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Report on Geological Mapping and Preliminary Geophysical Investigations carried out during the Field Season Summer 1976 in the Skorovas Area

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Skorovas Area by Ian Ferriday and Christopher Halls

INTRODUCTION

During the field season of 1976, several areas within the Skorovas region were mapped at 1:10,000 scale in order to satisfactorily complete the 1:25,000 regional geological map including the concession area held by Elkem Skorovas Gruber A/S. The specific areas dealt with in the following report are as follows (see also location map).

(a) North Finnkrudama - South Skorovasklumpen - East Skorovatn.

(b) Grubefjell - North Drikkvatnet (Vestre Overste Nesatnet).

(c) Nesaklumpen - South Olatjonna.

In area (a) work was carried out in continuation of the mapping carried out during the field season of 1975 during which the main emphasis was placed on mapping in the Finnkrudama-Nesapiggen region. During 1976 mapping was carried out in the terrain around the Natonnene topographic basin to the north and thence further northward in a belt including the southern and eastern flanks of Grondalsfjell extending to Store Skorovatn and the southern flanks of Skorovasklumpen and into the ground lying a short distance to the east of Skorovatn.

Area (b) includes the area within the Skorovas intrusive arc complex covering the ground from Dausjoen southward to Drikkvatn and in the flanks of Grubefjell eastward along the Vannledning.

Area (c) comprises the low ground lying to the south of Langtjönna and Olatjönna extending southward to the lower northern slopes of Svartberget.

A preliminary ground magnetometer survey was carried out in area (c) with a comparative traverse over the extrusives in the belt from Olatjönna to Stamnesjönna including the region of the contact with the polymict conglomerate and Limingen group sediments in the extreme south.

Area (a)

Lithological Units and Stratigraphy

Variably tectonised basic, intermediate and acid extrusives form the greater part of the area and this deformed supracrustal sequence is structurally overlain to the west and north west by the Gröndalsfjell plutonic complex the contact of which is clearly one of tectonic disjunction despite the extensive preservation of a narrow contact aureole of volcanic rocks within the main tectonic boundary. The Gröndalsfjell complex is composed of a range of gabbroic to dioritic rocks which display consistent geological relationships in terms of relative ages of intrusion. The oldest component lithologies are the xenolithic masses of relatively unaltered troctolitic hypersthene-bearing layered gabbro which are found in the vicinity of the Gröndalsfjell summit. These xenolithic masses are set in a matrix of hydrated (uralitised) gabbro which is intruded and encased within dioritic and quartz dioritic rocks which appear to have engulfed the earlier gabbro. The latest stage in the intrusive history of the complex is marked by the emplacement of a swarm of N.E. trending trondhjemite dykes. The intrusive diorite mass is bounded to the east by a 'xenolithic screen' in which masses of volcanics and earlier intrusive lithologies are incorporated within a dioritic matrix. Locally there is net veining by the later trondhjemite. The xenolithic zone is locally transitional to a coherent envelope of hornfelsed volcanic rocks, which, as far as can be established, extend northwards to form the bulk of Skorovasklumpen. The subparallel trondhjemite dykes extend to cut the aureole rocks also.

The extrusive rocks of area (a) lie structurally below the Gröndalsfjell complex as discussed above, however they lie structurally above the northern and western limbs of the Skorovas intrusive arc complex which also shows a wide range in the composition of its constituent lithologies from gabbro to trondhjemite. The plutonic rocks composing the arc have suffered considerably from the effects of tectonic deformation and no unaltered gabbros are preserved. Most of the rocks, both basic and acid, have developed a strong penetrative foliation, and the intrusion of the early basic members by trondhjemite magmas has produced spectacular net veining and extensive hybridisation on which the effects of deformation and retrograde metamorphism have been superimposed.

(1) Basic Lavas: In conformity with the general make up of the volcanic succession of the Skorovas region basalts and andesitic basalts are the dominant volcanic lithology. The basaltic sequence contains more acid lavas and pyroclastic horizons which, in this area, as in others parts of the Skorovas field, are closely associated with exhalative mineralisation. Throughout the area the basaltic lavas appear to be of approximately the same stratigraphic age. They consist of carbonate-rich pillow lavas with or without cusp fillings of jasperoid chert. The most typical development of the pillow lavas is found around the summit of Vestre Saettečuol in the south. Pillow lavas of similar lithology also occur tightly interfolded with dacitic pyroclastics to the north of Store Skorovatn. The pillow

lavas are evidently overlain or replaced upwards in sequence by carbonate-rich andesites which comprise the time-stratigraphic division lying directly beneath the dacitic pyroclastic units which mark the chief period of explosive volcanic activity in the Skorovas region. It is with this stratigraphic level that the important manifestations of mineralisation in the region are associated. The basic lavas of area (a) give only sparse evidence of mineralisation, chiefly in the form of magnetite and haematite bearing cherts in pillow cusps and margins or as discontinuous horizons with sparse concentrations of pyrite or magnetite.

(ii) Intermediate to acid lavas: Relatively small volumes of andesite and dacitic lavas occur in area (a). They occur as thin flows of less than 10m thickness and are subject to repetition by early folding (f_1). This is seen at X   Y.

(iii) Pyroclastic units: The pyroclastic facies of the volcanic sequence in the extended area (a) encompassed in this discussion varies widely with regard to texture. Lapilli tuffs with interspersed magnetite in the pyroclastic fragments and matrix are found throughout the area and are well seen both in the Finnkrudåma section and immediately to the N. of Store Skorovatn. In the Store Skorovatn section towards Skorovatn the pyroclastics also display coarser agglomeratic facies which are easily observed to the south of the Skorovatn Staldvik road in the vicinity of the Church (x   y). This well defined horizon of pyroclastic material extends from east Skorovatn, where it is truncated by the northern contact of trondhjemite of the intrusive arc complex, westward and to the north of Store Skorovatn. From the west of Store Skorovatn this horizon swings abruptly southward into the highly deformed and fractured zone between the Grøndalsfjell complex and the intrusive arc complex, where it is sheared out. Apart from the site east of Skorovatn, this horizon is in many localities difficult to recognise as a pyroclastic, due to the extreme degree of flattening and extension to which it has been subjected. Local strain shadows have aided preservation of original textures however and, together with the local occurrence of directly associated albeit thin jasper horizons, the pyroclastic nature of the horizon is in no doubt. South of Grøndalsfjell, a lithology of similar appearance occurs in a belt trending east-west from Spissknulen and is also sheared out northward beneath the east flanks of the Grøndalsfjell complex. This most probably represents the southerly continuation of the Skorovatn - Store Skorovatn pyroclastic horizon, and displays a distinctive ribbon-like banding of pale to dark green on weathered surfaces.

(iv) Intrusives: The Gröndalsfjell complex is plutonically the deepest level of the Gjersvik eruptive Group and in a structurally undisturbed sequence it should underly the major part of the supracrustal volcanic sequence. It has been exhumed by erosion as a result of the over-thrusting which has placed it in an overlying position with respect to the extrusives which form the lower southern and eastern slopes of Gröndalsfjell and Skorovasklumpen.

The Gröndalsfjell complex evidently results from an extended sequence of intrusive events involving magmas of tholeiitic and calc alkaline compositions. The age relations of the gabbro and diorite intrusives confirm the history of magmatic evolution to have been one of successive increases in acidity (diorite - quartz diorite - trondhjemite (granodiorite)) of the calc alkaline magmas which evidently invaded a pre-existing infrastructure of layered tholeiitic gabbros. Such field evidence fits well with the concept of the Gröndalsfjell complex as the plutonic foundation of an ancient island arc. At the level of exposure represented by the immediate area of Gröndalsfjell dioritic rocks are the dominant constituents of the complex while the earlier tholeiitic gabbros are preserved as isolated enclaves of layered troctolitic hypersthene gabbros. It is assumed that the gabbro component in the plutonic masses increases to the west at the level of the Heimdalshaugen massif which is probably the deepest plutonic level of the Gjersvik eruptive sequence.

