A POST CALEDONIAN SYENITE PORPHYRY DYKE IN THE WESTERN GNEISS REGION, TUSTNA, CENTRAL NORWAY*

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A syenite porphyry dyke intrudes the gneisses of the Western Gneiss Region. The dyke is undeformed and unmetamorphosed. The texture, mineralogy and chemistry show great similarities to the nordmarkite-ekerite series of the Permian intrusive rocks of the Oslo Region. An age of 297 ± 8 m.y. has been determined by the Rb-Sr isochron technique.

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Field occurrence

A syenite porphyry dyke was found in 1969 in the steep mountain side on the eastern part of the island, Tustna, in the northern part of the Møre district (Fig. 1) (Grid reference 579054, Kristiansund 1321 11, 1:50 000).

Geologically Tustna represents a part of the Western Gneiss Region. The island chiefly consists of gneisses/migmatites, amphibolites and garnet amphibolites-eclogites. The rocks have been divided into three different groups; the Frei Group, the Kristiansund Group and the Sandvik Group (Råheim 1972). The amphibolite facies metamorphism in the region has been dated at approximately 1700 m.y. (Pidgeon & Råheim 1972). Rb-Sr whole-rock and mineral isochron ages of approximately 390 m.y. from transgressive granite dykes and pegmatites and the 'lower intersection' age of zircons from the gneisses (Kristiansund Group) provide evidence for a Caledonian influence in the region (Pidgeon & Råheim 1972).

The dyke has intruded the gneisses and migmatites of the Frei Group. Its distribution is not yet known in detail, but it strikes 65°-70° ENE and has been followed for about 300 m on the mountainside. The dyke is about 10 m thick and is seen to cut the structure of the country rocks, xenoliths, apophysts and 10-20 cm thick chilled margins demonstrate its intrusive character. The dyke can be located from the road by a reddish talus slide.

Petrography

Macroscopically the rock has a reddish appearance with phenocrysts of plagioclase (Fig. 2). In the chilled margins phenocrysts of plagioclase (0.05-0.2 mm),

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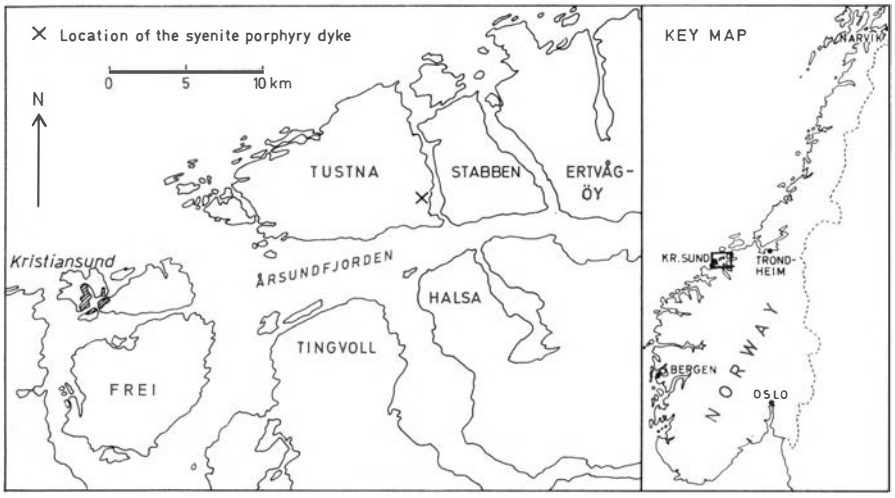

Fig. 1. Location map.

clinopyroxene, biotite and apatite occur. The groundmass consists mainly of alkali feldspars (microcrysts) and quartz (Figs. 3 and 4). In the central part of the dyke phenocrysts of plagioclase (3 × 2 mm) occur together with euhedral alkali feldspars (0.5-0.2 mm), clinopyroxene, biotite and small anhedral grains (0.001-0.1 mm) of quartz. Opaque oxides and euhedral apatite occur as accessory minerals. The rock possesses no preferred orientation except at the outermost contact to the country rock, where alkali feldspar (microcrysts) are oriented parallel to the contact and around phenocrysts (Fig. 3).

Fig. 2. The syenite porphyry with phenocrysts of plagioclase.

