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^{40}Ar-^{39}Ar analyses of pyroxenes from dolerite dykes from southeastern Varanger Peninsula, Finnmark

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Title:
^{40}Ar-^{39}Ar analyses of pyroxenes from dolerite dykes from southeastern Varanger Peninsula, Finnmark

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Summary:

Pyroxene separates from two dolerite dykes from eastern Varanger Peninsula (at Komagnes and on the island St.Ekkerøya) have been analysed by the ^{40}Ar-^{39}Ar method. The Komagnes dyke shows steps converging on a 'plateau' with an age of 344±17 Ma. The data from the St.Ekkerøya dyke do not yield any conclusive result; a total fusion age of c.640 Ma is shown to be meaningless, and cannot be considered as a crystallisation age for the dyke.

The data are compared with results from (1) an earlier K-Ar study and (2) a palaeomagnetic investigation on these same dykes; the former which yielded dates of c.350 Ma, and the latter a loosely Vendian age. The ^{40}Ar-^{39}Ar results have not provided us with any new reliable information on the age of these dykes which will resolve the conflict between the radiometric and palaeomagnetic 'ages'. The true crystallisation ages of the dykes remain enigmatic. Other isotopic methods may eventually help to provide a clearer indication of the true age of these dykes.

Keywords: Aldersbestemmelse,	dolerittgang,	
berggrunn	Varangerhalvøya	

CONTENTS

1 INTRODUCTION

On Varanger Peninsula, Finnmark, the only sign of igneous activity is provided by dolerite dykes which cut the Riphean to Vendian lithostratigraphic successions exposed on either side of the major, WNW-ESE trending Trollfjorden-Komagelva Fault Zone (TKFZ). The geology of this peninsula (Fig.1) is now well known through the systematic mapping and stratigraphic and sedimentological studies of Siedlecka & Siedlecki (1967) and Siedlecki (1980). For details of the lithostratigraphy we refer to the 1:250,000 map-sheet 'Vadsø' (Siedlecki 1980), and to the tables and descriptions provided in Siedlecka & Roberts (1992). A summary is shown here in Fig.2.

Investigations of the tectonic structure, low-grade metamorphism, micropalaeontology, palaeomagnetism, dolerite dyke geochemistry and remote sensing applications have also added greatly to our overall knowledge of the Late Proterozoic-Early Palaeozoic geological evolution of Varanger. A summary of the extensive bibliography is contained in Siedlecka & Roberts (1992) and Karpuz et al.(1993).

Radiometric dating studies, on the other hand, have been few. A K-Ar whole-rock investigation of dolerite/metadolerite dykes by Beckinsale et al. (1975) is the only detailed work so far published. In the present account we report the results of a ^{40}Ar-^{39}Ar study of pyroxenes from two separate dolerite dykes from locations south of the TKFZ.

