NGU Report 2002.042

Chemical characterisation of ilmenite, magnetite and apatite in the Bjerkreim-Sokndal Layered Intrusion, Rogaland, South Norway

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REPORT

Report no.: 2002.042	ISSN 0800-3416	Grading: Open

Title:
Chemical characterisation of ilmenite, magnetite and apatite in the Bjerkreim-Sokndal Layered Intrusion, Rogaland, South Norway

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County: Rogaland	Commune: Lund, Eigersund, Bjerkreim
Map-sheet name (M=1:250.000) Stavanger, Mandal	Map-sheet no. and -name (M=1:50.000) 1311 IV, Sokndal; 1312 III, Ørsdalsvatnet; 1212 II, Bjerkreim
Deposit name and grid-reference:	Number of pages: 25 Price (NOK): Kr. 130,- Map enclosures:

Fieldwork carried out:	Date of report:	Project no.:	Person responsible:
July 2001	May 31st, 2002	293700	[signature]

Summary:

During 2001 cooperation was established between NGU and Norsk Hydro Agri in order to locate combined resources of apatite, ilmenite and vanadian magnetite in the Bjerkreim-Sokndal Layered Intrusion in the Rogaland Anorthosite Province of south Norway. It had previously been recognized that a potential existed for finding coexisting apatite, low-MgO ilmenite and vanadium-rich magnetite in the northern part (the Bjerkreim-lobe) of the layered intrusion. It had also become apparent that none of the minerals are present in amounts that can support exploitation of one mineral alone. Fieldwork was undertaken during July 2001 with the purpose of locating and constraining the most promising areas in terms of volume and grade of the three target minerals in the Bjerkreim-lobe. Three apatite-bearing and oxide-rich zones were singled out, sampled and preliminarily constrained. These zones are located with one area in mega-cyclic unit (MCU) IBe (Åsen-Bjerkreim), containing up to 41 % of the three minerals, two areas in MCU IIIe (Helleland and Terland respectively), with up to 34 % of the three minerals, and in MCU IVe (Teksevatnet-Vasshus), with 32 % ilmenite, magnetite and apatite. The fieldwork and subsequent whole-rock chemical analyses (XRF) were described and discussed by Schiellerup et al. (2001).

In the apatite- and oxide-rich part of MCU IBe the MgO-content of ilmenite vary between 1.36 and 2.26 % with an average of 1.8 %. Stratigraphically dependant variation has not been resolved and the highest MgO contents in ilmenite tend to occur in the most mafic layers. In the two MCU III prospects at Helleland and Terland the MgO-content in ilmenite averages 2.2 and 2.5 % respectively, whereas the Teksevatnet profile yield an average of 1.4 % MgO in ilmenite. In the Teksevatnet profile the modal contrast between mafic and felsic layers is exceptional and the MgO-content of ilmenite is considerably higher in mafic layers (av: 2.1 %) than in felsic layers (av: 0.6 %). In MCU IV average ilmenite compositions have 1.0 % MgO in Terland, 1.3 in Lauvneset, 1.0 in Bilstad and 1.8 at Storeneset.

V_2O_3 in magnetite remains relatively constant, with averages of 0.92 in the MCU IBe samples, 0.94 in the MCU IIIe samples and 0.90 in the MCU IVe samples. No stratigraphic dependency has been observed except from in the uppermost and relatively oxide-poor part of the Terland profile.

Apatite compositions have been analyzed in five samples. All apatites are fluor-apatites with Cl/F ratios of 0.01-0.02.

The overall best mineral quality so far detected is to be found in the MCU IV profiles making the Teksevatnet-Bilstadvatnet area the most interesting of the prospects investigated.

Keywords: Apatite	Ilmenite	Magnetite
Vanadium	Bjerkreim-Sokndal Layered Intrusion	Rogaland Anorthosite Province
Norite		

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Appendix 1 Ilmenite, electron probe microanalyses.
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Appendix 3 Apatite, electron probe microanalyses.

1. INTRODUCTION

In 2001 a project was initiated between Norsk Hydro Agri and the Geological Survey of Norway to assess the potential for finding exploitable combined resources of ilmenite, magnetite and apatite in the Bjerkreim-Sokndal Layered Intrusion, Rogaland, South Norway. Field work and whole-rock chemistry was reported by Schiellerup et al. (2001) who recognized four areas of potential interest in the northern, Bjerkreim-lobe, of the layered intrusion (Fig. 1). In these four areas the total amount of apatite, ilmenite and magnetite exceeded 30 wt%. The areas were located with one area in megacyclic unit (MCU) IBe (Åsen-Bjerkreim), containing up to 41 % of the three minerals, two areas in MCU IIIe (Helleland and Terland respectively), with up to 34 % of the three minerals, and in MCU IVe (Teksevatnet-Vasshus), with 32 % ilmenite, magnetite and apatite.

In order to fully assess the economic significance of the possible targets the mineral quality had to be assessed. The present report therefore deals with the mineral chemistry of ilmenite, magnetite and apatite in the Bjerkreim-lobe and suggests that further action should be taken to constrain the volumes of the potential prospects.

2. BACKGROUND

The Bjerkreim-Sokndal Layered Intrusion consists of a series of 6 mega-cyclic units (MCU's), each repeating a distinct sequence of evolving mineralogies (Fig. 2, see also Schiellerup et al. 2001). Ilmenite always appears early in each of the evolving sequences, magnetite somewhat later, and apatite is a late phase to enter the mineral assemblage. Only three MCU's contain zones where ilmenite and magnetite are found together with apatite (Fig. 2). These zones are generally assigned the letter "e". Consequently, the fieldwork and subsequent geochemical work was aimed to locate oxide- and apatite-rich sequences of sufficient grade and mineral quality to be of economic interest within each of the three known "e-zones".

The most important and only major element controlling the quality of ilmenite is magnesium, and the mineral industry generally desire ilmenite with less than 1-1.5 % MgO. In reporting ilmenite compositions in this report we therefore chiefly focus on the variation in MgO content. At present, ilmenite mined at the Tellnes plant in Rogaland contain on average around 4 % MgO.

Magnetite in layered intrusions may be important carriers of vanadium, and presently a thick magnetite-dominated layer in the layered Bushveld Complex in South Africa is processed for vanadium. The Main Magnetite Layer, which is the only producing deposit in the Bushveld Complex, contain around 1.32 % V_2O_3 (Lee, 1996). Here we report vanadium contents as V_2O_3, which is the form of vanadium in magnetite. The commonly cited V_2O_5 is the commercially extracted end product.

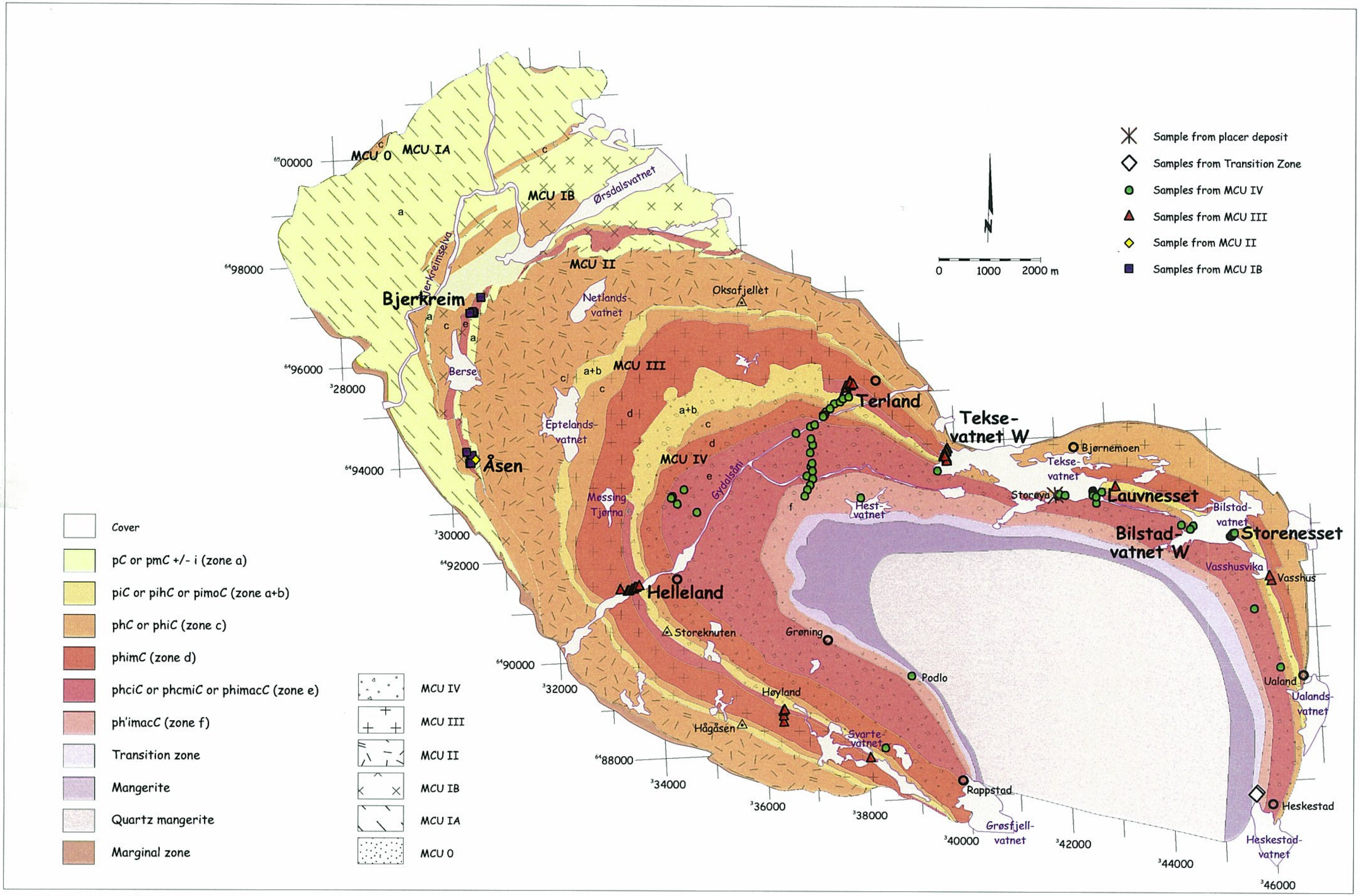

Fig. 1. Geological map of the Bjerkreim-lobe of the Bjerkreim-Sokndal Layered Intrusion with sample localities shown. For details on stratigraphic and cumulate nomenclature see Schiellerup et al. (2001).