The interaction between 'wet' dioritic magma and 'anhydrous' layered gabbro has produced a varied range of phenomena from simple envelopes of uralitic alteration to more diffuse zones of basification and hybridisation which should be made the subject of special study. The diorites are typically medium to coarse grained rocks, weathering pale to intermediate in colour and composed of plagioclase and hornblende. At the periphery of the complex hornblende diorite locally shows quartz and biotite-bearing facies. Another notable feature of the Gröndalsfjell diorites is the occurrence of extensive rhythmically banded appinitic pegmatoids which testify to the considerable influence of deuteric processes in what must be assumed to have been the higher levels of the diorite magma chamber. These phenomena have been figured and described by Walker (B.Sc. thesis on mapping and project work: Gröndalsfjell Gabbro 1973).

Preserved at the margin of the main body of gabbro/diorite of the Gröndalsfjell complex, and lying structurally beneath it, is a xenolithic zone of volcanic country rocks and gabbro within a dioritic or quartz dioritic matrix. This has been termed the 'xenolithic screen'. Within xenolithic rafts, basic lavas are preserved in various states of magmatic reaction and metamorphism. Some show well preserved pillow morphologies but with coarsened prograde amphibolite mineralogy in which amphiboles occur in distinct porphyroblastic clots. In other cases the lavas have undergone recrystallisation to coarse doleritic textures with a 'pepper and salt' appearance. Such doleritic looking lithologies dominate the coherent hornfels envelope which is preserved beyond the xenolithic screen in a four kilometre tract on the eastern slopes of Gröndalsfjell. The relations observed in the aureole have enabled the systematic examination of textures in thermally metamorphosed basic lavas and confirmed the transition from massive granular hornfelsed lavas to similar rocks preserving good pillow geometries. The volcanic identity of the aureole rocks is in no doubt and their textures are also similar to those observed in the sequences on Skorovasklumpen. The dolerite-textured lavas also show relict vesicle fillings which have undergone recrystallisation and fine pervasive veining by veins of epidote-quartz mineralogy frequently produces a distinctive reticular or linear pattern with certain preferred directions. This is noticeable particularly on the eastern flanks of Gröndalsfjell where, within several isolated rafts of hornfelsed lavas the fine veining shows consistent orientation. This suggests that the diorites were emplaced, to some extent, passively.

Thin bands of hornfelsed acid lavas are also preserved within the xenolithic screen and within the aureole envelope. They vary in aspect according to degree of metamorphic recrystallisation from fine aphanitic grey dacitic rocks to relatively granular biotite-quartz-feldspar hornfels. Definite pyroclastic rocks have not yet been identified although it is quite possible that some of the fine grained acid rocks could have been found as tuffs.

Within the xenolithic screen an exhalite horizon is preserved intermittently in rafts and xenoliths retaining a consistent north-south trend (x 67900 Y 7900 to X69150 Y 8190). This confirms the limited disturbance of the country rocks by the dioritic intrusion.

The lower eastern slopes of Gröndalsfjell are composed for the most part of a coherent belt of doleritic textured lavas which separates the dioritic-gabbroic complex of Gröndalsfjell from the belt of trondhjemite intrusives which help to define the southerly trending limb of the Skorovas intrusive arc complex. The lavas are relatively free from the pervasive net veining on the eastern boundary of the belt but thin parallel dykes of trondhjemite with a N.N.E. trend extend through and beyond the limits of the main Gröndalsfjell intrusive zone to cut the lavas.

The hornfelsed basic lavas with associated trondhjemitic intrusives continue northwards from the east Gröndalsfjell belt to connect with the main body of Skorovasklumpen via the western end of Store Skorovatn. The lower slopes of Skorovasklumpen are composed of lavas at lower metamorphic grade and it is assumed that a surface of tectonic disjunction separates the upper hornfelsed lava sequence from the lower more highly deformed, greenschist facies volcanics. The tectonic disjunction is marked by a break in slope which skirts the southern slopes of Skorovasklumpen and trends northeast around the shoulder separating Skorovasklumpen and Lillefjellklumpen. The precise detail of this inferred disjunction, probably continuous with the main thrust boundary at the base of the Grondalsfjell complex is difficult to define. It is, however, a boundary which marks a distinct change in metamorphic grade and intensity of deformation. The volcanic identity of the rocks composing the upper mass of Skorovasklumpen cannot be doubted. Recrystallised vesicles are common at sites along the summit and elsewhere (x 74130 Y 5960). The Skorovasklumpen sequence is distinctive by comparison with the Gröndalsfjell belt in that it also contains a significant volume of sheet-like dolerite intrusives and many of the flows (sills ?) are distinctly feldspar porphyritic Keratophyric flows, minor exhalite mineralisation and trondhjemitic intrusives are also present in the Skorovasklumpen sequence. There is a broadly conformable northwesterly trend to the strike of the Skorovasklumpen rocks with a steep northeasterly dip. This contrasts with the more variable easterly to northeasterly strike and shallow dips of the main planar (s_1) structure in the underlying highly deformed lower grade lavas. The best interpretation of this relationship can be made by assuming that the Skorovasklumpen sequence represents a relatively coherent and competent mass of hornfelsed (relatively higher grade epidote-amphibolite facies) lavas which originally composed the deeper part of the supracrustal volcanostratigraphy of the Gjersvik eruptive sequence. These formed the country rocks into which the gabbros and diorites were intruded at depth. Subsequently, during deformation those rocks have behaved in a more competent fashion relative to the lower grade lavas higher in the volcanic sequence. The Gröndalsfjell-Skorovasklumpen-Skorovatn-Grubefjell sequence can thus, in broad terms, be regarded as an inverted sequence produced by the forceful allochthonous emplacement of the Gjersvik eruptive complex.

Skorovas intrusive arc complex

Most of the general aspects of the geology of the intrusive arc have been described in detail in previous reports by R.D. Scott and R.J. Horsley (B.Sc. Mapping and Project Reports, 1973). An outline summary in this report will give emphasis to those aspects which bear directly on some problems of interpretation.

The Skorovas intrusive arc complex north of Fjelltjönna divides areas (a) and (b) of this report. It is composed of material of widely varying composition which reflects both the range in the primary composition of the constituent magmas (gabbro-diorite-quartz diorite-trondhjemite) and the degree to which they have been mixed during successive intrusive events to produce hybrid facies. The incorporation of a significant but indeterminate volume of the extrusive country rocks has also been involved. Added to the intrinsic complications produced by mixing of magmas, the influence of tectonic deformation and metamorphism is evident throughout the complex and tectonic and metamorphic facies effects are superimposed on the original intrusive relationships. The significance of many geological contacts within the complex is difficult to assess although it is possible to define the extremes of composition at the basic and acid ends. Even this is locally complicated by the effects of net veining of basic by acid components and allochemical metamorphism involving the silicification of basic rocks. Even the external boundaries of the arc are sometimes difficult to define because the basic lavas in the immediate contact zone appear to have suffered a 'hydrothermal' metamorphism resulting in a coarsened amphibolitic texture.

The recognisable components of the arc are as follows

(1) Hb Gabbro and mafic diorite with amphibolitic facies locally reduced by tectonism to talc-magnetite-amphibole schists.

(2) Diorite and Quartz Diorite with hybrid variants and locally coarse appinitic facies.

(3) Trondhjemite (leucocratic granodiorite) with hybrid variants and a local more potassic phase typical of the south trending limb of the arc adjacent to the Jantjonnene basin.

The complex hybrid nature of the arc is evident from the exposures which can be seen in following the path west from the mine office along the spur of land between Dausjoen and Skorovatn.

The prograde hydrothermal metamorphism of the basic lavas in the contact zone of the arc, taken together with the universally hydrated metamorphic assemblages encountered within the intrusive members of the arc suggests that the emplacement of the later dioritic and quartz-dioritic rocks probably took place under relatively wet and probably high level conditions.