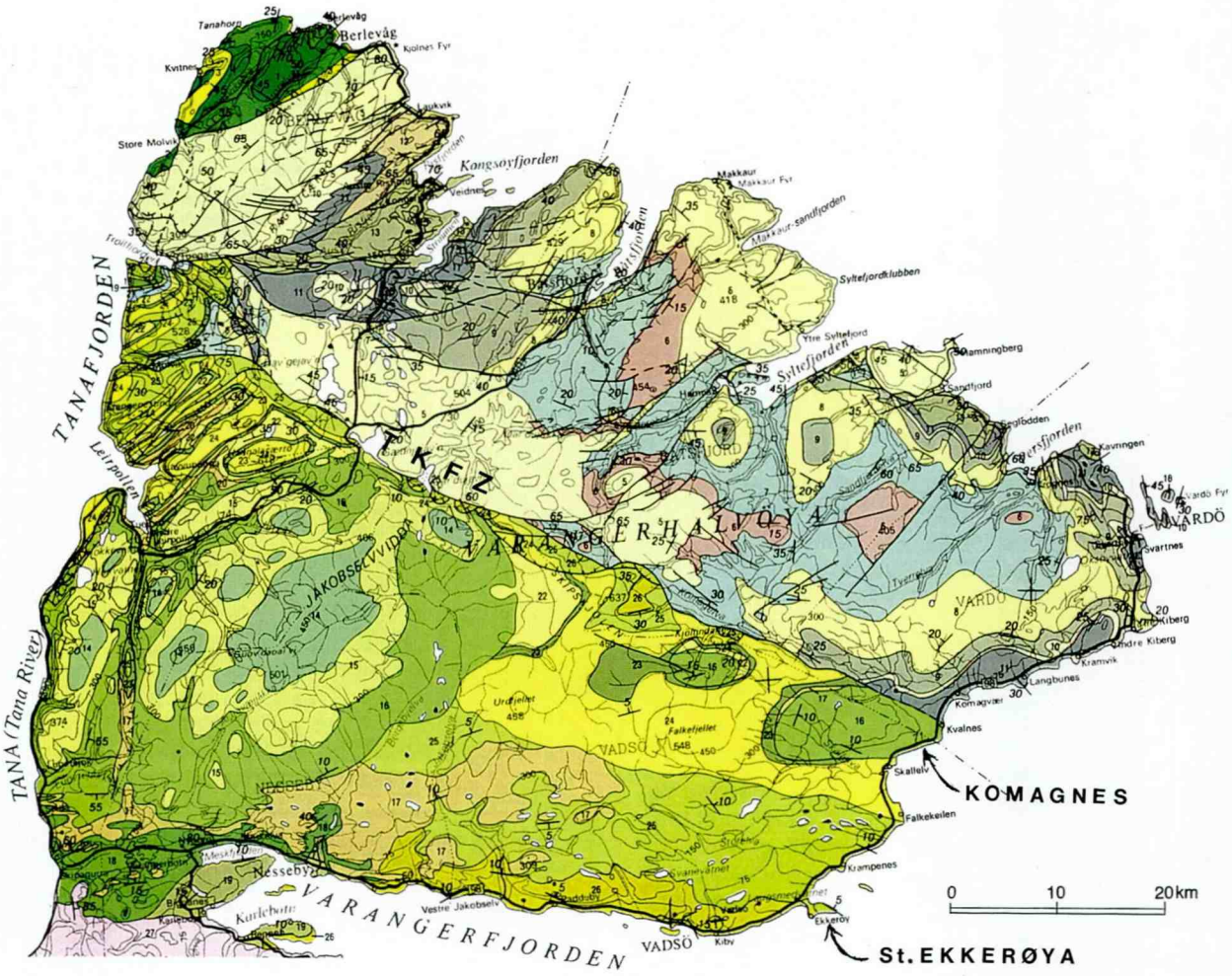
2 THE DOLERITE DYKES

2.1 Regional context

Dolerite dykes reach swarm proportions in certain parts of the Barents Sea Region (northeast of the TKFZ), especially in northwestern and central areas. On the contrary, dykes are extremely rare in the Tanafjorden-Varangerfjorden Region (southwest of the TKFZ). Based on their K-Ar results Beckinsale et al.(1975) distinguished two principal groups of dyke ages: (1) Circa 650 Ma, and (2) c.347 Ma (recalculated after Dalrymple 1979); and a third group (3) of strongly cleaved dykes with questionable dates of more than 1,000 Ma. Dykes of age-groups 1 and 3 are restricted to the rocks of the Barents Sea Region, whereas the far less common group 2 dykes occur on either side of the TKFZ.

Geochemically, the dykes of group 3, termed *metadolerites*, have been shown to carry signatures quite close to those of abyssal tholeiites, though somewhat transitional to a continental margin regime (Roberts 1975). Dykes of age-group 2, on the other hand, referred to as *dolerites*, have chemical features more akin to those of continental tholeiites. Chemical data do exist for the dykes of age-group 1, and may be published next year (D.Roberts, work in progress).

The metadolerites of the Kongsfjord area are strongly affected by a penetrative cleavage which is axial planar to abundant ENE-WSW folds (Roberts 1972). Dyke strike is generally subparallel to that of the fold axes, although a few dykes or dyke apophyses transect the folds yet still carry the pervasive cleavage (Roberts 1972, Siedlecka & Roberts 1992, Rice & Reiz 1994). In contrast to the metadolerites, the dolerites are comparatively fresh and unmetamorphosed. They generally trend between N-S and NE-SW.



