

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 756 AVHANDLINGAR OCH UPPSATSER ARSBOK 72 NR 18

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ZOLTAN SOLYOM, ROLAND GORBATSHEV  
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INGRID JOHANSSON

## THE OTTFJÄLL DOLERITES

GEOCHEMISTRY OF THE DYKE SWARM  
IN RELATION TO  
THE GEODYNAMICS OF THE CALEDONIDE OROGEN  
OF CENTRAL SCANDINAVIA



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## ABSTRACT

The Ottfjäll dolerites are major constituents of the Särvi Nappe in the central Scandinavian Caledonides. Their chemistry is essentially that of abyssal tholeiites. However, some peculiarities indicate that they were not formed in a purely oceanic environment. Geochemistry and tectonic setting suggest that the melts were produced during a period of moderately deep mantle melting. Most probably, the intrusion of the Ottfjäll dolerites was associated with the early stages of the late Precambrian continental break-up to form the pre-Caledonide precursor of the North Atlantic (the Iapetus Ocean). As such, the Ottfjäll dolerites occupy a geodynamic position different from that of most other Scandinavian Caledonide basaltoids.

## INTRODUCTION

Among the allochthonous nappes of the central Scandinavian Caledonides, the Särsv Nappe (Strömberg 1961) is distinguished by its strikingly abundant dolerite dykes. The dykes, known as Ottfjäll dolerites (Holmquist 1894, Strömberg 1961, 1969), intruded a host-rock sequence of about 2000 metres (Kumpulainen 1978) of unfossiliferous, feldspathic sandstones, which are intercalated with local meta-argillites (Strömberg 1961) and at least one probably glaciogenic diamictite (Röshoff 1975). Deformation was moderate and primary igneous and sedimentary features are often well preserved. The Särsv Nappe has considerable extent in the eastern, Swedish Caledonides. Its overall lithology differs from that of the arenite-dominated lower nappes, which are virtually free from basic intrusions, and the argillitic-arenitic, amphibolite-loaded Seve Nappe Complex (Gee 1975, 1977). Also in regard to metamorphism, the Särsv rocks with their generally coexisting muscovite and biotite/chlorite are intermediate between the greenschist facies of the subjacent arenite nappes and the amphibolite-granulite facies associations of the Seve Complex.

The dykes occur throughout the Särsv tectonic unit. In some areas, the incidence of dykes is sporadic, but very often their volume approaches and even exceeds that of the sediments. A very considerable dilation of the host rocks must thus have occurred throughout the Särsv Nappe area, which at the present level of erosion has an extent of at least 300 by 100 kilometres. In contrast to the essentially flat-lying, sill-like, conformable configurations of the basic rocks in the Seve Nappe Complex, the Ottfjäll dolerites almost exclusively form dykes which cut the bedding at high angles.

The extensive development of the Ottfjäll dolerites in the Särsv Nappe and their absence from the underlying allochthon and parautochthon of the Swedish Caledonides is of major importance in the interpretation of the structure and development of the orogen. This includes aspects of nappe derivation and displacement, the assessment of the overall role of basic igneous activity in the Scandinavian Caledonides, and the use of Ottfjäll dolerites as a reference group for the correlation between the type area of the Särsv Nappe shown in Fig. 1 and suggested equivalents farther west and north (Törnebohm 1896, Gee 1977). A subject of current discussion is also the question whether rocks which are geochemically similar to the Ottfjäll dolerites occur in the Precambrian basement, e.g. in the part of the Norwegian seaboard region described by Ramberg (1974). Thus, clearly, the Ottfjäll dyke swarm plays a crucial role in the understanding of Caledonide dynamics.

The present study is primarily concerned with the principal geochemical aspects of the Ottfjäll dolerites as a key to regional tectonics. A detailed field-geologic and petrographic study has been made by Strömberg (1969). The general tectonic contexts of the central Scandinavian Caledonides have lately been treated

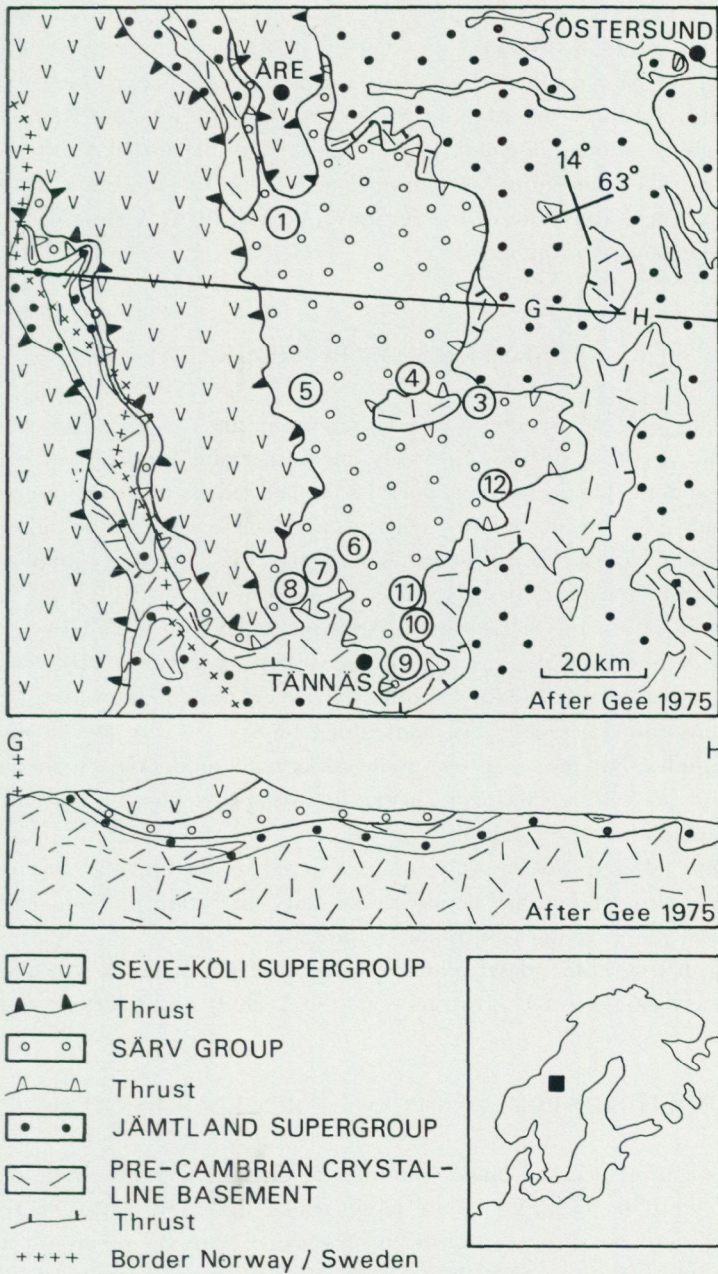


Fig. 1. Sampling sites of the Ottfjäll dolerites in the Särvi Nappe. 1. Ottfjället, 3. Abborsjön, 4. Äviksberget, 5. Dunsjöfjället, 6. Anåfjället, 7. Ormrøet, 8. Funåsdalsberget, 9. Ramberget, 10. Ulvberget, 11. Gråvålen, 12. Särvfjället. Sampling-group 2, which is not shown in the map, comprises drift-boulders from an area close to site 1.

by Gale and Roberts (1974) and Gee (1975, 1977), and the early, Iapetus Ocean, development stages by Roberts and Gale (1978). The intense, tectonic deformation at the base of the Särvi Nappe, which is of some consequence in the present study, has been described by Strömberg (1961, 1969) and Röshoff (1978). Palaeomagnetic studies (Bylund 1976) suggest that the Ottfjäll dykes originally described parallel trends but were rotated in relation to each other during nappe translation. Local inversions of stratigraphy (Wilson 1976) appear to be of minor overall importance (Strömberg 1969).

### ESSENTIALS OF PETROGRAPHY

The Ottfjäll dolerites exhibit some variation in macroscopic appearance. The predominant type is a fine- to finely medium-grained porphyritic rock with rather abundant plagioclase phenocrysts embedded in a fine-grained matrix. Other kinds of Ottfjäll dolerite contain plagioclase, pyroxene and olivine as their principal coarser constituents. There also exist wholly equigranular and dense, aphanitic rock varieties.

The extent of secondary alteration varies and there is a gamut from unaltered to low-grade metamorphic rocks. The secondary minerals include amphibole, serpentine, epidote, chlorite, and biotite. However, part of the biotite appears to be a primary mineral phase. The contents of biotite are very low in most of the studied samples, but there are also some rocks with moderately high contents of this mineral. As will be considered in the following text, these rocks tend to have deviating, alkali-basaltic compositions.

The most altered dolerite dykes are found in low-altitude localities. This suggests a causal relationship between secondary alteration and the development of the thrust plane at the base of the nappe.

General petrographic descriptions of the Ottfjäll dolerites are included in papers by Holmquist (1894), Strömberg (1961, 1969) and Claesson (1976).

### GEOCHEMISTRY: SAMPLING, PROCEDURES, RESULTS

This investigation is based on 123 samples of Ottfjäll dolerite obtained from 12 groups of sampling localities in the type area of the Särvi Nappe in the Härjedalen and southern Jämtland districts, Sweden (Strömberg 1961, 1969). The sampling sites are indicated in Fig. 1. In order to achieve an adequate coverage of the chemical variation within the individual dykes and between various dykes and dyke groups, the sampling altogether included 83 different dykes as well as series of several specimens from the same dyke. Generally, a representative sampling of many different dykes was carried out in each locality. In the vicinity

of sampling site 1 in Fig. 1 (Ottfjället), the sampling was extended to large, local boulders in the glacial drift. These boulders comprise a wide range of macroscopically different varieties of dolerite. Care was taken to sample boulders where the less common rock types were in contact with characteristically developed Ottfjäll dolerites. The analyses of these boulder-samples are included in the grand average and range data of Table 1, but are treated as a special group in Table 2.

The major components  $\text{SiO}_2$ ,  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$ , total iron as  $\text{Fe}_2\text{O}_3$ ,  $\text{CaO}$ , and  $\text{K}_2\text{O}$  were determined by X-ray fluorescence techniques employing glass beads.  $\text{MgO}$ ,  $\text{MnO}$ , and  $\text{Na}_2\text{O}$  were analysed by atomic absorption,  $\text{FeO}$  by potentiometric titration, and  $\text{P}_2\text{O}_5$  photometrically. The trace elements Rb, Y, Sr, Zr, and Nb were determined by X-ray fluorescence using powder pellets. All analytical results are referred to USGS rock standards. Details of the employed procedures will be given by Solyom and Johansson in a paper which is now in preparation.

