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A summary of the petrography and geochemistry of the Bindal Batholith

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REPORT

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Title:
A summary of the petrography and geochemistry of the Bindal Batholith

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Summary:

The Bindal Batholith is a composite intrusive complex which was emplaced into medium-grade supracrustal rocks of the Helgeland Nappe Complex. The plutonism postdated the internal amalgamation of the Helgeland Nappe Complex, which probably took place during a Middle Ordovician tectonothermal event, and predated the Silurian to Early Devonian, Scandian, collisional orogenic phase.

The batholith contains a wide spectrum of rock types with a general range in composition from mafic olivine gabbro to leucogranite. Equigranular and porphyritic granites and granodiorites are the most common rock types. The majority of the rocks are high-K calk-alkaline and metaluminous, but mafic to intermediate, calcic to alkali-calcic varieties and evolved, peraluminous granites are also present.

The composition of the rocks suggest that they were derived by partial melting of multiple sources such as depleted mantle and mafic lower crust, Th-enriched lower crust and various upper crustal rocks in a general setting of converging plates. Magmatic processes associated with subduction zones, and strike-slip movements and thrusting along deap-seated fault systems probably controlled the petrogenesis, ascent and emplacement of the granitoid magmas.

Keywords:	Berggrunnsgeologi	Dypbergart
Paleozoikum	Kjemisk analyse	Kaledonske fjellkjede
Fagrapport		

List of contents:

1 INTRODUCTION

Plutonic activity played an important part in the evolution of the Caledonian Mountain Belt (Stephens 1988). Since the review of igneous activity in the Scandinavian Caledonides by Stephens *et al.* (1985), a number of studies have been made of calk-alkaline batholiths in Norway, in particular the Sunnhordland Batholith in south-west Norway (Andersen & Jansen 1987), the Smøla-Hitra Batholith in central Norway (Gautneb & Roberts 1989) and the Bindal Batholith in north central Norway (Nissen 1986, Tørudbakken & Mickelson 1986, Nordgulen & Mitchell 1988, Gustavson 1988, Nordgulen & Schouenborg 1990). A summary of Caledonian granitoid plutonism in these batholiths has been provided by Nordgulen et al. (1988).

The Bindal Batholith (Fig. 1) is the largest intrusive complex in the Scandinavian Caledonides. It ranges in composition from mafic olivine gabbros through diorites, monzodiorites, tonalites and granodiorites to leucocratic granites, and a diversity of mafic and composite dykes form an integral part of the batholith (Nordgulen & Mitchell 1988). In this paper a brief, systematic description of the important lithologies of the batholith is provided, although the mafic and composite dykes have not been included.

A large number of samples from different parts of the Bindal Batholith have been petrographically and geochemically analysed. Although most of the fieldwork has been of a reconnaisance type, a comparatively large area in the southern part of the batholith has been mapped in detail, including thorough studies of selected plutons. The plutons along the eastern thrust front of the Helgeland Nappe Complex near Hattfjelldal and east of Majavatn (Fig. 1) have not been studied.

Generally, any one pluton may exhibit considerable textural variation; however, brevity requires the description of representative samples rather than a comprehensive discussion of every textural type. The rocks have been assigned to nine different groups, each of which may include several plutons. In addition to the groups depicted in Fig. 1, 2-mica granite dykes, which are present in several parts of the Bindal Batholith, are regarded as a separate group. In the second part of the paper, these rock groups are classified geochemically using a series of standard diagrams.

Sr-isotope data are available for more than 200 samples (Nordgulen & Sundvoll, 1992). The results show that the lowest initial ratios (0.704 - 0.705) occur in the eastern part of the batholith, whereas high values (>0.710) are obtained for numerous granites in the west. A smaller number of samples were selected for Pb-Pb and Sm-Nd isotope studies. The results show that the batholith has different types of source regions including crustal rocks of probable Proterozoic age (Birkeland et al. 1993). U-Pb zircon dates from several plutons range in age between 447 and 430 Ma, suggesting that the major part of the batholith was emplaced in the Late Ordovician to Early Silurian (Nordgulen & Schouenborg 1990, Nordgulen et al. in press).

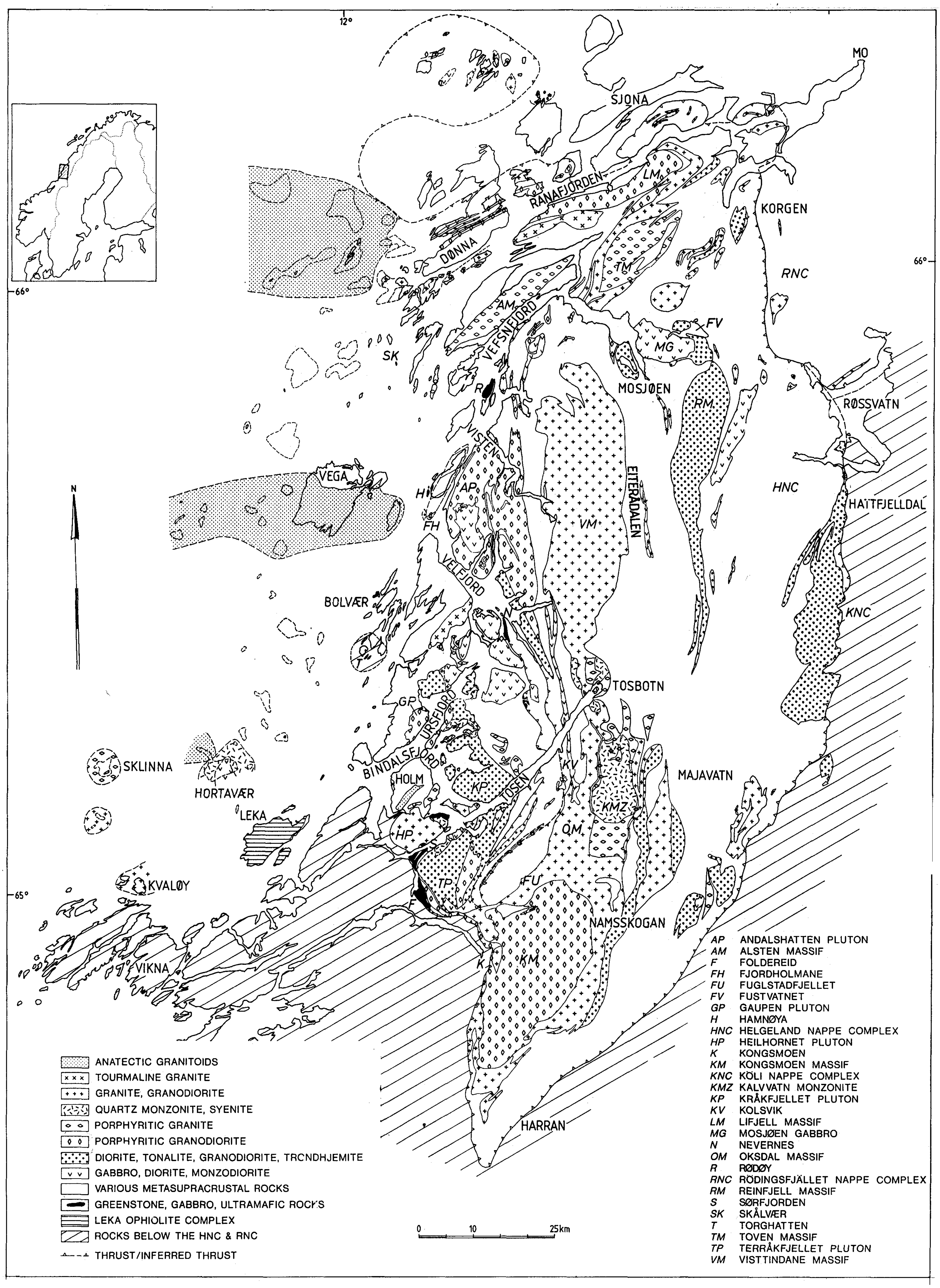


Figure 1. Geological map of the Bindal Batholith showing the main intrusive rock types. The map is from Nordgulen & Sundvoll (1992).

The objective of this paper is to provide a comprehensive account of the Bindal Batholith in which the geological and geochemical characteristics of each pluton, and the batholith as a whole, are summarised. Comparisons with other broadly similar batholiths are drawn, and the geochemical evidence for the nature of the source region and tectonic setting is presented. The question of the geochemical evolution of individual plutons and the processes involved has not been addressed in this paper.

2 REGIONAL SETTING OF THE BINDAL BATHOLITH

The Bindal Batholith (BB) is located in the Helgeland Nappe Complex (HNC), which is part of the Uppermost Allochthon in the Scandinavian Caledonides (Ramberg 1967, Kollung 1967, Myrland 1972, Gustavson 1978, 1988, Gee et al. 1985). In general, the HNC consists of metasupracrustal rocks which have mineralogical compositions indicative of amphibolite facies metamorphism. Recent mapping in the southwestern parts of the HNC suggests that two main types of metasupracrustal rocks are present (Thorsnes 1987, Nordgulen & Schouenborg 1990). The sequence of rocks which is presumed to be the oldest consists of migmatitic garnet-biotite gneisses, calc-silicate gneisses and marbles (Figs. 2 and 3). Although the precise age of these rocks is not known, Rb-Sr isotope data have suggested Precambrian ages for similar rocks from several localities elsewhere in the Uppermost Allochthon (Claesson 1979, Riis & Ramberg 1981, Cribb 1981, Graversen et al. 1981, Brattli et al. 1982, Tørudbakken & Brattli 1985). In the Namsskogan area, rocks of this type are cut by granitoids yielding Late Cambrian to Early Ordovician Rb-Sr whole-rock dates (Nissen 1986, 1988). However, a U-Pb zircon date of 437 ± 4 Ma for a mafic granodiorite in the same area suggests that that the Rb-Sr dates do not represent the crystallisation age for the plutons (Nordgulen et al. in press).

The younger metasupracrustal rocks occur as unconformable cover sequences to variably sized fragments shown as greenstone, gabbro and ultramafic rocks in Fig. 1. These fragments are interpreted to be remnants of tectonised ophiolite, and are thought to be similar in age to the Leka Ophiolite Complex (Fig. 1) which has been dated at 497 ± 2 Ma (Dunning & Pedersen 1988). Accepting this correlation, the cover sequences are Early Ordovician or younger (Thorsnes & Løseth 1991). The sequences, which consist of various conglomerates and grits, schists, psammites and marbles, were deformed, metamorphosed and juxtaposed with the older gneisses prior to being cut by major plutons of Late Ordovician age (Nordgulen & Schouenborg 1990, Nordgulen et al. in press).

Low-grade metavolcanic and metasedimentary rocks of the Köli Nappe Complex (Upper Allocthon) are situated below the HNC in the east (Foslie & Strand 1956, Lutro 1979, Dallmannn 1986,1987). These rocks are not present southwest of the HNC; there Proterozoic orthogneisses subjacent to strongly folded metasupracrustal rocks constitute the northern part of the Western Gneiss Region (Kollung 1967, Schouenborg 1988, 1989, Schouenborg et al. 1991). This area is commonly referred to as Vestranden, and the informal term Vestranden sequence has been assigned to the metasupracrustal rocks. A complex, imbricate thrust zone with highly

Figure 2. Migmatitic semipelitic gneiss with lenses of dark amphibolite. The hammer is 60 cm long. Locality: Mehammaren, Tosen; UTM: 38905-723130.

Figure 3. Migmatitic sillimanite-garnet gneiss with folded leucosomes cut by granitic dykes. The width of the photograph is c. 1 m. Locality: Målvika, Tosen; UTM: 40100-724395

deformed intrusive and metasupracrustal rocks separates the HNC from Vestranden (Roberts et al. 1983, Husmo & Nordgulen 1988).

Studies along the thrust zone between Foldereid and Bindalsfjord (Fig. 1) show that imbrication of ophiolitic rocks and of their cover sequence took place prior to the intrusion of the Heilhornet Pluton (Husmo & Nordgulen 1988). The Heilhornet Pluton (Fig. 1), which has been dated at 444 ± 11 Ma, also postdates initial thrusting of the HNC across the subjacent metasedimentary rocks of the Vestranden sequence (Nordgulen & Schouenborg 1990). Thus, the various tectonic elements of the HNC had largely been assembled and had experienced a protracted Ordovician history of deformation and metamorphism before the intrusion of the major parts of the Bindal Batholith. The final eastward translation of the HNC onto the margin of continent Baltica took place during the Late Silurian to Early Devonian Scandian collision event and post-dated intrusion of the BB (Nordgulen & Schouenborg 1990, Nordgulen et al. in press).

3 PETROGRAPHY

3.1 The southwestern part of the batholith

3.1.1 Introduction

The rocks in this area include a number of large plutons as well as smaller bodies of variable size and shape. In the Bindal area, the Kråkfjellet Pluton (Nordgulen 1984), the Terråkfjellet Pluton and the Heilhornet Pluton (Nordgulen & Schouenborg 1990) are prominent (Fig. 1). An intrusion of mafic olivine gabbro is present at Selfjordsalen (Nordgulen et al. 1989) northeast of the Kråfjellet Pluton, which include several bodies of hornblende gabbro.

In the Holm peninsula, north of the Heilhornet Pluton, small bodies of tourmaline granite and anatectic granite are common (Fig. 1). A megacrystic granite is located in the eastern part of the peninsula, and additionally some small bodies of diorite and gabbro are present.
Southwest of the island of Leka, megacrystic granite crops out on the Sklinna islands (Fig. 1). Further south, equigranular granites are present on Kvaløy and other islands in the northermost parts of the Vikna archipelago. Monzodioritic to quartz syenitic rocks occur east of Bindalsfjord (Harangsfjord) and i the Sørfjorden area. Monzodiorites, syenites and granites, which are present at Hortavær west of Leka, have been described by Gustavson & Prestvik (1979) and are not treated in this study.

3.1.2 Mafic gabbro at Selfjordsalen

Small, irregular bodies of mafic gabbro are discordantly intruded into migmatitic gneisses near the Kråkfjellet Pluton, north of Tosen (Fig. 1; see also Nordgulen et al. 1989). The gabbro cuts the regional S_2 foliation. The gneisses adjacent to the gabbro are contact metamorphosed, they contain sillimanite, garnet and spinel, and are both massive and very competent materials.

Rock type: Equigranular, medium- to coarse-grained mafic gabbro.
Mineralogy: The rock consists of anhedral olivine, subhedral to euhedral orthopyroxene, subhedral brown hornblende, clinopyroxene, and less amounts of biotite, plagioclase, actinolite and opaques. Orthopyroxene contains inclusions of olivine, and hornblende bears inclusions of olivine, orthopyroxene and clinopyroxene.
Mineral orientation, foliation: Massive texture.
Distinguishing features: Very mafic gabbro.

3.1.3 Hornblende gabbro and diorite

An elongate body of gabbro is present as a large inclusion in the Kråkfjellet Pluton southeast of Tosen (Fig. 1). Similar inclusions also occur along the northwest shore of Tosen (Nordgulen 1984), and comparatively small inclusions of medium-grained gabbro and diorite are present in the southern part of the Kråkfjellet Pluton (see Nordgulen et al. 1989 for details). The gabbros are cut by several generations of granitic, aplitic and pegmatitic dykes (Fig. 4).

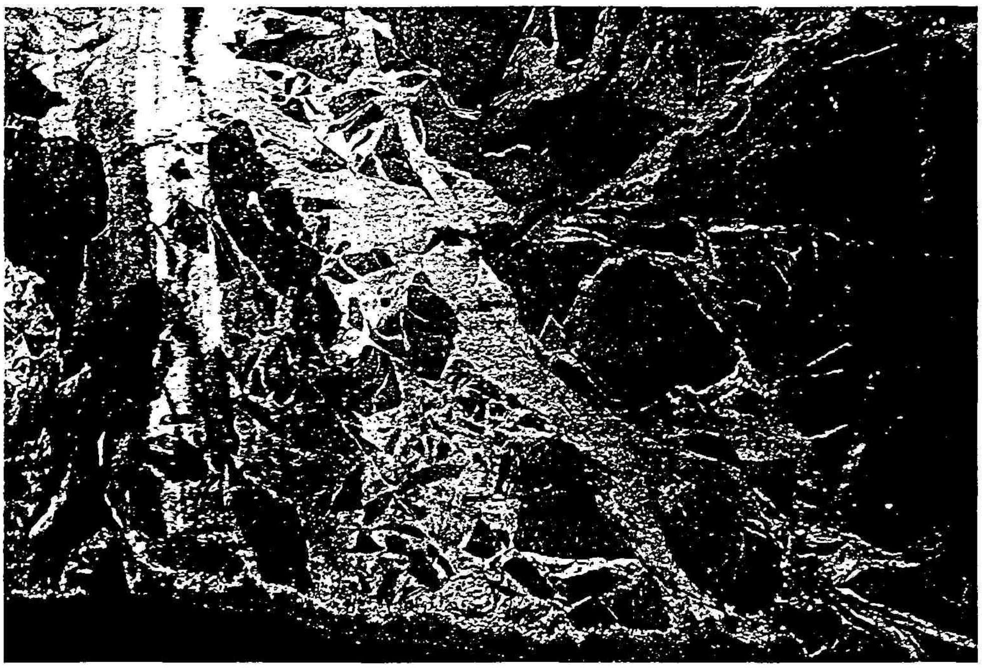


Figure 4. Medium-grained hornblende gabbro cut by a network of granitic dykes. The width of the outcrop is c. 4 m. Locality: Jøtulbukta, Tosen; UTM: 38450-722745.

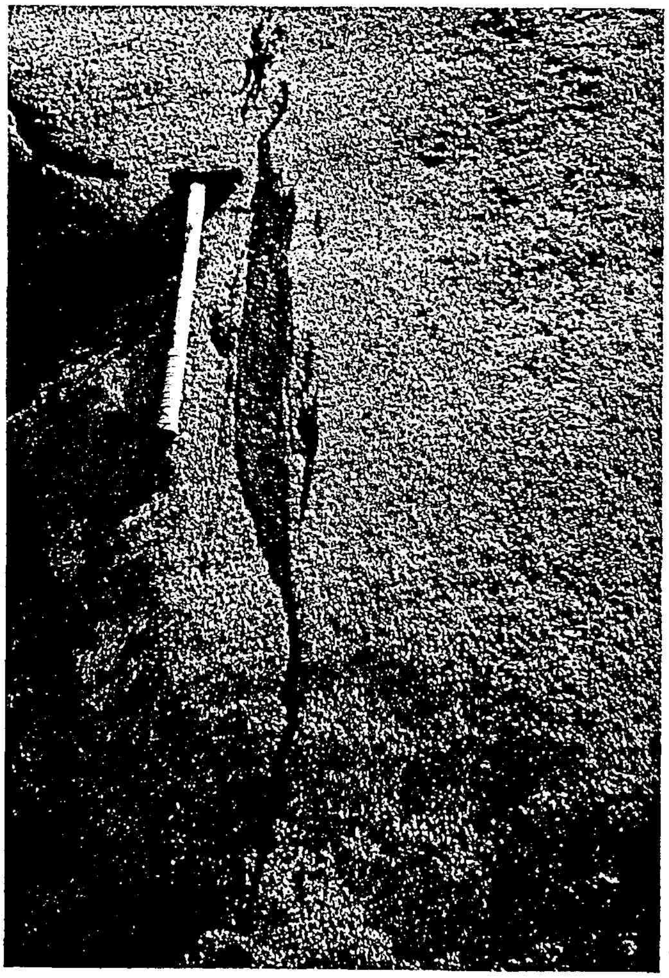


Figure 5. Medium-grained tonalite of the Kråkfjellet Pluton with mafic, biotite-rich schlieren oriented parallel to a well-developed mineral alignment defined by sub-parallel, tabular plagioclase crystals and flakes of biotite. The hammer is 60 cm long. Locality: Sæternesfjellet; UTM: 38010-722990.

Rock type: Medium- to coarse-grained hornblende gabbro with local development of coarse pegmatitic pods.
Mineralogy: Euhedral to subhedral, tabular, grey to dark pinkish grey, fresh plagioclase with good albite twinning and normal zoning in the labradorite range. The plagioclase may be aligned in meshwork with equant or slightly prismatic, subhedral hornblende. In some cases, large crystals of hornblende (<1.5 cm) have an ophitic texture with smaller laths of randomly oriented plagioclase. The hornblende is partly altered to magnesio-hornblende and actinolite. Small flakes of biotite grow randomly on amphibole. Accessory minerals: titanite, ilmenite, magnetite, pyrite, quartz, apatite (only in pegmatites) and secondary chlorite.
Mineral orientation, foliation: The rocks may have a well developed igneous fabric defined essentially by oriented tablets of plagioclase, but massive varieties are more common.
Distinguishing features: Dark gabbro with hornblende + plagioclase pegmatites.

3.1.4 The Kråkfjellet Pluton

The main part of pluton extends from Ursfjord in the northwest to Tosen in the southeast. South of Tosen it has a north-south trend and becomes narrower towards the south. The northern part of the pluton was described in detail by Nordgulen (1984). North of Tosen, the pluton is zoned with biotite tonalite in the south and west and hornblende-biotite granodiorite in the north.

A U-Pb zircon date of 443 ± 7 Ma shows that the Kråkfjellet Pluton is Late Ordovician to Early Silurian in age (Nordgulen et al. in press). It is regionally concordant, though on the outcrop scale it cuts the strong S_2 foliation in the migmatitic gneisses to the east and northeast. Elongate mafic enclaves and biotite-rich schlieren as well as prominent tabular rafts of metasedimentary rocks are oriented parallel to the fabric in the pluton (Fig. 5). Xenoliths of diorite and hornblende-gabbro are also present. The pluton is cut by dykes of aplite, pegmatite, granite as well as a plethora of basic and composite dykes.

Rock type: Medium- to coarse-grained tonalite and granodiorite. The southern part consists of medium- to fine-grained quartz diorite to tonalite which is more mafic than the major part of the pluton.
Mineralogy: Pale grey plagioclase (ca 50%) is present as tabular, subhedral laths with normal and oscillatory zoning. Minor alteration is usually confined to crystal cores. Grey microcline is generally interstitial, but may contain inclusions of plagioclase, biotite, quartz and hornblende. The quartz is glassy grey, and mostly occurs in recrystallised elongate clusters. Biotite may occur in large, shiny flakes (<8mm), but more commonly as smaller crystals assembled in clusters. Hornblende, when present, is generally subhedral and tends to be associated with biotite and accessories. Some grains are blebbed with tiny inclusions of iron ore. Accessory minerals: epidote (up to 2-3% in rare cases), allanite, titanite, apatite, zircon, monazite, opaques, white mica and chlorite.
Mineral orientation, foliation: Generally a well developed flattening type fabric defined by tablets of plagioclase, elongate quartz, and oriented single crystals and clusters of mafic minerals. Stronger, penetrative foliation in the south.
Distinguishing features: Tabular plagioclase, mineral orientation.

3.1.5 The Terråkfjellet Pluton

The Terråkfjellet Pluton (c. 100 km^2) is located southeast of Sørfjord (Fig. 1). With the exception of a megacrystic variety in the eastern part, the pluton has petrographic and chemical similarities with the Kråkfjellet Pluton. Mafic enclaves are present. Xenoliths comprise serpentinised dunite, diorite, and large rafts of foliated granite and metasedimentary rocks. The pluton is cut by granite, aplite and pegmatite, and rare basic sheets. The contact between the Terråkfjellet and Kråkfjellet Plutons is concordant with parallel mineral fabrics and xenolith trains in both units. To the north, the Terråkfjellet Pluton is separated from monzonitic rocks by a screen of calcareous metasedimentary rocks (Nordgulen et al. 1989). In the west, the pluton cuts through mylonitic rocks in the imbricate zone between Sørfjord and Kongsmoen (Husmo & Nordgulen 1988). Locally, however, the pluton becomes stongly foliated towards the imbricate zone, indicating that ductile deformation in the area occurred during more than one stage. Within the imbricate zone, strongly foliated to mylonitic intrusive rocks have been identified together with metasupracrustal rocks (Husmo & Nordgulen 1988, Nordgulen et al. 1989). Two samples of fairly dark, medium- to fine-grained quartz-syenitic rocks (N86-77 and -78) have been included in the monzonite-syenite group (Appendix 1). A medium-grained, foliated granite is represented by two samples (N86-79 and -81) and is included in the granite-granodiorite group although it has compositional features unlike any other granite in the BB (see 4.4).

The imbricate zone is considered to represent the boundary between the Helgeland Nappe Complex and subjacent metasedimentary rocks assigned to the Vestranden sequence in the west. To the north, the zone is cut by the Heilhornet Pluton, however, it is possible that a splay of the imbricate zone is present along the western contact of the megacrystic granite occurring to the north of the Heilhornet Pluton (see 3.1.13).

Rock type: Dominantly tonalite to granodiorite in the west and variably megacrystic granodiorite in the east. Medium-grained hornblende diorite occupies an area in the south. *Mineralogy:* Similar to the Kråkfjellet Pluton, however, monazite has not been found. The microcline megacrysts (<4 cm) are pale grey, subhedral to euhedral, and include other phases. The density of megacrysts may, however, vary on a metre scale. Hornblende diorites contain up to 15 % quartz and about equal amounts of biotite and hornblende.
Mineral orientation, foliation: Generally well developed in the megacrystic rocks (oriented K-feldspar). The equigranular tonalites and granodiorites have a flattening type fabric defined essentially by tabular plagioclase, lenticular quartz, biotite and/or clots of mafic minerals.
Distinguishing features: Unevenly distributed megacrysts in the east, otherwise a homogeneous rock with subhedral tablets of plagioclase.

3.1.6 The granite on Øksninga and associated rocks

A small granite stock intrudes metasedimentary rocks on the island Øksninga in Bindalsfjord, south of the Kråkfjellet Pluton (Fig. 1, see also Nordgulen et al. 1989). Granitic rocks of similar aspect are common as dykes in the Kråkfjellet Pluton. The granite has discordant contacts cutting the S_2 foliation in the metasedimentary wall rocks. Aplites, pegmatites and basic dykes cut the granite. The granite stock is correlated with the late granites occurring in a N-S trending belt along the central axis of the batholith (e.g. the Oksdal Massif, Fig. 1).

Rock type: Equigranular, grey, medium-grained granite to granodiorite.

Mineralogy: Subhedral to anhedral plagioclase, anhedral quartz and microcline. Biotite is usually more abundant than white mica, and the total mica content is generally less that 10 %. Accessory minerals: epidote, allanite, titanite, apatite, occasional grains of opaques.
Mineral orientation, foliation: Absent, or only a weak fabric revealed by preferred orientation of micas.
Distinguishing features: None.

3.1.7 Porphyroclastic granite east of the Kråkfjellet and Terråkfjellet Plutons

The rock is present as concordant, sheet-like bodies in the migmatitc gneisses northwest of Tosen and as an elongate, steep body present close to a tectonic boundary southeast of Tosen (Fig. 1). The granite generally has a very strong fabric which may be correlated with the regional S_2 foliation, locally, however, less deformed varieties occur (Fig. 6).

Rock type: Medium- to coarse-grained granite with variable amounts of white microcline megacrysts.
Mineralogy: The rock is commonly strongly deformed with eye-shaped 1-3 cm (maximum size 4-5 cm) porphyroclasts of microcline in a foliated groundmass. Grey to white, anhedral plagioclase may be partly saussuritised and is completely recrystallised in the most deformed samples. Grey, lenticular quartz and interstitial microcline. Finely recrystallised biotite and white mica are present in anastomosing foliae between the major phases. Accessory minerals: allanite, epidote, apatite, zircon and chlorite.
Mineral orientation, foliation: The rock is generally a strongly deformed porphyritic granite, but in places less strongly deformed varieties are present.
Distinguishing features: Strong foliation, white megacrysts which tend to be augen-shaped.

Figure 6. Foliated, porphyritic granite with abundant megacrysts of microcline. Pencil for scale. Locality: Skarstadfjellet; UTM: 39045-721955.

3.1.8 Foliated trondhjemite east of the Kråkfjellet Pluton

This rock type, which occurs as an elongate sheet parallel to the foliation in the enclosing banded psammites and amphibolites (see Nordgulen et al. 1989), has not been observed elsewhere in the HNC. Thus, its status as part of the BB per se may be questionable. The trondhjemite pinches out gradually towards the south and north.

Rock type: Pale grey, foliated, medium-grained trondhjemite.
Mineralogy: Recrystallised plagioclase and quartz are the dominant minerals. Biotite is present as small flakes parallel to the foliation. Garnet is commonly observed, usually as small crystals in dispersed, elongate clusters. Accessory minerals: muscovite, apatite, zircon, opaques, chlorite.
Mineral orientation, foliation: Very strong foliation.
Distinguishing features: Strong foliation, garnet present.

3.1.9 The Myra Monzonite (Sørfjorden)

Monzonitic rocks are present along Sørfjorden, between the Heilhornet and Terråkfjellet plutons (Fig. 1). A medium- to fine-grained variety cuts coarser monzonite. Mafic enclaves are locally common. The monzonites intrude various metasedimentary rocks, gabbros and ultramafic rocks. They are cut by granitic and mafic dykes.

Rock type: Medium- or medium- to coarse-grained monzonite.
Mineralogy: Subhedral, greyish white, zoned and twinned plagioclase; pinkish grey, euhedral to subhedral microcline; subhedral to euhedral hornblende (4 mm) and bronzy flakes of biotite (0.5 mm); minor quartz. Accessory minerals: allanite, epidote, titanite, apatite, zircon and opaques.
Mineral orientation, foliation: Variable, locally well developed foliation.
Distinguishing features: Large single crystals of hornblende, white weathering of feldspar.

3.1.10 The Harangsfjord area

Harangfjord is a E-W trending fjord situated between Ursfjord in the north and Bindalsfjord in the south (Fig. 1). The geology in the area is very complex with a number of intrusive rock types with metasedimentary inclusions, which are cut by abundant mafic and composite dykes as well as granitic, pegmatitic and aplitic dykes (cf. Fig 7). Monzodioroitc to quartz-monzonitic rocks ranging in composition between 55 and 64 % SiO_2 (Appendix 1) are the most abundant rock types. They are generally medium-grained and equigranular and contain biotite and hornblende as mafic minerals. Pegmatitic pods with characteristic elongate, skeletal amphibole crystals are present in some of the rocks (Fig. 8). The distribution of rock types in the Harangsfjord area suggest that the monzonitic rocks are younger than the tonalite of the Kråfjellet Pluton, which both to the south and the north of Harangsfjord. A special type of fairly mafic hornblende-porphyritic monzodiorite (B286 and B287; Appendix 1) occurs as a steep sheet which cuts the Kråkfjellet Pluton south of Harangsfjord (Nordgulen 1984).

Figure 7. Intrusive relationships in Harangsfjord. Medium-grained granodiorite is cut by a granitic dyke with angular inclusions of 1) fine-grained granite (above) and 2) foliated quartz diorite which is cut by a pegmatitc vein (below). Locality: Storvika. UTM: 37380-723880.

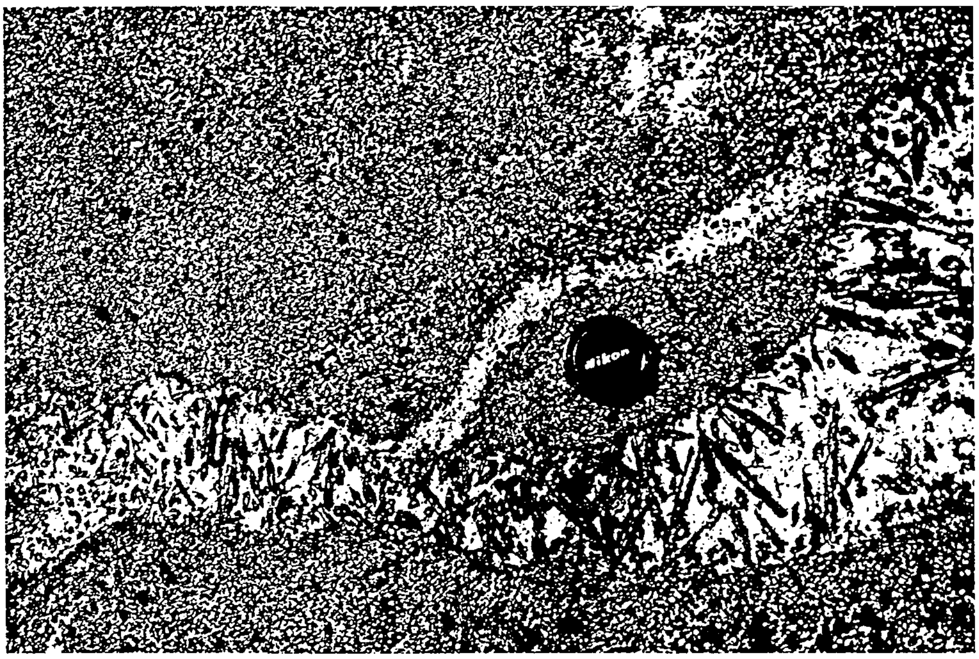


Figure 8. Medium-grained hornblende biotite quartz monzonite with a pegmatitc pod which contains skeletal, elongate amphibole crystals oriented more or less at right angles to the pegmatite wall. Locality: Båtnes, Harangsfjord; UTM: 37745-72385.

3.1.11 The Heilhornet Pluton

The Heilhornet Pluton (c. 50 km^2) is located in the southern part of the Holm peninsula (Fig. 1). It cuts the imbricate zone which marks the boundary between the HNC and the Vestranden sequence near Sørfjorden (Husmo & Nordgulen 1988); consequently it is younger than the initial thrusting of the HNC across subjacent rocks. The pluton has yielded a U-Pb zircon age of 444 ± 11 Ma (Nordgulen & Schouenborg 1990). The Heilhornet Pluton is zoned with the most evolved parts occurring in the central western parts of the pluton.

Rock type: Medium-grained quartz monzonite to granodiorite to granite; coarser grain size in the most evolved interior parts compared to the margin of the pluton.
Mineralogy: Subhedral, pale grey plagioclase and dull black subhedral hornblende (not present in the most evolved rocks); biotite as single grains or clusters which may occur in aggregates with hornblende. In the evolved parts of the pluton, fairly large single flakes of biotite occur. Quartz is recrystallised and shows undulose extinction; microcline is interstitial or present as larger grains enclosing other minerals. Accessory minerals: allanite, epidote, titanite, apatite, zircon, tourmaline, opaques, white mica, chlorite and calcite.
Mineral orientation, foliation: Strong fabric along the western contact, otherwise variably developed but commonly weak mineral orientation.
Distinguishing features: Variable texture; grey granodiorite with biotite and hornblende, pale grey coarser-grained granite with biotite.

3.1.12 The tourmaline granite

Tourmaline granites occur as irregular, fairly small stocks and dykes which intrude mica schists, calc-silicate rocks and marble at the Holm peninsula (Nordgulen & Bering 1987, Nordgulen et al. 1989). The tourmaline granite cuts S_2 in the metasedimentary rocks (Fig. 9). Folding and extension of granite dykes and veins is probably related to D_3 deformation (Fig 10).

Rock type: Fine-grained, grey to white granite.
Mineralogy: Anhedral plagioclase, microcline and quartz in sub-equal amounts. Fairly small flakes of biotite and white mica make up approximately 5-8 % of the rock. Accessory minerals: tourmaline, garnet, chlorite and rare opaques.
Mineral orientation, foliation: Foliation defined by oriented micas.
Distinguishing features: Tourmaline is present as an evenly distributed accessory mineral and is locally also concentrated in small rosette-like aggregates. Thin, white aplite veins and irregular pockets of pegmatite may also be rich in tourmaline.

3.1.13 The anatectic granites

The term anatectic granite has been used to characterise a granite body present in metasedimentary rocks at the Holm peninsula (see Nordgulen & Bering 1987). The granite is tabular with a steep attitude parallel to the foliation and lithological boundaries in the enclosing rocks. Contacts towards the metasedimentary rocks may be sharp or transitional. The granite is commonly riddled with xenoliths of the wall rock (psammite, calc-silicate rocks and schists), but inclusion free zones are also present.

Figure 9. Dykes of fine-grained tourmaline granite cut S_1/S_2 fabrics in calc-silcate rocks. Locality: Holm peninsula; UTM: 36485-723020.

Figure 10. Thin aplite veins related to tourmaline granite cut the axial surface of a tight F_2 fold in calc-silicate rocks. Extension of the vein shows that ductile deformation (D_3) took place after intrusion of the tourmaline granites. Locality: Holm peninsula; UTM: 36480-722800.

Rock type: Grey, medium-grained, equigranular granite with local occurrences of megacrystic granite.
Mineralogy: Subhedral, partly sericitised plagioclase and microcline with recrystallised mantles. Megacrysts of microcline are present in variable amounts in many areas. The megacrysts are white, euhedral, up to 4-5 cm in length, and with aspect ratios normally between 3:1 and 5:1. Deep brown biotite (<1 mm) occurs as single flakes or in clusters and may be partly chloritised. It is also present together with garnet and fibrolitic sillimanite in irregular, variably sized, mafic aggregates or clots. Quartz occurs in elongate, strongly recrystallised clusters (<5 mm). White mica is also present. Accessory minerals: opaques, chlorite, zircon and calcite.
Mineral orientation, foliation: A weak mineral orientation and/or orientation of enclaves is common.
Distinguishing features: Abundant metasedimentary xenoliths, local presence of white megacrysts.
Remarks: The anatectic granites are spatiallly associated with tourmaline granites, and tourmaline aplites and pegmatites occur both near and within the granite. This may indicate that these rock types are in some way related. In the metasedimentary rocks at the Holm peninsula, the field relations strongly suggest that wide-spread anatexis has taken place, resulting in diatexitic features in suitable lithologies. Although a genetic relationship between the diatexitic rocks and the intrusive, anatectic granite cannot be proved, these rocks may be an expression of the same or similar geological events (see also description of the Vega Granite, 3.2.11).

3.1.14 The megacrystic granite at Bindalseid

An isolated pluton of megacrystic granite is present north of Bindalseid (see Nordgulen et al. 1989) in the eastern part of the Holm peninsula (Fig. 1). Along the contact towards marble and calc-cilicate rocks in the west the megacrystic rock is highly strained and transformed into a fine-grained mylonite with relatively shallow dips towards the east-southeast. This mylonite zone may represent the continuation of the imbricate zone separating the HNC from subjacent rocks south of the Heilhornet Pluton. Towards Bindalsfjord in the east the rock is less deformed, but still penetratively foliated. Elongate mafic enclaves are present parallel to the foliation.