The morphology of the arc is evidently sheet like and the structural evidence shows that it dips to the west and north respectively beneath the hornfelsed aureole rocks and intrusives of the Grondalsfjell complex and the volcanic sequences of Skorovasklumpen. The arc has been strongly affected by flat-lying planes of dislocation (f_1 congruent) and also by high angle fractures which serve partly to define the boundaries of the arc and partly to produce a measure of internal complication. The main fractures and tectonic planes do not appear to have involved large displacements (i.e. larger than 10m.) although, due to the sheet-like form of the complex even small displacements may have a marked effect on outcrop pattern.

The arc complex is apparently physically separated from the Gröndalsfjell complex at the present level of erosion but there exists a compelling similarity between their compositions in the broad sense and the relative chronologies of intrusion in both complexes. It is geologically reasonable to infer that the arc complex and the Gröndalsfjell plutonic massif are related and that their obvious differences stem from the different levels which they represent within the original eruptive stratigraphy of the Gjersvik sequence. The arc complex could be regarded as a ridge-like apophysis rising into the higher levels of the volcanostratigraphy and accordingly being flattened and deformed with the supracrustal volcanics as a result of the plutonic-volcanic décollement caused during allochtonous emplacement of the Gjersvik Nappe.

It is possible to propose a palinspastic reconstruction in which the intrusives rise in stratigraphic level of emplacement from the Gröndalsfjell level to the arc complex. The extended sheet-like form of the arc cannot, however, be explained solely in terms of post intrusive tectonism and must reflect, to some extent, the early geometry of the intrusive mass. The primary geological control may have been a linear fault zone or such-like weakness which may have been the foundation of a chain of minor eruptive centres or the elongate axis of a single polygenic edifice.

The arc complex, while giving the impression of structural conformity owing to the broad parallelism of schistosity and the tectonically modified igneous contacts of the intrusives, is nevertheless clearly discordant in the stratigraphic sense. In the vicinity of Skorovatn for example (x 71360 Y 4200) the distinctive agglomeratic horizon which extends from the north shore of Store Skorovatn is truncated by the trondhjemite contact at a relatively high angle. It is evident from the trend of this pyroclastic horizon that it is probably continuous with those pyroclastics which occur to the south of the arc complex in the vicinity of the Reservedam and the Heisbahn section of Grubefjell. These horizons are stratigraphically related to the Skorovas ore body. Other regions in which the cross-cutting relationship of the intrusive arc are well displayed include S.E. Heklefjell (x 66890, Y 6720) and W. Grubefjell (x 69240, Y 6775). It is notable however that to the south of Drikkvatnet where a primary E.-W. contact of the arc complex with basic extrusives is preserved, the concordance between the intrusive mass and the stratigraphy within the extrusives is strikingly clear. The intrusive relationships shown by the various parts of the arc complex are therefore very variable as might be expected of an extensive high level intrusive. Undoubtedly some parts of the intrusive body were sill-like in form, transgressing the volcanostratigraphy in a step-wise fashion.

Approximately 3km east of Skorovatn, the intrusive mass forming the high ground to the north of Langtjönna and Olatjönna forms the northern margin of Area (c) described in this report. This intrusive mass is of sheet form and is part of the arc complex although the area of drift covered marsh in the vicinity of the Stallvikelva conceals the nature of the geological connections. The Olatjönna intrusive is composed of coarse phaneritic trondhjemite and quartz porphyry and displays certain characteristics of a high level intrusion. There is a well-developed hornfelsed aureole and the country rocks are cut by dykes and sills of quartz porphyry which originate in the intrusive body. There is compelling geological evidence that this intrusive also fed the eruptive centres in the vicinity of Blåhammeren - Svartberget. It is in this track that the relationships between quartz porphyry feeder dykes, pyroclastics and vasskis and jasper horizons is so explicitly developed.

Mineralisation in the rocks of Area (a)

Thin horizons of exhalative mineralisation occur at intervals within the extrusive succession of Area (a) and are chiefly found in direct association with pyroclastics of variable thickness and texture. The concentrations of this mineralisation are found at scattered localities along the pyroclastic horizon which extends from Skorovatn to east Gröndalsfjell and, by inference to Spissknulen along the southern margin of the Gröndalsfjell complex. A variety of 'vasskis style' mineralisation is found at intervals from the Skorovas Lia to the north shore of Store Skorovatn. This mineralisation varies in stratigraphic detail but is composed mainly of banded fine-grained magnetite and pyrite with admixture of chloritic or cherty material. An interesting development of banded grey cherty sediment with interbeds of magnetite and lesser sheets of pyrite is seen adjacent to the road at the N.E. corner of Store Skorovatn directly west of the layer. In the region S.W. of Store Skorovatn dislocated and extended shreds of magnetitic and pyritic sediments occur. In the belt of high deformation separating Gröndalsfjell and the arc intrusive complexes, the pyroclastic unit is sheared out and occurs only in intermittent scraps. Pyrite bearing exhalite mineralisation is, however, locally preserved in traces and gives evidence of having been cupriferous (x 69500 Y 7630).

Further south and in the tract westwards to Spissknulen mineralisation is chiefly in the form of haematitic jasper bands with some underlying development of banded pyrite-magnetite (x 67880 Y 7760 - at this locality the sequence of exhalative mineralisation has been considerably thickened by folding). In the belt to the south of Gröndalsfjell there are thin extended and dislocated horizons of pyritic mineralisation which are repeated in several features by the early phase of isoclinal folds. Conspicuous development of jasper bands is not observed and there is, locally, evidence that copper may occur in trace amounts (x 67570, Y 8800).

The westerly continuation of the N. Finnkrudåma acid flow-pyroclastic horizon has associated jasperoid chert horizons which extend into the Jantjönnene basin. In the zone to the east and northwards over Vestre Saettecuol and along the western shore of Fjelltjönne bands of jasper occur intermittently amongst the folded lavas. The carbonate rich lavas give evidence that they may be locally enriched in Cu (x 66340, Y 7600).

To the north of the Skorovatn-Store Skorovatn pyroclastic horizon thin bands of acid pyroclastic material are found with associated hematitic jaspers and also thin discontinuous horizons with pyrite and pyrite-magnetite mineralisation. These are interpreted as structurally repeated equivalents of the Skorovatn-Store Skorovatn pyroclastic unit.

Within the Gröndalsfjell complex, as previously mentioned, an exhalite horizon occurs within the xenolithic screen. This horizon is composed of a hornfelsed grey chert with a distinctly crystalline appearance which contains disseminations of pyrite and magnetite. Pyrrhotite is not, as might be expected, the dominant sulphide in this hornfelsed band. The surrounding rocks are distinctly amphibolitic. Other examples of prograded exhalative mineralisation occur at x 68930 Y 8040 and on the N.E. flank of Gröndalsfjell (x 71360, Y 8030).

No clear examples of exhalative mineralisation have been found within the hornfelsed amphibolitic lavas and sheet intrusions forming the upper rocks of Skorovasklumpen. This may be due to their inferred low stratigraphic position in the volcanic sequence. The basic volcanics do however contain disseminated pyrohotite but this is almost certainly of metamorphic origin as opposed to primary magmatic formation.

Structure

First Deformation (f_1): The tectonics of the Skorovas region are characterised by the extremely anisotropic response of the constituent lithologies of the Gjersvik eruptive sequence. The orientation of the early (f_1) fold axial planes at any locality, even prior to the second stage of deformation (f_2), are dependent upon the interplay between the regional Caledonian stress field (maximum principal stress N.E.-S.W.) and the local stress field which is the product of the varying geometry of the competent intrusive masses and their juxtaposition with relation to one another and the less competent supracrustal volcanic sequence. Within Area (a) anisotropies on all scales are observed and fold orientations are greatly influenced by the surrounding intrusive masses of Grondalsfjell and the arc complex. This is notably clear in the vicinity of the structurally modified contacts of these masses where progressive flattening of f_1 folds and componental movement parallel to f_1 axial planes accompanied nappe emplacement and produced f_1 congruent shearing parallel to the margins of the intrusives.