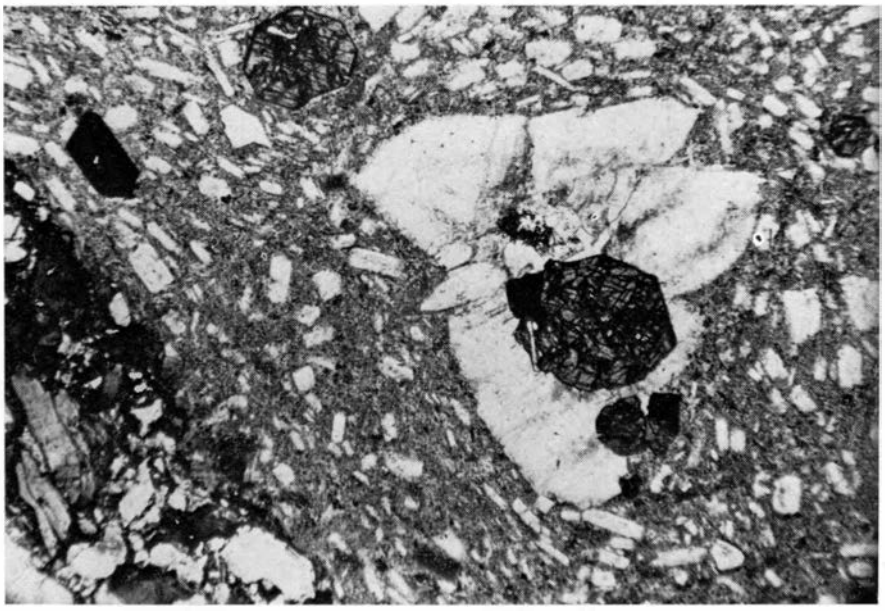

Fig. 3. From the contact to the country rock. Note the orientation of the microcrysts around the phenocryst and at the contact.

The phenocrysts have cores of multiply-twinned plagioclase (An_{25}) with rims of alkali feldspar. Alkali feldspar dominates the mineralogy and feldspars and quartz together form about 95% of the rock. In the alkali feldspar carlsbad twins are very common but baveno twins have also been observed.

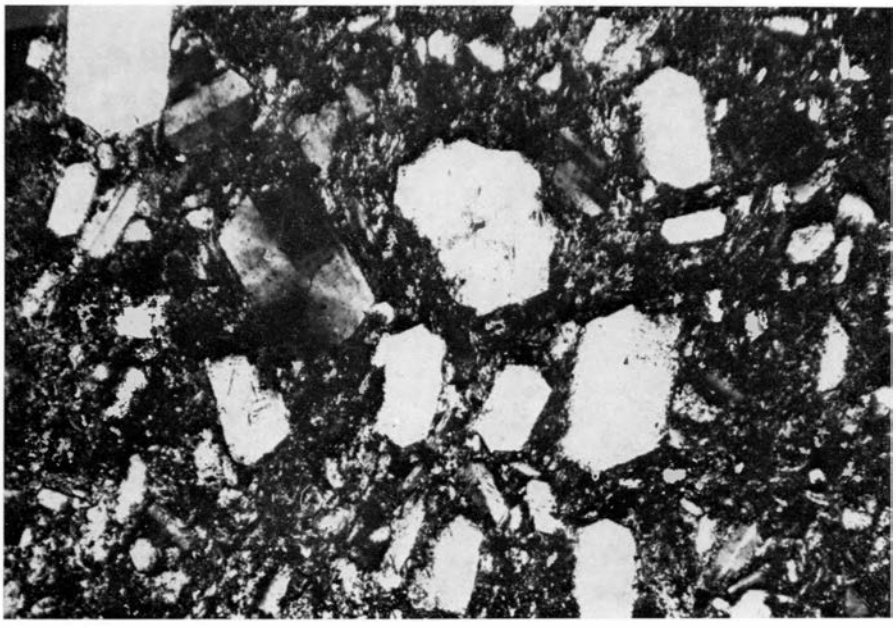

Fig. 4. Twins in alkali feldspar.

The mafic minerals are: biotite (0.1-0.5 mm) with pleochroism z = very dark green and x = yellow, aegerine augite (0.1-1 mm) with pleochroism x = green, y = light-green and z = green yellow, $x > y > z$, $2v_x = 80 \pm 2$. The larger grains are zoned, with the rims more acmitic than the central parts. This zoning is also found by microprobe analyses. The rims have 9.0% MgO, 14.5% FeO (total Fe) and 19.0% CaO, the cores have 10.3% MgO, 12.8% FeO (total Fe) and 19.9% CaO. According to Trøger (1959) the optic angle is in agreement with 20 mol $NaFe^{3+}$. This agrees with the calculated acmite content (18.4) from the chemical analyses given in Table 1.