Rock type: Foliated, porphyritic granite.
Mineralogy: Abundant, grey microcline megacrysts (<4 cm) with string perthite commonly enclose plagioclase and quartz. Tabular to equant, subhedral crystals of plagioclase contain small needles of muscovite which have grown in preferred directions. The feldspars are partly recrystallised along crystal margins. Quartz is present in elongate clusters (<10 mm) aligned in the foliation. Biotite and some white mica is present in thin, discontinuous foliae anastomosing around larger grains of quartz and feldspar. Accessory minerals: apatite, zircon, chlorite, tourmaline, opaques.
Mineral orientation, foliation: Pronounced foliation defined by oriented megacrysts and foliae consisting of quartz and micas. Mylonitic along the western contact.
Distinguishing features: Strong foliation, megacrysts.
Remarks: The mylonite zone along the western contact of the granite may represent the continuation of a part of the imbricate zone occurring south of the Heilhornet Pluton.

3.1.15 Diorites and gabbros at the Holm peninsula

Some small bodies of medium- to coarse-grained, equigranular gabbro to diorite are present in the metasedimentary rocks of the Holm peninsula (see Nordgulen & Bering 1987, Nordgulen et al. 1989). A small pluton occurring north of the Heilhornet Pluton (Fig. 1) is described.

Rock type: Coarse-grained, mafic gabbro to monzodiorite.
Mineralogy: Dark grey, elongate, euhedral plagioclase with good twinning. Aligned, stubby prisms of hornblende (<10 mm) constitutes c. 50 % of the rock. Clusters of biotite flakes (1-3mm) occur together with hornblende. Quartz and K-feldspar may be present in trace amounts. Accessory minerals: apatite, ilmenite, leucoxene.
Mineral orientation, foliation: Aligned tablets of plagioclase.
Distinguishing features: Large hornblende crystals, elongate plagioclase.
Remarks: The texture of this rock is similar to that of the Akset-Drevli Pluton of the Velfjord Massif (Barnes et al. 1992), and to the monzodiorite near Tosbotn (see 3.4.5).

3.1.16 The Sklinna Pluton

This pluton is located on the Sklinna islands southwest of Leka (Fig. 1). It consists of homogeneous, porphyritic 2-mica granite which is cut by some sheets of pegmatite and aplite. About 8 km south of Sklinna, on some small islands called Sklinnaflesin, medium- to coarse-grained, grey and pale pink granites with small dark enclaves are present. Some aplitic dykes cut the granite.

Rock type: Coarse-grained, porphyritic granite with grey or pink K-feldspar megacrysts.
Mineralogy: Euhedral to subhedral, grey or pale pink microcline megacrysts which enclose plagioclase, biotite and quartz. Subhedral to euhedral tablets of grey to white plagioclase which in some cases are clouded by fine sericite and overgrown by small flakes of muscovite. Quartz is present in elongate clusters (<10 mm) and as single grains which may enclose plagioclase. Biotite and white mica are present in flakes (1-3 mm), muscovite is commonly the most abundant mica. Accessory minerals: apatite, zircon, allanite, epidote, opaques, chlorite and calcite.
Mineral orientation, foliation: Weak orientation of megacrysts.
Distinguishing features: Grey or pink megacrysts.

3.1.17 The Kvaløy granite

This pluton is present on Kvaløya, Rauøya, Kråka and nearby islands in the northernmost part of the Vikna archipelago (Fig. 1). The granite is separated from Proterozoic gneisses to the south by an approximately E-W trending fault. The pluton consists essentially of medium-grained granite, however, an aplitic facies is locally developed in its central part. The granite is cut by grey and pale grey granite dykes and thin sheets of aplite and pegmatite. To the north and northwest of the granite, metasedimentary rocks with NE-SW trending foliation are exposed on a number of small islands. The main rock type is pale to dark grey greywacke with subordinate amounts of marble and white quartzite. The metasedimentary rocks are cut by dykes of deformed microgabbro. They are also cut by the Kvaløy granite, and large xenoliths of metagreywacke occur in the northern part of the pluton (Håvard Gautneb, pers. comm. 1986).

Rock type: Medium-grained, white to grey granodiorite.
Mineralogy: Grey to white, subhedral plagioclase is usually extensively altered, though both normal and oscillatory zoning can be observed in some grains. Anhedral, interstitial microcline with non-uniform development of microcline twinning enclose plagioclase and quartz. Quartz is present as single grains and in clusters (<8 mm). Biotite and muscovite (c. 1 mm, max 4 mm) occur together and are generally about equally abundant. Accessory minerals: apatite, zircon, opaques and chlorite.
Mineral orientation, foliation: Weak alignment of biotite.
Distinguishing features: None.
Remarks: Fairly strong alteration is common in these granites. Saussuritisation and sericitisation of plagioclase is accompanied by alteration of biotite to chlorite.

3.2 The central western part of the batholith

3.2.1 Introduction

In this part of the BB, several different plutonic rock types are present (Fig. 1). South of Velfjord, three fairly large mafic to intermediate plutons termed the Velfjord Massif by Kollung (1967) and Myrland (1972), intrude metasedimentary rocks which on a regional scale wrap conformably around the plutons (see Myrland 1972). The plutons have been described by Barnes et al. (1992). Together with the Mosjøen Gabbro (Tørudbakken & Mickelson 1986) and some smaller mafic bodies, especially between Ursfjord and Velfjord (Fig. 1), they form the most prominent expression of mafic plutonism in the HNC.

Some smaller bodies of porphyritic rocks (not shown on Fig. 1) are commonly associated with the plutons of the Velfjord Massif, and a similar association of mafic to intermediate intrusions and porphyritic granites is also present in the area between Ursfjord and Velfjord (Myrland 1972, Fig. 1). The granites have a range of textures, and mineralogical and compositional data suggest that they were derived from crustal source rocks. Migmatitic metasedimentary rocks, which appear to be grading into fairly dark, nebulitic diatexites with randomly oriented inclusions of amphibolite, vein quartz and quartzo-feldspathic material, can be observed in several localities in the Ursfjord and Velfjord region. The close spatial association between high-grade metasedimentary rocks, mafic intrusions and porphyritic granites of crustal origin, may indicate that the granites represent the product of significant crustal melting, which was possibly a result of transfer of heat consequent upon emplacement of the mafic plutons (Barnes et al. 1992).

The tonalitic rocks in the Ursfjord area are regarded as the northward extension of similar rocks belonging to the Kråkfjellet Pluton in Bindal (see earlier description). Monzonite is spatially associated with and cuts the tonalite northwest of Ursfjord, however, the areal extent of the monzonite has not been established. In the same area, there are also a number of smaller bodies of diorite and granite (see Myrland 1972).

East of Velfjord, the megacrystic Andalshatten Pluton has intruded foliated tonalite to granodiorite. The pluton also contains large rafts of diorite and metasedimentary rocks (Fig. 1). A somewhat similar porphyritic rock is the Gaupen Pluton in Ursfjord.

The most evolved intrusion in this part of the batholith is the NE-SW trending tourmaline granite south of Velfjord. In the westernmost coastal districts, a large body of anatectic granite forms most of the island of Vega, after which it is named.

3.2.2 The Gaupen Pluton

This rock is exposed on the Gaupen peninsula east of Ursfjord and along the western side of Ursfjord. Mafic enclaves are abundant. The granite is cut by a variety of granite, aplite and pegmatite dykes as well as different types of basic dykes. To the west of the Gaupen Pluton, a zone of partial melting in pelitic to semi-pelitic wall-rocks extends for up to 3 km away from the contact. This zone may be interpreted as result of contact metamorphism (Heldal & Hjelmeland 1987).

Rock type: Porphyritic, medium- to coarse-grained granite.
Mineralogy: Biotite occurs as single flakes and as linear clusters of recrystallised grains, possibly with hornblende. Pale pink, tabular to equant, euhedral to subhedral microcline megacrysts (<3 cm, b:c 1-2,1-3) contain inclusions of biotite and plagioclase. Microcline is also present in the groundmass together with white, subhedral to euhedral plagioclase
(c. 4 mm) and grey to dark grey quartz occurring as rounded grains in feldspars and as linear clusters. Accessory minerals: epidote, allanite, apatite, zircon, opaques, muscovite, chlorite.
Mineral orientation, foliation: Fairly well developed orientation of microcline megacrysts and biotite. Mafic enclaves are parallel to the fabric.
Distinguishing features: Pink K-feldspar megacrysts in medium-grained groundmass.

3.2.3 Monzonitic rocks in Ursfjord

Monzonitic rocks are present in the western parts of the tonalite occurring north of Ursfjord (the monzonites are not shown on Fig. 1). They are spatially associated with tonalites which chemically and texturally are similar to the Kråkfjellet Pluton. The relationship between monzonite and a leucocratic tonalite can be studied along road cuts at Mjønesodden (Fig. 11). Here it is clear that the tonalite is cut by quartz monzonite, and a pronounced mineral layering is developed in the latter close to the contact. However, the field relations in this area need to be reassessed before the relative proportions of tonalite and quartz monzonite can be established.

Rock type: Medium-grained, equigranular quartz monzonite.
Mineralogy: Grey to white, subhedral plagioclase (c. 4 mm), pale pinkish grey microcline
(c. 5 mm) is anhedrally intergrown with plagioclase. Colourless to bluish grey, anhedral quartz is assembled in clusters and is intergrown with books and flakes of biotite (up to 5 mm). Accessory minerals: titanite, epidote, apatite, zircon, opaques, muscovite.
Mineral orientation, foliation: Generally moderate, defined by oriented mafic minerals.
Distinguishing features: Large biotites.

Figure 11. Medium-grained, leucocratic tonalite (below) is cut by dark grey, medium-grained quartz monzonite with mineral layering due to enrichment of biotite occurring in wavy bands sub-parallel to the contact. Hammer (60 cm) for scale. Locality: Mjønesodden, Ursfjord; UTM: 37275-724650.

Figure 12. Porhyritic granite with grey microcline megacrysts aligned in medium-grained groundmass. The largest megacrysts are up to 8 cm in length.Width of photograph: c. 90 cm. Locality: Grøndalsfjellet; UTM: 37950-725565.

3.2.4 Mafic to intermediate intrusions between Ursfjord and Velfjord

Along coastal outcrops in Ursfjord (Fig. 1), fine-grained, massive diorites with inclusions of mica gneiss and amphibolite are present in the southwest. To the northeast, there is a medium-grained, dark, massive gabbro with few very dark inclusions. The contact between gabbro and diorite is not exposed.

In the area between Ursfjord and Velfjord (Grøndalsfjell), gabbro and diorite intrude and cut the foliation in metasedimentary rocks occurring to the southeast of an elongate body of tourmaline granite (Fig. 1, Myrland 1972). The metasediments consist of marble and migmatitic mica gneiss which may contain kyanite, sillimanite, garnet and staurolite. In places, the mica gneiss has a diatexitic structure with randomly oriented fragments of amphibolite, vein quartz and lenses of quartzo-feldspathic material occurring in a mica-rich "tonalitic" groundmass. These features are probably due to anatexis of the mica gneiss, and although similar phenomena are observed some distance away from exposed plutons, the anatexis may possibly be caused by upward transfer of heat during emplacement of the mafic intrusions.

Rock type: Medium- or fine-grained, equigranular gabbro to quartz diorite.
Mineralogy: There is a substantial variation in mineralogy and texture. The rocks are dominated by plagioclase, amphibole and biotite present in variable proportions. Plagioclase constitutes 10-65 % of the rocks and range in composition from labrador in mafic gabbros to andesine in the quartz diorites. Biotite, hornblende and sometimes actinolite with occasional clinopyroxene cores are the common mafic minerals. Small amounts of interstitial quartz and microcline may be present in the quartz diorites. Ilmenite enclosed in irregular aggregates of leucoxene is a common opaque phase, and in some samples of medium-grained diorite, small crystals of garnet are present. Other accessory minerals: apatite, titanite and zircon, epidote/clinozoisite, sericite, chlorite and calcite.
Mineral orientation, foliation: Both massive and foliated rocks are present.

3.2.5 Porphyritic granites between Ursfjord and Velfjord

Some irregular bodies of porphyritic granite (Fig. 12) occur in close spatial association with the gabbroic to dioritic plutons in the Grøndalsfjell-Sæternesfjell area west of southern Velfjord (Fig. 1). The boundaries towards metasedimentary and mafic rocks are usually sharp. Xenoliths of diorite are present in the porphyritic granite showing that the diorites are older. However, field relations also indicate that a close association between these rock types. On map sheet Velfjord (Myrland 1972), parts of the area shown as porphyritic granite is frequently an intimate mixture of diorite and porphyritic granite rather than porphyritic granite alone. Small, irregular occurrences of porphyritic granite are also present in the area shown as "diorite with transition to monzodiorite". In such cases, the porphyritic granite is commonly somewhat darker than normal, and isolated K-feldspar megacrysts may occur in the diorites. Blurred or transitional contacts also occur between diorite and porphyritic granite.

Rock type: Foliated, variably porphyritic granite.
Mineralogy: Pale grey to slightly pink or white megacrysts of microcline have variable size and shape from equant to tabular (5x1 cm, maximum 8x2 cm) to fairly small, eye-shaped grains in strongly foliated rocks. Locally the rock grades into equigranular granite. The groundmass is

medium- to fine-grained and granoblastic. The plagioclase is a pale grey, anhedral, weakly zoned oligoclase, commonly somewhat altered with incipient to strong recrystallisation along the margins of most grains. Quartz is recrystallised, and biotite occurs as small flakes, usually with strong preferred orientation. Muscovite and garnet are generally present. Accessory minerals: apatite, zircon, garnet, chlorite, opaques, leucoxene, clinozoisite.
Mineral orientation, foliation: Variable from preferred orientation of biotite and microcline megacrysts, to very strong foliation with augen-shaped microcline in highly recrystallised matrix.
Distinguishing features: Grey to white or slightly pink megacrysts, garnet and muscovite present.

3.2.6 Mafic to intermediate intrusions in Velfjord

These plutons, which were referred to as the Velfjord Massif by Kollung (1967) and Myrland (1972), exhibit a wide range of compositional and textural types. The rocks are generally medium- or coarse-grained and with compositions ranging from mafic gabbro to quartz monzonite (Kollung 1967, Barnes et al. 1992). Small bodies of foliated porphyritic granitoids (see below) are associated with and are probably younger than the plutons, which are also cut by mafic as well as granitic dykes.

The layering and foliation in the enclosing metasedimentary rocks wrap around the plutons (see Myrland 1972), and the contacts commonly have steep to intermediate outward dips. Prominent intrusive breccias are common along the contact zones towards calcareous rocks. The rocks intruded by the plutons comprise a sequence of pelitic to semi-pelitic schists and gneisses, banded calc-silicate rocks and marble, which were assigned to the Lower Nappe according to the tectonostratigarphic scheme of Thorsnes & Løseth (1991). To the northeast, the Lower Nappe is overlain by the Middle Nappe, which consists of ultramafic rocks forming the basement to a sequence of psammites, schists, conglomerates and marble. A dioritic intrusion, termed the Markafjellet Pluton by Kollung (1967), cuts the Middle Nappe and apparently also the thrust between the Lower and Middle Nappes (Thorsnes & Løseth 1991, Fig. 4). As the Markafjellet Pluton is similar to the rocks of the Velfjord Massif, this would imply that the mafic plutons post-date the juxtaposition of the Lower and Middle Nappes.

Rock type: Medium- and coarse-grained gabbro to quartz monzonite.
Mineralogy: Generally, the rocks have hypidiomorphic granular to subophitic textures. They consist essentially of plagioclase, augite, hypersthene, amphibole and some biotite. Olivine is present in the most mafic varieties. Microcline and quartz may occur as interstitial phases.
Accessory minerals: epidote, allanite, apatite, opaques, zircon and titanite.
Mineral orientation, foliation: Variable from massive or weakly foliated to strongly foliated with protomylonitic fabric.
Remarks: All the plutons are zoned, and the degree of deformation is variable within each pluton (for details, see Barnes et al. 1992).

3.2.7 Porphyritic rocks associated with the Velfjord Massif

A number of fairly small, irregular, foliated, equigranular to porphyritic intrusive rocks are associated with and occur adjacent to the plutons of the Velfjord Massif (not shown on Fig. 1). Geochemical data show that they are compositionally somewhat different from porphyritic granites occurring further west in the region between Ursfjord and Velfjord (Fig. 1, see 3.2.5). The rocks are probably younger than the mafic plutons. The mineral assemblages and chemical composition indicate that they originated by partial melting of pelitic source rocks during emplacement of the mafic intrusions (Barnes et al. 1992).

Rock type: Foliated porphyritic granite.
Mineralogy: Grey to white megacrysts of microcline have variable size and shape and may be tabular, rounded or eye-shaped. Locally the rock has very heterogeneous textural development and may grade into equigranular varieties. The groundmass normally has a fine-grained granoblastic texture with grey to white plagioclase, grey quartz, and small flakes of biotite. Muscovite is common, and garnet generally occurs in the groundmass. In some samples garnet is abundant with rounded crystals up to 5 mm across. Accessory minerals: apatite, zircon, monazite, garnet, sillimanite, orthopyroxene, chlorite, opaques.
Mineral orientation, foliation: Very strong foliation is common.
Distinguishing features: Grey to white megacrysts with irregular shape, garnet and muscovite present.

3.2.8 The tourmaline granite

The granite occurs as a thick SE-dipping sheet southwest of Velfjord (Fig. 1). A thin sheet of deformed porphyritic granite (not shown on Fig. 1), which becomes mylonitic towards calcareous rocks at the base, is generally present along the SE-dipping western contact of the tourmaline granite. Rafts of metasedimentary rocks are locally common near the contacts of the granite, and dykes of tourmaline granite cut the foliation in the metasedimentary rocks. Numerous sets of fractures and shear zones, some of which with quartz ± sulphide mineralisation, can be studied along road sections in Velfjord.

Tourmaline is generally present as an accessory mineral and also tends to occur in thin quartz+aplite or aplite veins. Locally, the granite contains orbicules consisting mainly of quartz, white mica and tourmaline. The orbicules are spherical to ovoid in shape and less than 5 cm in diameter (Fig. 14). Similar features occur in other leucocratic, generally peraluminous granites (Sinclair & Richardson 1992). A detailed study of quartz-tourmaline orbicules in the Seagull Batholith indicate that they are a magmatic-hydrothermal phenomenon and that they formed from B-rich fluids that were trapped in small segregations in a largely crystallised granite magma (Sinclair & Richardson 1992, Samson & Sinclair 1992).

Rock type: Fine- to medium-grained granite.
Mineralogy: Grey to white, subhedral and anhedral plagioclase and microcline are the dominant rock forming minerals together with grey, anhedral quartz. Biotite (<2 mm) occurs as as bronzy flakes and muscovite (<1 mm) as randomly oriented single flakes. Accessory minerals: garnet, tourmaline, apatite, zircon, opaques.
Mineral orientation, foliation: Moderate mineral alignment defined by biotite.
Distinguishing features: Single muscovite flakes.

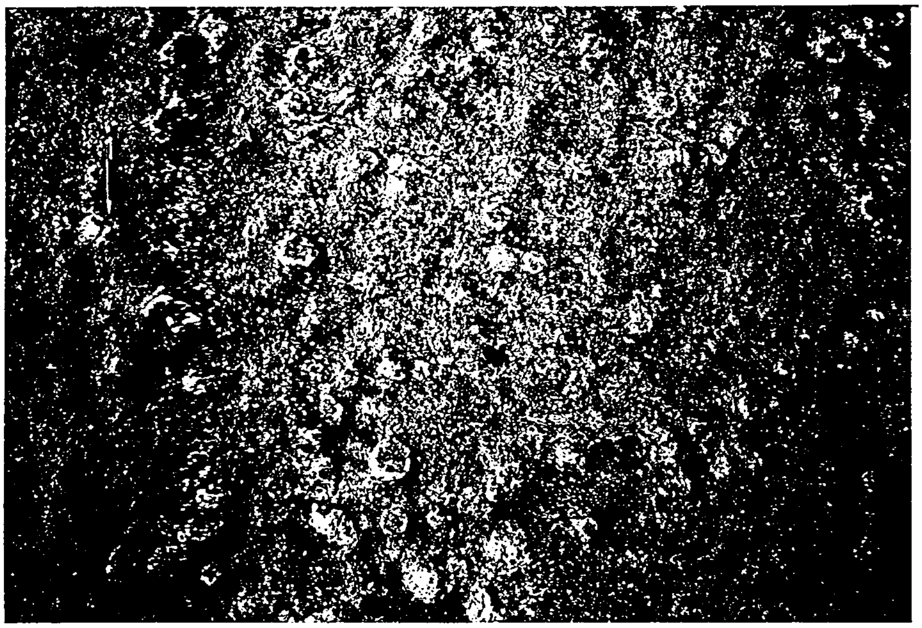


Figure 13. Tourmaline granite with concentration of tourmaline in the central part of thin, white aplite veins. Pencil for scale. Locality: Vandalsvik, Velfjord; UTM: 38215-726270.

Figure 14. Tourmaline granite with variably sized tourmaline-rich orbicules. Pencil for scale. Locality: Sæternesfjellet; UTM: 37710-726000.

3.2.9 The Andalshatten Pluton

This pluton covers an area of more than 300 km^2 between Velfjord in the south and Visten in the north (Fig. 1, see also Nordgulen et al. 1991). It varies in composition from mafic granodiorite in the NE to rocks transitional towards granite in the SW. A sample from the southwestern part of the pluton has yielded a U-Pb zircon date of 447 ± 7 Ma (Nordgulen et al. in press). The Andalshatten Pluton is generally megacrystic (Fig. 15), however, the size, shape and abundance of megacrysts is variable. In the least evolved NE part of the pluton, a strong foliation is present, and the megacrysts appear as rounded to lenticular augen (Fig. 16) The pluton commonly contains subhedral megacrysts up to 4cm in length (see below), however, areas with very high concentrations of megacrysts are found near the northern termination of the large diorite inclusion in the western part of the intrusion. Conversely, sparsely megacrystic to equigranular varieties are present in some areas near Velfjord.

The pluton contains abundant xenoliths which in the west consist dominantly of rusty, banded calc-silicate schists and psammites with local horizons of polymict conglomerates. In the SW, a large area is occupied by diorite, gabbro and minor hornblendite which are cut by veins and dykes of the porphyritic granodiorite (Fig. 17). The dioritic rocks display considerable textural variation and include medium- and fine-grained, massive or foliated types. Commonly, they contain megacrysts of plagioclase and microcline, and locally there appears to be transitional contacts between the granodiorite and the heterogeneous diorites (Fig. 18, see also Myrland 1972).

The central and eastern parts of the pluton contain inclusions of serpentinite and large N-S trending rafts of banded marble and migmatitic gneiss. The pluton also has small mafic enclaves with elongate, elliptical shapes. Rare granitic and aplitic dykes may occur adjacent to metasedimentary rafts. N-S trending, grey, microporphyritic granitic dykes, which may be up to several metres wide, cut the pluton. The dykes are chemically and isotopically related to their host (Nordgulen & Sundvoll, 1992). Different types of mafic dykes also cut the Andalshatten Pluton.

Rock type: Porphyritic granodiorite to granite with medium-grained groundmass.
Mineralogy: Greyish white, subhedral microcline megacrysts (< 4 cm, b:c 1:2,1:3). In the groundmass, greyish white plagioclase and microcline occur with aligned, lenticular clusters of quartz. Biotite usually grows in elongate aggregates in association with stubby prisms of hornblende. The more mafic varieties contain euhedral titanite (<3 mm) and epidote (<3 mm) with allanite cores. Other accessory minerals comprise apatite, zircon and opaques.
Mineral orientation, foliation: The western part of the pluton exhibits a flattening type mineral alignment defined by preferably oriented megacrysts, lenticular quartz and oriented biotite or clusters of mafics. In the east the fabric is stronger, and along the eastern contact the pluton has a pronounced foliation with parallel augen of microcline in a fairly strongly recrystallised ground mass.
Distinguishing features: Prominent K-feldspar megacrysts, abundant mafics.

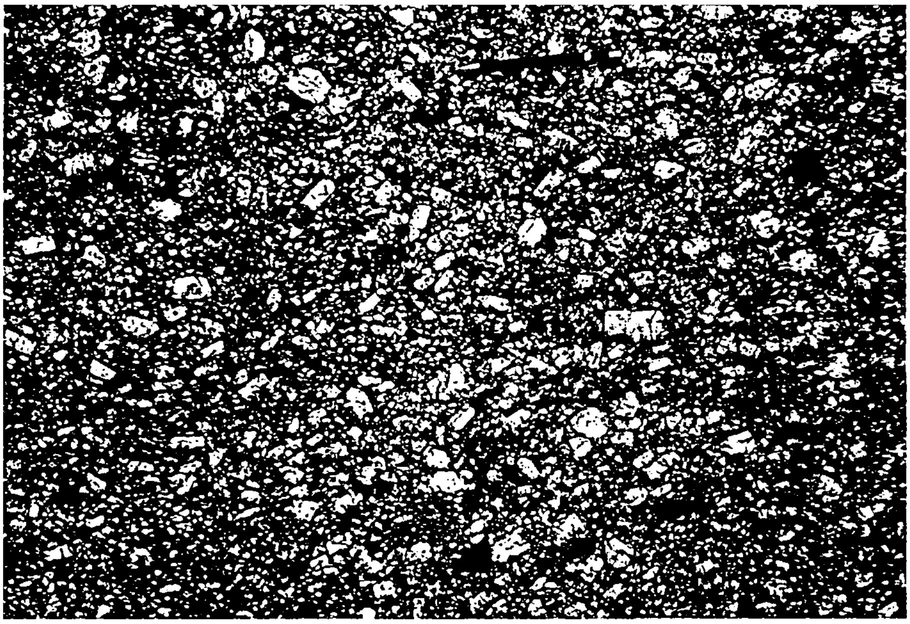


Figure 15. Megacrystic granodiorite of the Andalshatten Pluton (photograph of wet surface). Note the variation in size of the microcline megacrysts and small dark inclusions of fine-grained mafic material. The rock has a mineral orientation which is parallel to the pencil. Locality: Forvik; UTM: 38400-729100.

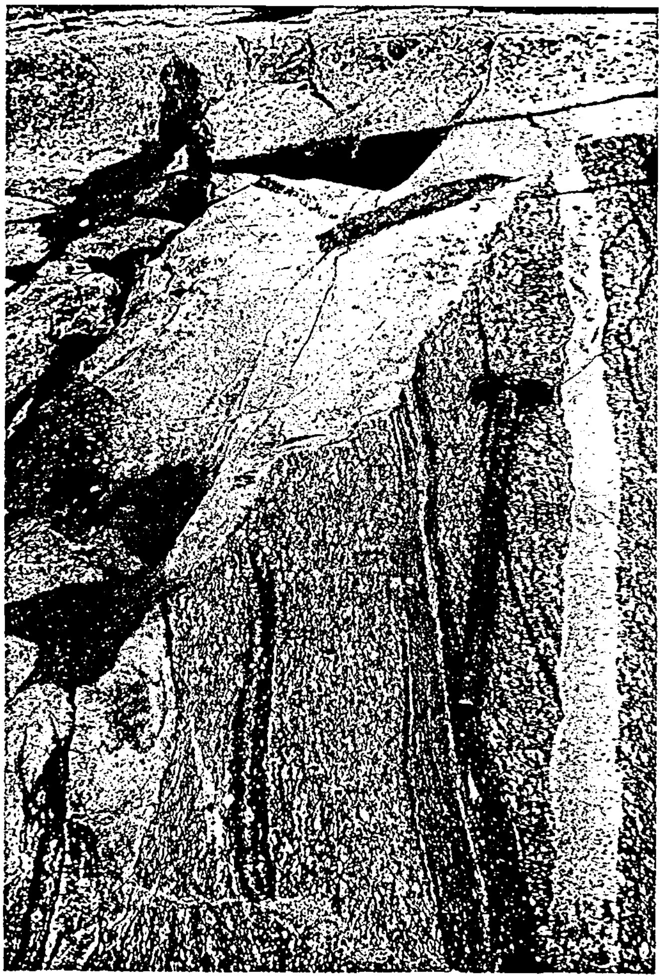


Figure 16. Strongly foliated megacrystic granodiorite (Andalshatten Pluton) with abundant mafic inclusions. The foliated rocks are cut by undeformed dykes and veins of leucocratic 2-mica granite. Hammer for scale: 80 cm. Locality: Visten; UTM: 39240-728315.

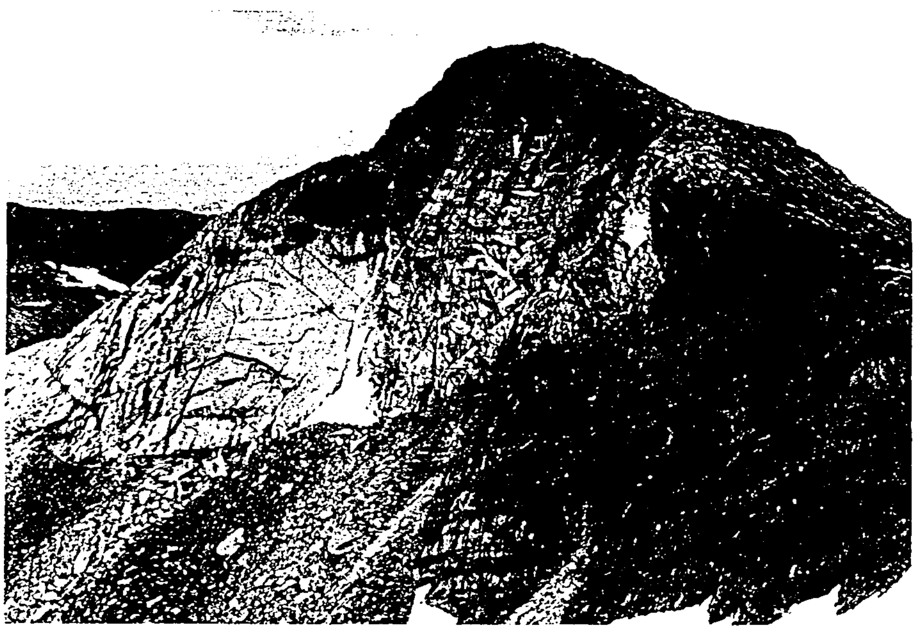


Figure 17. Porhyritic granodiorite of the Andalshatten Pluton (light grey) has intruded dark dioritic rocks. The figure shows the westward-facing cliff wall of Saltkartinden (966 m above sea level). The vertical height of the cliff is about 200 m. UTM: 38150-778160.

Figure 18. Medium-grained, foliated diorite with megacrysts of plagioclase and microcline. Megacryst-rich diorite may grade into veins and pods of granodioritic rocks similar to the Andalshatten Pluton (see below the knife). Locality: Forneshatten; UTM: 38320-727545.

3.2.10 Tonalitic rocks east of Velfjord

These rocks are present in a strike parallel zone along the eastern shore of Velfjord (Fig. 1). In general, the rocks are strongly foliated, and on outcrop scale they may exhibit notable heterogeneity in grain size and texture. Xenoliths of metasedimentary rocks, mostly calc-silicates, are present, and the tonalite is cut by grey diorite, pegmatite, aplite and mafic dykes. In the north, the tonalite is part of an elongate raft included in the Andalshatten Pluton together with concordant sheet-like zones of metasedimentary rocks (for details, see Nordgulen et al. 1991). In this area the rocks are partly granodioritic with more biotite than further south in Velfjord.

Rock type: Medium- to fine-grained leucotonalite.
Mineralogy: White, subhedral, partly recrystallised plagioclase (1-2 mm) with minor secondary muscovite growngg onto some grains. Quartz is pale grey and occurs as single grains and in elongate clusters (<5 mm). Biotite is more abundant than muscovite, and both micas are present as single flakes (c. 1 mm) aligned in the foliation. Accessory minerals: apatite, zircon and opaques.
Mineral orientation, foliation: Pervasive foliation
Distinguishing features: Strong foliation, muscovite present.

3.2.11 The Vega Granite

The Vega Granite is located on the island of Vega and adjacent islands in the central westernmost part of the BB (Fig. 1). A remarkable heterogeneity caused by the presence of metasedimentary inclusions is characteristic of the whole pluton, and in Figs. 20 and 21 examples of very inclusion-rich granite are shown. The contacts towards marbles and schists with local conglomerate horizons in the north are sharp and cross-cutting. The pluton is cut by a few granitic and mafic dykes.

Rock type: Medium-grained granodiorite to granite with abundant mafic clots and metasedimentary xenoliths.
Mineralogy: The feldspars are pale to brownish grey subhedral tablets. Plagioclase is variable sericitised and saussuritised. Quartz is grey to bluish grey and occurs as elongate, sometimes interconnected clusters aligned in the fabric. Biotite (c. 10 %) is present as small flakes (c. 1 mm). Muscovite is also common, and red-brown garnet (1-2 mm) may be present in fairly large amounts (up to 5%). Small mafic clots (5-20 mm) consisting mainly of garnet and biotite, are usually present in the rock. Accessory minerals: epidote, zircon, opaques, titanite/leucoxene, allanite, cordierite (?), tourmaline and calcite.
Mineral orientation, foliation: Moderate fabric defined by oriented biotite and lenticular quartz.
Distinguishing features: Mafic clots, abundant metasedimentary xenoliths.
Remarks: Apart from the anatectic granite north of the Heilhornet Pluton (Fig. 1), the Vega Granite appears to be unique among the studied plutons. It should be added, however, that at the Holm peninsula and in the region between Ursfjord and Velfjord there are metasedimentary rocks which exhibit partial melting phenomena similar to those associated with the anatectic granites. Granitic rocks that are probably derived from metasedimentary source rocks are also present in these areas.

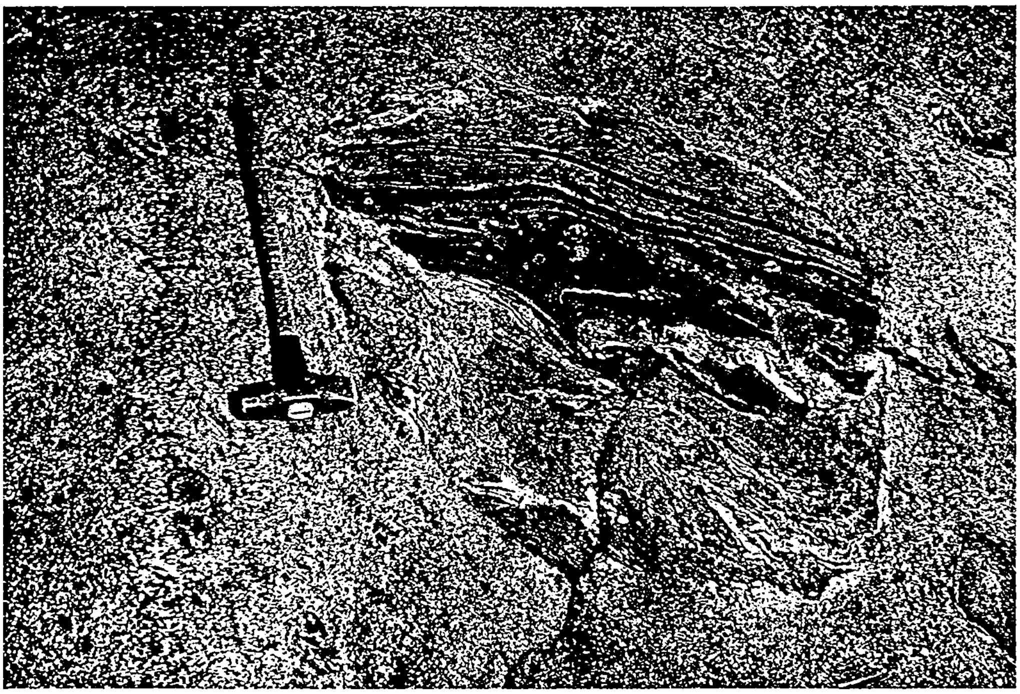


Figure 19. Heterogeneous Vega granite with abundant, small inclusions of metasedimentary rocks. A larger inclusion consisting of banded amphibolite and partly assimilated semipelitic material is c. 1 m across. Locality: Aunholmane;UTM: 63620-727985.

Figure 20. Vega granite with a large inclusion (c. 1 m in length) of dark, foliated amphibolite (calc-silicate rock) and abundant, more or less diffuse inclusions of metasedimentary material. Leucocratic, granitic material occurs along the margin of the large inclusion.
Locality: Aunholmane; UTM: 63620-727985.

Granites similar to those on Vega may also occur in the western part of the Hortavær intrusions (H. Furnes, pers. comm. 1987) as well as on the islands west of Dønna in the northwestern part of the batholith (S. Gjelle and M. Gustavson, pers. comm. 1987). Although the granites of the areas have not been part of this study, they are included as anatectic granitoids on Fig. 1.

The field evidence may suggest that the anatectic granites have been produced either by in situ anatexis followed by partial homogenisation, or alternatively by extreme contamination of melts transferred from lower levels in the crust. Sr-isotope data from a number of samples show substantial scatter, and high initial values are ubiquitous (Nordgulen & Sundvoll, 1992). This would suggest that crustal source regions were important in the genesis of the rocks.

3.3 The northernmost part of the batholith

3.3.1 Introduction

Some reconnaisance work has been done in this region in order to provide material for the geochemical data base. In addition, samples collected during an earlier NGU granite project have been analysed.

Three large plutons constitute the most prominent intrusions in the northernmost part of the BB. These are the Alsten and Toven Massifs, which consist of predominantly grey, porphyritic granite, and the Lifjell Massif consisting of fairly dark porphyritic granodiorite with pink microcline megacrysts (Fig. 1). The intrusions have elongate shapes and are oriented parallel to the regional NE-SW trending foliation in the metasupracrustal wall rocks.

