Bergvesenet

Postboks 3021, 7002 Trondheim

Rapportarkivet

Bergvesenet rapport nr	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering
BV 1738			Trondheim	
Kommer fra ..arkiv	**Ekstern rapport nr**	**Oversendt fra**	**Fortrolig pga**	**Fortrolig fra dato:**

Tittel

The geology of eastern Skorovasklumpen
A concise field report

Forfatter	Dato	Bedrift
Flitton, Stephen	1972	ELKEM A/S - Skorovas Gruber

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Namsskogan	Nord-Trøndelag	Trondheimske		

Fagområde	Dokument type	Forekomster
Geologi		Skorovasklumpen
Råstofftype	**Emneord**	
Malm/metall		

Sammendrag

T H E   G E O L O G Y   O F
E A S T E R N   S K O R O V A S K L U M P E N

A CONCISE FIELD REPORT

BY

STEPHEN FLITTON

CONTENTS

PREFACE

This report was written after eight weeks field mapping in the Skorovas area, in the county of North Trondelag, Norway. It is submitted as part of the requirements of the B.Sc. Honours Geology Degree course of the University of London.

INTRODUCTION

The base-metal bearing pyrite deposit of Skorovas, is associated with Caledonian rocks of the greenschist facies of regional metamorphism. An extensive geochemical and geophysical exploration programme had been instigated to cover an area within an eight to ten mile radius of the ore body, with the prospect of locating similar masses of ore. Aerial geophysical surveys had revealed marked negative anomalies in an area immediately to the north of the village of Skorovas and, in the light of these anomalies, the mining company, Elkem Skorovas Gruber, proposed a detailed lithological and structural mapping project of this region. This is a field report of part of the project, which was undertaken in association with Messrs. Allan Burch, Volker Hirsinger and Quentin Palmer, under the supervision of Dr. Christopher Halls, (all of Imperial College, London).

The mapping area is dominated by the 990 metre summit of Skorovasklumpen (klumpen meaning hill or "clump"), and a seemingly endless succession of depressions and cold fronts sweeping in from the Atlantic bringing long periods of low cloud and heavy rain.

Rock exposure is almost 100% on the summit, and can be described as moderately good for most of the area. The only problems arise around the 550 to 600 metre contours, where a shoulder of flat-lying land on the southern and eastern flanks of the "klumpen" is blanketed in marsh, and in a few mapping localities below the tree line. Exposure can be considerably improved by peeling back the turf cover to reveal excellent, glacially scoured surfaces.

The hill is disected by a narrow gorge named "Stygdalen"- "The Ugly Valley" which provides some excellent sections through the greenstones.

Somewhat unfortunately, the northern flank of Skorovasklumpen has been partly flooded as part of the Tunsjöflyene Hydro-electric scheme.

PREVIOUS WORK

The area to the north of the mine has never been geologically mapped on a scale of 1 : 5000. It is included on the Tromse sheet published by the Norges Geologiske Undersökelse to the scale of 1 : 100,000. This regional map was constructed by the Norwegian state geologist Steiner Foslie in the 1930's. No sheet memoir has ever been published although Foslie did write a paper on the ore body itself (published 1939). Colour photographs of Foslie's original field maps were examined and these revealed far more of his field interpretation than the published sheet. He interpreted the upper flanks of Skorovasklumpen as an intrusive gabbroic body within finer grained greenstones.

In 1960 Tore Gjelsvik prepared a paper on the Skorovas deposit for the XXI International Congress in which he summarises some of the ideas and conclusions up to that date. To quote Gjelsvik, "The greenstone formation at Skorovas can be subdivided into three parts:

1. At the base, banded, limy greenschists of clearly sedimentary origin, containing blue quartzites with thin Vasskis (sedimentary pyrite) bands.

2. Alternating greenstone flows and pyroclastics, some of which are keratophyres.

3. The upper part, within which the deposits are situated, mainly spilitic flows (amygdales commonly noted) and some thin intercalated keratophyre flows.

A band of Tronhjemite separates parts 1 and 2 and forms an extensive contact zone of hybride greenstones. <u>The top of the mountain north of the mining village consists of gabbro containing a small deposit of nickeliferous pyrrhotite</u>."

"In the sedimentary greenschists small, isoclinal folding is observed, but generally the series appears only to be slightly folded and a flat dip towards the east prevails in the mine area."

"Wall rock alteration is distinct and includes chloritisation, sericitisation, silicification, carbonatisation, and talc formation."

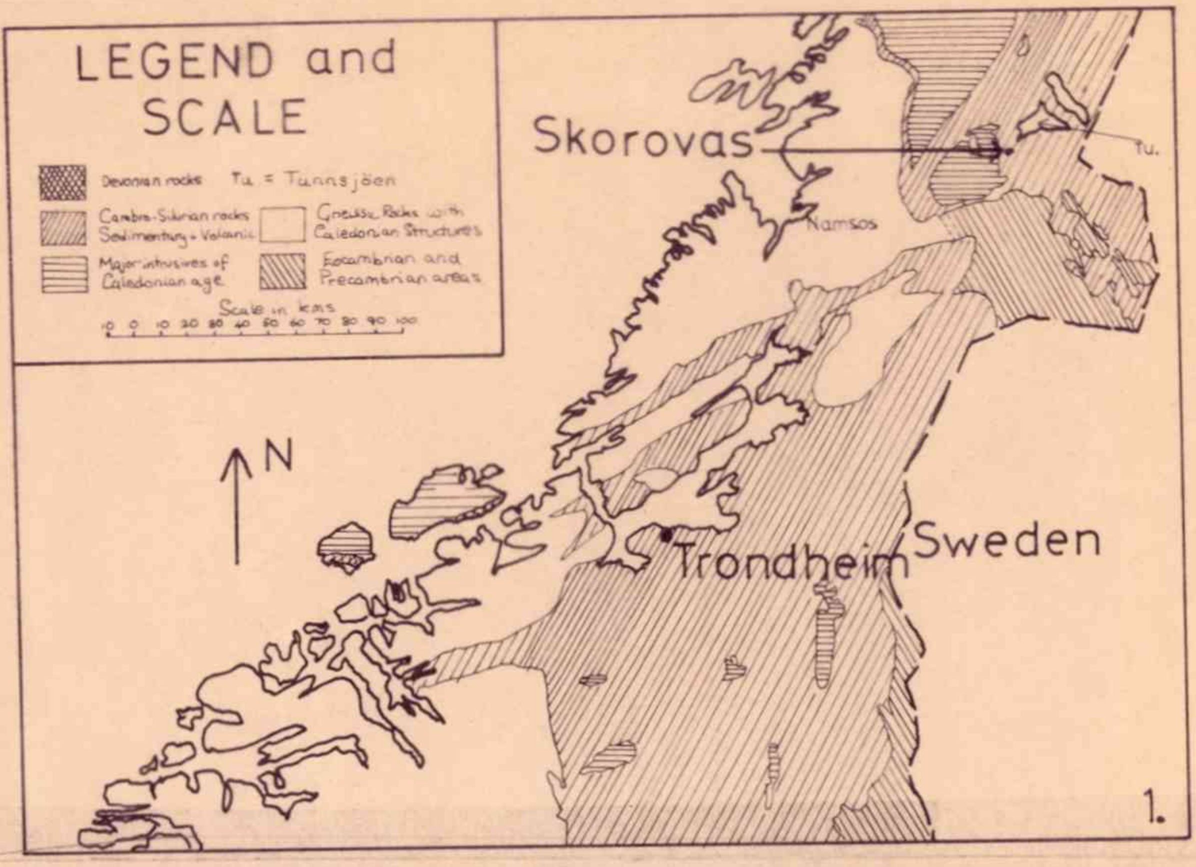
"S. Foslie (1939), who made the first detailed investigation of the deposit, considers it to be of epigenetic (hydrothermal metasomatic), whereas Chr. Oftedahl (1958) recently suggested a syngenetic origin (volcanic exhalative). The genetic question is not definitely settled, although the present author is in favour of an epigenetic origin, although he finds it premature to state whether it is formed by replacement by magmatic emanations, or by remobilisation of syngenetic deposits during the subsequent orogenesis."

Gjelsvik's summary appears to cover most of the important points about the area.

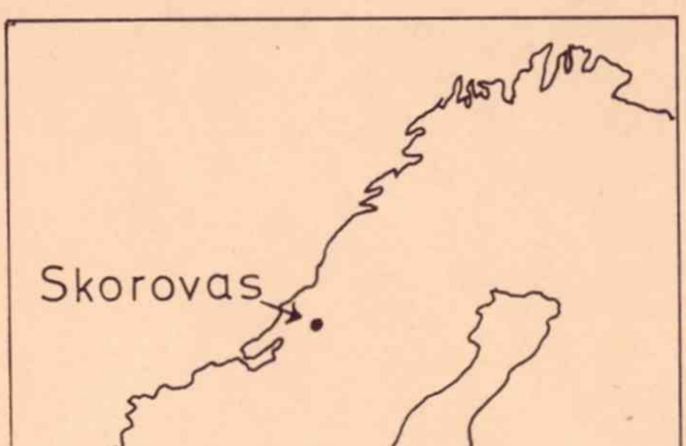
The works of Dr. E.H. Rutter et. al. on the geology of the Løkken areas has also been noted, since Gjelsvik considers the Skorovas greenstones to belong to the same group (the Støren group) as those at Løkken. A close similarity in lithologies appears to occur, but the abundant pillow structures of Løkken have no equivalents at Skorovas. A similar comparison may be made with the greenstone units of the Mostadmarka and Selbustrand area of Trondelag descibed by T. Torske, (1965).

TECHNIQUES

Aerial photographs covering the entire mapping area and a 1 : 10000 scale map of the southern half of this area were made available by Elkem Skorovas Gruber. Initially, structural information was plotted on the photographs using transparent overlays and a data point system. During this period, a 1:5000 scale pantographic enlargement of the map was constructed by members of the field party, and was then utilised for direct data recording, as this greatly facilitated interpretation in the field. The northern flank of the hill had to be mapped on to photographs, but this data was systematically transferred to a 1 : 5000 photomosaic, and eventually on to a similarly scaled extension of the map, constructed from the mosaic. All structural data has been recorded as lower hemisphere projections on to an equal area net.



GEOLOGICAL SETTING of SKOROVAS



LITHOLOGIES

Introduction

The following mapable lithological types have been identified in the field. (The criteria of identification, field descriptions, and suggested interpretations are cited after this introduction).

1. Schistose greenstones
2. Massive greenstones and metagabbros
3. A "transition facies" between the schistose and massive types
4. Quartz keratophyres
5. Trondhjemite
6. Pyrite and pyrrhotite
7. Fault breccias

In general terms, the massive greenstones overlie the schistose, this juxtaposition being obviously of structural origin at some localities, and probably stratigraphic at others. Foslie mapped the massive rocks as intrusive gabbros, but detailed inspection has revealed these to be of more volcanic origin, possibly representing a pile of lavas and sills and ash beds, cross-cut by fine grained dykes. Small intrusive bodies of gabbro or metagabbro have been identified within the pile. The pyrrhotite at grid reference (043045) appears to be associated with one of these metagabbro bodies.

