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LONG VACATION PROJECT 1969

THE GEOLOGY OF AN AREA TO THE NORTH-EAST OF SVORKMO, SØR-TRØNDELAG.

by

A. S. MEDLYCOTT

INDEX.

INTRODUCTION

The Orkla Grube-Aktiebolag is a mining company centred on Løkken, a town approximately 55 km. south-west of Trondheim. The Company mines cupiferous iron pyrites and exports this as a concentrate to the European Continent, mainly Germany. The orebody is found in the submarine spilitic greenstones of the Støren Series, and is of limited extent.

It is part of the Company's policy to increase its knowledge generally and so it is carrying out a systematic geological survey of the surrounding region.

One of the remaining unmapped areas was a tract of land 14 km. north of Løkken to the north-east of Svorkmo. Consequently, this mapping was undertaken in order to further the geological knowledge of the region and to correlate the known stratigraphical succession and structure of adjoining areas, which have been mapped by Th. Vogt (1945), Carstens C.W. (1952), Chadwick et al (1964), Carter P. (1966) and Rutter, Chaplow and Matthews (1968)

Topographical field maps supplied by the Company were on a scale of 1:5000 (12" :1 mile) and aerial photographs of the area were also supplied on a scale of 1:15,000.

NATURE OF LINES MAPPED

Detailed geological mapping of this area had not previously been undertaken, in fact not many years ago it had been declared unmappable. The topographical maps, however, were very good, but even so the positioning of outcrops was at times difficult. Due to a number of factors it was impossible to follow one lithology constantly in the field and one was obliged to make a note of the rock type, take readings and then plot the "best fit" line in the evenings. The factors that made the geology difficult were poor exposure, intense folding, and probably faulting, producing repetition of strata; rapid facies change along the strike; peat bogs, pine forests, and a lack of roads, tracks and streams. The whole area was extensively glaciated so clitter methods were meaningless.

STRATIGRAPHICAL SUCCESSION

The rock types seen in this region were sub-divided in 1945 by Vøgt into the Støren Series (mainly volcanic) of Arenigian age and the Hovin Series (mainly sedimentary) of Llanvirnian and LLandeilian age. Carstens, C.W. (1951) recognised the Støren Series (Bymark Group) to be underlain by the Røros Group, (mainly metamorphosed argillaceous sedimentary rocks). However, Blake (1962) using graptolite evidence from the Bogo Shales of the Fjeldheim Beds showed these Lower Hovin Series sediments to be of Middle Arenigian age. Thus, the Lower Hovin sediments are Lower Ordovician, the Støren Series is probably Upper Cambrian and the Røros Group is Lower or Middle Cambrian.

There is a break between the Støren Series and the Hovin Series and there is also a break between the deposition and metamorphism of the Røros Group and the extrusion of the lavas of the Støren Series.

LOCAL STRATIGRAPHICAL SUCCESSION

TABLE 1

VOGT	CARTER P.	CHADWICK B.	MEDLYCOTT A.	AGE
HOVIN SERIES	HOVIN SERIES Upper Arenaceous Sequence. (sst. and grit).	HOVIN SERIES Nyplassen Beds (shales and sst).	HOVIN SERIES Absent	LLANVIRNIAN
Hølonda Andesites	Porphyrites (intr usive &/or extrusive).	Intrusive Porphyrites	Absent	
Limestone Shale	Shale & Lst. Sequence	Fjeldheim Beds Shales Limestones Sandstones	Limestones Shales Sandstones	MIDDLE ARENIGIAN
Gaustad Breccia Almas Mudstone	Lower Arenaceous Sequence (lst. sst. & grit)			
Venna Conglomerate	Conglomerates	Fjeldheim Conglomerate	Absent	LOWER ARENIGIAN
BREAK	BREAK	BREAK	BREAK	
STØREN SERIES Upper Greenstone Houe Slate Jaren Beds Lower Greenstone	STØREN SERIES Tuffs and Undifferentiated Lavas	STØREN GROUP Sedimentaries Volcanics and Pyroclastics	STØREN SERIES Sedimentaries and Lavas	Upper Cambrian
BREAK	BREAK	BREAK	BREAK	
RØROS GROUP Absent	RØROS GROUP Absent	RØROS GROUP Absent	RØROS GROUP Garnet Schists Mica Schists Trondheimite bearing rocks.	MIDDLE CAMBRIAN (or older)

THE RØROS GROUP

These rocks are the oldest in the area, being at least Middle Cambrian and probably considerably older. They are seen only in the north-west of the area mapped, with a general north-east/south-west trend. The group has been very roughly divided into two parts, but this division has no stratigraphical significance. The two groups seen are, (1)those schists containing Trondheimite Dykes and, (2) various other schists.

(1) Trondheimite is a quartz diorite and in this area it was intruded intopsammitic schists as dykes of various sizes. These intrusions were prior to or contemporaneous with the main folding movements, (Locality No. 508). Where present, the dykes are so numerous, folded and indistinct, that no direction or orientation readings could be taken. The schists, in general, lack garnets, although the latter do occasionally occur in the dykes themselves.

Trondheimite Slide

Slide No. 293.

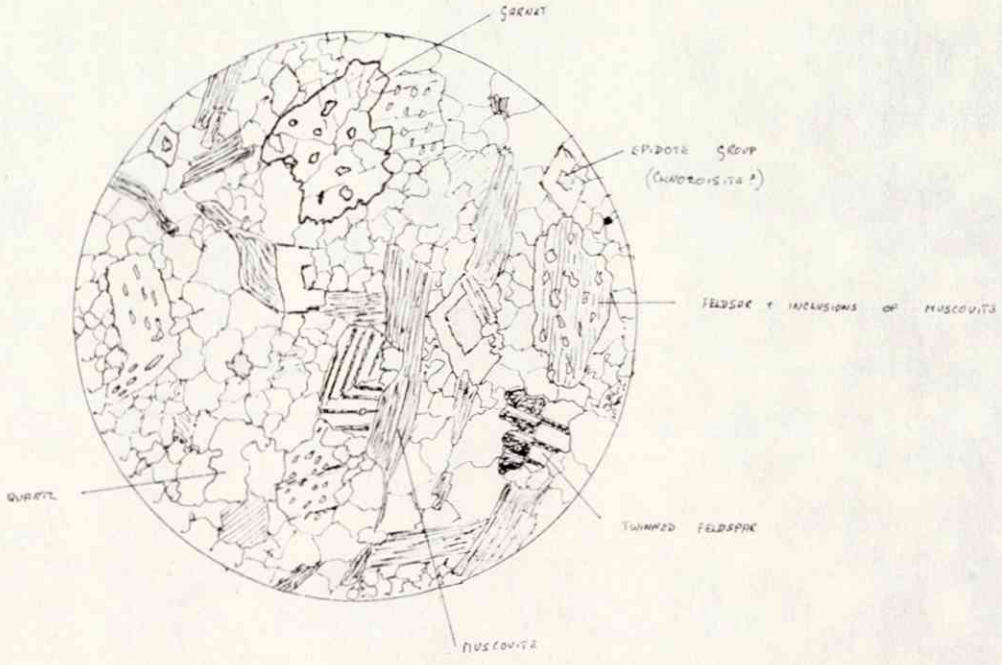
Locality No. 652

Minerals present:-

Quartz	Garnet
Plagioclase Feldspar	Clinozoisite
Muscovite	

TRONDHEIMITE

Figure No. 1.



