

The Bjergebakke dyke – a kullaite from Bornholm

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The Bjergebakke dyke is a 2–3 m wide dyke trending northwest and cutting through the Almindingen granite in the central part of Bornholm.

Along the contact there is an approximately 1 cm thick white zone consisting almost exclusively of albite, and the dyke has suffered from later autometasomatic alteration, mainly albitisation.

The dyke consists of feldspar, albite as well as potassium feldspar, chlorite, mica and opaque minerals, mainly titanomagnetite, beside traces of calcite and amphibole.

The composition of the feldspars, chlorite, mica and titanomagnetite have been determined by electron microprobe analysis.

Whole rock analyses, major elements as well as trace elements were carried out in two profiles across the dyke with sample distances of 30 and 25 cm respectively.

It is concluded that the present distribution of elements is due to autometasomatic alteration and that any original magmatic differentiation can no longer be seen.

Both the direction of and the mineralogical and chemical composition of the Bjergebakke dyke is quite similar to that of the kullaites in Scania, but whereas the dykes in the Precambrian of Bornholm are considered to be Precambrian, the kullaites have been considered post-Silurian.

Age determinations of these rocks are being undertaken.

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Introduction

The Precambrian of Bornholm covers the northernmost three quarters of the island and consists mainly of granites and gneisses. These rocks are cut by several dolerite dykes trending between north and northeast. However, in the quarry at Bjergebakke (fig. 1) a 2 to 3 m wide dyke trending northwest ($130^{\circ}/88^{\circ}\text{SW}$) occurs; this dyke is not of doleritic composition, but has a composition quite similar to the kullaite dykes in Scania.

The Bjergebakke dyke is strongly altered by autometasomatism, but nevertheless its similarity with the kullaite dykes has warranted a closer study. The Bjergebakke dyke has the same trend and the same mineralogical and chemical composition as the kullaites, but whereas the kullaites are considered to be post-Silurian (Hjelmqvist 1930), all dykes on Bornholm are usually considered to be Precambrian, because they are never seen cutting the Eocambrian and Lower Palaeozoic sediments occurring south of the Precambrian of this island.

The Bjergebakke quarry is situated just north of the road between Rønne and Svaneke 9 km

east of Rønne. In the quarry the dyke can be followed over a distance of 100 m. The width of the dyke varies from 3 m in the southeastern part to 2 m in the northwestern part.

On the northwestern wall of the quarry an only 5 cm thick veinlet is seen about 50 cm west of the

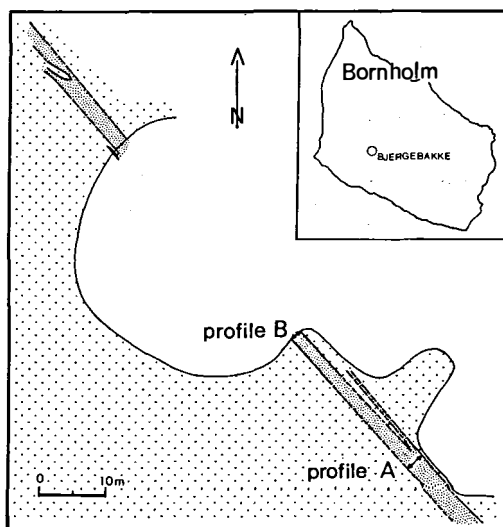


Fig. 1. Sketch map of the Bjergebakke quarry

Table 1. Average modal composition of the two profiles in volume percentages

	A-profile	B-profile
Feldspar	51.4 ± 2.9	51.2 ± 3.7
Chlorite	35.1 ± 3.3	32.3 ± 6.3
Mica	4.9 ± 1.7	7.6 ± 4.3
Opaque minerals	4.6 ± 0.8	4.7 ± 0.6
Apatite	1.8 ± 0.8	3.3 ± 0.4
Calcite	tr.	tr.
Epidote	2.2 ± 0.7	0.7 ± 0.7
Titanite	0.1 ± 0.1	0.4 ± 0.1

main dyke. The veinlet continues into the wall but thins out and after 80 cm it vanishes. Digging in the bottom of the quarry has shown that this veinlet is connected to the main dyke. Splitting-up of the dyke can also be observed in the southeastern part where a 50 cm thick vein can be followed for about 15 m.

The Bjergebakke dyke cuts through the Almindingen granite which constitutes the main part of the quarry. Along the contacts between dyke and granite the dyke margin is frequently developed as an approximately 1 cm thick white zone of alteration.

Sampling

Samples were collected from two profiles across the dyke (fig. 1). The A-profile is 3 m wide and samples were taken from both contacts inwards with a distance of 30 cm between samples, except that 60 cm from the SW contact no sample could be obtained because of lack of exposure. In the B-profile the dyke is 2 m wide and samples were taken from both contacts inwards with a sample interval of 25 cm. In the laboratory the two contact samples of the B-profile were each split in two, one representing 0–3 cm from the contact, the other representing 3–6 cm from the contact. The 5 cm veinlet were sampled in full width.

In order to see to what extent the dyke intrusion with its white border zone of alteration had influenced the country rock, the granite country rock was also sampled. Samples were taken from the NW wall as well as the SW wall of the quarry at distances of 5 cm, 50 cm, 3 m and 16 m from the contact respectively.

Sample description

The contact samples are dense grey with phenocrysts of feldspar about 1 mm in length and miarolitic cavities up to 2 mm in diameter. The sample from the NE contact of the B-profile contains a few discontinuous streaks about 0.1 mm thick of pyrite.

The remaining samples are all fine-grained and grey. The grain-size increases from the contacts inwards until 60 cm from the contact in the A-profile and until 50 cm in the B-profile, after which the grain size remains constant. The samples have reddish spots consisting of clusters of feldspar in glomeroporphyritic aggregates, frequently having miarolitic cavities more or less filled with chlorite. The size of the glomeroporphyritic aggregates is generally 2–3 mm, but in the B-profile they occasionally reach 10 mm. The size of the miarolitic cavities varies from less than 1 mm to about 2 mm.

The contact samples have trachytic texture, in the other samples the texture is trachytic to intersertal.

The 5 cm veinlet is dense black with phenocrysts of feldspar up to 1 mm in length and miarolitic cavities less than 1 mm; the texture is trachytic.

The granite samples are medium-grained reddish grey and without visible differences; the texture is best described as equigranular, although some of the feldspar grains are up to 1 cm in diameter.

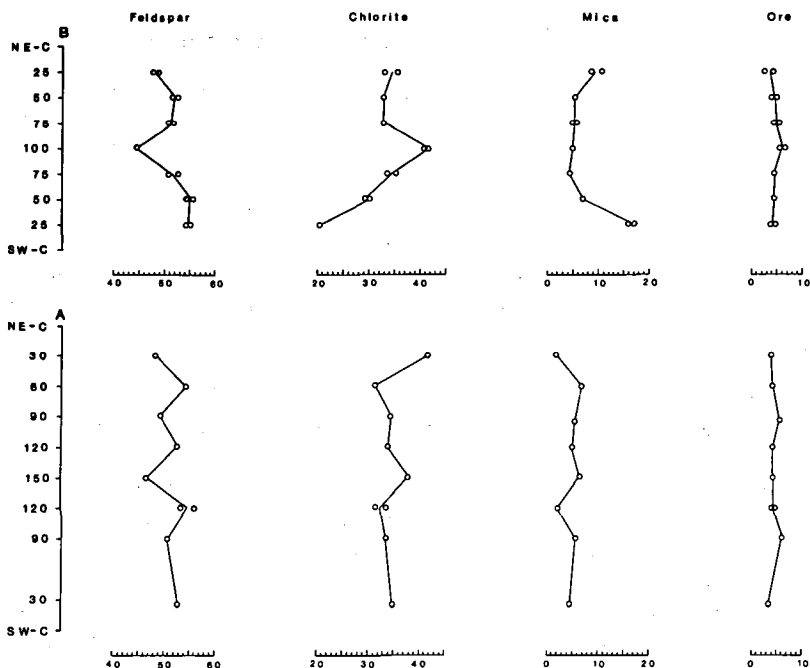
Mineralogical composition

Modal compositions have been determined by point counting of at least 1500 points in each sample; the contact samples, however, have too small a grain-size to allow point counting. For the samples of the B-profile and one of the samples of the A-profile (120 cm from the SW contact), 1500 points have been counted in each of two different thin sections.

The average composition of the two profiles are rather similar (table 1). Calcite is found only in the samples nearest to the contacts, and in the sample 25 cm from the SW contact of the B-profile some grains of amphibole is encountered.