BARENTS SEA REGION

Berlevåg Formation (Tanahorn Nappe)

- 1 Phyllite
- 2 Metasandstone and phyllite
- 3 Metasandstone

Løkvikfjellet Group

- 4 Sandstone and mudstone
- 5 Feldspathic sandstone

Barents Sea Group

- 6 Tyvjofjellet Formation
- 7 Båtsfjord Formation
- 8, 9, 10, 11 Båsnæringen Formation
- 12, 13 Kongsfjord Formation

TANAFJORDEN-VARANGERFJORDEN REGION

Vestertana Group

- 14 Breivika Formation
- 15, 16 Stappogiedde Formation
- 17 Mortensnes Formation
- 18 Nyborg Formation
- 19 Smalfjord Formation
- 20 Mudstone, sandstone and tillite, undifferentiated

Tanafjorden Group

- 21 Grasdalen Formation
- 22 Hanglečærro Formation
- 23 Vagge Formation
- 24 Gamasfjellet Formation
- 25 Dakkovarre, Stangenes and Grønneset Formation
- 26 Vadsø Group
- 27 Proterozoic and Archaean crystalline basement

Fig.1. Geological map of Varanger Peninsula showing the locations of the sampled dykes (Komagnes and St.Ekkerøya). TKFZ -- Trollfjorden-Komagelva Fault Zone. The map is taken from Siedlecka & Roberts 1992.

