The Geology of the Fjeldheim-Gåsbakken Area, Sør-Trøndelag.

By

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With one geological map and one figure in the text.

Abstract.

The geology of an area south of Trondheim is described and a geological map is presented. This area has not been studied in detail before. Rocks of the Støren Group and the Lower Hovin Group are exposed. The latter group is divided into the basal Fjeldheim Conglomerate, the Fjeldheim Beds and the Nyplassen Beds. The graptolitic Bogo Shale and equivalents of the Hølonda Limestone are included within the Fjeldheim Beds. The Hølonda Porphyrites are shown to be intrusive sill-like bodies in this area. A stratigraphical correlation with the adjacent Hølonda-Horg district is given.

Foreword.

The present paper is a result of the work during the summers of 1960 and 1961 by a group of advanced students of the Geology Department of the Imperial College in London.

Orkla Grube-Aktiebolag, the mining company working the Løkken mine, had an interest in furthering geological work in areas around their mine. When Professor Chr. Oftedahl of Trondheim introduced the young British geologists to the area, much valuable help was given them by the mining company. Especially to be mentioned is the keen interest taken in the geological work by mining engineer Per Sandvik. Mr. Erling Sagvold gave valuable assistance in the field.

The undersigned had the pleasure of visiting Mr. Chadwick and his companions in the working area in July 1961 and got an impression of

the very detailed and painstaking work given to the rocks of the area. Thus the present publication appears as a very valuable and highly welcome addition to our knowledge of the stratigraphy and structure of the Trondheim Region.

Trygve Strand.

Introduction.

The Fjeldheim–Gåsbakken Area, which is some 70 kms south-west of Trondheim, lies between the villages of Løkken in the west and Hølonda in the east. The area was mapped by the authors during the summers of 1960 and 1961 (see inset on main map), and forms a continuation of the Hølonda–Horg district to the east mapped by Th. Vogt (1945); it is in part covered by the geological map produced by C. W. Carstens (1952). No detailed work has previously been undertaken in the Fjeldheim–Gåsbakken Area.

Field maps on scales of 1 : 10,000 and 1 : 15,000 were constructed from aerial photographs loaned by the Orkla Grube Aktiebolag, Løkken. Mosaics of these photographs were used to construct the final map, the whole then being reduced photographically; because of distortion, particularly around the margins of the map, the scale given is only approximate.

The oldest rocks in the area are those of the Støren Group, an Upper Cambrian or Lower Ordovician group of submarine spilitic pillow lavas with subordinate sediments. Following unconformably on the Støren Group come the Lower Hovin sediments of Lower and Middle Ordovician age. The coarse polygenous Fjeldheim Conglomerate, equivalent to the Venna and Stokvola Conglomerates, was the earliest to be laid down, consisting very largely of water worn boulders from the underlying Støren Group. This conglomerate is followed by the Fjeldheim Beds, a very variable group of rocks equivalent to the Hølonda Shales and Sandstones and the Hølonda Limestone of the Hølonda region, (Vogt, 1945). The Fjeldheim Beds, generally greenish or grey in colour and commonly tuffaceous, include various shales, sandstones, grits, conglomerates, breccias and limestones. Sedimentary structures such as graded and current bedding frequently occur and are useful in determining relative ages. A graptolitic shale, described by Blake (1962), and localities containing brachiopods occur; fossil localities are indicated on the map by the symbol Fo. Rapid facies changes along the strike are prevalent and this, coupled with lack of exposure and faulting, makes

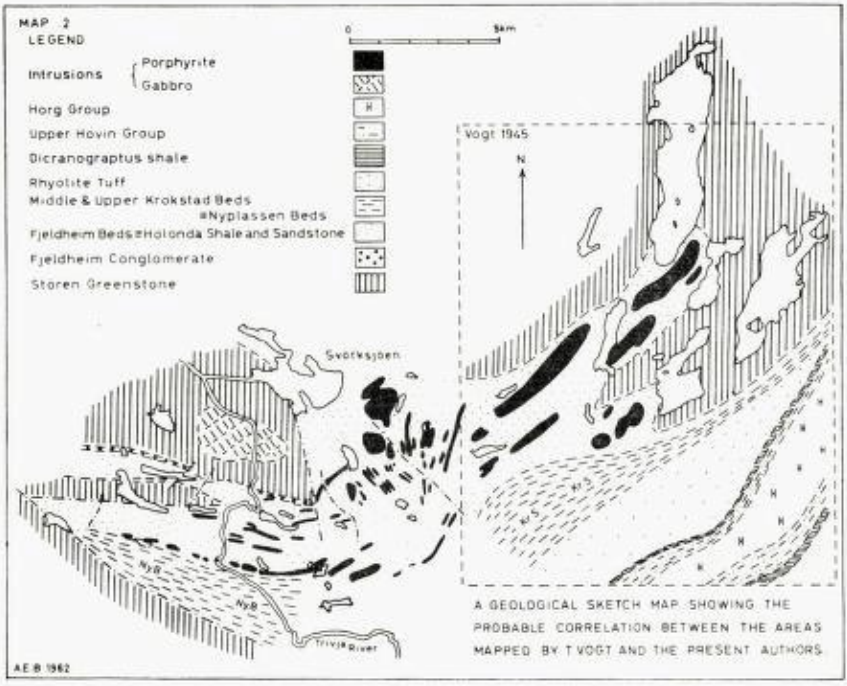

Fig. 1. Map showing the correlation between the areas mapped by Th. Vogt and the present authors.

