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A report on the geology of an area north of Gåsbakken, Sør-Trøndelag, Norway

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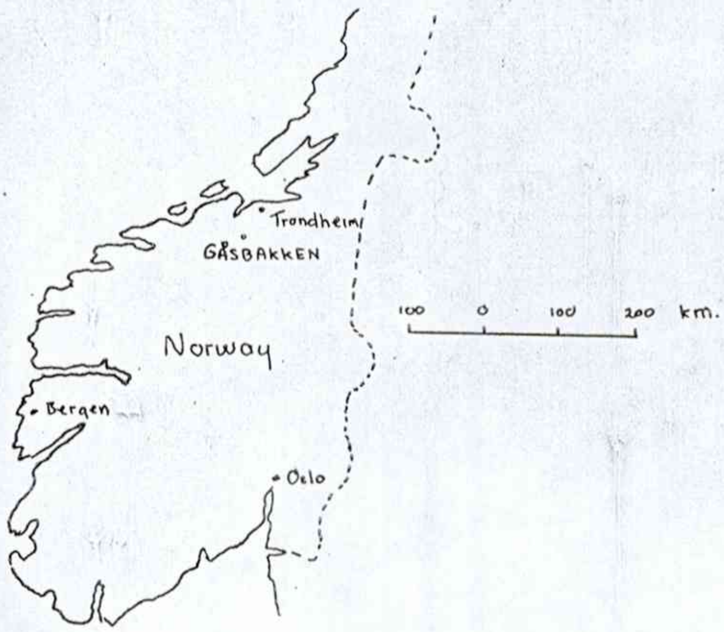
Sammendrag

Carter (81)

a report on the geology of

An Area North of Gåsbakken

Sør Trondelag. Norway.



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The Area Mapped.

The area which was mapped consisted of some 60 sq km in lower palaeozoic outcrops situated just north of the village Gåsbakken (Hølonda) which is circa 60 km south west of Trondheim, Sør Trondelag, Norway. The topography of the area was hilly with the hills rising to over 500 metres high from steep valleys at 250 metres above sea level - in fact the valleys seemed to be cutting through a plateau of a general height of 500 m above s.l. Most communication is through the valleys, the valley sides are forest covered (predominantly coniferous) save where they have been cleared for grazing and arable land. The hill tops are very much bog covered and many of the valleys are occupied partly or wholly by lakes. Accordingly the exposure is poor[I] and only general observations of major structures and lithological sequences were made.

Reasons for Choice of Area

It was decided to map in the area north of Gåsbakken for two main reasons.

Firstly the management of Orkla Grube Aktiebolag - an iron pyrite mine situated at Løkken near the Orkla valley (Orkladalen) - promised, and gave, valuable aid in the way of finding accomodation, and such facilities as the freedom of the mine's private geological collection. The company also provided aerial photographs, transport between the field and the mine at the beginning & end of the field mapping, cooking utensils, transport of specimens free of charge to London, and free accomodation at the companies hotel during visits to Løkken. Manager Per Sandvick provided much kindly aid and hospitality during my visit and took great interest in the progress of the work.

I II .. ect - photographs. Appendix B.

Secondly, the particular area north of Gåsbakken was chosen because of its key position for the correlation of three previously mapped areas in the district, mapping in the area north of Gåsbakken completed mapping between these areas. The previously mapped areas referred to were described by Vogt in 1945 (Geology of part of the Hølonda-Horg district, Norsk. Geol. Tidsskr Vol 25, pp 449-524), Carstens C.W. in 1951 (Løkkensfeltet Geologi. Norsk. Geol. Tidsskr. 29) and Chadwick et. al. (Norges. Geol. Und. Nr 223. årbok 1962 pp 43-60). In 1952 Carstens CW published a map (Geologisk karte over Løkkenfeltet - Norges Geografiske Oppmåling) which was of the area described in his 1951 paper mentioned above.

Methods and Equipment

Mapping equipment used included a prismatic compass, a clinometer, rapidograph pen, aerial photographs with kodatrace overlays, note book and pencils, 2 lb hammer. Transport was predominantly by foot, also using a bicycle and a rowing boat[II] - the horses[I] in the area being used only for ploughing and carting. The usually boggy ground was firm underfoot due to an exceptionally fine summer, save for the last two weeks spent in the area when some rain fell.

The topographical map covering the area published by the Norwegian Ordnance Survey at 1:100,000 was not amenable to great enlargment. Field maps could not be drawn up from the aerial photographs to include enough detail of the topographical and vegetation features for accurate positioning of the outcrops. Accordingly mapping was carried out using the aerial photographs with kodatrace overlays as field maps. No geological information save indication of alluvium was marked directly onto the overlays. In each case the position of the outcrop investigated was marked with a dot on the overlay (outcrops were usually too small and widely spaced to justify mapping in the boundaries of the outcrops), the dot was numbered and beside that number in the field note book was noted all the information presented by the outcrop. The overlays or "traces" were numbered with Roman numerals and outcrop numbering started with no. 1 for each overlay. This method of field mapping made for a faster covering of the ground and made mapping possible even during rainy weather.

Rock samples were collected, and 18 sections of these studied in London, both to illustrate typical and non-typical lithologies and structures. Over 700 outcrops were studied during a 6 weeks mapping period, and geological mapping was not confined merely to the area previously not mapped but was continued into the previously mapped areas for purposes of correlation.

In London a mosaic map or plan of roads and rivers was constructed from the aerial photographs at a scale of ≃ 1:17.000 (the scale of the aerial photographs used as field maps). Photographic distortion made construction of the mosaic difficult but the resulting map is considered sufficiently accurate for the plotting of the geological information gained. A copy of the map with the relevant geological information is submitted with this report.

It can be seen from the overlays that mapping was done by traverses rather than studying every exposure in the area. This was done for two reasons. Firstly the traverses followed lines of good exposure eg streams, lake sides, roads, tracks which cut down through the cover into the underlying rock - especially useful in forested areas, dry parts of plateaux etc. The exposure in the areas between the traverses was usually poor or non existant - this could be seen whilst doing the traverses. Secondly it made for rapid mapping of the large area undertaken.

Previous Work and Regional Correlation

As the main object of the mapping was to correlate the areas already mapped, it is neccessary to give a short account of previous work and note ~~th~~ especially the lithological sequences established by the previous workers. Table II summarises ~~previous~~ sequences established by previous workers and shows probable correlations with the area north of Gåsbakken and the sequence established there.

Th. Vogt The work of Th. Vogt, published in 1945 as above mentioned, in the low grade metamorphosed rocks of the Hølonda-Horg district to the east and north of the area north of Gåsbakken, established the stratigraphy of these rocks very firmly.

Vogt describes the Støren ~~Group as~~ Series as consisting primarilly of exceedingly thick effusive 'greenstone' lavas with pyroclastic material and some intercalated sedimentary horizons. He describes the Hove Slate (none of which was found in the area north of Gåsbakken) and the Jåren beds of the Jårengrenda as so intercalated. The effusive greenstones were described as including pillow lavas, red jasper beds up to 1m thick, some bands of shale only a few metres thick, and some breccias and conglomerates. The effusives which make up most of the Støren Series are described as typically basaltic but metamorphosed to contain much calcite, and some chlorite epidote albite, quartz, and titanite.

Overlying the Støren Series Vogt places the Hovin Series at the base of which he ~~finds~~ describes the Venna Conglomerate which includes inconsiderably rounded fragments of a characteristic calcite rich sandstone. The overlying Gaustadbakk Breccia consists mainly of fragments of Støren Greenstone up to a few cm. in size, fragments of red jasper, and of several sedimentaries.

The matrix is found to consist of sandstone grains, quartz and albite - this matrix also occurs as seperate beds within the breccia as well as beds of green sandstone and chocolate covered shale. The thickness varies abruptly.

The Hølonda Shales and Sandstones consist particularly of a typically unfoliated reddish purple mudstone & black grey shales. The latter show rusty stripes & dots after weathered grains of pyrrhotite. Thin sandstones were found to occur and the whole unit was found to vary from 50 m or less in thickness to ~~over~~ some 100^s metres

Vogt describes the Hølonda Limestone as fine grained and usually bluish grey in color but occasionally light grey to yellow grey. It contains some intercalated dark grey shale and varies in thickness down to only a few metres thick. The fossil fauna is varied but sparse - the trilobite evidence suggested to Vogt a Llanvirnian or Llandeilian age.

There has been some controversy over the origin of the Hølonda Porphyrites which Vogt considers to be extrusive and therefore in its correct stratigraphic position above the Hølonda Limestone. Vogt distinguishes 2 types of Porphyrite in the Hølonda Horg district. Firstly the Berg type which he considers to be a normal andesite with thick largely altered tabular crystals of plagioclase and some pyroxene in a very fine grained ground mass, secondly Vogt describes the Almås type which has more crowded plagioclase and pyroxene phenocrysts, and Vogt considers this to be intermediate between andesite and basalt in composition. The evidence Vogt describes for a probable extrusive origin for the porphyrites is mainly concerned with the lack of very much contact metamorphism and chilling, the pyroclastic layer often found just under the porphyrites, and chemical evidence. Vogt claims that on chemical evidence the Berg type could well be effusive but a similar origin for the Almås type was in doubt. He noted that all the porphyrites are found at the same horizon stratigraphically but that wedging out of the limestone complicates the picture.

Structurally Vogt shows the Støren and Hovin to be folded together very tightly, with the strike generally North East – South West. Vogts map shows the Høvin Series to the south east of the Støren outcrop lying between the Sårengrenda and the Bövra to be dipping steeply towards the North West. The Såren Beds on the other side of the Støren greenstone outcrop he shows to be dipping south east.

Carstens C.W. In 1952 Carstens C.W. published his map Kart over Løkkenfeltet which included the area south of the road from Gåsbakken towards Ø. the Orkla valley. The present mapping was extended into this area. He shows the rocks as belonging to the Bymark (synonym for Støren) and Høvin Series. From a study of the rocks in the area mapped by Carstens his general definitions of the lithology were obviously the same as those of Vogt. In 1951 in Løkkenfeltets Geologie – Carstens describes the area covered by the map and makes it clear that he considers the porphyrites to be intrusive.

Chadwick et.al. In 1962 (N.G.U. Yearbook) a paper titled The Geology of the Fjeldheim – Gåsbakken Area was published by 4 students of Imperial College. The paper described an area south of lake Sverksjøen including both Støren and Høvin series rocks. The sequences they established are broadly similar to those established by Vogt in the Holonda Horg district, but rapid facies changes both vertically & horizontally made detailed correlations difficult.

The Støren Series of Chadwick et.al. is essentially the same as that of Vogt.

Chadwick et.al. considered the Hovin Series in the Fjeldheim - Gåsbakken area as 3 main groups, the Fjeldheim Conglomerate at the base, followed by the Fjeldheim Beds, followed by the Nyplassen Beds.

The Fjeldheim Conglomerate was found to consist mainly of water worn boulders of Støren Series rocks.

The Fjeldheim Beds were described as very variable, generally greenish or grey in color & mainly various shales, sandstones, grits, conglomerates, breccias, & limestones. The beds are very tuffaceous. Some of the shales show "rust marks".

The Nyplassen Beds ~~were~~ are predominantly grey silty shale with brown alteration specks lying on cleavage planes.

Chadwick et.al. believe the porphyrites to be sill like bodies although they agree with Vogt on the lack of much contact metamorphism usually, & general absence of chilled margins. But in a few places they find chilled, and even glassy margins, & also veining of the porphyrite into the country rock. They comment on the probable pyroclastic nature of the fragments of porphyrite in the limestone under the porphyrite.

Prof. Strand comments in the paper that the porphyrites may represent a subvolcanic episode during the deposition of the Fjeldheim Beds.

The area north of Gåsbakken

A general statement of the stratigraphy of the rocks cropping out in the area north of Gåsbakken is neccesary in order to outline the definitions of the names used and to show how these major named series correlate with the major named series of Vogt, Carstens, and Chadwick et.al.

The oldest rocks in the area (from structural evidence) are the basic effusives termed "greenstones" by previous workers. The present investigator followed the greenstones along the strike into the map areas of Vogt and Carstens where these were defined as Støren Series. A study in the field of Carstens' mapped boundary between the Støren and Høvin Series west of Sverksjoen was carried out to establish this boundary for the area north of Gåsbakken There being no fossils discovered the boundary had to be fixed on lithological evidence only. The boundary as marked on Carstens map was found to be straddled with a thick conglomeratic series. Previous workers appear to have fixed the actual boundary between the Støren and Høvin Series at different levels in this conglomeratic series — which almost invariably occurs between horizons definitely ascribed to Støren or Høvin Series respectively. The present investigator regards the exact fixing of this boundary as a true "time plane" as impracticable as no fossils are found and as most conglomerates are, by their nature, diachronous. Never-the-less, the difference is very noticeable between the basic Støren greenstone volcanics, and the sedimentary rocks above. Accordingly this lithological boundary is that used by the present investigator as the Støren/Høvin Series boundary by the present investigator in the area north of Gåsbakken.

The Høvin Series in which the present investigator includes the above mentioned conglomerate as well as all the horizons stratigraphically above include also grits, tuffs, sandstones, shales, and limestones. Any one ~~broad~~ major lithological unit may extend along its' strike over the whole area, and these correlate very well with units of the standard Høvin Series as established by Vogt in the Hølonda area, and also correlate well with the sequence established in the Fjeldheim – Gåsbakken area by Chadwick et.al. However, individual rock bands of any lithological type may disappear along the strike, probably due in most cases to facies change laterally. Individual bands are also very difficult to follow because of the poor exposure.

The stratigraphical position of the Porphyrites, as above mentioned, is much in dispute, but structurally they lie near the top of that part of the Høvin Series represented in the area, and are considered with the Høvin Series. The top of the Høvin Series is not seen in the area north of Gåsbakken and correlations with Vogt suggest that all the rocks in this area are of Lower Høvin age.

The standard Høvin Series established by Vogt in the Hølonda area (the south western portion of the Hølonda-Horg district) is given in Table I. Correlations (probable) between this established statigraphy, & that of Chadwick et.al., and the sequence established in the area north of Gåsbakken, are shown in Table II.

Having made a general statement upon the stratigraphy of the rocks cropping out in the area north of Gåsbakken and having defined the major Series in both ~~the~~ terms of both lithology and regional correlation, a detailed survey of these Series and subdivisions thereof will be made. The survey will start with the oldest rocks – the Støren Series.

The Støren Series

The Støren Series rocks occuring in the area can by defined as those rocks lying below the thick conglomeratic sequence, which lies between definite Støren and Høvin Series rocks (ie rocks assigned to the same series by all previous workers), in most places. The conglomerate is therefore assigned to the Høvin series in all cases in the area north of Gårbakken. In most cases the conglomerates or other Høvin Series rocks appear to lie directly upon the effusive greenstone lavas of the Støren Series, but the actual contact is never exposed. However, in the Støren Series outcrop shown on the map west and south of Sverksjøen, non effusive rocks occur between the top of the effusive greenstones and the conglomeratic sequence above - these non effusive Støren rocks will be discussed below in more detail. The true relationship of the Jåren beds (as defined by Vogt) to the effusive greenstones will also be discussed.

?|

Firstly it will be useful to describe the effusive greenstone inliers that are directly overlain, or appear to be directly overlain, by rocks of the Høvin Series.