Table 1 lists the means, standard deviations and variation ranges for all 123 analysed samples. The individual analyses are listed in Table 4. Averages for the various sampling-site groups of specimens and the boulder-samples are given in Table 2. As is seen from this table, the variations in chemical composition between the various sites are rather small. The analytical results also show that petrographic differences, such as grain-size, macroscopic appearance, frequency of phenocrysts, etc., which commonly induced the sampling of more than one specimen per dyke, are generally not coupled with significant deviations from average chemistry. Exceptions are some samples from wall-rock contacts and a few of the boulder specimens. Here, the most obvious differences are in the aberrantly high contents of K and Rb, which in a group of deviating specimens are associated with a marked general trend towards alkali-basaltic geochemical characteristics. This aspect is considered in a special section (p. 14). The determinations of Nb comprised altogether 26 specimens and were made expressly to compare the normal, tholeiitic with the deviating, alkali-basaltic groups of Ottfjäll dolerites. Because of this, the alkali-basaltic variety is strongly overrepresented in this lot of samples and the mean Nb contents are not listed in Table 1. Data for the separate groups will be found in Table 3.

The existence of a group of samples with transitional alkali-basaltic compositions is also evident in Fig. 2, which is a plot of the normative mineral compositions of the Ottfjäll dolerites in the ne-ol-di-hy-qz system. The CIPW-norms have been calculated after correction for the oxidation of iron as proposed by Le Maitre (1976). The plotted compositions center around the di-hy tie-line and thus there is a range between somewhat quartziferous and mildly olivine-bearing tholeiites. However, for all but the deviating samples considered above, the variation range is very limited.

In the classification of basaltic rocks, attention is attracted by chemical com-

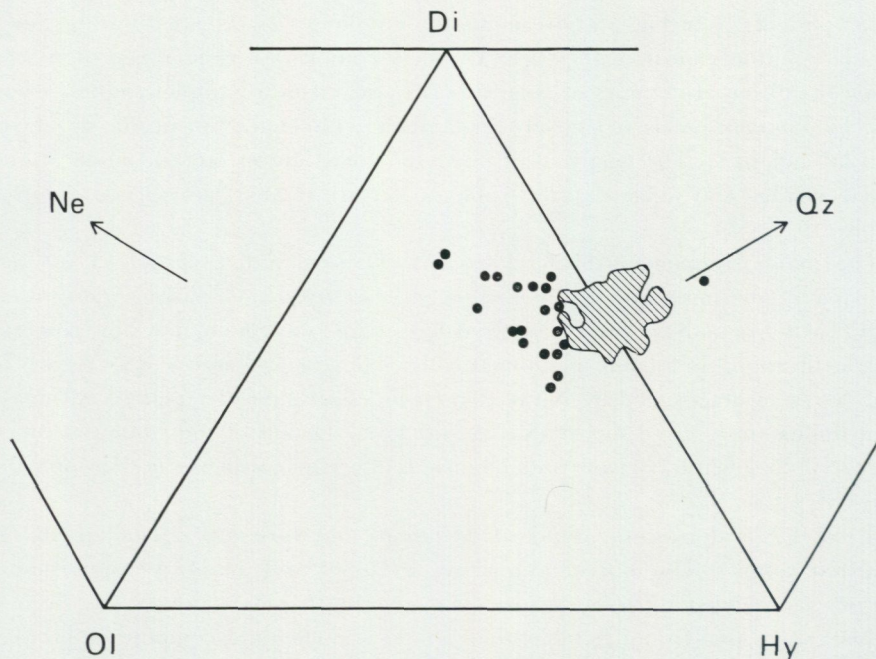


Fig. 2. CIPW-norms of Ottfjäll dolerites plotted in the ne-ol-di-hy-qz-diagram. The ruled areas in this and the following figures comprise all of the 123 analyzed samples not specially marked by dots.

ponents, which characterize and discriminate between different principal types of melt. On the basis of statistical treatments of rock analyses from a variety of recent geodynamic environments, generally valid genetic-tectonic attributions of basaltic melts and their products have been attempted (Floyd and Winchester 1975, Pearce 1976, Pearce and Cann 1973, Pearce *et al.* 1975, 1977). In this context, special interest is focused on elements characterized by relative immobility during secondary processes of rock alteration. Among the so-called incompatible elements, which are particularly important in the classification of basaltic rocks, only Ti, Zr, Y, Nb, and a few others possess the high degree of stability which is required to render them useful as checks and complements of classification systems based on more mobile components. Consequently, these elements attain particular importance in altered basaltoids, where other approaches often fail to yield consistent results. The interrelations of relatively immobile elements have been widely employed in the present study.

Within the framework of a general subdivision of basaltic rocks, the Ottfjäll dolerites fall almost entirely outside the alkali-basalt fields of MacDonald and Katsura (1964), and Kuno (1968). In Fig. 3, the compositions concentrate in the upper part of the field characteristic of abyssal tholeiites (Miyashiro 1975a). The impression of very moderate crustal contamination is brought out by the

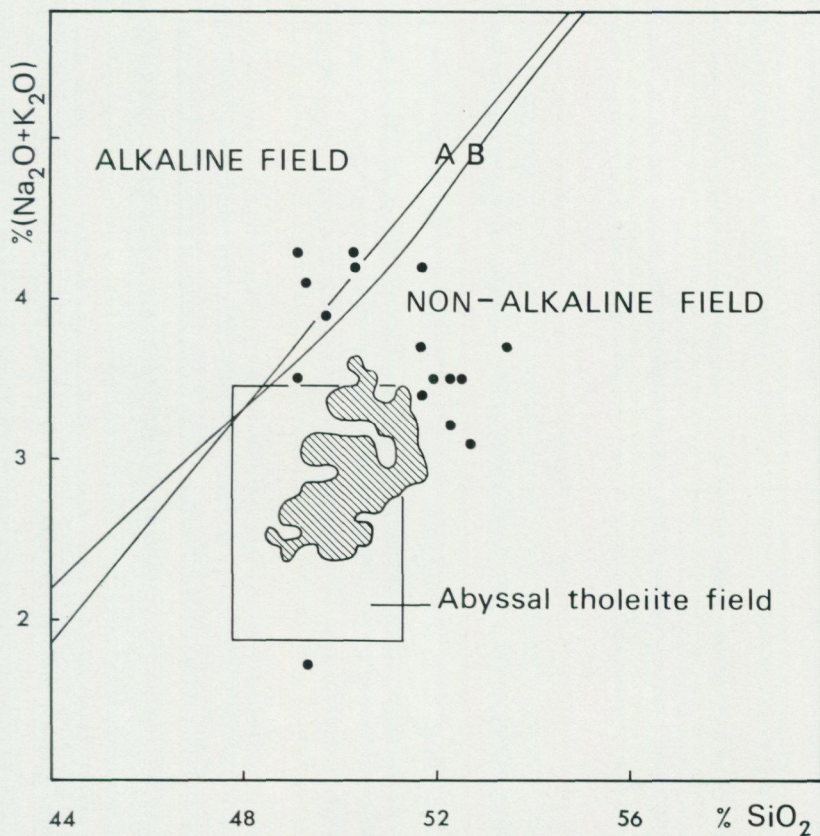


Fig. 3. Total alkalis—silica variation diagram (wt. %) for the Otffjäll dolerites. The boundaries A (MacDonald and Katsura 1964) and B (Kuno 1968) divide the diagram into alkaline and non-alkaline fields. Most of the analyses concentrate in the abyssal tholeiite field of Miyashiro (1975a).

generally low potassium contents indicated in Tables 1 and 2. However, potassium tends to be slightly more abundant than in typical oceanic-ridge and sea-floor tholeiites. Potassium is moderately high in the alkali-basaltic and a few other samples, which, mainly for this reason, approach or enter the field of alkali basalts in Fig. 3. These samples, of course, influence strongly the range data of Table 1, but have lesser effects on the standard deviations and most sampling-site data of Table 2.

A tendency towards high-alumina relations in an otherwise overwhelmingly tholeiitic group of rocks is demonstrated in Fig. 4. The existence of samples with alkali-basaltic affinities is obvious here too.

Because alkalis are reputedly mobile in metamorphic environments, the conclusions regarding the predominantly tholeiitic character of the Otffjäll dolerites were tested employing variation diagrams based on other components. Figs.

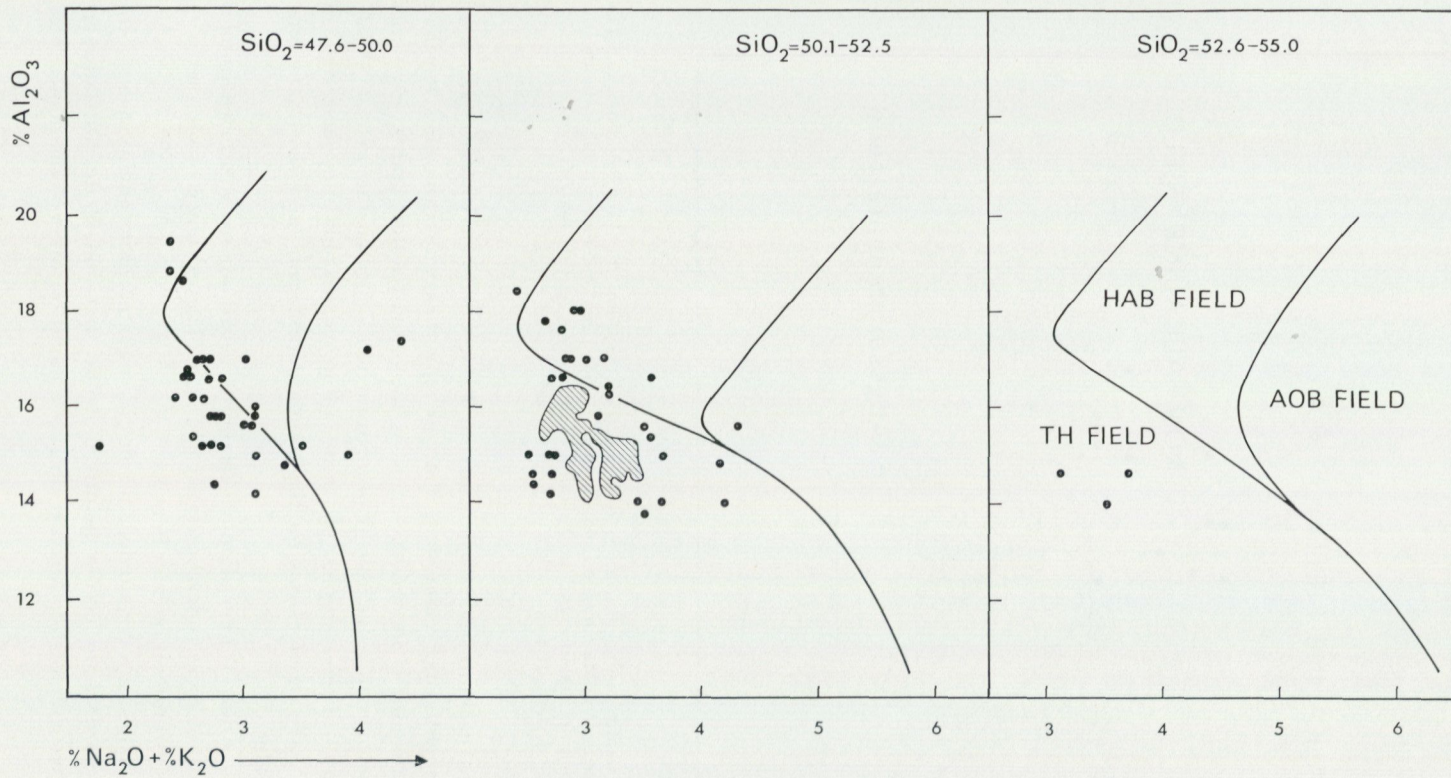


Fig. 4. Aluminum — total alkalis — silica variation diagrams (Kuno 1968) for the Otffjäll dolerites (wt. %). Kuno's compositional fields are: TH — tholeiite, HAB — high-alumina basalt, AOB — alkali olivine basalt.

