# Intrusive Rocks of the Northern Iveland-Evje Area, Aust-Agder

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In the northern Iveland–Evje area extensive magmatic activity occurred during the so-called Sveconorwegian igneous period. Two intrusive episodes can be distinguished though apparently they occurred close in time. The oldest intrusions are represented by amphibolites which were emplaced under plutonic conditions and thus were able to deform the gneissic host rock (globulitic type of intrusion). At the close of this first episode basic dykes were intruded. During the second episode monzonite and granite were intruded, followed by monzonitic conical sheets and radiating dykes. Aplitic dykes and pegmatites brought the igneous activity to a close.

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## Introduction

The Iveland–Evje area is dominated by an elongated body of amphibolite measuring 35 km in a north-south direction and 10–15 km east-west. The massif was mapped and described by Barth (1947) as the Iveland–Evje amphibolite. Well known from the area are the many pegmatites containing rare minerals (for descriptions see Andersen 1926, 1931; Barth 1928, 1931, 1947; Bjørlykke 1934, 1937) and the nickel mineralisation (Vogt 1893, 1923; Bjørlykke 1947).

This paper presents the results of a re-mapping of the northern part of the Iveland–Evje area and deals with the magmatic rocks found there.

The re-mapping was carried out by the author in 1967 and 1968 with two more short stays in 1970 and 1973. During the first field season the author was a member of the team working on the 'Telemark Project' (1962–1967) organised by the Mineralogisk–Geologisk Museum, Oslo. The mapping was carried out at scale 1 : 25 000 and is more detailed than the earlier mapping by Barth (1947).

In the area mapped (Plate 1) there are two main rock units: the regional amphibolite facies gneisses and the younger magmatic rocks. The gneisses will not be treated in any detail in this paper. Their outcrop pattern only partly reflects the regional gneiss structure, since it is influenced by the shape of the main body of magmatic rocks. The latter comprises *the Høvringsvatn Complex* (Pedersen 1973) and *the Flåt Complex*. Only a part of the Flåt Complex has been mapped as yet. The complexes are examples of intrusions emplaced under plutonic conditions in deep crustal environments.

## Description of the intrusive rocks

### THE HØVRINGSVATN COMPLEX

The Høvringsvatn Complex is situated around the lake Høvringsvatn northeast of Evje (Plate 1). The outcrop of the complex is elliptical in shape with a NNE–SSW orientation of the longest axis. The complex includes amphibolite, monzonite, granite, aplite and pegmatite. It is surrounded by gneisses to the west, north and east.

Barth (1947) described the amphibolite from the locality Bertesknapen (Bertesknapen amphibolite) as a schistose amphibolitic rock, but the present author's observations indicate that in general the amphibolitic rocks only rarely possess a marked schistose structure (in the sense of Turner & Weiss 1963).

The modal compositions of the rocks described below are given in the Appendix (p. 9).

*Amphibolite*: Amphibolite is the oldest unit of the Høvringsvatn Complex. It crops out mainly in a large area in the marginal part of the Høvringsvatn Complex and in a smaller isolated area in the centre of the complex (Plate 1). In addition it occurs as layers and lenses enclosed in the younger rocks. The contact with the gneiss is not exposed, but structural investigations indicate that the outer border of the amphibolitic body trends parallel to the strike of the foliation in the surrounding gneiss. The structures in the amphibolite also indicate that it wedges out to the north.

The amphibolite has a varying appearance. Normally it is a fine- to medium-grained dark rock, sometimes alternating with irregular light bands. In the western part a more pronounced banding is seen, while to the east the rock has an almost homogeneous appearance. Here, however, it is possible in places to find some coarse-grained bands consisting almost entirely of hornblende. There is only rarely any sign of a preferred mineral orientation.

In the western part the amphibolite occasionally contains both hypersthene and diopside (sample no. 4883, see Appendix). The hypersthene grains are replaced to a certain degree by hornblende. Exsolution lamellae of diopside are seen in the hypersthene.