In the north east of the map area at Krokstad* Saetar a large inlier of lavas occurs - this is in direct continuation with the 'Lower Støren Greenstone' outcrop shown in the far west of Vogt's map area. The lavas are typically epidote rich from secondary alteration, giving the characteristic green color, no structures or statification by composition were noticeable. A characteristic tuff layer was found to outcrop just inside the south eastern boundary of the outcrop. Wheras the western boundary of the inlier is not accurately determinable due to paucity of outcrop, the south eastern boundary is well marked. Although no direct contact is seen, a distance of only some 20m. seperates

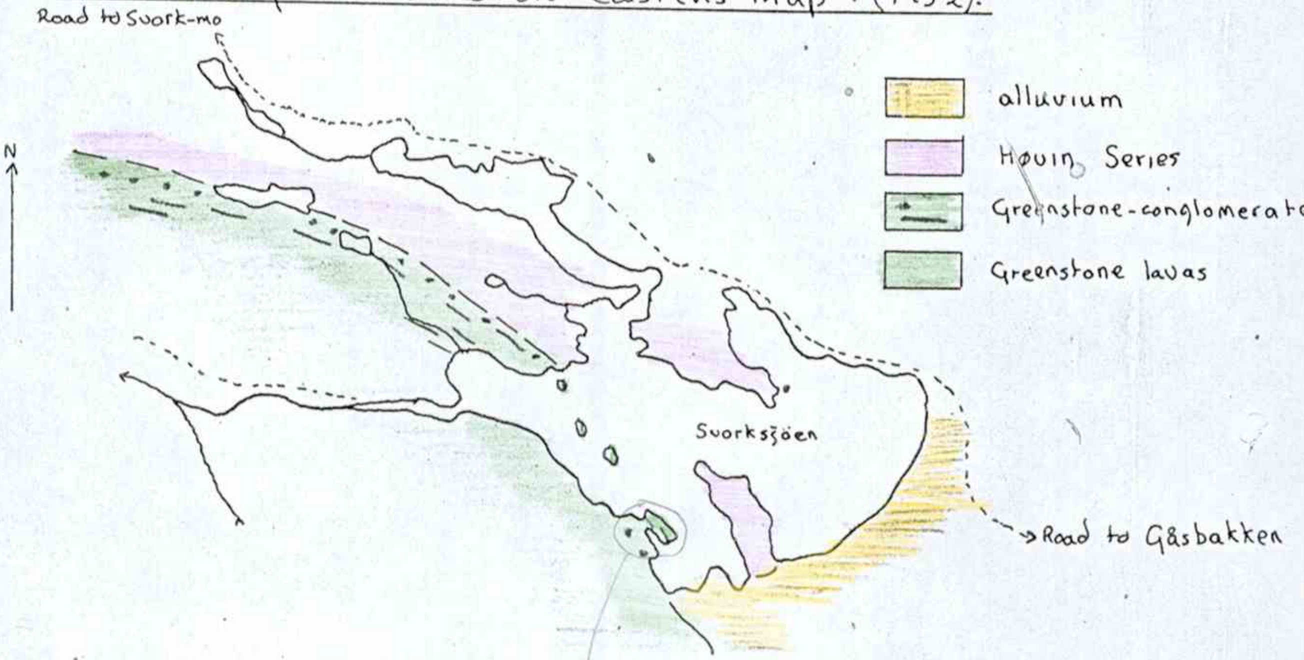
*for Krokstad read Konstad in all of report.

outcrops of definite greenstone and typical conglomerate respectively. The inlier reaches a maximum width of approximately 1-km. in the area and, from structure in the surrounding Høvin sedimentary rocks shown on the map, probably represents the core of a tightly folded anticline, with the western limb inverted, and the axis plunging gently to the south west.

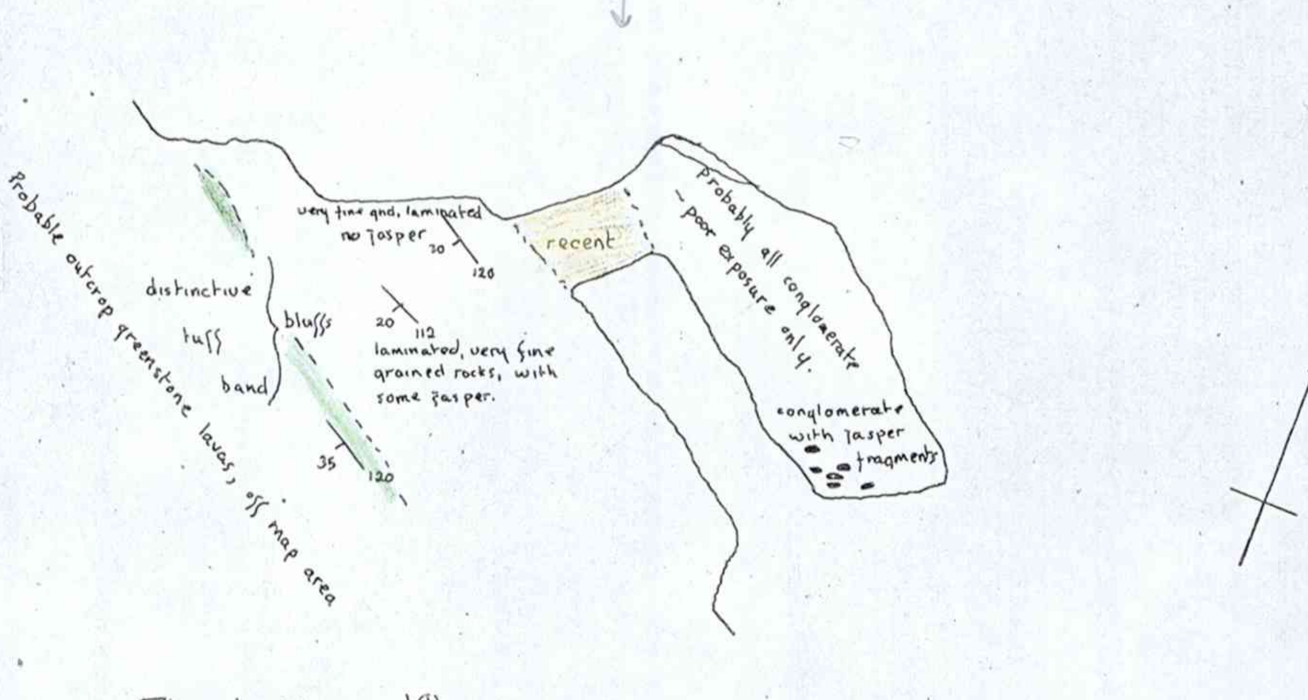
To the North of Snotonud in the north west of the map area a small inlier of typical greenstone lav occurs. This is never seen in direct contact with the Hørvin Series but the conglomerate, in one outcrop at the ~~western~~ end of Snotonud and south of the inlier, is seen to be resting, with no apparent unconformity, on green shales. These shales could be lying between the lavas and the conglomerates - or may only represent a thin band of which the bottom is not seen, and which is normally interstratified in the conglomeratic sequence. Similarly to the outcrop of the green stone lavas around Krokstad Saetar, mentioned above, the inlier appears to be the core of an anticline, the nose of which is well shown by nearly horizontal Hørvin Series shales to the immediate west of the inlier at Korsliën. The inlier would appear to be plunging gently to the west, from its probable outcrop shape, however in this western part of the map area, in which the inlier is situated, minor structures such as minor fold axes and rodding parallel to these axes indicate a general gentle plunge to the east. This is indicated on the map.

As noted in the general statement of the stratigraphy of the area, the boundary between the Støren and Høvin series shown on Carstens 1952 map, to the west and south west of Sverksjoen was examined to establish a lithological boundary to be used in establishing the boundary between these Series throughout the area. A detailed study of the boundary as it occurs on a portion of the south western shore of Svertksjöen will be given below, as will an account of this boundary along its strike to the north west.

The Boundary as marked on Carstens map. (1952).



Geology of Part of the south west shore of Svorksjöen (of present investigator)



The tuff band[1] shown, ~~which~~ is very distinctive and outcrops in other parts of the area, as at Krokstad Seatar where it has allready been mentioned, and in the area north west of Svertksjöen which will be discussed below. The tuff consists of large idiomorphic crystals, up to 5mm long, of felspar and quartz in a fine grained matrix mainly of

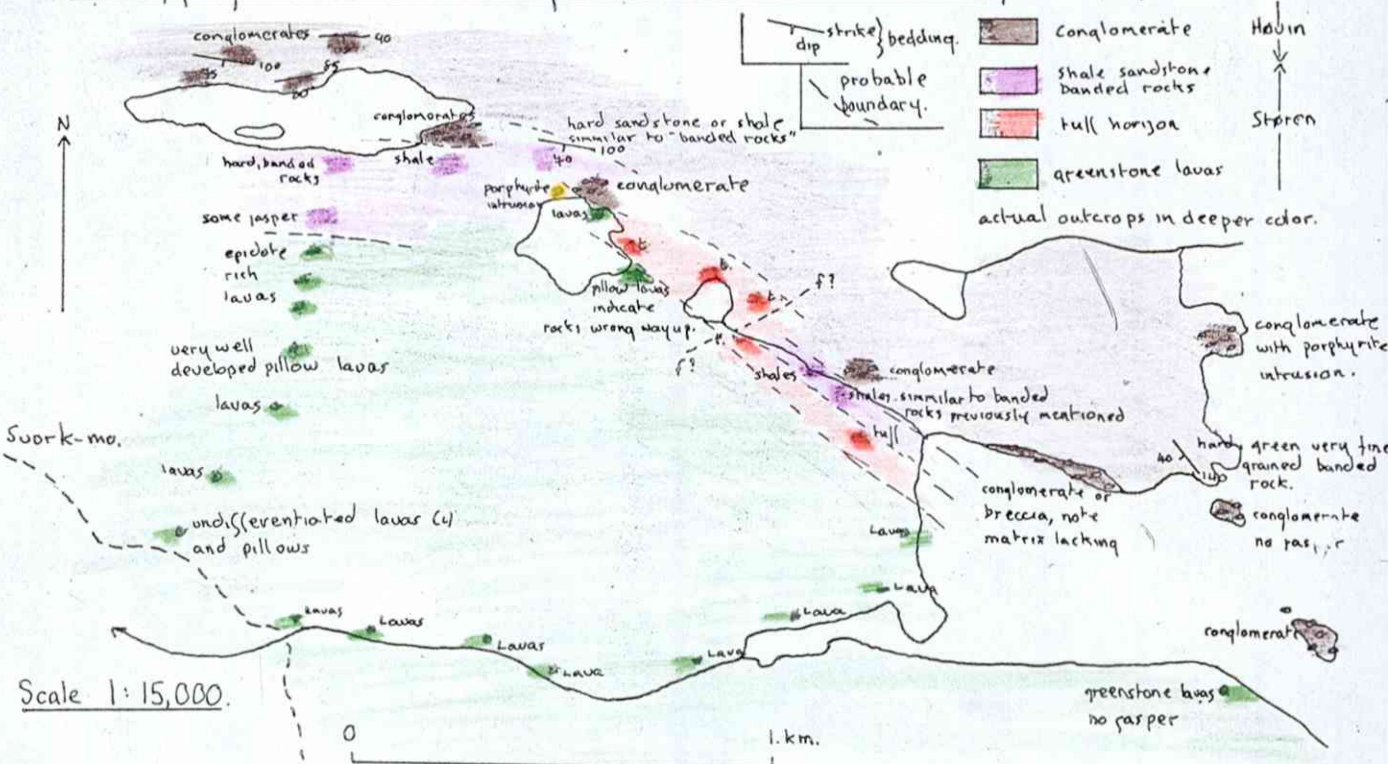
(1) etc. - drawings appendix A.

white mica, which is probably a secondary alteration product after fine grained felspar. ^(lime and felspar)^ Chlorite has developed in cracks and around the edges of the idiomorphic crystals. The band is variable in composition, having only scattered idiomorphic crystals in some outcrops, but being predominantly composed of these crystals in other outcrops. The ~~top~~ bottom of the tuff band was not seen in this part of the area but a short investigation inland would certainly have revealed the bottom, and the greenstone lavas below.

The laminated fine grained beds which lie stratigraphically above the distinctive tuff band (n.b all the beds here are inverted) are probably predominantly sedimentary but could in part be laminated lava flows, though this is more doubtful, heavy alteration of the rocks makes this difficult to decide.

The isthmus between the peninsula which is orientated parallel to the shore, and the shore or mainland itself, is of very recent sediments rarely reaching more than 1m. high above lake level. The only outcrops on this peninsula are of conglomerate including jasper fragments. The conglomerate includes much greenstone material and the ragged edges of many of the jasper fragments probably result from the original position of the jasper as the matrix in-between the pillow lavas of the Støren greenstones – rather than from brecciation. This conglomerate is identical with the conglomerates which make up the three small islands arranged parallel to the south west shore and the general strike of the rocks. The three islands and the peninsula described above are all shown to be Støren on Carstens 1952 map. The only difference the present investigator could find between these conglomerate outcrops, and those further to the north east – acknowledged to be Høvin Series by Carstens, was the lack of rounding of ^(some of)^ the jasper fragments, though even in the conglomerate outcrops just discussed many of the jasper fragments are rounded - sometimes well rounded. The present investigator does not consider this difference to justify the placing of the boundary between the Støren and Høvin Series, between these conglomerates. The conglomerates discussed, of greenstone material, clearly indicate the ending of the Støren greenstone volcanic episode ~~and +~~ with uplift, and the beginning of the Høvin sedimentary episode. As the conglomerate represents the probable uplift, the boundary can best be placed underneath this, including the laminated fine grained rocks and tuff band only in the Støren Series.

Geology of an area including the north west shore of Svorksjöen



The above map is very much self explanatory. Between the main greenstone lava and the main Høvin conglomerate lie two other horizons. The tuff band, seen to be about 50 m thick but probably variable is identical in type with the tuff found in the area described on the south western shore of Svorksjöen. The rock between the tuff horizon and the conglomerate, variable between 50 m & several hundred metres in thickness, is similar to the banded rocks mentioned as occuring between the tuff and the conglomerate on the south western shore of Svorksjöen. The boundary is not constant and probably affected by faulting.

Under the tuff horizon there is a thick sequence of lavas, the bottom of which is not seen in the area. The lavas are epidote rich basic lavas and include both undifferentiated massive, and pillow varieties.(2) The areas in which good development of pillow lavas can be seen are shown on the map above, pillow lavas are not seen in any of the other Støren Series inliers in the area north of Gåsbakken. The pillows have an epidote rich rim situated just inside the surface, this rim or shell occupies the centre of some of the smaller pillows. Due to the sagging into earlier pillows of later ones (more plastic) the characteristic "V"-ing developes giving excellent younging data which show the Støren rocks of this area west of Svorksjöen to be inverted. The pillows lie in an apparently amorphous or cryptocrystalline quartz matrix, termed jasper by all previous workers on account of its' red color.

The areas of Støren Series rocks described above are the only out crops of this Series in the area mapped by the present investigator. However it is neccessary to examine those areas of rocks in the area which have been assigned to the Støren Series by previous workers, (see correlation map), and are thought not to belong to the Støren Series by the present investigator. The beds in question are the Jåren Beds as described by Vogt which crop out in the Jårengrenda in the north east of the map area (and the extreme west of Vogts map area); and also the Støren greenstone (& also the Røros Group schists - the next beds below the Støren Series) shown on Carstens 1952 map to crop out just south of the road from Gåsbakken and Rektorli to Svork-mo in the north west of the area.

Firstly the so called Jåren Beds - the major Støren greenstone inlier mapped by Vogt which crops out just to the east of the map area was examined by the present investigator whilst traversing over Vogt's Upper Greenstone - Jåren Beds - Lower Greenstone supposed succession along a section through Klegstad. The sedimentary Jåren Beds which lie, geographically, between the greenstone inlier just to the east of the map area (Upper Greenstone of Vogt) and the greenstone inlier described above situated at Krokstad Saetar, were thought by Vogt to be normally intercalated in the greenstones unless major thrusting were to be inferred. The present investigator suggests that the Jåren Beds are in fact Lower Høvin Series sediments and lavas lying in a syncline between the Støren greenstone inliers. The map of the whole area shows how these beds are in fact a synclinal branch of the larger Høvin series outcrop to the southwest. The sections shown in Fig I illustrate Vogts explanation of the so called Jåren Beds and show how, with new evidence produced by the present investigator, the 'Jåren Beds' are in fact Høvin Series. As mentioned above in the description of the Støren greenstone inlier round Krokstad Saetar a conglomerate was found to lie just above the greenstone - this conglomerate was not found by Vogt. Also the Porphyrites, which Vogt regarded primarily as normally interbedded lava flows in the Høvin Series - and therebye a lithological "index fossil" for the Series, are found occupying the core of the syncline in the south western portion of the syncline. Unfortunately the Porphyrite outcrop wedges out along the strike of the syncline 1 km south west of Klegstad on the border of Vogt's map area.

