Geochemistry of mafic dykes in the Corrovarre Nappe, Troms, North Norway

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Tholeiitic metadolerite dyke rocks in the Corrovarre Nappe of the Kalak Nappe Complex in North Troms show chemical traits which indicate T-MORB affinities, with fairly flat, chondrite-normalised REE patterns and a $(La/Nb)_N$ just over 1. The low initial $^{87}Sr/^{86}Sr$ ratio, 0.7030, and lack of Th enrichment suggest that the magma was not contaminated to any extent during upward passage from a secondarily slightly LIL element-enriched but primarily depleted mantle source. Element abundances and ratios and the low initial Sr ratio are comparable to those from Tertiary T-MORB dykes and lavas from the Vøring Plateau. It is suggested that the Corrovarre dykes, Sm/Nd-dated to c. 580 Ma, penetrated a continental crust which had thinned appreciably since the time of initial rifting. The dykes probably intruded just prior to the actual inception of sea-floor spreading along this segment of the Baltoscandian margin.

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Introduction

One of the most characteristic features of the thick, arkosic sandstone sequences which compose the Middle Allochthon in the Caledonides of Scandinavia is the widespread occurrence of dolerite dykes. Locally, and especially in higher thrust-sheets, the dykes reach swarm proportions. In terms of the tectonomagmatic evolution of the orogen, these mafic dykes are considered to represent a rift-related magmatism coeval with crustal distension leading to the development of the Iapetus Ocean (Roberts & Gale 1978, Andreasson et al. 1979, Solyom et al. 1979, 1985, Stephens et al. 1985).

In northern Norway, mafic dykes are common in many parts of the metasandstone-dominated Kalak Nappe Complex (KNC) in Finnmark (Sturt & Ramsay 1965, Gayer & J. Roberts 1971, Gayer et al. 1978, 1985). Further south, in Troms, dykes are also abundant locally in the KNC (Lindahl 1974), but they have received little attention until now. In a companion paper in this volume, Zwaan & van Roermund 1990) describe field relationships associated with a dolerite dyke swarm in the highest part of the KNC in North Troms. The present short contribution deals with the petrochemistry of these dykes.

Regional setting

In this part of the Caledonides of Troms the KNC is divided into several nappes (Zwaan 1988), the two highest of which, the Nabar and Corrovarre Nappes, carry numerous metadolerite dykes and some larger mafic bodies

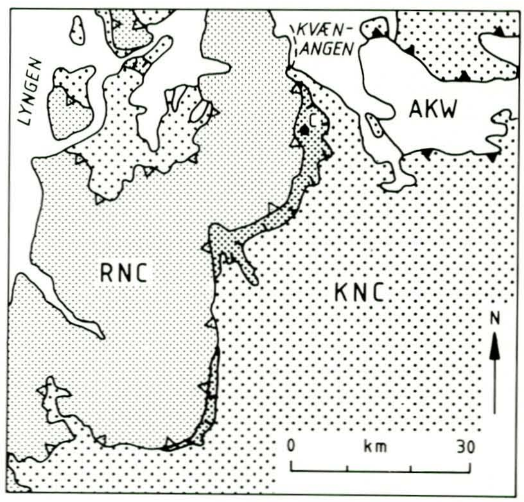

Fig. 1. Simplified tectonostratigraphic map of part of the North Troms region to show the location of Corrovarre (C). The Corrovarre Nappe (dark grey ornament) is a part of the Kalak Nappe Complex (KNC). These units are overlain by the Reisa Nappe Complex (RNC). AKW - Alta-Kvænangen Window.

intruding dominantly arkosic, assumed Late Proterozoic metasediments. The KNC is structurally overlain by the Reisa Nappe Complex (RNC) (Fig. 1), which differs markedly from the Corrovarre and lower nappes in the general character of its lithologies as well as in structural grain. The metasediments of the KNC carry a prominent NW-SE stretching lineation and were metamorphosed and deformed during an early Caledonian event, equivalent to one or more phases of the 'Finnmarkian' orogeny; Late Cambrian and/or Early to Middle Ordovician (Dallmeyer 1988a,b, Roberts 1988). In some of the nappes in northwest Finnmark, geochronological evidence of a pre-Caledonian, possibly Sveconorwegian, orogenic event has been recorded (Daly et al. 1990). The KNC rocks were also thermally overprinted in Silurian time (Dallmeyer 1988a). By contrast, RNC rocks, part of the Upper Allochthon, are dominated by metagreywackes, calc-schists, marbles and conglomerates, and carry Late Ordovician to Early Silurian fossils in the basal Vaddas Nappe (Binns & Gayer 1980). The entire RNC metasedimentary assemblage was initially deformed and metamorphosed during the 'Scandian' orogenic event, in Mid to Late Silurian time (Zwaan 1988).

The dykes and host rocks studied by Zwaan & van Roermund (1990) form part of the Corrovarre Nappe (CN), which has been subdivided into lower and upper tectonic units. Within the upper unit three formations have been distinguished, each of which carries locally abundant mafic dykes in varying states of preservation; full details are given in Zwaan & van Roermund (1990). In the centre of the lensoid nappe body, strains are minimal and dykes are disposed at high angles to cross-bedded arkoses. Towards the highly sheared, mylonitic margins of the CN, the original dykes thin and swing into a foliation- or banding-parallel orientation, and have been converted into garnet-hornblende(-biotite) schists (Zwaan & van Roermund 1990).