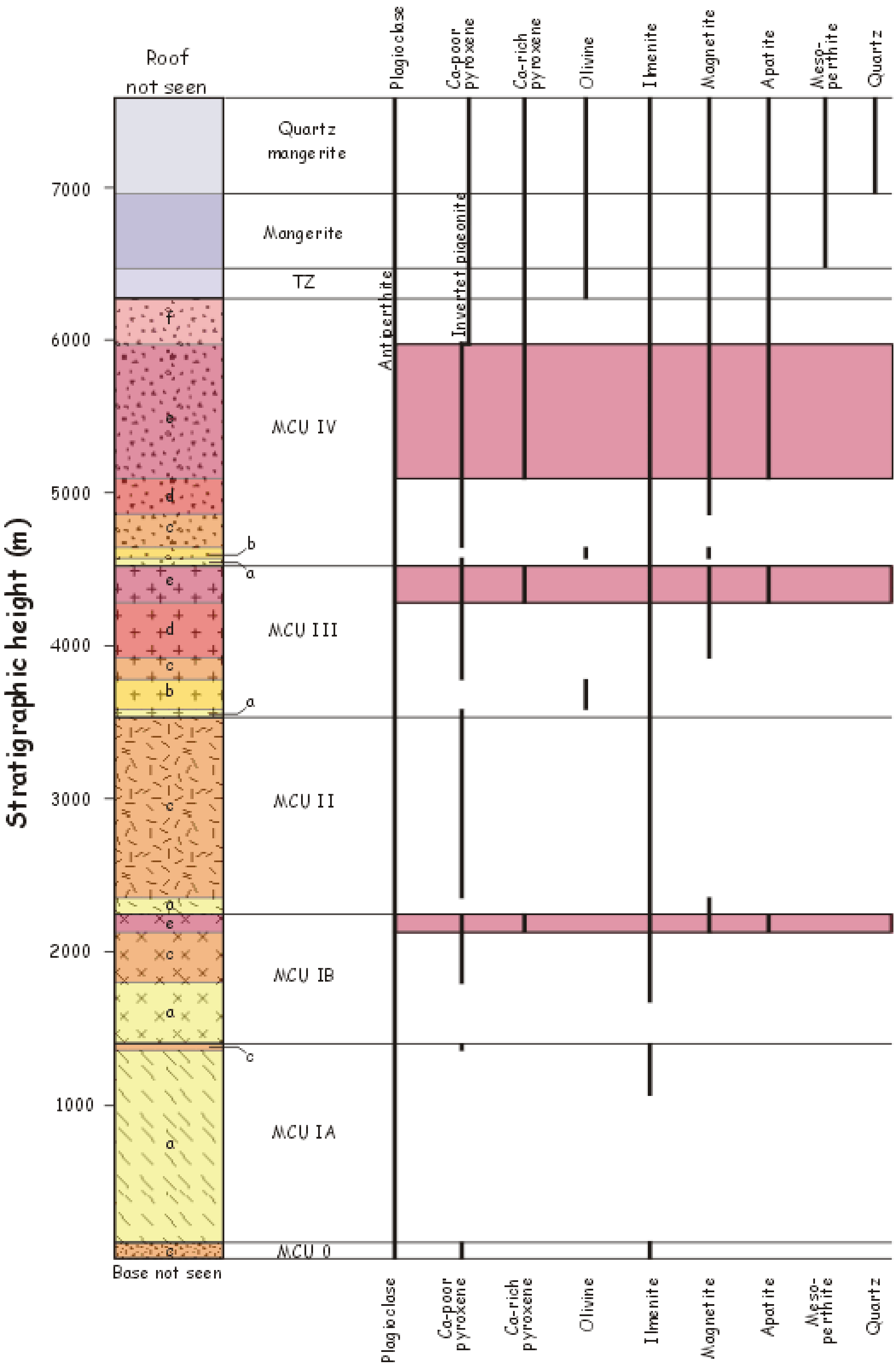

Fig. 2. Cumulate stratigraphy in the Bjerkreim-lobe of the Bjerkreim-Sokndal Layered Intrusion. The layered series is made up by 6 megacyclic units (MCU's) subdivided into a sequence of zones (a-f), defined by the presence or absence of certain index minerals. Three apatite-bearing sequences are found in the Bjerkreim-lobe (expanded red intervals): MCU IBe, MCU IIIe and MCU IVe-f.

3. ANALYTICAL PROCEDURE

Ilmenite and magnetite compositions have been obtained on the SEM-facility at the Geological Survey of Norway using a LEO1450VP scanning electron microscope equipped with an EDS detection system and a single WDS spectrometer. All data reported are EDS (energy dispersive) analyses. Oxides and silicates were used as standards and only vanadium was analysed using a pure element standard. Analyses were performed with an acceleration voltage of 15 kV and a 4 nA beam current. Counting time was set to 40 seconds live time. All samples denoted GBM as prefix (Appendices 1 and 2) originate from an earlier study. These samples were analysed at the Jeol JXA-8600 Superprobe situated at the Department of Earth Sciences, University of Aarhus.

Where nothing else is indicated, all analyses given in appendices 1-3 and figs. 4-10 are averages of 6 spot analyses, generally in three or more individual grains. The points that were analysed represent areas without visible exsolutions of hematite (for ilmenite) and pleonastic spinel or ilmenite (for magnetite).

4. RESULTS

For the present study 90 thin sections have been characterised with respect to ilmenite and magnetite compositions. We also include 22 samples from a previous study (Meyer et al. 2001 a,b) involving laser-ICP-MS and electron probe microanalyses (EPMA). In addition a few representative apatite analyses are presented in Appendix 3.

In the following the results are discussed for each megacyclic unit and profile in turn and displayed in figs. 4-10. The names and locations referred to are all indicated in Fig. 1. For each profile the P_2O_5 content from whole rock analyses (Schiellerup et al. 2001) is shown together with the MgO content in ilmenite and the V_2O_3 content in magnetite.

4.1 Megacyclic unit IB

4.1.1 Åsen

The profile at Åsen (Fig. 3) is situated in MCU IB. The zone of interest has a thickness of 45 m. This zone has relatively high P_2O_5 content with a maximum of 5.11 %. The average P_2O_5 in the sequence is 3.96 %, which corresponds to a normative whole rock apatite content of 9.2 wt% (normative apatite calculated from XRF analyses, Schiellerup et al. 2001). For both ilmenite and magnetite the compositions are relatively constant: The MgO-content in ilmenite is in average 1.97 % and V_2O_3 in magnetite 0.93 %. The total content of value minerals in this 45 m thick sequence has been estimated to 36 wt% (apatite 9 wt%, ilmenite 16 wt% and magnetite 11 wt%).

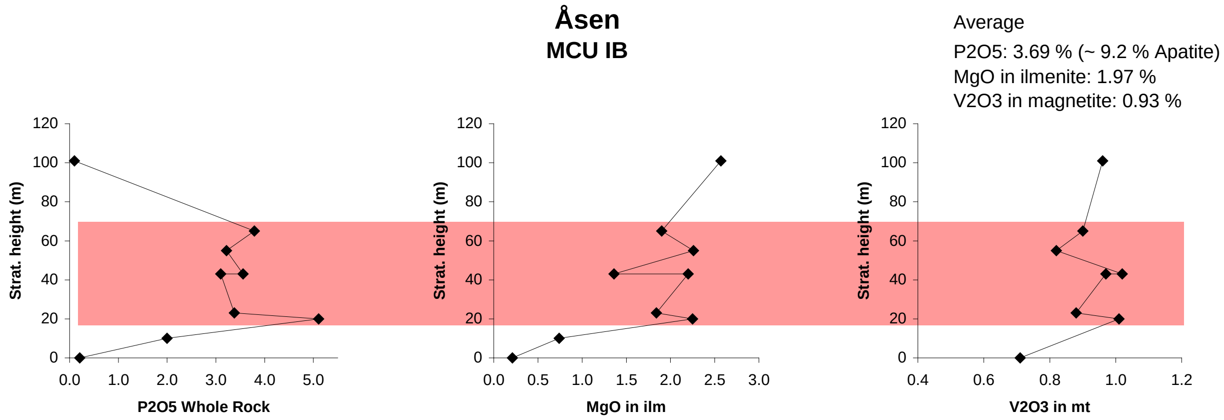

Fig. 3. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Åsen Profile, MCU IB.

4.1.2 Bjerkreim SW

This profile (Fig. 4) consists of four samples defining a zone of 50 m thickness in MCU IB SW of Bjerkreim. The average P_2O_5 content of the whole rock analyses is 2.87 %, which corresponds to 7 wt% apatite in the rock. Ilmenite has an MgO content of 1.31 % in average and magnetite 0.90 % V_2O_3. There is a tendency for increasing MgO in ilmenite and falling V_2O_3 in magnetite with increasing stratigraphic height. The amount of apatite (7 wt%), ilmenite (13 wt%) and magnetite (9 wt%) gives a total of 29 wt% value minerals.

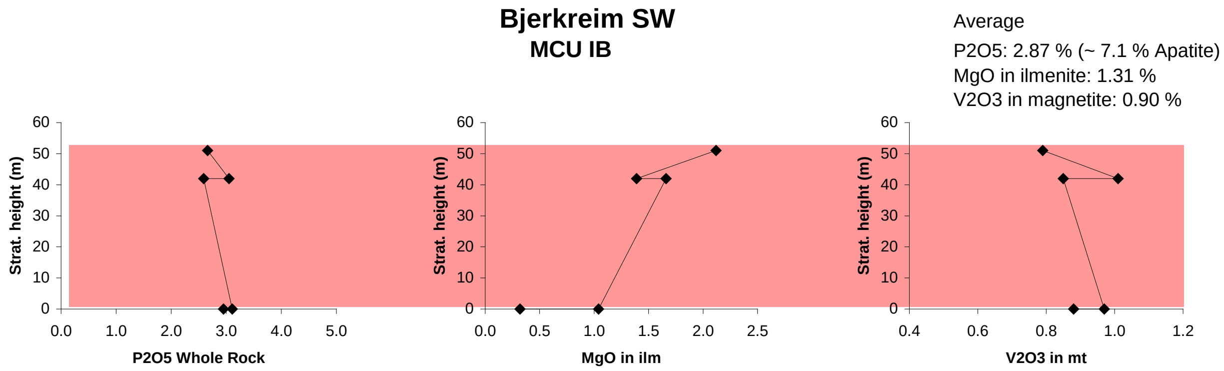

Fig. 4. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Bjerkreim SW Profile, MCU IB.

4.2 Megacyclic unit III

4.2.1 Helleland

The Helleland profile (Fig. 5) is represented by 10 samples of which 9 defines a 116 m thick apatite-bearing zone. The average composition of this zone is: 3.35 % P_2O_5 in whole rock, 2.20 % MgO in ilmenite and 0.97 % V_2O_3 in magnetite. From the whole rock analyses the total amount of value mineral was estimated to 29 % (apatite 8 %, ilmenite 13 % and magnetite 8 %).