Kart over Hølonda-området, kartlagt av Th. Vogt, (til høyre) og Fjeldheim–Gåsbakken-området (til venstre).

detailed stratigraphical correlations within the Fjeldheim Beds impossible.

The Nyplassen Beds, succeeding the Fjeldheim Beds, are considered to be equivalent to the Middle and Upper Krokstad Shales and the lower part of the Krokstad Sandstone of the Hølonda-Horg district. They consist of arenaceous shales and sandstones with some grit and conglomerate bands, and appear to be the highest representatives of the Hovin succession occurring in the area mapped.

Evidence such as the great variety of rock types and rapid facies changes along the strike indicate that the Lower Hovin sediments in the Fjeldheim–Gåsbakken area were probably laid down in an unstable near-shore environment with a certain amount of pene-contemporaneous erosion in some places.

The structure of the area appears basically simple, with the general

trend (F_1) swinging round from N.E.–S.W. in the east to E.–W. in the west. The Hovin sediments in the west lie in two synclines with axial planes (F_1) dipping about 60° N and having overturned northern limbs. They are separated by a topographical ridge of Støren rocks (the Fjeldheim Ridge). The southern syncline, which has lost its southern limb due to faulting, is bounded by the South Fjeldheim and Frilsjøen Greenstone Faults. The two synclines appear to come together in a complicated area east of the Trivja river. In the finer grained sediments throughout the area there is usually a well marked axial plane cleavage (F_1) and this is often disturbed by a later cleavage (F_2) which is apparently related to the change in trend already mentioned. The whole area was metamorphosed to chlorite grade during the Caledonian orogeny.

The land-surface was smoothed during the Pleistocene glaciation and rock exposure is generally poor. Recent and Pleistocene deposits are not shown on the map, though areas of alluvium and moraine are common, particularly in low-lying areas.

Acknowledgements

The authors wish to thank Prof. Chr. Oftedahl for introducing them to the area. They are extremely grateful to the Orkla Grube Aktiebolag, in particular Bergingeniør Per Sandvik, for all their help and encouragement.

The Støren Group.

This group of rocks was named originally by Kjerulf (1875), after the type locality at Støren, and the name has since been applied by, amongst others, Th. Vogt (1945) and Holtedahl (1960). C. W. Carstens introduced the term Bymark Group as a synonym in 1920. The rocks of the Støren Group are the oldest in the area mapped, being of uppermost Cambrian or lowermost Ordovician age: their base was not seen. Vogt (1945) suggested a general correlation with the Arenigian Ballantrae Volcanic rocks of the Southern Uplands of Scotland, but a somewhat earlier date is indicated by the occurrence of a graptolitic shale of Middle Arenigian age within the overlying Hovin Group (Blake, 1962).

Rocks of the Støren Group outcrop in the extreme northern part of the area as far east as Svorksjøen, and in the extreme south on the northern slopes of Grefstadfjeldet. They also form the Fjeldheim Ridge, which is

fault bounded in the south and probably also in the north to the west of Prestbuvatnet.

The Støren Group is dominantly volcanic, consisting of extrusive spilitic lavas and associated pyroclastics with some intercalations of sedimentary rocks, all regionally metamorphosed to chlorite grade giving the rocks their characteristic green colour – hence the "Støren Greenstones". No representatives of the Jåren Beds, (Vogt, 1945) were found. The lavas include pillow and massive varieties. "Pillow agglomerates", feldspathic tuffs, red, green and blue-grey phyllites, pyritous black shales, jasper deposits, and some conglomeratic beds around Fjeldheim make up the rest of the group. The sedimentary rocks are insignificant in volume compared with the extrusive lavas.

Pillow lavas are particularly well exposed on Grefstadfjeldet in the south-west, as well as along the new road cutting north of L. Buan, along the Trivja gorge east of Fjeldheim, and on Malberget. The pillows vary in size up to a metre or so, and generally have well-marked chilled margins of paler green colour than the frequently vesicular interior. They have suffered variable amounts of deformation, due perhaps in part to weight of superincumbent rocks but mainly to later tectonic stresses related to the Caledonian earth movements. Though deformed it is still possible to determine the "way-up" of the flows, and on Grefstadfjeldet they are "right way-up" while along the Trivja gorge north of the dam they are inverted. The pillows are frequently enclosed in a reddish or greenish fine grained matrix.

Massive lavas are perhaps more abundant than the pillow lavas. They are commonly veined with chlorite, epidote, calcite and quartz, and tend to be uniformly very fine grained and usually lacking in vesicles. Petrographically, the massive lavas differ from the pillow lavas in their paucity of feldspar, albite being abundant in the pillow lavas. Chlorite, calcite and quartz are abundant throughout, and epidote and actinolitic amphibole are locally very common, especially in the massive lavas; leucoxene and pyrite are universal accessory minerals.