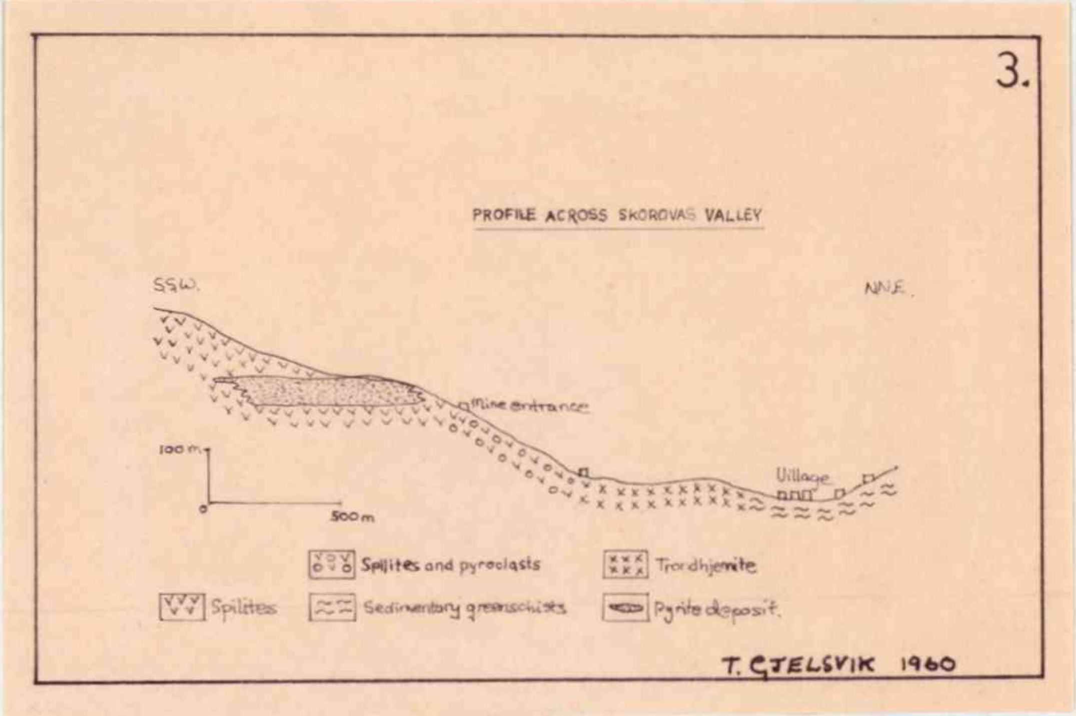
Linear bodies of the keratophyre are more or less confined to the massive greenstones, their numbers and volume apparently increasing towards the summit of Skorovasklumpen. These are believed to represent acid lavas by the author.

The trondhjemite is locally variable in composition. In places it has an obviously intrusive relationship with the massive greenstones, and in others a more uncertain relationship with the schistose rocks.

Pyrite and pyrrhotite occur as bodies of various dimensions within the schistose and massive rocks.

FIGURE 3.

Profile across the Skorovas valley by T. Gjelsvik (1960) showing the relationship of the ore body to the greenstones and trondhjemite.



Numerous fault breccias can be observed, especially along dislocations in the more massive rocks. These can attain a thickness of one metre or more

1. THE SCHISTOSE GREENSTONES.

The schistose greenstones can be identified in the field by the presence of a usually well-developed penetrative schistosity in a fine-grained chloritic rock. Laminae of felsic material and calcareous material can be frequently observed, these having a thickness in the order of 1 centimetre or less, and oriented almost invariably parallel to the schistosity.

Fresh exposures of the schists, occurring in recently blasted pylon sockets to the north of the north-eastern corner of Store Skorovatn, reveal consistent banding of felsic material and chloritic material which has been folded and is cross-cut by a weak penetrative schistosity. A more detailed discussion and description of this is given later, the following description and discussion being concerned with those schists in which the laminae are oriented parallel to the schistosity.

Frequently the laminae are picked out by preferential weathering of the calcereous component of the calc-rich schists or the chloritic component of the acid rich schist. This gives a clearly visible fluted surface. (See photograph 19). The types of laminae may be distinguished by their hardness, the rotten nature of some of the more calcareous rich exposures, and the presence of a lime-loving flora on others.

The purely chloritic schistose rocks usually produce a much smoother, weathered surface.

Horizons dominated by calcareous laminae and others dominated by felsic laminae seem to occur at fairly consistent levels within the schists, and indication of these levels is given on the map.

Close examinations of the calc-rich schists reveals some laminae to be of calcite and others to be of epidote, apparent by its characteristic colour.

Both felsic and calcareous laminae are fairly non-continuous, the maximum length being three to four metres, whilst the majority are about twenty to thirty centimetres.

Numerous thin sections of schistose specimens were inspected. These revealed the following assemblages:

1. Chlorite + quartz + calcite ± epidote
2. Chlorite + Quartz + epidote ± muscovite
3. Chlorite + quartz.

Sections of a wide variety of orientations all show the trace of the alignment of flaky minerals to be parallel to the trace of the penetrative fabric, calculated from hand specimens oriented in the field. Similarly the stringers of calcite, epidote, or quartz are aligned parallel to the schistosity, the latter mineral usually being strained. In all cases the stringers consist of fine-grained anhedral crystal mosaics.

An outcrop of Vasskis facies occurs near the village of Skorovas, consisting of alternating two to three centimetre thick bands of iron sulphides and oxides (black and dark grey in colour), and lighter buff coloured felsic-rich layers. In this, the penetrative schistosity is parallel to the banding, which is generally accepted to be a primary sedimentary structure. (See Photographs 1 and 2)

On Foslie's original map, there is a postulated boundary joining the felsic-schists to the north of the village with an outcrop of so-called sheared trondhjemite to the south-east of the village of Stalvik.(062033) Whilst it is difficult to dispute the sheared trondhjemite origin for the acid schists, detailed mapping suggests that the horizons north of the village are not the same as those represented to the south-east of Stalvik. (See map). The great pausity of exposure along Foslie's postulated line of outcrop, however, makes the more concrete disproval of his tentative idea, impossible.

As previously mentioned, the schistose greenstones near Store Skorovatn are banded, these bands being two to three centimetres in thickness. They are folded (type 1c and 2) and in the field a weak penetrative schistosity cuts across the folds in an orientation more or less parallel to their axial planes. (See section on structures).

In the numerous thin sections made from these rocks, one can observe alternating light-coloured quartz bands, and darker chloritic and epidotic bands on a much finer scale than those observed in the field; that is with a thickness of one to three centimetres. Microfolding is also most evident in these sections (See photomicrograph 1). The finer grains of epidote and chlorite in the darker bands appear not to be folded around the fold hinges, but aligned more or less parallel to the trace of the axial planes of the microfolds. Some coarser grains of the chlorite cut across the banding, but have the same orientation as the finer flakes within the bands. (See figure 3).

Most of the microfolds are of 1c and 2 type (Ramsay 1967), and there is also thin-section evidence of small displacements of the folded bands along the penetrative schistosity. (See figure 4).

The Origin of the Schistose Greenstones

The origin of the schistose rocks is by no means certain. Several authors (for example Gjelsvik) have put forward a sedimentary origin, and cite the occurrence of the Vasskis facies in part of the schistose succession as evidence in support of this. The assumption that the Vasskis is of sedimentary origin seems to be largely based on the regularity and consistency of the iron oxide-sulphide banding. The small outcrop at Skorovas has provided insufficient evidence to cast new light on this matter.

The quartz epidote and chlorite banding in the schistose rocks may be a reflection of the primary banding, but no apparently primary structures can be observed in the fine-grained minerals in thin section. Similarly, the occurrence of the calcareous rich and felsic rich laminae at fairly consistent and laterally traceable horizons within the schists may be a reflection of a primary compositional variation.

No thin sections of Foslie's "sheared trondhemite" from near Stalvik were examined. Several sections of acid schists from outcrops to the north of Skorovas were inspected. They contain no large crystalloblastic feldspars, which suggests they are not of "sheared Trondhemite" origin.

The mineralogy of the schistose series in general suggests that, if they are of sedimentary origin, they represent a series of metapelites, which were calc-rich at certain horizons.

2. THE MASSIVE GREENSTONES AND METAGABBROS

These are broadly composed of three field components: a "fine-grained", a "medium-grained", and a gabbroic component.

The "fine-grained" appears largely structureless in the field. It is usually light to mid grey-green in colour. In thin section, there is typically an ophitic texture, with the feldspars and some quartz set in pleochroic ferromagnesium minerals of extremely fine grain. Some chlorite and disseminated pyrite also occur.

Since most of the massive rocks had been previously mapped, (and, in the author's opinion, misinterpreted) as an intrusive gabbroic body, particular attention was paid to the identification and distributional mapping of rocks with an obviously gabbroic texture, (see lithological map). In these, large crystals of feldspar, and randomly oriented amphiboles are visible. This is supported by thin section inspection which shows the metagabbros to consist of a mosaic of coarse, subhedral feldspar of albitic composition (universal stage) and coarse ragged randomly oriented blue-green amphiboles. Occasionally, some finer needles of what may be later amphibole are developed, usually with a preferred orientation.

In the field, distinction between the metagabbros and "medium-grained" component is not always a simple task. The latter can usually be distinguished by being finer grained than the gabbro, but where crystalloblastic feldspar is abundantly developed, the distinction becomes more difficult.

As a field rule, only those rocks in which both coarse grained amphibole and coarse feldspars occur together were mapped as metagabbros. The application of this rule is borne out by thin section evidence. Some sections of the "medium-grained" rocks have a typically crystalloblastic texture, in which ragged blue-green amphiboles and usually altered feldspars are set in a very "messy", heavily altered, fine-grained groundmass. If this be a relict primary texture, then some of the non gabbroic "medium-grained" massive greenstones may represent porphyritic lavas.

One word of caution should, however, be given. Assuming heavy alteration to affect both "medium-grained" and gabbroic types, it is possible that the feldspars or some of the feldspars in a gabbroic mosaic could be altered to give an apparently fine-grained groundmass, with apparently crystalloblastic feldspar and amphibole. This, of course, would not be representative of a primary texture.

Fortunately, several other volcanic primary textures can be identified within the "medium-grained" types. These include amygdales, commonly infilled with either epidote or feldspar, sometimes showing a radial structure, and having diameters between 3 to 4 mm and 3 to 4 cm. Some in the vicinity of the mine are partly infilled with pyrite. A lithic tuff texture can be distinguished in a small exposure near the pyrhotite showing. (See photomicrograph 2). In the same area, apparently graded beds may be distinguished, the grading being picked out by feldspars. The interfaces between the beds can be regarded as primary planar features (So). Some of the "fine grained" members of the massive greenstones occur as dyke like bodies within the "medium-grained" types.

In one thin section cut across the contact between the "fine" and "medium grained" massive rocks, the randomly oriented laths of feldspar in the fine component become aligned parallel to the contact in its immediate vicinity. This alignment is displaced around a crystalloblast of albite (universal stage). The small proportion of chlorite in the "fine grained" rock seems to increase towards the contact, these flakes showing a similar alignment to the feldspar laths. The exact line of contact is masked by the development of a band of alteration products, which may have formed with an adjacent band of medium grained epidotes. The "medium grained" rock consists of randomly oriented pleochroic blue-green amphiboles some of which may be primary (those with straight boundaries?) and others probably secondary (those with ragged boundaries). Heavily altered feldspars also occur in this rock. The exact significance of the alteration and epidotisation along the contact is not fully understood.

Massive rocks near to the summit at grid reference (017034) are brecciated, the clasts being separated by a very fine grained felsic matrix, which in thin section seems to be composed entirely of an anhedral mosaic of fine grained quartz. One of the clasts can be seen to be discontinously rimmed by epidote. This rim is not evident in the field.

The outcrop is roughly circular in plan and a few off-shoot veins of brecciated material can be traced for distances of 5 to 6 metres.

In these veins, the clasts are compositionally similar to those in the main body, but are much smaller in diameter, the relative average dimensions being 3 to 4 cms and 30 to 40 cms. (see photographs 5 and 6).

Most of the clasts are angular (see photograph 6) and some have undergone tectonic flattening to different degrees. The brecciation may well be a result of the injection of the felsic material.

At another locality on the southern flank of the "klumpen", at grid reference (012039) a "fine grained" massive rock shows a dyke like relationship to the "medium grained" type.

The contact between the two types is not marked by an epidote band.

Another possible primary volcanic texture is suggested by the flattened shard like inclusions in the quartz-keratophyres. In thin section these consist of very fine grained iron stained material, the exact mineralogy of which is difficult to determine.

The exact relation-ship of the "fine-grained", "medium grained" crystalloblastic feldspar bearing, and vesicule bearing types in the field is very difficult to fathom. An indication of their distributions is given on the lithological map; it should be pointed out that this is merely an indication and by no means a comprehensive representation.

The origin of the massive greenstones:

From the field and thin section evidence of the primary textures, it does not seem unreasonable to broadly interpret the massive rocks as a pile of metamorphosed lavas and pyroclastics, intruded by dykes and sills of fine grained dolerites, and apparently irregular bodies of gabbro. The exact spatial relationships of these types is by no means fully understood, and will require intensive mapping on a very large scale before any reasonable conclusions on the matter may be drawn.

