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Syenitic and associated intrusions of the Kap Edvard Holm region of Kangerdlugssuaq, East Greenland

W. A. Deer, D. R. C. Kempe and G. C. Jones

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Syenitic and associated intrusions of the Kap Edvard Holm region of Kangerdlugssuaq, East Greenland

W. A. DEER, D. R. C. KEMPE and G. C. JONES

Deer, W. A., Kempe, D. R. C. & Jones, G. C. Syenites and associated intrusions of the Kap Edvard Holm region of Kangerdlugssuaq, East Greenland. Meddr Grønland, Geosci. 12: 26 pp. Copenhagen 1984-10-05.

Kap Edvard Holm, near Kangerdlugssuaq, forms part of one of the six Tertiary igneous centres of southern East Greenland. The plutonic rocks are mainly cumulate gabbros but there are several syenite masses, together with some minor granophyres and other acid rocks. The larger syenites – Kap Boswell, Kap Deichmann, and Hutchinson Gletscher I – are intruded as conical masses into the gabbros with an intermediate ring of igneous breccia. The petrography, mineralogy, and bulk chemistry of the rocks are reported. The syenites are generally nordmarkitic, containing hedenbergite and aegirine-augite, and amphiboles ranging from hastingsite, ferroedenite, and ferrorichterite (katophorite) to arfvedsonite, while aenigmatite is quite common in the Kap Boswell and Barberkniven syenites and veins. Many rock and mineral analyses are given. An estimate of the composition of the parent magma gives a nordmarkitic liquid very close to that of the main peripheral intrusions at Kangerdlugssuaq and also to the quartz trachytic late differentiate of the Azores alkali basalt. This agrees with the authors' earlier suggestion that all the syenite masses were most probably the products of a quartz trachyte magma, fractionated in the case of the main intrusion to yield the range of rock types occurring there, and itself produced by differentiation of an alkali basalt magma such as yielded some of the many dykes present in the region. An alternative explanation, proposed by Brooks & Gill (1982), that the main intrusion derived from the reaction of a foyaitic magma, fractionated from a nephelinitic parent, with the enclosing gneisses and basalts, could not have been repeated so exactly throughout the minor peripheral intrusions at Kangerdlugssuaq and again at Kap Edvard Holm.

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One of the six Tertiary igneous centres of southern East Greenland (Wager 1934) occurs in the Kangerdlugssuaq area and contains a number of alkaline intrusions, mainly syenites, in addition to the gabbros of Skaergaard, Kaerven, and Kap Edvard Holm (Fig. 1). The general geology of the area, with extensive bibliographies, has been reviewed several times by Wager & Deer (1939), Wager (1965), Wager & Brown (1968), Kempe et al. (1970) and, most recently, by Deer (1976) and Brooks & Nielsen (1982), who give a sequence of the country rocks and the Tertiary igneous events. The alkaline rocks of the main Kangerdlugssuaq alkaline intrusions were described in detail by Kempe et al. (1970) and Kempe & Deer (1970), and the minor peripheral intrusions by Deer & Kempe (1976). The petrogenesis of these rocks was discussed by Pankhurst et al. (1976) and by Kempe & Deer (1976).

The syenites of the Kap Edvard Holm region, farther south, have not been fully described, although a brief account is given by Deer (1976) of the two larger masses – Kap Deichmann and Kap Boswell (Fig. 2). The earlier gabbro cumulates and other basic rocks, on the other hand, have been reported fully by Deer & Abbott (1965), Elsdon (1969, 1970, 1971a and b, 1972, 1982), and Abbott & Deer (1972).

It is the purpose of this paper, therefore, to present a detailed account of the mineralogy and petrology of the syenitic and related rocks of Kap Edvard Holm. The two larger syenite bodies – Kap Deichmann and Kap Boswell – occur in the northeast corner and southeastern part of the region (Fig. 2). There are also the Sortskær islands (see Fig. 1) and the Hutchinson Gletscher I and II syenites, in the northeast; the Barberkniven syenites and granophyres, in the southeast;

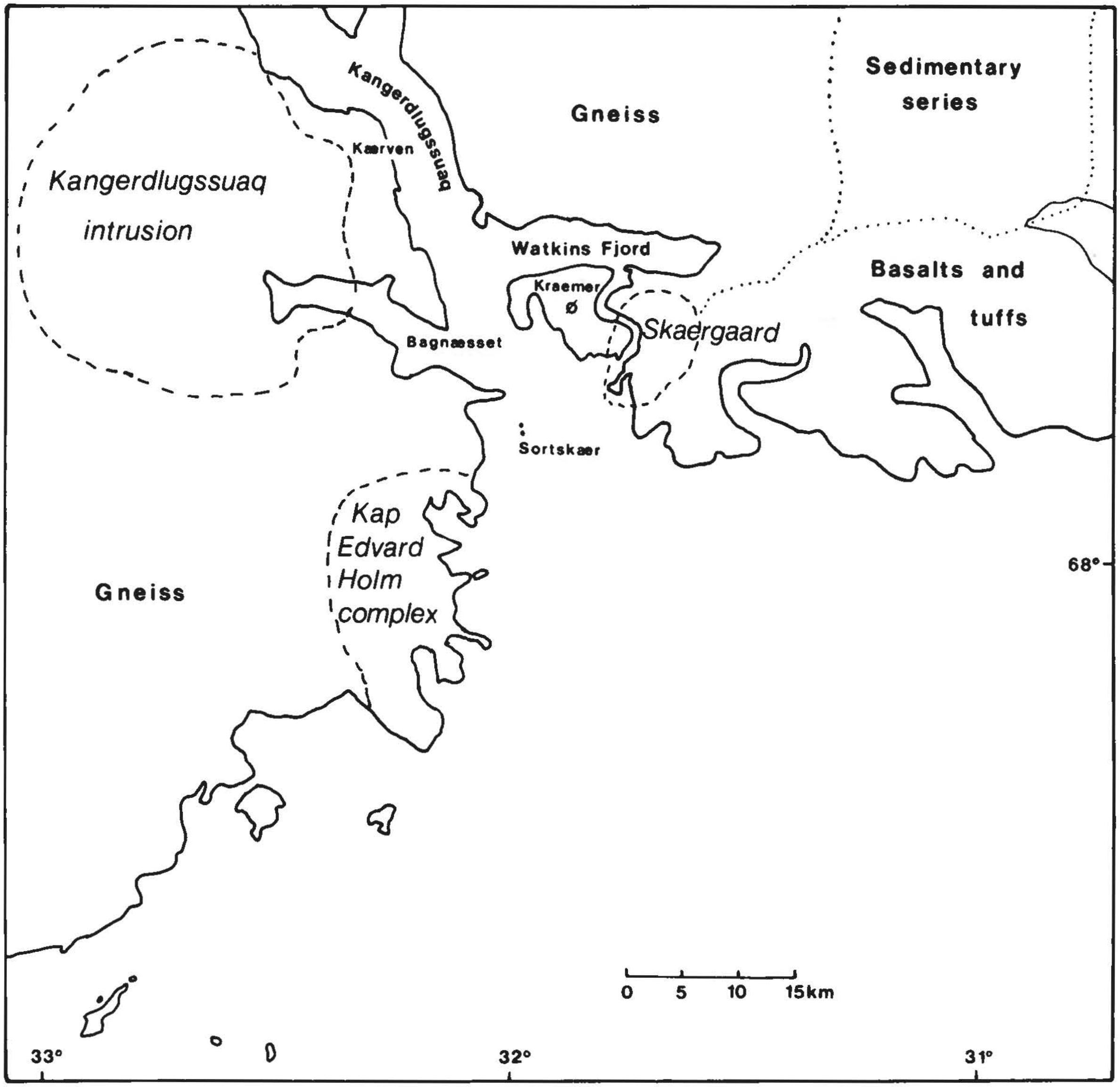

Fig. 1. Geological sketch-map of the Kangerdlugssuaq region to show the major plutonic complexes (after Deer 1976).

and three zones of igneous breccia. The largest of these, Kontaktbjerg, in the northwest, is cut by a N–S-trending zone of hybrid rocks. C. K. Brooks (pers. comm. to D. R. C. K., 1983) has mapped much of the area and considers the Kap Deichmann, Kap Boswell, and the Barberkniven masses to be more complicated than is shown, with up to three separate intrusive phases. The northern Kap Deichmann and Hutchinson Gletscher syenites tend to form one related group, whilst the southern Kap Boswell and Barberkniven intrusions form another.

The larger Kap Boswell, Kap Deichmann, and Hutchinson Gletscher I bodies have been intruded as conical masses into the earlier gabbros, the walls dipping outwards at from 45° to, more commonly, 80° and bordered, at Kap Boswell, by a ring of igneous breccia (Fig. 3). The relative areal proportions of the six major bodies are given in Table 1; Kap Boswell can be seen to represent more than half the total. The relative proportions of the rock types forming the units of the main Kangerdlugssuaq intrusion to the north were reported in Kempe et al. (1970), and of the various minor peripheral intrusions, both older and younger than the main mass, in Deer & Kempe (1976). The syenites considered here are all earlier than the main Kangerdlugssuaq intrusion, which has been dated at approx-

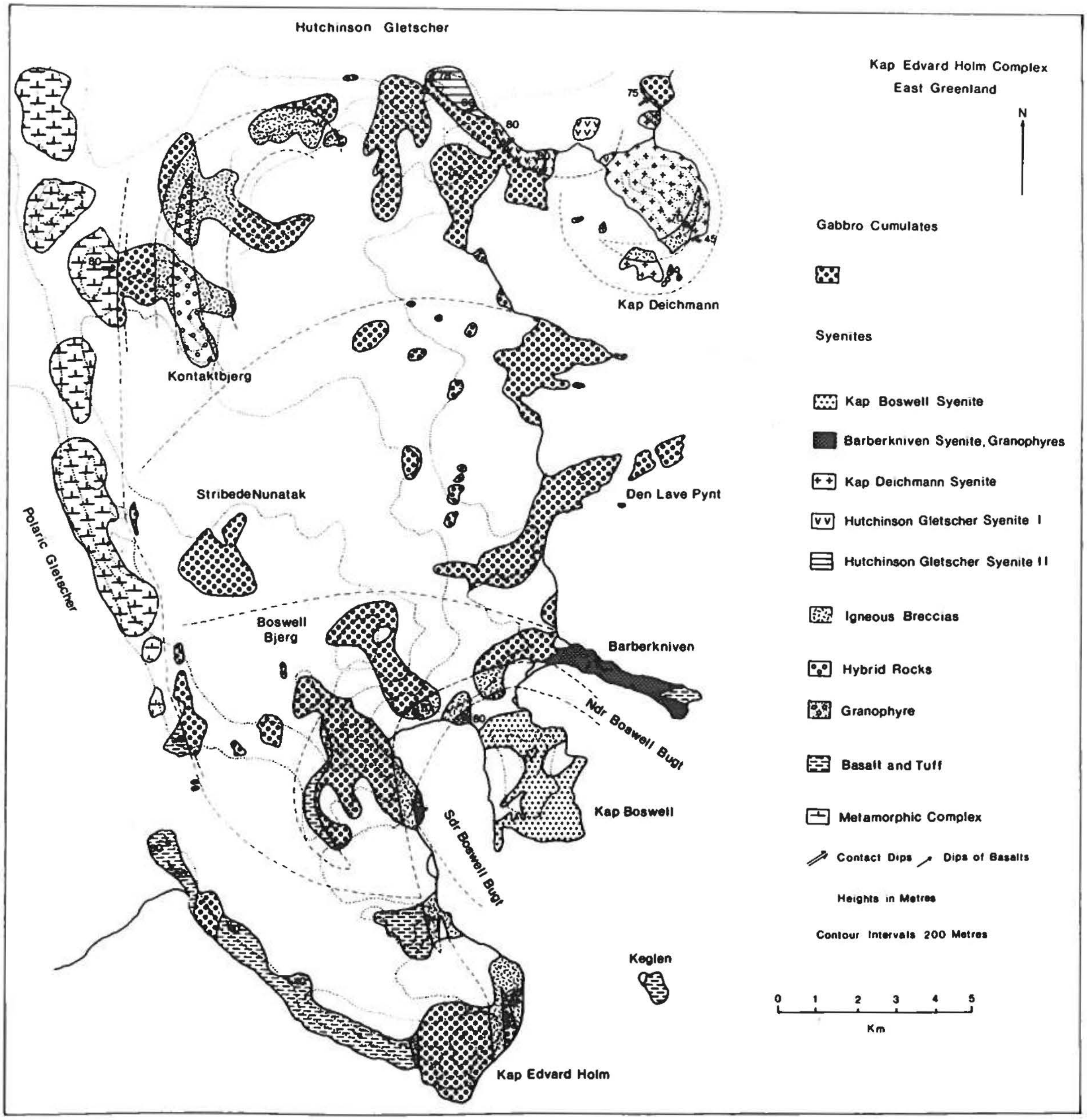

Fig. 2. Geological map of the Kap Edvard Holm complex, East Greenland.

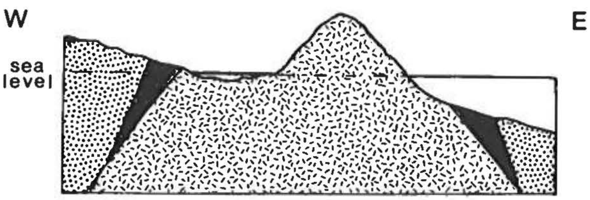

Fig. 3. Diagrammatic section, not to scale, across the Kap Boswell Syenite from approximately west to east. The syenite intrudes the Upper Layered Series of the Gabbro Cumulates, with an intermediate ring of igneous breccia. A similar situation occurs at Kap Deichmann.

Table 1. Relative areal proportions of the five major Kap Edvard Holm syenite intrusions and the Kontaktbjerg Breccia Zone.

	%
Kap Boswell	57.4
Barberkniven	2.2
Kap Deichmann	17.2
Hutchinson Gletscher I	5.7
Hutchinson Gletscher II	1.5
Kontaktbjerg Breccia Zone	16.0
	100.0

The areal proportions are based on the presumed extent of the outcrops as shown on Fig. 2.