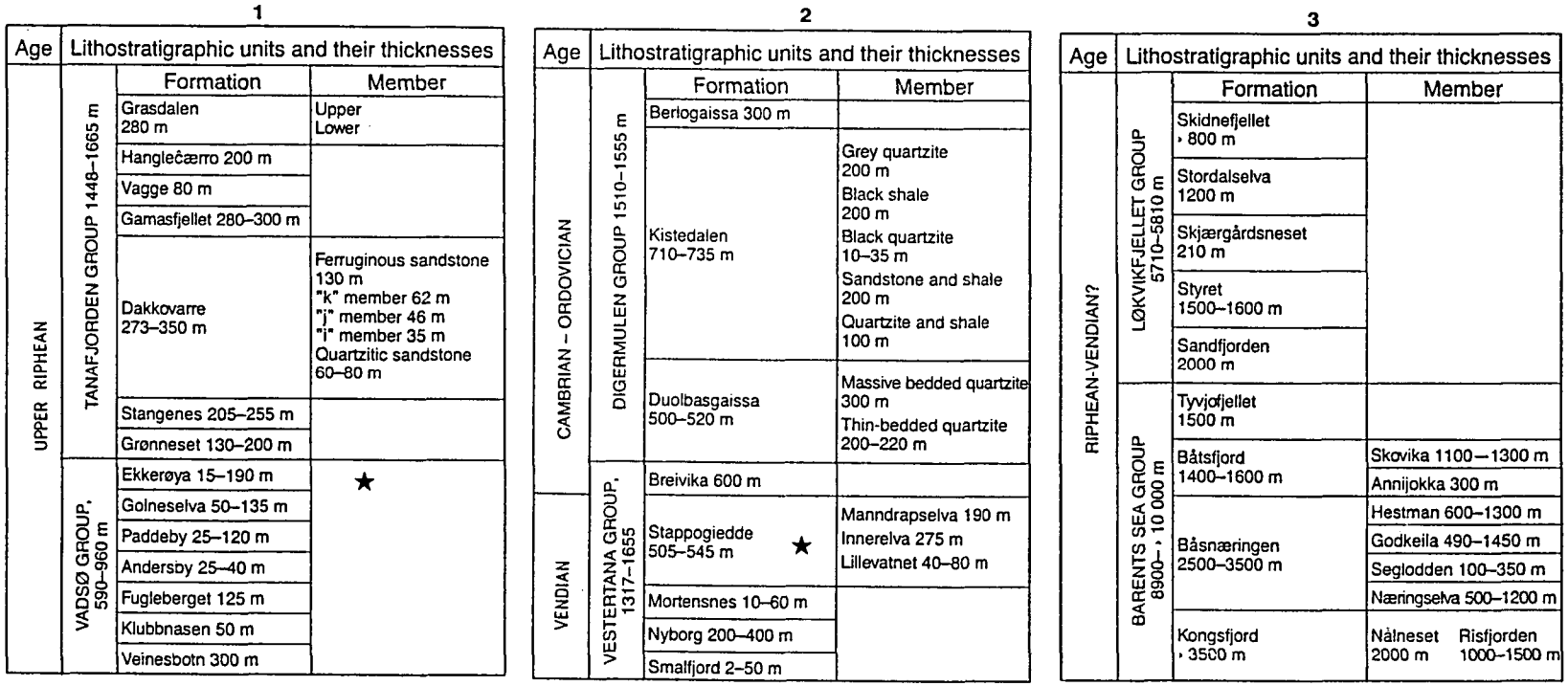


Fig.2. Lithostratigraphic successions, Varanger Peninsula. Columns 1 and 2 are from the Tanafjorden-Varangerfjorden Region (SW of the TKFZ, Fig.1) and column 3 from the Barents Sea Region (NE of the TKFZ). The stars mark the locations of the dykes (column 1, St.Ekkerøya dyke; column 2, Komagnes dyke) within the lithostratigraphy. Modified from Siedlecka & Roberts (1992).

2.2 Sample preparation

In an endeavour to tie down the intrusive age of the dolerites more closely we sampled from two separate, isolated dykes, one from near Komagnes and the other from the island of St.Ekkerøya (Fig.1). The uniform mineralogy of these dykes is dominated by plagioclase and clinopyroxene; and the texture is mostly subophitic. Optical properties of the colourless pyroxene denote that it is a pigeonite, although the outermost parts of some zoned grains are more augitic in composition (Roberts 1975).

At NGU, pyroxene separates were prepared from completely fresh material. The mineral separates were irradiated in the Petten reactor in The Netherlands. Full experimental details of the irradiation calibration, argon extraction and calculation procedures can be found in Rex et al.(1993).

2.3 Results

Komagnes dyke
The age spectrum (Fig.3) shows that the steps are converging on a 'plateau' with an age of 344±17 Ma (total fusion age 331±17 Ma). If the data (Table 1) are plotted on a correlation diagram (^{36}Ar-^{40}Ar against ^{39}Ar-^{40}Ar), the steps, which are defining the age of 344 Ma, fall on this line; which, in turn, cuts the axes of the atmospheric argon isotopic ratio and the ^{39}Ar-^{40}Ar ratio agreeing with the 344 Ma age, thus adding weight to this age.

St.Ekkerøya dyke
The ^{40}Ar-^{39}Ar step heating analysis of the pyroxene from this dyke (Fig.4) does not yield a conclusive result. The total fusion age of 640 Ma is meaningless as it is composed of temperature steps varying in age from 150 to 1442 Ma. When the data are plotted on a correlation plot, no correlation is observed, confirming that the 640 Ma date should not be considered as an age for this particular dyke.

3 DISCUSSION

The plateau age of 344±17 Ma for the Komagnes dyke would, under normal circumstances, probably be taken to represent the age of intrusion of this dolerite into the lower Stappogiedde and older formations. Although the spectra shown in Fig.3 give little reason for repudiating this interpretation, it should be noted that a palaeomagnetic study on this same dyke has favoured an older, *Vendian* age (Torsvik et al. 1995).

In the palaeomagnetic investigation, the Komagnes dyke was compared to a similar dolerite dyke on the Sredni Peninsula in NW Russia. On Sredni, the lithostratigraphic succession is somewhat similar to that in the southern and southeastern parts of Varanger Peninsula, southwest of the TKFZ. Two separate radiometric determinations (K-Ar and ^{40}Ar-^{39}Ar) on the Sredni dyke had yielded a Vendian to earliest Cambrian age (Sinitsin 1967, Roberts & Onstott 1995). In their palaeomagnetic analysis Torsvik et al.(1995) showed that the Komagnes dyke is situated very close to the Sredni dyke on the refined apparent polar wander path (APWP) for the Neoproterozoic-Early Phanerozoic period (Fig.5), in this case corresponding to a Vendian age. Moreover, there were no signs of a younger thermal event, i.e. broadly equivalent to a Carboniferous age, in their palaeomagnetic data.