The Mosjøen Gabbro (Fig. 1) is the largest mafic pluton in the batholith. It has been described in detail by Mickelson (1986) and Tørudbakken & Mickelson (1986), and here only some chemical analyses are included for comparative purposes. Near Mosjøen, a pluton termed the Fustvatnet Tonalite is present north and east of the Mosjøen Gabbro (Fig. 1, see Gjelle et al. 1990 for details). This pluton is clearly different from the Reinfjell Massif, which has been described by Theisen (1986). Further to the north, the sub-circular Helfjell Granite is present in addition to smaller plutons of diorite, monzonite and granite (Fig. 1).

The northwestern coastal districts of the batholith have not been investigated in this study, and the map is based on data from Gustavson & Gjelle (1992) and M. Gustavson and S. Gjelle (pers. comm. 1987).

3.3.2 The Alsten Massif

The Alsten Massif is located NW of Vefsnfjord (Fig. 1) and has the shape of an elongate, NE-SW trending sheet with steep attitude parallel to the foliation in the pluton and the wall-rock. A sub-horzontal NE-SW lineation is also present in the rocks. The intrusion is up to 6 km wide, and is exposed along strike for at least 30 km. Some large rafts of metasedimentary rocks are included in the pluton. The pluton has been studied at only a few localities in its southwestern part.

Rock type: Porphyritic granite.
Mineralogy: Grey, subhedral, tabular megacrysts (<3 cm) of microcline (b:c=1:3) aligned in the foliation. Plagioclase and microcline are present as grey, anhedral grains in the groundmass. Quartz is bluish grey and present in anastomosing clusters with biotite and feldspars. Accessory minerals: muscovite, garnet, zircon, apatite, epidote and opaques.
Mineral orientation, foliation: Strong, penetrative foliation.
Distinguishing features: Abundant, medium-sized microcline megacrysts, small garnets.

3.3.3 The Lifjell Massif

The intrusion is located SE of Ranafjorden (Fig. 1). It has an elongate shape (NE-SW) and is exposed along strike for about 35 km. It has a strong, steeply dipping foliation which strikes parallel to the long axis of the intrusion. Similar rocks are present at the island Dønna and on other islands NW of Ranafjorden. The description is based on studies along Ranafjorden in the westernmost part of the pluton.

Rock type: Porphyritic granodiorite.
Mineralogy: Pink, subhedral microcline megacrysts (<4 cm) occur as augen aligned in the foliation. The rock is rich in biotite and hornblende occurring as small crystals forming dense, elongate aggregates. The rest of the groundmass consists of augen and lenticles of both feldspars in addition to smaller amounts of strongly recrystallised quartz. Accessory minerals: dark brown, euhedral titanite, apatite, zircon and opaques.
Mineral orientation, foliation: Very strong and penetrative foliation.
Distinguishing features: Pink, augen-shaped megacrysts in a very dark groundmass.

3.3.4 Tourmaline granites south of Ranafjorden

An elongate granite body is present south of the Lifjell Massif. Studies along Ranafjorden in the western parts of the intrusion has shown that this is a medium-grained tourmaline granite with associated fine-grained dykes with abundant tourmaline. Dykes of tourmaline granite cut the Lifjell Massif.

Rock type: Medium-grained tourmaline granite.
Mineralogy: Biotite is present as books and flakes forming irregular, clotty masses. Muscovite usually occurs with biotite, but is also sprinkled through the rock. The feldspars, which cannot be differentiated in hand specimen, are grey with small blebs of colourless or pale grey quartz. Accessory minerals: Tourmaline, garnet, apatite, opaques, chlorite and calcite.
Mineral orientation, foliation: Strong foliation defined by biotite aggregates.
Distinguishing features: Abundant muscovite. Clots of biotite.

3.3.5 The Toven Massif

As shown on Fig. 1, the Toven Massif consists of both porphyritic and equigranular granite. However, studies along Vefsnfjord show that the field relations are considerably more complex than depicted on the map. In this area, several different rock types have intruded migmatitic garnet mica gneiss. The intrusives comprise mafic gabbro, diorite, foliated porphyritic granite, various types of medium-grained granitic dykes, as well as pegmatitic and aplitic dykes. The dykes cut the strong foliation in the gneiss and the porphyritic granite. In the eastern part of the massif large rafts, dominantly of calcite marble, are present (Gustavson & Gjelle 1992). Porphyritic granite occurring along the Vefsnfjord is briefly described here.

Rock type: Foliated porphyritic granite.
Mineralogy: Partly recrystallised augen of grey microcline (1-3 cm). The feldspars in the groundmass constitute a grey, recrystallised mosaic broken by dark grey quartz in lenticular clusters, and flakes of recrystallised biotite and muscovite aligned in the foliation. Accessory minerals: apatite, opaques and rounded or skeletal garnet.
Mineral orientation, foliation: Pervasive foliation.
Distinguishing features: Abundant grey augen, strong foliation, garnet present.

3.3.6 The Fustvatnet Tonalite

The pluton is located N of Fustvatnet and also east of the Mosjøen Gabbro south of Fustvatnet. From previously published maps (e.g. Gustavson 1981), the Fustvatnet Tonalite may possibly be regarded as the northward extension of the Reinfjell Massif. It is clear, however, that these bodies have distinctly different textures and should be regarded as separate intrusive units (see also Gjelle et al. 1990).

Rock type: Medium-grained, equigranular tonalite.
Mineralogy: Euhedral, pale grey, translucent plagioclase (c. 6 mm) with good twinning forms meshwork with euhedral, dull black prisms of hornblende (c. 4 mm). Small flakes of biotite have grown on hornblende, and quartz is present as subhedral to euhedral, translucent clusters. K-feldspar is present in trace amounts. Accessory minerals: dark brown, euhedral titanite, epidote, apatite, zircon and opaques.
Mineral orientation, foliation: Well developed alignment of hornblende and tabular plagioclase.
Distinguishing features: Prominent single hornblende.

3.3.7 The Helfjell Granite

This granite occurs in plan as an almost circular body in metasedimentary rocks north of the Mosjøen Gabbro (Fig. 1). The layering in the enclosing rocks wraps concordantly around the pluton (see Gustavson 1981, Gjelle et al. 1990).

Rock type: Medium-grained, equigranular granite.
Mineralogy: Greyish white, subhedral, zoned and twinned plagioclase (1-3 mm) and anhedral microcline (<3 mm); both feldspars may be partly recrystallised. Quartz occurs as recrystallised single grains and in elongate clusters. Flakes of muscovite and biotite (c. 1 mm) are more or less aligned in the foliation. Accessory minerals: apatite, allanite, epidote, zircon and opaques.
Mineral orientation, foliation: Strong, contact-parallel foliation along the margin of the pluton, weak foliation in the central part.

3.3.8 Monzonite north of Luktvatnet

An intrusion shown as monzonite on the map published by Gustavson & Gjelle (1992) has been studied along road sections in its southern part. The pluton appears to be complex and consists of coarse-grained monzodiorite with local porphyritic development of hornblende ("appinitic" texture) cut by medium-grained rocks of tonalitic to granodioritic composition.

Rock type: Medium-grained tonalite/granodiorite.
Mineralogy: Pale grey, anhedral and partly recrystallised plagioclase and K-feldspar. Biotite is present as very small flakes forming local concentrations in the rock. Quartz is pale grey with a brownish tinge and occurs as single grains and globular clusters including biotite. Accessory minerals: prominent, occasional 2 mm needles of euhedral allanite rimmed by anhedral epidote, white mica, apatite, titanite, zircon, opaques.
Mineral orientation, foliation: Moderate alignment of biotite.
Distinguishing features: Fine biotite.

3.4 The central eastern part of the batholith

3.4.1 Introduction

In the region between Mosjøen and Tosbotn, there are two major N-S trending plutons; the Visttindane Massif in the west and the Reinfjell Massif in the east (Fig. 1). Some minor elongate granite bodies occur south of Mosjøen. Granites similar to the Visttindane Massif continue towards the Oksdal Massif and the Fuglstadfjell area southeast of Tosen. In the Tosbotn region, monzodiorites and porphyritic granites are present (Fig. 1). A narrow zone of dioritic rocks can be followed from the Oksdal Massif in the south, across Tosen and to the area east of Velfjord in the north..

East of the Reinfjell Massif, an elongate NNE-SSW trending intrusion known as the Klubbfjell Massif (Theisen 1986, Gustavson 1988) is shown as diorite/gabbro on Fig. 1. On the map published by Gustavson (1981), it is depicted as porphyritic granite, and Gustavson (1988) stated that the pluton probably has variable composition, consisting of fairly dark and slightly porphyritic lithologies. The pluton has not been studied in this project.

Along the eastern boundary of the HNC, the map shows a fairly large body of quartz-diorite, tonalite etc. (Fig. 1). These rocks have not been investigated in detail, but some observations, by the author, in the Hattfjelldal region show that a number of different intrusive rocks ranging from mafic gabbro to leucogranite are present. The rocks are variably deformed and metamorphosed. Chemical data are not available from this area.

3.4.2 Foliated granitoids south of Mosjøen

10-20 km south of Mosjøen, lenticular, strike-parallel bodies of granite are present (Fig. 1). Rocks of similar aspect also occur further south in the Vefsn valley where they are spatially associated with the Reinfjell Massif. The rocks are strongly deformed with a penetrative foliation parallel to the foliation in the wall-rocks, and primary textures generally are not preserved.

Rock type: Foliated, medium-grained leucogranite.
Mineralogy: Greyish white feldspars are anhedral and occur as augen in the foliation. Anhedral, colourless quartz is present as lenticular ribbons aligned in the foliation. Muscovite is coarser and more abundant than biotite, both micas are present as flakes parallel to the foliation. Accessory minerals: epidote, apatite, zircon, opaques and chlorite.
Mineral orientation, foliation: Strong foliation.
Distinguishing features: Foliation, abundant muscovite.

3.4.3 The Reinfjell Massif

The Reinfjell Massif is a large intrusive body occurring SE of Mosjøen (Fig. 1). The massif is elongate parallel to the N-S trending regional foliation in the enclosing metasedimentary rocks. It consists of tonalite with abundant strike-parallel, tabular xenoliths and rafts of the wall rocks (Theisen 1986). For this study, samples from the southern part of the massif are described.

Rock type: Medium-grained tonalite.
Mineralogy: White plagioclase is present as augen in foliae together with flakes of biotite (25 %) which are present as nearly continuous clusters. Quartz occurs as pale grey, lenticular clusters. K-feldspar cannot be distinguished in hand specimen, but some small grains of interstitial microcline are present. Accessory minerals: Titanite, apatite, zircon and opaques.
Mineral orientation, foliation: Strong foliation defined by aligned plagioclase, biotite foliae and lenticular quartz.
Distinguishing features: Abundant biotite.

3.4.4 The Visttindane and Oksdal Massifs

The Visttindane Massif is a large intrusive body of medium-grained, equigranular granite (Fig. 21) present in the region between Velfjord and Visten in the west and Eiteràdalen in the east (Fig. 1). From Tosbotn the granite extends about 60 km to the north, and it is up to 15 km wide. In addition to the area near Tosbotn, the massif has been studied along two E-W profiles (Visten-Eiterådalen and Velfjord-Eiterådalen). The northermost part of the granite has not been visited. In the eastern part of the Visttindane Massif, large xenoliths of the wall rocks are abundant, occurring in a considerable area up to several kilometres away from the contact. The granite cuts discordantly across the strong foliation in the migmatitic gneisses and marbles of the wall rocks. Dykes of granite, aplite and pegmatite, some of which bear tourmaline, are common along the borders of the massif. In some cases, the dykes may extend more than 1 km into the wall rocks. The granite cuts porphyritic rocks and monzodiorite near Tosbotn.

Rocks generally similar to the Visttindane Massif are also present southeast of Tosen in the Oksdal Massif and in the Fuglstadfjell area (Fig. 1, see also Nordgulen et al. 1989, 1990). However, in the Oksdal Massif the field relations are more complex, and rocks of tonalitic composition occur in intimate association with granites and granodiorites. Dykes and smaller bodies of a highly evolved granite are more common than in the Visttindane Massif. In the Fuglstadfjell region, pale grey to white, medium- to fine-grained homogeneous granites are present.

Rock type: Generally medium-grained granite (locally tonalites and granodiorites are present).
Mineralogy: White, subhedral, twinned plagioclase (1-3 mm) with normal zoning is slightly altered in some samples. Grey to white, subhedral to anhedral microcline may include biotite, quartz and plagioclase. Dispersed flakes of biotite (<1 mm) may be partly chloritised. Anhedral, colourless to grey quartz occurs as rounded to oval single grains and irregular, recrystallised clusters. Small flakes of white mica can sometimes be distinguished. Accessory minerals: apatite, titanite, zircon, opaques and chlorite.
Mineral orientation, foliation: Normally a faint alignment of biotite. In some regions the alignment is more pronounced, especially adjacent to large raft trains south of Tosen.

Figure 21. Medium-grained, equigranular granite of the Visttindane Massif. Photograph of boulder in the stream at Austefjorddalen, Visten; UTM: 39860-728090.

3.4.5 Monzodiorite near Tosbotn

The rock described occurs on the northern shore of Tosen (Fig. 1), ca 3 km from Tosbotn (map sheet 1825-1 Tosbotn, UTM 40180-724475). A U-Pb zircon date on the rock has yielded an age of 430 ± 7 Ma (Nordgulen et al., in press). The monzodiorite is cut by medium-grained granite assigned to the Visttindane Massif. Xenoliths of porphyritic granite indicates that the monzodiorite is younger than the porphyritic granite near Tosbotn.

The texture of the monzodiorite is very similar to that commonly observed in the Akset-Drevli Pluton (Barnes et al. 1992) of the Velfjord Massif. The rocks are also chemically comparable (see below). This raises the possibility that the mafic plutons in Velfjord may be temporally related to the monzodiorite in Tosen, and thus of Early Silurian age.

Rock type: Coarse-grained, mafic monzodiorite.
Mineralogy: The rock consists essentially of pale pink, euhedral laths of plagioclase (<20 mm) in sub-ophitic intergrowth with euhedral hornblende prisms (<15 mm) overgrown by shiny black flakes of biotite (<2 mm). Some small grains of quartz and interstitial K-feldspar. Accessory minerals: titanite, opaques, apatite and zircon.
Mineral orientation, foliation: Crude alignement of plagioclase and hornblende prisms.
Distinguishing features: Pink, twinned plagioclase laths, large prismatic hornblende.

3.4.6 Porphyritic rocks in the Kalvvatn-Tosbotn area

This rock type occurs in the Tosbotn region and adjacent to the northern parts of the Kalvvatn Monzonite (Fig. 1). The rocks exhibit a relatively large textural variation, especially in the shape and abundance of megacrysts. Thus, near the northern part of the Kalvvatn Monzonite, as well as in xenoliths within it, porphyritic rocks with few and scattered megacrysts are not uncommon.

Rock type: Porphyritic granite with medium-grained groundmass. Mineralogy: Variably sized, subhedral to euhedral white megacrysts locally up to 5 cm in length. Medium-grained groundmass, usually well foliated, with grey, anhedral feldspars, lenticular clusters of grey quartz and elongate aggregates and flakes of biotite (<1 mm). Accessory minerals: allanite, epidote, apatite, zircon and opaques.
Mineral orientation, foliation: Moderate, locally strong with aligned K-feldspar megacrysts and foliated groundmass.

3.4.7 Dioritic rocks east of Lande, Tosen

Between Velfjord and Tosbotn, a fairly narrow, N-S trending zone of dioritic rocks occurs as an elongate sheet terminating against the Oksdal Massif in the south and the Visttindane Massif in the north (Fig. 1). Generally, the zone consists of medium-grained foliated diorite to monzodiorite with fabrics parallel to the foliation in the migmatitic gneiss in which they occur. The description provided here is based on reconnaisance studies along coastal outcrops north of Tosen. In places, the diorite is cut by heterogeneous intrusive breccias. The groundmass of the breccias is commonly medium-grained and range in composition from mafic diorite to

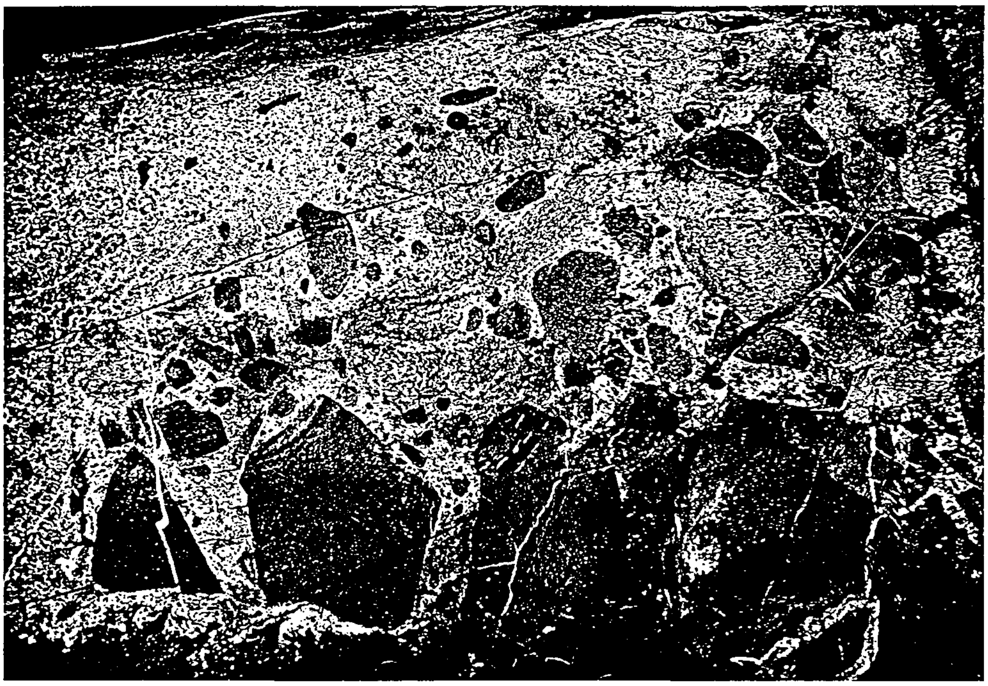


Figure 22. Intrusive breccia with angular to sub-rounded inclusions of various types of intrusive rocks in a granodioritic groundmass. Lens cap for scale. Locality: Elvvika, NE of Lande; UTM: 39820-724020.

Figure 23. Foliated, medium-grained quartz diorite with thin aplite veins is cut by sub-vertical breccia dyke. The breccia dyke has granodioritic groundmass and contains abundant inclusions of foliated quartz diorite and dark, fine-grained diorite.
Locality as in Fig. 22.

quartz monzodiorite to granodiorite. Angular to rounded inclusions of broadly similar composition are present in variable abundance, and range in size from less than 1 cm to larger than 1m across (Fig. 22). The breccias may also form dykes which cut the fabric in the diorite (Fig. 23). Numerous types of mafic, composite and pegmatitic to aplitic dykes are also present. Several textural types of diorite occur including rocks with acicular amphibole. Locally, needle-shaped amphiboles up to several centimetres in length are oriented parallel or sub-parallel to each other. The main type of foliated diorite is described below.

Rock type: Medium-grained, equigranular, foliated diorite to monzodiorite .
Mineralogy: Anhedral to subhedral, grey plagioclase and subhedral hornblende, sometimes forming small clots, are the main minerals. Biotite is present as small single grains. Quartz and microcline are interstitial. Epidote and titanite are comparatively abundant. Other accessory minerals: apatite, zircon and opaques.
Mineral orientation, foliation: Strong foliation defined by oriented mafic minerals.
Distinguishing features: Heterogeneous intrusive breccias may be present.

3.5 The southeastern part of the batholith

3.5.1 Introduction

The region described here is located between Harran and Tosbotn in the southeastern part of the HNC (Fig. 1). In the Tosbotn-Namsskogan area, new mapping has been carried out since map sheet Mosjøen was published by Gustavson (1981), and the geology depicted on Fig. 1 is simplified from Nordgulen et al. (1989, 1990). The most prominent intrusions in the area are the Kalvvatn Monzonite and the Kongsmoen Massif in the south. East of the Kalvvatn Monzonite, migmatitic garnet gneisses and some marbles alternate with tonalitic to granitic rocks which commonly contain variable amounts of metasedimentary xenoliths. The rocks occur in comparatively narrow, steep belts parallel to the NE-SW to N-S strike direction.

West of the Kalvvatn Monzonite there are also narrow belts of metasedimentary rocks, and east of Tosen contacts between granite and migmatitic gneiss are often transitional (see Nordgulen et al. 1990). South of the Kalvvatn Monzonite metasedimentary rocks occur as prominent raft trains both in porphyritic rocks and in the equigranular granites of the Oksdal Massif. Minor bodies of hornblendite and gabbro are present in the gneisses and occur as inclusions in the granitoids.

Along the eastern boundary of the HNC, east of Majavatn-Namsskogan, there are some plutons of tonalitic to granitic composition, however, these rocks have not been part of this study.

3.5.2 The Kalvvatn Monzonite

The pluton is homogeneous and measures 15 km along the N-S strike direction and 6-8 km in the E-W direction (Fig. 1). It has a well developed planar mineral fabric with steep to intermediate dips towards the east. Mafic enclaves, which are oriented parallel to the fabric, are abundant in most parts of the pluton. Numerous granitic to aplitic and pegmatitic dykes cut the monzonite.

Rock type: Medium- to coarse-grained quartz monzonite.
Mineralogy: White plagioclase and microcline (<12 mm) are present in a coarse interlocking fabric with non-distinct grain boundaries. Euhedral, dull black prisms of hornblende (<10 mm) are common, though some of the hornblende grains are more ragged and enclose feldspar. Small flakes of biotite occur on hornblende. Anhedral, colourless quartz is present as small blebs (<2 mm) between feldspar laths. In the northwestern part of the pluton the texture is characterised by prismatic amphibole needles in a medium-grained groundmass. Accessory minerals: distinctly euhedral, dark reddish brown titanite, epidote, apatite, zircon and opaques.
Mineral orientation, foliation: Well developed mineral alignment defined by hornblende prisms and tabular feldspar.
Distinguishing features: Stubby hornblende prisms, abundant euhedral titanite.

3.5.3 Porphyritic granite

This rock crops out in the Kalvfjellet area south of the Kalvvatn Monzonite (Fig. 1) in the southern part of the Majafjellet map sheet (Nordgulen et al. 1990). It has abundant xenoliths of metasedimentary rocks, which tend to form raft trains parallel to a moderate fabric in the pluton. There are also some inclusions of hornblendite and gabbro. Field relations indicate that it is older than the Kalvvatn Monzonite. Contacts towards granite in the south and west are not clear, and locally a transitional contact appears to be present. However, regional considerations would favour a younger age for the equigranular granites.

Rock type: Porphyritic granite.
Mineralogy: Subhedral to anhedral megacrysts of white microcline (<2 cm) with inclusions of biotite and subhedral tablets of plagioclase (1 mm). In the groundmass, there are white, subhedral to anhedral feldspars (c. 3 mm). Quartz is partly recrystallised and occurs as brownish grey, irregular to linear clusters. It is often associated with biotite which is present as single flakes (<1 mm) or in occasional concentrations. Some small flakes of muscovite are present in minor amounts. Accessory minerals: apatite, epidote, zircon, opaques, chlorite and calcite.
Mineral orientation, foliation: Moderate to weak defined by oriented megacrysts and biotite.
Distinguishing features: Relatively small K-feldspar megacrysts contrast with medium-grained groundmass.

3.5.4 Tonalite northwest of Namsskogan

The tonalite is located NW of Namsskogan (Fig. 1) where it occurs as an elongate body parallel to the regional NE-SW strike direction (Nissen 1986). Xenoliths of migmatitic gneiss are common and are oriented parallel to the foliation in the pluton, which is cut by granitic and pegmatitic veins. Nissen (1986) obtained a Rb-Sr whole-rock date of 503 ± 26 Ma for tonalites west of Namsskogan. However, a sample of the same unit collected SE of the Kalvvatn Monzonite (Fig. 1) yielded a U-Pb zircon date of 437 ± 4 Ma, which is interpreted as the crystallisation age for the rock (Nordgulen et al. in press).

Rock type: Medium- to coarse-grained tonalite to granodiorite.
Mineralogy: The rock is dominated by grey, subhedral plagioclase. Small megacrysts of microcline (<10 mm) with inclusions of plagioclase are present, implying that this rock should be

termed mafic granodiorite rather than tonalite. Small grains of biotite (15-20 %) occur as books and flakes in foliae and occasionally as isolated dark clots. Quartz is present in anhedral, pale grey, lenticular clusters usually associated with biotite. Accessory minerals: clinopyroxene, hornblende, titanite, epidote, allanite, apatite, zircon, opaques and chlorite.
Mineral orientation, foliation: Strong to moderate foliation.
Distinguishing features: Abundant small biotites.

3.5.5 Granodioritic rocks northwest of Namsskogan

East of the tonalite in Frøyningsdalen the intrusive rocks consist dominantly of light grey, equigranular granodioritic rocks (Nissen 1986, 1988, Nordgulen et al. 1990). The colour index and textures are somewhat variable, however, sharp contacts between clearly different rock types have not been observed in this region. The rocks are therefore treated as one unit although there may be a range in composition from leucocratic tonalites to granite within the group.

Rock type: Grey, equigranular, medium-grained granodioritic rocks.
Mineralogy: White to pale grey, subhedral plagioclase and microcline constitute c. 70 % of the rocks. The microcline may locally exhibit incipient development of megacrysts. Biotite (c. 10 %) may occur as dispersed single flakes or in mossy aggregates on foliation planes. Quartz is pale grey and may be present as anhedral single crystals or as globular or linear clusters with biotite inclusions. Muscovite is occasionally present in trace amounts. Common accessory minerals: epidote, allanite, apatite, zircon, titanite, chlorite and opaques.
Mineral orientation, foliation: Usually moderate defined by lenticular quartz and oriented biotite.

3.5.6 The Kongsmoen Massif

This megacrystic pluton covers a large area in the southernmost part of the batholith (Fig. 1). East of Kongsmoen the rock becomes strongly deformed and mylonitised towards the western boundary of the HNC (Roberts et al. 1983). Only the northwestern part of the pluton has been investigated in this study. Large rafts of metasedimentary rocks and diorites are present in the pluton. In the north it is cut by equigranular granites, and also by dykes of granite, aplite and pegmatite.

Rock type: Porphyritic granite to granodiorite.
Mineralogy: Subhedral to euhedral pink megacrysts of microcline (<5 cm) with inclusions of small tablets of plagioclase. In the groundmass there is subhedral plagioclase (<3 mm) and anhedral microcline, and quartz occurs as single grains or in clusters. Hornblende is present as subhedral to euhedral, stubby prisms and contains inclusions of titanite and opaques. Biotite in small flakes (1 mm) is generally less abundant than hornblende. Accessory minerals: titanite, epidote, apatite, zircon, opaques and chlorite.
Mineral orientation, foliation: Moderately oriented megacrysts, weak foliation in the groundmass. Mylonitic fabrics along the western boundary.
Distinguishing features: Pink megacrysts in fairly dark matrix.

3.6 Granite dykes

These rocks are present with variable abundance in the BB. Since there is limited variation in texture and mineralogy, they are treated as one group. The majority of the dyke rocks sampled for this study are from the southern parts of the batholith.

The dykes vary in thickness from thin veins to prominent sheets more than 100 m wide (Figs. 4 and 16). They cut the regional S_2 foliation, but are affected by late open folds assigned to D_3. The dykes are generally among the youngest igneous phases in any one area.

Rock type: Medium- to fine-grained 2-mica granite and granodiorite.
Mineralogy: Grey to white, subhedral to anhedral microcline and plagioclase, the latter usually with normal zoning. Quartz occurs as single grains or in clusters. Biotite is present as small flakes (ca 1mm) or in clusters and is generally more abundant than muscovite. Accessory minerals: titanite, epidote, apatite, zircon, opaques and chlorite.
Mineral orientation, foliation: Variable. In some rocks there is a pronounced orientation of biotite and lenticular clusters of quartz.

4 GEOCHEMISTRY

4.1 Introduction

This account of the geochemistry of the BB is based on chemical analyses of c. 500 samples. For some plutons, which have been studied in detail, only a limited number of representative analyses have been selected from a larger set of samples, reducing the number of analyses presented here to 346. Each sample in this population has been assigned to one of 9 different groups established by field and petrographic criteria (Fig. 1):

1. Gabbro, diorite and monzodiorite
2. Tonalite, granodiorite and trondhjemite
3. Porphyritic granodiorite
4. Porphyritic granite
5. Quartz monzonite and syenite
6. Granite and granodiorite
7. Tourmaline granite
8. Anatectic granite
9. Granitoid dykes

4.2 Analytical procedures

The major elements and 20 trace elements have been determined by XRF spectroscopy on Philips instruments at Midland Earth Science Associates (Nottingham, UK), Caleb Brett Laboratories (Merseyside, UK) and at the geochemical laboratory of NGU (Trondheim). A limited number of major element analyses were made at the University of Bergen. The analyses were done on glass discs for the major and on pressed powder pellets for the trace elements. Analyses of standards, and re-analyses of samples at different laboratories have shown that precision and inter-laboratory differences are acceptable for qualitative interpretation of the data.

4.3 Major element relations

The samples from the BB have a range in composition from c. 44 to 76 % SiO_2. In the AFM diagram (Fig. 24), the rocks of the BB plot in the calc-alkaline field, and they are similar to the Scottish granitoids although the latter ones tend to plot slightly closer to the M-apex. Harker diagrams show that for the mafic rocks (SiO_2 < 55%), many elements exhibit substantial compositional variation at similar levels of SiO_2. However, considering the whole compositional spectrum, the major element data show that TiO_2 (Fig. 25), Fe_2O_3 (total Fe), MgO, CaO, P_2O_5 (Fig. 26) and MnO decrease with increasing SiO_2. Al_2O_3 and Na_2O increase slightly in mafic rocks. In more evolved rocks Al_2O_3 decreases whereas Na_2O is essentially constant. K_2O has variable abundances but generally increases with SiO_2 (see below).

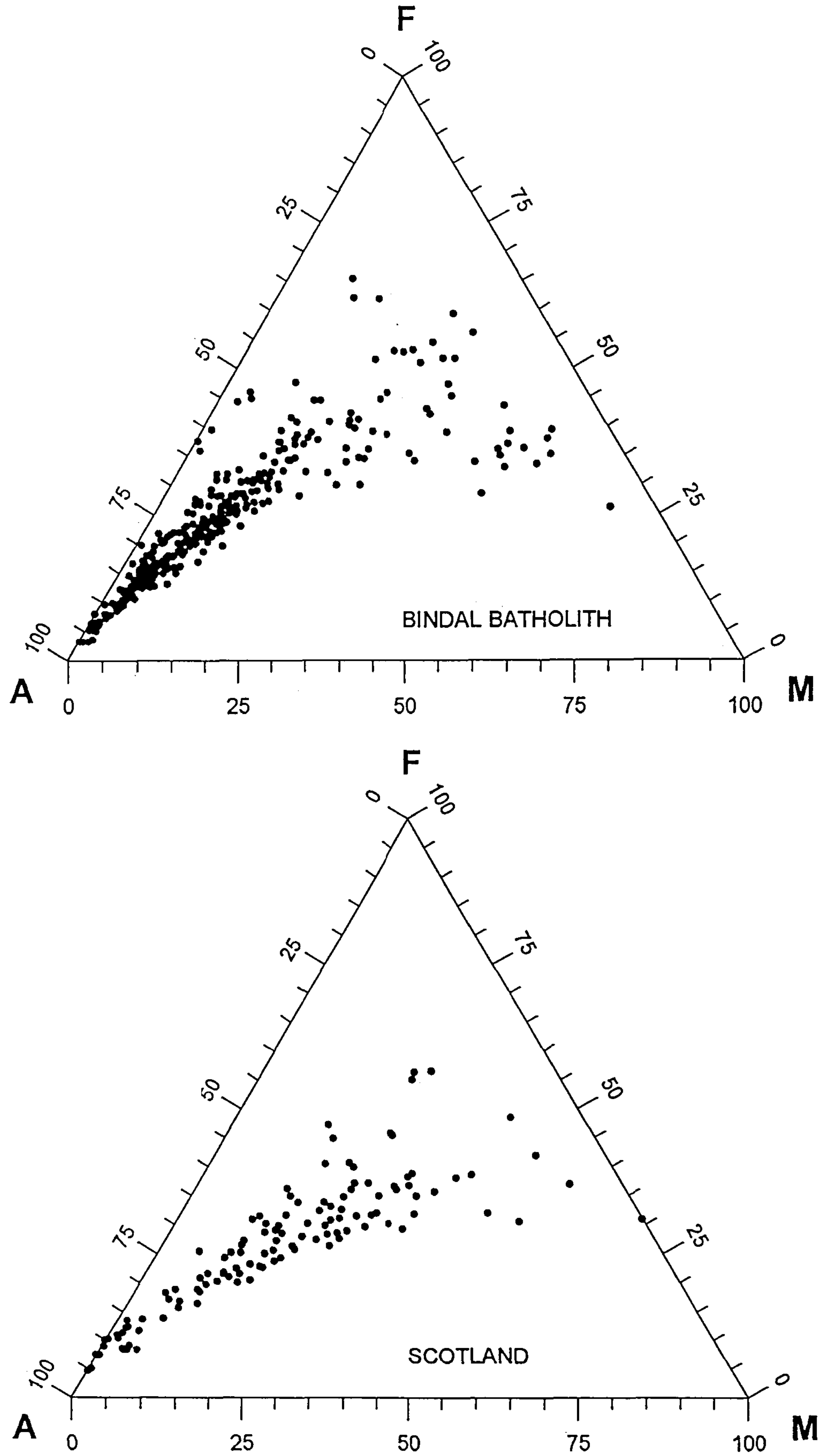


Figure. 24. AFM diagram showing the calc-alkaline nature of the Bindal Batholith (346 samples). Data from Caledonian granites in Scotland and Southern Uplands (Stephens & Halliday 1984) are shown for comparison.

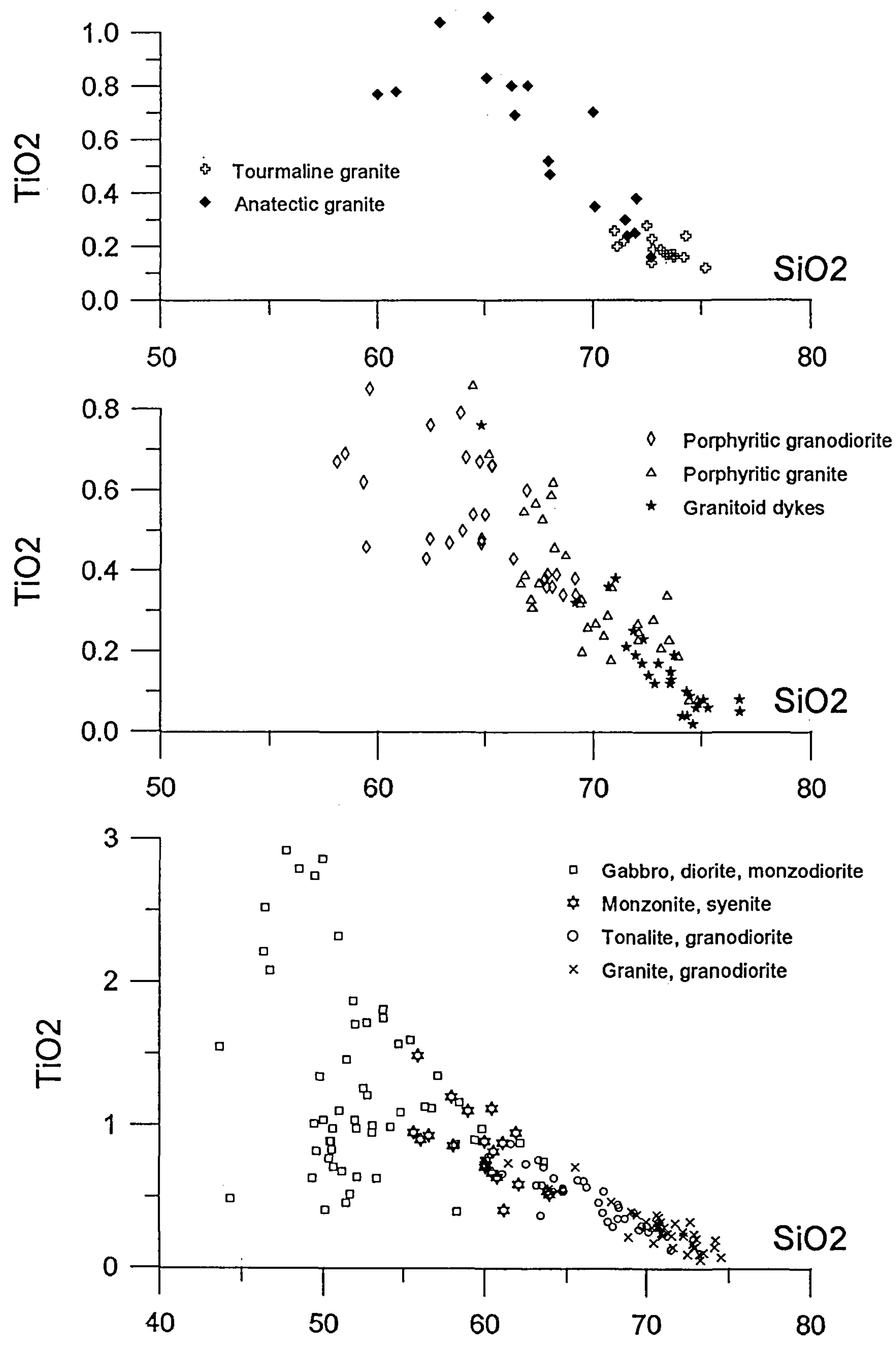


Figure 25. TiO_2 (wt %) plotted against SiO_2 (wt %). For the tonalite/granodiorite and granite/granodiorite groups 50 % of the data have been plotted.

