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

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Summary:

The Rogaland Anorthosite Province in southwest Norway is well known for its many ilmenite deposits, of which Tellnes is at present the only one in production. In addition to ilmenite, the province carries a significant potential for apatite and vanadium-rich magnetite occurring in the layered series of the Bjerkreim-Sokndal Layered Intrusion. The current study was undertaken in order to locate exploitable resources of combined apatite, ilmenite and vanadian magnetite in the Bjerkreim-lobe of the Bjerkreim-Sokndal intrusion.

The Bjerkreim lobe is the largest and most extensive part of the Bjerkreim-Sokndal intrusion and forms a c. 200 km^2 large synformal body. The layered series has a total thickness of >6000 m in the hinge area of the synform, thinning gradually to zero along the limbs. Three laterally extensive zones contain apatite. These are denoted MCU IBe, MCU IIIe and MCU IVe-f, and have in the current study been investigated systematically for the presence of exploitable resources of apatite and oxides. Ilmenite and magnetite are present throughout all three apatite-bearing zones, the economic value of these minerals, however, is strongly dependant on their chemical compositions.

MCU IBe contain a seemingly persistent 3 km long and 15-20 m to 50 m wide mafic sequence with 9 % apatite, 16 % ilmenite and 11 % magnetite on average. Individual samples in MCU IBe contain up to 41 % of the three minerals. In MCU IIIe two areas yield average value mineral quantities amounting to 34 % in a 100 m section and 29 % in a 130 m section respectively. The lateral extent of these areas have, however, not been fully determined. At the base of MCU IVe a 30-90 m thick mafic sequence may be followed for 3500 m from the south bank of Bilstadvatnet to Storøya in Teksevatnet. This zone contains on average 10 % apatite, 14 % ilmenite and 8 % magnetite. Available data and known relations on mineral chemistry indicate that the MgO-content of ilmenite is low in all three apatite-bearing zones. However, additional and systematic mineral chemical analyses are required to fully assess the economic potential of the prospects. The highest V_2O_5 –content in magnetite is expected to be found in the MCU IBe prospect, but the systematic variation of V_2O_5 in magnetite in the Bjerkreim-Sokndal intrusion is to a large extent uninvestigated.

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

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1. INTRODUCTION

The present work was initiated by Norsk Hydro Agri in order to assess the potential for economic mineral deposits in the layered Bjerkreim-Sokndal Intrusion in Rogaland, South Norway. The minerals of interest are apatite, vanadian magnetite and ilmenite; the primary target for Norsk Hydro Agri in this project is apatite. However, because there is a demand for Mg-poor ilmenite and V-rich magnetite worldwide, the combined resources of these two minerals and apatite in the Bjerkreim-Sokndal Intrusion could form deposits of economic importance. Previous studies have revealed concentrations up to 11 vol% apatite, 19 vol% ilmenite and 23 vol% magnetite (Korneliussen et al., 2001) in a sample from the Sokndal-lobe of the intrusion. The purpose of the current study was to locate similar zones in the Bjerkreim-lobe where apatite, magnetite and ilmenite coexist in sufficient concentration and tonnage to be of potential economic value. The aims were to locate areas containing as much as 40 % apatite, ilmenite and magnetite and to estimate the magnesium and vanadium content of ilmenite and magnetite respectively.

Fieldwork was coordinated by the Geological Survey of Norway and carried out during July 2001 by Henrik Schiellerup, Christian Tegner and Gurli B. Meyer from the Geological Survey of Norway and Brian Robins from the University of Bergen. This report is based on field data, as well as major and trace element data from a total of 149 samples. 25 samples form part of an older profile (the Terland profile) which were collected in 1999 and 2000 in a similar study. 91 samples were analyzed for major and trace elements by XRF (Appendix 3).

2. BACKGROUND

2.1 The Bjerkreim-Sokndal Layered Intrusion

The stratigraphy, mineralogy and petrology of the Bjerkreim-Sokndal Layered Intrusion (Fig. 1) have been studied almost continuously since the late 19^{th} century. Detailed maps of the phase layering (i.e. the appearance and disappearance of mineral phases in the stratigraphic sequence) in the Bjerkreim-lobe now exist, primarily through more recent work at the universities of Bergen and Århus (e.g. Wilson et al., 1996). However, most studies of the intrusion have maintained their primary focus on magma chamber processes, and very little data exist on the mineral proportions critical to economic considerations.

In the Bjerkreim-lobe, the Bjerkreim-Sokndal Layered Intrusion is characterized by a stratigraphic sequence consisting of 6 megacyclic units (MCU's), each derived from the repeated influx of magma into the Bjerkreim-Sokndal magma chamber. From base to top these have been numbered: 0, IA, IB, II, III and IV (Fig. 2). In addition, each MCU may be divided into a number of zones (a-f) based on the presence or absence of certain mineral phases. In a generalized sequence each zone is defined by the following mineralogy:

- a: plagioclase + ilmenite
- b: plagioclase + olivine + ilmenite + magnetite
- c: plagioclase + orthopyroxene + ilmenite
- d: plagioclase + orthopyroxene + ilmenite + magnetite
- e: plagioclase + orthopyroxene + clinopyroxene + <u>apatite</u> + ilmenite + magnetite
- f: plagioclase + inverted pigeonite + clinopyroxene + <u>apatite</u> + ilmenite + magnetite

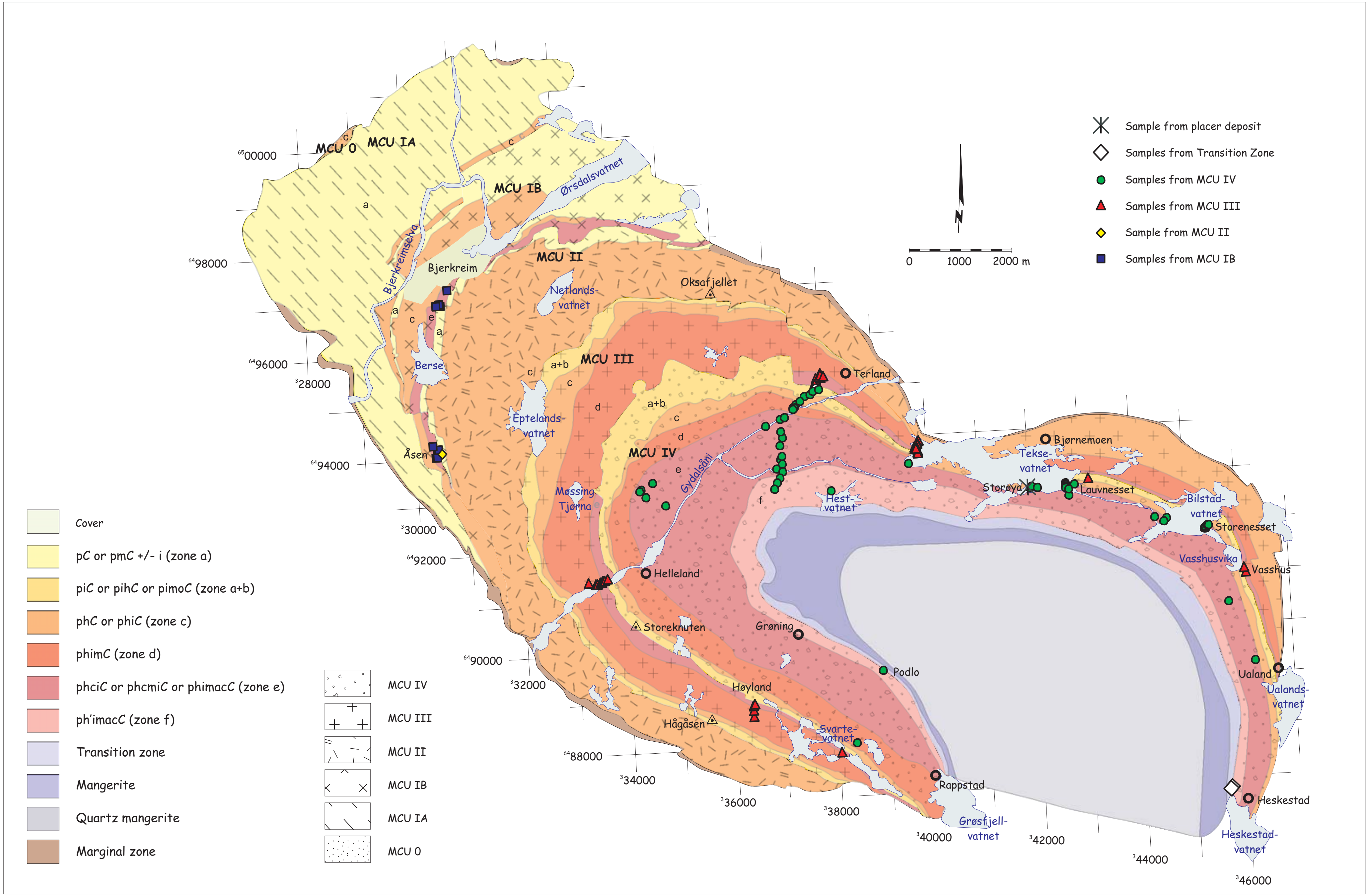


Fig. 1. Geological map of the Bjerkreim-lobe of the Bjerkreim-Sokndal Layered Intrusion. Sample localities are shown. Abbreviations are given in Appendix 2.

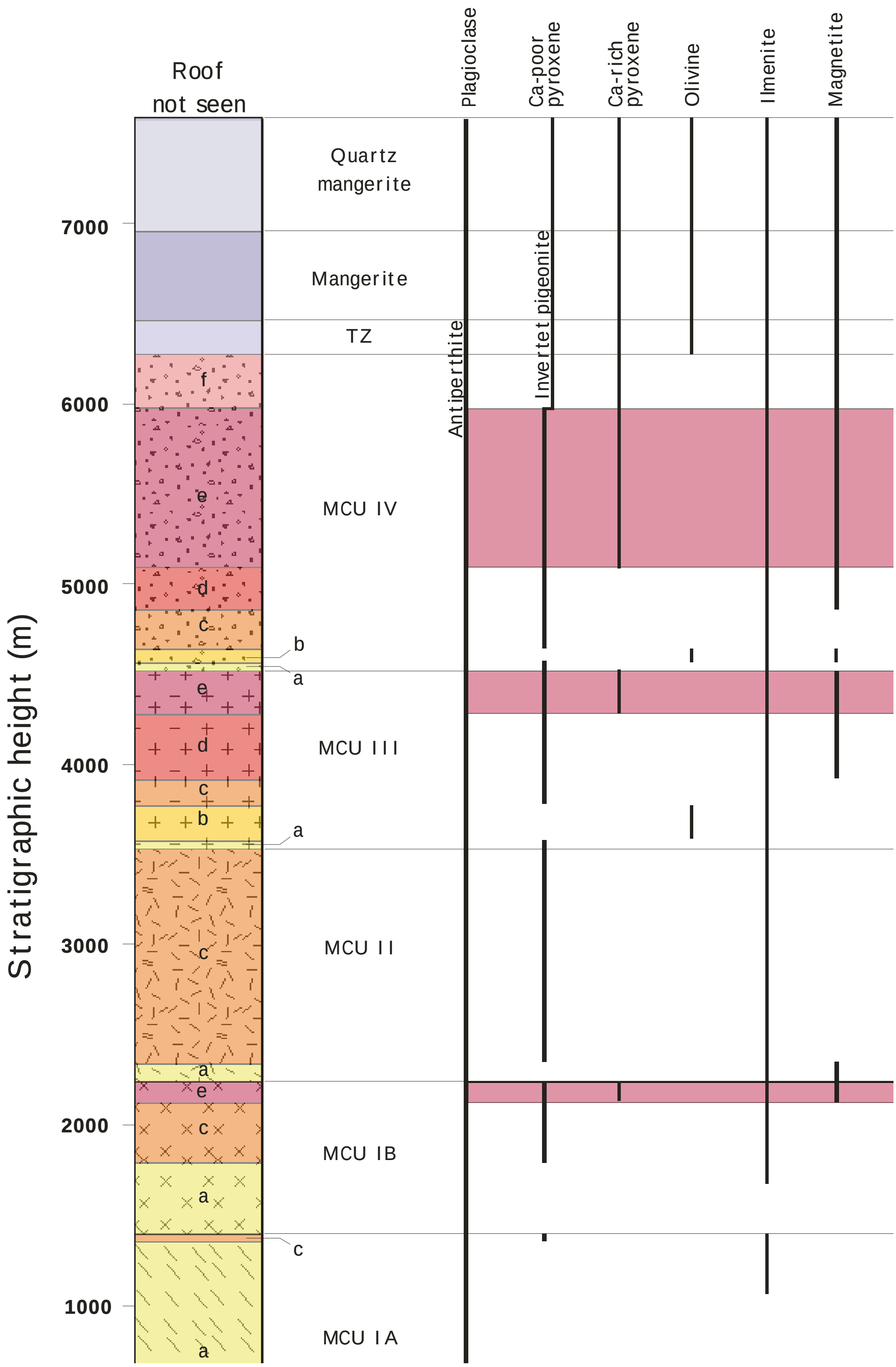


Fig. 2. Cumulate stratigraphy in the Bjerkreim-lobe of the Bjerkreim-Sokndal Layered Intrusion. The layered series is made up by 6 mega-cyclic units (MCU's) subdivided into a sequence of zones (a-f), defined by the presence or absence of certain index minerals. Three apatite-bearing sequences are found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

Only the uppermost megacyclic unit (MCU IV) displays the complete zone stratigraphy. In the other MCU's the range of zones developed are more variable. MCU IVf thus represents the uppermost zone in the layered series of the Bjerkreim-Sokndal intrusion. An olivine-bearing "transition zone" is overlying MCU IVf, which is in turn followed by mangeritic and quartz-mangeritic rocks.

2.2 Sampling strategy

In developing targets for exploration, four important points concerning the formation and compositional behavior of apatite and the oxides in the Bjerkreim-Sokndal Intrusion and other layered intrusions have to be considered.

1. In the Bjerkreim-Sokndal Intrusion apatite is stratigraphically constrained to the e- and f-zones (Fig. 2) that are found in the uppermost parts of MCU IB, MCU III and MCU IV. In these zones, apatite coexists with plagioclase, Ca-poor and Ca-rich pyroxene, ilmenite and magnetite. The transition zone (TZ), overlying the layered series, may also contain abundant apatite, as observed in the Sokndal-lobe of the intrusion. In the mangerites and quartz mangerites forming the center of the complex (Fig. 1), apatite is found only as an accessory. Attention has therefore been directed towards the three zones of interest: MCU IBe, MCU IIIe, MCU IVe + f and TZ (Fig. 2). It should be noted that theoretical considerations imply that apatite is most abundant during the initial stages of apatite crystallization – i.e. in the basal portions of the e-zones.

2. In Rogaland a correlation between ilmenite and silicate compositions exists. The composition of ilmenite, and most notably its Mg-content, is controlled primarily by the evolving composition of the crystallizing magmas. Evolving magmas, such as the ones responsible for the Bjerkreim-Sokndal intrusion, will produce ilmenites with successively lower Mg-content. Low-Mg ilmenite is therefore most likely to be found in the more evolved zones of the megacyclic units – i.e. predominantly in the e-and f-zones. All apatite-bearing units are thus likely to carry ilmenite with a relatively low content of MgO.

