Rb-Sr age determination of the Kattsund-Koster dyke swarm in the Østfold-Marstrand belt of the Sveconorwegian Province, W Sweden – SE Norway

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The Kattsund-Koster dyke swarm in the Sveconorwegian Province of the Baltic shield is a dense swarm of evolved tholeiites derived from N-MORB type parental magmas selectively contaminated with K, Rb and Ba. In the Koster archipelago the NNE-SSW trending dyke swarm enters a ductile sinistral shear zone in the margin of which the dolerites are partially recrystallised metadolerites. In the highly deformed interior of the shear zone the dykes are completely recrystallised to amphibolites.

Rb-Sr isotope analyses have been carried out on samples of the dolerites and the partially recrystallised metadolerites. A profile through one dolerite yields a whole rock age of 1421 ± 25 Ma with a $(^{87}Sr/^{86}S)_0$ ratio of 0.7028 ± 0.0002. Samples of the dolerites and partially recrystallised metadolerites lie close to the isochron.

The age of 1421 Ma indicates that the dyke swarm is the oldest member of a 1420–1300(?) Ma old bimodal suite of tholeiites and potassic granites, which were injected into the crust under tensional conditions.

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Introduction

The Sveconorwegian Province in the southwestern part of the Baltic Shield (Fig. 1) is seen by numerous authors as the counterpart of the Grenville Province in North America (e.g. Wynne-Edwards and Hasan 1970; Patchett et al. 1978; Berthelsen 1980; Baer 1981; Gower and Owen 1984). A recent review of the evolution of the Norwegian part of the province is given by Demaiffe and Michot (1985).

During the 1200-850 Ma old Sveconorwegian orogeny much strain was localised in major shear zones that cut up the Sveconorwegian Province into large crustal segments (Berthelsen 1980). The segments in the eastern part of the province, i.e. east of the Kristiansand-Bagn shear zone (Hageskov 1981), consist essentially of pre-Sveconorwegian crustal material, the history of which is incompletely known. One of these segments is the Kongsberg-Bamble-Østfold Segment (Fig. 1).

In the Østfold – Marstrand belt (Daly et al. 1983), which forms the eastern part of the Kongsberg-Bamble-Østfold segment (Hageskov 1981), the youngest rocks affected by Sveconorwegian reworking under amphibolite facies conditions are potassic granites (now gneisses) and numerous mafic dykes and sheets. The mafic intrusives include the Orust dykes (Daly et al. 1983), the younger mafic dykes and sheets in Østfold (Berthelsen 1970; Hageskov 1978; Hageskov and Pedersen 1981), the Kattsund dykes (Hageskov 1978) and the Koster dykes (DeGeer 1899; Asklund 1950; Hageskov 1985). It used to be thought that all these mafic intrusives were about the same age (around 1200 Ma) and that they were first deformed and metamorphosed during the Sveconorwegian orogeny. The mafic intrusives are now mainly transformed to amphibolites.

The Orust dykes, seen in the southern part of the Østfold-Marstrand belt, are a suite of mafic to ultramafic amphibolites followed by some dykes of intermediate and acid compositions (Daly et al. 1983). It has been suggested that the Orust dykes are the equivalents of the Koster and Kattsund dykes (Daly et al. 1983). The Orust dyke suite however differs from the Kattsund and the Koster dykes by including intermediate and