SLIDE NO.: 293

LOCALITY NO.: 652

Quartz.

A variety of grain sizes; forms a substantial proportion of the rock.

Plagioclase Feldspar.

These are well twinned. Two distinct sizes, large and small ones. Show good perthitic twinning. The large ones are full of inclusions of muscovite, and the twin lamellae go straight through these inclusions but the micas are in optical orientation.

Muscovite

In some cases slightly strained, especially a large crystal in the centre of the picture. This was thought, at first, to be two crystals, but the dark bridge was due to partial extinction caused by stress. No biotite, and therefore probably not a true Frondheimite.

Garnet

Only one seen in the slide but more in the actual rock. It has inclusions of mica and feldspar and is probably an Almandine garnet.

Clinozoisite

Has good crystal form and also good zoning. (Dark in the centre and lighter at the rim). The crystals are euhedral to sub-hedral.

(2) The mica schists are metamorphosed sandstones

and shales, the grade being considerably higher than the bulk of the Støren and Hovin rocks. The predominant metamorphic mineral is garnet, but hornblende, chlorite, biotite and muscovite schists do occur. It is thought that these different schists are due to a compositional effect rather than a metamorphic effect, as no good isograds could be mapped out. This may have been possible if the Røros Group rocks to the south-east has been present to a greater extent.

Garnet Schist Slide

Slide No. 289.

Locality No. 672.

Minerals present:-

Garnet	Quartz
Muscovite	Sphene
Biotite	Green Hornblende
	Clinozoisite

Garnet

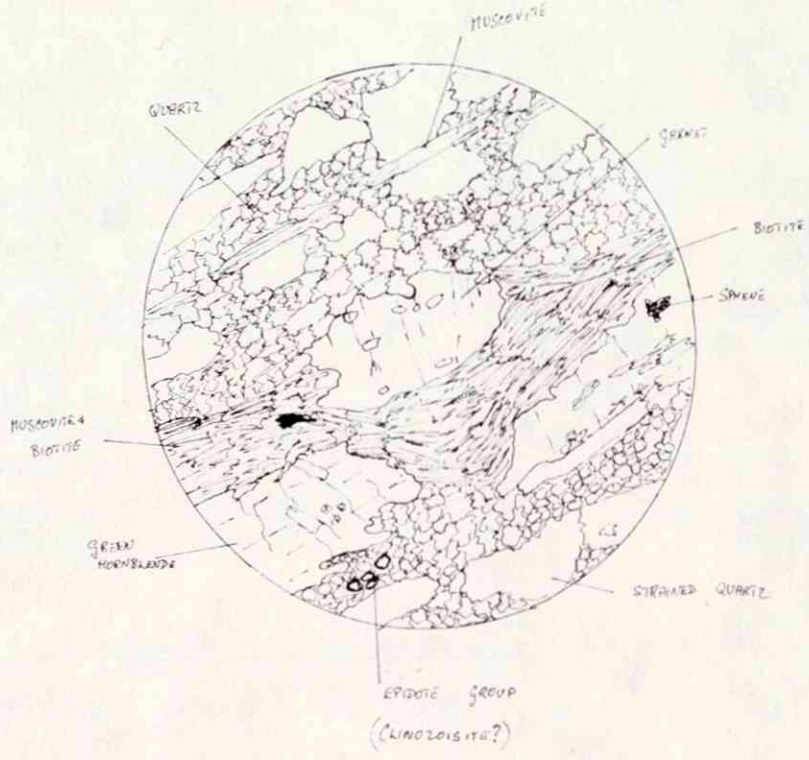
Fairly common metamorphic mineral. It tends to develop in the mica layers and thus the micas show bending of schistocity around the garnet crystal. The garnet has inclusions of mica and quartz.

Mica

The schistocity is picked out by alternating bands of mica and quartz. The mica is made up of biotite and

GARNET SCHIST

Figure No. 2



SLIDE NO.:289

LOCALITY NO.: 672

muscovite, but these minerals are seen individually as inclusions and as separate minerals.

Quartz.

A variety of crystal size but all showing "stylolytic" type of contact with each other. The larger crystals are very markedly strained with pronounced undulatory extinction. The smaller grains do not show this effect but may be too small.

Sphene.

Occurs only in a few places as brown, almost isotropic, sub-hedral fragments. Seen to be included in hornblende and also in the mica bands.

Hornblende.

A strange watery green variety not showing much cleavage at all. However, it does form a distinctive band. The hornblende appears to show pleochroic halos, which seems strange.

Clinozoisite

This is only of limited extent, occurring in a small band. It shows the anomolous blue birefringence colours typical of these rocks but they are slightly altered and do not show good crystal form.

THE RØROS GROUP JUNCTION

The nature of the contact of the Røros Group with the overlying rocks is a problem. In the field the typical Hovin Series grey phyllites appear to lie conformably over the older Røros Group rocks, but this contact was only seen in one place.

The metamorphic grade of the Hovin Series sediments in the contact area is approaching garnet stage and small garnets of good crystal form were seen in typical Hovin Series sandstones. Because of the good crystal form no transport is implied and thus they must be original metamorphic minerals and not detrital grains. These small garnets tend to blur contact so that the division is indistinct. However, in the one place where the contact was seen, the relations were very clear. On one side of the fence typical grey phyllites (Hovin) and on the other side garnet hornblende schists were found. (Røros - garnets up to 1.5 cms. diameter). (Locality no 656/657).

There are now several questions to be answered.

(1) Where is the intermediate Støren Series?

There is no evidence at all in the field for these rocks so it is thought that they were either never deposited here or were deposited and subsequently eroded away into the Løkken trough in the south, to form the conglomerates.

(2) Could there be a faulted relationship?

This could be so, as large north-east/south-west faults were seen to the south-west of our area by Lindberg P. (1969).

However, a fault of the magnitude needed to remove all the Støren Series (if deposited) would produce a great deal of shatter and breccia. Again, there is no evidence of slickensiding or of a quartz infill of the fault zone, which is so characteristic of this area.

The relationship, therefore, is probably that of a low angle unconformity between the Røros Group and the Hovin Series. The angle of unconformity has been reduced by the earth movements affecting the area.

THE STØREN SERIES

The base of these rocks was not seen. They apparently occupy the cores of synclines within the younger Hovin Series, which suggests that they have been inverted.

