

A Post-Caledonian Ultrabasic Biotite Lamprophyre Dyke of the Island Ytterøy in the Trondheimsfjord, Norway

By

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Abstract.

A lamprophyre having pronounced alnöitic – kimberlitic affinities is described. It is suggested that the intrusion of the dyke is connected with Permian rift faulting.

Introduction.

The island of Ytterøy lies about 50 km NNE of Trondheim in the middle of the fjord, fig. 1. It is 14 km long and elongated in a NE-SW direction. The island chiefly consists of greenschists and quartz-augengneisses representing various metamorphic volcanic rocks belonging to the Støren group – this being a lithostratigraphic unit in the Trondheim region comprising spilitic and associated nonfossiliferous sedimentary rocks. The age is considered to be Lower Ordovician.

A bed of limestone about 20 m thick occurs in the greenschists in the southern part of the island at Sandstad. The strike is E 40–50° S and the dip 10–20° NE. The limestone is a rather pure calcitic marble very low in magnesia. It is quarried by Meraker Smelteverk and used in the production of carbide.

The limestone is cut by a dyke which in the field is characterized by large phenocrysts mostly of biotite in a very finegrained, dark groundmass, fig. 2. It has the appearance of a completely fresh rock; the contacts with the limestone are hair-sharp and the dyke has obviously not been affected by Caledonian metamorphism. This lamprophyric rock is unique in several respects. The occurrence of a young dyke in this area was rather unexpected as the nearest post-Caledonian dykes are situated more than 300 km away. The composition is also uncommon as shown by the description that follows.