3. The vanadium content of magnetite also depends on the magmatic evolution. Vanadium is strongly partitioned into magnetite and the concentration of V_2O_5 in an evolving magma will tend to increase prior to magnetite crystallization and decrease rapidly once magnetite begins to crystallize. The most vanadium-rich magnetites are therefore expected to form at the base of the b- and d-zones where magnetite first appears. High-V magnetite in combination with apatite and ilmenite, is therefore most likely to be found in the stratigraphically lowermost part of the e-zones. According to theory, favorable scenarios may develop where the underlying d-zone is relatively thin, such as for MCU IVe on the eastern flank of the Bjerkreim-lobe, or in the actual absence of b- and d-zones, such as for MCU IBe. These particular areas have been thoroughly studied.

4. The P_2O_5 content of the Bjerkreim-Sokndal cumulates displays a positive correlation with Mg, Ti and Fe, and a negative correlation with Na. This correlation shows that apatite is more abundant in dark (mafic) layers than in light colored layers. A focus on plagioclase-poor cumulates has therefore been maintained. These are also the most interesting in terms of oxide-contents. Instead of chip sampling across layered sections, the sampling strategy involved sampling of complementary melanocratic (mafic) and leucocratic (felsic) layers accompanied by notes on the extent and nature of modal layering.

3. FIELD AND SAMPLE DATA

All sample points were located by GPS with a precision of 5-10 meters and coordinates referred to in this report are given with reference to WGS84 (World Geodetic system 1984). Sample locations are shown in Fig. 1 and the corresponding UTM-coordinates tabulated in Appendix 1. Samples have in general been collected along profiles perpendicular to the modal layering and the spacing varies from a few decimeters to 50 meters. In areas regarded as having only little economic potential, isolated reconnaissance samples were collected.

3.1 Megacyclic unit IB

MCU IB distinguishes itself from the MCU's III and IV in one important way: It does not contain any magnetite-bearing b- or d-zones, which means that the first appearance of apatite and magnetite is simultaneous at the base of zone MCU IBe (Fig. 2).

The MCU IBe is a relatively narrow zone of apatite, magnetite and ilmenite-rich cumulates extending south and southwest from the hinge axis of the intrusion near the village of Bjerkreim. The zone is 40-90 m wide and may be followed along strike for approximately 4 km (Fig. 1). The stratigraphy has been offset by a number of minor faults. South of Berse lake the zone is exposed in the slopes of a deep erosional valley, and to a large part covered by glaciofluvial sediments. North of Berse lake, the zone is densely overgrown. It is therefore difficult to obtain a continuous impression of the extent and potential of the zone. Sampling has taken place mainly along two profiles at Åsen and Bjerkreim, south and north of Berse lake. Both profiles contain prominent sequences dominated by melanocratic rocks in intensely layered cumulates.

15 samples have been collected from this zone: 9 in the major profile at Åsen, and 6 in profile and isolated exposures south of Bjerkreim. At Åsen a melanocratic apatite-, ilmenite- and magnetite-rich sequence, which covers a stratigraphic interval of around 60 m, begins approximately 10 m above the base of MCU IBe. In major parts of this sequence mafic layers make up 60-70% of all exposures. A similar series of layered melanocratic cumulates in MCU IBe are also exposed north of Berse lake (Fig. 1). The melanocratic sequence here is not as extensive as at Åsen (15-30 m). Both the zone and the layered sequence tend to wedge out on approaching Bjerkreim. In the northernmost exposures, closer to Bjerkreim, the melanocratic series is only about 10 m thick and somewhat more leucocratic.

<u>*Summary of observations*</u>

Poor exposure makes it difficult to confidently assess the persistency and aerial extent of the MCU IBe target area. However, the overall similarities observed in profiles across the zone in terms of layering and mafic index do suggest that a prominent apatite-, ilmenite- and magnetite-rich zone exists. The zone varies in thickness from 15-20 to as much as 60 m and is likely to be laterally continuous for at least 3 km.

Fig. 3. (above) Exposures of mafic apatite- and oxide-rich layered cumulates in MCU IBe at Åsen Gård. (below) Rock sample from the mafic cumulates at Åsen Gård. The blue magnet is 2 cm across.

3.2 Megacyclic unit III

MCU IIIe is a more continuous feature of the Bjerkreim-lobe than the MCU IB. It may be followed along strike from Rappstad in the southern extension of the western flank to Ualand in the eastern flank – a total distance of approximately 25 km – but is absent for about 8 km in the central part of the intrusion. The stratigraphic thickness of the zone is variable, decreasing from up to 300 m in the central most part to around 50 m on the flanks.

MCU IIIe in the western flank of the intrusion has been sampled primarily in two profiles at Høyland and Helleland. For most of its lateral extent in the southern part of the western flank, MCU IIIe remains relatively leucocratic and without sequences with intense layering.

Investigations at Svartevatnet and around Høyland did not reveal the presence of cumulates significantly enriched in apatite and oxides. Layering is virtually absent and the gabbronoritic cumulates are fairly leucocratic. Further north, as observed in the Helleland (E39) profile, more melanocratic sequences are developed. The melanocratic, apatite- and oxide-rich sequence at Helleland is on the order of 160 m thick and consists of 3-30 cm thick mafic layers alternating with more felsic layers. Dark layers make up 40-60% of the sequence. However, the absolute contrast in mafic index between layers is rather poor and even the relatively felsic layers are moderately melanocratic. Layered rocks from MCU IIIe at Storeknuten, south of Helleland, are shown in Fig. 4.

Fig. 4. Modally layered cumulates from the upper apatite-bearing part of MCU III, south of Storeknuten (Fig. 1). Several layers are modally graded.

The eastern flank is overall more melanocratic than the western flank and extensive sampling has been performed at Terland, Teksevatnet (west end), Bilstadvatnet and Vasshus. The melanocratic zones encountered in the surveys seem to be laterally persistent over considerable distances. At Terland in the lowest part of the Terland profile (Fig. 1) the MCU IIIe zone has a total stratigraphic thickness of 250 m. In the lower part of this zone there is an interval of dm- to cm-scale layered cumulates with a relative high content of ilmenite, magnetite and apatite. The stratigraphic thickness of this melanocratic interval is approximately 130 m. At Teksevatnet, 2.5 km further southeast, the thickness of MCU IIIe has been reduced to around 80 m. Apart from a 15 m interval of more homogenous gabbronoritic rock, MCU IIIe at Teksevatnet remains intensely layered and enriched in mafic silicates, oxides, and apatite. In this sequence 2-30 cm thick melanocratic layers dominate over leucocratic layers. The thickness of MCU IIIe and the stratigraphic location of melanocratic sequences in the Terland and Teksevatnet profiles are rather dissimilar. It is, however, probable that a melanocratic apatite- and oxide-rich sequence is laterally persistent between these two profiles. At the east end of Teksevatnet investigations were somewhat hampered by poor exposure, but a melanocratic gabbronorite was also encountered in the top of MCU IIIe at Bjørnemoen.

Further to the southeast, oxide- and apatite-rich rocks have been documented in the uppermost part of MCU IIIe east of Vasshusvika (sample NH-56). This area is densely covered and the extent of apatite-rich rocks is not known. However, a sample collected 70 m north of NH-56 in 2000 (Korneliussen et al., 2001) was equally rich in apatite and contained more than 12 vol% apatite.

<u>*Summary of observations*</u>

Although the presence of a persistent melanocratic apatite- and oxide-enriched sequence has not been fully documented (partly due to lakes and sedimentary cover) in MCU IIIe, melanocratic sequences are at least very frequent. In the western flank the extent of the 160 m thick melanocratic sequence encountered in Helleland is uncertain, but the sequence is likely to continue further north. However, 1500 m north of the Helleland profile MCU IIIe disappears, thus limiting the lateral extent of this sequence. A conspicuous oxide-and apatite-rich sequence is present in both the Terland and Teksevatnet profiles that may be laterally continuous (over 2 km) with a thickness of 65-130 m. Potential prospects in MCU IIIe are absent on the southeastern shore of Bilstadvatnet, and the extent of the apatite- and oxide-rich rocks encountered at Vasshus remains uncertain. The Vasshus and Terland-Teksevatnet MCU IIIe prospects are, however, not fully connected.

3.3 Megacyclic unit IV and Transition Zone

The two uppermost zones in MCU IV (the e- and f-zones) cover a very large area of the Bjerkreim-lobe. Both along the western flank and in the central part of the intrusion, MCU IVe has a stratigraphic thickness exceeding 1 km and the zone may be followed along strike for more than 20 km. Only in one case has an interesting target been explored in MCU IVf (Podlo, Fig. 1). The transition zone of the Sokndal-lobe is in certain places characterized by the occurrence of very oxide-rich cumulates, but similar rocks have not been encountered in the Bjerkreim-lobe. Samples have been collected through the Transition zone at Heskestad, but mainly for reference purposes.

Surveys of MCU IVe on the western flank of the Bjerkreim-lobe have not revealed the presence of significant amounts of apatite-, ilmenite- and magnetite-enriched rocks. The same applies to the central part of the intrusion, near the hinge axis north of Helleland, where samples have been collected, but no apparent prospects were encountered. In MCU IVe, as in MCU IIIe, the most promising areas are found in the eastern flank of the Bjerkreim-lobe. Sampling here has been concentrated in profiles at Terland, the eastern end of Teksevatnet (Lauvneset) and at Bilstadvatnet. Again fairly persistent melanocratic and intensely layered sequences have been encountered.

In Terland the MCU IVe zone has a total stratigraphic thickness of 1100 m. In contrast to MCU IIIe, no fine-scale layered sequences were observed in this profile. Only a few isolated dm or cm-thick layers were observed in the generally m-scale layered homogenous sequence of leuconorite and leucogabbronorite. However extensive cover in the valley of Gydalåni may hide fine-scale layered sequences. At the west end of Teksevatnet, 2.5 km further east, the lower part of MCU IVe appears fairly leucocratic. Layering is present but melanocratic layers only make up around 20% of the rock. However, on Storøya (a peninsula in Teksevatnet) about 1 km further east, a 10-15 m section dominated by melanocratic layers is exposed close to the base of MCU IVe. From Storøya to southeast of Bilstadvatnet, a distance of at least 4 km, melanocratic sequences seem to characterize the lower part of MCU IVe. On Lauvneset (east end of Teksevatnet) the oxide- and presumably apatite-rich zone has expanded to cover a stratigraphic interval of around 40 m dominated by 5-30 cm thick melanocratic layers in the lower part (Fig. 5), and more homogenous melanocratic rocks in the upper part. Further southeast, similar melanocratic rocks are exposed due to canal building, and on the north shore of Bilstadvatnet a 40 m thick melanocratic sequence is exposed, occupying the same stratigraphy as the Lauvneset and Storøya sequences. On the southern shore of Bilstadvatnet the same sequence is found on Storeneset. Here the sequence is around 90 m thick and consists of either intensely layered cumulates or more homogenous melanocratic rocks, from about 20 m above the base of MCU IVe.

Fig. 5. Mafic, modally layered rocks at Lauvneset (south shore of Bilstadvatnet). Apatite- and oxide-rich cumulates in MCU IVe.

<u>*Summary of observations*</u>

The apatite- and oxide-rich sequence close to the base of MCU IVe in the east flank is fairly well documented and appears to be a persistent feature for at least the 3500 m between Storøya in Teksevatnet and south of Bilstadvatnet. The zone may, however, continue further south. Samples from isolated exposures at Vasshus and Ualand in the lower part of MCU IVe in the southern part of the east flank remain relatively melanocratic.

3.4 Heavy sand deposits

Along most of the banks of both Teksevatnet and Bilstadvatnet as well as in the streams connecting the lakes placer deposits rich in magnetite and ilmenite can be found. Locally the sand forms large areas along the banks. The sand predominantly derive from the rocks of the Bjerkreim-Sokndal Intrusion. A single heavy sand sample (NH-11) was collected at the southern shore of Teksevatnet (Storøya). The sample was collected from sand deposited upon dm- to cm-scale layered melanocratic rocks of MCU IVe.

4. GEOCHEMISTRY AND RESULTS

New data has been collected from 91 samples analyzed by XRF, which confirm the correlation of P_2O_5 and TiO_2 in the cumulates of the Bjerkreim-Sokndal Intrusion (Fig. 6). The highest P_2O_5-content analyzed is 5.47 %, corresponding to approximately 13.7 wt% apatite, and the highest TiO_2-content in apatite-bearing samples is 9.61 %, equivalent to about 19.3 wt% ilmenite. However, most of the apatite- and oxide-rich rocks tend to contain between 3 and 4 % P_2O_5 and 6.5 to 8.5 % TiO_2 (Fig. 6). The details of the geochemical systematics are discussed below, focussing on each of the three target zones in turn.

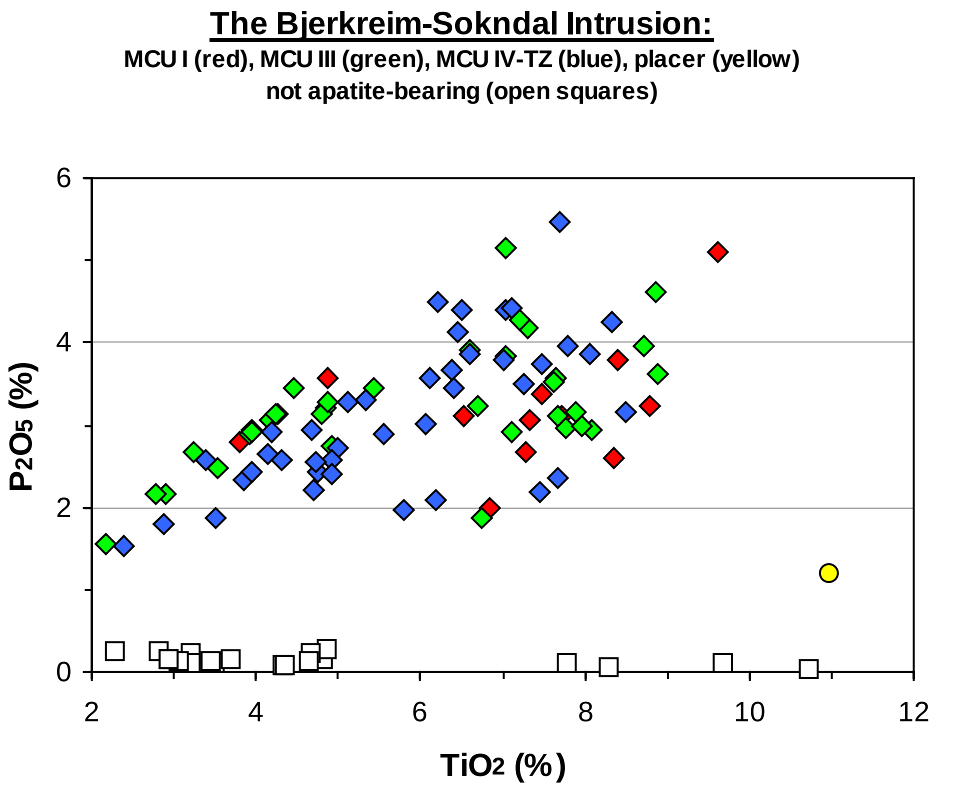
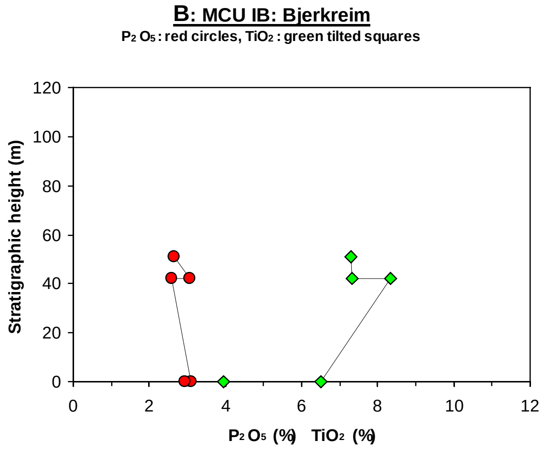


Fig. 6. P_2O_5 vs. TiO_2 in rock samples from the Bjerkreim-lobe, displaying a positive correlation in apatite-bearing zones. A heavy sand sample from Teksevatnet is included (yellow circle).