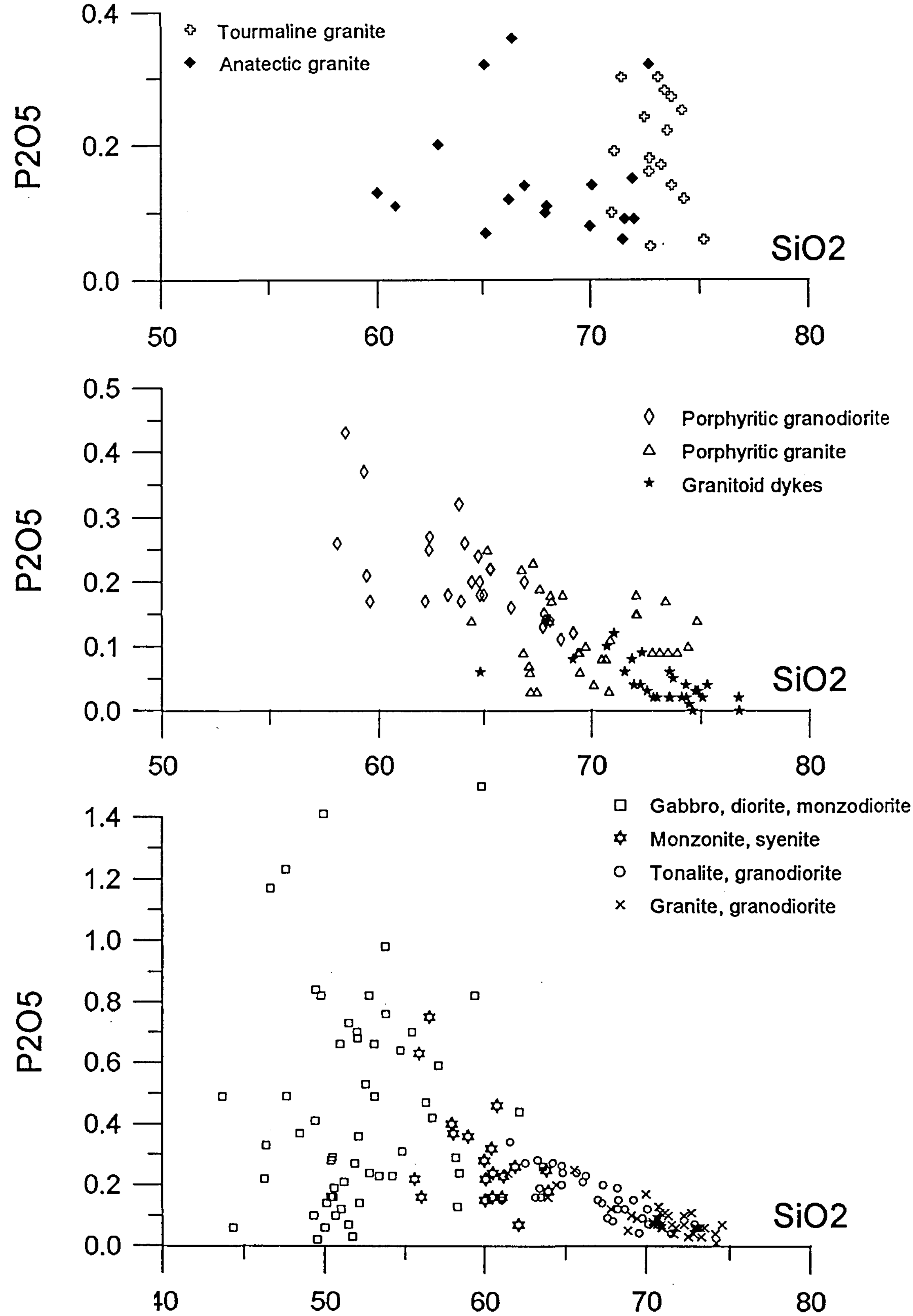


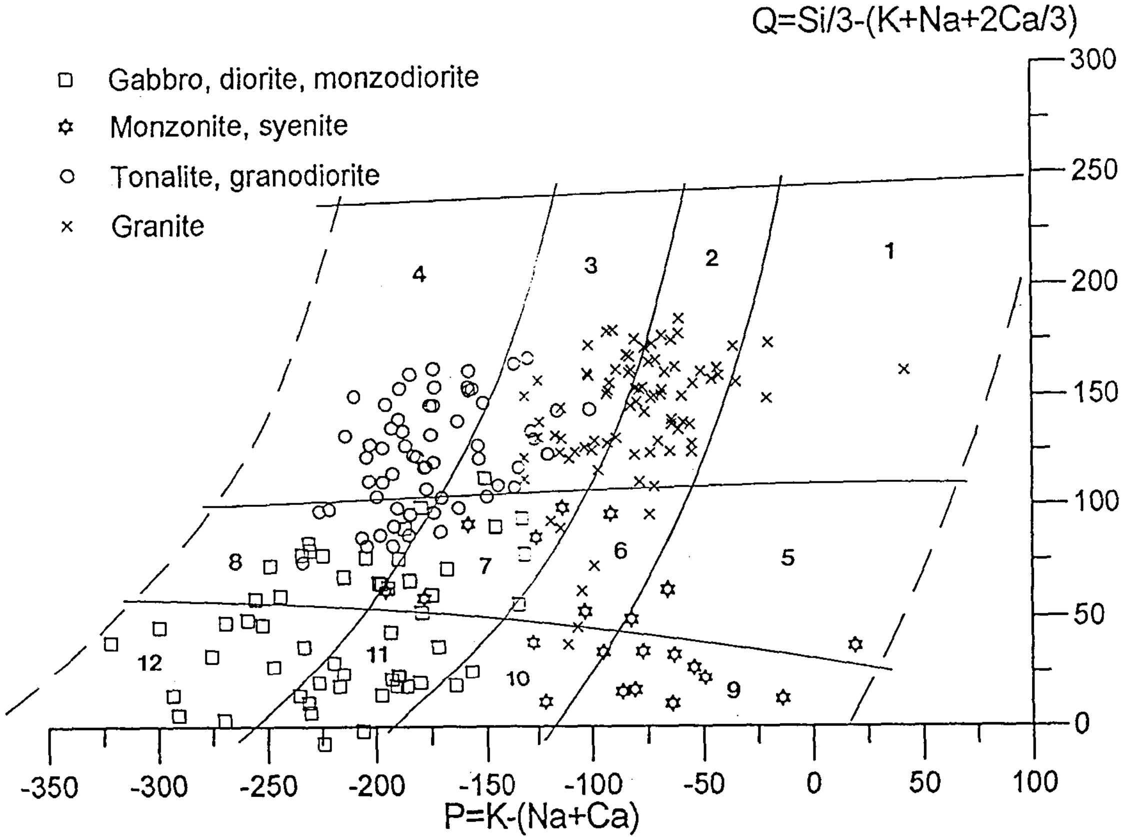
Figure 26. P_2O_5 (wt %) plotted against SiO_2 (wt %). For the tonalite/granodiorite and granite/granodiorite groups 50 % of the data have been plotted.

The classification diagrams of Debon & LeFort (1983) are used to classify the rocks, especially since these diagrams separate better between the rocks of mafic composition than diagrams based on modal composition (e.g. Streckeisen 1976). Plotting the data in the nomenclature diagram generally confirms the earlier field classification and shows a wide range of petrographic types (Fig. 27). The mafic to intermediate rocks plot in fields 7, 8, 11 and 12. Notice that quartz monzonitic to monzonitic rocks from the most evolved part of the Velfjord Massif are included in this group. A significant proportion of the rocks with less than 56 % SiO_2 have fairly high contents of K_2O (Fig. 29) and plot on calc-alkaline to alkali-calcic trends (Fig. 30). The plutons of Velfjord Massif provide an important example of rocks having these compositional characteristics (Barnes et al. 1992). However, a number of samples have low K_2O and are calcic to calc-alkaline; e.g. the Mosjøen Gabbro. The large compositional variation within this group is also illustrated by Figs. 31 and 32. Generally, mafic to intermediate rocks exhibit a large scatter in element content which may be attributed to cumulate effects. This is also reflected in the considerable range in the content of mafic minerals shown by the characteristic minerals diagram (Fig. 28).

Rocks of tonalitic to granodioritic composition are represented by a few comparatively large plutons including the Kråkfjellet Pluton and the Reinfjell Massif (Fig. 1). Generally, the tonalites have higher CaO, lower K_2O (Fig. 29) and lower total alkalies (Fig. 32) than granodiorites and granites. The rocks are calcic to calk-alkaline and commonly show fairly high values for Na_2O (5-6 %) and Sr (Figs. 31 and 34). Although they overlap in composition with the granite-granodiorite group, the tonalites tend to have higher contents of mafic minerals and, with some exceptions showing positive A-values, they are metaluminous and dispersed in field IV of the characteristic minerals diagram (Fig. 28).

Porphyritic granites and granodiorites plot in two distinctly different but overlapping fields in Fig. 27. A number of granodiorites have Q-values less than 100, showing transition towards monzonitic composition. This is also reflected in Fig. 30 where the megacrystic granodiorites plot on both calc-alkaline and alkali-calcic trends. Compared with the granites, the granodiorites tend to have less quartz and higher contents of mafic minerals and plot in field IV of Fig. 28. The generally metaluminous nature of the rocks separates them from those classified as granites. This confirms the broad two-fold division of the megacrystic rocks based on field and petrographic criteria.

The porphyritic granites generally contain biotite + muscovite ± garnet, and although there is considerable variation within the group, most of the samples plot in the fields of peraluminous rocks (II and III) in Fig. 28. Some plutons are uniformly evolved (e.g. Sklinna), whereas others display fairly large compositional variation. Samples associated with mafic to intermediate intrusions in the Velfjord area (SiO_2: 64-71 %) are distinguished by having positive A-values combined with rather high contents of mafic minerals (B>45, Fig. 28). Those from the area between Ursfjord and Velfjord (see 3.2.5) have lower contents of HFS-elements than those associated with the Velfjord Massif (see 3.2.7); however, the rocks are otherwise very similar. Field and petrographic evidence and high initial Sr values indicate that



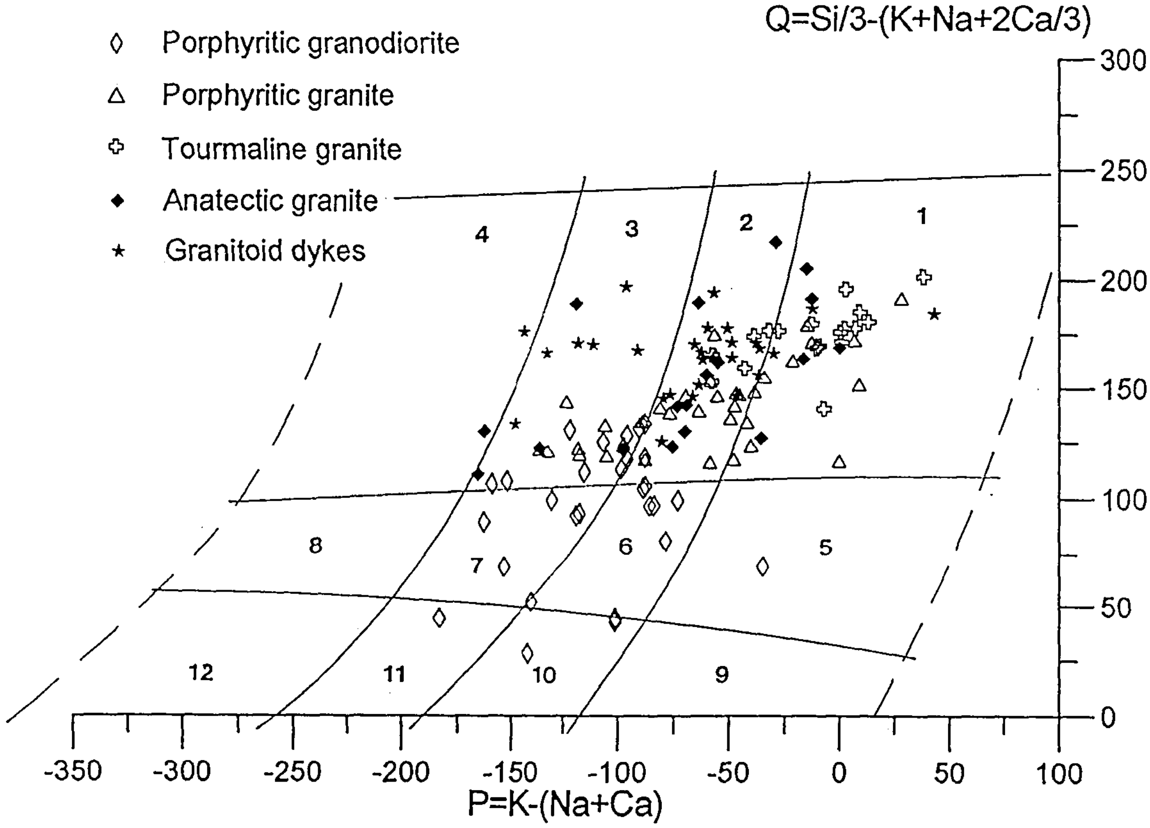


Figure 27. Nomenclature diagram after Debon & LeFort (1983). Units are in gram-atoms x 10^3 of each 100 gram of rock. The fields shown are: 1) granite, 2) adamellite, 3) granodiorite, 4) tonalite, 5) quartz syenite, 6) quartz monzonite, 7) quartz monzodiorite, 8) quartz diorite, 9) syenite, 10) monzonite, 11) monzogabbro, 12) gabbro.

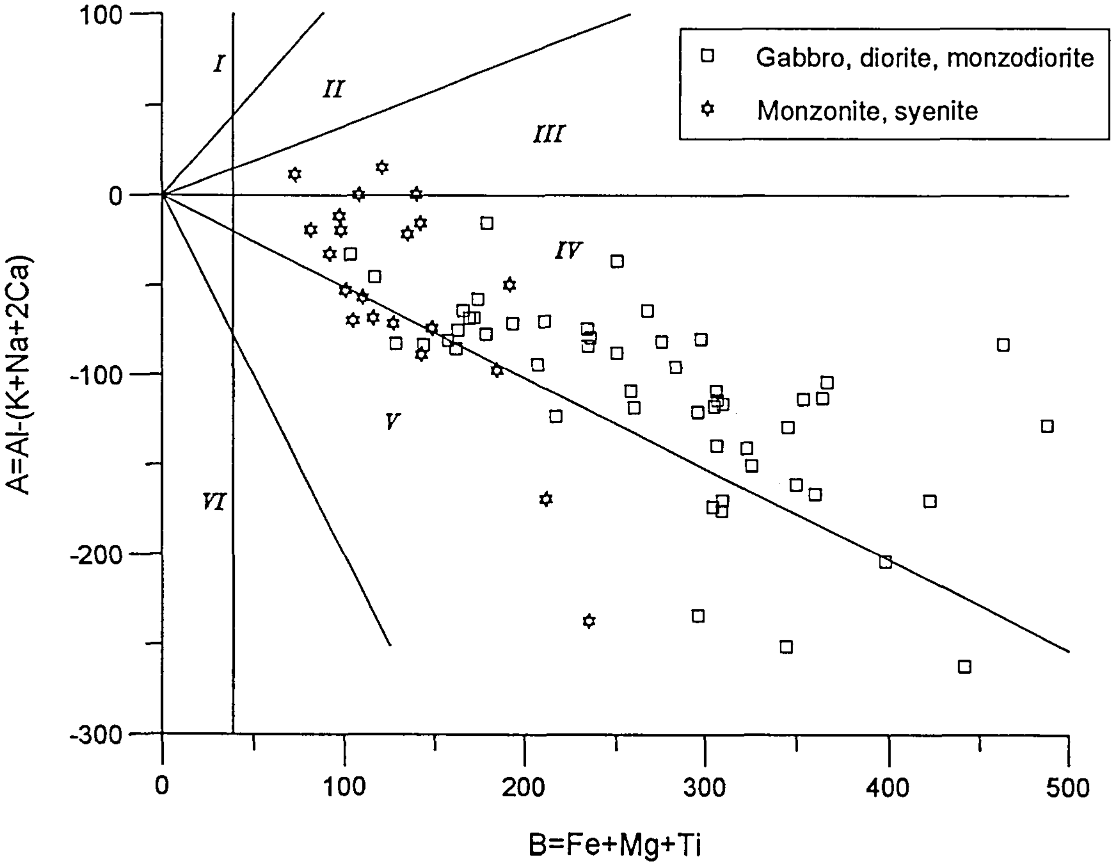
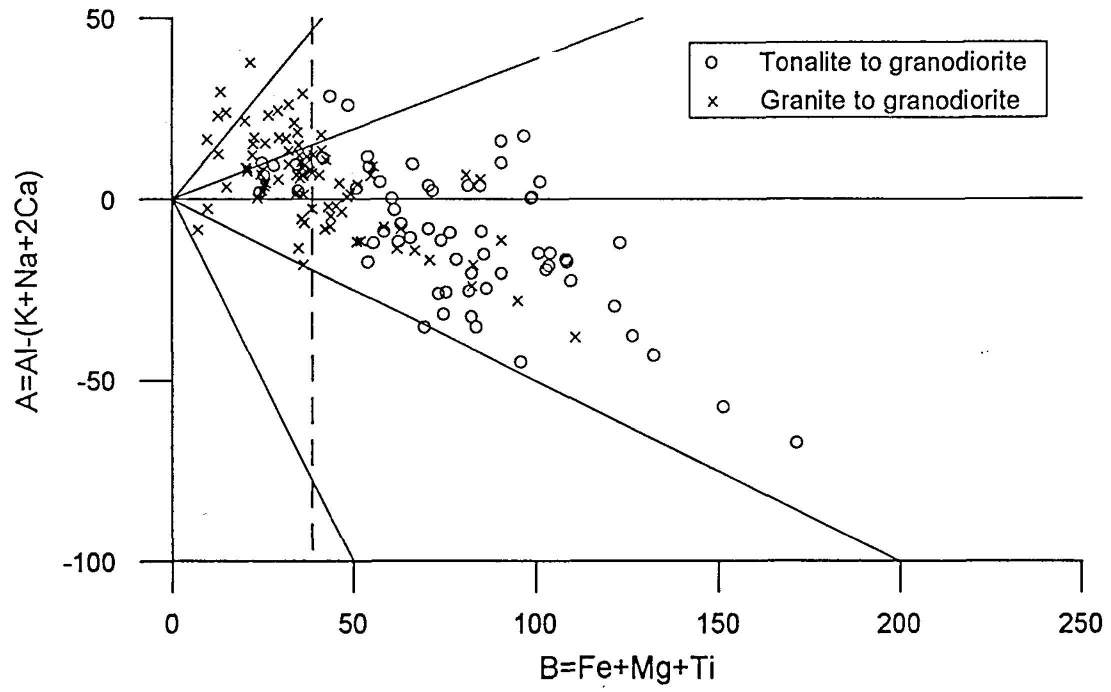


Figure 28. "Characteristic minerals" diagram after Debon & LeFort (1983). Units are in gram-atoms x 10^3 of each 100 gram of rock. The diagram is divided into six sectors numbered from I to VI with the following characteristic minerals: I) Mu>Bi, II) Bi>Mu, III) Bi, IV) Bi ± Hbl ± Opx ± Cpx ± Ol ±, V) ± Cpx ± Hbl. Rocks with B values less than 38.8, equivalent to c. 7 % of mafic minerals, are termed leucogranites.



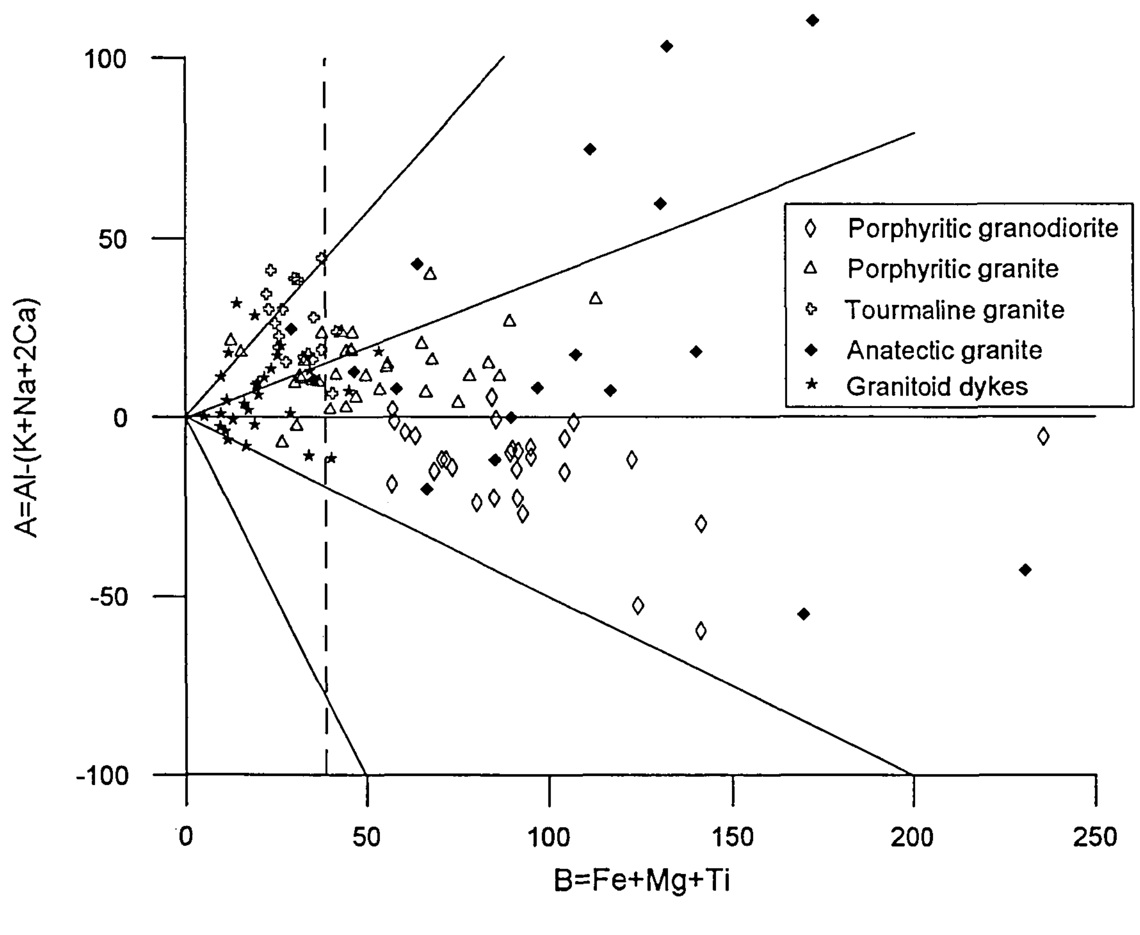


Figure 28 (continued). "Characteristic minerals" diagram, see previous page for an explanation of the figure.

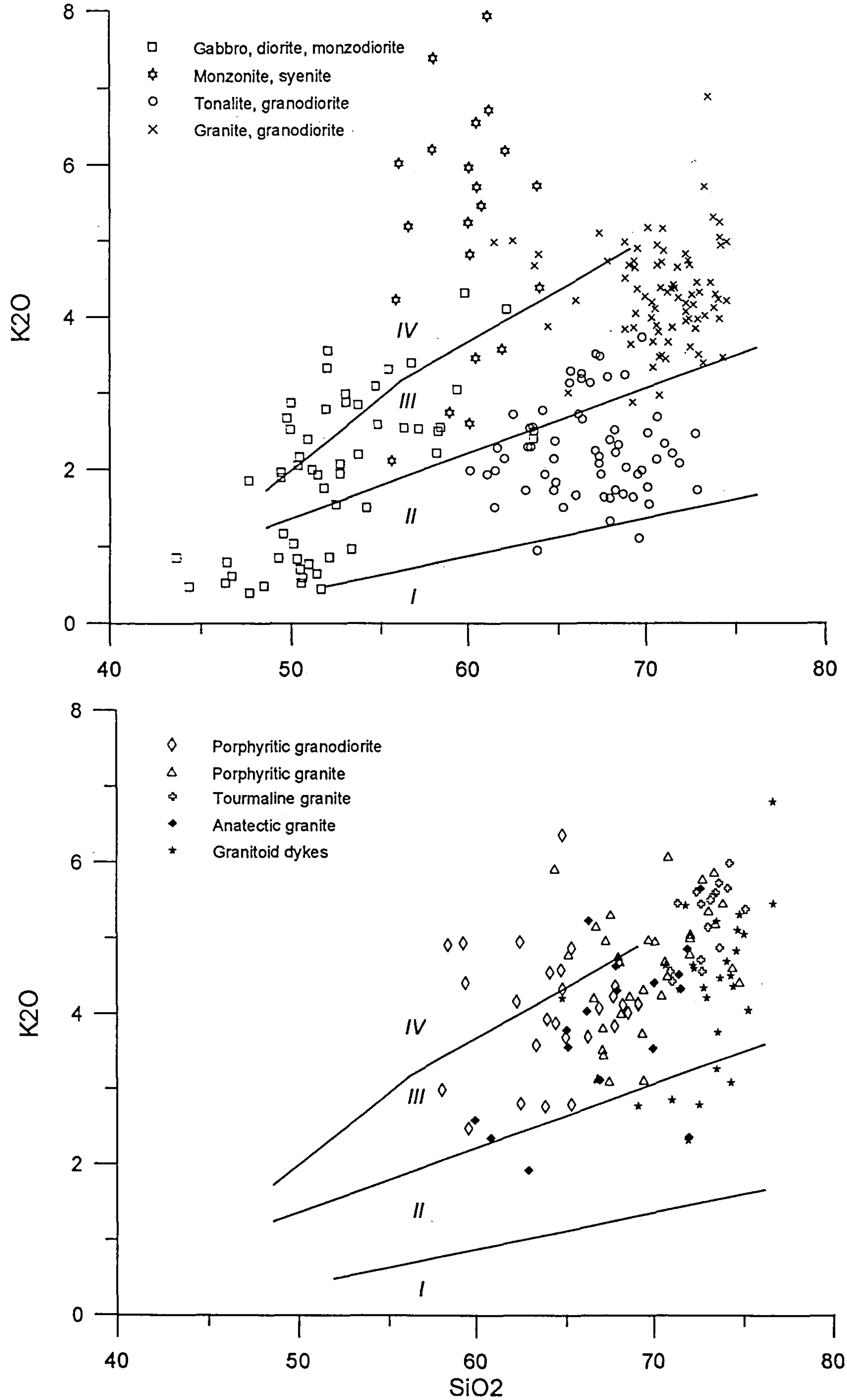


Figure 29. K_2O (wt %) plotted against SiO_2 (wt %). Compositional fields adapted from Pecerillo & Taylor (1976). I) Low-K calc-alkaline, II) Calc-alkaline, III) High-K calc-alkaline, IV) Shoshonite.

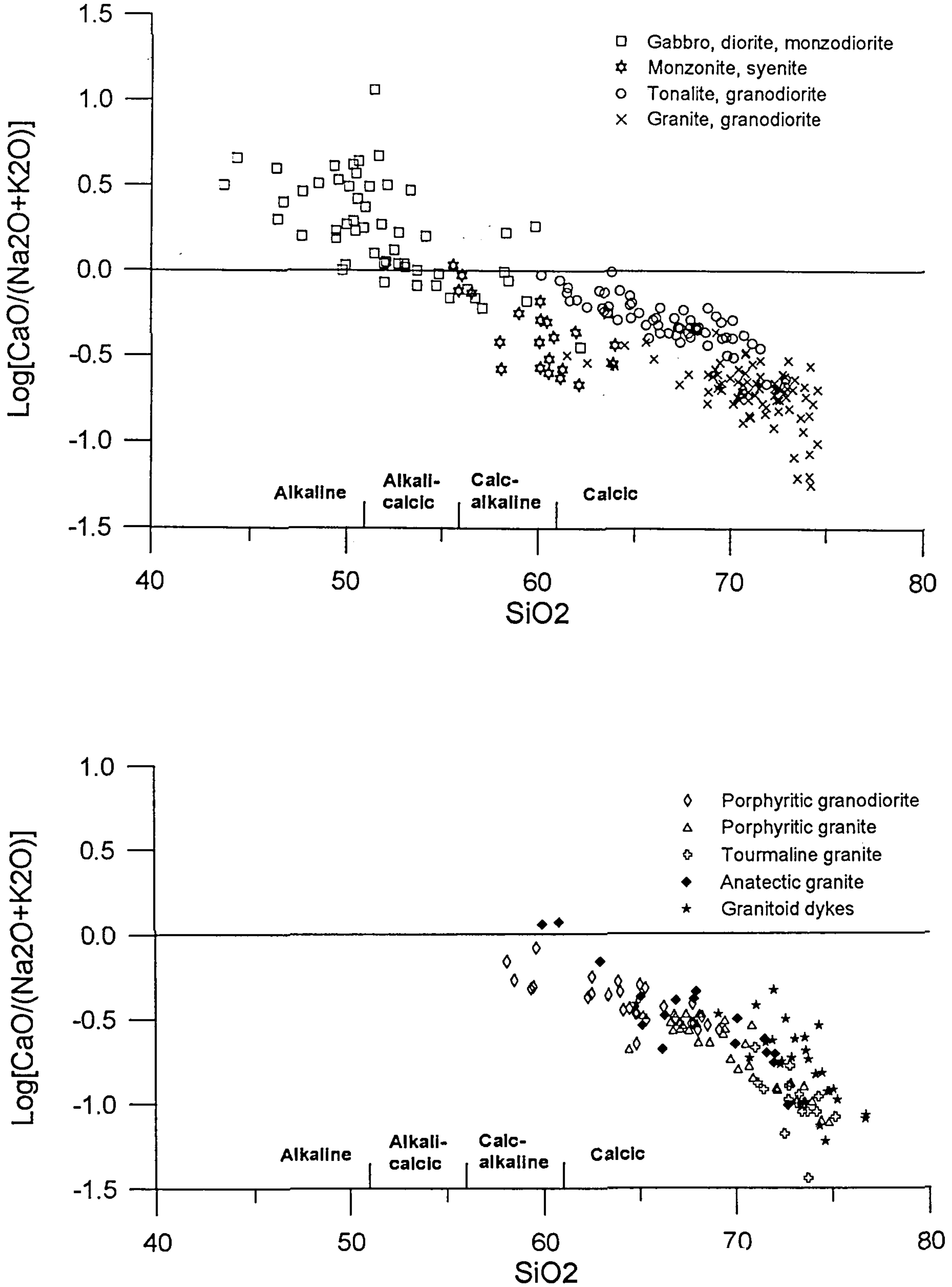


Figure 30. Log $CaO/(Na_2O+K_2O)$ plotted against SiO_2 (wt %). The alkali-lime index (Peacock 1931) for a rock series is defined as the SiO_2 value for which $CaO=Na_2O+K_2O$.

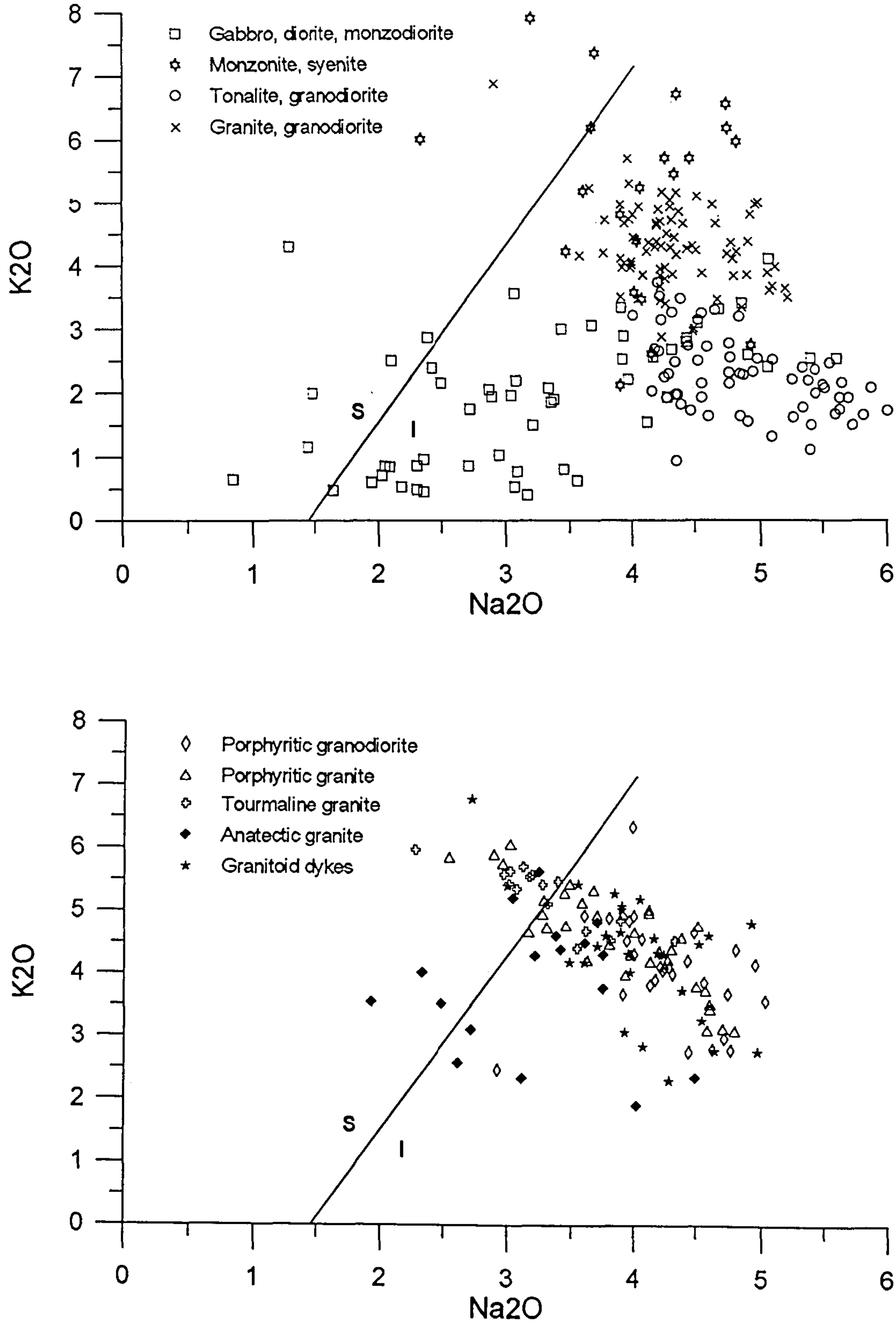
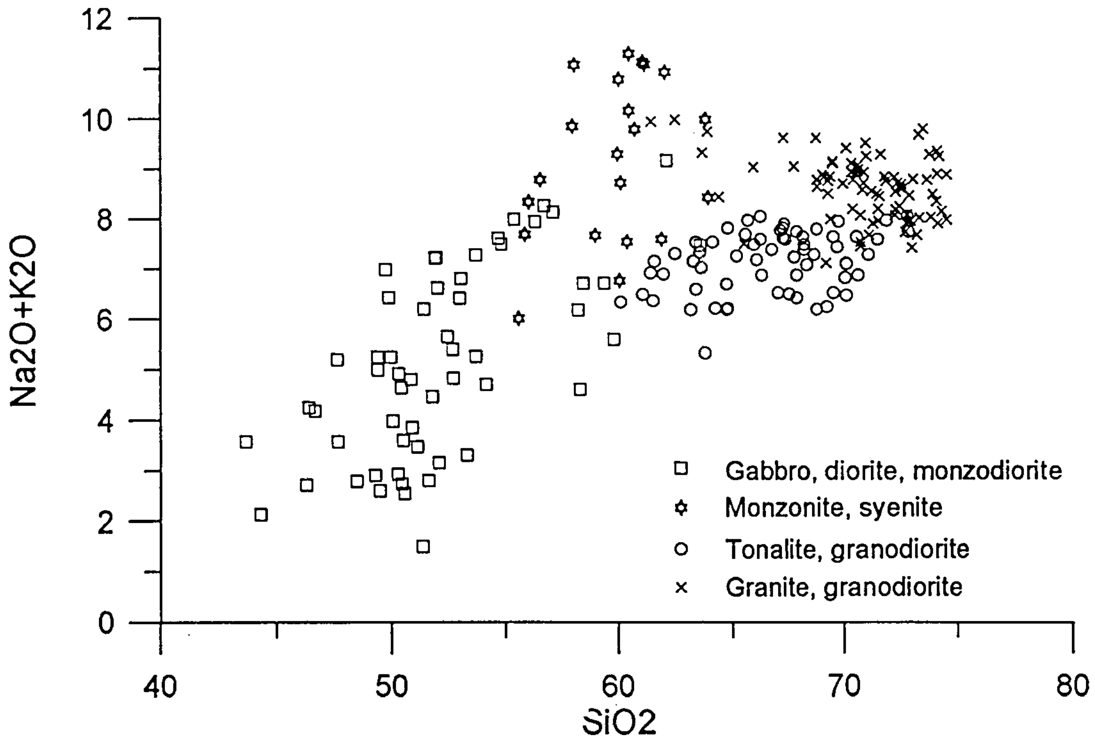


Figure 31. K_2O (wt %) pplotted against Na_2O (wt %). The line separating S- and I-type rcoks is derived from Chappell & White (1974).



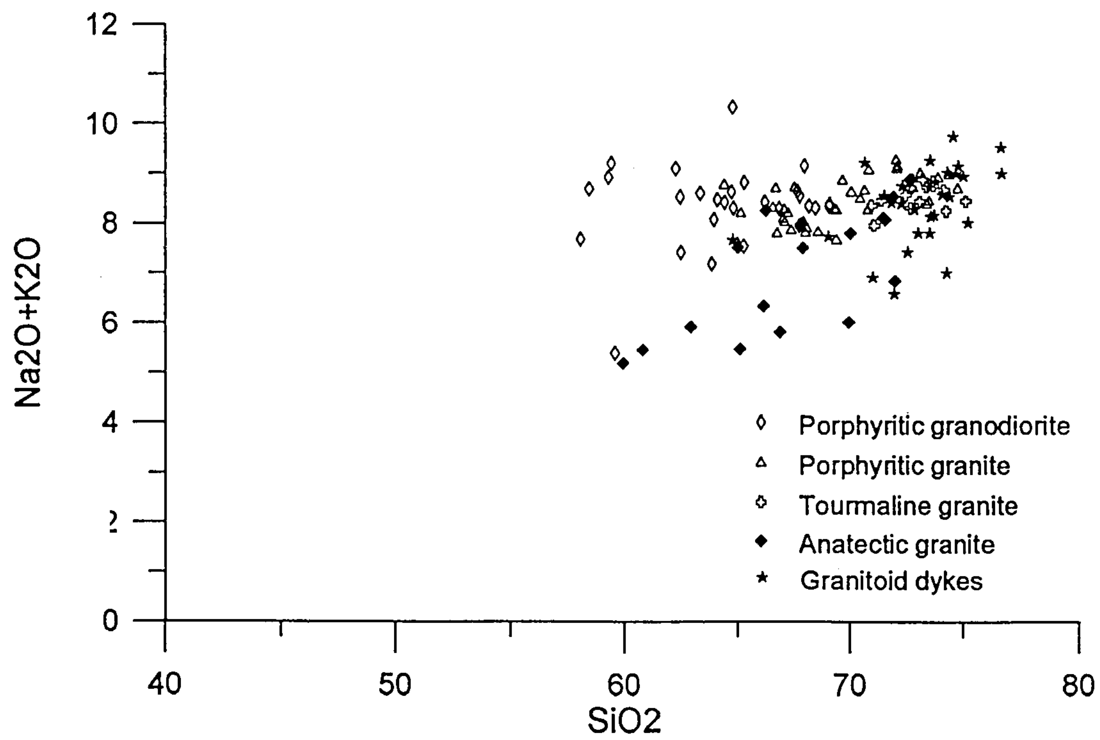


Figure 32. Na_2O+K_2O (wt %) plotted against SiO_2 (wt %).

these granites represent crustal melts (Barnes et al. 1992, Nordgulen & Sundvoll 1992), and they may thus be regarded as transitional towards rocks classified as anatectic granites.