The pillow agglomerates consist of what appear to be small pillows and lapilli, up to a metre in length, in a coarse to fine grained, dark green, feldspathic matrix. Exposures include one on the south-east side of Malberget and another near the mouth of the Skolda river, Svorksjøen. Some angular fragments of jasper are frequently included within the "agglomerate". The pillow agglomerates may be true pyroclastic agglomerates or perhaps altered palagonitic breccias.

The Hovin Group.

Unlike the preceding Støren Group, the Hovin Group in the Fjeldheim–Gåsbakken area consists almost entirely of sedimentary rocks, though many of these sediments are tuffaceous. As would be expected, the group here is more similar to that of the Hølonda area, (Vogt, 1945), than to that of the type area at Hovin further to the east.

The lower Hovin Group only is represented in the Fjeldheim–Gåsbakken area, and it has been divided as follows: –

3. Nyplassen Beds: consist mainly of arenaceous shales and sandstones. The Beds, which are named after the type locality at Nyplassen, are developed in the southern part of the area.
2. Fjeldheim Beds: a variable sub-division which includes equivalents of the Hølonda Shales and Sandstones and the Hølonda Limestone.
1. Fjeldheim Conglomerate: the basal conglomerate of the Hovin Group; it is largely made up of fragments from the Støren Greenstones.

The Fjeldheim Conglomerate.

The basal conglomerate of the Hovin Group lying directly upon the Støren Greenstones is here termed the Fjeldheim Conglomerate. It has been called the Greenstone Conglomerate by C. W. Carstens (1951) and H. Carstens (1960).

The Fjeldheim Conglomerate is seen only in the northern part of the area where it is exposed as an almost continuous belt of varying width extending from the south of Malberget westwards along the north of the North Fjeldheim syncline to at least as far as Høidalen. A break in this belt occurs north of L. Buan where shales and sandstones of the succeeding Fjeldheim Beds come to lie directly upon the Støren Group. Either the conglomerate was never deposited here or it was removed by contemporaneous erosion. On the south of the syncline the conglomerate is seen only on the south side of Mjovatnet, its general absence being due, at least in part, to locally faulted contacts between the Støren and Hovin Groups. A similar type of conglomerate occurs on the northern shore of Svorksjøen where in places it has suffered substantial deformation with the growth of authigenic chloritoid. Other conglomerates of similar type

are found on Bjørkliodden and on the shore of Svorksjøen, east of Fuglåshogstret.

The Fjeldheim Conglomerate is a coarse, typically unsorted, polygenous deposit with a true thickness varying from 0–180 m or more. No angular unconformity on the underlying Støren Group is apparent. The fragments making up the conglomerate are angular to rounded, varying in size from less than a centimetre up to 1.5 m in diameter, and consist of a wide variety of rock types. These include jasper, greenstone, fine grained pink and olive green "felsites", soft white tuffaceous material, pale green quartzose grits, white and dark grey quartzites, and sedimentary rocks similar to those of the overlying Hovin shales and sandstones. The fragments are enclosed in a variable amount of fine to coarse grained matrix which is generally dark green in colour. This matrix is usually sparse. The conglomerate locally grades into bands of dark green shales, sandstones and grits which often contain scattered boulders of greenstone and jasper. The finer sediments within the conglomerate sometimes show graded bedding.

The age of the Fjeldheim Conglomerate is not certain. The occurrence of Middle Arenig graptolites in the Hovin sediments south-east of Fjeldheim suggests that the conglomerate is probably Lower Arenigian.

The Fjeldheim Beds.

For convenience of description the Fjeldheim Beds in the Fjeldheim–Gåsbakken area will be considered in three separate sub-areas: – (a) The North-west, (b) The South-west, and (c) The East.

(*a*) *The North-west Sub-area.*

This sub-area lies to the north of the Fjeldheim Ridge and comprises the Fjeldheim Beds within the asymmetrical North Fjeldheim syncline. This syncline is overturned to the north, the beds on the northern limb being inverted as shown by graded bedding. The Fjeldheim Beds here either grade stratigraphically upwards from the Fjeldheim Conglomerate or lie directly on the Støren Group. There is no intervening breccia horizon corresponding to the Gaustadbakk Breccia of the Hølonda area, (Vogt, 1945). The top of the Fjeldheim Beds is not seen here.

The Fjeldheim Beds consist of alternating thin bands, usually 2–3 cms thick, of feldspathic grits, sandstones and shales; the shale bands pre-

dominate. Their colour varies from darkish green to grey green, though the coarser feldspathic bands often weather to white. Small brown alteration specks, after pyrrhotite or pyrite, are common. Some conglomeratic and limestone patches occur, the latter being mostly confined to the eastern part of this sub-area. Another type of deposit, a thin-bedded sandstone with fine grained jasper fragments, occurs near L. Buan. Many exposures show well-developed graded bedding, and slump structures and small-scale current bedding are not uncommon. The conglomerates within the Fjeldheim Beds are polygenous, with many fragments of jasper and greenstone. These conglomerates tend to be confined to the lower part of the succession and are very similar to the Fjeldheim Conglomerate, though they are generally less coarse.

