A note on the cumulate stratigraphy of the Fongen-Hyllingen gabbro complex, Trondheim Region, Norway

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Phase layering, accompanied by extensive cryptic variation, in the Caledonian synorogenic Fongen-Hyllingen layered gabbro complex allows three cumulate sequences to be distinguished, on the basis of which successive magma influxes are interpreted.

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The Fongen-Hyllingen complex is a large synorogenic layered mafic intrusion occupying ca. 160 km^2 in the Trondheim Region of the Norwegian Caledonides. The general geology and structure of the complex have been discussed by Wilson & Olesen (1975) and its synorogenic nature was established by Olesen et al. (1973). Despite deformation and amphibolite-facies metamorphism, sufficient primary textures and minerals are preserved for the mode of crystallization to be studied. Nilsen (1973) described the southern (Hyllingen) part of the complex and suggested that the differentiation products in this area combined tholeiitic and calc-alkaline characteristics. These conclusions were questioned by Robins (1974). It is the object of this note to outline the cumulate stratigraphy of the Fongen-Hyllingen complex.

A map of the Fongen-Hyllingen gabbro complex is given in Fig. 1. As shown by Wilson & Olesen (1975), the deepest levels of the intrusion are exposed in the northwest; rhythmic layering in the northern segment of the complex has a synformal disposition interpreted to reflect the original internal structure, emphasized later by deformation. Along the western margin of the complex, layering is locally overturned, but it has been established that the rhythmically layered sequence of the Ruten area overlies that of the Fongen area.

Cumulate stratigraphy

Thin-section interpretations of the cumulus/intercumulus status (Wager et al., 1960) of individual phases show that there is a major break between the Fongen layered sequence and the overlying Ruten sequence. They also confirm the suggestion made by Wilson & Olesen (1975) that the Hyllingen rocks represent the stratigraphically highest part of the layered complex.

Our preliminary results establish the cumulate stratigraphy shown in Fig. 2. The earliest cumulates occurring in the extreme northwest of the complex are represented by weakly layered ultramafites consisting of olivine (Fo_{87}) and subordinate chromite as cumulus phases. Plagioclase (An_{78}+) enters as a cumulus phase just before chromite ceases to occur. Above these olivine-plagioclase cumulates there is an unexposed gap, estimated as being some 700 m wide. Above this gap are gabbros containing cumulus plagioclase and two pyroxenes with sporadic intercumulus olivine. Intercumulus magnetite/ilmenite grains occur before olivine returns as an abundant cumulus phase. Magnetite/ilmenite appears as a cumulus phase when plagioclase reaches a composition of about An_{55}. The uppermost phase boundary in the Fongen sequence is marked by the entry of cumulus apatite which is present through a vertical interval of about 250 m. A light-brownish amphibole occurs as an intercumulus phase throughout most of the Fongen sequence. The Fongen suc-