The main difference between the two profiles

Fig. 2. Variations across the dyke of the main minerals



is that the B-profile is richer in mica and poorer in chlorite than the A-profile.

As regards variations across the dyke, correspondence between the two profiles is rather poor. Fig. 2 shows the variation across the dyke in the content of main minerals (apatite, epidote, titanite and calcite are omitted). (Where in the B-profile and at 120 cm from the SW contact of the A-profile only one point (circle) is shown, the counts for the two different thin sections are identical).

In the B-profile the feldspar content decreases from the SW contact inwards towards the middle of the dyke where there is a minimum. From the middle towards the NE contact feldspar increases until 50 cm from the contact and then decreases against the contact. In the A-profile the amount of feldspar fluctuates, but the minimum in the middle of the dyke can be recognized.

In the B-profile chlorite increases rapidly from the SW contact towards the middle where there is a maximum; near the NE contact there seems to be again a slight increase. In the A-profile the maximum in the middle can be recognized, but chlorite decreases inwards in the contact zone.

In the B-profile mica decreases abruptly from both contacts inwards. In the A-profile mica fluctuates but increases from both contacts inwards.

It is the difference between the two profiles in behaviour of chlorite and mica that causes the difference in average composition.

Opaque minerals show a slight increase from both contacts inwards in both profiles, but whereas the B-profile has a maximum in the middle of the dyke, the trend in the A-profile changes so that there is a low in the middle.

Feldspar

Feldspar laths constitute about half of the rock and give rise to a trachytic texture at and near the contacts. In the interior of the dyke the texture varies between trachytic and intersertal.

Average size of the feldspar laths is about 0.15x0.75 mm, except at the actual contacts where the average size of feldspar laths is 15x75 μ m, but phenocrysts up to 0.15x0.75 mm are also present at the contacts.

The feldspar is not fresh, being strongly altered to sericite and epidote, and it is not possible in the microscope to distinguish plagioclase from potassium feldspar. Electron microprobe analyses have however proved the presence of potassium feldspar as well as albite. These two minerals are generally intimately intergrown. The back



Fig. 3. Photo of the back scatter electron image of the microprobe. Dark grey albite, light grey potassium feldspar. Scale bar is 5 μm

scatter electron image of the microprobe can distinguish potassium feldspar from albite, as the latter is somewhat darker than potassium feldspar. Fig. 3 shows the intimate intergrowth of these two minerals.

Electron microprobe analyses of feldspar have been carried out on the samples of the B-profile from the SW contact to the centre and also on the sample of the 5 cm veinlet. In this sample and in the contact sample, however, all attempts to analyse what appears to be potassium feldspar have resulted in sericite analyses. The results of the

electron microprobe analyses are shown in table 2 for albite and table 3 for potassium feldspar.

It can be seen from the tables that the variation between different grains in the same sample are as large as the variation in feldspars from different samples across the dyke, so no variation across the dyke can be established for either albite or potassium feldspar.

The average of the 34 albite analyses is $\text{Ab } 95.1 \pm 1.9$ $\text{An } 3.8 \pm 1.8$ $\text{Or } 1.1 \pm 0.9$, and the average of the 14 analyses of potassium feldspar is $\text{Or } 95.9 \pm 1.9$ $\text{Ab } 3.6 \pm 1.8$ $\text{An } 0.6 \pm 0.6$.

Table 2. Plagioclase analyses

Distance from contact in cm	0	25	50	75	100	5 cm veinlet
Number of analyses	4	3	6	4	8	9
SiO ₂	67.53±0.49	68.14±0.74	66.41±0.89	67.76±0.25	67.52±0.72	68.37±1.07
TiO ₂	0.04±0.03	0.07±0.06	0.09±0.09	n.d.	0.03±0.04	0.03±0.02
Al ₂ O ₃	20.67±0.12	19.73±0.44	19.89±0.41	19.88±0.35	20.54±0.68	20.54±0.29
Cr ₂ O ₃	0.00±0.01	0.04±0.07	0.04±0.05	0.05±0.07	0.04±0.06	0.01±0.01
FeO	0.23±0.10	0.32±0.08	0.36±0.25	0.06±0.09	0.28±0.19	0.20±0.08
MnO	0.01±0.02	0.03±0.05	0.05±0.09	0.02±0.02	0.02±0.03	0.01±0.01
NiO	0.02±0.02	n.a.	n.a.	n.a.	n.a.	0.01±0.02
MgO	0.01±0.01	n.d.	0.07±0.07	0.02±0.04	0.03±0.04	0.03±0.02
CaO	0.88±0.14	0.34±0.18	1.02±0.50	0.65±0.04	1.00±0.40	0.53±0.18
Na ₂ O	10.27±0.49	10.95±0.28	10.46±0.16	10.44±0.23	10.84±0.36	10.59±0.56
K ₂ O	0.29±0.17	0.11±0.08	0.09±0.10	0.09±0.03	0.20±0.20	0.25±0.14
Sum	99.95±0.91	99.74±1.49	98.48±0.70	98.96±0.69	100.50±1.16	100.59±0.71
Cations based on 32 O						
Si	11.809±0.043	11.938±0.044	11.811±0.088	11.935±0.045	11.778±0.117	11.867±0.095
Al	4.261±0.032	4.074±0.035	4.169±0.068	4.126±0.050	4.223±0.115	4.204±0.057
Ti	0.005±0.004	0.009±0.008	0.013±0.013	n.d.	0.004±0.005	0.004±0.004
Cr	0.000±0.000	0.005±0.009	0.005±0.008	0.007±0.009	0.005±0.008	0.000±0.000
Mg	0.003±0.002	n.d.	0.020±0.019	0.005±0.010	0.008±0.010	0.008±0.005
Ni	0.002±0.002	n.a.	n.a.	n.a.	n.a.	0.001±0.003
Fe	0.034±0.015	0.047±0.012	0.053±0.037	0.009±0.013	0.041±0.027	0.029±0.012
Mn	0.002±0.002	0.004±0.008	0.007±0.014	0.003±0.004	0.004±0.005	0.003±0.003
Na	3.482±0.143	3.721±0.071	3.608±0.048	3.564±0.060	3.666±0.129	3.563±0.211
Ca	0.163±0.025	0.065±0.033	0.196±0.099	0.122±0.008	0.185±0.074	0.099±0.034
K	0.065±0.038	0.024±0.018	0.021±0.023	0.019±0.008	0.046±0.045	0.056±0.031
Mol%						
Ab	93.9±0.5	97.7±0.5	94.4±2.3	96.2±0.3	94.1±2.3	95.9±0.9
An	4.4±0.6	1.7±0.8	5.1±2.5	3.3±0.2	4.8±2.0	2.7±0.9
Or	1.8±1.0	0.6±0.5	0.6±0.6	0.5±0.2	1.2±1.1	1.5±0.8

n.d. not detected

n.a. not analysed for

The electron microprobe analyses of the feldspar as well as of the chlorite, mica, amphibole and titanomagnetite were carried out with a Jeol Superprobe JCSA 733 with 15.0 kV accelerating voltage and a sample current of 20.0 nA using albite, hematite, wollastonite, potassium feldspar, MgO, Al₂O₃, TiO₂, Cr, Mn and Ni as standards. In the analyses of titanomagnetite total iron was divided between ferrous and ferric iron by the method suggested by Finger (1972).

The 1 cm thick white zone of alteration at the border of the dyke

X-ray investigation by the Guinier method (E. Leonardsen, Institute of Mineralogy, University of Copenhagen) has revealed that this altered material has a grain size about 1 µm and the only crystalline phase visible on the Guinier film is a plagioclase very near to albite.

A chemical analysis carried out by the Geolog-

ical Survey of Greenland, where SiO₂, Al₂O₃, CaO, K₂O, MgO, MnO, Fe₂O₃, TiO₂ and P₂O₅ were determined by X-ray fluorescence (I. Sørensen) and Na₂O by atomic absorption (J. Kystol), sums up to only 97% and shows a high content of TiO₂ (1.98%), which is not consistent with plagioclase being the only phase present. According to the Guinier investigation this TiO₂ must be either amorphous or below the detection limit.

If only the contents of Na₂O, CaO and K₂O are taken into consideration, the analysis gives a plagioclase with the composition Ab 87.9 An 10.6 Or 1.5 in mole percentages, which is somewhat more calcic than the plagioclase in the dyke proper.

