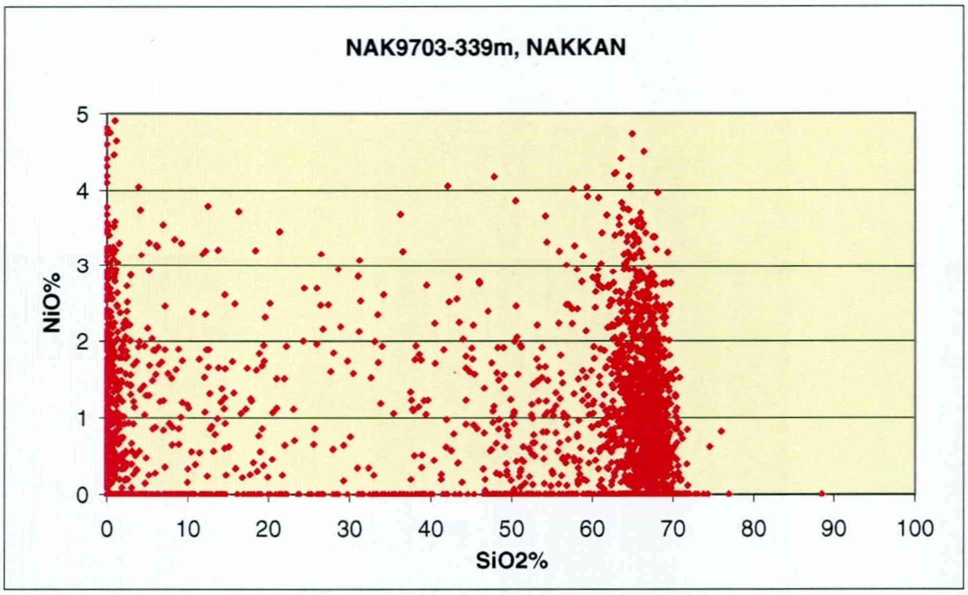
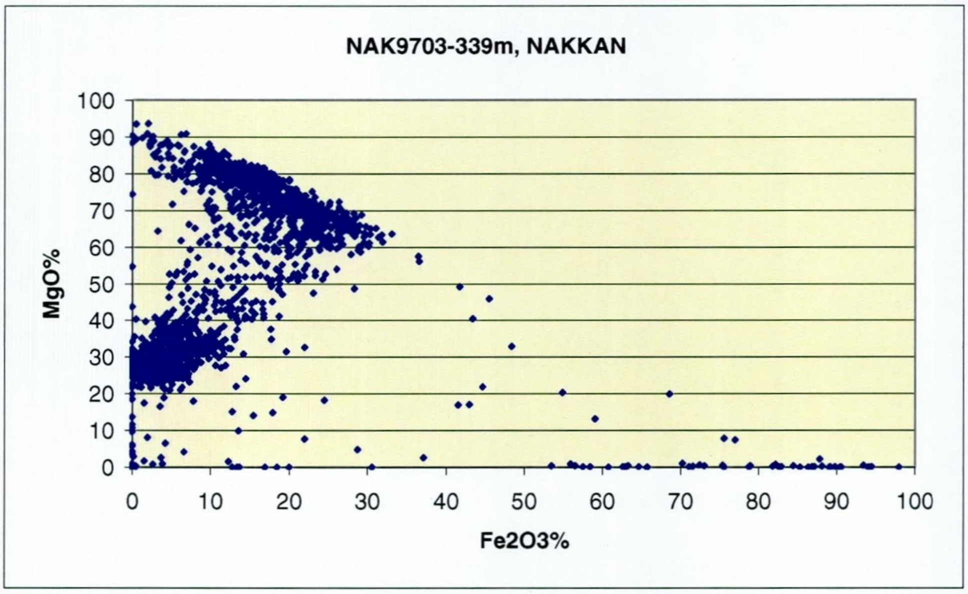