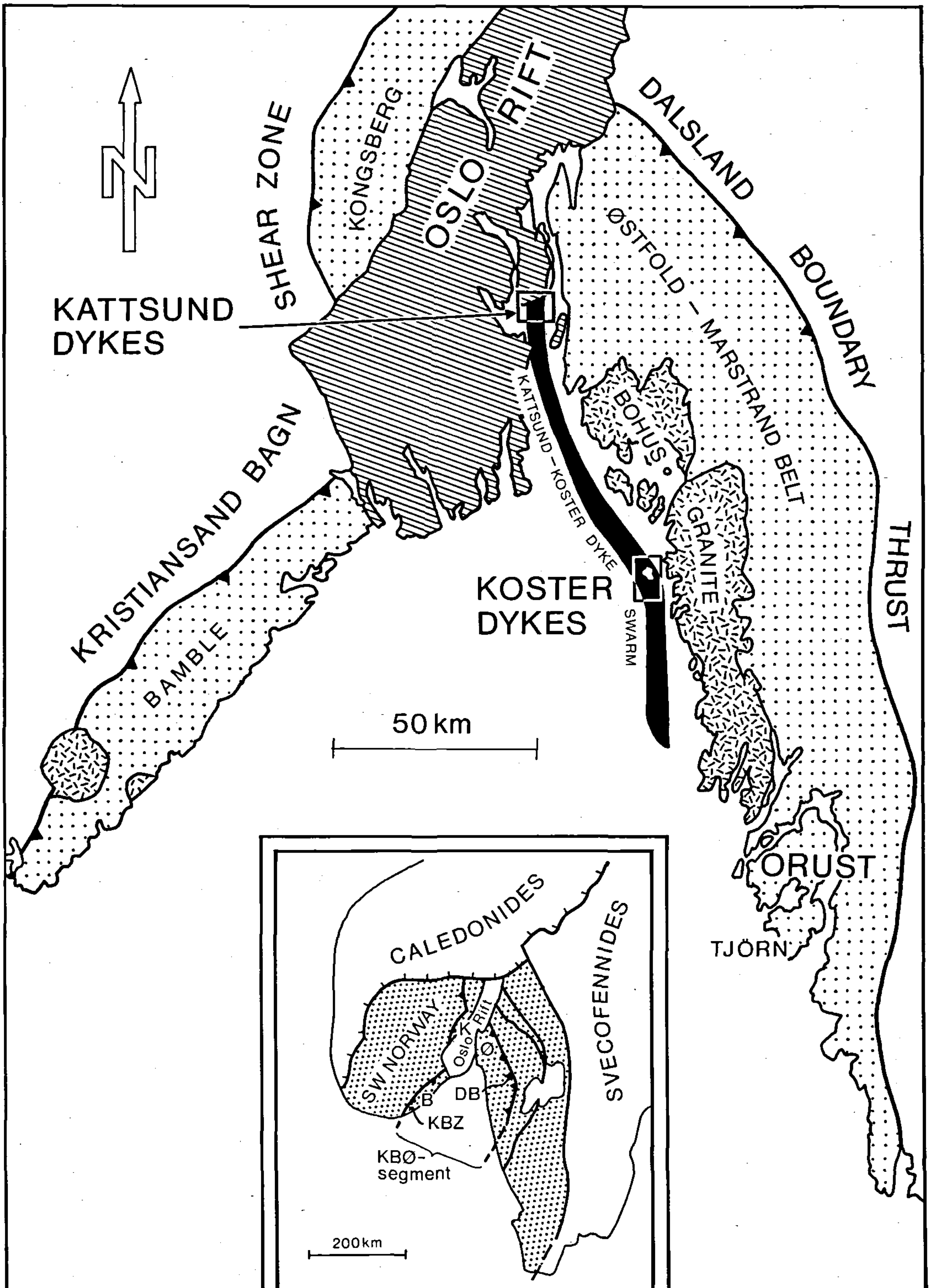

Fig. 1. The Kattsund-Koster dyke swarm and the Kongsberg-Bamble-Østfold segment of the Sveconorwegian Province (shown in the inset map as the KBØ segment). KBZ = Kristiansand-Bagn shear zone, DB = Dalsland boundary thrust.

acid compositions. The Orust dykes postdate the Assmunderöd-Myckleby augen granite and the Hällevikstrand amphibolite (Daly et al. 1983), both of which yield a Rb-Sr whole rock age of about 1400 Ma (Daly et al. 1979). The minimum age of the dykes is given by a metamorphic age of 1090 Ma obtained by Rb-Sr whole rock age determination on the dykes themselves (Daly et al. 1983).

The younger mafic dykes and sheets in Østfold, including the globuliths of Berthelsen (1970), cut the Moss-Filtvet augen gneiss (granite) which yields a Rb-Sr whole rock age of 1320 ± 22 Ma (Hageskov and Pedersen 1981). This age was interpreted as the time of the formation of the granite. The dykes and sheets have been involved in a metamorphic event dated by the Rb-Sr whole rock method at 1015 Ma (Hageskov and Pedersen, op. cit.). Some of the sheets are net-veined acid-basic intrusions one of which has been investigated by the Rb-Sr method (Hageskov and Pedersen 1986). From this study it appears that mixing between a highly evolved tholeiitic magma and a potassic quartz monzonitic magma (similar to the basic members of the Moss-Filltvet granite) may have taken place 1300 Ma ago.

Hageskov (1984, 1985, 1987) correlated the Kattsund dykes of Oslofjorden (Hageskov 1978) with the Koster dykes of Bohus Län (DeGeer 1899, Asklund 1950, Hageskov 1984, 1985), and grouped these together as the the Kattsund-Koster dyke swarm. This swarm is a dense swarm of olivine tholeiitic and quartz tholeiitic dykes. In the Koster archipelago the dyke swarm enters a ductile NW-SE trending sinistral shear zone which follows the swarm northwards. In the shear zone the dykes are heavily deformed and completely recrystallised to amphibolites, but outside the shear zone they are undeformed and almost fresh.

The age of the shear zone is not exactly known, but it is thought to be about 1000 Ma. Rb-Sr age determination on the host rock of the Kattsund dykes yielded an age of 1225 Ma (Hageskov and Pedersen 1981). This age was believed to be the maximum age of the Kattsund dyking. However, the age of the dyke swarm presented in this paper as well as ongoing studies indicate a much older age.

The age of the Kattsund-Koster dykes is of considerable interest because: 1) the dykes are suggested to be structural markers for Sveconorwegian tectonic-metamorphic events, 2) the dyking indicates an important episode of tension and magmatism which could be contemporary with similar events in the Grenville province of North America. In this paper Rb-Sr data on both the fresh and the partially recrystallised Koster dykes are presented.

The Kattsund-Koster dyke swarm

The Kattsund-Kloster dyke swarm is suggested to be related to an intra-continental spreading zone in which the dyke swarm developed by continued injection of tholeiitic magma into simple dilatational joints (Hageskov 1985, 1987). In the Koster archipelago, where undeformed dykes are seen, the intensely dyked area is at least 8 km wide. In this the crust is regularly dyked by about 700 dykes of mean width of 2.2 m (measurements on undeformed dykes). This dyking caused a crustal extension of 15–20% in the Koster area.

The dyke swarm consists exclusively of tholeiitic dykes and it includes highly evolved dyke members (Hageskov 1987). The parental magmas of both the Koster and the Kattsund dykes were olivine tholeiitic and can be characterised as normal (N) MORB contaminated with K, Rb and Ba. Fractionation of olivine, clinopyroxene and plagioclase caused a strong enrichment of total iron and titanium and of incompatible minor and trace elements, suggesting fractionation at shallow level.