Chlorite

Next to feldspar chlorite is the most abundant mineral in the Bjergetbakke dyke. The chlorite is

Table 3. Potassium feldspar analyses

Distance from contact in cm	25	50	75	100
Number of analyses	2	3	6	3
SiO ₂	64.56±0.49	63.31±0.20	64.25±0.37	63.89±0.09
TiO ₂	0.05±0.06	0.13±0.01	0.13±0.10	0.14±0.06
Al ₂ O ₃	18.56±0.23	18.08±0.14	18.24±0.26	17.92±0.31
Cr ₂ O ₃	0.01±0.01	0.04±0.04	0.02±0.03	0.06±0.08
FeO	0.15±0.12	0.17±0.09	0.12±0.10	0.24±0.20
MnO	0.09±0.04	0.01±0.01	0.01±0.01	0.01±0.02
MgO	0.02±0.03	0.11±0.10	0.06±0.12	0.03±0.02
CaO	0.04±0.02	0.14±0.05	0.05±0.04	0.25±0.19
Na ₂ O	0.48±0.00	0.64±0.17	0.24±0.15	0.39±0.10
K ₂ O	15.34±0.15	15.64±0.18	15.63±0.20	15.84±0.07
Sum	99.28±0.97	98.26±0.54	98.74±0.84	98.76±0.72
Cations based on 32 O				
Si	11.976±0.017	11.925±0.047	11.996±0.039	11.974±0.058
Al	4.058±0.014	4.012±0.024	4.014±0.028	3.958±0.047
Ti	0.006±0.008	0.017±0.002	0.019±0.015	0.020±0.008
Cr	0.002±0.003	0.007±0.006	0.003±0.004	0.008±0.011
Mn	0.012±0.006	0.003±0.002	0.001±0.002	0.003±0.005
Mg	0.006±0.008	0.029±0.028	0.015±0.033	0.008±0.007
Fe	0.022±0.020	0.025±0.015	0.017±0.016	0.039±0.032
Na	0.170±0.003	0.233±0.064	0.086±0.055	0.143±0.036
Ca	0.008±0.006	0.028±0.011	0.011±0.007	0.049±0.037
K	3.630±0.003	3.756±0.033	3.724±0.057	3.788±0.031
Mol%				
Or	95.4±0.2	93.5±1.3	97.5±1.3	95.2±1.2
Ab	4.5±0.1	5.8±1.5	2.2±1.4	3.6±0.9
An	0.2±0.1	0.7±0.3	0.3±0.2	1.2±0.9

Table 4. Chlorite analyses

Distance from contact in cm	0	25	50	75	100
Number of analyses	6	5	10	8	8
SiO ₂	26.56±0.47	27.69±0.97	27.17±0.99	27.49±0.78	28.70±0.55
TiO ₂	0.04±0.02	0.08±0.05	0.04±0.06	0.02±0.03	0.53±0.85
Al ₂ O ₃	16.95±0.22	16.29±0.58	16.99±1.55	17.18±1.46	15.86±0.70
Cr ₂ O ₃	0.02±0.02	0.00±0.01	0.03±0.05	0.09±0.06	0.02±0.04
FeO	32.77±0.69	33.40±2.97	31.24±1.95	31.29±1.75	32.17±1.55
MnO	0.69±0.03	0.82±0.12	0.68±0.18	0.72±0.26	0.53±0.12
NiO	0.01±0.02	n.a.	n.a.	n.a.	n.a.
MgO	8.38±0.30	9.87±1.88	10.63±1.93	11.13±1.72	10.65±1.11
CaO	0.22±0.05	0.31±0.13	0.22±0.08	0.12±0.06	0.20±0.07
Na ₂ O	0.00±0.01	0.30±0.18	0.59±0.20	0.17±0.17	0.13±0.12
K ₂ O	0.09±0.07	0.16±0.03	0.04±0.03	0.10±0.07	0.56±0.96
Sum	85.73±0.69	88.94±0.53	87.62±0.68	88.29±1.06	89.36±1.37
Cations per half unit cell based on 14 O					
Si	3.00±0.05	3.02±0.07	2.98±0.10	2.98±0.10	3.09±0.05
Al ^{IV}	1.00±0.05	0.98±0.07	1.02±0.10	1.02±0.10	0.91±0.05
Al ^{VI}	1.26±0.04	1.11±0.04	1.17±0.12	1.17±0.08	1.10±0.05
Fe	3.10±0.06	3.05±0.31	2.86±0.20	2.84±0.19	2.89±0.13
Mn	0.07±0.01	0.08±0.01	0.06±0.02	0.07±0.02	0.05±0.01
Mg	1.41±0.04	1.60±0.29	1.73±0.30	1.80±0.25	1.71±0.18
Sum ^{VI}	5.83±0.05	5.84±0.05	5.83±0.04	5.87±0.05	5.75±0.21
Fe/Fe+Mg	0.687±0.072	0.655±0.063	0.624±0.059	0.613±0.050	0.629±0.026

n.a. not analysed for

Table 5. Mica analyses

Distance from contact in cm	50	50	75	75	100
Number of analyses	1	1	1	1	4
SiO ₂	38.85	41.26	37.40	36.59	36.34±0.40
TiO ₂	0.54	0.35	0.04	0.48	0.22±0.06
Al ₂ O ₃	22.58	22.11	24.12	23.77	23.74±0.30
Cr ₂ O ₃	0.01	0.06	0.00	0.00	0.01±0.02
FeO	8.40	6.83	5.46	8.09	7.54±0.59
MnO	0.15	0.21	0.00	0.19	0.12±0.07
NiO	n.a.	n.a.	n.a.	n.a.	0.17±0.29
MgO	4.29	3.70	2.70	1.02	0.96±0.13
CaO	10.61	11.30	22.17	21.51	22.03±0.22
Na ₂ O	0.78	0.26	0.00	0.00	0.07±0.03
K ₂ O	0.20	0.24	0.08	0.10	0.03±0.04
Sum	86.41	86.32	91.97	91.75	91.21±1.10
Cations per half unit cell based on 11 O					
Si	2.96	3.11	2.74	2.73	2.73±0.01
Al ^{IV}	1.04	0.89	1.26	1.27	1.27±0.01
Al ^{VI}	0.99	1.07	0.83	0.82	0.83±0.01
Ti	0.03	0.02	0.00	0.03	0.01±0.01
Fe	0.54	0.43	0.34	0.50	0.47±0.03
Mn	0.01	0.01	0.00	0.01	0.01±0.01
Mg	0.49	0.42	0.30	0.11	0.11±0.01
Ca	0.87	0.91	1.74	1.72	1.77±0.01
Na	0.12	0.04	0.00	0.00	0.01±0.00
K	0.02	0.02	0.01	0.01	0.00±0.01
Sum ^{XII}	1.01	0.97	1.75	1.73	1.78±0.02
Sum ^{VI}	2.06	1.95	1.47	1.47	1.43±0.02
Fe/Fe+Mg	0.524	0.506	0.531	0.820	0.811±0.028

n.a. not analysed for

greenish and distinctly pleochroic. The composition of the chlorite has been determined by electron microprobe analysis in five samples of the B-profile taken from contact to middle of the dyke at 25 cm intervals. The results are shown in table 4.

According to the classification of Foster (1962) the chlorite is a brunsvigite; according to the nomenclature of Bayliss (1975) the chlorite should be termed magnesian chamosite.

It is not possible to make any safe conclusions about the variation in composition of the chlorite across the dyke, as the variation in composition between different chlorites occurring at the same distance from the contact is almost as great as the difference in composition between chlorites occurring at different distances from the contact. However, the results are consistent with a decrease in Fe and an increase in Mg from the contact until 75 cm from the contact, but from

here to the middle of the dyke this trend is reversed.

