New occurrences of undersaturated syenites from the southern Blosseville Coast, East Greenland

C. KENT BROOKS

Brooks, C. K.: New occurrences of undersaturated syenites from the southern Blosseville Coast, East Greenland. *Bull. geol. Soc. Denmark,* Vol. 38, pp. 153–159, Copenhagen, February 18th, 1991.

This note reports hitherto undescribed nepheline-sodalite syenites from I. C. Jacobsen Fjord and Ryberg Fjord. Numerous syenite erratics have been encountered at I. C. Jacobsen Fjord. They are believed to come from a single intrusion in the immediate neighbourhood which has not yet been located. They consist largely of perthite with nepheline, sodalite, salitic pyroxene, hastingsitic amphibole, sphene and Fe-Ti oxide. They resemble the pulaskites of the Kangerdlugssuaq intrusion.

On the side of the Sorgenfri Gletscher at the head of Ryberg Fjord an extensive area of peralkaline syenite has been found. It consists of perthite, nepheline, sodalite, aegirine, arfvedsonite and very Fe-rich biotite. It is cut by tholeiitic dykes of a late generation of the coastal dyke swarm.

These syenites bridge a gap between previously known examples and suggest that the magma type was much commoner than thought originally.

C. K. Brooks, Institut for Petrologi, Øster Voldgade 10, DK-1350 Copenhagen K. April 10th, 1987.

The East Greenland sector of the North Atlantic Tertiary igneous province is remarkable for the abundance of syenites. While many of these syenites are oversaturated (nordmarkites), some are undersaturated and have been called (Kempe et al., 1970) pulaskites (0–10% feldspathoids) and foyaites (10% feldspathoides) although this is not in strict occordance with established terminology. Feldspathoidal syenites occur in the Kangerdlugssuaq intrusion, Borgtinderne and Werner Bjerge with minor outcrops at Lilloise Bjerge (Fig. 1).

It has been suggested (Brooks & Gilll, 1982) that these nepheline syenites arise by fractional crystallisation of a nephelinite magma, such as is known from several localities in East Greenland (see Brooks & Nielsen, 1982). It has further been suggested that the occurrence of undersaturated magmas may be tectonically controlled (e.g. Brooks, 1973). In this respect, additional occurrences of such rocks may be critical and two examples are reported in this note. These occurrences are remote from currently known outcrops.

I. C. Jacobsen Fjord

Numerous nepheline syenite blocks were found during mapping at the labelled site in I. C. Jacobsen Fjord (Fig. 2). In spite of an intensive search and numerous low altitude helicopter passes in the hinterland no outcrop has been located in the area. It is possible that the outcrop is concealed by snow or glacier ice but it is recommended that future workers in the area keep a sharp lookout, as it is unlikely the blocks have been transported very far in this closed drainage basin.

The rocks are white to grey in colour and pinkish nepheline can generally be recognized in hand specimen. As the country rocks here are basaltic the blocks are very conspicuous. Their grain size varies from medium to coarse and the texture from hypidiomorphic to laminated with prominent aligned tabular alkali feldspars up to about 1 centimetre in length.

Feldspar generally makes up around 90% of the rock. The rocks are hypersolvus and this feldspar is a braid perthite with a composition, judged from the C.I.P.W. norm, around $Or_{50}Ab_{50}$. Pyroxene and amphibole tend to occur in clusters with amphibole being the more abundant: indeed in one rock pyroxene is absent. While pyroxene occurs in the clusters with amphibole, the latter mineral also occurs independantly. Pyroxene is a salite with only about 7% of the aegirine molecule while the amphibole is a potassian hastingsite according to the nomenclature of Leake (1978). Analyses of these minerals are given in Table 1. Similar amphiboles can be