*Basic dykes*: Generally it is only possible to follow these dykes in the Høvringsvatn Complex over short distances (Fig. 1). This is due partly to poor exposures and partly to the irregular intrusive form of the dykes. The dykes never exceed one metre in width and are often no more than 20–30 cm wide.

The dykes are of amphibolitic composition, and pyroxenes have never been observed (see Appendix). Two types can be distinguished:

a) Dark dykes made up entirely of fine-grained amphibolite; these may carry plagioclase mesocrysts. Biotite is also present and shows a preferred orientation parallel to the contacts. Small patches of ultramafic rock have been observed in the central parts of one of these dykes.

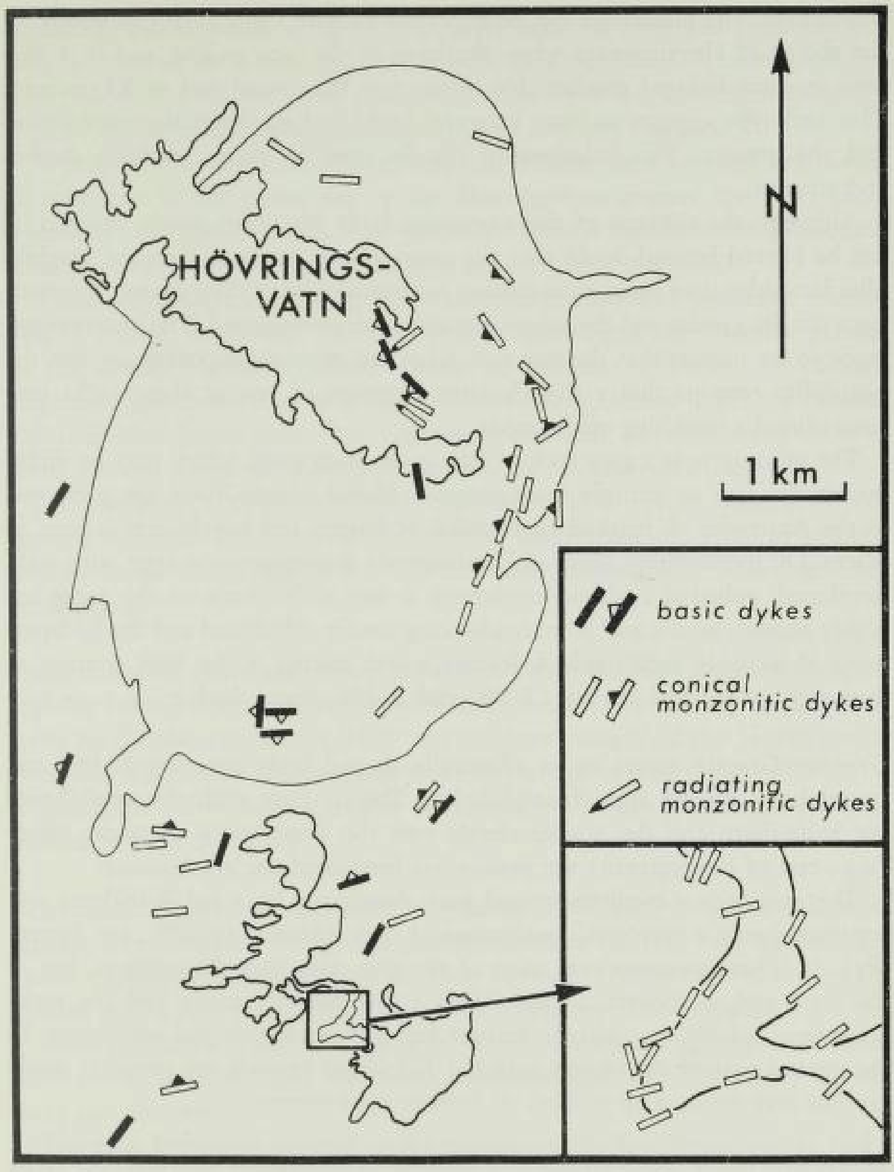


*Fig. 1.* Basic and monzonitic dykes within the Høvringsvatn Complex.

b) Complex dykes with a fine-grained border zone and a coarse-grained central part. The contact between the central part and the border zone is very well defined. The central part is dominated by aggregates of amphiboles which are orientated perpendicular to the contacts. Nearer to the border zone plagioclase-rich material with scattered amphibole aggregates is present. The rock-type making up the fine-grained border zone is the same as the amphibolite of dyke type *a*.

