A probable Permian hydrothermal alteration age for a quartz syenite dyke from Stabben, Nordmøre

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A Rb-Sr whole-rock isochron from a quartz-syenite dyke at Stabben, Nordmøre, has provided an age of 263 ± 6 Ma. This could be taken to indicate a crystallisation age for the dyke, i.e., Early Permian. The age, however, does not conform with an earlier published age for a similar dyke on the nearby island of Tustna, or with a published Middle/Late Carboniferous palaeomagnetic pole for the Stabben dyke. It may be that the isochron is dating hydrothermal alteration of the dyke. The presence of such dykes with a deep mantle magmatic source, along the Møre-Trøndelag Fault Zone, emphasises the fundamental nature of the fault and indicates that a period of tensional conditions pertained during the time of emplacement of the dykes.

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Introduction

The Møre-Trøndelag Fault Zone (MTFZ) is a major, NE-SW-trending structure transecting the Caledonides of Central Norway (Gabrielsen & Ramberg 1979, Grønlie & Roberts 1989), and is regarded as a fault-zone with a long and complex history (Grønlie et al. 1994). The occurrence of rare, undeformed and unmetamorphosed, quartz syenite dykes in the Nordmøre segment of the MTFZ has been reported by Råheim (1974), Askvik & Rokoengen (1985) and Sturt & Torsvik (1987). The presence of such intrusions within the general setting of the MTFZ is of interest as it indicates tensional conditions along the fault zone either before or at the time of their emplacement.

A quartz syenite dyke on the island of Tustna (Fig.1) has yielded a Rb-Sr isochron of 297 ± 8 Ma (Råheim 1974), and this has been taken to indicate an intrusion age for the dyke. In reality, however, the slope of the isochron is controlled by a single biotite analysis and hence the age must be interpreted to represent a minimum age for the dyke. Råheim showed that the mineralogy and geochemistry of the Tustna dyke is very similar to that of dykes of the nordmarkite-ekerite series in the Oslo Graben. According to Råheim (1974) the Tustna dyke is apparently older than the nordmarkite-ekrite dykes which have yielded a whole-rock Rb-Sr isochron age of 276 ± 7 Ma (Heier & Compston 1969). Sturt & Torsvik (1987) made a palaeomagnetic study of a similar quartz syenite dyke, on the nearby island of Stabben (Fig.1), and using the published age of the Tustna dyke produced a pole of assumed Mid/Late Carboniferous age.

In order to confirm of the age of intrusion of the quartz syenite dykes, the present authors decided to make an extensive collection of material from the Stabben dyke which is excellently exposed at sea-level on the southeastern corner of the island of Stabben. From these samples 8 were selected with a reasonable range in Rb-Sr values to form the basis, hopefully, for a definitive isochron.

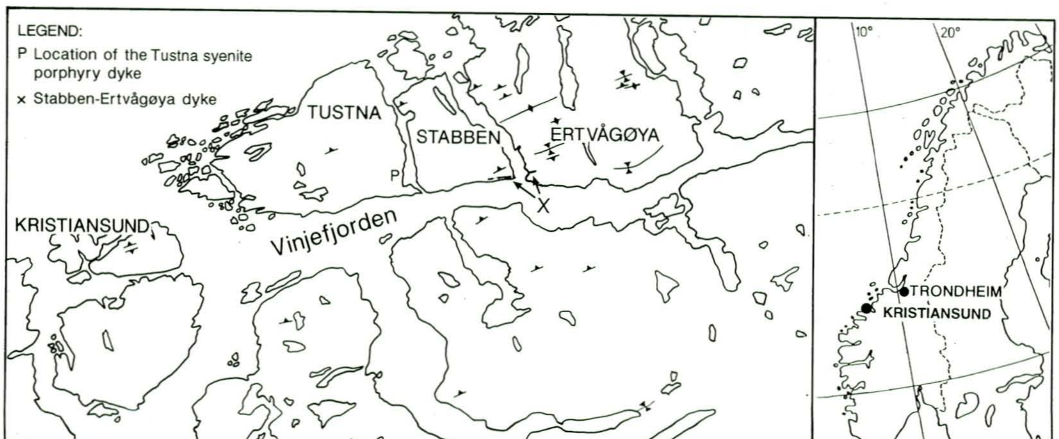

Fig 1. Locality map.