The outcrops shown by Carstens 1952 map, in the north east of the area, of Støren and Røros Series rocks were found to be completely fictitious - the area in which they are supposed to outcrop is all definitely Hovin Series. The Porphyrites crop out in the supposed area of the thin Støren greenstone band. In the supposed Røros area, ~~chlorite~~ biot schists and amphibole growth in tuffs and/or sandstones of the Høvin Series are found. These will be described below.

The Hovin Series

The Høvin Series which overlies the Støren Series is represented in the area mapped by four main sequences of strata which for convenience may be termed the Lower Arenaceous Sequence, the Limestone and Shale Sequence, the Porphyrites, and the Upper Arenaceous Sequence. These names are strictly for local use only in the area under consideration and are not being put forward as alternatives for the many names that have allready been given for the rocks of the Lower Hovin Series in the adjacent areas by previous workers. The outcrop of the Hovin Series is continuous - the Støren Series rocks occuring only as inliers in the area mapped.

Lower Arenaceous Sequence

This sequence is made up of conglomerates[(3), III], grits[(4)], sandstones[(5) VIII], and tuffaceous material with very local developements of limestone and shale. The sequence thins from circa 600 m. by Langsjøen to circa 300 m. in the Jårengrenda.

The pebbles of the conglomerates are usually scattered and rarely in contact whith each other; the matrix is usually poorly sorted. Poor sorting is a general feature of the Lower Arenaceous Sequence and in one outcrop alone grain size may vary from cobbles and grits to argillaceous bands. Overall it can be said that the beds become coarser downwards. The pebbles in the conglomerates are usually jasper, and also pebbles of a green fine grained probably volcanic rock - similar pebbles were said by Chadwick et. al. (1962) to be derived from the Støren greenstones. The jasper fragments range in size up to blocks almost a metre in diameter in the conglomerate exposed in road cuttings along the northern shore of Svorksjøen, and the jasper fragments are often less well rounded than the well rounded pebbles derived from the greenstones.

There is some mystery as to the origin of the jasper fragments in the conglomerate. The exposed greenstones in the area do not have jasper in very great quantities or as large aggregates – and a great number of jasper fragments, sometimes of large size as described above, occur in the conglomerate. However Vogt describes beds up to 1m thick of jasper in the Hølonda-Horg district – and such beds when eroded would supply the conglomerates with the large blocks which do occur. Also the jasper would survive erosion better than the greenstone lavas and thus become concentrated in the conglomerates.

The beds of the Lower Arenaceous Sequence sometimes show good sedimentary structures which provide excellent younging data.(6) An outcrop on the southern shore of Morsjoen in the north of the area shows a sharply bottom contact of a layer of pebbles lying on fine sandstones – but the layer grades upwards gradually through grits with scattered pebbles, into sandstones, over a distance at right angles to the bedding of 2 metres. In cliffs in the valley north of Sjomoen there occur what appear to be turbidite units 30 cm. thick with gritty bases and shaly tops – examples of load casting of arenaceous beds into shaly beds occur nearby. False bedding is shown in an outcrop on the hill just west of Sundet.

A large outcrop of rocks of the Lower Arenaceous Sequence is brought to the surface by the northern limb of the syncline which runs from Bouerdals-haugen in the west of the area to Kleqstad in the north east – the core of which is occupied by the Porphyrites. The large area of this outcrop, an area containing Rektorli Snoton and Morsjoen, is probably due to many fold axes[IV] which repeatedly bring it to the surface.

These fold axes are indicated by the minor folding(?) shown in some exposures and by the Støren greenstone inliers. These rocks are essentially similar to the rocks of the southern limb of the syncline, ie they are composed mostly of conglomerates, grits, sandstones and arkoses, and tuffaceous material. However lime nodules occur along bedding planes and thin beds of limestone or marble, rarely more than 10 m thick, also are exposed. The conglomerates are of less importance and a grit with pale green grains scattered in a finer grained matrix is very common. Shale horizons occur which are very similar in lithology to the shales of the Limestone and Shale Sequence described below, these shale horizons appear locally to be fairly thick but wedge out rapidly, presumably due to facies change. Poor exposure throughout this northern outcrop of the Lower Arenaceous Sequence makes the following of any one limestone or shale band impossible.

The rocks in the fault block to the immediate south of Morsjøen are predominantly conglomeratic, steeply dipping, and of great thickness unless they have undergone intense folding. No evidence for folding was found in these rocks. The conglomerates include very few sandstone and shale horizons, and the age of the rocks in this fault block cannot be determined as the top and bottom are not seen. The rocks are however lithologically very similar to the conglomerates of the lower arenaceous, but some of the pebbles are very similar to the grit with scattered pale green grains described above.

The exposures of the Lower Arenaceous Sequence along the road by Blokkan and Estenstad in the Jårengrenda are of a very hard, pebble free, occasionally gritty, grey green sandstone. This also occurs in the hills to the south east arround Trotland.

The continuation of this outcrop to the north east at Restad shows a more typical slightly schistose conglomerate with scattered pebbles, containing also some lime nodules.

The sandstones mentioned above throughout the Lower Arenaceous Sequence outcrops are predominantly arkosic, the mineral grains include a wide range of minerals and rock fragments but quartz and alkali felspar grains predominate. Heavy minerals also are common sedimentary constituents, and in fact some of these rocks could be water lain tuffs, however it is often difficult to distinquish what could be water lain tuffs from arkosic sandstones formed from rapidly eroding greenstone material.

Many conglomerates occur in the area and they appear usually to be local developments and it would be incorrect to attach any of the proposed names for the various conglomerates of the Lower Hovin series in adjacent areas to the conglomerates exposed in the area.

Limestone and Shale Sequence

It is convenient to take together the limestones and shales which lie above the Lower Arenaceous Sequence, as their outcrops suggest that they are local developments within the same general horizon. The Sequence varies in thickness from over 300m in the Jårengrenda to nil in the extreme west. The Sequence outcrops on the southern limb of the syncline from Boverdalshaugen to Restad, on both eastern and western limbs of the syncline through Konstadlökken, and in the hills immediately to the north of Gåsbakken.

The limestones[x] develope locally at or near the top and bottom of the Sequence and sometimes continue along the strike for quite considerable distances. The limestones can be white, grey, or black, always recrystallised, and coarse or fine grained depending on the ammount of re-crystallization. It is therefore difficult to ascertain their original form of deposition, although recognisable reef breccias sometimes occur, for instance in exposures between Konstadlokken and Blokkan. The limestones also often contain "ruckled bands" of arenaceous material - fairly fine grained - which are usually 1-3 mm thick. The ruckled bands are probably sedimentary features and illustrate well the plastic deformation of the limestones.

The shales are predominantly grey and sometimes green in color. Inclusions or flecks of a weathered iron mineral, said by Vogt to be pyrrhotite when describing similar shales in the Hølonda-Horg district, often occur. Occasional sandy bands indicate the bedding and the shales also sometimes contain lime nodules. In most exposures of the shale it is impossible to tell whether the foliation which is always seen is a sedimentary feature or a tectonic feature. However when the bedding can definitely be seen the foliation is seen to be parallel to the bedding. Minor folding is often well shown by the shales and a lineation is sometimes seen parallel to the fold axis, the mica flakes of the shales of a few exposures have undergone "strain-slip" or "herring bone" cleavage and one exposure shows the interference pattern of two fold axial directions.(8) By and large the shales appear to have undergone only low grade metamorphism and well cleaved slates have not been produced.

The Porphyrites

It is convenient to deal with the Porphyrites here as they occur, at least structurally, above the Limestone-Shale Sequence and below the Upper Arenaceous Sequence. The Porphyrites occur for the most part, as a single sheet varying from a maximum of circa 300m thick arround Konstadlökken to nil near Klegstad. They occupy the cores of the syncline from Boverdalshaugen in the west towards Kleqstad in the north east, and the syncline through Konstad lökken. Porphyrites also outcrop in the hills to the immediate north of Gåsbakken.

The two pioneer workers in adjacent areas, Carstens C.W, and Th. Vogt, clearly disagreed as to the stratigraphical relationships of the porphyrites to the surrounding rocks. The former worker regarded them as intrusive and probably discordant in most cases, the latter regarded them as lavas normally interbedded in the Hovin Series. Vogt even subdivided the porphyrites stratigraphically into Alnås and Berg types, but he acknowledged a discordant intrusive nature for a minority of the outcrops. Chadwick et al. considered them to be mainly concordant intrusions. The present investigator considers the problem not solved and notes:-

(a) the Porphyrites contain no phenocrysts in the bottom 2-3 cms of the outcrop in exposures at Boverdalshaugen and Konstadlökken:

(b) the phenocrysts are dragged out along the base of the contact in the possible flow direction, near Konstadlökken[a]:

(c) in places the limestone underlying the Porphyrite veins into surrounding shales, for example good veining is seen at the tip of Ramsberget - a peninsula jutting out into Svorksjöen. This could have been due to heating of the limestone:

(d) Half a kilometer north of Gåsbakken just south of the nearbye lake, a wedge of limestone about 2m. thick, is included within the Porphyrite. From the basal contact of the wedge, branching veins of coarser grained calcite cut through the ruckled arenaceous bands and finer grained limestone - suggesting infilling of cracks produced during contact metamorphism, by $CaCO_3$ rich liquids.[b]

(e) no typical lava flow features were noted.

All the above data suggest an intrusive origin for the Porphyrites but there are two lines of evidence which suggest an extrusive origin for the Porphyrites:-

(f) in the area mapped the limestones and shales in contact show little or no contact metamorphism. Pronounced baking of the shales and great recrystallisation of the limestone could be expected near the contact of a sill which is some 300m at its maximum thickness.

(9) There is often a prominent pyroclastic layer[(x) XI] found just underneath the porphyrite. This layer is found in exposures near the farms Engan and Konstad løkken and near the lake Blokketj and elsewhere. The layer contains blocks of the underlying limestone, and typically twisted bombs of porphyrite, all in a matrix of indefinite composition but which is often calcareous. The bombs can scarcely have been formed underground - displaying as they do the indications of flight.

Unfortunately, due to poor exposure, in the area mapped the top of the Porphyrites is never seen directly in contact with the overlying sandstones - However from the map it can be seen that the Porphyrites are fairly consistent concordant sheets lying between the Limestone Shale Sequence and the Upper Arenaceous Sequence above.

UPPER ARENACEOUS SEQUENCE

The Upper Arenaceous Sequence forms a continuous outcrop from Restad in the north east of the map area extending south westerly along the strike down the Jårengrenda until they are cut off by the major fault south of Morsjoen. Thes Sequence is equivalent to the Restadgrotås sandstones of Vogts Jåren Beds. A green-white exposure surface is given by the beds, the material of which is better sorted than that of the Lower Arenaceous Sequence beds. They form fine grits, sandstones, and some shaly bands. The Sequence is about 115 m thick with the top not seen.

The rock of the Lower Arenaceous Sequence are the youngest pre-Quaternary rocks cropping out in the area

Intrusive Rocks

The only intrusive rocks that crop out in the area are of porphyrite – very similar in make up to the porphyrite of the large sheets. Definite discordant intrusion of porphyrite occur in the Støren and Hovin Series rocks. Outcrops occur:-

(a) South of Langkjøs in the west of the map area, by the side of the small lake immediately to the south of Langkjøs. The porphyrite intrudes Støren Series rocks but no pronounced baking was seen.

(b) South of Langkjøst, also in the west of the map area, near the shore of Langkjøst, porphyrite is seen to intrude Hovin Series conglomerates.

(c) A porphyrite dyke intrudes the Lower Hovin Series conglomerates which are exposed by the lake side of Svörksjöen – on the western shore, just north of the boundary between the Støren and Hovin Series. The dyke exposure is shown on the map. The porphyrite contains some of the rounded pebbles from the conglomerate which it intrudes.

In none of these instances was baking of the country rock obvious, but the rocks into which they were intruded, being coarse arenaceous sediments, would be unlikely to show the effects of great heat transfer. These dykes could have been feeders for the Porphyrite sheets above.

Before giving an account of the youngest sediments in the area, it will be useful to consider the major structures which affect the Lower Palaeozoic rocks described above.

STRUCTURE OF THE AREA

The rocks of the area are affected by folding and faulting.

Folding

The major fold directions in the area are not constant in strike and probably result from the interaction of two fold phases, accordingly for a clearer understanding of the folding the area will be subdivided and the structures will be considered in each of these smaller areas.

The areas to be considered will be:-

ⓐ the North Western Area - this consists of all the land west of a north-south line drawn through Sundet, excluding the land to the south of an east-west line drawn through Sundet and Langkjos. This area therefore includes Langkjosen, Rektorli, and Snoton:

ⓑ a North Eastern Area which will include all the land north west of the fault block just south of Morsjoen; Morsjoen itself, Konstad Saetar, and the Jarengrenda are all situated in this area:

ⓒ a Central Area including Svorksjoen, Konstadlokken, and Blokkerj, and:

ⓓ a South Eastern Area including the hills immediately north of Gasbakken.

All these areas are outlined on the trend map submitted with this Report. The minor structures such as minor fold axes, sedimentary structures giving younging data, lineation directions, and bedding are all shown on the main geological map. General conclusions will be drawn from a complete view of the structures of the whole area and relevant work by previous workers in adjacent areas will be noted.

North Western Area

The major folding in the North Western Area is fairly simple having been formed by only one phase of folding, but minor folds and shearing(12) have been produced in a few places by a second phase of folding. The discovery of all the probably existing major fold axes was not possible due to the poor exposure - only when a lithological change occurs are the fold limbs well shown. This is true of the major syncline running through Bouerdals-haugen which has a core of the Limestone and Shale Sequence and the Porphyrites, and it is true of the anticline just north of Snotonud which brings Støren greenstone to the surface.

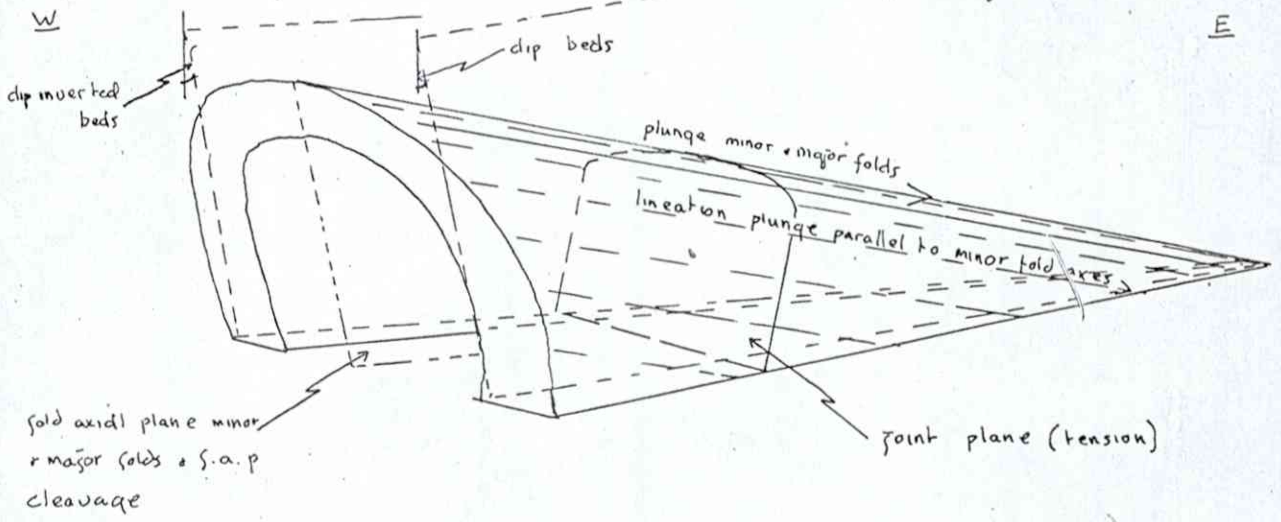
The major structures trend east-west and most of the bedding planes dip steeply to the south, only about 20% of the readings taken showed the beds to be dipping north-wards. Unless the whole of the area is occupied by one limb of a great fold, which is unlikely because lithological evidence shows at least one major syncline and minor folds(13) suggest many more, the folds must be tightly folded with one limb usually overturned.