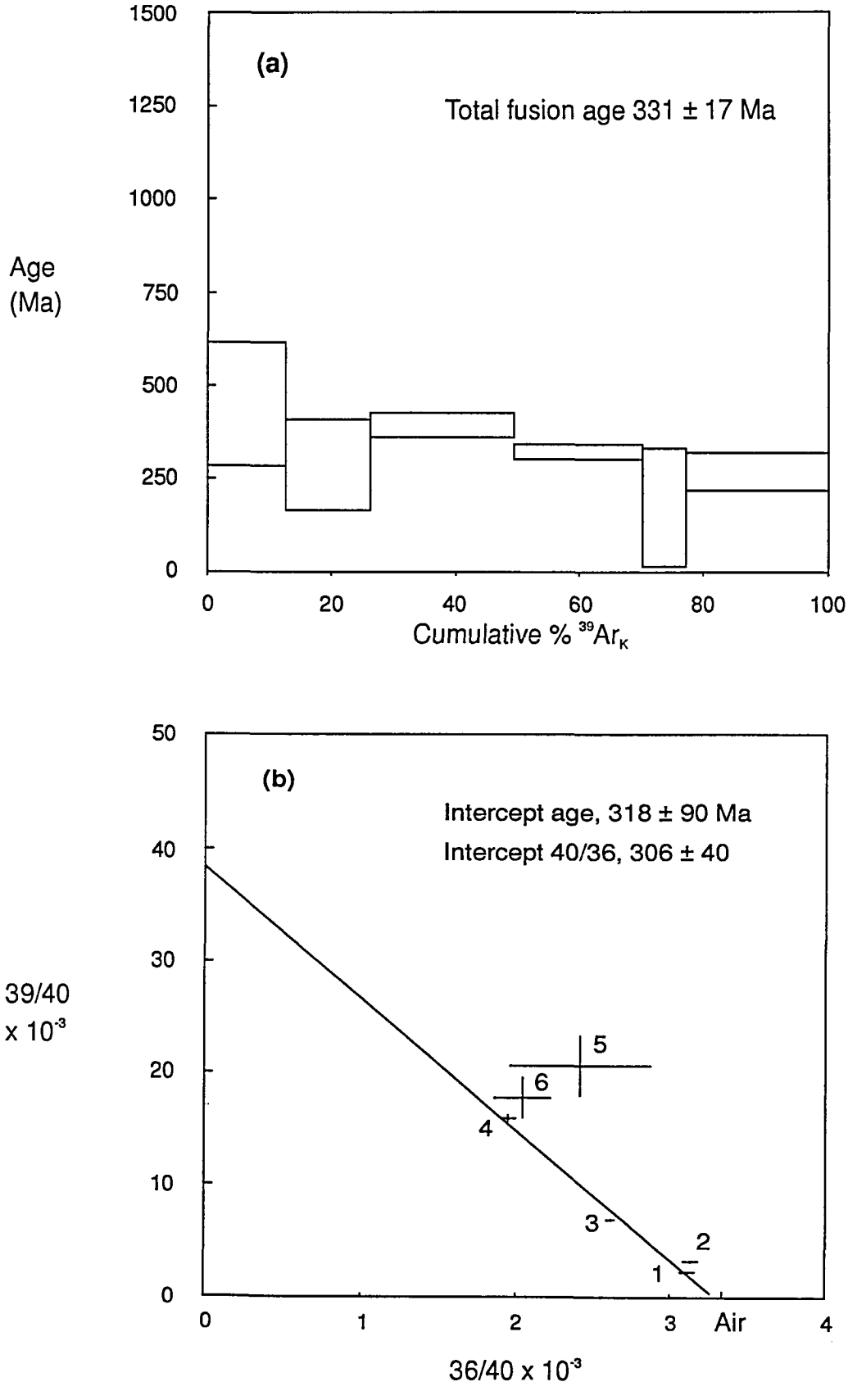


Fig.3. Age spectrum (**a**) and correlation plot (**b**) for the Komagnes dyke.