3. THE ROCKS OF THE TRANSITION ZONE

This zone is somewhat difficult to delimit (much of it crops out on the marsh covered shoulder of land around the 550 to 600 metre contour), and only tentative boundaries are shown on the lithological map. The zone is identified by the very complex spatial relationship between the schistose and the massive rocks. Within an area of a few square metres, the two types can occur in an irregularly distributed array of exposures, which is impossible to map with any accuracy on a scale of 1:10000. Frequently, the massive rocks occur as pod like inclusions in the schistose rocks and vice versa. Traversing the zone, moving from the schistose rocks on one side to the massive rocks on the other, it is sometimes posible to observe a gradual change from dominantly schistose rocks with inclusions of massive greenstone, to dominantly massive rocks with includions of schistose.

Some of the "medium-grained" rocks from the zone occasionally display a weak fabric which in thin section appears to be created by the preferred orientation of chlorite flakes and needles of secondary amphiboles. This has been considered as a "transition facies", lithologically between the massive an schistose greenstones by the author.

The interpretation of the transition zone is a difficult matter, and more exploration and mapping will be required before an accurate picture may be formulated. From his field observations, the author tentatively suggests that it represents in part, the complex interface between the lower schistose rocks and the upper more massive rocks, cropping out on a more or less horizontal shoulder of land. The picture is probably further complicated by a series of east-west striking high angle faults, which cut across the shoulder and probably give rise to the series of parallel gullies cutting the shoulder in an east-west direction. (see section on structures).

4. THE QUARTZ KERATOPHYRES

The distribution of the quarts keratophyres is largely restricted to the massive greenstones. They form linear bodies within the greenstones, being about 1.5 metrs in width and of variable length, usually in excess of 3 metres. Near to the summit, their volumes and abundance seem to increase, and the linear nature of the bodies becomes less apparent. This latter observation may be attributed to the differences in orientation between the flattish area around the summit and the steep southern flank. There also appear to be more bodies on the southern than on the northern flank.

In the field the rock is white, and is frequently iron stained. Some of the fresher exposures reveal brown streaks which may posibly be primary in origin, and resemble flattened shards in unmetamorphosed acid tuffs.

The bodies usually have a weak fabric, parallel to the long axis of the bodies. In thin section, this fabric seems to be produced by the alignment of chlorite flakes, which form a minor fraction of the mineralogical composition. The main components are quartz and feldspar which form a very fine grained groundmass in which are set large euhedral crystalloblasts of feldspar which are albitic in composition (universal stage). There are also stringers of anhedral mosaics of quartz, these stringers having the same alignment as the chlorite flakes. There are also randomly oriented stringers or veins of calcite. The iron brown streaks seen in the field are too fine grained to determine mineralogically in thin section.

Some of the bodies are clearly folded and faulted (see photographs 26 and 27) the folding probably being related to an early stage of deformation (F1 or F2).

The strike of the linear bodies has a fairly consistent NNW-SSE orientation, although this swings towards an east-west line in the region of grid references (023031) and (029033). Topographically above the pyrrhotite showing, the numerous keratophyres are frequently intimately associated with small pods of pyrite. Graded bedding observed in this area, shows the keratophyres to have the same orientation as the primary planar structures (at least in this vicinity).

5. TRONDHJEMITE.

A sheet of trondhjemite crops out on both the north and south sides of the "klumpen". That to the south is in contact with the schistose rocks, and figure 3 shows its relationship with the rocks around the mine, according to Gjelsvik (1960). The contact with the greenschist is relatively simple. The schists have a more glassy field appearance possibly due to contact metamorphism, and the ferromagnsium mineral content of the trondhjemite increases towards the contact. Large pods of greenschist also occur within the sheet. The southerly contact of the sheet is extremely complex, and in places this appears to be due to faulting.

The northerly sheet has a marked intrusive contact with the massive greenstones, as revealed by excellent stream sections. At the contact, the trondhjemite becomes extremely fine-grained, and often bears xenolithic inclusions of the greenstone. The ferromagnesium mineral content in this sheet seems to be more variable, and this variance is apparently not related to the contact.

The southerly sheet appears to underlie the greenschists, whilst the intrusive contact of the northerly sheet dips very steeply to the north. In thin section, the rock consists of heavily altered feldspars set in an anhedral mosaic of quartz. Some of the euhedral feldspar outlines are just visible through the alteration products, which include epidote. These crystals appear to have formed along the traces of the feldspar cleavage planes.

2V and maximum extinction angle determinations on a universal stage show the present feldspar composition to be andesine - oligoclase.

As previously mentioned, Foslie interpreted the felsic schists near Stalvik (grid reference 062033) as sheared trondhemite. No thin sections from this locality were examined, but the field appearance of these rocks is very similar to that of the felsic schists to the north of Skorovas village. Comment on their possible origins has already been passed. (see page 8).

6. THE OCCURENCE OF IRON - RICH MINERALS.

The mineralisation in the area has been studied in detail by Quentin Palmer, and hence this is not a detailed account, but a few conclusions drawn from field observations. There seem to be about seven modes of occurrences of iron rich minerals in the field.

1. Massive pyrite and chalcopyrite occur as pods within the schists. These have a maximum length of about 2.5 metres, and about 0.5 metres in width. The long axis of the pod is usually aligned to the trace of the schistosity. Similar pods occur quite abundantly in the more massive rocks in the region of grid reference (040045), although here they seem associated with, and parallel to, abundant linear keratophyres. Some of these keratophyres also show a strong rusty weathering product, indicative of disseminated iron - rich materials within their matrices. Most of the pyrite pods weather to a similar rusty colour.

2. Fine-grained disseminated pyrite can be identified within the schistose and massive rocks.

3. Distinct cubes of pyrite similarly occur as disseminations.

4. A pyrrhotite body seems to be associated with the metagabbro at grid reference (044044).

5. As banded Vasskis facies at grid reference (021017) in the village of Skorovas.

6. As post-office red haematite staining along some fault planes.

7. As narrow bands of magnetite (1 - 2cm thick) in the schists near Store Skorovatn. (010021).

7. FAULT BRECCIAS

Most of the major fractures discernable on the aerial photographs seem to be faults with distinct breccias, often in excess of one metre thickness. Two types of breccias can be observed.

The most common is a fine-grained, light green rock with a subvitreous lustre. It is heavily veined with epidote from which the distinctive light green colour-ation is probably derived. Close examination in the field shows it to be heavily altered this masking most of the cataclastic texture (see photographs 7 and 8).

The second type is more myolinitic, and is easily fragmented when hit with a hammer. It weathers to a fluted surface (see photographs 9 and 10).

These faults and breccias are far better developed in the massive than in the schistose rocks, which is probably a function of their relative competencies.

STRUCTURES

Introduction

Three phases of folding may be recognised in the field representing stages in the progressive deformation of the area.

It is difficult to relate structures seen in the schistose rocks to those seen in the massive, but the author is of the opinion that the latest phase is evident only in the massive greenstones whilst the earlier phases are more apparent in the schists. This may be a function of the distribution of strain, and also of competency differences between the schistose and massive types.

The earliest structures (F1) are isoclinal folds, plunging axially at a low angle between east and north east. Their axial planes dip gently northwards.

A penetrative schistosity has developed, more or less parallel to the axial planes of these structures, (S1). This in turn is folded, dominantly by open crenulations, plunging axially to the north east or south west at a wide range of angles (F2). It is possible that much of the mapping area is situated on the southern limb of a major open synform (F2).

A fracture cleavage (S2) is well developed in the more massive rocks. This cross cuts any weak penetrative fabric, which is usually parallel to the penetrative schistosity of the schistose greenstones. It is not possible to relate the development of the fracture cleavage to any major structure.

The cleavage is also folded into large scale gentle flexures near to the summit of the "Klumpen". These flexures have been termed F3 structures.

This identification of structures was carried out in the field by applying the following simple criteria:-

1. F1 structures fold the primary banding in the shists, and these folds are cross- cut by the penetrative schistosity. Where folding of primary structures occurs in the massive rocks, this may also be

mapped as F1. Folding of the linear keratophyre bodies bears a similar designation.

2. F2 structures fold the penetrative schistosity, and the laminae parallel to it in the schistose rocks, and fold the penetrative fabric (where developed) in the massive greenstones.

3. F3 folding affects the fracture cleavage in the massive rocks.

The results of the structural data measurements are plotted on the stereograms in figure 5. In most of these, the data is drawn from the entire area, as numerous other stereographic projections indicate that sub-division of the area is unnecessary to reveal the structural elements.

Some of the results shown in the stereograms, and others obtained from the plots for subareas, are plotted on the map of major structural trends.

FIELD OBSERVATIONS CRITERIA AND CONCLUSION

1. The F1 structures:

In many exposures of the schistose rocks, the laminae created by the compositional variations are mainly parallel to the penetrative fabric. In some localities, however, notably those to be north-east of Store Skorovatn (010021), folded compositional banding shows a marked angular divergence to the weak penetrative schistosity.

These folds are mainly of the types 1c and 2 (Ramsay 1967) have a half wave length of ½ metre or less, are of variable amplitudes, and have axial planes dipping very gently northwards (max dip 10 degrees). Some are more or less isoclinal, others more complicated. (See photograph 11). In the field, the penetrative fabric can be observed to be parallel to the axial plane of these folds. This is supported by thin section evidence, which shows the quartz-epidote chlorite banding to be folded into microfolds identical in style to the larger folds. Although the flaky minerals are extremely fine-grained, it appears from thin sections that the flakes are not folded around the hinges of the microfolds, but are alligned parallel to the trace of the penetrative fabric. There is also sectional evidence that some of the flaky material in the primary bands shows the first stages of redistribution parallel to the schistosity. (See photomicrograph 1).

A few grains of coarser secondary mica appear to cross the banding parallel to the schistosity. In all of the suitably oriented sections, the penetrative fabric can be observed to be parallel to the projected trace of the axial planes of the microfolds.

It would seem, therefore, that at this locality the schistosity is axial plane to the folding of the primary banding (that is S1 is parallel to the axial plane of F1 structures). It would, of course, be desirable to check if this holds true for other outcrops of the schists, but the lack of suitable exposure makes this rather difficult.

Many of the fresh exposures reveal the primary banding to be parallel to the penetrative fabric, and it is possible to postulate large-scale isoclinal F1 folding, with axial planes dipping gently northwards, to account for this and yet to maintain the conclusions drawn from the exposures near Store Skorovatn.

From s and z asymmetries in the primary banding near Store Skorovatn, it is possible to propose a large scale isoclinal F1 fold with a half wavelength of 100 metres, and an axial plane striking approximately east west and dipping gently northwards at about ten degrees. (see schematic section).

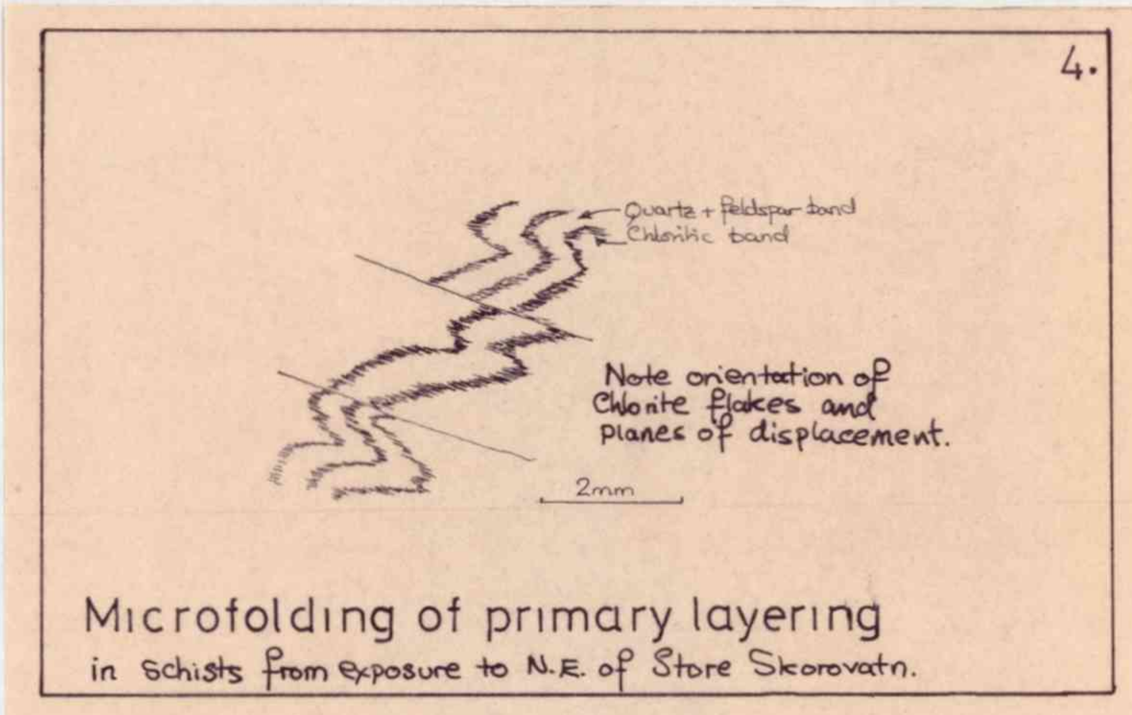
Extensive measurements of S1 were made throughout the schists, and it seems possible to make the generalisation that the planar penetrative fabric dips more steeply moving northwards through the schists. This is probably a function of faulting. The schematic sections show a series of steeply dipping and vertical faults, which seem to cause repetitions in the schist-transition zone boundary. Some dislocations have been located by the occurrence of cataclastic material, and it is possible that a series of east west trending gullies which cross-cut the 550-600 metres shoulder on the southern flank have formed by preferential erosion along pre-existing fault lines. More intensive mapping is required to verify or contradict this, but the lack of exposure imposes limitations.