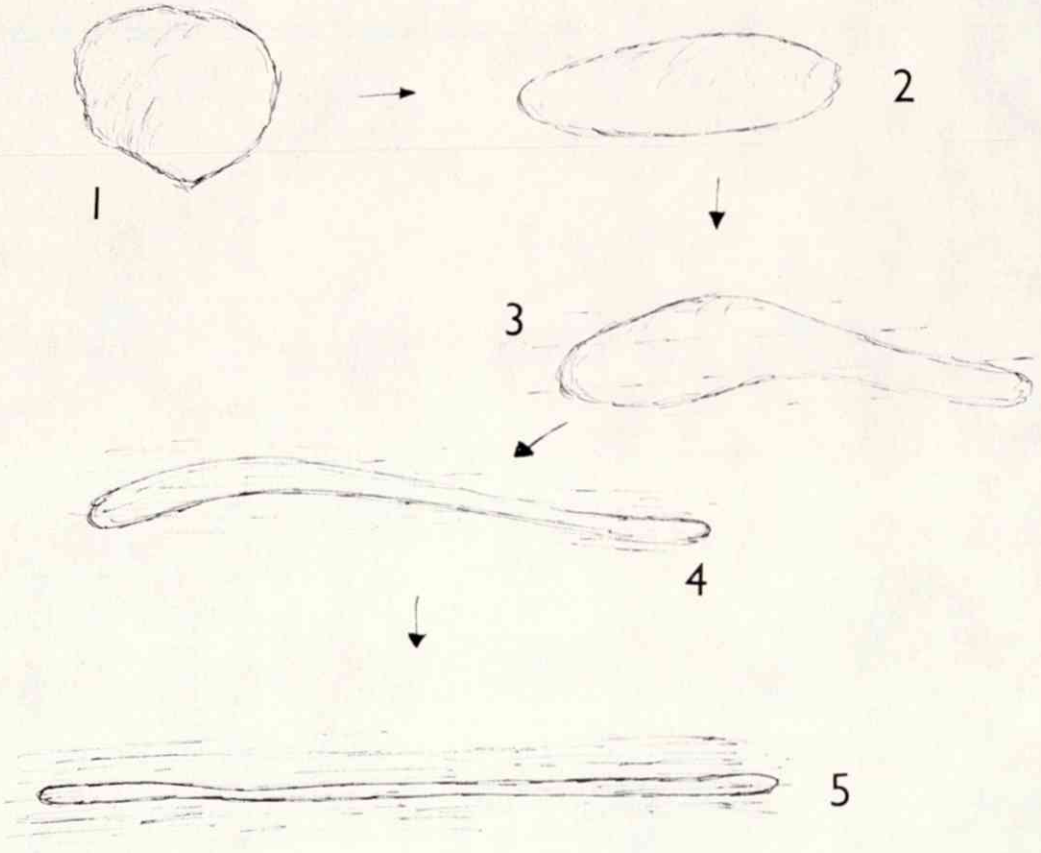
The series is predominantly volcanic having been extruded as submarine spilitic lavas. Some intercallations of ashes and ordinary sedimentary rocks are evident. The rocks were metamorphosed to Greenschist Facies grade during the Caledonian Orogeny, giving them a typical green colour; hence the term "Greenstone".

Only in one place to the n.n.e. of Svorkmo were good pillow lava structures seen, and these were quite deformed - their long axis taking on a rough orientation. These pillows were compared with the undeformed pillow structures seen in the bus station at Løkken and it was concluded that the latter had escaped deformation due to the thicker pile of protecting volcanics lying above. Probably also these was less deformation in the south. No unambiguous way-up structures of "V-ing" in semi-molten pillows could be determined in the pillows of our area.

In this area, especially after Rutter's paper, (1968), it was difficult to decide whether some of these rocks were Støren Series or Hovin Series. Apart from the aforementioned locality, no good pillows were seen. It is thought that during the Caledonian Orogony the pillows became extensively physically internally deformed and took on a schistocity;

the inter-pillow boundaries becoming more diffuse with increasing flattening. The resulting rock can be called a chlorite-epidote-albite schist but may well be mistaken for a chloritic green sandstone of the lower Hovin Series. In fact, not until textures had been studied under a microscope, was a supposed volcanic rock deemed to be sedimentary.

Figure No. 3 - Deformation path of a pillow lava.



Chlorite - Albite - Epidote Schist.

There has been an attempt to sub-divide the greenstones on a geochemical basis by Dr. W, Skiba and Dr. I. Butler. It is interesting to note that in undeformed pillows the rims are poor in Na and rich in Mg in comparison with the composition of the core. However, the deformed pillows have lost their primary zonal structure and also the zonal distribution of Na ad Mg. Thus, as deformation proceeds, the pillows change both physically and chemically.

The pillows seen were much smaller than the Løkken pillows, being only 30 - 40 cms. long and made up of chlorite and epidote with calcite and occasionally albite and amphibole.

It is possible to pick out individual pillows by the concentrations of the minerals present. Around the margin there is an external area of dark amphibole. The rim itself is fine grained, whereas the interior may have calcite filled vesicles. There is a good deal of structureless quartz associated with the submarine lavas. This is an indication of a silica-rich sea, due to the underwater effusion of silica during the lava extrusion. Massive non-pillowy lavas were also seen in greater abundance than the pillowy type. The former of these is fine grained and tends to be more uniform with no vesicles.

Spilitic Greenstone Slide

Slide No. 295

Locality No. 255

Minerals present:- Mode?

Calcite

Biotite (brown and green) ! It reduction.

Quartz

Chlorite

Epidote

Haematite

Clinozoisite .

Calcite.

Quite abundant in the rock, but this is typical. Shows goodrhombohedral twinning and grey/fleshy colours.

Biotite.

Seen in one place in a very contorted state. The cleavage is completely folded and the birefringence is undulatory. It is associated with green biotite.

Quartz.

This, too, shows undulatory extinction due to strain produced by folding. It is usually fine grained, filling in between other minerals. In the large grained examples, where the strain is seen, there are also stylolytic crystal interfaces.

Chlorite.

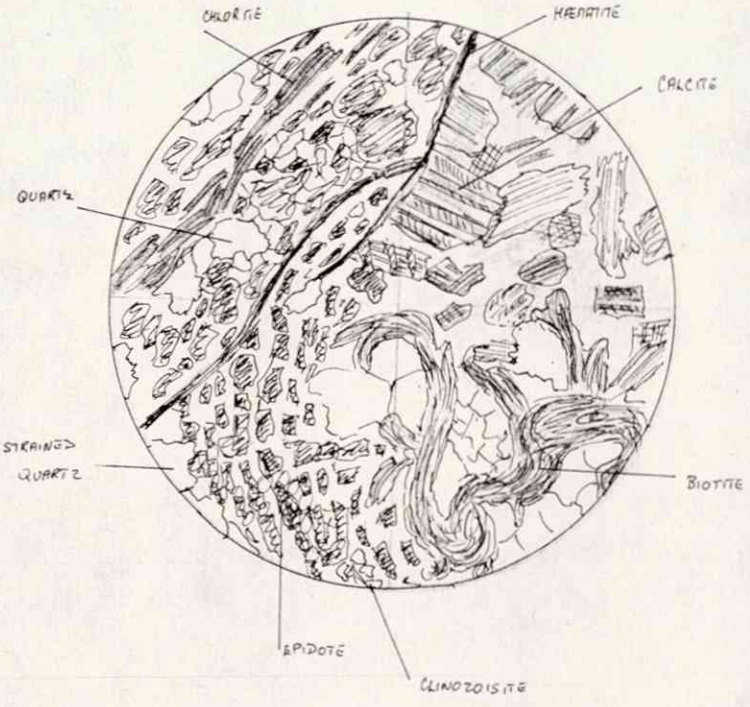
Good pale green -- colourless pleochroism and 001 cleavage. It is associated with haematite.