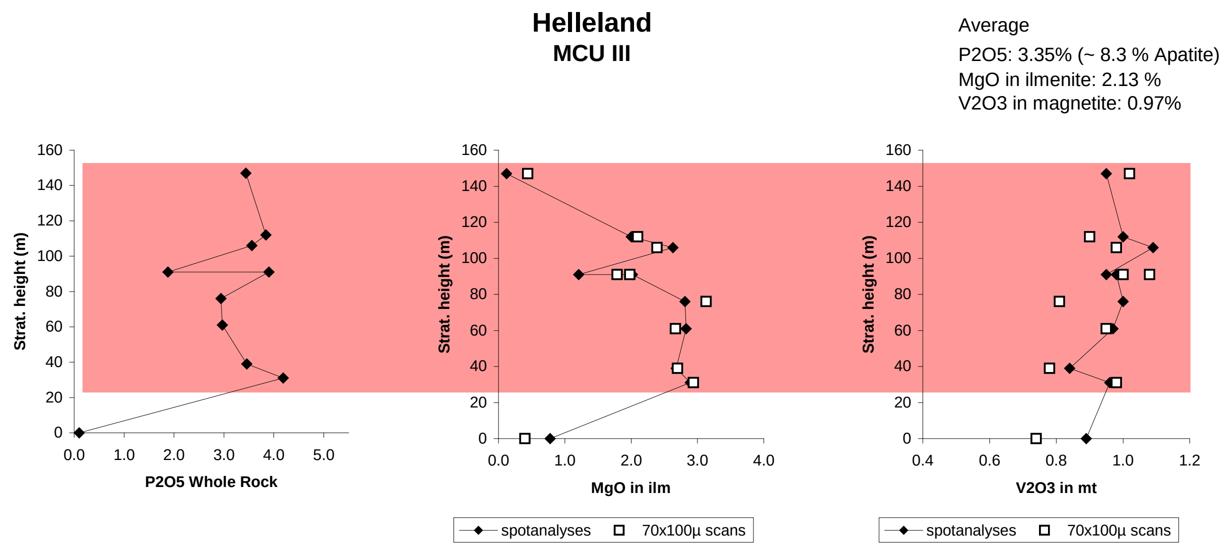

Fig. 5. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Helleland Profile, MCU III. Scanned (70x100µm areas) probe analyses are shown by open squares. For a discussion of the significance of spot versus attempted bulk (scanned) analyses see section 4.5.

4.2.2 Teksevatnet West

This profile (Fig. 6) represents the upper part of MCU III (Fig. 1+2). The apatite-bearing zone is highlighted and covers an 81m thick sequence. The P_2O_5 content in this zone is in average 3.1 % corresponding to approximately 8 % apatite in the rock. The highest apatite content is found at 178 m height in a mafic (dark) layer with 5.16 % P_2O_5 which is equivalent to 13 wt% normative apatite. A sample taken from the corresponding felsic (light) layer at 178 m has a P_2O_5 content of 2.15 %, equivalent to 5 % apatite in the rock. The same correlation is seen for other pairs of mafic and felsic layers: mafic layers are generally enriched in apatite relative to felsic layers. In this profile the scale of layering is from 1-2 cm up to a few dm.

The MgO in ilmenite shows a zigzag-shaped curve: all mafic layers (marked with an 'm') have relatively high MgO, while all felsic layers have relatively low MgO values. The lowest MgO is 0.22 % MgO (below the zone of interest at 111 m), while the highest MgO is 2.65 % (232m). There is no systematic trend from the lower part of the profile to the upper. The average MgO in ilmenite in the apatite-bearing zone (highlighted) is 1.40 %. Calculations from the whole rock analyses indicate an average ilmenite content in the rock of 11 %.

The V_2O_3 content in magnetite does not show the same systematics as MgO in ilmenite. In the Teksevatnet West profile the lowest V_2O_3 is 0.48 % (below the zone of interest at 111 m) and the highest V_2O_3 content is 1.09 % (204 m). The average V_2O_3 in magnetite in the apatite-bearing zone is 0.99 %. Calculations from the whole rock analyses indicate an average magnetite content in this 81 m thick interval of 6.6 %.

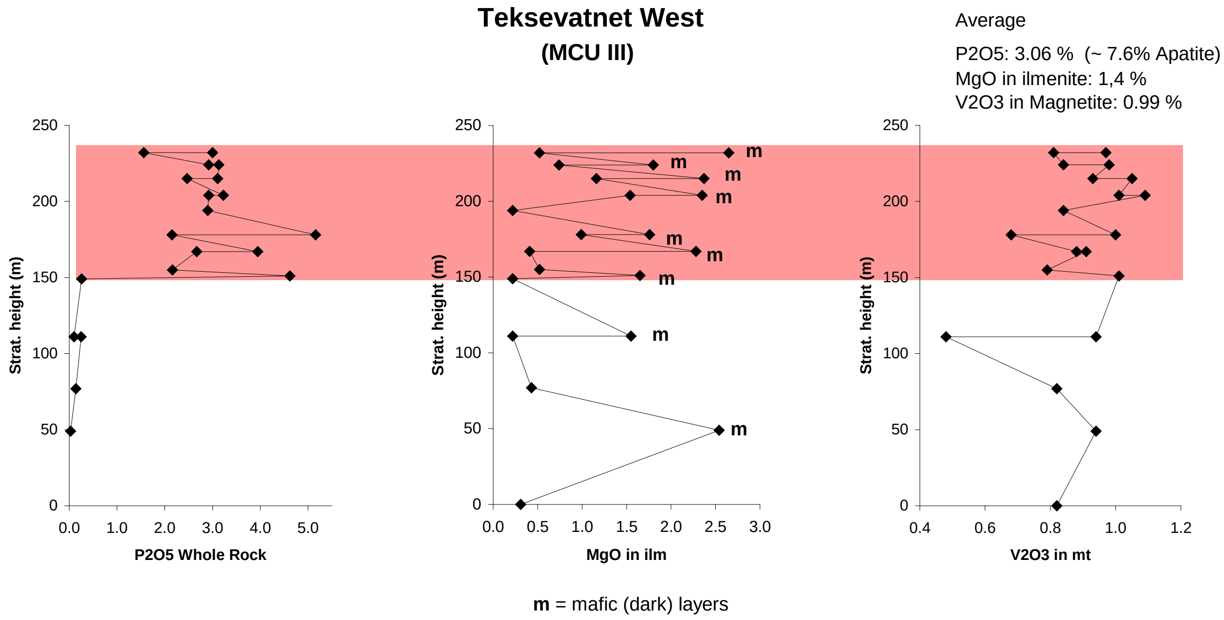

Fig. 6. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Teksevatnet W Profile, MCU III. Analyses designated the letter "m" derive from conspicuous mafic layers.

4.2.3 Terland MCU III

The Terland profile (Fig. 7) covers two megacyclic units: MCU III and IV. In contrast to the other profiles described in this report, all zones were sampled in the Terland profile, also the non-apatite bearing ones. This study was carried out to see how ilmenite and magnetite compositions vary through a larger portion of the Bjerkreim-Sokndal Layered Intrusion (Meyer et al. 2001a+b). In fig. 7 two apatite-bearing zones are highlighted: one in MCU III and another in MCU IV. These are described individually in the following.

The apatite-bearing zone in MCU III of the Terland profile has a thickness of 245 m of which a 130 m section carries a total content of value minerals in excess of 30 %. The average P_2O_5 content in this section is 3.8 % which corresponds to around 9 wt% normative apatite. Whereas P_2O_5 is only slightly raised compared with the rest of the profile, the oxide phases are significantly more abundant in the 130 m section highlighted in Fig. 7 (Schiellerup et al., 2001).

MgO in ilmenite increases from less than 1.0 % in the lowermost sample to a maximum of 2.96 % and then decrease again to an almost constant level of 1.5 %. The average composition of ilmenite in the highlighted sequence is 2.5 % MgO. Again there is a tendency for oxide-rich samples to carry ilmenite with elevated MgO-contents. From whole rock analyses (Schiellerup et al. 2001) it is estimated that the 130 m thick Terland-MCU III prospect contains around 15 wt% ilmenite.

V_2O_3 in magnetite remains relatively constant throughout the apatite-bearing zone with 0.96 % V_2O_3 in average over the 245 m. The normative magnetite content in the prospect is calculated to 10 wt% containing 0.94 % V_2O_3.

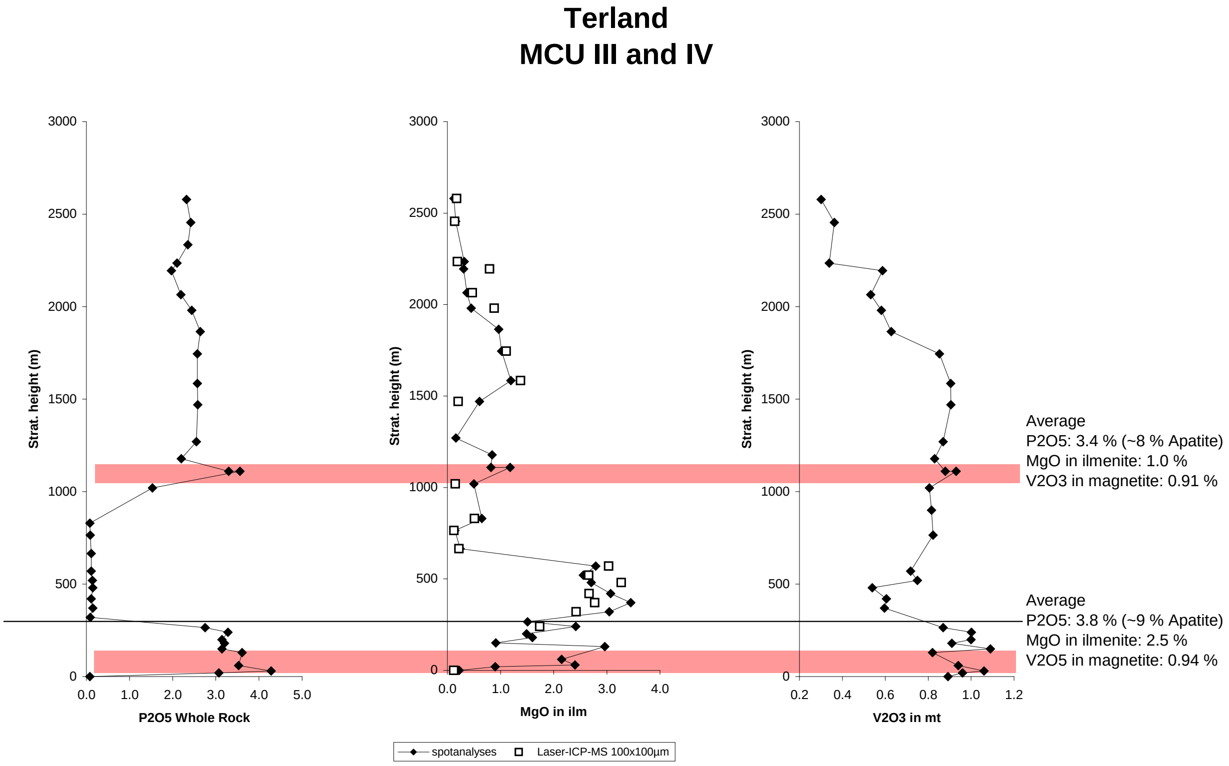

Fig. 7. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. MgO in ilmenite also by laser-ICP-MS (open squares). Samples from the Terland Profile, MCU III and IV.