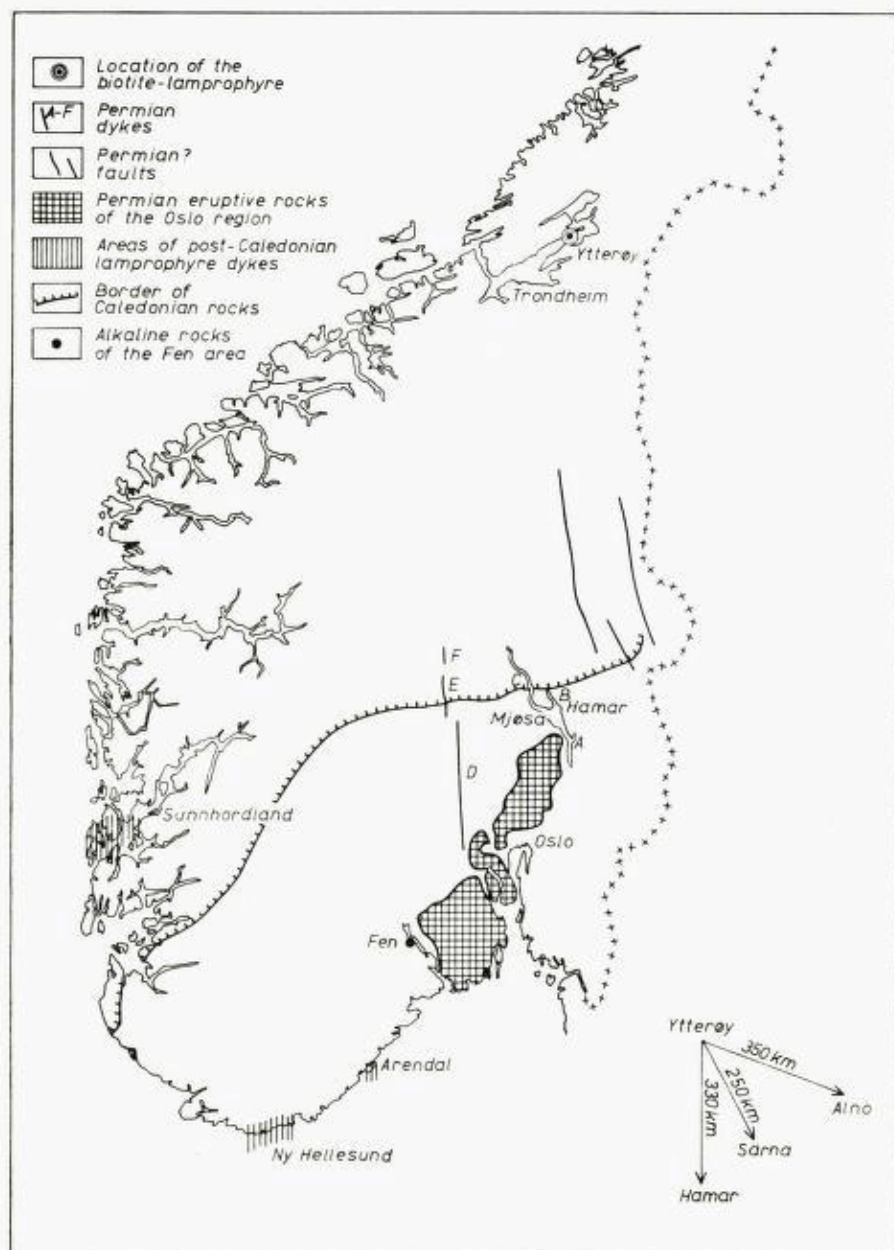


Fig. 1. Map showing the location of the biotite lamprophyre dyke of Ytterøy in relation to alkaline rock provinces. A - biotite camptonite dyke, Tangen. B - ultra-basic hornblende monchiquite dyke, Furuberget. C, E, F - diabase dykes. D - rhomb porphyry dyke.



Fig. 2. Biotite lamprophyre. Hand specimen. $\frac{3}{4}$ nat. size.

The thickness of the dyke is 80–90 cm, the strike N 60° E and the dip 70° towards SE. According to statements of the workers of the quarry, the exposed length was originally 10–15 m. Now only 3–4 meters of the dyke remains accessible for a detailed study. No continuation of the dyke was found in the greenschists, but very few outcrops exist in the surroundings.

Petrography.

Large plates of biotite are the most abundant porphyritic constituent. Phenocrysts of carbonate-chlorite pseudomorphs after olivine are less common, but it is sometimes difficult to distinguish such pseudomorphs from amygdales filled with calcite and a green chlorite substance.

The fine-grained groundmass consists mainly of biotite, clinopyroxene, calcite, analcite, and magnetite. Accessories are alkali-feldspar, pyrite and apatite.

White spots – ocelli – and patches consist chiefly of analcite (confirmed by X-ray powder analyses).

Thin carbonate veins, 1–2 mm wide, penetrate the rock in different directions. Most of them are parallel to the walls and occur on both sides



Fig. 3. Biotite lamprophyre — limestone contacts. Polished specimens. $\frac{1}{2}$ nat. size. The left picture (a) shows the porphyritic border facies, 15 mm wide. «Anomalous» large inlets of biotite above the discontinuity. To the right (b) is demonstrated fine-grained chilled margin and increase in the size and amount of phenocrysts from the contact. The white contact layer is seen in both pictures.

in a 10–15 cm broad zone beginning about 10 cm from the contacts. Calcite veins are in majority. Magnesite veins are bordered by thin chlorite — calcite zones. The veins commonly pass through the biotite inlets and seem to push the cleavage planes away from one another.

Xenoliths are very scarce. On careful inspection of a number of samples only two were found. Both are slightly reddish and discus-shaped with a diameter of 12–15 mm. They consist of quartz and calcite surrounded by a rim of green chlorite. The red colour is due to hematite dust. The quartz xenoliths were obviously derived from beds of red jasper which are commonly associated with the greenstones.



Fig. 4. Biotite lamprophyre. Photomicrographs, 26 X. Right: Phenocryst of biotite contiguous to an analcite ocellus. Left: Pseudomorphs after olivine.

The contact relations are illustrated in fig. 3. The phenocrysts, the minerals of the groundmass, and the ocelli may gradually increase in size away from the contact (fig. 3b), but usually a strongly porphyritic facies of the lamprophyre separates the non-porphyritic chilled zone from the limestone (fig. 3a). Thin offshoots from the dyke are always of the porphyritic type having phenocrysts of biotite and olivine pseudomorphs in a very fine-grained matrix which could not be resolved under the microscope. A thin, white layer (probably glassy) — 0,5–3,0 mm wide — is invariably present at the contacts. The limestone itself has been subjected to some alteration in a narrow zone — only 0,05–0,1 mm thick. Recrystallization and introduction of matter have resulted in a finegrained equigranular layer of pigmented calcite in which abundant regular isotropic or nearly isotropic crystals of low refractive index (analcite?) plus small cubes of pyrite occur.