Monzonitic to syenitic rocks are among the least common in the batholith (Fig. 1). Generally, they are shoshonitic to high-K calc-alkaline (Fig. 29), and they show a wide range in abundance for many elements (Appendix 1). A few samples plot as quartz monzodiorites in Fig. 27, but the majority of the rocks plot in the monzonite and syenite fields. Except for two weakly peraluminous quartz monzonitic samples (HR 46 and N89-21, Appendix 1), the rocks are metaluminous and plot in fields IV and V of the characteristic minerals diagram (Fig. 28). This is consistent with petrographic data which show that hornblende and clinopyroxene are common minerals in the most mafic rocks of the group. The rocks from the Sørfjorden area (Fig. 1) are compositionally somewhat different from other samples in this group and have comparatively high contents of Fe_2O_3, MnO and Ga, and low contents of Al_2O_3, MgO, P_2O_5 and Sr (Appendix 1).

It should be noted that the plutons of the Velfjord Massif are fairly alkali rich and reach monzonitic to quartz monzonitic compositions in their most evolved parts. The compositional overlap between rocks assigned to the gabbro-diorite and monzonite-syenite groups may indicate a genetic link between some of these rocks.

Samples classified as granite and granodiorite plot essentially in the adamellite and granodiorite fields (Fig. 27). The Heilhornet Pluton is compositionally different from other rocks in the group. Some samples from the more mafic part of the intrusion plot as quartz monzonites and have fairly high contents of mafic minerals, including hornblende. This is consistent with the tendency towards alkaline affinity exhibited by this pluton (Nordgulen & Schouenborg, 1990). Generally, about 50 % of the rocks in this group have low contents of mafic minerals and are classified as variably peraluminous, leucogranites with biotite + muscovite (fields I-III in Fig. 28). However, a number of samples are metaluminous to weakly peraluminous biotite granites and granodiorites. Despite a limited range in SiO_2, the distribution of the granites in Fig. 30 shows that the rocks are calc-alkaline, with the alkali-calcic Heilhornet Pluton making an exception to this rule.

The tourmaline granites have SiO_2 contents > 71 % and are among the most evolved rocks in the batholith (Fig. 29, Table 1). They are peraluminous with muscovite and biotite as characteristic minerals, and plot in the leucogranite field Fig. 28 (e.g. they contain less than c. 7 % of mafic minerals). A few samples of highly evolved porphyritic granites have chemical properties which are similar to the tourmaline granites including a comparatively high content of P_2O_5 in many samples (Fig. 26). High contents of P_2O_5 in evolved granites is not uncommon and is thought to be a result of elevated stability of apatite in peraluminous melts (e.g. Bea et al. 1992, London 1992).

The granitic dykes, which are a common late phase in the batholith, have been plotted as one group although they range from tonalite to granite in composition (Fig. 27, Appendix 1). They are essentially leucogranitic (Fig. 28), but vary in Al-saturation with the lowest A-values tending to occur in samples with comparatively high K_2O. The dykes contrast with the tourmaline granites in having somewhat lower contents of mafic minerals and a less pronounced degree of Al-saturation.

The anatectic rocks comprise a heterogeneous set of samples which plot as quartz-rich granite to quartz-poor granodiorite in Fig. 27. They have a large range in composition (60-72% SiO_2), and show substantial variation in the content of many elements. Some of them contain abundant mafic minerals including a considerable amount of garnet in some samples. This is reflected in Fig. 28 which shows an extreme scatter both in the content of mafic minerals and in aluminium saturation. The rocks tend to have relatively low contents of Na_2O (Fig. 31), and the total alkali contents overlap with those of tonalitic to granodioritic rocks (Fig. 32). These features suggest that the composition of the samples is affected to a variable degree by minor inclusions of metasedimentary origin. The rocks have variable Sr isotope compositions with high initial ratios (Nordgulen & Sundvoll 1992). Both field and chemical data would indicate a strong crustal influence for these rocks, i.e. they are essentially S-type in the sense of Chappell & White (1977).

In the K_2O vs. SiO_2 plot of Pecerillo & Taylor (1972), the tonalitic rocks plot in the normal calc-alkaline field (Fig. 29). Most of the rocks are high-K calc-alkaline, and some plot in the shoshonite field. This pattern of variable alkalinity is also illustrated in the log (CaO/Na_2O+K_2O) vs. SiO_2 plot (Fig. 30). The tonalites define a calcic to calc-alkaline trend, whereas the more K_2O-rich rocks plot on an alkali-calcic to alkaline trend. Brown et al. (1984) referred to this plot as an "arc maturity diagram". For the BB, it is clear that the analysed samples plot along a relatively broad array which include rocks of different derivation. This illustrates the composite nature of the batholith, and a maturity index as defined by Brown et al. (1984) cannot be assigned to it.

The rocks of the BB are dominantly I-type following the classification originally devised by Chappell & White (1974). Fig. 31 shows that only a few samples plot in the S-type field. This includes some K-rich mafic monzodiorites and some highly evolved granites and monzonitic rocks. Tourmaline granites and anatectic granites, which are at least partly of crustal origin (Nordgulen & Sundvoll 1992, Birkeland et al. 1993), plot in both fields. In this diagram the extremely Na_2O-rich tonalites should also be noted.

Some compositional parameters for the BB are summarised in Table 1. To conclude, the BB consists predominantly of high-K, calc-alkaline, metaluminous to weakly peraluminous rocks. In the western part of the batholith, S-type anatectic granitoids are fairly abundant, and small bodies of megacrystic rocks of probable crustal origin, but with A-type affinity, are associated with the mafic plutons in Velfjord. Following the classification of Debon & LeFort (1983), the rocks belong to the cafemic or alumino-cafemic association and include both calc-alkaline and subalkaline (monzonitic) types. In Harker diagrams, mafic to intermediate rocks display a large scatter in values reflecting variation in the content of mafic and felsic minerals; this feature is indicative of cumulus processes. Samples of intermediate to felsic composition plot along rather well defined trends suggesting control by crystal liquid separation.

Table 1. Summary of some compositional parameters for the main rock groups of the Bindal Batholith

Group	SiO_2-range	Alkali/lime	Al-saturation	Other features
Gabbro-diorite-monzodiorite	44 - 63	Calcic to alkali-calcic	<0.96	
Tonalite-granodi-trondhjemite	60 - 71	Calcic to calk-alkaline	0.83 - 1.10	High Na_2O, high Sr
Porph. granodiorite	58 - 69	Calk-alkaline	0.85 - 1.02	Partly high Sr
Porph. granite	65 - 74	Calk-alkaline	0.98 - 1.15	Partly high Rb
Monzodiorite-quartz monz - syenite	56 - 64	Calc-alkaline to alkali-calcic	0.51 - 1.05	High K_2O, low CaO, variable Ba and Sr
Granite-granodiorite	62 - 73	Calk-alkaline	0.90 - 1.14	Variable Sr
Tourmaline granite	71 - 75	Not defined	1.03 - 1.19	High P_2O_5 and Rb, low Ba and Sr
Anatectic granite	61 - 72	Not defined	0.86 - 1.57	Erratic variation for some traces, low Ba & Sr, high Rb
Granitoid dykes	69 - 76	Not defined	0.96 - 1.11	Large spread in K_2O, Rb, Ba and Sr

4.4 Trace element relations

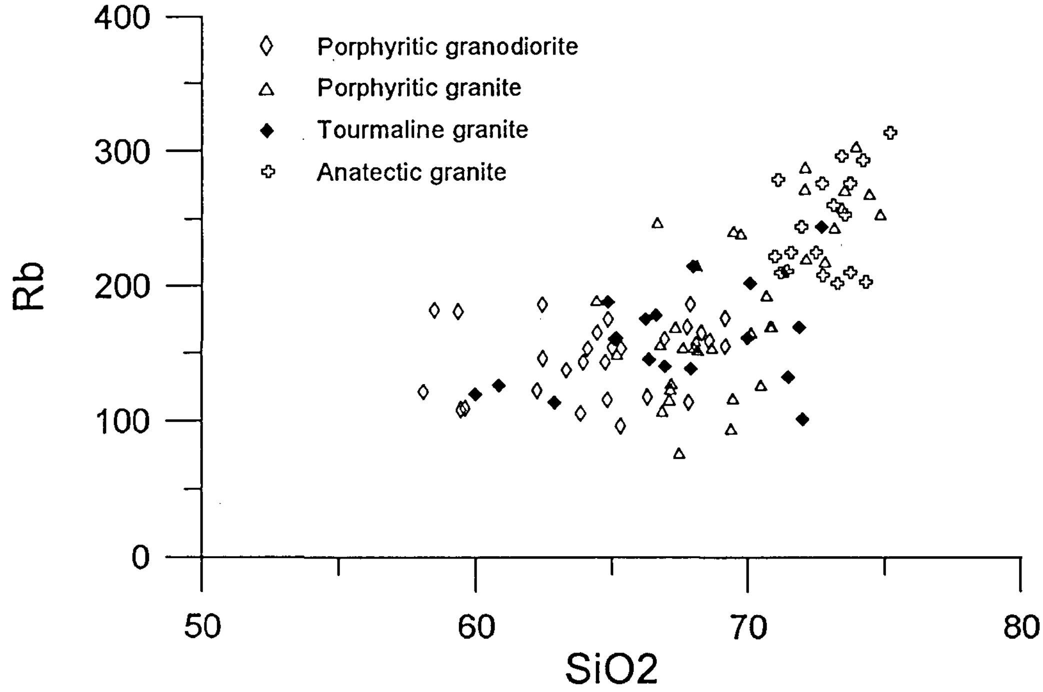
Rubidium, Sr and Ba are mainly fractionated into the rock-forming minerals of granitoids, and patterns of their variation are useful in data analysis. In the BB, rocks of mafic to intermediate composition generally have Rb contents lower than 100 ppm with the highest abundances recorded in evolved parts of the Velfjord Massif (Fig. 33). Porphyritic and equigranular granites and granodiorites mostly contain 75-200 ppm Rb. In contrast, the tonalites have 50-100 ppm Rb, a feature which in accordance with the low content of K_2O in these rocks. The tonalite-granodiorite group has overall low Rb and high Sr (Fig.34); however, the data also show that two sub-groups having comparatively high and low Rb/Sr ratios are present (Fig. 36). Among the most evolved rocks are the tourmaline granites with 200-300 ppm Rb. High Rb values are also recorded in some porphyritic granites, the anatectic granites and in the Heilhornet Pluton. The Heilhornet Pluton is compositionally different from the remaining rocks in the granite-granodiorite group and plot along well-defined trends with high Rb and Rb/Sr and low Sr (Figs. 33, 34 and 36). It is also distinguished by high contents of LRE- and HFS-elements.

Two samples of granite (N86-79 and N 86-81, Appendix 1) collected in the strongly deformed imbricate zone at the base of the HNC south of the Heilhornet Pluton (not shown on Fig. 1) record very high values for Rb (c. 500 ppm, Fig. 33) and Rb/Sr (c. 60, Fig 36). They also have high Fe/Mg ratios, low CaO/Na_2O+K_2O, high contents of HFS- and LRE-elements, and unusually high values for Ga. These features show that the granite is A-type in the sense of Whalen et al. (1987). Rocks similar to this granite are not present anywhere else in the BB.

The granite dykes exhibit a large range in Rb contents, consistent with the heterogeneous nature of this group (Fig. 33). This feature is also seen in the Harker diagrams for Sr and Ba (Figs. 34 and 35).

Strontium and Ba generally show more complex variation than Rb; nevertheless, a coherent grouping of samples is clearly present (Figs. 34 and 35). Although the most mafic rocks exhibit highly variable abundances, it appears that for rocks with less than c. 60 % SiO_2, both Sr and Ba are incompatible. For more evolved rocks, both elements are notably impoverished towards acidic compositions. Tonalites, granodiorites and granites generally have comparatively high Sr, whereas fairly low Ba is recorded in most tonalites. Anatectic granitoids tend to have low Sr and low to intermediate Ba, and porphyritic rocks have variable but overall intermediate abundances compared to the rest of the BB. The monzonitic rocks are extremely variable in Sr and Ba, and some of the samples have very high values for both elements. Among the most evolved rocks, the granitoid dykes tend to have higher Sr and Ba than the tourmaline granites and the porphyritic granites.

Considering the absolute values of these elements, a number of plutons in the BB have very high (>600 ppm) contents of Ba and Sr. This feature persists in basic (<50 % SiO_2) as well in the more evolved rocks (>70 % SiO_2). High Ba and Sr are almost ubiquitous in



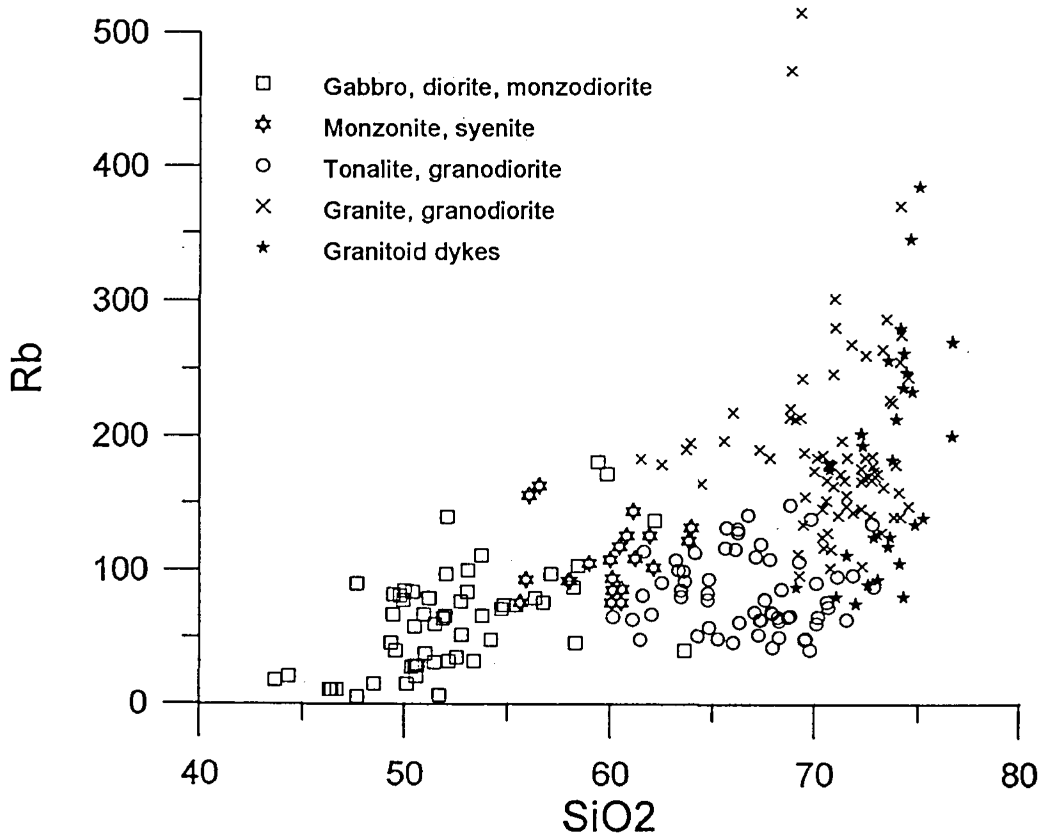


Figure 33. Rb (ppm) plotted against SiO_2 (wt %).

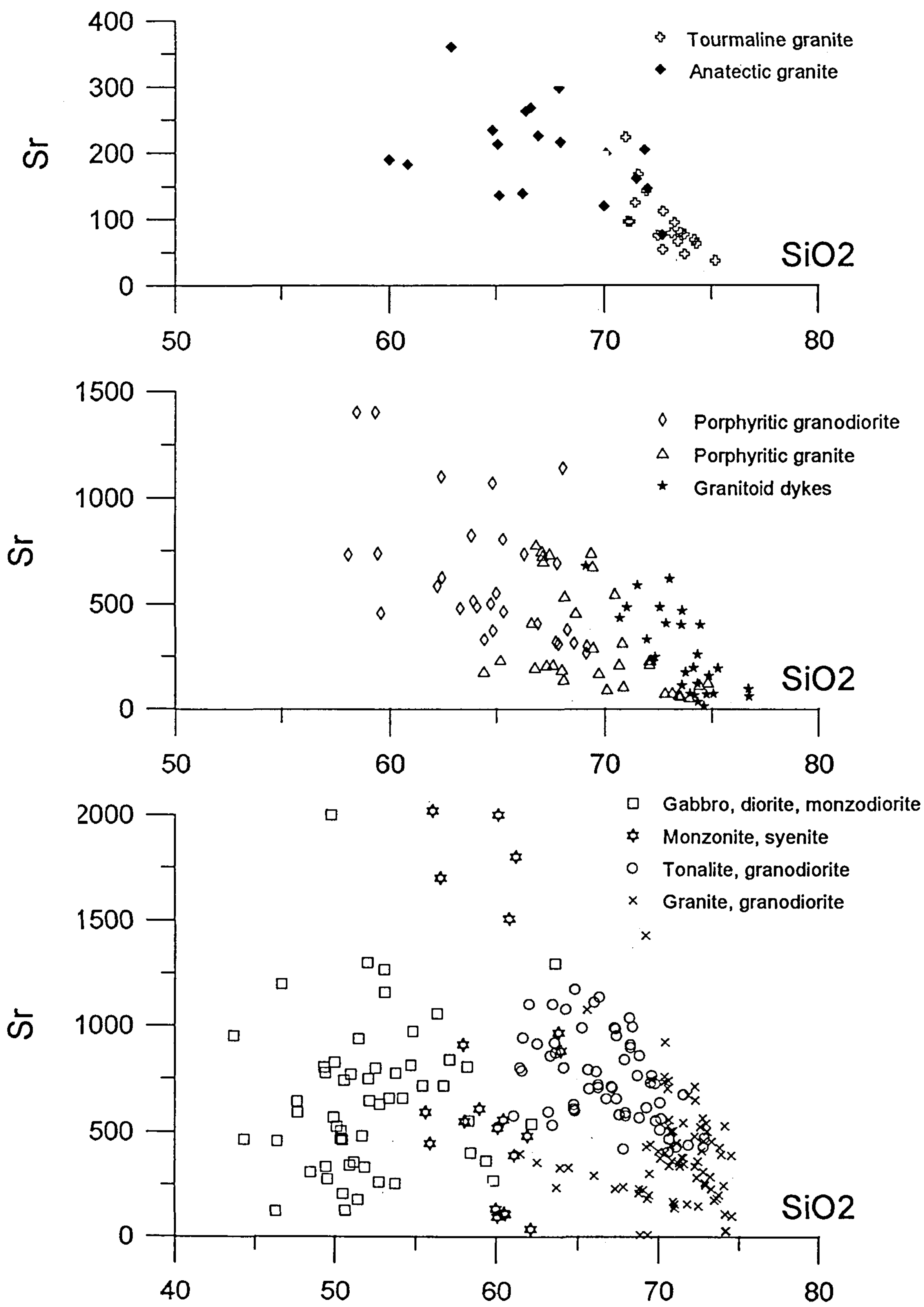


Figure 34. Sr (ppm) plotted against SiO_2 (wt %)

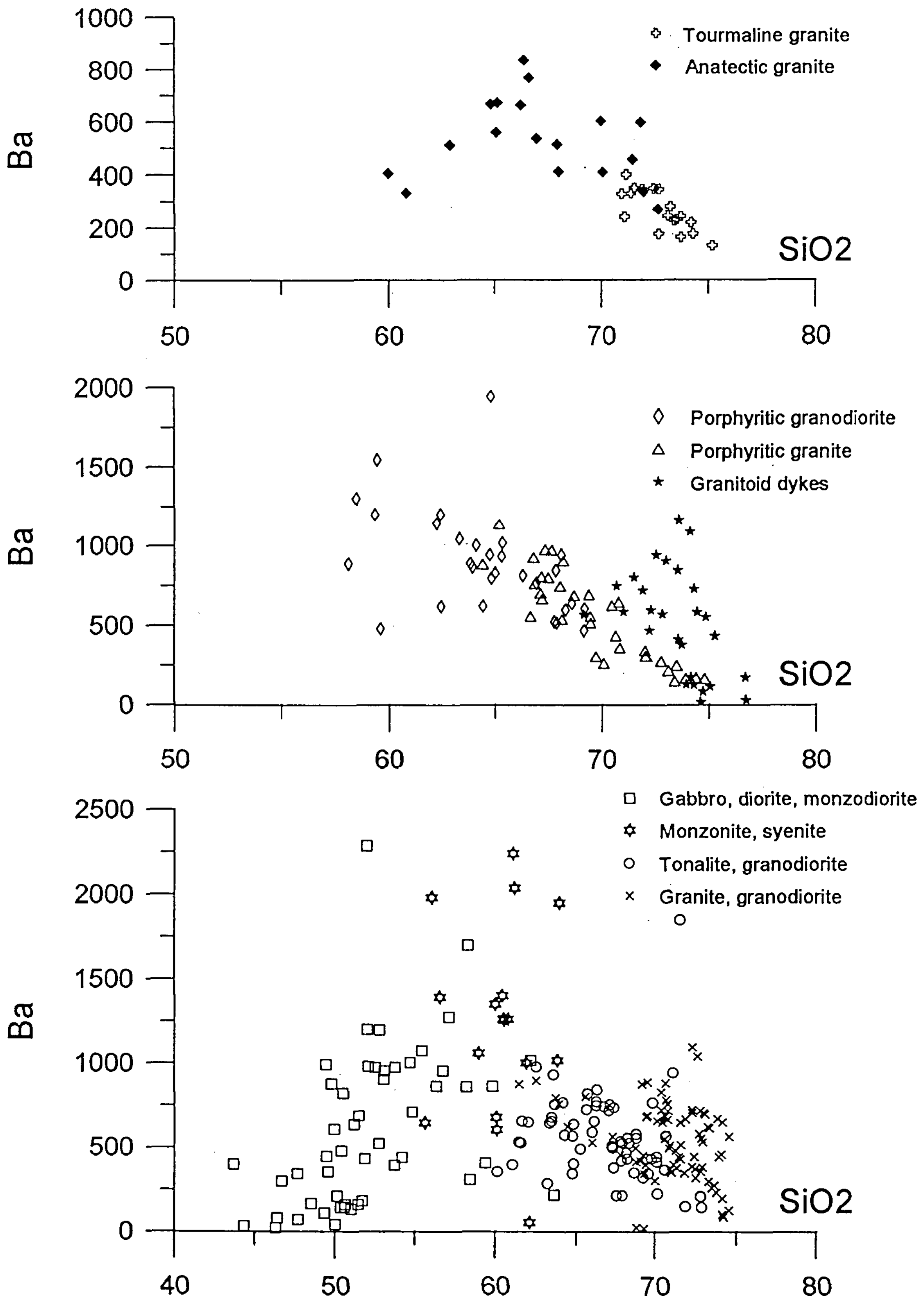
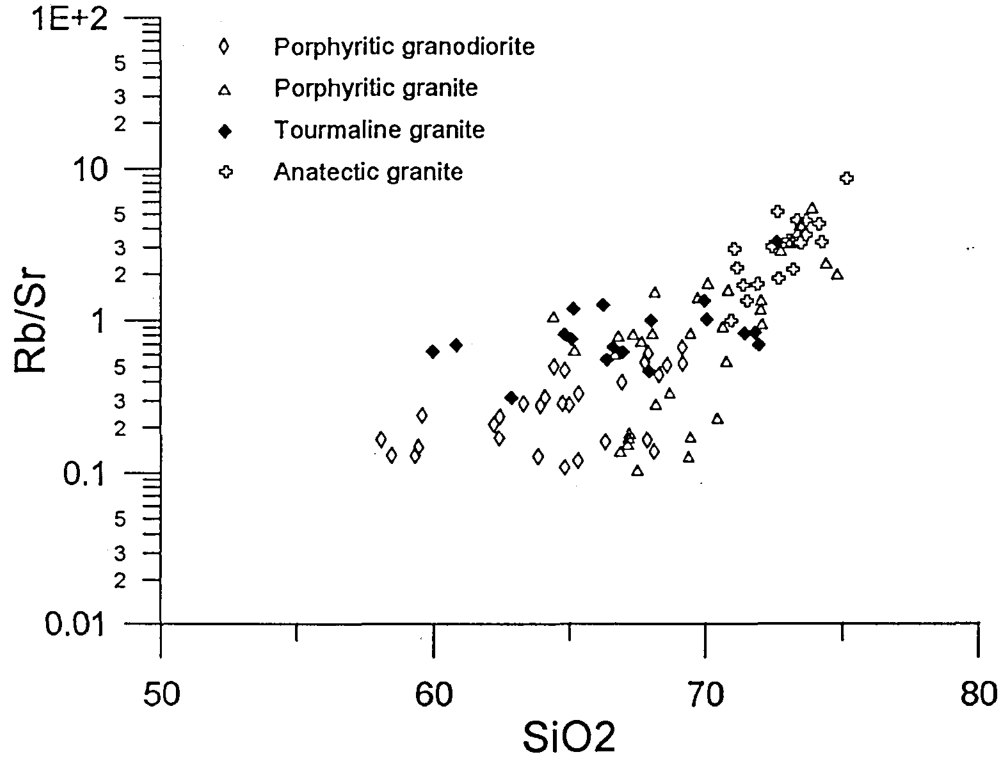


Figure 35. Ba (ppm) plotted against SiO_2 (wt %).



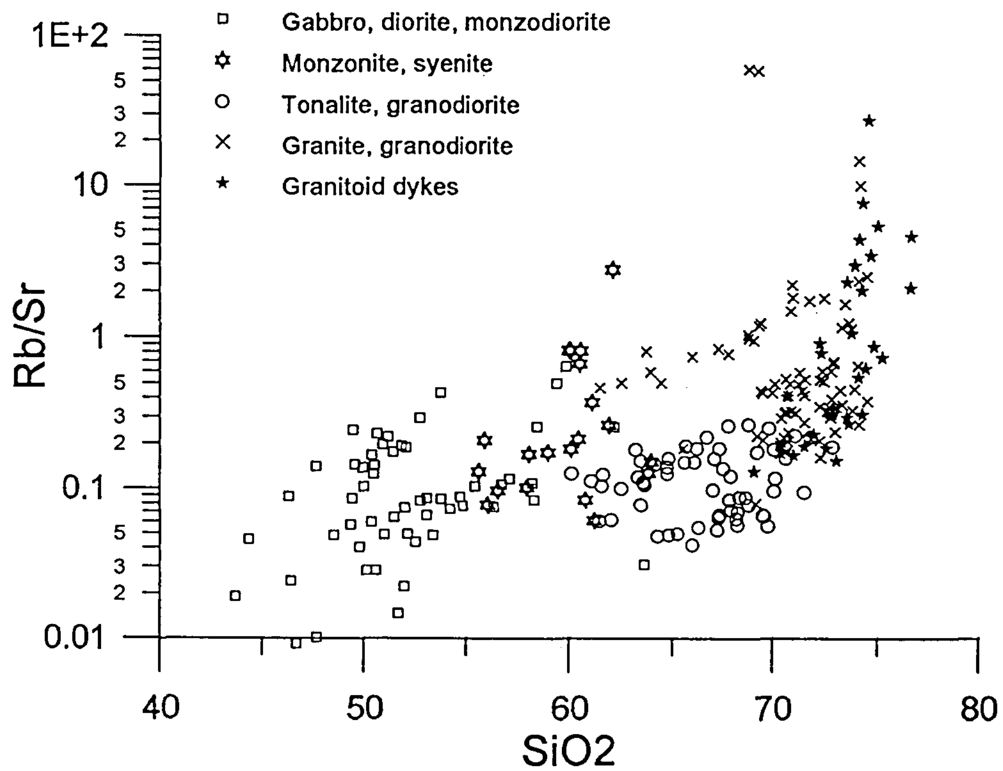


Figure 36. Log Rb/Sr plotted against SiO_2 (wt %).

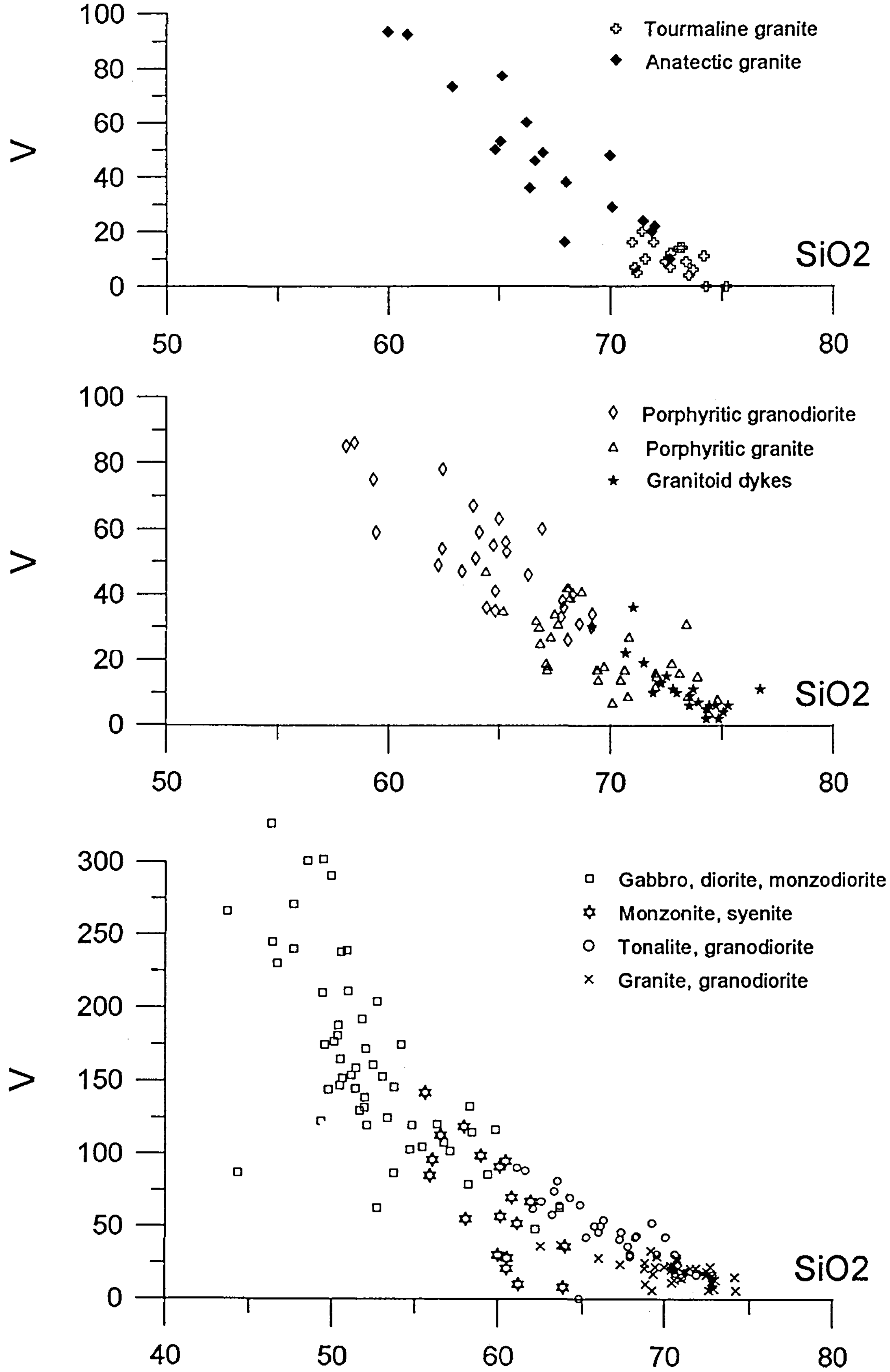


Figure 37. V (ppm) plotted against SiO_2 (wt %). For the tonalite/granodiorite and granite/granodiorite groups 50 % of the data have been plotted.

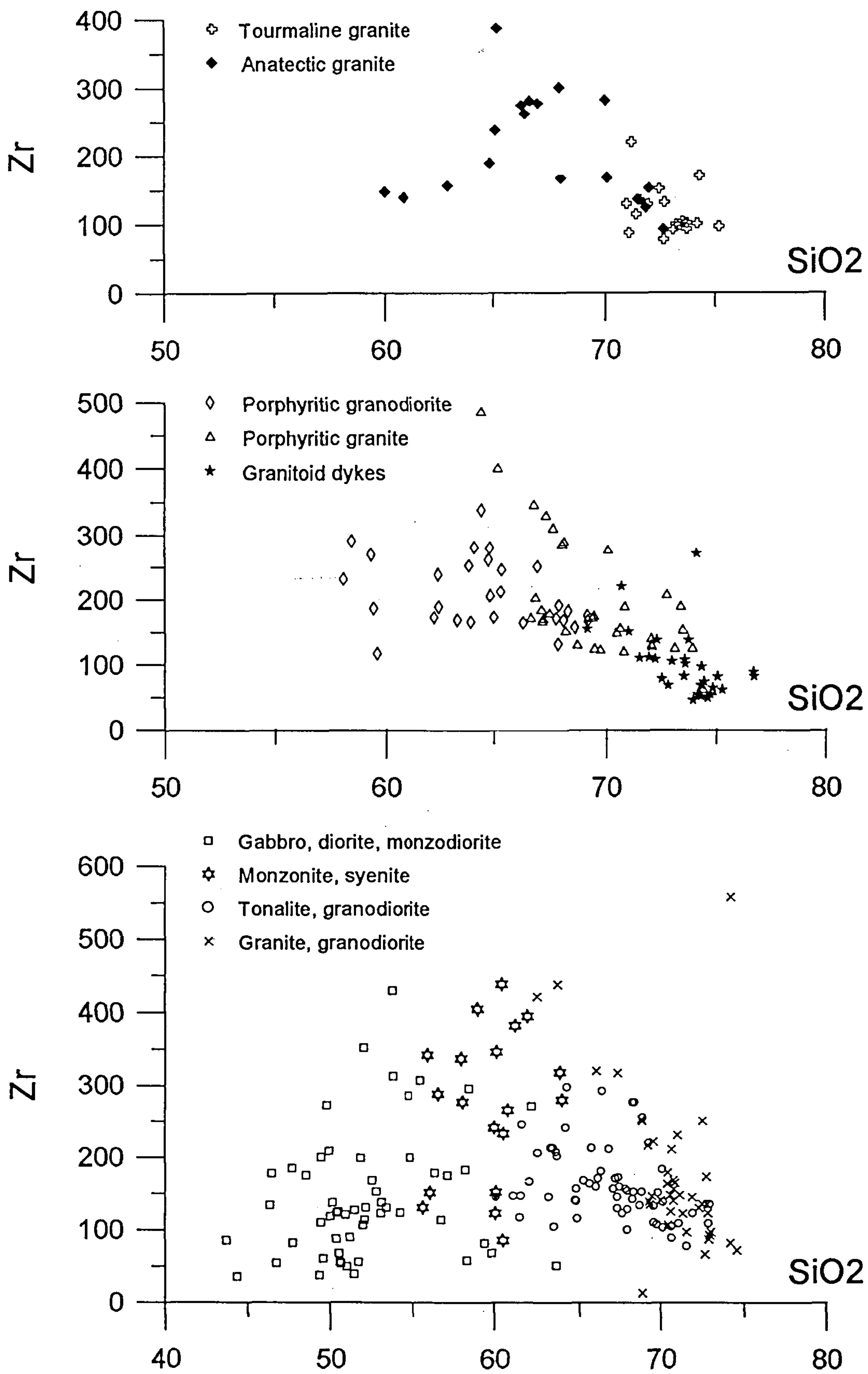


Figure 38. Zr (ppm) plotted against SiO_2 (wt %). For the tonalite/granodiorite and granite/granodiorite groups 50 % of the data have been plotted.