2. The F2 structures

Two styles of folding can be seen to affect the penetrative schistosity and the laminations parallel to it in the field. The first and by far the commonest style is an open crenulation; the second is a chevron style.

FIGURE 4.

Sketch of microfolding of felsic schist from exposures to the north east of Store Skorovatn. Note the orientation of the flakes in the chloritic bands and the orientation of the planes of displacement.



The open crenulations have an approximate amplitude of 10 - 20 cm and a half - wavelength of 30 - 50 cm. (See photographs 18 and 21) Within the zone delimited on the structural map, these open folds occur parasitically in the limbs of larger scale F2 folds, all of which have been sheared. The shearing makes it impossible to quote any wavelength or amplitude dimensions. (See photographs 19 and 20)

The chevron style of folding occurs at only a handful of isolated localities. They have an amplitude of 20 - 50 cm and a similar range of half - wavelength dimensions. Both chevrons and open crenulations show the same approximate axial trend. (North-east to south-west).

The chevrons at grid reference 029014 occur within a large pod of greenschist apparently enclosed within the southernmost sheet of trondhjemite. (See photograph 17).

Ramsay (1967) proposes a mechanism whereby such folds are formed when compression is parallel to the layering, and when such layers are of consistent thickness and are well - developed. Hence the isolated exposures of chevron folds are tentatively suggested to have formed only where the axes of the strain ellipse were suitably oriented, and where the laminae parallel to the penetrative schistosity, were well - developed and of consistent thickness.

One exposure of kink bands was observed (see photograph 16) and a similar mechanism of formation has been proposed for these.

To the east-north-east of the Church at Skorovas, a single small exposure shows two separate styles of folding with two different axial directions affecting the penetrative schistosity. (See photograph 21). One style is a very open gentle crenulation and has an axial direction plunging to the north east, in common with the majority of F2 folds in the mapping area. The other is a much tighter fold style which plunges axially to the north-north-west. This is sufficiently well developed to impart a weak crenulation cleavage at this locality. (See photograph) This is the only example of crenulation cleavage seen in the mapping area.

It would be foolish to draw any conclusions from the structures seen in this single small exposure, but one must bear it in mind that the crenulation cleavage is approximately parallel to the fracture cleavage developed in the more massive rocks.

Poles to the planes of the tectonically flattened clasts in the injection breccia are plotted on figure 6. Once again to draw too many conclusions from such a small exposure would be unwise, but the orientation of the planes of flattening does suggest the tectonism may be related to the earlier phases of deformation. (The planes of flattening may be parallel to planes containing F1 or F2 axial directions).

In the vicinity of the fault plane at grid reference (013031), F2 axial directions are highly divergent. The measurements made here were mainly on a folding of a weak penetrative schistosity in the more massive greenstones. A fracture cleavage (S2) is also developed in the rocks (See appropriate section), and this obviously cuts across the penetrative fabric. The fracture cleavage is also folded, and hence one may reason that the penetrative fabric has been folded during at least two different phases of the progressive deformation of the area. It is also possible that some of the folding of the penetrative schistosity is related to the fault movement, not only along the plane of the major fault in the area, but also along numerous minor fault lines, only a few of which have been accurately mapped. It is therefore hardly surprising that the F2 axial directions "box the compass", and it is obvious that a far more detailed analysis of this area will be needed prior to the formulation of a more accurate picture.

3. The fracture cleavage and F3 structures.

A fracture cleavage is only developed in the massive greenstone facies rocks, and not in the greenschists. Its relationship to stuctures in the more schistose rocks is by no means clear. Where a weak penetrative fabric is developed in the more massive rocks, the fracture cleavage clearly cuts across and therefore postdates it. This penetrative fabric is on the majority of exposures parallel to the penetrative schistos-ity of the schistose rocks. It therefore does not seem unreasonable to suggest that the fracture cleavage is post S1, and PURELY ON THIS BASIS, it has been termed S2. It should be emphasised though, that this in no way implies a relationship to F2 structures.

The exclusion of the fracture cleavage from the schists is probably a function of the behaviour of two rock types of different competencies (that is more competent massive and the less competent schistose rocks), during the progressive deformation.

The fracture cleavage is generally steeply dipping and strikes roughly south-south-east to north-north-west. It is certainly not a penetrative fabric, the planes being spaced at intervals usually in excess of 30 cm.

Folding of the cleavage it is not always immediately obvious, and on large expanses of the southern flank of the "Klumpen", the planes have a very consistent orientation, and are not folded. Small scale flexures of the cleavage can be seen at grid reference (011036).

These are of very low amplitude (10 to 20 cm), and have a wave-length of less than 1 metre. Near the summit, of the "Klumpen", however, very large-scale flexures may be seen (grid reference 01104). These have an amplitude of only a few metres, but have a half wavelength of 50 - 100 metres. The axial directions of these major flexures are quite consistent, and plunge a few degrees (usually less than 10) to the north-north-west or south-south-east.

Near to the summit, erosion has picked out the flexures into corrie-like formations.

4. The Faulting

The outcrop of the more massive rocks is dissected by a highly complex array of faults, of which only a mere outline is shown on the map.

The faults may well be late stage structures since they displace the fracture cleavage and the minor F3 folds, and no folding of the fault planes was observed.

From the measurements made, it is rather difficult to draw any conclusions as to the general orientation of the fault planes. It appears that much of the southern flank of the "Klumpen" is cut by high angle or vertical faults striking approximately north-south. Many of these are marked by thin zones of breccia.

The possibility of high angle faults striking east-west across the shoulder of land at the 550 to 660 metre contour level has already been discussed.

Extremely detailed mapping in the north-eastern corner of the mapping area revealed a highly complex system of faults disrupting the outcrop of the greenstone - trondhjemite contact. One important point to note in this respect is that the contact is not displaced across Stygdalen.

The exact nature of the feature picked out to form this gorge is by no means certain. In the region of grid reference (020041) the valley broadens somewhat, and the steep cliff faces (15 to 20 metres high) on either side at this location seem to be fault controlled. Two faults marked by distinct breccias run normal to the trend of Stygdalen, but do not continue across it. They, in fact, terminate against the northern and southern walls of the gorge, in the regions of grid references 020040 and 018039. Their attitudes suggest that they may have been the same fault displaced by dislocations parallel to Stygdalen.

Careful mapping within this section of the valley shows there to be a series of more or less parallel faults, having the same trend as Stygdalen. Most are marked by distinct breccias and are of high angles of dip.

The very distinct fault at grid reference (010033) obviously does not continue across the gorge.

On the aerial photograph of the area to the west of the mapping area (the area mapped by Messers Hirsinger and Burch), Stygdalen can be seen to be parallel to a very well-developed fracture cleavage in the layered gabbro body.

o

More detailed examination is obviously needed, and, at the present stage, it is probably best to consider the feature as a major fracture, along parts of which faulting and displacement have occurred.

As far as the mapping area covered by the author is concerned, probably the most significant faults are low angle structures dipping at 40 to 50 degrees. On the southern flank, one of these faults begins at grid reference (010033) and can be traced with a high degree of certainty as far east as grid reference (050033).

At grid reference (028028) this fault carries the massive greenstones over the schistose rocks, and the escarpment to the east of this reference appears to be fault controlled. Rods of quartz on the plane beneath the fault breccia at (028028) plunge very gently to the east-north-east. No "slickenside" effect could be detected in this rodding - this would have provided a useful indication as to the two fault walls' relative movements.

The displacement of the fine-grained dyke in the foot wall rocks of a minor high angle fault at grid reference (013038) suggest that this is a reversed fault.

By far the most conclusive evidence as to the relative fault movements is the displacement of the greenstone - trondhjemite contact at grid reference (016052). Several fine stream sections along the north flank of the "klumpen" show the contact to dip steeply northwards. Hence the southwards displacement of the contact in the foot wall indicates that this is the relatively downthrown side. The 40 degrees eastwards dip of the fault plane means that this may be termed a low angle fault showing reversed movement.

This fault can be traced across the ridge to the east of the summit, and it apparently terminates in Stygdalen. Its influence on other contacts and structures is difficult to determine.

Structural Conclusions

To summarise the section on structures, it should be pointed out that although three phases of folding have been identified, no really large-scale structures have been mapped in the area covered by the author (in conjunction with Quentin Palmer).

This is probably due to the size of the area, and the limited number of lithological types.

The maximum size of identified structures is about 100 metres half wavelength. This applies to the large-scale F3 flexures near to the summit, and the postulated F1 structure near to Store Skorovatn.

Major structures have been identified to the west of the mapping area in the territory covered by Volker Hirsinger and Allan Burch. A high degree of correspondence can be noted between the structures identified in the two areas, bearing in mind that the early folds in the western area have been identified as folding primary banding and penetrative schistosity, and hence correspond to the F1 and F2 structures in the author's area. Similarly the late folds of the western area correspond to the F3 flexures in the author's territory.

Some of the structures in the western area can be relates to the layered gabbro and granite bodies, and the author advises reference to the report compiled by Volker Hirsinger. It is possible that much of the structural data recorded in the eastern area show more consistent trends and orientations due to the absence of such bodies in the former.

Towards the north of the western mapping area, cropping out north of the "klumpen", schistose greenstones lithologically similar to the schists in the south, have their penetrative schistosities dipping towards the south. This could be interpreted as a major synformal structure, presumably related to the F2 folding in that it is the penetrative fabric which changes orientation. The trend of the trace of the axial plane of this synform whould be north east to south west (approx).

If the interpretation cited above be correct, then the massive greenstones occur more or less in the core of the synform, and the schists to the south on its southern limb. This would account for much of the authors area in terms of a major structure.

The joint plane data recorded on stereogram K shows a fairly random distribution of points and it would not be wise to try to relate the distribution to any major structure.

STEREOGRAMS

The following stereograms are all equal area lower hemisphere projections.

Stereogram A. (44 points) F1 axial directions from the entire area.

Stereogram B. (105 points) F2 axial directions from the entire mapping area.

Stereogram C. (16 points) F3 axial directions from the major structures in the north west of the mapping area, near to the summit of the "klumpen".

Stereogram D. (19 points) Poles to bedding and primary banding planes (So) from the entire area.

Stereogram E. (187)points) Poles to planes of penetrative schistosity (S1) from the entire area.

Stereogram F. (171 points) Poles to planes of fracture cleavage (S2) from the entire mapping area.

Stereogram G. (41 points) These two stereograms demonstrate the

Stereogram H. (43 points) increase in the angle of dip of the planes of the penetrative schistosity moving northwards. The data for G is taken from north of the zone of shearing of F2 folds (see structural map), and that for H from the zone of shearing and exposures to the south of the zone.

