ENCLOSURE 1

THE FONGEN - HYLLINGEN COMPLEX

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NGU Norges geologiske undersøkelse Geological Survey of Norway

This geological map has been compiled from contributions by M.Sc. and Ph.D. students at the University of Aarhus, Denmark, under the supervision of J. Richard Wilson. Most of the mapping was performed on a scale of about 1:10.000 based on enlargements of the 1:50.000 topographic maps of Tydal and Ålen, sometimes supplemented by aerial photographs. Most of this mapping took place in the period 1974 - 1996, before GPS equipment was available. Individual mapping areas are identified in Figure 1, together with references to the theses in which the detailed maps can be found.

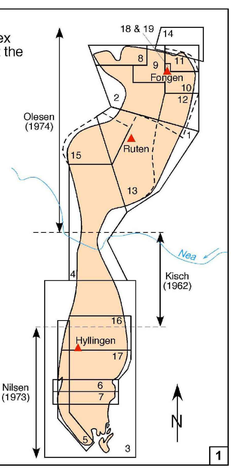
The Fongen-Hyllingen Complex comprises two intrusive bodies: the Fongen-Hyllingen Intrusion and the small Treknatten Intrusion. The mafic to ultramafic Treknatten Intrusion (~3 km^2) is emplaced in the northern part of the layered mafic Fongen-Hyllingen Intrusion (~160 km^2). The Treknatten Intrusion was first partially mapped by Knudsen (1990) and later described by Sørensen & Wilson (1996).

The geology of the country rocks adjacent to the Fongen-Hyllingen Complex has largely been taken from Olesen (1974), Kisch (1962) and Nilsen (1973), as indicated in Figure 1.

Areas of the Fongen-Hyllingen complex mapped by M.Sc. and Ph.D. students at the University of Aarhus, Denmark.

1.	Thy, P.	(1977)
2.	Esbensen, K.H.	(1978)
3.	Larsen, S.B.	(1982)
4.	Svane, J.O.	(1983)
5.	Engell-Sørensen, O.	(1985)
6.	Jakobsen, N.N.	(1985)
7.	Habekost, E.M.	(1987)
8.	Naldal, P.	(unpublished)
9.	Knudsen, L.G.	(1990)
10.	Sørensen, H.S.	(1990, 1994)
11.	Paasch, B.	(1991)
12.	Nielsen, K.Aa.	(1991)
13.	Meyer, G.B.	(1994, 1999)
14.	Thjømøe, P.A.	(1995)
15.	Pedersen, A.	(unpublished)
16.	Kock-Hansen, K.	(1997)
17.	Thayssen, F.	(1998)
18.	Josephsen, K.	(2003)
19.	Holm, D.H.	(2003)

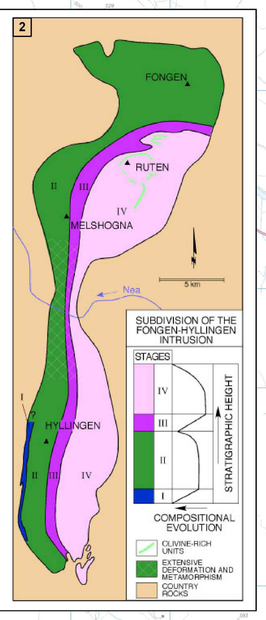
These students were supervised by J. Richard Wilson

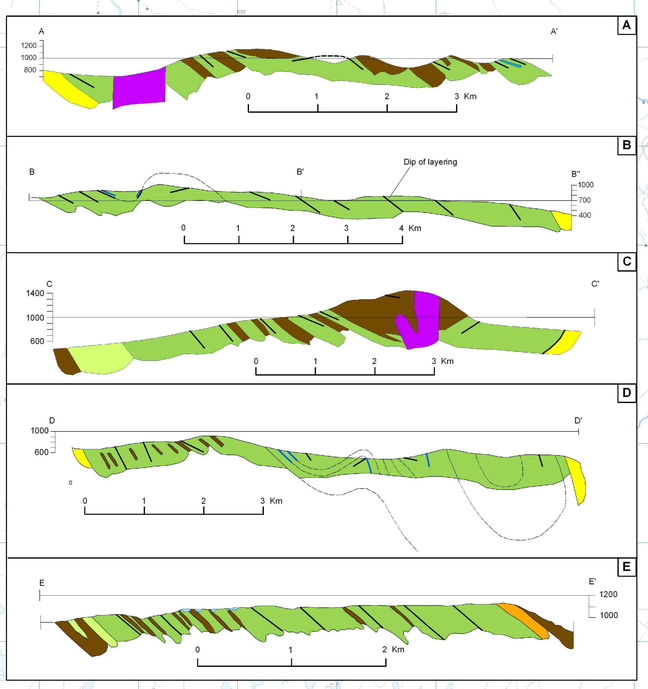


The reference list is at the end of main text accompanying this map

Lateral correlation in the Fongen-Hyllingen layered intrusion

As shown in Figure 2, the Fongen-Hylingen layered intrusion has been subdivided into four Stages (I-IV) on the basis of mineral chemistry (e.g. An% in plagioclase, Fo% in olivine, Mg/Fe ratio in pyroxenes). This was established in a series of profiles normal to the modal layering. Stage I (a basal reversal) has only been recognised in the southern Hyllingen area. Stage II has fairly constant mineral compositions through the lower part; these become more evolved towards the top. This stage is characterised by abundant raft-like country rock inclusions. Stage III represents a systematic compositional regression. The most primitive compositions in the entire layered intrusion occur at the Stage III/IV boundary. Mineral compositions become gradually more evolved upwards through Stage IV, ending with low temperature end-member mineral compositions at the roof in the eastern Hyllingen area. The lower part of Stage IV in the Ruten area contains several olivine-rich units that reflect repeated, minor episodes of magma addition. While this subdivision illustrates lateral correlation in the layered intrusion, it does not show compositional variations along strike. These are particularly evident in the Hyllingen area where rocks become systematically more evolved along strike towards the southern country rock contact. Precise lateral correlation through the deformed and metamorphosed interval on either side of the Nea river is difficult, but Stages II, III and IV can be recognised to the north (Melshogna area) and south (Hyllingen area).