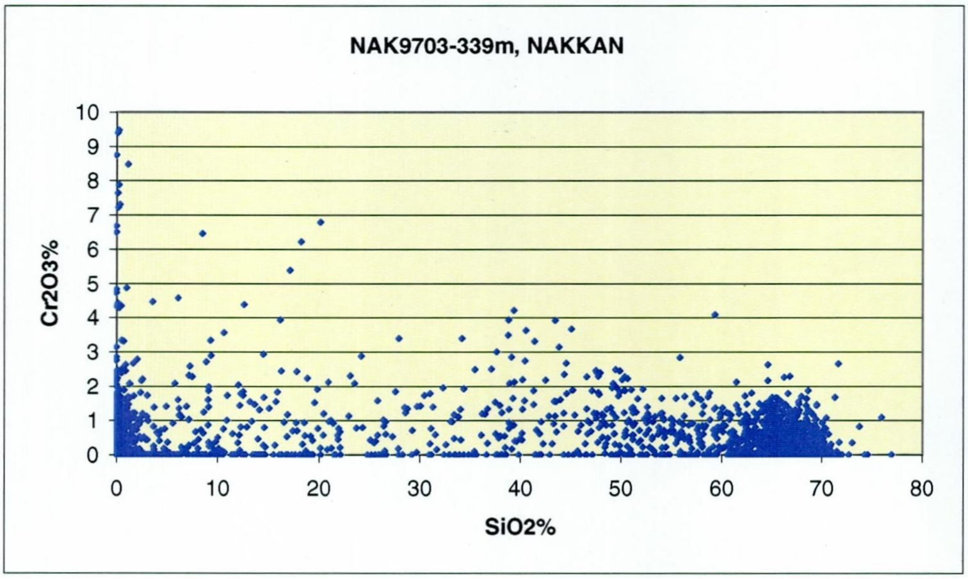
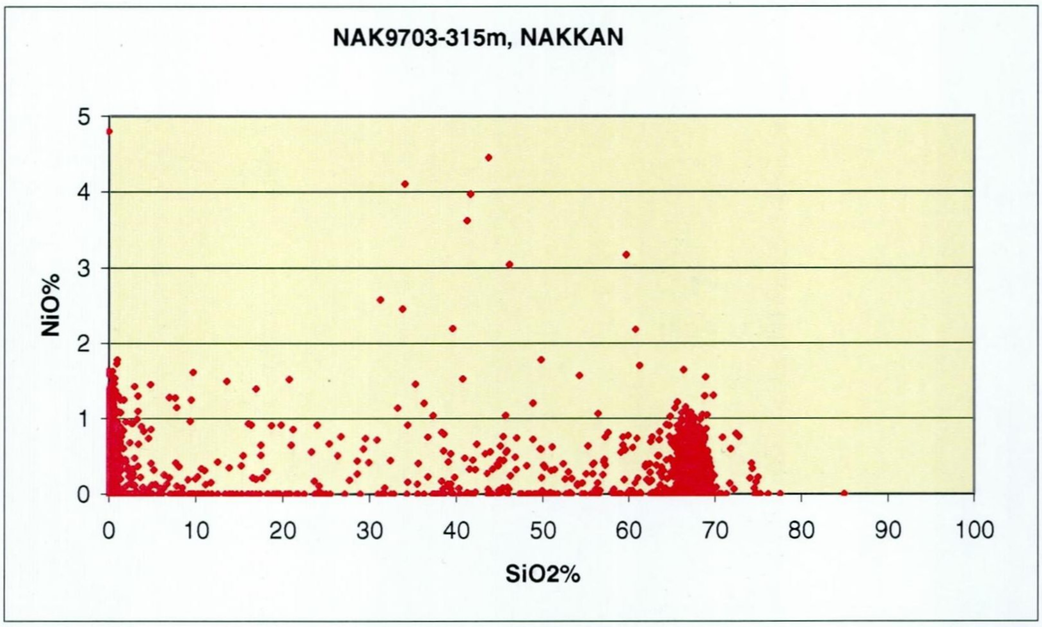