Stereogram J. (8 points) Poles to planes of flattening in the tectonised injection breccia. The orientation suggests that the tectonism is related to one of the earlier stages of folding

Stereogram K. (183 points) Poles to joint planes from the entire mapping area.

figure 5

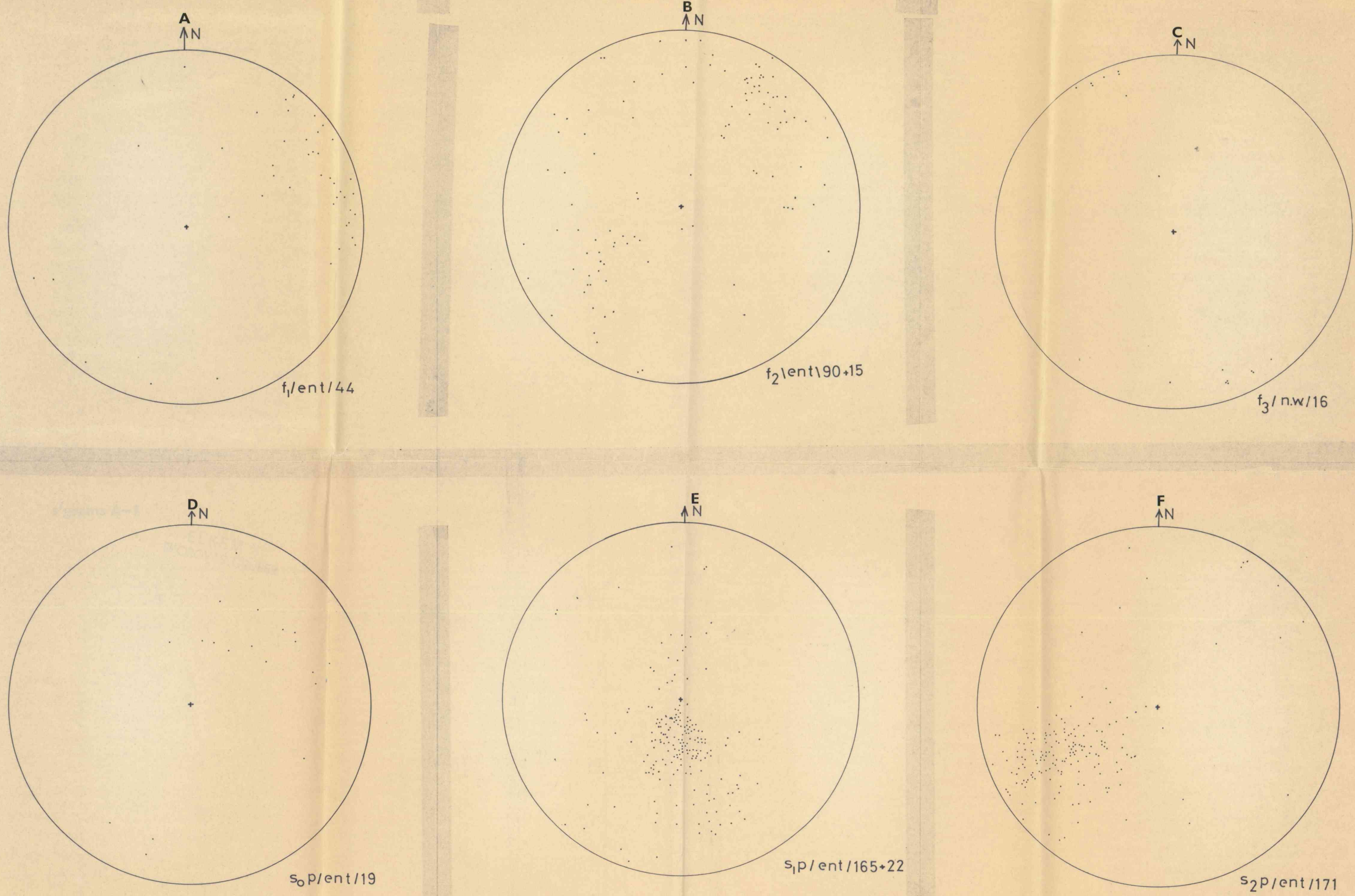
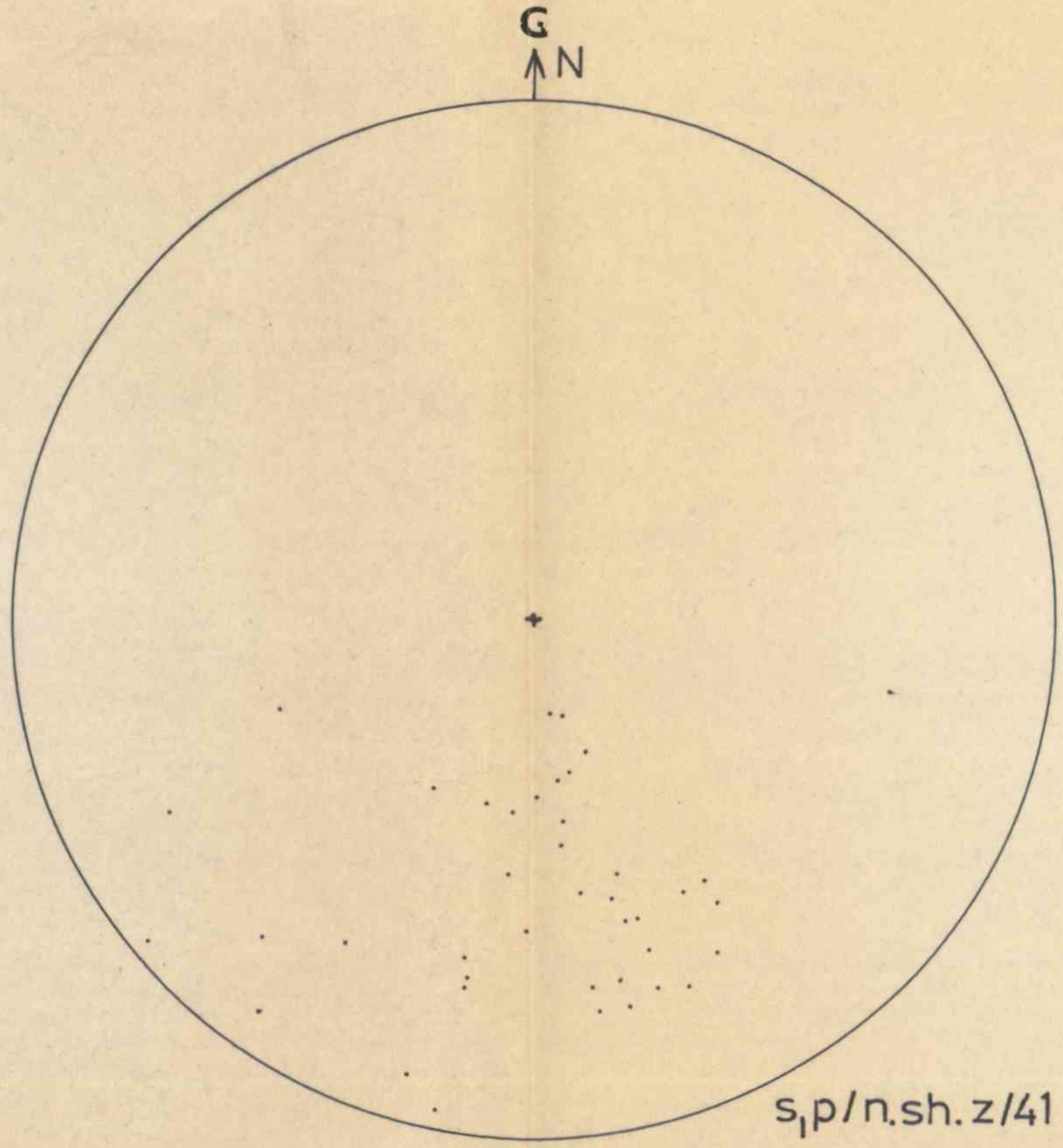
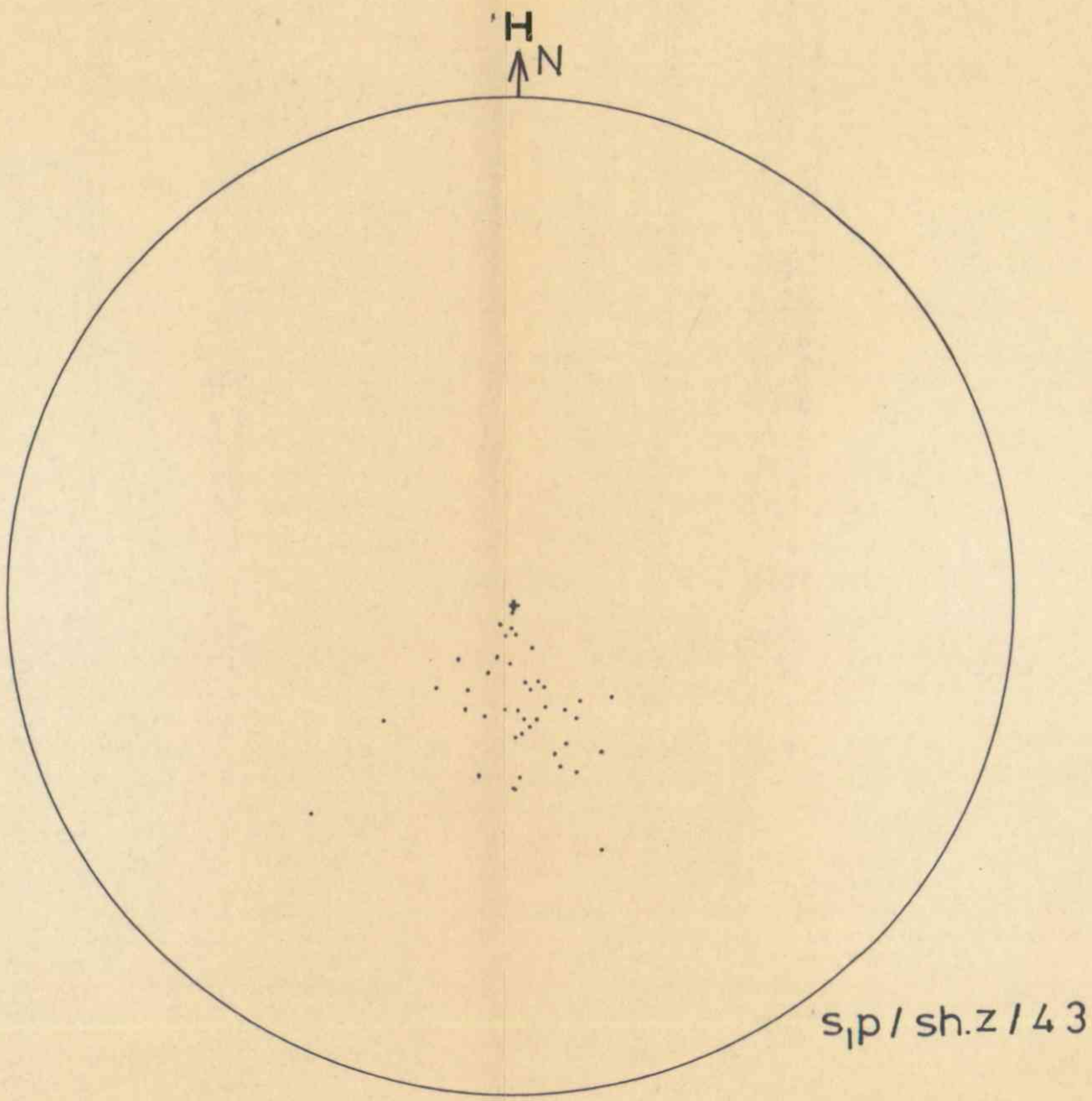

A
N
f_1/ent/44
B
N
f_2\ent\90+15
C
N
f_3/ n.w/16
D
N
s_op/ent/19
E
N
s_1p/ent/165+22
F
N
s_2p/ent/171