5a and b illustrate the P, Ti and Zr relationships and their interpretation as suggested by Floyd and Winchester (1975). The general inferences from Figs. 3 and 4 are confirmed. For the main, tholeiitic group of Ottfjäll dolerites, the classification is in agreement also with the Y/Nb ratios, which will be considered below (Fig. 9).

Basaltic rocks of tholeiitic affinities occur in oceanic as well as continental environments. Possibilities to distinguish between the two are of obvious importance in the interpretation of ancient geodynamic developments. Employing the statistical inferences of Pearce *et al.* (1975) regarding the  $\text{TiO}_2$ - $\text{K}_2\text{O}$ - $\text{P}_2\text{O}_5$  relations (Fig. 6), we find that the Ottfjäll dolerites are intermediate between typical oceanic and continental tholeiites, but trend strongly towards oceanic characteristics. Also the occurrence of the dyke swarm in an essentially arenitic, continental-margin type setting indicates that the Ottfjäll dolerites do not represent a purely oceanic environment. In this regard, the situation is rather similar to that of the Tertiary basaltic lavas and dykes of Greenland (Pearce *et al.* 1975).

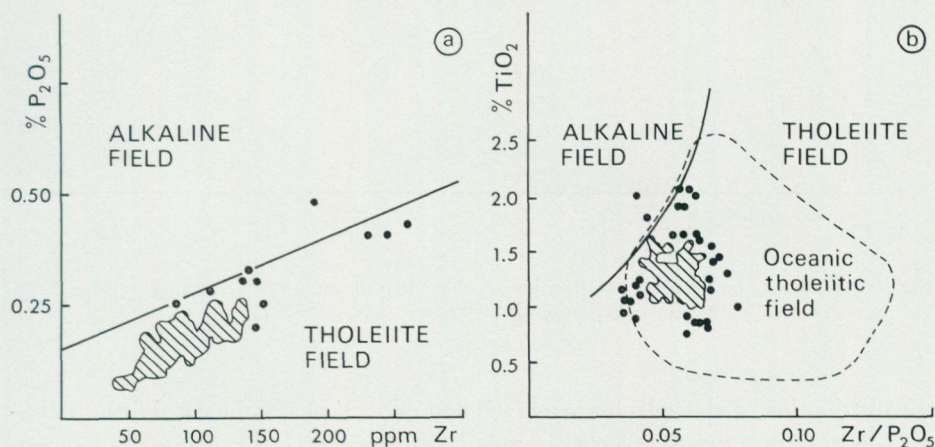


Fig. 5. Discrimination between alkaline and tholeiitic dolerites employing Floyd and Winchester's (1975)  $\text{P}_2\text{O}_5$  — Zr and  $\text{TiO}_2$  —  $\text{Zr}/\text{P}_2\text{O}_5$  diagrams.

In oceanic environments, tholeiites occur in a variety of geodynamic settings such as mid-oceanic ridges, spreading back-arc- and other marginal seas, some kinds of oceanic islands and, of course, island arcs. The abyssal tholeiites of oceanic ridges are chemically closely similar to low-K tholeiites of immature island arcs. Compilations by Miyashiro (1974, 1975a, 1975b) suggest that in advancing fractional crystallization  $\text{FeO}^x$  (total Fe as FeO) and  $\text{TiO}_2$  are enriched more rapidly in abyssal tholeiites than in the low-K tholeiites of island arcs, where the contents of  $\text{TiO}_2$  exhibit little variation in the relevant range of  $\text{FeO}^x/\text{MgO}$  ratios. Such relations are explained by the melt compositions, the activities of gases and

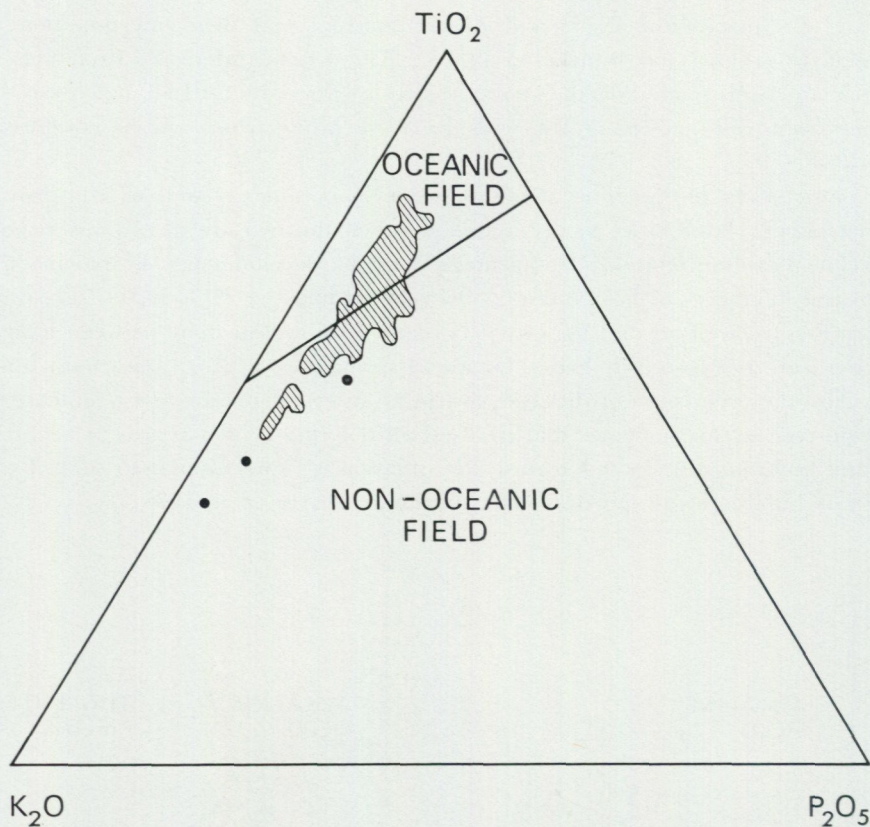


Fig. 6. Oceanic — non-oceanic affinities of the Ottfjäll dolerites according to the  $\text{TiO}_2$  —  $\text{K}_2\text{O}$  —  $\text{P}_2\text{O}_5$  (wt. %) diagram of Pearce *et al.* (1975).

the distribution of elements between melt and mineral phases during the crystallization. Plots of the Ottfjäll dolerites in the diagrams of Fig. 7 demonstrate an obvious similarity with abyssal tholeiites. These relations are particularly marked in Fig. 7c. The  $\text{FeO}^x/\text{MgO}$  ratios vary between 0.7 and 2.2, which is characteristic of abyssal tholeiites in contrast to the more differentiated series of low-K tholeiites in island arcs. In the Ottfjäll dolerites, we thus have a fairly undifferentiated group of rocks, that is quite different from the calc-alkaline series.

In the discriminant geotectonic groupings based on Ti-Zr-Y-Sr relations and shown in Fig. 8 (Pearce and Cann 1973), the Ottfjäll tholeiites clearly concentrate in the ocean-floor field. Among the few samples showing a formal within-plate affinity (Fig. 8a), we again find all the specimens which in the preceding figures exhibited alkali-basaltic affinities.

The use of classification plots involving Sr (e. g. Fig. 8c) is ambiguous in the case of the Ottfjäll dolerites. This is due to the presence of plagioclase

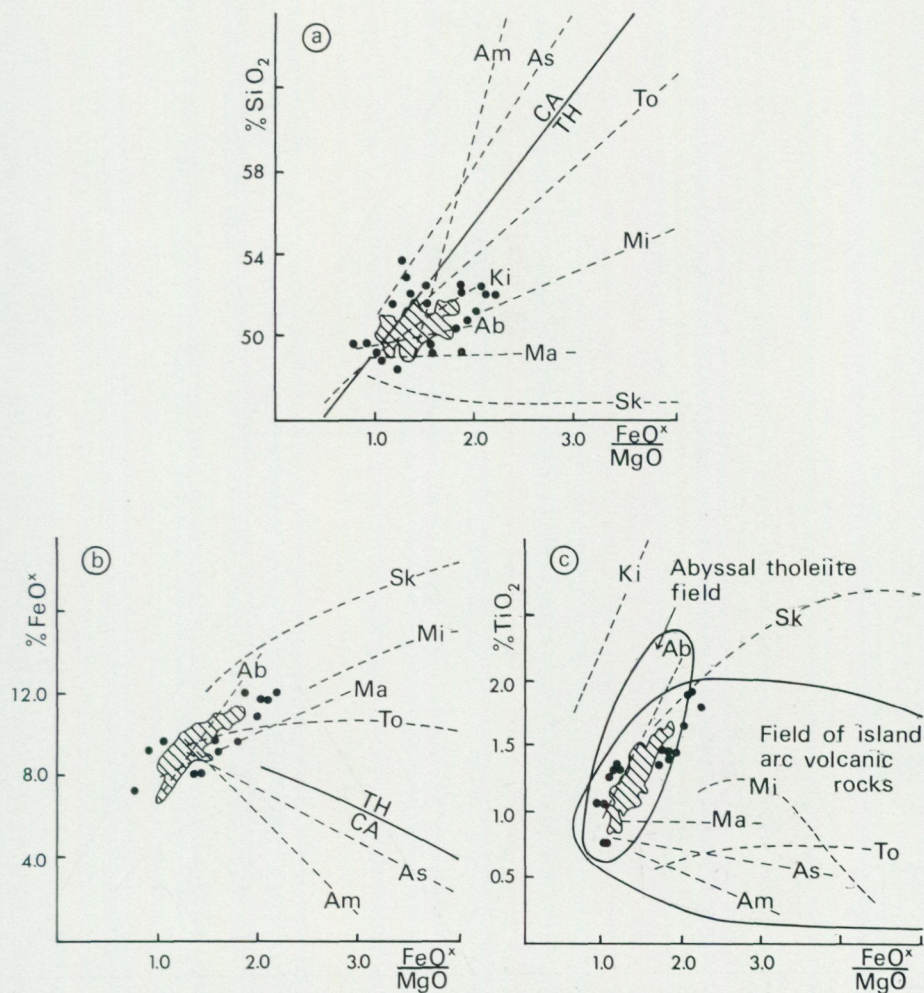


Fig. 7. Plot of the Ottfjäll dolerites in the  $\text{SiO}_2$ — $\text{FeO}^x/\text{MgO}$ ,  $\text{FeO}^x$ — $\text{FeO}^x/\text{MgO}$  and  $\text{TiO}_2$ — $\text{FeO}^x/\text{MgO}$  variation diagrams according to Miyashiro (1975a). The unbroken lines in a and b separate the tholeiitic (TH) and calc-alkaline (CA) series. The broken lines are trends of CA-series (Am = Amagi and As = Asama volcanoes) and TH-series rocks (To = Toufa Island, Mi = Miyake-jima, Ma = Macauley Islands, Ki = Kilauea, Sk = Skaergaard intrusion). Ab represents the trend of abyssal tholeiites.