On the south of Malberget banded grey-green shales and sandstones pass stratigraphically up into an impure grey limestone some 50 m thick which contains obscure fossil remains. This limestone is similar to the Hølonda Limestone described by Kiær (1932) and Vogt (1945); (similar limestones are found elswhere within the Fjeldheim Beds at varying levels and it appears that the Hølonda Limestone is best regarded as a particular type of limestone occurring at several horizons in the upper part of the Fjeldheim Beds, rather than as a distinct formation of its own). Above this particular limestone south of Malberget there are fissile grey shales which are probably identical to the Skjegstad Shales further to the east, (Vogt, 1945, p. 474). These shales are particularly well-developed near Bjønlivatnet and Stornæve. Within this shale, by a track north of Bjønlivatnet, a number of poorly preserved brachiopods were discovered by Chadwick in 1961. The specimens were shown to Dr. W. T. Dean of the British Museum (Natural History), who very tentatively identified some of them as clitambonitid brachiopods. In the East Sub-area another fossil locality was discovered at a comparable horizon in a green shale near St. Fuglås. A comparatively well preserved brachiopod was found having a general resemblance to the genus *Rafinesquina*. Unfortunately this identification could not be confirmed because of the absence of any internal structures. If these brachiopod groups are in fact present it seems unlikely that the age of the fauna can be earlier than Middle Ordovician. The specimens do not appear to correspond to any of those described by Reed (in Kiær, 1932) from the Hølonda Limestone further to the east.

(*b*) *The South-west Sub-area*

Here a westward pointing triangular outcrop of lower Hovin rocks is bounded to the north and south by the South Fjeldheim and Frilsjøen Greenstone Faults. The Fjeldheim Beds form the inverted northern limb of the South Fjeldheim syncline, the probable trough of which is occupied by the succeeding Nyplassen Beds. The Fjeldheim Conglomerate is not represented here, presumably because it is faulted out. Smaller faults criss-cross the area and, coupled with the rapid facies changes along the strike and lack of extensive exposure, make detailed correlations within the sub-area almost impossible.

The Fjeldheim Beds are much more variable than in the North-west Sub-area. For example, the succession to the west of the Bogo river, from north to south, is: – conglomerate; bluish-black slate; coarse feldspathic grit; a mélange zone 2 m thick, probably occupying a fault zone; the Bogo graptolitic shale; tuffaceous conglomerates and grits passing up into banded shales and sandstones and, finally, grey shales. Thin limestones also occur in the succession, while elsewhere in the sub-area purple breccias, some possible basic lava flows, and a black radiolarian chert deposit (on the west bank of the Trivja river, some 700 m north of Blomli) are also found.

Lying fairly near the base of the Fjeldheim Beds is the Bogo Shale which has been described by Blake (1962). This shale is exposed along and to the west of the Bogo river, while another possible exposure occurs on the southern bank of the Trivja river south of Storbuvatnet. The Bogo Shale is a dark grey fissile shale with irregularly distributed pyrite. Some thin grit and calcareous bands are included within the shale. At two exposures along the Bogo river and another to the west in the bed of a tributary stream, a number of graptolites have been found, preserved as pyritous or carbonaceous impressions, with subordinate inarticulate brachiopods of "Obolus" type, phyllocarid fragments and some hyolithids. The following graptolites have been identified (Blake, 1962): –

Dichograptus octobrachiatus (Hall) subsp. *minimus* (Blake), *Trichograptus* cf. *fergussoni* (Hall), *Didymograptus extensus* (Hall), *Didymograptus* cf. *leptograptoides* (Monsen), *Didymograptus* cf. *filiformis* (Tullberg), *Didymograptus* sp., *Isograptus caduceus* (Salter) var. *divergens* (Harris), *Isograptus caduceus* (Salter) var. *velata* (Harris), *Tetragraptus quadribrachiatus* (Hall), *Tetragraptus bigsbyi* (Hall), *Tetragraptus* sp., *Phyllograptus anna* (Hall), *Hallograptus inutilis* (Hall), *Glossograptus*

hincksi (Hopkinson), *Glossograptus hincksi* var. *fimbriatus* (Hopkinson), *Glyptograptus dentatus* (Brongniart).

The Bogo Shale is considered to come from within the *Phyllograptus densus* zone (3 b γ) of the Middle Arenigian. Monsen (1937) has described forms such as *Dichograptus octobrachiatus, Didymograptus extensus* vars., *D. filiformis, D. leptograptoides, Isograptus* sp., *Tetragraptus quadribrachiatus, T. bigsbyi,* from this zone in the Oslo region. However, the specimens of *Tetragraptus quadribrachiatus* from the Bogo Shale may be young specimens of *Trochograptus diffusus* (N. Spjeldnæs, personal communication), and the fauna may correspond to the 3 b ε or the upper part of the 3 b δ zone. The similar shale exposed on the Trivja river contains only indeterminate graptolite fragments.