The amount of phenocrysts varies greatly. Volumetric analyses show between 10 and 15 % of biotite and few percent of olivine pseudomorphs in the central parts. Olivine is, however, more abundant than biotite in some central parts of the dyke, fig. 4, and in the porphyritic marginal zone. Irregular patches of a leucocratic facies of the lamprophyre con-

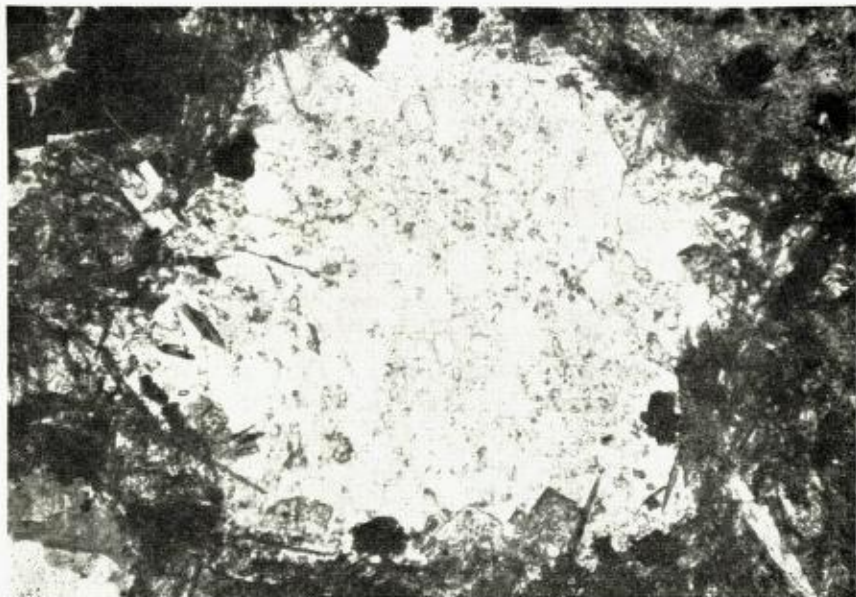


Fig. 5. Analcite ocellus in biotite-lamprophyre. Photomicrograph, 142 X.

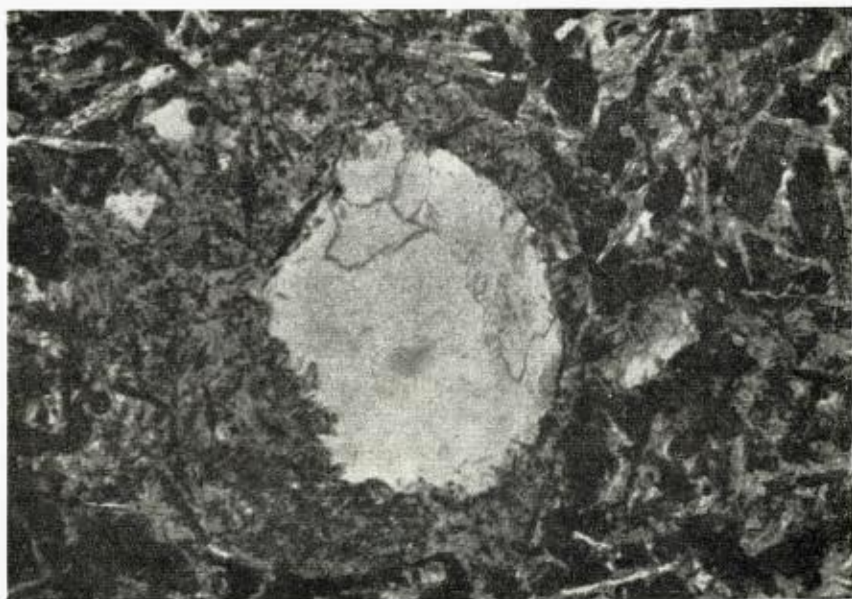


Fig. 6. Feldspar ocellus with analcite (upper part) and calcite in the central area. Camptonite Sunnhordland, Norway. Photomicrograph, 74.5 X.

tain no olivine and but a few biotite crystals. The biotite phenocrysts are usually well oriented parallel to the walls.

The discontinuity induced by the sudden appearance of phenocrysts at the selvage suggests that the dyke was formed by a multiple intrusion. This is, however, doubtful, and the writer has seen similar concentrations of olivine at the contacts in camptonitic and vogesitic lamprophyres.

The biotite phenocrysts display the usual dark borders so often noted in mica lamprophyres. The outline is hexagonal, rounded, or quite irregular. The refractive index $\gamma = 1.620 \pm 0.002$. A chemical analysis and the formula of the biotite are given in Table I. The biotite is close to phlogopite in composition and plots in the field of biotites from ultramafic rocks in the triangular diagram of E. W. Heinrich (1946). The formula was calculated on the basis of the cationic and anionic valence content of the unit cell = 44 (M. D. Foster 1961). The phlogopite is slightly deficient in (K + Na). This is partly compensated by the introduction of some Ba in the interlayer group, but the possibility of diadochic replacement of K by Mg is not suggested by the formula. Similar phlogopitic biotites also occur in biotite lamprophyres of the minette, the kersanite, and the alnøite type (H. Willams 1936, S. R. Nockolds 1947, W. C. Brøgger 1921).