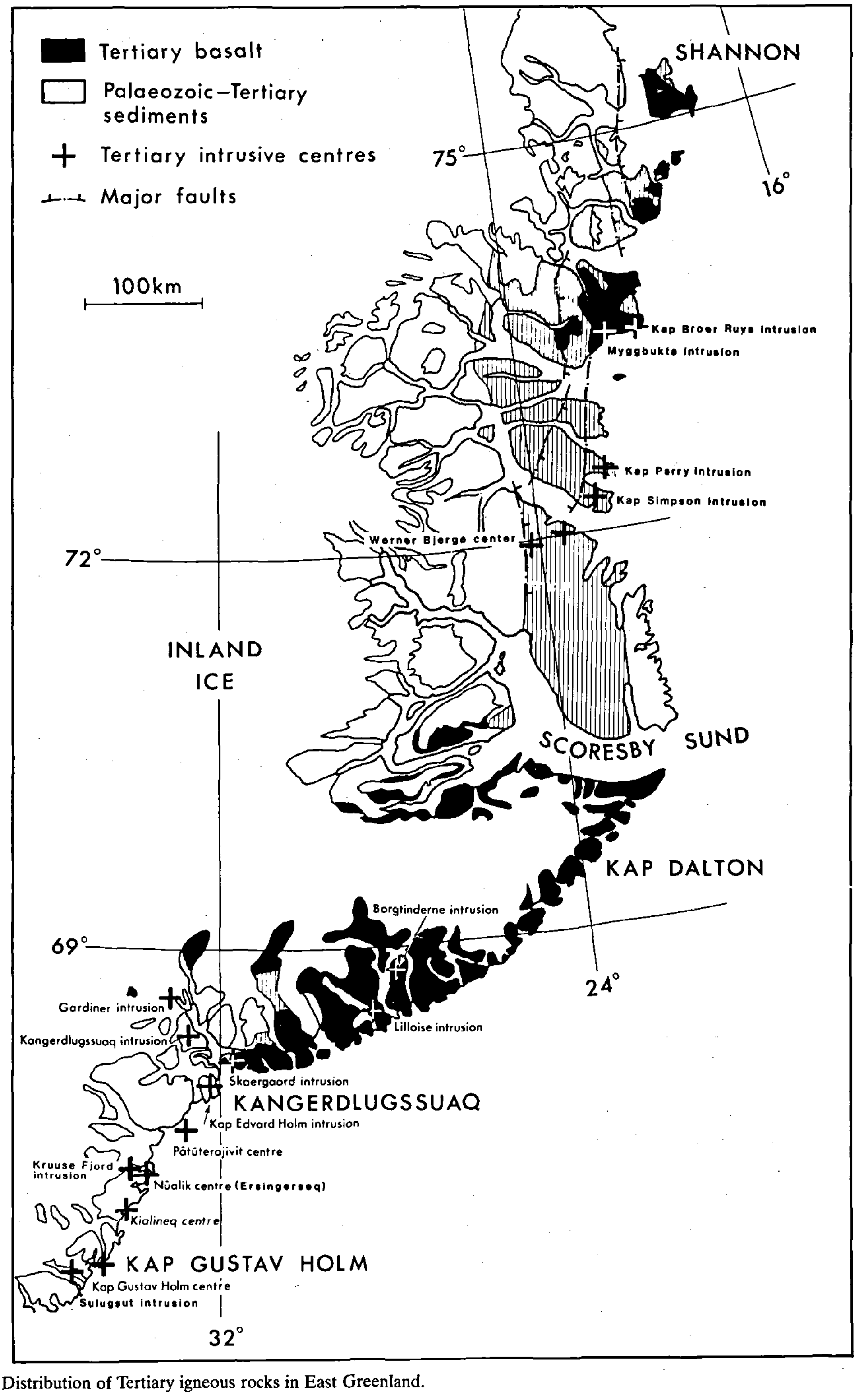
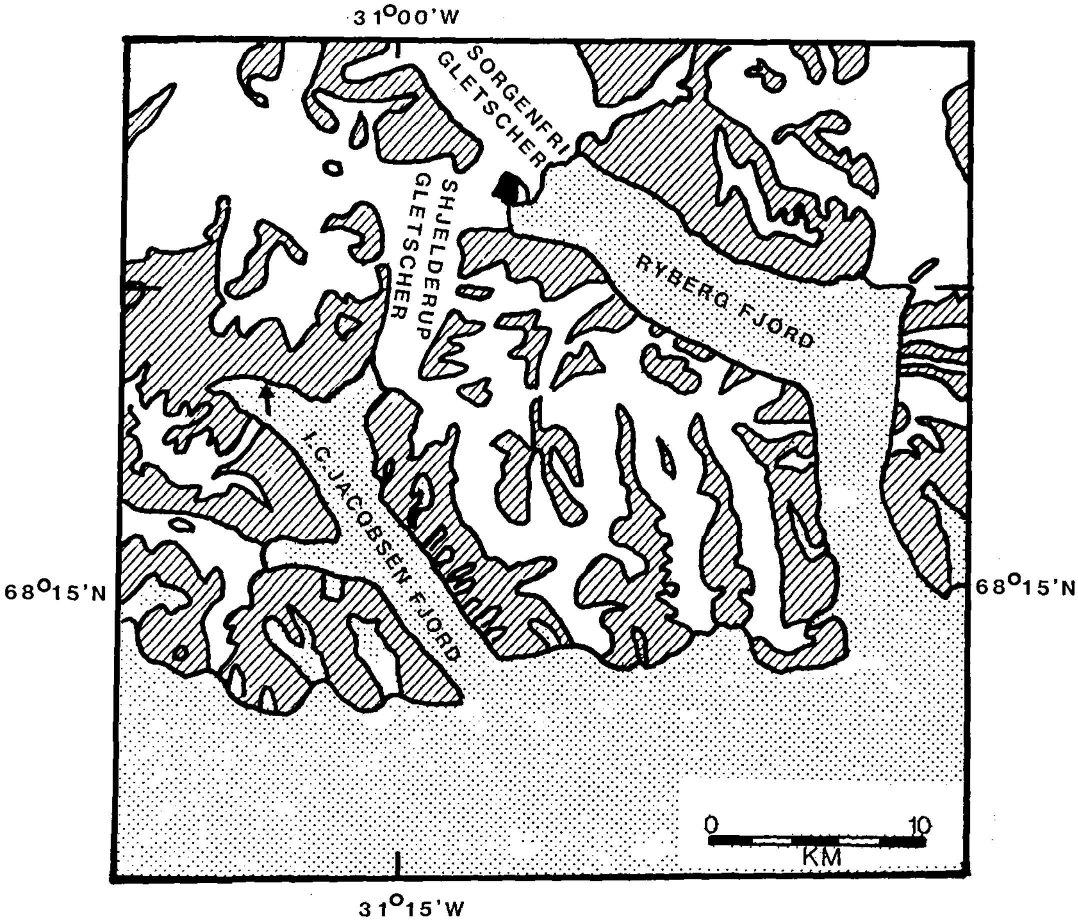