Within larger volume of unaltered extrusive material for example in the vicinity of Jantjönnene and south to Finnkrudama, f_1 fold orientations are conformable with the typical regional trend, that is to say north-east south-west.

The hornfelsed amphibolitic lavas of Skorovasklumpen are essentially massive and compact and have behaved tectonically in a similar fashion to the plutonic massifs. The Skorovasklumpen massif shows a consistent internal strike and dip which displays a north-westerly trend with vertical to north-easterly dips. This structural grain is evidently discordant with the trend shown by the volcanics of lower metamorphic facies which underlie the amphibolitic unit on the slopes to the north of Skorovatn. In this case the strike is trending east north-east to north-east with shallow dips towards the north or north-west.

Second Deformation (f_2): Second stage folding of open style with broad wave lengths and low amplitude similar to that occurring east of the vannledning and east of Tredjevatnet, occurs in the north Finnkrudama-Jantjönnene area. As in other parts of the Skorovas region such open post schistosity folding is a result of compensatory buckling of supracrustal volcanics during adjustments following the primary stages of emplacement of the Gjersvik nappe and exerts only a secondary influence on the outcrop pattern.

In addition to the broad open folding post schistosity folds of smaller and tighter style are frequently encountered. This style of folding however is specifically confined to structural planes in which strain has been concentrated during the first and second stages of deformation. Crenulation folding of this style is found in the calcareous chlorite schists which are a tectonic facies of the pillowed basalts which occurs commonly along the planes of tectonic disjunction at the margins of the Gröndalsfjell and intrusive arc massifs. The penetrative effects of this crenulation have commonly resulted in the generation of a crenulation cleavage (s_2). The presence of these second stage minor structures within these restricted shear zones provides further confirmation of the heterogeneous strain which characterises the deformation of the Gjersvik eruptive sequence. Tight f_2 buckle folds are also observed within the pyroclastic horizon to the north and north-east of Store Skorovatn. The axial trend of the small scale f_2 fold structures is generally north to north-east with steep to intermediate dips of the axial plane towards the north-west or west.

Fractures: The majority of low to intermediate planes of tectonic disjunction (f_1 congruent) and those of high angle are in some way associated with the contact zones of the intrusive complexes in area (a). Apart from those fractures (lineaments) in the Kronglefjell-Nesåpiggen area this region contains the highest concentration of fractures in the Skorovas concession area. The eastern and southern margins of the Gröndalsfjell complex and the margins of the hornfelsed extrusives of east Gröndalsfjell and Skorovasklumpen are defined by a series of imbricate low to high angle reverse faults dipping to the north and west. Within the zones separating the Gröndalsfjell complex and the arc complex there are, in addition, a series of later high angle fractures of minimal displacement which add complication to an already complex structural framework. Within the intrusive complexes themselves high to low angle imbricate fractures of low displacement are common. It is evident that most of the high angle fractures involve only minor displacement and can be regarded as of a compensatory nature.

The most important line of tectonic discontinuity is that which is marked by the outcrop of the plane which separates the low grade relatively deformed extrusives of the Skorovas area from the hornfelsed rocks (showing prograde amphibolitic mineralogy) which form the slopes of east Gröndalsfjell and the massif of Skorovasklumpen. This plane of disjunction (perhaps better described as a zone) trends approximately south west from the eastern shoulder of Skorovasklumpen towards the west end of Store Skorovatn whence its swings sharply southward continuing to form the contact between the arc complex and the prograded lavas of eastern Gröndalsfjell. A few hundred metres to the north of Jantjönna (658) this important plane swings abruptly westward to Spissknulen. The fracture plane dips at low to medium angles to the north or north-west beneath Gröndalsfjell and Skorovasklumpen. In view of the geological evidence, the occurrence of intense tectonic facies and f_2 crenulations in the zone immediately surrounding the outcrop of this plane it must be assumed that this is one of the major second order thrust horizons within the Gjersvik nappe. It has been influential in the development of post f_1 structure but its initiation clearly dates from the first period of tectonism which produced the major translation of the Gjersvik nappe.

Area (b)

Lithological Units and Stratigraphy

This area is separated from area (a) to the west and north by the Skorovas intrusive arc complex. The central topographic feature is Grubefjell which is composed of a volcanic sequence ranging in composition from basalt to dacite (keratophyre). The sequence includes a relatively large volume of pyroclastic rocks including metahyalocastite pillow and flow breccias and acid to intermediate agglomerates and tuffs. Exhalative mineralisation associated with the latter lithologies lies stratigraphically peripheral to the Skorovas orebody. The orebody extends to outcrop as a zone of massive pyritic horizons with minimal base metal content set in a complex matrix of variably silicified, sericitised, and pyrite impregnated basic to acid volcanic host rocks. Minor dykes and sills of basic to acid composition are common, particularly in those horizons lying stratigraphically and structurally beneath the ore zone in the S.W. Kvitjönna - S. Dausjöen area.

(i) Basic Lavas: Both pillowed, brecciated and unstructured massive basaltic flows occur in the Grubefjell succession. For the most part the basaltic rocks are pillowed and display persistent flow horizons in which distinctive cusp fillings of epidote or grey chert which may in certain cases extend to form a more or less coherent matrix around individual pillows. This phenomenon is best observed on the north western slopes of Grubefjell where individual horizons of pillowed basalts 10-20m in thickness display either chert or epidote cusp fillings.

The basalts are characteristically vesicular and the mineralogy of the vesicle fill is variable, including carbonate chlorite, epidote, stilpnomelane and occasionally pyrite. There is no systematic zoning with respect to the vesicle mineralogy within flow units. The dimensions of vesicles 3-8mm (rarely several cm) in diameter indicates that the depth of eruption did not exceed 750m and it is likely that it was considerably less (Moore J.G. 1965 The petrology of deep sea basalt near Hawaii. Am. Jour. Sci. 263, p.40-52).

The basalts of the Grubefjell succession show evidence of strong pervasive hydrothermal alteration. One evident reason for this is that the rocks are host to the Skorovas orebody and it may be assumed that the formation of the orebody took place in the immediate vicinity a thermal or eruptive focus which would generate a vigorous hydrothermal circulation. The alteration zone surrounding the orebody is most strikingly shown in the vicinity of the Skorovas gossan. Primarily basaltic to basaltic-andesitic lavas have been permeated by silica and iron-bearing solutions which have caused pyritisation and silicification of the basic wall rocks. In more stratigraphically distal situations the basic lavas in contact with the pyrite-bearing acid pyroclastic horizon have suffered a more subtle silicic alteration to produce an intermediate andesitic appearance.

Throughout the Grubefjell area the basaltic rocks in the stratigraphic vicinity of the ore and the peripheral pyroclastics and exhalites are notably iron rich. They may also be enriched in copper judging by the occurrence of Viscaria alpina at a number of localities (X 68510, Y 5910; X 68800, Y 6330). Iron occurs in both sulphide and oxide form as pyrite and magnetite impregnations. Further detailed petrographic and geochemical work on the lavas is required before the intercorrelation between the occurrence of iron as pyrite or as magnetite and the relative abundance of other base metals in the lavas will be understood.

The basic lavas of the Grubefjell succession show complicated stratigraphic and outcrop relationships with associated andesitic rocks. The state of deformation and the relative alteration of these rocks compound the problem of field mapping. The occurrence of flow breccias, hyaloclastites, persistent jasperoid bands on marked horizons of a particular type of pillow cusp filling have provided the best basis for distinction of significant flow contacts. The contact geometry is nevertheless often difficult to interpret and interdigitation may be as much due to the complex primary relationships of the flow units in the vicinity of the eruptive centre as to the effects of later folding.

(ii) Intermediate Lavas: The extrusive sequence in the Grubefjell area includes a greater proportion of andesitic rocks than is otherwise found in the Skorovas region. The andesites are intercalated with basaltic flows both stratigraphically above and below the Skorovas ore horizon. The main development of andesites is thus clearly located in the Grubefjell sequence and the major thickness lies immediately beneath the stratigraphic level of the orebody. The rocks are of variable appearance in the field, characteristically compact and show variable development of vesicles. They are normally pale blue green weathering rocks but in the presence of iron enrichment they have a darker grey-brown colour becoming even darker where stilpnomelane forms a significant component of the mineral assemblage. Locally they may also show pillow structures and the field distinction between andesites and basaltic andesites is obviously not easy to make.