Minor structures such as minor folding, rodding and lineations, tension gashes and open joints, and shear zones, are better seen in this area than elsewhere in the map area. The evidence of the minor structures confirms the stratigra-phical or lithological, and bedding plane orientation evidence, for major folding striking east-west.

The axes of the minor folds, which were best developed in the shales of the Lower Arenaceous Sequence and of the Limestone and Shale Sequence, plunge on average at 10° towards 85°N. The majority of the axes measured (i.e. 17 out of 23) plunge at between 0° and 20° towards between 66°N and 110°N.

The rodding which was well developed in the sandstones and the lineations which were well developed in some of the finer rocks, plunge down the bedding surface at 20° towards 90°N on average. The majority (that is 17 out of 22 readings taken, 4 of the five remaining plunges were fairly similar) plunge at between 0° and 30° towards between 75°N and 100°N.

In three exposures both lineations and fold axes were seen together and the lineations were seen to be parallel to the fold-axes.[3] In one exposure the lineation was seen definitely to go over the fold axis, but only at a slight angle to the axis.[4] In fact the lineations and rodding are rather more constant in plunge over the area than the fold axes. Both appear to have been formed by the same movements but, to account for slight differences between orientations, the lineations may possibly have been formed ~~by~~ slightly earlier.



Diagrammatic representation of folding etc. in Western Area

When plotted on a stereogram the π poles to the axial planes of the folds appear to lie on a great circle, the pole of which plunges approximately 10° towards 80°N. This indicates that the line common to all the axial planes corresponds to the average fold axis orientation shown by the minor folds and lineations. The axial planes, of which 12 were measured, vary in dip from vertical to nearly horizontal, this suggests possibly a very wide fanning of the axial planes. A second phase of folding with a similar orientation to the phase which produced the minor folds could be inferred, but there is no other evidence to suggest this.

The joint planes, open joints & tension gashes[iii] commonly dip very steeply towards the west but they have a very wide range of strike orientations from 150°N to 215°N. This is a wider range of strikes than the range of plunge directions of the minor folds. The mean of the π poles to the joint planes plunges at 5° to 100°N which is very close to the mean plunges of the minor folds and the lineations. The poles to the joint planes being, in most cases, the stretching or movement direction, there may be some connection between the production of the joint planes and the formation of the folds. It may be that the joints represent extension along the fold axes in the final stages of the folding. The wide range of strikes could be due to a fold axis plunging at 80° towards 280°N, as the poles to the joint planes appear to lie on or near a great circle, the pole of which would be the fold axis mentioned. However no other evidence for this possibility, which presupposes an identical orientation for all the joint planes before "folding", was found. The wide range of strike orientations of the joints & tension cracks is most likely connected with the fairly wide range of orientations or directions of plunge of the minor axes.

In one exposure to the east of Rortz, minor folding of the same orientation as to what is thought to be second phase folding in other parts of the map area, is seen with the axial plane dipping at 57 to 255°N with a strike of 165°N.

Just north of the western end of Langtjosen in a road cutting a shear zone approximately 3 cm wide is seen to affect the rodding in the sandstone.[ix] The shear plane strikes at 5°N and dips at 80° towards the west. A similar shear zone affecting bedding planes in sandstone occurs in an exposure a little to the west of the above mentioned exposure. The shear zone plane strikes at 15°N and dips at 85° to the west. The shear zones obviously postdate the first fold phase as they affect f1 structures, they may be related to the major f2 folding which will be described below.

North Eastern Area

All the beds in this area strike NE-SW. The vast majority of the bedding plane readings taken show the beds to be dipping on average 50° towards the south east, within a very wide range of orientations. (see stereogram on North Eastern Area). The axial planes of the minor folds (3 readings) dip, on average 52° to the south east. The mean plunge of the lineations shown in the rocks at the west end of Morsjoen is 30° towards 56°N. When plotted on a stereogram these lineations are seen to lie close to the mean of the axial planes of the minor folds measured. It is improbable that such a high plunge of the lineations, which are seen to be parallel to the axis of an minor fold, to the north east is constant over the area. The outcrop shape (such as it can be determined) of the Støren greenstone inlier suggests the plunge to be in the opposite direction in the central and eastern part of this area.

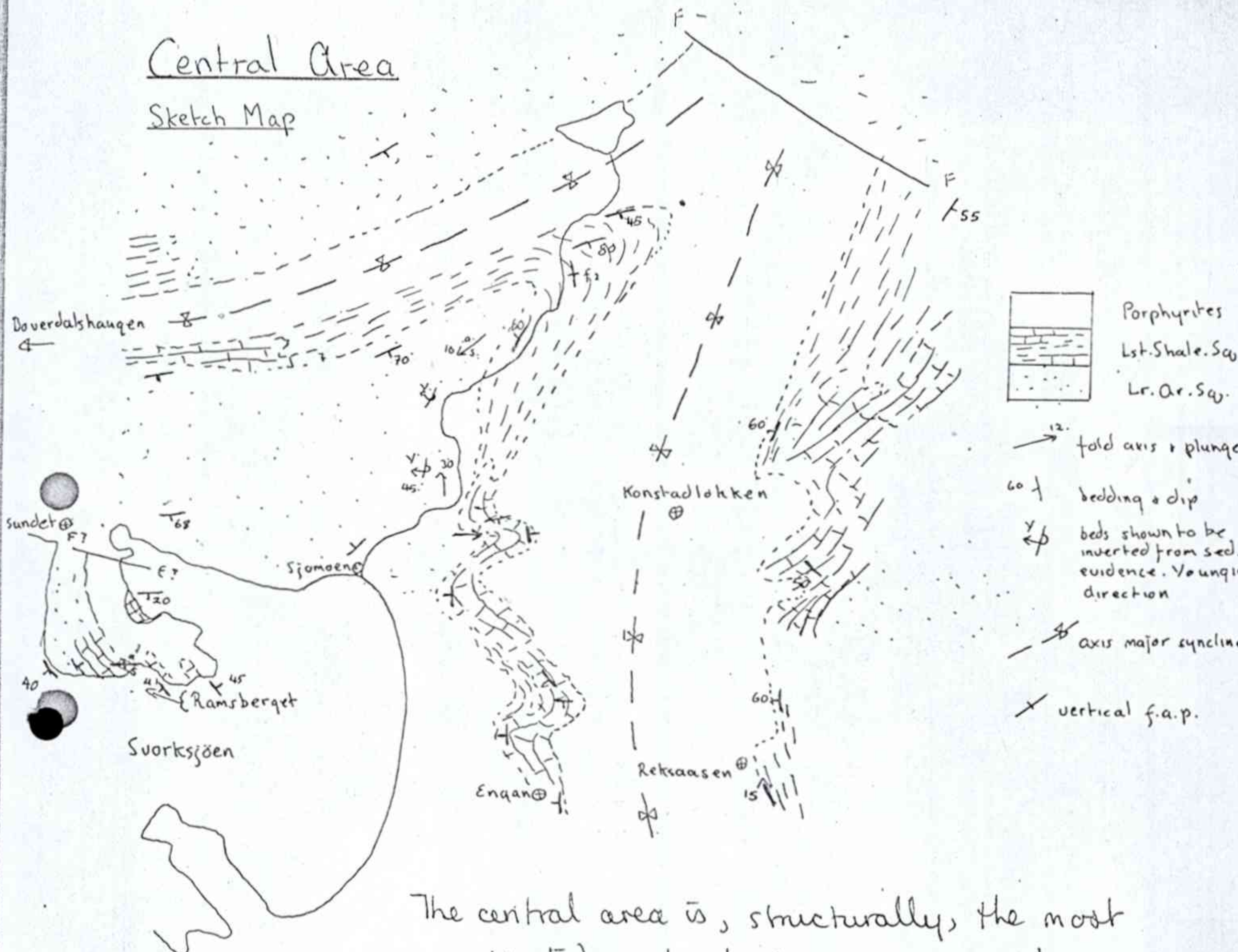
At one place on the northern shore of the eastern tip of Morsjoen a good axial plane cleavage is developed, striking 52°N and dipping 61° to the south east. The grit bands are isoclinally folded about the cleavage.(15)

The fold axial plane of a minor fold seen in an exposure in the Jårengrenda which strikes at 140°N and dips 50° towards the south west folds grey shales in a very open but very brittle fold. This folding may be related to a second phase of folding.

The major structures seen are the anticlinal axis plunging gently south west which brings Støren greenstones to the surface at Konstad Saetar & the syncline through the Jårengrenda which has a core of Porphyrites and the Upper Arenaceous Sequence. From bedding plane orientation the major structures appear to have the same fold axial plane orientation as the minor folding mentioned above. The folds must therefore have one limb overturned (from bedding.).

Central Area

Sketch Map



The central area is, structurally, the most complicated part of the area mapped. The major structures are oriented in two different directions and probably are due to two different fold phases. The poor exposure however makes a detailed study impossible, but such evidence as exists for two fold phases will be presented below.

Firstly the evidence presented by the bedding plane ~~evider~~ orientation and also stratigraphic evidence. There is a syncline striking through Konstad lokken in a roughly north - south direction, with a core of Porphyrites and Limestone Shale Sequence. This syncline may well link up with the syncline striking through Boverdalshaugen described in the Western Area, and may, though interupted by the fault block south of Morsjoen, link up with the syncline striking along the Järengrenda in the North Eastern Area.

The stratigraphical evidence for such a syncline, ie youngest rocks forming the core, can be seen on the sketch map above. The bedding plane orientations measured on both limbs of the north-striking syncline, with few exceptions, strike roughly north-south and dip to the west at an average dip of 45°. The westwards dip of the bedding on both limbs suggests the western limb to be inverted. Indeed in Lower Arenaceous Sequence rocks north of Morsjoen turbidites + load casting prove the beds to be inverted on the western limb.

Of the four axial planes to minor folds measured 2 were vertical with strikes of 140°N and 160°N respectively. The axial planes shown by a minor fold in shale on the eastern limb of the syncline, to the south east of Konstadløkken, strikes at 170°N but dips at 47° towards the east(w) – bedding planes suggest the f.a.p. must dip at ≃ to the west. The plunge of the minor fold axis in the above mentioned exposure is 15° towards the north north west. Of the eight fold axial plunges measured in the area 2 plunged at a shallow angle towards 350°N, 4 plunged at 0°–30° to the west south west and two plunged at 20° and 30° towards the east south east. The north plunging axes may well be the 'second phase' structures which probably produced the main syncline through Konstadløkken. The rest are probably "1st phase" + maybe swung round by the second phase of folding.

The east-west and north east-south west folding and bedding planes are probably the result of a first phase of folding, this includes the major syncline running through Beverdalshaugen + Blokketj + many minor structures. These "first phase" structures by and large dip towards the south.

The nature of the interference between "first phase" and "second phase" structures, is difficult to determine. The overturned western limb of the syncline striking through Konstadløkken is, logically, the overturned eastern limb of an adjacent anticline. Similarly the overturned southern limb of the syncline striking through Beverdalshaugen + Blokketj. must be the overturned northern limb of an adjacent anticline. This suggests that inbetween these two major synclines lies an anticline (at least in the sense that the oldest rocks occupy the core) which has both limbs overturned. It may be that this strange structure could result from 2 anticlines with axial planes dipping towards each other as is shown in the section across the whole map area. However the nose of this 'anticline', although only very poorly exposed, does not show the bulbous and bilobate outcrop margin one would expect from the above mentioned possibility. This problem will be studied in more detail below.

South East Area

Of the minor structures in this complex area only the bedding plane orientation provides a sufficient ammount of information. Thirteen bedding plane orientations were recorded and these had strikes of between 160°N and 40°N, the dip is is generally about 40° westwards (5 readings) or 65° westwards (4 readings). The minor folding (17) – only 2 measurable folds were found – indicates a wide range of fold orientation.

The outcrops of the different Sequences show an arcuate strike change, the beds strike north easterly in the north and south easterly in the south, with the dip generally towards the west – this can be seen on the geological map. The area would appear to be the continuation along the axis of the anticline represented by the Støren inlier outcropping to the immediate east of the Jårengrenda. The centre of the area is occupied by rocks of the Limestone Shale Sequence and the Porphyrites. The western part is occupied by rocks of the Lower Arenaceous Sequence. The eastern part of this area – which seperates it from the syncline striking through Konstad lokken is occupied by Lower Arenaceous Sequence rocks in the north but is covered by Recent deposits in the south.

The rocks of this area do not form a simple anticline, probably more than one fold axis (major) folds the rocks, and some of these axes may be at right angles.

Structural Correlation with Adjacent Areas

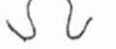
The use of stratigraphy in the determination of the structure of the rocks in the area north of Gåsbakken, that is, the use of inliers of older rocks and outliers of younger rocks to show anticlines and synclines respectively, involves circular logic. This, however, is defensible on the grounds that the stratigraphy used to determine the major structures correlates very well with the successions worked out by previous workers in adjacent areas. Also, as can be seen from the trend map and the correlation map submitted with this report, the major structures correlate very well with those worked out in the adjacent areas. Some of the evidence noted by previous workers in the adjacent areas is useful when considering the structure of the rocks in the area north of Gåsbakken.

Chadwick et. al. stated that the structure of the Fjeldheim – Gåsbakken area appears to be basically simple, with the general trend (F_1) swinging round from NE-SW in the east to E-W in the west. The Hovin sediments in the west lie in two synclines, with axial planes (F_1) dipping about 60° N, and having overturned northern limbs. In the finer grained sediments throughout the area there is usually a well marked axial plane cleavage (F_1) and this is often disturbed by a later cleavage (F_2) which is apparently related to the change in trend already mentioned.

Vogt found the structure of the Hølonda-Horg district to be determined by SW – NE striking synclines which are overturned towards the south east, that is, the beds predominantly dip north west. However Vogt showed the Jåren beds (shown by the present writer to be in fact Hovin Series rocks) to be dipping in the opposite direction, that is towards the south east (~~Table~~ Fig I. In other words Vogt found the beds to be dipping toward the Støren greenstone inlier, immediately to the east of the

Jårengrenda, on both limbs.

In the area mapped, neither "f1" nor "f2" cleavages were developed, save only locally and very rarely, consequently the two were never found together in the same exposure in the area, and correct time relations could not be worked out. Two general trends were noted in the area mapped, parallel respectively to the (f1) and (f2) trends found by Chadwick et al. Consequently the present writer considers it permissible to use the evidence for two definite phases of folding in the Fjeldheim–Gåsbakken area, to determine the time relations of the folding in the area north of Gåsbakken. Also some evidence for two fold phases was found in exposures at the western end of Langkjosen described in the section dealing with the folding in the Western area of the area mapped. Shear planes were found striking 5°N and 15°N respectively, and dipping at 80° and 85° respectively towards the west. These zones affect the (f1) rodding of the sandstone. These shear zones may be related to the north–south, westward dipping major folding in the central area of the area mapped. The north–south striking minor folds found in many places in the area mapped are never seen to affect (f1) rodding or folding. However it does seem probable that, as Chadwick et al. found, the two dominant trends are the result of two fold phases and the change in trend of the E–W structures to an SW–NE trend may well be due to the second north south striking phase.

As can be seen from the trend map, the bedding and axial planes in the area mapped dip to the south and south east, but in the adjacent areas the bedding planes and axial planes dip to the north and north west. In fact the Støren inliers immediately to the south of Langkjosen in the west, and immediately to the east of the Jårengrenda, which may have been a continuous f1 anticline before the f2 folding round Gåsbakken, appear to lie between the north dipping rocks to the south and the southerly dipping rocks to the north. Both the Støren greenstone inliers mentioned above appear to have inward dipping contacts with the Høvin Series rocks. Such a bulbous  anticline would, if pitching gently as both inliers appear to do, have a bulbous shaped nose outcrop margin, in fact the nose of the inlier mentioned in the west is cut off by a fault, and the inlier mentioned in the east has its nose buried under peat and boggy ground.