Other shales in the sub-area are generally paler in colour, though the shaly layers of the banded shales and sandstones are frequently dark grey and often pyritous. The shales which are associated with the porphyry intrusion on the ridge south of Storbuvatnet are a pale buff colour, while the shales in the south are pale grey with small brown alteration specks after pyrite or pyrrhotite (Vogt, 1945, p. 474). This grey shale, which is well exposed along the Rauå river, is probably comparable to the Skjegstad Shale. A bluish-black "slate", harder and more flinty than other shales in the sub-area, is exposed along the Bogo river north of the Bogo Shales.

Coarser sediments within the Fjeldheim Beds include conglomerates, grits, sandstones and purple breccias similar to the Gaustadbakk Breccia of the Hølonda district, (Vogt, 1945). The conglomerates, which are typically feldspathic, are well-developed to the south of the Bogo Shale and west of the Bogo river, south of Prestbuvatnet, and between Blomli and the ridge south of Storbuvatnet. Unsorted fragments of feldspathic tuff predominate and these are sub-angular to rounded and up to 30 cms in diameter. They are enclosed in a gritty, less feldspathic matrix which sometimes shows bedding and graded bedding. The feldspathic nature of the conglomerates is best seen on recently cleaned surfaces where the individual feldspar grains have a creamy white colour. In fact, more than 50 % of the rock is made up of albite. Occasional greenstone and jasper fragments occur within these feldspathic conglomerates. The most northerly conglomerate exposure, to the west of Prestbuvatnet, has a similar high feldspar content and contains irregular fragments of pale grey crystalline limestone. Limestone fragments also occur locally in the conglomerates south of Prestbuvatnet and north of Blomli; in places the

rock approaches a conglomeratic limestone. Patches of finer, non-tuffaceous, dark green conglomerates, which are made up mainly of well-rounded fragments of greenstone and jasper, occur within the feldspathic conglomerates. Such a conglomerate was found some 300 m north of Blomli.

Banded shales and sandstones within the Fjeldheim Beds are generally found to the south of the main conglomerate masses. The individual bands of these banded beds average 2 cms in thickness, though the coarser bands are often somewhat thicker. Graded bedding is usually well-developed, with feldspathic grit or sandstones grading stratigraphically upwards into dark grey shale. Such graded bedding is well-displayed in the exposures by the Bogo Bridge and along the strike to the E.S.E. The grading indicates that here the beds are inverted. Slump bedding is also quite common and current bedding is occasionally visible. Rather finer grained and less feldspathic banded sandstones occur between the Trivja and Rauå rivers.

In the eastern part of the sub-area, to the east of the Trivja river, purple breccias comparable to the Gaustadbakk Breccia occur within the Fjeldheim Beds. As well as coarse breccia or agglomerate, these purple beds include shale, sandstone and grit bands and occasional limestone horizons. Fragments of greenstone, jasper, limestone, tuffaceous sediments, grits and sandstones occur in the coarser deposits. The fragments are generally angular to sub-angular and are contained in a purple sandy matrix. The purple colour of these beds appears to be due to finely disseminated hematite. The purple beds are not confined to a single horizon but occur above and below, as well as grading laterally into, greenish feldspathic conglomerates.

The limestone which occurs as fragments within the conglomeratic deposits is similar to that of the separate bands within the Fjeldheim Beds. It is crystalline, pale greyish in colour, and has a brecciated appearance which is due probably to sedimentation rather than tectonism. Some crinoid ossicles and indistinct fossil remains were found in the limestone band 800 m north of Blomli. Other obscure fossils were found on the southern shore of Storbuvatnet in a limestone similar to the typical Hølonda Limestone.

The basic lava flow which has been mentioned above was found to the east of the mouth of the Bogo river. This possible lava is a dense, sparsely porphyritic brown rock lying above a grey shale. A similar rock type was also found some 500 m to the south-east.

(c) *The East Sub-area*

The North and South Fjeldheim synclines bend round to strike N.E.–S.W. in this sub-area, and the Fjeldheim Beds form a continuous outcrop from Svorksjøen in the north to the most southern part of the mapped area.

The beds in the northern part are essentially similar to those of the North-west Sub-area, with banded grey-green shales and sandstones of the Fjeldheim Beds, grey Skjegstad Shales and Hølonda Limestone. The sandstone bands commonly show graded bedding. Coarse sediments are generally absent, although an exposure of dark green breccia occurs in the middle of some marshy ground west of St. Fuglås. Two fossil localities occur near St. Fuglås and at one, already mentioned, a brachiopod of *Rafinesquina* type was found. At the other, further to the south, a turretted gasteropod of *Hormotoma* type was found in a limestone.