The andesites which stratigraphically underly the ore horizon are relatively massive and light coloured. They contain appreciable amounts of carbonate which has led to the use of the term calc-andesites to describe them. Their most typical aspect is seen on S.W. Grubefjell at (X 68760, Y 6200) and also in sections on the western slopes of Nesaklumpen (X 68470, Y 4540). At the Grubefjell locality they occur stratigraphically beneath pillowed basalts which in turn underlie the local expression of the major phase of explosive volcanism and mineralisation in the extrusive sequence. Also at this locality the calc-andesites and pillowed basalts contain interrupted bands of exhalative mineralisation of 1-2m extent. The mineralogy of these bands is chiefly pyrite + quartz + chlorite. Stilpnomelane is also locally present. There is also evidence for the occurrence of trace amounts of copper (X 68750, Y 5040).

Andesites lying stratigraphically above the Skorovas ore horizon tend to be pillowed and also display chert cusp fillings. The pillow structures have suffered some flattening and dislocation and it appears that fragments of chert from an underlying exhalative horizon have been disruptively broken and entrained within the andesitic lava together with spongy looking siliceous and epidotic lumps which have apparently been produced by the disruption of a metamorphically hydrated and altered flow top from an underlying (basaltic ?) unit. At one locality (X 69275, Y 6410) angular fragments of chert up to 20cm in diameter have been incorporated from a deep red compact jasper horizon lying less than 2m stratigraphically below. The entrained clasts of jasper show a bleached margin of 1-2cm width in which the hematite of the jasper has been converted to magnetite. The andesites lying stratigraphically above the pyroclastic and exhalite-bearing level associated with the major episode of mineralisation in the Grubefjell sequence (the ore horizon) are also abundantly vesicular and locally contain quartz filled vesicles of up to 5-6cm maximum dimension.

(iii) Acid Lavas: In the Grubefjell area (b) there are two main outcrops of acid lavas (dacite - keratophyre). The first is that which lies above, within and in the lateral vicinity of the Skorovas orebody. The second is that which occurs in the region of N. Drikkvatnet and the southern end of the vannledning within area (b), as in other parts of the Skorovas region, there is evidence that the extrusives are physically continuous with intrusive feeders of similar composition. This would be exposed in the vicinity of an eruptive centre. This type of relationship has already been described from the Finnkrudåma area (X 6400, Y 7150; discussed in Field Report 1975), and is also seen in the vicinity of N.E. Svartberget (maps and reports 1973, 1974). The acid lavas are notably massive at outcrop and owing to their siliceous composition they weather with a pale surface and support a growth of bright yellow-green lichen. They are variably porphyritic and the bulk of the rock is composed by the aphanitic groundmass. Internally, the lavas may show a fragmented texture, with cementation by a reticular framework of quartz veins. Such textures are clearly seen on the N.W. slope of Grubefjell in the pyroclastic horizon extending westwards from the orebody. These rocks may be a pyroturbidite facies in the volcanic sequence.

The general availability of silica in the acid rocks has facilitated the formation of box-like and sigmoid sets of quartz-filled joints during metamorphism and deformation. In parts of the sequence these veins can be a useful diagnostic feature.

Stratigraphically, the sulphide exhalite mineralisation in the vicinity of Skorovas and N. Drikkvatnet is tied closely to the occurrence of dacitic lavas and their feeder dykes/sills. The acid lavas appear to occur at several levels in the stratigraphy of the mineralised zone which includes, in addition, varying proportions of flow breccias, hyaloclastite pillow breccias, and a variety of tuffaceous pyroclastics including horizons of pyritic mineralisation with or without jasperoid cherts.

(iv) The ore zone: Pyroclastic facies and exhalative mineralisation

(1) Flow breccias and hyaloclastite pillow breccias. The stratigraphic succession in the mineralised zone of Grubefjell contains significant volumes of these lithologies. The textures of those rocks are best observed on water worn or glaciated pavements where differential weathering has 'developed' them. On roughly weathered or blasted surfaces, for example at the northwest end of the Vannledning path, these pyroclastic textures do not show up. Flow breccias are most commonly developed at the tops of pillowed units. Pillow breccias commonly display a rusty red ferruginous weathering surface which is probably a result of contemporaneous oxidation of the lava fragments, which, in the units close to exhalite mineralisation, are notably enriched in iron. Good examples of this lithology can be seen at (X 68220, Y 6500) on S.W. Grubefjell. Examples of the commoner grey-green pillow breccias occur at (X 68350, Y 5900) on Grubefjell, (X 68210, Y 6050) on S. Grubefjell and

(X 71180, Y 6160) to the west of Dausjoen. Clearly recognisable hyaloclastite textures occur in N. Drikkvatnet at (X 68130, Y 5375). Both pillow breccia and hyalocastite lithologies show gradational relationships to non-brecciated flow material.

(2) Acid to intermediate pyroclastic lithologies. A range of acid pyroclastic material occurs within the area varying from very fine chloritic, quartz chlorite and coarser lapilli tuffs to agglomerates of dacitic aspect.

Fine grained to variably agglomeratic dacitic rocks are closely related to the stratigraphic level of the Skorovas orebody. They extend as a continuous belt northeastward from the eastern contact of the intrusive arc complex on Grubefjell (878 m) to Nordre Grubefjell (750 m) and continue northeastward toward the north of the Reservedam. The dacitic belt shows a complex geometry of intercalation with silicified and brecciated basaltic and andesitic lithologies. The dacitic rocks themselves appear to have suffered silicification and are weakly impregnated with pyrite. Flattened fiamme-like textures can be seen at some localities on the weathered surface of these rocks (X 69610, Y 6740). These may be flattened pumice rocks or dacite clasts incorporated in a pyroturbidite (submarine avalanche of pyroclastic origin). This type of lithology has not been observed in the vicinity of mineralised horizons in the N. Drikkvatnet area.

Lapilli tuffs and fine agglomerates composed of blue grey acid fragments, densely impregnated with magnetite and set in a compact chlorite-silica rich matrix are a characteristic lithology closely associated with the Skorovas orebody and may be found both stratigraphically above and below it (X 69920, Y 5440). These rocks are also found at the level of the mineralisation in the vicinity of N. Drikkvatnet (X 68230, Y 5900). Such pyroclastics occur in several thin horizons stratigraphically and structurally underlying the Skorovas orebody and it is inferred that these horizons are equivalent to the pyroclastic horizons of the Skorovatn - Store Skorovatn tract referred to in the description of Area (a).

Coarser textured acid agglomerates with fragments $>$ 20 cm. diameter are locally associated with horizons of pillow breccias and hyaloclastites with which they show intercalative relationships. They consist of subangular blue-grey or pale grey coloured clasts of quartz porphyritic dacite in a fine grained matrix of quartz and chlorite. This lithology is seen on N. Grubefjellet (X   Y   ).

(3) Exhalative mineralisation. The Skorovas orebody together with the 'Sydmalmen' and the massive sulphide horizons of N. Drikkvatnet and their related base metal poor peripheral facies constitute the main expression of exhalative hydrothermal mineralisation in the area. The peripheral facies include a variety of lithologies in combinations including haematite and magnetite-bearing chert bands (jasperoids) with, locally, compact magnetite and thin bands with sparse disseminations of pyrite and, or, magnetite.