The mafic dykes

Field relationships and petrography

For purposes of the present study, sampling was concentrated in the less deformed central parts of the CN along the ridge Corrovarre (1:50,000 map-sheet Kvænangen 1734 I). In this area, sampled dykes vary in thickness from 3m to 10m. As little mesoscopic variation could be ascertained in the character of the dykes, the sampling initially took the form of a pilot study (Zwaan & Roberts 1981) and concentrated on the central portions of individual dykes. The resultant chemical data, discussed below, confirmed the homogeneity of the dykes.

The dykes on Corrovarre trend NNW-SSE to N-S and are generally fine- to medium-grained, rarely porphyritic. Marginal zones to the thicker dykes are finer grained and schistose, while some of the thinner dykes are garnetiferous along their strongly schistose margins. An even-grained subophitic texture prevails, with plagioclase and clinopyroxene as the principal minerals; some metamorphic hornblende, garnet and biotite are present, especially along sheared margins and along apophyses. Relationships between the dykes and the locally migmatised and contact-metamorphosed host metasediments, which also contain some disrupted and boudined mafic dykes pre-dating the main swarm, are described in detail by Zwaan & van Roermund (1990).

Geochemistry

Major elements for the thirteen samples taken for this study were determined by classical wet chemical methods at NGU, Trondheim, in 1978. Trace elements were analysed on rock powders using a manual Philips 1540 spectrometer. Calibration curves were made with USGS rock standards as control samples. Rare earth elements were analysed by INAA at the Department of Physico-Chemical Geology, University of Leuven, Belgium.

Major and trace element concentrations, mean values and ranges for the Corrovarre mafic dykes are presented in Table 1. The major element data show a clear homogeneity with unusually low standard deviations and variation ranges. Element concentrations and ratios have been plotted in a variety of diagrams in order to assess the petrochemical character of the dykes. An alkalies-silica plot shows the samples to be clearly sub-alkaline (Fig. 2a). A Hughes (1973) plot of alkali variation, not reproduced here, indicates that the samples plot well outside the field of spilitisation. The tholeiitic character is brought out by the trend of iron-enrichment in the AFM dia-

Table 1. Dolerite dykes, Corrovarre, major and trace element compositions.

Sample no.	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	RZ10	RZ11	RZ12	RZ28
SiO_2	47.79	47.35	48.35	47.47	47.81	47.86	48.59	48.13	48.97	48.00	49.17	47.67	47.61
Al_2O_3	15.09	15.10	15.10	15.18	15.54	14.86	15.39	14.68	15.08	15.92	15.01	14.76	14.32
Fe_2O_3	1.40	1.17	1.84	.64	.08	4.57	.42	1.28	.92	.24	.90	1.72	2.36
FeO	10.04	10.99	9.05	10.54	10.35	6.91	10.96	9.91	9.98	9.30	10.53	10.72	10.14
TiO_2	1.90	2.27	1.80	1.80	1.86	1.94	2.00	1.92	1.89	1.79	2.02	2.35	2.13
MnO	.24	.26	.24	.23	.23	.22	.19	.23	.19	.22	.26	.25	.21
MgO	7.42	7.30	7.31	7.33	7.67	8.43	7.11	7.26	7.16	7.74	6.75	6.57	6.98
CaO	11.37	10.86	11.40	11.67	11.57	10.91	11.28	11.38	11.52	11.46	10.69	10.83	10.40
Na_2O	2.03	2.47	1.94	2.38	2.19	2.26	2.33	2.04	2.34	2.10	2.45	2.52	2.60
K_2O	.47	.38	.60	.39	.25	.29	.22	.30	.23	.29	.31	.75	.40
P_2O_5	.13	.20	.14	.09	.14	.11	.12	.11	.12	.12	.14	.17	.23
L.O.I.	.37	.05	.77	.61	.51	.68	–	1.02	–	.95	.61	.36	.69
Sum	98.25	98.40	98.54	98.33	98.20	99.04	98.39	98.26	98.12	98.13	98.84	98.67	98.07
Nb	<5	7	7	6	6	8	<5	<5	5	6	7	9	9
Zr	116	158	119	106	115	154	124	111	125	113	134	166	158
Y	40	50	39	38	41	45	41	38	44	37	45	44	52
Sr	192	176	219	203	170	166	164	174	169	194	178	232	173
Rb	9	12	14	11	7	6	<5	<5	6	7	10	11	19
Zn	123	162	142	143	122	101	94	117	96	111	107	119	106
Cu	82	75	74	61	73	76	71	84	57	77	74	60	36
Ni	65	90	59	68	84	136	56	59	59	81	44	43	88
Cr	264	203	280	254	244	277	213	274	230	282	156	108	243
Ba	48	80	118	85	39	46	46	46	43	56	59	83	59

gram (Fig. 2b), and also by the linear spread in Miyashiro (1975) plots (Fig. 2c,d).