*Monzonite*: The monzonite can be observed in nearly continuous outcrops on the shores of Høvringsvatn when the level of the lake is low, and it is also seen in some isolated patches, for instance at Gautestad and at Kleppsland. This rock-type appears to form a central body that underlies the amphibolite and the granite. This relationship can be seen in many roadside ditches and streams.

Although the contacts of the monzonite body are often poorly exposed, it can be proved beyond doubt that the monzonite is younger than the amphibolite but older than some cross-cutting monzonitic dykes. The contact relations between the granite and the monzonite are more complicated. The observations made so far suggest that the two rock-types are penecontemporaneous, but the possibility remains that a slightly later intrusion of one of these rocks may have caused a remelting of the other.

The monzonite is a grey rock of fine to medium grain which may be either weakly foliated or entirely homogeneous. Modal compositions are presented in the Appendix. A marked aggregation of biotite and hornblende is seen in places. On the southern shore of Høvringsvatn a homogeneous type with well-developed, euhedral feldspar mesocrysts is met with. Some of the rocks are highly altered, biotite and hornblende being totally chloritised and the feldspars being thoroughly sericitised. A feature worth noting is the high content of accessory sphene and apatite (2–5% and 1–3%, respectively).

*Granite*: Granite occurs as an elliptically shaped body covering 15 $km^2$ and containing a central area of amphibolite. The contacts with the amphibolite are knife-sharp and the granite clearly cuts the amphibolite. In some places (e.g., east of Rasevetvatn) the granite has brecciated the amphibolite.

The granite is a medium-grained rock dominated by a red K-feldspar and containing only a very small percentage of dark minerals ($< 2\%$, see Appendix). It is homogeneous over most of the area, also near the contacts, but in the west and south-west it grades into a fine-grained variety and the rocks sometimes exhibit a cataclastic texture and a characteristic red coloration. In the central part of the pluton euhedral K-feldspar crystals are present; single crystals may measure up to 2 cm $\times$ 3 cm in cross-section.

*Monzonitic dykes*: Structurally it is possible to distinguish between two types of minor monzonitic intrusions: conical sheets and radiating dykes. The terms conical sheets and radiating dykes are used to distinguish these intrusions from typically subvolcanic cone sheets and radial dykes, although the intrusion mechanism was probably the same.

The conical sheets form semicircular outcrops and their dips point towards a centre just south of Høvringsvatn (Fig. 1). In spite of many interruptions it is possible to follow them from Gautestad to west of Vikstøl. The radiating dykes have been observed in the outcrops on the shores of Høvringsvatn (Fig. 1). Outside the Høvringsvatn Complex monzonitic dykes are seen at Flåt cutting the Mykleås amphibolite and the marginal granite of the Flåt

Complex, and in several roadside exposures between Evje and Byglandsfjord they are seen to cut biotite gneiss, but here their structural attitude is not yet understood. The widths of the dykes vary from some few centimetres to more than 20 m; individual dykes are only rarely of constant thickness.

Where the monzonitic dykes intrude amphibolite their contacts are almost straight, but in the gneiss and in the Høvringsvatn granite they may show extremely irregular contacts. This obviously reflects the different rheological conditions of the host rocks at the time of monzonite intrusion.

The monzonitic dykes are light grey and fine-grained with a distinct orientation of biotite, amphibole and also sphene, apatite and ore minerals parallel to the contact. In some of the dykes an incipient formation of biotite–amphibole aggregates may be observed. Some of the thicker dykes are banded. The individual bands show little contrast in the field, the differences being in grain size and the proportions and orientations of component minerals.

The monzonitic dykes are often associated with aplitic material which appears as border aplites, cross connections, sheet veins and more or less discordant veins. Often the aplites are intensely ptygmatically folded or even boudinaged.