According to the chemical investigations (Hageskov 1987) the Kattsund dyke magma appears to be more contaminated with respect to K, Rb and Ba than the Koster dyke magma, but also other element concentrations show differences. Thus contents of Al, Ti, Ca, P, La, U, Y, Nb, Ni and Cr are higher in the Koster dykes, while the contents of Si and V are lower. These chemical differences show that the Koster dyke magma was probably derived from a mantle less depleted/melted than the mantle from which the Kattsund dykes were derived, and that the Koster and the Kattsund dykes were tapped from separate reservoirs; there is evidence suggesting that these reservoirs were refilled from time to time (Hageskov 1987).

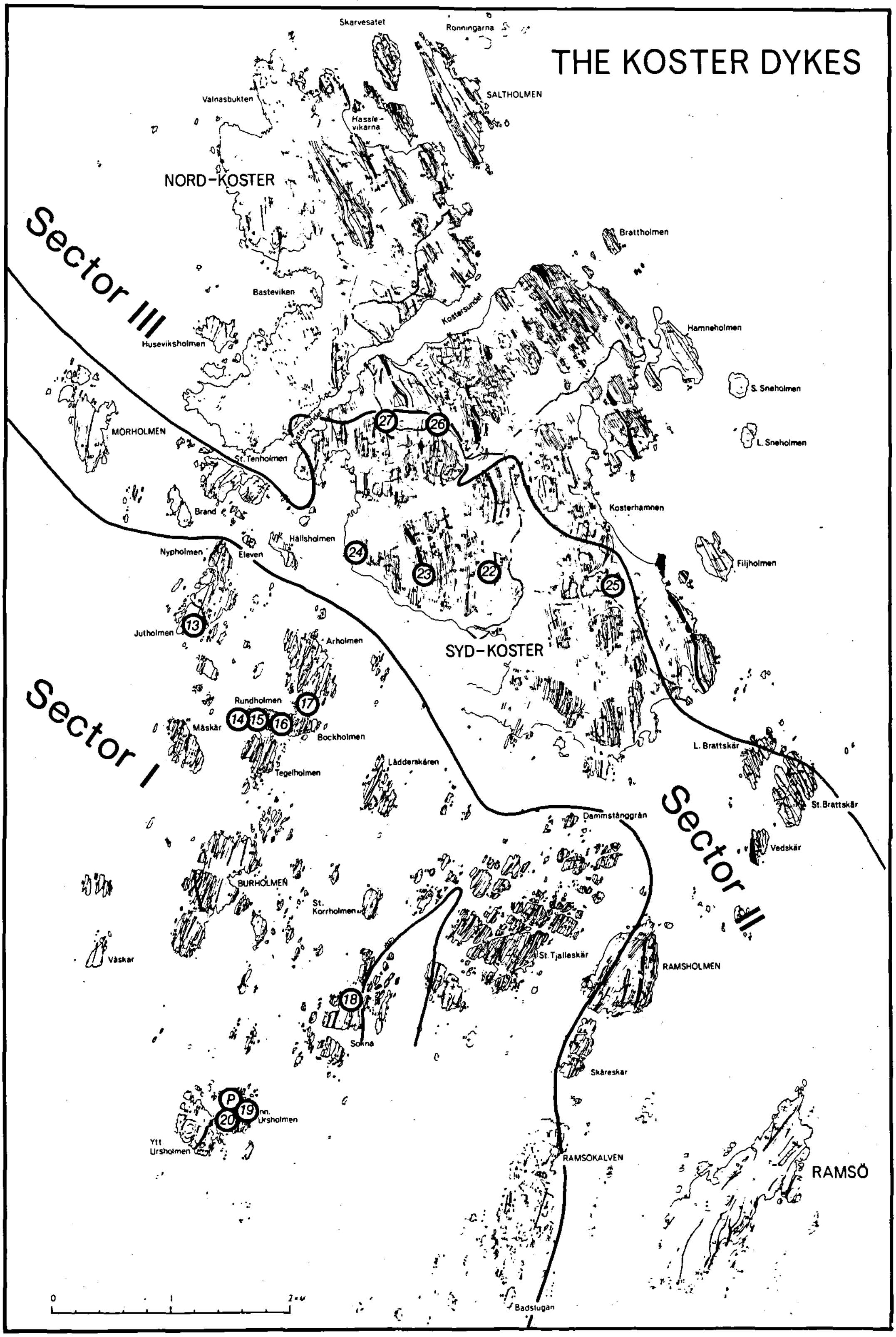

Fig. 2. Map of the Koster archipelago showing the Koster dykes, the sector division and the locations of the samples. P indicates the profile.