Epidote.

Present in substantial proportions, in fact in places

SPILITIC GREENSTONE

Figure No. 4



SLIDE NO.: 295

LOCALITY NO.: 255

the rock could be called an epidolite. Small crystals with high colours, (greens, reds, yellows) are often seen. These crystals are usually surrounded by quartz.

Haematite.

The veins of haematite help to define the cleavage in places, but usually no good cleavage has been set up.

Clinozoisite.

Only a few blue crystals seen locally.

The rock is very dirty with ore and is generally rather messy. The extent of the deformation can be seen with reference to the deformed biotite lathes. The ore is a mixture of pyrite and haematite.

STØREN SERIES - HOVIN SERIES JUNCTION

After the Støren Series rocks had been deposited, there was un uplift, probably due to early Caledonian earth movements. There is evidence in all adjoining areas for this break in the form of the Venna = Fjeldheim Conglomerate, this being composed of fragments of Støren Series lavas and jasper. This conglomerate was not seen in situ anywhere in our area, although large glacial erratics were fairly common. The same is true of the geology to the west of this area which was being mapped at the same time by a Norwegian student, P. Lindberg. This suggests that this northern area was the upland region from which the material was rapidly stripped and transported into the Løkken trough, where conglomerates are abundant.

THE HOVIN SERIES

There does not appear to be a very marked degree of angular unconformity between the Støren Series and the Hovin Series. Of the four divisions of the Hovin Series mentioned by Carter (1966) only the lower members are present; there being no outcrops of the Upper Arenaceous Sequence and only one outcrop of the Porphyrites in the extreme south where R.C. Standley was working.

The Hovin Series is made up entirely of sedimentary material but some bands are tuffaceous. The rocks in this area are similar to those further south, but in general they are more fine -grained, being shales rather than sandstones. The Series consists of shales (phyllites), calcareous shales, impure limestones, pure recrystallised limestones, sandstones, and occasionally cherts. The boundaries between these various lithologies are very indistinct because of the grading from one to the other. Correlation is also made difficult by rapid facies change along the strike and intense folding. It was expected that we would find good younging criteria but the graded bedding, current bedding, slumping and load casting mentioned by other workers were not seen well enough to provide definite "ways up".

The shales are predominantly grey although green varieties occur. These shales have now been metamorphosed to phyllites or "Glimmerschieffer", and they occupy the greater part of the succession. Flecks of brown staining occur widely on the

cleavage planes, these being alterations after pyrrhotite and pyrite.

The calcareous shales and impure limestone are again predom inantly grey although the decalcified weathering surface tends to become brown or buff. The calcareous shales occasionally contain limey nodules. The shales and limestones are interbedded, the individual bands being about 1 - 5 cms. thick.

The limestones are usually grey although a white variety was seen. The are both coarse or fine-grained depending on the degree of recrystallisation. The coarse-grained variety, with calcite veins, is very distinctive, especially in the road section between Monset and Solsjøen. The recrystallisation has destroyed any fossils that may have been present. These limestones often contain bands of arenaceous material (Locality No. 146) which, due to differential weathering, stand out, showing ruckling. This illustrates well the plastic deformation of the limestones during folding.

The sandstones and cherts are usually grey or black but at Locality No. 488 a brownish iron-rich sandstone was found. This was analysed and showed a high Fe percentage but very little Cu.

INTRUSIONS

(a) Minor Intrusions

One small dyke was seen in the north of the area but it was not possible to trace it over a long distance because of exposure. The dyke was non porphoritic and contained a mass of euhedral green-brown hornblende crystals.

Hornblende Dyke Slide.

Slide No. 291.

Locality No. 418.

Minerals present:-

Hornblende	Sphene
Quartz	Haematite
Epidote	Muscovite.

The sec tion is thick and hence tends to give anomolous colours.

Hornblende.

A green variety which shows very good green-brown pleochroism. Some sections show good cleavage intersections at approximately 35°. The hornblende has not many inclusions but those present are sphene, muscovite, and quartz. Most of the slide is made of hornblende.

Quartz.

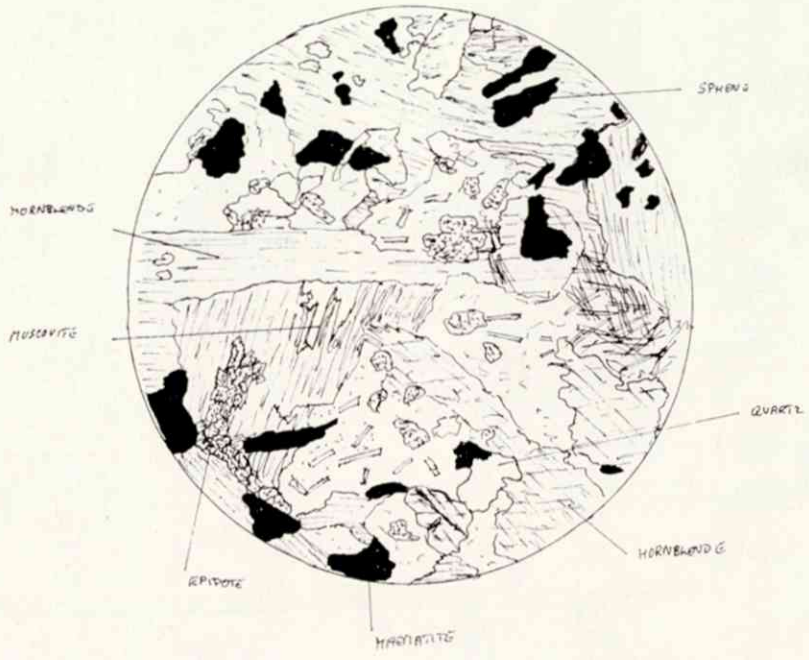
Not a great deal of quartz. It occurs mainly in the fine-grained groundmass, but also as inclusions.

Epidote.

Occurs locally in the groundmass as an alteration

HORNBLENDE DYKE

Figure No. 5.



SLIDE NO.: 29I

LOCALITY NO.: 418

product of the hornblende.

Sphene.

Occurs as a brown, almost opaque, crystal with no good crystal form.

Haematite.

Only seen as a minor accessory.

Muscovite

Seen in the groundmass and as inclusions.

The dyke was intruded into schistose sandstones of the Hovin Series. Associated with the intrusion is a contact metamorphism series which has produced large biotite crystals, the size and frequency of which decreases away from the contact. The biotite lathes grow across the schistocity.

Contact Metamorphosed Schist Slide.

Slide No. 300.

Locality No. 419.

Minerals present:-

Quartz	Biotite
Ore	Amphibole

Quartz.