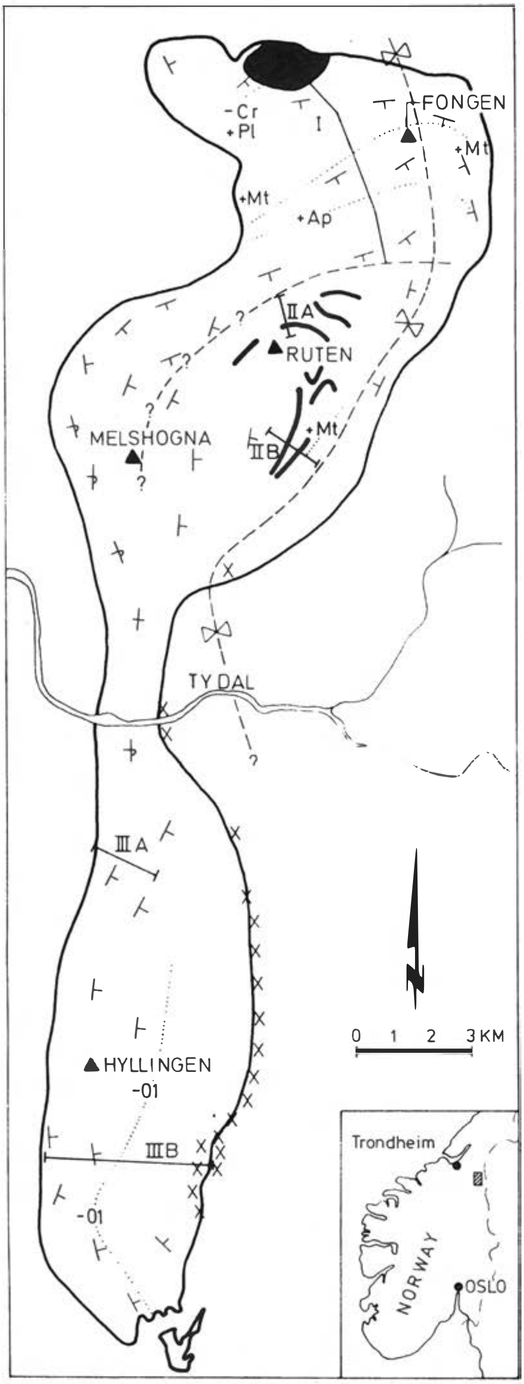


Fig. 1. Simplified geological map of the Fongen-Hyllingen gabbro complex, based on Wilson & Olesen (1975, fig. 2). Strike and dip symbols show orientation of rhythmic layering. Thick solid lines represent ultramafic units. Dark area denotes weakly layered ultramafic rocks. Dotted lines indicate entry or exit of some critical cumulus phases: Cr = chromite; Ol = olivine; Pl = plagioclase; Mt = magnetite/ilemenite; Ap = apatite. Exit of olivine in Hyllingen is from Nilsen (1973). Diagonal crosses indicate extreme differentiates. Dashed line shows approximate location of boundary between first (Fongen sequence) and second (Ruten sequence) magma influxes. Solid lines I, IIA, IIB, IIIA, and IIIB show profiles from which the thicknesses given in Fig. 2 were estimated. Post-emplacement synformal hinge line is also indicated.

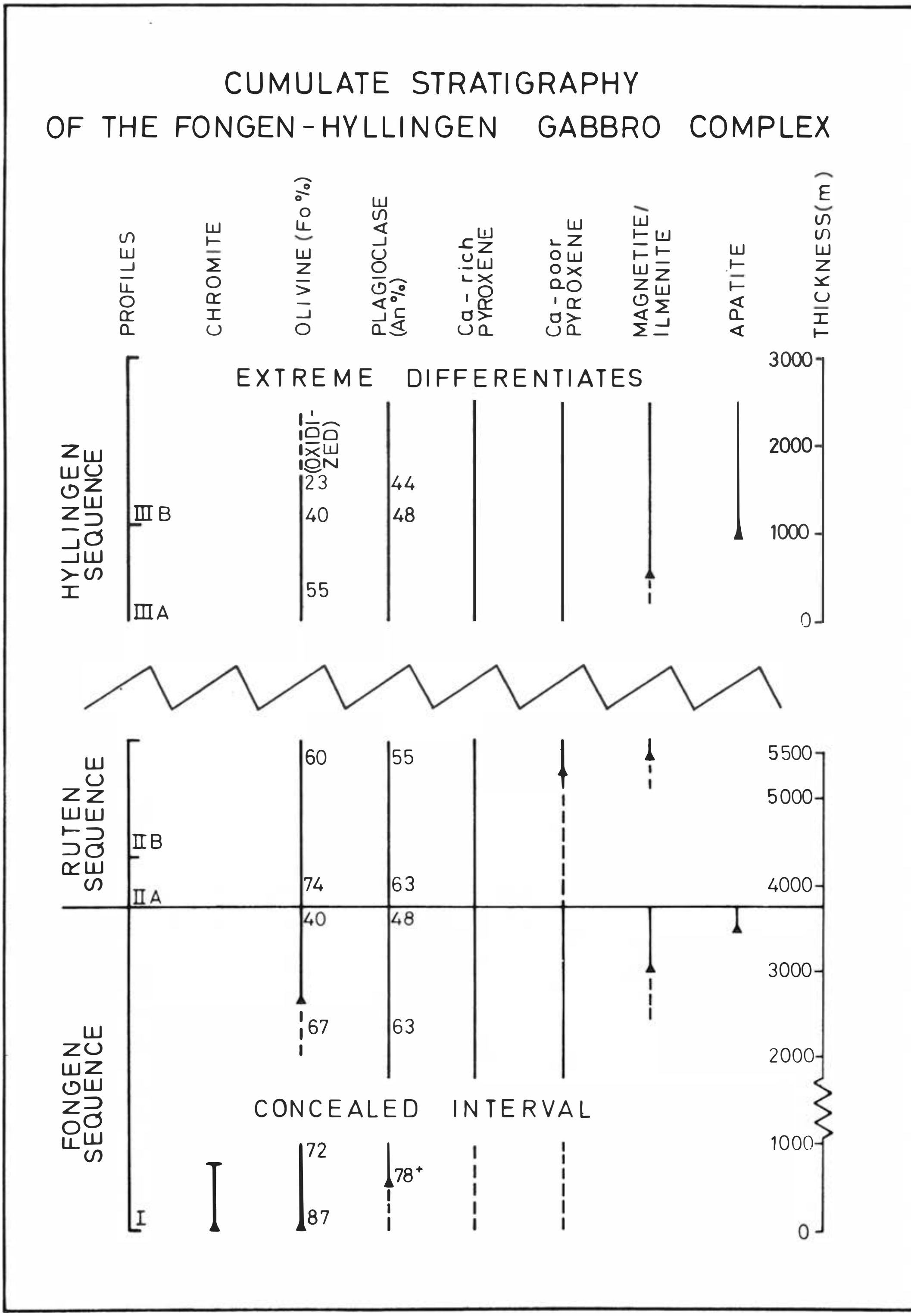
cession is estimated to be almost 4000 m thick. A positive aeromagnetic anomaly is present over the part of the sequence characterized by the presence of cumulus magnetite (Norges Geologiske Undersøkelse, Tydal 1721 III). The anomaly ceases abruptly over the Ruten area corresponding to the base of the succeeding layered sequence lacking cumulus magnetite.