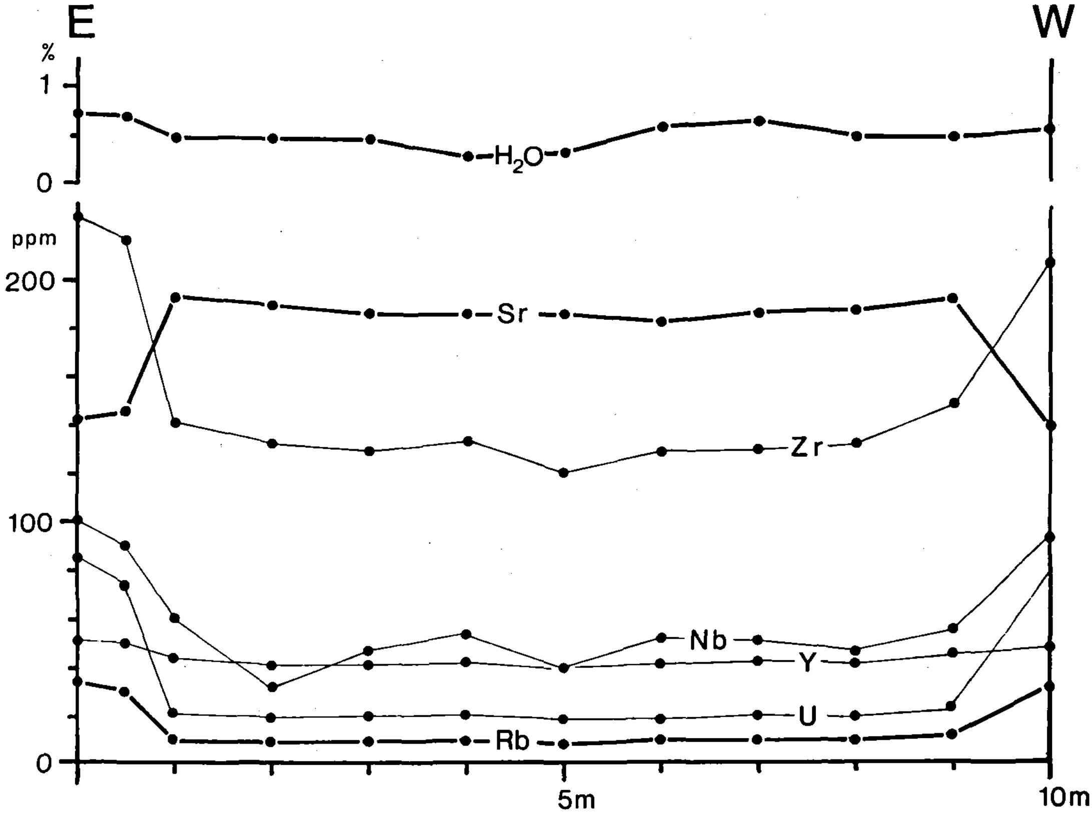

Fig. 3. Variation of selected elements across the 10 m wide sector I dyke investigated. The ppm values shown for Nb and U are 10 respectively 100 times to high.

The sector division of the Koster archipelago

In the small Koster archipelago (11 × 6.5 km) the undeformed and almost fresh dykes can be followed over a distance of less than 3 km into the strongly deformed and totally recrystallised amphibolites of the ductile NW-SE trending shear zone. The area with unaffected dykes was named sector I (Hageskov 1984), whereas the area covering intensely deformed and synkinematically recrystallised dykes was called sector III. Between these two sectors there is a transitional zone sector II, where the dykes are deformed and transformed to metadolerite with preserved doleritic texture. The sector division is shown in Fig. 2.

Sector I.

In this sector undeformed and almost fresh dyke rocks occur, and it is seen that the dyke swarm comprises NNE-SSW trending dykes (the NNE dykes) steeply dipping towards WNW. The NNE dykes cut a few older NE-SW and NW-SE trending dykes, which possibly were emplaced in conjugate fractures (Hageskov 1985).

Most of the dykes are aphyric dolerites, but about 5 to 10% are porphyritic with small (< 1 cm) phenocrysts of olivine and/or plagioclase. The dykes show sharp, chilled margins in contact with the host gneiss. The chilled margins may be porphyric with phenocrysts of olivine and plagioclase. Mineralogically the dyke rock is composed of plagioclase (An $_{75\text{-}35}$), clinopyroxene, ± olivine, ± orthopyroxene, hornblende, biotite, apatite, ilmenite, ± pyrrhotite, ± pyrite, titanomagnetite and zircon. Olivine in contact with plagioclase has reacted to form a double corona of orthopyroxene and hornblende. The olivine may to a varying degree have been replaced by biotite-ilmenite symplectites. This reaction presumably took place during or immediately after the late magmatic crystallisation, as proposed by

Zeck et al. (1982). Orthopyroxene is only seen as a product of these reactions. The plagioclase is dusty brown and shows normal zoning in places followed by oscillations. In chilled margins the plagioclase may be skeletal. Locally, incipient metamorphic reactions in the form of alteration of the clinopyroxene to amphibole are seen.

The isotopic study in this paper treats the Rb-Sr isotope distribution across a 10 meter thick sector I dyke. The dyke has been studied petrographically and geochemically by Hageskov (1987). The dyke rock in the profile is a fresh olivine bearing dolerite in which coronas have developed in a late magmatic stage by olivine-plagioclase reactions. In the chilled margins a slight alteration is seen, which formed minute grains of biotite and a pale green hornblende. However, both small phenocrysts of olivine and oscillatoric zoned plagioclase as well as the plagioclase and clinopyroxene of the groundmass is rather well preserved. The slight alteration of the chilled margins could have taken place in connection with the cooling of the dyke, or it could be a slight effect of the amphibolite facies metamorphism associated with the shear zone.