*Aplites*: Aplitic dykes are present throughout both the Høvringsvatn Complex and the Flåt Complex as decimetre-thick discordant veins. They cut all rock-types except the pegmatites. Near the southern margin of the Høvringsvatn Complex, where they are most common, they are of coarser grain.

The aplites often have a weakly developed preferred orientation of biotite parallel to their contacts.

*Pegmatites*: Pegmatites are most commonly developed in the amphibolite terrain. Here some of the famous giant pegmatites carrying rare minerals are found, especially east and south of Høvringsvatn (Andersen 1931). In the granite only a few centimetre-thick quartz veins have been observed.

Other pegmatite bodies and veins occur in the surrounding gneiss. None of these are as large as those inside the complexes and apparently they do not carry rare minerals.

The most important minerals in the pegmatites are K-feldspar, quartz, and a little plagioclase. In some pegmatites albite (often cleavelandite) is observed. Biotite and in some cases green muscovite are common.

## THE FLÅT COMPLEX

The area of intrusive rocks occurring south-west of the Høvringsvatn Complex is provisionally called the Flåt Complex. The Flåt Complex includes two rock units, the marginal granite and the Mykleås amphibolite. *The marginal granite* is a grey, nearly homogeneous rock dominated by K-feldspar megacrysts which may define a lineation. *The Mykleås amphibolite* (named by Barth 1947) is a fine- to medium-grained, dark grey or black amphibolite easily distinguished from the Høvringsvatn amphibolite on account of its porphyritic texture.

Noteworthy for both the marginal granite and the Mykleås amphibolite is the large amount of sphene (2–7%) and apatite (1–10%). The contact between the marginal granite and the Mykleås amphibolite is not exposed.

The Flåt Complex apparently forms a separate intrusion. Mapping of the complex has not yet been completed, however, and all that can be said at present about the age relations between the two complexes is that the Flåt Complex is older than the monzonitic dykes of the Høvringsvatn Complex since both the marginal granite and the Mykleås amphibolite are cut by these dykes. The Flåt Complex is therefore left out of the following discussion of the structural evolution.

## The structural evolution

A structural analysis has revealed no clear evidence of a regional deformation having affected the intrusive complexes. The Høvringsvatn Complex, which is elongated in the NNE–SSW direction, is clearly discordant in relation to the regional structures in the gneisses in which folds with WNW–ESE axis dominate the pattern. On outcrop scale, however, the gneiss foliation is seen to be concordant with the border of the complex, and near the contact the fold axes change attitude so that they become oriented parallel to the contact (Fig. 2). This local concordance could be the result of a forceful intrusion of the complex into *plastic* surroundings.

The Høvringsvatn amphibolite was the first rock to be emplaced and this amphibolitic intrusion can be compared to the metabasic bodies in the Moss area, Østfold, described as globuliths by Berthelsen (1970). Berthelsen (1970, p. 73) defined a globulith as: 'an intrusive body or a group of closely associated bodies of globular or botryoidal shape and with almost concordant contacts resulting from the effect of the intrusion/s on its/their immediate surroundings'. He imagined that their intrusion took place 'in a regionally preheated rock complex under plutonic conditions with pressures and temperatures (and $P_{H_2O}$) not much below those required to start regional anatexis'.

The intrusion of basic dykes terminated the episode of basic intrusive activity. In the Høvringsvatn Complex this basic intrusive episode was followed by an episode during which intermediate and acid rocks were emplaced. As mentioned earlier these rocks — the Høvringsvatn monzonite and the Høvringsvatn granite — show very complicated contact relations and it has not yet been possible to establish their chronological order.

The amphibolitic body in the centre of the Høvringsvatn granite conceivably forms a huge xenolith which sank into the granite from the roof. The more or less 'chaotic' structures characteristic of the amphibolitic member make it difficult if not impossible to prove this by structural analysis, but the fact that the body considered to be a xenolith is heavily veined by granitic apophyses concurs with this interpretation.