phenocrysts, which suggests a syn-crystallization redistribution of Sr between various parts of the melt. Because the plagioclase of the phenocrysts most probably started crystallizing before the intrusion of the dykes, gravitational differentiation may have resulted in an overall enrichment of Sr in the erupted melt portions. This mechanism is hardly of any consequence for the mutual relations of the other elements specifically considered in the present study.

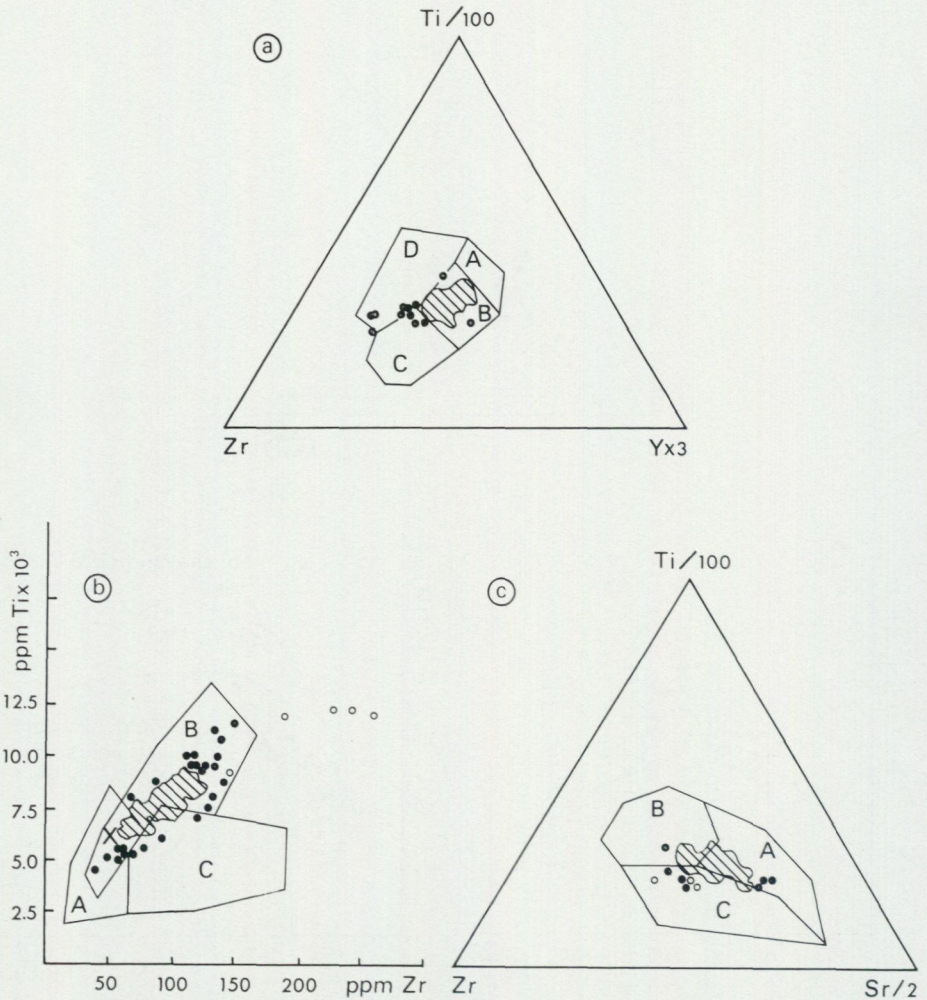


Fig. 8. Plot of the Ottfjäll dolerites in the discriminant diagrams of Pearce and Cann (1973). A: field of low-K tholeiites. B: ocean-floor basalts. C: calc-alkali basalts. D: within-plate basalts. The field X in diagram b is the overlap area of A, B, and C. Tholeiitic dolerites are marked by ruled areas and dots, alkali-basaltic dolerites by open circles.

#### THE DEVIATING SAMPLES: AN INDICATION OF TWO MELT TYPES AMONG THE OTTFJÄLL DOLERITES

In the preceding sections we found that approximately ten percent of the 123 samples of Ottfjäll dolerite show more or less pronounced deviations from the ranges and trends of chemical variation, which can be considered normal in this tholeiitic rock group. One of these samples is exceptionally low in alkalis. This

rock is from a locality close to the basal thrust of the nappe. The loss of alkalis is here obviously due to marked epidotization and chloritization.

In the rest of the deviating dolerites, the most obvious departures from the average are found in the higher contents of K, Rb and total alkalis, and the consequent trend towards alkali-basaltic characteristics in Figs. 3 and 4. In some cases, the aberrant behaviour can be accounted for by the contamination by alkalis from the surrounding sediments, which are relatively rich in K and Rb. Related processes also result in the acquisition of excess argon as demonstrated by Claesson (1976).

In other cases, however, the samples deviating in K and Rb exhibit marked deviations also in their contents of other elements such as Ti, Zr, P, and Nb (Table 3). In five samples this results in pronounced alkali-basaltic overall

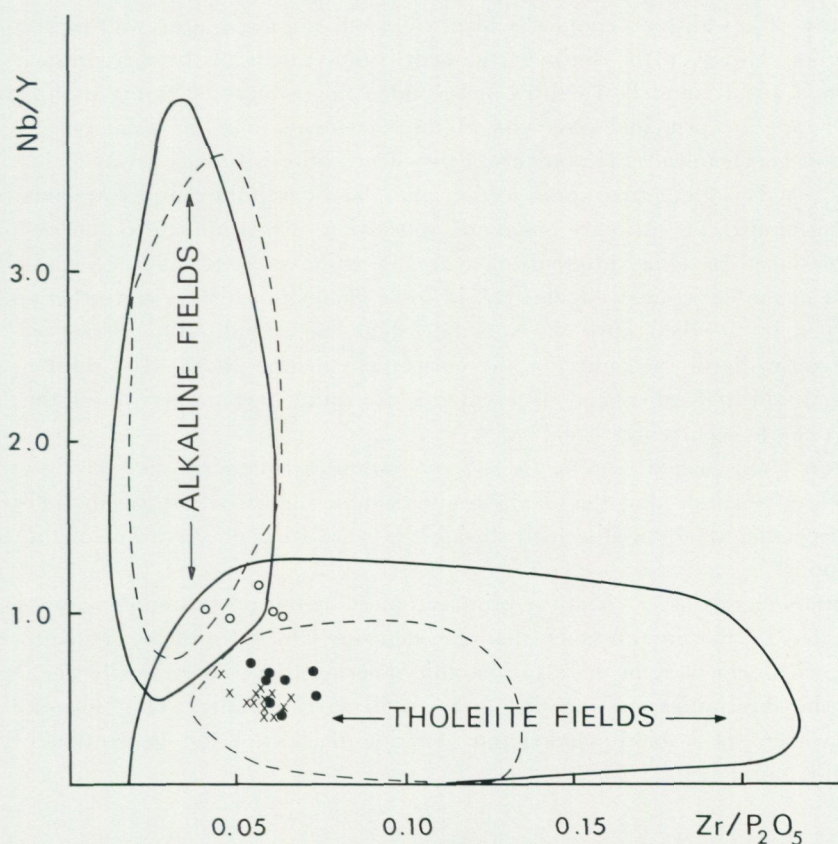


Fig. 9. Nb/Y—Zr/P<sub>2</sub>O<sub>5</sub> plot for deviating and normal Ottfjäll dolerites. Open circles: alkali-basaltic dolerites. Dots: other deviating dolerite samples. Crosses: thirteen randomly selected tholeiitic Ottfjäll dolerites analysed for Nb. Horizontally aligned fields: variation trends for tholeiitic rocks. Vertically aligned fields: variation trends for alkaline basalts. The broken and unbroken lines are for oceanic and continental rocks, respectively (Floyd and Winchester 1975).

characteristics. These samples are marked by open circles in Fig. 9 and in some of the other discriminant variation diagrams. Table 3 considers separately the five alkali-basaltic samples, the remaining eight deviating samples, and a reference group of thirteen randomly selected normal tholeiitic Ottfjäll dolerites. Nb was determined in these twenty-six specimens only. Fig. 9 shows that most of the deviating samples follow a tholeiitic trend in the Nb/Y vs. Zr/P<sub>2</sub>O<sub>5</sub>-diagram of Floyd and Winchester (1975). The five alkali-basaltic samples, in contrast, form a separate group, which tends to fall in with the variation patterns of alkaline rocks. The Y/Nb ratios of 0.99 and 2.08 are also in agreement with, respectively, within-plate alkali-basaltic and tholeiitic affinities as suggested by Pearce and Cann (1973).

Four of the alkali-basaltic samples stem from drift-boulders (site-group 2, Table 2), the fifth is from Ottfjället (site 1). Only one of them derives from the vicinity of a wall-rock contact, which, by itself, argues against wall-rock contamination. However, the decisive argument is the paucity of the surrounding sediments in e.g. Ti and P. To this can be added the stability of biotite and apatite, which are the principal reservoirs of these elements, and the immobility of Ti in most geochemical environments even when biotite is broken down.