In the south of this sub-area, purple breccias of the Gaustadbakk type predominate, with rapid alternations of purple grits and sandstones and subordinate shales. Green coloured sediments occur occasionally within these purple beds. The purple breccias are similar to those of the South-west sub-area, consisting of angular fragments of quartzite, greenstone, limestone, jasper and blue-grey and red shales, sandstones and grits. The sandy matrix is similar to the interbedded sandstone bands, with angular quartz grains, much calcite and epidote; finely disseminated hematite is probably the cause of the purple colour. Though lenses of breccia up to 1.5 m thick occur, these purple deposits are usually well-bedded. Graded and current bedding are common. Green sandstones and grits sometimes alternate with the purple beds, as for example in the valley between Stornæve and Rød where a green tuffaceous breccia or conglomerate, similar to those of the South-west sub-area, is also present. Occasional thin bands of limestone, identical to fragments in the breccia, are also found within the purple beds.

Stratigraphically overlying the purple beds are banded, dark grey and grey-green shales with interbedded thin sandstones, occasional limestones and tuffaceous bands. Rusty brown alteration specks are characteristic and the sandstones frequently show graded bedding. Limestones are best developed near Lille Fuglås and S. W. of Gåsbakken, where they occur as light to dark blue-grey lenses within the banded shales and sandstones. No fossils were found in the southern part of this area.

The Nyplassen Beds.

The southern-most part of the Fjeldheim–Gåsbakken area is occupied by the Nyplassen Beds, a group of arenaceous shales and subordinate grits and conglomerates. Their contact with the grey shales of the Fjeldheim Beds in the north and with the Støren Group in the south is not seen – the contact zone in each case being occupied by marshy ground. The outcrop area is generally low-lying and poorly drained, with exposures occurring on small, low mounds.

The dominant rock type is a grey, silty shale, typically with brown alteration specks lying on cleavage planes. Unlike the shales within the Fjeldheim Beds, a shaly parting is not developed and a cleavage parting (F_1) takes its place. This cleavage is very regular in orientation and the bedding shows small-scale folds. Though generally regular, the cleavage is frequently "rucked" or corrugated, i.e. an F_2 effect. Thin sandstone and grit bands occur within the shale sequence, and relatively thick grit horizons are also found. The coarser beds are very similar to those of the Fjeldheim Beds, being feldspathic and tuffaceous. In the southern part thick conglomerate lenses occur. The conglomerates are coarse, dark green and generally unbedded with fragments of jasper, quartzite, pale grey crystalline limestone, greenstone and other igneous rocks; secondary pyrite cubes are locally abundant. These conglomerates are fairly similar to the Fjeldheim Conglomerate.

Intrusions.

(*a*) *The Hølonda Porphyrites*

Th. Vogt (1945) described two types of Hølonda Porphyrite from the Hølonda–Horg district. Firstly, the Berg type which consists of thick, largely altered, tabular phenocrysts of plagioclase and rarer phenocrysts of altered pyroxene in a very fine grained groundmass; secondly, the Almås type which has more crowded plagioclase and pyroxene phenocrysts. In the Fjeldheim–Gåsbakken area a number of Hølonda Porphyrite masses occur, with the Berg type predominating. However, both types may occur within the same mass and they have not been distinguished on the map.

Petrographically, the Porphyrites consist of phenocrysts of plagioclase and pyroxene in a fine grained groundmass of albite, epidote, clino-

zoisite, chlorite and leucoxene. Small amounts of quartz and apatite are often present and at two localities (one just east of Gåsbakken, the other 150 m west of Mjovatnet) stilpnomelane is abundant. Axinite and clinozoisite have been found in thin veins cutting the porphyrite. The plagioclase phenocrysts are either partly or completely saussuritised, with "ghosts" of lamellar twinning still visible. When only partly altered the plagioclase can be recognised as albite, though these phenocrysts are regarded as having been originally more calcic. Uralitic hornblende and green penninite chlorite replace the pyroxene phenocrysts, though the cores are commonly preserved. The pyroxene is a pale green to colourless augite with a large extinction angle ($Z \wedge c - 40°$) and large 2V (57°). Lamellar twinning is characteristic.

The problem of the intrusive or extrusive nature of the Hølonda Porphyrites has been the subject of some controversy. Vogt (1945) considered them to be largely, if not entirely, extrusive in the Hølonda–Horg district, while in the Løkken area C. W. Carstens (1951) considered them to be intrusive. The present investigations show that the Porphyrites are intrusive in the Fjeldheim–Gåsbakken area. They occur in sill-like bodies confined to horizons within the Fjeldheim Beds. Features noted by Vogt, such as the generally concordant contacts with the country rocks, the lack of any extensive contact metamorphism, and the general absence of chilled margins, were confirmed. However, chilled margins were found in a few places, for example, along the road east of Gåsbakken. Fragments of porphyrite up to 15 cms in length were found in limestone bands 150 m S.E. of St. Fuglås. These fragments may well be of pyroclastic origin as suggested by Vogt. The intrusive nature of the Hølonda Porphyrites is indicated by both positive and negative evidence. Though generally concordant with the bedding of the country rocks, the porphyrite can be seen cutting across bedding planes at a number of localities, for instance, N.W. of Blomli where the porphyrite not only cuts the bedding of the stratigraphically overlying graded sandstones, but also sends veins into the sediments. At other localities the porphyrite can be seen having a smooth contact with contorted shales, e.g. 1000 m E. of Storbuvatnet. Though chilled margins of the porphyrite are generally absent, chilled and even glassy margins were found in places, e.g. N.W. of Blomli mentioned above. Baked shales at porphyrite contacts are not uncommon, e.g. near Stornæve and on the road east of Gåsbakken. Baked shales also occurs as xenoliths within the porphyrite. Quartz veins sometimes occur along the contacts between the porphyrites and country rocks. All these