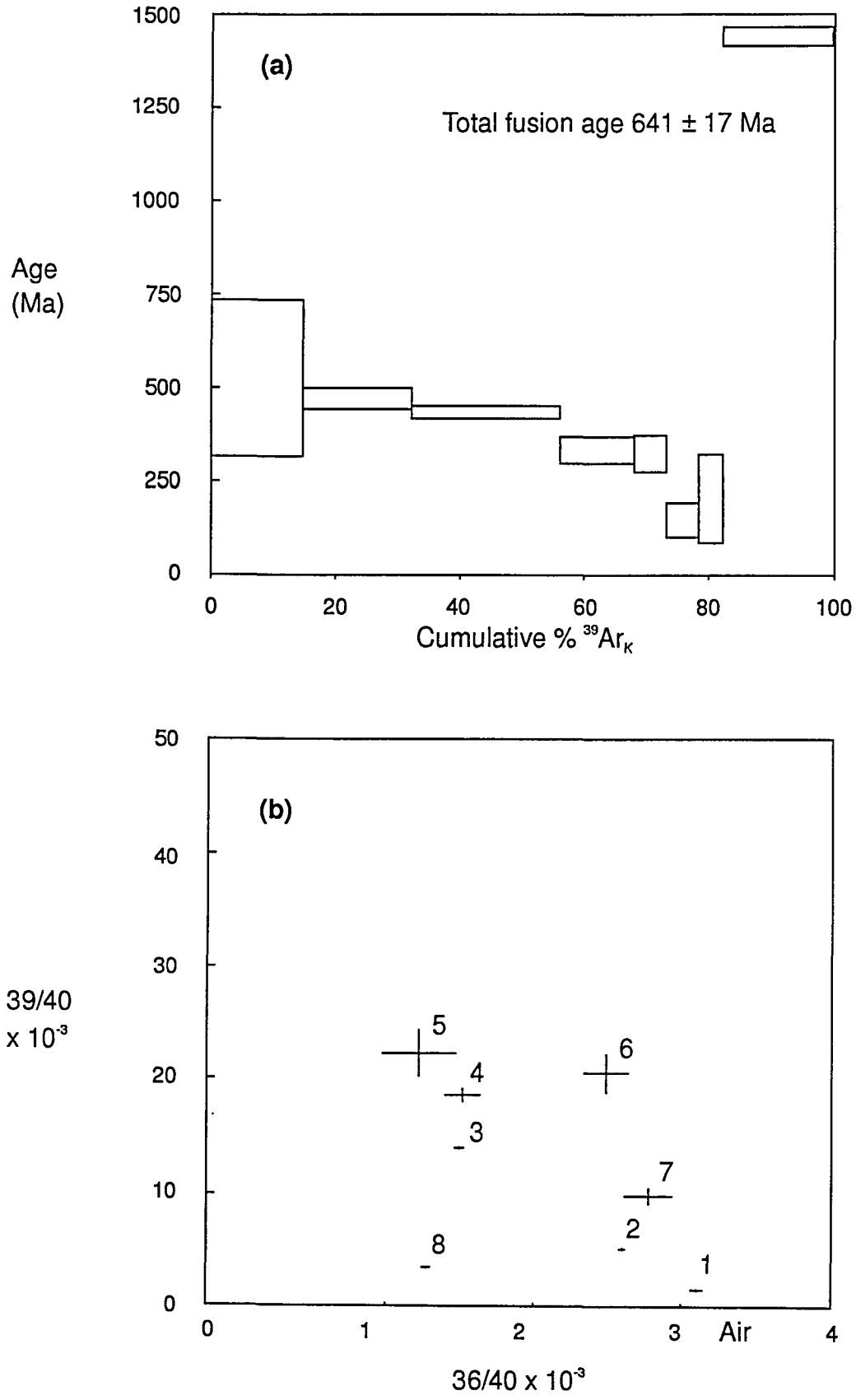


Fig.4. Age spectrum (**a**) and correlation plot (**b**) for the St.Ekkerøya dyke.