A great deal of fine-grained, well rounded, interlocking quartz. Thus, the original rock was probably a sandstone.

Ore.

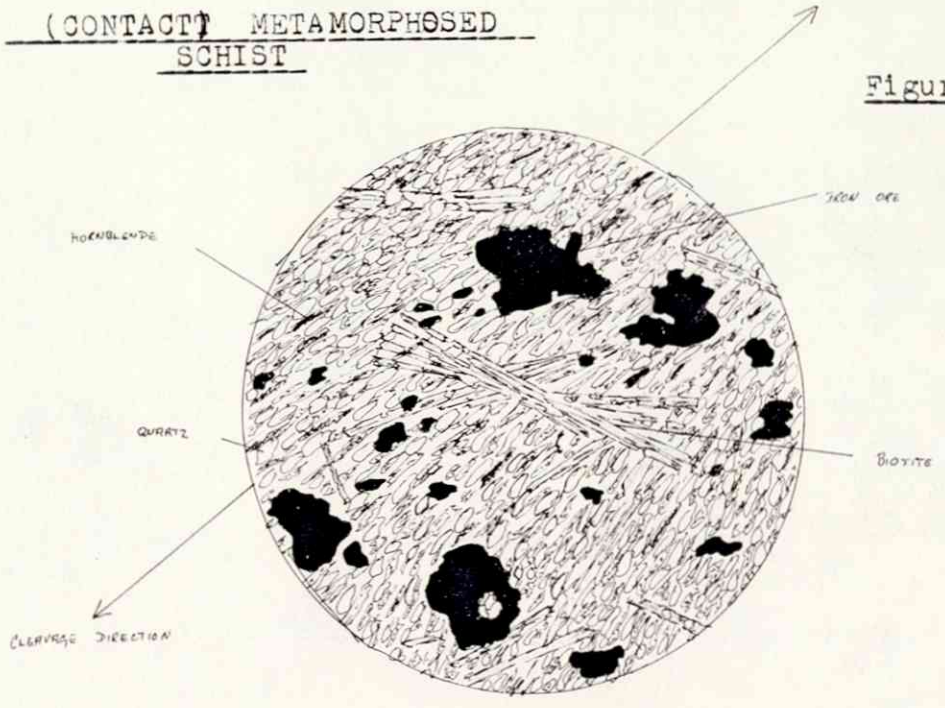
A good deal of iron ore present throughout the rock.

Amphibole.

A greenish variety with a high extinction angle. Under

(CONTACT) METAMORPHOSED SCHIST

Figure No. 6.



SLIDE NO.: 300

LOCALITY NO.: 419

ordinary light the hornblende marks out the cleavage.

Biotite.

Brown and pleochroic. Some of the blades lie along the cleavage but others grow across the cleavage. This shows well that the biotite is secondary to the cleavage and is a direct result of the intrusion. The biotite has a strange, mottled texture.

There is possibly a small amount of K feldspar in the matrix with the quartz.

(b) Gabbro.

The outcrop of these rocks was limited to a small area to the north-east of Lake Damlitj. The exact limit of this body was uncertain owing to the similarity of the greenstones into which it was intruded. The gabbro becomes finer grained towards the margins. It is mainly coarse-grained but in places it has undergone considerable saussuritisation and only relic crystals can be seen.

Metamorphosed Gabbro Slide.

Slide No. 290.

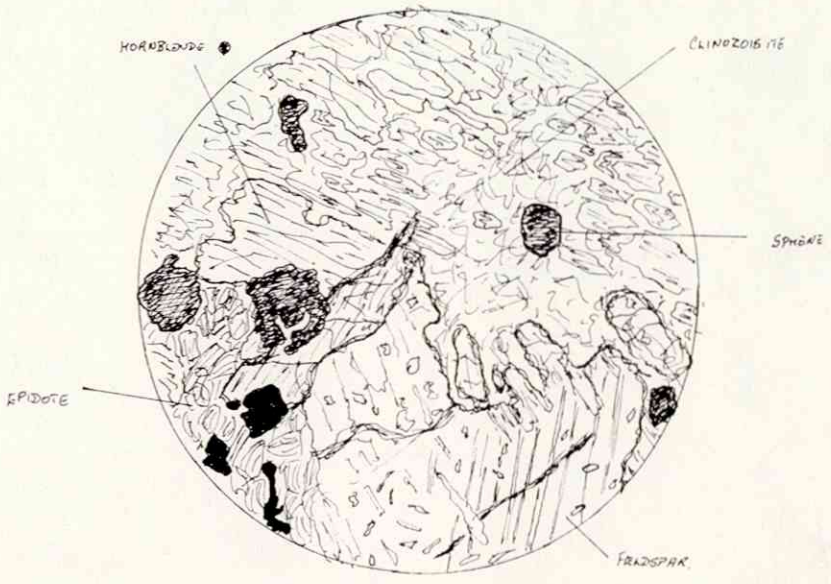
Locality No. 232

Minerals present:-

Epidote	Feldspar
Clinozoisite	Hornblende
Sphene.	

METAMORPHOSED GABBRO

Figure No. 7.



SLIDE NO.: 290

LOCALITY NO.: 232

Epidote.

Small crystals with high yellow birefringence colours. An abundance of epidote in the groundmass.

Clinozoisite.

Characteristic anomolous blue colours and parallel extinction. Abundance of this in the groundmass.

Sphene.

There are many anhedral crystals showing brown colours that hardly change in polarised light. The sphene is thought to be an alteration product after pyroxene.

Feldspar.

There are some fairly large relic feldspar crystals which have some inclusions. One of the crystals shows fine lamellae twinning. Some crystals show stress effects in undulatory extinction.

Hornblende.

Shows green-colourless pleochroism. It is a low angle extinction form and therefore may be tremolite.

STRUCTURAL GEOLOGY.

The rocks of the area were deformed during the Caledonian orogeny. The intensity of deformation was seen to be greater in this area than further south in and around the Løkken syncline. It is possible to distinguish at least two phases of deformation with a possible tightening of the F2 structures.

(a) First of F1 phase of Folding.

The evidence for this is in the presence of a penetrative cleavage and schistocity. This can be seen to be parallel to the fold axial surfaces of small F1 folds where the original bedding is still obvious. These F1 folds were usually, but altogether infrequently, seen in the thin bedded sandstones and shales. The major F1 structures trend w.s.w. - e.n.e. in the south but in the east they become more n.e. - s.w. Only the F1 phase appears to have produced a significant amount of internal deformation in the rocks of this area. This was only seen in the pillow lavas and, to a certain extent, in the limestones.

(b) Second or F2 phase Folding.