Fig. 1. Distribution of Tertiary igneous rocks in East Greenland.



syenite intrusion-black **syenite erratics-arrow**

Fig. 2. Map of I. C. Jacobsen Fjord – Ryberg Fjord area showing location of syenite intrusion (black) and area in which syenite erraties (arrow) were found. Glacier ice unornamented.

found in the Kangerdlugssuaq (Brooks & Gill, 1982) and Werner Bjerge intrusions (Brooks et al., 1982) even to the extent of the potassian nature. Sphene is an important constituent in these syenites occurring up to 10% by volume in large euhedral crystals. Again this is a common feature of East Greenland syenites such as the Kangerdlugssuaq pulaskites. Sphene often occurs in clusters with opaque Fe-Ti oxides, which are especially abundant in the amphibole-rich types. Apatite is a ubiquitous accessory. Nepheline and sodalite make up more than 10% of rock in some cases. There is little sign of alteration in the rocks apart from an incipient alteration of nepheline to cancrinite.

While most samples are homogeneous, occasional samples are found where the mafic minerals are concentrated into indistinct wavy bands and schlieren. These samples are amphibole- and ore-rich.

Chemically these rocks are similar to other East Greenland examples (Table 2 and Fig. 3). The only sample which has been analysed is a laminated type, which is probably the most undersaturated type. It resembles the Kangerdlugssuaq pulaskites (Kempe et al., 1970), as would be expected from its mineralogy and, like the majority of these, it is not peralkaline. No samples yet recovered are as undersaturated as the Kanger-

Table 1. Mafic minerals of Ryberg Fjord and I. C. Jacobsen Fjord syenites.

	pyroxene		amphibole		mica
	GM40653	GM55299	GM40653	GM55299	GM55299
SiO_2	49.95	51.52	40.03	45.40	32.12
TiO_2	0.55	0.09	3.39	0.20	0.26
Al_2O_3	2.53	0.88	10.87	4.61	7.91
FeO	14.57	31.20*	17.92	32.72	40.29
MnO	0.97	0.16	1.03	1.08	1.43
MgO	7.93	0.00	8.66	0.76	0.24
CaO	20.95	1.19	11.08	1.76	1.15
Na_2O	1.74	13.23	2.99	8.18	0.14
K_2O	0.04	0.03	1.53	1.45	6.83
sum	99.23	98.30	97.50	96.18	90.37

cations on basis of:

	6 oxygens		16 cations		22 oxygens
Si	1.493	2.007	6.182	7.256	5.915
Ti	0.016	0.003	0.393	0.024	0.035
Al	0.116	0.040	1.974	0.870	1.715
Fe	0.473	0.911*	2.306	4.375	6.184
Mn	0.032	0.005	0.134	0.015	0.222
Mg	0.463	0.000	2.006	0.183	0.066
Ca	0.873	0.050	1.905	0.306	0.227
Na	0.131	0.997	0.870	2.541	0.051
K	0.001	0.001	0.301	0.297	1.607

*Fe calculated as Fe_2O_3 and Fe^{3+}.
For sample identification see Table 2.

dlugssuaq or Werner Bjerge foyaites or the "light syenites" of Borgtinderne (Brown et al., 1978).

Ryberg Fjord

The only previous allusion to this syenite is the map in Soper et al. (1976) although no description of it appears in the text. A helicopter landing was made on this body (Fig. 2) in 1982 and samples were collected. An additional sample has been obtained from Dr. N. J. Soper.

The rock is light coloured, almost white, in sharp contrast to the basalts which is cuts. Its present exposure is close to the base of basalts, the underlying sediments outcropping close by. Exposure is excellent, the Sorgenfri glacier having only recently receeded leaving fresh, highly polished rock surfaces with only a scattering of moraine.

The outcrop is just over 1 kilometre in diameter and the rocks appear homogeneous. The most striking feature of the outcrop is that it is made up of angular fragments of a medium grained syenite enclosed in a finer grained variety. The clasts are up to several decimetres in size and no preferential concentrations have ben noted. As there is little difference between the syenite types, either mineralogically or chemically, it appears that this is a case of autobrecciation, possibly arising during the intrusive event. A pecu-

Table 2. Feldspatoidal syenites of Ryberg Fjord and I. C. Jacobsen Fjord, Southern Blosseville Kyst, East Greenland.

	1	2	3	4	5
SiO_2	63.40	61.87	61.82	59.55	48.84
TiO_2	0.01	0.01	0.02	0.73	3.77
Al_2O_3	17.82	17.31	17.40	19.59	12.91
Fe_2O_3	2.04	2.98	2.72	1.17	1.81
FeO	1.92	2.02	2.37	1.19	12.69
MnO	0.07	0.11	0.12	0.06	0.21
MgO	0.00	0.00	0.00	0.45	5.54
CaO	0.43	0.46	0.47	1.46	9.94
Na_2O	8.93	8.72	8.83	7.09	2.55
K_2O	4.04	4.30	4.41	6.66	0.60
P_2O_5	0.22	0.20	0.19	0.07	0.37
L.O.I.	0.77	1.45	1.17	1.08	1.38
sum	99.54	99.33	99.42	99.10	100.61
C.I.P.W. weight norm					
Q	–	–	–	–	1.30
OR	23.88	25.41	26.06	39.36	3.55
AB	61.36	55.36	53.42	38.61	21.58
NE	4.23	5.27	6.25	11.58	–
AC	5.63	7.65	7.87	–	–
NS	–	–	0.19	–	–
DI	0.62	0.87	0.97	2.65	20.70
WO	–	–	–	0.61	–
HY	–	–	–	–	19.47
OL	2.30	2.44	3.11	–	–
MT	0.13	0.48	–	1.70	2.62
IL	0.01	0.02	0.04	1.39	7.16
AP	0.51	0.46	0.44	0.16	0.86
agpaitic index	1.07	1.10	1.11	0.96	–
molecular percent					
SiO_2	74.47	74.30	74.08	72.43	–
Al_2O_3	12.34	12.25	12.29	14.04	–
Na_2O	10.17	10.15	10.36	8.36	–
K_2O 3.0	3.03	3.29	3.37	5.17	–

1. "New Nunatak" at head of Ryberg Fjord – coarse syenite (GM55299A).
2. "New Nunatak" at head of Ryberg Fjord – microsyenite (GM55299B).
3. "New Nunatak" at head of Ryberg Fjord – sample supplied by Dr. N. J. Soper, Sheffield University.
4. Erratic block, North side, head of I. C. Jacobsen Fjord (GM40653).