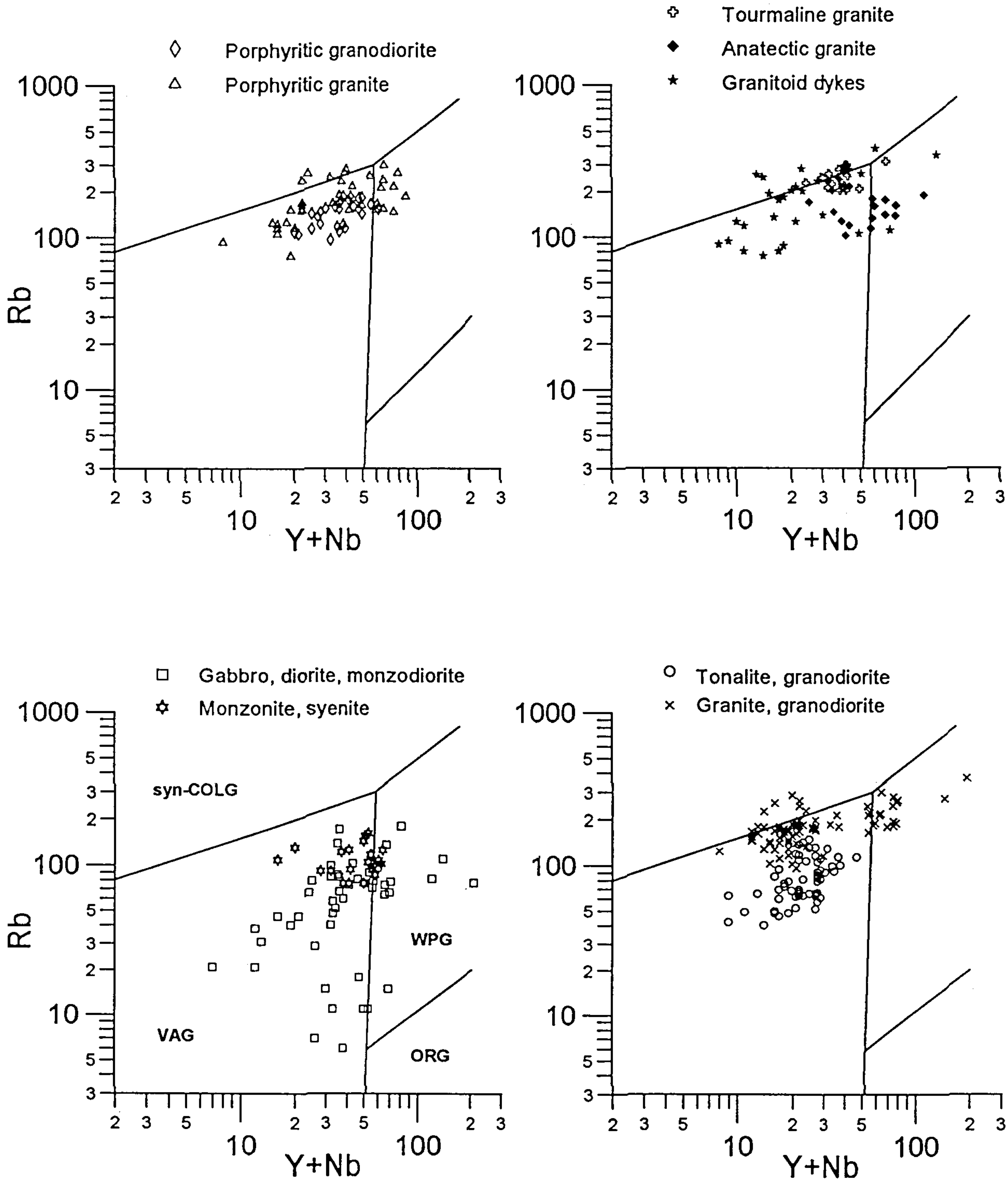


Figure 39. Log Y+Nb (ppm) plotted against Rb (ppm). According to Pearce et al. (1984), the diagram can be used for tectonic classification of granitoids. VAG: volcanic arc granite, ORG: ocean ridge granite, WPG: within-plate granite, syn-COLG: syn-collision granite.

tonalite-granodiorite plutons, in porphyritic granodiorites, and partly in the gabbro-diorite-(monzodiorite) and monzonite groups. Only a minor proportion of the BB has Rb/Sr ratios greater than 1. This group includes the tourmaline granites, some of the granites, porphyritic granites and anatectic granites, and strongly evolved 2-mica granite dykes. The granites generally have higher Rb/Sr ratios than the tonalites, and among the granites the Heilhornet Pluton plots along a separate trend with higher Rb/Sr than other rocks in the group.

High Sr contents indicate that the melts were generated from a source in which plagioclase was not stable (e.g. Miller 1978). Hence, fairly low degrees of melting of sub-crustal rocks would yield a Sr-rich melt, and further enrichment of Sr may occur by fractionation of minerals such as hornblende (Dempsey et al. 1990). Contamination of Sr-rich magma by crustal melts, which would have considerably lower Sr contents, would cause limited changes in the Sr content of the original magma. An implication of this is that the Sr isotope system would be fairly insensitive to crustal contamination. For the Nd isotope system the situation would be different. Apart from some LREE-enriched monzodioritic to monzonitic rocks, sub-crustal melts would generally be comparatively low in Nd, and interaction with crustal material would yield magmas with highly variable Nd isotopic compositions. This would explain the fairly negative ε_{Nd} values combined with low to intermediate $(^{87}Sr/^{86}Sr)_0$ values (< 0.708) which are common in Caledonian batholiths (Harmon et al 1984, Dempsey et al. 1990, Skjerlie 1992, Birkeland et al. 1993).

The transition metals show overall decreasing abundances with increasing SiO_2, and a Harker diagram for V is shown as an example (Fig. 37). Some of the most lithophile elements (Rb, Pb and partly Th) are consistently incompatible, but exhibit a fairly wide dispersion in abundance at constant SiO_2. For other elements, the variation is more complex. Nevertheless, for intermediate to acidic rocks (SiO_2 >65 %), a number of elements, including the LREE and Zr (Fig. 38), clearly decrease in abundance towards acidic compositions. The mafic to intermediate rocks generally have highly variable trace element contents. Some elements, however, including Ba and Zr, are positively correlated with SiO_2 (SiO_2<58 %).

Pearce et al. (1984) attempted the classification of granites by certain combinations of trace elements which were thought to reflect the composition of disparate source regions mobilised by different tectonic regimes. In the plot of Rb vs Y+Nb (Fig. 39) it is clear that the majority of the samples fall in the field of volcanic arc granites (VAG). However, only the rocks assigned to the tonalite-granodiorite group plot exclusively in this field. A number of the more strongly fractionated rocks, including 2-mica granites, leucocratic granite dykes and tourmaline granites, plot close to the boundary of, or into the field of syn-collision granites (syn-COLG). Several rock types are also represented in the within-plate granite (WPG) field. Among these are granites from the Heilhornet Pluton, porphyritic granites with high Rb contents, about 50 % of the anatectic granites, and the more evolved varieties of K-rich mafic to intermediate intrusions. The anatectic granites show a considerable range in Y+Nb abundance and plot both in the VAG and WPG fields, but not in the syn-COLG field. Generally, these rocks appear to have erratic variation in many trace elements. The porphyritic granites which plot in the WPG field are those associated with the Velfjord Massif. These rocks have A-type characteristics including high Ga/Al- and Fe/Mg-ratios, and high abundances of HFS-elements.

In summary, the rocks of the BB plot essentially in the VAG field with some evolved rocks straddling the boundary towards the syn-COLG field. The rocks plotting in the WPG field comprise those with A-type tendency, S-type anatectic granitoids, and evolved parts of mafic to intermediate K-rich monzodioritic plutons. Thus, the diagram appears to be fairly useful in discriminating between different groups of rocks. However, it is less certain if it ca really be employed to differentiate between rocks belonging to different tectonic regimes (see below).

5 DISCUSSION

5.1 Compositional variation: differentiation vs. source

Studies of various radiogenic isotopes have shown that contrasting source regions, including mantle or mantle-derived rocks, Th-enriched lower crust as well as evolved upper crust, were involved in the generation of the BB (Nordgulen & Sundvoll 1992; Birkeland et al. 1993). Since these parameters are considered to be practically stable during differentiation, other chemical variables have to be taken into account in order to provide a more detailed evaluation of the effects of source and differentiation on rock compositions.

Some compositional features of the main rock groups are shown in Appendix 1. It is clear that some of the important rock groups show transition from metaluminous to weakly peraluminous compositions. This may reflect differentiation from a predominantly I-type magma population; however, the differences in Al-saturation between rock groups, combined with other characteristic chemical features such as alkali-lime index (Fig. 30), show that variable Al-saturation is also a source effect.

The influence of the source region is also illustrated by other compositional variables. On Harker diagrams, clearly different trends can be distinguished for many elements (Figs. 26, 27, 31, 33, 34, 35, 37 and 38). The trends defined for the different groups of rocks persist over a wide compositional range and do not converge towards a common mafic end member. This would indicate that the various trends are a result of differentiation of magmas which originated from different sources, or in varying proportions from the available source rocks.

Within the main groups, less obvious but still distinct major element trends characterise single plutons. The fact that a number of intrusions have a considerable range in composition (up to more than 10 SiO_2 units), permit comparison of chemical features characteristic of individual plutons. Among the tonalite-granodiorite rocks, there is a consistent chemical difference between the Kråkfjellet Pluton and the Terråkfjellet Pluton. At similar SiO_2, the Terråkfjellet Pluton has slightly lower CaO, Na_2O and Al_2O_3, and somewhat higher MgO and K_2O. As pointed out above, the Heilhornet Pluton is characteristically different from other plutons in the granite-granodiorite group. Among the three plutons of the Velfjord Massif, there are comparatively small compositional differences which can be related to variation in the source (Barnes et al. 1992).

Compositional variation which is not related to differentiation is also present within single plutons. This is the case for the Hillstadfjellet Pluton of the Velfjord Massif (Barnes et al. 1992), where two trends having different K_2O-contents are present. In the Kråkfjellet Pluton, Sr and Zr plot along two well-defined trends consistent with differentiation of magmas with different starting compositions (Nordgulen 1984).

Considering only some selected megacrystic rocks, a plot of Sr vs Zr (Fig. 40) shows that several different groups are present. Rocks which were classified in the field as

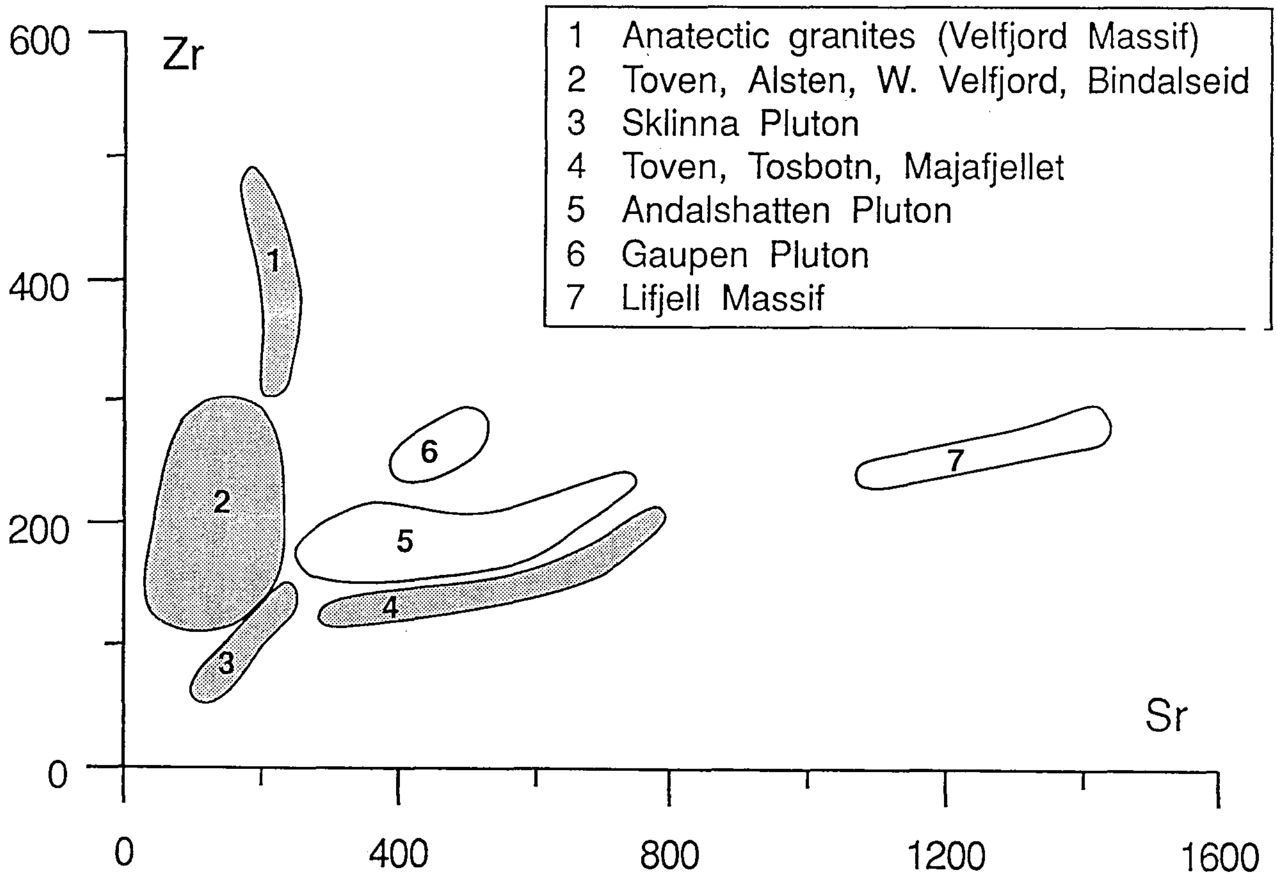


Figure 40. Zr (ppm) plotted against Sr (ppm). The diagram shows the variable contents of these elements in porphyritic granites and granodiorites of the Bindal Batholith (see text).

granodiorites have overall higher Sr contents than the granites; however, various granites in the Tosbotn-Majafjellet area and parts of the Toven Massif plots along a trend similar to the granodiorites. The Toven Massif also plot in group 2 (Fig. 40), indicating that it consists of different rock types. Megacrystic granites associated with the Velfjord Massif (group 1) have high contents of Zr and other HFS-elements, and were probably generated by anatexis of pelitic rocks (Barnes et al. 1992). These rocks have highly variable compositions, and the apparent trend observed in Fig. 40 has no obvious significance. Granites from the Alsten and Toven massifs and from smaller granite bodies in western Velfjord and at Bindalseid have moderate contents of Sr and Zr and are plotted together in group 2. The Sklinna Pluton displays a distinct trend with decreasing Zr and Sr with increasing SiO_2. This is also the case for some plutons of granodiorite. The Lifjell Massif is distinguished by its very high Sr content. The Gaupen Pluton is similar to parts of the Andalshatten Pluton, although there is distinct contrast in the content of Zr. The contrasting element abundances between the groups presumably reflect variation in magma composition, whereas the compatible behaviour of Sr and Zr observed in some of the groups is probably a result of differentiation of each particular magma type.

The peraluminous rocks of S-type affinity generally exhibit limited geochemical variation (e.g. the tourmaline granites), or they show a strong scatter which is superposed on the general trend, particularly for many trace elements. The latter effect is especially pronounced among the anatectic rocks and probably reflects variable efficiency in the separation of magma from partially melted source rocks.

The granitic dykes of the batholith lie on the evolved extension of several different trends. This is consistent with the idea that they are late differentiates which may be related to several different plutons or groups of plutons.

Granite suites comprising groups of plutons (Cobbing & Pitcher 1983) are not well developed in the BB. However, the fairly alkali-rich rocks of the Velfjord Massif together with the monzodiorite to quartz monzonite plutons show generally similar geochemical properties and may define a suite. Other suites may include the voluminous N-S trending granite-granodiorite belt along the central axis of the batholith (Fig. 1), and the tourmaline granites and the anatectic granites. Some plutons may form their own unit, as the Kråkfjellet, Terråkfjellet and Heilhornet Plutons appear to do.

To conclude, the selected groups and plutons of the BB show different points of origin and different trends on many diagrams. The trends on Harker diagrams are similar, but absolute abundances for several major and trace elements differ, also suggesting different sources. With the exception of the anatectic granites, for which a variable rate of partial melting and variation in unmixing of melt from restite may control some of the compositional variation, it is thought that magmatic differentiation controls enrichment and depletion trends in the rocks. There is no evidence of significant assimilation and contamination at a high level in the crust; however, such processes are probably relevant during interaction between mafic melts and deep crust at sites of granitoid magma formation (Miller et al. 1988).

5.2 Comparison with other batholiths

Intrusive rocks associated with destructive plate margins show a broad range of petrographic and geochemical variation. Granitoids occurring in continental plutonic arcs such as the Peninsular Ranges Batholith (PRB) in California (DePaolo 1981, Gromet & Silver 1987, Silver & Chappell 1988) and the Coastal Batholith in Peru (e.g. Pitcher et al. 1985), are generally considered to be related to subduction of oceanic crust. There is a lithological range from mafic gabbro to leucocratic monzogranite with tonalite as the dominant rock type. The PRB has a distinctly calcic nature (alkali-lime index: 62-65) with fairly high Na_2O/K_2O (Silver & Chappell 1988). A well developed W to E asymmetry is reflected in the abundance of rock types as well as geochemical and isotopic properties. These transverse compositional changes indicate that the relative importance of different source regions varies across the continetal arc (Silver & Chappell 1988). However, the isotope data from these rocks indicate that they were generated mostly from juvenile source materials.

In the Late Silurian to Devonian granitoids of the Lachlan Fold Belt (LFB) in SE Australia two major rock groups have been recognised. I-type rocks are considered to be derived from crustal igneous rocks, whereas S-type rocks were generated from metasupracrustal rocks which had gone through a weathering cycle (Chappell & White 1974, White & Chappell 1977, 1983, 1988). Gabbros are extremely rare, and granodiorite is the dominant rock type. The I-type rocks are somewhat less abundant than the S-types, and they have metaluminous, calc-alkaline compositions with lower Na_2O and higher K_2O than those of the PRB (Chappell & Stephens 1988). The isotopic properties of the I-type rocks indicate that they were derived from older I-type rocks in the crust (McCulloch & Chappell 1982).

The granitoid plutonism of the Caledonian Fold Belt (CFB) in northern Britain and Ireland has been reviewed by e.g. Brown et al. (1981), Pankhurst & Sutherland (1982) Stephens & Halliday (1984) and Harmon et al. (1984). Although there is a range in ages from 500 to 390 Ma, the main activity occurred between 430 and 390 Ma (the Newer Granites). Generally, these are classified as metaluminous, calk-alkaline I-type rocks (Stephens & Halliday 1984); however, S-type granites occur in the Southern Uplands (Cairnsmore of Fleet), in the Lake District, and in SE Ireland (Leinster) (Stephens 1988, Chappell & Stephens 1988). Sr and Nd isotope data show similarities with the LFB with ε_{Nd} varying between +3 and -10 (Stephens & Halliday 1984). Combined with O and Pb isotope data, it was concluded that at least three different sources, including mantle rocks, lower to intermediate crust and upper crustal material, were involved in the genesis of the granitoids (Harmon et al. 1984). While the granitoids of the CFB have much in common with those of the LFB, the CFB I-type rocks are generally less calcic with higher Na and K values and higher Na/K ratios. S-type rocks are far less common in the CFB, whereas the mafic pyroxene-mica diorites and appinitic rocks are not reported from the LFB (Chappell & Stephens 1988). The high Na and Na/K ratios of some rocks of the CFB are features similar to those of plutonic arc granites exemplified by the PRB.

The BB is a composite igneous complex consisting predominantly of granodiorites and granites with smaller but significant proportions of more mafic rocks as well as anatectic S-type rocks and rocks of more alkaline affinity. The batholith has, on average, higher K and lower Ca than plutonic arcs at continental plate margins, e.g. the Coastal Batholith (Cobbing & Pitcher 1983) and the PRB (Gromet & Silver 1987, Silver & Chappell 1988). The relative abundance of mafic plutons is also clearly less than in these batholiths. Apart from the calcic mafic rocks, tonalites with high Na, low K/Na and low initial Sr ratios are probably the only rocks that may be similar to plutonic arc granites. In common with the CFB granitoids of Britain and Ireland, the BB tends to have somewhat lower Ca and higher K and Na than the LFB intrusions. Plutons of probable S-type affinity are present in the BB, but as in the CFB, these are clearly subordinate in abundance to the I-type rocks. Gabbroic to dioritic rocks appear to be more common in the BB than in the LFB, and rocks of appinitic affinity, which occur in the British and Irish plutons, but not in the Australian ones (Chappell & Stephens 1988), are locally present in the BB. Comparing the data published by Stephens & Halliday (1984) with those reported here, it appears that monzonitic to syenitic rocks, anatectic rocks and low-K tonalites are significantly less represented in the CFB. Thus, compared to the CFB, the BB seems to have a somewhat expanded compositional spectrum of rock types.

Considering trace element chemistry, high contents of Sr and Ba are recorded in a number of plutons in the BB. This is a well known feature of Caledonian plutons in Scotland, especially those assigned to the Argyll Suite by Stephens & Halliday (1984). High values of Sr and Ba are uncommon in the rocks of the LFB and PRB, but are present in several plutons of the Inner Cordilleran Batholiths (Miller & Barton 1990).

The isotope data so far available from the BB support the general correlation outlined above. Initial Sr ratios are variable and increase from fairly low values (0.704-0.705) in the east to intermediate (0.705-0.710) and high (>0.710) values in the central and western parts of the batholith (Nordgulen & Sundvoll, 1992). Values for ε_{Nd} are less than 0, and in the ε_{Nd}-ε_{Sr} diagram the batholith defines a curved array which to a large extent overlaps with that of Australian I- and S-type granites as well as granitoids of the CFB (Birkeland et al. 1993). Information gained from geochemical and isotopic studies, including data on feldspar Pb (Birkeland et al. 1993), strongly suggests that the BB to a variable extent is the product of crustal recycling, although melts from juvenile sub-crustal reservoirs may be represented by the mafic rocks. These conclusions correspond closely with those obtained from studies of similar rocks in other mountain belts (e.g. Chappell & Stephens 1988, Miller & Barton 1990).

To conclude, the general geological setting as well as the chemical and isotopic composition of the BB are broadly similar to plutons in the British and Irish Caledonides as well as those of the Lachlan Fold Belt in eastern Australia. The I-type rocks of the BB are also similar to those described from the eastern part of the Sierra Nevada Batholith and from the Idaho Batholith (Bateman & Chappell 1979, Bateman 1983, Miller & Barton 1990).

5.3 Origin of the Bindal Batholith

The general nature of the multiple source rocks for the BB has been described by Nordgulen & Sundvoll (1992) and Birkeland et al. (1993). It should be pointed out, however, that compositional parameters can only to a certain extent constrain models for the source and generation of granitoid magmas (Miller et al. 1988). This is the case even in relatively simple tectonic situations such as that of the PRB. A major problem is the nature of the depleted component of the source region, which may be composed of a range of different types present in the mantle wedge above the subduction zone, or as a mafic underplate of crystallised mafic plutonic rocks (Pankhurst et al. 1988). Enriched, lithospheric mantle may also be part of the source region, and the characteristics of the more evolved, crustal component(s) can only be described in general terms. The difficulty present in the modelling of the source and evolution of granitoids reflects the inherent variability displayed by these rocks and is an obstacle to their use as indicators of tectonic environment.

Pitcher (1983, 1987) proposed that the tectonic setting of a batholith may be deduced from the general characteristics of the granitoids and their wall-rocks. According to this classification, the BB belongs to the Caledonian I-type group characterised by being generated in a post-collision uplift environment. Chappell and Stephens (1988) maintained that underplating and intrusion into the crust may create the source region from which I-type granitoids subsequently may be generated. Thus, I-type rocks have an infracrustal origin, and are probably a result of large-scale crustal remelting caused by massive transfer of heat from the mantle. Granitoids in such settings contrast with those of e.g. the PRB in that there is no clear connection between the generation of the granitoids and active subduction. However, Miller & Barton (1990) argued that the generation of similar I-type rocks of the Inner Cordilleran Batholith may be related to processes above a shallowing subducting slab relatively remote from the subduction zone and the main plutonic arc.

The tectonic classification of Pearce et al. (1984) is based on the concept of a constant relationship between available source rocks and tectonic setting. The BB consists of a wide variety of rocks with distinct chemical and isotopic properties (Birkeland et al. 1993). Although the age of all the different units of the batholith is not known, it is conceivable that the different types originated in broadly similar tectonic settings, and that they were derived in variable proportions from a spectrum of possible sources, as suggested by Miller et al. (1988). Thus it would seem that at least for I-type rocks, characterised by a large proportion of different crustal sources, a tectonic classification based only on the contents of trace elements will be difficult to apply. Furthermore, granites of different types may occur in a number of settings, indicating that the source materials are not as distinct to a particular tectonic environment as typological classifications would appear to assume (Cobbing 1990).

In the case of the BB, the increase in initial Sr-ratios from east to west may tentatively suggest the presence of a westward-dipping subduction zone (Nordgulen & Sundvoll, 1992), but the rocks of the HNC do not record any independent evidence for subduction during the time of plutonism. Such evidence may, however, be present in the case of the Sunnhordland and

Smøla-Hitra Batholiths, both of which intrude Early to Middle Ordovician island-arc related volcanic rocks (Andersen & Jansen 1987, Gautneb & Roberts 1989). Since the batholiths are essentially synchronous in time, it may be argued that a similar mechanism caused the intrusion of the BB as well.

Other tectonic models are also possible. If the HNC is considered to be a result of amalgamation of microplates, the plutonism may have occurred during microplate convergence and destruction prior to the Scandian collision. In such environments, the juxtaposition of crustal fragments may have occurred by strike-slip tectonics and thrusting as well as by consumption of oceanic crust in subduction zones. This would suggest that the magmatism may have been partly controlled by movement along fundamental faults which could cause initiation of partial melting and provide pathways for the rising magmas (Leake 1978, 1990, Hutton 1988, Hutton & Reavy 1992, Andersen et al. 1991). The presence of elongate, strike-parallel intrusions may suggest that deep-seated faults exerted some control on magma generation and emplacement; however, the presence of such faults has not been documented in the HNC. This is probably to be expected, considering the effects of Scandian thrust tectonics as well as later extensional deformation which would have tended to obliterate the evidence of early fault activity.

Without speculating further, it is concluded that the BB was generated in a tectonic environment characterised by converging plates. Subduction of oceanic crust, strike-slip tectonics and thrusting may have influenced the generation and emplacement of the different types of plutons. Some of the mafic rocks may be a result of melting of sub-crustal rocks. However, most of the magmas are considered to have been generated by melting in variable proportions of various types of crustal rocks. Heating of the crust due to crustal thickening and upward transfer of heat and magmas above subduction zones may have provided the energy for the generation of melts from suitable source rocks.

6 SUMMARY AND CONCLUSIONS

The Bindal Batholith is a composite intrusive complex which occurs in metasupracrustal rocks of the Helgeland Nappe Complex (Uppermost Allochthon) in north central Norway. It consists of more than 50 intrusions varying in size and shape from small irregular bodies and sub-rounded stocks to large, commonly elongate plutons covering more than 100 km² at the present level of exposure. The intrusions include a variety of rock types ranging in composition from mafic gabbros to leucogranite, but granite and granodiorite are the dominating rock types. Mafic and composite dykes, various types of granitic to tonalitic dykes, and aplites and pegmatites are commonly associated with the intrusions. Most of the magmatism probably took place in the Late Ordovician to Early Silurian and apparently pre-dated the final Scandian thrusting of the Helgeland Nappe Complex across continent Baltica.

The contacts between plutons and the wall-rocks may be concordant or strongly discordant, and in some plutons large xenoliths of metasedimentary rocks, and in cases also intrusive rocks form prominent raft trains. Mafic enclaves are present in a number of plutons and are usually oriented parallel to the mineral alignment in the host.

Primary hypidiomorphic to allotriomorphic igneous textures which may have been modified to some extent by recrystallisation during deformation are generally preserved. Pyroxenes are present in gabbros and monzogabbros, otherwise biotite, hornblende and epidote are the common mafic minerals. A number of plutons contain microcline megacrysts. The megacrysts are usually grey or pinkish grey, and only a couple of plutons contain red megacrysts. In most plutons, alteration is limited to weak saussuritisation or sericitisation combined with some retrogression of mafic minerals.

A variably developed mineral alignment, which may be defined by sub-parallel orientation of microcline megacrysts, tabular plagioclase, single grains and clusters of mafic minerals, and elongate single crystals and/or clusters of quartz, may be present in tonalitic, monzonitic and granodioritic plutons. Mafic enclaves, schlieren and metasedimentary xenoliths are usually aligned in the fabric. In more evolved plutons, which commonly have allotriomorphic textures, biotite and muscovite may be oriented and define a foliation. Within zones of strong ductile deformation, the intrusive rocks are in some cases transformed into mylonites in which only remnants of the primary minerals remain.

A number of plutons are petrographically and compositionally zoned. Examples of this are provided by the plutons of the Velfjord Massif (Barnes et al. 1992), the Kråkfjellet Pluton (Nordgulen 1984), the Heilhornet Pluton (Nordgulen & Schouenborg 1990), and the Andalshatten Pluton (Nordgulen et al. in press). However, there are also large intrusions which show only a limited compositional variation.

The composition of the batholith is predominantly high-K calc-alkaline and metaluminous. However, among the mafic to intermediate rocks both calcic and alkali-calcic varieties are present. The evolved rocks, which are metaluminous to peraluminous, may be the products of differentiation of more than one magma type, or they may represent crustal melts little modified by differentiation processes. The batholith belongs to the cafemic and alumino-cafemic association of Debon & LeFort (1983), and includes both calk-alkaline and subalkaline types.

Major and trace element data augmented by radiogenic isotope data suggest that the batholith was derived by extraction of magmas from source rocks such as depleted mantle or mafic lower crust, Th-enriched lower crust, and various types of upper crust. Although juvenile melts may be represented by the mafic plutons, most of the batholith is regarded as a product of crustal re-cycling. Accordingly, the compositional spread in the batholith reflects the likelihood that the plutons originated from variable contributions of magma from the source regions available. Generally, the compositional spread within plutons may be a result of variation in partial melt composition combined with the effects of variable segregation of melt from the source rocks, and differentiation processes after the melting event. The presence of more than one compositional trend in single plutons may probably be explained by differentiation acting on single magma pulses with somewhat variable initial composition.

The rock types present in the Bindal Batholith preclude its derivation in a subduction-related continental arc similar to that of the Coastal Batholith and the Peninsular Ranges Batholith. The batholith has broad compositional similarities with the granitoids of the Caledonian Fold Belt in Scotland and the Lachlan Fold Belt in Australia. A general feature of these batholiths appears to be the presence of highly heterogeneous source regions yielding granitoids covering an expanded compositional spectrum compared to those associated with continental arcs. This makes it difficult to unravel the tectonic situation during the plutonic event using only selected compositional variables, and points to the importance of assessing all the available information gained from field and laboratory work in tectonic modelling. Based on the information so far available, it is concluded that the Bindal Batholith may have originated through the combined effects of several processes operating in a convergent tectonic regime. The processes involved may have included subduction of oceanic crust with upward transfer of mafic magma and heat above the subduction zone, strike-slip tectonics with juxtaposition of microplates, thrusting and crustal thickening.

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APPENDIX 1

GEOCHEMICAL ANALYSES, BINDAL BATHOLITH

GABBRO, DIORITE AND MONZODIORITE

	-------------- Gabbros and diorites in the Bindal area -------------------										
	B112	B3341	B3342	B567	B569	B700	B712	B387	B641	N8710	B718
SiO2	51.15	52.10	53.32	50.88	50.48	49.32	49.99	54.15	53.01	53.04	50.60
TiO2	.68	.64	.63	2.32	.83	.63	1.04	.99	.95	1.00	.71
Al2O3	8.51	16.79	17.29	14.42	16.71	17.36	15.84	16.33	18.07	17.79	10.78
Fe2O3	9.37	6.99	7.01	12.86	9.88	8.14	9.82	8.99	8.05	7.93	9.14
MnO	.16	.13	.13	.19	.16	.13	.17	.14	.16	.13	.17
MgO	13.39	8.03	8.44	5.46	8.82	10.04	6.96	6.06	3.97	3.84	12.74
CaO	10.82	10	9.84	8.52	10.09	11.83	9.75	7.45	7.00	7.13	11.13
Na2O	1.48	2.30	2.35	2.42	2.03	2.05	2.38	3.21	3.43	3.93	1.95
K2O	1.99	.86	.96	2.39	.71	.85	2.87	1.50	2.99	2.88	.60
P2O5	.21	.14	.23	.66	.16	.10	.06	.23	.66	.49	.10
LOI	.95	1.39	1.20	1.49	1.20	1.65	.59	.73	.66	.81	.62
TOTAL	98.71	98.78	100.83	101.69	100.27	102.05	99.84	99.78	98.40	98.96	98.53
Sc	35	*	*	*	*	34	27	24	13	13	42
V	154	120	125	239	165	123	*	175	*	153	152
Cr	1017	37	37	133	180	69	*	97	*	57	1167
Co	42	44	43	65	59	44	*	31	*	25	43
Ni	146	31	32	32	102	44	*	37	*	23	181
Cu	41	*	*	*	*	8	*	20	*	27	10
Zn	*	60	57	117	68	*	*	*	*	79	*
Ga	11	*	*	*	*	14	19	20	23	23	10
Rb	79	32	32	67	29	46	85	48	84	100	29
Sr	356	645	658	342	205	803	827	657	1266	1159	125
Ba	27	*	*	*	*	110	44	438	904	953	160
Y	25	9	10	20	10	11	24	21	19	19	16
Zr	90	131	131	121	68	38	119	124	123	138	54
Nb	636	8	10	22	8	5	881	12	13	13	10
La	62	5	5	27	*	9	88	37	54	48	7
Ce	32	25	24	68	10	*	33	53	104	61	15
Nd	18	14	16	39	8	12	16	27	42	29	12
Pb	8	*	*	*	*	6	12	13	17	15	6
Th	10	*	9	*	*	4	*	*	12	16	*

	Harangsfjord		Holm area		Elvvika, Lande		Kalklavt.		Luktvt	- Andalshatten -		
	B286	B287	N8865	N8866	N88105	N8902	N8903	N8657	N8958	N8807	N8937	N8938
SiO2	50.45	52.70	46.32	47.67	58.25	51.97	49.77	59.84	58.33	51.40	50.35	49.43
TiO2	.89	1.21	2.21	3.33	.87	1.71	1.34	.98	.40	.46	.89	1.01
Al2O3	12.11	13.18	13.50	16.76	17.08	17.40	18.12	7.71	11.23	5.96	15.69	19.45
Fe2O3	9.04	8.08	14.49	12.24	6.11	8.45	8.59	5.52	6.00	6.57	8.83	9.02
MnO	.15	.12	.22	.19	.09	.11	.12	.10	.13	.14	.14	.15
MgO	11.95	9.37	7.58	4.62	3.49	4.32	5.08	5.52	8.99	15.21	7.55	4.40
CaO	7.87	7.98	10.83	8.31	6.08	6.11	6.91	10.18	7.63	17.26	9.56	8.85
Na2O	2.49	2.89	2.18	3.35	3.97	3.91	4.32	1.29	2.10	.85	2.87	3.37
K2O	2.16	1.94	.53	1.85	2.21	3.33	2.67	3.06	2.50	.65	2.05	1.89
P2O5	.29	.24	.22	1.23	.29	.68	.82	1.50	.13	.07	.28	.41
LOI	1.13	1.28	1.65	.35	.53	.71	.69	.29	.97	.90	.75	.87
TOTAL	98.53	99	99.72	99.92	98.97	98.71	98.43	99.92	98.52	99.46	98.85	98.84
Sc	24	51	47	22	16	16	17	26	29	53	28	23
V	147	204	327	271	79	139	144	117	133	145	188	210
Cr	1080	283	276	81	95	56	39	24	629	2452	352	15
Co	42	35	49	37	18	22	31	39	32	31	32	21
Ni	251	82	60	24	39	20	27	46	152	83	80	7
Cu	27	16	36	27	*	19	12	67	10	8	38	23
Zn	*	*	104	96	79	111	139	62	65	44	77	94
Ga	16	15	20	22	22	*	*	13	*	5	*	*
Rb	58	52	11	90	87	97	81	172	46	31	84	67
Sr	463	629	124	643	805	1300	2000	268	551	177	504	776
Ba	822	1197	23	341	860	1200	877	862	1700	160	477	993
Y	21	24	50	38	21	39	30	29	13	11	26	23
Zr	125	153	134	185	183	352	273	69	58	39	124	110
Nb	12	10	3	16	14	21	16	7	8	2	10	13
La	35	43	20	75	69	74	78	29	*	30	29	35
Ce	66	46	26	119	105	128	146	93	25	14	58	62
Nd	30	21	26	63	47	*	*	56	*	9	*	*
Pb	11	16	4	14	22	29	15	17	16	4	12	18
Th	14	*	*	9	1	*	*	19	*	*	*	*

	- Mosjøen Gabbro -			------------- Ursfjord and Grøndalsfjellet ----------							
	N87134	N87135	N87149	N87118	N87172	N87173	N8748	N8750	N8753	N8754	N8756
SiO2	46.42	58.47	47.70	52.03	50.54	50.95	48.51	49.44	53.69	52.69	44.32
TiO2	2.52	1.16	2.92	.98	.98	1.10	2.79	2.74	1.81	1.72	.49
Al2O3	16.42	16.46	17.06	16.99	17.90	18.29	15.45	15.30	15.09	15.16	16.57
Fe2O3	13.97	6.38	11.21	8.51	9.59	9.58	14.36	15.09	13.71	15.62	10.82
MnO	.21	.10	.19	.14	.12	.14	.24	.22	.25	.24	.14
MgO	6.33	2.78	5.88	5.60	6.08	6.60	6.11	3.37	2.29	2.05	12.90
CaO	8.57	5.85	10.20	7.48	9.41	9.02	9.02	7.67	5.22	5.87	9.63
Na2O	3.45	4.17	3.17	3.07	3.07	3.09	2.30	3.04	3.08	3.33	1.65
K2O	.80	2.55	.40	3.56	.53	.77	.49	1.96	2.19	2.07	.48
P2O5	.33	.24	.49	.36	.19	.12	.37	.84	.98	.82	.06
LOI	.30	.38	.44	.68	.75	.12	.26	.30	1.11	.24	2.38
TOTAL	99.33	98.54	99.66	99.40	99.17	99.77	99.90	99.96	99.42	99.81	99.43
Sc	26	17	24	19	29	23	34	24	18	43	14
V	245	115	240	172	238	211	301	302	87	63	87
Cr	32	39	52	38	38	49	98	29	13	6	109
Co	56	21	38	31	29	44	47	41	25	20	71
Ni	20	9	17	26	22	8	42	*	3	8	143
Cu	18	11	22	6	36	19	7	15	18	19	17
Zn	111	53	80	82	61	59	130	162	172	187	66
Ga	21	22	19	19	23	21	23	26	27	28	16
Rb	11	103	6	140	21	38	15	82	111	77	21
Sr	456	401	592	748	741	770	309	334	256	261	464
Ba	81	306	72	979	144	134	167	446	391	521	34
Y	47	31	22	26	10	12	40	71	69	117	5
Zr	178	296	82	114	56	50	175	201	429	736	36
Nb	13	12	16	9	2	*	29	49	69	93	2
La	20	25	21	51	21	20	16	49	67	133	*
Ce	65	58	39	64	25	14	69	118	113	278	*
Nd	24	26	11	22	20	16	33	76	64	143	3
Pb	13	22	10	19	9	12	9	19	16	15	9
Th	8	15	*	18	*	8	9	11	11	17	5