The nature of the (f2) 'syncline' cutting across the (f1) anticline described above, is difficult to determine. First phase structures in general appear to plunge 10–20° towards this syncline from evidence in the area mapped and from Vogts mapping. The syncline produced by the second phase of folding which causes the Hovin Series rocks to be folded down across the probably previously continuous anticline with a Støren Series core, could then be interpreted as a broad warp oriented at right-angles to the main first phase trend. However, evidence from the limbs of the Limestone Shale Sequence and Porphyrites core arround Konstad løkken suggest a tightly folded syncline. As this tightly folded syncline could occupy the centre of a broad warp, the two are not incompatible. The western limb of the synclinal warp has been cut out by a major fault as mapped by Chadwick et. al.. The eastern limb appears to have reoriented the original first phase trends, which arround Gåsbakken in the South Eastern Area of the area mapped, run parallel to the second phase produced structures. These reoriented structures are seen to be continuous with the SW–NE striking structures to the north east.

The interference of these phases as described north of Szomoen in the Central Area is far from understood, a further study of the rocks in that area, in Ramsberget, and in the hills north of Gåsbakken may help the understanding of the fold phase relationships

Faulting

The only obvious major faulting is that produced by two parallel faults striking WNW-ESE located just south of Morsjoen, cutting across the probable junction of the f_1 and f_2 synclines. The rocks within the fault block are lithologically very similar to the conglomerates of the Lower Arenaceous Sequence, and if they are equivalent to these it suggests that the centre block is upthrown. The faults appear to die out rapidly in both directions and may in fact form a wedge. Both faults, especially the northernmost one, are well marked by cliffs - sometimes very high such as those rising from the southern shore of Morsjoen, rows of bluffs, troughs, and boggy ground. Reasonable exposure on both sides of the faults shows beds finishing abruptly against the faults. There was no exposure of the actual fault planes but the constancy of strike of the faults across hilly ground suggests them to be nearly vertical.

More faulting may well affect the rocks of the area but was not discovered due to poor exposure.

Metamorphism

The area has suffered only low grade metamorphism and in fact lies in a belt of low grade rocks, metamorphosed during the Caledonian orogeny, which has a curved outcrop from Tronheim in the north east, through Gåsbakken, and towards the west. There has been little growth of metamorphic minerals but recrystallisation especially of quartz and felspar is general throughout the area.

Chlorite is the only mineral produced during regional metamorphism in the rocks in the southern part of the area, and is most abundant in some of the conglomerates which have a chloritic shistose matrix. Examples are the exposures at the west end of Langkjosen and exposures on the north east shore of Svorksjoen near Sjomoen. Metamorphism appears to become slightly more intense northwards, chief indications being a greater recrystallisation of the limestones into marbles and greater recrystallisation of the arenaceous sediments.

In the extreme north west of the area, near the road junction between the Rektorli to Svork-mo and the Gåsbakken to Svorkmo roads, higher grade metamorphism has occured. The schists exposed in the quarry just south of the road junction show great developement of green biotite (≃ 35% of the rock) and a much weathered iron mineral (≃ 20% of the rock). The schist contains widely scattered small grains of quartz and felspar (less than 5% of rock) some of which show solution boundaries. The matrix which makes up about 40% of the schist is very fine grained and probably quartz or felspar or both.

The rocks exposed in road cuttings along the Rektorli road a few metres to the east of the junction show much fibrous amphibole growth (tremolite-actinolite). The rock itself is very fine grained, and the grains, though unidentifiable due to their small size, are probably quartz or felspar or both. The grains show much recrystall--isation with all the grains showing solution boundaries. The grains are well sorted and indicate the bedding. In the hand specimen the plane of parting of the rock is parallel to the bedding as seen in thin section, the parting is therefore probably bedding and possibly has resulted from opening up by F_1 folding. The fibrous amphiboles, in the hand specimen appear to lie on these bedding plains usually as partially radiating clusters and often with individual crystals up to 2cm long but less than 1mm wide. In cross section the crystals are also seen sometimes to cross the bedding. In thin section the amphiboles are seen to have well shaped crystal boundaries but to be seived - containing inclusions of the grains of the matrix at reduced sizes. The crystals are sometimes bent through a few degrees, presumably due to movements later than their formation, but no fold axial plains are obvious. The amphiboles cut across the bedding and are not oriented in any linear direction and are therefore probably post f1 - they are not seriously affected by any movements.

Many of the rocks are very epidote rich, the sandstones especially being very often rich in secondary epidote which indicates an originally calcareous nature. The secondary epidote crystals in the sandstones appear to be concentrated in the coarser bands - which may have been more limy, and this emphasises the bedding. Good examples of this "epidote banding" are shown in road cuttings through sandstones and conglomerates beside Blokkets[VIII]. The epidote crystals are idiomorphic. The Støren greenstones also are often rich in secondary epidote, the way in which the epidote concentrates inside the surfaces of the pillows of the pillow lavas has been described above.

The Porphyrites have generally been very much altered and the phenocrysts of olivene and plagioclase are rarely in their original state - the plagioclase is often completely replaced by sericite. Samples from an exposure of porphyrite near Trotland show calcite occupying cavities in very much altered porphyrite. In this case the calcite is not pseudomorphic after the original phenocrysts - though completely altered these are still visible as ghosts.

Recent Erosion and Deposition

The topography of the area is an undulating plateau cut by deep valleys, sometimes the valley sides have cliffs and steep slopes as in the western part of the area, or have quite gentle slopes of the order of 10° as in the Jårengrenda (ie. gentle by comparison with the 20° slopes plus in the rest of the area). The valleys have been very much excavated by the ice and now only very small "misfit" streams occupy most of the valleys – also many of these overdeepened valleys contain lakes – as can be seen from the geological map.

Recent deposits are predominantly glacial moraines, lake alluvium, and forest peat. The only probable moraine is that damming the south end of the lake at Reksaasen in the south east of the area. The height of the lake is some 20 m above the height of Reksaasmyren into which the valley opens lower down from the lake. Reksaasmyren itself is of lake alluvium and indicates an earlier extension of the lako Suorksjöen, the old shoreline is clearly visible roughly alongside the Suorkmo – Gåsbakken road.

Reksaasmyren is the only large deposit of lake alluvium in the area, in most cases the valley sides slope steeply into the lakes, sometimes with gravel beaches only poorly developed. Suorksjöen is indeed the only lake in the area with sandy beaches – and one beach is composed solely of wood chippings (fine) and pine needles, presumably from the sawing of a great deal of wood. Many of the valley bottoms are however covered in a mantle of detritus visible in some cases as alluvial fans, for the most part the detritus is covered with a thin soil cover and grass.

The hillsides are covered in forest peat and often the rocks are only exposed where trees have toppled over, and the uplifted roots have stripped off the peat cover to reveal the rock underneath. The plateaux are bog covered frequently & often have coarse grasses growing. Forest cover may originally have extended over the plateaux and still does in some areas.

Often a fairly good soil cover occurs where the ground is cultivated, although the soil contains many stones. The Norwegian farmers cultivate all possible cultivatable land and even grow sparse cereals in what can only be described as coarse pebbly gravel. Such human interference can be conducive to the growth of soils but in places may result in the stripping off of what little soil there is. There has been some drastic clearance of the forest on the hillside, despite forestry preservation laws, and the cleared ground has been deeply ploughed which will greatly aid erosion.

Acknowledgements

I am happy to acknowledge the friendly aid of Per Sandvick and the Orkla Grube Aktiebolag, and the experienced judgements on my work and ideas in the field by Dr. Janet Seton Peacey of Imperial College, London; and Cambridge. My sincere thanks go to the Knubben family of Sundet[IX] with whom I stayed during my work in the field.

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Chadwick et. al. 1962 - The Geology of the Fjeldheim - - Gåsbakken Area. N.G.U. 1962 pp. 43-60 (Årbok)

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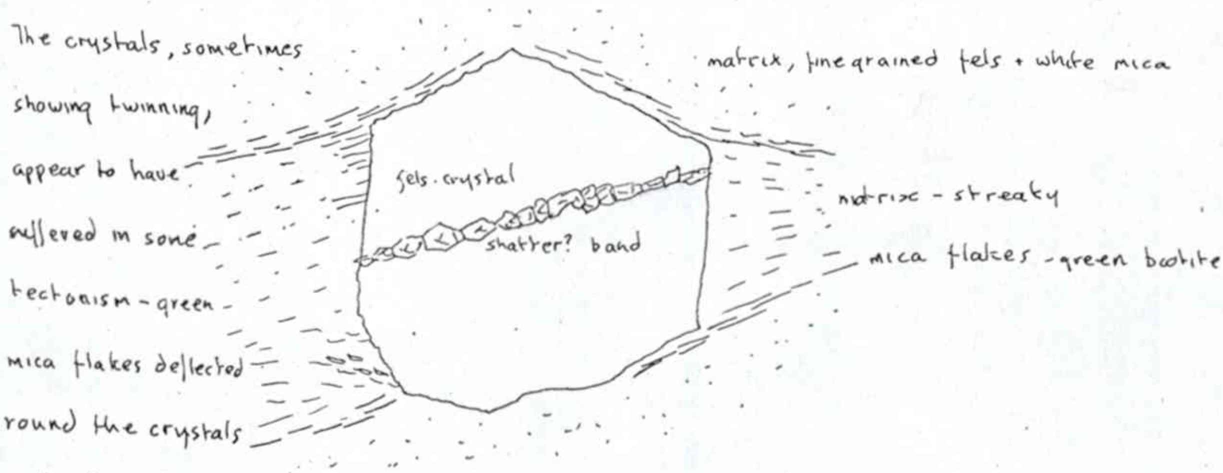
ab. N.G.U. - Norges Geologiske Undersökelse
N.G.T: Norsk Geologiske Tiddskrift.

N.B. no trace was found of the thrust shown by H. Carstens (reference above) as outcropping down the Jørengrenda.

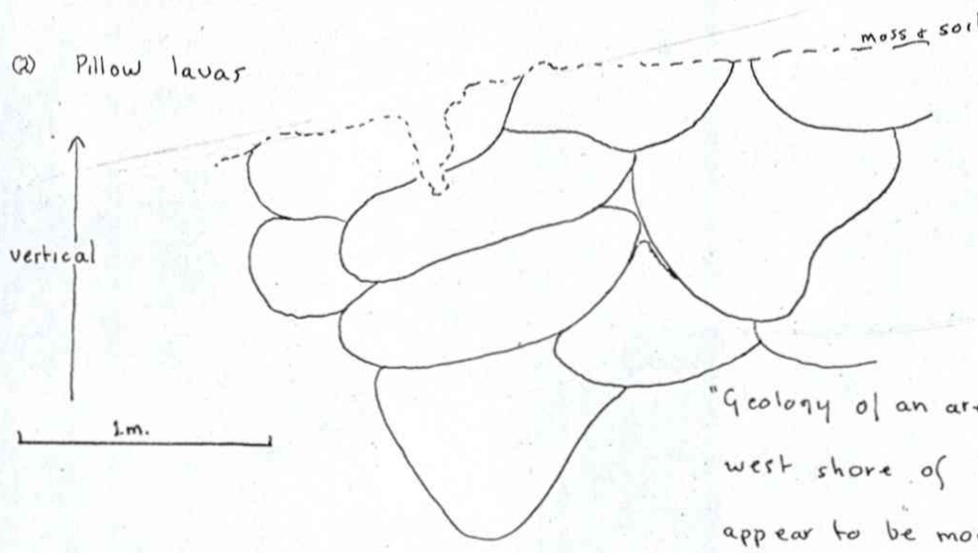
Appendix A.

(1) Thin Section Tuff Band



and shatter belts within the crystals. Also get chlorite as alteration product.

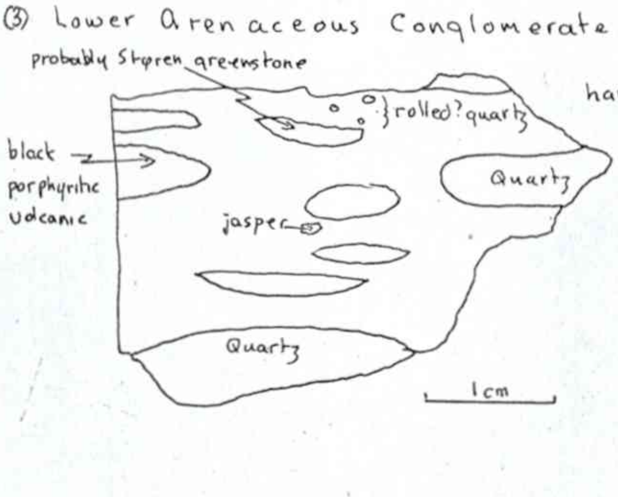
(2) Pillow lavas



field sketch. pillows, exposure inbetween the two smaller lakes shown on the sketch map "Geology of an area including the north west shore of Svorksjoen". The appear to be more vesicular towards the rim but no marked chilling. A good matrix was not preserved in this exposure - however jasper was found to constitute the matrix in other exposures

The pillows are seen in a nearly vertical section, the beds are dipping "out of the paper" & the pillows show younging upwards.

(3) Lower Arenaceous Conglomerate from the northern L.A.S. outcrop.



hand specimen

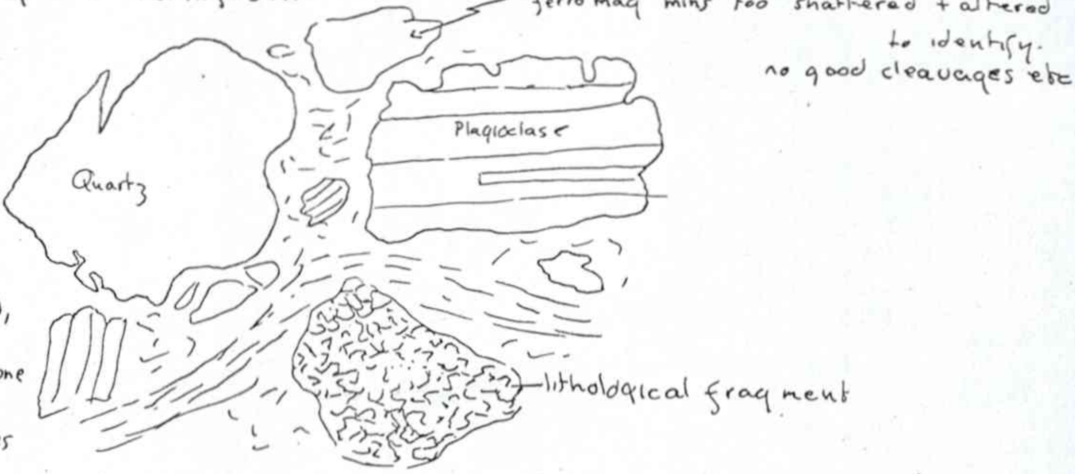
In this example the pebbles of the conglomerate appear to have suffered a great amount of flattening, note less greenstone & jasper fragments, than usual. Fragments black porphyritic not seen before.

Finer grnd. matrix often contains broken individual crystals of plagioclase.

(4) Høum Series Grit – Lankʒosen.

thin section.

The grit contains a lot of probably tuffaceous material, is very poorly sorted, crystals have undergone some solution at edges



(ie qtz. + plag.) and the rock is very unsorted. It may represent a water laid tuff.