Exhalite mineralisation lying stratigraphically beneath the main ore horizon occurs in association with thin bands of lapilli tuffs of acid composition which outcrop to the west and immediately to the south of Dausjoen. The thin horizons consist of banded pockets of fine grained or sparsely disseminated pyrite with associated magnetite and with or without thin intercalations of pale grey or purple jasperoid. The lack of persistent bands of jasperoid in association with the sulphide-magnetite mineralisation may be due to the fact that large volumes of this material are incorporated in the cusp space and margins of the stratigraphically adjacent basalt lavas. It appears that the period of eruptive activity which produced the thickness of basalts and andesite underlying the orebody was also marked by hydrothermal exhalative activity and intermittently by emission of small amounts of acid pyroclastic material. The colloidal silica emitted during the eruptive-hydrothermal process was evidently available in quantity to be stirred up and trapped in the interstices between pillow units. These cherts are most commonly grey or dark grey and the iron is, for the most part, in the form of magnetite. The mixture of basic eruptive and acid pyroclastic/hydrothermal activity with the co-eval formation of iron and silica hydrosols can also be considered to explain the local enrichment of Fe and Cu in the lavas as well as the accumulation of the iron hydrosols in local pockets to produce thin pyrite-magnetite bands.

The main stage of explosive acid volcanism is seen in the Heishuset - N. Drikkvatnet succession of pillow breccias, hyaloclastites and predominantly acid pyroclastics which form a mixture of host rock lithologies in association with which relatively rich accumulations of massive sulphide were formed, notably the Skorovas orebody, the sydmalmen and the N. Drikkvatnet sulphides. The Skorovas orebody is the subject of a detailed study now being made by Reinsbakken (1977). Aspects of the general wallrock chemistry have been described by Gjelsvik (1963, 1965). Detailed accounts of the structure and stratigraphy of parts of the ore lens system have been given by Ferriday (Reports to Elkem Spigerverket Skorovas Gruber: Geology of K02 44-57 5 (1974), Geology of the Løftet ore lenses (1974), Geology of the southern eastern orebody (1975), Geology of the southern main orebody (1975).

At surface the Skorovas orebody is defined as a gossan zone of altered and sulphide impregnated acid to basic lavas and acid pyroclastics. Locally, massive pyritic lenses outcrop at surface and on the northern and eastern flanks of Nordre Grubefjell the volcanic sequence in the vicinity of the ore has been cut by numerous basaltic, andesitic and acid dykes and sills which have fed the various flow units. Pyritic impregnation and alteration of the host pyroclastics decreases westwards along strike in the direction of the contact with the intrusive arc complex northwest of Grubefjellet (878). This relationship suggests that the pyroclastic unit is, towards the west, increasingly distal with respect to the concentration of hydrothermal activity.

Coherent jasperoid chert horizons are stratigraphically closely associated with the pyroclastic facies and mineralisation of the main ore horizon as seen at (X 69175, Y 615) on Grubefjellet and (X 69520, Y 5750) on Nordre Grubefjellet, where the horizons occur at the boundary separating pillow breccias, hyaloclastites and pyroclastics from the succeeding andesite and basalt flows. Similar horizons occur in the mine and have been described in the Reports on the Southern Eastern Orebody and Southern Main Orebody (1975). Jasperoid chert horizons have not been identified within the gossan zone however despite the presence of definite silicification and pyritisation of the volcanics. It is likely that the gossan outcrop represents a hydrothermal alteration zone lying at a slightly lower stratigraphic level than that at which the main orebody was syngenetically precipitated.

The so called 'Sydmalmen' is presently under investigation and is composed of Cu and Zn enriched pyritic ore of distinctly sedimentary aspect. The precise volume of this orebody is not yet known and further exploratory drilling is needed. The morphology of the body will no doubt be similar in style to the main Skorovas orebody, being made up by a complex of lenticular elements. Such lenticles have been proven by drilling to occur from around section 73 S in the vicinity of the mine towards the Finnkjerringhullet locality of N.W. Drikkvatnet. At this point the ore is stratigraphically equivalent to that which outcrops in the Finnkjerringskjerp but lies structurally approximately 100 m beneath. The Finnkjerring mineralisation is, in turn, stratigraphically equivalent to the sulphide mineralisation of N.E. Drikkvatnet.

The sulphide skjerps of the N. Drikkvatnet area have been described by Foslie and by Oftedahl (Oversikt over Grongfeltets skjerp og malmforekomster N.G.U. 202 1958 and N.G.U. Rektangelkart: 1:100,000 Trones 1958). More recently Hirsinger and Scott have reported on these occurrences (R.S.M. Project reports to Skorovas Gruber 1973).

The mineralisation consists of up to 2 m thickness of locally Cu and Zn enriched massive pyrite with limited lateral extent. The massive pyrite is gradational to zones carrying up to 4 m thickness of disseminated pyrite. The sulphides which have a chlorite-rich siliceous (locally tuffaceous) matrix are located within a horizon of predominantly pyroclastic character typified by the blue-grey magnetite enriched facies. Banded magnetitic cherts and haematitic jasperoid cherts are not well developed in the immediate section containing the sulphide mineralisation but do occur at stratigraphically equivalent horizons within 50-70 m of the sulphide skjerps.

The massive sulphide horizons of both Grubefjellet and N. Drikkvatnet are inclined at low angles ($0-20^{o}$) to the S.E. and show a gross concordance with the primary volcanostratigraphic layering (S_0) and the subsequently imposed schistosity (S_1), lying along the limbs of the first generation isoclinal folds (f_1).

Base metal impoverished exhalative mineralisation occurs at stratigraphically equivalent levels peripheral to the major massive sulphide horizons in the area. At outcrop the most common facies is composed of finely banded magnetite bearing cherts or violet-grey to purple weakly magnetitic jasperoid cherts. Truly haematitic jasper horizons are relatively rare (N. Grubefjell X 69175 Y 6150) and it is assumed that, for the most part, exhalite precipitation took place in the area under relatively reducing conditions. Disseminated pyrite occurs in horizons of limited extent closely associated with violet-grey or purple jasperoid cherts. The most significant occurrence of this type is located close to the intrusive arc complex near its contact on S. Grubefjell (X 68630 Y 6450). At this locality, disjunct horizons of disseminated pyrite set in a dark siliceous matrix (probably Mn-rich) occur in association with pillow breccias and thin pyroclastic horizons. Locally the pyrite is replaced by pyrrhotite, a phenomenon which, in the Skorovas area, suggests the influence of contact metamorphism by the adjacent basic intrusives of the arc complex.

An important feature of the Grubefjell sequence as a whole is the general abundance of stilpnomelane which occurs in several distinctive modes.

It may form an integral part of the metamorphosed groundmass of the basaltic and andesitic lavas and minor intrusives above and below the orebody. It also occurs as distinctive vesicle infillings and as fine veinlets or patchy shred-like segregations within the lower lavas which accordingly weather with a distinctive dark blackish or greenish brown colour.

(v) Intrusives: The contacts of the intrusive arc complex define the northern and western margins of Area (b). The variable influence of penetrative hydrothermal/metamorphic transformation of the country rocks, together with the effects of post intrusive tectonic deformation lead to difficulties in the interpretation of contact relationships.

Within the area, as mentioned above, minor intrusive bodies of acid to basic composition (trondhjemite-diorite-gabbro) occur commonly within the volcanic succession and there is a notable concentration of sheet-like intrusive bodies in the stratigraphic vicinity of the orebody itself. The acid sheets appear to be, in part, continuous with extrusive facies. Lithologically they are feldspar-quartz porphyries. The groundmass is notably aphanitic, dense and pale grey in colour, frequently with a scattering of pyritic impregnation.

Sills and discordant dykes of basaltic to andesitic composition can also be traced over limited distances through the succession and often their physical continuity with flow material can be demonstrated.