Examination of the chemistry of the rock from the central part of the dyke (Table 2) shows that it has great similarity with some syenitic rocks of the Permian igneous suite from the Oslo Region. The chemistry of the Tustna dyke compares favorably with that of the nordmarkite-ekerite series (Brøgger 1933) (see Table 2). This is borne out by the mineral chemistry and the texture of the rock as the most important mafic mineral is aegerine augite, this is also characteristic of the nordmarkites and ekerites (Barth 1944).

The age of the syenite porphyry dyke

It was considered important to determine the age and initial Sr^{87}/Sr^{86-} ratio of the rock in an attempt to clarify its relationship to the plutonic rocks of the Oslo Region (Heier & Compston 1969) and the ultrabasic biotite lamprophyre dyke of the island Ytterøy in Trondheimsfjorden (Carstens (1961), Storetvedt (1967) and Priem et al. (1968)).

Analytical procedure

The rocks were crushed in a steel jaw-crusher and finely ground in a tungsten-carbide Sieb mill. Rb and Sr were determined by X-ray fluorescence spectrography on all the whole-rock samples. Bias in the ratio Rb/Sr was monitored by comparison with simultaneous isotope dilution analysis. Rb and Sr of the biotite and one of the whole rocks (72-138) were determined by isotope dilu-

Table 1. Chemical analyses of the clinopyroxene

SiO_2	51.0	Ti-diop	0.9
TiO_2	0.3	Tscherm	3.9
Al_2O_3	2.3	Fe^{3+} – Ts	0.8
Fe_2O_3	6.7	Acm	18.1
FeO	7.9	Di + Hd	74.1
MgO	9.4	En + Fs	2.1
CaO	19.6		
Na_2O	2.5		
	99.7		99.9

Calculation methods are given in Griffin (1971).
Microprobe analyses by W. L. Griffin.

Table 2. Chemical analyses of the syenite porphyry from Tustna and for comparison the average of 4 analyses of the nordmarkite-ekerite series of the Oslo Region.

Nordmarkite-ekerite series		Syenite porphyry from Tustna			
SiO_2	67.19	67.80	Norm	Mode	
TiO_2	0.61	0.24	9.6 q	quartz	9.4
Al_2O_3	15.88	16.10	23.0 or	alkali feldspar	85.5
Fe_2O_3	2.33	1.41	58.0 ab		
FeO	0.77	0.65	0.5 an	plagioclase (phenocrysts)	2.0
MnO	0.19	0.12	0.9 wo		
MgO	0.23	0.28	1.1 hy	aegirine-augite	1.6
CaO	0.60	0.72	0.5 mt	biotite	0.4
Na_2O	6.14	6.50	0.7 hm	iron ore	0.8
K_2O	5.54	4.80	0.7 il		
$H_2O^{-110°}$	0.05	0.05	0.3 ap		
$H_2O^{+110°}$	0.63	0.02			
P_2O_5	0.02	0.07			
Co_2	–	0.02			
$\sum$	100.18	98.96	100.0		99.7

Nordmarkite-ekerite series (Brøgger 1933).
Syenite porphyry. Analyst: B. Th. Andreassen.

tion using a mixed Rb^{85}-Sr^{84} spike, checked against international standards as in the paper by de Laeter et al. (1973).

Unspiked measurements of Sr^{87}/Sr^{86} were made for all samples except for the biotite and for these and the spiked analyses, variable mass-discrimination in Sr^{87}/Sr^{86} was corrected by normalising Sr^{88}/Sr^{86} to 8.3752. Mass spectrometry was performed on a Nuclide 12-60-SU mass spectrometer using procedures similar to those described by Heier & Compston (1969). The Rb-Sr isochron age was calculated by the least square method of McIntyre et al. (1966).

Table 3. Analytical data.

No.	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
72–135 Whole rock	116.2	93.8	3.580	.72372
72–136 "	114.2	101.2	3.262	.72305
72–138 "	120.7*	74.3*	4.698	.72850
72–139 "	115.6	119.9	2.788	.72081
72–140 "	95.5	130.1	2.122	.71801
72–139 Biotite 90 %	375.6*	64.5*	16.927	.77934
72–137a	127.2	137.1	2.658	.72066
72–137b	114.0	144.6	2.280	.72104

* determined by isotope dilution.