In conclusion the MCU III prospect at Terland contains higher amounts of value minerals than the Teksevatnet West profile: The normative content is 9 wt% apatite, 15 wt% ilmenite and 10 wt% magnetite, which gives a total of 34 wt% value minerals. However the MgO of ilmenite is relatively high at Terland (2.50 %) compared to the other prospects while the V_2O_3 content in magnetite is approximately similar (0.94 %).

4.3 Megacyclic unit IV

4.3.1 Terland MCU IV

The zone highlighted in MCU IV in Terland (Fig. 7) is a relatively poorly constrained zone with a total value mineral content in excess of 25 % and P_2O_5 content above 3 %. The zone is located stratigraphically at the immediate entry of cumulus apatite where also others of the MCU IV-profiles peak in P_2O_5 contents. The zone as defined here has a thickness of less than 100 m.

In the profile P_2O_5 increases abruptly in the lowermost part from a minimum of 1.53 % P_2O_5 to a maximum of 3.65 %. The average P_2O_5 in the highlighted zone is 3.4 % corresponding to 8 wt% normative apatite in the rock.

Ilmenite compositions are somewhat variable in this sequence starting with compositions of 0.5 % MgO then increasing to 1.18 % MgO and then again gradually decreasing to a minimum value of 0.16 % MgO. Subsequently the MgO content increases again and reach a maximum of 1.19 % after which there is a gradual fall to almost Mg-free ilmenite in the uppermost part of the profile (above the highlighted zone). In the section richest in value minerals in MCU IV at Terland, the MgO in ilmenite is 1.0 % in average and the normative ilmenite content of the rock around 11 wt%.

The vanadium content in magnetite is almost constant in the lower 750 m of the profile with a minimum of 0.81 % V_2O_3 and a maximum of 0.93 %. In the highlighted section (Fig. 7) the average V_2O_3 in magnetite is 0.91 % and the normative magnetite content of the rock calculated to 6 wt%.

4.3.2 Bilstadvatnet West

The profile at Bilstadvatnet West (Fig. 8) consists of only four samples defining a zone of 60 m thickness in MCU IV. The average P_2O_5 content of the whole rock analyses is 4.39 %, which corresponds to 11 wt% apatite in the rock. Ilmenite has an MgO of 1.04 % in average and magnetite 0.87 % V_2O_3. The amount of apatite (11 wt%), ilmenite (13 wt%) and magnetite (8 wt%) gives a total of 32 wt% value minerals. This makes the Bilstadvatnet profile one of the more interesting profiles with respect to both the content of value minerals and the quality of these phases. The prospect investigated here covers the same stratigraphic sequence as the part of the Terland MCU IV profile richest in value minerals (Fig. 7).

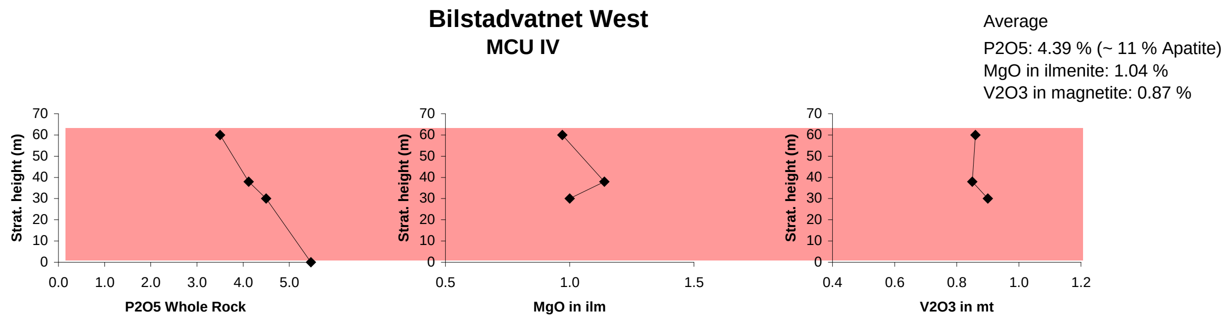

Fig. 8. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Bilstadvatnet West Profile, MCU IV.

4.3.3 Storeneset

The Storeneset profile (Fig. 9) covers a 93 m thick sequence of MCU IV stratigraphically equivalent to the highlighted zones of Terland-MCU IV (Fig. 7) and Bilstadvatnet (Fig. 8). It displays a generally constant P_2O_5 content, except for the uppermost part where P_2O_5 falls to zero within a 20 m thick sequence. MgO in ilmenite increases through the upper part of the profile, while V_2O_3 in magnetite remains relatively constant. The whole rock P_2O_5 is in average 3.73 %, the MgO of ilmenite 1.8 % and V_2O_3 of magnetite 0.98 %. The total amount of apatite (9 wt%), ilmenite (15 wt%) and magnetite (9 wt%) is 32 wt%. Together with the neighbouring Bilstadvatnet West profile, the Storeneset profile is one of the most interesting of the 8 profiles reported here, with respect to abundance and quality of the value minerals.

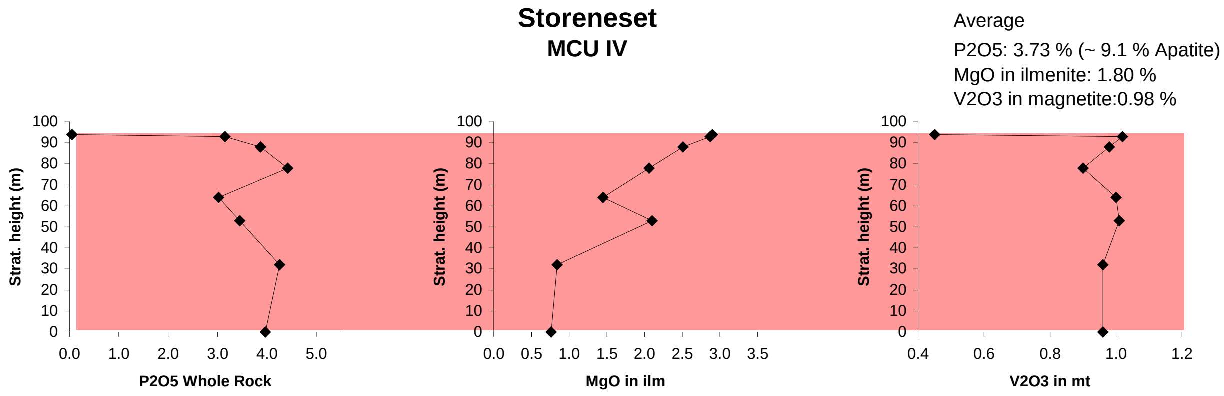

Fig. 9. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Storeneset Profile, MCU IV.

4.3.4 Lauvneset

In this profile a 35 m thick sequence has been highlighted in fig. 10, characterised by total value mineral contents in excess of 30 %. The zone runs an average of 4.0 % P_2O_5 in whole rock composition, an MgO in ilmenite of 1.47 % and V_2O_3 in magnetite of 0.84 %. An estimate of the total amount of value minerals in this sequence gives an average of 31 wt% with 10 % apatite, 13 % ilmenite and 8 % magnetite (Schiellerup et al. 2001). Lauvneset is characterised by a similar content of value minerals as the Storeneset and Bilstadvatnet profiles. The three profiles have been sampled across the same stratigraphic interval of MCU IV, and a continuous 30-100 m wide zone with more than 30 % value minerals is likely to extend at least from the Lauvneset to the Storeneset localities (Fig. 1). The lower value mineral contents obtained from the Terland MCU IV section may indicate a decrease in amounts of value minerals further west.

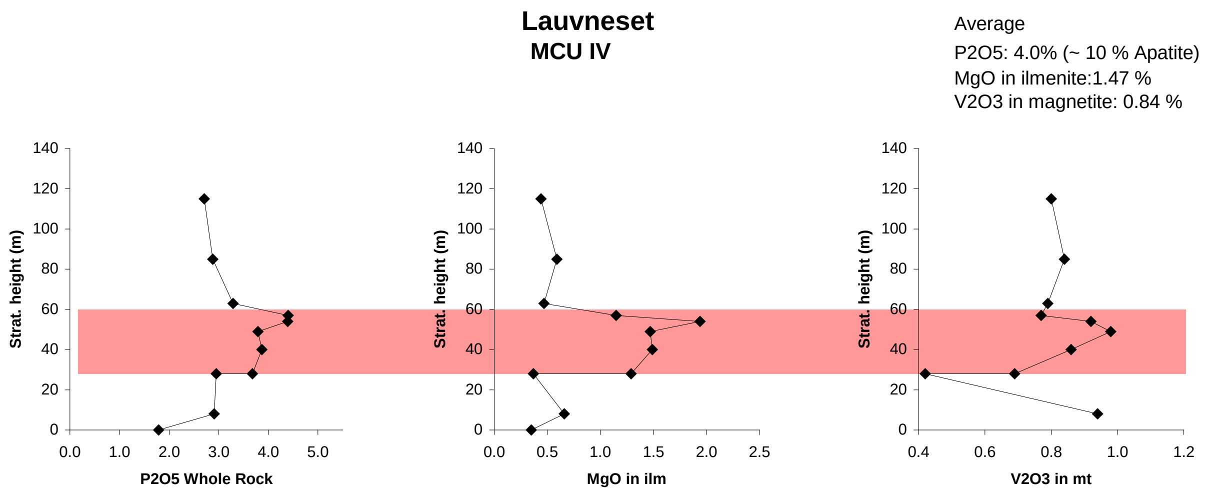

Fig. 10. XRF whole rock P_2O_5 analyses and electron probe microanalyses of MgO in ilmenite and V_2O_3 in magnetite. Samples from the Lauvneset Profile, MCU IV.

4.4 Apatite

In a number of layered intrusions where apatite is a significant phase a strong variation in apatite chemistry with stratigraphy may be observed. Both the Bushveld Complex in South Africa and the Stillwater Complex in Montana, USA, display strong variations in Cl/F ratios in apatite (Cawthorn, 1994, Boudreau et al., 1997). In the Stillwater Complex most apatites are Cl-dominated though cumulus apatites in layered intrusions most often are strongly F-dominated.

However, no systematic study of the apatite compositions in the Bjerkreim-Sokndal Intrusion has been conducted and in the present investigation only a few samples were targeted to obtain an indication of the compositional status. Apatite has been analysed in 5 samples and the data presented in App. 3. All investigated e-zones are represented and no systematic compositional variability is observed. All apatites analysed are fluor-apatites with a Cl-content close to the detection limit by EDS-detection (500-900 ppm). The measured Cl/F ratios vary between 0.01 and 0.02.

4.5 Note on representativity of spot analyses

A test was carried out to evaluate how ilmenite and magnetite compositions would differ from spot to bulk analyses. The results were shown in part in Fig. 5 but are illustrated fully for magnetite in fig. 11. In this test, areas of 70x100µm where analysed using the same conditions as for spot analyses. The test shows that only 1 out of 9 analyses (70x100µm scans) yields significantly different V_2O_3 values for bulk and spot analyses. The 8 out of the 9 samples have approximately the same values of V_2O_3 by both methods. The SiO_2, TiO_2 and Al_2O_3 contents are higher in the bulk analyses than in the spot analyses due to the presence of spinel and ilmenite exsolutions and silicate cracks in the magnetite. For the purpose of this report spot analyses have been preferred in order to secure consistent data, which makes comparison of compositions in and between profiles more accurate. For V_2O_3 in magnetite it is concluded that no significant differences exists between EPMA spot analyses and bulk compositions.