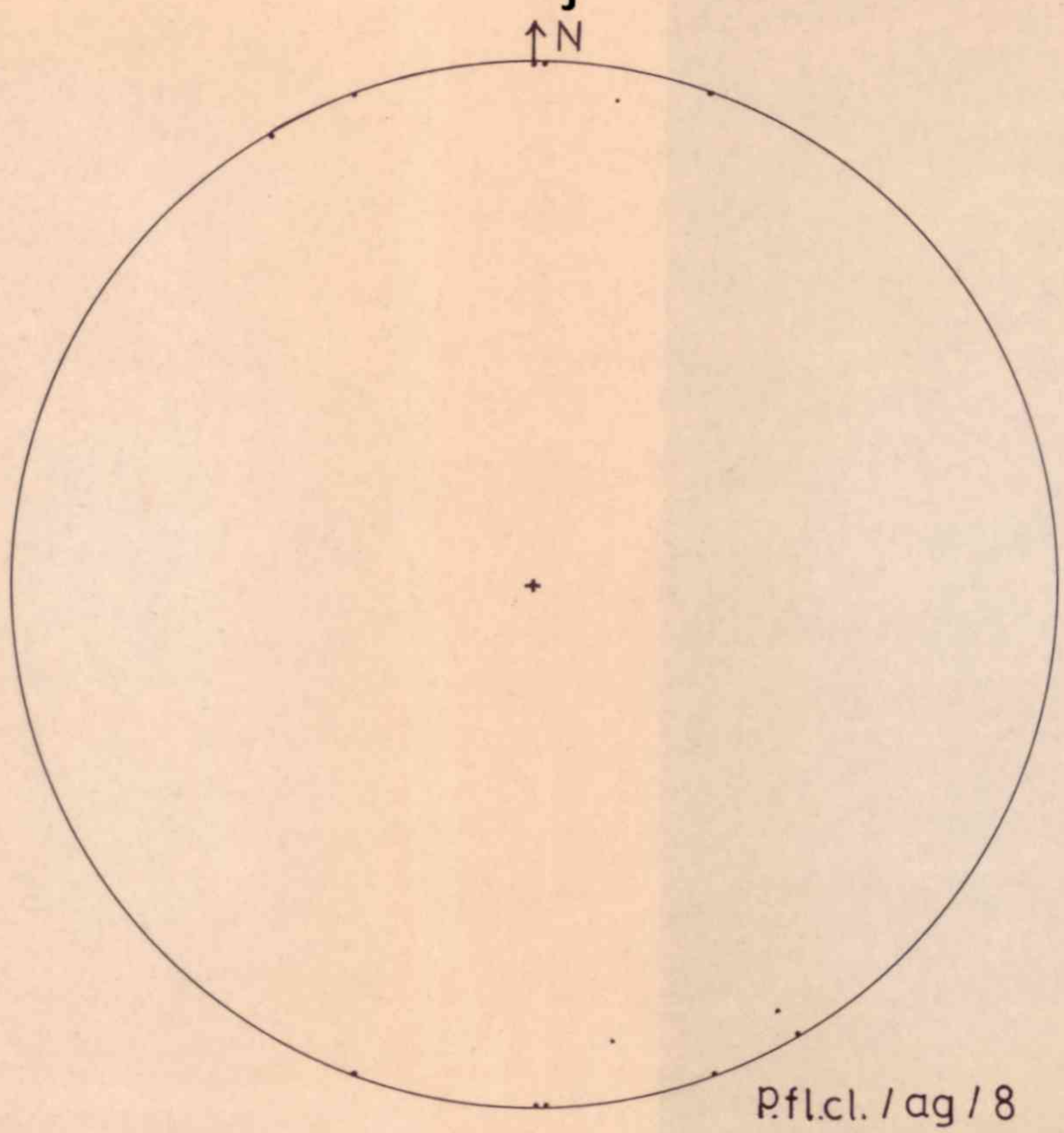
figure 6





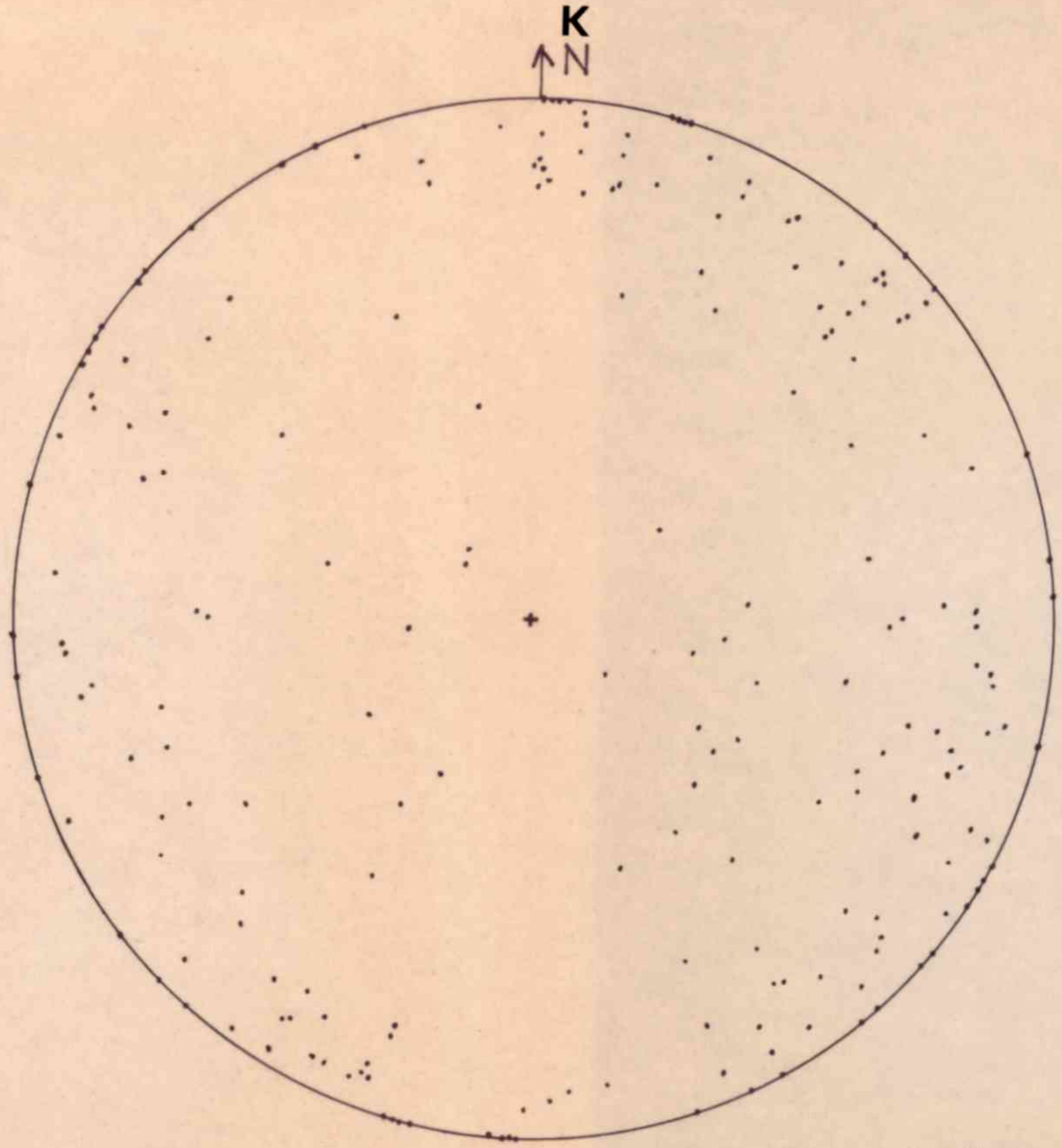
s'grams G & H

figure 7



s'gram J

figure 8



s'gram K

METAMORPHIC GRADE AND FACIES

From the mineralogical assemblages observed in thin section, the rocks in the mapping area fall within the quartz-albite-muscovite-chlorite subfacies of the Barrovian-type greenschist facies. (Winkler 1967).

A single small crystal of a dark rust-brown phyllosilicate was observed in one thin section of the massive greenstones. The size of the crystal prohibits identification under the microscope. Stilpnomelane has been identified in some thin sections of the keratophyres by Quentin Palmer.

According to Winkler (1967) the exclusion of the blue-green amphiboles from the more schistose rocks, and their presence in the massive rocks, is indicative of a higher mole fraction of carbon dioxide in the former during recrystallisation.

RECRYSTALLISATION AND TECTONISM

Only a few tentative conclusions may be drawn from the field and thin section observations.

In the schistose rocks, the recrystallisation to form flaky chlorite and muscovite seems to be syn- or post- F1 since they do not appear to be bent around the F1 fold hinges. Since it is this alignment which imparts the penetrative fabric in the schists, the recrystallisation must be considered as pre-F2, by definition.

Most of the amphiboles in the more massive rocks show random orientation, and it is difficult to relate the few exceptions to the tectonic scheme. In many cases the weak fabric developed is parallel to the penetrative schistosity in the schists. This weak fabric appears to be imparted by the alignment of very small chlorite flakes and amphibole needles, and on this evidence one may tentatively suggest that the recrystallisation bringing about their formation is syn- or post-F1 and pre-F2.

DESCRIPTION OF CROSS SECTION

The line of the section is indicated on the lithological map. It should be pointed out that the line of section is not straight and this should be borne in mind when considering the orientations shown on the section.

At the southern end of the section (to the north east of Store Skorovatn) chloritic schistose greenstones are exposed. Some are calc rich and others felsic rich. Blast holes to house electricity cable poles provide excellent fresh sections, showing the schists to be isoclinally folded, with the fold axial planes dipping gently to the north. The penetrative schistosity in these rocks is more or less parallel to the axial planes.

The isocline shown on the section has been labeled F1. From s and z shaped asymmetrical folds, one can fathom the two limbs of a large scale F1 fold along the line of the section. This is shown as an antiform in the diagram, but in the field there is no evidence to indicate whether this is so, or whether the structure is synformal. The antiform is drawn merely to give an indication of style and scale.

Moving northwards along the line of section, one passes into a peat-blanketed, poorly exposed region which the author has termed the transition zone. Here one encounters a "transition facies" lithologically between the schistose and more massive greenstones. This is identified in the field as a medium grained greenstone, frequently crystalloblastic, showing a weak penetrative schistosity. The exact nature of the transition zone is by no means clear, the scattered small outcrops showing a seemingly chaotic relationship between the massive, schistose and transition types. Such an array is impossible to show in the section, and only a very schematic representation is given.

The transition zone is cut by a number of straight, shallow, steep sided gullies, which are interpreted by the author as having formed by preferential weathering along the lines of several parallel high angle faults trending roughly east-west. Movement along these faults may have complicated the outcrop pattern in the transition zone.

The northern limit of the transition zone is marked by a sharp, break in slope. Near to this boundary, the penetrative fabric can be observed to be folded. Two styles are developed; one an open crenulation and the other a much tighter chevron style. The former is by far the most common in this area.

Almost coincidental with the break in slope, there is a low angle fault marked very clearly by a breccia. This seems to be the most significant fault on the southern flank of the hill and it can be traced easily for several hundreds of metres.

The line of the section crosses the fault where it carries massive greenstones on to a small body of metagabbro.

Following the section northwards again, one passes into massive greenstones, with quite abundant linear keratophyre bodies, some of which are folded and faulted.

A small body of injection breccia is encountered on the southern side of Styggdalen, and in this area the fracture cleavage (labeled S2) is well displayed.

The exact nature of the geological feature controlling the formation of the gorge of Styggdalen is uncertain. Possibly it is the line of a major fracture parallel to the well developed fracture system in the body of layered gabbro to the south west of Store Skorovatn.

Moving from Styggdalen to the summit one can observe massive greenstones, some vesicular and others crystalloblastic. Within these are numerous larger keratophyre bodies.

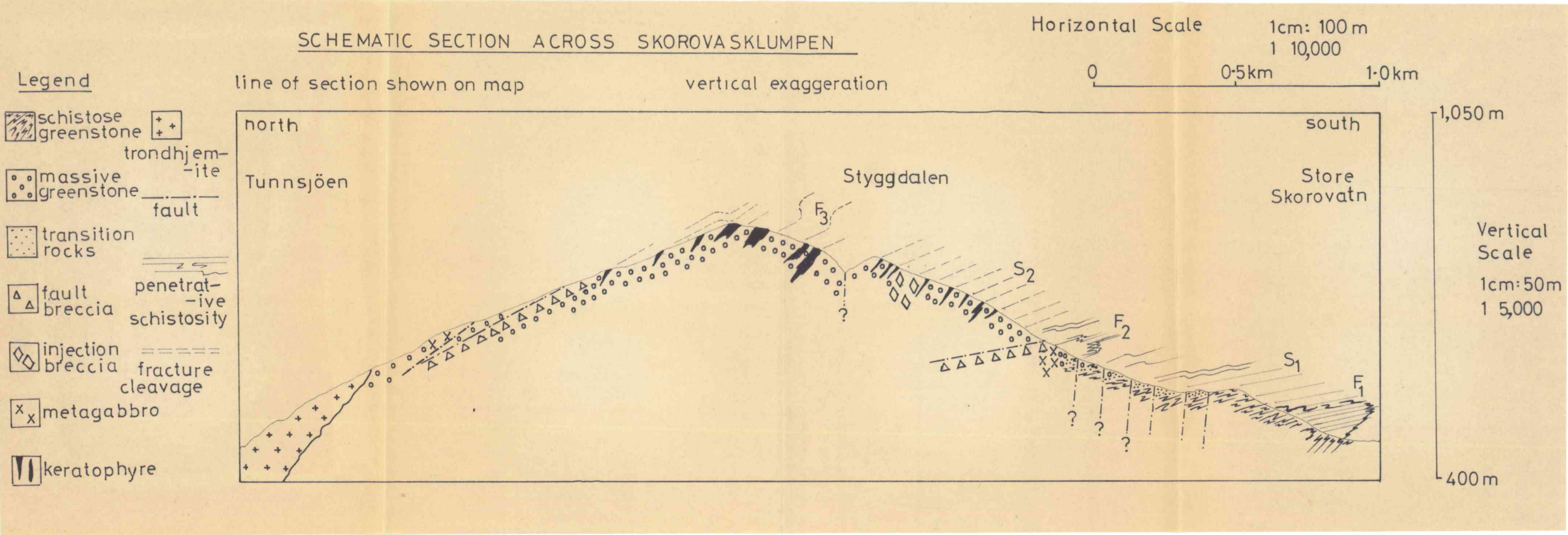
In corrie-like hollows around the summit, large scale F3 flexuring of the fracture cleavage may be seen.