4.1 Megacyclic unit IB

The two main profiles covering the apatite-bearing part of MCU IB (Åsen Gård and Bjerkreim) are shown in Figs. 5A and 5B. At Åsen Gård, TiO_2 and P_2O_5 increase abruptly at the base of the profile to 5.11 % and 9.61 % respectively, corresponding to approximately 13 % apatite and 19 % ilmenite (by weight). However, the average P_2O_5- and TiO_2-content in the 60 m thick apatite-bearing sequence is somewhat lower with 3.5 % P_2O_5 and 7.7 % TiO_2 (9 % apatite and 16 % ilmenite). The P_2O_5 content of cumulates within the apatite-bearing zone do not seem to be significantly correlated with the TiO_2-content. Poor correlation of P_2O_5 and TiO_2 is also observed in the Bjerkreim profile where we find averages of 2.9 % P_2O_5 and 6.7 % TiO_2 in a 50 m sequence. The poor correlation of TiO_2 and P_2O_5 in the MCU IB profiles implies that whereas the average P_2O_5-contents in these profiles are fairly well constrained, the TiO_2-contents are more difficult to assess.



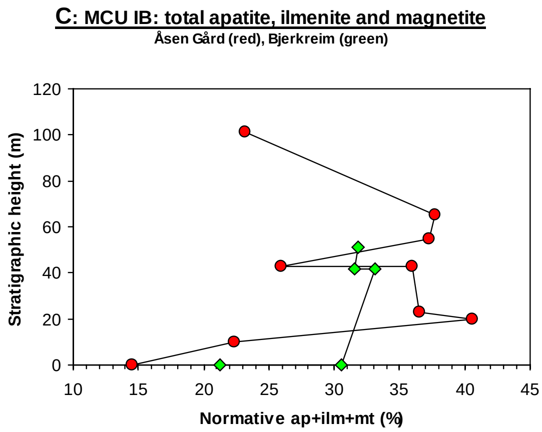


Fig. 7. Geochemical plots, MCU IB. P_2O_5 and TiO_2 in the Åsen Gård (A) and Bjerkreim (B) profiles vs. stratigraphic height. In C, the calculated normative contents of apatite, ilmenite and magnetite in the two profiles are presented. The stratigraphic zero-points are not geologically fixed.

The mineralogy of the investigated zone is well constrained (Wilson et al., 1996) and it is possible to estimate the content of the appropriate mineral phases by calculating a *normative* rock composition from the XRF-analyses of the major elements (Appendix 3). In this way we can derive an estimate of the magnetite-content of the cumulates in MCU IB. For a 50 m section of the Åsen Gård profile (the lowermost apatite-bearing sample being anomalous) we obtain an average of 10 % magnetite, whereas the Bjerkreim profile yields a slightly lower average of 9 % magnetite.

The total content of value minerals in the MCU IB profiles has been estimated from the normative calculations and presented in Fig. 7C as wt%. One sample in the Åsen Gård profile has an estimated content of apatite, ilmenite and magnetite of 41 % whereas the total average content of value minerals (i.e. apatite, ilmenite and magnetite) amounts to 36 % in this profile. In the Bjerkreim profile, which was not sampled as densely, the values are again slightly lower, with most samples containing between 30 and 33 % apatite, ilmenite and magnetite.

Summary of geochemical results

In MCU IB 50 m of the apatite-bearing section has been shown to contain an average of 9 % apatite, 16 % ilmenite and 11 % magnetite (by weight) in the Åsen Gård area, with a single sample containing up to 41 % of the three minerals. Further north, towards Bjerkreim, the *same zone yields somewhat lower grades, totaling between 30 and 33 % of value minerals. It is not clear whether the data reflect systematic or sporadic variations along MCU IB, and details on the mineral chemistry are lacking to confidently assess the economic value of the oxides.*

4.2 Megacyclic unit III

Three of the collected profiles across MCU III have been analyzed for major and trace elements (Appendix 3 and 4). All three profiles are located in the central or eastern part of the Bjerkreim-lobe where the most interesting prospects are found. West of the hinge axis a profile has been investigated along the E39 at Helleland and the data are shown in Fig. 8A. The poor color contrast between layers noted in the field is also evident in the geochemistry. The P_2O_5 content rises to a maximum of 4.2 % at the base of the apatite-bearing zone, but the profile is characterized by an average of 3.4 % P_2O_5 through a stratigraphic interval of 130 m. In the same sequence TiO_2 makes up 6.8 % on average, but tend to be higher in the central 70 m of the profile. The highest content of TiO_2 measured in the Helleland profile is 8.1 %.

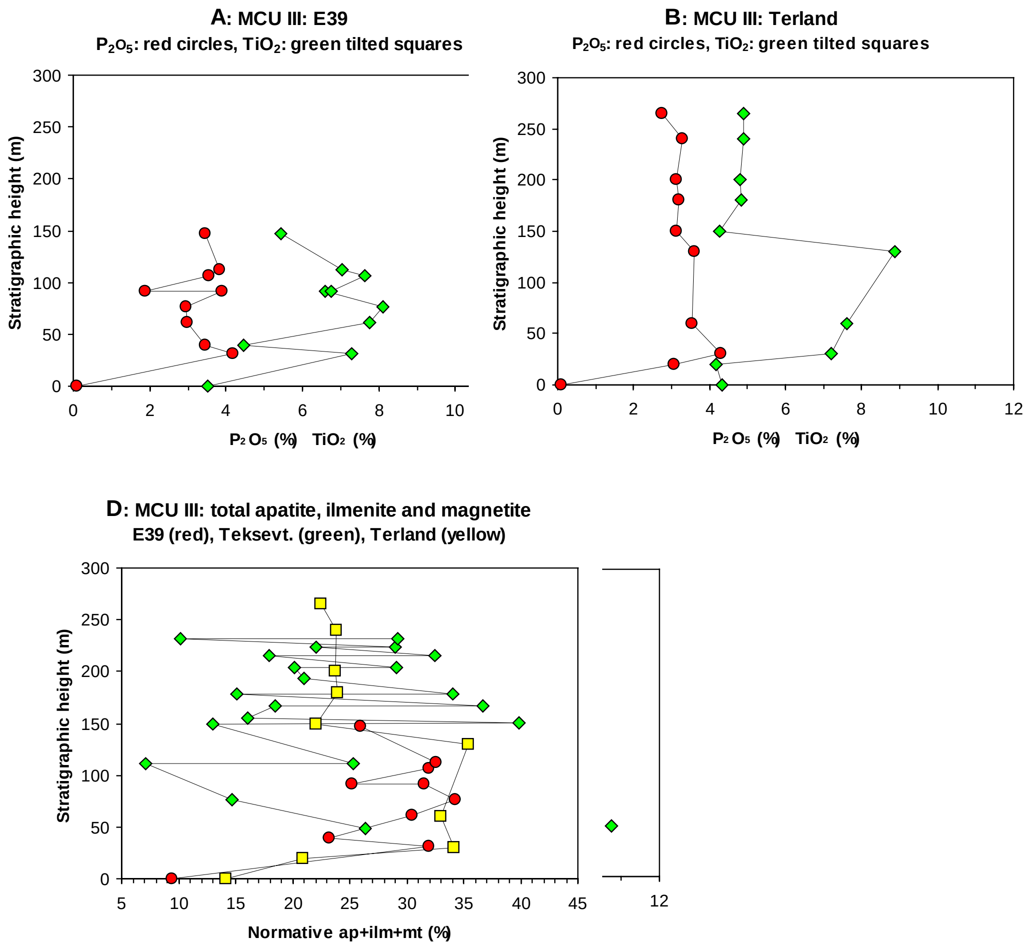


Fig. 8. Geochemical plots, MCU III. P_2O_5 and TiO_2 in the Helleland (E39) (A), Terland (B) and Teksevatnet (C) profiles vs. stratigraphic height. In D the calculated normative contents of apatite, ilmenite and magnetite in the three profiles are presented. The stratigraphic zero-points are not geologically fixed.

In the immediate vicinity of the hinge axis of the Bjerkreim-lobe MCU III does not contain an apatite-bearing zone. Where apatite-bearing cumulates reappear east of the hinge axis, the Terland profile has been analyzed. As in Helleland and Åsen Gård, we observe an abrupt increase in P_2O_5 as apatite becomes a cumulus phase, reaching a maximum of 4.3 % before slowly dropping off to less than 3 % over 220 m (Fig. 8B). The most interesting part of this zone is the lowermost 100 m in which apatite and ilmenite are particularly abundant, and average P_2O_5- and TiO_2-contents are 3.8 and 7.9 % respectively. The highest TiO_2-content observed in this zone is 8.9 %.

Again, we may calculate a normative composition to estimate the content of apatite, ilmenite and magnetite. In the Helleland (E39) profile, the 130 m section yields an estimated average composition of 8 % apatite, 13 % ilmenite and 8 % magnetite. Higher averages are obtained in the Terland profile with 9 % apatite, 15 % ilmenite and 10 % magnetite across the 100 m interval. Although individual samples in the Teksevatnet profile contain up to 40 % value minerals, the strong contrast between mafic and felsic layers in this section results in a relatively low average value mineral content of only 25 %. The total value mineral contents for the three profiles are shown in Fig. 8D.

Further east along MCU III, the densely sampled Teksevatnet profile has been analyzed and shown in Fig. 8C. Apart from a few high-P_2O_5 samples (up to 5.2 %), the average P_2O_5-content remains constant at around 3.1 %. At Teksevatnet there is a strong contrast between mafic and felsic layers, which is also evident from the highly scattered nature of the TiO_2-analyses. The highest TiO_2-concentration in the apatite-bearing sequence is 8.9 %, and the average TiO_2-content measured is 5.4 %. However, due to the sampling strategy and the predominance of mafic layers in this sequence, the overall average TiO_2 content here is likely to be slightly underestimated.

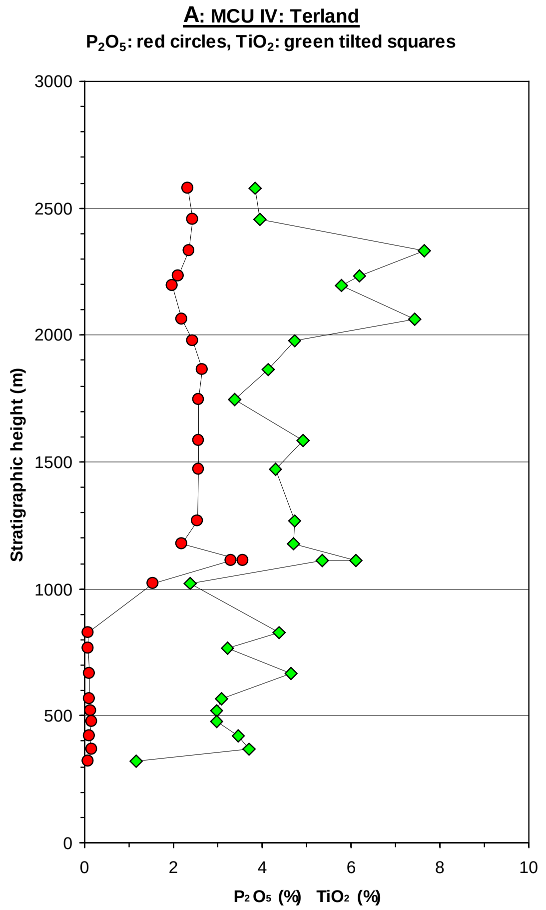
<u>*Summary of geochemical results*</u>

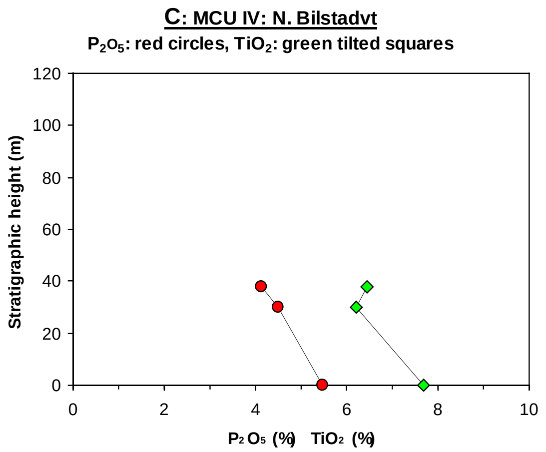
Two areas on either side of the hinge axis of the Bjerkreim-lobe are characterized by elevated contents of value minerals: The Helleland area on the western flank contains an average of 29 % value minerals across a 130 m profile, and the Terland area on the eastern flank contains 34 % value minerals across a 100 m stratigraphic section. Further east, the prospect at Teksevatnet yields lower concentrations of apatite, ilmenite and magnetite totaling around 25 %, which limit the most interesting prospects to the areas around the hinge axis (though it should be noted that apatite is absent in the immediate vicinity of this axis). The single sample from the poorly investigated apatite-bearing zone at Vasshus is, however, also characterized by an elevated value mineral content of 32 %.

4.3 Megacyclic unit IV and Transition Zone

Potential prospects in the apatite-bearing zone in MCU IV are confined to the eastern flank of the Bjerkreim-lobe, where four sampled profiles have been analyzed. From west to east these profiles are located at Terland, Lauvneset (Teksevatnet), the north bank of Bilstadvatnet, and Storeneset (Bilstadvatnet) (Fig. 1). Major and trace element data are presented in Appendices 3 and 4, and data for P_2O_5 and TiO_2 are displayed in Figs. 7A-D.

As for most other profiles, the appearance of apatite as a cumulus mineral in MCU IV at Terland is marked by an increase in P_2O_5 from 0 to 3.6 % followed by a decrease to relatively constant values of around 2.5 % (Fig. 9A). TiO_2 is much more variable in the apatite-bearing sequence, averaging 5.0 % with a maximum of 7.7 % TiO_2. The only economically interesting part of the Terland profile is the sequence where P_2O_5 is at its maximum upon the entry of cumulus apatite. The thickness of this level is difficult to assess from the current data, but P_2O_5 is unlikely to exceed 3 % in more than a 100 m section of the profile. The existence of an apatite-rich sequence at the base of MCU IVe in Terland has therefore been documented, but the extent and composition of this sequence is not well resolved by the data.