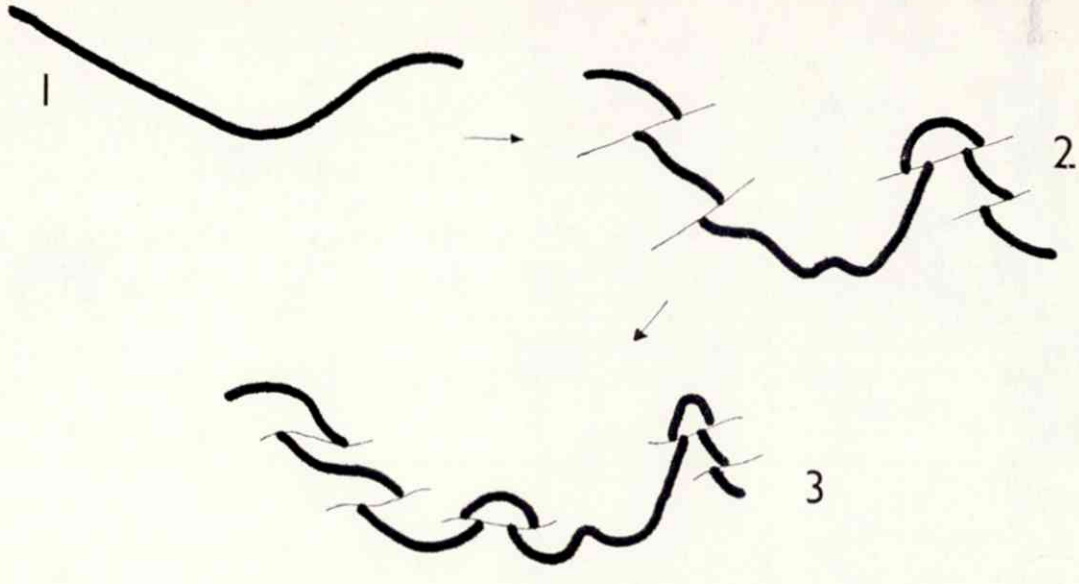
The phase took place after the main metamorphism and was not intense enough to produce any internal deformation. The F2 folding is superimposed on the F1 folding and this produces interference effects. In places an ill defined F2 cleavage is set up but this was not often seen. A

n.w. - s.e. trending anticline is seen in the n.w. of the area of Hovin and Støren rocks and this confuses the over-all picture. It is interesting to note that Carter (1966) mentioned a n.w. striking syncline running through Gasbakken.

(c) Tightening Phase.

This is a late stage effect in the development of the F2 structures, when the rocks were less ductile. The effects are seen especially in thin bedded limestones where the F2 folds tighten and then produce little thrust planes and concertina the folds. (e.g. Locality No. 148).

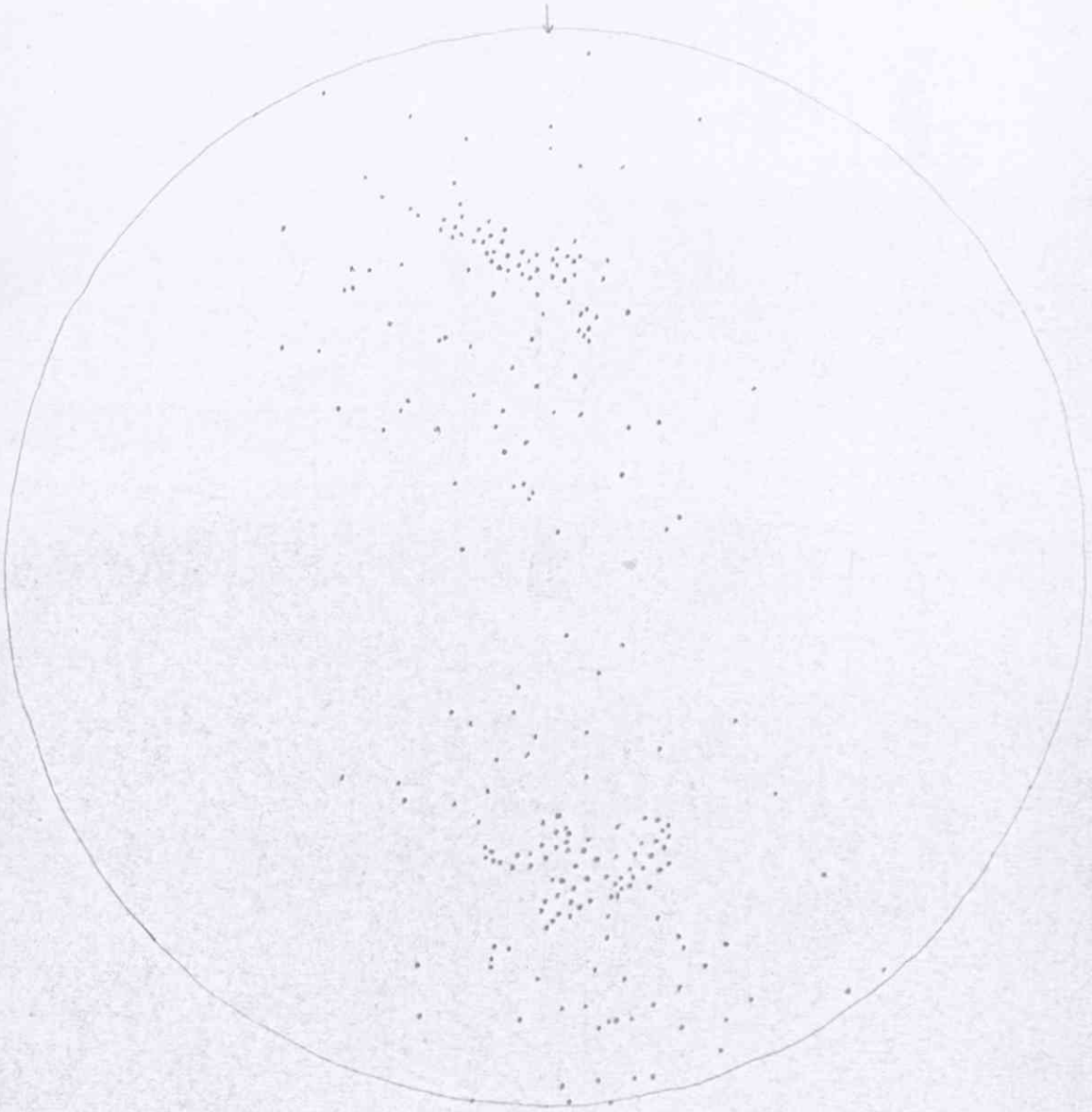
Figure No. 8.