ESK9102-56.22m, St.Esjeklumpen
Cr2O3%
SiO2%
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80

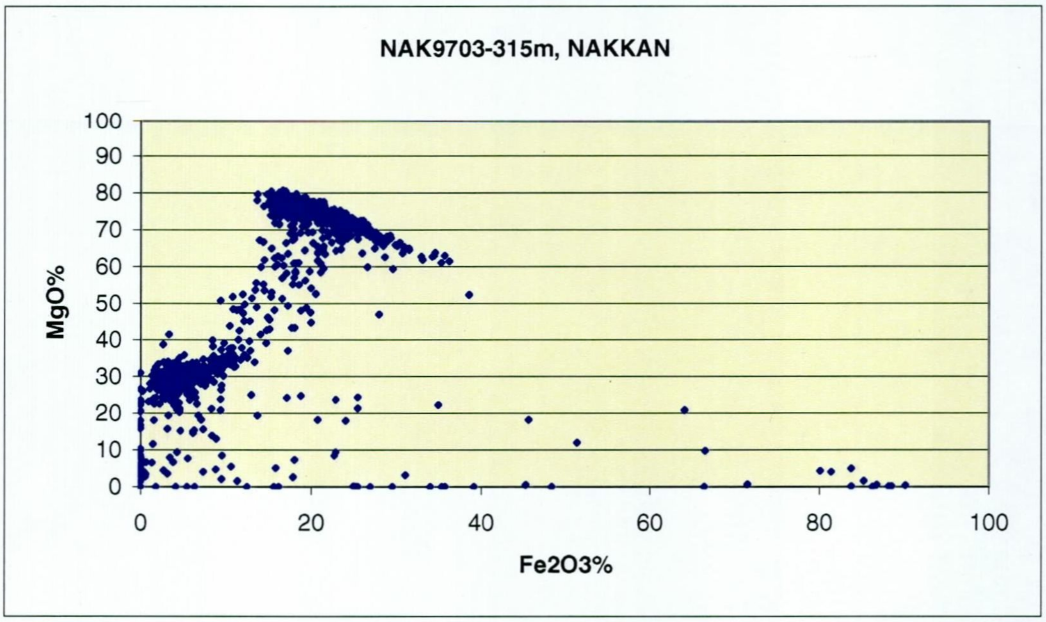

NAK9703-339m, NAKKAN
NiO%
SiO2%
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100


NAK9703-339m, NAKKAN
MgO%
Fe2O3%
0
10
20
30
40
50
60
70
80
90
100

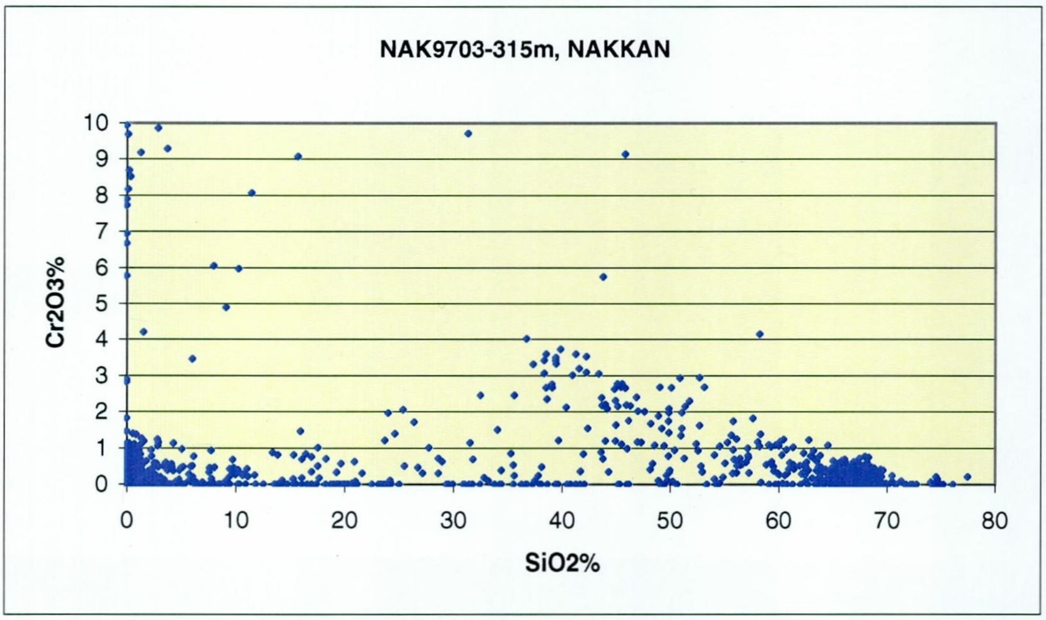

NAK9703-339m, NAKKAN
Cr2O3%
SiO2%
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80



NAK9703-315m, NAKKAN
NiO%
SiO2%
0
1
2
3
4
5
10
20
30
40
50
60
70
80
90
100



NAK9703-315m, NAKKAN
MgO%
Fe2O3%
0
10
20
30
40
50
60
70
80
90
100



NAK9703-315m, NAKKAN
Cr2O3%
SiO2%
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80