The distribution of magnetic minerals (essentially titanomagnetite) in the Fongen-Hyllingen layered intrusion is illustrated by the aeromagnetic map (Figure 3). It is noteworthy that, in many places, there is a correlation between the aeromagnetic anomalies and the Stage-boundaries (from Figure 2).

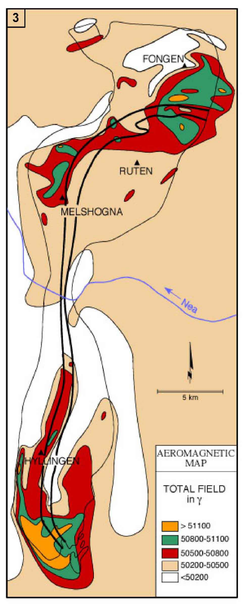
In the northern part of Figure 3 the Stage II/III boundary is parallel with the trend of the anomaly north of Melshogna. Magnetite is a cumulus phase in the upper part of Stage II and the Stage II/III boundary reflects the base of a compositional regression where cumulus magnetite rapidly disappears. Modal layering, which is parallel with the Stage boundaries, is quite steep in this area. Towards the northeast, north of Ruten, the anomaly is no longer parallel with the Stage II/III boundary but is displaced towards the south. This is believed to reflect the fact that modal layering (and consequently the Stage boundary) dips gently (~20°) to the south here and the aeromagnetic anomaly reflects the presence of magnetite-bearing cumulates below the surface.

Stage II continues towards the south from Melshogna, but there is little or no positive aeromagnetic anomaly. This is believed to reflect the role of metamorphism (often accompanied by deformation) in the central, narrow part of the intrusion on either side of the Nea valley (Figure 2). Amphibolite facies metamorphism has transformed the original magnetite-bearing cumulates of Stage II into essentially non-magnetic ilmentite-bearing metagabbros and/or foliated amphibolites.

In the northern Hyllingen area there are three roughly north-south trending positive anomalies that coalesce towards the south. The central anomaly is a continuation of the magnetite-bearing upper part of Stage II (the lower part of Stage III is also magnetite-bearing here) from the northern part of the intrusion. Modal layering dips ~40° to the east. The western anomaly reflects the presence of evolved magnetite-bearing rocks in the basal reversal of Stage I. The eastern positive anomaly initially reflects the return of magnetite as a cumulus phase during fractionation in Stage IV. This effect is supplemented by the extensive alteration of iron-rich olivine to magnetite-grunerite symplectites towards the top of Stage IV.

The largest positive aeromagnetic anomaly in the Fongen-Hyllingen Intrusion occurs in the southern Hyllingen area where the three north-south trending anomalies unite. This reflects the fact that modal and cryptic layering are discordant in this part of the intrusion. Towards the south, along the strike of modal layering, the cumulates become increasingly evolved. This is demonstrated both by systematic changes in the compositions of the solid-solution minerals (as discussed elsewhere) and the successive appearance of magnetite, apatite and zircon. It is the appearance of magnetite along strike that is largely responsible for the positive aeromagnetic anomaly in Stage III and the lower part of Stage IV. Magnetite-grunerite symplectites replacing iron-rich olivine in the highly evolved cumulates in the extreme south of Hyllingen contribute to the positive anomaly. It is noteworthy that the positive anomaly extends further to the south than the outline of the intrusion, indicating that it extends a short distance below the present level of exposure. This feature is also apparent to the east of Fongen in the northern part of the intrusion.

The distribution of the aeromagnetic anomalies in Figure 3 therefore indicates several important features of the Fongen-Hyllingen layered intrusion: the major influx of new, relatively primitive magma; the presence of discordant relations between modal and cryptic layering; and the effect of metamorphism.



LEGEND

COUNTRY ROCKS
- Metabasalt (inclusions converted to hornfels)
- Metapelite (inclusions converted to hornfels)
- Undifferentiated metapelite/metabasalt
- Metaperidotite
- Quartz diorite (trondhjemite)

FONGEN - HYLLINGEN INTRUSION
- Layered gabbro/diorite (locally metamorphosed). H = hornblende-rich
- Olivine-rich gabbro (locally metamorphosed)
- Unlayered marginal diorite (P = Pegmatitic)
- Quartz-bearing syenite
- Granitic pegmatite
- Felsic dyke
- Shear zone (gabbro/diorite altered to foliated amphibolite)
- Olivine-rich units
- Permanent ice/snow

TREKNATTAN INTRUSION
- Dunite, troctolite, olivine gabbro

- Fault
- Vertical modal layering
- Strike and dip of modal layering
- Strike and dip of foliation
- Overturned
- BZ Bleached zone (in Hyllingen area)
- QV Quartz vein (south Hyllingen area)
- MD Metadolerites
- Abandoned mine
- Trough structure
- Major river/stream
- Minor river/stream
- Lake
- Road
- Tractor path
- Marked path
- Track
- Bridge
- House
- Hut
- Farm
- Tourist hut
- 100 meter contour

A dark shade of each colour has been used for areas of outcrop; light shades have been used for interpretation.

N

0 1 000 2 000 3 000 4 000 5 000 m

Scale 1:30 000
WGS 84 / UTM zone 32