As noted in the petrographic section, the alkali-basaltoid samples are relatively rich in biotite. The primary magmatic generation of this mineral by an excess of K, produced by some differentiation or absorption process, may be expected to result in the enrichment of the rock in some elements which would otherwise be retained in the melt until the very late stages of crystallization. However, this mechanism hardly accounts for the enrichment in phosphorus. In addition, late pegmatitoid and other acid differentiates are quite uncharacteristic of the Ottfjäll dolerite occurrences.

From these genetic arguments and the overall geochemical characteristics, we therefore conclude that the alkali-basaltic samples actually indicate the existence of a specific, alkali-basaltic melt during the generation of the dykes in the Särvi Nappe.

Although this aspect is not a primary object of the present study, attention is attracted by the circumstance that the elements which correlate positively with the enrichment of K in the alkali-basaltic dolerites, have energetically favourable sites in the lattices of apatite and, particularly, biotite. This suggests the involvement of a biotite(phlogopite)-bearing mantle in the generation of the alkali-basaltic melts.

## CONCLUSIONS

The present study clearly identifies the Ottfjäll dolerites of the central Scandinavian Caledonides as a predominantly tholeiitic group of rocks exhibiting

pronounced ocean-floor affinities. The potassium contents are somewhat higher than those of typical abyssal tholeiites, which argues against a direct analogy with these rocks.

The geological setting of the Ottfjäll dolerites in the allochthon of the Särvi Nappe suggests that they have been transported to their present position from a site situated farther west. According to a study by Claesson (1976), the Rb-Sr age of the Ottfjäll dolerites is late Precambrian ( $735 \pm 260$  Ma). This dating is supported by the lithology and metamorphic status of the enclosing sediments, which are very similar to other late Precambrian sedimentary rocks occupying a marginal position in relation to the Baltic Shield (Bjørlykke *et al.* 1977). A current study by Kumpulainen (1978) suggests deposition mainly by terrigenous sedimentation in a system of braided rivers. The total sediment thickness is considerable. The very moderate tectonic reworking and metamorphism suggest that the Särvi sediments have not been involved in the Svecokarelian, Sveconorwegian or other pre-900 Ma orogenic events characterizing much of western Sweden as well as southern and central Norway (Krogh 1977, Moore and Qvale 1977). Thus, the 1800–1900 Ma or higher K-Ar ages of the Ottfjäll dolerites (Point *et al.* 1976) are in agreement neither with their Rb-Sr age and the geological setting, nor the common Caledonide regeneration of the K-Ar systems in the area. Most probably, they are unrelated to the formation of the dyke swarm and are due to post-formational Ar-capture, conceivably associated with later, possibly Caledonide metamorphism (Dalrymple and Lanphere 1969, Dalrymple *et al.* 1975, Hayatsu and Carmichael 1970, Claesson 1976). This reworking may also contribute to the wide error limits of the Rb-Sr age.

Taking into consideration the tectonic setting and geochemistry, we suggest that the Ottfjäll dolerites formed during a period of crustal tension, dilation and break-up in the depositional area of the Särvi sediments. The steeply cross-cutting attitude of the Ottfjäll dykes indicates that the sediments were well consolidated/cemented prior to the intrusion of the dolerites. Our suggestion is supported by the particular combination of extreme dyke frequency in a large area, abyssal tholeiitic, ocean-floor type geochemical characteristics, moderately low potassium contents, a rather low initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio (Claesson 1976) and the setting in a thick sedimentary sequence of mainly continental origin. An obvious inference is that the Ottfjäll dolerites intruded in connection with the massive generation of basaltic melt at moderate depths in the mantle during the initial stages of opening of the pre-Caledonide Iapetus Ocean (Gale and Roberts 1974, Gee 1975, Roberts and Gale 1978). This is in agreement with inferences arrived at by other approaches. In contrast, neither dyke geochemistry and the lack of complementary intermediate volcanics and hypabyssals, nor the state of deformation suggest an association with minor orogenic events occurring at approximately this time or somewhat earlier (Johnson 1975, Rankin 1975, Rast *et al.* 1975). The inferred origin suggests a formation site to the west of the

present coast of Norway and the one-time sparagmite grabens considered by Bjørlykke *et al.* (1977). However, rocks indicated to be Ottfjäll dolerites also cut the Precambrian basement in the Svansjön basal unit of the Särvi Nappe (Strömberg 1961, Röshoff 1978). Thus the Särvi sediments were apparently not deposited on oceanic crust. The suggested formation time of the Ottfjäll dolerites is rather early in the break-up process. A minor contribution of alkali-basaltic melts in the formation of the Ottfjäll dolerites is indicated by the present study. In a continental break-up, such rocks will generally be expected to occur somewhat earlier or more peripherally than the semi-oceanic tholeiites (Gass 1970). There is thus a need for further investigations to clarify whether alkali-basaltic rocks exist in other parts of the Särvi Nappe. The age of the alkali dolerites in relation to that of the main swarm of Ottfjäll dykes also requires further consideration. However, the essentially tholeiitic nature of the Ottfjäll dyke rocks and their association with the early stages of a break-up process appear to be firmly established.

#### ACKNOWLEDGEMENTS

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 NGT = Norsk Geologisk Tidsskrift  
 NGU = Norges geologiske undersøkelse  
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Table 1. Chemical composition of the 123 Ottfjäll dolerites (weight per cent for the oxides, ppm for the elements).

	Mean	Std.dev.	Minimum	Maximum	Range
SiO <sub>2</sub>	50.46	0.860	48.59	53.57	4.98
TiO <sub>2</sub>	1.28	0.254	0.73	2.04	1.31
Al <sub>2</sub> O <sub>3</sub>	15.61	1.120	13.90	19.43	5.53
Fe <sub>2</sub> O <sub>3</sub>	1.97	0.715	1.03	7.53	6.50
FeO	7.72	1.104	2.51	10.26	7.75
MnO	0.17	0.021	0.13	0.23	0.10
MgO	6.95	0.824	4.93	9.97	5.04
CaO	11.10	0.755	8.77	12.96	4.19
Na <sub>2</sub> O	2.43	0.301	1.29	3.09	1.80
K <sub>2</sub> O	0.58	0.329	0.20	2.04	1.84
P <sub>2</sub> O <sub>5</sub>	0.17	0.067	0.07	0.47	0.40
H <sub>2</sub> O <sup>-</sup>	0.06	0.031	0.01	0.16	0.15
L.O.I.	1.50	0.439	0.81	3.17	2.36
Rb	16	15.7	3	106	104
Sr	255	46.1	191	529	338
Y	26	4.4	16	38	22
Zr	96	34.2	41	262	221
Mn	1356	160.1	981	1819	838

Table 2. Average composition ( $\bar{x}$ ), standard deviation (s), and range (R) data of Ottfjäll dolerites from the 12 groups of sampling localities (weight per cent for the oxides, ppm for the elements).

Group	1 (n=10) Ottfjället			2 (n=15) Ottfjället drift-boulders			3 (n=10) Abborrsjön			4 (n=6) Åviksberget		
	$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R
SiO <sub>2</sub>	50.41	0.53	1.94	50.60	1.29	4.33	50.02	0.53	1.76	49.97	0.55	1.47
TiO <sub>2</sub>	1.28	0.32	1.11	1.48	0.36	1.01	1.20	0.13	0.42	1.15	0.13	0.34
Al <sub>2</sub> O <sub>3</sub>	15.21	0.92	2.70	15.22	1.02	3.47	15.92	0.99	2.70	15.61	0.87	1.92
Fe <sub>2</sub> O <sub>3</sub>	2.62	1.83	6.50	1.89	0.29	0.98	2.20	0.68	1.90	2.11	0.64	1.65
FeO	7.00	1.72	6.00	8.08	0.99	3.34	7.34	0.89	2.83	7.50	1.33	3.36
MnO	0.18	0.02	0.05	0.18	0.02	0.06	0.17	0.01	0.04	0.17	0.02	0.04
MgO	7.28	0.55	1.82	6.72	1.14	4.27	6.70	0.61	2.05	7.19	0.46	1.23
CaO	11.67	1.03	3.59	11.18	0.90	3.25	11.23	0.58	1.66	11.69	0.27	0.78
Na <sub>2</sub> O	2.33	0.19	0.51	2.62	0.26	0.85	2.14	0.45	1.22	2.29	0.23	0.60
K <sub>2</sub> O	0.59	0.37	1.26	0.76	0.33	1.00	0.92	0.55	1.76	0.44	0.14	0.42
P <sub>2</sub> O <sub>5</sub>	0.23	0.09	0.31	0.28	0.08	0.23	0.16	0.03	0.10	0.13	0.02	0.06
L.O.I.	1.47	0.36	1.04	1.32	0.26	0.76	1.82	0.54	1.78	1.29	0.45	1.20
Rb	19	25	85	17	9	30	35	31	100	12	6	17
Sr	258	49	167	292	98	333	275	35	121	242	24	58
Y	26	4	13	27	4	12	27	4	16	24	4	11
Zr	101	36	130	136	61	190	93	17	59	78	12	36
Mn	1360	128	423	1433	159	447	1339	100	305	1332	105	264

Table 2 (continued)

Group	5 (n=18) Dunsjöfjället			6 (n=11) Anåfjället			7 (n=14) Ormrøet			8 (n=13) Funäsdalsberget		
	$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R
	SiO <sub>2</sub>	50.22	0.64	2.09	50.71	0.70	2.70	51.38	0.84	2.84	50.83	0.64
TiO <sub>2</sub>	1.15	0.23	0.84	1.26	0.17	0.55	1.36	0.28	1.07	1.35	0.21	0.80
Al <sub>2</sub> O <sub>3</sub>	16.11	1.62	5.14	15.75	0.73	2.38	15.42	1.35	4.20	15.55	0.93	2.89
Fe <sub>2</sub> O <sub>3</sub>	1.89	0.54	1.56	1.77	0.25	0.70	1.76	0.32	1.22	1.83	0.19	0.70
FeO	7.19	0.99	3.72	7.88	0.59	1.73	8.13	1.05	3.32	7.88	0.83	2.74
MnO	0.17	0.02	0.08	0.17	0.01	0.04	0.17	0.02	0.07	0.17	0.02	0.06
MgO	6.91	0.56	2.31	7.31	1.01	4.20	6.69	1.01	4.03	7.02	0.84	2.46
CaO	11.34	0.80	2.70	10.86	0.43	1.43	10.60	0.70	2.13	10.69	0.68	2.77
Na <sub>2</sub> O	2.23	0.20	0.76	2.61	0.17	0.65	2.63	0.23	0.94	2.56	0.23	0.78
K <sub>2</sub> O	0.60	0.35	1.06	0.35	0.13	0.37	0.45	0.09	0.31	0.58	0.23	0.77
P <sub>2</sub> O <sub>5</sub>	0.14	0.04	0.15	0.15	0.04	0.11	0.17	0.04	0.15	0.18	0.03	0.13
L.O.I.	1.58	0.44	1.56	1.25	0.23	0.75	1.21	0.31	1.22	1.46	0.24	0.74
Rb	16	11	32	7	3	12	8	3	11	13	9	34
Sr	251	24	81	229	25	70	249	20	72	243	26	90
Y	25	4	16	24	5	18	26	6	21	27	4	14
Zr	86	26	89	81	21	69	93	21	78	103	27	80
Mn	1304	176	617	1278	98	280	1303	175	541	1313	134	449