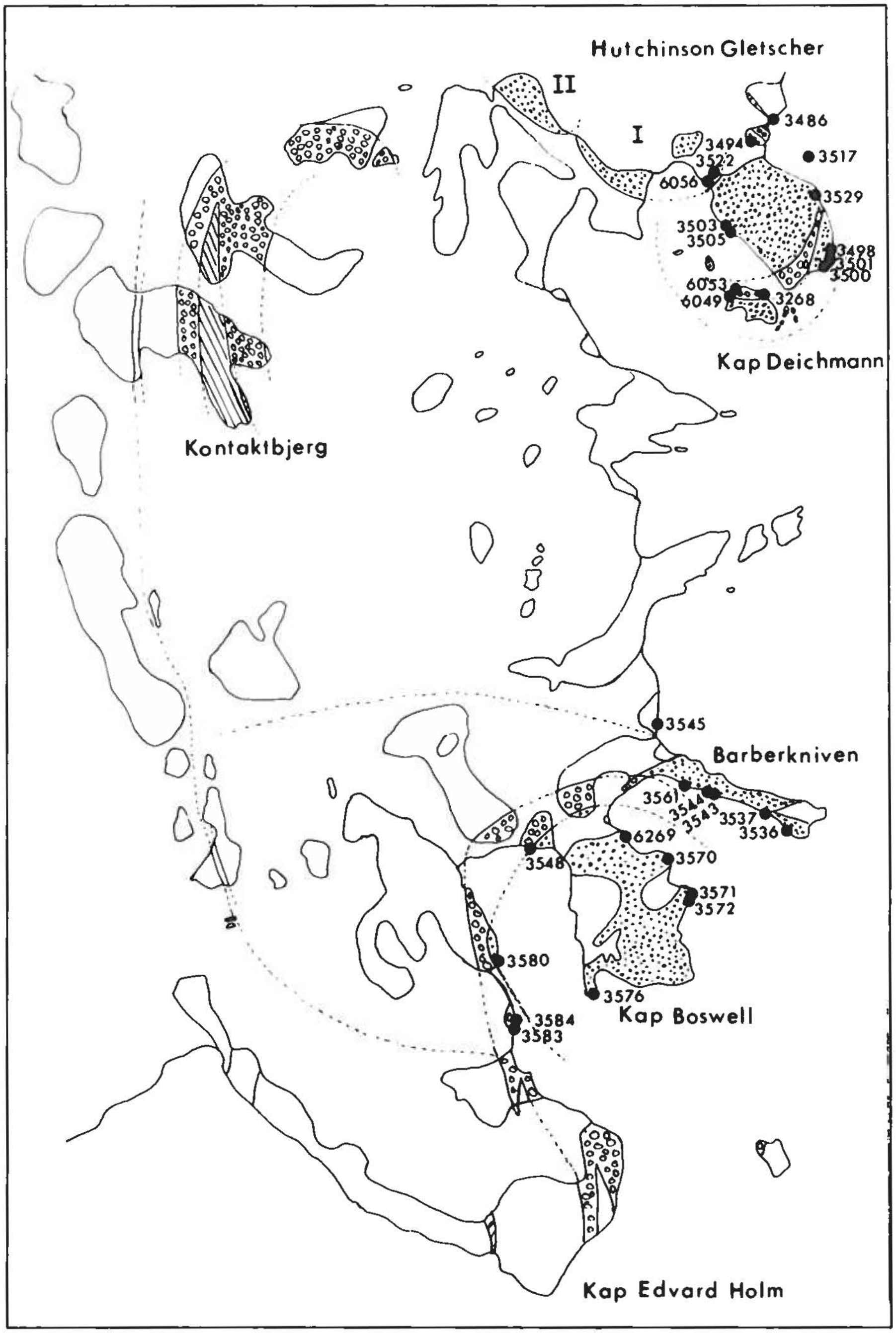

Fig. 4. Locality map, showing the positions of some of the described and analysed specimens. Dots: syenites. Circles: igneous breccias. Diagonal shading: hybrid rocks.

imately 50 m.y., and their total areal extent is probably similar to that of all the Kangerdlugssuaq minor peripheral intrusions taken together. The areal relationship of the three groups is therefore of the order of: main intrusion 70%; minor peripheral intrusions 15%; and Kap Edvard Holm intrusions 15%. All the main and peripheral syenites at Kangerdlugssuaq are intruded into the grey gneiss of the metamorphic complex, or into earlier syenitic bodies, except for a small area to the northeast. The Kap Edvard Holm syenites have been intruded into the earlier gabbros or, rarely, an earlier syenite. On the east the syenites form most of the coast line; apart from a small area to the northeast all the plateau basalts which once covered the metamorphic complex have been stripped off by erosion, although xenoliths are incorporated into the syenites.

The rock analyses (see Fig. 4) were all made by classical 'wet' techniques. In the case of minerals, some

Table 2. Analyses of Kap Boswell Syenites.

	1	2	3	4	5	6
SiO_2	62.66	62.40	63.77	63.05	63.62	63.10
TiO_2	0.41	0.37	0.60	0.49	0.74	0.52
Al_2O_3	18.16	17.46	15.66	17.58	16.41	17.05
Fe_2O_3	1.89	2.22	2.47	1.74	2.26	2.12
FeO	2.47	3.47	3.81	3.30	4.01	3.41
MnO	0.09	0.10	0.11	0.10	0.10	0.10
MgO	0.39	0.21	0.24	0.24	0.13	0.24
CaO	1.95	1.76	1.45	1.24	1.18	1.52
Na_2O	6.48	6.75	6.58	6.55	6.82	6.64
K_2O	4.66	4.63	4.39	5.31	4.61	4.72
H_2O^+	0.39	0.26	0.49	0.29	0.24	0.33
H_2O^-	0.22	0.19	0.17	0.21	0.04	0.17
P_2O_5	0.15	0.05	0.08	0.10	0.05	0.09
Total	99.92	99.87	99.82	100.20	100.21	100.01

Norms

	1	2	3	4	5	6
q	2.10	0.62	4.95	0.64	2.77	2.20
or	27.54	27.37	25.95	31.38	27.25	27.90
ab	54.83	57.11	55.67	55.42	57.70	56.18
an	6.71	3.67	0.23	2.89	0.55	2.78
di	1.69	4.14	5.62	2.89	4.39	3.64
hy	2.57	2.47	1.83	3.41	2.47	2.54
mt	2.74	3.22	3.58	2.52	3.28	3.07
il	0.78	0.70	1.14	0.93	1.41	0.99
ap	0.35	0.12	0.19	0.24	0.12	0.21

Modal analyses	1	2	3
Microperthitic alkali feldspar	79	85	80
Sodic plagioclase	4	5	2.5
Quartz	4	3	5
Amphibole	7	1.5	5
Pyroxene	5	4	5
Biotite	0.5	–	–
Aenigmatite	0.5	1.5	2.5

1. Arfvedsonite-aegirine syenite, E. G. 3570, south side Ndr Boswell Bugt. Anal. W. A. Deer.
2. Aegirine syenite, E. G. 3571, northeast point, Kap Boswell. Anal. W. A. Deer.
3. Aegirine-aenigmatite syenite, E. G. 6269, east of col between Ndr and Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
4. Arfvedsonite syenite, E. G. 3576, southwest point, Kap Boswell. Anal. W. A. Deer and J. Johnston.
5. Aenigmatite-arfvedsonite-aegirine syenite, E. G. 3580, west side Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
6. Mean composition of Kap Boswell Syenite.

were determined by the classical method but the majority, in which total iron is recorded as FeO*, were analysed by G. C. Jones using a Cambridge Instruments Microscan Mk 9 microprobe. The microprobe analyses have been recalculated to give an estimate of Fe^{3+}: Fe^{2+} on the basis of a fixed number of cations and oxygens in the structural formulae. The two aenigmatite probe analyses were recalculated on the same Fe^{3+}: Fe^{2+} ratio as the third, in which Fe^{2+} has been determined chemically.

Petrography and mineralogy

Kap Boswell Syenite

The Kap Boswell Syenite has an approximately circular form, and is some 5 km in diameter. The marginal part of the intrusion consists of an igneous breccia, varying in width between 400 and 1000 m, in which abundant xenoliths of both gabbro cumulates and basalt are enclosed in a syenite matrix. The breccia zone is sharply defined, the contact with the main syenite dipping outwards at angles between 45° and 50° (Fig. 3). The outer contact of the breccia zone with the cumulates of the Upper Layered Series is also sharp, and dips outwards at 70°, although there is some veining of the basic rocks by the syenite matrix of the breccia.

The syenite (see Fig. 4) is light in colour and coarse-grained; the ferromagnesian constituents, commonly occurring in aggregates, constitute between 10 and 15 per cent of the rock. The essential minerals are microperthite, albite, quartz, hedenbergite, aegirine-augite and aegirine, alkali amphibole, and aenigmatite; the last can locally be abundant. Accessory constituents include biotite, fayalite, and smaller amounts of apatite, sphene, ilmenite, and zircon. Modal analyses of three syenites are given in Table 2.

The syenite matrix of the igneous breccia has a similar mineralogy but contains more microperthite; the albite has the composition Ab_{93}.

Veins of coarse microsyenite occur in the main syenite. These have a granular texture and consist of microperthite, arfvedsonite, hedenbergite, aenigmatite, and up to 15% quartz. Accessory minerals include ilmenite, apatite, and astrophyllite, with minute blebs of fluorite locally distributed within the quartz plates. Albite, fayalite, and sphene are notably absent.

Microperthite is the main constituent and occurs in subhedral and anhedral veins varying in size between 0.5 and 1.5 cm. The feldspar, locally sericitized, is clouded with minute grains of iron oxide and is commonly twinned on the Carlsbad law. Bulk composition varies from Or_{40-70} when clear, to Or_{18} when turbid. Plagioclase, Ab_{95}, absent from some rocks, occurs in subhedral laths 1–2 mm in length, the cores of which are sometimes untwinned and grade outwards to albite-twinned margins. The habit of the quartz, 0.5–2 mm in size, is similar to that of the plagioclase but generally the laths occupy interstitial areas between the large microperthite crystals.

The greater proportion of the ferromagnesian minerals occurs in aggregates or clots approximately 1.5 cm in maximum length, in which the individual constituents range in size between 1 and 2 mm. Some of the minerals, especially the pyroxene, also form isolated grains;

Table 3. Analyses of Kap Boswell rocks.

Gabbro and Basalt Xenoliths in Kap Boswell Igneous Breccia

	1	2	3	4	5	6
SiO_2	45.85	42.58	42.59	33.58	43.89	46.80
TiO_2	1.52	2.06	3.03	6.33	2.34	3.20
Al_2O_3	17.82	16.57	15.01	9.64	13.32	14.99
Fe_2O_3	5.54	7.35	5.31	8.13	5.04	5.16
FeO	7.76	8.94	10.90	14.42	11.56	10.40
MnO	0.12	0.07	0.13	0.22	0.12	0.25
MgO	5.61	6.24	8.28	9.50	8.45	4.47
CaO	10.70	13.35	10.25	13.35	11.52	10.19
Na_2O	3.55	2.22	2.69	1.31	2.30	3.38
K_2O	0.60	0.22	0.61	0.18	0.33	0.48
H_2O^+	1.04	0.46	0.64	0.96	0.65	0.34
H_2O^-	0.17	0.27	0.28	0.34	0.26	0.13
P_2O_5	0.08	0.04	0.47	2.97	0.07	0.29
Total	100.36	100.37	100.19	100.93	99.85	100.08
Norms						
or	3.55	1.30	3.61	1.06	1.95	2.84
ab	22.78	13.23	17.43	8.16	16.89	28.60
an	30.92	34.60	27.08	19.89	25.05	24.32
ne	3.93	3.01	2.89	1.59	1.39	–
di	17.55	25.33	16.78	21.69	25.81	20.07
hy	–	–	–	–	–	4.90
ol	9.32	7.50	16.94	16.55	15.94	4.66
mt	8.03	10.66	7.70	11.79	7.31	7.48
il	2.89	3.91	5.75	12.02	4.44	6.08
ap	0.19	0.09	1.11	7.01	0.17	0.68

1. Gabbro xenolith, E. G. 6260, west Ndr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
2. Gabbro xenolith, E. G. 3554, north of col between Ndr and Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
3. Gabbro xenolith, E. G. 3557, west Ndr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
4. Oxide-rich gabbro xenolith, E. G. 3558, west Ndr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
5. Gabbro xenolith, E. G. 3327, west Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
6. Basalt xenolith, E. G. 6259, northwest Barberkniven. Anal. W. A. Deer and J. Johnston.

Syenite Veins

	1	2	3	4
SiO_2	63.45	67.30	68.80	55.05
TiO_2	0.77	0.59	0.50	1.59
Al_2O_3	16.73	14.80	13.14	17.31
Fe_2O_3	0.97	1.23	2.73	3.42
FeO	4.78	4.52	3.17	4.81
MnO	0.05	0.03	0.07	0.07
MgO	0.10	0.18	0.20	3.75
CaO	1.39	0.78	1.00	7.28
Na_2O	6.71	5.81	5.66	3.65
K_2O	4.74	4.30	4.15	1.99
H_2O^+	0.13	0.15	0.28	0.59
H_2O^-	0.10	0.07	0.08	0.12
P_2O_5	0.11	0.04	0.14	0.43
Total	100.03	99.80	99.92	100.06
q	1.37	12.75	17.90	6.43
or	28.02	25.42	24.53	11.76
ab	56.77	49.16	44.49	30.88
an	1.54	1.61	–	24.98
ac	–	–	3.00	–
di	4.11	1.76	3.54	6.70
hy	4.87	5.89	2.37	9.63
mt	1.41	1.78	2.46	4.96
il	1.46	1.12	0.95	3.02
ap	0.26	0.09	0.33	1.01

1. Microsyenite vein, E. G. 3572, northeast point of Kap Boswell. Anal. W. A. Deer and J. Johnston.
2. Quartz syenite vein, E. G. 3583, west side Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
3. Quartz-rich vein, E. G. 6271, eastern end of col between Ndr and Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.
4. Aegirine microsyenite vein, E. G. 3548, Kap Boswell, east of Sdr Boswell Bugt. Anal. W. A. Deer and J. Johnston.

Table 4. Chemical analyses of pyroxenes from Kap Boswell Syenite and Veins.

	1	2	3	4	5	6	7	8	9	10
SiO_2	49.75	49.69	49.19	47.26	49.13	49.07	49.16	48.79	47.26	48.48
TiO_2	0.51	0.47	0.38	0.54	0.14	0.14	0.09	0.11	0.54	0.28
Al_2O_3	0.48	0.38	0.21	0.32	0.23	0.27	0.19	0.17	0.34	0.21
FeO*	20.55	21.08	24.71	25.68	26.84	23.98	27.69	27.32	26.90	27.73
MnO	1.74	1.88	1.59	2.02	2.20	1.96	1.80	1.86	1.79	1.81
MgO	6.05	4.83	2.99	1.89	1.12	2.35	0.49	0.58	1.29	1.10
CaO	20.02	19.56	17.31	19.95	16.25	18.47	12.70	13.18	19.39	14.95
Na_2O	0.51	1.15	2.24	0.98	3.42	2.06	5.63	4.96	0.67	3.66
K_2O	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Cr_2O_3	nil	0.02	nil	nil	0.02	nil	nil	nil	0.03	nil
NiO	nil	nil	nil	nil	0.01	nil	nil	0.06	0.3	0.03
Total	99.61	99.06	98.62	98.64	99.36	98.30	97.75	97.03	98.24	98.25
Fe_2O_3	1.28	2.38	5.61	4.66	9.85	5.07	15.44	12.98	2.18	10.47
FeO	19.40	18.94	19.66	21.49	17.98	19.42	13.80	15.64	24.94	18.31
Total	99.74	99.28	99.18	99.11	100.32	98.81	99.30	98.27	98.40	99.27

Number of ions on the basis of 4 cations and 6 oxygens

	1	2	3	4	5	6	7	8	9	10
Si	1.974	1.986	1.986	1.942	1.975	1.993	1.979	1.989	1.968	1.970
Al	0.022	0.014	0.010	0.016	0.011	0.007	0.009	0.008	0.017	0.010
Al	0.000	0.004	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000
Ti	0.015	0.014	0.012	0.017	0.004	0.004	0.003	0.003	0.017	0.009
Fe^{3+}	0.038	0.072	0.170	0.144	0.298	0.155	0.468	0.398	0.068	0.320
Fe^{2+}	0.644	0.633	0.664	0.739	0.604	0.660	0.464	0.533	0.868	0.622
Mn	0.058	0.064	0.054	0.070	0.075	0.067	0.061	0.064	0.063	0.062
Mg	0.358	0.288	0.180	0.116	0.067	0.142	0.029	0.035	0.080	0.067
Ca	0.851	0.837	0.749	0.879	0.700	0.804	0.548	0.576	0.865	0.651
Na	0.039	0.089	0.175	0.078	0.267	0.162	0.439	0.392	0.054	0.288

1. Hedenbergite, core of zoned crystal, Kap Boswell Syenite, E. G. 3576.
2. Hedenbergite, centre of zoned crystal, Kap Boswell Syenite, E. G. 3576.
3. Hedenbergite, rim of zoned crystal, Kap Boswell Syenite, E. G. 3576.
4. Aegirine-augite, core of zoned crystal, Kap Boswell Syenite, E. G. 3571.
5. Aegirine-augite, rim of zoned crystal, Kap Boswell Syenite, E. G. 3571.
6. Aegirine-augite, core of zoned crystal, Kap Boswell Syenite, E. G. 3571.
7. Aegirine-augite, rim of zoned crystal, Kap Boswell Syenite, E. G. 3571.
8. Aegirine-augite, rim of zoned crystal, Kap Boswell Syenite, E. G. 3571.
9. Hedenbergite, core of zoned crystal, Kap Boswell Veins, E. G. 3572.
10. Aegirine-augite, rim of zoned crystal, Kap Boswell Veins, E. G. 3572.