For ilmenite a comparison of bulk versus spot analyses can be seen in fig. 7 (the Terland profile). In this profile the ilmenite has been analysed both by Laser Ablation ICP-MS (Meyer et al. 2001a + b) and SEM analyses (this work). The Laser Ablation analyses were carried out as raster analyses in areas of 100x100 µm areas, ablating into 30µm depth of the material. As can be seen from fig. 7 there is no significant difference between the MgO values obtained by SEM spot analyses and the Laser Ablation analyses. It is therefore concluded that an ilmenite concentrate produced from the Bjerkreim-Sokndal Intrusion would have MgO-contents similar to those obtained by the SEM analyses.

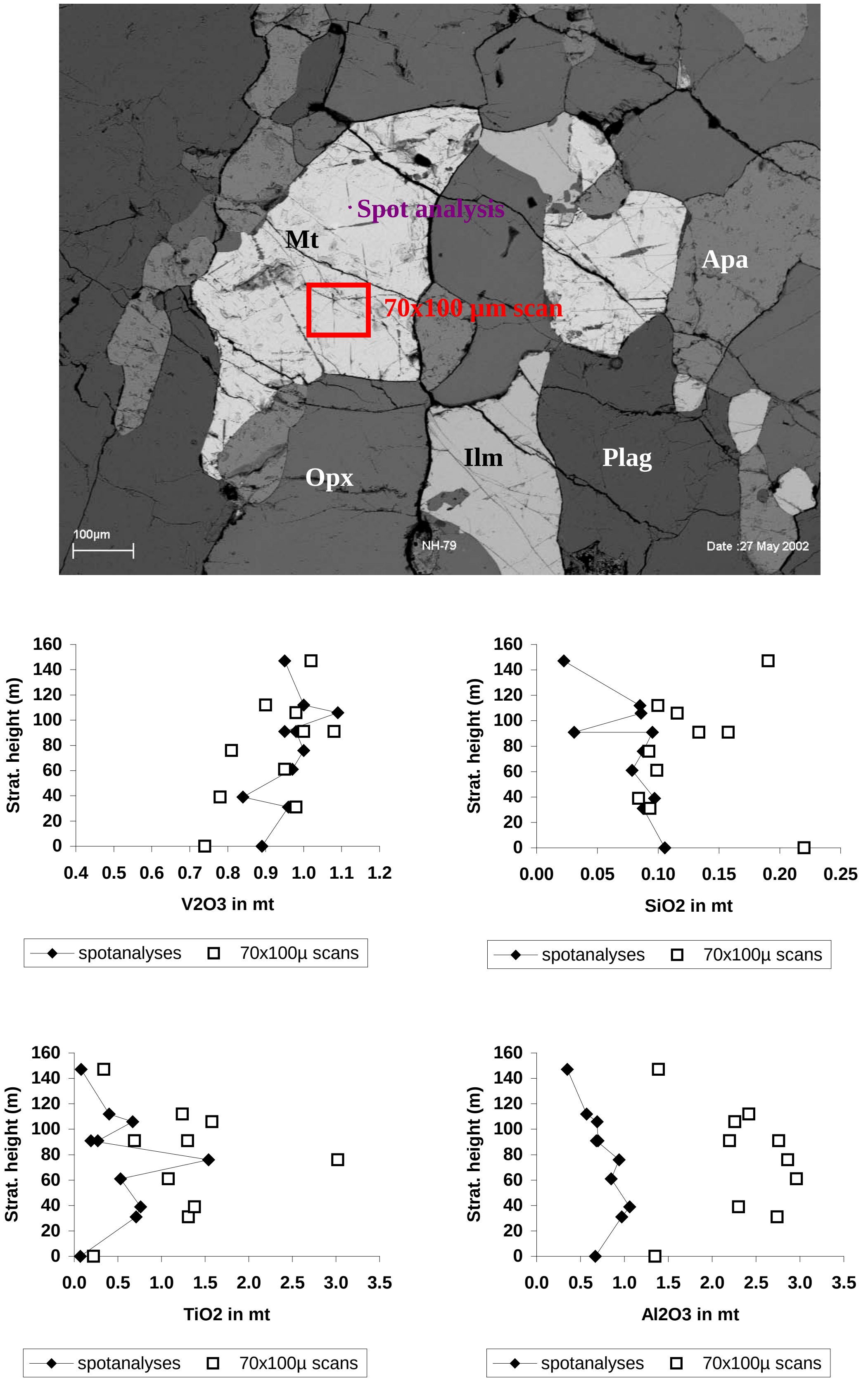

Fig. 11. Back scattered electron micrograph showing the difference of spot and "bulk" probe analysis. Phases present are plagioclase, orthopyroxene, apatite, ilmenite and magnetite. The resulting difference between spot and "bulk" probe analyses are displayed in the four plots below.

5. CONCLUSIONS

As reported by Schiellerup et al. (2001) four areas of apatite-, ilmenite- and magnetite-rich cumulates are located in the apatite-bearing e-zones of the Bjerkreim-Sokndal intrusion:

In MCU IB the prospect consists of an at least 3 km long zone varying in thickness between 15-20 and 60 m averaging between 32 and 36 wt% apatite, ilmenite and magnetite in the calculated norm. The MgO content in ilmenite in this zone is 1.8 % in average and the V_2O_3 content in magnetite 0.91 %.

In MCU III two isolated areas have been investigated: In Helleland (Fig. 1) a 130 m profile contains an average norm of 29 % apatite, ilmenite and magnetite. The lateral extension of this zone is poorly constrained but presumably less than 1500 m. The MgO content in ilmenite in this zone is 2.13 % on average and the V_2O_3 content of magnetite 0.97 %. On the eastern flank of the Bjerkreim-lobe MCU III has been investigated along profiles at Terland and further east at Teksevatnet. At Terland, a 100 m stratigraphic section contain around 34 % apatite, ilmenite and magnetite. In the Terland profile MgO in ilmenite average 2.5 % and V_2O_3 in magnetite 0.94 %. The lateral extent of the Terland MCU III prospect is also poorly defined but probably on the order of 1000-2000 m. At Teksevatnet the content of the value minerals is considerably reduced

In MCU IV the basal portion of the apatite-bearing sequence contains a seemingly persistent zone extending from Storeneset on the south bank of Bilstadvatnet (Fig. 1) to Storøya in Teksevatnet. The zone varies in thickness from 30 to 90 m along a lateral distance of 3500 m, presuming lateral continuity between the investigated profiles. Lateral persistency further west towards Terland is uncertain and the Terland profile is itself not completely resolved in the relevant sequence. The calculated normative content of apatite, ilmenite and magnetite average 32 wt%. The average MgO contents in ilmenite in the profiles vary between 1 % in the Terland and Bilstadvatnet profiles to 1.5 % in the Lauvneset profile and 1.80 % in the Storeneset profile. The V_2O_3 content of magnetite remains relatively constant at around 0.9 %.

Particularly the MCU III targets at Helleland and Terland are relatively poorly constrained in terms of lateral extent, but all investigated areas may carry volumes large enough to be of exploitable interest. However, mineral chemistry in the MCU III targets disclose relatively high MgO contents in ilmenite (>2 %) which makes this zone less interesting than the MCU IB and MCU IV prospects. The MCU IB prospect between Åsen and Bjerkreim is poorly exposed, but the two profiles examined yield somewhat lower average MgO contents in ilmenite (1.8 %) than observed in MCU III. The largest prospect (>150,000 m^2), and the prospect which presents the highest quality ilmenite is, however, the base of MCU IVe, in a zone extending at least from Storeneset to Teksevatnet, presuming lateral continuity between the investigated profile. We therefore conclude that among the investigated areas this zone represents the most obvious candidate for further exploration.

We also note that besides the Terland profile, which covers several kilometres of stratigraphy, any stratigraphic dependency of the ilmenite composition has not been resolved in the short profiles collected. On the small stratigraphic scales the effect is possibly overshadowed by the variation in MgO-contents in ilmenite hosted by melanocratic and leucocratic layers.

Any stratigraphic dependency of the V_2O_3 content in magnetite has also not been resolved. In all investigated samples, apart from the very top of MCU IV, the V_2O_3 content is almost constant fluctuating around 0.9 %.

6. SUMMARY STATEMENT AND FUTURE WORK

In the current survey of occurrences of ilmenite, apatite and vanadian magnetite in the Bjerkreim-Sokndal Layered Intrusion four target areas were singled out for further investigations (Schiellerup, 2001). These targets have been analysed for major and trace element contents by XRF, and subsequently mineral chemically characterised using electron probe microanalysis. Based on the present data it is concluded that the most promising prospect is confined to a 3500 m long and 30-90 m wide zone in MCU IV in the Bilstadvatnet-Teksevatnet area. We advise that further exploration be conducted in this area with a few additional investigations in the other potential areas.

In MCU IB the target is relatively well constrained. It is poorly exposed and the major exposures have been investigated. Any additional examination will require drilling.

In MCU III better control is needed on the lateral extent and character of the targets at Helleland and Terland in spite of the indications of somewhat poorer ilmenite quality here than in the other zones.

In MCU IV the lateral persistency of the target has to be better constrained. It is not clear if an oxide- and apatite-rich zone continues from Storøya in Teksevatnet towards Terland or beyond Storeneset towards Vasshus (Fig. 1). The aerial estimate of the prospect rely on the presence of a continuous zone between the investigated profiles and all exposures in the target zone should be examined. The base of MCU IVe, which hosts the MCU IV prospect is not fully resolved in the Terland profile and additional sampling should be conducted here.

We advise that this survey is conducted with a brief field period during 2002, followed immediately by the geochemical investigations (XRF, EPMA) of a limited number of additional samples. The above suggestions should conclude the preliminary field and geochemical investigations needed to assess the potential of the Bjerkreim-lobe as host to significant deposits of combined resources of apatite, ilmenite and vanadian magnetite.