Temp	$^{39}Ar_K$	$^{37}Ar_{Ca}$	$38Ar_{Cl}$	Ca	$*^{40}Ar$	%Atm	Age	Error	$\%^{39}Ar_K$
°C	{ Vol. x 10^{-9} cm^3 }			K	$^{39}Ar_K$	^{40}Ar	{ Ma }		
Komagnes Dyke, sample weight 0.09278g, J value 0.007397 ± 1.0%									
Total fusion age 331.1 ± 16.6Ma (weight %K 0.02 , *40Ar 3.24 x 10^{-7} cm^3g^{-1})									
630	0.14	1.03	0.041	14.8	38.57	92.2	452.8	88.6	12.6
715	0.15	0.70	0.025	9.2	23.44	92.9	288.5	61.0	13.7
855	0.25	0.63	0.033	4.9	33.10	77.4	395.1	15.7	23.0
920	0.23	0.45	0.040	3.9	26.50	57.7	323.0	9.7	21.0
970	0.08	0.38	0.013	9.8	13.70	71.7	174.2	78.5	7.0
1340	0.25	148.1	0.070	1175.0	22.11	60.5	273.3	24.6	22.7
St. Ekkeroya, sample weight 0.10528g, J value 0.007384 ± 1.0%									
Total fusion age 640.6 ± 16.3Ma (weight %K 0.04 , *40Ar 12.4 x 10^{-7} cm^3g^{-1})									
710	0.33	2.68	0.137	16.1	46.02	93.2	527.8	104.2	14.7
830	0.39	1.30	0.089	6.6	40.77	78.8	474.8	13.7	17.4
920	0.54	1.37	0.106	5.0	37.29	47.8	438.8	8.4	24.1
970	0.27	1.44	0.067	10.7	27.86	48.4	337.5	18.8	11.8
1010	0.12	1.41	0.036	23.4	26.90	40.1	326.9	24.6	5.3
1060	0.12	4.32	0.050	71.2	11.78	75.7	150.5	23.7	5.3
1120	0.09	10.82	0.055	244.4	16.46	83.8	206.9	58.4	3.9
1360	0.39	309.9	0.666	1565.0	165.8	41.6	1442.1	12.9	17.4

Errors are 1σ, $^{*40}Ar$ = volume of Radiogenic ^{40}Ar, gas volumes corrected to STP.

J calibration using Hornblendes Hb3gr, MMHb1 and Fy12a see Roddick, (1983).

Table 1. The ^{40}Ar-^{39}Ar analytical data.

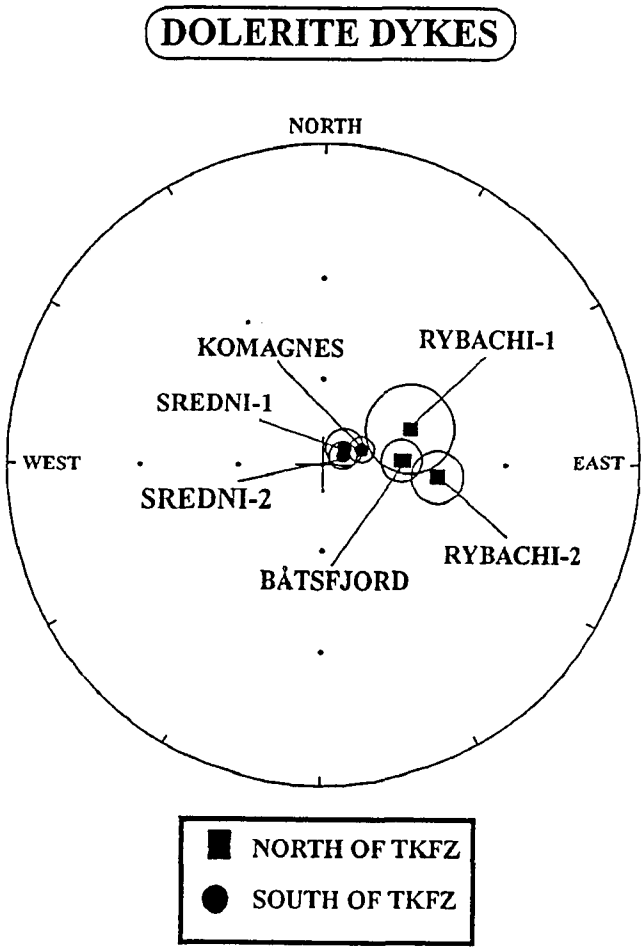


Fig.5: Palaeomagnetic data from Torsvik et al.(1995). Mean directions and 95% confidence circles for the Sredni, Rybachi and Komagnes dykes. A dyke from Båtsfjord is also shown (= group 1 of Beckinsale et al. 1975). TKFZ -- Trollfjorden-Komagelva Fault Zone.