Anal. G. C. Jones. FeO* = total iron.

some occupy wedge-shaped areas between the microperthites and some occur as subhedral crystals.

The pyroxenes display considerable variation. One group (Table 4; Fig. 5) consists of hedenbergites of composition in the region of $Ac_5Hd_{70}Di_{25}$ in the yellowish cores, zoned outwards to green rims of composition about $Ac_{20}Hd_{70}Di_{10}$. A second group varies between paler cores of composition $Ac_{10}Hd_{82}Di_8$ and green aegirine-augite rims of $Ac_{27}Hd_{70}Di_3$, or between $Ac_{16}Hd_{74}Di_{10}$ and $Ac_{40}Hd_{59}Di_1$. This latter type predominates in the veins, with examples zoned from $Ac_5Hd_{93}Di_2$ to $Ac_{34}Hd_{65}Di_1$. Compared with the Kangerdlugssuaq intrusion pyroxenes, those from Kap Boswell, and Kap Deichmann, are much more hedenbergitic, with less of the Ac molecule. They are low in Al_2O_3 and contain virtually no K_2O ($< 0.05\%$) but, as at Kangerdlugssuaq, are high in MnO.

The alkali amphibole also varies considerably, from greyish brown ferrorichterite (katophorite) up to 2 mm in length to greyish blue arfvedsonite which may replace the higher temperature primary ferrorichterite. A brownish green variety, commonly showing schiller structure and containing many minute inclusions of iron oxide, may replace the pyroxene which, with grains of aenigmatite, it commonly encloses. This third variety is also arfvedsonitic (Table 5); it locally forms green fibrous needles. The amphiboles also are generally low in Al_2O_3.

Table 5. Chemical analyses of minerals from Kap Boswell Syenite and Veins.

Amphiboles

	1	2	3	4	5
SiO_2	47.78	47.61	48.93	47.06	48.41
TiO_2	2.16	1.31	1.59	1.06	1.32
Al_2O_3	1.70	1.38	0.59	0.98	1.81
Fe_2O_3	–	–	–	–	11.25
FeO	28.00	34.00	32.93	32.47	23.81
MnO	1.20	2.02	2.16	1.72	0.75
MgO	4.30	1.09	0.34	1.69	0.06
CaO	5.61	4.25	2.62	4.77	1.18
Na_2O	5.27	5.35	7.01	4.87	7.37
K_2O	1.29	1.23	1.51	1.38	1.52
Cr_2O_3	–	–	–	0.02	ND
NiO	–	–	0.01	0.01	ND
H_2O^+	ND	ND	ND	ND	0.94
H_2O^-	ND	ND	ND	ND	0.13
F	ND	ND	ND	ND	2.95
O = F	–	–	–	–	1.24
Total	97.31	98.24	97.69	96.03	100.26
Fe_2O_3	2.45	8.34	2.75	6.65	–
FeO	25.80	26.50	30.46	26.49	–
Total	97.56	99.08	97.96	96.67	–

Number of ions on the basis of 13 cations and 23 oxygens

	1	2	3	4	5
Si	7.552	7.549	7.882	7.634	7.618
Al	0.317	0.258	0.112	0.187	0.334
Fe^{3+}	0.131	0.193	0.006	0.179	0.048
Al	0.000	0.000	0.000	0.000	0.000
Ti	0.257	0.156	0.193	0.129	0.156
Fe^{3+}	0.160	0.802	0.327	0.633	1.284
Fe^{2+}	3.410	3.513	4.103	3.593	3.134
Mn	0.161	0.271	0.295	0.236	0.100
Mg	1.013	0.258	0.082	0.409	0.014
Ca	0.950	0.722	0.452	0.829	0.199
Na	1.615	1.645	2.190	1.532	2.248
K	0.260	0.249	0.310	0.286	0.304
OH	–	–	–	–	2.456

*1. Ferrorichterite, Kap Boswell Syenite, E. G. 3576. Anal. G. C. Jones.
*2. Ferrorichterite, Kap Boswell Syenite, E. G. 3571. Anal. G. C. Jones.
*3. Arfvedsonite, Kap Boswell Syenite, E. G. 3576. Anal. G. C. Jones.
*4. Ferrorichterite, Kap Boswell Veins, E. G. 3572. Anal. G. C. Jones.
5. Arfvedsonite, Kap Boswell Veins, E. G. 3552. Anal. W. A. Deer (Deer et al. 1963: 368).
ND: not determined. *FeO = total iron.

Aenigmatites

	1	2	3
SiO_2	41.41	40.80	40.16
TiO_2	8.30	8.77	8.77
Al_2O_3	nil	0.52	0.68
Fe_2O_3	4.46	–	–
FeO	35.87	39.59	39.05
MnO	1.78	2.24	1.99
MgO	1.35	0.34	0.28
CaO	nil	0.38	0.51
Na_2O	6.87	7.36	7.59
K_2O	0.04	nil	nil
Cr_2O_3	ND	nil	0.01
NiO	ND	nil	0.01
H_2O^+	nil	ND	ND
Total	100.08	100.00	99.05
Fe_2O_3	–	4.42	4.36
FeO	–	35.61	35.12
Total	–	100.44	99.46

Number of ions on the basis of 20 oxygens

	1		2		3	
Si	5.893		5.811		5.778	
Al	0.000	6.00	0.087	6.00	0.115	6.00
Fe^{3+}	0.107		0.102		0.107	
Ti	0.888		0.939		0.949	
Fe^{3+}	0.371		0.372		0.365	
Fe^{2+}	4.269	6.03	4.241	5.95	4.226	5.92
Mg	0.286		0.072		0.060	
Mn	0.215		0.270		0.243	
Ca	0.000		0.058		0.079	
Ca	0.000		0.000		0.000	
Na	1.896	1.90	2.032	2.03	2.117	2.12
K	0.007		0.000		0.000	

1. Kap Boswell Veins, E. G. 3584. Anal. P. E. Brown and A. Chadwick.
*2. Kap Boswell Veins, E. G. 3572. Anal. G. C. Jones.
*3. Kap Boswell Veins, E. G. 3572. Anal. G. C. Jones.
ND: not determined. *FeO = total iron.
Fe^2: Fe^3 in 2 and 3 calculated to same ratio as in 1.

Continued on next page.

Fayalite (Fo_6, Table 5) occurs as individual subhedral to anhedral crystals about 1 mm in size. Some are partially or completely replaced by bowlingite, as well as by iron oxide and the greyish blue arfvedsonitic amphibole. Replacement of ilmenite (Table 5) by sphene and possibly aenigmatite is commonly apparent; aenigmatite is especially common in the veins (Table 5).

Barberkniven

The main syenite consists of square or rectangular twinned subhedral crystals of microperthite, partly sericitized, with interstitial wedges of quartz. There is some interstitial albite.

Some large clove brown to bluish olive green amphi-

Table 5 (continued)

Fayalite	
SiO_2	30.09
TiO_2	0.06
FeO*	61.57
MnO	5.65
MgO	2.16
CaO	0.20
Total	99.73
Number of ions on the basis of 4 oxygens	
Si	1.003
Ti	0.002
Fe*	1.716
Mn	0.160
Mg	0.107
Ca	0.007

$Fo_{5.9}Fa_{94.1}$
Kap Boswell Syenite, E. G. 3576.
Anal. G. C. Jones.
FeO*, Fe* = total iron.

Ilmenite		
TiO_2	50.33	
FeO*	43.96	
MnO	3.75	
NiO	0.07	
MgO	0.04	
Total	98.15	
Fe_2O_3	2.85	
FeO	41.39	
Total	98.37	
Number of ions on the basis of 4 cations and 6 oxygens		
Ti	1.945	4.00
Fe^{2+}	1.779	
Fe^{3+}	0.110	
Mn	0.163	
Mg	0.003	

Kap Boswell Veins, E. G. 3572.
Anal. G. C. Jones.
FeO* = total iron.

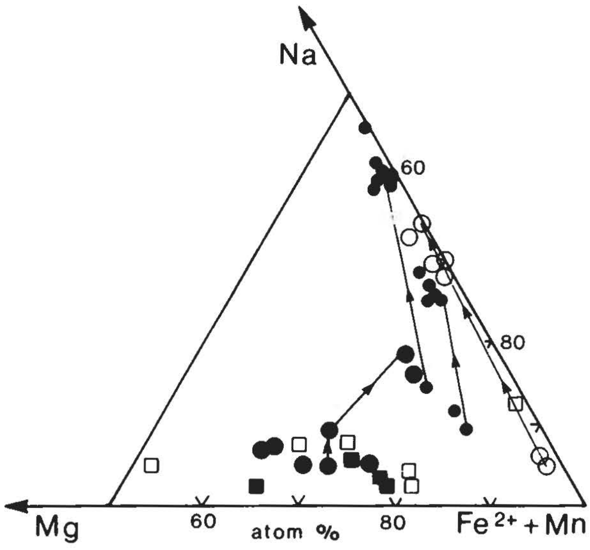

Fig. 5. Plot of some Kap Edvard Holm pyroxenes (Na-Mg-(Fe^{2+} + Mn) atom %). Solid circles: Kap Boswell Syenites (large circles, E. G. 3576; small circles, E. G. 3571). Open circles: Kap Boswell Syenite Veins. Solid squares: Kap Deichmann Syenites. Open squares: Kap Deichmann Igneous Breccia Syenites. Tie-lines connect analyses of cores, intermediate zones, and rims. Data from Tables 4 and 9.

boles lie between the alkali feldspars, whilst the dominant ferromagnesian mineral is a very dark green pyroxene, both in euhedral crystals and in plumose 'hourglass' aggregates intergrown with aenigmatite. The only common accessory mineral is apatite.

Fine-grained syenitic xenoliths occur in the main syenite. Perthitic alkali feldspar is the main mineral, with some granular quartz and some intergranular albite. There are dark green to brown to grey amphibole grains and fewer anhedral aegirines, and some aenigmatite. There are a very few small apatite needles.

The intrusion contains microsyenitic bodies, often granophyric, consisting mainly of quartz and perthite, much of it in a beautiful graphic intergrowth. There are some green aegirines, ores, zircon, sphene, and trace amounts of green amphibole, biotite and, locally, calcite. Some bodies contain more ferromagnesian minerals, others comprise a mosaic of laths of albitic plagioclase and fibrous amphibole.

There are also small masses of microgranite, consisting of quartz and rather less alkali feldspar. These main minerals are accompanied by small pale green crystals of hedenbergitic pyroxene, ore, and traces of a green hastingsitic amphibole. In some cases the microgranite is porphyritic and spherulitic, consisting of radiating sheaves of perthitic alkali feldspar again granophyrically intergrowth with quartz. There are some phenocrysts of perthite, green hedenbergitic pyroxene, ore grains and 'perlitic' lines of minute grains of the ore, and traces of chevkinite.

Kap Deichmann Syenite

The Kap Deichmann Syenite is also approximately circular and some 4 km in diameter. Only in the extreme northeast is its margin in contact with an earlier rock – gabbro cumulates of the Lower Layered Series – and here the contact dips outwards at 75°. To the northwest, the syenite is cut by the later sub-circular Hutchinson Gletscher Syenite I. The Deichmann Syenite contains a crescentic outcrop of igneous breccia, concave to the northwest and reaching a width of 600 m. Both northwest and southeast contacts dip to the northwest at angles of 70° and 45°, respectively. There is no positive evidence as to age relationships but it is thought that the igneous breccia predates all the syenites but followed the gabbros, and in the case of Kap Deichmann forms a large, xenolithic, included sheet.

The syenite has large plates of microperthite, reaching 1 cm in size, as its main constituent mineral. Albitic plagioclase forms regular patches of exsolved material within, and also rows of crystals between the perthite grains. Hedenbergitic pyroxene forming aggregated and single crystals is the most abundant ferromagnesian mineral, accompanied by an olive green hastingsitic amphibole and minor fayalite. Some quartz is present, although less than at Kap Boswell, with accessory biotite, apatite, and opaque oxide (Table 7). Brooks & Nielsen (1982: 14) report trough-banding layering of fayalite and pyroxene.

The igneous breccia – porphyritic microsyenite con-

Syenites

	1	2	3
SiO_2	66.41	65.18	61.58
TiO_2	0.56	0.30	0.46
Al_2O_3	15.73	14.77	14.88
Fe_2O_3	2.46	3.70	1.93
FeO	2.31	2.72	2.29
MnO	0.25	0.03	0.04
MgO	0.31	0.38	0.97
CaO	0.51	1.20	3.74
Na_2O	6.82	6.51	6.20
K_2O	4.83	4.75	4.74
H_2O^+	0.10	0.40	0.40
H_2O^-	0.05	0.11	0.19
P_2O_5	0.10	0.07	0.15
CO_2	–	–	2.31
Total	100.44	100.12	99.88
Norms			
q	7.01	7.33	4.67
or	28.55	28.07	28.02
ab	54.02	49.53	50.15
ac	3.24	4.89	2.03
di	1.61	4.71	2.46
hy	2.61	1.42	3.70
mt	1.94	2.92	1.78
il	1.06	0.57	0.87
ap	0.24	0.17	0.35
cc	–	–	5.25

1. Aegirine-aenigmatite syenite, E. G. 3537, 400 m WNW of Barberkniven point. Anal. W. A. Deer (Deer 1976).
2. Fine-grained aegirine syenite xenolith, E. G. 3536, in aegirine-aenigmatite syenite. Small island south of Barberkniven point. Anal. W. A. Deer.
3. Aegirine microsyenite, E. G. 3544, 2000 m WNW of Barberkniven point. Anal. J. H. Scoon.