As basaltic lavas and dyke rocks of tholeiitic affinity occur in continental as well as oceanic environments, a common means of discrimination, in this case, would be to employ the TiO_2-K_2O-P_2O_5 diagram of Pearce et al. (1975). Here (Fig. 2e), the Corrovarre dolerites plot within the 'oceanic' field. Thus, the chemical classification is not in accord with the dyke/ host rock geological relationships.

Trace elements have long proved valuable in mafic rock chemistry in assisting in the classification of magmatic associations, particularly the relatively immobile, incompatible elements such as Y, Nb and Zr, the heavy rare earths (HREE) and to a certain extent the light rare earths (LREE). The now familiar Pearce & Cann (1973) Ti-Zr-Y discriminant diagram (Fig . 3a) positions the Corrovarre dyke samples firmly in the ocean floor basalt field. In a TiO_2-Zr variation plot (Pearce 1980) the samples again cluster in the same (MORB) field although, significantly, at the high-Ti/high-Zr end overlapping into the within-plate domain (Fig. 3b).

Ratios between the elements Hf, Ta and Th are known to be useful magma discriminants (Wood et al. 1979, Wood 1980). Although only two representative samples have been analysed for these elements they both show transitional (T-)MORB signatures (Fig. 4). The significance of this is discussed below. Rare earth element (REE) chondrite-normalised patterns for these same two samples display almost flat 'slopes' with just a hint of upward-convexity in the LREE sector, and no Eu anomalies (Fig. 5). $(La/Yb)_N$ ratios for the samples are 1.18 and 1.07. These patterns and ratios strongly resemble those from the Tertiary T-MORB tholeiitic rocks from parts of the North Atlantic region (Upton et al. 1984, Viereck et al. 1988). This can also be seen in a chondrite-normalised La/Sm vs. La/Yb variation plot (Fig. 6). On rock-MORB normalising diagrams (Fig. 7), the Corrovarre dykes show a moderate enrichment in the large-ionic lithophile (LIL) elements and a negative P anomaly. These patterns are, again, quite typical of T-MORB products.

Discussion

The chemistry of the Corrovarre metadolerites clearly indicates a magmatism of tholeiitic character and one which, based on most major and trace element plots, would favour comparison with basaltic rocks of ocean-floor affinity. It is evident, however, from the geological setting, that the hypabyssal rocks do not represent magma from an oceanic milieu. The dykes intrude a thick sequence of sandstones