The geochemical investigation shows a symmetrical element variation across the dyke and that the marginal parts of the dyke consist of a slightly more evolved tholeiite than the rest of dyke. Incompatible and immobile trace elements as Nb, Y, Zr and La are enriched in the chilled margins relative to the dyke centre (Fig. 3). Rb is also higher in the chilled margins than in the centre of the dyke, whereas Sr is lower. The original magmatic distribution of the elements indicates that Rb had to be higher in the contacts, but it is hard to decide whether the contacts are also contaminated by Rb.

Sector II.

The NNE trending dykes continue northward into sector II where they generally have a N-S trend. In connection with this rotation minor dextral shears have been located in the dyke margins and in thin dykes which reacted imcompetently. In the dyke margins a 1 cm wide foliated zone commonly developed as the result of the shearing. In the incompetent minor dykes a sigmoidal foliation is developed, and these dykes are recrystallised throughout. Otherwise the dyke rocks still show doleritic texture and chilled mar gins are still visible. The dyke rock in this sector is a metadolerite, which to a varying degree has been amphibolitised. Thus some dykes show essential amounts of primary minerals in contrast to others that are nearly completely recrystallised to amphibolite. The olivine is replaced by complex aggregates of ilmenite, biotite, hornblende, ± orthopyroxene and ± sphene.

Sector III.

Whereas the dykes in sector II are situated in the marginal part of the ductile shear zone, the dykes of sector III have undergone further anticlockwise rotation and are now situated in the highly strained, interior part of the shear zone. All dykes have been transformed completely to recrystallised amphibolites without any primary minerals. The dyke rock has a pronounced linear stretching fabric, having a lineation defined by plagioclase aggregates and hornblende nematoblasts. This lineation is in places overgrown by synkinematic garnet. The constriction deformation seen in the shear zone was formed by a composite, simple shear-pure shear mechanism involving a horizontal sinistral shear of at least 10.9. The strain axes of the finite strain ellipsoid (volume = 1) are: X= 7.07, Y= Z= 0.18. The deformation took place without significant volume change; a volume increase of 1% has been calculated (Hageskov 1985).

The amphibolite essentially consists of plagioclase (An_{35-25}), hornblende and minor biotite that has been more or less replaced by chlorite. No titanomagnetite is present. Fresh ilmenite occurs in some dykes, but in other dykes it is altered to sphene.

Rb-Sr age determinations

Sampling

The samples selected for Rb-Sr age determination were collected in sectors I and II (see Fig. 2). In sector I samples were collected along a profile across a single 10 metre wide dyke and from the central part of 8 aphyric dykes. The samples from sector II were taken in originally aphyric dykes of a width ≥ 2.5 metres. Studies on the chemical changes connected with the metamorphism of the

Table 1. Analytical results: whole rock samples from profile.

Sample no.	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
1	30.5	134	0.655±7	0.7164±2
2	28.2	140	0.585±6	0.7148±2
3	10.0	185	0.156±4	0.7060±2
4	8.6	184	0.135±4	0.7059±2
5	9.1	177	0.149±4	0.7057±2
6	9.4	181	0.151±4	0.7058±2
7	8.3	181	0.132±4	0.7056±2
8	9.6	179	0.155±4	0.7058±2
9	9.8	183	0.155±4	0.7060±2
10	8.5	184	0.134±4	0.7057±2
11	10.1	189	0.155±4	0.7059±2
12	31.4	137	0.663±7	0.7161±2

Age: 1421 ± 25 Ma, $(^{87}Sr/^{86}Sr)_0$: 0.7028 ± 0.0002, MSWD: 0.63

sector II and III dykes show that dykes of these widths have a well preserved primary igneous chemistry (Hageskov 1987).

Special attention was given to the profile where samples were taken from both chilled margins and at following distance to the eastern margin: 1/2 m, 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 7 m, 8 m and 9 m. These samples have all been used in the whole rock age determination. From the two samples in the dyke centre both plagioclase (of various densities) and clinopyroxene have been separated.

Analytical technique

The $^{87}Sr/^{86}Sr$ ratio measurements were carried out on a Variant MAT Th-5 mass spectrometer. The isotope ratios were normalised to a $^{87}Sr/^{86}Sr$ value of 0.7080 ($^{88}Sr/^{86}Sr$: 8.3752) for the Eimer and Amend $SrCo_3$. Rb/Sr ratios were determined by X-ray fluorescence analysis using a Philips automatic PV 1400 with G-2 as standard (Rb/Sr: 0.355). All errors are given at the 1-sigma level. The concentration calculations for Rb and Sr in the whole rock dyke samples were performed with the help of the mass absorption coefficients of Heinrich (1966). The Sr concentrations in the minerals investigated were determined by conventional isotope dilution technique (^{84}Sr spike). Analytical data are given in Tables 1, 2 and 3.

Age calculations were carried out by the program of Williamson (1968) using a ^{87}Rb decay constant of 1.42×10^{-11} a^{-1}. Errors in age and initial Sr isotope ratio are given at the 95% confidence level.

Results

From the profile (including all samples) a whole rock age of 1421 ± 25 Ma with a $(^{87}Sr/^{86}Sr)_0$ ratio of 0.7028 ± 0.0002 and a MSWD of 0.63 has been obtained (Fig. 4). Analysed minerals from two of the samples (nos 5 and 6) are seen to plot in a characteristic way in the isochron diagram. The plagioclases with densities above 2.69 fall within the experimental error on the isochron and the plagioclases with densities between 2.67 and 2.69 fall above the isochron while the clinopyroxenes fall below the isochron.