Microgranites and Granophyres

	1	2	3	4	5	6
SiO_2	71.18	71.15	71.75	72.64	73.60	72.06
TiO_2	0.39	0.31	0.39	0.27	0.27	0.33
Al_2O_3	13.36	13.27	13.30	13.92	12.96	13.36
Fe_2O_3	2.44	2.70	2.21	1.56	1.53	2.09
FeO	1.97	1.96	1.90	1.94	1.05	1.74
MnO	0.14	0.09	0.08	0.07	0.08	0.09
MgO	0.13	0.12	0.20	0.16	0.16	0.15
CaO	1.15	1.15	0.86	0.72	0.47	0.87
Na_2O	4.58	4.90	4.65	4.54	4.69	4.67
K_2O	4.30	4.04	4.21	4.05	4.69	4.26
H_2O^+	0.22	0.24	0.38	0.12	0.06	0.20
H_2O^-	0.04	0.06	0.09	0.10	0.00	0.06
P_2O_5	0.02	0.02	0.04	0.03	0.03	0.03
Total	99.92	100.01	100.06	100.12	99.59	99.91
q	25.44	24.84	26.25	28.14	27.40	26.35
or	25.42	23.88	24.88	23.94	27.72	25.18
ab	38.75	41.46	39.35	38.41	39.68	39.51
an	3.20	2.29	2.99	3.38	0.46	2.91
cor	–	–	–	0.83	–	–
di	2.05	2.57	0.87	–	1.38	1.03
wo	–	0.13	–	–	–	–
hy	0.49	–	1.22	2.36	0.08	0.93
mt	3.54	3.91	3.20	2.26	2.22	3.03
il	0.74	0.59	0.74	0.51	0.51	0.63
ap	0.05	0.05	0.09	0.07	0.07	0.07

1. Ferroaugite microgranite, E. G. 3561, 2800 m WNW of Barberkniven point. Anal. M. S. Haslop.
2. Ferroaugite granite porphyry, E. G. 3543, 2000 m WNW of Barberkniven point. Anal. W. A. Deer.
3. Ferroaugite granophyre, E. G. 3563, Barberkniven ridge above E. G. 3561. Anal. W. A. Deer.
4. Granophyre, E. G. 3584, Barberkniven ridge above E. G. 3561. Anal. W. A. Deer.
5. Ferroaugite granophyre, E. G. 3545, 2000 m WNW of Barberkniven point. Anal. J. H. Scoon.
6. Mean composition of the acid intrusions of Barberkniven.

Xenoliths in Syenites and acid rocks

	1	2	3	4
SiO_2	47.04	47.69	47.90	72.66
TiO_2	3.24	2.44	2.56	0.29
Al_2O_3	16.09	16.43	15.93	14.31
Fe_2O_3	3.61	3.65	2.71	0.32
FeO	10.21	8.56	8.56	2.36
MnO	0.15	0.17	0.16	0.08
MgO	4.94	5.61	6.48	0.17
CaO	10.21	9.14	11.01	0.37
Na_2O	3.39	3.66	2.49	4.75
K_2O	0.82	1.35	0.76	4.17
H_2O^+	0.21	0.37	0.72	0.31
H_2O^-	0.10	0.02	0.34	0.00
P_2O_5	0.15	0.64	0.24	0.03
Total	100.16	99.73	99.86	99.82
q	–	–	–	26.41
or	4.85	7.98	4.49	24.65
ab	26.80	28.86	21.07	40.19
an	26.27	24.42	30.05	1.64
ne	1.02	1.14	–	–
cor	–	–	–	1.38
di	19.28	13.66	18.72	–
hy	–	–	11.26	4.16
ol	9.91	11.87	3.87	–
mt	5.23	5.29	3.93	0.46
il	6.15	4.63	4.86	0.55
ap	0.35	1.51	0.57	0.07

1. Basalt xenolith, E. G. 3566, in granophyre, E. G. 3563, Barberkniven ridge. Anal. W. A. Deer.
2. Basalt xenolith, E. G. 3562, in pyroxene microgranite, E. G. 3561, western end of Barberkniven. Anal. W. A. Deer.
3. Gabbro xenolith, E. G. 3565, in granophyre, E. G. 3563, Barberkniven ridge. Anal. W. A. Deer.
4. Biotite-garnet-orthoclase-quartz xenolith, E. G. 3540, in aegirine-aenigmatite syenite, E. G. 3537, 400 m WNW of Barberkniven point. Anal. J. H. Scoon.

Table 7. Analyses of Kap Deichmann Syenites,

	1	2	3	4
SiO_2	61.69	59.38	68.45	66.50
TiO_2	0.58	0.66	0.28	0.28
Al_2O_3	16.93	16.44	17.24	17.03
Fe_2O_3	1.85	1.94	0.84	2.58
FeO	3.91	7.83	1.88	1.96
MnO	0.29	0.25	0.04	0.01
MgO	0.53	0.41	0.04	0.20
CaO	2.08	2.98	1.24	1.04
Na_2O	5.48	5.01	5.53	6.13
K_2O	5.64	5.12	4.14	4.15
H_2O^+	0.18	0.34	0.50	0.20
H_2O^-	0.40	0.10	0.06	0.12
P_2O_5	0.13	0.19	0.12	0.06
Total	99.69	100.65	100.36	100.26
Norms				
q	1.94	–	16.98	12.14
or	33.34	30.26	24.47	24.53
ab	46.37	42.39	46.79	51.87
an	4.94	7.25	5.37	4.77
cor	–	–	1.70	0.71
di	3.91	5.54	–	–
hy	4.53	10.26	2.47	1.52
mt	2.68	2.81	1.22	3.74
il	1.10	1.25	0.53	0.53
ap	0.31	0.45	0.28	0.14

Modal analyses	1	2	3
Microperthitic alkali feldspar	68.5	74.4	59.1
Sodic plagioclase	22.7	9.7	17
Quartz	2.5	2.2	16.6
Amphibole	2	1.3	6.3
Pyroxene	1.9	6.2	–
Fayalite olivine	1.5	4.9	–
Accessories	0.9	1.3	1

1. Fayalite-hedenbergite syenite, E. G. 3498, east point, Kap Deichmann. Anal. M. S. Haslop.
2. Fayalite-hedenbergite syenite, E. G. 3494, Nunatak V, Hutchinson Gletscher. Anal. W. A. Deer.
3. Marginal syenite, E. G. 3486, 0.5 m from contact with gabbro, Nunatak III, Hutchinson Gletscher. Anal. W. A. Deer.
4. Aplitic syenite vein. E. G. 3503, southwest Kap Deichmann. Anal. W. A. Deer.

taining basaltic xenoliths and xenolithic minerals – also consists predominantly of partially perthitic alkali feldspar. The large and small phenocrysts of perthite are sometimes zoned around cores of plagioclase (oligoclase-andesine), and albite borders some crystals. The matrix consists mainly of granular alkali feldspar. A variety of ferromagnesian minerals occurs. Some large euhedral fayalites are present, some locally or completely rimmed by or altered to olive green hastingsitic amphibole and some biotite; the last two minerals also occur in aggregates. There are large phenocrysts of pale green hedenbergitic pyroxene, and large ilmenites and titanomagnetites. The same minerals occur in the finer-grained matrix, with apatite needles as a common accessory; this mineral occurs as inclusions in the fayalite. No quartz is found in the microsyenite. A few zircons are present. The originally basic xenoliths now consist of oligoclase, with hastingsitic amphibole, pyroxene, oxide, and apatite intergrowths.

The green hedenbergitic pyroxenes (commonly $Ac_4Hd_{76}Di_{20}$) and hastingsitic hornblendes, respectively, from the main Kap Deichmann Syenite are reported in Table 9. The amphiboles, unlike those at Kap Boswell, are rich in Al_2O_3 as is appropriate for hastingsites. The pyroxenes from the igneous breccia microsyenite, of a similar but more variable composition than those from the main syenite, are also given in Table 9, together with the ore minerals ilmenite and titaniferous magnetite from the breccia.

Hutchinson Gletscher Syenite I

The typical syenite consists predominantly of microperthitic feldspar and, in contrast to the Hutchinson Gletscher Syenite II, plagioclase is relatively unimportant. Amphiboles, pyroxene, and biotite occur in small amounts, and quartz is also a minor constituent (Table 10). The microperthite forms hypidiomorphic grains and encloses minute inclusions of iron oxide orientated parallel to the cleavage planes of the feldspar. The albitic component of the microperthite occurs in irregular, elongated vein-like patches; there is local alteration of the feldspar to sericite and kaolinite. The crystals of plagioclase are rimmed by the microperthite and largely replaced by the alkali feldspar.

The pyroxene, some of which is peripherally altered to amphibole, occurs in anhedral, non-pleochroic, pale green grains; its optical properties suggest a ferroaugitic composition. The main amphibole forms both subhedral and anhedral brown crystals, pleochroic from pale greenish to dark greenish brown. Its composition (Table 11) shows it to be a ferroedenite; it is partially replaced by a more sodium-rich amphibole, pleochroic from light greenish brown to light bluish green. The biotite (Table 11) is strongly pleochroic, with an iron-magnesium ratio of 64, corresponding closely with the Fe-Mg ratio, 63, of the hornblende. Ore, zircon, and apatite are the main accessory minerals.

Hutchinson Gletscher Syenite II

This syenite is a grey and relatively coarse-grained rock consisting essentially of microperthite and plagioclase, with minor amounts of albite, quartz, amphibole, biotite, pyroxene, and ore. Microperthite is the dominant mineral, occurring in Carlsbad-twinned crystals. Some of the larger grains have an optically discontinuous rim,

Table 8. Analyses of Kap Deichmann rocks.

Igneous Breccia Syenites	1	2	3	4
SiO_2	65.48	60.01	62.27	61.46
TiO_2	0.28	0.88	0.45	0.60
Al_2O_3	18.24	18.68	17.39	18.58
Fe_2O_3	1.88	1.59	2.00	0.32
FeO	1.73	4.40	4.17	5.98
MnO	0.07	0.11	0.10	0.06
MgO	0.21	1.33	0.52	0.36
CaO	0.74	2.88	2.43	2.84
Na_2O	6.11	5.95	5.56	5.42
K_2O	5.16	3.76	4.22	4.18
H_2O^+	0.31	0.17	0.41	0.32
H_2O^-	0.09	0.15	0.20	0.21
P_2O_5	0.05	0.06	0.19	0.12
Total	100.35	99.97	99.91	100.45
Norms				
q	7.84	0.67	6.02	3.17
or	30.50	22.22	24.94	24.71
ab	51.70	50.34	47.04	45.86
an	3.34	13.16	10.04	13.31
cor	1.38	–	–	0.27
di	–	0.62	0.67	–
hy	1.81	8.52	6.39	10.73
mt	2.73	2.31	2.90	0.46
il	0.53	1.67	0.85	1.14
ap	0.12	0.14	0.45	0.28

1. Syenite, E. G. 6049, syenite of Igneous Breccia, large island, south of Kap Deichmann. Anal. W. A. Deer and J. Johnston.
2. Syenite, E. G. 3505, syenite of Igneous Breccia, south Kap Deichmann. Anal. W. A. Deer and J. Johnston.
3. Syenite, E. G. 3529, syenite of Igneous Breccia, north Kap Deichmann. Anal. W. A. Deer and J. Johnston.
4. Syenite, E. G. 6053, syenite of Igneous Breccia, large island, south of Kap Deichmann. Anal. W. A. Deer and J. Johnston.

Gabbro and Basalt Xenoliths in Igneous Breccia	1	2	3	4	5
SiO_2	47.46	49.27	46.63	45.32	44.95
TiO_2	2.10	1.58	2.76	2.46	3.23
Al_2O_3	15.75	15.17	15.87	18.07	14.05
Fe_2O_3	2.40	1.38	1.88	1.82	1.11
FeO	9.71	11.70	11.86	9.73	14.24
MnO	0.23	0.18	0.20	0.16	0.16
MgO	6.76	5.52	5.71	5.83	5.32
CaO	11.23	10.25	10.35	12.81	8.55
Na_2O	3.12	3.47	3.76	2.50	3.70
K_2O	0.53	0.59	0.67	0.80	1.04
H_2O^+	0.37	0.51	0.40	0.18	0.74
H_2O^-	0.26	0.11	0.12	0.14	0.11
P_2O_5	0.48	0.20	0.25	0.17	2.75
Total	100.40	99.93	100.46	99.99	99.95
or	3.13	3.49	3.96	4.73	6.15
ab	24.95	29.24	22.08	13.33	31.31
an	27.41	24.08	24.45	35.73	18.66
ne	0.79	0.06	5.27	4.24	–
di	20.64	21.27	20.99	22.00	4.86
hy	–	–	–	–	3.70
ol	14.28	15.70	14.64	11.94	20.31
mt	3.48	2.00	2.73	2.64	1.61
il	3.99	3.00	5.24	4.67	6.13
ap	1.13	0.47	0.59	0.40	6.49

1. Basalt xenolith, E. G. 3268, Igneous Breccia, large island, south of Kap Deichmann. Anal. W. A. Deer and J. Johnston.
2. Basalt xenolith, E. G. 3501, Igneous Breccia, south Kap Deichmann. Anal. W. A. Deer and J. Johnston.
3. Basalt xenolith, E. G. 6049, Igneous Breccia, large island, south of Kap Deichmann. Anal. W. A. Deer and J. Johnston.
4. Basalt xenolith, E. G. 3517, small island north of Kap Deichmann. Anal. W. A. Deer and J. Johnston.
5. Gabbro xenolith, E. G. 3500, Igneous Breccia, east Kap Deichmann. Anal. W. A. Deer and J. Johnston.

within which inclusions are more abundant than in the central area of the crystal; the rim also contains coarser albite lamellae than the centre. The plagioclase occurs in smaller grains than the microperthite whilst the albite is anhedral to subhedral in form, interstitial to the alkali feldspar. The quartz grains are also anhedral and occur in aggregates of small crystals interstitial to the microperthite.

The pyroxene is present mainly in aggregates of some seven or eight small individual grains and is closely associated with biotite and ore. The latter also occurs as inclusions in the pyroxene, which is commonly rimmed and flecked with a pale bluish green amphibole and biotite. The amphibole occurs in three different habits: as subhedral crystals, irregular grains, and as subradiating aggregates. The subhedral amphibole is a brownish green hornblende, pleochroic from pale to light brownish green to light bluish green. The colouration is patchy and the mineral contains inclusions of ore and apatite. The aggregates consist mainly of a colourless amphibole, and are associated with a brownish green amphibole, biotite, and ores. Some of the aggregates are surrounded by pale bluish green amphibole, pyroxene, biotite, and small quartz grains. These small multimineralic patches probably owe their origin to the modification of one or more earlier ferromagnesian minerals. The biotite is present in relatively few but large subhedral crystals, pleochroic from gold to dark golden brown. Accessory minerals include epidote, oxides, zircon, apatite, and sphene.

Table 9. Chemical analyses of minerals from Kap Deichmann Syenite and Igneous Breccia Microsyenite.