	Kalklavt.	Tosbotn	--- Mafic to intermediate plutons in Velfjord (Velfjord Massif) ---									
	N8657	N8688	N8726	N8727	N8728	VF01	VF02	VF10	VF11	VF41	VF42	VF43
SiO2	59.84	51.93	51.44	46.69	43.66	53.70	54.70	52.46	50.32	56.36	54.83	56.76
TiO2	.98	1.04	1.46	2.08	1.55	1.75	1.57	1.26	.77	1.13	1.09	1.12
Al2O3	7.71	18.40	19.82	19.82	19.29	17.68	18.83	18.03	13.97	18.76	19.53	17.95
Fe2O3	5.52	6.96	7.61	10.37	12.35	8.70	7.63	8.94	8.60	6.22	6.59	6.25
MnO	.10	.09	.11	.13	.17	.14	.13	.15	.15	.13	.13	.14
MgO	8.84	4.71	2.37	4.19	6.88	2.54	2.06	4.37	9.10	2.10	2.66	2.64
CaO	10.18	7.88	7.76	10.60	11.24	5.98	6.20	7.47	12.31	6.23	7.12	5.69
Na2O	1.29	4.43	4.28	3.56	2.71	4.44	4.52	4.12	2.09	5.40	4.91	4.86
K2O	3.66	2.79	1.93	.62	.86	2.85	3.09	1.54	.84	2.54	2.59	3.40
P2O5	1.50	0.70	.73	1.17	.49	.76	.64	.53	.16	.47	.31	.42
LOI	.29	.74	.62	.17	.60	.52	.03	.39	1.06	.55	.05	.42
TOTAL	99.92	99.67	98.14	99.38	99.81	99.06	99.39	99.28	99.37	99.90	99.80	99.66
Sc	26	14	13	18	31	15	15	20	51	10	12	13
V	117	132	159	230	266	146	103	161	181	121	120	108
Cr	24	144	53	51	74	32	18	88	615	22	12	23
Co	39	26	20	27	36	27	21	31	38	11	17	18
Ni	46	63	14	33	27	26	19	44	84	4	8	13
Cu	67	24	35	48	28	42	35	18	47	8	13	14
Zn	62	97	84	92	92	119	88	114	54	76	68	71
Ga	13	22	23	22	21	23	23	22	14	22	22	22
Rb	172	66	60	11	18	66	71	35	28	79	74	76
Sr	268	2977	936	1197	952	775	813	797	470	1057	972	716
Ba	862	2286	686	299	399	974	1005	974	143	861	709	953
Y	29	17	27	28	38	42	34	27	19	34	26	32
Zr	69	107	127	55	86	313	286	168	88	179	200	114
Nb	7	7	11	5	9	28	22	*	*	23	15	19
La	29	54	63	50	32	84	75	31	14	59	42	55
Ce	93	104	103	107	85	143	148	68	36	118	101	112
Nd	56	49	52	47	51	59	62	44	25	44	43	41
Pb	17	21	19	12	9	25	25	19	8	20	19	24
Th	*	3	16	5	6	5	6	5	11	18	9	*

--- Mafic to intermediate plutons in Velfjord (Velfjord Massif) ---

	VF44	VF45	VF46	VF48	VF50	VF53	VF54	VF55	VF56	VF59
SiO2	62.16	57.15	63.62	50.10	51.80	49.93	51.64	49.54	59.40	55.44
TiO2	.88	1.35	.75	.41	1.87	2.86	.52	.82	.90	1.60
Al2O3	16.42	17.44	16.88	24.26	15.40	14.79	16.24	13.21	16.68	17.51
Fe2O3	5.26	7.20	4.35	4.26	11.49	12.80	7.06	10.96	7.42	7.94
MnO	.17	.16	.10	.07	.19	.18	.15	.18	.10	.15
MgO	1.60	2.53	1.58	2.81	5.54	4.44	8.06	13.65	3.02	2.40
CaO	3.26	4.91	4.18	12.34	8.24	6.97	13.07	8.84	4.45	5.57
Na2O	5.07	5.61	5.06	2.95	2.72	3.92	2.35	1.44	3.67	4.68
K2O	4.10	2.53	2.40	1.03	1.75	2.52	.45	1.16	3.05	3.31
P2O5	.44	.59	.26	.14	.27	1.41	.03	.02	.82	.70
LOI	.46	.13	.85	1.58	.48	.16	.61	.56	.35	.69
TOTAL	99.82	99.61	100.02	99.95	99.77	99.99	100.16	100.38	99.86	99.99
Sc	7	10	15	19	24	18	33	25	13	14
V	48	102	63	177	192	291	130	175	86	105
Cr	3	7	57	21	84	47	236	211	43	20
Co	8	11	15	16	36	33	29	58	14	20
Ni	3	6	11	4	22	30	49	184	17	15
Cu	7	6	9	16	23	92	21	26	10	40
Zn	91	102	29	51	103	127	50	66	128	96
Ga	20	21	21	17	23	23	16	17	32	22
Rb	137	97	40	15	64	78	7	40	181	74
Sr	536	838	1295	526	333	567	481	276	362	717
Ba	1016	1275	214	209	431	606	182	353	406	1075
Y	43	34	14	25	44	49	24	27	50	41
Zr	271	175	51	138	199	209	56	61	82	307
Nb	24	22	5	5	22	22	2	5	31	25
La	76	63	13	24	27	88	20	11	39	64
Ce	159	135	23	58	71	201	31	14	76	133
Nd	57	60	15	35	38	82	21	20	54	53
Pb	32	23	11	7	14	25	11	12	19	26
Th	22	12	2	2	6	14	2	5	5	10

MONZONITE, QUARTZ MONZONITE AND QUARTZ SYENITE

------------------- Harangsfjord ----------------------

	B528	B748	B788	B792	HR26	HR45	HR46	HR47	N8921
SiO2	58.00	59.00	60.44	61.11	58.08	60.09	63.96	55.63	61.92
TiO2	1.20	1.10	1.12	.88	.86	.73	.52	.95	.95
Al2O3	19.67	18.22	17.42	17.60	18.75	16.72	17.55	17.87	17.38
Fe2O3	3.95	6.34	6.25	4.10	4.38	5.80	3.32	7.64	5.50
MnO	.04	.10	.10	.10	.09	.10	.04	.12	.09
MgO	1.74	1.97	1.91	1.44	1.27	2.14	1.00	3.39	1.62
CaO	3.79	4.35	3.80	2.59	2.88	4.47	3.05	6.42	3.35
Na2O	3.67	4.93	4.08	3.20	3.70	4.16	4.04	3.90	4.02
K2O	6.19	2.74	3.46	7.92	7.37	2.60	4.38	2.11	3.57
P2O5	.40	.36	.32	.16	.37	.22	.18	.22	.26
LOI	.63	.53	.66	.45	.46	.99	.54	.83	.50
TOTAL	98.99	99.64	99.76	99.77	98.22	98.01	98.58	99.08	99.16
Sc	*	10	17	7	7	11	2	14	15
V	119	99	95	52	55	91	36	142	67
Cr	5	17	17	*	2	8	6	15	24
Co	16	13	14	5	13	16	9	25	10
Ni	7	9	9	5	11	12	10	26	8
Cu	*	10	11	8	9	16	7	24	11
Zn	45	80	82	35	26	61	47	78	75
Ga	*	24	24	16	15	19	22	20	*
Rb	92	105	118	144	92	94	132	76	126
Sr	908	607	557	389	548	518	877	591	481
Ba	*	1059	1402	2237	3873	603	1946	645	1000
Y	15	35	36	32	19	26	9	26	42
Zr	337	405	438	759	277	152	280	131	395
Nb	13	18	19	18	13	16	11	12	22
La	36	76	91	32	64	45	101	33	105
Ce	54	161	201	73	65	82	151	56	210
Nd	27	68	75	38	28	30	46	23	*
Pb	*	19	21	28	23	20	29	17	23
Th	*	28	10	2	10	21	28	18	*

	----- Tosbotn area ----				--------------- Bindal area -----------------						
	B661	N8667	N8836	N8839	N8666	B719	B721	N86109	B568	N8677	N8678
SiO2	56.07	56.59	61.20	63.84	68.67	62.08	60.07	60.50	55.91	60.52	60.01
TiO2	.90	.93	.41	.54	.44	.59	.71	.67	1.49	.82	.89
Al2O3	12.49	14.69	18.73	16.65	15.84	16.03	16.27	16.52	16.08	15.61	15.01
Fe2O3	6.62	6.45	3.43	3.62	2.68	7.33	8.00	7.17	9.60	9.46	9.49
MnO	.10	.11	.05	.07	.04	.20	.23	.22	.16	.31	.32
MgO	5.66	4.80	1.34	1.60	1.14	.07	.28	.27	1.85	.58	.76
CaO	7.80	6.45	2.88	2.79	2.71	2.31	2.93	2.83	5.90	3.07	3.51
Na2O	2.33	3.61	4.36	4.27	3.62	4.75	4.82	4.74	3.47	4.46	4.07
K2O	6.01	5.18	6.71	5.71	4.23	6.17	5.96	6.55	4.22	5.70	5.23
P2O5	.16	.75	.23	.25	.18	.07	.15	.16	.63	.24	.28
LOI	.63	.42	.34	.26	.13	.08	0	0	1.18	.05	.54
TOTAL	99.43	99.96	99.68	99.62	99.68	99.67	99.43	99.63	99.71	100.17	99.94
Sc	13	13	10	8	3	4	1	7	*	9	11
V	96	113	10	8	*	41	*	21	85	28	30
Cr	202	151	30	33	*	28	*	3	15	12	12
Co	24	21	2	5	*	7	*	5	44	7	7
Ni	65	55	9	17	*	10	*	*	8	4	3
Cu	30	19	14	3	*	*	*	4	*	4	4
Zn	*	92	56	57	*	47	*	68	110	109	53
Ga	15	21	19	22	28	20	24	22	*	23	24
Rb	156	163	109	122	102	154	76	76	93	86	108
Sr	2019	1698	1800	965	37	458	94	114	446	106	132
Ba	1979	1391	2035	1015	53	688	677	1263	*	1256	1349
Y	39	35	14	24	63	10	26	23	26	37	39
Zr	151	288	382	318	1319	131	123	86	342	233	242
Nb	12	18	2	13	*	9	24	18	30	21	22
La	81	91	96	70	152	17	40	27	54	31	39
Ce	157	182	113	152	288	36	75	52	99	82	84
Nd	84	74	45	55	121	21	41	24	56	33	39
Pb	27	37	30	39	27	27	10	13	*	13	16
Th	11	24	9	11	14	6	9	2	*	4	4

PORPHYRITIC GRANODIORITE

	------------------------- Andalshatten Pluton ------------------									
	APS26	N8803	N8805	VF20	VF21	VF22	VF23	VF24	VF39	VS10
SiO2	59.60	63.97	64.84	67.73	67.85	68.56	69.17	69.15	62.50	58.09
TiO2	.85	.50	.48	.38	.39	.34	.34	.38	.76	.67
Al2O3	15.40	17.39	16.41	15.74	15.68	15.56	15.57	15.24	17.55	19.14
Fe2O3	6.68	3.83	4.12	3.14	3.28	2.66	2.79	3.10	4.62	5.82
MnO	.09	.06	.07	.07	.09	.08	.07	.08	.07	.09
MgO	5.68	1.51	1.13	.98	.99	.92	.74	.79	2.22	2.41
CaO	4.50	3.71	2.84	2.55	2.55	2.38	2.26	2.25	4.13	5.31
Na2O	2.92	4.17	4	4.43	4.20	4.31	4.28	4.21	4.62	4.71
K2O	2.47	3.92	4.32	4.22	4.36	4.01	4.12	4.13	2.80	2.98
P2O5	.17	.17	.18	.13	.14	.11	.12	.12	.27	.26
LOI	.98	.34	.29	.34	.24	1.01	.53	.45	.43	.16
TOTAL	99.33	99.58	98.68	99.71	99.77	99.94	99.88	99.91	99.97	99.66
Sc	18	12	10	5	4	3	6	7	7	9
V	170	51	41	33	36	31	34	30	78	85
Cr	198	29	22	12	12	11	3	15	49	33
Co	23	10	8	6	6	4	9	4	11	10
Ni	105	11	8	4	8	5	3	4	15	10
Cu	24	2	2	4	4	2	4	3	5	11
Zn	97	56	61	41	46	35	36	38	75	75
Ga	*	21	21	20	19	18	18	19	25	24
Rb	109	143	175	169	186	159	155	176	146	121
Sr	456	514	372	317	308	312	296	265	625	732
Ba	478	866	796	521	513	637	604	466	619	889
Y	23	17	19	22	26	20	17	25	16	26
Zr	117	166	206	171	191	157	167	175	189	232
Nb	13	8	18	14	16	14	13	16	12	12
La	39	53	85	42	48	35	30	35	31	41
Ce	51	74	120	105	86	62	55	72	77	103
Nd	*	37	44	39	35	24	22	27	33	38
Pb	19	27	29	30	37	30	32	34	17	18
Th	*	9	22	24	29	17	23	26	10	15

	---- Andalshatten Pluton -----					Kongsmoen	Lifjell Massif		
	VS12	VS14	VS16	VS17	VS18	N8633	L41	L51	L71
SiO2	65.01	63.36	59.45	62.29	68.26	68.06	62.47	59.33	58.47
TiO2	.54	.47	.46	.43	.39	.36	.48	.62	.69
Al2O3	16.51	17.68	20.18	18.58	15.74	16.00	17.04	17.12	17.02
Fe2O3	4.24	3.97	3.82	3.72	3.17	2.14	3.79	4.60	5.21
MnO	.07	.09	.07	.07	.06	.03	.07	.07	.09
MgO	1.79	1.50	1.52	1.33	1.09	1.03	1.53	2.36	2.70
CaO	3.77	3.78	4.53	3.88	2.69	2.47	3.79	4.32	4.66
Na2O	3.91	5.03	4.80	4.95	4.25	4.48	3.60	4.00	3.80
K2O	3.68	3.58	4.40	4.16	4.11	4.68	4.94	4.93	4.90
P2O5	.18	.18	.21	.17	.14	.14	.25	.37	.43
LOI	0	.21	.35	.18	.13	.27	.45	.33	.36
TOTAL	99.69	99.84	99.79	99.75	100.04	99.65	98.01	98.05	98.33
Sc	7	6	5	6	4	5	6	9	10
V	63	47	59	49	40	26	54	75	86
Cr	20	12	15	18	13	24	18	44	43
Co	7	9	8	11	6	4	9	17	18
Ni	6	8	8	9	10	11	10	22	22
Cu	7	4	3	5	5	2	11	15	17
Zn	51	40	47	48	44	46	59	73	79
Ga	22	19	22	22	19	20	*	*	*
Rb	154	137	108	122	165	156	186	181	182
Sr	551	479	737	584	375	1140	1100	1400	1400
Ba	828	1044	1546	1142	596	941	1200	1200	1300
Y	23	17	14	18	20	14	26	29	32
Zr	173	169	187	173	182	168	239	270	291
Nb	13	10	6	10	14	8	12	18	17
La	46	39	48	43	52	41	70	79	84
Ce	96	74	90	91	109	84	145	162	184
Nd	33	29	33	29	37	32	*	*	*
Pb	26	28	27	29	32	36	43	42	34
Th	18	12	9	15	27	12	17	20	17

	---- Terråkfjellet Pluton -----					------- Gaupen Pluton --------				
	B774	B775	B806	B808	N8685	N8690	UR01	UR02	UR03	UR18
SiO2	67.80	65.30	63.87	66.27	64.83	64.45	65.34	64.76	66.90	64.13
TiO2	.36	.66	.79	.43	.47	.54	.66	.67	.60	.68
Al2O3	15.84	16.94	17.13	16.31	17.77	17.52	16.32	16.53	15.60	16.57
Fe2O3	2.90	4.01	4.55	3.26	2.62	4.11	3.86	4.17	3.94	4.48
MnO	.07	.07	.08	.07	.03	.07	.11	.09	.10	.10
MgO	1.31	1.48	1.61	1.36	.74	1.06	1.35	1.39	1.32	1.60
CaO	3.08	3.65	3.79	3.14	2.31	3.04	2.74	2.92	2.60	3.00
Na2O	4.13	4.76	4.44	4.74	3.99	4.56	3.96	4.06	4.23	3.94
K2O	3.83	2.79	2.76	3.69	6.35	3.87	4.86	4.57	4.07	4.54
P2O5	.15	.22	.32	.16	.20	.20	.22	.24	.20	.26
LOI	.26	.24	.37	.61	.45	.53	.34	.61	.45	.34
TOTAL	99.74	100.13	99.70	100.04	99.75	99.95	99.76	100.02	100.02	99.64
Sc	7	5	6	7	7	8	9	9	9	6
V	38	56	67	46	35	36	53	55	60	59
Cr	14	8	7	16	14	11	11	16	12	25
Co	8	8	7	16	5	6	7	8	10	12
Ni	8	5	4	8	6	3	9	11	9	9
Cu	5	7	11	2	9	11	10	7	8	8
Zn	34	88	76	38	45	68	46	50	59	61
Ga	20	24	26	20	21	23	21	18	20	20
Rb	113	96	105	117	115	165	153	143	160	153
Sr	692	806	824	734	1070	329	463	501	406	487
Ba	845	934	888	814	1940	621	1019	943	766	1005
Y	15	18	12	20	28	28	37	30	26	27
Zr	131	212	253	164	280	338	246	262	251	281
Nb	10	14	9	15	11	27	24	19	18	20
La	56	71	89	43	69	26	53	67	52	41
Ce	83	109	156	80	153	54	84	136	107	82
Nd	30	47	65	33	58	22	41	47	47	37
Pb	25	24	17	21	33	27	25	30	28	28
Th	12	11	20	16	8	12	14	12	16	19

PORPHYRITIC GRANITE

	Alsten Masssif		Bindalseid		--------- Tosbotn-Namsskogan ---------					
	N87153	N8950	N8873	N8874	N8666	N8847	N8856	N8959	N8960	N8875
SiO2	73.14	73.51	72.80	73.93	68.67	67.45	68.15	70.49	69.38	69.46
TiO2	.21	.23	.28	.19	.44	.37	.46	.24	.32	.20
Al2O3	14.09	14.18	13.84	14.11	15.84	16.55	16.73	15.67	15.98	15.69
Fe2O3	1.99	2.16	2.42	1.87	2.68	2.42	2.74	1.52	1.70	1.80
MnO	.04	.04	.04	.04	.04	.02	.03	.02	.02	.04
MgO	.31	.32	.32	.29	1.14	.75	1.00	.39	.47	.89
CaO	.94	1.07	1.15	.91	1.78	2.69	2.67	1.89	2.13	2.29
Na2O	3.67	3.28	2.96	3.48	3.62	4.79	3.93	4.27	4.57	3.97
K2O	5.35	5.18	5.77	5.45	4.23	3.10	4.00	4.24	3.74	4.32
P2O5	.09	.09	.09	.09	.18	.03	.17	.08	.09	.06
LOI	.45	.62	.31	.48	.13	.44	.38	.58	.52	.27
TOTAL	100.28	100.67	99.98	100.82	99.68	98.60	100.28	99.39	98.92	98.98
Sc	2	6	9	11	4	5	7	*	5	5
V	16	9	19	15	41	34	39	14	17	14
Cr	19	10	25	38	28	14	55	17	11	39
Co	3	*	4	*	7	4	6	*	*	7
Ni	6	5	6	7	10	5	6	*	*	12
Cu	*	*	3	1	*	*	*	*	*	*
Zn	31	52	50	41	47	29	67	36	39	29
Ga	22	*	22	24	21	23	24	*	*	22
Rb	243	271	218	303	154	76	152	126	94	241
Sr	77	65	77	56	458	737	536	549	741	293
Ba	213	244	274	165	688	799	904	624	694	514
Y	43	51	48	43	10	10	12	9	5	14
Zr	126	154	209	126	131	180	152	150	173	125
Nb	22	28	26	23	9	9	10	6	*	8
La	51	57	93	57	17	81	31	21	36	26
Ce	92	123	192	99	36	128	59	45	68	60
Nd	44	*	78	35	21	56	30	*	*	24
Pb	26	37	30	24	27	26	28	33	28	46
Th	20	*	27	13	6	33	11	*	*	13

	------- Sklinna Pluton --------					---------- Toven Massif ---------				
	S120A	S120E	S122	S124	S130	N87150	N8955	N8956	T31	T5641
SiO2	72.09	72.07	74.41	74.81	72.12	73.43	68.09	69.45	70.68	70.82
TiO2	.23	.27	.08	.08	.25	.34	.62	.33	.29	.18
Al2O3	14.75	14.56	14.60	14.02	14.83	12.63	14.92	16.15	14.43	15.15
Fe2O3	1.55	1.51	.69	.84	1.53	2.71	4.56	2.02	2.14	1.39
MnO	.09	.05	.06	.04	.05	.03	.06	.03	.02	.02
MgO	.33	.35	.11	.15	.40	.47	.99	.66	.39	.29
CaO	1.13	1.13	.71	.67	1.11	.82	1.79	2.35	1.45	2.40
Na2O	4.12	4.51	4.38	4.30	4.12	2.54	3.16	4.58	4	3.80
K2O	4.99	4.78	4.60	4.41	5.04	5.86	4.68	3.11	4.68	4.49
P2O5	.18	.15	.10	.14	.15	.17	.18	.09	.08	.03
LOI	.29	.35	.29	.51	.11	.37	.55	.56	.49	.26
TOTAL	99.74	99.73	100.03	99.96	99.71	99.38	99.61	99.34	98.65	97.95
Sc	2	3	4	4	4	6	11	6	*	*
V	16	12	4	8	15	31	42	17	17	9
Cr	10	19	18	3	19	16	34	16	7	37
Co	*	*	*	*	3	3	7	*	*	*
Ni	3	4	3	*	3	10	10	*	*	*
Cu	4	1	3	12	4	*	8	*	*	*
Zn	47	49	13	16	38	35	69	56	33	34
Ga	23	20	21	24	22	21	*	*	*	*
Rb	288	272	268	253	220	258	215	116	193	170
Sr	214	231	115	128	233	69	141	677	213	316
Ba	304	340	169	164	303	147	538	556	434	647
Y	16	16	13	13	21	42	45	10	25	12
Zr	131	141	63	59	129	191	290	176	157	121
Nb	24	23	11	19	22	13	18	10	11	10
La	29	33	9	11	30	22	30	24	27	21
Ce	69	65	*	*	54	45	73	44	58	43
Nd	32	32	11	13	27	18	*	*	*	*
Pb	31	31	29	28	34	26	29	29	35	43
Th	15	15	4	13	17	17	*	*	12	*

	Toven Massif					Porphyritic rocks in Velfjord				
	T61	T691	T711	T731	T881	VF47	VF51	VF52	VF58	VF57
SiO2	70.11	66.82	67.09	67.13	67.16	67.60	67.30	65.18	66.76	64.43
TiO2	.27	.39	.33	.31	.31	.53	.57	.69	.55	.86
Al2O3	14.13	16.68	16.87	16.96	16.65	16.06	15.89	16.47	16	16.22
Fe2O3	2.75	2.43	2.10	2.01	2.01	3.54	3.58	4.65	3.94	5.45
MnO	.04	.03	.02	.02	.03	.03	.06	.08	.08	.11
MgO	.27	.81	.62	.57	.62	.61	.64	.80	.76	1.37
CaO	1.38	2.65	2.47	2.30	2.41	2.35	2.36	2.75	2.36	1.84
Na2O	3.70	4.70	4.60	4.50	4.60	3.44	3.27	3.45	3.58	2.89
K2O	4.95	3.13	3.52	3.81	3.45	5.30	4.96	4.78	5.15	5.91
P2O5	.04	.09	.07	.06	.03	.19	.23	.25	.22	.14
LOI	.49	.65	.35	.39	.32	.37	.89	.70	.58	.61
TOTAL	98.13	98.38	98.04	98.06	97.63	100.00	99.75	99.80	100.00	99.84
Sc	7	*	*	*	*	6	7	9	8	12
V	7	25	19	17	18	31	27	35	30	47
Cr	*	22	26	13	48	7	9	9	10	28
Co	*	6	*	*	*	4	7	7	10	10
Ni	*	*	*	*	*	6	7	8	4	17
Cu	*	*	*	*	*	7	5	9	13	25
Zn	64	59	53	50	52	53	61	65	54	56
Ga	*	*	*	*	*	26	26	25	24	20
Rb	165	107	115	123	127	154	169	149	156	189
Sr	95	781	750	730	702	212	209	234	198	179
Ba	261	764	701	805	666	971	976	1140	925	885
Y	38	8	6	8	9	37	36	49	43	62
Zr	278	204	185	167	171	311	330	401	347	486
Nb	11	8	10	8	9	22	24	25	22	24
La	73	53	16	24	16	67	65	72	50	70
Ce	164	81	47	41	45	127	145	158	106	151
Nd	*	*	*	*	*	57	59	72	40	61
Pb	30	26	29	35	29	33	31	26	32	39
Th	24	*	11	11	*	29	27	30	24	49

TONALITE AND GRANODIORITE

	Fustvatnet			Vefsn	Kråkfjellet Pluton							
	N87140	N87141	N87144	N87139	B520	B523	B526	B529	B538	B551	B552	B726
SiO2	61.10	60.14	63.20	61.47	70.10	68.88	68.23	68.42	69.28	66.37	64.28	64.77
TiO2	.66	.81	.58	.51	.30	.46	.45	.37	.39	.50	.63	.55
Al2O3	16.86	16.65	18.62	17.88	14.79	16.35	16.26	15.90	15.56	16.31	16.81	17.22
Fe2O3	5.06	5.64	3.75	4.18	2.69	3.30	3.48	2.82	3.13	3.50	4.30	4.10
MnO	.08	.08	.05	.07	.09	.07	.06	.11	.08	.07	.08	.06
MgO	3.19	3.65	1.47	2.73	.92	1.75	1.50	1.22	1.09	1.63	1.89	1.63
CaO	5.61	5.92	4.72	5.10	2.72	3.73	3.52	3.29	3.36	4.14	4.71	4.39
Na2O	4.55	4.35	4.47	5.41	4.35	4.16	5.10	4.76	4.60	4.22	4.28	4.47
K2O	1.92	1.97	1.71	1.50	2.47	2.02	2.51	2.31	1.62	2.65	1.92	1.71
P2O5	.15	.17	.16	.14	.12	.32	.19	.14	.15	.39	.27	.21
LOI	.52	.44	.46	.41	.33	.59	.29	.37	.29	.31	.44	.47
TOTAL	99.70	99.81	99.19	99.40	98.65	99.54	101.43	99.49	99.30	99.88	99.34	99.59
Sc	9	11	7	8	7	5	8	*	8	4	5	6
V	90	106	58	79	42	60	42	44	52	57	70	59
Cr	79	89	16	62	6	18	13	11	14	16	20	21
Co	20	22	15	13	12	17	12	13	15	16	21	10
Ni	31	44	5	34	9	14	13	11	10	14	16	11
Cu	7	16	6	*	*	*	*	*	*	*	*	11
Zn	51	55	46	42	63	64	57	56	72	63	74	*
Ga	20	20	22	20	20	21	21	20	19	19	21	19
Rb	63	65	107	48	90	66	65	86	106	61	51	78
Sr	572	521	594	799	507	856	1036	994	611	1132	1078	627
Ba	396	355	284	531	439	552	464	521	317	839	571	338
Y	19	17	14	12	14	12	11	13	13	13	12	16
Zr	147	145	145	117	183	256	276	277	220	292	298	141
Nb	8	8	10	7	17	16	16	15	15	16	15	12
La	13	16	30	5	21	43	31	39	34	52	41	51
Ce	26	35	51	15	51	73	56	62	66	89	80	91
Nd	9	14	18	13	23	34	21	27	27	36	39	32
Pb	24	17	20	17	22	18	18	21	20	24	13	16
Th	9	5	13	9	5	11	13	11	9	11	12	15

	Kråkfjellet Pluton											
	B727	B729	B730	B749	B751	B752	UR06	UR09	UR13	UR21	UR23	UR24
SiO2	64.87	61.55	64.79	67.35	67.31	67.43	68.29	67.94	68.73	65.25	64.82	69.58
TiO2	.54	.65	.56	.42	.39	.44	.35	.37	.35	.50	.55	.33
Al2O3	17.43	17.95	17.77	16.10	16.26	16.34	16.64	16.52	16.47	17.17	16.59	16.05
Fe2O3	3.95	4.94	4.07	3.01	2.80	3.03	2.60	2.59	2.61	3.35	3.72	2.28
MnO	.07	.07	.06	.08	.06	.07	.04	.06	.06	.06	.08	.05
MgO	1.64	2.14	1.74	1.27	1.18	1.27	.85	1.00	1.04	1.34	1.71	.86
CaO	4.03	5.08	4.24	3.52	3.53	3.46	3.27	3.16	3.19	4.07	4.05	3.01
Na2O	4.39	4.37	4.55	5.52	5.65	5.64	5.64	5.34	5.60	5.74	5.44	5.70
K2O	1.82	1.97	2.13	2.07	2.16	1.92	1.72	2.38	1.66	1.50	2.36	1.92
P2O5	.24	.26	.26	.16	.14	.19	.12	.13	.12	.17	.20	.09
LOI	.43	.50	.49	.21	.34	.21	.32	.45	.43	.69	.19	.08
TOTAL	99.40	99.49	100.65	99.71	99.83	100.07	99.84	99.93	100.27	99.83	99.71	99.97
Sc	16	13	11	5	6	7	2	5	5	5	7	5
V	65	78	*	46	41	49	32	30	29	42	54	30
Cr	28	33	*	15	13	20	6	6	6	21	19	4
Co	10	14	*	6	5	5	5	10	7	8	9	5
Ni	12	16	*	10	5	11	3	3	*	5	9	2
Cu	12	14	*	6	5	4	2	5	3	3	4	4
Zn	*	*	*	35	38	43	34	33	32	38	46	25
Ga	21	22	19	20	21	22	21	20	22	21	22	20
Rb	93	81	83	63	52	63	50	69	65	49	57	48
Sr	597	784	606	984	989	952	892	839	760	989	1169	730
Ba	401	521	566	494	505	373	429	415	347	487	637	429
Y	15	15	14	13	12	13	9	11	11	9	15	10
Zr	116	147	139	145	130	160	142	128	134	168	157	110
Nb	14	14	14	10	9	9	7	6	11	7	13	6
La	33	29	25	34	20	37	19	17	25	33	44	14
Ce	50	43	21	76	35	64	39	40	55	59	66	15
Nd	22	23	13	29	23	22	17	22	27	24	32	18
Pb	15	17	18	16	19	20	17	18	21	15	17	16
Th	5	3	3	13	7	9	11	8	11	14	7	12

	Ursfjord			Lande	Luktvt	Tosbotn-Namsskogan					Terråkfjell	
	UR25	UR27	UR28	N8906	N8957	N8632	N8646	N8961	N8962	N8963	B766	B767
SiO2	69.77	66.01	71.52	60.13	63.45	63.46	70.17	67.83	67.62	70.67	66.15	68.85
TiO2	.30	.45	.13	.76	.37	.58	.31	.46	.33	.20	.61	.45
Al2O3	15.98	16.59	16.15	16.87	19.38	16.24	16.22	15.83	17.25	15.52	16.39	15.53
Fe2O3	2.31	3.32	1.03	4.29	2.58	4.83	2.10	2.67	2.19	1.45	3.72	2.90
MnO	.06	.08	.03	.06	.03	.09	.04	.04	.04	.02	.06	.05
MgO	.92	1.47	.40	1.88	1.17	2.59	.97	1.25	.90	.56	1.26	.94
CaO	3.02	3.86	2.65	4.45	4.36	4.88	3.30	3.06	3.79	2.87	3.79	2.80
Na2O	5.44	5.82	5.38	3.91	4.98	4.30	4.91	4.01	4.85	4.19	4.45	4.55
K2O	1.98	1.65	2.19	4.81	2.53	2.29	1.54	3.20	1.62	2.67	2.72	3.23
P2O5	.09	.17	.04	.44	.19	.16	.06	.10	.09	.05	.21	.17
LOI	.21	.37	.21	.87	.42	.38	.21	.65	.98	.61	.39	.42
TOTAL	100.08	99.79	99.72	98.48	99.44	99.80	99.84	99.11	99.65	98.82	99.75	99.88
Sc	7	5	2	8	6	14	7	9	8	*	4	4
V	28	46	12	57	47	81	31	36	28	18	50	43
Cr	5	16	4	14	19	58	21	35	17	27	9	4
Co	7	9	*	*	*	13	6	*	*	*	9	4
Ni	2	7	*	8	*	18	6	14	*	*	3	3
Cu	1	3	3	45	28	12	3	*	*	*	7	4
Zn	27	44	18	53	37	58	37	47	54	31	75	57
Ga	20	21	16	*	*	18	20	*	*	*	23	23
Rb	40	46	63	85	85	80	65	108	78	72	116	149
Sr	724	1110	674	2000	1100	529	561	418	579	464	782	564
Ba	431	586	1844	1700	654	676	225	537	209	562	650	573
Y	9	10	6	18	7	17	6	11	6	8	15	13
Zr	107	160	77	346	213	105	103	156	122	105	171	152
Nb	5	7	3	15	9	6	7	11	13	10	12	12
La	14	26	12	107	38	13	*	34	*	14	52	38
Ce	34	38	*	172	75	32	*	66	*	20	65	57
Nd	22	24	11	*	*	18	7	*	*	*	34	24
Pb	17	16	51	25	25	17	19	24	20	17	24	27
Th	4	10	4	*	*	5	*	*	*	*	11	14

	Terråkfjellet Pluton											
	B768	B769	B770	B772	B773	B784	B785	B786	B793	B797	B798	B799
SiO2	63.34	69.84	61.63	66.31	63.62	67.19	67.38	63.67	68.30	66.82	65.74	64.17
TiO2	.76	.43	.87	.58	.71	.53	.54	.74	.43	.65	.62	.77
Al2O3	17.14	15.32	17.45	16	17.14	15.84	15.82	17.11	15.85	16.32	16.52	17.02
Fe2O3	4.61	2.72	5.11	3.65	4.39	3.40	3.23	4.43	2.96	3.72	3.76	4.40
MnO	.09	.06	.09	.08	.08	.07	.07	.09	.05	.06	.06	.07
MgO	1.71	.87	1.88	1.18	1.58	1.16	1.07	1.56	1.23	1.21	1.22	1.46
CaO	4.30	2.48	4.67	3.43	4.14	3.26	2.97	4.34	3.38	3.16	3.16	3.82
Na2O	4.85	4.21	4.87	4.84	4.77	4.23	4.39	4.53	5.25	4.24	4.65	4.76
K2O	2.29	3.72	2.27	3.18	2.54	3.51	3.48	2.49	2.21	3.13	3.29	2.77
P2O5	.28	.15	.34	.22	.26	.19	.20	.27	.15	.23	.24	.29
LOI	.40	.32	.59	.32	.43	.51	.40	.29	.29	.38	.40	.43
TOTAL	99.77	100.14	99.78	99.78	99.66	99.89	99.55	99.51	100.10	99.92	99.67	99.97
Sc	9	4	6	4	7	4	5	8	6	6	7	5
V	74	41	88	54	64	53	46	67	43	58	50	72
Cr	10	*	6	4	10	6	4	8	22	7	12	4
Co	11	4	11	7	*	8	9	12	8	9	3	11
Ni	6	2	5	*	4	3	3	4	9	4	4	4
Cu	7	3	8	5	19	5	6	5	4	6	5	6
Zn	89	65	95	61	69	66	64	87	34	71	74	94
Ga	27	22	27	22	25	23	22	24	20	23	27	25
Rb	100	138	114	128	99	110	119	91	62	141	132	113
Sr	856	551	942	705	916	704	653	871	906	655	699	799
Ba	641	763	655	748	926	751	733	753	554	743	818	767
Y	22	12	22	19	21	17	14	21	12	14	15	30
Zr	213	151	245	180	208	171	172	202	152	212	213	242
Nb	16	10	15	13	13	12	7	14	9	9	12	17
La	58	35	61	37	56	43	74	44	34	32	50	86
Ce	88	77	124	57	89	62	107	83	74	96	121	162
Nd	48	28	45	26	43	28	51	40	30	37	45	70
Pb	21	31	18	18	16	24	27	22	18	27	23	22
Th	11	10	18	13	13	7	12	10	6	16	16	16

	Terråkfjellet			Ursfj	Velfj
	N8672	N8673	N8675	N8923	N8811
SiO2	62.55	65.65	66.30	62.05	70.13
TiO2	.73	.49	.57	.58	.26
Al2O3	17.86	16.99	16.14	17.87	16.11
Fe2O3	4.59	3.24	3.50	4.10	1.95
MnO	.07	.05	.06	.07	.03
MgO	4.59	3.24	3.50	1.83	.65
CaO	4.52	3.64	3.60	4.66	2.18
Na2O	4.59	4.53	4.32	4.76	5.34
K2O	2.71	3.13	3.25	2.13	1.76
P2O5	.27	.18	.23	.24	.07
LOI	.37	.45	.72	.84	.41
TOTAL	99.93	99.53	99.93	99.13	98.89
Sc	9	6	4	10	6
V	67	47	54	62	18
Cr	15	10	8	23	27
Co	10	5	7	10	6
Ni	6	3	2	11	2
Cu	3	3	6	6	*
Zn	91	64	59	56	34
Ga	25	23	22	*	22
Rb	90	117	131	67	60
Sr	913	788	721	1100	633
Ba	976	724	769	644	409
Y	15	13	14	12	12
Zr	206	163	180	166	138
Nb	13	9	11	10	5
La	67	31	36	45	19
Ce	117	50	69	81	21
Nd	39	22	31	*	16
Pb	21	24	16	20	16
Th	6	8	8	*	6