As the analyses were made by electron microprobe water was not determined and there is no distinction between Fe⁺⁺ and Fe⁺⁺⁺. It has, however, been calculated how much Fe⁺⁺⁺ is needed to satisfy the equation $R^{+++VI/2} - R^{+++IV/2} = 6 - \text{sum}^{VI}$. Assuming that the analyses are good enough to give a total between 99 and 100% if H₂O had been determined, and thus using 100 (or 99) minus the sum of the analyses as H₂O values, it has also been calculated how much Fe⁺⁺⁺ is needed to balance 36 (O+OH), where O and OH are calculated from the O values from the analyses. Fe⁺⁺⁺ values determined in this way are in good agreement with the Fe⁺⁺⁺ values determined by the equation $R^{+++VI/2} - R^{+++IV/2} = 6 - \text{sum}^{VI}$, except in the contact sample where the sum of the analysis is too low to allow any Fe⁺⁺⁺. Correspondence between the two values

Table 6. Analyses of chlorite intergrown with mica

Distance from contact in cm	50	75	100
Number of analyses	3	3	5
SiO ₂	27.49±0.49	26.52±0.66	27.90±0.40
TiO ₂	2.37±0.31	1.51±0.51	2.25±0.33
Al ₂ O ₃	16.39±0.13	16.99±0.39	16.03±0.23
Cr ₂ O ₃	0.04±0.08	0.00±0.00	0.02±0.03
FeO	32.65±0.69	34.20±1.00	30.77±0.70
MnO	0.79±0.09	0.71±0.07	0.77±0.06
NiO	n.a.	n.a.	0.04±0.04
MgO	7.54±0.62	6.98±0.70	8.15±0.55
CaO	0.28±0.09	0.36±0.06	0.59±0.39
Na ₂ O	0.53±0.32	0.09±0.09	0.11±0.03
K ₂ O	1.74±0.30	1.00±0.67	1.80±0.44
Sum	89.82±0.78	88.37±0.62	88.43±0.37
Cations per half unit cell based on 14 O			
Si	2.99±0.03	2.94±0.05	3.05±0.03
Al ^{IV}	1.01±0.03	1.06±0.05	0.95±0.03
Al ^{VI}	1.09±0.01	1.17±0.03	1.12±0.02
Ti	0.19±0.03	0.13±0.04	0.19±0.03
Fe	2.97±0.08	3.18±0.12	2.81±0.09
Mn	0.07±0.01	0.07±0.01	0.07±0.01
Mg	1.22±0.10	1.16±0.11	1.33±0.08
Ca	0.03±0.01	0.04±0.01	0.07±0.05
Na	0.11±0.07	0.02±0.02	0.03±0.01
K	0.24±0.04	0.14±0.09	0.25±0.06
Sum ^{VI}	5.94±0.04	5.90±0.04	5.87±0.02
Fe/Fe+Mg	0.709±0.021	0.733±0.023	0.679±0.018

n.a. not analysed for

'VI' sum of cations except Si and Al^{IV}

of Fe⁺⁺⁺ for the contact sample is obtained if the sum of analysis including H₂O is assumed to be only a little less than 97%. The number of Fe⁺⁺⁺ ions obtained by these calculations is small, varying from 0.06 to 0.31.

The values of the Fe/Fe+Mg ratio can not be used to confirm the correspondence between Fe/Fe+Mg in chlorites and Fe/Fe+Mg in whole rock shown by Cathelineau & Nieva (1985) for the range 0.2 to 0.8 of the Fe/Fe+Mg ratio as the differences obtained are not significant.

Mica

Next to feldspar and chlorite mica is the most abundant mineral in the Bjergebakke dyke. In the microscope the mica has a striking similarity to biotite, but the electron microprobe analyses

show that we are dealing with a rather peculiar mica that is rich in CaO without being a margarite.

The electron microprobe analyses have revealed that not all that appears in the microscope to be mica is really mica. There is an intimate intergrowth between mica and a chlorite with a composition different from that of the chlorite in free grains. This intergrowth is similar to the intergrowth between albite and potassium feldspar and can be seen in the back scatter electron image of the microprobe as the chlorite intergrown with mica is somewhat lighter than the mica. Furthermore the difference under the microscope between the mica and the amphibole (only encountered in the sample 25 cm from the SW contact of the B-profile) is very subtle, the amphibole showing only a few degrees deviation from straight extinction. Unfortunately only amphibole analyses were obtained from this sample, but mica is certainly also present.

Analyses of mica are given in table 5. From these it can be seen that towards the centre MgO and K₂O in the mica decreases and CaO increases and there is a pronounced increase in the ratio of Fe/Fe+Mg at the very centre.

Chlorite intergrown with mica

In the microscope chlorite intergrown with mica cannot be distinguished from the mica, but in the back scatter electron image of the microprobe the chlorite is somewhat lighter than the mica.

Table 6 shows the results of the electron microprobe analyses of the chlorite intergrown with mica at 50, 75 and 100 cm distance respectively from the SW contact of the B-profile. No variation across the dyke can be seen, but comparison with table 4 shows that chlorite intergrown with mica is considerably richer in K and Ti and poorer in Mg than the chlorite in free grains. However, the chlorite intergrown with mica is, like the chlorite in free grains, a brunsvigite in the nomenclature of Foster (1962) and a magnesian chamosite in the nomenclature of Bayliss (1975).

Amphibole

In the Bjergebakke dyke amphibole is encountered only in the sample taken 25 cm from the

Table 7. Amphibole analyses

Average of 5 analyses taken 25 cm from SW-contact			
SiO ₂	40.12±0.32	Cations based on 23 O	
TiO ₂	4.62±0.07	Si	5.92±0.04
Al ₂ O ₃	12.90±0.27	Al ^{IV}	2.08±0.03
Cr ₂ O ₃	0.06±0.08		Sum 8.00
FeO	14.56±1.44	Al ^{VI}	0.16±0.01
MnO	0.28±0.06	Ti	0.52±0.02
MgO	11.28±0.91	Cr	0.01±0.02
CaO	11.14±0.22	Fe ⁺⁺⁺	0.33±0.03
Na ₂ O	2.91±0.25	Mg	2.48±0.18
K ₂ O	0.82±0.13	Fe ⁺⁺	1.48±0.14
Sum	98.69±0.97	Mn	0.04±0.02
			Sum 5.02
		Na	0.83±0.08
		Ca	1.78±0.02
		K	0.15±0.02
			Sum 2.76

The distribution of Fe⁺⁺ and Fe⁺⁺⁺ is calculated by summing total cations except Na, Ca and K to 13 (Robinson et al. 1982, p. 8)

SW contact of the B-profile. The appearance of the amphibole in the microscope is very similar to that of the mica, and the amphibole can only be distinguished from the mica by deviating a few degrees from straight extinction.

Table 7 shows the result of 5 electron microprobe analyses of the amphibole. It belongs to the group of calcic amphiboles and is a kaersutite (Hawthorne 1981).

Opaque minerals

The opaque minerals consist mainly of titanomagnetite which is generally more or less altered to maghemite and turbid sphene. Besides titanomagnetite there occur varying amounts of small thin laths of ilmenite and some grains of pyrite and chalcopyrite.

The size of the titanomagnetite grains lies mainly between 40 µm and 80 µm. The dimensions of the ilmenite laths is about 1 µm x 30 µm. The pyrite grains can reach about 0.2 mm in diameter, but most pyrite grains lie between 5 µm and 30 µm in diameter. The chalcopyrite grains lie mainly between 5 µm and 40 µm in diameter, but a few grains are close to 0.1 mm.

The distribution of ilmenite, pyrite and chalcopyrite across the dyke is similar and distinctive with minima in the middle and at the contacts, and maxima about halfway between contacts and middle. The total amount of these three minerals however is so small compared to the amount of titanomagnetite, that this distribution cannot be seen from the curve for ore shown in fig. 2, the shape of thin curve being determined by the amount of titanomagnetite.

The composition of the titanomagnetite has been investigated by electron microprobe analy-

Table 8. Analyses of titanomagnetite

Distance from contact in cm	Distance from contact				
	0	25	50	75	100
Number of analyses	10	6	6	10	6
MgO	0.26±0.24	0.20±0.09	0.16±0.21	0.12±0.10	0.05±0.12
Al ₂ O ₃	5.26±2.06	2.72±0.78	0.60±0.21	1.70±0.49	1.33±0.52
TiO ₂	20.05±3.56	19.28±2.07	10.08±4.48	11.81±3.14	10.02±3.29
Cr ₂ O ₃	0.03±0.02	0.04±0.09	0.08±0.10	0.04±0.05	0.02±0.04
MnO	0.59±0.17	0.52±0.15	0.86±0.52	0.66±0.48	0.47±0.49
FeO	49.35±3.23	48.55±2.00	39.41±4.66	41.46±2.83	40.01±3.04
Fe ₂ O ₃	24.46±6.19	28.69±4.50	48.82±8.97	44.21±6.29	48.09±7.01
Cations based on 32 O					
Mg	0.109±0.106	0.087±0.038	0.074±0.097	0.054±0.045	0.021±0.052
Al	1.813±0.703	0.950±0.269	0.210±0.181	0.605±0.169	0.478±0.184
Ti	4.423±0.790	4.310±0.450	2.299±1.011	2.677±0.705	2.280±0.739
Cr	0.009±0.008	0.010±0.022	0.019±0.023	0.011±0.013	0.005±0.007
Mn	0.143±0.043	0.131±0.038	0.223±0.137	0.168±0.124	0.121±0.124
Fe ⁺⁺	12.102±0.803	12.083±0.450	10.008±1.128	10.450±0.678	10.129±0.709
Fe ⁺⁺⁺	5.402±1.390	6.429±1.032	11.169±2.104	10.037±1.472	10.966±1.661
Sum	24.001	24.000	24.002	24.002	24.000
Fe ₂ TiO ₄ /Fe ₃ O ₄					
Average	71/29	67/33	38/62	44/56	38/62
Range	86/14-60/40	73/27-59/41	63/37-26/74	60/40-24/76	54/46-22/78