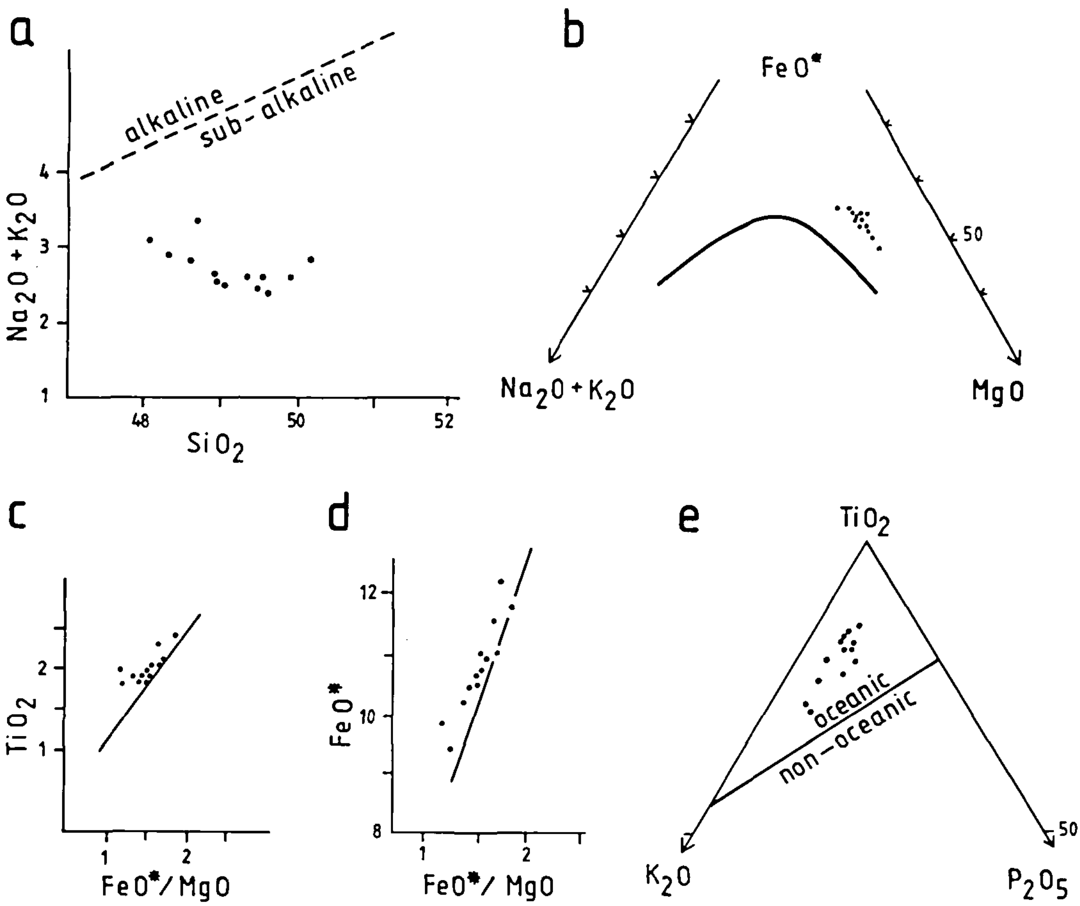

Fig. 2. The Corrovarre dolerite dykes plotted on a variety of diagrams. (a) SiO_2 vs. $Na_2O + K_2O$, volatile-free. (b) AFM diagram, showing the typical tholeiite trend for the Corrovarre dykes. (c) TiO_2 vs. Fe^{tot}/MgO. The full line shows the average trend for abyssal tholeiites (Miyashiro 1975). (d) FeO^{tot} vs. FeO^{tot}/MgO, showing the average trend for abyssal theoleiites (Miyashiro 1975). (e) TiO_2-K_2O-P_2O_5 diagram (Pearce et al. 1975) discriminating between tholeiites of oceanic and continental affinities.

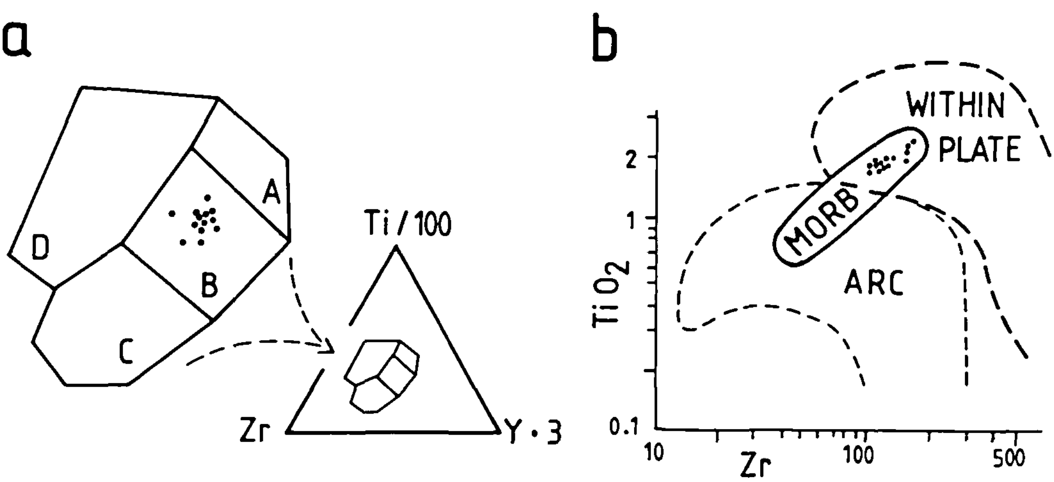

Fig. 3. (a) Ti-Zr-Y discrimination diagram of Pearce & Cann (1973), with the Corrovarre mafic dykes plotted. Field A - low-K tholeiites: B - ocean-floor tholeiites: CD - calc-alkaline basalts: D - within-plate tholeiites. (b) TiO_2 vs. Zr plot (Pearce 1980).

which are generally considered to have once formed part of the Baltoscandian miogeocline, and we must therefore re-examine the geochemical evidence from the point of view of rift-related magmatism.

An indication that the chemistry does, in fact, depart from a normal-OFB situation was given by the TiO_2-Zr plot (Fig. 3b), and underlined by the Hf-Th-Ta diagram which shows a clear T-MORB affinity (Fig. 4). On this latter diagram, as well as on the MORB-normalised trace element variation and REE plots (Figs. 5 & 7), the Corrovarre samples show comparable positions or patterns to those, for example, from the Palaeogene Upper Series tholeiitic lavas and dykes recovered by drillcore from the Vøring Plateau (Viereck et al. 1988). It is also of interest that the low initial $^{87}Sr/^{86}Sr$ ratios (mean 0.7032) for these Vøring Plateau tholeiites are similar to that reported by Zwaan & van Roermund (1990), 0.70303, for a dyke from Corrovarre.

Analogies are also found in the geochemical traits of plateau basalt magmatism from NE Greenland (Upton et al. 1984) and of Recent tholeiitic lavas from NE Atlantic mid-ocean ridges (Neumann & Schilling 1984). Furthermore, a simple visual comparison of element concentrations in the 'average' Corrovarre dyke with those in average mid-oceanic ridge and continental tholeiites (Table 2) substantiates the conclusion that the Corrovarre magma was of a somewhat 'transitional' character.

In seeking a possible analogy for the continental margin tectonic setting of the Corrovarre dykes, the Vøring Plateau situation is appealing in several ways. The Vøring Plateau is underlain by continental crust, and separated from Norway by an intracontinental, Mesozoic, rift system. Early Tertiary sediments intercalated with the lavas denote a shallow-water, near-coastal, rifted-margin environment.

At Corrovarre, lavas, which one would assume to have been produced via the chemically homogeneous feeder dyke swarm, are lacking. The Corrovarre Nappe is, however, the structurally highest tectonic unit of the KNC in this region and, thus, any pre-existing higher formations including volcanic horizons would presumably have been removed either by erosion or by tectonic excision.