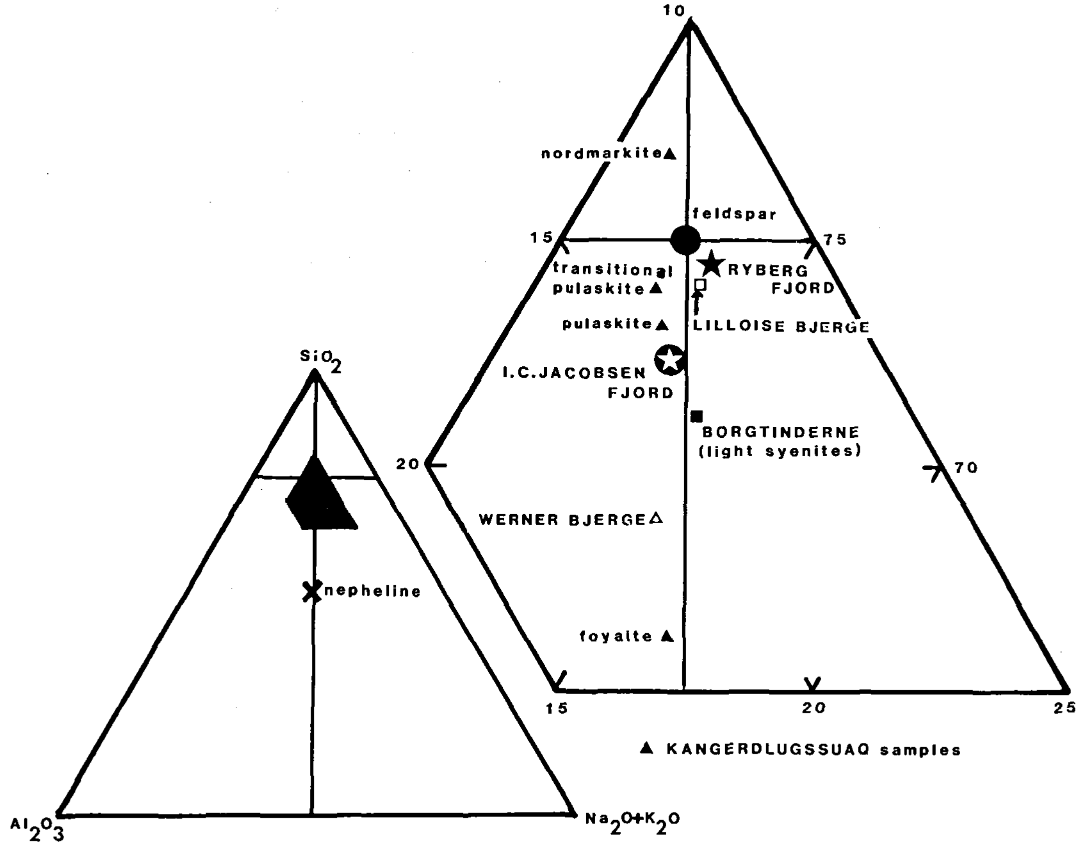


Fig. 3. Portion of diagram SiO_2-Al_2O_3-alkalis (molecular percent) showing locations of East Greenland syenites. In this diagram, feldspathoidal syneites lie below the horizontal line passing through the alkali feldspar composition and peralkaline rocks to the right of the vertical line.

liarity of the coarser grained rock is its blotchiness where the normally greyish alkali feldspar has been bleached adjacent to the clots of mafic minerals. It is suggested that this might possibly be caused by dehydration reactions initiated by an increase in temperature at the time of brecciation and intrusion.

Three samples have been analysed for major elements (Table 2); a coarser grained type, the finer grained matrix type and the sample collected by Soper. There is no significant difference between them. They are less undersaturated than the samples from I. C. Jacobsen Fjord, being roughly equivalent to the Kangerdlugssuaq transitional pulaskites (Kempe et al., 1970). However, they differ from both the Kangerdlugssuaq and I. C. Jacobsen examples in being paralkaline with an agpaitic index (Na_2O + K_2O/Al_2O_3) of about 1.10. On the molecular SiO_2-Al_2O_3-total alkalis diagram (Fig. 3 c.f. Gill, 1972) they fall close to syenites from the Lilloise Bjerge intrusion, although at that locality, syenites are only present in subordinate amounts as dykes and sheets cutting peridodites and gabbros (Brown, 1973; Brown et al., 1987).