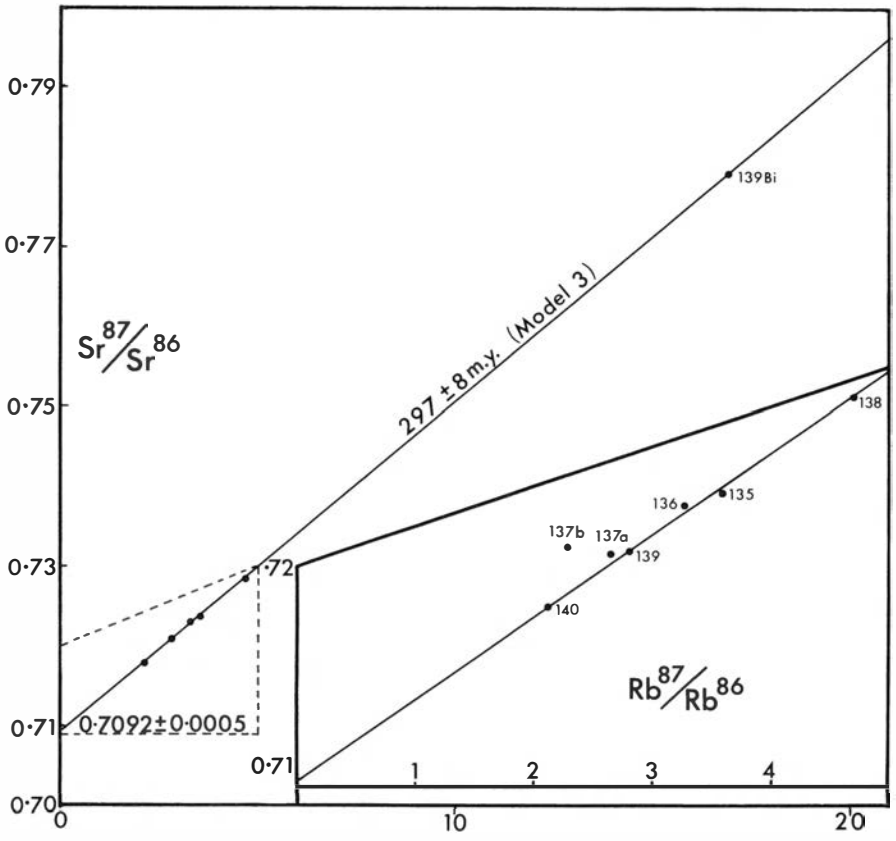

Fig. 5. Rb-Sr isochron plot of the analytical results of whole-rocks and biotite (Bi) from the syenite porphyry. The dots in the inset represent approximately 2σ limits of error.

Analytical results

The analytical data are listed in Table 2. The coefficient of variation for Rb^{87}/Sr^{86} due to experimental error was taken as 0.8% for all samples and the standard deviation for Sr^{87}/Sr^{86} was taken conservatively as 1×10^{-4}.

The data when regressed (McIntyre 1966) has a value for the mean square of weighted deviates (MSWD) of 2.65. The MSWD in this case is on the limit of being statistically significant, so that the McIntyre Model 1 fit (296 ± 7 m.y., $\lambda = 1.39 \times 10^{-11}$ yr^{-1}) in which all the scatter about the isochron can be assigned to experimental error, is not considered appropriate. The McIntyre Model 3 fit where the scatter about the isochron is due principally to geological variation in the initial $^{87}Sr/^{86}Sr$ gives an age of 297 ± 8 m.y. and an initial ratio of 0.7092 ± 0.0005. Sample 72-136 plots above the isochron (see Fig. 5). This is best explained by a higher initial Sr^{87}/Sr^{86} ratio caused by contamination from the country rock, particularly when two of the samples 72-137a and b from the outermost chilled margin (one of the samples, 71-137b is seen to have partly resorbed country rock) also plots above the isochron.

Because of this clear sign of contamination the samples 72-137a and b have been excluded from the regression of the data, if also 72-136 is excluded the MSWD for the remainder becomes 1.35 which is a Model 1 fit at the 95% level. This, however, makes very little difference in age and initial ratio (296 ± 8, 0.7092 ± 0.0004) compared to those reported above, mainly because the slope of the isochron is largely controlled by the biotite.

However, the most conservative age and initial ratio is considered to be those given by McIntyre Model 3 (297 ± 8 m.y., 0.7092 ± 0.0005).