In an orogen-wide context, the geochemistry of the Corrovarre dolerites is comparable on first sight to that of the majority of early,

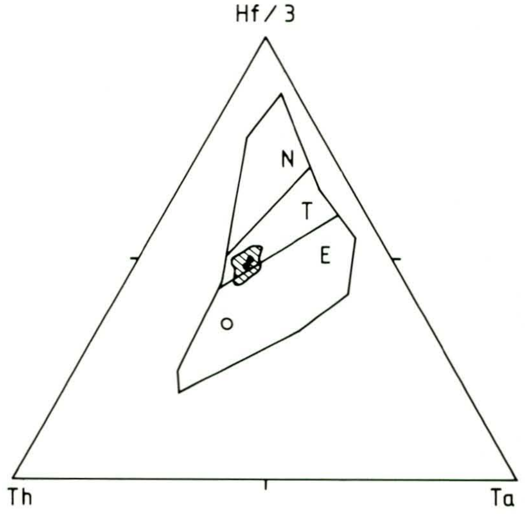

Fig. 4. Th-Hf-Ta plot (Wood 1980) showing the location of representative samples RZ4 and RZ10 (dots) from Corrovarre. N - N-MORB: T - T-MORB: E - E-MORB and within-plate tholeiitic products. The shaded area shows the plot of the Palaeogene Upper Series tholeiitic dykes and lavas from the Vøring Plateau (see text for discussion). Circle - average value of Särv Nappe tholeiitic dykes (Solyom et al. 1985).

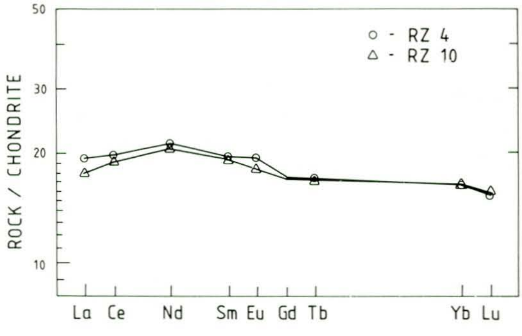

Fig. 5. Chondrite-normalised REE patterns for the Corrovarre samples RZ4 and RZ10.

tholeiitic basalt dykes intruding the miogeoclinal sandstones of the Middle Allochthon; i.e., in the Särv and Leksdal Nappes and equivalents of Central Norway and Sweden (Andreasson et al. 1979, Solyom et al. 1979). In certain areas, however, a subordinate group of dolerite dykes has been identified with alkaline or mildly alkaline to 'transitional' (to within-plate) petrochemical characteristics (Andreasson et al. 1979, Gayer et al. 1985, Solyom et al. 1985). Dykes of both groups are conside-

Table 2. Average major and trace elements of the Corrovarre dolerites, compared with means for ocean-floor tholeiites (OFB) and continental tholeiites (CON).

	Mean	*S.D.*	*Range*	*OFB*[1]	*CON*[1]
SiO_2	48.06	.57	1.82	49.91	48.81
TiO_2	1.97	.18	.56	1.43	2.47
Al_2O_3	15.07	.34	1.60	16.20	14.41
Fe_2O_3	1.35	1.18	4.33	–	13.20[3]
FeO	9.95	1.13	4.08	10.24[2]	–
MgO	7.31	.48	1.86	7.74	5.96
CaO	11.18	.33	1.27	11.42	10.05
Na_2O	2.27	.19	.66	2.82	2.90
K_2O	.37	.16	.53	0.24	0.95
MnO	.23	.02	.07		
P_2O_5	.14	.03	.14		
H_2O^-	.08	.08	.15		
CO_2	.25	.18	.51		
H_2O+	1.25	.38	1.14		
(n)	(13)				
(ppm)					
Zr	130	20	52	92	149
Y	43	4	15	30	25
Sr	185	22	68	131	401
Rb	9	3	c.15	3	15
Zn	119	21	68	–	–
Cu	70	8	48	73	99
Ni	71	25	93	106	68
Cr	235	54	156	310	139
Ba	62	24	79	8	338
Nb	6	2	c. 5	5	25

1. Mean values, OFB and CON, from Pearce (1975).
2. Total Fe as FeO.
3. Total Fe as Fe_2O_3.

red to be of Late Precambrian age, cutting tillites in the Särv Nappe. $^{40}Ar/^{39}Ar$ dating has yielded an intrusion age of 665 ± 10 Ma (Claesson & Roddick 1983) for one dyke in the main group of Ottfjället (Särv) tholeiites, but Rb-Sr whole-rock dates are older (720-745 Ma: Claesson 1976, Krill 1980). In NE Finnmark, metadolerites on Varanger Peninsula have yielded K-Ar ages of c.640 Ma (Beckinsale et al. 1975). These dykes also show 'transitional' geochemical signatures (Roberts 1975).

There is general agreement that the mafic dyke swarms reflect a rift-related magmatism associated with continental distension and fracturing, leading to ultimate break-up. In theory, and hypothetical models (e.g. Solyom et al. 1985), the alkaline dykes are considered to have intruded at an earlier stage than the main tholeiites, at a time when the distending crust was thickest and magma contamination at a maximum. This is recorded to a certain extent in the geochemical data from Finnmark (Gayer et al. 1985, D. Roberts unpubl. results), dykes in the highest thrust-sheets in the KNC showing the more consistant MORB signatures.