Table 9. Whole rock analyses

	A-profile		B-profile		5 cm veinlet	
	Average of 12 analyses	Standard deviation	Average of 14 analyses	Standard deviations		
SiO ₂	51.97	1.08	51.84	1.44	52.88	
TiO ₂	1.67	0.08	1.66	0.07	1.63	
Al ₂ O ₃	18.18	0.18	18.15	0.32	17.77	
Fe ₂ O ₃	3.39	0.64	2.43	0.46	0.56	
FeO	5.65	0.77	6.49	0.51	7.91	
MnO	0.23	0.04	0.25	0.05	0.21	
MgO	2.67	0.36	2.48	0.24	2.19	
CaO	3.11	0.58	3.86	0.42	3.60	
Na ₂ O	5.34	0.69	5.52	0.73	7.03	
K ₂ O	2.69	0.50	2.53	0.54	2.78	
H ₂ O	3.51	0.19	3.29	0.31	2.83	
P ₂ O ₅	0.84	0.03	0.82	0.03	0.84	
Sum	99.25	0.22	99.32	0.18	100.23	
Total Fe as FeO	8.70	0.42	8.68	0.50	8.41	
C.I.P.W. weight norms						
Q	0.09					
or	16.50	16.45	15.55	15.50	16.55	16.55
ab	49.75	49.65	51.20	50.57	45.12	45.85
an	10.15	10.15	14.10	14.05	8.80	8.80
wo	di				1.42	1.42
					0.54	0.58
fs				0.88	0.84	
en	hy	7.64	3.38	1.01		
fs		4.62	4.26	0.95		
fo	ol		3.18	4.60	5.34	4.14
fa			4.02	4.28	7.18	6.85
ne				0.32	11.09	10.65
mt	3.65	1.31	2.60	1.29	0.59	1.17
il	2.42	2.42	2.42	2.42	2.24	2.24
ap	1.84	1.84	1.84	1.84	1.79	1.79
c	3.34	3.33	1.48	1.50		

ses in a section from the SW contact to the centre of the B-profile.

Generally the outer parts of the ore grains were avoided during the electron microprobe analyses, but in the contact sample a few analyses of the rims were intentionally made.

The analysed grains all contain a small but varying amount of SiO₂ and CaO, obviously due to the alteration to turbid sphene. Accordingly the analyses have been recalculated to 100% minus SiO₂ and CaO. The result is shown in table 8, the analysed rims from the contact sample being omitted.

The variation in composition between different grains at the same distance from the contact and different positions inside the same grain is rather large, but it can be seen that the amount of TiO₂

decreases from the contact inwards. The range in Fe₂TiO₄/Fe₃O₄ indicates that this decrease continues right to the centre, whereas the average values of Fe₂TiO₄/Fe₃O₄ indicate that the decrease stops about 50 cm from the contact (the sample 75 cm from the contact is thought to be erroneously high).

FeO decreases with TiO₂ and Fe₂O₃ shows a corresponding increase. Cr₂O₃, if present, is near the detection limit.

The analyses of the rims of titanomagnetite from the contact sample (not shown in table 8) have a Fe₂TiO₄/Fe₃O₄ ratio 49/51 corresponding to a distance between 25 and 50 cm from the contact. This suggests that crystallisation at the contact was finished when the main crystallisation about 50 cm from the contact took place.

Table 10. Trace element analyses

	A-profile			B-profile			5 cm veinlet	
	Average of 12 analyses	Contact only		Average of 14 analyses	Contact 0-3 cm	Contact 3-6 cm		
	Standard deviation			Standard deviation				
Rb	96	19	68	89	27	34	82	71
Ba	980	172	871	1052	167	531	1570	1520
Pb	9	8	13	4	3	8	2	18
Sr	696	144	788	886	128	559	998	423
La	90	5	97	88	6	97	96	86
Ce	169	10	179	174	14	202	188	187
Nd	68	4	75	68	6	82	74	77
Y	33	7	45	30	4	41	34	45
Th	11	1½	13	10	2	11	11	11
Zr	344	16	370	336	11	357	342	363
Nb	108	2½	111	108	1	109	109	112
Zn	65	15	83	55	10	71	58	52
Cu	4	4	<3	4½	3½	<3	<3	<3
Co	24	1	23	23	2	21	21	22
Ni	3	2	<2	<2		<2	<2	<2
Sc	6	1	5	6	1	5	5	5
V	64	9	72	58	5	53	53	58
Cr	<3		<3	<3		<3	<3	<3
Ga	17	1	17	17	1½	22	16	16
K/Y	749	215	355	702	271	221	669	526
K/Rb	247	19	232	253	20	262	274	333
Rb/Th	8.8	2.2	5.4	8.4	3.4	3.3	7.5	6.5
La/Th	8.4	1.1	7.8	8.9	1.5	9.2	8.8	7.8
Y/Zr	0.09	0.01	0.12	0.09	0.01	0.11	0.10	0.12

Whole rock analyses

Major elements

12 chemical analyses have been made from the A-profile and 14 from the B-profile; duplicate samples were made of the samples taken 60 and 90 cm from the NE contact of the A-profile and 25, 50 and 125 cm from the SW contact of the B-profile. The 5 cm veinlet was analysed as a whole.

The analyses were carried out in the laboratory of the Geological Survey of Greenland by Ib Sørensen. H_2O^+ was determined by the Penfield method and Fe^{++} by wet chemistry. Mg was determined by complexometric titration, Na by flame photometry, and the remaining elements were analysed by XRF on glass discs.

Table 9 shows the average values of the two profiles and the values obtained for the 5 cm veinlet together with the calculated CIPW weight norms. The norms were calculated with the ratio Fe_2O_3/FeO as found by analyses (first column) as

well as with this ratio adjusted to 0.15 (second column).

In the QAPF-diagram the averages of the A- and B-profiles both plot in the trachyte field whereas the 5 cm veinlet just reaches the tephritic phonolite field.

Most of the individual analyses of the two profiles also plot in the trachyte field with neither Q nor F, but the two contact samples of the A-profile plot in the alkali-trachyte field and have Q (1.89 and 2.49 respectively), also the three central samples of the A-profile have Q (max. 0.79) but plot in the trachyte field. The contact samples of the B-profile plot near the border to the alkali-trachyte field. No analyses of the B-profile have Q, but the samples 3-6 cm and 25 cm from the SW contact and the sample 0-3 cm from the NE contact have a small amount of F (max. 1.17 ne).

Use of the CIPW weight norms with the Fe_2O_3/FeO ratio adjusted to 0.15 does not result in change of fields but Q disappears from the A-profile without any ne being introduced, and the amount of ne in the B-profile increases.

In the TAS diagram (Le Bas et al. 1986) the

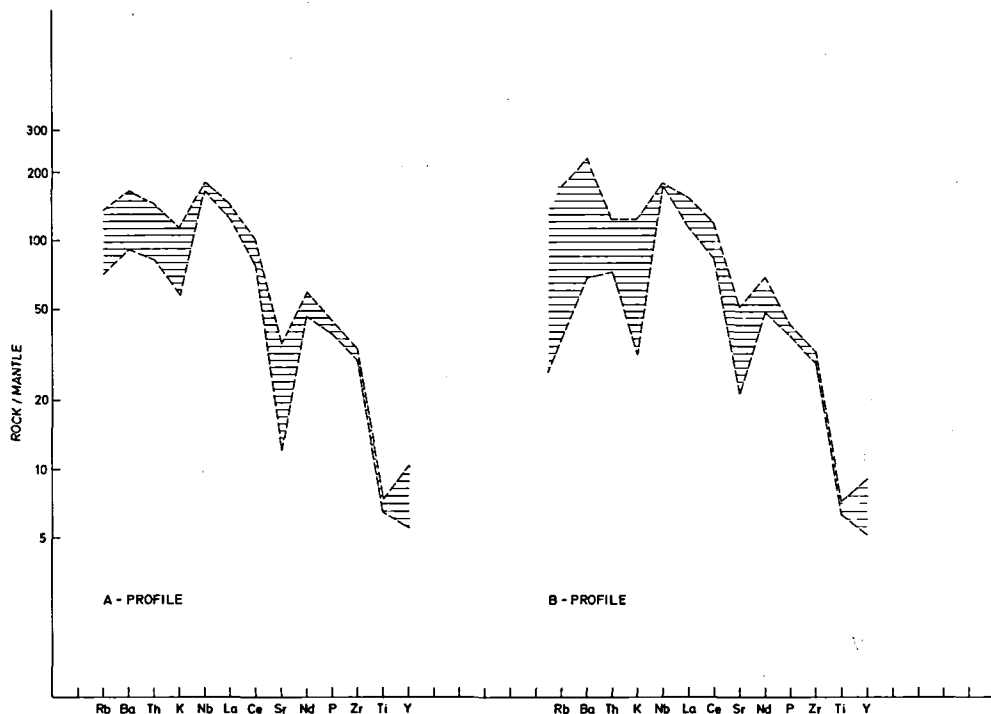


Fig. 4. 'Spidergrams' for the two profiles. The element concentrations are normalised to 'primordial mantle' values, and arranged from left to right in order of decreasing incompatibility (Wood et al. 1979)