The closing stage of the younger intrusive episode was marked by the intrusion of monzonitic conical sheets and radiating dykes inside the Høvrings-

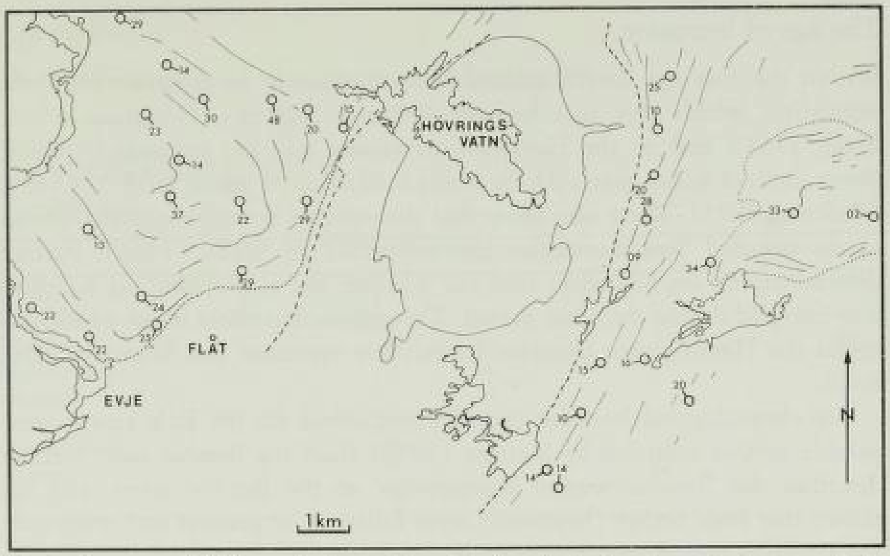


*Fig. 2.* Constructed fold axes in the gneisses showing their changing attitude towards the margin of the intrusive complexes.

vatn Complex and other monzonitic dykes in the gneiss and in the Flåt Complex. The monzonitic dykes are cut by aplitic dykes. In places, however, both the monzonite and the aplitic veins can be seen to be influenced by shearing and flattening. This deformation could well have been caused by the stresses set up during the emplacement of the conical sheets. The intimate association of aplite and monzonite in many of these dykes suggests a close time relationship between the intrusion of these two rock-types. Possibly the pegmatites were also intruded just after the monzonite.

Two intrusive episodes, an older basic and a younger intermediate/acid phase, can thus be distinguished in the Høvringsvatn Complex. Both episodes ended with a period of dyke emplacement. The whole of this intrusive development apparently took place under plutonic conditions. The lack of fine-grained contact zones in the Høvringsvatn monzonite and the Høvringsvatn granite indicates that these intrusions were emplaced into host rocks already having quite elevated temperatures. The dyke generations provide evidence of tensional conditions in the crust, but as dykes of both generations show irregular to scalloped contacts, they need not be taken as evidence of uplift of the complex at the termination of each of the intrusive episodes. In consequence these episodes are considered to have followed one after the other almost without interruption and they are believed to have been emplaced at a deep level in cratonic crust (Berthelsen 1972).

The Høvringsvatn Complex is therefore classified as a discordant anorogenic intrusion. Its age, therefore, can be considered a *real* minimum age for the surrounding basement rocks.

## The age of intrusion

Within the area age determinations have been made on minerals from the pegmatites, which gave ages between 900 and 1000 m.y. (Neumann 1960; Broch 1964), and on the Høvringsvatn granite and the monzonitic conical sheets, both of which gave a Rb/Sr whole rock isochron age of 1038 ± 43 m.y. (Pedersen 1973). These ages show that the younger intrusive episode belongs to the so-called 'Sveconorwegian igneous period' of Welin (1966). Further determinations are needed to find out whether the amphibolite, as believed, was intruded during the same period. The gneissic basement rocks which surround the Høvringsvatn Complex conceivably represent pre-Sveconorwegian rocks.

The chronology of intrusive episodes established for the Evje area is comparable to that compiled by Starmer (1972) from the Bamble area. Starmer describes the 'Sveconorwegian regeneration' of the Bamble series, and has shown that basic bodies (hyperites) were followed by granites and granitoids, the intrusive period terminating with pegmatites.