(5) Lower Arenaceous Sequence (Høum Series) sandstone. shows rodding. Langkʒosen

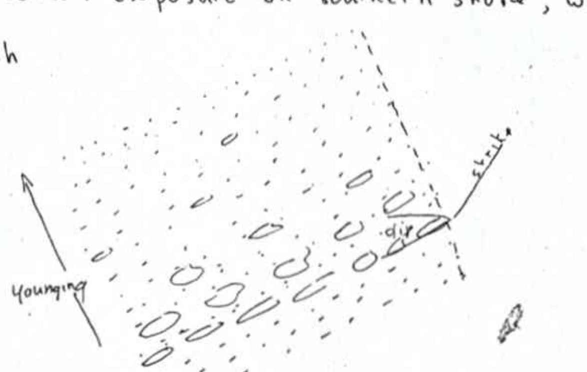
thin section

Viewed end on to rodding ∴ not seen, bigger crystals of qtz + orthoclase form the rods, matrix finer grained + + muscovite

chlorite and iron staining. Rock may be termed an arkosic sandstone

(6) Younging data. Exposure on southern shore, western end of Horssoen

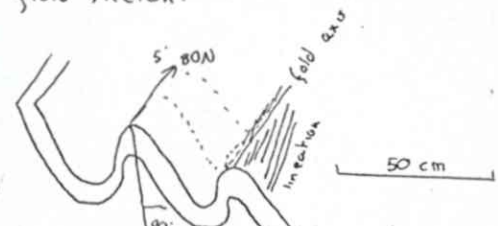
field sketch



somewhat diagramatic sketch to show how pebble band lies on top of sandy beds – the no. of pebbles decreases gradually upwards until no pebbles – only sandy rock. Gives good younging indication.

(7) Minor folding. (a) in shales (b) in limestone, Northern L.A.S. outcrop

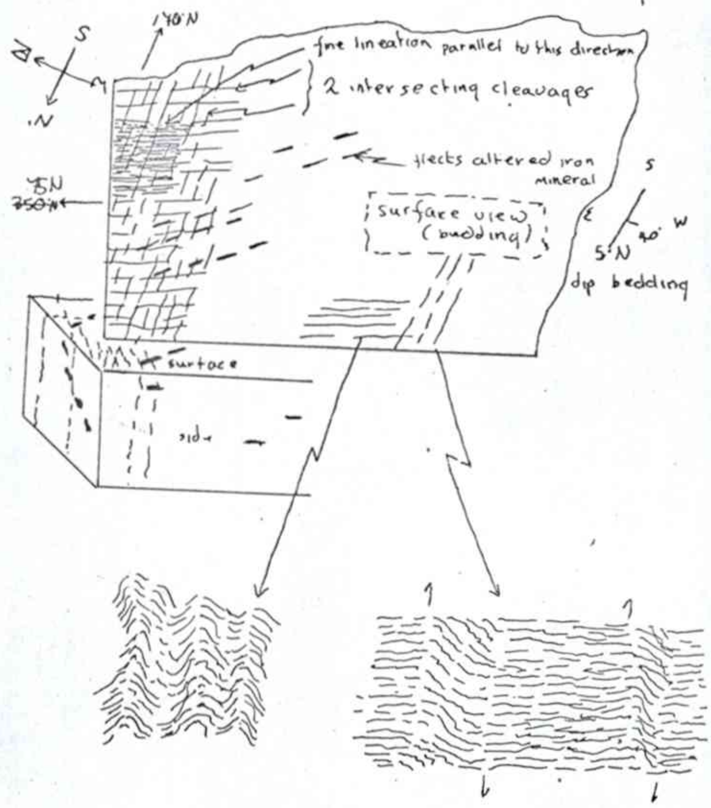
field sketch.



folding in predominantly shaly rocks, many such minor folds noted in area arround Rektorli. N.B. in this case the lineation appears not quite parallel to the folding. N.B. no cleavage.

folding in limestone bed on western shore of Mjoud. Note it is difficult to place this folding in either f₁ or f₂ orientations.

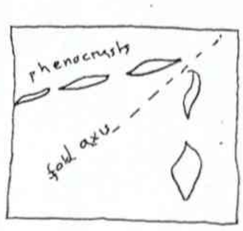
(8) "Herring bone" or strain slip cleavage. 2 cleavage directions. shales E of konstadlokken



The two cleavage directions probably correspond to f¹ and f², however the cleavages would appear to dip steeply but in the opposite direction to the probable major f₁ & f₂ fold axial planes. The "f₁" cleavage appears to be of the "strain slip" type & as a result has a good lineation where it intersects the bedding plane - as well as more widely spaced impressions. The "f₂" cleavage folds the earlier lineation over a series of more widely spaced shear zones. The grid of lineations produces a "saddle & dome" effect. The iron flecks lie in a different plane - possibly a tensional plane. The real relationships of these cleavages to the major folding are uncertain.

(9) Porphyrite - phenocrysts dragged out along base. exposure east of konstadlokken

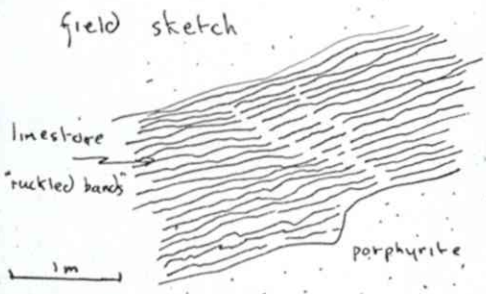
field sketch



Note in sketch of exposure appear to get more "ruckled band" (arenaceous bands in limestone - usually folded) nearer to contact. Note in enlargement base of porphyrite phenocrysts dragged out - none are ever found bent over the fold axial planes ∴ therefore it is more likely that they are flow distorted than fold distorted.

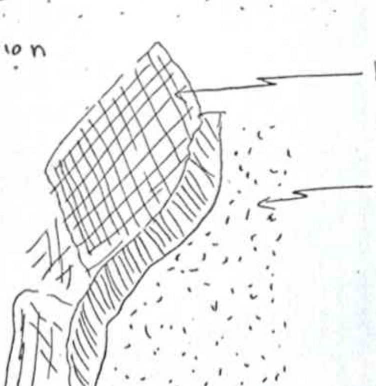
(10) Calcite veining, limestone wedge in Porphyrite, North of Gåsbakken.

field sketch

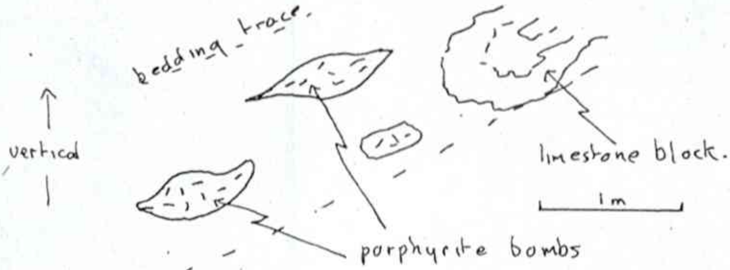


The limestone forms a wedge within the Porphyrite mass. The "stream" like 'intrusions' or veins of pure & coarsely crystalline calcite protrude up cutting through the ruckled arenaceous bands from the lower contact. They branch & thin upwards, occasionally ruckled bands cross streams.

thin section

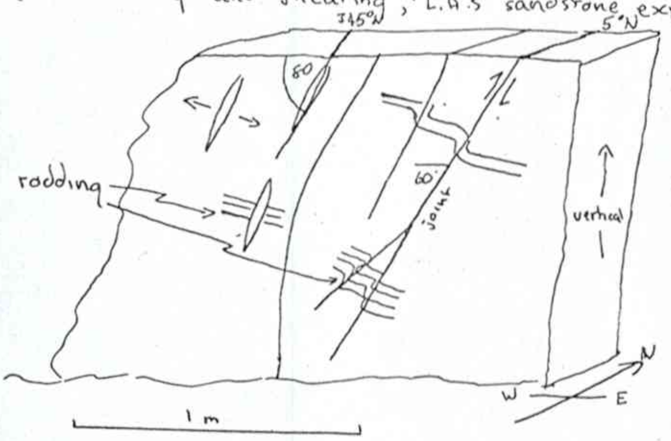


(11) Pyroclastic Layer – hillside between Konstadlokken & Blokkan.



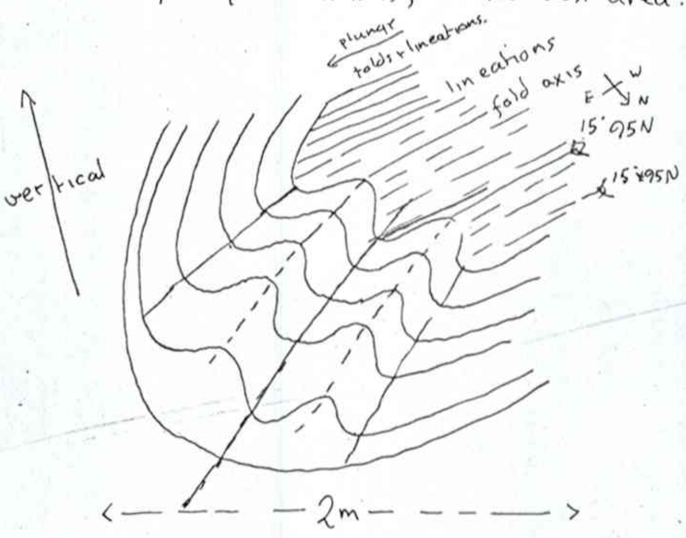
The agglomerate includes blocks of limestone up to 1m - the ruckled bands may follow the outlines of the blocks or be cut by these: Characteristic shaped bombs of porphyrite occur – the phenocryst have no orientation wheras they often lie on or in distinct planes in the large porphyrite masses. Matrix appears "ground up" is predominantly calcareous & appears to contain scattered phenocrysts from the porphyrite

(12) Jointing and shearing, L.A.S sandstone exposure at W. end of Langkjosen.



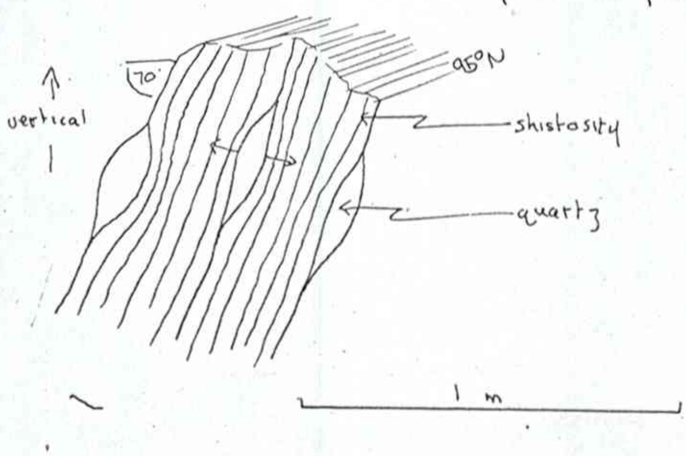
On the western side of the exposure tension gashes, striking 345°N & dipping 80° westwards occur, quartz filled, the do not affect the rodding (f1) other than to break it – ie no shearing movement.
On the eastern side of the exposure jointing occurs which has a shear component, as can be seen the (f1) rodding is affected. The shearing may be related to (f2) folding.

(13) Minor folding & lineations, North West area.



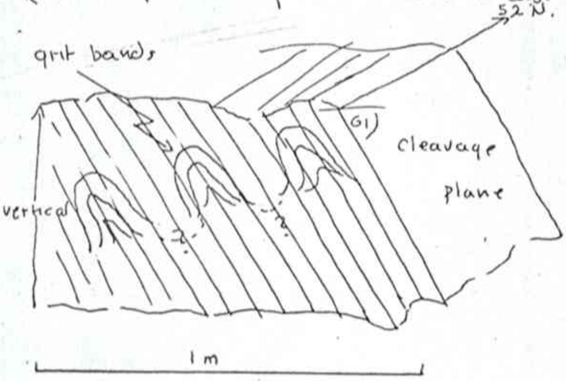
Note in this fine grained rock within the lower Arenaceous Sequence just south of Bouverdalshaugen the lineation is seen to be parallel to the fold axes.
N.B. fold axial planes very flat – sometimes as little as 10° southwards

(14) Tensional indications. Quarry at road junction 0.5 km south west of Rektorli.



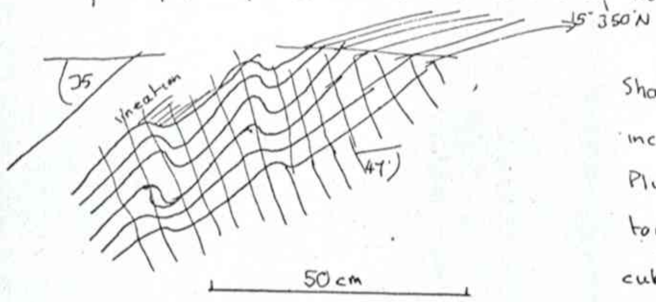
In the chlorite schists in the quarry above mentioned, quartz veins follow the schistosity & bulq out in such a way as to suggest tension $\angle^{s}$ to shistosity. Note this is at $\angle^{s}$ to the tension direction usually found

(15) F.a.p. cleavage. North shore east end Morsjoen



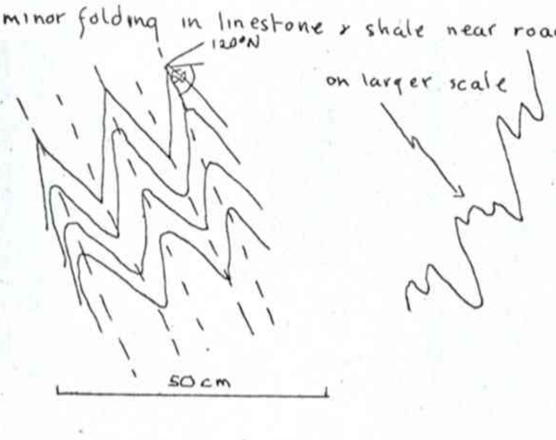
This exposure in the North Eastern Area shows the grit bands folded about axial planes which correspond to widely spaced cleavage planes. Note only the anticlinal cores are seen, the synclinal cores were not visible, some pinching out of these could have occured

(16) minor folding, exposure in shales south of konstadlokken.



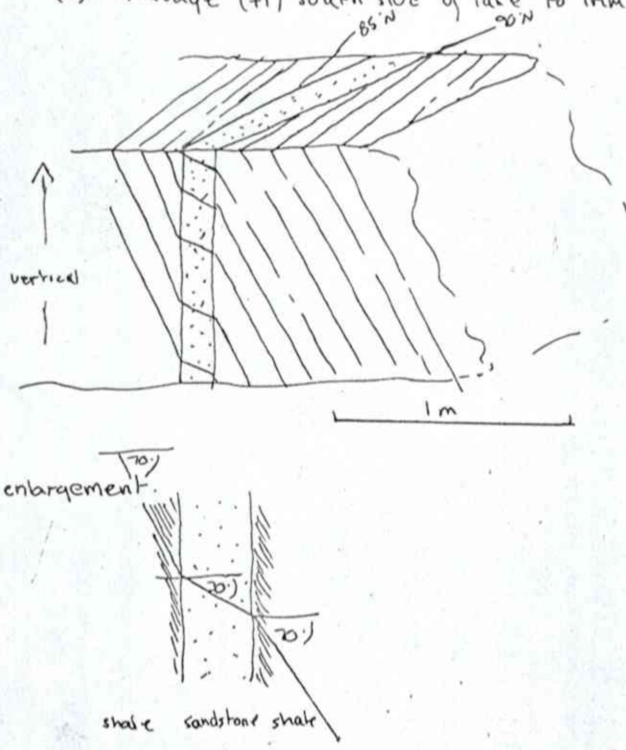
Shaly rocks folded with f.a.p striking at 170°N, incipient f.a.p cleavage dips ± 47° eastwards. Plunge minor folds 15° N, some plunge towards south. The incipient cleavage, as it cuts the folded surface, causes a lineation parallel to the fold axes.

(17) minor folding in limestone & shale near road, just N of road, through Gåsbakken



Very tight nearly isoclinal folding in limestone and shales, south eastern area. No cleavage. Plunge of minor fold's 10° westward.

(18) Cleavage (f₁) south side of lake to immediate south of Rektorli



This exposure is the only locality in the North Western Area where cleavage (f₁) can be seen. N.B. the cleavage is less steep than the bedding indicating "overturned" beds - actually nearly vertical with an anticline to the south and younging to the north. N.B. cleavage strike not quite parallel to bedding strike - poss indicates gentle plunge of anticline towards east.