The clinopyroxene forms thin, colourless laths ($0,2 \times 0,02$ mm); the composition is probably diopsidic.

The magnetite is a homogenous titan-magnetite. The content of TiO_2 in magnetite separated from the central part is 13,94 % (chemical analysis).

The analcite ocelli form approximately 8 % per volume in the central parts of the dyke. They commonly have a nearly circular outline as shown in fig. 5. Calcite often occurs in the periphery, and alkali feldspar may also be present. Biotite sometimes projects into the ocelli, but there is no tendency to a tangential arrangement of biotite around them. Large phenocrysts of biotite commonly lie contiguous to an ocellus, fig. 4. Related to the ocelli are the schlieren which consist of analcite, calcite, and magnetite. They are nearly devoid of phenocrysts. S. I. Tomkeieff (1952) explained the formation of similar analcite ocelli in a hornblende trachybasalt xenolith of the Traprain Law phonolite in terms of liquid immiscibility.

The mineralogical characteristics of the biotite lamprophyre: phenocrysts of biotite, olivine pseudomorphs, and abundance of calcite in the

matrix suggest a close relationship with alnöitic-kimberlitic rocks, although neither melilite nor perovskite have been found. The Ytterøy lamprophyre is similar to the so-called damtjernite of the Fen area, but more fine-grained. The identity of damtjernite and alnöite has been clearly established by H. von Eckermann (1958) who notes that alnöites and damtjernites are two different names for the same rock. According to Eckermann's (1948) classification the biotite lamprophyre of Ytterøy is a carbonatite alnöite or alvikitic alnöite. The resemblance to the analcite-bearing alvikitic alnöite (no. 67 in Eckermann's paper) must especially be pointed out. The writer would also like to emphasize the similarity with the so-called biotite-monchiquite of Magnet Cove, Arkansas, USA.

The analyses of the biotite lamprophyre presented in Table 2 confirm that the composition is close to the damtjernite. The high content of TiO_2 is a feature which the lamprophyre shares with potassic ultrabasic rocks of Uganda: katungites and their associates (R. A. Higazy 1954). The difference in content of Na_2O in 1a and 1b should be noted. 1b is a rather olivine-rich facies of the lamprophyre low in analcite. It is often associated with leucocratic analcite-rich segregations remarkably high in potash suggesting the presence of potash-analcite.

Extending the comparison between the biotite lamprophyre of Ytterøy and the alnöites it is suggested that the narrow belt of alteration in the limestone adjacent to the lamprophyre may correspond to the fenitization zone around the alnöitic dykes.

Post-Caledonian dykes.

Post-Caledonian basic dykes are extremely scarce in the Norwegian Caledonides. H. Reuch (1888) described young diabase and lamprophyre dykes from Sunnhordland on the west coast. The lamprophyres usually form narrow dykes which strike NNW-SSE and dip rarely vertically. According to observations by Reuch, A. Kvale (1937), A. J. Skordal (1948), and myself the lamprophyres comprise mostly vogesitic and camptonitic types. A single dyke of minette which, however, has not the same fresh appearance as the other lamprophyres, also occurs here. The vogesites have phenocrysts of augite and olivine pseudomorphs in a groundmass of augite, brown hornblende (kaersutite), alkali feldspar, chlorite, and calcite. Ocelli filled with alkali feldspar, analcite, calcite, and some brown hornblende are abundant, fig. 6. These correspond to the segregations of analcite in alkaline diabases described by G. W.

Tyrrell (1928), K. Yagi (1953), and others. The camptonites differ from the vogesites in having plagioclase in the groundmass instead of alkali feldspar, and in the absence of typical ocellar structures. Calcite amygdalae are, however, usually present. These lamprophyres from the west coast of Norway are similar to those along the southern coast (H. Carstens 1959) for which a Permian age has been proposed. Lamprophyres of the same kind occur in the Fen area as late magmatic dykes obviously related to the formation of this carbonatite province (S. Svinndal, personal communication). Age determinations indicate, however, an early Cambrian age of the Fen rocks (H. Neumann 1960).

Of considerable interest is the fact that some of the lamprophyre dykes of the Oslo region have distinct alnöitic character. W. C. Brøgger (1933) mentioned an occurrence of a mica camptonite at Gran, Hadeland, and a similar dyke was recently found by A. Hjelle (1960) south of Hamar at lake Mjøsa (A in fig. 1).