Fig 2. Essentially concordant contact between quartz syenite dyke and country-rock banded gneisses, SE Stabben.

The Stabben dyke

The Stabben dyke intrudes the Precambrian country rocks at the southeastern and southwestern corners, respectively, of the islands of Stabben and Ertvågøya (UTM648042-672044) (Fig.1). The dyke, which is c.3.5 m thick, can be traced for some 1200 m along the southern shore of Stabben. It then passes beneath sea-level and reappears as two dykes, one up to 2 m and another <50 cm in thickness, on the southwestern corner of Ertvågøya. These dykes can be traced along strike for a further 1300 m. The total exposed length of the dykes is thus >2500 m. The dykes trend at c.N80°E, parallel to a fault along Vinjefjord.

The main dyke is essentially concordant with the foliation of the country-rock gneisses (Fig.2), though it may be strongly discordant where it follows prominent fractures or small faults (Fig.3). The contacts are also commonly displaced along small faults, indicating tectonic activity after dyke emplacement. The dyke rock has a characteristic pale brownish-red colour though in places it is bleached adjacent to joint surfaces. The latter are sometimes decorated by sporadic pyrite and calcite crystals, indicating some post-crystallisation hydrothermal alteration.

The dyke rock consists essentially of scattered alkali feldspar (5.4%) and sporadic mafic phenocrysts (2.9%) in a fine-grained alkali feldspar (80.4%) matrix. In thin-section it is seen to have a porphyritic to glomeroporphyritic texture (Fig.4) with phenocrysts and glomeroporphyritic aggregates of alkali feldspar (up to 5 mm) and smaller phenocrysts of quartz (8.8%) and an altered pyribole (now chlorite) set in a finer grained matrix. Råheim (1974) has shown that the Tustna dyke bears aegerine-augite both as phenocrysts and

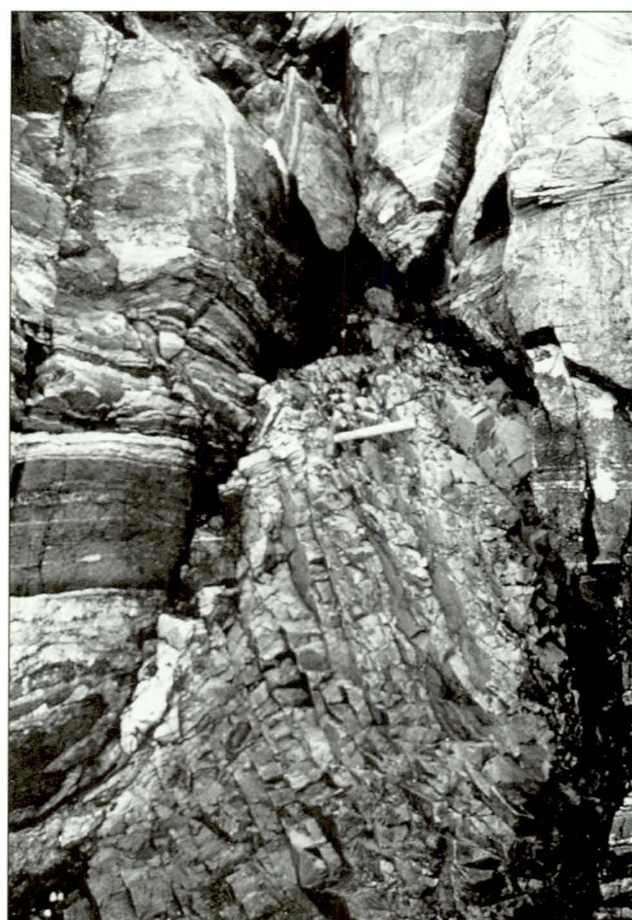

Fig 3. Strongly discordant contact between quartz syenite dyke and country-rock gneisses, where the dyke intrudes along a small fault.