Pyroxenes

	1	2	3	4	5
SiO_2	49.23	50.82	51.32	50.29	47.67
TiO_2	0.51	0.06	0.28	0.27	0.55
Al_2O_3	0.67	0.46	0.73	0.92	3.88
FeO*	21.64	18.42	16.41	22.65	25.49
MnO	1.32	1.25	0.67	1.32	1.01
MgO	5.72	7.43	9.68	4.34	7.38
CaO	19.82	21.00	20.71	19.63	10.04
Na_2O	0.44	0.28	0.47	0.64	0.95
K_2O	nil	nil	nil	0.27	0.63
Cr_2O_3	0.02	0.02	0.02	nil	nil
NiO	nil	nil	nil	nil	nil
Total	99.37	99.74	100.29	100.33	97.60
Fe_2O_3	1.42	0.34	1.59	0.31	1.51
FeO	20.37	18.12	14.98	22.37	24.14
Total	99.49	99.75	100.43	100.36	97.75

Number of ions on the basis of 4 cations and 6 oxygens

	1	2	3	4	5
Si	1.964	1.993	1.970	1.997	1.922
Al	0.032	0.007	0.030	0.003	0.078
Al	0.000	0.014	0.003	0.040	0.106
Ti	0.015	0.002	0.008	0.008	0.017
Fe^{3+}	0.043	0.010	0.046	0.009	0.046
Fe^{2+}	0.680	0.594	0.481	0.743	0.814
Mn	0.045	0.042	0.022	0.044	0.034
Mg	0.340	0.434	0.554	0.257	0.443
Ca	0.847	0.882	0.852	0.835	0.434
Na	0.034	0.021	0.035	0.049	0.074
K	0.000	0.000	0.000	0.014	0.032

1. Hedenbergite, Kap Deichmann Syenite, E. G. 3498.
2. Hedenbergite, Kap Deichmann Syenite, E. G. 3498.
3. Hedenbergite, Kap Deichmann Igneous Breccia, E. G. 6053.
4. Hedenbergite, Kap Deichmann Igneous Breccia, E. G. 6053.
5. Altered hedenbergite, Kap Deichmann Igneous Breccia, E. G. 6053.

Anal. G. C. Jones.
FeO* = total iron.

Amphiboles

	1	2
SiO_2	40.43	41.37
TiO_2	2.96	1.84
Al_2O_3	9.90	7.65
Fe_2O_3	4.21	–
FeO	21.76	27.46
MnO	0.78	0.96
MgO	5.31	4.30
CaO	10.41	10.12
Na_2O	1.96	2.10
K_2O	0.92	1.31
H_2O^+	1.66	ND
Total	100.30	97.11
Fe_2O_3		5.50
FeO		22.51
Total		97.66

Number of ions on the basis of 13 cations and 23 oxygens

	1	2
Si	6.324	6.562
Al	1.676	1.430
Fe^{3+}	–	0.008
Al	0.146	–
Ti	0.347	0.219
Fe^{3+}	0.494	0.649
Fe^{2+}	2.836	2.986
Mn	0.103	0.129
Mg	1.246	1.017
Ca	1.645	1.720
Na	0.593	0.646
K	0.184	0.265
OH	1.730	–
α	1.684	
β	1.696	
γ	1.708	

1. Ferrotschermakitic hornblende (hastingsitic hornblende), Kap Deichmann Syenite, E. G. 3486. Anal. M. T. Lwin.

*2. Hastingsitic hornblende, Kap Deichmann Syenite, E. G. 3498. Anal. G. C. Jones.

ND: not determined.
*FeO = total iron.

Oxide minerals

	1	2
SiO_2	0.18	0.02
TiO_2	12.21	49.39
Al_2O_3	0.41	0.05
FeO*	83.07	45.69
MnO	0.41	2.28
MgO	–	0.02
CaO	0.01	0.02
Cr_2O_3	0.01	–
NiO	0.07	–
Total	96.37	97.47
Fe_2O_3	45.42	4.02
FeO	42.20	42.07
Total	100.94	97.87

	Number of ions on the basis of 32 oxygens	Number of ions on the basis of 4 cations and 6 oxygens
Ti	2.770	1.919
Al	0.146	
Cr	0.002	
Fe^{3+}	10.311	0.156
Fe^{2+}	10.649	1.818
Ni	0.017	
Mn	0.105	0.100
Mg	0.000	0.002

*Fe^2: Fe^3 determined by stoichiometry.

*1. Titaniferous magnetite, Kap Deichmann Igneous Breccia Microsyenite, E. G. 6053.

2. Ilmenite, Kap Deichmann Igneous Breccia Microsyenite, E. G. 6053.

Anal. G. C. Jones.
FeO* = total iron.

Table 10. Analyses of Hutchinson Gletscher rocks.

Syenite I	1	2	3	4
SiO_2	62.96	61.45	59.27	62.52
TiO_2	0.75	0.90	0.88	0.78
Al_2O_3	17.93	18.04	19.70	17.40
Fe_2O_3	1.90	1.96	4.17	1.67
FeO	3.06	3.73	2.69	3.00
MnO	0.04	0.20	0.07	0.10
MgO	0.39	1.18	0.05	0.21
CaO	1.73	2.48	2.03	1.87
Na_2O	6.38	5.51	6.99	6.01
K_2O	4.53	3.60	2.97	6.01
H_2O^+	0.26	1.05	0.10	0.28
H_2O^-	0.07	0.14	0.19	0.14
P_2O_5	0.12	0.11	0.05	0.09
Total	100.12	100.35	99.98	100.08
Norms				
q	3.44	6.98	2.88	0.39
or	26.77	21.28	17.55	35.52
ab	53.98	46.62	59.14	50.85
an	6.91	11.59	9.74	2.76
cor	–	0.84	1.42	–
di	0.76	–	–	5.17
hy	3.47	7.05	0.30	0.86
mt	2.75	2.84	6.05	2.42
il	1.42	1.71	1.67	1.48
ap	0.28	0.26	0.12	0.21

Modal analyses	1	3
Microperthitic alkali feldspar	92	85
Sodic plagioclase	–	4
Quartz	2	0.5
Amphibole	3	1
Pyroxene	1	4.5
Biotite	1	0.5
Accessories	1	4.5

1. Hornblende syenite, E. G. 3522, northwest shoulder, Kap Deichmann. Anal. W. A. Deer.
2. Syenite, E. G. 6056, northwest shoulder, Kap Deichmann. Anal. W. A. Deer and J. Johnston.
3. Chilled syenite, E. G. 3817, at contact with Lower Layered Series of the Kap Edvard Holm gabbros. Anal. W. A. Deer. Total includes ZrO_2 0.82.
4. Xenolith of Kap Deichmann Syenite, E. G. 3823, in Hutchinson Gletscher Syenite I. Anal. W. A. Deer and J. Johnston.

Syenite II	1	2	3
SiO_2	59.84	60.56	63.61
TiO_2	0.62	0.68	0.68
Al_2O_3	18.82	18.56	17.80
Fe_2O_3	2.32	1.81	2.64
FeO	3.10	3.27	1.99
MnO	0.16	0.17	0.05
MgO	1.18	1.08	0.86
CaO	2.67	2.58	1.88
Na_2O	5.37	5.59	5.44
K_2O	5.46	5.40	4.23
H_2O^+	0.31	0.37	0.55
H_2O^-	0.21	0.19	0.18
P_2O_5	0.15	0.18	0.17
Total	100.21	100.44	100.08
q	–	–	10.74
or	32.27	31.92	25.00
ab	45.43	47.30	46.03
an	11.13	9.61	8.22
cor	–	–	1.26
di	0.94	1.69	–
hy	3.64	3.58	2.59
ol	1.39	1.46	–
mt	3.36	2.62	3.83
il	1.18	1.29	1.29
ap	0.35	0.42	0.40

1. Hornblende-biotite syenite, E. G. 3214. Anal. W. A. Deer.
2. Hornblende-biotite syenite, E. G. 6081. Anal W. A. Deer and J. Johnston.
3. Microsyenite dyke, E. G. 6082, cutting hornblende-biotite syenite. Anal. W. A. Deer and J. Johnston.

The presence of the small ferromagnesian aggregates and the partial replacement of the more calcium-rich plagioclase are indicative of some degree of contamination of the syenite magma by the incorporation of basic material. The absence of xenoliths of gabbroic composition in any part of the Hutchinson Gletscher Syenite II suggests that the assimilation process began before the magma was intruded. Contamination of the syenite is also indicated by its composition (Table 10), particularly by the relatively high contents of calcium, magnesium, and aluminium. The syenite is cut by a few microsyenite dykes.

Sortskær islands

The small Sortskær islands to the northeast of the

Table 11. Chemical analyses of minerals from Hutchinson Gletscher Syenite I (E. G. 3522).

	Amphibole (ferroedenite)	Biotite
SiO_2	45.07	35.27
TiO_2	1.14	3.81
Al_2O_3	7.65	15.22
Fe_2O_3	2.89	1.69
FeO	20.09	22.17
MnO	0.97	0.38
MgO	7.82	7.28
CaO	10.49	1.16
Na_2O	1.59	0.47
K_2O	0.51	8.91
H_2O^+	1.69	3.00
Total	99.91	99.56
Number of ions on the basis of 24 (O, OH)		
Si	6.906	5.568
Al	1.094	2.432
Al	0.285	0.380
Ti	0.132	0.453
Fe^{3+}	0.333	0.208
Fe^{2+}	2.565	2.907
Mn	0.126	0.057
Mg	1.797	1.718
Ca	1.722	0.151
Na	0.471	0.198
K	0.099	1.793
OH	1.726	3.152
α	1.676	1.610
β	1.686	
γ	1.694	1.670

Anal. M. T. Lwin.

complex contain small masses and veins of syenite and acid microsyenite; some of the rocks resemble those of the Snout Series of Kangerdlugssuaq (Deer & Kempe 1976).

The main syenite comprises large perthitic alkali feldspars, often sericitized, with brown to grey-green hastingsitic amphibole and quartz. A few cores of augitic pyroxenes remain, almost totally altered to amphibole. The accessory minerals are sphene, chlorite, ore, and orthite, with zircon and apatite needles. In some sections the alkali feldspars have andesine cores, and the amphiboles are longitudinally twinned.

The microsyenites, which form veins, are quartz-rich, sometimes porphyritic with phenocrysts mainly of microperthite but with some of albite. There are amphibole and biotite, largely altered to green chlorite, minor pyroxene, and accessory sphene, zircon, orthite, and a little ore. In other cases the vein rocks are granular and almost free from amphibole and biotite. Modes of a syenite and a microsyenite are given in Table 12, and analyses of an amphibole from each in Table 13.

Kontaktbjerg Breccia Zone

The Kontaktbjerg Breccia Zone in the northwest includes a quartz syenite body with gabbro xenoliths, and a homogeneous hybrid rock, cutting the igneous breccia. Modes of a syenite, three xenoliths, and a hybrid are given in Table 14. The high proportions of alkali

Table 12. Analyses of Sortskær islands Syenites and Acid Veins.

	1	2	3	4
SiO_2	64.33	64.63	72.56	76.02
TiO_2	0.69	0.46	0.18	0.21
Al_2O_3	16.93	17.42	14.24	12.98
Fe_2O_3	0.82	1.28	2.05	1.11
FeO	3.61	2.61	1.30	0.61
MnO	0.02	0.04	1.01	0.02
MgO	0.73	0.46	0.03	0.05
CaO	2.06	1.60	1.14	0.45
Na_2O	5.38	6.27	4.34	3.13
K_2O	4.88	4.82	4.34	5.52
H_2O^+	0.14	0.39	0.17	0.22
H_2O^-	0.17	0.06	0.13	0.03
P_2O_5	0.16	0.18	0.02	0.02
Total	99.92	100.22	101.51	100.37
Norms				
q	7.43	5.06	27.24	35.70
or	28.84	28.49	25.65	32.63
ab	45.52	53.05	36.72	26.48
an	7.64	5.16	5.53	2.10
cor	–	–	0.38	1.09
di	1.31	1.37	–	–
hy	6.00	3.50	2.34	0.12
mt	1.19	1.86	2.97	1.42
hm	–	–	–	0.13
il	1.31	0.87	0.34	0.40
ap	0.38	0.42	0.05	0.05

Modal analyses	1	2
Microperthitic alkali feldspar	81.5	86
Quartz	8	5
Amphibole	8	5.5
Pyroxene	0.5	1
Accessories	2	2.5

1. Hornblende microsyenite vein, E. G. 3460.
2. Hornblende syenite vein, E. G. 3459.
3. Porphyritic microgranite vein, E. G. 3457.
4. Quartz porphyry vein, E. G. 3458.

Anal. W. A. Deer and J. Johnston.

Table 13. Chemical analyses and optical properties of amphiboles from Sortskær Syenites.

	1	2
SiO_2	42.90	42.65
TiO_2	1.71	1.92
Al_2O_3	9.95	9.62
Fe_2O_3	2.85	2.79
FeO	20.48	19.51
MnO	0.61	0.47
MgO	6.65	6.99
CaO	11.03	11.14
Na_2O	2.02	2.08
K_2O	0.82	0.81
H_2O^+	1.52	1.85
Total	100.54	99.83
α	1.678	1.673
β	1.689	1.688
γ	1.700	1.698
γ : z	14°	19°
$2V_\alpha$	60°	64°

Numbers of ions on the basis of 24 (O,OH)

	1		2	
Si	6.601	8.00	6.564	8.00
Al	1.399		1.436	
Al	0.401	5.16	0.306	5.03
Ti	0.198		0.222	
Fe^{3+}	0.329		0.321	
Mg	1.525		1.614	
Fe^{2+}	2.626		2.502	
Mn	0.079		0.061	
Na	0.602	2.58	0.619	2.60
Ca	1.819		1.820	
K	0.161		0.160	
OH	1.558	1.56	1.899	1.90

1. Brownish green ferroedenitic hornblende, hornblende syenite, E. G. 3459.
2. Brown ferroedenitic hornblende, hornblende microsyenite, E. G. 3460.
Anal. M. T. Lwin.

feldspar in one xenolith and of two pyroxenes in another are notable. Analyses of biotites from a xenolith and a homogeneous hybrid are given in Table 15.

Mineral chemistry

In summarizing chemical variations in the minerals from the main intrusive masses, a few points are notable.

The pyroxenes at Kap Boswell are hedenbergitic, zoned outwards to aegirine-augite. There are two types in the syenites, one containing very little diopside molecule (Fig. 5), while a variety containing even less diopside occurs in the veins. At Kap Deichmann the pyroxenes in both syenites and igneous breccia syenites are all hedenbergitic. At Kap Boswell, the Al_2O_3 content of the pyroxenes is low, whilst at Kap Deichmann it is average. The more acmitic pyroxenes of the main Kangerdlugssuaq intrusion are richer in Al_2O_3 and in K_2O, but are similar in their high MnO to the Boswell and Deichmann pyroxenes.

In the case of the amphiboles, the ferrorichterite (katophorite) at Kap Boswell appears to be locally replaced by arfvedsonite, whilst another generation of arfvedsonite is also present. These generally low-alumina amphiboles contrast with the relatively alumina-rich hastingsitic hornblendes at Kap Deichmann. The Hutchinson Gletscher I and Sortskær islands syenites contain ferroedenitic hornblendes, with normal contents of Al_2O_3.