Note on the 'Chlor-fleck' greenstones: The lithology which has been variously described as 'gabbroic textured' or 'chlor-fleck' greenstone occurs in relatively thick horizons in contact with the sheared acid eruptives and pyroclastics within the stratigraphic level of occurrence of the Skorovas orebody (see Southern Main Orebody Report, Ferriday 1975). Similar looking rocks have been found in other parts of the Skorovas region (Tredjevatn area). The lithology is usually distinctly schistose and is composed of quartz, feldspar, chlorite, carbonate and, in addition, talc. The flecked appearance is caused by the presence of lenticular concentrations of chlorite which are evidently produced by retrograde alteration of primary mafic silicates and reorganised during the penetrative refabrication of the rocks resulting from the intense shearing which took place in the volcanic envelope in the immediate vicinity of the massive sulphide ore horizon during the stages of early deformation (f_1). Petrographic examination reveals the presence of relict igneous textures in this rock but the 'chlor-fleck' lithology must be regarded as a tectonic facies the formation of which is dependent upon the high shear strain imposed upon the basic to intermediate lithologies in the immediate vicinity of the orebody. A proportion of intrusive material is also probably involved in the formation of the chlor-fleck facies.

Area (b) Structure

(i) First deformation (f_1): The predominant structural grain of the area is given by the N.N.E. - S.S.W. orientation of the f_1 isoclinal fold axes. The axial planes dip from 0-20° to the southeast quadrant. The tectonic buttress effect provided by the intrusives of the arc complex during the early and later deformations has, however, led to a parallelism between the axes of f_1 folds and the contacts of the arc. Thus, from the dausjoen area to the vicinity of Nordre Grubefjellet there is a gradual change in the orientation of f_1 axes from east west to north-north-east - south-south-west. The form of the larger scale f_1 folds is shown on the accompanying sections. They display s assymmetry when viewed in section looking north. This is consistent with a position on the lower limb of a large E.S.E. facing recumbent fold, the identity of which can be broadly equated with the Gjersvik Nappe.

The majority of the f_1 isoclinal fold structures have evidently suffered from the effects of tectonic flattening, distension and disjunction of their limbs by componental shearing. The dislocated style tends to conceal the nature of folding on all scales. Well-preserved isoclinal structures of intermediate scale are, however, preserved for instance in sections of the orebody (profiles 73-74 S near 6 W). An outstanding example can also be seen at surface on Grubefjellet (X 69380, Y 5800) with an amplitude of 5-6 m and an axial trend of approximately 015°.

(ii) Second deformation (f_2): Post schistosity folding of broad open style similar to that occurring in the Gruvetjonne-Vannledning section (Report on Geology of Eastern Skorovas, 1974) and in the Saettecuol-Cevoker section (Report on Geology of the Finnkrudama-Nesapiggen area, 1975) is also developed in Area (b). The gentle f_2 synformal structure trending east west across the Gruvetjonne tract is continued into Area (b) but the effect is subdued to the west of Nordre Grubefjellet. This structure gives the Skorovas orebody a slightly downbowed profile on a north-south section.

Post schistosity folding of tighter style occurs within the volcanic sequence in a belt from 100-500 m running parallel to the contact of the intrusive arc complex in the tract from west of Dausjoen to southwest of

Kvitjonne, also in the S. Grubefjellet area. The main feature of the fold system is an antiform trending parallel to the contact westward from Dausjoen. This folding can be visualised as a buckling effect against the tectonic buttress created by the competent lithologies of the intrusive arc which was combined with discrete shearing on planes along, and parallel to, the intrusive contacts and along an E.N.E.-W.S.W. trend. Defined zones of f_2 crenulation cleavage are associated with these planes of shearing.

In the environment of the orebody the contrast in the mechanical properties of the massive pyritic ore lenses and the associated wall rocks has led to remarkably anisotropy of the stress distributions and consequent heterogeneous strain. Tight f_2 folds with a S.S.E.-N.N.W. axial trend deform the wall rocks in the immediate vicinity of the orebody. This tight fold style is found only in the thinner ore lenses and their extrusive envelope occurring within the extent of the mechanical influence of the shear stresses imposed by the larger, more massive ore lenses during the stages of f_2 deformation. This style of folding is a consequence of the intrinsic f_1 geometry and mechanical contrasts existing within the ore zone and although it is not a general feature of the Skorovas region it is obviously important with respect to the planning of mine development.

(iii) Fractures: In common with Area (a), the most significant planes of structural disjunction are f_1 congruent and were initiated as planes of weakness during the primary stages of isoclinal folding and tectonic emplacement. They subsequently provided horizons for compensatory shearing and displacement during second stage folding and tectonic adjustment. Individually, within the area under consideration these fractures have suffered displacements of the order of a few metres or tens of metres only.

Several well developed high-angle fractures traverse the area and their strike is broadly parallel to the f_1 axial trend N.N.E.-S.S.W. These could be regarded as planes of adjustment developed during the isostatic compensation following nappe emplacement. Minor drag-fold disturbance of schistosity occurs adjacent to these fractures and is of a distinctly separate style to other minor post schistosity fold structures. Displacements on these high-angle planes is limited to a few metres at most.

Area (c)

Stratigraphy: This area stands apart from Areas (a) and (b) in that a major component of the eruptive sequence is of quartz porphyritic composition with both intrusive and extrusive facies. The lithologies are notably more porphyritic in character than the dense aphanitic-looking feldspar phyric dacite-keratophyre rocks of area (b). The acid extrusives and pyroclastics of this area appear to occur at a stratigraphic level separating two groups of basaltic rocks. The basalts occurring to the south and stratigraphically underlying the principal level of acid extrusives mostly display well-developed pillow structure while the upper lavas consist of a mixture of both massive flow units and pillowed rocks. Coarse phaneritic trondhjemite and quartz porphyry of the intrusive arc complex form the northern boundary of Area (c).

(i) Basic Lavas: The predominantly well-pillowed basalts occurring in the southern tract of this area lie structurally above but stratigraphically below the major acid horizon. The contact zone with acid extrusives just to the south of Olatjonna is also observed repeated in the vicinity of Stommes-tjonna where basalts of the lower unit are in contact with calc-alkaline or transitional series basalts and associated exhalative mineralisation. Andesitic lavas of the upper unit, together with horizons of exhalative mineralisation are also repeated as a result of f_1 isoclinal folding and outcrop on the N.W. flanks of Svartberget. The alteration of the pillowed basalts of the lower unit has produced epidote-rich segregations which occur as selvedges and cusp fillings amongst the pillows. The lavas are mineralogically rich in carbonate which occurs both in the groundmass mineralogy of the altered rock and also as vesicle fillings. Epidote does not occur conspicuously as vesicle fillings.

The basalts of the upper unit which structurally underlie, but stratigraphically overlie, the major unit of acid extrusives in the S. Olatjonna - Nesklumpen area are characterised by the pervasive development of epidote throughout their fabric. Some facies are massive and display pervasive veining by epidote, others show abundance of epidote filled vesicles. There are local facies of what are also believed to be upper unit basalts which have abundant grey jasperoid chert cusp fillings. These are taken to be the stratigraphic equivalent of similar facies on Grubefjell (c.f. Area (b)). It is difficult to base stratigraphy, at the level under discussion, on the alteration mineralogy of the lavas and it is also clear that both upper and lower units contain carbonate in definite amounts as a result of retrograde alteration of calcium-bearing feldspars. Nevertheless, insofar as it is possible to generalise it appears that the lavas of the upper unit are distinct from those of the lower unit in not containing conspicuous amounts of secondary carbonate.

(ii) Intermediate to acid lavas: In the eruptive succession of Area (c), andesitic lavas occur in the sequences both above and below the main horizon of acid extrusives. In general they occur above as is the case in the eruptive succession of Area (b) (Grubefjell). Pillowed andesites having chert cusps also occur on N.E. Nesaklumpen (X 68320, Y 3300) lying stratigraphically above porphyritic acid extrusives and separated from these by an exhalite horizon with magnetite and coherent banded jasperoid chert.

Acid extrusive material is present almost universally flows and pyroclastics of quartz porphyry lithology. The main outcrop of the porphyritic extrusive rocks lies in a belt from Nesaklumpen to S. Olatjonna. This belt is believed to be the stratigraphic equivalent of the important unit of porphyritic intrusives and extrusives which occur in the Blahammertjonna tract.