averages of the A- and B-profiles both plot on the border between the trachyandesite and the basaltic trachyandesite fields, whereas the 5 cm veinlet plots on the border between the trachyandesite and the tephriphonolite fields. The contact analyses of both profiles plot in the trachyandesite field while all the other analyses plot in the basaltic trachyandesite field.

The analyses, however, all have about 3% water. A main reason for this investigation of the Bjergebakke dyke is its close resemblance to the kullaites from Scania described by Hennig (1899) and Hjelmqvist (1930), and classified by Johannsen (1937) as syenodiorite porphyries (2211'A). The kullaites also have a large amount of water: 2.76 and 2.59% in the two analyses published by Johannsen (1937) and 3.69 and 4.00% in two recent analyses (personal communication Hans Olsson).

Trace elements

Trace elements were analysed directly on pressed powder pellets by J. Bailey, Institute of Petrol-

ogy, University of Copenhagen, by X-ray fluorescence using a Phillips PW 1400 (funded by the Danish Natural Science Research Council) and the techniques of Norrish & Chappell (1977).

Table 10 gives the average composition of the two profiles and the composition of the contacts and of the 5 cm veinlet.

The values of Sr, La and Nb are unusually high, and for a rock of trachytic composition the values of Y, Co and V are high and the values of Rb, Zr, Zn and Ga are low. Wood et al. (1979) found the highest ratio of K/Y (a highly incompatible element against a slightly incompatible element) in alkalibasalts erupted in the southern part of the eastern active zone in Iceland, this value being 190.

The contacts of the Bjergebakke dyke are depleted in K relative to Y with K/Y ratios of 355 and 221 for the two profiles respectively, whereas the interior of the dyke has K/Y ratios about 850. Wood et al. (1979) consider such a large variation to rule out a relation to a single parental liquid by low pressure crystal fractionation. In the Bjergebakke dyke, however, the depletion in K at the

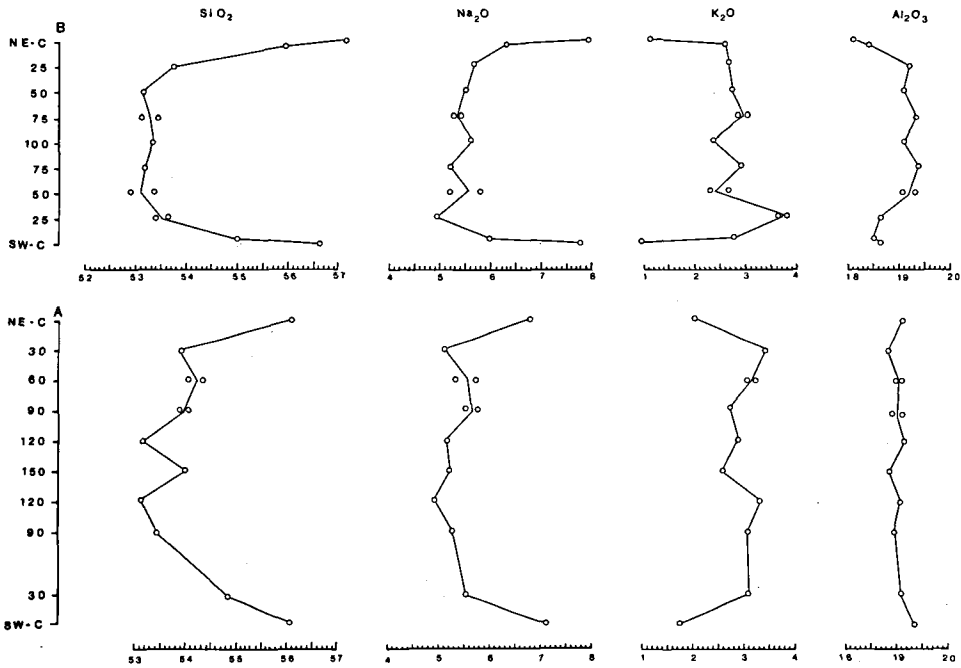


Fig. 5. Variations across the dyke in SiO_2 , Na_2O , K_2O and Al_2O_3

contacts could be due to later autometamorphic processes.

The ratio of K/Rb is rather constant across the dyke with average values of 247 and 253 for the

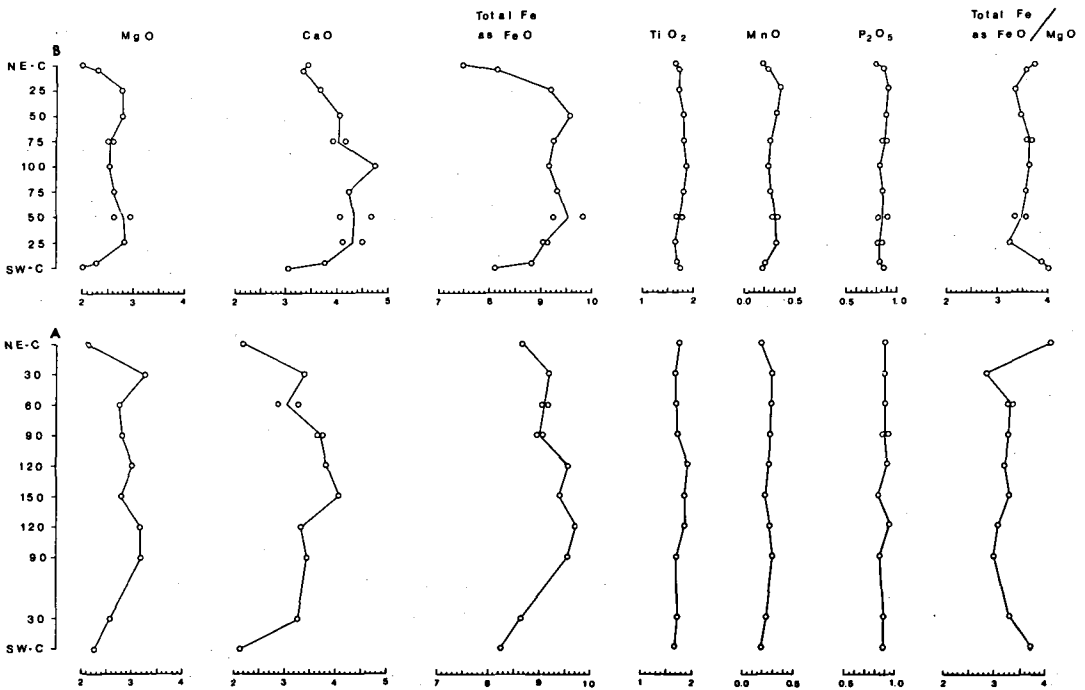


Fig. 6. Variations across the dyke in MgO , CaO , total Fe as FeO , TiO_2 , MnO , P_2O_5 and the ratio of total Fe as FeO to MgO

two profiles respectively, which, however, are lower than the ratio in the bulk Earth (300; Ganapathy & Anders 1974). The value of K/Rb for the 5 cm veinlet exceeds 300.

The average ratio of Rb/Th of the two profiles is 8.8 and 8.4 respectively which is close to the value of 9 in the bulk Earth (Ganapathy & Anders 1974), but the contacts are depleted in Rb relative to Th having a Rb/Th ratio of 5.4.

The average ratio of La/Th of the two profiles is 8.4 and 8.9 respectively, which is higher than the ratio of 7.4 in the bulk Earth (Ganapathy & Anders 1974), but the 5 cm veinlet and the contacts of the A-profile have a value of 7.8.

The Y/Zr ratio is somewhat higher for the contacts than in the interior of the dyke.