No obvious transgressive contacts between the Fongen and overlying Ruten sequences have been observed in the field, and the boundary zone consists of weakly layered olivine, two pyroxene gabbros with additional magnetite/ilmenite, and often notably abundant brown amphibole.

The Ruten sequence is at least 1800 m thick and commences with gabbros in which olivine, plagioclase, and Ca-rich pyroxene are cumulus phases. Ultramafic horizons up to 30 m thick are present within the sequence and can be traced laterally for up to 3 km. Sedimentary structures are particularly well developed in these ultramafic units. The most magnesian olivine determined in the Ruten sequence has a composition of Fo_{74}, compared with Fo_{87} near the base of the Fongen sequence. Towards the top Ca-poor pyroxene, magnetite/ilmenite are found as cumulus phases co-existing with olivine, Ca-rich pyroxene and plagioclase. The presence of cumulus magnetite is again reflected by aeromagnetic anomalies centred to the southeast of Ruten mountain. Apatite has not been found in the Ruten sequence.

In a small valley at the extreme south of the Ruten area there are some sheared rocks consisting of albite-oligoclase, microperthite, and

Fig. 2. Cumulus relationships of the Fongen, Ruten, and Hyllingen sequences. Location of stratigraphic profiles shown on map, Fig. 1. Solid lines – cumulus; dashed lines – intercumulus, except for oxidized olivine relicts at top of Hyllingen sequence. Cumulus olivine and plagioclase compositions (determined by microprobe) are given. The stratigraphic relationship of the Hyllingen sequence to the Fongen and Ruten sequences is not certain (see text). The extreme differentiates at the top of the Hyllingen sequence are described in the text. Assuming a constant dip and no tectonic breaks, about 700 m of layered cumulates are estimated to be hidden in the concealed interval in the Fongen sequence.


CUMULATE STRATIGRAPHY
OF THE FONGEN-HYLLINGEN GABBRO COMPLEX
PROFILES
CHROMITE
OLIVINE (Fo %)
PLAGIOCLASE (An %)
Ca-rich PYROXENE
Ca-poor PYROXENE
MAGNETITE/ ILMENITE
APATITE
THICKNESS (m)
EXTREME DIFFERENTIATES
HYLLINGEN SEQUENCE
III B
III A
(OXIDI-ZED)
23
40
55
44
48
3000
2000
1000
0
RUTEN SEQUENCE
II B
II A
60
74
55
63
5500
5000
4000
FONGEN SEQUENCE
I
40
67
72
87
48
63
78+
3000
2000
1000
0
CONCEALED INTERVAL

blue-green pleochroic amphibole together with subordinate quartz, biotite, sphene, allanite, zircon, and apatite. These rocks are separated from those of the Ruten sequence by an unexposed gap and their structural relations are not clear.