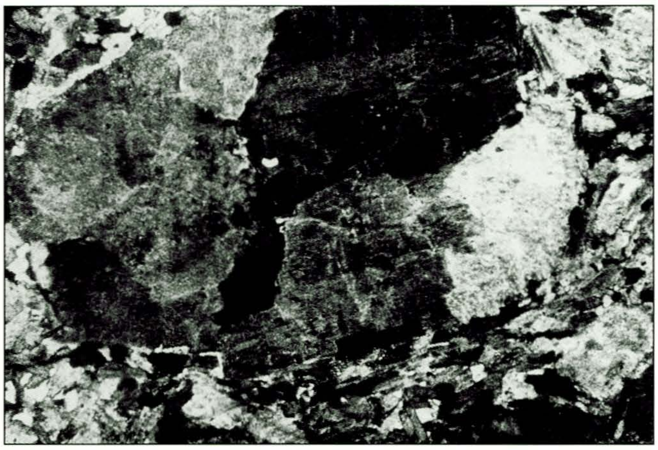

Fig 4. Glomeroporphyritic aggregate of alkali feldspar in fine-grained matrix. Scale bar = 0.5 mm.

in the matrix. Unfortunately, this mineral is not preserved in the chlorite aggregates in the material examined from Stabben. The matrix consists mainly of subhedral alkali feldspar with lesser amounts of anhedral quartz, opaques, euhedral apatite and aggregates of chlorite, and the tabular feldspar shows a fairly well marked, parallel orientation.

The chilled margins of the dyke consist of about 5% scattered glomeroporphyritic feldspar (diameter 3-5 mm), 20% idiomorphic K-feldspar microcrysts (0.1 x 0.3 mm), 1-2% subidiomorphic quartz, a few idiomorphic apatites (up to 1 mm in length), some pseudomorphs after pyribole and a few grains of idiomorphic opaque minerals. These are all set in a very fine-grained matrix.

	Mean	Mol.p.	Tustna	Oslo
SiO_2	66.05	1.099	67.19	67.80
TiO_2	0.32	0.004	0.61	0.24
Al_2O_3	17.11	0.168	15.88	16.10
Fe_2O_3	1.78	0.011	2.33	1.41
FeO	0.96	0.013	0.77	0.65
MnO	0.04	0.001	0.19	0.12
MgO	0.22	0.005	0.23	0.28
CaO	1.27	0.023	0.60	0.72
Na_2O	6.41	0.103	6.14	6.50
K_2O	5.05	0.054	5.54	4.80
P_2O_5	0.09	0.001	0.02	0.07
CO_2				0.02
L.O.I.	0.30		0.68	0.07
SUM	99.60		100.18	98.96

Table 1. Mean, major element, chemical composition of the quartz syenite porphyry dyke from Stabben-Ertvågøya (5 analyses, this paper). The table also shows the similarity between the composition of the Stabben-Ertvågøya dyke and that on Tustna, and with the nordmarkite-ekerite series of the Oslo Graben (Råheim 1974).

The feldspar phenocryst and groundmass feldspars are both unmixed to an antiperthite with irregular exsolution patches, blebs and strings of microcline in albite. This is indicated by extinction angles and relief under the polarising microscope and confirmed by microprobe and electron microscope analyses. The patches, blebs and strings range in diameter up to 100 microns.

Chemical analyses of the dyke rock are given in Table 1. According to the modal composition of the rock the alkalies must be almost entirely sited in the alkali feldspar, though naturally some of the Na would have resided in any former aegerine augite. The mean major element analyses of the rock have been recalculated to cation proportions giving a Na:K ratio of 0.103:0.054 (Table 1). Electron-microprobe analyses indicate Ca^{2+}, to give an average value of 0.005 based on 24 oxygens. This indicates a primary alkali feldspar composition close to Or_{34} (minimum)Ab_{66} with a negligible An component.

The feldspars are turbid and clouded by minute haematite flakes, and a former pyribole is now pseudomorphed by chlorite. Secondary calcite and sporadic radiating aggregates of an unidentified yellowish-green mineral with low birefringence are also present. These features attest to a secondary hydrothermal alteration of the dyke.

Rb-Sr geochronology

The analytical work was carried out at the laboratory of isotope geology at the Mineralogical-Geological Museum, University of Oslo. Isochron calculations followed the procedures of York (1969) using the values 1.42×10^{-11} a^{-1} and 6.54×10^{-12} a^{-1} for the decay constant of ^{87}Rb (Steiger & Jäger 1977). The _ notation follows De Paulo & Wasserburg (1976a) using UR values for Rb-Sr reported by De Paulo & Wasserburg (1976b).