Fig. 4 shows "spidergrams" for the two profiles. The element concentrations are normalised to "primordial mantle" values, and arranged from left to right in order of decreasing incompatibility (Wood et al. 1979).

Chemical variations

Major elements

The variations in chemical composition for major elements across the dyke are shown in figs 5 and 6. The values used are recalculated to 100% based on water-free composition, but the use of the oxide values found by chemical analyses does not change either the trends or the shape of the curves. In the A-profile two analyses were made of the samples taken 60 and 90 cm from the NE contact. In the B-profile two analyses were made of the samples taken 25, 50 and 125 cm from the SW contact. Where only one point is shown in the figures for these samples the two analyses have given identical values.

Across the dyke the value of SiO₂ decreases abruptly from the contacts inwards and then a weak increase against the centre of the dyke can be noted.

The behaviour of Al₂O₃ is peculiar. Both profiles show a minimum at the centre, but while in the A-profile Al₂O₃ decreases inwards from the contacts all the way to the centre, in the B-profile it first increases.

Na₂O decreases abruptly from the contacts inwards and there are some undulations across the dyke, including a weak maximum at the centre.

K₂O increases abruptly from the contacts inwards and then undulates across the dyke, including a weak minimum at the centre.

CaO increases from the contacts inwards and shows a maximum at the centre of the dyke. Also MgO increases from the contacts inwards; the fluctuations across the dyke include a weak minimum at or near the centre.

TiO₂ is somewhat higher in the central parts of the dyke than in the border parts. Total Fe as FeO increases from the contacts inwards and shows a minimum at the centre.

Fe₂O₃ (not shown) decreases from the contacts inwards and then increases towards the centre, whereas FeO (not shown) increases from the contacts inwards and then decreases towards the centre.

MnO and P₂O₅ are fairly constant, but both may show a weak minimum at the centre. MnO furthermore shows a weak initial increase from the contacts inwards.

Trace elements

The distribution of trace elements across the dyke is not shown in a figure but tentatively described in the following:

Rb and Ba behave similarly to K₂O. The behaviour of Sr resembles K₂O and that of Zr resembles SiO₂.

La, Ce, Nd and Zn have a minimum at the centre and increase towards the contacts.

Y decreases from the contacts inwards and is rather constant in the interior of the dyke.

Pb, V, Th, Nb, Cu and Ni vary, and Pb and V fluctuate.

Co, Sc and Cr are rather constant across the dyke, and so is Ga except for an increase at the actual contact shown only in the B-profile (which shows up probably because the contact sample here was split into two pieces, one 0-3 and the other 3-6 cm from the contact).

When plotted against Rb on log-log paper only the highly incompatible elements Ba and K result in 45° lines, although concerning Ba the contact samples are too high in Ba to fit the 45° line. When the contact samples are omitted the 45° direction can also be seen for the elements Nd and Zr; however, for these elements it would not be correct to talk about a line, rather a band. The

contact samples are too high in Nd and Zr to fit the otherwise established band.

When plotted against Zr on log-log paper no 45° lines are seen for any element, but 45° bands can be established for Nb (only in the A-profile), Ce, Nd and Y. When the contact samples are omitted 45° bands can also be established for Rb (only in the A-profile), Ba (only in the A-profile) and K, but the contact samples are too low in these elements to fit the otherwise established band.

Composition of the 5 cm veinlet

When the 5 cm veinlet was sampled in full width it was thought that the veinlet was so thin that it probably did not extend upwards for more than a few metres, so that the intruding magma was prevented in penetrating further upwards. The composition of the veinlet in full width possibly therefore represented the average of the magma.

Comparing the composition of the 5 cm veinlet (trace elements as well as major elements) with the variations across the dyke it is seen that the 5 cm veinlet does not correspond to the average composition of the dyke but to the composition found between 5 and 10 cm from the contacts. This could be interpreted as a result of the veinlet opening did not take place until the first 5 to 10 cm of the main dyke had solidified, but the present composition of the 5 cm veinlet could also be the result of a different degree of later autometasomatic alteration.

Analyses of the granite country-rock

In an attempt to find out to what extent the intrusion of the Bjergebakke dyke with its 1 cm alteration zone of albite influenced the granite country-rock, analyses were made of granite samples taken 5 cm, 50 cm, 3 m and 16 m from the contact in two different profiles, one at the north-west wall of the quarry and one at the southwest wall.

No significant differences can be seen concerning major elements except for a slight increase in FeO and decrease in Fe₂O₃ from 5 cm to 3 m from the contact without however any change in total Fe.

Concerning trace elements, Rb, Ba and Y increase from 5 cm from the contact until 3 m from the contact, Rb from 195 to 230 ppm, Ba from 640 to 740 ppm and Y from 40 to 50 ppm. Zn increases from 1 to 15 ppm in the interval 5 cm to 50 cm from the contact.

Any further chemical changes because of the dyke intrusion must be confined to the few cm of the granite nearest to the contact.

Significance of the chemical variations

The variations across the dyke in SiO₂, Na₂O, MgO, CaO, total Fe as FeO and the ratio of total Fe as FeO against MgO indicate a development from the contacts inwards from felsic to mafic.

It is not uncommon to find dykes with a felsic to mafic trend from margin to interior. Ross (1983) has found such a trend in Columbia River basalt dykes from the southeastern Columbia Plateau. Ross attributed the chemical trend to the relative enrichment in silica and incompatible elements in the glass and therefore in the glassy dyke margins compared to their more crystalline interiors. Also Kalsbeek & Taylor (1985) found a felsic to mafic trend from margins to interior in dykes from Greenland. Kalsbeek & Taylor interpreted the variations across the dykes as the result of the dyke material being tapped from a zoned magma chamber in which the magma near the roof was more fractionated, whereas the magma deeper down was less fractionated and contained large amounts of early crystallised olivine, augite and plagioclase. Kalsbeek & Taylor (1986) also investigated variations across a 100 m wide basic dyke which can be followed 400 km along strike in central West Greenland and found a felsic to mafic trend from margins to interior, and interpreted the variations as due to a combination of enrichment of early formed crystals in the central part of the dyke, and intrusion of more fractionated magma at first, followed by more primitive magma.

The variations in the Bjergebakke dyke are similar to those found by Kalsbeek & Taylor (1985, 1986) except that in the Bjergebakke dyke K₂O increases from the contacts inwards.

During this work the author has been tempted to interpret the variations from the contacts inwards as due to preeruptional differentiation so

Table 11. Whole rock analyses

	A-profile			B-profile				
	Average of contacts	Standard deviation	Center added 20% NaAlSi ₃ O ₈	Average of contacts	Standard deviation	Center added 20% NaAlSi ₃ O ₈		
SiO ₂	53.85	0.10	54.44	54.31	0.87	54.13		
TiO ₂	1.63	0.01	1.48	1.62	0.03	1.48		
Al ₂ O ₃	18.41	0.25	18.18	17.73	0.21	18.44		
Fe ₂ O ₃	4.23	0.11	2.88	2.02	0.32	2.63		
FeO	4.30	0.18	4.88	6.05	0.81	4.96		
MnO	0.18	0.01	0.17	0.18	0.02	0.18		
MgO	2.09	0.07	2.21	2.09	0.15	2.02		
CaO	2.04	0.01	3.22	3.29	0.30	3.78		
Na ₂ O	6.67	0.23	6.13	6.75	0.93	6.48		
K ₂ O	1.81	0.18	2.03	1.82	0.92	1.90		
H ₂ O	3.24	0.16	3.05	2.84	0.27	2.84		
P ₂ O ₅	0.85	0.01	0.64	0.81	0.03	0.67		
Sum	99.30	0.33	99.31	99.51	0.31	99.51		
Total Fe as FeO	8.10	0.28	7.47	7.86	0.54	7.33		
C.I.P.W. weight norms								
Q	2.11		0.62					
or	10.90	10.85	12.30	12.25	11.05	11.05	11.35	
ab	61.55	61.45	56.55	56.45	61.60	60.15	59.30	57.80
an	4.55	4.55	12.05	12.00	11.55	11.50	14.75	14.75
en	} hy	5.96	3.58	6.28	3.65		0.91	
fs		1.88	5.44	3.76	4.67		0.67	
fo	} ol	1.77		1.97	4.43	4.43	3.58	4.25
fa		2.70		2.53	4.63	6.32	2.60	5.95
ne				0.15	0.96		0.87	
mt	4.56	1.20	3.09	1.11	2.13	1.11	2.81	1.02
il	2.30	2.28	2.18	2.16	2.26	2.26	2.16	2.16
ap	1.84	1.84	1.36	1.36	1.66	1.66	1.36	1.36
c	4.37	4.35	1.81	1.83	0.54	0.56	0.51	0.50

that the magma first erupted was more differentiated than the later erupted magma, and the variations in the central part of the dyke as due to post-eruptive differentiation, but the behaviour of K₂O and the fact that the dyke has suffered from later autometamorphic processes as shown for instance by the presence of the one cm thick borderzone of pure albite makes such an interpretation rather unsafe.