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Oxide wt%	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	V_2O_3	Cr_2O_3	FeO	MgO	MnO	SUM	Strat. (m)	UTM-E	UTM-N	MCU
Teksevatnet W profile														
NH-122	0,03	47,72	0,18	8,01	0,45	-0,09	41,94	0,31	0,41	98,96	0	339853	6493866	3d
NH-12	0,08	48,97	0,34	7,78	0,38	-0,05	39,20	2,54	0,31	99,55	49	339834	6493820	3e
NH-13	0,10	47,11	0,58	7,91	0,21	0,06	41,20	0,43	0,39	97,99	77	339821	6493795	3e
NH-14	0,11	46,75	0,54	9,77	0,33	0,03	41,25	0,22	0,39	99,38	111	339790	6493769	3e
NH-15	0,04	47,52	0,22	8,31	0,43	-0,03	39,59	1,55	0,38	98,00	111	339790	6493769	3e
NH-16	0,11	45,58	0,56	10,93	0,36	-0,11	40,23	0,22	0,36	98,24	149	339761	6493739	3e
NH-17	0,08	49,19	0,32	7,46	0,56	-0,08	40,92	1,65	0,37	100,47	151	339748	6493728	3e
NH-51	0,09	47,40	0,46	9,02	0,37	-0,06	41,34	0,52	0,35	99,50	155	339789	6493721	3e
NH-18	0,10	47,86	0,66	7,91	0,34	-0,03	41,93	0,41	0,37	99,55	167	339764	6493717	3e
NH-19	0,06	49,55	0,25	7,75	0,43	-0,08	40,02	2,28	0,47	100,73	167	339764	6493717	3e
NH-20	0,09	46,19	0,53	12,64	0,32	0,11	39,32	0,99	0,45	100,64	178	339786	6493696	3e
NH-21	0,07	49,69	0,38	5,30	0,39	-0,10	41,01	1,76	0,53	99,03	178	339786	6493696	3e
NH-22	0,09	46,16	0,52	9,31	0,29	-0,10	40,64	0,22	0,47	97,60	194	339807	6493671	3e
NH-23	0,09	48,00	0,42	7,49	0,39	0,05	40,01	1,54	0,40	98,39	204	339821	6493654	3e
NH-24	0,08	50,01	0,20	4,49	0,20	0,05	40,29	2,35	0,49	98,16	204	339821	6493654	3e
NH-25	0,09	48,88	0,50	5,25	0,43	0,00	41,39	1,16	0,49	98,20	215	339810	6493636	3e
NH-26	0,08	50,19	0,22	5,05	0,14	-0,05	40,44	2,37	0,46	98,90	215	339810	6493636	3e
NH-27	0,09	48,92	0,48	5,00	0,32	0,04	42,28	0,74	0,39	98,26	224	339812	6493645	3e
NH-28	0,02	50,39	0,13	3,71	0,40	0,00	41,64	1,80	0,46	98,56	224	339812	6493645	3e
NH-29	0,10	48,22	0,54	7,05	0,41	-0,16	41,96	0,52	0,47	99,10	232	339810	6493627	3e
NH-50	0,06	49,87	0,11	6,73	0,28	0,05	39,76	2,65	0,36	99,87	232	339810	6493627	3e
Terland profile														
GBM.BJ.0032	0,05	47,20	0,01	10,40	0,30		41,87	0,22	0,17	100,23	0	337910	6495200	3d
NH-41	0,08	47,16	0,49	9,73	0,44	-0,09	40,33	0,90	0,47	99,50	20	337990	6495234	3e
NH-40	0,07	50,24	0,21	4,66	0,09	-0,12	40,49	2,40	0,41	98,45	30	337976	6495207	3e
NH-39	0,05	49,52	0,18	3,86	0,27	-0,11	40,29	2,15	0,40	96,62	60	337975	6495177	3e
NH-38	0,06	50,86	0,18	3,66	0,08	0,07	40,01	2,96	0,45	98,32	130	337908	6495191	3e
NH-37	0,07	48,41	0,45	8,86	0,30	-0,04	41,56	0,91	0,35	100,86	150	337886	6495149	3e
NH-36	0,08	46,47	0,32	11,12	0,21	0,03	38,60	1,60	0,33	98,76	180	337905	6495107	3e
NH-35	0,09	47,25	0,51	9,06	0,53	-0,09	39,45	1,49	0,38	98,67	200	337900	6495075	3e
GBM.BJ.0031	0,06	49,45	0,04	7,70	0,26		39,79	2,42	0,36	100,08	240	337855	6495100	3e
NH-34	0,08	46,77	0,40	10,72	0,31	0,05	38,97	1,51	0,39	99,20	265	337903	6495036	3e
GBM.BJ.0030	0,07	49,15	0,01	8,44	0,26		38,46	3,05	0,31	99,74	320	337850	6495000	4a
GBM.BJ.0029	0,04	49,72	0,01	8,99	0,22		38,18	3,45	0,37	100,98	370	337945	6494930	4b
GBM.BJ.0028	0,03	49,77	0,03	7,75	0,21		38,90	3,07	0,37	100,13	420	337840	6494915	4b
GBM.BJ.0027	0,04	49,50	0,07	8,16	0,24		39,33	2,71	0,36	100,41	480	337795	6494900	4b
GBM.BJ.0026	0,05	49,11	0,04	7,96	0,23		39,22	2,56	0,38	99,55	520	337730	6494895	4b
GBM.BJ.0025	0,04	48,84	0,02	7,86	0,24		38,56	2,79	0,37	98,73	570	337675	6494870	4b
GBM.BJ.0024	0,06	47,79	0,02	9,10	0,26		42,15	0,24	0,40	100,02	665	337580	6494820	4c
GBM.BJ.0023	0,06	45,81	0,01	12,36	0,31		40,49	0,14	0,44	99,64	765	337560	6494750	4c
GBM.BJ.0022	0,03	47,34	0,01	9,62	0,28		41,09	0,65	0,32	99,35	830	337555	6494690	4c
GBM.Bj.9913	0,04	46,41	0,02	11,15	0,32		40,26	0,50	0,58	99,28	1020	337575	6494675	4e
NH-32	0,08	47,76	0,33	9,05	0,52	-0,06	40,27	1,18	0,57	99,70	1110	337244	6494441	4e
NH-33	0,07	48,16	0,36	7,16	0,36	-0,16	41,41	0,82	0,43	98,61	1110	337244	6494441	4e

Oxide wt%	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	V_2O_3	Cr_2O_3	FeO	MgO	MnO	SUM	Strat. (m)	UTM-E	UTM-N	MCU
NH-31	0,08	46,12	0,24	11,00	0,45	0,00	39,51	0,84	0,46	98,71	1178	337174	6494287	4e
NH-30	0,08	46,77	0,42	10,31	0,66	-0,11	41,23	0,16	0,54	100,05	1270	336881	6494294	4e
GBM.Bj.9905	0,03	49,48	0,09	5,88	0,23		42,89	0,60	0,52	99,72	1470	337175	6494150	4e
GBM.Bj.9904	0,08	48,49	0,03	8,41	0,23		41,03	1,19	0,44	99,90	1585	337200	6494000	4e
GBM.Bj.9903	0,04	48,56	0,05	8,55	0,24		41,37	1,02	0,48	100,30	1745	337100	6493850	4e
GBM.Bj.9902	0,04	46,29	0,42	11,99	0,26		39,47	0,96	0,43	99,85	1865	337200	6493750	4e
GBM.Bj.9901	0,05	49,19	0,04	6,63	0,22		42,95	0,45	0,48	100,00	1980	337150	6493625	4e
GBM.Bj.9906	0,03	50,58	0,01	3,61	0,19		44,23	0,37	0,60	99,63	2065	337100	6493500	4e
GBM.Bj.9907	0,06	49,93	0,03	5,18	0,18		43,77	0,30	0,58	100,03	2195	337050	6493425	4e
GBM.Bj.9908	0,03	50,16	0,04	4,34	0,14		43,90	0,32	0,64	99,57	2335	337300	6493400	4e
GBM.Bj.9910	0,03	50,07	0,04	4,62	0,17		44,12	0,16	0,62	99,83	2455	337100	6493150	4f
GBM.Bj.9911	0,05	49,41	0,02	5,35	0,16		43,63	0,12	0,58	99,30	2580	337000	6493100	4f
Bjerkreim S														
NH-74	0,09	45,75	0,29	10,66	0,57	0,06	40,14	0,38	0,32	98,25		330776	6497258	1Be
Bjerkreim SW profile														
NH-68	0,07	46,88	0,12	10,23	0,21	0,01	38,03	2,12	0,34	98,01	51	330610	6496946	1Be
NH-69	0,08	47,61	0,19	9,44	0,36	0,03	39,96	1,39	0,37	99,44	42	330603	6496983	1Be
NH-70	0,08	46,74	0,16	10,68	0,51	-0,03	38,62	1,66	0,45	98,87	42	330603	6496983	1Be
NH-71	0,05	46,86	0,20	9,63	0,47	0,04	39,89	1,04	0,39	98,58	0	330533	6496965	1Be
NH-72	0,06	47,54	0,35	9,12	0,07	-0,05	41,73	0,32	0,44	99,59	0	330533	6496965	1Be
Åsen profile														
NH-60	0,09	47,31	0,44	9,72	0,33	0,01	41,73	0,21	0,43	100,28	0	330329	6494222	1Ad
NH-61	0,09	46,56	0,44	11,81	0,33	-0,01	40,01	0,74	0,53	100,50	10	330396	6494023	1Bc
NH-62	0,06	47,79	0,28	10,86	0,46	-0,10	38,61	2,25	0,35	100,56	20	330407	6494036	1Be
NH-63	0,06	49,65	0,26	5,32	0,16	0,05	40,72	1,84	0,64	98,71	23	330419	6494004	1Be
NH-64	0,07	49,84	0,16	5,02	0,10	0,02	40,43	2,20	0,46	98,31	43	330418	6494151	1Be
NH-65	0,09	47,19	0,55	7,11	0,56	-0,08	39,49	1,36	0,52	96,79	43	330418	6494151	1Be
NH-66	0,06	50,62	0,18	4,32	0,48	-0,04	41,05	2,26	0,44	99,36	55	330439	6494156	1Be
NH-67	0,07	48,73	0,31	5,96	0,22	0,00	40,03	1,90	0,40	97,62	65	330456	6494157	1Be
NH-73	0,07	49,83	0,08	6,91	0,32	-0,03	39,86	2,57	0,37	99,97	101	330562	6494084	1Be
Bilstadvt. W														
NH-52	0,09	46,76	0,36	11,39	0,28	0,08	40,04	0,97	0,28	100,25	60	344408	6492115	4e
NH-53	0,08	46,62	0,24	11,76	0,45	-0,03	39,58	1,14	0,31	100,15	38	344603	6492025	4e
NH-54	0,08	46,84	0,35	9,82	0,46	-0,02	39,90	1,00	0,43	98,86	30	344603	6492044	4e
Storeneset profile														
NH-108	0,09	47,67	0,11	10,54	0,46	-0,06	37,37	2,90	0,33	99,41	94	345386	6491841	4e
NH-106	0,08	49,14	0,16	7,53	0,41	-0,07	38,60	2,87	0,47	99,18	93	345386	6491841	4e
NH-110	0,08	50,75	0,27	4,84	0,46	-0,07	40,67	2,51	0,49	99,99	88	345395	6491838	4e
NH-111	0,08	49,38	0,30	5,99	0,28	-0,06	40,41	2,06	0,32	98,76	78	345407	6491841	4e
NH-112	0,09	49,91	0,39	4,10	0,18	0,05	41,74	1,45	0,55	98,46	64	345415	6491862	4e
NH-113	0,08	51,28	0,22	3,38	0,38	-0,06	41,89	2,10	0,48	99,75	53	345423	6491877	4e
NH-114	0,07	49,39	0,34	6,18	0,37	-0,05	42,37	0,84	0,54	100,05	32	345437	6491905	4e
NH-115	0,06	49,15	0,21	5,15	0,33	-0,05	42,47	0,76	0,37	98,45	0	345478	6491911	4e