In thin section the Ryberg Fjord rocks are made up largely of perthite laths, often forming a felty or trachytoid texture. The normative composition of this rock indicates that the feldspar is much more sodium-rich than those from I. C. Jacobsen Fjord. In addition the rocks contain minor aggregates of nepheline and sodalite, alkali pyroxene, very dark (in some orientations completely opaque) biotite and blue alkali amphibole. The last also has a tendency to form mossy patches enclosing feldspar.

Analyses of the mafic minerals are given in Table 1, which again illustrates the profound difference as compared to the I. C. Jacobsen Fjord syenites. Pyroxene is almost pure aegirine with only small amounts of other components. In particular, Ti is low, in contrast to e.g. alkali pyroxenes from the Gardiner Complex syenites (Nielsen, 1979). The amphobole is a potassian arfvedsonite (Leake, 1978) while biotite is extremely Fe-rich, probably with a high Fe^{3+} content, although this cannot be determined from the microprobe analyses. No equivalent to this biotite has been found in, for example, the compilation of Deer et al. (1962). It is a very Fe-rich annite or lepidomelane, whereas biotites from Kangerdlugssuaq (Brooks & Gill, 1982, although only one analysis of biotite was presented) the Werner Bjerge complex (Brooks et al., 1982) and Borgtinderne (Brown et al., 1978) are more Mg- and Al-rich.

In summary, from the mineralogical and chemical data, the Ryberg Fjord syenites are difficult to match with any other published East Greenland syenite, although there is a chemical similarity to some of the Lilloise material.

Rb Sr and Nd isotopic data, together with a long list of trace elements have been determined by P. M. Holm on the Ryberg Fjord rocks and will be reported elsewhere. The three samples fall on an Rb-Sr isochron with an age of 57.7+/−4.7 with an initial ratio of 0.7043+/−5. These figures, while not particularly accurate, show that the syenite is approximately the same age as other syenites in the Kangerdlugssuaq area (Brooks & Nielsen, 1982), not substantially younger as is the case with the Werner Bjerge syenites (Rex et al., 1979) and that it is derived from a similar source material which resembles "bulk earth" compositions.

A few dykes cut the syenite, although far fewer than cut the surrounding basalts, which are also hosts to an intense doleritic sill complex in this area. Some of these dykes where intruded prior to the consolidation of the syenite and have irregular outcrops and crenulate margins. These dykes contain plagioclase and possibly olivine phenocrysts, although the olivine is now altered to green amphibole. An analysis of one of one of these dykes is shown in Table 2. It is a tholeiite and probably a member of the group which is consanguinous with the Skaergaard intrusion (Brooks & Nielsen, 1978). In contrast to the syenite, but in common with other tholeiites, the isotopic composition shows that it originated in a depleted source region similar mid-ocean ridge basalts.

Conclusions

These two occurrences of feldspathoidal syenites bridge the almost 100 kilometre wide gap between the previously known occurrences of Kangerdlugssuaq and Borgtinderne. Their presence indicates that the processes leading to the formation and emplacement of such magmas are probably not as specialised as previously thought. There does not appear to be any special tectonic feature in these areas and certainly nothing to compare with Kangerdlugssuaq Fjord.

Indeed, the theory of tectonic control was earlier weakened with the discovery of the Borgtinderne intrusion, a mass of feldspathoidal syenite situated in an apparently featurless area of basalts.

The syenite in I. C. Jacobsen Fjord is strikingly similar both chemically and mineralogically to others in East Greenland, the Ryberg Fjord example less so. Nevertheless a similar mode of origin for all these feldspathoidal syenites is likely. Undersaturated syenites are otherwise unknown in the rest of the North Atlantic Province such as the Hebrides, the Faeroes or West Greenland. On a worldwide basis they are found both in the ocean basins and in continental areas and their isotopic signatures support the impression that continental crust plays little part in their genesis. Oversaturated syenites on the other hand are much more variable both chemically and isotopically and this led to the suggestion of Brooks and Gill (1982) that they were formed from the undersaturated magmas by reaction with Archaean crust. As this area is still very imperfectly explored further syenites may yet be found.

Acknowledgements. Samples from I. C. Jacobsen Fjord were discovered and collected by Troels Nielsen and a sample from Ryberg Fjord was kindly donated by Dr. N. J. Soper, Sheffield University.