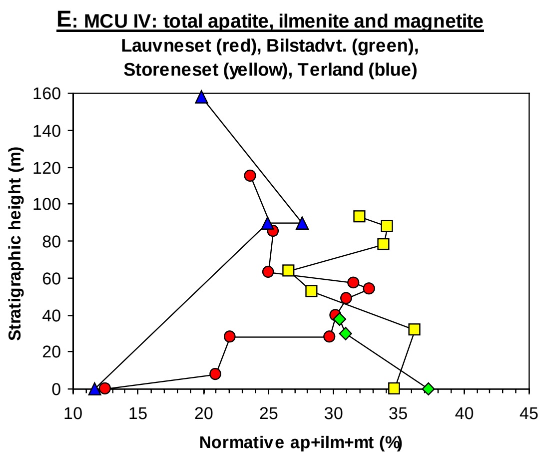


Fig. 9. Geochemical plots, MCU IV. P_2O_5 and TiO_2 in four profiles on the eastern flank vs. stratigraphic height (A-D). In E the normative contents of apatite, ilmenite and magnetite in the profiles are presented. The stratigraphic zero-points are not geologically fixed.

At Lauvneset on the east bank of Teksevatnet, sample resolution is better and we observe a slower rise in P_2O_5 accompanying the appearance of cumulus apatite. P_2O_5 rises to a maximum of 4.4 % over a stratigraphic interval of 60 m and then drops off to less than 3 % (Fig. 9B). The part of the profile richest in apatite is also enriched in ilmenite, and a 35 m section of the profile yields average values of 4.0 % P_2O_5 and 6.7 % TiO_2, corresponding to 10 % apatite and 13 % ilmenite.

Further east the same sequence has also been observed and analyzed at Bilstadvatnet, without the basal portion of the apatite-bearing zone being exposed (Fig. 9C). Three samples from a 38 m interval contain 4.7 % P_2O_5 and 6.8 % TiO_2 on average, and up to a maximum of 5.5 % P_2O_5 and 7.7 % TiO_2. At Storeneset on the opposite bank of Bilstadvatnet P_2O_5 remains relatively constant in the base of MCU IVe. The basal 90 m of this zone contain 3.7 % P_2O_5 and 7.5 % TiO_2 on average (Fig. 9D).

Calculations on the major element compositions again yield estimates of the normative mineralogy of the investigated samples. Average normative mineral modes in the four profiles from west to east are given below, with an indication of the stratigraphic thickness to which these averages apply (see also Fig. 9E).

MCU IVe	*west* Terland	Lauvneset	Bilstadvatnet	*east* Storeneset
apatite (wt%)	8	10	12	9
ilmenite (wt%)	11	13	14	15
magnetite (wt%)	6	8	8	9
value min (wt%)	26	31	33	32
strat. seq. (m)	<100	30	>38	93

<u>*Summary of geochemical results*</u>
In the basal part of MCU IVe a sequence seems to be developed with systematically elevated contents of apatite, ilmenite and magnetite, totaling between 30 and 35 wt% on average. The sequence is encountered in profiles from the south bank of Bilstadvatnet to Teksevatnet and have a thickness varying between 30 and 93 m. West of Teksevatnet the corresponding cumulates are not significantly enriched in oxides, and the apatite content is unknown, but at Terland, further west, the presence of apatite- and oxide-enriched cumulates have again been documented. The sampling density in Terland has, however, not been tight enough to resolve the extent of a <100 m zone, and it remains uncertain if the most apatite rich cumulates have been accounted for here.

4.4 Heavy sand sample (placer)

One sample of heavy mineral sand was collected along the banks of Teksevatnet (NH-11). The sample turned out to be relatively low in P_2O_5 for its oxide content, when compared with the Bjerkreim-Sokndal cumulates (Fig. 6). The sample contains only 3 % apatite, but around 23 % ilmenite and 7 % magnetite, both of which are of unknown composition.

4.5 Note on vanadium in magnetite

A rough estimate of the maximum vanadium-content of magnetite in the investigated cumulates may be obtained simply by dividing the whole rock V_2O_5 content analyzed by the estimated proportion of magnetite in each sample. The result is shown in Fig. 10, where total V_2O_5 in magnetite are plotted against the normative apatite content. This plot does not take into account the amount of V_2O_5 hosted by other phases, and even though magnetite is the only phase present in which vanadium is compatible, the V_2O_5 content thus calculated could be overestimated. From Fig. 10, we estimate that the average V_2O_5 content in magnetite is on the order of 1.5 %, which is considerably higher than that found in most analyzed magnetites from the Bjerkreim-Sokndal Intrusion (e.g. Duchesne, 1972; Schiellerup, 2001).

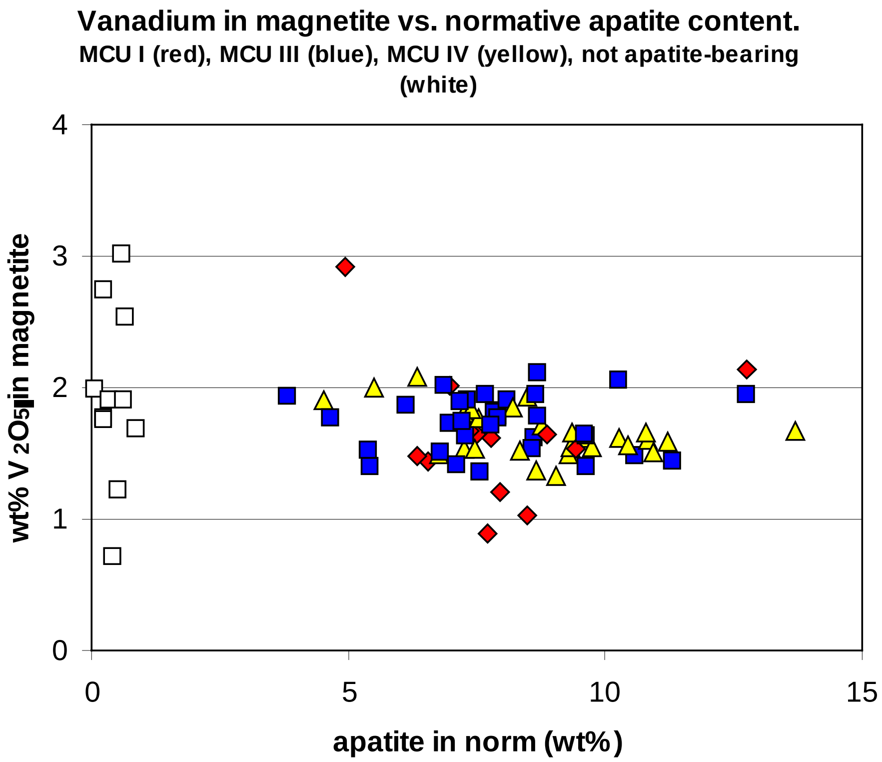


Fig. 10. Calculated V_2O_5 in normative magnetite, assuming that all measured V_2O_5 is hosted by magnetite, vs. calculated apatite content in normative composition.

High-V_2O_5 samples among apatite-free cumulates presumably result where magnetite is a cumulus phase prior to apatite saturation, thus depleting the residual melt in vanadium before apatite appears in the cumulates. Similarly, high-V_2O_5 samples present in the apatite-bearing rocks from MCU IB are a consequence of the simultaneous saturation of the magma in both apatite and magnetite. This means that the apatite-bearing cumulates in MCU IB are likely to carry magnetite with a high V_2O_5-content. It is notable, however, that very few samples carry magnetites with less than 1.3 % V_2O_5 when calculated this way. A detailed investigation of the magnetite composition in the sampled rocks must be undertaken in order to determine, quantitatively, the vanadium content of magnetite. Although not economic by itself, magnetite containing in excess of 1 % V_2O_5 could still be an economically viable by-product of apatite exploitation.

4.6 Note on magnesium in ilmenite

The primary composition of ilmenites from mafic intrusions in Rogaland show a conspicuous correlation with the mineralogical composition of the cumulates in which they are found (Schiellerup, 2001). More specifically, ilmenites from apatite-bearing cumulates in general contain relatively little MgO. Furthermore, post-magmatic equilibration with Mg-rich silicates may act to further reduce the Mg-content of ilmenites, particularly in large intrusions such as Bjerkreim-Sokndal. A low MgO-content is therefore expected in ilmenites from the prospects sampled in this study. In a previous study involving some of the samples now presented in the Terland profile, analyzed ilmenites from the apatite-bearing part of MCU IV was shown to contain less than 1.3 % MgO, and a sample from MCU III contained only 0.2 % MgO (Meyer et al., 2001a,b). However, in order to fully evaluate ilmenite qualities in the investigated prospects, more detailed work on mineral chemistry has to be performed.

5. CONCLUSIONS

Three apatite, ilmenite and magnetite-rich stratigraphic zones have been identified, sampled and investigated for their economic potential. The three most promising areas in these zones are (Fig. 1):

- The MCU IBe-zone southwest of Bjerkreim.
- The MCU IIIe-zone around and to the north of Helleland and on the eastern flank of the Bjerkreim-lobe, between Terland and Teksevatnet.
- The MCU IVe-zone of the eastern flank of the Bjerkreim-lobe between Teksevatnet and Vasshus.

<u>In MCU IB</u> the prospect consists of an at least 3 km long zone, varying in thickness between 60 and 15-20 m and containing on average 36 % value minerals in a southern profile and 32 % in a northern profile. Average abundances of 9 % apatite, 16 % ilmenite and 11 % magnetite have been obtained across a 50 m section at Åsen Gård. Trace element data indicate the presence of relatively vanadium-rich magnetite in this area, whereas the MgO content of ilmenite is unknown.

<u>In MCU III</u> two areas qualify as economically interesting: Highest abundances of economic minerals have been found around Terland, with 9 % apatite, 15 % ilmenite and 10 % magnetite across a 100 m stratigraphic section. At Teksevatnet, 2 km east of Terland these concentrations are significantly reduced, and further investigations are required to assess the lateral persistence of the Terland prospect. In Helleland a 130 m profile yield an average composition of 8 % apatite, 13 % ilmenite and 8 % magnetite. The lateral extent of this zone is not known in detail, but it is presumably less than 1500 m. An additional area of potential interest is the area around Vasshus, which is both poorly exposed and investigated (composition and areal extent). Two samples from here indicate value mineral abundances in excess of 30 % (this work and Korneliussen et al., 2001). The MgO-content of ilmenite in the MCU III prospects are expected to be low (≤ 1 %?), whereas the vanadium content of magnetites are unknown. Mineral chemical data are required to fully assess the economic potential.

<u>In MCU IV</u> the basal section of the apatite-bearing sequence contains a seemingly persistent zone extending from Storeneset on the south bank of Bilstadvatnet to Storøya in Teksevatnet. This zone contains on average (in three profiles and isolated samples) 10 % apatite, 14 % ilmenite and 8 % magnetite. The zone varies in thickness between 30 and 90 m along the lateral distance of 3500 m. Again the MgO-content of ilmenite is expected to be low and the V_2O_5-content of magnetite unknown.

6. SUMMARY STATEMENT AND FUTURE WORK

Given the overall similarities in mineralogical compositions of the three main targets, it is impossible to evaluate the relative value of the prospects without more detailed knowledge of the quality of the oxides. In all three areas large tonnages are present, with grades of apatite, ilmenite and magnetite in excess of 30 %. It is therefore imperative that mineral chemical data are obtained from ilmenites and magnetites from the relevant areas. The MCU IV target is by far the largest as a subvertical "body" at least 210,000 m^2 in cross section. The MCU III target(s) are less well constrained aerially but are, at least in the Terland area, slightly richer. Additional field work is therefore also required to better constrain the volumes. We also recommend that additional exploration should be undertaken in the Vasshus area in MCU III. Due to the poor exposure in this area, the further investigations must involve drilling. Detailed exploration in the MCU IB target area is also hampered by poor exposure, but in terms of grades the apatite-bearing part of MCU IB seems to be the richest, with up to 41 % apatite, ilmenite and magnetite in investigated samples. In summary, the suggestions for future work include:

- Detailed microanalytical studies of ilmenite, magnetite and apatite to determine compositions and variations in compositions within each prospect and between the different prospects.
- Further field work and geochemical analyses to fully determine the extent, size and grade of the targeted prospects.
- A petrographic study to determine the textural characteristics and the ore quality.

7. REFERENCES

Duchesne, J.C. (1972). Iron-titanium oxide minerals in the Bjerkreim-Sogndal Massif, south-western Norway. *J. Petrol*. **13**, 57-81

Korneliussen, A., Furuhaug, L., Gautneb, H., McEnroe, S., Nilsson, L.P. & Sørdal, T. (2001). Forekomster med ilmenitt, vanadiumholdig magnetitt og apatitt i norittiske bergarter i Egersundfeltet, Rogaland. *Geological Survey of Norway report* **2001.014**, 29 pp.

Meyer, G.B., Mansfeld, J. & Grundvig, S. (2001a). Laser-ICP-MS studies of the Ilmenite-Haematite Solid Solution series in the Bjerkreim-Sokndal Intrusion, SW Norway – methods and results. *GAC/MAC joint annual meeting 2001, abstracts*, p. 101

Meyer, G.B., Mansfeld, J. & Grundvig, S. (2001b). LA-HR-ICP-MS studies of ilmenite in MCU IV of the Bjerkreim-Sokndal intrusion, SW Norway. *Geological Survey of Norway report* **2001.042**, 84-85

Schiellerup, H. (2001). Igneous processes in anorthosites and ilmenite-bearing plutons in the Rogaland Anorthosite Province, Southwest Norway. Unpublished PhD thesis, Norwegian University of Science and Technology. 147 pp.