Discussion

Post-Caledonian dykes are scarce in the Norwegian Caledonides. The nearest known dyke to the syenite porphyry dyke of Tustna is situated some 155 km to the north-east of the island Ytterøy in Trondheimsfjorden. This dyke, which is an ultra basic biotite lamprophyre, was discovered and described by H. Carstens (1961). On the basis of the alkaline chemistry of the dyke, Carstens suggested that it might have been connected with Permian rift faulting.

Storetvedt (1967) reported on the direction of natural remanent magnetization in the Ytterøy dyke. He concluded that the paleomagnetic data, suggest a late Caledonian age for the intrusion of the dyke. However, the difference between the Middle and Upper Devonian fields, the Carboniferous and the Permian fields for Europe is not great (Runcorn 1970) and the use of paleomagnetic data for age determinations can only be an estimation which has to be supported by other age determination methods.

A Rb-Sr age of 248 ± 10 m.y. (using 0.705 as initial ratio) and a K-Ar age of 363 ± 15 m.y. have been reported by Priem et al. (1969) for the Ytterøy dyke, thus giving support both for a late Caledonian (Devonian) age and a Permian age. They have, however, concluded that there can be little doubt that the K-Ar age sets a reliable date for the intrusion of the dyke and explain the Permian Rb-Sr age through loss of radiogenic strontium or introduction of Sr from the country rock (marble). However, the K-Ar age could be apparently high due to excess argon. Excess Ar^{40} has been reported in biotites (phlogopitic) from rocks related to the biotite lamprophyre by Zartman et al. (1967) and Lovering & Richards (1964). In fact it might be more than a coincidence that the biotites when plotted on a Rb-Sr isochron give an age of about 278 ± 25 (initial ratio: 0.7019 ± 0.0048) even if Priem et al. (1968) explain the difference in Rb^{87}/Sr^{86} and Sr^{87}/Sr^{86} between the two biotite concentrates as due to different amounts of included calcite (interpreted as introduced from the country rock). According to Carsten's (1961) description the calcite has not necessarily been introduced from the country rock, but rather has been formed in the rock itself. However, since the K-Ar age of this dyke is regarded as important in the discussion on the direction of natural remanent magnetization of Middle and Upper Devonian (Storetvedt & Petersen 1972) an attempt to get a final conclusion on the age of the Ytterøy lam-

prophyre by doing Rb-Sr work on whole rock samples as well as suitable minerals in addition to the phlogopitic biotite (clinopyroxene and alkali feldspar) should be made.

From this it appears that Carstens suggestion of a Permian age for the Ytterøy lamprophyre should still be considered reasonable and it opens up the possibility that the Ytterøy lamprophyre and the syenite porphyry of Tustna could be related both in time and chemistry to the alkaline igneous activity of the Oslo Region. However, Heier & Compston (1969) reported an age of 276 ± 7 m.y. in their Rb-Sr studies of the plutonic rocks of the Oslo Region. This is about 21 m.y. younger than the age of the syenite porphyry of Tustna, making a direct correlation in time difficult as the difference is outside the limits of error.

The initial ratios of the plutonic rocks of the Oslo Region (0.7041 ± 0.0002, Heier & Compston (1969)) are distinctly lower than that of the Tustna magma (0.7092 ± 0.0005), thus the latter may have been contaminated. Two samples (72-137a and b) from the outermost chilled margin plot above the 297 m.y. isochron. One of the samples had darker patches of almost resorbed country rock, clearly explaining the higher initial ratio to be a result of 'contamination'. Similarly, at greater depth, the magma could have dissolved and homogenized some xenoliths completely before the magma solidified. The difference in initial ratios between the Tustna dyke (0.7092 ± 0.005) and the plutonic rocks of the Oslo Region (0.7041 ± 0.0002, Heier & Compston (1969)) could therefore be mainly due to crustal contamination and explain the higher initial ratio in the case of the Tustna dyke.

It is of some interest to look at the age difference between the Tustna dyke and the plutonic rocks of the Oslo Region in relation to the distance between them and the possibility that the formation of the rocks concerned could be related to movement of the continental plate over fixed mantle magma sources ('hot spots'), causing magmatic activity as the continental plate moved by (v. Breemen & Bowden 1973, Duncan et al. 1972). The distance between the syenite porphyry dyke of Tustna and the central part of the Oslo Region is about 410 km with an age difference of 21 ± 15 m.y. This gives a movement rate between 6.8-1.1 cm/yr which is of the right order of magnitude compared with the recent spreading rates of ocean floors and continents (Heirtzler et al. 1968). In an attempt to test this idea the dykes occurring north of the Oslo Region should be dated to see if they get progressively older to the north.

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