Fayalite is present both at Kap Boswell and, more abundantly, at Kap Deichmann, but aenigmatite is found only in the syenites and syenite veins at Kap Boswell, locally constituting up to some three percent of the rocks, and in small amounts in the closely related Barberkniven syenites. This is the only known instance of this mineral in the Kangerdlugssuaq region, although astrophyllite and chevkinite occur in the main intrusion, and chevkinite more abundantly in the minor peripheral masses.

There is no clear explanation for the presence of aenigmatite at Kap Boswell and Barberkniven alone. C. K. Brooks (pers. comm. to D. R. C. K., 1983) considers that it reflects the higher peralkalinity of these rocks, despite the lack of acmite in the norms of the analysed Boswell samples. Nevertheless, the agpaitic coefficients (mol. props $(Na_2O+K_2O)/Al_2O_3$) of the Kap Boswell (average 0.94) and Barberkniven (average 1.05, with average 3.4 acmite in the norms) rocks are much higher than those of Kap Deichmann (average 0.84; see Fig. 9); note also, however, the average in the main Kangerdlugssuaq intrusion of 0.95, with a range of 0.82–1.01 (Kempe et al. 1970: 39). Some ilmenite is present at Kap Boswell but it is found in rather greater amounts, accompanied by titaniferous magnetite, at Kap Deichmann. In general, therefore, the presence of aenigmatite at Kap Boswell and Barberkniven may be

Table 14. Analyses of Kontaktbjerg Breccia Zone rocks.

	1	2	3	4	5	6	7
SiO_2	65.56	63.53	54.92	54.49	43.39	57.46	76.72
TiO_2	0.63	0.74	1.66	1.60	2.73	1.62	0.03
Al_2O_3	17.04	16.85	16.99	16.89	14.88	15.63	12.40
Fe_2O_3	2.47	2.32	3.65	1.18	6.25	1.71	0.83
FeO	1.94	2.90	5.31	7.51	10.02	6.41	0.68
MnO	0.05	0.05	0.07	0.11	0.08	0.08	0.00
MgO	0.21	1.08	3.82	4.53	7.33	3.54	0.02
CaO	1.35	3.02	6.98	7.18	12.85	6.23	0.48
Na_2O	5.48	5.34	4.08	4.06	1.70	3.80	3.49
K_2O	4.73	3.41	1.65	1.29	0.10	2.59	5.51
H_2O^+	0.19	0.17	0.55	0.86	0.48	0.48	0.09
H_2O^-	0.15	0.29	0.07	0.11	0.11	0.12	0.09
P_2O_5	0.05	0.27	0.35	0.25	0.11	0.37	0.02
Total	99.85	99.97	100.10	100.06	100.03	100.04	100.36
Norms							
q	12.25	11.34	5.31	1.92	–	6.57	34.17
or	27.96	20.15	9.75	7.62	0.59	15.31	32.57
ab	46.37	45.18	34.52	34.35	14.38	32.15	29.53
an	6.37	11.94	23.18	24.06	32.68	17.95	1.90
cor	0.57	–	–	–	–	–	–
di	–	1.05	7.39	8.19	24.56	8.69	0.31
hy	1.10	4.45	10.07	17.61	6.11	12.36	0.40
ol	–	–	–	–	6.62	–	–
mt	3.58	3.36	5.29	1.71	9.06	2.48	1.20
il	1.20	1.41	3.15	3.04	5.18	3.08	0.06
ap	0.12	0.64	0.83	0.59	0.26	0.87	0.05

Modal analyses	1	2	3	4	5
Alkali feldspar	80	60.5	10	7	13.5
Plagioclase	3	20	52.5	55	52
Quartz	11.5	9.5	4.5	1	6.5
Amphibole	2	6	11	13	5
Clinopyroxene	1.5	1.5	10.5	15	7
Orthopyroxene	–	–	–	2.5	1
Biotite	–	–	8.5	4.5	14
Fe-Ti oxide	2	2.5	3	2	1

1. Quartz syenite, E. G. 6137, Igneous Breccia, east Kontaktbjerg. Anal W. A. Deer and J. Johnston (Deer 1976).
2. Altered gabbro xenolith, E. G. 6142, Igneous Breccia, east Kontaktbjerg. Anal. W. A. Deer and J. Johnston.
3. Altered gabbro xenolith, E. G. 3264, Igneous Breccia, southwest Kontaktbjerg. Anal. W. A. Deer.
4. Altered gabbro xenolith, E. G. 6143, Igneous Breccia, east Kontaktbjerg. Anal. W. A. Deer and J. Johnston.
5. Gabbro xenolith, E. G. 6141, Igneous Breccia, east Kontaktbjerg. Anal. W. A. Deer and J. Johnston.
6. Homogeneous hybrid, E. G. 6148, Hybrid Zone, Kontaktbjerg. Anal. W. A. Deer.
7. Micrographic granite vein, E. G. 6138, Igneous Breccia, east Kontaktbjerg. Anal. W. A. Deer and J. Johnston.

partially explained by a tendency to greater peralkalinity, reflected by the presence of aegirine-augite and arfvedsonite, and by lower oxygen fugacity, reflected by the relative abundance of Fe-Ti oxides in the two groups of syenites and at Boswell by the local replacement of ilmenite by aenigmatite as well as sphene.

Rock chemistry

The syenitic and associated rocks of Kap Edvard Holm show similar, or possibly rather less, variation than those of the Kangerdlugssuaq intrusions. The majority are nordmarkites (syenites with a small content of normative quartz) accompanied by some veins and minor intrusions of microgranite and granophyre. There

Table 15. Chemical analyses of biotites from Kontaktbjerg Breccia Zone rocks.

	1	2
SiO_2	39.16	36.51
TiO_2	4.70	4.40
Al_2O_3	14.77	14.83
Fe_2O_3	0.23	2.58
FeO	13.94	18.32
MnO	0.10	0.12
MgO	14.00	10.14
CaO	tr.	tr.
Na_2O	0.72	0.31
K_2O	8.66	9.34
H_2O^+	3.23	3.27
Total	99.53	99.82
α	1.584	1.608
β = γ	1.639	1.666

Numbers of ions on the basis of 24 (O,OH)

	1		2	
Si	5.825	8.00	5.601	8.00
Al	2.175		2.399	
Al	0.416	5.83	0.278	5.77
Fe^{3+}	0.018		0.296	
Ti	0.527		0.506	
Mg	3.124		2.334	
Fe^{2+}	1.732		2.342	
Mn	0.009		0.016	
Na	0.196	1.86	0.092	1.92
Ca	0.000		0.000	
K	1.660		1.830	
OH	3.157	3.16	3.345	3.35

1. Biotite, homogeneous hybrid, E. G. 3264.
2. Biotite, altered gabbro xenolith, E. G. 6148.
Anal. M. T. Lwin.

Table 16. Average analyses of the main Kap Edvard Holm rock groups.

	1	2	3	4	5	6	7	8	9
SiO_2	63.10	66.52	64.39	72.06	64.01	62.31	61.55	61.34	45.11
TiO_2	0.52	0.62	0.44	0.33	0.45	0.55	0.83	0.66	2.78
Al_2O_3	17.05	14.89	15.13	13.36	16.91	18.22	18.27	18.39	15.37
Fe_2O_3	2.12	1.64	2.70	2.08	1.80	1.48	2.43	2.26	3.94
FeO	3.41	4.16	2.44	1.74	3.90	4.07	3.12	2.79	10.61
MnO	0.10	0.05	0.11	0.09	0.15	0.09	0.10	0.13	0.17
MgO	0.24	0.16	0.55	0.15	0.30	0.61	0.46	1.04	6.34
CaO	1.52	1.06	1.82	0.87	1.84	2.22	2.03	2.37	10.92
Na_2O	6.64	6.06	6.51	4.67	5.54	5.76	6.22	5.47	2.97
K_2O	4.72	4.40	4.77	4.26	4.76	4.33	4.28	5.03	0.64
H_2O^+	0.33	0.19	0.30	0.20	0.31	0.30	0.42	0.41	0.54
H_2O^-	0.17	0.08	0.12	0.06	0.17	0.16	0.14	0.19	0.20
P_2O_5	0.09	0.10	0.11	0.03	0.13	0.10	0.09	0.17	0.41
Total	100.01	99.93	99.39	99.90	100.27	100.20	99.94	100.25	100.00
Norms									
q	2.20	10.66	5.30	26.35	7.40	4.34	3.09	3.02	–
or	27.90	26.01	28.19	25.18	28.13	25.59	25.30	29.73	3.78
ab	56.18	51.27	51.27	39.51	46.87	48.73	52.63	46.28	21.57
an	2.78	0.44	–	2.91	7.22	10.36	9.30	10.65	26.72
ne	–	–	–	–	–	–	–	–	1.93
cor	–	–	–	–	–	0.26	–	0.05	–
ac	–	–	3.35	–	–	–	–	–	–
di	3.64	3.67	7.03	1.03	0.93	–	0.16	–	20.31
hy	2.54	3.82	0.49	0.94	5.47	7.03	3.60	5.00	–
ol	–	–	–	–	–	–	–	–	13.00
mt	3.07	2.38	2.23	3.02	2.61	2.15	3.52	3.28	5.71
il	0.99	1.18	0.84	0.63	0.85	1.04	1.58	1.25	5.28
ap	0.21	0.24	0.26	0.07	0.31	0.24	0.21	0.40	0.97

1. Kap Boswell Syenites (average of 5 analyses).
2. Kap Boswell Syenite Veins (average of 3 analyses).
3. Barberkniven Syenites (average of 3 analyses).
4. Barberkniven Micrograntes and Granophyres (average of 5 analyses).
5. Kap Deichmann Syenites (average of 4 analyses).
6. Kap Deichmann Igneous Breccia Syenites (average of 4 analyses).
7. Hutchinson Gletscher Syenite I (average of 4 analyses).
8. Hutchinson Gletscher Syenite II (average of 3 analyses).
9. Kap Boswell, Barberkniven, and Kap Deichmann Igneous Breccias and Xenoliths (average of 14 analyses).

are also the basic xenoliths of basalt and gabbro which occur in the Kap Boswell, Kap Deichmann, and Barberkniven Syenites, and at Kontaktbjerg, and the three zones of igneous breccia.

Analyses of all these rocks are given in Tables 2 – Kap Boswell Syenites; 3 – Kap Boswell Syenite Veins and Igneous Breccia Xenoliths; 6 – Barberkniven Syenites, Microgranites and Granophyres, and Xenoliths; 7 – Kap Deichmann Syenites; 8 – Kap Deichmann Igneous Breccia Syenites and Igneous Breccia Xenoliths; 10 – Hutchinson Gletscher Syenite I and II rocks; 12 – Sortskær islands Syenites and Acid Veins; and 14 – Kontaktbjerg Breccia Zone rocks. Finally, in Table 16, average compositions of nine categories of syenitic and associated rocks are given.

The analyses are plotted in three triangular diagrams: Qz-Ne-Ks; the feldspar system, Ab-Or-An; and the FMA diagram, FeO*-MgO-(Na_2O+K_2O), where FeO* is total iron oxide as FeO. In the first of these – Qz-Ne-Ks (Fig. 6) – the nordmarkitic syenites, with five of the Kontaktbjerg Breccia Zone rocks, form a cluster close to the feldspar join on the quartz side. The Barberkniven and two of the Sortskær acid rocks plot near the oversaturated (granite) minimum, together with one (acid) Barberkniven xenolith and the Kontaktbjerg micrographic granite vein. Most of the basic xenoliths and igneous breccia rocks form a third group close to the quartz-nepheline join, on the nepheline side.

The feldspar diagram Ab-Or-An (Fig. 7) shows a cluster of nordmarkites on the albite-orthoclase join, near the temperature minimum at around $Or_{30\text{-}40}$, with up to 10% An; the Barberkniven and Sortskær acid rocks form part of this group. The Kontaktbjerg Breccia Zone rocks, and three groups of xenoliths, do not cluster but string out towards the anorthite corner, close to the Ab-An join. The most anorthite-rich rock is a Kontaktbjerg specimen, with An_{68}.

The third triangular diagram, the FMA plot (Fig. 8), shows two main clusters. The first, towards the major bend in the tholeiite fractionation curve, contains the

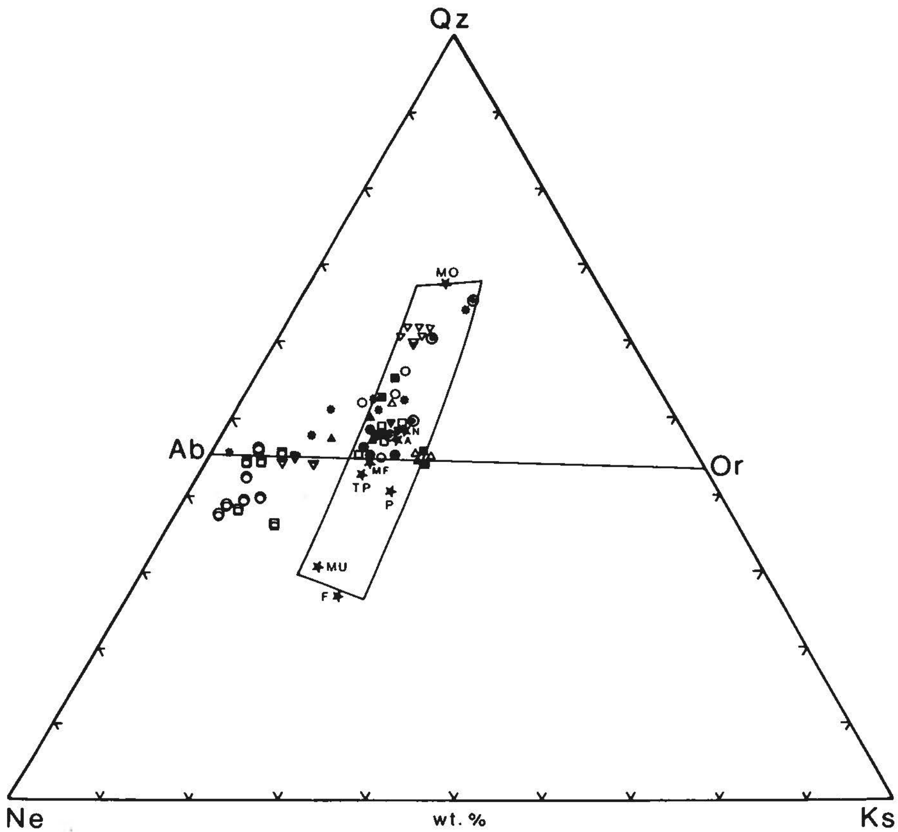

Fig. 6. Kap Edvard Holm rock analyses plotted in the normative system Qz-Ne-Ks (wt %). Solid circles: Kap Boswell Syenites. Open circles: Kap Boswell Syenite Veins. Double open circles: Kap Boswell Igneous Breccia Gabbro and Basalt Xenoliths. Solid inverted triangles: Barberkniven Syenites. Open inverted triangles: Barberkniven Microgranites and Granophyres. Double open inverted triangles: Xenoliths in Barberkniven Syenite and Acid Rocks. Solid squares: Kap Deichmann Syenites. Open squares: Kap Deichmann Igneous Breccia Syenites. Double open squares: Kap Deichmann Igneous Breccia Gabbro and Basalt Xenoliths. Solid triangles: Hutchinson Gletscher Syenite I rocks. Open triangles: Hutchinson Gletscher Syenite II rocks. Asterisks in circles: Sortskær islands Syenites and Acid Veins. Asterisks: Kontaktbjerg Breccia Zone rocks. Lettered stars: MO, oversaturated minimum at 715°C; MF, feldspar minimum at 865°C (both from Tuttle & Bowen 1958); MU, undersaturated minimum at 750°C (Hamilton & MacKenzie 1965), all at P_{H_2O} = 1000 bars. Average compositions of main Kangerdlugssuaq intrusion rocks: N, nordmarkite, with quartz nordmarkite (QN, not shown) just above it, towards Qz; TP, transitional pulaskite; P, pulaskite; F, foyaite. A, average composition of the main Kangerdlugssuaq intrusion, with the average composition of the main and minor peripheral intrusions (not shown) just above it, towards Qz. Note: basic xenoliths and breccias (double symbols and some asterisks), with low Qz+Ne+Ks totals, are shown only for comparison.