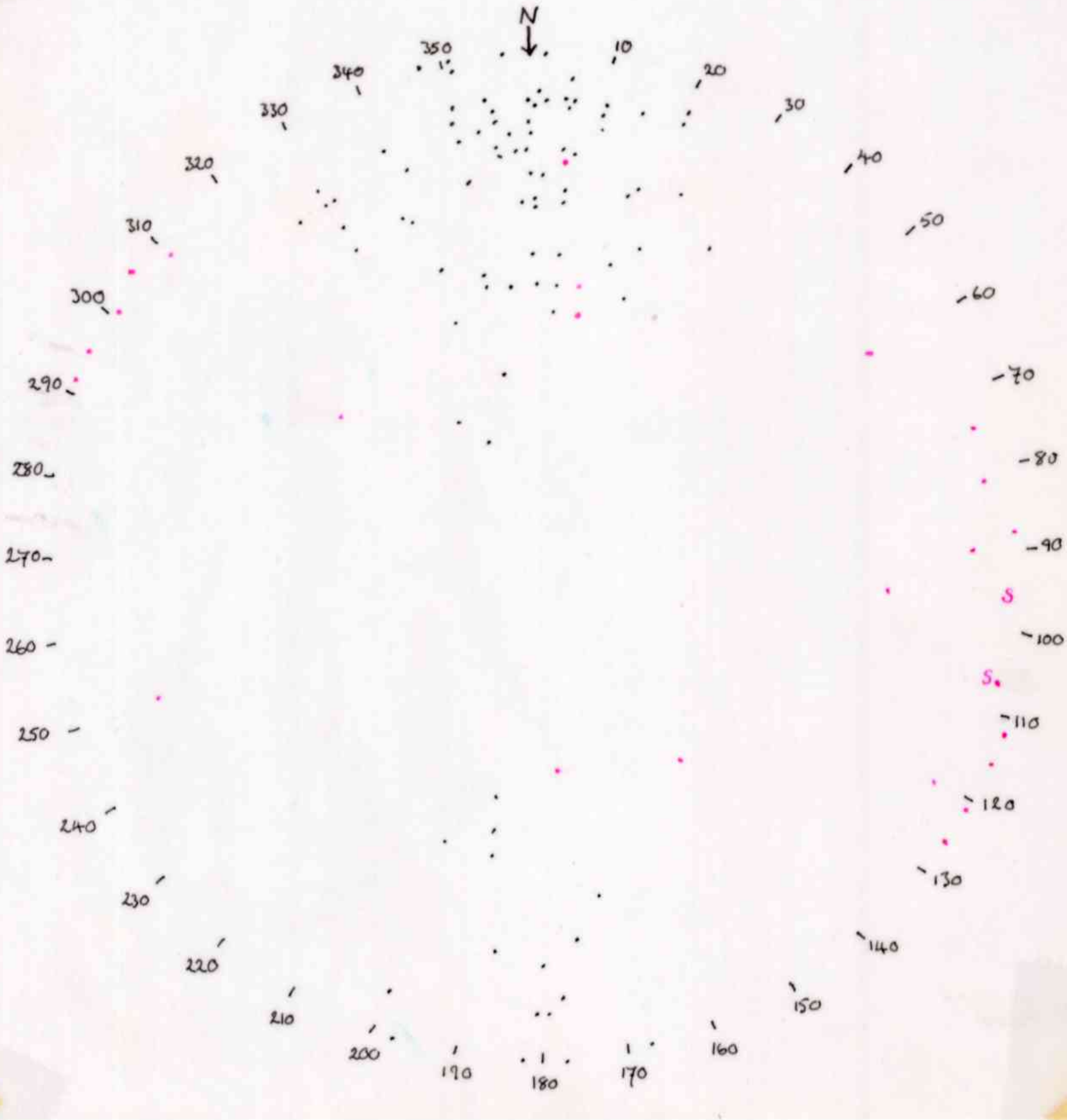
Cleavage deflected by hard sandstone band in shales.

APPENDIX B.

STEREOGRAMS.

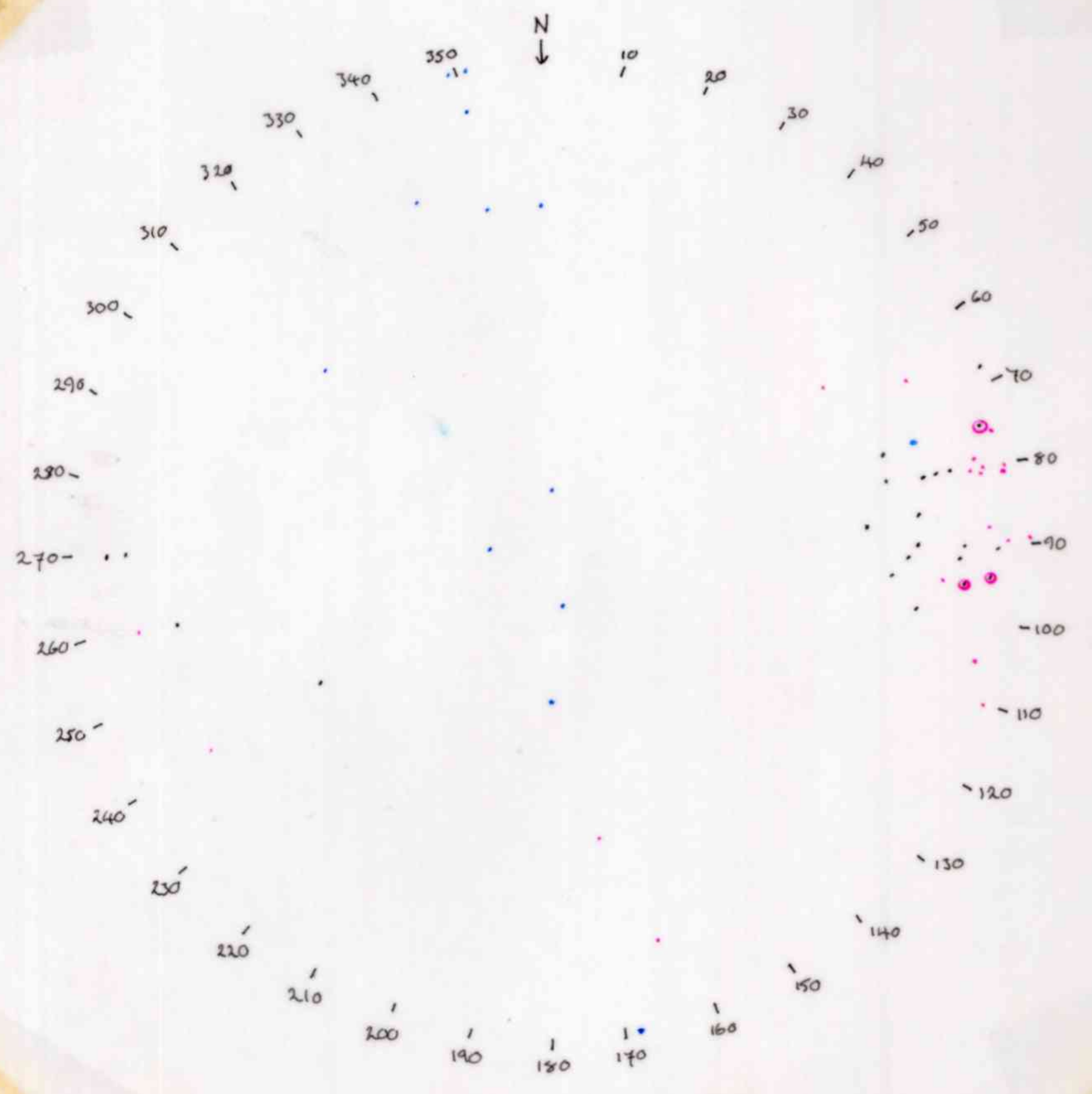
WESTERN AREA.

- • pole to probable and definite bedding planes
- • pole to joint plains + tension cracks
- S pole to shear plane



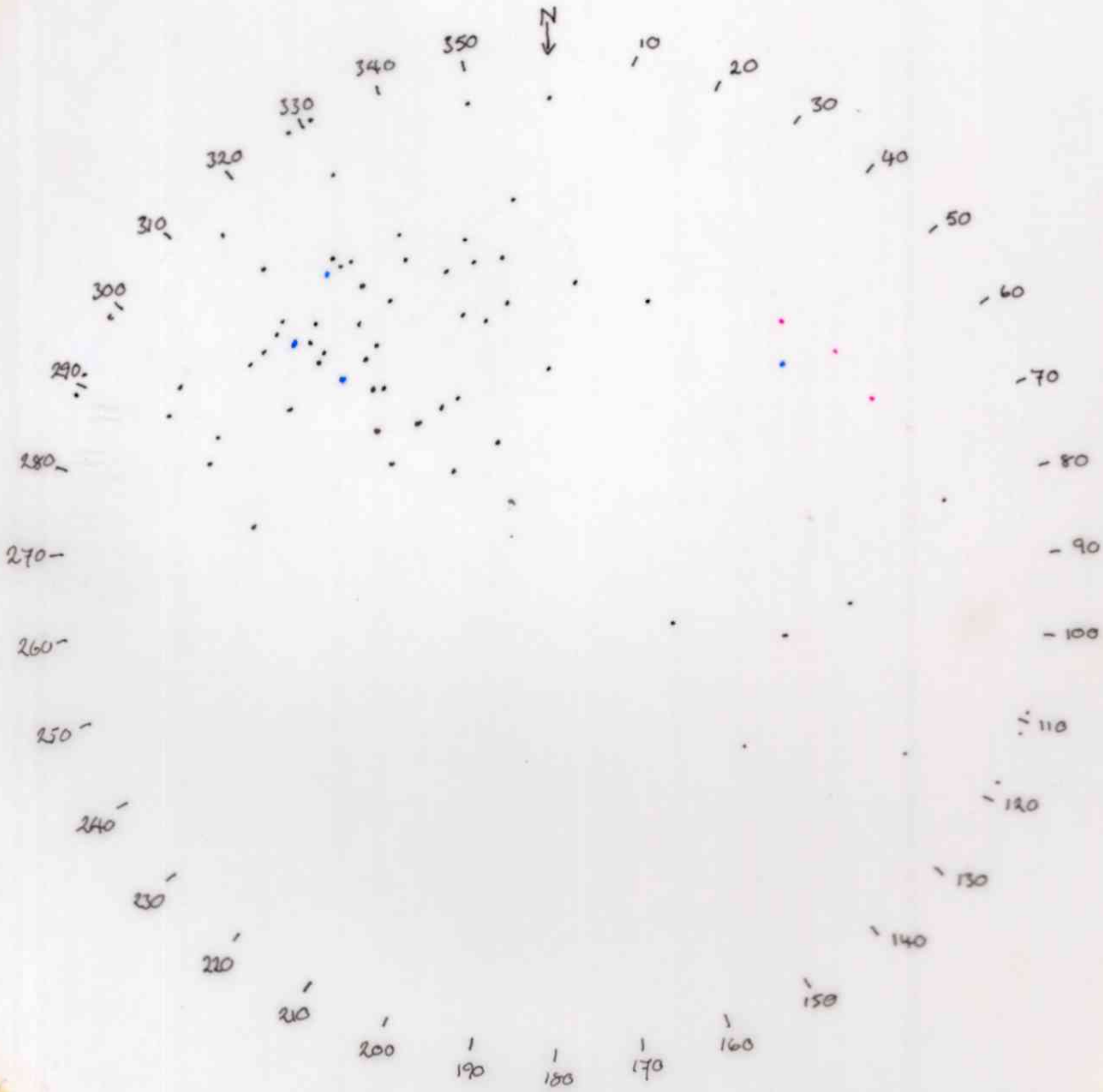
WESTERN AREA - FOLDING

- plunge of lineation and rodding
- plunge minor fold axes and lineation coinciding in one fold.
- plunge minor fold axes.
- poles to axial planes.