Oxide wt%	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	V_2O_3	Cr_2O_3	FeO	MgO	MnO	SUM	Strat. (m)	UTM-E	UTM-N	MCU
Lauvneset profile														
NH-95	0,10	45,66	0,60	10,38	0,42	0,05	40,11	0,35	0,32	97,99	0	342871	6492847	4e
NH-96	0,10	45,61	0,55	10,24	0,49	-0,05	39,36	0,66	0,47	97,44	8	342870	6492838	4e
NH-97	0,09	46,98	0,39	9,28	0,40	0,01	41,27	0,37	0,31	99,10	28	342699	6492868	4e
NH-98	0,08	46,07	0,28	9,50	0,25	-0,02	38,75	1,29	0,37	96,57	28	342699	6492868	4e
NH-99	0,08	47,33	0,26	9,80	0,26	0,01	39,53	1,49	0,37	99,13	40	342697	6492853	4e
NH-100	0,08	48,19	0,28	6,31	0,26	-0,14	40,20	1,47	0,51	97,16	49	342703	6492840	4e
NH-101	0,07	48,48	0,27	6,25	0,35	0,04	39,48	1,94	0,65	97,53	54	342700	6492835	4e
NH-102	0,09	47,90	0,37	8,04	0,35	-0,11	40,59	1,15	0,43	98,81	57	342706	6492830	4e
NH-103	0,10	47,83	0,48	8,42	0,33	-0,01	41,71	0,47	0,46	99,78	63	342712	6492818	4e
NH-104	0,10	46,72	0,46	9,51	0,39	-0,04	40,55	0,59	0,41	98,68	85	342711	6492794	4e
NH-105	0,09	46,84	0,49	8,48	0,42	-0,09	40,78	0,44	0,55	98,00	115	342753	6492742	4e
Helleland profile														
NH-78	0,11	46,90	0,51	10,37	0,33	0,08	40,41	0,78	0,37	99,86	0	333244	6491420	3d
NH-79	0,09	49,44	0,40	6,79	0,37	-0,09	38,91	2,89	0,39	99,19	31	333382	6491412	3d
NH-80	0,07	50,05	0,44	5,41	0,36	0,02	39,95	2,68	0,28	99,27	39	333408	6491414	3d
NH-81	0,08	49,82	0,32	6,30	0,49	-0,08	39,27	2,83	0,48	99,52	61	333475	6491430	3d
NH-82	0,06	50,10	0,24	5,87	0,38	-0,03	39,58	2,81	0,46	99,47	76	333512	6491437	3d
NH-83	0,07	49,14	0,39	7,76	0,19	0,10	40,08	2,02	0,50	100,26	91	333532	6491450	3e
NH-84	0,03	49,01	0,21	6,99	0,32	0,01	41,52	1,21	0,39	99,69	91	333532	6491450	3e
NH-85	0,08	49,36	0,28	7,03	0,48	-0,12	39,32	2,63	0,38	99,43	106	333544	6491475	3e
NH-86	0,06	48,30	0,29	7,74	0,33	-0,02	39,51	2,00	0,36	98,57	112	333561	6491460	3e
NH-87	0,02	47,75	0,04	8,36	0,21	0,11	42,16	0,12	0,56	99,33	147	333622	6491495	3e
Helleland profile - 70x100µ scan														
NH-78	0,11	43,98	0,64	15,72	0,50	-0,03	38,46	0,40	0,37	100,16	0	333244	6491420	3d
NH-79	0,07	49,23	0,28	6,78	0,30	-0,02	38,55	2,94	0,47	98,61	31	333382	6491412	3d
NH-80	0,10	50,01	0,51	5,86	0,21	-0,01	39,87	2,70	0,29	99,54	39	333408	6491414	3d
NH-81	0,08	49,24	0,24	7,11	0,37	0,03	39,02	2,67	0,49	99,25	61	333475	6491430	3d
NH-82	0,07	49,62	0,19	6,75	0,35	0,03	38,51	3,13	0,53	99,18	76	333512	6491437	3d
NH-83	0,07	48,78	0,36	7,25	0,27	-0,03	39,98	1,98	0,35	99,02	91	333532	6491450	3e
NH-84	0,12	47,91	0,52	7,31	0,45	-0,04	39,55	1,79	0,34	97,95	91	333532	6491450	3e
NH-85	0,09	49,07	0,30	7,10	0,38	-0,01	39,43	2,39	0,43	99,18	106	333544	6491475	3e
NH-86	0,09	48,48	0,49	7,32	0,38	0,02	39,35	2,10	0,50	98,72	112	333561	6491460	3e
NH-87	0,13	45,79	0,37	9,58	0,37	0,01	39,87	0,44	0,52	97,08	147	333622	6491495	3e

Appendix 2

Oxide wt%	MgO	Al_2O_3	SiO_2	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	Fe_2O_3	SUM	Strat. (m)	UTM-E	UTM-N	MCU
Teksevatnet W profile														
NH-122	0,07	0,63	0,04	0,35	0,82	0,17	0,04	31,14	65,93	99,20	0	339853	6493866	3d
NH-12	0,52	0,47	0,10	0,28	0,94	0,00	-0,06	30,46	66,35	99,06	49	339834	6493820	3e
NH-13	0,11	0,91	0,11	0,07	0,82	-0,04	-0,01	30,99	65,98	98,94	77	339821	6493795	3e
NH-14	0,04	0,60	0,05	0,09	0,48	0,04	-0,09	30,66	66,19	98,06	111	339790	6493769	3e
NH-15	0,24	0,49	0,05	0,09	0,94	0,03	0,00	30,18	65,47	97,48	111	339790	6493769	3e
NH-17	0,43	0,73	0,09	0,25	1,01	0,12	-0,07	30,76	66,28	99,60	151	339748	6493728	3e
NH-51	0,17	0,82	0,10	0,04	0,79	0,04	0,02	30,75	66,26	98,98	155	339789	6493721	3e
NH-18	0,11	0,96	0,12	0,09	0,91	-0,02	0,04	30,91	65,92	99,05	167	339764	6493717	3e
NH-19	0,48	0,47	0,07	0,28	0,88	0,09	0,11	30,44	66,34	99,16	167	339764	6493717	3e
NH-20	0,13	0,81	0,09	0,15	0,68	-0,08	0,01	30,41	65,13	97,34	178	339786	6493696	3e
NH-21	0,37	0,78	0,09	0,60	1,00	0,04	0,01	30,51	64,25	97,65	178	339786	6493696	3e
NH-22	0,23	0,87	0,10	0,08	0,84	0,00	0,07	30,29	65,19	97,67	194	339807	6493671	3e
NH-23	0,32	0,85	0,10	0,24	1,09	0,09	0,02	30,45	65,14	98,30	204	339821	6493654	3e
NH-24	0,58	1,02	0,09	1,60	1,01	-0,08	0,12	31,27	62,37	97,98	204	339821	6493654	3e
NH-25	0,27	1,20	0,10	2,11	1,05	-0,09	0,01	32,35	61,04	98,05	215	339810	6493636	3e
NH-26	0,43	0,78	0,10	1,35	0,93	-0,06	-0,03	31,08	62,93	97,50	215	339810	6493636	3e
NH-27	0,19	1,01	0,09	1,23	0,98	-0,04	0,09	31,20	62,33	97,08	224	339812	6493645	3e
NH-28	0,31	0,91	0,07	1,36	0,84	0,17	0,09	31,47	62,99	98,21	224	339812	6493645	3e
NH-29	0,16	1,17	0,11	0,39	0,81	0,04	0,05	30,88	64,48	98,09	232	339810	6493627	3e
NH-50	0,53	0,35	0,07	0,20	0,97	0,04	0,05	30,53	67,16	99,90	232	339810	6493627	3e
Terland profile														
GBM.BJ.0032	0,02	0,35	0,05	0,09	0,89	0,07	0,01	30,73	66,38	98,58	0	337910	6495200	3d
NH-41	0,03	0,80	0,10	-0,05	0,96	-0,06	0,08	29,92	64,20	95,97	20	337990	6495234	3e
NH-40	0,18	0,42	0,07	0,24	1,06	-0,01	0,06	30,49	65,44	97,94	30	337976	6495207	3e
NH-39	0,33	0,47	0,07	0,27	0,94	-0,01	0,02	28,93	62,33	93,34	60	337975	6495177	3e
NH-38	0,40	0,64	0,06	1,69	0,82	0,06	-0,05	29,80	58,73	92,14	130	337908	6495191	3e
NH-37	0,05	0,66	0,08	0,09	1,09	0,12	-0,04	31,76	67,70	101,52	150	337886	6495149	3e
NH-36	0,22	0,90	0,09	0,14	0,91	0,02	0,02	30,49	65,16	97,94	180	337905	6495107	3e
NH-35	0,33	0,64	0,09	0,13	1,00	0,00	-0,03	30,66	66,43	99,25	200	337900	6495075	3e
GBM.BJ.0031	0,04	0,24	0,13	0,10	1,00	0,07	0,01	30,85	66,12	98,56	240	337855	6495100	3e
NH-34	0,24	0,79	0,08	0,17	0,87	0,01	0,01	30,55	65,62	98,33	265	337903	6495036	3e
GBM.BJ.0029	0,12	0,25	0,10	0,08	0,60	0,57	0,02	30,53	65,88	98,13	320	337850	6495000	4a
GBM.BJ.0028	0,13	0,27	0,01	0,40	0,60	0,64	0,02	30,79	65,62	98,49	370	337945	6494930	4b
GBM.BJ.0027	0,24	0,57	0,13	0,27	0,54	0,31	0,02	30,56	65,36	97,99	420	337840	6494915	4b
GBM.BJ.0026	0,09	0,22	0,06	0,06	0,75	0,78	0,01	30,42	65,50	97,90	480	337795	6494900	4b
GBM.BJ.0025	0,14	0,23	0,11	0,08	0,72	0,40	0,01	30,72	66,39	98,80	520	337730	6494895	4b
GBM.BJ.0023	0,01	0,21	0,01	0,07	0,82	0,08	0,01	30,84	66,96	99,02	570	337675	6494870	4b
GBM.BJ.0033	0,27	0,19	0,00	0,05	0,82	0,45	0,01	30,22	66,38	98,40	765	337560	6494750	4c
GBM.Bj.9913	0,08	0,19	0,06	0,07	0,81	0,07	0,01	30,73	66,82	98,83	1020	337575	6494675	4e
NH-32	0,36	0,64	0,09	0,13	0,93	0,04	0,02	30,43	65,96	98,60	1110	337244	6494441	4e
NH-33	0,29	0,54	0,09	0,07	0,88	0,04	-0,03	30,29	65,95	98,11	1110	337244	6494441	4e
NH-31	0,20	0,83	0,09	0,10	0,83	0,08	0,02	30,56	65,87	98,58	1178	337174	6494287	4e
NH-30	0,25	0,71	0,09	0,11	0,87	-0,01	0,15	30,45	65,74	98,36	1270	336881	6494294	4e
GBM.Bj.9905	0,18	0,42	0,27	0,19	0,91	0,09	0,01	30,95	65,57	98,59	1470	337175	6494150	4e