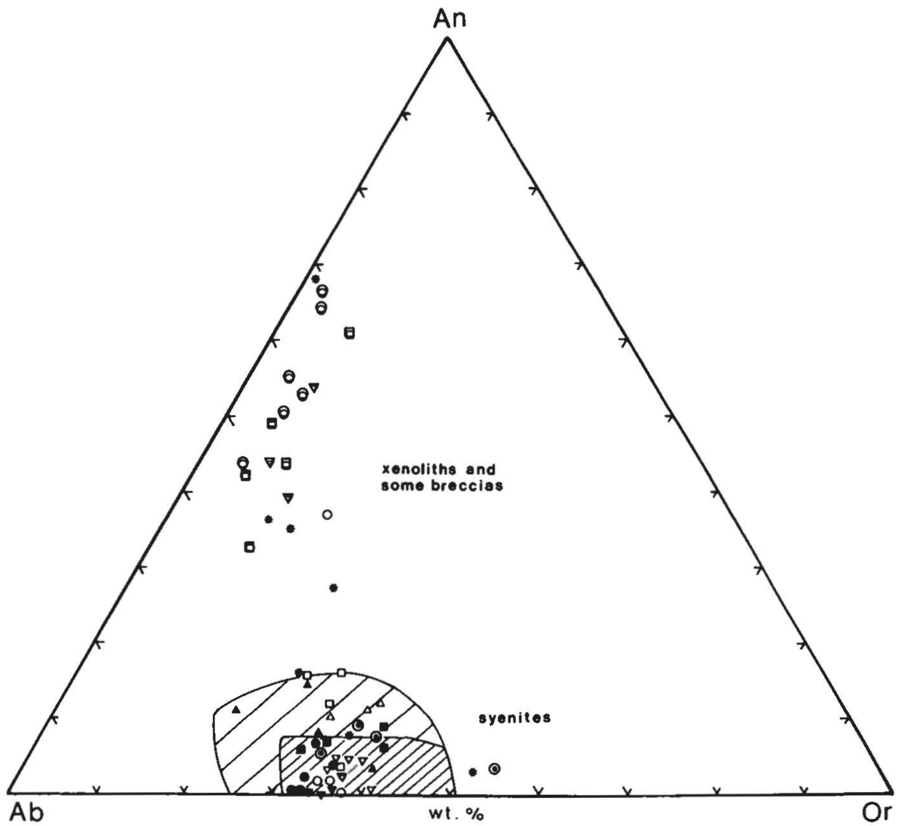

Fig. 7. Kap Edvard Holm rock analyses plotted in the normative feldspar system Ab-Or-An (wt %). Symbols (Kap Edvard Holm rocks only) as in Fig. 6. Kangerdlugssuaq main intrusion feldspars, apart from the foyaite, plot in the area shown closely hatched, and the minor peripheral intrusion feldspars, with one exception, in the areas shown closely and widely hatched.

xenoliths and one of the Kontaktbjerg Breccia Zone rocks. Three more of the latter, and a Kap Boswell Syenite Vein, string out towards the alkali corner, and the remainder, mostly syenites, form a long cluster along the FeO*-alkalis join, centred at about Fe_{33}, near the end of the tholeiite fractionation curve. One Sortskær vein approaches nearer to the alkali corner.

An 'ore potential' diagram was used by Kempe & Deer (1970: 60) to illustrate the change in ore mineralogy from the outer, first formed nordmarkites of the main Kangerdlugssuaq intrusion, through the pulaskites, to the inner foyaite. The predominant oxides change from ilmenite, through a hematite-rich zone, to magnetite + sphene, illustrated by plotting Fe_2O_3 against FeO/TiO_2 and CaO/TiO_2 in a triangular diagram. At Kap Edvard Holm, the rocks form a belt along the magnetite + sphene – ilmenite join, slightly on the ilmenite side of centre, in no apparent pattern. Compared with Kangerdlugssuaq, more ilmenite relative to magnetite + sphene, and much less hematite, is indicated. No light is thrown on the restricted presence of aenigmatite, which occurs only at Kap Boswell and Barberkniven.

In Fig. 9, (Na_2O+K_2O), Al_2O_3, Fe_2O_3*(total), MgO, and CaO are plotted against SiO_2 for the average compositions of the main rock groups. If the Barberkniven acid rocks are excluded, Al_2O_3 shows a marked increase, and MgO and CaO slight increases, with decreases in SiO_2. Fe_2O_3* and the alkalis remain more or less constant. Comparison with the trends shown by the main and peripheral Kangerdlugssuaq syenites shows a resemblance between Kap Edvard Holm and the main intrusion in the case of Al_2O_3 and Fe_2O_3*, whilst Kap Edvard Holm is intermediate between the two Kangerdlugssuaq groups for MgO and CaO. It is also intermediate between them for the alkalis, which for the main intrusion show a steep rise whilst the peripheral syenites show an equally steep decrease.

As might be expected from their geographical distribution, there are chemical similarities between the Kap Deichmann and the two Hutchinson Gletscher syenites in the north, and between the Kap Boswell and the Barberkniven syenites in the south. These similarities are particularly apparent in Figs 7 and 9, less so in Fig. 8, whilst Fig. 6 shows no clear relationship. The chemical differences probably reflect derivation of the northern and southern groups of syenites from different magmatic pulses, produced by high level fractionation of the parent magma.

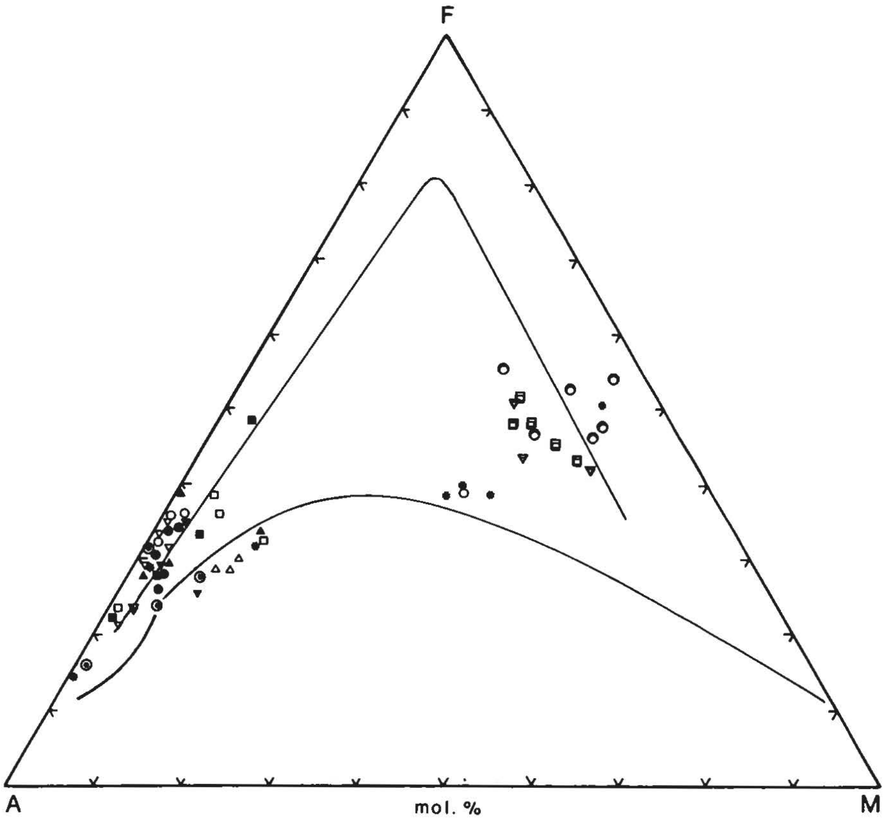

Fig. 8. Kap Edvard Holm rock analyses plotted in the FMA diagram (mol. %). Symbols as in Fig. 6. Upper thin line, the tholeiitic Skaergaard intrusion trend, from gabbro to granophyre (Wager & Deer 1939). Lower thin line, approximating to the alkali basalt differentiation trend, is the Kangerdlugssuaq minor peripheral intrusion trend, from Deer & Kempe (1976, fig. 3). The short, thick curved line links the average compositions of the principal rock types in the Kangerdlugssuaq main intrusion (QN, N, TP, P, F: see Fig. 6).

Petrogenesis

No firm conclusion was reached concerning the origin of the main Kangerdlugssuaq intrusion and the minor peripheral intrusions by Kempe & Deer (1976). However, these authors, struck by the close resemblance between the composition of the postulated Kangerdlugssuaq magma and that of the quartz trachytic late differentiate of the Azores alkali basalt (Le Maitre 1962, and Table 17), regarded differentiation from an alkali basalt magma, such as yielded many of the dykes of the region (cf. Deer 1976), as the most likely origin. They discussed a number of ways in which the original oversaturated magma crossed the thermal barrier in order to yield an undersaturated fraction, again without reaching a firm conclusion. Pankhurst et al. (1976), however, showed that the outer part of the intrusion had undergone considerable chemical interaction with the surrounding gneisses, on the basis of strontium and oxygen isotopic evidence, suggesting that such interaction might result from the circulation of hot meteoric water. They agree with Kempe & Deer that such an incursion of meteoric water supports Kempe's (1966: 242) original suggestion that depression of the liquidus surface at the feldspar minimum by increased P_{H_2O} might have enabled the fractionating liquid to cross the thermal barrier from the over- to the undersaturated regions of the Qz-Ne-Ks system.

In a recent paper, Brooks & Gill (1982) present the results of their microprobe analyses of the pyroxenes and amphiboles from the main Kangerdlugssuaq intrusion. The analyses show wide compositional ranges – from augitic to acmitic in the case of the pyroxenes, and from actinolite through richterite and katophorite to arfvedsonite in the case of the amphiboles. Predictably, there are much wider variations than were shown by the limited wet chemical analyses of seven pyroxenes and five amphiboles, including vein material, presented by Kempe & Deer (1970). However, the microprobe data in the present work also show similar ranges, both in zonation and bulk chemistry, in the minerals from the Kap Edvard Holm syenites. Nevertheless, Brooks & Gill (1982) regard this variation as evidence that simple crystal fractionation, with some systematic variations in the pyroxene and amphibole compositions, as suggested by Kempe & Deer (1976), cannot account for the Kangerdlugssuaq intrusion. Instead, they regard the lack of consistent variation as supporting the isotopic data of Pankhurst et al. (1976) and propose a model in which an original foyaitic magma, perhaps derived by

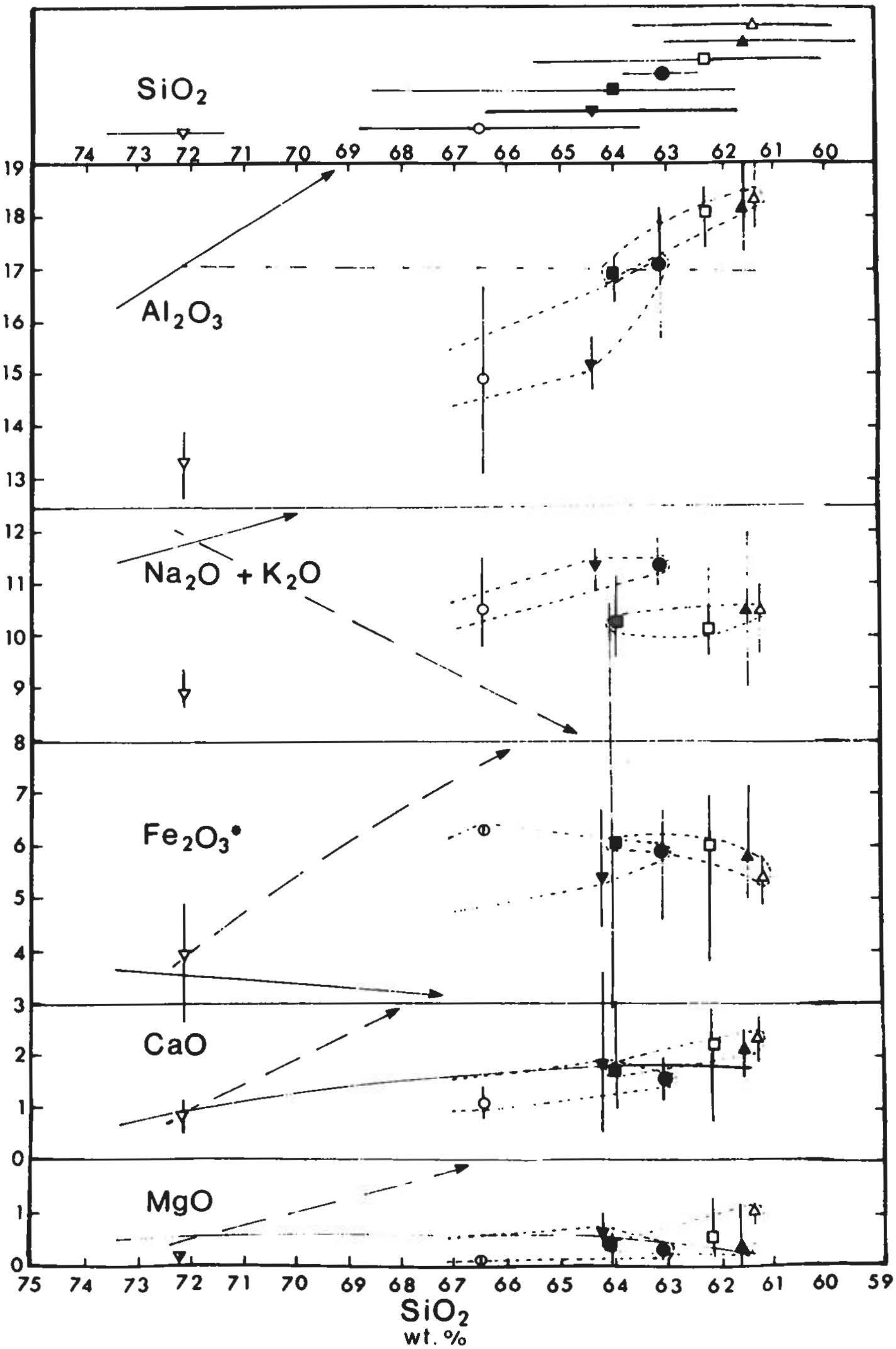

Fig. 9. Some oxide variations, plotted against SiO_2 (wt %), for average compositions and ranges of some Kap Edvard Holm rocks; vertical lines through symbols show range of values. The ranges of SiO_2 are shown horizontally at the top. Solid circle: Kap Boswell Syenites. Open circle: Kap Boswell Syenite Veins. Solid inverted triangle: Barberkniven Syenites. Open inverted triangle: Barberkniven Microgranites and Granophyres. Solid square: Kap Deichmann Syenites. Open square: Kap Deichmann Igneous Breccia Syenites. Solid triangle: Hutchinson Gletscher Syenite I rocks. Open triangle: Hutchinson Gletscher Syenite II rocks. Solid lines indicate the trend of the average compositions of the five rock types making up the main Kangerdlugssuaq intrusion, and dashed lines indicate the general trend of the Kangerdlugssuaq minor peripheral intrusions. Dotted lines enclose Kap Boswell and Barberkniven rocks, and Kap Deichmann and Hutchinson Gletscher I and II rocks.

extensive fractionation of a nephelinitic parent such as gave rise to the syenites, ijolites, and urtites of the nearby Gardiner complex (Nielsen 1979), reacted with the enclosing gneisses and basalts to produce the pulaskites and nordmarkites which form 99.4% by volume of the whole intrusion (Kempe et al. 1970). This explanation is close to Wager's (1965) suggestion that melting of the gneiss was the main mechanism whereby the syenitic magma was generated, although Kempe & Deer (1976) quoted the $^{87}Sr/^{86}Sr$ ratio for the main pulaskite of 0.7043, determined by Hamilton (1966), close to the average figure of 0.705 for primary basalt, as strong evidence against large scale involvement of the gneiss, which has a ratio (0.725) close to that of average continental crust.