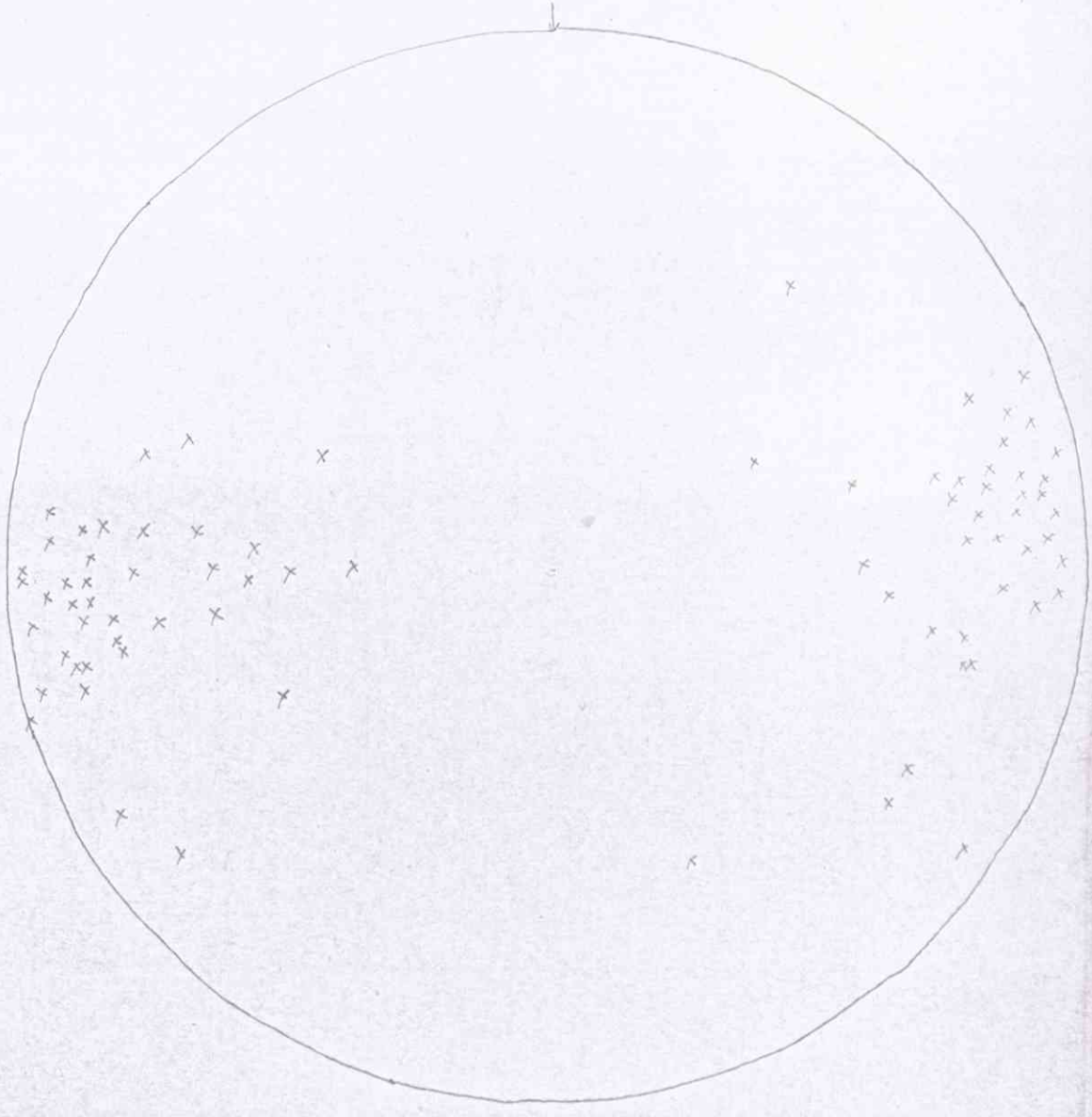
(d) Faulting.

The faulting appears to have occurred only on a minor scale. However, the faults are difficult to pick out in such a folded and recently glaciated environment. There are probably more faults present than were actually seen and mapped. Those faults that were inferred had a n.n.e. trend. This is in agreement with the general trend of adjoining areas.

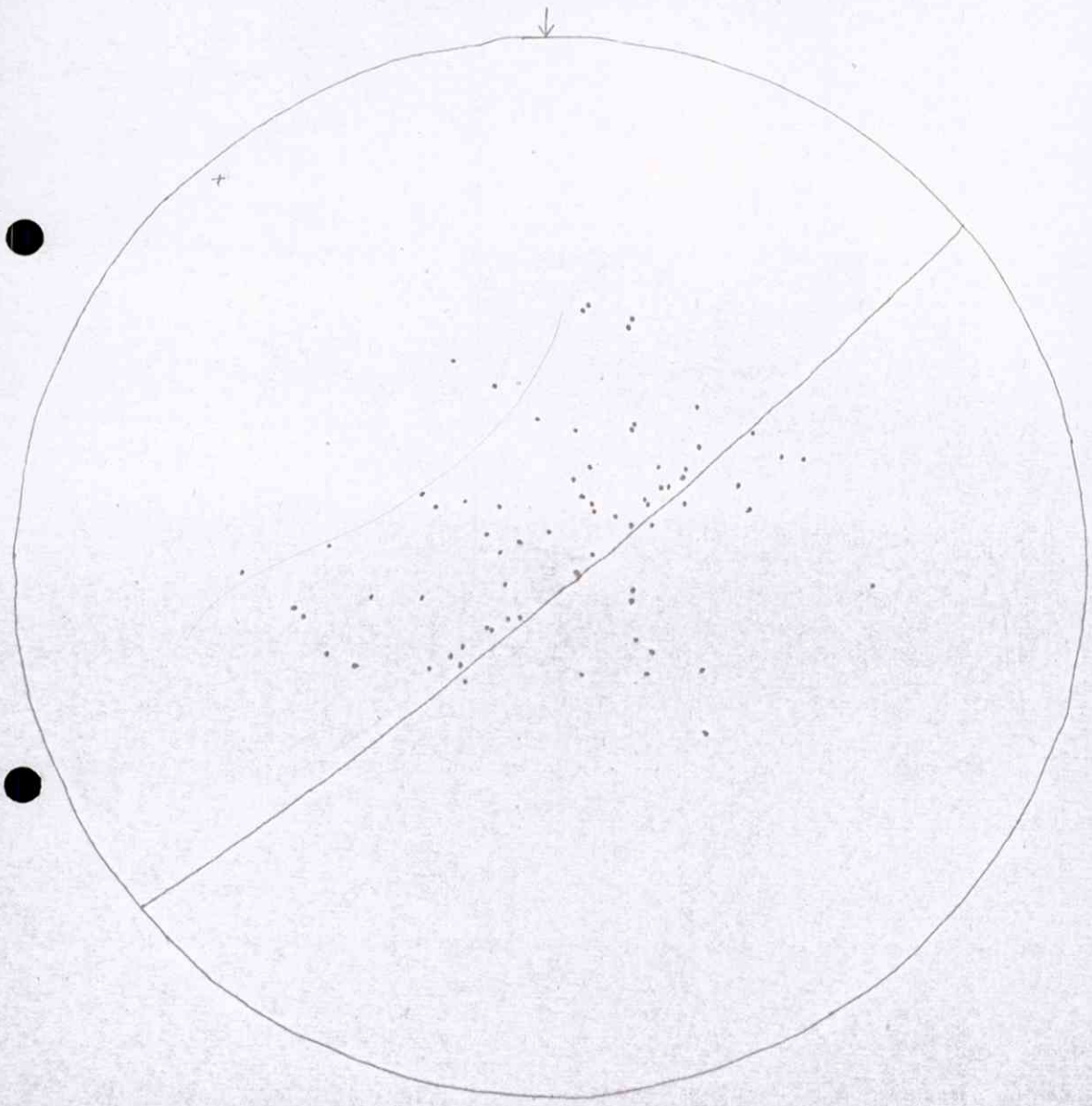
SOUTHERN AREA E.–W. TRENDING ROCKS.