In Troms, the Corrovarre dykes, in the structurally highest and most outboard, miogeoclinal part of the KNC, accord with this general picture and have yielded a comparatively young Sm-Nd mineral age of 582 ± 30 Ma (Zwaan & van Roermund 1990). The Corrovarre tholeiites, moreover, show little or no evidence, in their chemistry and $^{87}Sr/^{86}Sr$ ratio, of crustal contamination. Like the Tertiary lavas and dykes of the Vøring Plateau (Viereck et al. 1988), they may reflect magma generation from a secondarily, slightly LIL-element enriched, but primarily depleted mantle source, presumably intruding through a comparatively thin continental crust. The few boudined and altered mafic dykes at Corrovarre which clearly predate the main swarm (p.) may be representative of an earlier phase in the protracted rifting process. No chemical data are at present available from these particular dykes.

It has been argued, from stratigraphic and isotopic evidence in the Newfoundland Appalachians (Williams & Hiscott 1987), that continental break-up and sea-floor spreading in that part of the orogen began at about 570-550 Ma, with rifting starting some 50 m.y. earlier. In the southern Appalachians the phase of rifting lasted longer. Accepting the strong similarity of chemical signature between the Corrovarre dolerites and the Vøring Plateau Tertiary tholeiites, and the fact that the Vøring Plateau rocks mark the final opening of the NE Atlantic, then it is reasonable to infer that the Corrovarre rift-related magmatism, at around 580 Ma, occurred at just a short time before the initiation of sea-floor spreading along this particular segment of the continental margin. This also broadly coincides with a world-wide transgression, in Early Cambrian time. Spreading was probably not synchronous along the variably indented rifted margin, and may not have commenced until later in the Cambrian period in some segments.

Conclusions

The geochemistry of metadolerite dykes in the Corrovarre Nappe denotes a tholeiitic magmatism, with several element variation diagrams indicating OFB affinities. Examination of the analytical data, however, shows certain departures from average element values for

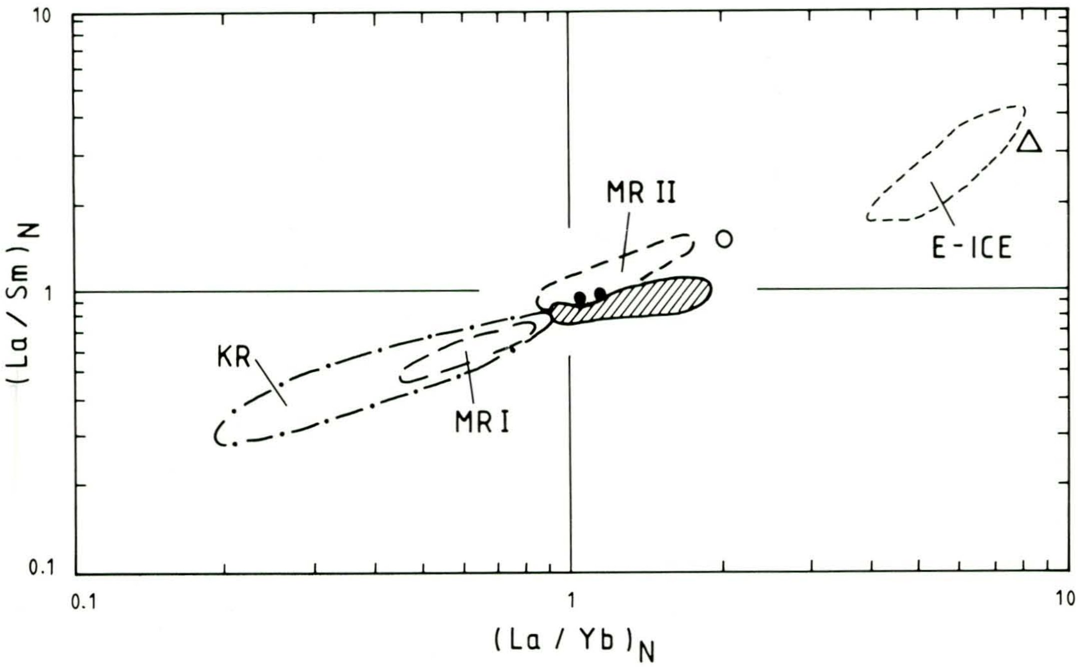

Fig. 6. A chondrite-normalised plot of ratios La/Sm vs. La/Yb. The Corrovarre samples RZ4 and RZ10 are marked as dots. The lined area is that of the Palaeogene Upper Series, T-MORB tholeiitic lavas and dykes from the Vøring Plateau (Viereck et al. 1988). Fields for some Recent basalts shown for comparison are: - KR - Kolbeinsey Ridge: MRI - Mohns Ridge from 73° to 74°N: MRII - Mohns Ridge between 240 km N of Jan Mayen and 74°N. E-ICE - Miocene flows, eastern Iceland. Circle - average of representative Särv Nappe tholeiitic dykes (Solyom et al. 1985). Triangle - average of representative Särv Nappe 'mildly alkaline' tholeiitic dykes (Solyom et al. 1985).