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# Appendix

Modal compositions of the rocks described in the text

## HØVRINGSVATN COMPLEX

### *Amphibolite*

| | *4710* | *4729* | *4883* | *4884* | *1048* | *1049* | *1112* |
|---|---|---|---|---|---|---|---|
| Quartz | | 4 | 2 | 16 | 1 | x | |
| Plagioclase | 67 | 45 | 37 | 21 | 60 | 58 | 40 |
| Hornblende | 32 | 48 | 38 | 13 | 20 | 40 | 60 |
| Hypersthene | | | 8 | | | | |
| Diopside | | | 9 | | | | |
| Accessories | x | x | 1 | x | 4 | x | |
| Ore minerals | x | 3 | 5 | | 1 | 2 | x |
| Chlorite | | | | | 14 | | |
| Biotite | | x | 1 | 50 | | | |

x: $<$ 1%

### *Basic dykes*

| | *1173* | *058* | *4867* |
|---|---|---|---|
| Plagioclase | 17 | 21 | 19 |
| Hornblende | 60 | 77 | 75 |
| Biotite | 17 | | 4 |
| Sphene | 4 | | |
| Ore minerals | | 2 | 2 |
| Epidote | x | | |
| Chlorite | 1 | | |

x: $<$ 1%

### *Monzonite and granite*

| | *1050* | *1162* | *054* | *4862* | *4863* | *4864* | *1098* |
|---|---|---|---|---|---|---|---|
| Quartz | 9 | 10 | 11 | 32 | 22 | 16 | 3 |
| Plagioclase | 31 | 29 | 17 | 24 | 32 | 18 | 27 |
| K-feldspar | 28 | 29 | 37 | 41 | 43 | 63 | 46 |
| Amphibole | 13 | 14 | 14 | x | x | | 10 |
| Biotite | | | 15 | 1 | 2 | 2 | 8 |
| Sphene | 3 | 2 | 3 | 1 | 1 | 1 | 3 |
| Apatite | 1 | 1 | 1 | x | x | x | 2 |
| Zircon | | x | | | x | | |
| Ore minerals | | | x | 1 | x | x | 1 |
| Carbonate | | 1 | | x | | | |
| Fluorite | | | x | | x | | |
| Chlorite | 15 | 13 | | | | | |
| Epidote | | | 1 | x | x | x | |