The quartz syenite dyke from Stabben gave an age of 263 ± 6 Ma with an MSWD of 1.62 and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7102 ± 6. Isotopic analysis showed the dyke rocks to have $\varepsilon Sr(T) = +84.8$ and $\varepsilon Nd(T) = -10.1$ (Fig. 5). These values indicate that the syenite magma has been strongly contaminated by crustal material and shows little evidence of an

Sample	ppm Rb	ppm Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
1A	148.7	59.25	7.2824	.73670 ± 3
1C	137.9	35.13	11.4085	.75282 ± 3
1F	136.2	37.27	10.6149	.74996 ± 3
1G	145.8	44.01	9.6253	.74671 ± 3
1J	135.4	58.57	6.7052	.73541 ± 3
1M	63.6	40.89	4.5107	.72714 ± 3
2A	137.8	31.88	12.5696	.75724 ± 3
2B	148.0	29.68	14.5011	.76433 ± 3

Table 2. Rb-Sr contents and isotopic data

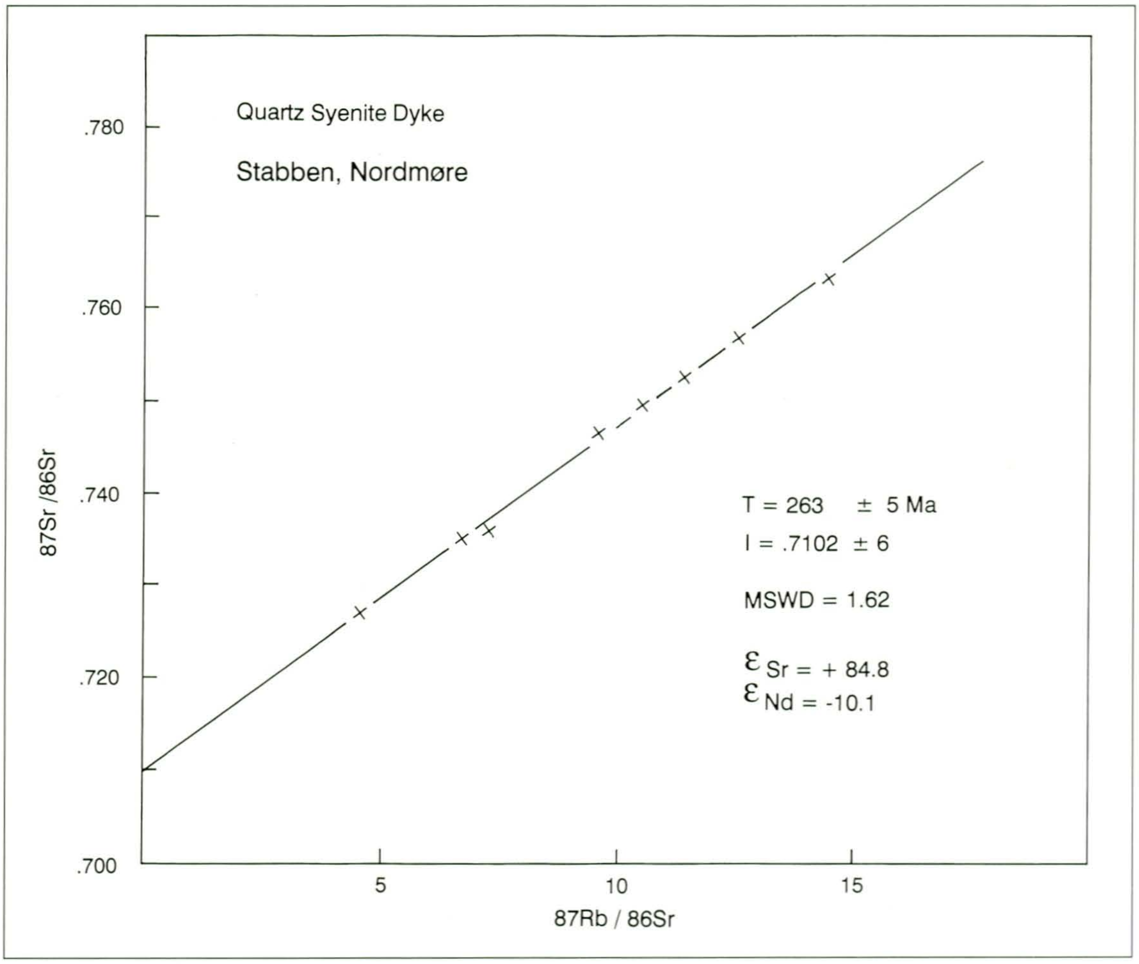

Fig 5. Isochron diagram for the Stabben quartz syenite.

eventual mantle origin. The analytical data are shown in Table 2.

Discussion

The authors submit that the isochron age of 263 ± 6 Ma could, at first sight, be considered to provide an age for the crystallisation of the Stabben quartz syenite dyke. It is, however, significantly younger than the age published by Råheim (1974) for the quartz syenite dyke from Tustna, and which is likely to represent a minimum age for its emplacement. The petrography and geochemistry of the Stabben and Tustna dykes are virtually identical, except for the more marked hydrothermal alteration of the Stabben dyke, and it is likely that they were coeval. Sturt & Torsvik (1987), moreover, obtained a Late Carboniferous palaeomagnetic pole for the Stabben dyke, and an examination of additional palaeomagnetic data from this same dyke has confirmed this result (T.Torsvik, pers.comm.1996) . These observations thus do not lend support to an interpretation of the isochron as an age of crystallisation. Indeed, the isochron may, in fact, be dating the hydrothermal alteration of the dyke.

The isochron age of the Stabben quartz syenite dyke reported in this paper fits well with the isochron recorded for the nordmarkite-ekerite dykes by Heier & Compston (1969), and with the ages of syenitic rocks in the northern part of the Oslo Graben (e.g., the Øyangen syenite at 266 ± 8 Ma) reported in Sundvoll & Larsen (1990). It is also of interest that the isochron