The porphyritic rocks are universally characterised by the presence of glassy, rounded (magmatically corroded) or fragmented quartz phenocrysts from less than 1mm up to 4mm in diameter. The precise distinction between those quartz porphyritic eruptives of intrusive and those of extrusive character is not always easily made in the field. Detailed mapping however reveals the shallowly cross cutting relationships of dyke and sill-like bodies. The extrusive porphyritic facies have distinctly less massive internal fabrics and display a weakly developed foliation. Pyrite occurs in both extrusive and intrusive facies of the quartz porphyries as disseminations and locally, sulphidic skjerps provide stratigraphic criteria for the extrusive origin of certain of the quartz porphyry horizons. (Notably in the S. and S.W. Olatjonna area.) Thin flows of feldspar phyric dacite with coarse quartz-filled vesicles also occur locally.

(iii) Pillow breccias and pyroclastics: Pillow breccias are restricted in occurrence to the area S. and S.W. of Olatjonna where they are located at the highest stratigraphic level of the underlying carbonate-rich pillow unit in association with acid to intermediate pyroclastic facies. They are assumed to be stratigraphically equivalent to those occurring on Grubefjell and they resemble them strongly. No sulphidic mineralisation has been observed however in this lithology in Area (c).

Pyroclastic facies of intermediate to acid composition occur in substantial volumes within the area, varying from agglomerates with dacitic clasts in a quartz-chlorite-feldspar matrix to fine dacitic (keratophryic) tuffs with quartz-eye phenocrysts. The various pyroclastic facies together with the porphyry bodies help to compose the major horizon of acid eruptives which occurs in area (c). This horizon shows a complex pattern of structural and stratigraphic intercalation with the overlying and underlying basaltic to intermediate lava units.

(iv) Intrusives: Intrusive facies in Area (c) are dominantly acid phaneritic or quartz porphyritic rocks. Gabbroic intrusives occur only as intermittent sheets or tectonised lenses in the lava succession.

The numerous minor sill-like intrusives of acid composition which cut the volcanic stratigraphy at low angles appear to have been supplied by magma from the quartz porphyry body outcropping immediately to the north of Langtjonna and Olatjonna. It is worth noting that the coarser quartz porphyries of the N. Olatjonna-Langtjonna area do not contain significant amounts of pyrite as impregnation while pervasive pyritic dissemination is common within the quartz porphyries in the belt of acid extrusives and related intrusives in the belt immediately to the S. of Olatjonna.

(v) Exhalative mineralisation: Exhalative mineralisation is not well developed in the area under consideration although horizons of pyritic impregnation are clearly associated with the quartz porphyry eruptives to the south and west of Olatjonna. The volume of quartz porphyritic intrusive material in this area is conspicuous and it would appear that much of the potential mineralisation may be trapped as disseminations within a large volume of hypabyssal intrusive dykes and sills of quartz porphyry.

There is some evidence that acid-eruptive activity in this section is represented within the eruptive sequence by several episodes. The first was evidently a phase of intrusion leading to dacitic and pyroclastic extrusive activity within the lava sequence; these units were cut by later quartz porphyry dykes which also cut the polymict conglomerate and the Limingen sediments as demonstrated by the relationships observed in the sequence between Havdalsvatn and south of Stamnestjonne. The history of acid intrusive activity was therefore extended and occured in at least two chronologically distinct periods.

The results of a preliminary ground magnetometer survey:
A Geometrics proton magnetometer was used in the S. Olatjonna and Stamnestjonna areas with the initial intention of examining the anomaly signatures of various exhalite horizons. During the first traverse across the volcanics

and into the conglomerates made from S. of Olatjonna to the S.E. of Stamnestjonna two apparently significant anomalies were detected.

(1) In the traverse across the S. Olatjonna acid horizons.

(2) In the tract east of Stamnestjonna.

This first anomaly was investigated further by making six traverses with closely spaced data points. This defined a complex anomaly paralleling the local f_1 trend. Because of concealment of bedrock geology by drift, further traverses were carried out over well developed and exposed magnetite-pyrite bearing exhalite horizons to the north and north east of Store Skorovatn.

The reconnaissance traverse over the section from S. Olatjonna to East Stamnestjonna had a length of 2.7 km and measurements were made at intervals of 25 m. This traverse defined broad anomalies in the immediate areas of S. Olatjonna and E. Stamnestjonna of 52,200 to 53,700 gammas. An estimation of the normal background variation within the sequence was made on the basis of this traverse and assessed as 51,200-51,600 gammas.

A second traverse of 800 m length was carried over the E. Stamnestjonna tract. This was also based on a measurement interval of 25 m and lay parallel and to the northeast of the longer traverse. This confirmed the presence of several second order anomalies within the Stamnestjonna area.

The preliminary survey over the S. Olatjonna acid horizons consisted of six traverses spaced at 100 m intervals. Measurements were made at 5 m intervals. The surveyed area is one lacking in detailed relief and has intermittent tree cover and there is only sparse exposure. Accordingly a careful note was made of the geological exposure, when present, at each magnetometer reading point on the traverse. This gave a reasonable control over outcrop pattern in the traversed area.

The magnetometric profiles confirmed the broadly anomalous character of the area and showed that the zone of anomaly is composed of several individual broad and high magnitude anomalies. The nature of the anomaly surface is not easy to define by correlation between profiles at the 100 m interval used and for further investigations a 50 m interval between traverses would be preferable. It would also be necessary to correct the readings for the diurnal variation in the Earth's field.

Because the zone of the principal anomalies occurs in a poorly exposed area it is difficult to provide a clear geological explanation for the high contrasts in the magnetic profiles. It is evident, however, that the areas of interest lie in the vicinity of the contacts of an important unit of sulphide impregnated quartz porphyry. The most significant anomalous track lies between traverses O-III to the north of the Olatjonna high angle, low displacement fracture. The broad anomaly signature defined most clearly in traverse I evidently has a relatively deep source when comparison is made with the abrupt profile produced by the magnetite-rich mineralisation in the exhalite horizon to the northeast of Store Skorovatn. At the best the depth of origin of the anomaly could be estimated as being between 10 to 40 m.

For the present considerable work remains to be done in investigating the types of magnetic anomalies which can occur in volcanostratigraphy of the Gjersvik Group. It is probably worthwhile to run a number of control traverses over well-exposed prophyry contacts, gabbroic sheets and units of magnetite-rich lavas as well as other horizons of exhalative mineralisation.

Structure

(i) First deformation (f_1): The orientation of the isoclinal axes of f_1 generation varies from N.E.-S.W. to N.N.E.-S.S.W. with axial planes of shallow dip (15-20^{o}) to the southeast quadrant. The form and scale of the major isoclinal folds can be reconstructed in section on the basis of inferred repetition of the stratigraphy. Complete isclinal structures on the intermediate to small scale are preserved only locally because of the flattened and disjunct style of deformation. The best examples are seen in the slopes to the E.N.E. of Nesaklumpen where trondhjemite quartz porphyry dykes have preserved good isoclinal morphology in the accommodating lava sequences (X , Y).

(ii) Second deformation (f_2): Post schistosity folding of open style such as occurs in the Cevoker and Gruvetjonna areas is restricted to the area of Nesaklumpen which lies within the area of f_2 dome and basin folding with rectilinear axial pattern which is characteristic of the tract extending N.E.-S.W. through the Skorovas region from N. Cevoker to N.E. Nesaklumpen. In the Nesaklumpen area the folding is quite gentle with an axial trend of approximately N-S to N.N.E.-S.S.W. but because of relief effects there is a marked influence on outcrop pattern which, in this area, is quite complex.

(iii) Fractures: The most obvious lineaments in this area are high-angle fractures of low individual displacement. There are also f_1 congruent planes of disjunction which parallel the structural grain (N.N.E.-S.S.W.) in this area and can be followed over extended strike lengths. The strongest strike-oblique fracture in the region is the prominent Langtjonna-Ostre Overste Nesavatn fracture which has been responsible for post-schistosity folding in its immediate vicinity. Despite the deformed state of the rocks in the margins of this high-angle feature, the displacement has probably not been large (maximum magnitude of tens of metres).