Table 2 (continued)

Group	9 (n=3) Ramberget			10 (n=6) Ulvberget			11 (n=8) Gråvålen			12 (n=9) Särvfjället		
	$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R
SiO <sub>2</sub>	49.53	0.48	0.87	49.99	0.37	0.97	49.94	0.72	2.08	50.45	0.75	1.92
TiO <sub>2</sub>	1.26	0.21	0.40	1.28	0.16	0.39	1.23	0.14	0.35	1.27	0.26	0.75
Al <sub>2</sub> O <sub>3</sub>	15.35	0.39	0.71	15.53	0.49	1.35	15.53	0.91	2.39	15.71	1.40	4.42
Fe <sub>2</sub> O <sub>3</sub>	1.61	0.10	0.19	2.50	1.15	3.26	1.71	0.35	1.05	2.01	0.38	1.16
FeO	8.56	1.28	2.48	7.51	1.05	3.17	8.41	0.94	2.71	7.78	1.20	3.26
MnO	0.19	0.04	0.08	0.19	0.02	0.07	0.18	0.02	0.06	0.19	0.02	0.08
MgO	7.26	1.03	2.05	6.98	0.70	1.82	7.19	0.55	1.60	6.65	0.90	2.64
CaO	10.58	0.61	1.07	11.09	0.32	0.85	11.36	0.26	0.72	10.95	0.73	2.44
Na <sub>2</sub> O	2.44	0.16	0.31	2.24	0.48	1.27	2.42	0.13	0.43	2.50	0.23	0.66
K <sub>2</sub> O	0.71	0.54	0.98	0.56	0.29	0.72	0.36	0.08	0.24	0.55	0.26	0.89
P <sub>2</sub> O <sub>5</sub>	0.13	0.03	0.05	0.15	0.03	0.07	0.13	0.03	0.07	0.15	0.04	0.12
L.O.I.	2.24	0.73	1.45	1.86	0.70	1.91	1.54	0.25	0.78	1.74	0.41	1.35
Rb	25	22	40	18	14	38	9	3	7	23	16	55
Sr	238	27	51	261	21	59	231	24	67	268	32	98
Y	27	5	8	27	3	7	27	4	12	27	6	18
Zr	82	16	29	86	18	43	79	19	41	93	28	78
Mn	1478	329	656	1458	162	477	1400	135	426	1455	188	595

Table 3. Comparative analyses of deviating alkali-basaltic (n=5), other deviating (n=8), and normal tholeiitic (n=13) OtTFjäll dolerites (weight per cent for the oxides, ppm for the elements)  $\bar{x}$  is the mean, s is the standard deviation.

Groups	alk.-bas.		other dev.		normal thol.	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
TiO <sub>2</sub>	1.93 ± 0.21		1.42 ± 0.22		1.29 ± 0.24	
K <sub>2</sub> O	1.29 ± 0.24		0.87 ± 0.28		0.62 ± 0.51	
P <sub>2</sub> O <sub>5</sub>	0.40 ± 0.06		0.20 ± 0.03		0.16 ± 0.04	
Zr	215 ± 46		125 ± 18		91 ± 25	
Y	29 ± 4		28 ± 4		26 ± 5	
Nb	29 ± 3		16 ± 3		12 ± 3	
Y/Nb	0.99 ± 0.07		1.81 ± 0.36		2.08 ± 0.27	

Table 4. Chemical analyses (contents of major elements in weight per cent and contents of trace elements in ppm)

Group 1. Ottfjället										
Sample no.	71T	72T	73	73T	74	75K	76	77K	78	79K
SiO <sub>2</sub>	50.10	50.32	50.15	50.68	49.96	50.68	49.67	51.61	50.51	50.39
TiO <sub>2</sub>	1.32	1.07	1.25	1.27	0.93	1.51	0.91	1.36	1.14	2.02
Al <sub>2</sub> O <sub>3</sub>	14.94	14.57	15.48	14.67	16.51	14.31	17.01	14.32	15.49	14.76
Fe <sub>2</sub> O <sub>3</sub>	2.29	7.53	1.65	1.66	1.71	2.45	2.29	1.03	2.34	3.24
FeO	7.06	2.51	7.85	8.16	7.09	8.51	6.24	8.17	6.93	7.51
MnO	0.17	0.20	0.17	0.18	0.16	0.20	0.15	0.17	0.17	0.18
MgO	7.81	7.79	7.18	7.46	7.38	6.66	7.21	8.02	7.10	6.20
CaO	12.10	11.90	12.13	12.13	12.96	11.06	12.61	10.83	11.63	9.37
Na <sub>2</sub> O	2.09	2.08	2.49	2.47	2.18	2.55	2.28	2.23	2.29	2.59
K <sub>2</sub> O	0.59	0.46	0.43	0.46	0.31	0.59	0.32	0.78	0.38	1.57
P <sub>2</sub> O <sub>5</sub>	0.20	0.23	0.19	0.20	0.17	0.25	0.19	0.22	0.16	0.47
H <sub>2</sub> O <sup>-</sup>	0.04	0.09	0.09	0.04	0.04				0.03	0.07
L.O.I.	1.50	1.68	0.91	0.98	1.24	1.39	1.80	1.39	1.84	1.95
Sum	100.21	100.43	99.97	100.36	100.64	100.16	100.68	100.13	100.01	100.32
Rb	21	15	8	9	5	17	<3	18	10	87
Sr	266	263	225	216	225	224	287	246	246	383
Y	24	22	26	30	21	34	24	24	25	32
Zr	107	83	92	83	60	117	77	119	81	190
Mn	1314	1568	1344	1402	1239	1553	1145	1349	1314	1370
Nb								17		32

Table 4 (continued)

Group 2. Ottfjället, drift-boulders										
Sample no.	80K	81	82	83	85T	86	87	88	89	90
SiO <sub>2</sub>	53.57	50.47	52.85	49.79	51.32	50.03	49.24	49.40	50.50	50.97
TiO <sub>2</sub>	1.17	2.04	1.19	1.29	1.60	1.20	1.56	2.03	1.60	1.09
Al <sub>2</sub> O <sub>3</sub>	14.62	15.52	14.59	14.25	14.92	15.97	15.16	17.27	14.50	15.68
Fe <sub>2</sub> O <sub>3</sub>	1.97	2.38	1.56	1.78	1.84	1.69	2.21	1.91	1.97	1.49
FeO	6.74	7.42	7.53	9.28	8.97	7.87	7.59	7.37	9.49	7.91
MnO	0.16	0.22	0.17	0.22	0.19	0.18	0.18	0.17	0.21	0.17
MgO	6.92	5.73	6.94	6.97	6.19	6.93	7.23	5.25	6.33	7.54
CaO	9.54	10.04	11.21	11.61	10.65	12.11	11.92	11.10	10.96	11.68
Na <sub>2</sub> O	2.78	2.93	2.44	2.49	2.83	2.42	2.56	2.77	2.75	2.33
K <sub>2</sub> O	0.94	1.38	0.65	0.63	0.58	0.38	0.92	1.28	0.70	0.44
P <sub>2</sub> O <sub>5</sub>	0.19	0.41	0.20	0.21	0.26	0.23	0.31	0.41	0.30	0.20
H <sub>2</sub> O <sup>-</sup>	0.05	0.04	0.04	0.01	0.01	0.07	0.02	0.06	0.06	0.09
L.O.I.	1.67	1.57	1.13	1.68	1.08	1.28	1.56	1.39	0.92	0.96
Sum	100.32	100.15	100.50	100.21	100.44	100.36	100.46	100.41	100.29	100.55
Rb	27	38	15	15	9	8	21	30	14	9
Sr	196	461	222	230	276	264	389	529	268	249
Y	25	26	27	28	33	27	25	28	31	21
Zr	121	230	97	104	117	91	147	244	135	82
Mn	1254	1699	1293	1701	1467	1420	1374	1322	1588	1320
Nb	15	30					24	28		

Table 4 (continued)

Sample no.	Group 2. Ottfjället, drift-boulders					Group 3. Abborrsjön				
	91	92	93	94	95	22K	23	24	25	26K
SiO <sub>2</sub>	49.97	49.84	50.00	49.29	51.80	50.62	50.22	49.71	50.02	49.93
TiO <sub>2</sub>	1.39	1.16	1.03	1.99	1.79	1.22	1.15	1.05	1.17	1.33
Al <sub>2</sub> O <sub>3</sub>	15.09	14.32	15.10	17.42	13.95	15.60	17.56	17.05	16.95	14.86
Fe <sub>2</sub> O <sub>3</sub>	2.01	1.71	1.40	2.20	2.23	2.20	1.82	1.52	1.80	2.09
FeO	8.53	8.25	7.12	7.04	10.08	7.37	7.08	6.90	7.24	8.86
MnO	0.19	0.18	0.16	0.16	0.21	0.17	0.16	0.16	0.17	0.20
MgO	6.72	9.20	8.40	4.93	5.54	6.64	6.28	7.28	5.97	6.37
CaO	11.51	11.95	12.79	10.83	9.86	10.88	11.97	12.16	11.37	10.85
Na <sub>2</sub> O	2.56	2.30	2.19	3.04	2.96	2.28	2.39	2.35	2.24	2.50
K <sub>2</sub> O	0.56	0.44	0.51	1.31	0.69	0.71	0.42	0.36	0.75	0.87
P <sub>2</sub> O <sub>5</sub>	0.27	0.24	0.19	0.42	0.32	0.15	0.14	0.14	0.15	0.20
H <sub>2</sub> O <sup>-</sup>	0.06	0.07	0.06	0.01	0.05	0.03	0.03	0.03	0.02	0.02
L.O.I.	1.37	1.03	1.26	1.65	1.24	1.87	1.07	1.51	1.91	1.64
Sum	100.23	100.69	100.21	100.29	100.72	99.74	100.29	100.22	99.76	99.72
Rb	12	9	15	31	13	14	9	7	22	33
Sr	240	218	218	360	255	264	265	256	257	295
Y	29	23	23	33	33	37	27	21	26	28
Zr	111	85	72	262	140	90	91	80	102	116
Mn	1479	1405	1276	1258	1647	1314	1222	1245	1280	1527
Nb				32						

Table 4 (continued)