Microprobe analyses were made by J. G. Rønsbo and chemical analyses of the rocks by the Geological Survey of Greenland under the direction of Ib Sørensen. Unpublished Sr isotope data was kindly supplied by Paul M. Holm.

Fieldwork and the Copenhagen microbe were both financed by the Danish Natural Sciences Research Foundation.

Dansk sammendrag

To nye forekomster af nepheline syeniter er rapporteret. Den ene kendes kun som erratiske blokke fra I. C. Jacobsen Fjord. Disse blokke består af perthit, nefelin, sodalit, hastingsitisk amfibol, titanit og Fe Ti oxider. De ligner pulaskiterne fra Kangerdlugssuaq intrusionen. Den anden forekomst, i Ryberg Fjord, er en ca. 1 km stor intrusion i basalterne, der i undermætningsgrad ligner Kangerdlugssuaq pulaskiter, men i modsætning til disse, er stærkt peralkalin. Den indeholder aegirin, arfvedsonit og meget Fe-rig biotit.

Disse forekomster viser, at undeermættede syeniter er langt mere udbredt i denne del af Østgrønland end hidtil formodet og at et specielt tektonisk miljø ikke længere er anset for at være vigtigt for deres dannelse.

References

Brooks, C. K. 1973: Rifting and doming in southern East Greenland. *Nature Phys. Sci.* 244, 23–25.

Brooks, C. K. & Gill, R. C. O. 1982: Compositional variation in the pyroxenes amphiboles of the Kangerdlugssuaq intrusion, East Greenland: further evidence for the crustal contamination of syenite magma. *Mineral. Mag.* 45, 1–9.

Brooks, C. K. & Nielsen, T. F. D. 1978: Early stages in the differentiation of the Skaergaard magma as revealed by a closely related suite of dike rocks. *Lithos* 11, 1–14.

Brooks, C. K. & Nielsen, T. F. D. 1982: Phanerozoic, development of the Kangerdlugssuaq area, East Greenland. *Meddr. Grønland Geosci.* 9, 30 pp.

Brooks, C. K., Engell, J., Larsen, L. M. & Pedersen, A. K. 1982: Mineralogy of the Werner Bjerge alkaline complex, East Greenland. *Meddr. Grønland Geosci.* 7, 35 pp.

Brown, P. E. 1973: A layered plutonic complex of alkali basalt parentage: the Lilloise intrusion, East Greenland. *J. geol. Soc. Lond.* 129, 405–418.

Prown, P. E., Brown, R. D., Chambers, A. D. & Soper, N. J. 1978: Fractionation and assimilation in the Borgtinderne syenite, East Greenland. *Contrib. Mineral. Petrol.* 67, 25–34.

Brown, P. E., Chambers, A. D. & Becker, S. M. 1987: A large soft-sediment fold in the Lilloise intrusion, East Greenland. *In* Parsons, I. (*editor*); *Origins of igneous layering,* 125–143, Dordrecht, Reidel.

Deer, W. A., Howie, R. A. & Zussman, J. 1962: Rock forming minerals, 55–84. London, Longmans.

Gill, R. C. O. 1973: Chemistry of peralkaline phonolite dykes from the Grønnedal-Ika area, South Greenland. *Contrib. Mineral. Petrol.* 34, 87–100.

Leake, B. E. 1978: Nomenclature of amphiboles. *Mineral. Mag.* 42, 533–563.

Kempe, D. R. C., Deer, W. A. & Wager, L. R. 1970: Geological investigations in East Greenland. Part VIII. The petrology of the Kangerdlugssuaq intrusion, East Greenland. *Meddr. Grønland* 190 (2), 49 pp.

Nielsen, T. F. D. 1979: The occurrence and formation of Ti-aegirines in peralkaline syenites. An example from the Tertiary ultramafic alkaline Gardiner complex, East Greenland. *Contrib. Mineral. Petrol.* 69, 235–244.

Soper, N. J., Higgins, A. C., Downie, C., Matthews, D. W. & Brown, P. E. 1976: Late Cretaceous early Tertiary stratigraphy of the Kangerdlugssuaq area, East Greenland, and the age of opening of the north east Atlantic. *J. geol. Soc. Lond.* 132, 85–104.

Rex, D. C., Gledhill, A. R., Brooks, C. K. & Steenfelt, A. 1979: Radiometric ages of Tertiary salic intrusions near Kong Oscars Fjord, East Greenland. *Rapp. Grønlands geol. Unders.* 95, 106–109.