age of this dyke is almost identical with the Rb-Sr isochron age for the Torpa klint syenite dyke, in Scania, at 261 ± 6 Ma (Sundvoll & Larsen 1993) and is distinctly younger than the mænaite syenite dykes of the Oslo area at 290 ± 11 and 285 ± 7 Ma (Sundvoll & Larsen 1993). The presence of dykes of syenitic composition, which apparently have a petrological affinity to the magmatic province of the Oslo Graben, is of considerable interest and implies a deep mantle source for the parent magma. As pointed out above, however, the ε values for Sr and Nd show that the syenite magma which gave rise to the Stabben dyke had been strongly contaminated by crustal material. This deep magmatic source emphasises the fundamental nature of the MTFZ. The Walls Boundary Fault in Shetland, which is considered to be a correlative structure to the MTFZ, has for example been shown to penetrate the crust/mantle boundary (McBride 1995).

The position of the Stabben dyke in time and space is of considerable interest and strongly suggests that tensional conditions existed along this part of the MTFZ during Late Carboniferous/Early Permian times. Grønlie & Torsvik (1989) concluded from the palaeomagnetic signature of mineralised open-network breccias and thorium-enriched carbonate veins along the MTFZ in inner Trondheimsfjord, that these were formed during the Permian in an extensional regime. Palaeomagnetic studies and Rb-Sr data on biotite (256 Ma) also indicate a Permian age for a lamprophyre dyke from Ytterøy (Torsvik et al.1988). Thus, there seems to be accumulating evidence that, for at least part of Permo-Carboniferous times, the MTFZ was operating as an extensional structure.

There remains an enigma, however, concerning the lack of fit between the isochron age presented here, and the Late Carboniferous palaeomagnetic pole position (Sturt & Torsvik 1987) which fits well with the Rb-Sr age published by Råheim (1974) for the Tustna dyke . It is planned to collect samples of the Tustna dyke to obtain both palaeomagnetic and new geochronological data to address this issue; and U-Pb zircon analyses will be obtained from both the Stabben and the Tustna dykes in order to try to resolve the issue of the initial crystallisation age of the dyke system.

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