Sample no.	Group 3. Abborrsjön					Group 4. Åviksberget				
	27	28K	29	30	31	51K	52	53T	54	55
SiO <sub>2</sub>	49.59	50.66	50.45	50.10	48.90	50.42	49.73	49.77	50.56	49.09
TiO <sub>2</sub>	1.06	1.26	1.46	1.21	1.04	1.24	1.07	1.06	1.32	0.98
Al <sub>2</sub> O <sub>3</sub>	15.82	15.07	14.91	15.10	16.29	15.03	16.78	15.30	15.02	16.65
Fe <sub>2</sub> O <sub>3</sub>	1.89	1.32	2.93	3.17	3.22	2.03	3.39	1.74	1.80	1.76
FeO	8.22	8.26	7.14	6.25	6.03	8.53	5.31	7.50	8.67	6.60
MnO	0.17	0.19	0.17	0.17	0.18	0.18	0.16	0.17	0.18	0.15
MgO	8.02	6.75	6.07	6.82	6.77	6.97	6.80	8.03	6.87	7.36
CaO	11.21	10.64	10.50	10.93	11.81	11.69	11.86	11.79	11.22	12.00
Na <sub>2</sub> O	2.51	2.34	2.17	1.29	1.35	2.43	2.09	1.96	2.56	2.25
K <sub>2</sub> O	0.28	1.00	1.47	2.04	1.29	0.27	0.43	0.69	0.41	0.43
P <sub>2</sub> O <sub>5</sub>	0.10	0.16	0.20	0.16	0.15	0.13	0.13	0.13	0.17	0.11
H <sub>2</sub> O <sup>-</sup>	0.02	0.02	0.02	0.02	0.02	0.10	0.10	0.07	0.05	0.13
L.O.I.	1.12	1.90	1.90	2.44	2.85	0.97	0.90	1.43	0.98	2.10
Sum	100.01	99.57	99.39	99.70	99.90	99.99	98.75	99.64	99.81	99.61
Rb	8	43	58	106	54	5	12	22	8	11
Sr	206	271	297	327	314	218	276	220	253	259
Y	24	28	30	28	25	25	22	24	30	20
Zr	62	94	121	93	84	76	74	77	102	66
Mn	1341	1487	1308	1312	1357	1401	1247	1285	1408	1194
Nb				12						

Table 4 (continued)

Group 4. Åviksberget		Group 5. Dunsjöfjället								
Sample no.	56	57	58	59	60	61	62	62T	63	63K
SiO <sub>2</sub>	50.25	50.54	50.72	49.31	50.68	50.93	50.17	51.13	50.32	50.01
TiO <sub>2</sub>	1.22	1.20	1.40	1.21	1.21	1.27	0.86	1.19	1.08	1.04
Al <sub>2</sub> O <sub>3</sub>	14.86	15.34	15.59	16.00	16.65	14.66	17.85	15.72	16.64	14.96
Fe <sub>2</sub> O <sub>3</sub>	1.93	2.17	2.39	2.42	2.66	1.24	1.36	1.40	1.22	2.67
FeO	8.40	7.10	7.29	6.87	6.30	7.61	6.06	8.02	7.12	6.95
MnO	0.19	0.18	0.18	0.18	0.16	0.16	0.14	0.16	0.14	0.18
MgO	7.11	6.68	6.26	6.97	6.18	8.49	6.81	6.84	7.26	7.76
CaO	11.56	10.62	10.27	10.89	10.39	9.80	12.07	11.51	11.41	11.99
Na <sub>2</sub> O	2.45	2.14	2.19	2.00	2.30	2.43	2.27	2.48	2.30	1.80
K <sub>2</sub> O	0.38	0.95	1.31	1.11	1.24	0.86	0.36	0.33	0.42	0.70
P <sub>2</sub> O <sub>5</sub>	0.12	0.16	0.18	0.14	0.16	0.22	0.11	0.13	0.14	0.12
H <sub>2</sub> O <sup>-</sup>	0.08	0.06	0.07	0.07	0.09	0.08	0.13	0.06	0.10	0.10
L.O.I.	1.36	2.32	2.10	2.52	2.15	1.61	1.45	0.96	1.28	1.50
Sum	99.91	99.46	99.95	99.69	100.17	99.36	99.64	99.93	99.43	99.78
Rb	10	26	35	32	35	24	9	4	7	30
Sr	228	255	246	249	270	258	288	239	294	219
Y	26	25	30	26	26	29	20	25	24	25
Zr	74	92	124	84	105	130	69	82	83	77
Mn	1458	1393	1378	1406	1276	1233	1105	1272	1112	1409
Nb					13	19				

Table 4 (continued)

Sample no.	Group 5. Dunsjöfjället									Group 6.
	64	64K	65	66	67	68	69	70	70K	9
SiO <sub>2</sub>	49.38	50.24	50.89	50.68	49.04	49.07	50.15	50.06	50.56	49.40
TiO <sub>2</sub>	1.10	1.33	1.57	1.14	0.73	0.83	0.87	1.12	1.51	1.06
Al <sub>2</sub> O <sub>3</sub>	17.06	14.30	14.29	14.36	19.43	18.74	18.35	15.80	14.32	15.46
Fe <sub>2</sub> O <sub>3</sub>	1.45	2.73	2.11	1.94	1.71	1.17	1.55	1.62	2.15	1.90
FeO	7.15	7.87	8.65	8.02	5.25	6.64	5.65	7.91	8.97	7.35
MnO	0.17	0.21	0.20	0.18	0.13	0.14	0.13	0.18	0.20	0.16
MgO	6.66	6.86	6.55	7.58	6.76	6.72	6.50	6.94	6.59	9.97
CaO	11.85	11.28	10.87	11.62	12.43	12.39	12.50	11.64	10.57	10.54
Na <sub>2</sub> O	2.17	2.12	2.56	2.28	2.10	2.10	2.00	2.38	2.51	2.33
K <sub>2</sub> O	0.46	0.58	0.46	0.25	0.26	0.26	0.38	0.34	0.51	0.20
P <sub>2</sub> O <sub>5</sub>	0.13	0.17	0.20	0.11	0.07	0.08	0.10	0.10	0.20	0.13
H <sub>2</sub> O <sup>-</sup>	0.11	0.12	0.09	0.11	0.10	0.10	0.10	0.09	0.16	0.04
L.O.I.	1.78	1.44	1.14	1.08	1.54	1.38	1.37	1.48	1.25	1.24
Sum	99.47	99.25	99.58	99.35	99.55	99.62	99.65	99.66	99.50	99.78
Rb	12	24	9	6	7	7	11	6	12	< 3
Sr	262	231	261	230	243	214	295	222	243	198
Y	25	30	33	26	17	19	21	25	33	16
Zr	80	100	119	65	41	51	63	61	115	59
Mn	1287	1616	1517	1405	1034	1117	999	1392	1526	1214
Nb			17					10		10

Table 4 (continued)

Sample no.	Group 6. Anåfjället									
	9K	10	10T	11	11K	12	12T	13	14	14G
SiO <sub>2</sub>	51.33	50.41	50.69	50.23	50.21	50.72	51.29	52.10	50.80	50.67
TiO <sub>2</sub>	1.25	1.24	1.29	1.21	1.35	1.27	1.50	1.60	1.07	1.07
Al <sub>2</sub> O <sub>3</sub>	14.83	15.44	15.62	16.26	15.57	16.20	14.70	15.45	16.68	17.08
Fe <sub>2</sub> O <sub>3</sub>	1.63	1.98	1.92	1.88	2.04	1.51	1.70	2.10	1.40	1.40
FeO	8.50	7.82	7.97	7.64	8.39	7.64	8.49	8.72	7.14	6.99
MnO	0.17	0.17	0.17	0.16	0.18	0.16	0.18	0.18	0.14	0.15
MgO	7.54	7.60	7.13	7.36	6.68	6.98	6.94	5.77	7.23	7.20
CaO	10.96	11.05	11.08	11.32	11.15	10.79	10.40	9.89	11.20	11.11
Na <sub>2</sub> O	2.63	2.61	2.71	2.67	2.67	2.53	2.63	2.98	2.44	2.46
K <sub>2</sub> O	0.26	0.25	0.28	0.24	0.27	0.49	0.57	0.57	0.37	0.37
P <sub>2</sub> O <sub>5</sub>	0.11	0.14	0.13	0.15	0.15	0.17	0.22	0.20	0.14	0.11
H <sub>2</sub> O <sup>-</sup>	0.03	0.03	0.05	0.07	0.04	0.06	0.03	0.04	0.06	0.06
L.O.I.	0.93	1.22	0.95	1.04	1.30	1.33	1.38	1.15	1.49	1.68
Sum	100.17	99.96	99.99	100.23	100.00	99.85	100.03	100.75	100.16	100.35
Rb	5	8	4	5	6	9	6	14	7	8
Sr	203	225	233	208	193	263	247	248	248	252
Y	25	23	25	21	25	22	32	34	21	21
Zr	74	71	73	67	68	95	110	128	74	71
Mn	1354	1313	1305	1272	1403	1207	1360	1381	1123	1129
Nb								15		

Table 4 (continued)

Group 7. Ormruef										
Sample no.	15	16	17	17Ö	17V	18	18P	18V	19	19G
SiO <sub>2</sub>	50.78	49.98	49.72	51.80	51.58	52.34	51.57	52.42	51.53	51.09
TiO <sub>2</sub>	1.29	1.42	0.82	1.22	1.23	1.45	1.41	1.89	1.53	1.29
Al <sub>2</sub> O <sub>3</sub>	14.99	15.65	16.24	15.12	15.04	15.15	15.27	13.90	14.27	16.07
Fe <sub>2</sub> O <sub>3</sub>	1.76	2.01	1.20	1.84	1.80	1.71	1.27	2.42	2.01	1.68
FeO	8.43	8.64	6.18	7.68	7.79	8.29	8.35	9.50	8.90	7.85
MnO	0.17	0.19	0.13	0.16	0.16	0.16	0.17	0.19	0.18	0.16
MgO	7.46	6.73	9.78	6.91	6.78	6.49	6.71	5.75	6.42	6.70
CaO	11.01	11.21	11.37	10.75	10.58	10.28	10.21	9.34	10.31	11.05
Na <sub>2</sub> O	2.51	2.69	2.06	2.52	2.51	2.74	2.62	2.90	2.68	2.54
K <sub>2</sub> O	0.44	0.36	0.35	0.40	0.49	0.45	0.52	0.62	0.54	0.39
P <sub>2</sub> O <sub>5</sub>	0.15	0.17	0.09	0.17	0.13	0.18	0.21	0.24	0.21	0.18
H <sub>2</sub> O <sup>-</sup>	0.01	0.05	0.06	0.01	0.01	0.04	0.07	0.05	0.12	0.07
L.O.I.	0.96	1.03	1.59	1.32	1.35	1.30	2.03	1.04	1.13	1.10
Sum	99.96	100.13	99.59	99.90	99.45	100.58	100.41	100.26	99.83	100.17
Rb	5	6	7	7	12	7	14	10	10	6
Sr	231	198	238	239	229	267	269	257	255	260
Y	23	30	17	25	25	28	26	38	29	23
Zr	84	98	57	85	82	101	93	135	109	88
Mn	1434	1434	981	1246	1276	1232	1286	1497	1428	1262
Nb	12									