Oxide wt%	MgO	Al_2O_3	SiO_2	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	Fe_2O_3	SUM	Strat. (m)	UTM-E	UTM-N	MCU
GBM.Bj.9904	0,04	0,35	0,10	0,13	0,91	0,07	0,01	30,83	66,08	98,52	1585	337200	6494000	4e
GBM.Bj.9903	0,06	0,40	0,03	0,18	0,85	0,07	0,01	31,05	66,74	99,40	1745	337100	6493850	4e
GBM.Bj.9902	0,23	0,62	0,34	0,21	0,63	0,05	0,01	30,80	65,07	97,96	1865	337200	6493750	4e
GBM.Bj.9901	0,04	0,32	0,09	0,08	0,58	0,05	0,01	30,72	66,47	98,36	1980	337150	6493625	4e
GBM.Bj.9906	0,03	1,10	0,09	0,81	0,53	0,04	0,02	31,38	63,86	97,86	2065	337100	6493500	4e
GBM.Bj.9907	0,02	0,31	0,05	0,15	0,59	0,05	0,01	30,63	66,22	98,03	2195	337050	6493425	4e
GBM.Bj.9908	0,10	1,15	0,19	2,38	0,34	0,03	0,04	32,69	60,50	97,42	2335	337300	6493400	4e
GBM.Bj.9910	0,46	0,67	0,16	1,54	0,36	0,03	0,07	31,32	63,03	97,65	2455	337100	6493150	4f
GBM.Bj.9911	0,10	0,55	0,23	0,34	0,30	0,03	0,01	31,29	66,17	99,01	2580	337000	6493100	4f
Bjerkreim S														
NH-74	0,32	0,44	0,07	0,19	0,99	0,06	-0,03	30,43	65,97	98,44		330776	6497258	1Be
Bjerkreim SW profile														
NH-68	0,39	0,43	0,09	0,02	0,79	-0,03	0,02	29,66	65,48	96,85	51	330610	6496946	1Be
NH-69	0,38	0,53	0,10	0,22	1,01	-0,03	0,03	30,58	66,09	98,92	42	330603	6496983	1Be
NH-70	0,53	0,34	0,09	0,16	0,85	0,09	-0,03	29,89	65,95	97,87	42	330603	6496983	1Be
NH-71	0,20	0,34	0,06	0,08	0,97	0,02	0,02	30,43	66,16	98,28	0	330533	6496965	1Be
NH-72	0,10	0,58	0,05	0,09	0,88	-0,04	-0,02	30,69	66,17	98,50	0	330533	6496965	1Be
Åsen profile														
NH-60	0,11	0,87	0,11	0,07	0,71	0,15	-0,02	31,24	66,87	100,11	0	330329	6494222	1Ad
NH-62	0,30	0,58	0,07	0,28	1,01	-0,02	0,07	30,87	66,63	99,79	20	330407	6494036	1Be
NH-63	0,46	0,75	0,07	0,94	0,88	0,02	0,12	30,96	64,51	98,71	23	330419	6494004	1Be
NH-64	0,44	0,92	0,07	0,85	0,97	0,02	0,06	31,06	64,47	98,85	43	330418	6494151	1Be
NH-65	0,14	1,07	0,11	0,37	1,02	0,03	-0,03	30,30	63,29	96,30	43	330418	6494151	1Be
NH-66	0,44	1,15	0,08	1,63	0,82	0,00	0,11	31,87	63,01	99,11	55	330439	6494156	1Be
NH-67	0,55	0,89	0,08	1,93	0,90	-0,01	0,01	31,40	61,48	97,23	65	330456	6494157	1Be
NH-73	0,35	0,54	0,08	0,14	0,96	0,08	0,01	30,32	65,85	98,32	101	330562	6494084	1Be
Bilstadvt. W														
NH-52	0,34	0,53	0,09	0,12	0,86	0,06	-0,01	30,54	66,54	99,07	60	344408	6492115	4e
NH-53	0,44	0,75	0,09	0,26	0,85	0,01	0,05	30,36	65,57	98,38	38	344603	6492025	4e
NH-54	0,42	0,66	0,08	0,14	0,90	0,04	-0,02	29,83	64,94	96,99	30	344603	6492044	4e
Storeneset profile														
NH-108	0,78	0,32	0,11	0,55	0,45	0,30	0,04	30,24	66,27	99,06	94	345386	6491841	4e
NH-106	0,70	0,42	0,08	0,27	1,02	0,01	0,02	30,01	66,39	98,92	93	345386	6491841	4e
NH-110	0,55	0,78	0,09	0,84	0,98	-0,05	0,08	30,58	64,23	98,07	88	345395	6491838	4e
NH-111	0,44	0,44	0,09	0,29	0,90	0,04	0,06	30,11	65,40	97,76	78	345407	6491841	4e
NH-112	0,44	0,89	0,10	1,22	1,00	0,07	0,03	31,11	62,78	97,64	64	345415	6491862	4e
NH-113	0,44	0,63	0,09	0,24	1,01	0,05	-0,08	30,45	65,85	98,68	53	345423	6491877	4e
NH-114	0,36	0,51	0,09	0,27	0,96	0,03	-0,02	30,67	66,28	99,15	32	345437	6491905	4e
NH-115	0,44	0,61	0,08	0,10	0,96	-0,04	0,04	30,04	65,78	98,01	0	345478	6491911	4e
Lauvneset profile														
NH-96	0,23	0,85	0,11	0,08	0,94	-0,07	-0,09	29,41	63,23	94,68	8	342870	6492838	4e
NH-97	0,07	0,42	0,08	0,10	0,42	0,03	0,05	30,05	65,12	96,35	28	342699	6492868	4e
NH-98	0,41	0,69	0,08	0,09	0,69	0,02	0,01	28,11	61,61	91,72	28	342699	6492868	4e

Oxide wt%	MgO	Al_2O_3	SiO_2	TiO_2	V_2O_3	Cr_2O_3	MnO	FeO	Fe_2O_3	SUM	Strat. (m)	UTM-E	UTM-N	MCU
NH-99	0,38	0,51	0,09	0,12	0,86	0,03	0,07	29,39	64,30	95,75	40	342697	6492853	4e
NH-100	0,56	0,56	0,10	0,12	0,98	0,01	0,09	29,56	64,94	96,91	49	342703	6492840	4e
NH-101	0,44	0,64	0,09	0,16	0,92	0,09	-0,02	28,94	62,95	94,21	54	342700	6492835	4e
NH-102	0,32	0,63	0,09	0,17	0,77	0,07	0,04	30,06	65,05	97,21	57	342706	6492830	4e
NH-103	0,20	0,62	0,10	0,03	0,79	0,02	0,01	30,04	65,17	96,98	63	342712	6492818	4e
NH-104	0,10	0,73	0,08	0,12	0,84	-0,05	0,04	29,96	64,09	95,90	85	342711	6492794	4e
NH-105	0,22	0,90	0,10	0,11	0,80	0,00	0,00	29,93	64,18	96,24	115	342753	6492742	4e
Helleland profile														
NH-78	0,24	0,67	0,11	0,07	0,89	0,00	0,07	30,33	65,57	97,94	0	333244	6491420	3d
NH-79	0,40	0,97	0,09	0,71	0,96	0,05	0,02	30,30	63,16	96,66	31	333382	6491412	3d
NH-80	0,36	1,06	0,10	0,76	0,84	-0,05	0,06	31,10	64,46	98,69	39	333408	6491414	3d
NH-81	0,56	0,85	0,08	0,53	0,97	0,02	-0,01	30,39	64,95	98,34	61	333475	6491430	3d
NH-82	0,58	0,94	0,09	1,54	1,00	0,14	0,05	31,07	62,08	97,49	76	333512	6491437	3d
NH-83	0,36	0,68	0,10	0,19	0,98	0,01	0,01	30,23	65,25	97,80	91	333532	6491450	3e
NH-84	0,24	0,70	0,03	0,27	0,95	0,07	0,01	29,93	64,12	96,33	91	333532	6491450	3e
NH-85	0,47	0,69	0,09	0,67	1,09	0,00	0,03	30,46	64,49	97,99	106	333544	6491475	3e
NH-86	0,37	0,57	0,08	0,40	1,00	-0,01	0,13	30,25	64,70	97,50	112	333561	6491460	3e
NH-87	-0,06	0,35	0,02	0,08	0,95	-0,01	0,00	30,24	64,98	96,55	147	333622	6491495	3e
Helleland profile - 2660 Mag - 70x100µ														
NH-78	0,91	1,35	0,22	0,22	0,74	0,09	0,05	29,55	64,17	97,30	0	333244	6491420	3d
NH-79	1,12	2,74	0,09	1,31	0,98	-0,12	-0,03	30,47	61,32	97,89	31	333382	6491412	3d
NH-80	0,87	2,30	0,08	1,38	0,78	0,06	0,04	30,96	61,99	98,46	39	333408	6491414	3d
NH-81	1,01	2,96	0,10	1,08	0,95	0,00	0,08	29,72	59,92	95,82	61	333475	6491430	3d
NH-82	1,15	2,86	0,09	3,02	0,81	0,02	0,16	32,02	57,85	97,99	76	333512	6491437	3d
NH-83	0,77	2,20	0,13	1,30	1,00	-0,11	0,02	30,50	60,49	96,30	91	333532	6491450	3e
NH-84	0,68	2,76	0,16	0,69	1,08	0,01	-0,02	29,97	60,37	95,70	91	333532	6491450	3e
NH-85	0,78	2,26	0,12	1,58	0,98	0,14	0,06	30,96	60,23	97,11	106	333544	6491475	3e
NH-86	0,82	2,42	0,10	1,24	0,90	0,02	-0,01	30,64	60,69	96,82	112	333561	6491460	3e
NH-87	0,86	1,39	0,19	0,34	1,02	0,03	-0,18	29,70	63,75	97,10	147	333622	6491495	3e

Appendix 3

Oxide wt%	F^-	P_2O_5	Cl^-	CaO	SUM	Strat. (m)	UTM-E	UTM-N	MCU
Teksevatnet W profile									
NH-18	3,65	42,32	0,09	53,51	99,57	167	339764	6493717	3e
NH-25	5,12	42,70	0,06	52,68	100,57	215	339810	6493636	3e
Terland profile									
NH-30	4,16	42,99	0,05	53,77	100,97	1270	336881	6494294	4e
Åsen profile									
NH-61	4,58	42,41	0,05	53,48	100,52	10	330396	6494023	1Bc
Storeneset profile									
NH-112	4,85	41,82	0,05	53,93	100,64	64	345415	6491862	4e