Attention is called to the high content of calcite in the biotite lamprophyre compared to the vogesites and the camptonites. The fact that the Ytterøy dyke is intrusive in limestone while the other lamprophyres in the Caledonides cut granites and non-calcareous metamorphics might be suggestive of limestone syntexis, but no other indications of assimilation have been observed. Lamprophyres are in general fairly high in CO_2 and other volatiles as H_2O , P, and S. Related to the abundance of volatile matter is the inherent property of lamprophyres to segregate ocelli or schlieren, thereby demonstrating a differentiation potential which under favourable conditions may give birth to more special rock types. The biotite lamprophyre of Ytterøy has affinities both with the above mentioned vogesitic and camptonitic dykes and with kimberlites. E. Sæther's (1957) suggestion that the alkaline rocks and the carbonatites of the Fen area originated from a kimberlitic – alnöitic magma thus ties up the carbonatite problem with the evolution of the lamprophyres.

The isolated occurrence of the biotite lamprophyre in relation to young dykes and larger alkaline provinces is remarkable, fig. 1. Did the magma ascend through a narrow fissure from deep in the earth's crust, or is the dyke a manifestation of a nearby (subsurface?) alkaline intrusion? Alkaline rocks are commonly associated with rift faulting, and it may be suggested that the Ytterøy dyke is connected with the same system of vertical faults as formed the Oslo graben. Permian faults and dykes – striking NNW-SSE – occur north of Mjøsa and may continue further north to the fjord at Trondheim.

Acknowledgments.

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Table 1.

Chemical composition and structural formula of biotite separated from the lamprophyre (central part).

	Weight percent ¹⁾	Cations per unit cell	Charge
SiO ₂	37.29	5.535	tetrahedral group = 8.000
		{ 2.465	
		{ 0.217	
Al ₂ O ₃	15.33	0.314	octahedral group = 5.634
TiO ₂	2.77	0.169	
Fe ₂ O ₃	1.48	0.650	
FeO	5.27	4.456	
MgO	20.16	0.004	
MnO	0.04	0.142	interlayer group = 1.835
Na ₂ O	0.49	1.693	
K ₂ O	8.94		+ 2.465
CaO	1.40		+ 0.634
CO ₂	1.08		+ 1.844
H ₂ O+	6.16		
	99.92		

- 1) Analysis of biotite contaminated with calcite.
Analyst: M. Varga.

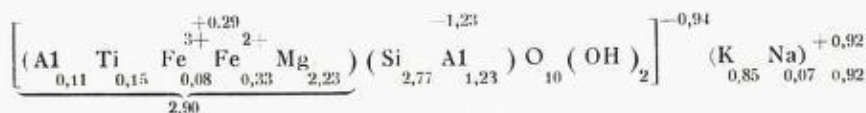
FORMULA:

Table 2.

Chemical composition of biotite lamprophyre and damtjernite.
Weight per cent.

	1a	1b	2	3	4	5
SiO ₂	35.46	33.73	39.31	29.16	42.67	37.04
TiO ₂	4.60	4.22	3.25	4.15	2.08	3.16
Al ₂ O ₃	10.09	9.33	15.68	10.26	12.06	12.67
Cr ₂ O ₃	0.15	0.18				
Fe ₂ O ₃	5.40	5.58	3.63	6.38	3.57	4.53
FeO	7.81	8.70	7.26	8.55	6.83	7.55
MnO	0.21	0.15	0.21	0.14	0.26	0.20
MgO	7.25	10.82	8.21	8.03	5.60	7.28
CaO	12.79	10.16	12.50	16.34	11.93	13.59
BaO	0.28	0.19	0.42		0.03	
Na ₂ O	2.67	0.84 ¹⁾	0.35	0.83	2.26	1.15
K ₂ O	2.83	3.18 ¹⁾	4.93	2.72	4.14	3.93
H ₂ O÷	0.63	2.32	0.13	0.22	0.16	0.17
H ₂ O+	3.00	2.85	1.65	2.05	2.28	1.99
P ₂ O ₅	0.85	0.67	0.52	1.20	0.94	0.88
CO ₂	5.42	5.81	1.20	10.24	4.81	5.42
S	0.40	0.36	0.20	0.33	0.37	0.30
	99.84	99.09	99.45	100.60	99.99	99.86

- 1a. Biotite lamprophyre, selvage. Analyst: B. Th. Andreassen.
- 1b. Biotite lamprophyre, central part. Analyst: B. Th. Andreassen.
2. Damtjernite, boulder at Melteig, Fen (W. C. Brøgger 1921).
3. Damtjernite, Brånan, Fen (W. C. Brøgger 1921).
4. Damtjernite Ormen, Fen (W. C. Brøgger 1921).
5. Average of 2,3 and 4.

¹⁾ Leucocratic segregation: Na₂O = 2.75, K₂O = 5.37.