GRANITE AND GRANODIORITE

	Tosbotn-Kolsvik area											
	N8656	N8658	N8659	N8660	N8661	N8662	N8663	N8664	N8665	N8669	N8687	N8689
SiO2	71.46	71.30	71.25	69.99	71.53	71.12	71.58	70.85	72.26	72.70	70.76	72.38
TiO2	.27	.25	.25	.33	.28	.29	.27	.30	.25	.33	.30	.20
Al2O3	15.35	15.53	15.48	15.89	15.30	15.32	15.24	15.48	14.72	14.18	15.08	15.21
Fe2O3	1.61	1.60	1.52	1.99	1.70	1.80	1.65	1.77	1.71	1.81	2.08	1.22
MnO	.03	.10	.04	.03	.02	.03	.03	.03	.05	.03	.04	.02
MgO	.48	.53	.51	.69	.54	.61	.47	.52	.50	.56	.78	.33
CaO	1.75	1.71	1.58	2.05	1.97	2.16	1.81	1.90	1.78	1.89	2.43	1.50
Na2O	4.14	4.23	4.24	4.44	4.33	4.23	4.03	4.20	4	3.58	4.48	3.98
K2O	4.36	3.66	4.31	4.26	3.86	3.44	4.41	4.37	4.06	4.15	2.96	4.73
P2O5	.10	.10	.09	.17	.08	.11	.08	.11	.08	.11	.09	.08
LOI	.26	.21	.50	.43	.40	.40	.43	.43	.34	.29	.61	.24
TOTAL	99.81	99.81	99.72	99.54	100.03	99.51	100	99.96	99.74	99.64	99.61	99.88
Sc	4	6	4	5	4	3	3	4	3	5	7	2
V	17	19	13	22	22	19	18	21	20	22	28	11
Cr	26	12	10	15	9	9	8	10	10	7	15	10
Co	*	3	3	4	4	3	3	4	6	3	4	*
Ni	3	4	*	5	5	3	4	*	4	3	5	*
Cu	2	*	1	*	*	2	2	*	*	2	1	1
Zn	50	45	48	55	52	48	48	53	45	51	43	48
Ga	21	23	23	23	22	22	21	22	20	19	19	22
Rb	167	197	172	174	156	141	184	178	176	141	102	169
Sr	380	337	351	408	378	448	350	363	338	409	502	284
Ba	438	374	476	300	429	396	513	495	384	579	757	442
Y	10	12	10	13	10	8	11	11	12	9	13	8
Zr	140	122	139	141	135	148	155	165	135	173	140	115
Nb	9	10	9	13	10	9	11	10	15	10	7	8
La	18	14	18	12	15	14	17	15	23	21	10	18
Ce	26	20	32	27	28	20	31	31	22	50	26	32
Nd	13	14	14	15	13	11	16	14	12	20	21	15
Pb	26	27	26	24	22	26	25	26	26	25	29	28
Th	10	8	11	4	8	7	13	11	8	13	12	10

	Tosbotn-Kolsvik			Oksdal Massif								
	B610	B611	B666	N87115	N87120	N87121	N87122	N87123	N87124	N87125	N87127	N8822
SiO2	72.80	72.93	72.44	70.75	71.88	72.89	73.77	72.24	74.13	74.54	72.81	65.57
TiO2	.25	.24	.27	.29	.19	.21	.08	.23	.09	.08	.18	.71
Al2O3	15.10	14.65	15.18	15.73	15.33	15.46	14.89	14.94	14.58	14.59	15.35	16.16
Fe2O3	1.64	1.56	1.67	1.85	1.19	1.29	.65	1.33	.68	.66	1.21	3.06
MnO	.04	.03	.03	.03	.01	.02	0	.01	0	0	.02	.04
MgO	.42	.37	.44	.59	.33	.38	.15	.29	.15	.14	.31	1.34
CaO	1.59	1.61	1.69	2.02	1.69	1.78	1.07	1.06	.75	.87	1.66	2.84
Na2O	4.23	3.99	4.27	4.27	5.88	6.01	3.98	4.01	3.66	3.91	5.56	4.49
K2O	3.84	3.96	3.97	3.79	2.07	1.71	5.30	4.81	5.23	4.97	2.46	3.00
P2O5	.08	.06	.91	.13	.06	.07	.04	.10	.07	.07	.07	.25
LOI	.39	.31	.29	.32	.25	.26	.24	.35	.46	.37	.19	.73
TOTAL	100.37	99.68	100.34	99.77	98.88	100.05	100.18	99.37	99.80	100.22	99.81	98.19
Sc	2	*	3	4	6	2	*	*	3	*	3	3
V	10	8	16	27	16	20	5	18	*	*	16	45
Cr	5	3	15	15	11	14	19	8	8	6	12	36
Co	3	2	3	5	4	5	*	6	3	*	3	5
Ni	5	4	4	3	*	*	*	*	*	*	*	11
Cu	5	4	7	*	*	*	*	*	*	*	*	*
Zn	*	*	*	35	17	20	10	46	3	7	20	50
Ga	21	19	22	22	23	21	22	23	25	24	22	28
Rb	185	170	184	179	96	87	225	166	255	244	134	197
Sr	312	248	361	435	439	470	201	479	110	99	427	1076
Ba	353	531	368	661	146	140	232	720	195	124	207	799
Y	16	14	10	8	4	4	8	10	8	13	6	14
Zr	123	162	136	168	123	135	79	130	61	72	108	240
Nb	17	13	13	5	4	*	6	8	8	9	2	13
La	17	24	17	35	18	9	16	32	14	21	9	68
Ce	26	44	23	55	17	10	25	53	30	30	15	106
Nd	11	16	16	15	8	4	10	14	12	12	6	43
Pb	26	30	24	24	21	18	37	23	36	33	22	23
Th	11	23	11	16	7	7	16	14	20	19	7	15

	Oksdal Massif									
	N8823	N8824	N8827	N8860	N8647	N8670	N87107	N87108	N87109	N87110
SiO2	70.41	73.30	72.60	73.50	72.88	70.13	72.98	69.54	74.14	73.83
TiO2	.30	.06	.09	.11	.15	.28	.15	.34	.15	.14
Al2O3	15.81	13.71	14.74	14.21	15.10	15.78	14.87	16.14	14.99	14.33
Fe2O3	1.72	.37	.35	.36	1.01	1.77	1.49	2.06	1.31	1.01
MnO	.03	0	0	0	.03	.13	.02	.03	.04	.03
MgO	.41	.07	.17	.15	.34	.41	.48	.51	.45	.26
CaO	2.14	.78	1.72	.61	1.54	1.56	2.17	1.83	2.17	1.67
Na2O	4.86	3.97	4.31	2.91	4.01	4.25	3.91	4.22	3.92	3.91
K2O	3.33	5.70	4.28	6.88	4.44	5.16	3.50	4.89	3.97	4.11
P2O5	.09	.03	.03	.06	.06	.13	.06	.14	.04	.03
LOI	.65	.40	.80	.37	.32	.29	.38	.22	.61	.54
TOTAL	99.74	98.39	99.08	99.17	99.87	99.69	100	99.93	101.78	99.86
Sc	5	1	4	3	3	2	3	5	*	4
V	20	7	6	2	7	17	13	20	15	7
Cr	41	51	10	16	9	6	15	9	22	5
Co	5	3	*	*	*	*	4	*	*	5
Ni	4	2	5	6	3	3	7	*	2	*
Cu	2	*	*	*	*	*	*	*	*	*
Zn	71	3	5	9	28	48	25	48	25	11
Ga	26	20	18	20	21	23	17	23	17	17
Rb	186	264	170	286	174	184	127	188	140	140
Sr	920	230	524	175	260	375	540	441	527	427
Ba	920	295	1038	256	381	657	704	690	647	669
Y	12	16	12	11	11	12	11	12	10	12
Zr	179	54	67	60	93	166	97	184	82	97
Nb	8	6	5	9	7	9	5	9	5	9
La	31	22	17	20	7	32	27	30	15	15
Ce	60	*	28	35	28	50	43	30	21	30
Nd	26	11	13	28	15	22	19	15	4	6
Pb	16	46	21	39	29	32	25	28	27	32
Th	7	5	5	11	6	15	13	20	10	9

	Fuglstadfjellet					Bindalsfj	Majafjellet			Sørfjorden	
	N8631	N8636	N8637	N8638	N8639	N86108	N8843	N8846	N8857	N8679	N8681
SiO2	74.54	71.52	73.91	72.82	73.33	70.77	69.27	67.96	67.96	74.20	74.13
TiO2	.11	.23	.09	.17	.14	.36	.29	.41	.29	.20	.18
Al2O3	14.10	14.75	14.53	14.49	14.39	15.01	15.98	16.46	15.96	12.46	12.93
Fe2O3	1.04	1.78	.75	1.39	1.17	2.28	2.22	2.52	1.87	2.54	2.37
MnO	.04	.06	.03	.05	.03	.07	.03	.03	.03	.05	.04
MgO	.26	.69	.18	.60	.34	.61	.79	.82	.95	.09	.13
CaO	1.59	2.34	1.54	1.92	1.83	2.50	3.12	3.19	3.30	.52	.59
Na2O	3.77	4.09	4.19	4.09	4.00	4.05	4.24	5.26	5.09	4.31	4.31
K2O	4.20	3.85	4.29	3.84	4.01	3.47	2.87	1.61	1.31	4.93	5.03
P2O5	.02	.07	.02	.04	.03	.13	.11	.10	.08	.01	.05
LOI	.40	.56	.37	.43	.51	.50	.41	.33	.53	.24	.40
TOTAL	100.07	99.94	99.90	99.84	99.78	99.75	99.32	98.69	97.37	99.53	100.17
Sc	4	4	4	4	3	4	6	3	9	*	4
V	9	21	7	16	7	26	6	29	22	6	8
Cr	13	16	9	23	10	9	26	11	24	6	27
Co	*	3	*	*	*	4	4	5	4	*	*
Ni	3	6	*	6	5	3	*	*	6	4	5
Cu	*	*	*	3	*	3	*	*	*	*	*
Zn	26	35	19	38	26	58	42	44	27	122	83
Ga	16	16	16	18	16	19	21	25	22	33	30
Rb	148	148	179	178	162	116	96	68	42	275	370
Sr	390	541	393	456	455	496	430	573	590	28	26
Ba	562	644	441	552	612	717	451	213	525	86	101
Y	8	12	9	16	7	15	10	10	6	84	107
Zr	81	97	61	87	105	156	139	154	100	558	493
Nb	4	7	8	10	6	15	11	10	3	61	88
La	5	24	4	7	16	30	34	33	36	96	88
Ce	10	26	*	14	16	62	31	44	19	197	164
Nd	11	18	9	11	11	25	17	22	16	76	65
Pb	38	32	42	28	35	35	27	17	8	15	26
Th	3	4	2	5	5	12	9	4	5	20	46

	Heilhornet Pluton								
	HH07	HH209	HH270	HH345	HH395	HH396	N8698	N87163	N87164
SiO2	70.90	72.48	67.82	66	70.97	67.34	64.45	68.84	63.92
TiO2	.33	.30	.47	.52	.23	.41	.54	.40	.56
Al2O3	14.26	13.82	15.43	16.20	15.07	16	17.52	15.44	17.28
Fe2O3	2.79	2.58	3.67	4.03	2.13	3.37	4.11	3.16	4.30
MnO	.06	.08	.08	.10	.05	.10	.07	.07	.10
MgO	.48	.37	.75	1.02	.37	.77	1.06	.73	.88
CaO	1.54	1.30	2.23	2.71	1.34	2.07	3.04	2.16	2.68
Na2O	4.23	3.94	4.32	4.82	4.36	4.52	4.56	4.28	4.93
K2O	4.70	4.67	4.72	4.21	5.15	5.09	3.87	4.50	4.81
P2O5	.06	.06	.12	.18	.06	.11	.20	.09	.16
LOI	.35	.23	.33	.40	.16	.43	.53	.30	.30
TOTAL	99.71	99.82	99.95	100.20	99.89	100.23	99.95	99.98	99.92
Sc	2	*	4	6	4	6	8	6	10
V	18	19	34	28	12	24	36	25	33
Cr	12	16	21	*	6	14	11	11	9
Co	3	*	8	7	4	*	6	4	3
Ni	9	3	7	4	3	3	3	10	7
Cu	*	*	*	*	*	*	*	*	*
Zn	50	48	49	62	41	58	68	44	67
Ga	20	20	20	22	20	20	23	21	22
Rb	246	260	184	218	301	190	165	221	195
Sr	167	146	238	293	138	229	329	228	331
Ba	365	317	455	529	347	561	621	411	756
Y	39	40	37	34	33	33	28	34	43
Zr	257	251	304	320	194	317	338	251	368
Nb	36	39	21	30	32	27	27	22	33
La	76	29	57	45	22	121	26	77	123
Ce	95	109	90	91	71	187	54	124	184
Nd	43	29	33	37	8	63	22	49	61
Pb	35	30	27	32	38	30	27	27	28
Th	50	47	32	25	35	33	12	23	29

	Heilhornet Pluton								Kvaløy Pluton		
	N8762	N8765	N8769	N8776	N8779	N8780	N8787	N8788	S84A	S92	S109A
SiO2	68.81	71.80	71.01	69.42	62.51	61.46	63.70	69.08	72.52	74.30	71.64
TiO2	.34	.32	.29	.38	.62	.74	.63	.40	.10	.11	.15
Al2O3	15.31	14.08	14.73	14.96	17.47	17.37	17.00	15.14	15.44	14.54	15.64
Fe2O3	2.84	2.59	2.44	2.97	4.84	5.58	4.70	3.10	.94	1.06	1.06
MnO	.07	.05	.08	.05	.10	.11	.10	.06	.04	.04	.03
MgO	.49	.42	.36	.65	1.08	1.28	.96	.72	.30	.31	.34
CaO	1.58	1.27	1.29	1.87	2.90	3.16	2.67	2.12	1.50	1.36	1.54
Na2O	4.64	4.20	4.38	4.20	4.99	4.97	4.66	4.20	5.08	4.67	4.91
K2O	4.97	4.64	4.86	4.64	4.99	4.97	4.66	4.67	3.60	3.46	4.37
P2O5	.08	.06	.07	.09	.18	.24	.19	.10	.03	.04	.04
LOI	.65	.35	.38	.30	.30	.48	.38	.33	.16	.19	.00
TOTAL	99.79	99.77	99.87	99.53	99.74	99.69	99.76	99.92	99.71	100.07	99.71
Sc	4	4	6	2	11	5	4	5	2	4	3
V	21	15	14	25	36	46	37	27	5	8	11
Cr	28	14	16	10	17	11	21	17	*	*	11
Co	5	4	*	7	6	11	4	5	*	*	*
Ni	3	4	*	4	7	3	9	6	*	*	*
Cu	*	*	*	*	*	*	*	*	*	3	4
Zn	46	53	42	38	70	82	73	40	21	23	20
Ga	20	20	20	20	23	23	24	21	16	17	19
Rb	214	268	280	243	179	183	190	213	102	101	120
Sr	209	156	155	198	357	397	236	225	364	313	768
Ba	495	345	351	395	894	875	792	420	756	651	931
Y	33	43	41	34	39	43	43	34	13	13	11
Zr	253	236	231	236	421	476	437	249	58	59	123
Nb	30	37	35	20	31	33	35	21	5	6	6
La	51	62	80	60	115	99	92	79	5	9	10
Ce	102	104	103	133	166	153	150	120	0	13	15
Nd	35	39	41	45	60	48	51	48	6	16	16
Pb	28	31	32	26	29	25	26	24	42	37	44
Th	39	39	37	30	29	30	32	31	4	*	*

	-------- Velfjord -------				--------- Visttindane Massif ----------					
	N8806	N8809	N8810	N88107	N8837	N8838	VF33	VF34	VF36	VF37
SiO2	69.46	70.62	73.22	69.34	67.10	70.66	69.55	73.04	70.37	71.09
TiO2	.32	.26	.10	.31	.46	.38	.49	.21	.34	.22
Al2O3	15.55	15.31	15.42	15.50	15.90	15.70	15.84	14.71	15.72	15.72
Fe2O3	2.59	2.07	1.04	2.30	3.34	1.63	1.91	1.31	1.71	1.70
MnO	.06	.04	.03	.04	.05	.01	.02	.04	.04	.05
MgO	.76	.79	.30	.88	1.35	.56	.55	.26	.41	.44
CaO	2.32	1.45	1.53	2.10	3.44	1.67	1.99	1.36	2.00	2.71
Na2O	3.94	5.50	4.27	3.78	4.26	4.06	4.78	4.48	4.75	4.95
K2O	4.04	2.12	3.39	4.72	2.24	4.93	4.36	4.31	4.18	2.32
P2O5	.09	.11	.06	.13	.15	.08	.13	.06	.08	.05
LOI	.34	.65	.59	.33	.34	.34	.21	.21	.05	.48
TOTAL	99.46	98.91	99.95	99.44	98.62	100.03	99.82	99.99	99.64	99.72
Sc	7	7	4	8	8	4	1	3	2	5
V	22	30	8	17	8	4	29	15	23	15
Cr	23	36	9	65	24	10	8	*	22	20
Co	5	5	4	*	10	3	4	3	*	4
Ni	6	6	6	10	10	5	3	2	*	3
Cu	*	1	*	*	*	1	6	*	5	2
Zn	40	44	25	40	57	48	61	40	54	25
Ga	19	23	20	22	21	25	24	23	23	19
Rb	134	76	128	214	69	178	155	172	125	95
Ba	680	364	619	342	719	780	885	694	827	941
Sr	303	405	287	181	708	555	745	502	734	428
Y	13	12	10	20	15	8	7	13	4	12
Zr	146	89	69	135	156	216	222	110	163	108
Nb	11	6	4	16	7	6	5	6	4	5
La	38	13	28	44	52	68	49	17	13	18
Ce	43	10	30	60	77	90	111	27	17	46
Nd	24	11	19	34	34	44	40	20	16	17
Pb	32	16	34	35	19	31	32	29	26	34
Th	23	6	4	10	9	20	15	11	12	13

	------------------- Visttindane Massif --------------------								
	VS01	VS02	VS03	VS04	VS05	VS06	VS07	VS08	VS09
SiO2	70.90	69.20	70.36	71.85	70.64	70.56	72.27	70.59	72.77
TiO2	.25	.41	.29	.23	.32	.29	.26	.23	.19
Al2O3	15.83	16.49	16.11	15.41	15.67	15.58	15.11	16.01	14.95
Fe2O3	1.58	2.00	1.67	1.47	1.73	1.69	1.56	1.60	1.33
MnO	.04	.06	.05	.04	.05	.05	.04	.04	.04
MgO	.54	.55	.40	.34	.44	.47	.39	.53	.28
CaO	1.71	2.32	1.66	1.38	1.90	1.75	1.60	1.89	1.46
Na2O	5.22	5.20	5.12	4.51	5.06	4.79	4.36	4.97	4.33
K2O	3.49	3.64	3.98	4.24	3.88	4.10	4.17	3.64	4.55
P2O5	.07	.12	.08	.08	.09	.08	.07	.08	.05
LOI	.16	0	.05	.16	.32	.29	.29	.16	0
TOTAL	99.79	99.99	99.77	99.73	100.09	99.67	100.13	99.74	99.96
Sc	2	4	2	3	3	4	2	5	*
V	10	33	19	21	20	23	26	13	12
Cr	4	6	*	6	*	8	*	8	*
Co	3	*	4	*	*	4	3	5	*
Ni	4	2	*	*	3	*	*	3	3
Cu	2	7	4	4	1	3	5	3	4
Zn	46	59	63	48	57	58	45	56	50
Ga	25	24	26	24	25	23	23	22	23
Rb	163	112	146	143	128	152	146	167	167
Sr	504	1426	758	671	740	701	710	528	564
Ba	509	874	720	667	686	692	703	550	715
Y	10	11	11	9	12	10	8	13	7
Zr	126	217	154	145	153	148	144	125	135
Nb	11	6	8	6	7	7	4	9	5
La	13	57	31	25	19	23	24	13	20
Ce	10	97	48	54	50	47	28	26	18
Nd	14	41	30	26	24	26	19	13	15
Pb	28	27	27	30	31	28	25	30	30
Th	12	8	10	14	10	14	9	8	12

	Helfjell		Vefsn					
	H11	H81	N87137	N87138	N87145	N87146	N87147	N87148
SiO2	68.86	69.34	69.59	72.28	70.65	74.09	70.45	73.65
TiO2	.22	.24	.27	.11	.29	.10	.18	.11
Al2O3	16.37	16.80	16.65	15.06	15.05	14.73	15.53	15.27
Fe2O3	1.59	1.74	1.91	1.14	2.09	.74	1.32	1.01
MnO	.03	.03	.03	.01	.02	.01	.03	.03
MgO	.27	.31	.59	.28	.31	.18	.23	.25
CaO	1.68	1.77	3.29	1.67	1.17	1.18	1.54	1.21
Na2O	4.80	4.90	5.40	4.23	4.41	4.12	5.10	4.34
K2O	3.83	3.85	1.10	3.94	4.66	4.22	3.67	4.44
P2O5	.05	.07	.04	.05	.07	.08	.07	.10
LOI	.33	.30	.29	.33	.35	.66	.52	.35
TOTAL	98.03	99.35	99.15	99.11	99.05	100.12	98.64	100.75
Sc	*	*	2	*	2	3	2	*
V	10	8	24	9	19	8	11	10
Cr	*	*	9	3	12	11	8	7
Co	*	*	5	*	4	4	3	4
Ni	*	*	*	*	4	4	*	*
Cu	*	*	*	*	*	*	*	*
Zn	45	53	27	18	58	16	34	24
Ga	*	*	20	16	25	20	21	22
Rb	123	138	49	103	180	158	117	227
Sr	472	515	760	647	339	245	401	185
Ba	634	668	341	1095	880	458	647	271
Y	8	9	7	11	17	10	12	16
Zr	144	172	132	96	211	64	107	60
Nb	13	12	4	4	20	8	7	8
La	25	19	23	15	43	6	20	16
Ce	58	52	36	26	74	28	16	15
Nd	*	*	19	6	33	10	9	3
Pb	24	27	19	34	24	32	21	33
Th	*	*	8	11	21	8	11	12

TOURMALINE GRANITE

	Holm Peninsula									
	HH330	HH331	HH332	HH333	HH334	HH335	HH336	HH337	N87166	N87167
SiO2	72.73	73.25	73.53	73.71	73.41	74.18	72.48	73.72	73.11	71.42
TiO2	.23	.18	.17	.17	.17	.16	.28	.16	.19	.22
Al2O3	14.11	14.14	13.89	14.10	14.19	14.04	14.27	14.35	14.54	14.13
Fe2O3	1.76	1.38	1.33	1.38	1.37	1.41	1.62	1.11	1.49	1.71
MnO	.04	.05	.04	.07	.09	.06	.04	.04	.04	.04
MgO	.42	.34	.28	.22	.16	.30	.57	.32	.38	.46
CaO	1.10	1.00	.87	.78	.77	.77	.57	.32	.85	1.01
Na2O	3.27	3.39	3.19	3.12	3.17	3.02	2.97	3.89	3.31	3.01
K2O	5.44	5.49	5.59	5.72	5.56	5.65	5.60	4.86	5.13	5.45
P2O5	.18	.17	.22	.27	.28	.25	.24	.14	.30	.30
LOI	.40	.42	.59	.27	.62	.13	.93	.53	.57	.81
TOTAL	99.67	99.82	99.72	99.80	99.78	99.99	100.11	99.91	99.91	98.55
Sc	3	2	6	4	3	4	5	*	4	6
V	12	14	4	6	9	11	9	6	14	20
Cr	4	*	*	*	*	*	10	4	12	21
Co	*	*	5	*	3	*	4	*	6	5
Ni	2	2	*	*	4	2	4	2	*	4
Cu	5	4	3	4	4	4	3	*	*	3
Zn	33	20	23	24	21	21	40	22	32	21
Ga	17	16	17	17	18	18	21	19	18	17
Rb	208	202	253	276	296	293	225	210	260	211
Sr	112	95	80	77	66	69	75	47	79	125
Ba	345	280	232	243	228	220	348	164	245	330
Y	32	24	24	24	21	21	27	20	12	20
Zr	132	100	104	102	99	101	152	93	92	115
Nb	17	14	18	19	21	20	12	12	21	19
La	37	24	19	18	21	20	33	21	23	20
Ce	67	62	49	43	36	35	60	32	12	28
Nd	31	25	25	27	20	23	35	27	3	14
Pb	41	43	32	39	30	32	25	27	26	29
Th	23	14	16	12	13	9	16	13	14	13

	Rana			Velfjord				
	N8951	N8952	N8953	N8743	N88108	VF60	VF61	VF62
SiO2	71.10	74.28	75.17	70.99	72.70	71.19	71.95	71.57
TiO2	.20	.24	.12	.26	.14	.27	.25	.24
Al2O3	14.48	12.72	13.31	15.43	14.40	14.71	14.95	14.99
Fe2O3	1.68	1.91	1.62	1.46	1.07	2.38	1.49	1.49
MnO	.05	.02	.06	.02	.05	.05	.03	.06
MgO	.32	.24	.17	.65	.30	.31	.50	.81
CaO	1.04	.90	.70	1.79	.88	1.13	1.49	1.60
Na2O	3.54	2.27	3.07	3.81	3.61	3.54	3.70	3.75
K2O	4.42	5.98	5.37	4.55	4.70	5.98	4.84	4.32
P2O5	.19	.12	.06	.10	.16	.09	.15	.09
LOI	1.20	.59	.35	1.13	.59	.40	.75	1.20
TOTAL	98.21	99.26	100.01	100.19	98.57	100.05	100.10	100.16
Sc	6	11	6	2	6	5	6	7
V	7	*	*	16	7	5	16	10
Cr	11	7	7	22	33	4	5	8
Co	*	*	*	7	3	4	3	4
Ni	*	*	5	4	6	3	3	7
Cu	*	*	*	*	*	5	4	4
Zn	33	25	45	28	30	41	30	19
Ga	*	*	*	22	23	19	21	20
Rb	279	203	313	222	276	210	244	225
Sr	96	63	37	223	54	96	143	168
Ba	242	176	131	328	177	400	346	350
Y	21	27	50	21	19	21	18	15
Zr	88	171	97	130	78	220	129	136
Nb	20	14	20	13	19	19	12	9
La	*	99	23	28	23	72	24	19
Ce	16	218	52	48	24	150	46	44
Nd	*	*	*	24	17	45	22	31
Pb	28	41	39	27	25	32	27	36
Th	*	*	*	19	8	30	12	9

ANATECTIC GRANITE

	Vega Pluton								
	VG01	VG08	VG09	VG13	VG17	VG18	VG20	VG21	VG23
SiO2	69.98	67.97	62.94	65.14	70.09	66.21	72.00	66.93	60.84
TiO2	.70	.47	1.04	1.06	.35	.80	.38	.80	.78
Al2O3	14.19	15.60	17.16	15.52	15.28	15.85	14.56	15.22	16.60
Fe2O3	4.85	3.03	5.76	6.60	2.01	5.83	2.66	5.41	5.34
MnO	.06	.06	.06	.07	.07	.09	.07	.08	.07
MgO	4.85	3.03	5.76	6.60	2.01	5.83	2.66	5.41	5.34
CaO	1.36	3.44	4.14	1.58	2.47	1.32	1.34	2.39	6.45
Na2O	2.48	3.21	4.02	1.93	3.41	2.32	4.49	2.71	3.11
K2O	3.53	4.30	1.91	3.55	4.40	4.03	2.35	3.11	2.34
P2O5	.08	.11	.20	.07	.14	.12	.09	.14	.11
LOI	.91	.05	.32	1.30	.40	1.16	.74	.77	.68
TOTAL	99.84	99.92	99.76	99.92	99.77	99.72	99.70	99.68	100.68
Sc	13	7	16	13	4	12	6	11	16
V	48	38	73	77	29	60	22	49	92
Cr	49	35	*	65	12	51	19	36	41
Co	14	6	15	20	5	17	7	14	20
Ni	18	16	*	27	9	25	12	20	27
Cu	20	6	4	10	7	23	1	6	13
Zn	62	38	71	85	35	73	26	52	48
Ga	21	20	21	22	21	24	20	22	18
Rb	161	214	113	161	202	175	101	140	126
Sr	120	216	361	136	199	139	146	226	183
Ba	600	411	510	669	408	661	335	534	332
Y	41	30	42	52	23	50	29	55	29
Zr	281	167	157	387	168	273	153	276	139
Nb	18	13	15	27	11	19	12	14	10
La	22	41	36	55	32	57	25	41	16
Ce	52	62	80	123	58	111	60	94	22
Nd	28	33	39	49	37	54	27	44	17
Pb	21	24	24	17	29	19	28	18	17
Th	7	24	7	22	11	19	11	16	9

	Vega		Holm Peninsula						
	VG24	VG25	B341	B342	B344	B346	B347	B348	B349
SiO2	67.89	59.97	71.48	65.06	72.68	66.33	66.56	64.83	71.86
TiO2	.52	.77	.30	.83	.16	.69	.55	.76	.25
Al2O3	15.64	15.83	14.99	16.49	14.29	15.61	15.71	16.57	14.92
Fe2O3	3.62	6.24	1.85	4.42	1.50	3.63	4.02	4.61	1.44
MnO	.05	.09	.05	.06	.07	.06	.05	.07	.05
MgO	3.62	6.24	.79	2.05	.35	1.44	1.60	1.62	.58
CaO	3.35	5.99	1.94	3.21	.87	2.72	3.04	2.96	1.96
Na2O	3.37	2.61	3.60	3.75	3.24	3.04	3.20	3.48	3.00
K2O	4.62	2.58	4.51	3.78	5.64	5.22	4.14	4.20	5.42
P2O5	.10	.13	.06	.32	.32	.36	.36	.06	.08
LOI	.45	.24	.11	0	.77	.43	.40	.40	.32
TOTAL	100.19	99.90	99.69	99.97	99.88	99.52	99.63	99.55	99.90
Sc	3	17	7	9	4	4	7	8	6
V	16	93	24	53	10	36	46	50	20
Cr	10	195	14	28	10	28	14	29	14
Co	6	24	5	14	*	7	10	12	5
Ni	5	80	7	13	4	7	11	17	6
Cu	22	11	1	14	2	5	6	6	5
Zn	47	60	38	79	31	54	54	67	18
Ga	22	20	18	25	14	20	19	23	18
Rb	138	119	132	160	244	145	178	188	169
Sr	298	190	161	213	76	263	268	234	204
Ba	513	405	455	558	269	834	766	664	594
Y	57	33	49	40	18	18	42	98	17
Zr	300	148	136	237	93	261	280	189	124
Nb	21	10	9	20	19	17	16	15	8
La	77	27	37	54	10	59	61	50	12
Ce	162	64	85	109	20	138	146	118	29
Nd	69	30	40	47	14	48	55	56	25
Pb	26	15	52	28	36	37	33	31	43
Th	30	5	21	16	4	27	31	26	5

GRANITOID DYKES

	AP		KM	KMZ		Sørfjord	KP	TP				
	N8818	N8819	N8634	N88110	N88111	N8797	B465	N8713	B761	B765	B800	B805
SiO2	76.74	76.71	74.46	72.86	74.12	73.03	74.34	72.57	73.56	73.62	75.27	71.96
TiO2	.05	.08	.09	.12	.04	.17	.04	.14	.12	.13	.06	.19
Al2O3	13.10	12.85	14.17	13.92	13.84	14.87	14.10	15.64	14.96	14.79	14.05	15.78
Fe2O3	.73	.92	.81	.88	.53	1.32	.60	1.10	.99	.99	.96	1.53
MnO	.01	.03	.02	.02	.02	.01	.02	.01	.04	.03	.15	.06
MgO	.13	.17	.20	.27	.10	.32	.07	.33	.25	.22	.06	.52
CaO	.76	.78	1.30	1.55	1.27	1.85	.67	2.36	1.90	1.67	.83	3.06
Na2O	3.55	2.72	4.19	3.95	3.89	3.60	4.52	4.64	4.54	4.39	3.97	4.28
K2O	5.44	6.79	4.35	4.33	4.68	4.20	4.49	2.78	3.26	3.75	4.04	2.31
P2O5	0	.02	.01	.02	.02	.02	.02	.03	.02	.02	.04	.04
LOI	.20	.28	.35	.50	.13	.41	.40	.32	.34	.40	.43	.29
TOTAL	100.71	101.35	99.95	98.42	98.63	99.80	99.27	99.93	99.99	100.01	99.87	100.01
Sc	24	29	2	8	15	4	5	4	3	4	3	3
V	*	11	6	11	114	10	*	15	6	9	6	10
Cr	17	46	7	25	101	3	9	18	*	*	*	3
Co	2	5	*	*	29	3	1	*	3	*	*	*
Ni	7	3	4	4	61	*	3	*	*	*	*	*
Cu	*	*	2	1	7	*	4	*	2	1	1	5
Zn	8	14	18	18	116	11	*	34	10	9	19	45
Ga	17	14	17	19	28	17	27	21	21	21	19	19
Rb	269	200	247	125	105	93	261	89	118	125	139	75
Sr	60	96	398	407	195	617	35	483	400	468	191	329
Ba	30	170	582	570	1091	905	*	942	847	1164	432	720
Y	25	18	10	15	29	4	25	5	7	6	22	9
Zr	82	88	73	68	271	105	96	78	82	101	61	111
Nb	15	5	4	6	20	5	26	3	4	4	8	5
La	14	40	7	4	65	18	*	17	10	16	15	21
Ce	8	57	9	*	108	20	*	15	14	29	29	27
Nd	55	37	6	13	49	5	*	1	17	21	25	20
Pb	55	37	43	41	16	29	54	27	37	35	31	25
Th	24	29	14	5	8	7	18	8	6	13	10	11

	TP	--- Velfjord-Tosbotn ---				--- Ursfjord ----			Vefsn	------ VM ------		
	B809	N8734	N8735	N8736	N8737	UR05	UR19	UR22	N87151	VS11	VS13	VF31
SiO2	71.53	74.31	71.04	72.27	73.76	70.71	74.85	72.34	69.13	73.57	74.17	73.96
TiO2	.21	.10	.38	.17	.19	.36	.07	.23	.32	.15	.06	.07
Al2O3	14.70	14.90	15.57	14.39	14.50	15.14	13.70	14.69	16.33	14.35	14.60	14.19
Fe2O3	1.60	.91	2.25	1.00	1.19	1.91	.70	1.41	2.01	1.14	.86	.72
MnO	.04	.01	.04	.01	.02	.05	.04	.03	.02	.03	.05	.04
MgO	.47	.26	.82	.29	.33	.49	.08	.35	.65	.17	0	.04
CaO	1.97	2.01	2.66	1.43	1.48	1.73	1.07	1.54	2.62	.94	.88	.74
Na2O	4.24	3.92	4.07	3.77	3.70	4.59	3.84	4.16	4.97	4.05	4.32	4.48
K2O	4.32	3.08	2.85	4.63	4.46	4.63	5.30	4.59	2.77	5.21	4.59	5.22
P2O5	.06	.04	.12	.04	.05	.10	.03	.09	.08	.06	.05	.08
LOI	.56	.56	.58	.32	.49	.37	.42	.48	.35	.08	.05	.11
TOTAL	99.70	100.11	100.36	98.33	100.19	100.08	100.09	99.91	99.24	99.76	99.62	99.65
Sc	2	*	2	*	*	2	3	5	4	2	*	5
V	19	5	36	13	11	22	2	13	30	6	*	7
Cr	5	19	13	23	11	6	*	*	26	*	3	*
Co	5	4	8	4	*	4	*	*	4	*	*	*
Ni	3	*	*	2	*	2	4	3	4	*	*	2
Cu	2	*	10	*	*	3	1	3	*	2	*	2
Zn	15	20	48	12	18	51	5	34	22	47	38	18
Ga	18	17	22	18	21	24	18	23	22	26	26	21
Rb	111	80	80	202	182	175	134	193	87	256	279	213
Sr	588	258	483	225	173	431	156	247	678	113	65	73
Ba	802	729	585	466	375	747	550	595	566	409	170	128
Y	66	7	11	10	10	10	11	8	11	9	11	13
Zr	110	68	151	108	138	221	64	138	155	107	54	45
Nb	7	4	6	10	8	7	5	7	7	4	12	8
La	29	9	19	26	26	66	18	45	17	29	10	5
Ce	47	32	36	33	48	99	28	79	20	64	14	*
Nd	24	9	9	17	21	40	16	34	10	28	14	3
Pb	24	29	23	29	29	38	47	37	21	34	35	33
Th	11	11	12	26	27	35	13	27	9	21	10	8

	VM	------- OM -------		
	VF38	N88100	N8877	N8879
SiO2	74.31	74.63	75.07	74.73
TiO2	.06	.02	.08	.06
Al2O3	14.30	14.41	13.95	14.09
Fe2O3	.58	.35	.85	.54
MnO	.03	.20	.09	.01
MgO	.06	.02	.23	.15
CaO	.73	.59	1.08	1.05
Na2O	4.97	4.92	3.90	3.90
K2O	4.54	4.82	5.04	5.09
P2O5	.05	0	.02	.03
LOI	.32	.09	.18	.42
TOTAL	99.94	100.05	100.49	100.08
Sc	3	6	4	5
V	2	*	4	6
Cr	3	19	51	17
Co	*	*	*	*
Ni	*	9	7	6
Cu	3	24	1	19
Zn	6	5	27	12
Ga	25	33	22	30
Rb	236	345	384	233
Sr	118	13	73	69
Ba	125	16	115	82
Y	23	62	40	14
Zr	51	48	81	54
Nb	9	71	21	14
La	*	27	12	22
Ce	*	29	*	34
Nd	15	16	9	17
Pb	38	53	58	46
Th	5	12	9	10

* Below detection limit or not analysed.

The pluton/massif in which the dykes have intruded is shown above the analyses.

Abbreviations: AP: Andalshatten Pluton, KM: Kongsmoen Massif, KMZ: Kalvvatn Monzonite, KP: Kråkfjellet Pluton, TP: Terråkfjellet Pluton, VM: Visttindane Massif, OM: Oksadal Massif