Wilson, J.R., Robins, B., Nielsen, F.M., Duchesne, J.C. & Vander Auwera, J. (1996). The Bjerkreim-Sokndal layered intrusion, southwest Norway. In: R.G. Cawthorn (ed.) *Layered Intrusions*, Elsevier Science B.V., Amsterdam, 231-256

Sample	Easting	Northing	MCU	Locality
NH-1	342766	6492643	4e	Teksevatnet SE
NH-2	342766	6492643	4e	Teksevatnet SE
NH-3	342766	6492643	4e	Teksevatnet SE
NH-4	342766	6492643	4e	Teksevatnet SE
NH-5	342010	6492825	4e	Storøya
NH-6	342020	6492827	4e	Storøya
NH-7	342020	6492827	4e	Storøya
NH-8	342143	6492798	4e	Storøya
NH-9	342143	6492798	4e	Storøya
NH-10	342143	6492798	4e	Storøya
NH-11	341948	6492834	-	Storøya
NH-12	339834	6493820	3e	Teksevatnet V
NH-13	339821	6493795	3e	Teksevatnet V
NH-14	339790	6493769	3e	Teksevatnet V
NH-15	339790	6493769	3e	Teksevatnet V
NH-16	339761	6493739	3e	Teksevatnet V
NH-17	339748	6493728	3e	Teksevatnet V
NH-18	339764	6493717	3e	Teksevatnet V
NH-19	339764	6493717	3e	Teksevatnet V
NH-20	339786	6493696	3e	Teksevatnet V
NH-21	339786	6493696	3e	Teksevatnet V
NH-22	339807	6493671	3e	Teksevatnet V
NH-23	339821	6493654	3e	Teksevatnet V
NH-24	339821	6493654	3e	Teksevatnet V
NH-25	339810	6493636	3e	Teksevatnet V
NH-26	339810	6493636	3e	Teksevatnet V
NH-27	339812	6493645	3e	Teksevatnet V
NH-28	339812	6493645	3e	Teksevatnet V
NH-29	339810	6493627	3e	Teksevatnet V
NH-30	336881	6494294	4e	Terland
NH-31	337174	6494287	4e	Terland
NH-32	337244	6494441	4e	Terland
NH-33	337244	6494441	4e	Terland
NH-34	337903	6495036	3e	Terland
NH-35	337900	6495075	3e	Terland
NH-36	337905	6495107	3e	Terland
NH-37	337886	6495149	3e	Terland
NH-38	337908	6495191	3e	Terland
NH-39	337975	6495177	3e	Terland
NH-40	337976	6495207	3e	Terland
NH-41	337990	6495234	3e	Terland
NH-50	339810	6493627	3e	Teksevatnet V
NH-51	339789	6493721	3e	Teksevatnet V
NH-52	344408	6492115	4e	Bilstadvatnet N
NH-53	344603	6492025	4e	Bilstadvatnet N
NH-54	344603	6492044	4e	Bilstadvatnet N
NH-55	344639	6492083	4d	Bilstadvatnet N
NH-56	346123	6490991	3e	Vasshus
NH-57	346101	6491070	3e	Vasshus
NH-58	346101	6491070	3e	Vasshus
NH-59	346239	6489249	4e	Ualand
NH-60	330329	6494222	1Ad	Åsen
NH-61	330396	6494023	1Bc	Åsen
NH-62	330407	6494036	1Be	Åsen

Sample	Easting	Northing	MCU	Locality
NH-63	330419	6494004	1Be	Åsen
NH-64	330418	6494151	1Be	Åsen
NH-65	330418	6494151	1Be	Åsen
NH-66	330439	6494156	1Be	Åsen
NH-67	330456	6494157	1Be	Åsen
NH-68	330610	6496946	1Be	Bjerkreim SW
NH-69	330603	6496983	1Be	Bjerkreim SW
NH-70	330603	6496983	1Be	Bjerkreim SW
NH-71	330533	6496965	1Be	Bjerkreim SW
NH-72	330533	6496965	1Be	Bjerkreim SW
NH-73	330562	6494084	1Be	Åsen
NH-74	330776	6497258	1Be	Bjerkreim S
NH-75	338044	6495202	3e	Terland
NH-76	338041	6495203	3e	Terland
NH-77	343147	6492960	3e	Teksetjørni
NH-78	333244	6491420	3d	E39 Helleland
NH-79	333382	6491412	3d	E39 Helleland
NH-80	333408	6491414	3d	E39 Helleland
NH-81	333475	6491430	3d	E39 Helleland
NH-82	333512	6491437	3d	E39 Helleland
NH-83	333532	6491450	3e	E39 Helleland
NH-84	333532	6491450	3e	E39 Helleland
NH-85	333544	6491475	3e	E39 Helleland
NH-86	333561	6491460	3e	E39 Helleland
NH-87	333622	6491495	3e	E39 Helleland
NH-88	338034	6487895	3e	Svartevatnet
NH-89	338361	6488026	4e	Svartevatnet
NH-90	336355	6488664	3d	Høyland
NH-91	336362	6488783	3d	Høyland
NH-92	336346	6488870	3e	Høyland
NH-93	336368	6488891	3e	Høyland
NH-94	336372	6488909	3e	Høyland
NH-95	342871	6492847	4e	Lauvneset
NH-96	342870	6492838	4e	Lauvneset
NH-97	342699	6492868	4e	Lauvneset
NH-98	342699	6492868	4e	Lauvneset
NH-99	342697	6492853	4e	Lauvneset
NH-100	342703	6492840	4e	Lauvneset
NH-101	342700	6492835	4e	Lauvneset
NH-102	342706	6492830	4e	Lauvneset
NH-103	342712	6492818	4e	Lauvneset
NH-104	342711	6492794	4e	Lauvneset
NH-105	342753	6492742	4e	Lauvneset
NH-106	345386	6491841	4e	Storeneset-Bilstadvatnet
NH-107	345386	6491841	4e	Storeneset-Bilstadvatnet
NH-108	345386	6491841	4e	Storeneset-Bilstadvatnet
NH-109	345386	6491841	4e	Storeneset-Bilstadvatnet
NH-110	345395	6491838	4e	Storeneset-Bilstadvatnet
NH-111	345407	6491841	4e	Storeneset-Bilstadvatnet
NH-112	345415	6491862	4e	Storeneset-Bilstadvatnet
NH-113	345423	6491877	4e	Storeneset-Bilstadvatnet
NH-114	345437	6491905	4e	Storeneset-Bilstadvatnet
NH-115	345478	6491911	4e	Storeneset-Bilstadvatnet
NH-116	345792	6490405	4e	Vasshus

Sample	Easting	Northing	MCU	Locality
NH-117	343368	6473829	4e	Bakka
NH-118	343368	6473829	4e	Bakka
NH-119	343323	6473918	4e	Bakka
NH-120	337439	6494593	4e	Liavoll
NH-121	339657	6493419	4e	Teksevatnet SW
NH-122	339853	6493866	3d	Teksevatnet V
NH-123	334613	6493293	4e	Hovland
NH-124	334367	6493156	4e	Hovland
NH-125	334341	6493130	4e	Hovland
NH-126	334466	6493024	4e	Hovland
NH-127	334466	6493024	4e	Hovland
NH-128	334842	6492852	4d	Hovland
NH-129	345685	6486808	TZ	Ualand
NH-130	345646	6486789	TZ	Ualand
NH-131	338942	6489423	4f	Podlo Gård
GBM.Bj.9901	337150	6493625	4e	Øyni
GBM.Bj.9902	337200	6493750	4e	Øyni
GBM.Bj.9903	337100	6493850	4e	Øyni
GBM.Bj.9904	337200	6494000	4e	Øyni
GBM.Bj.9905	337175	6494150	4e	Øyni
GBM.Bj.9906	337100	6493500	4e	Øyni
GBM.Bj.9907	337050	6493425	4e	Øyni
GBM.Bj.9908	337300	6493400	4e	Øyni
GBM.Bj.9909	337200	6493250	4f	Øyni
GBM.Bj.9910	337100	6493150	4f	Orrestad
GBM.Bj.9911	337000	6493100	4f	Orrestad
GBM.Bj.9912	338100	6492950	4f	Hestadvatnet
GBM.Bj.9913	337575	6494675	4e	Tuftene
GBM.Bj. 0022	337555	6494690	4c	Tuftene
GBM.Bj. 0023	337560	6494750	4c	Tuftene
GBM.Bj. 0024	337580	6494820	4c	Terland
GBM.Bj. 0025	337675	6494870	4b	Terland
GBM.Bj. 0026	337730	6494895	4b	Terland
GBM.Bj. 0027	337795	6494900	4b	Terland
GBM.Bj. 0028	337840	6494915	4b	Terland
GBM.Bj. 0029	337945	6494930	4b	Terland
GBM.Bj. 0030	337850	6495000	4a	Terland
GBM.Bj. 0031	337855	6495100	3e	Terland
GBM.Bj. 0032	337910	6495200	3d	Terland
GBM.Bj. 0033	337446	6494593	4d	Tuftene

Sample descpriptions, Norsk Hydro apatite project. Bjerkreim–Sokndal Layered Intrusion, 2001.

UTM coordinates listed separately.

Sampling along south bank of Teksevatnet.

NH-1. MCU 4e. SE corner of Teksevatnet. Coarse norite composed of centimetre-sized plagioclase and orthopyroxene from centre of pegmatoidal orthopyroxenite body c. 1 m thick and 4 to 5 metres long. NH-1 from the more leucocratic center of the body which consists essentialy of plagioclase, interstitial oxides and sulfide. Body wedges out to the E but extends to W into Teksevatnet. Same locality as described previously by LPN – his samples LPN-243. Magnetite and apatite present. 3x4 cm quartz xenolith observed in outcrop.

NH-2. MCU 4e. SE corner of Teksevatnet. Coarse opx'enite (with magnetite and apatite) from basal zone of pegmatoidal orthopyroxenite body described above.

NH-3. MCU 4e. SE corner of Teksevatnet. Coarse opx'enite (with magnetite and apatite) from upper zone of pegmatoidal orthopyroxenite body described above.

NH-4. MCU 4e. SE corner of Teksevatnet. Host MCU 4e norite adjacent to samples NH 1–3. The host norite contains several % biotite, which is unusual for BKSK norites.

NH-5. MCU 4e. Tekseåa immediately N of bridge mid way between Teksevatnet and Bilstadvannet. MCU 4d norite, close to lower contact of magnetite-in. Fairly massive.

NH-6. MCU 4e. North coast of island in Teksevatnet. MCU 4e norite, average of 20 cm thick melanocratic zone.

NH-7. MCU 4e. North coast of island in Teksevatnet. 10 cm thick, relatively melanocratic layer, MCU 4e. Sample is not particular melanocratic though.

NH-8. MCU 4e.NE tip of island in Teksevatnet. Xenolith composed of hornfelsed 'gneiss' (c. 20 x 80 cm). Mica abundant, quartz not observed, otherwise noritic composition. Several cm-thick layers composed entirely of opx aggregates observed within and around xenolith.

NH-9. MCU 4e. NE tip of island in Teksevatnet. Chips of largest opx aggregate with cm-sized magnetite and ilmenite grains. apatite present? From the base of hornfelsed xenolith.

NH-10. MCU 4e. NE tip of island in Teksevatnet. Host MCU 4e norite, mica not observed.

NH-11. (in MCU 4e). North coast of island in Teksevatnet. Heavy and dark beach sand mainly composed of ilmenite, magnetite and opx.

Section of MCU 3e at W coast of Teksevatnet (section perpendicular to strike).

NH-122. MCU-3d. Norite, normal phimC a few metres above magnetite-in. 47 m N of NH-12. Sampled at N corner of W end of Teksevatnet. ÷47 m in section.

NH-12. MCU 3d. phimC from 10 cm melanocratic layer. 0 m.

NH-13. MCU 3e. phimaC, typical average, massive norite. 29 m from NH-12.

NH-14. MCU 3e. phimaC. 20 cm thick leucocratic layer. 67 m from NH-12

NH-15. MCU 3e. phimaC. 18 cm thick melanocratic layer adjacent to sample NH-14. 67 m from NH-12.

NH-16. MCU 3e. phimaC. Leuconorite host, massive. 110 m from NH-12.

NH-17. MCU 3e. phimaC. 15 cm thick melanocratic layer c. 2 m above NH-16. 112 m from NH-12.

NH-51. MCU 3e. phimaC. leucocratic norite host, massive. 115 m from NH-12.

NH-18. MCU 3e. phimaC. Leuconorite host, massive. 119 m from NH-12.

NH-19. MCU 3e. phimaC. Melanocratic layer, trough layer up to 20 cm thick, wedging out to W. 120 m from NH-12.

NH-20. MCU 3e. phimaC. Leuconorite host, massive. 128 m from NH-12.

NH-21. MCU 3e. phimaC. Melanocratic ‘smile’ layer up to 15 cm thick. 129 m from NH-12.

NH-22. MCU 3e. phimaC. Norite, massive. Melanocratic layers close but cannot be sampled due to high water level. 147 m from NH-12.

NH-23. MCU 3e. phimaC. Norite host, massive. 157 m from NH-12.

NH-24. MCU 3e. phimaC. 20 cm melanocratic layer, lateral persistent in outcrop (>5 m). 160 m from NH-12.

NH-25. MCU 3e. phimaC. 10 cm norite layer. 170 m from NH-12.

NH-26. MCU 3e. phimaC. Melanocratic norite, >80% mafics. 170 m from NH-12.

NH-27. MCU 3e. phimaC. 10 cm norite layer. 181 m from NH-12.

NH-28. MCU 3e. phimaC. 30 cm melanocratic norite layer, >80% mafics. 181 m from NH-12.

NH-29. MCU 3e. phimaC. 20 cm norite layer. 192 m from NH-12.

NH-50. MCU 3e. phimaC. 20 cm melanocratic norite layer. 192 m. Top of MCU 3e at 206 m from NH-12.

Section at Terland, MCU 3-4.

A profile was sampled from Terland to Hestadvatnet in 1999 and 2000 (GBM.Bj – samples). The samples have been incorporated into the current study and the GBM.Bj sample localities are shown in appendices 1 and 2. Samples NH30 to NH41 were sampled along the same profile line in order to extract more detailed information from the apatite-, ilmenit- and magnetite-bearing sequences.

NH-30. 1165 m. MCU 4e. phimacC. Road cut (road to Tonstad) exposing weakly modally layered leuconorite. (Orientation of layering 80/70°South.)

NH-31. 1065 m. MCU 4e. PhimacC. Road cut close to 19 km mark of main road between Tonstad and Egersund. Homogeneous leucogabbronorite with few xenoliths of hornfels. Magmatic lamination marks a plane oriented: 84/ 85° S.

NH-32. 1005 m. MCU 4e. PhimacC. Small road cut along the Tonstad road. Layering at dm- to m-scale (100/64° SSW). Sample from a 20 cm thick relatively mafic layer of gabbronorite. Few xenoliths.

NH-33. 1005 m. MCU 4e. PhimacC. Same locality as NH-32. Sample from a 50 cm thick relatively felsic layer of gabbronorite.

NH-34. 315 m. MCU 3e. PhimacC. Slope just below the top of Aråsen and stratigraphically just below the ilmenite layers marking the MCU 3/4 boundary. Slightly altered leucogabbronorite.

NH-35. 240 m. MCU 3e. PhimacC. 75 m north of NH-35 along the same slope. Weakly layered leocogabbronorite.

NH-36. 210 m. MCU 3e. PhimacC. Small hill just north of old track. Homogeneous gabbronorite. Only weak layering (125/90°).

NH-37. 190 m. MCU 3e. PhimacC. 40 metres north of NH-36 by the roots of a brought down three. No visible modal layering.

NH-38. 165 m. MCU 3e. PhimacC. 150 m. north of NH-34 by a stump of a three on a small hill. From last outcrop to this one there is a marked change from homogeneous leuconorite with little or no modal layering to dark gabbronorite with modal layering at cm- to dm-scale. The rocks are slightly altered. The contents of magnetite and apatite are relatively high. The sample is from the most mafic layer in the outcrop. Layering: 140/85° NE.

NH-39. 100 m. MCU 3e. PhimacC. Crossing a field following the old track up to a small hill. Strongly modally layered melanogabbronorite (90/80°N). The sample is taken 20 m east of the track by an old stump of a three. Several layers wedge out or get truncated by layers above. Indicates stratigraphic-up to the south. A few xenoliths of hornfels are observed. The sample is from a 20 cm thick isomodal mafic layer.

NH-40. 50 m. MCU 3e. PhimacC. Small hill close to beehives. Dm-scale layered melanogabbronorite. The sample is taken from the middle part of a 40 cm thick mafic layer. Layering: 100/86° N.

NH-41. 15 m. MCU 3e. PhimacC. Just behind the beehives some 15 m south of old sample locality GBM.Bj.0032. Still apatite and magnetite, but less mafic and layering in dm-scale. From the lower and relative mafic part of a 30 cm thick layer.

NH-75. MCU 3e. Terland Gård. Close to samples in the Terland profile. Melanocratic magnetite-apatite norite, noritic texture, from 10 cm thick layer in >3 m thick mafic dominated sequence.