Table 4 (continued)

Sample no.	Group 7. Ormruet				Group 8. Funäsdalsberget					
	20	21	21K	21B	1	2	2K	3	3C	4
SiO <sub>2</sub>	51.78	51.06	52.56	51.04	50.43	50.12	50.71	50.88	50.90	49.36
TiO <sub>2</sub>	1.66	1.05	1.67	1.04	1.16	1.10	1.47	1.11	1.38	1.16
Al <sub>2</sub> O <sub>3</sub>	14.05	18.10	13.93	18.10	16.16	16.96	14.97	16.29	14.69	15.84
Fe <sub>2</sub> O <sub>3</sub>	1.81	1.55	2.06	1.58	1.92	1.52	1.78	1.77	2.22	1.80
FeO	9.34	6.70	9.42	6.71	6.81	6.82	8.38	7.03	7.99	8.14
MnO	0.20	0.14	0.19	0.14	0.16	0.15	0.18	0.15	0.17	0.18
MgO	6.06	5.92	6.06	5.84	7.57	7.53	7.09	7.96	7.36	7.89
CaO	9.78	11.47	9.61	11.47	10.98	11.32	10.66	11.23	10.52	11.54
Na <sub>2</sub> O	2.91	2.59	3.00	2.60	2.45	2.31	2.74	2.37	2.74	2.35
K <sub>2</sub> O	0.54	0.34	0.52	0.31	0.37	0.53	0.53	0.36	0.42	0.38
P <sub>2</sub> O <sub>5</sub>	0.21	0.14	0.21	0.15	0.17	0.15	0.18	0.15	0.19	0.13
H <sub>2</sub> O <sup>-</sup>	0.07	0.05	0.04	0.01	0.06	0.05	0.06	0.08	0.12	0.07
L.O.I.	1.24	0.81	0.88	1.16	1.70	1.74	1.23	1.15	1.64	1.20
Sum	99.65	99.92	100.15	100.15	99.94	100.30	99.98	100.53	100.34	100.04
Rb	11	<3	7	5	6	15	11	7	5	6
Sr	248	270	250	269	254	249	248	246	241	191
Y	29	18	30	20	23	21	29	21	29	26
Zr	112	71	121	71	76	77	105	72	88	71
Mn	1522	1064	1503	1077	1210	1166	1386	1172	1327	1381
Nb	14							11		

Table 4 (continued)

Sample no.	Group 8. Funäsdalsberget							Group 9. Ramberget		
	5K	6	6P	7	7K	8	8K	42	43	44
SiO <sub>2</sub>	51.33	51.25	51.54	50.97	51.83	50.58	50.93	49.76	49.85	48.98
TiO <sub>2</sub>	1.34	1.49	1.26	1.40	1.90	1.32	1.46	1.42	1.34	1.02
Al <sub>2</sub> O <sub>3</sub>	14.44	14.88	16.92	16.25	14.07	15.38	15.24	15.09	15.17	15.80
Fe <sub>2</sub> O <sub>3</sub>	1.73	1.80	1.90	1.69	2.11	1.65	1.93	1.51	1.61	1.70
FeO	8.77	8.66	7.07	7.81	9.55	7.58	7.78	9.61	8.95	7.13
MnO	0.19	0.18	0.15	0.17	0.21	0.15	0.17	0.23	0.19	0.15
MgO	7.36	6.50	5.88	5.79	5.50	7.82	6.97	6.16	7.40	8.21
CaO	10.68	10.28	10.87	10.45	8.77	10.81	10.84	9.88	10.92	10.95
Na <sub>2</sub> O	2.58	2.73	2.69	2.38	3.09	2.40	2.47	2.58	2.47	2.27
K <sub>2</sub> O	0.40	0.61	0.48	0.80	1.13	0.71	0.78	1.33	0.35	0.46
P <sub>2</sub> O <sub>5</sub>	0.18	0.20	0.21	0.20	0.26	0.18	0.20	0.15	0.14	0.10
H <sub>2</sub> O <sup>-</sup>	0.06	0.08	0.08	0.08	0.06	0.05	0.05			
L.O.I.	1.32	1.35	1.22	1.89	1.58	1.53	1.39	2.37	1.45	2.90
Sum	100.38	100.01	100.27	99.88	100.06	100.16	100.21	100.09	99.84	99.67
Rb	10	16	8	18	39	14	15	50	10	15
Sr	193	238	255	248	234	281	276	230	217	268
Y	28	29	27	29	35	25	24	30	31	22
Zr	89	107	109	114	151	132	143	93	88	64
Mn	1461	1399	1179	1286	1615	1192	1289	1819	1452	1163
Nb		14		16	21	13	15	12		

Table 4 (continued)

Sample no.	Group 10. Ulvberget						Group 11. Gråvålen			
	32	32K	33	34	35T	36	37	37K	38	38K
SiO <sub>2</sub>	50.08	49.75	50.34	50.07	50.33	49.37	48.59	50.28	49.30	50.32
TiO <sub>2</sub>	1.10	1.15	1.49	1.22	1.24	1.45	1.13	1.12	1.09	1.21
Al <sub>2</sub> O <sub>3</sub>	16.07	15.82	14.72	15.62	15.72	15.20	16.59	15.87	16.52	14.53
Fe <sub>2</sub> O <sub>3</sub>	1.78	2.58	1.42	2.10	2.45	4.68	2.20	1.54	1.71	2.02
FeO	7.60	6.96	9.15	7.96	7.39	5.98	7.61	7.93	7.55	8.30
MnO	0.16	0.18	0.23	0.18	0.18	0.19	0.17	0.17	0.17	0.19
MgO	8.13	7.04	6.43	7.40	6.31	6.55	7.86	7.31	6.77	7.45
CaO	11.27	11.30	10.45	11.25	11.10	11.18	11.50	11.41	11.57	11.57
Na <sub>2</sub> O	2.44	2.09	2.61	2.46	2.51	1.34	2.21	2.43	2.39	2.36
K <sub>2</sub> O	0.27	0.99	0.80	0.32	0.61	0.39	0.28	0.41	0.42	0.33
P <sub>2</sub> O <sub>5</sub>	0.12	0.13	0.18	0.13	0.14	0.19	0.11	0.11	0.10	0.12
H <sub>2</sub> O <sup>-</sup>	0.05	0.09	0.06	0.04	0.04	0.05	0.05	0.04	0.06	0.06
L.O.I.	1.26	1.93	1.90	1.30	1.61	3.17	1.49	1.41	2.09	1.48
Sum	100.33	100.01	99.78	100.05	99.63	99.74	99.79	100.03	99.74	99.94
Rb	6	43	22	6	20	9	5	12	12	5
Sr	233	259	269	241	269	292	205	225	240	218
Y	24	23	30	27	26	30	25	25	23	25
Zr	69	76	105	75	81	112	68	64	64	70
Mn	1278	1419	1755	1382	1420	1493	1345	1336	1282	1459
Nb						14				

Table 4 (continued)

Sample no.	Group 11. Gråvålen				Group 12. Särvfjället					
	39	39K	40	41	45	45K	46	47	48K	49
SiO <sub>2</sub>	50.41	50.40	49.57	50.67	51.11	51.36	51.17	50.19	51.09	49.44
TiO <sub>2</sub>	1.28	1.44	1.11	1.43	1.43	1.66	1.54	1.04	1.45	1.02
Al <sub>2</sub> O <sub>3</sub>	15.49	14.88	16.19	14.20	16.38	14.76	14.53	15.65	14.18	16.90
Fe <sub>2</sub> O <sub>3</sub>	1.82	1.15	1.37	1.90	2.22	2.53	1.79	2.21	1.99	1.73
FeO	8.23	9.39	8.02	10.26	7.64	8.71	9.34	7.20	9.43	7.12
MnO	0.18	0.19	0.16	0.22	0.17	0.19	0.19	0.17	0.21	0.20
MgO	7.14	6.83	7.89	6.29	5.37	5.45	6.25	7.72	6.38	7.03
CaO	11.39	11.06	11.49	10.85	10.55	9.94	10.57	11.68	10.56	11.32
Na <sub>2</sub> O	2.44	2.54	2.33	2.64	2.63	2.76	2.65	2.40	2.84	2.38
K <sub>2</sub> O	0.39	0.47	0.23	0.38	0.56	0.55	0.56	0.23	0.42	0.62
P <sub>2</sub> O <sub>5</sub>	0.16	0.17	0.11	0.17	0.18	0.22	0.18	0.10	0.14	0.12
H <sub>2</sub> O <sup>-</sup>	0.04	0.04								
L.O.I.	1.31	1.60	1.59	1.33	1.81	1.62	1.49	1.13	1.47	1.98
Sum	100.28	100.16	100.06	100.34	100.05	99.75	100.26	99.72	100.16	99.86
Rb	9	10	5	12	26	19	20	5	17	23
Sr	259	272	227	205	296	271	245	226	233	254
Y	28	30	23	35	31	35	33	22	30	28
Zr	94	105	64	105	117	137	124	60	88	93
Mn	1390	1435	1264	1690	1341	1478	1504	1288	1628	1587
Nb			9							

Table 4 (continued)

Group 12. Särvfjället			
Sample no.	49K	49H	50
SiO <sub>2</sub>	50.31	49.66	49.69
TiO <sub>2</sub>	1.14	1.24	0.91
Al <sub>2</sub> O <sub>3</sub>	14.84	15.53	18.60
Fe <sub>2</sub> O <sub>3</sub>	2.47	1.74	1.37
FeO	6.33	8.08	6.17
MnO	0.22	0.20	0.14
MgO	8.01	6.88	6.72
CaO	10.76	10.77	12.38
Na <sub>2</sub> O	2.23	2.44	2.18
K <sub>2</sub> O	1.12	0.58	0.28
P <sub>2</sub> O <sub>5</sub>	0.14	0.15	0.10
H <sub>2</sub> O <sup>-</sup>			
L.O.I.	2.48	2.15	1.54
Sum	100.05	99.42	100.08
Rb	31	60	8
Sr	280	324	281
Y	24	25	18
Zr	74	89	59
Mn	1675	1513	1080
Nb			9

PRISKLASS D

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