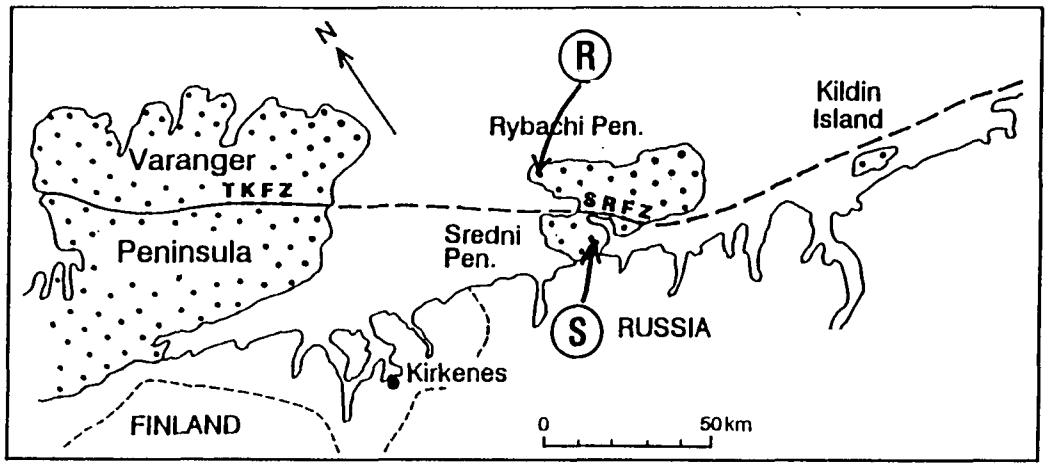


Fig.6. Location of the dykes mentioned in the text, from the Rybachi (R) and Sredni (S) Peninsulas, NW Russia. the dotted ornament indicates the outcrop of Neoproterozoic (to earliest Palaeozoic on Varanger Peninsula) sedimentary successions.

The ^{40}Ar-^{39}Ar mineral data reported here and the palaeomagnetic results of Torsvik et al.(1995) are thus in mutual conflict. The Komagnes dyke cuts through the central part of the Stappogiedde Formation which, on fossil evidence, is considered to represent the uppermost formation in the Vendian (Farmer et al. 1992). For the palaeomagnetic data to be viable, the dyke must therefore have intruded towards the end of the period of deposition of the Stappogiedde Formation. The succeeding formation, the Breivik, is Cambrian in age, but unfortunately this is not exposed in this eastern part of the Varanger Peninsula.

The only other dolerite dykes of marginal relevance to this discussion are those occurring in the northwestern part of the Rybachi Peninsula in NW Russia (Fig.6). These dykes, which show a transitional, continental to oceanic tholeiitic geochemistry, have yielded ^{40}Ar-^{39}Ar mineral (px + plag) isochron ages ranging from 402±9 to 376±5 Ma, with model ages of 400-450 Ma (Roberts & Onstott 1995). According to the interpretation of these authors "the model ages are probably recording a partial argon loss during a weak Caledonian overprint event" while the "376 Ma isochron age is interpreted as recording a minimum age for resetting by a very low-grade thermal event, perhaps coeval with initiation of a Late Devonian to Carboniferous rifting episode". Palaeomagnetic data for these same dykes are suggesting a probable Late Vendian to Cambrian age (Torsvik et al. 1995).

The true crystallisation age of the Komagnes and St-Ekkerøya dykes is thus somewhat enigmatic. Other isotopic methods, e.g. Sm-Nd or U-Pb on zircon (however, the Zr contents are low, c.80 ppm), may eventually help to resolve this problem.

4 CONCLUSIONS

No age spectrum has been obtained from the St.Ekkerøya dyke. A total fusion age is considered to be meaningless and should not be regarded as reflecting the crystallisation age of this particular dyke. The Komagnes dyke, on the other hand, does show steps on an age spectrum, which in this case converge towards a plateau age of 344±17 Ma.
Consideration of these results, and comparison with previously published K-Ar and palaeomagnetic data, leads us to the conclusion that the true intrusive age of these dykes remains enigmatic.

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