Passing down the northern flank, the massive rocks are cut by a low angle reversed fault, clearly marked by a zone of breccia.

Another small body of metagabbro within the massive greenstones may also be seen.

The northwards dipping contact with the trondhjemite can be examined in several stream sections, and fine grained off-shoot veins are quite common.

The intrusive sheet dips northwards beneath the waters of the Tunsjoflyene hydro electric scheme dam.



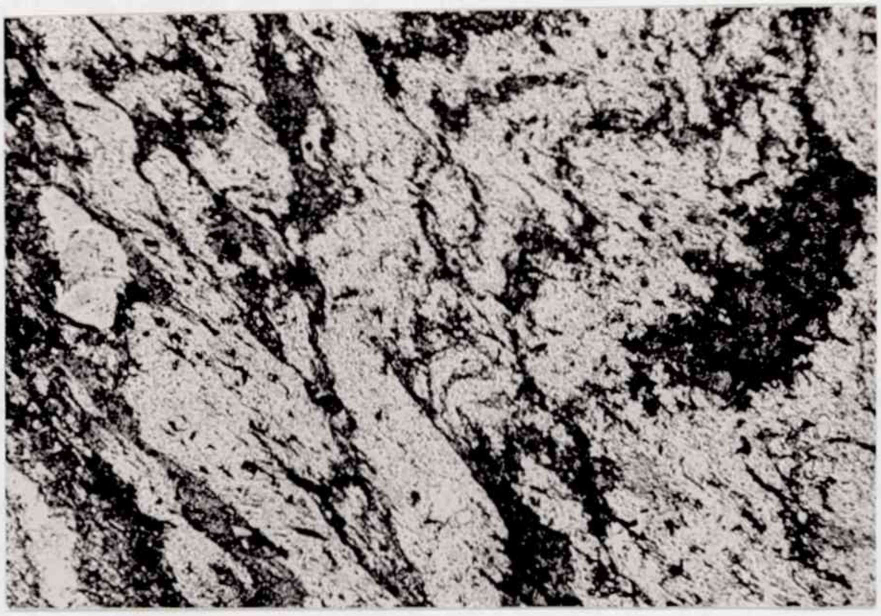
cross section

PHOTOMICROGRAPH 1;

Microfolding of the felsic and chloritic layers in the schists to the north east of Store Skorovatn. The hinge zone of one of these folds is shown in the top centre of the photograph. The penetrative fabric is axial plane to thrse folds - this relationship is best seen under much lower magnification. (plane polarised light.Mag X)

PHOTOMICROGRAPH 2:

Texture of the lithic tuff exposed in a small drainage ditch section in the north east of the mapping area. (plane polarised light. Mag X)



pm 1

pm 2

PHOTOGRAPHS 1 & 2:

The small outcrop of Vasskis in the village of Skorovas at grid reference (021018). The layering and weak penetrative fabric are parallel.

PHOTOGRAPH 3:

F1 folding of the primary layering in the schists near Stalvik, at grid reference (062034).


1


2


3

PHOTOGRAPH 4:

Deflection of the penetrative fabric around pods of quartz within the schists.

PHOTOGRAPH 5:

Small vein of injection breccia, associated with the main body of breccia at grid reference (016035).

4

5

PHOTOGRAPH 6:

Gabbroic clasts in the injection breccia at grid reference (016035).

6

PHOTOGRAPH 7:

The low angle fault at grid reference (015029) showing the zone of epidote green breccia with a sub-vitreous lustre. Compare this breccia to that in the same fault plane at grid reference (019028) shown in photographs 9 and 10.

PHOTOGRAPH 8:

One of the numerous north south striking high angle faults cutting the massive greenstones on the southern flank of the "klumpen". The breccia is similar to that described above.

7

8

PHOTOGRAPHS 9 & 10:

The major low angle fault cutting the southern flank of the "klumpen". (Grid reference 019028).

Note the highly cataclastic nature of the breccia and compare with the breccia in the same fault at grid reference (015029), shown in photograph 7.

9

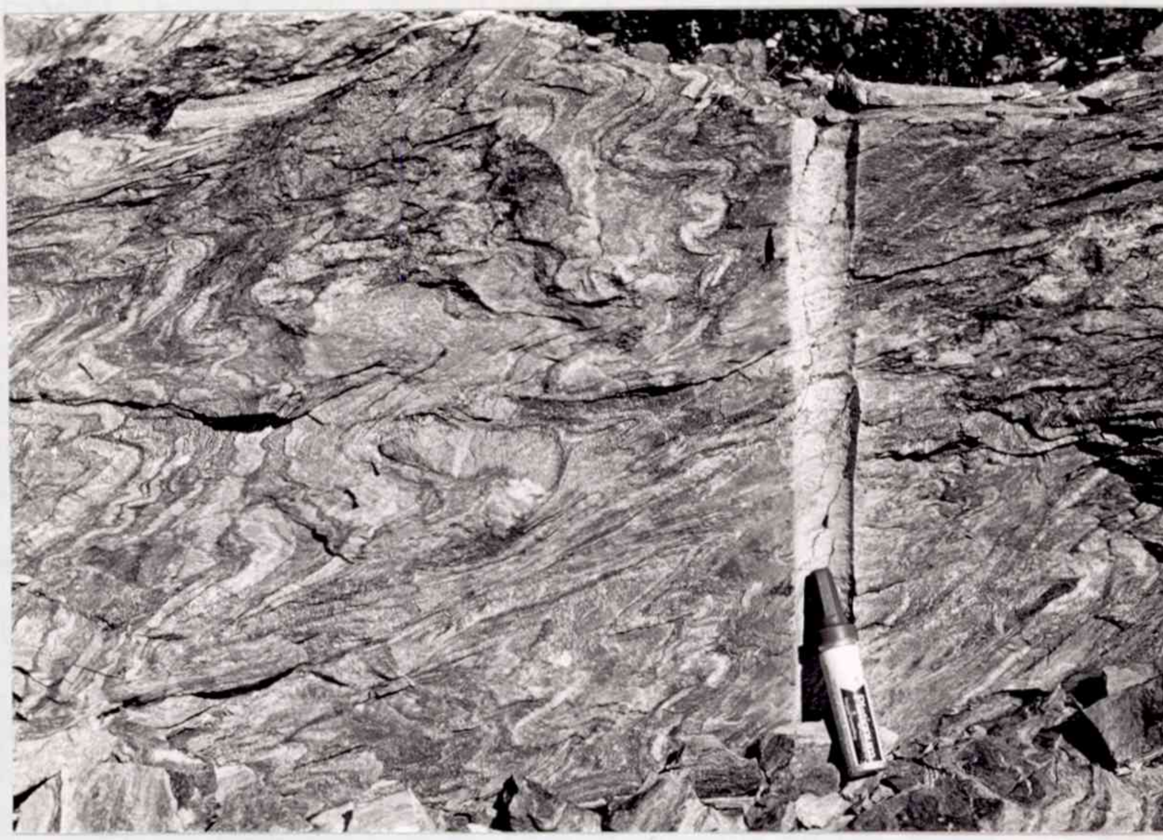
10

PHOTOGRAPH 11:

F1 folds at grid reference (008021) to the north-east of Store Skorovatn.

PHOTOGRAPH 12:

F3 folding of the fracture cleavage developed in the massive greenstones.



11

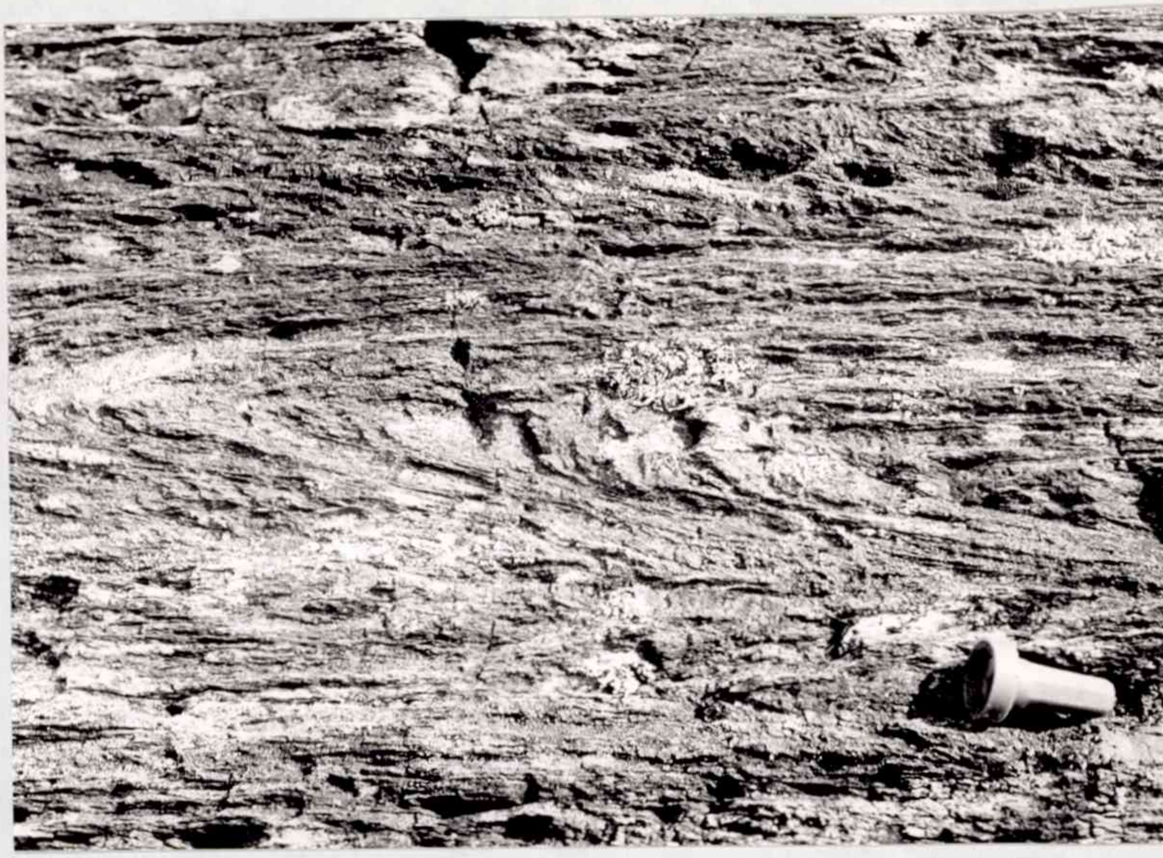
12

PHOTOGRAPH 13:

Possible F1 isoclines in the schistose greenstones at grid reference (010021).

PHOTOGRAPH 14:

Large scale F1 folds at the same location as the upper photograph (grid reference 010021).



13

14

PHOTOGRAPH 15:

F2 chevron style folds in felsic schists.

PHOTOGRAPH 16:

Kink bands in finely laminated felsic schists.

15

16

PHOTOGRAPH 17:

F2 chevron style folding of the penetrative fabric in a large pod of schistose rocks within the southern sheet of trondhjemite, at grid reference (029013).