features indicate an intrusive origin for the porphyrites. This origin is supported by the absence of either sub-aerial or submarine extrusive lava flow features such as vesicular and amygdaloidal flow tops or pillow structures.

The age of the Hølonda Porphyrites is not certain. Their upper age limit is set by the regional metamorphism of Caledonian age which has affected them as well as the country rocks. It is significant that the intrusions are restricted to the Fjeldheim Beds and they are not known to intrude the younger Nyplassen Beds. On the basis of this and the evidence given above, Prof. Strand (personal communication) has suggested that they may well represent a sub-volcanic phase during the deposition of the Fjeldheim Beds.

(*b*) *Other Minor Intrusions*

In the west of the area a number of dyke-like intrusions occur. These are generally very similar petrographically to the Hølonda Porphyrites, with phenocrysts of albite and augitic pyroxene contained in a fine grained groundmass. The only exception is a single dyke to the west of Prestbuvatnet which differs from the other minor intrusions in being non-porphyritic and containing an abundance of euhedral to anhedral greenish-brown hornblende.

(*c*) *Gabbro*

Three masses of gabbro, within the Støren Group, were examined very briefly. One occurs east of Urvatnet, another south of Frilsjøen, and the third in the extreme south-east of the area. The gabbro appears generally similar in each mass and is a coarse grained, largely altered, holocrystalline rock. It is composed of completely saussuritised feldspar and partly unaltered ophitic augite with pale green uralitic hornblende, colourless tremolite, chlorite, epidote and leucoxene. The gabbro intrusions appear to become-finer grained towards their margins, though their actual contacts could not be found with certainty because of the similarity of the dark green fine-grained marginal gabbro and the neighbouring greenstones.

Stratigraphical Correlations.

The correlations between the Fjeldheim–Gåsbakken and Hølonda–Horg areas are shown in Table 1 and Fig. 1, which are largely self-

Table 1. *Correlation between the beds in the Fjeldheim–Gåsbakken and Hølonda–Horg Areas.*

	Fjeldheim–Gåsbakken	Hølonda Area	Horg Area
Upper Hovins	Absent	Absent	Hovin Sandstane
			Volla Conglomerate
Lower Hovin Group			Break
			Dicranograptus Shale
			Krokstad Sandstone
	Nyplassen Beds		Krokstad Shale, middle and upper part
	Fjeldheim Beds	Hølonda Limestone	
		Hølonda Shales and Sandstones	
		Gaustadbakk Breccia	Langeland Slate and the Bruaberg Breccia
			Krokstad Shale, Lower part
	Fjeldheim Conglomerate	Venna Conglomerate	
	Break	Break	Break
Støren Group	Støren Greenstones	Støren Greenstones	Støren Greenstones

explanatory. Th. Vogt (1945), Holtedahl (1960), and H. Carstens (1960) have discussed correlations between the Hølonda–Horg district and other parts of Norway. General correlations, between the Fjeldheim and Venna Conglomerates, the Fjeldheim Beds and the Hølonda Shales and Sandstones, and the Nyplassen Beds and the Middle and Upper Krokstad Beds, appear to be reasonably satisfactory.

A number of factors prevented more detailed correlations within the Fjeldheim Beds themselves. These factors include rapid facies changes both in a horizontal and a vertical sense, lack of distinct marker horizons, minor faulting, and poor exposure. However, it was possible to establish that the Hølonda Limestone is in fact a number of different limestone horizons; and the Gaustadbakk Breccia also appears to occur at differing levels within the Fjeldheim Beds. To the west of the Fjeldheim–Gåsbakken area C. W. Carstens (1952) has mapped further outcrops of Hovin sediments, and some exposures of a graptolitic shale similar to the Bogo Shale have been found to the west of Løkken (P. Sandvik, personal communication). This area awaits a detailed investigation.

The age of the Lower Hovin rocks is still the subject of discussion. The Bogo Shale is undoubtedly Middle Arenigian and although its exact position is still uncertain it comes from somewhere within the 3b γ - 3b ε zones. The other fossiliferous formation, the Hølonda Limestone, has yielded dateable fossils in the Hølonda–Horg area and is suggested by Vogt (1945) to be Upper Llanvirnian to Lower Llandeilian and by T. Strand (1947) to be Llandeilian in age. To the south of the area mapped a fossiliferous limestone, the Kalstad Limestone, has been described by Kiær (1932), and dated as Upper Caradocian to Ashgillian by Cowper Reed and Høeg (in Kiær, 1932).