Considering the regional samples (Fig. 5) it is clear that most of the samples from sector I fall on the isochron or very close to it. Exceptions are samples no 18 which falls below the isochron, indicating a lower limit for the $(^{87}Sr/^{86}Sr)_0$ ratio of 0.7018, and samples nos 19 and 20 which fall

Table 2. Analytical results: mineral samples from profile.

Sample no.	density	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
5cpx		4.4	13.6	0.936	0.7179±2
5p2	2.67–2.69	4.4	430	0.030	0.7038±2
5p3	2.69–2.75	0.6	374	0.005	0.7029±2
5p4*	2.69–2.75	2.4	339	0.020	0.7032±2
5p5	> 2.75	13.7	314	0.126	0.7054±2
6cpx1		5.2	14.3	1.055	0.7191±2
6cpx2		2.6	14.0	0.541	0.7092±2
6p2	2.67–2.69	8.6	431	0.058	0.7043±2
6p3	2.69–2.75	2.6	377	0.020	0.7032±2
6p4	> 2.75	5.6	129	0.124	0.7053±2

* magnetic

Table 3. Analytical results: regional collected samples.

Sample no.	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$(^{87}Sr/^{86}Sr)_0$
Sector I					
13	22.0	175	0.368± 5	0.7101±2	0.7026
14	18.7	148	0.374± 5	0.7099±2	0.7023
15	17.7	169	0.307± 4	0.7094±2	0.7031
16	38.5	140	0.806± 8	0.7190±2	0.7028
17	29.3	159	0.542± 5	0.7138±2	0.7028
18	34.6	129	0.776± 8	0.7176±2	0.7018
19	40.1	131	0.887± 9	0.7219±2	0.7038
20	69.7	128	1.559±13	0.7364±2	0.7046
Sector II					
22	22.1	142	0.442± 2	0.7106±2	0.7014
23	15.8	174	0.263± 4	0.7076±2	0.7022
24	48.0	154	0.901±13	0.7212±2	0.7028
25	27.4	153	0.518± 8	0.7124±2	0.7018
26	20.7	180	0.333± 5	0.7096±2	0.7028
27	7.1	182	0.133± 3	0.7047±2	0.7024

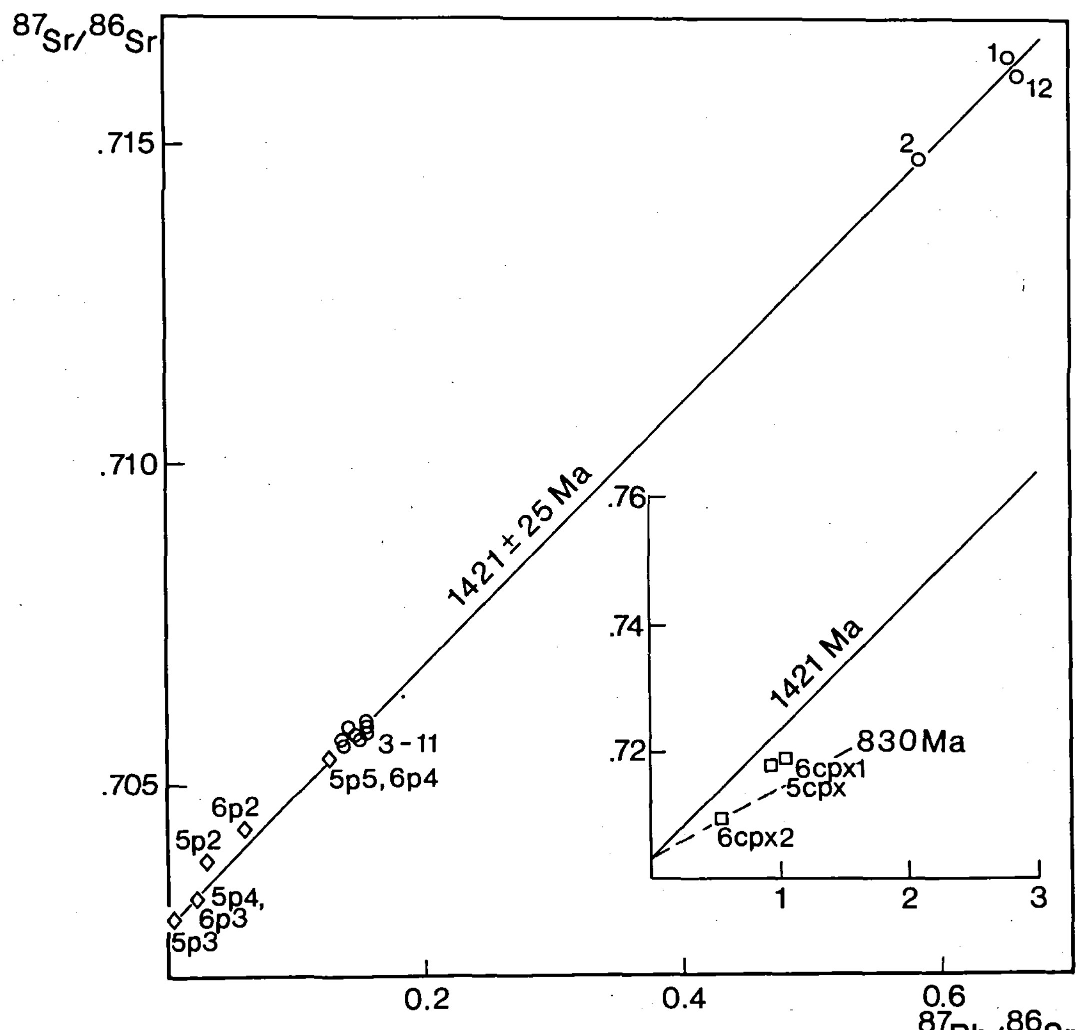

Fig. 4. Rb-Sr evolution diagram based on whole rock samples and minerals (circles = whole rock samples, diamonds = plagioclases, squares = clinopyroxenes).