x: $<$ 1%

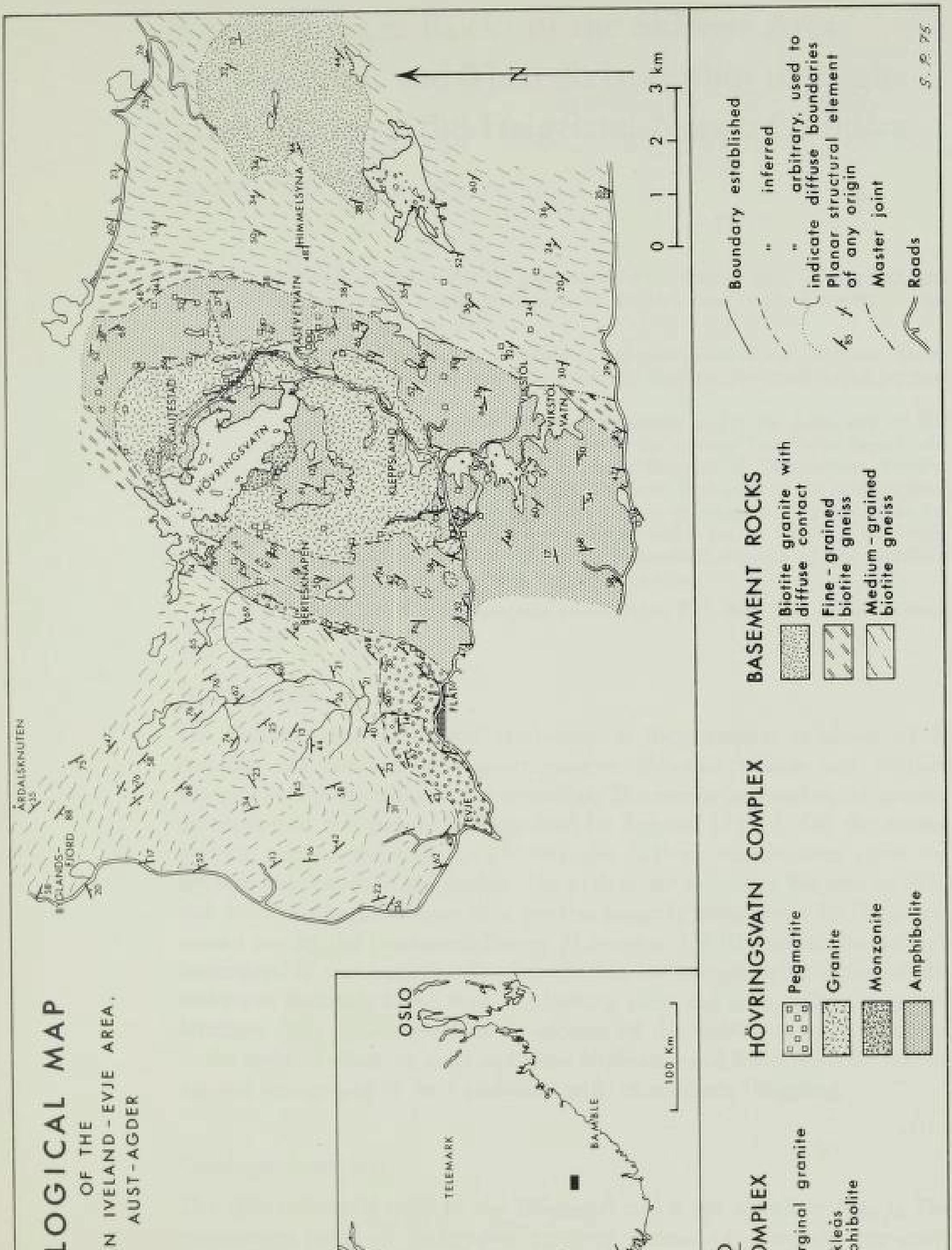
Specimens 1050, 1162 and 054 – Høvringsvatn monzonite
Specimens 4862, 4863 and 4864 – Høvringsvatn granite
Specimen 1098 – monzonitic cone sheet

FLÅT COMPLEX

| | *4875* | *4877* | *4818a* | *4872* |
|---|---|---|---|---|
| Quartz | 4 | 10 | 9 | 12 |
| Plagioclase | 71 | 46 | 50 | 40 |
| K-feldspar | | | | 36 |
| Amphibole | 3 | 18 | 11 | 1 |
| Biotite | 13 | 4 | 13 | 7 |
| Sphene | 5 | x | 5 | 2 |
| Apatite | 2 | 5 | 4 | 1 |
| Ore minerals | 1 | 8 | 3 | 1 |
| Chlorite | x | 8 | 5 | x |
| Epidote | x | x | x | x |

x: < 1%

Specimens 4875, 4877 and 4818a – Mykleås amphibolite
Specimen 4872 – marginal granite (only a rough estimate based on 1301 points)


GEOLOGICAL MAP
OF THE
NORTHERN IVELAND - EVJE AREA,
AUST-AGDER
OSLO
TELEMARK
ROGALAND
BAMBLE
100 Km
ÅRDALSKNUTEN
BYGLANDSFJORD
HÖVRINGSVATN
KLEPPSLAND
HIMMELSYNA
VIKSTØL
VIKSTØLVATN
FLÅT
EVJE
N
0 1 2 3 km
LEGEND
FLÅT COMPLEX
Marginal granite
Mykleås amphibolite
HÖVRINGSVATN COMPLEX
Pegmatite
Granite
Monzonite
Amphibolite
BASEMENT ROCKS
Biotite granite with diffuse contact
Fine - grained biotite gneiss
Medium - grained biotite gneiss
Boundary established
" inferred
" arbitrary, used to indicate diffuse boundaries
Planar structural element of any origin
Master joint
Roads
S.P. 75