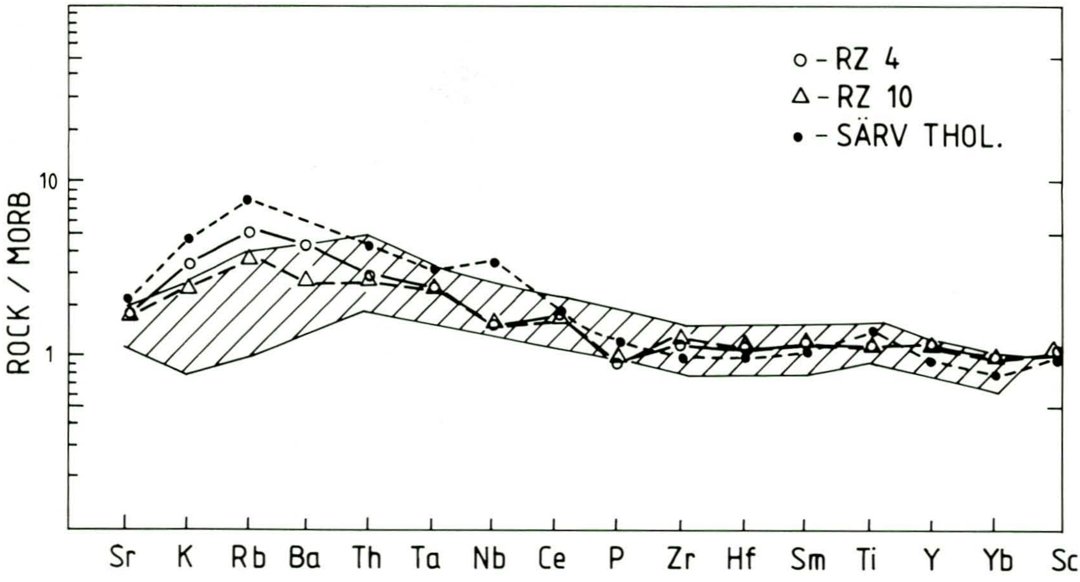

Fig. 7. MORB-normalised trace element patterns for Corrovarre samples RZ4 and RZ10, compared with the average for representative Särv Nappe tholeiitic dykes (Solyom et al. 1985). The lined area shows the range for most of the Palaeogene Upper Series T-MORB lavas and dykes from the Vøring Plateau (Viereck et al. 1988).

ocean-floor rocks, and close scrutiny in fact reveals a bias towards T-MORB affinities with fairly flat, chrondrite-normalised, REE patterns and a $(La/Yb)_N$ of just over 1. The low initial $^{87}Sr/^{86}Sr$ ratio, 0.7030, and lack of Th enrichment suggest that the magma was apparently not contaminated to any noticeable extent during its upward passage from a slightly LIL-enriched, but primarily depleted mantle source.

Element concentrations and ratios, and the low initial Sr ratio are comparable to those from the Tertiary T-MORB tholeiitic lavas and dykes from the Vøring Plateau. It is therefore suggested that the Corrovarre dykes, Sm-Nd-dated to 582±30 Ma, penetrated a continental crust which had thinned considerably since the time of initial rifting; and also that the dykes intruded at a fairly short time before the actual inception of sea-floor spreading along this particular segment of the Baltoscandian margin. Elsewhere, spreading may not have commenced until later in the Cambrian period.

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References

Andreasson, P.G., Solyom, Z. & Roberts, D. 1979: Petrochemistry and tectonic significance of basic and alkaline-ultrabasic dykes in the Leksdal Nappe, northern Trondheim Region, Norway. *Nor. geol. unders. 348,* 47-72.

Beckinsale, R.D., Reading, H.G. & Rex, D.C. 1975: Potassium-argon ages for basic dykes from East Finnmark: stratigraphical and structural implications. *Scott. J. geol. 12,* 51-65.

Binns, R.E. & Gayer, R.A. 1980: Silurian or Upper Ordovician fossils at Guolasjav'ri, Troms, North Norway. *Nature 284,* 53-55.

Claesson, S. 1976: The age of the Ottfjället dolerites of the Särv Nappe, Swedish Caledonides. *Geol. Fören. Stockh. Förh. 98,* 370-374.

Claesson, S. & Roddick, K.C. 1983: $^{40}Ar/^{39}Ar$ data on the age and metamorphism of the Ottfjället dolerites, Särv Nappe, Swedish Caledonides. *Lithos 16,* 61-73.

Dallmeyer, R.D. 1988a: Polyorogenic $^{40}Ar/^{39}Ar$ mineral age record within the Kalak Nappe Complex, northern Scandinavian Caledonides. *J. geol. Soc. London 145,* 705-716.

Dallmeyer, R.D. 1988b: Polyphase tectonothermal evolution of the Scandinavian Caledonides. *Geol. Soc. Spec. Publ. 38,* 365-379.

Gayer, R.A. & Roberts, J.D. 1971: The structural relationships of the Caledonian nappes of Porsangerfjord, West Finnmark, N. Norway. *Nor. geol. unders. 269,* 21-67.

Gayer, R.A., Powell, D.B. & Rhodes, S. 1978: Deformation against metadolerite dykes in the Caledonides of Finnmark, Norway. *Tectonophysics 46,* 99-115.