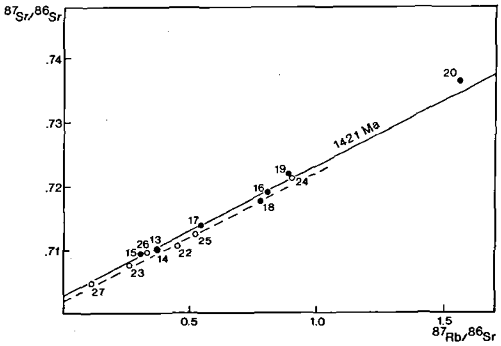

Fig. 5. Rb-Sr evolution diagram showing the profile isochron and the sector I and sector II samples. Filled-out circles: sector I, open circles: sector II. The broken line indicates the lower limit "isochron" drawn through samples no 18, which gives the lowest ($^{87}Sr/^{86}Sr)_0$ value.

above the isochron, indicating an upper limit for the ($^{87}Sr/^{86}Sr)_0$ ratio of 0.7046. All sector II samples (except no 22) fall between the isochron and the lower limit "isochron". Assuming an age for the dykes of 1421 Ma ($^{87}Sr/^{86}Sr)_0$ ratios have been calculated from all the regional samples (Table 3).

Discussion

The age of 1421 ± 25 Ma obtained on the whole rock samples from the profile across a single dyke is interpreted as the age of formation of the dyke swarm. As seen from the isochron diagram (Fig. 4) samples from the interior of the dyke (≤ 1 meter from the dyke margins) plot in a narrow group while the sample (no 2) collected 1/2 meter from the contact as well as the chilled margins have much higher $^{87}Rb/^{86}Sr$ ratios and accordingly higher $^{87}Sr/^{86}Sr$ ratios. These higher $^{87}Rb/^{86}Sr$ ratios are ascribed to the more evolved stage of the marginal part of the dyke, but a contamination of the chilled margin with Rb from the host gneiss cannot be excluded. This interpretation is strongly supported by the position of the heavy plagioclases (d > 2.69) from two samples which fall on the isochron. Clinopyroxenes fall below the isochron indicating a post-intrusive event which affected the dyke and most probably caused loss of radiogenic Sr from the clinopyroxene and gain of radiogenic Sr by the plagioclase with density between 2.67 and 2.69. This post-intrusive event may be as young as 830 Ma (Fig. 4).

The regional samples exhibit a distribution in the isochron diagram that is very close to the whole rock isochron from a single dyke. ($^{87}Sr/^{86}Sr)_0$ ratios of unaltered, or only slightly altered samples range from 0.7018 to 0.7046 for sector I samples, and from 0.7014 to 0.7028 for sector II samples. The most evolved samples yield the highest ($^{87}Sr/^{86}Sr)_0$ ratio, but otherwise there is no clear systematic variation in ($^{87}Sr/^{86}Sr)_0$ ratios (Fig. 6).

The age of the formation of the dyke swarm has important consequences for the understanding of the crustal development in the Østfold-Marstrand belt, and a revision of the event stratigraphy is necessary (Fig. 7). This revision, however, clears up some problems and gives a more coherent picture of the evolution of the belt. Some important consequences are:

1. The "younger" pre-Sveconorwegian mafic dykes and sheets, which are widespread in the belt, were injected at different times in the period 1420–1300 (?1200) Ma. The Kattsund-Koster dyke swarm is definitively older than the younger basic dykes and sheets of Østfold (i.e. those cutting the 1320 Ma old Moss-Filtvet augen gneiss) and the Orust dykes.
2. The regional orogenic event resulting in the formation of N-S trending folds in Østfold must be older than 1420 Ma. This event was previously regarded as younger than 1320 Ma (Hageskov and Pedersen 1981) but can now be correlated with the D_2 event known from the southern part of the Østfold-Marstrand belt (Park et al. 1979; Hageskov 1985; Samuelsson and Åhäll 1985).
3. The emplacement of the Kattsund-Koster dyke swarm appears to be an early event in a

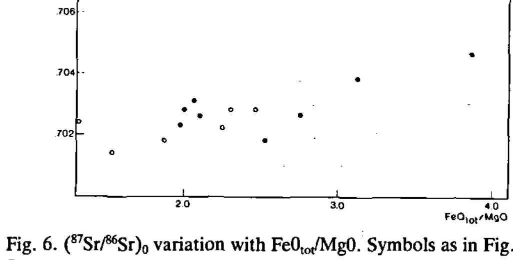

Fig. 6. ($^{87}Sr/^{86}Sr)_0$ variation with FeO_{tot}/MgO. Symbols as in Fig. 5.