The layered rocks of the Hyllingen area are separated from the Fongen-Ruten area by about 3 km of poor exposures, and the nature of the stratigraphic relationship of the Hyllingen rocks with those to the north is not yet clear. The rhythmically layered rocks of the Hyllingen sequence dip about 30–40° to the east; a thickness of about 3 km is exposed. The lowest rocks in profile IIIA (Fig. 1) have plagioclase of approximately An_{50} and olivine (Fo_{55} some 300 m from the base) together with Ca-rich and Ca-poor pyroxenes as cumulus phases. An upward general change in olivine and plagioclase compositions towards lower temperature solid solutions can be seen in Fig. 2. Magnetite/ilmenite and apatite are present some 500 m and 1000 m respectively above the lowest exposed rocks in the extreme NW. Most of the Hyllingen area is characterized by a strong positive aeromagnetic anomaly (Norges Geologiske Undersøkelse, Ålen 1720 IV). This cumulate paragenesis is interpreted as representing the upper part of a thick, differentiated gabbroic sequence. According to Nilsen (1973) olivine is absent above the 1500 m level in the Hyllingen section, though our observations suggest that heavily oxidized relicts occasionally persist to within about 500 m of the top of the sequence. Further upwards the rocks grade into monzonites with notable green Ca-amphibole and finally quartz-bearing syenites and quartz-bearing alkali syenites at the very top of the sequence. The latter consist dominantly of albite-oligoclase and microcline together with ferrohastingsite, quartz, allanite, stilpnomelane, hedenbergite, sphene, apatite, iron oxides, and zircon. Texturally they do not qualify as cumulates but clearly represent the extreme magmatic differentiates. There is a close resemblance between these rocks at the top of the Hyllingen sequence and those occurring in the southern part of the Ruten area.

Discussion and conclusions

On the basis of the established cumulate stratigraphy and cryptic variation the northern segment of the Fongen-Hyllingen layered gabbro complex can be subdivided into a lower (Fongen) sequence and an overlying (Ruten) sequence, interpreted as representing two successive magma influxes. The Hyllingen part of the complex represents fractionation products of a relatively highly evolved gabbroic magma, which is relevant to the discussion by Nilsen (1973, 1974) and Robins (1974) as to the nature of the differentiation of the Hyllingen magma. It explains, for example, the high TiO_2 concentrations characteristic of the Hyllingen succession noted by Nilsen (1973) since ilmenite occurs as a cumulus phase together with magnetite throughout most of this 'upper zone', excluding the extreme differentiates. It is notable from the evidence presented in Fig. 2 that the cumulus parageneses and the compositions of the coexisting olivine and plagioclase match, with an overlap for the top of the Fongen sequence and the base of the Hyllingen sequence, suggesting a direct genetic relationship. The possibility that the Hyllingen sequence represents the upper part of the Ruten sequence or that of a hidden layered series can nevertheless not be ruled out.

The fact that calcium-rich and calcium-poor pyroxenes crystallized together throughout large parts of the layered complex, the upward trend of strong iron enrichment in individual minerals, and quartz-bearing final differentiates point towards a tholeiitic parent magma. However, as re-emphasized by Robins (1974), the nature of the magmatic differentiation trend can only be established when a representative series of 'average cumulates', whose compositions can be related to successive parental liquids, have been analysed. We are currently investigating the geochemical evolution of the Fongen-Hyllingen complex.

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References

Nilsen, O. 1973: Petrology of the Hyllingen gabbro complex, Sør-Trøndelag, Norway. *Nor. Geol. Tidsskr. 53,* 213-231.

Nilsen, O. 1974: A reply. Petrology of the Hyllingen gabbro complex, Sør-Trøndelag, Norway. *Nor. Geol. Tidsskr. 54,* 421-422.

Olesen, N. Ø., Hansen, E. S., Kristensen, L. H. & Thyrsted, T. 1973: A preliminary account on the geology of the Selbu-Tydal area, the Trondheim region, Central Norwegian Caledonides. *Leidse Geol. Meded. 49,* 259-276.

Robins, B. 1974: A discussion. Petrology of the Hyllingen gabbro complex, Sør-Trøndelag, Norway. *Nor. Geol. Tidsskr. 54,* 417-419.

Wager, L. R., Brown, G. M. & Wadsworth, W. J., 1960: Types of igneous cumulates. *J. Petrol. 1,* 73-85.

Wilson, J. R. & Olesen, N. Ø. 1975: The form of the Fongen-Hyllingen gabbro complex, Trondheim region, Norway. *Nor. Geol. Tidsskr. 55,* 423-439.