NH-76. MCU 3e. Terland Gård. Discordant and irregular (pegmatitic) orthopyroxenite body 1-10 cm wide, several metres long. No apatite visible.

Section W shore of Bilstadvannet, MCU 4e.

NH-52. MCU 4e. Melanocratic norite (phimaC), massive. Loose block from dump of material dug out from Tekseåa channel c. 50 m W of Bilstadvatnet.

NH-53. MCU 4e. Melanocratic norite layer (phimaC), 30 cm. From 27 m thick mafic intensely layered sequence (122/35N) where melanocratic layers dominate over leucocratic layers (c. 65%). NH-53 sampled 12 m (horizontally) below top of melanocratic sequence.

NH-54. MCU 4e. Melanocratic norite layer (phimaC). From 30 m thick mafic sequence where melanocratic layers dominate over leucocratic layers. 25 m below (horizontally) top of sequence. Sample somewhat more leucocratic than NH-53

NH-55. MCU 4e. Melanocratic norite layer (phimaC), 3 cm. From base of magnetite–in level. Appears to contain apatite. Isoclinal folds and erosional discordances.

Section NE shore of Vasshusvika (connected to Bilstadvatnet), MCU 3e.

NH-56. MCU 3e. Very melanocratic norite layer (phimaC), c. 10 cm. From section where melano layers dominate over leucocratic layers found along the NE shore of Vasshusvika.

NH-57. MCU 3e. c. 100 m north of NH-56 along bank of Vasshusvika. Same melanocratic-dominated sequence – mafic layers make up 70-80% over at least 15+ m. NH-57 is a relatively leucocratic 7 cm thick layer (phimaC). The melanocratic sequence is laterally consistent for at least 200 m.

NH-58. MCU 3e. See NH-57. Melanocratic layer (phimaC) – 40 cm thick.

Sampling at Ualand.

NH-59. MCU 4e. Melanocratic layer in layered norite sequence. At railway bridge crossing farm road to Ualand Gård.

Section at Åsen Gård E and NE of Saglandsvatnet, MCU 1Be.

This section is not well exposed and runs from E side of the farm and downslope to the river.

NH-60. MCU 1B-d (?). Massive magnetite norite. Representative norite of the unit (1B-d?) underlying MCU 1B-e. 0 m in section.

NH-61. MCU 1B-e. Ilmenite gabbronorite (apparently without apatite). + 30 m from NH-60 (horizontally across strike).

NH-62. MCU 1B-e. Magnetite-apatite-ilmenite gabbronorite. +33 m.

NH-63. MCU 1B-e. Magnetite-apatite-ilmenite gabbronorite. Weathered outcrops with some modal layering. (124/63NE). +35 m.

NH-64. MCU 1B-e. Melanocratic sequence covering a stratigraphic interval of approximately 40-50 m. Mafic layers make up 60-70% of outcrops of magnetite-apatite-ilmenite gabbronorite. Sample of magnetite-rich layer. +50 m. Layering on dm scale.

NH-65. MCU 1B-e. Half a meter above NH-64. Magnetite-apatite-ilmenite gabbronorite. Sample of complementary leucocratic norite layer. +51 m.

NH-66. MCU 1B-e. Melano magnetite-apatite-ilmenite gabbronorite. Sequence dominated by this rock type with fewer normal norite layers. +60 m.

NH-67. MCU 1B-e. Melano magnetite-apatite-ilmenite gabbronorite in layered sequence about half this type and half of more normal noritic type. Sample taken c. 15 vertical metres above the river. +70 m.

NH-73. MCU 1B-e. Magnetite-apatite gabbronorite. From melanocratic layer at the top of exposed section. Sample taken c. 10 vertical metres above river, perhaps 100 m north of NH-67 and perhaps same stratigraphic level or slightly above NH-67.

Section south of Bjerkreim village, MCU 1Be.

Section through a 25-30 m thick layered sequence of magnetite-apatite-ilmenite gabbronorite. Rock is magnetic and contains visible apatite. Minor E-W faulting to disturb stratigraphy.

NH-68. Top of melanocratic sequence below base MCU II. The top c. 10+ m of MCU IA do not display pronounced modal layering, but are overall fairly melanocratic. The layered melanocratic sequence below this zone has a thickness on the order of 20m. NH-68 from top of layered melanocratic sequence phaimC.

NH-69. Relatively leucocratic layer c. 3 m stratigraphically below NH-68. Sample not particular leucocratic though.

NH-70. Melanocratic magnetite-apatite norite with abundant visible apatite. Sample locality few dm's from NH-69. (4/50E)

NH-71. MCU 1B-e. Magnetite-apatite gabbronorite from dark layer in 15-20 m thick layered sequence. In forest to the N of small farm some tens of metres above new road cut.

NH-72. MCU 1B-e. Magnetite-apatite gabbronorite. Less melanocratic than NH-71. 20 cm below NH-71.

NH-74. MCU 1B-e. Not in actual sequence with NH-68-72, but somewhat further to the northeast along strike. Magnetite-apatite gabbronorite from diffuse melanocratic layer in the middle portion of section (almost average rock). Layering in this sequence strikes N020 and dips 40° to the E. This section is more than 10 m thick and sampled at farm road. It is dominated by normal magnetite gabbronorite with apatite (?) with intermittent dark layers 5-15 cm thick. Many melanocratic magnetite-apatite gabbronorite loose blocks in the area.

Sampling at Bjørnemoen.

NH-77. Top portion of MCU-3e. Bjørnemoen. Melanocratic magnetite-apatite norite. Close to deformed MCU 4a rocks.

Section at Helleland across MCU-3d and 3e (along E39).

MCU-3e is a c. 175 m thick stratigraphic sequence at this point in the central portion of the intrusion.

NH-78. MCU-3d. phimC. Only weakly magnetic, homogeneous and massive norite with occasional cm-thick slightly more melanocratic layers. Sample of massive host. 0 m.

NH-79. MCU-3d. phimC. Layered sequence appearing rather melanocratic on average. Sample from melanocratic and very magnetic layer. Melanocratic layers generally 2-5 cm's thick. +140 m. (110/50NE)

NH-80. MCU-3d. phimC. Fine-scale layered sequence below apatite in (as mapped). 2-5 cm melanocratic layers in more leucocratic host rock. NH-80 sampled in relatively leucocratic average rock. +164 m.

NH-81. MCU-3d. phimC. Isomodal melanocratic layer in layered sequence. Melanocratic layers make up c. 75%. Sample from 10 cm thick melanocratic layer (110/50NE) (ap??). +231 m.

NH-82. MCU-3d. Melanocratic layer in what is mapped as phimC – suspect, however, the presence of apatite. Melanocratic layers (1-6 cm thick) make up around 20%. Poor contrast between mafic and felsic layers (120/42NE). +264 m.

NH-83. MCU-3e. Melanocratic layer in phcimaC. Modally well layered rock, with melanocratic layers making up 40-60%. These layers are generally between 3 and 30 cm thick. 5 m above conspicuous change in vegetation and the mapped lower contact of MCU-4e. +289 m.

NH-84. MCU-3e. Same locality as NH-83. Leucocratic layer. +289 m..

NH-85. MCU-3e. phcimaC. Intense modal layering with mafic layers making up around 40%, but with poor absolute contrast in mafic index between relatively mafic and felsic layers. Melanocratic layer. Most layers are 5-10 cm thick. (122/45NE). +307 m.

NH-86. MCU-3e. phcimaC. Melanocratic layer in intensely modally layered sequence where 5-10 cm thick mafic layers make up about 50% of the rock. Again poor absolute contrast between mafic and felsic rock. +323 m.

NH-87. MCU-3e. phcimaC. Not particularly melanocratic sample from poorly layered sequence. Sample represent avrage rock. +395 m.

Samples at Svartevatnet, west flank of BKSK.

NH-88. MCU-3e. SW end of Svartvatnet. Fresh and newly made outcrop in forest road cut. No magnetite found in top of MCU 3e which in general is leucocratic. Only very few melanocratic layers are found. Apatite not observed. Sample of typical leuconorite.

NH-89. MCU-4d. Melanocratic layer along road east of Svartevatnet.

Section at Høyland Gård, west flank of BKSK, MCU 3e.

NH-90. MCU-3d. phimC. Negative apatite test. Relatively homogenous norite with isolated cm-wide layers. Sample from host-rock making up about 95% of rock. NH-90 reference point in profile: 0 m.

NH-91. MCU-3d. phimC. Uncertain apatite test. Leucocratic rock with dispersed, few cm thick, more melanocratic layers. Sample from leucocratic host. (115/90). +122 m.

NH-92. MCU-3e. phcimaC. On the contact of apatite-in (as mapped). Still leucocratic with rare mafic and few cm thick more melanocratic layers. +203 m.

NH-93. MCU-3e. phcimaC. As NH-92, but more yelowish colored rock yielding positive result in apatite test. +228 m.

NH-94. MCU-3e. phcimaC. 5 m below from MCU III/IV contact. Leucocratic and fairly homogenous rock with yellowish weathering. +254 m.

Section at Lauvneset, E end of Teksevatnet, MCU 4e.

NH-95. Base MCU-4e. phimaC. Leucocratic. A few metres above north shore of little bay. Strong modal layering not observed. –25 m.

NH-96. Base MCU-4e. phimaC. Leucocratic. A few metres above north shore of little bay. –20 m.

NH-97. MCU-4e. phimaC. Normal norite from strongly layered and dominantly melanocratic sequence with trough structures etc. Sample from 5 cm tick layer. N tip of Lauvneset. 0 m.

NH-98. MCU-4e. phimaC. Sample of 10 cm melanocratic layer. This rock type dominate the outcrop. +1 m.

NH-99. MCU-4e. phimaC. Very melanocratic layer, 15 cm. One of many such layers alternating with 2-5 cm 'normal' norite. +5 m.

NH-100. MCU-4e. phimaC. Melanocratic 30 cm thick layer. Immediately above trough structure of melanocratic layers. +10 m.

NH-101. MCU-4e. phimaC. Average melanocratic rock. Strong vertical lineation. Numerous 1 cm to dm hornfelsed gneiss xenoliths. +18m.

NH-102. MCU-4e. phimaC. Average melanocratic rock. Same outcrop pattern as above sample. +25 m.

NH-103. MCU-4e. phimaC. Average leucocratic rock. Above +40 m the rock is more normal norite or leuconorite and layering is sparse. +50 m.

NH-104. MCU-4e. phimaC. Average leucocratic rock. +72 m.

NH-105. MCU-4e. phimaC. Average norite. Meter-sized gneis-hornfels xenoliths. Sample taken at the point at S end of Lauvneset. Samples NH-1-4 are c. 85 m further to the S on the other side of Teksevatnet/Tekseåa. +130 m.

Section at Storeneset, east end of Bilstadvannet, MCU 4e.

The base of this section is strongly modally layered with bifurcating layers not unlike the chromitite layers at Dwars River in the Critical Zone of the Bushveld Complex. General strike of layering in west (upper) part of section is 146-55E (overturned).

NH-106. MCU 4e. Fine grained pyroxene-rich magnetite–orthopyroxene melanocratic layer, containing interstitial sulfides (pyrite). c. 10 cm thick (>90% mafics). ÷2.6 m in section (reference to NH-108). Top of intensely layered and melanocratic sequence about 20 m thick.

NH-107. MCU 4e. Anorthosite layer (>90% plagioclase) adjacent to sample NH-106. Layer c. 15 cm thick. ÷2.5 m.

NH-108. Ilmenite–orthopyroxene melanocratic layer about 10 cm thick. 0 m in section. Sample represent unmagnetic melanocratic layers found in the top 2 m below anorthosite inclusion on tip of nes.

NH-109. MCU 4e. Anorthosite layer (>90% plagioclase) adjacent to sample NH-108 (÷mt). ÷0.1 m.

NH-110. MCU 4e. 15 stratigraphic metres below the strongly layered sequence at Storeneset (samples NH-106 to 109), the sequence turns much more mafic with graded layer contacts, in contrast to above with strong isomodal layering. Sample of average melanocratic norite. ÷ 15 m in section.

NH-111. MCU 4e. Sample of melanocratic layer composed of ~80% mafics and ~20% plagioclase and ?apatite, 25 cm thick layer. Sequence similar to NH-110. ÷25 m in section.

NH-112. MCU 4e. After a 5 m leucocratic interval, the rocks again develop intense layering and a melanocratic character. NH-112 from mafic layer in top of new melanocratic sequence, where mafic layers make up c. 60%. ÷30 m in section.

NH-113. MCU-4e. Section continues to be dominantly mafic. Sample of phimaC of melanocratic layer. Layering on a cm to dm scale. ÷53 m in section.

NH-114. MCU-4e. Relatively melanocratic layer in intensely layered rock, but now with lesss contrast between mafic and felsic layers. Sample almost represent average rock. ÷82 m in section.

NH-115. MCU-4e. Average melanocratic phimaC layer. Only few layers and contrast in mafic index is not great. ÷114 m. This level is judged to be 20 m above base of MCU-4e.

NH-116. MCU-4e. Sample of 10 cm thick melanocratic layer, approximately in the middle portion of MCU-4e at Vasshus.

Section at Bakka, Sokndal loben.

NH-117. Melanocratic phimaC with mafic index above 80% from 40 cm thick dark layer. High content of visible apatite. Sample taken at base of section at road turn above river.

NH-118. phimaC norite with mafic index of 50-60% from adjacent to NH-117. Several % biotite in sample.

NH-119. Very melanocratic phimaC (mafic index >80%) from melanocratic sequence c. 20 stratigraphic meter above NH-117.

Sampling at Liavoll.

NH-120. MCU-4e. Massive ilmenite-magnetite oxide body. Apatite not observed. Sampled where Tonstadveien cross Liavollsveien. This unusual oxide body is c. 3x2 in outcrop, but may be bigger because base is not exposed. RH side of the oxide body is in contact with what appears to be a leuconorite xenolith (1 to 2 m across) that in turn is enclosed in MCU-4e norite close to Terland profile.

Sampling at south bank of Teksevatnet.

NH-121. MCU-4e. SW corner of Teksevatnet on the S shore ~30 m E of bridge and ‘sluse’. Sample of 4 cm thick melanocratic layer in beautifully modally layered sequence. Dark layers are 1-4 cm thick, mainly isomodal some graded layers also observed. Mafic to leucocratic proportion is ~1:5.

Section at Hovland Gård, MCU-4e.

This section in the central portion or hinge-zone of BKSK is in general leucocratic. Strong modal layering and melanocratic sequences are not observed.

NH-123. MCU-4e. Between Hovland and Erretjørn. Leucocratic phcimaC. (32/41SE). Poorly developed modal layering.

NH-124. MCU-4e. Conspicuous mafic layer in phcimaC, but poor exposure prevents the assessment of relations.

NH-125. MCU-4e. Homogenous leucocratic norite with porphyritic plagioclase and poor lamination. Modal layering almost absent.

NH-126. MCU-4e. 3 m long and 10 cm thick oxide-rich lens or layer – relations uncertain – could be xenolithic.

NH-127. MCU-4e. Homogenous norite hosting lens (see NH-126). Poor lamination and hardly any layering.