Gayer, R.A., Humphreys, R.J., Binns, R.E. & Chapman, T.J. 1985: Tectonic modelling of the Troms and Finnmark Caledonides based on high-level igneous rock geochemistry. *In* Gee, D.G. & Sturt, B.A. (eds.) *The Caledonide orogen - Scandinavia and related areas.* John Wiley & Sons, Chichester, 931-952.

Hughes, C.J. 1973: Spilites, keratophyres and the igneous spectrum. *Geol. Mag. 109,* 513-527.

Krill, A.G. 1980: Tectonics of the Oppdal area, Central Norway. *Geol. Fören. Stockh. Förh. 102,* 523-530.

Lindahl, I. 1974: *Økonomisk geologi og prospektering i Vaddas, Rieppefeltet, Nord-Troms.* Unpubl. Dr. ing. thesis, Univ. of Trondheim, 316 pp.

Miyashiro, A. 1975: Volcanic rock series and tectonic setting. Ann. Rev. Earth Planet. Sci. 3, 251-269.

Neumann, E.R. & Schilling, J.G. 1984: Petrology of basalts from the Mohus-Knipovich Ridge; the Norwegian-Greenland Sea. *Contr. Min. Petrol. 85,* 209-223.

Pearce, J.A. 1980: Geochemical evidence for the genesis and eruptive setting of lavas from Tethyan ophiolites. *Proc. Int. Ophiolite Symp. Cyprus 1979,* 221-272.

Pearce, J.A. & Cann, J.R. 1973: Tectonic setting of basic volcanic rocks de termined using trace element analyses. *Earth Planet. Sci. Lett. 19,* 290-300.

Pearce, T.H., Gorman, B.E. & Birkett, T.C. 1975: The TiO_2-K_2O-P_2O_5 diagram: a method of discriminating between oceanic and non-oceanic basalts. *Earth Planet. Sci. Lett. 24,* 419-426.

Roberts, D. 1975: Geochemistry of dolerite and metadolerite dykes from Varanger Peninsula, Finnmark, North Norway. *Nor. geol. unders. 322,* 55-72.

Roberts, D. 1988: Reinterpretation of Finnmarkian deformation on western Sørøy, northern Norway: some comments. *Nor. Geol. Tidsskr. 68,* 309-312.

Roberts, D. & Gale, G.H. 1978: The Caledonian-Appalachian Iapetus Ocean. *In* Tarling, D.H. (ed.) *Evolution of the Earth's crust.* Academic Press, London, 255-342.

Solyom, Z., Gorbatschev, R. & Johansson, I. 1979: The Ottfjäll dolerites: geochemistry of the dyke swarm in relation to the geodynamics of the Caledonide orogen of central Scandinavia. *Sver. geol. unders. C756.*

Solyom, Z., Andreasson, P.G. & Johansson, I. 1985: Petrochemistry of Late Proterozoic rift volcanism in Scandinavia. II - The Särv Dolerites (SD) - volcanism in the constructive arms of Iapetus. *Univ. Lund Publ. in Geology 35,* 42 pp.

Stephens, M.B., Furnes, H., Robins, B. & Sturt, B.A. 1985: Igneous activity within the Scandinavian Caledonides. *In* Gee, D.G. & Sturt, B.A. (eds.) *The Caledonide orogen - Scandinavia and related areas.* John Wiley & Sons, Chichester, 623-656.

Sturt, B.A. & Ramsay, D.M. 1965: The alkaline rocks of the Breivikbotn area, Sørøy, northern Norway. *Nor. geol. unders. 231,* 142 pp.

Upton, B.G.J., Emeleus, C.H. & Beckinsale, R.D. 1984: Petrology of the northern East Greenland Tertiary flood basalts: evidence from Hold with Hope and Wollaston Forland. *J. Petrol. 25,* 151-184.

Viereck, L.G., Taylor, P.N., Parson, L.M., Morten, A.C., Hertogen, J., Gibson, I.L. & the ODP Leg 104 Scientific Party 1988: Origin of the Palaeogene Vøring Plateau volcanic sequence. *Geol. Soc. Spec. Publ. 39,* 69-83.

Williams, H. & Hiscott, R.N. 1987: Definition of the Iapetus rift-drift transition in western Newfoundland. *Geology 15,* 1044-1047.

Wood, D .A. 1980: The application of a Th-Hf-Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crustal contamination of basaltic lavas of the British Tertiary Volcanic Province. *Earth Planet. Sci. Lett. 50,* 11-30.

Wood, D.A., Jorun, J.L. & Treuil, M. 1979: A re-appraisal of the use of trace elements to classify and discriminate between magma series erupted in different tectonic settings. *Earth Planet. Sci. Lett. 45,* 326-336.

Zwaan, K.B. 1988: Nordreisa, berggrunnsgeologisk kart - M 1:250 000. *Nor. geol. unders.*

Zwaan, K.B. & Roberts, D. 1981: Feltforhold og geokjemien av diabasganger på Corrovarre, Kvænangen, Nord-Troms: en foreløpig rapport. *Unpubl. NGU-report,* 14 pp.

Zwaan, K.B. & van Roermund, H.L.M. 1990: A riftrelated mafic dyke swarm in the Correvarre Nappe of the Caledonian Middle Allochthon, Troms, North Norway, and its tectonostratigraphic significance. *Nor. geol. unders. Bull. 419,* 00 00.

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