FOLD AXES



AREA OF N.W. TRENDING ANTICLINE.



PLUNGE OF FOLD AXIS: 4° TO 320°

RÖROS GROUP ROCKS.

LOCAL CORRELATION

The stratigraphy and structure of the area correlates reasonably well with those established for adjacent areas by previous workers. The probable correlation of the strata is as shown in Table 1 on page 5. The Geological sketch map (Fig. 9) indicates the continuity of the strata along the strike into surrounding areas. The area to the north has not been mapped and the area westwards across the River Orkla was mapped last summer but is, as yet, unpublished. P. Carter's area is to the s.e. and J.E. Matthew's area is to the s.w.

Figure 9a. is a tracing paper overlay showing the continuation of the main anticlines and synclines into the area mapped.

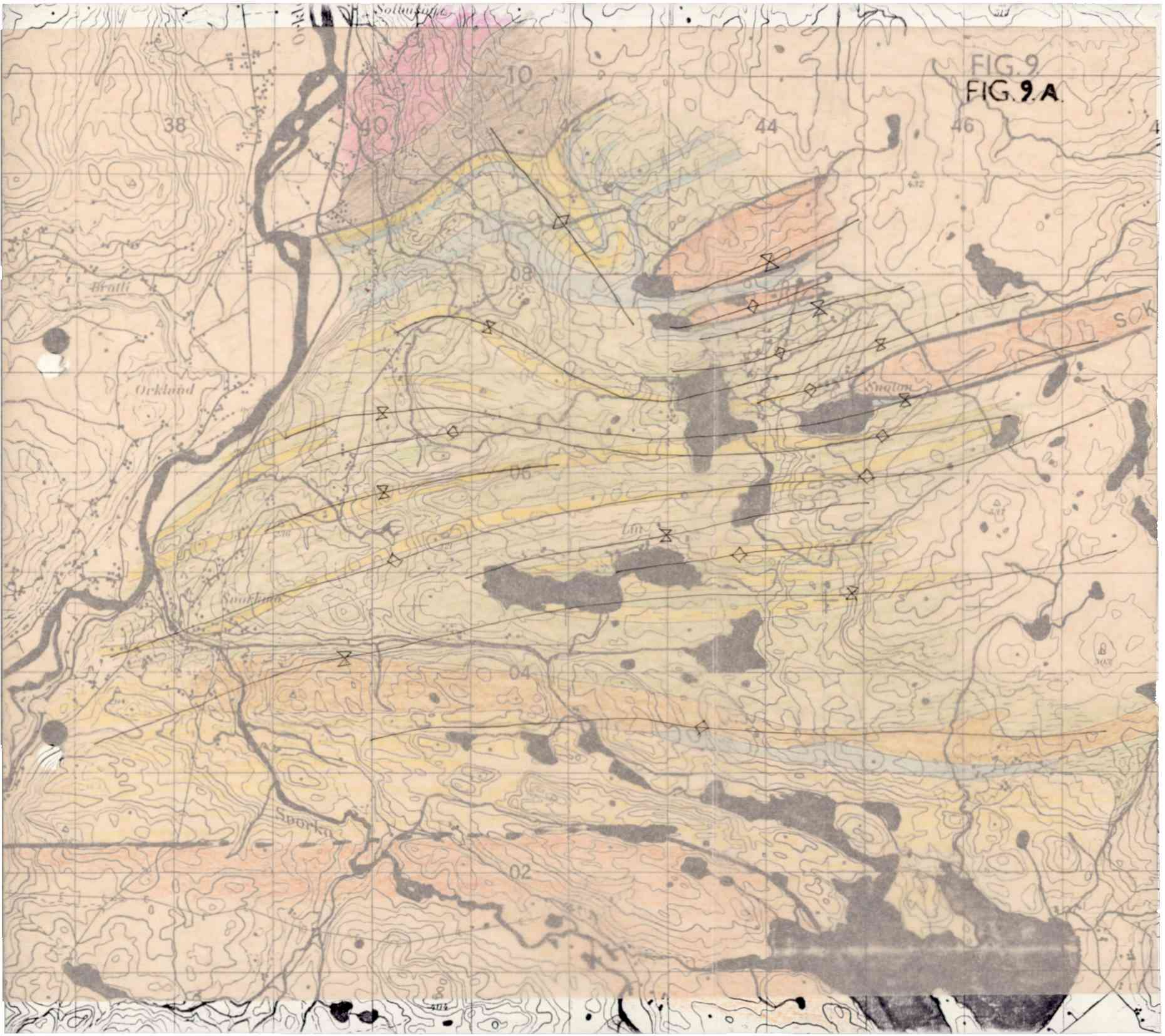


FIG. 9
FIG. 9.A.
10
38
40
42
44
46
08
06
04
02
Bratli
Orkland
Snaken
Snorkna
Lm
SOK

SEQUENCE OF EVENTS.

The geological structure is most conveniently summarised in the following outline of the geological history of the area.

(i) Deposition and lithification of the sediments of the Røros Group.

(ii) Uplift and metamorphism of the Røros Group sediments to produce garnet schists, etc.

(iii) (a) The northern area remained as a landmass and Røros Group rocks were eroded and transported south.

(b) The southern area was submerged and the pillow lavas of the Støren Series were erupted. The gabbros were intruded.

(iv) Uplirt and erosion leading to the formation of the basal conglomerates, (not in the north) and the other Hovin Series sediments.

(v) Burial by superincumbent sediments and lithification.

(vi) Development of the F1 folds with e. - w. trending axes, and of the schistocity parallel to the fold axial planes.

(vii) Regional metamorphism to Greenschist Facies grade in the south - the grade is higher in the north.

(viii) Refolding of the F1 schistocity to produce the F2 structures.

(ix) F2 tightening phase producing thrusts.

(x) Uplift, faulting and jointing.

(xi) Glaciation and erosion.

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A GEOLOGICAL MAP OF AN AREA N.E. OF SVORKMO

LEGEND

3	SANDSTONES AND QUARTZITES
16	PHYLLITES
23	SLATES
10	LIMESTONES
19	GREENSTONES
21	METAGABBRO
18	PORPHYRITES
20	HORNBLENDE DYKE
22	AMPHIBOLITES AND GARNET SCHISTS
8	TRONDHEIMITE BEARING SCHISTS

SCALE 1:10,000

1 KM

SOLBLI

MONSET

DAMLITJ

HESTHAUGEN

DALTJ

ORKLA

RIVER

LÖFTEN

ORKLAND

HAAKENSLOKKEN

SVORKMO

SOLSJÖEN

SNÖTONV$^{D.}$

MJOV^{D}

LIAV$^{D.}$

RYV$^{D.}$

RORTJ

A.S.MEDLYCOTT. JANUARY 1970

THE GEOLOGY OF THE AREA NORTH EAST OF SVORKMO