NH-128. MCU-4e. Higher in stratigraphy than NH-123-127. Continuing homogenous norite with abundant inclusions and jotunite dykes and veinlets (Lomland dyke)

Section at Heskestad, Transition Zone.

NH-129. Transition zone. phicmaC. Sample of few meter thick melanocratic layer in central part of transition zone. This is the only melanocratic layer oberserved in this transect across the TZ. Apatite is visible.

NH-130. Transition zone. phicmaC. Sample of typical normal biotit-rich gabbronorite next to NH-130.

Podlo, MCU-4f. West flank of BKSK.

NH-131. MCU-4f – close to base of transition zone. p$\underline{h}$cimaC. 1-1.5 m thick oxide-rich layer almost without plagioclase. Due to poor exposure along strike no more oxide-rich rocks may be observed in the vicinity. According to Brian Robins similar exposures may be found a further 100 m to the south along strike, and the zone may thus be laterally persistent for a considerable distance.

Abrevations and cumulus terminology:

BKSK = Bjerkreim-Sokndal Intrusion

MCU = Macro Cyclic Unit

TZ = Transition Zone

p: plagioclase

h: Ca-poor pyroxene

i: ilmenite

m: magnetite

o: olivine

a: apatite

c: Ca-rich pyroxene

$\underline{h}$: inverted pigeonite

C: -cumulate

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	L.O.I.	SUM
NH-11	37,25	5,05	27,46	10,98	11,59	4,71	0,89	0,19	0,26	1,20	-0,43	99,15
NH-12	37,64	7,17	27,34	10,74	13,45	2,50	0,97	0,18	0,19	0,03	-0,71	99,49
NH-13	48,15	18,84	13,56	4,83	4,84	6,37	3,96	0,64	0,09	0,14	-0,07	101,35
NH-14	53,85	20,67	7,79	2,29	4,12	7,04	4,71	0,83	0,07	0,25	0,19	101,82
NH-15	39,81	7,87	25,82	9,68	11,95	3,14	1,46	0,29	0,19	0,10	-0,56	99,76
NH-16	50,34	19,01	10,87	4,88	4,21	6,78	4,20	0,82	0,08	0,26	-0,13	101,31
NH-17	30,00	4,67	29,61	8,87	11,27	8,84	0,66	0,14	0,20	4,62	-0,86	98,02
NH-18	46,85	17,66	11,68	3,23	4,14	9,62	3,81	0,77	0,09	2,67	0,10	100,60
NH-19	32,13	4,26	29,52	8,72	12,46	7,81	0,57	0,12	0,22	3,95	-0,92	98,83
NH-20	48,43	18,88	9,81	2,77	3,60	9,38	4,23	0,84	0,08	2,15	-0,05	100,11
NH-21	34,36	6,52	23,83	7,04	11,06	10,16	1,05	0,21	0,19	5,16	-0,60	98,97
NH-22	45,16	16,68	13,50	3,91	4,59	9,72	3,57	0,63	0,09	2,90	0,03	100,80
NH-23	45,61	16,23	12,83	3,95	4,92	10,35	3,47	0,68	0,10	2,92	-0,01	101,05
NH-24	37,49	6,50	24,13	6,70	11,30	9,78	1,08	0,19	0,20	3,23	-0,47	100,11
NH-25	46,54	16,17	12,83	3,53	5,48	9,98	3,49	0,63	0,11	2,47	-0,09	101,15
NH-26	34,95	4,07	28,19	7,66	12,63	9,01	0,53	0,09	0,23	3,11	-0,57	99,90
NH-27	44,15	15,52	14,30	4,26	5,21	10,59	3,28	0,54	0,11	3,13	0,00	101,09
NH-28	36,46	3,38	27,25	7,10	13,87	9,82	0,35	0,06	0,23	2,92	-0,62	100,82
NH-29	51,04	17,88	8,67	2,17	5,29	9,69	4,08	0,67	0,09	1,56	0,04	101,18
NH-30	44,38	15,02	14,11	4,73	6,32	9,66	3,13	0,49	0,12	2,55	0,23	100,73
NH-31	44,21	15,68	13,87	4,71	5,41	10,32	3,23	0,52	0,11	2,20	0,21	100,46
NH-32	38,94	9,26	21,21	6,11	9,78	9,34	1,77	0,29	0,17	3,56	-0,38	100,06
NH-33	41,23	12,36	17,84	5,34	7,80	9,85	2,40	0,39	0,14	3,30	-0,27	100,38
NH-34	42,63	13,79	16,36	4,91	6,86	9,90	2,75	0,46	0,12	2,75	-0,17	100,37
NH-35	42,64	14,86	16,13	4,80	6,07	9,49	3,03	0,50	0,11	3,14	-0,11	100,65
NH-36	41,90	14,05	16,88	4,84	6,58	9,37	2,93	0,47	0,12	3,20	-0,15	100,20
NH-37	43,55	15,50	14,77	4,25	5,84	9,70	3,19	0,52	0,11	3,14	-0,09	100,49
NH-38	32,37	3,80	29,46	8,88	12,49	9,62	0,47	0,06	0,22	3,61	-0,59	100,39
NH-39	34,23	5,52	26,50	7,61	11,36	9,77	0,83	0,12	0,20	3,53	-0,41	99,26
NH-40	34,06	5,80	25,86	7,20	11,17	9,57	0,92	0,13	0,19	4,28	0,16	99,34
NH-41	44,15	15,65	14,08	4,17	6,07	9,73	3,19	0,49	0,10	3,07	-0,12	100,58
NH-50	35,83	3,01	27,32	7,96	14,72	8,36	0,29	0,06	0,23	3,00	-0,94	99,85
NH-51	48,56	18,75	10,72	2,91	3,75	9,28	4,13	0,80	0,09	2,16	0,04	101,19
NH-52	36,39	6,68	24,88	7,25	10,65	9,22	1,16	0,26	0,22	3,50	-0,63	99,58
NH-53	37,24	7,23	22,28	6,46	10,33	10,36	1,26	0,27	0,20	4,12	-0,40	99,35
NH-54	36,62	6,94	22,67	6,20	10,88	10,13	1,18	0,25	0,20	4,50	-0,42	99,14
NH-55	32,63	5,35	24,77	7,69	10,66	10,73	0,84	0,18	0,21	5,47	0,01	98,52
NH-56	35,03	5,65	24,74	7,89	11,18	9,37	0,67	0,67	0,22	3,15	0,19	98,75
NH-57	51,16	21,84	7,53	2,83	3,83	8,08	4,52	0,66	0,06	0,24	0,06	100,81
NH-58	46,97	2,98	23,64	4,68	21,71	2,33	0,28	0,15	0,24	0,21	-0,85	102,35
NH-59	35,04	5,56	25,50	7,47	11,18	9,48	0,90	0,18	0,22	3,74	-0,72	98,56
NH-60	48,70	16,71	15,27	3,21	5,89	7,00	3,45	0,58	0,12	0,21	0,01	101,15
NH-61	42,59	10,32	16,12	6,85	7,15	11,53	2,34	0,38	0,16	2,00	-0,25	99,18
NH-62	31,93	9,21	22,52	9,61	5,58	12,07	1,92	0,34	0,15	5,11	-0,48	97,97
NH-63	33,53	5,42	29,47	7,48	10,86	7,46	0,89	0,15	0,23	3,38	-0,47	98,40
NH-64	33,80	3,72	31,52	7,71	12,78	6,52	0,47	0,08	0,26	3,10	-0,70	99,26
NH-65	41,64	13,30	17,53	4,87	6,35	9,72	2,84	0,50	0,14	3,56	0,11	100,56
NH-66	31,89	3,14	30,29	8,79	11,71	9,32	0,35	0,04	0,25	3,22	-0,58	98,43
NH-67	32,71	6,07	27,05	8,39	9,00	10,90	1,01	0,17	0,20	3,79	-0,39	98,89
NH-68	35,49	5,26	27,32	7,28	11,20	9,94	0,75	0,11	0,19	2,66	-0,35	99,84
NH-69	35,99	5,64	25,68	7,33	10,75	10,21	0,94	0,11	0,20	3,05	-0,35	99,55
NH-70	34,35	3,75	28,63	8,34	12,09	9,11	0,50	0,06	0,23	2,59	-0,66	99,01
NH-71	37,03	8,67	23,20	6,52	8,69	9,83	1,64	0,25	0,17	3,11	-0,15	98,97
NH-72	44,15	15,16	14,09	3,94	5,15	10,68	3,30	0,47	0,10	2,95	0,22	100,21
NH-73	38,38	4,35	27,43	7,79	14,22	7,54	0,45	0,06	0,20	0,10	-0,34	100,17
NH-74	44,64	15,94	13,13	3,81	4,70	10,71	3,49	0,51	0,09	2,80	0,28	100,10
NH-78	51,00	19,21	10,51	3,51	5,74	6,76	4,03	0,52	0,09	0,10	0,00	101,48
NH-79	34,86	7,06	23,36	7,30	10,43	10,55	1,19	0,16	0,18	4,19	-0,64	98,64
NH-80	42,30	14,73	15,43	4,45	6,39	9,99	2,95	0,44	0,11	3,46	-0,03	100,21
NH-81	35,91	6,98	25,05	7,77	10,87	9,26	1,18	0,17	0,19	2,97	-0,54	99,82
NH-82	32,74	4,77	29,31	8,09	11,56	9,30	0,69	0,09	0,21	2,94	-0,56	99,14
NH-83	36,66	9,20	22,63	6,60	8,71	10,19	1,72	0,27	0,16	3,90	-0,25	99,77
NH-84	40,92	11,96	20,51	6,74	8,03	7,71	2,35	0,37	0,15	1,88	-0,15	100,47
NH-85	35,41	6,27	25,17	7,64	11,05	9,79	1,01	0,17	0,19	3,56	-0,49	99,78
NH-86	35,71	7,65	24,04	7,03	9,80	9,88	1,28	0,23	0,18	3,84	-0,26	99,40
NH-87	40,17	13,50	16,13	5,43	5,66	10,95	2,77	0,55	0,10	3,44	1,46	100,15
NH-95	50,30	19,90	7,89	2,88	3,53	9,34	4,35	0,77	0,07	1,79	0,33	101,16
NH-96	43,87	15,39	14,79	4,19	6,30	9,40	3,14	0,53	0,11	2,91	-0,03	100,59
NH-97	43,72	13,29	15,25	4,68	6,81	8,94	2,84	0,67	0,14	2,95	0,22	99,50
NH-98	37,63	6,58	23,71	6,37	10,94	9,41	1,27	0,27	0,22	3,68	-0,43	99,66
NH-99	37,15	6,39	23,45	6,59	11,27	9,49	1,10	0,24	0,21	3,87	-0,50	99,26
NH-100	35,95	5,71	24,82	7,02	11,75	9,23	0,96	0,21	0,21	3,79	-0,52	99,13
NH-101	35,25	6,99	23,68	7,04	10,29	10,20	1,23	0,25	0,20	4,39	-0,40	99,12
NH-102	36,52	7,00	22,93	6,51	10,45	10,05	1,26	0,25	0,20	4,40	-0,36	99,21
NH-103	42,40	14,32	15,91	5,11	5,44	9,51	3,08	0,64	0,12	3,29	0,28	100,09
NH-104	41,89	14,28	16,65	5,55	5,24	9,56	3,06	0,61	0,13	2,88	0,12	99,95
NH-105	42,43	14,78	15,72	5,00	4,80	9,79	3,31	0,66	0,12	2,71	-0,06	99,27
NH-106	32,83	1,88	30,83	8,50	15,87	6,84	<0.1	0,01	0,23	3,15	-1,01	99,11
NH-107	55,83	24,99	2,31	0,55	1,08	8,83	5,92	0,79	0,02	0,36	0,31	100,97
NH-108	44,53	2,39	23,75	8,29	21,13	1,85	0,16	0,05	0,25	0,05	-0,94	101,54
NH-109	56,82	26,93	1,21	0,30	0,39	9,06	5,87	0,82	0,01	0,17	0,23	101,81
NH-110	32,24	3,77	28,33	8,05	13,04	9,21	0,41	0,08	0,22	3,87	-0,60	98,62
NH-111	34,12	6,86	24,56	7,11	10,03	10,87	1,19	0,20	0,18	4,42	-0,61	98,94
NH-112	39,28	8,86	20,90	6,07	9,31	10,69	1,72	0,28	0,17	3,02	-0,46	99,84
NH-113	38,14	7,75	22,21	6,41	10,35	10,15	1,39	0,24	0,19	3,45	-0,60	99,66
NH-114	32,94	5,98	26,23	8,33	10,19	10,20	1,01	0,18	0,19	4,26	-0,46	99,05
NH-115	33,50	5,70	26,24	7,79	10,67	10,16	0,92	0,16	0,20	3,97	-0,55	98,75
NH-120	<0.01	1,47	48,45	37,07	3,14	0,06	<0.1	<0.01	0,14	0,01	-1,87	87,57
NH-129	43,23	10,34	21,56	4,92	5,49	8,17	2,61	1,29	0,24	2,41	-0,44	99,82
NH-130	48,72	14,17	15,53	3,52	4,00	7,41	3,79	1,59	0,17	1,88	-0,26	100,51
NH-131	9,79	2,94	47,78	24,83	6,96	0,50	<0.1	0,02	0,20	0,01	-1,76	91,33