Sammendrag.

Fjeldheim–Gåsbakken-områdets geologi.

Fjeldheim–Gåsbakken-området i Sør-Trøndelag ligger mellom Hølonda-bygden i øst og Løkken Verk i vest. Området ble geologisk undersøkt og kartlagt somrene 1960 og 1961 av en gruppe viderekomne geologistudenter fra Imperial College i London.

De eldste bergarter i området er basaltiske lavaer som er de massive grønnsteiner i Støren-gruppen. De yngre, overliggende sedimenter i Hovin-gruppen finnes i den vestlige del av området i to synklinaler hvor lagene er foldet og klemt sammen mellom de massive Støren-grønnsteiner. I den østlige del finnes Hovin-bergartene over nesten hele området og fortsetter inn i Hølonda-området, som tidligere er blitt beskrevet og kartlagt av nu avdøde professor Th. Vogt.

Det underste lag i Hovin-gruppen er Fjeldheim-konglomeratet med boller av bl. a. rød jaspis fra de underliggende Støren-bergarter. Over

konglomeratet følger Fjeldheim- og Nyplassen-lagene, som er en vekslende følge for det meste av sandsteiner og konglomerater og tildels vulkanske tuff-dannelser. I Fjeldheim-lagene finnes det også noen lag av kalkstein med dårlig oppbevarte fossiler og et 60 m tykt lag av svart skifer, Bogo-skiferen, hvor det er blitt funnet mange arter av meget godt oppbevarte graptoliter. Disse fossiler gir grunnlag til en nøyaktig bestemmelse av lagets plass i den geologiske aldersfølge, det hører til den eldste del av ordovicium og svarer til graptolitskiferen 3 b i Oslo-feltet.

I Fjeldheim-lagene trengte det inn smeltemasser som størknet til ganger parallellt med lagene. Det ble dannet porfyrer med store, firkantete innsprengninger av feltspat, de kalles Hølonda-porfyritter.

References.

Blake, D. H., 1962: A New Lower Ordovician Graptolite Fauna from the Trondheim Region. Norsk. Geol. Tidsskr. Vol. 42. pp. 223–238.

Carstens, C. W., 1920: Oversigt over Trondhjemsfeltets bergbygning. Det Kgl. Norske Vidensk. Selsk. Skr. 1919 No. 1.

— 1951: Løkkensfeltet geologi. Norsk Geol. Tidsskr. Vol. 29 pp. 9–25.

— 1952: Geologisk kart over Løkkenfeltet. Norges Geografiske Oppmåling, 1952.

Carstens, H., 1960: Stratigraphy and Volcanism of the Trondheimsfjord Area, Norway. Norges Geol. Unders., No. 212 b.

Holtedahl, O., 1960: Geology of Norway. Norges Geol. Unders., No. 208.

Kjerulf, Th., 1875: Om Trondhjems stifts geologi. Nyt Mag. for Naturvid. Vol. 21.

Kiær, J., 1932: The Hovin Group in the Trondheim Area. With palaeontological contributions by O. A. Høeg, A. Hadding, F. R. C. Reed, A. F. Foerste, T. Strand, L. Størmer and the author. Norsk Vid. Akad. Skr. No. 4.

Monsen, A., 1937: Die Graptolithenfauna im Unteren Didymograptusscheifer (Phyllograptus-scheifer) Norwegens. Norsk Geol. Tidsskr., Vol. 16. pp. 57–263.

Strand, T., 1949: New Trilobites from the Hølonda Limestone. Norsk Geol. Tidsskr., Vol. 27., pp 74–88.

Vogt, Th., 1945: The Geology of part of the Hølonda–Horg district. Norsk Geol. Tidsskr., Vol. 25, pp. 449–527.

THE GEOLOGY of the FJELDHEIM–GÅSBAKKEN AREA

LEGEND

INTRUSIVE ROCKS

- Holanda Porphyrites
- Minor Intrusions
- Gabbro

LOWER HOVIN GROUP

NYPLASSEN BEDS

- Arenaceous Shales
- Conglomerate

FJELDHEIM BEDS

- Grey Shales
- Limestone
- Graptolitic Shales
- "Slate"
- Banded Shales & Sandstones
- Purple Breccias
- Conglomerate

FJELDHEIM CONGLOMERATE

STOREN GROUP

BEDDING PLANES dip in degrees

CLEAVAGE F_1 "

CLEAVAGE F_2 "

FAULTS — known , inferred

SCALE

km. 1 0 1 2 3


rksjoen
BJORKLIODDEN
TROTLAND
GÅSBAKKEN
HOLONDA KIRKE
ST FUGLAAS
MALBERGET
533 m
L. FUGLAAS
STORNÆVE
ROD
st. Damtj.
B.C. 1960
B.C. 1961
D.H.B. 1960
J.W.R. 1961
A.E.B. 1961
A
B
Mjovatnet
Prestbuvatnet
metres
SECTION A-B SCALE vertical = horizontal
4 km
BRIAN CHADWICK DECEMBER 1962