	KOSTER AREA	WESTERN ØSTFOLD	BOHUS LÄN
SVECONORWEGIAN OROGENESIS C. 1200 - 850 Ma	D_5 Local folding and shearing		
	EKENÄS PEGMATITES	BOHUS (IDDEFJORD) GRANITE C. 900 Ma	
	D_{4c-d} Asymmetric folds, greenschist facies D_{4b} Ductile sinistral shear zone, horizontal stretching composite shear deformation. Amphibolite facies. D_{4a} Formation of Kyrkosund synform by flexural slip, initiation of a ductile shear zone, amphibolite facies.	Late asymmetric folds N-S trending sinistral ductile shear zone with composite shear deformation, N-plunging stretching fabric. Amphibolite facies. N-S trending ductile shear zone with W-plunging stretching fabric. Amphibolite facies metamorphism (~ 1015 Ma). Folding, regional southwards facing folds with steep E-W axial surfaces and westwards plunging axes.	D_{4-6} Greenschist facies *Pegmatites* (950 Ma) D_3 Amphibolite facies (~ 1090 Ma)
ANOROGENY		Basic dykes and sheets, netveined intrusions (~ 1300 Ma). Moss-Filtvet augen granite (1320 ± 22 Ma) Røyken granites (pre.lim. age 1380 Ma)	Mafic dykes (with some silicic members) Gabbro-dolerite-augen granite association e.g.: Askim granite 1357 ± 30 Ma Stigfjorden augen granite (1416 ± 21 Ma)
	THE KATTSUND-KOSTER DYKE SWARM (1421 ± 25 Ma)		
	D_1 Folding and boudinage, greenschist facies		
	PEGMATITE NETVEINED ACID-BASIC DYKES AND SHEETS, METADOLERITE- METAGABBRO METADOLERITE		
OROGENESIS C. 1600 - 1500 Ma	D_{2b}: Open to close folds with subvertical axial surfaces and N NE plunging fold axes. Amphibolite facies, migmatitisation. D_{2a}: Close to isoclinal folds with subvertical axial surfaces. Minor shears. Amphibolite facies and migmatitisation.	Folding. Regional folds with N-S axial surfaces. High amphibolite facies and migmatitisation.	D_2 Regional folding amphibolite facies. Migmatitisation 2+ Acid basic dykes Migmatitisation 2

Fig. 7. Event stratigraphy in the Østfold-Marstrand belt based on Hageskov (1985), Hageskov and Pedersen (1981), Åhäll and Daly (1985).

1425-1300 (?1200) Ma old anorogenic interval during which tensional tectonics, and basic and acid magmatism acted in the crust. In the Østfold belt the dyke swarm pre-dated the intrusion of the Röyken granites (~1380 Ma), the Moss-Filtvet granite (1320 Ma) and the younger basic dykes, sheet and netveined acid-basic intrusions (1300 Ma). Possibly the presence of a large volume of basic magma in the lower crust was responsible for the partial melting of crustal material resulting in the formation of these potassic granites with high $(^{87}Sr/^{86}Sr)_0$ ratios (Hageskov and Pedersen 1981, 1986).

Åhäll and Daly (1985) describe and discuss a ca. 1420-1220 Ma old group of intrusives (the C-Group) seen in the southern part (Bohus Län) of the Østfold – Marstrand belt and correlate these intrusives with intrusives in adjacent areas. An older age for the C-Group has recently been indicated by an U-Ph age of 1511 ± 17 Ma obtained on C-Group gabbro (Åhäll et al. 1986). Some of the intrusives of the C-Group (the gabbro-dolerite-augen granite association and the Orust dykes) belong to the above mentioned anorogenic interval, while other C-Group rocks such as the post-D_2 and pre-D_3 intrusives on Koster underwent a metamorphic event (D_3) prior to the anorogenic episode.

Conclusion

The recent investigations in the Østfold-Marstrand belt indicate that extensive tholeiitic magmatism took place in the period 1420–1300 (?1200) Ma, during which time tensional conditions prevailed. The Kattsund-Koster dyke swarm dated at 1421 ± 25 Ma ($(^{87}Sr/^{86}Sr)_0$ = 0.7028 ± 0.0002) marks the onset of these conditions, which arose at the same time as similar conditions and activity in the Grenville Province of North America, where for example the Michael gabbroes (Fahrig and Loveridge, 1981), the Mealy dykes and the Harp dykes were intruded (for reviews, see Emslie et al. 1978, 1984).

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Dansk sammendrag

Kattsund-Kloster gangsværmen i det baltiske skjolds sveconorvegiske provins er en tæt sværm af differentierede tholeiiter afledt fra modermagmaer af N-MORB type, som selektivt er kontamineret med K, Rb og Ba. I Koster skærgården bliver den NNØ-SSV forløbende gangsværm involveret i en blød sinistral shearzone, i hvis rand doleriterne delvis er rekrystalliseret til metadoleriter. I den intens deformerede indre del af shearzonen er gangene totalt omkrystalliseret til amfiboliter.

Der er udført Rb-Sr isotopanalyser på doleriterne og metadoleriterne. Et profil gennem en doleritgang giver en Rb-Sr bjergartsalder på 1421 ± 25 mio år med et $(^{87}Sr/^{86}Sr)_0$ forhold på 0.7028 ± 0.0002. Prøverne fra doleriterne og metadoleriterne plotter tæt til denne isokron.

Kattsund-Koster gangsværmens alder på 1421 mio år indicerer at gangsværmen er det ældeste led i en 1420–1300(?) mio år gammel bimodal suite af tholeiiter og kaliumrige graniter, som intruderede skorpen under tensionale forhold.

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