Brooks & Gill (1982) touched briefly on the vexed question of the availability of sufficient heat energy but concluded only that the crust was 'probably already at an elevated temperature when the highly reactive alkaline magmas from deeper levels were intruded' (p. 9). Other evidence for 'hybridization' cited by Brooks & Gill includes the large dark crystals of low-albite and orthoclase microperthite developed both in the nordmarkites and transitional pulaskite and in the basaltic inclusions. Similarly, the alkaline amphiboles occurring in the same syenites and also replacing the augitic pyroxenes in the basaltic blocks are also cited as evidence. Certainly, this replacement occurs, but an alkaline (?trachytic) magma reacting with basaltic xenoliths would have just this metasomatizing effect on pre-existing plagioclases and pyroxenes. Further, meteoric groundwater reacting with the syenites would affect the $^{87}Sr/^{86}Sr$ ratios of the rocks decreasingly inwards, so that the outer rocks are most affected, and the inner pulaskite (see above) and foyaite (the original foyaite magma of Brooks & Gill) are the least affected. This does not, however, necessarily imply hybridization from inside outwards.

Study of the Kap Edvard Holm rocks does little to resolve the problem of petrogenesis directly. The acid masses and veins, analagous to the Snout Series and Biotite Granite at Kangerdlugssuaq, as well as the xenoliths, hybrid rocks, and igneous breccias, provide no insight on the problem.

In the case of the five syenite masses, however, the fact that they are all nordmarkites, similar to those of the Kangerdlugssuaq main intrusion and, especially, to the earlier peripheral syenites, is highly relevant. It seems most unlikely that the process of hybridization proposed by Brooks & Gill (1982) could have produced one large (diameter 33 km) syenite intrusion at Kangerdlugssuaq, several small syenite masses, also at Kangerdlugssuaq, and several more small syenite masses at Kap Edvard Holm, all with nordmarkitic compositions (the average composition in the case of the main Kangerdlugssuaq intrusion) so close to each other

Table 17. Kangerdlugssuaq and Kap Edvard Holm alkaline intrusions – average compositions.

	1	2	3	4	5	6
SiO_2	65.40	64.90	63.23	65.3	63.7	64.5
TiO_2	0.71	0.72	0.53	0.7	0.5	0.8
Al_2O_3	16.99	16.96	17.04	17.1	17.2	17.2
Fe_2O_3	1.40	1.46	2.09	1.5	2.1	2.4
FeO	1.83	2.02	3.45	2.0	3.5	2.1
MnO	0.12	0.12	0.11	–	–	–
MgO	0.54	0.79	0.28	0.8	0.3	0.3
CaO	0.86	1.32	1.63	1.3	1.6	1.4
Na_2O	6.48	6.26	6.34	6.3	6.4	6.3
K_2O	5.20	4.96	4.70	5.0	4.7	5.0
H_2O^+	0.22	0.23	0.33	–	–	–
H_2O^-	0.08	0.09	0.17	–	–	–
P_2O_5	0.17	0.17	0.10	–	–	–
Total	100.00	100.00	100.00	100.0	100.0	100.0
Norms						
q	5.33	5.71	3.65	5.6	3.6	5.7
or	30.74	29.30	27.78	29.6	27.8	29.6
ab	54.83	52.92	53.64	53.3	54.2	53.3
an	1.92	3.48	4.16	3.6	4.3	3.9
di	1.02	2.68	2.85	2.3	3.1	2.5
hy	2.10	1.76	3.15	2.1	3.0	0.1
mt	2.03	2.11	3.03	2.2	3.0	3.5
il	1.35	1.37	1.01	1.3	1.0	1.5
ap	0.40	0.40	0.24	–	–	–

1. Average composition of main Kangerdlugssuaq intrusion (Kempe et al. 1970, table 11).
2. Average composition of main and minor peripheral intrusions (Deer & Kempe 1976, table 7).
3. Average composition of Kap Edvard Holm syenites, calculated from analyses 1; 3; 5; 6; and 7 and 8 averaged, in Table 16, in the proportions given in Table 1.
4. Analysis 2 recalculated to 100% on an MnO, P_2O_5, and H_2O free basis (Kempe & Deer 1976, table 3).
5. Analysis 3, recalculated to 100% on an MnO, P_2O_5, and H_2O free basis.
6. Average late differentiate (quartz trachyte), Azores (Le Maitre 1962).

and to that of the Azores late differentiate (see Table 17). The Kap Edvard Holm average chemical composition differs significantly from the Kangerdlugssuaq and Azores averages only in its slightly higher total iron content, compensated for a slightly lower silica figure. Some simple mechanism must surely have operated in each case, such as crystal fractionation of an alkali basalt magma. A large scale influx of hot meteoric water may well have occurred also, to produce the breaks in the several trends mentioned by Kempe & Deer (1976: 121) as well as the isotopic compositions noted by Pankhurst et al. (1976).

Finally, referring specifically to the Kap Edvard Holm rocks, the average composition given in Table 17, no 3, suggests that small amounts of quartz trachyte magma, with minor chemical differences, as well as some acid magma, were variously intruded there as in the case of the Kangerdlugssuaq peripheral intrusions. The minor hybrid rocks and igneous breccias came about as a result of the intrusion of small masses of these magmas into, generally, a mainly cumulate gabbro body. Returning to the main Kangerdlugssuaq intrusion, it is repeated that differentiation of an alkali basalt magma to produce a magma of quartz trachytic composition, which in turn yielded the nordmarkites and pulaskites by fractional crystallization, remains the most satisfactory explanation. The foyaite, still thought of as a 'slag', with its admittedly unusual ferromagnesian mineralogy (Kempe & Deer 1976: 113), may well be another artefact of the meteoric groundwater incursion which, it is generally agreed, seems to have occurred.

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1982

8. P. R. Dawes and J. W. Kerr (eds):
"Nares Strait and the drift of Greenland: a conflict in plate tectonics". 392 pp.

Exploration in the Nares Strait region in the late 19th and early 20th centuries was connected with the seaway's position as a principal route of geographic discovery. Few of the early expeditions were directed towards obtaining data for the young science of geology. At the turn of the century, with the passing of the main era of geographical discovery, including the race for the North Pole and the establishment of Greenland's insularity, geological understanding of the region advanced rapidly and geologists more or less became 'standard' members of expeditions to this part of the Arctic.

Systematic geological studies in the Nares Strait region began when Lauge Koch mapped the Greenland side of the Strait in the period 1916–23; such investigations on the Canadian side by the Geological Survey of Canada took place in the 1950s and later. Early private expeditions and later work by university and petroleum and mineral enterprises have also contributed many geological data, as have several 'military operations' centred on Thule Air Base in Greenland. Regional geological mapping in Greenland was renewed by the Geological Survey of Greenland in the 1970s and continues today.

Cooperative Danish–Canadian projects, initiated by "Operation Grant Land" in 1965–66 in northern Nares Strait, have aimed at coordinating field studies in order to better assess correlation of stratigraphy and structure across the Strait.

Greenland and Nares Strait held important positions in the early ideas about the horizontal mass movements of the continents, and both Frank B. Taylor and Alfred Wegener featured the narrow linear channel between Ellesmere Island and Greenland in their respective theories of continental drift. These two creative theorists built on the immense global knowledge assembled by Eduard Suess, who published one of the earliest appraisals of the region. Early geological maps of the Nares Strait region by Bailey Willis and Lauge Koch were used by Wegener in support of his theory of continental drift.

1982

9. C. K. Brooks and T. F. D. Nielsen:
"The Phanerozoic development of the Kangerdlugssuaq area, East Greenland". 30 pp.

This paper presents an up-to-date description of the state of knowledge on the post-Precambrian geology of the Kangerdlugssuaq area, which is a key area for the early stages of continental break-up in the North Atlantic. The area is analogous to present-day Iceland but differs from Iceland in that continental crust is present and the erosional level is deeper.

The area was affected by the Caledonian orogeny as revealed by the Batbjerg intrusion, which contains screens of Palaeozoic limestones and unique potassic rocks which relate it to the Assynt Province of Scotland.

Basin formation in the early Cretaceous heralded a period of sedimentation and volcanism which formed deposits several kilometres in thickness. The basalts are believed to have been extruded just prior to anomaly 24 (i.e. 55 – 53 m.y. ago) which reaches the coast just north of this area. The basalts are overwhelmingly tholeiites of "plume" type and include picrites. They may be derived from two different mantle sources.

Layered gabbroic intrusions which are penecontemporaneous with the basalts are widespread in the area and a number of ultramafic plugs also occur. Syenites, both under- and oversaturated, are the most voluminous rock types of the area at the present erosional level and are somewhat later. The syenites show abundant signs of contamination with the country rocks.

The Gardiner complex is the eroded core of a nephelinitic volcano and contains melilite rocks and carbonatites. Related nephelinitic lavas are found in inland areas.

In the area many dike swarms are recognized which vary from tholeiitic to strongly alkaline suites emplaced between ca. 55 and 35 m.y. ago and which give good evidence of the magmatic and chronological development of the area.

Tertiary tectonism includes three main elements: the well known coastal flexure, a major dome centred on Kangerdlugssuaq and regional plateau uplift.

1983

10. B. Fredskild:
"The Holocene vegetational development of the Godthåbsfjord area, West Greenland". 28 pp.

Holocene pollen and macrofossil diagrams from four low arctic lakes at Godthåbsfjord are presented. Each core has been divided into radiocarbon-dated palaeovegetation zones, based on the remnants of terrestric plants. The PV zones are physiognomically similar, but differences as to the composition and frequency of species can be seen between the two lakes in the interior and the two lakes from the outer coast area. The vegetation which invaded the deglaciated soil was open but rich in species, and 64 species or genera have been determined from the pioneer stage (*c.* 9400–8000 B.P.). Open soil plants were dominating, but dwarf-shrubs entered the vegetation, with species from snow-patches and snow-covered heaths dominating in the beginning. By *c.* 8000 B.P. *Salix glauca* and *S. herbacea* immigrated, and gradually the pioneer plants and chionophilous dwarf-shrubs were decimated. This *Salix-Cyperaceae* stage lasted until *c.* 6300 B.P., when *Betula nana* spread all over the area within a few centuries. A *Betula nana-Juniperus* stage lasted until *c.* 3500 B.P. In the subcontinental interior this was followed by an *Alnus crispa-Betula nana* stage, which in turn was replaced by a *Betula nana-Ericales* stage around 1800 B.P. *Alnus* has never been able to grow at the maritime outer coast, where *Betula, Cyperaceae, Empetrum* and other *Ericales* dominated after *c.* 3500 B.P. Later on, *Empetrum, Cyperaceae* and snowbed plants gradually spread at the expence of *Betula nana*.

After the deglaciation the temperature increased, reaching today's values between 8000 and 7500 B.P. At which time during the coming millennia the temperature curve peaked is not known, but it may have been fairly late, presumably during the *Betula nana-Juniperus* stage. Major climatic changes are registered in the interior at 3900–3600 and 1800 B.P., and at the outer coast at *c.* 3600 and 2500–2000 B.P.

From around 8000 B.P. the development of the lakes is fairly independent of the physical conditions of the surroundings, being dependent mainly on the trophic stages of the lakes. These pass through a succession: highly productive, eutrophic – less productive, mesotrophic – very poor, oligotrophic. As well as in the flora and fauna, these stages are reflected in the sediment, which at the beginning was a clay gyttja followed by a jelly-like gyttja and, finally, by a loose, watery gyttja consisting mainly of precipitated humus. Chemical analyses of one of the cores confirm the oligotrophication.

The pollen influx in the pioneer stage is less than 100 grains per cm^2 per year, increasing during the Hypsithermal to *c.* 300 in three of the lakes and *c.* 1000 in the richest one, but since then the influx decreases somewhat upwards.

A survey of the immigration or first appearance of some species palynologically important to South and West Greenland shows big time lags in the spreading of some species, e.g. *Thalictrum* and *Angelica,* whereas others, like *Empetrum* and *Juniperus,* have a more effective dispersal capacity.

1983

11. Alastair G. Dawson:
"Glacier-dammed lake investigations in the Hullet lake area, South Greenland".

Results are presented on the evolution of former glacier-dammed lakes and on former glacier oscillations in the Hullet lake area, South Greenland. In this area, the presence of 15 well-developed lake shorelines between 684 and 570 m a.s.l. indicate a complex sequence of Neoglacial lake level changes, several of which may have been associated with catastrophic lake drainage and the rapid emptying of lake waters through a c. 23 km subglacial tunnel beneath Sydgletscher and the Kiagtût sermiat glacier. The oldest lake had a volume of c. 950×10^6 m^3 and its sudden drainage resulted in local neotectonic crustal deformation. Lichen measurements of *Rhizocarpon geographicum* on glacial moraine debris suggest that a major Neoglacial expansion of glacier ice had taken place by c. 2350 years B. P. and was followed by widespread ice retreat and stagnation. There is no evidence to indicate an expansion of glacier ice in the Hullet area during the Little Ice Age. The progressive retreat of Sydgletscher was accompanied by the formation of a series of ice-dammed lakes each of which was drained subglacially. The drainage of the lakes is suggested as having been both a slow and a rapid (jökulhlaup) process. Evidence of slow lake drainage is illustrated by the last lake drainage event that took place during October 1981. During this period c. 60% of the volume of lake water drained slowly over a 14 day period with an average discharge of c. 200 m^3s^{-1}.

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