Therefore it has been calculated what effect the addition to the centre samples of different amounts of NaAlSi₃O₈ would have, and it is found that the addition of 20% albite to the centre sample analyses results in compositions very similar to those of the contact samples (table 11). The norms were calculated with the ratio Fe₂O₃/FeO as found by analyses (first column) as well as with this ratio adjusted to 0.15 (second column). The contact samples, however, are somewhat enriched in Na₂O, total Fe, TiO₂ and P₂O₅ and depleted in CaO and K₂O relative to the mod-

ified centre samples. The behaviour of SiO₂ and Al₂O₃ is opposite in the two profiles. From the B-profile where the contacts are represented by samples 0-3 and 3-6 cm from the contact respectively, it can be seen that the enrichment in Na₂O relative to K₂O takes place very close to the contact - between 3 and 6 cm.

On these grounds the author finds that the chemical variations across the dyke therefore most probably are due to later autometamorphic alteration, mainly in the form of albitisation.

Conclusions

In the TAS diagram the contact samples of the Bjergebakke dyke plot in the trachyandesite field, whereas all the samples from the interior of the dyke plot in the basaltic trachyandesite field.

The feldspar present is an intimate intergrowth of albite with the composition $Ab_{95.1}An_{3.8}Or_{1.1}$ and potassium feldspar with the composition $Or_{95.9}Ab_{3.6}An_{0.6}$.

There are no original dark silicate minerals left in the Bjergebakke dyke, they are completely altered to amphibole, mica or chlorite.

The composition of the chlorite seems to decrease in FeO and increase in MgO from contact to 75 cm from the contact, from here to the centre this trend is reversed.

The composition of the mica decreases in MgO and K_2O and increases in CaO from contact to centre, the Fe/Fe+Mg ratio is very high at the centre.

The composition of the titanomagnetite decreases in TiO_2 from the contact inwards.

The chemical variations across the dyke could be interpreted as due to pre-eruptive differentiation at and near the contacts, and to post-eruptive differentiation in the central part of the dyke, but it is believed that the present distribution of elements across the dyke is caused by later autometamorphic alteration, mainly in the form of albitisation. As regards both orientation and mineralogical and chemical composition the Bjergebakke dyke is quite similar to the kullaite in Scania, but whereas all the dykes in the Precambrian of Bornholm have hitherto been considered Precambrian, the kullaite is considered post-Silurian.

A preliminary age determination by Poul Martin Holm, Institute of Petrology, University of Copenhagen, has shown the kullaite from Scania to be older than the Bjergebakke dyke. No final decision as to the age of these dykes can be made before further age determinations of both Scania kullaite and the Bjergebakke dyke, as well as some of the dolerites of Bornholm, have been carried out.

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Dansk sammendrag

I stenbruddet ved Bjergebakke, der ligger lige nord for vejen mellem Rønne og Svaneke 9 km øst for Rønne, skæres Almindingen-graniten af en 2-3 m bred gang. Gangen er næsten lodret og stryger NW-SØ ($130^{\circ}/88^{\circ}$ SW). Denne retning er væsentligt afvigende fra retningen af de bornholmske doleriter, og Bjergebakkegangen har da heller ikke doleritisk sammensætning, men såvel retning som sammensætning af Bjergebakkegangen svarer ganske nøje til de skånske kullaite, det vil sige gangen består væsentligst af plagioklas, kalifeldspat, chlorit, biotit og titanomagnetit.

Grænsen mellem Bjergebakkegangen og Almindingen-graniten udgøres af en 1 cm mægtig hvid omdannelseszone, der næsten udelukkende består af albit.

Bjergebakkegangen er undersøgt i to profiler, et 3 m bredt A-profil og et 2 m bredt B-profil (Fig. 1). I A-profilet er der taget prøver med 30 cm afstand, i B-profilet med 25 cm afstand. Der er også undersøgt prøver af en 5 cm bred udløber, der findes på NW-væggen 50 cm W for hovedgangen. Udløberen fortsætter ind i væggen, men tynder ud og forsvinder efter 80 cm. Gravning i bunden af bruddet har vist, at udløberen er forbundet med hovedgangen. Endvidere er Almindingen-graniten undersøgt i 5 cm, 50 cm, 3 m og 16 m afstand fra gangkontakten i to profiler, et på bruddets NW-væg og et på SW-væggen.

Den gennemsnitlige modale sammensætning af de to profiler er vist i tabel 1, variationen på tværs af gangen er vist i fig. 2.

Tabel 2 og 3 viser sammensætningen af henholdsvis plagioklas og kalifeldspat på tværs af gangen, og fig. 3 viser, hvor tæt disse mineraler er sammenvoksede.

Tabel 4, 5 og 6 viser sammensætningen på tværs af gangen for henholdsvis chlorit, glimmer og chlorit sammenvokset med glimmer.

Tabel 7 viser analyser af amfibol, der kun er fundet i en af prøverne, nemlig prøven 25 cm fra SW-kontakten af B-profilet.

Tabel 8 viser variationen af titanomagnetit på tværs af gangen.

Tabel 9 og 10 er bjergartsanalyser af henholdsvis hoved- og sporelementer. Fig. 5 og 6 viser variationen på tværs af gangen for hovedelementerne, og fig. 4 viser 'spidergrams' for sporelementerne.

Endelig sammenligner tabel 11 sammensætningen af kontaktprøverne med prøverne fra gangmidten, hvis disse tilføres 20% albit.

I TAS diagrammet falder kontaktprøverne af Bjergebakkegangen i trakyandesitfeltet, medens alle øvrige prøver falder i feltet for basaltisk trakyandesit.

Variationerne i mineralernes sammensætning på tværs af gangen er meget små, og ofte er forskellen mellem forskellige prøver ikke større end forskellene mellem forskellige korn i samme prøve. Tydeligst ses det, at Ti-indholdet i titanomagnetiten falder fra kontakten indefter i gangen.

Den kemiske sammensætning af den 5 cm brede udløber svarer til den kemiske sammensætning af gangen i 5 til 10 cm afstand fra kontakten og viser således ikke, som forventet ved prøveudtagningen, gangens gennemsnitssammensætning.

Analyserne af Almindingen-graniten taget henholdsvis 5 cm, 50 cm, 3 m og 16 m fra gangkontakten viser kun ganske små forskelle. For hovedelementerne vedkommende er den eneste variation, at der er en svag stigning i FeO fra 5 cm til 3 m. Denne stigning er ledsaget af et tilsvarende fald i Fe_2O_3 , så total jern er uændret. Af sporelementerne viser Rb, Ba og Y stigning fra 5 cm til 3 m, og Zn fra 5 cm til 50 cm. Yderligere ændringer i Almindingen-granitens sammensætning som følge af gangintrusionen må derfor være begrænset til de 5 cm nærmest gangkontakten.

Den kemiske variation på tværs af gangen vil kunne tolkes som et resultat af, at det først intruderede magma har været

mere differentieret end senere tilkommet magma, der så har undergået en svag differentiation mod gangmidten (tydeligst eksemplificeret af SiO₂ i fig. 5). Variationen i K₂O stemmer imidlertid ikke med en sådan antagelse, og tilstedeværelsen af den 1 cm tykke omdannelseszone af albit langs kontakten kan også tyde på, at variationerne på tværs af gangen er resultatet af autometasomatiske omdannelser, væsentligst i form af albitisering. Tabel 11 viser, at der er ret stor overensstemmelse mellem kontaktprøverne og prøverne fra gangmidten, hvis man til prøverne fra gangmidten adderer 20% albit.

Såvel retningen af Bjergebakkegangen som dens mineralogiske og kemiske sammensætning svarer nøje til kullaiterne i Skåne, men medens alle gangene i det bornholmske grundfjeld anses for at være prækambriske, så anses kullaiterne for at være postsilure.

Foreløbige aldersbestemmelser af Poul Martin Holm, Institut for Petrologi, giver kullaiter fra Skåne en højere alder end Bjergebakkegangen, men aldersbestemmelserne anses ikke for endelige og yderligere aldersbestemmelser, der også omfatter de bornholmske doleriter, er under udførelse.

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