Sample	Mo ppm	Nb ppm	Zr ppm	Y ppm	Sr ppm	Rb ppm	U ppm	Th ppm	Pb ppm	Cr ppm	V ppm	As ppm	Sc ppm	S %	Cl %	F %	Ba ppm	Sb ppm	Sn ppm	Cd ppm	Ag ppm	Ga ppm	Zn ppm	Cu ppm	Ni ppm	Yb ppm	Co ppm	Ce ppm	La ppm	Nd ppm	W ppm
NH-11	<5	8	53	14	148	<5	<10	<10	13	12	274	<10	45	<0.1	<0.1	0,10	62	<10	<10	<10	<10	21	192	<10	<5	<16	72	<15	21	103	<30
NH-12	<5	<5	68	<5	181	<5	<10	<10	<10	<10	322	<10	46	<0.1	<0.1	<0.1	89	<10	<10	<10	<10	25	198	49	69	<16	115	<15	11	<10	<30
NH-13	<5	<5	61	7	604	5	<10	<10	10	16	295	<10	19	<0.1	<0.1	<0.1	268	<10	<10	<10	<10	30	87	35	39	<16	67	<15	<10	20	<30
NH-14	<5	<5	35	6	617	6	<10	<10	<10	<10	121	<10	14	<0.1	<0.1	<0.1	317	<10	<10	<10	<10	28	52	<10	5	16	47	23	<10	11	<30
NH-15	<5	<5	67	<5	212	6	<10	<10	<10	<10	335	<10	19	0,19	<0.1	<0.1	109	<10	<10	<10	<10	24	165	25	6	<16	117	<15	12	<10	<30
NH-16	<5	<5	69	8	567	<5	<10	<10	<10	<10	205	<10	20	<0.1	<0.1	<0.1	323	<10	<10	<10	<10	29	57	<10	5	<16	43	15	<10	19	<30
NH-17	<5	<5	45	32	169	<5	<10	<10	<10	17	529	<10	34	0,19	<0.1	0,43	61	<10	<10	<10	<10	28	193	30	6	<16	128	24	31	129	<30
NH-18	<5	<5	42	27	552	<5	<10	<10	<10	<10	257	<10	20	<0.1	<0.1	0,11	272	<10	<10	<10	<10	27	58	<10	<5	16	32	38	15	36	<30
NH-19	<5	<5	39	28	145	<5	<10	<10	<10	<10	465	<10	40	<0.1	<0.1	0,27	52	<10	<10	<10	<10	22	196	18	<5	<16	98	35	26	127	<30
NH-20	<5	<5	35	24	600	8	<10	<10	<10	<10	207	<10	15	<0.1	<0.1	<0.1	301	<10	<10	<10	<10	28	60	<10	<5	17	38	43	17	33	<30
NH-21	<5	<5	38	39	237	<5	<10	<10	<10	<10	474	<10	39	<0.1	<0.1	0,35	85	<10	<10	<10	<10	21	149	10	<5	<16	87	56	41	123	<30
NH-22	<5	<5	33	28	526	<5	<10	<10	<10	<10	317	<10	25	<0.1	<0.1	0,14	234	<10	<10	<10	<10	26	75	13	5	<16	50	47	16	49	<30
NH-23	<5	<5	40	26	504	5	<10	<10	<10	<10	309	<10	24	<0.1	<0.1	0,15	241	<10	<10	<10	<10	28	63	13	<5	<16	31	47	22	55	<30
NH-24	<5	<5	41	30	202	<5	<10	<10	<10	<10	471	<10	44	<0.1	<0.1	0,27	82	<10	<10	<10	<10	25	147	15	<5	<16	70	20	26	76	<30
NH-25	<5	<5	35	25	505	<5	<10	<10	<10	<10	298	<10	34	<0.1	<0.1	0,13	221	<10	<10	<10	<10	25	62	<10	<5	19	41	41	19	42	<30
NH-26	<5	<5	40	25	122	<5	<10	<10	<10	<10	447	<10	35	<0.1	<0.1	0,31	47	<10	<10	<10	<10	24	178	20	<5	<16	82	<15	32	80	<30
NH-27	<5	<5	28	29	484	<5	<10	<10	<10	<10	332	<10	31	<0.1	<0.1	0,16	175	<10	<10	<10	<10	31	65	10	<5	<16	51	49	15	50	<30
NH-28	<5	5	40	28	95	<5	<10	<10	<10	<10	483	<10	38	<0.1	<0.1	0,27	42	<10	<10	<10	<10	24	167	<10	<5	<16	74	<15	22	81	<30
NH-29	<5	<5	30	19	541	6	<10	<10	<10	<10	136	<10	26	<0.1	<0.1	<0.1	224	<10	<10	<10	<10	28	46	10	<5	17	34	33	11	19	<30
NH-30	<5	<5	22	22	505	<5	<10	<10	<10	<10	286	<10	27	<0.1	<0.1	<0.1	193	<10	<10	<10	<10	29	75	17	27	<16	58	42	16	61	<30
NH-31	<5	<5	20	24	502	<5	<10	<10	<10	<10	326	<10	25	<0.1	<0.1	0,11	192	<10	<10	<10	<10	25	72	22	13	<16	53	24	15	42	<30
NH-32	<5	<5	25	27	321	<5	<10	<10	<10	<10	387	<10	26	<0.1	<0.1	0,24	118	<10	<10	<10	<10	24	126	29	9	<16	90	21	19	76	<30
NH-33	<5	<5	21	25	418	<5	10	<10	<10	<10	370	<10	25	<0.1	<0.1	0,19	147	<10	<10	<10	<10	26	99	28	10	<16	71	41	20	71	<30
NH-34	<5	<5	26	23	421	<5	<10	<10	<10	<10	392	<10	33	<0.1	<0.1	0,15	155	<10	<10	<10	<10	27	86	19	9	<16	56	28	10	48	<30
NH-35	<5	<5	21	24	481	<5	<10	<10	<10	<10	377	<10	19	<0.1	<0.1	0,16	176	<10	<10	<10	<10	30	92	15	<5	<16	52	44	19	55	<30
NH-36	<5	<5	20	26	452	<5	<10	<10	<10	<10	382	<10	22	<0.1	<0.1	0,18	166	<10	<10	<10	<10	28	96	18	<5	<16	50	34	17	53	<30
NH-37	<5	<5	17	25	499	<5	11	<10	<10	<10	342	<10	20	<0.1	<0.1	0,14	188	<10	<10	<10	<10	27	80	11	<5	<16	45	39	20	49	<30
NH-38	<5	<5	36	27	114	<5	<10	<10	<10	<10	500	<10	47	<0.1	<0.1	0,34	38	<10	<10	<10	<10	24	183	15	<5	<16	64	24	19	125	<30
NH-39	5	<5	30	27	172	<5	<10	<10	<10	<10	504	<10	42	<0.1	<0.1	0,31	56	<10	<10	<10	<10	24	157	11	<5	<16	70	<15	15	92	<30
NH-40	<5	<5	28	30	186	<5	<10	<10	<10	<10	453	<10	29	<0.1	<0.1	0,38	50	<10	<10	<10	<10	26	151	18	<5	<16	69	19	31	93	<30
NH-41	<5	<5	16	18	486	<5	<10	<10	<10	<10	313	<10	18	<0.1	<0.1	0,16	170	<10	<10	<10	<10	27	76	16	6	<16	71	33	15	45	<30
NH-50	5	<5	35	23	88	<5	<10	<10	<10	<10	423	<10	43	<0.1	<0.1	0,25	38	<10	<10	<10	<10	20	172	14	<5	<16	112	<15	21	88	<30
NH-51	<5	<5	40	26	572	6	<10	<10	<10	<10	219	<10	21	<0.1	<0.1	<0.1	289	<10	<10	<10	<10	26	75	10	<5	<16	49	44	20	34	<30
NH-52	<5	<5	53	33	233	<5	<10	<10	<10	<10	399	<10	32	0,13	<0.1	0,32	102	<10	<10	<10	<10	26	166	23	<5	<16	95	57	28	132	<30
NH-53	<5	<5	41	34	266	<5	<10	<10	<10	<10	392	<10	30	0,12	<0.1	0,36	100	<10	<10	<10	<10	23	144	30	6	<16	84	51	30	101	<30
NH-54	<5	<5	39	38	262	<5	<10	<10	<10	<10	387	<10	35	0,11	<0.1	0,32	100	<10	<10	<10	<10	21	135	39	17	<16	91	45	24	89	<30
NH-55	<5	<5	38	38	212	<5	<10	<10	<10	<10	453	<10	39	0,15	<0.1	0,41	72	<10	<10	<10	<10	22	175	53	41	<16	100	44	31	128	<30
NH-56	<5	<5	40	31	184	101	<10	<10	<10	<10	503	<10	38	<0.1	<0.1	0,27	62	<10	<10	<10	<10	24	156	15	<5	<16	91	20	26	99	<30
NH-57	<5	<5	39	7	684	<5	<10	<10	<10	<10	158	<10	17	<0.1	<0.1	<0.1	277	<10	<10	<10	<10	26	42	<10	13	19	34	19	<10	15	<30
NH-58	<5	<5	53	7	31	5	<10	<10	<10	44	177	<10	34	<0.1	<0.1	<0.1	61	<10	<10	<10	<10	18	190	11	45	<16	151	<15	10	<10	<30
NH-59	<5	<5	49	33	194	<5	<10	<10	<10	<10	434	<10	30	<0.1	<0.1	0,30	74	<10	<10	<10	<10	23	166	21	7	<16	69	31	37	112	<30
NH-60	<5	<5	24	6	518	<5	<10	<10	<10	46	300	<10	21	<0.1	<0.1	<0.1	248	<10	<10	<10	<10	26	100	<10	25	<16	51	<15	<10	<10	<30
NH-61	<5	<5	40	25	315	<5	<10	<10	<10	<10	369	<10	45	<0.1	<0.1	0,13	164	<10	<10	<10	<10	22	63	26	11	<16	39	19	10	68	<30
NH-62	<5	<5	48	49	335	<5	11	<10	<10	<10	610	<10	33	<0.1	<0.1	0,33	139	<10	<10	<10	<10	31	99	21	8	<16	32	57	34	167	<30
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NH-71	<5	<5	13	23	273	<5	<10	<10	<10	<10	522	<10	43	<0.1	<0.1	0,26	93	<10	<10	<10	<10	28	112	45	22	<16	67	<15	24	55	<30
NH-72	<5	<5	9	23	490	<5	<10	<10	<10	<10	335	<10	25	<0.1	<0.1	0,13	190	<10	<10	<10	<10	30	57	42	22	<16	50	29	<10	35	<30
NH-73	<5	<5	40	10	54	<5	<10	<10	<10	<10	464	<10	53	<0.1	<0.1	0,10	37	<10	<10	<10	<10	28	148	68	39	<16	103	<15	<10	21	<30
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NH-78	<5	<5	28	8	608	<5	<10	<10	<10	<10	192	<10	18	<0.1	<0.1	<0.1	258	<10	<10	<10	<10	31	59	<10	7	<16	55	<15	<10	<10	<30
NH-79	<5	<5	17	25	243	<5	<10	<10	<10	<10	502	<10	41	<0.1	<0.1	0,37	61	<10	<10	<10	<10	23	142	<10	<5	<16	59	18	23	101	<30
NH-80	<5	<5	10	24	461	<5	<10	<10	<10	<10	364	<10	24	<0.1	<0.1	0,22	156	<10	<10	<10	<10	25	84	17	8	<16	51	31	13	45	<30
NH-81	<5	<5	22	22	215	<5	<10	<10	<10	<10	470	<10	45	0,24	<0.1	0,24	62	<10	<10	<10	<10	22	151	29	5	<16	116	<15	18	91	<30
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NH-83	<5	<5	21	26	299	<5	<10	<10	<10	<10	478	<10	29	<0.1	<0.1	0,30	109	<10	<10	<10	<10	26	121	21	<5	<16	72	27	24	76	<30
NH-84	<5	<5	19	16	367	<5	<10	<10	<10	<10	415	<10	27	<0.1	<0.1	0,13	136	<10	<10	<10	<10	28	117	20	<5	<16	74	<15	<10	57	<30
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NH-86	<5	<5	25	30	252	<5	<10	<10	<10	<10	489	<10	31	<0.1	<0.1	0,31	88	<10	<10	<10	<10	25	146	31	<5	<16	106	30	30	89	<30
NH-87	<5	<5	23	29	418	<5	10	<10	<10	<10	439	<10	34	<0.1	<0.1	0,17	170	<10	<10	<10	<10	28	93	22	7	<16	77	35	18	63	<30
NH-95	<5	<5	40	18	610	<5	17	<10	<10	<10	133	<10	23	<0.1	<0.1	<0.1	268	<10	<10	<10	<10	29	41	<10	19	22	31	37	<10	29	<30
NH-96	<5	<5	26	18	481	<5	<10	<10	<10	<10	318	<10	14	<0.1	<0.1	0,11	179	<10	<10	<10	<10	27	76	22	42	<16	68	29	11	41	<30
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NH-98	<5	<5	45	32	234	<5	<10	<10	<10	<10	356	<10	28	<0.1	<0.1	0,37	98	<10	<10	<10	<10	22	153	40	6	<16	90	36	20	85	<30
NH-99	<5	<5	50	36	230	<5	<10	<10	29	<10	396	<10	39	0,11	<0.1	0,27	98	<10	<10	<10	<10	22	152	16	<5	<16	93	38	33	91	<30
NH-100	<5	<5	47	37	198	<5	<10	<10	<10	<10	403	<10	37	0,15	<0.1	0,33	79	<10	<10	<10	<10	23	154	19	<5	<16	95	40	21	103	<30
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NH-102	<5	<5	42	38	270	<5	<10	<10	<10	<10	384	<10	50	0,10	<0.1	0,36	100	<10	<10	<10	<10	22	134	21	<5	<16	76	53	36	112	<30
NH-103	<5	<5	58	39	477	6	<10	<10	<10	<10	320	<10	21	<0.1	<0.1	0,18	212	<10	<10	<10	<10	27	103	13	<5	<16	63	58	21	74	<30
NH-104	<5	<5	61	33	467	<5	<10	<10	<10	<10	353	<10	27	<0.1	<0.1	0,16	213	<10	<10	<10	<10	29	91	28	6	<16	55	52	27	77	<30
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NH-106	<5	<5	24	19	50	<5	<10	<10	<10	<10	426	<10	42	<0.1	<0.1	0,34	20	<10	<10	<10	<10	23	203	22	6	<16	119	<15	33	72	<30
NH-107	<5	<5	19	6	689	<5	<10	<10	<10	<10	47	<10	13	<0.1	<0.1	<0.1	309	<10	<10	<10	<10	27	10	<10	<5	23	12	25	<10	<10	<30
NH-108	<5	<5	75	6	28	<5	<10	<10	<10	61	162	<10	34	<0.1	<0.1	<0.1	37	<10	<10	<10	<10	19	189	<10	124	<16	130	<15	<10	<10	<30
NH-109	<5	<5	18	8	894	<5	15	<10	<10	<10	17	<10	12	<0.1	<0.1	<0.1	330	<10	<10	<10	<10	27	<5	<10	<5	25	<10	32	<10	<10	<30
NH-110	<5	<5	27	30	117	<5	<10	<10	<10	<10	504	<10	35	0,18	<0.1	0,38	40	<10	<10	<10	<10	25	180	36	10	<16	123	18	35	112	<30
NH-111	5	<5	28	34	239	<5	<10	<10	<10	<10	498	<10	27	0,17	<0.1	0,35	77	<10	<10	<10	<10	27	136	25	9	<16	101	41	19	101	<30
NH-112	<5	<5	30	25	281	<5	11	<10	<10	<10	440	<10	34	<0.1	<0.1	0,23	109	<10	<10	<10	<10	26	113	<10	<5	<16	63	34	18	80	<30
NH-113	<5	<5	30	28	262	<5	<10	<10	<10	<10	464	<10	41	<0.1	<0.1	0,23	92	<10	<10	<10	<10	24	134	<10	<5	<16	55	27	33	73	<30
NH-114	<5	<5	39	35	208	<5	<10	<10	<10	<10	487	<10	33	0,14	<0.1	0,36	74	<10	<10	<10	<10	24	163	23	<5	<16	104	32	36	131	<30
NH-115	<5	<5	38	35	192	<5	<10	<10	<10	<10	493	<10	43	0,15	<0.1	0,38	63	<10	<10	<10	<10	24	161	27	<5	<16	100	34	27	115	<30
NH-120	<5	15	195	<5	<5	<5	<10	<10	<10	478	<10000	<10	65	0,95	<0.1	0,24	<10	19	<10	<10	<10	30	360	93	233	<16	114	<15	54	<10	35
NH-129	<5	6	106	49	500	28	<10	<10	<10	<10	79	<10	49	0,11	<0.1	0,21	575	<10	<10	<10	<10	27	181	<10	<5	<16	49	92	54	98	<30
NH-130	<5	8	84	41	717	30	<10	<10	<10	<10	63	<10	30	<0.1	<0.1	0,11	835	<10	<10	<10	<10	27	117	<10	<5	<16	25	71	37	65	<30
NH-131	<5	9	80	<5	6	<5	<10	<10	<10	230	<5000	<10	57	0,93	<0.1	0,17	<10	17	<10	<10	<10	27	338	451	368	<16	195	<15	29	23	<30