17

PHOTOGRAPHS 18, 19, & 20:

Sheared F2 structures in the vicinity of grid reference (025022). Photograph 18 shows the parasitic crenulations on the limbs and towards the hinge of the larger F2 closure. The plane of the displacement is obscured by the vegetation.

Photograph 19 shows the fluted appearance of many outcrops of the schists, due to the preferential weathering of the less resistant laminae.

18

19

20

PHOTOGRAPHS 21, 22, & 23: From the vicinity of grid reference (025018) to the north east of the church at Skorovas.

PHOTOGRAPH 21:

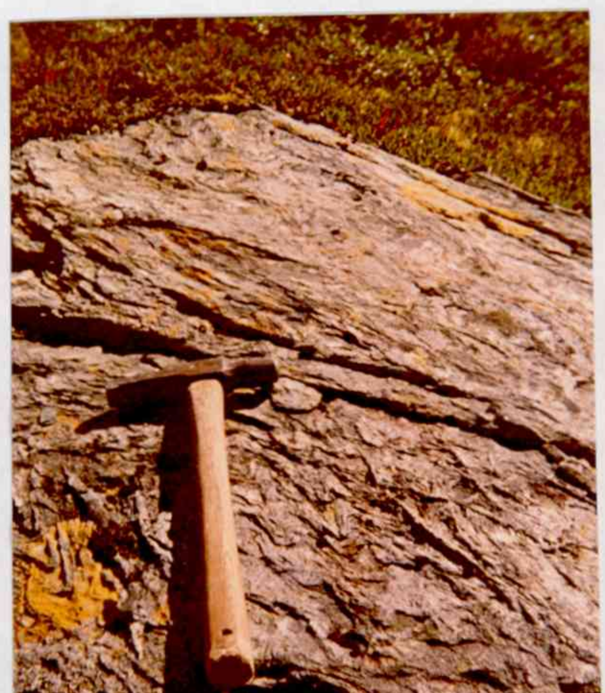
Two different styles of F2 folding with two different axial directions (indicated by the pens). The arrows show the directions of plunge.

PHOTOGRAPH 22:

The development of a weak crenulation cleavage in the schists, produced by the tighter F2 folds shown above, and in photograph 23.

21

22



23

PHOTOGRAPH 24

Probably F2 folding of the penetrative fabric in the schistose rocks at grid reference (025022).

PHOTOGRAPH 25

An offshoot-vein of very fine grained trondhjemite intruded into massive greenstones on the northern flank of Skorovasklumpen, at grid reference (040054).

24

25

PHOTOGRAPHS 26 & 27

Folded and faulted linear keratophyre bodies on the southern flank of Skorovasklumpen.

26

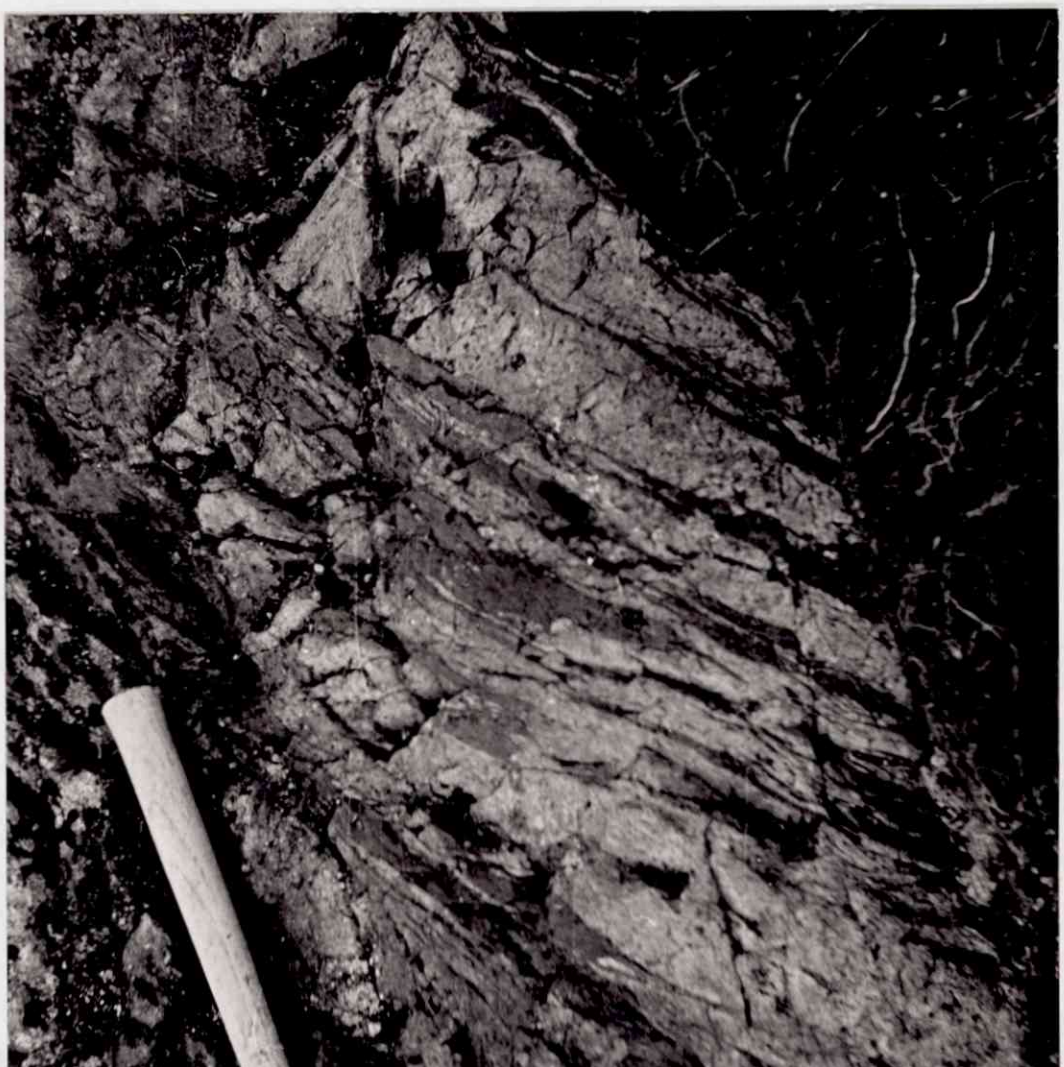
27

PHOTOGRAPHS 28, 29 & 30 (Overleaf)

Stages in the deformation of the clasts in the injection breccia at grid reference (016035).

28

29



GENERAL CONCLUSION AND FUTURE WORK

The author thinks it reasonable to conclude that the detailed mapping of eastern Skorovasklumpen has shown it to be an area of both lithological and structural interests and that future work ought to be concerned with relating the small scale structures of the mapping area to larger scale and possibly regional structures.

With this in mind future work could include the detailed mapping of the area to the north of Tunsjoflyene, and possibly more detailed mapping of the southernmost sheet of trondhjemite.

REFERENCES

Foslie, S., 1939. Skorovas Kisfelt i Grong. Norsk Geol. Tidsskr. 19.

Gjelsvik, T., 1960. The Skorovas Pyrite Deposit, Grong area, Norway. XXI International Congress.

Oftedahl, Chr., 1958. Oversikt over Grongsfeltets skjerp og malmforekomster. Norges Geol. Unders. 202.

Torske, T., 1965. Geology of the Mostadmaka and Selbustrand area, Trondelag. Norges Geol. Unders. 232.

Rutter

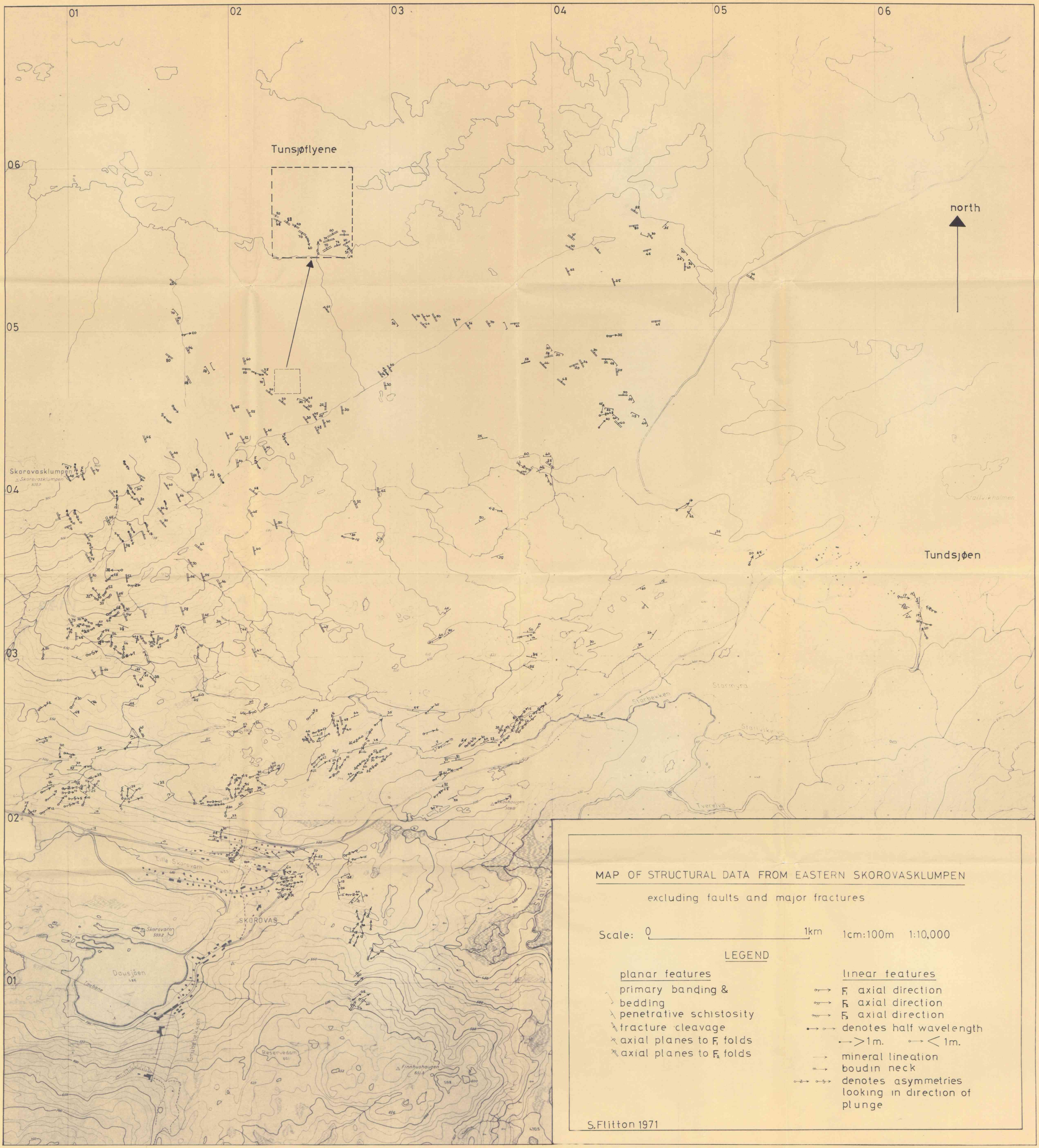
ACKNOWLEDGMENTS

I wish to express my grateful thanks to all who assisted in the completion of this project and the preparation of this report.

I am indebted to Elkem Skorovas Gruber A/S for its generous financial aid, and the provision of excellent food and accommodation.

My special thanks go to Dr. Christopher Halls, for his assistance and supervision in the field, and also to Herr Arve Haugen of Elkem.

Thanks also to my fellow students in the field, to the good people of Skorovas for a pleasant stay, and to Miss Jane Ducker for unravelling my handwriting and typing the first copy.



01
02
03
04
05
06
Tunsjøflyene
north
Skorovasklumpen
Tundsjøen
Lille Skorovarn
SKOROVAS
Skorovarn
Dausjøen
Storbekken
Storfmyra
Finnhushaugen
Reservedam
MAP OF STRUCTURAL DATA FROM EASTERN SKOROVASKLUMPEN
excluding faults and major fractures
Scale: 0 1km 1cm:100m 1:10,000
LEGEND
planar features
primary banding & bedding
penetrative schistosity
fracture cleavage
axial planes to F1 folds
axial planes to F2 folds
linear features
F1 axial direction
F2 axial direction
F3 axial direction
denotes half wavelength
>1m. <1m.
mineral lineation
boudin neck
denotes asymmetries looking in direction of plunge
S.Flitton 1971