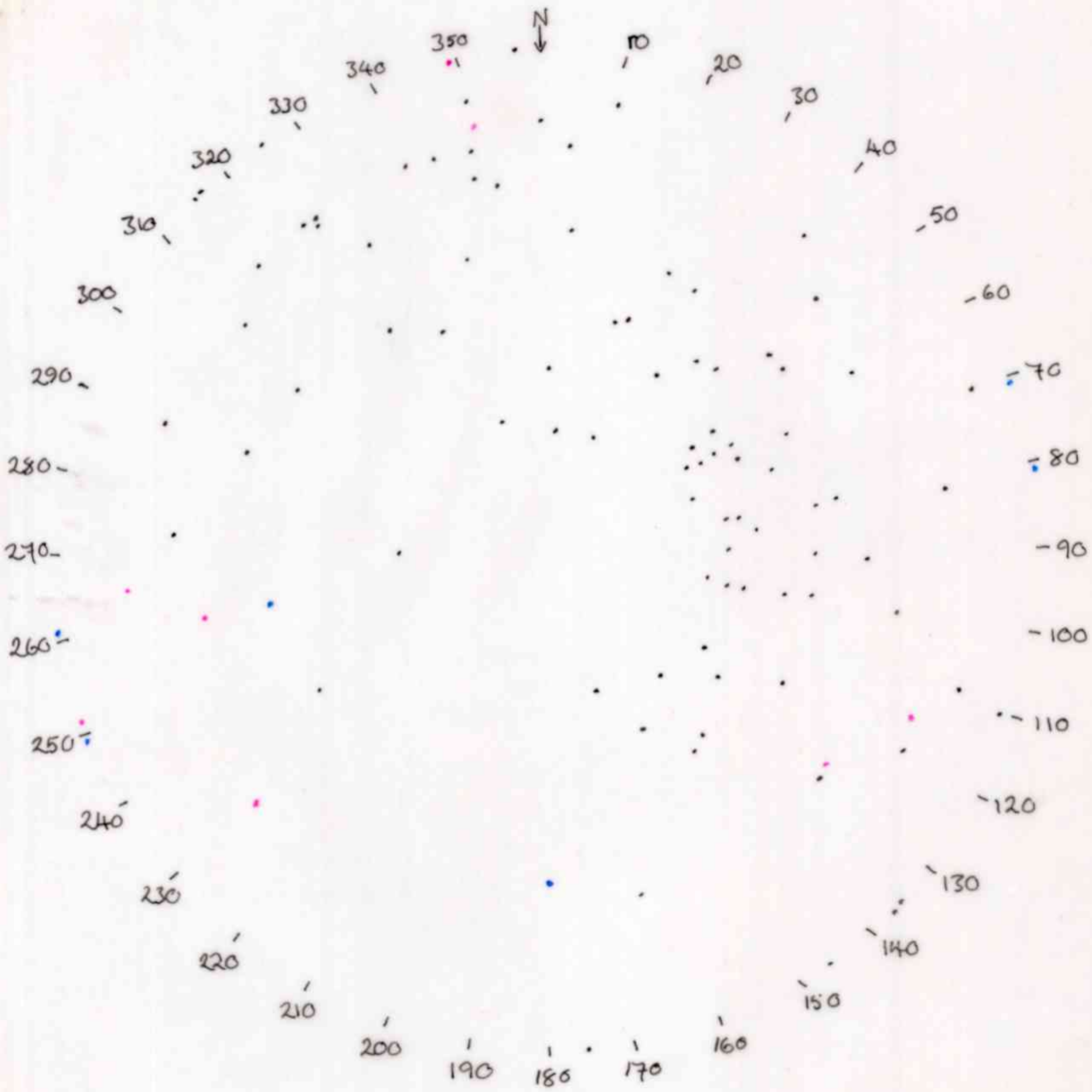
North Eastern Area

- π poles to bedding planes
- lineation plunge
- pole to axial plain minor fold



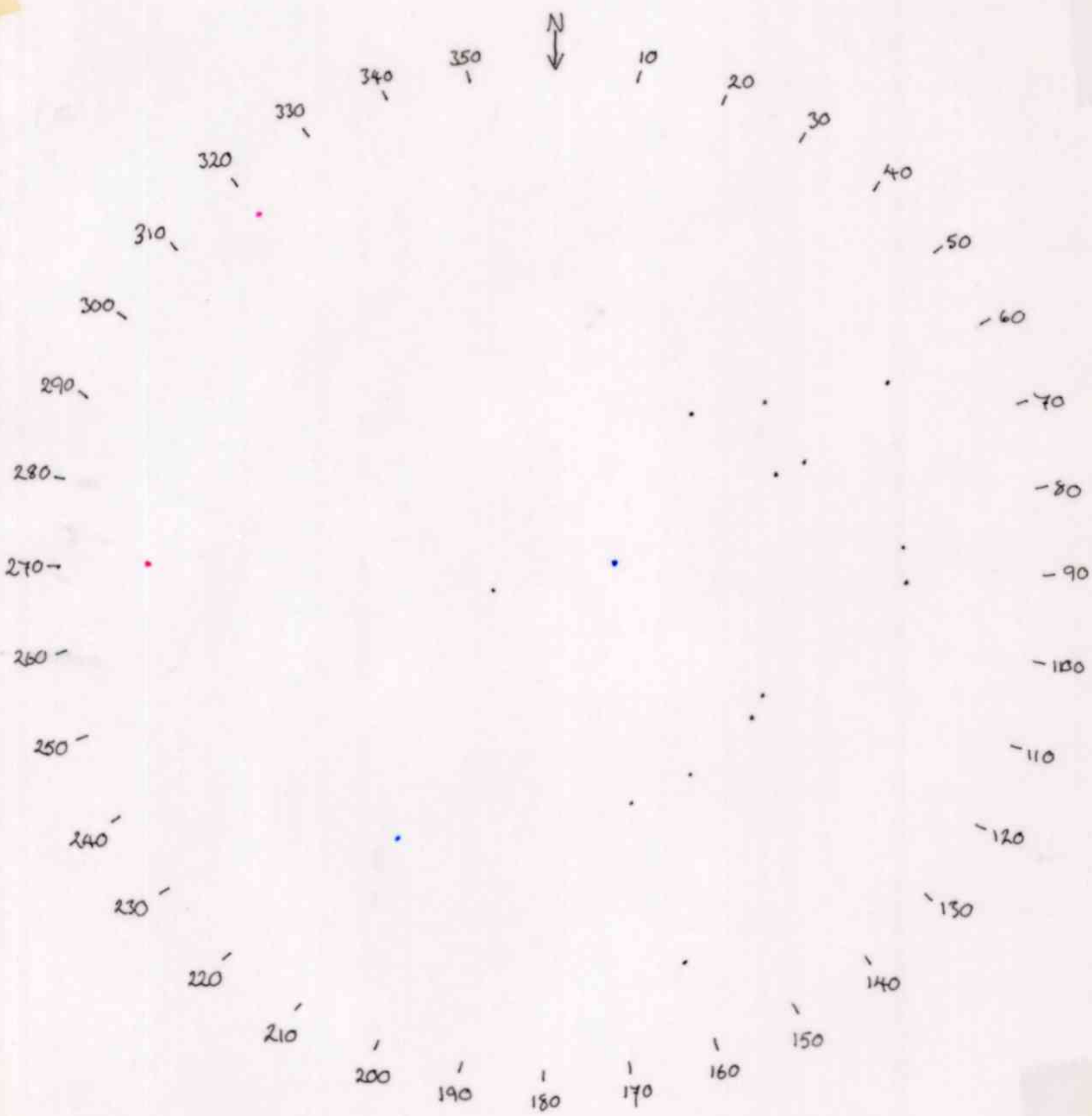
CENTRAL AREA

- π poles to bedding planes
- plunge fold axes
- poles to fold axial planes



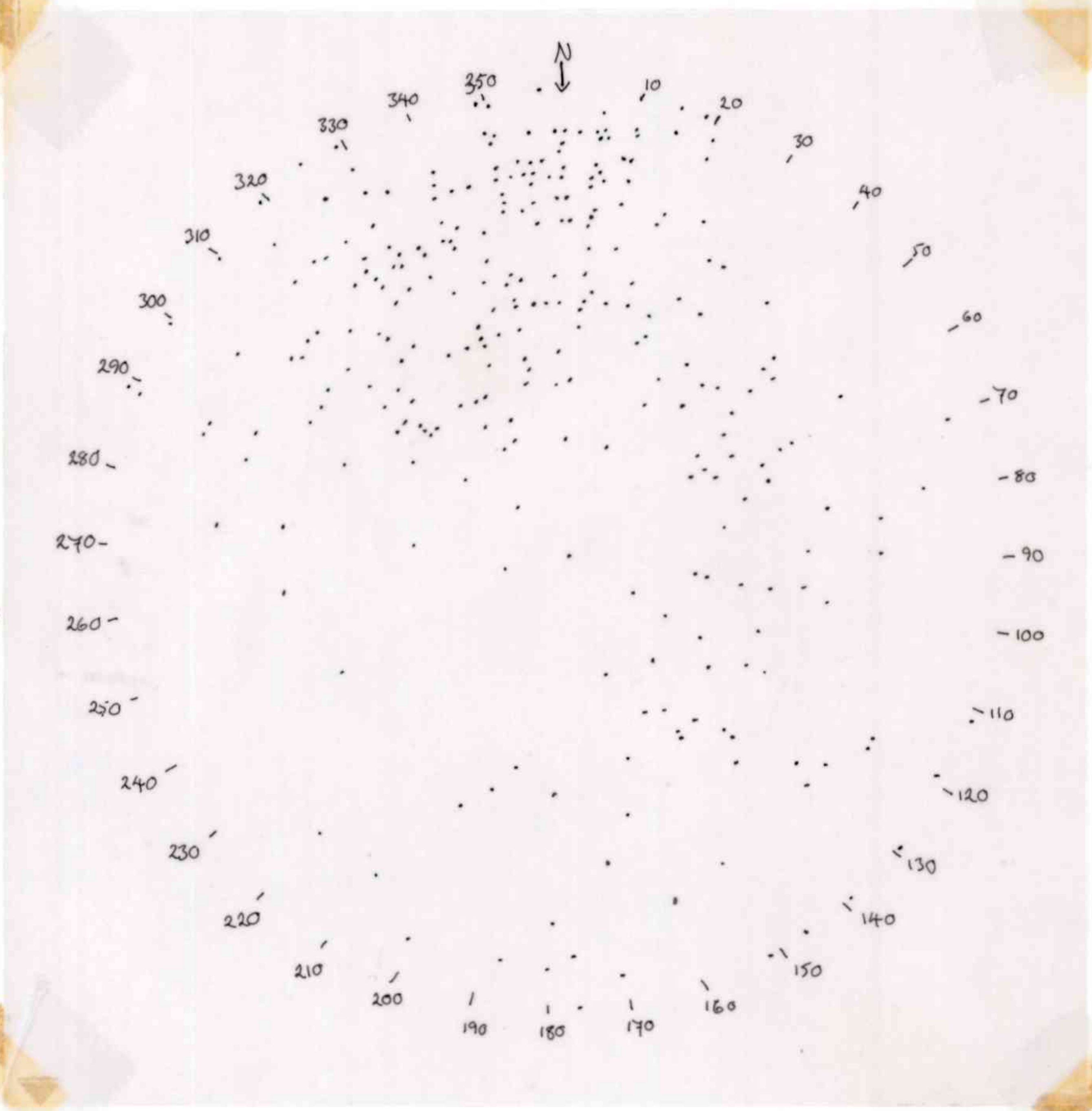
SOUTH EASTERN AREA

- π pole to bedding planes
- plunges minor fold axes
- poles to fold axial planes



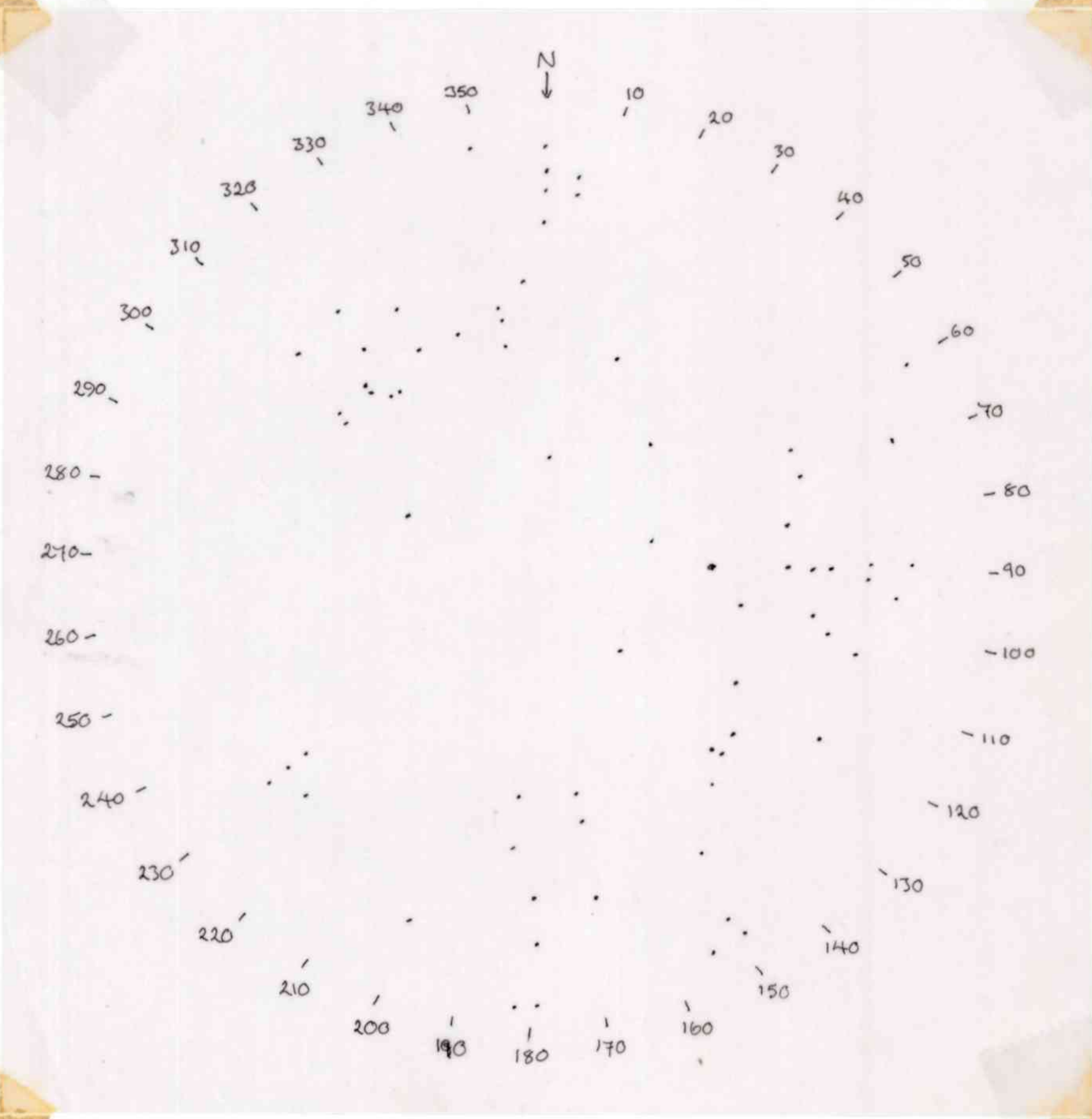
WHOLE AREA

• π poles to bedding planes



TREND MAP

- π poles to bedding planes shown on trend map.



Appendix C

GEOLOGICAL MAPS ETC

Plan 1 - (a) Structural outline map of area mapped by the author, and adjacent mapped areas, to indicate broad structural outline of whole area.

(b) Geological sections across Jårengrenda:-

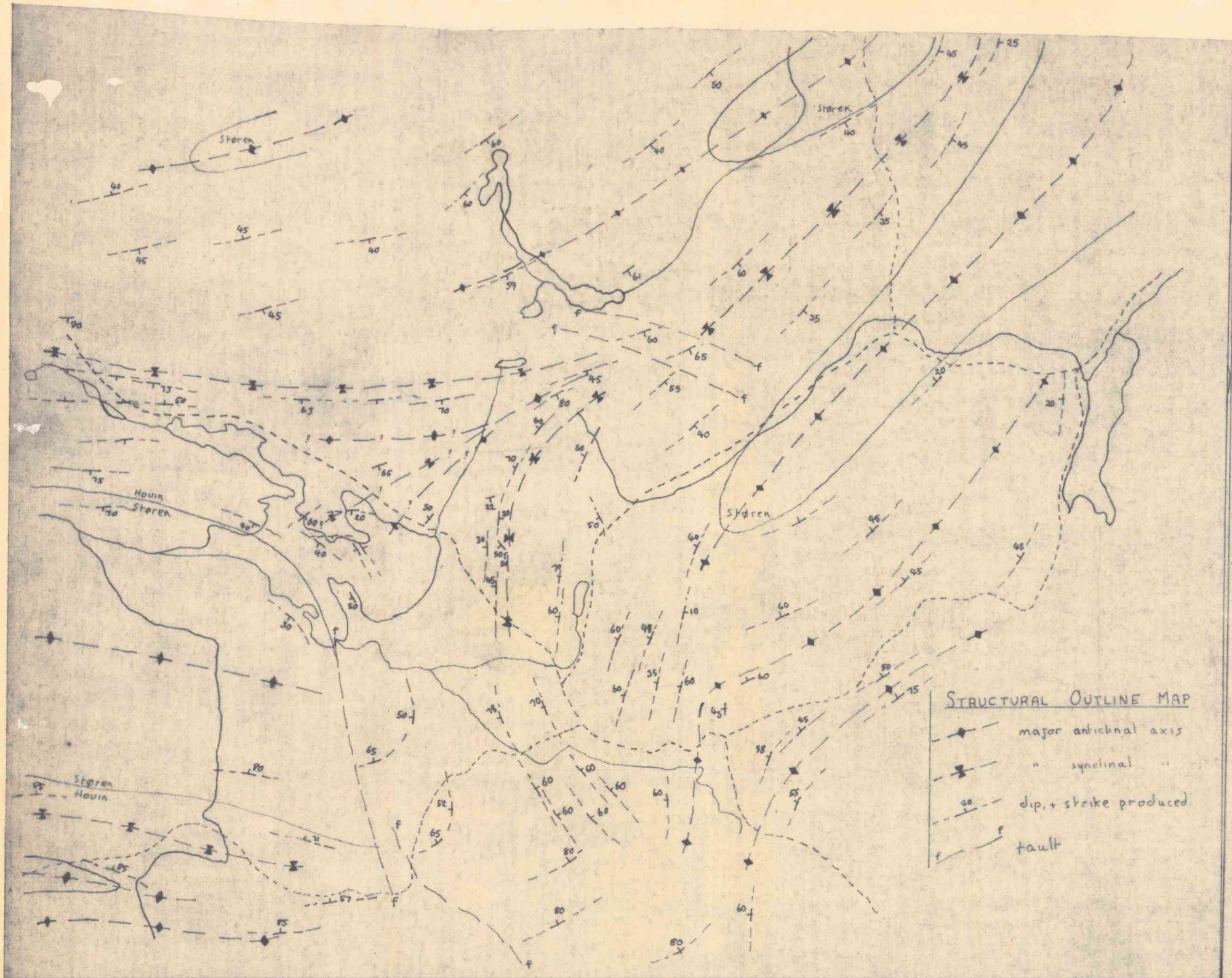
Vogt 1945 Carter 1963 Generalised Section	Fig. I.

Plan 2 - (a) General Geological map to indicate correlation of area mapped by the author with adjacent mapped areas.

(b) Tables :- Table I - Vogt's sequence for Hølonda Area.
Table II - Probable correlation of successions noted by author and those of adjacent areas.
Table III - The "Jåren Beds" and their real stratigraphic position.

(c) Vertical North - South East geological section across area mapped by author.

Plan 3 - Detailed Geological Map "An Area North of Gåsbakken" noted symbols and hachuring used to indicate exposed beds.


Støren
Houin
STRUCTURAL OUTLINE MAP
major anticlinal axis
" synclinal "
dip. + strike produced
fault

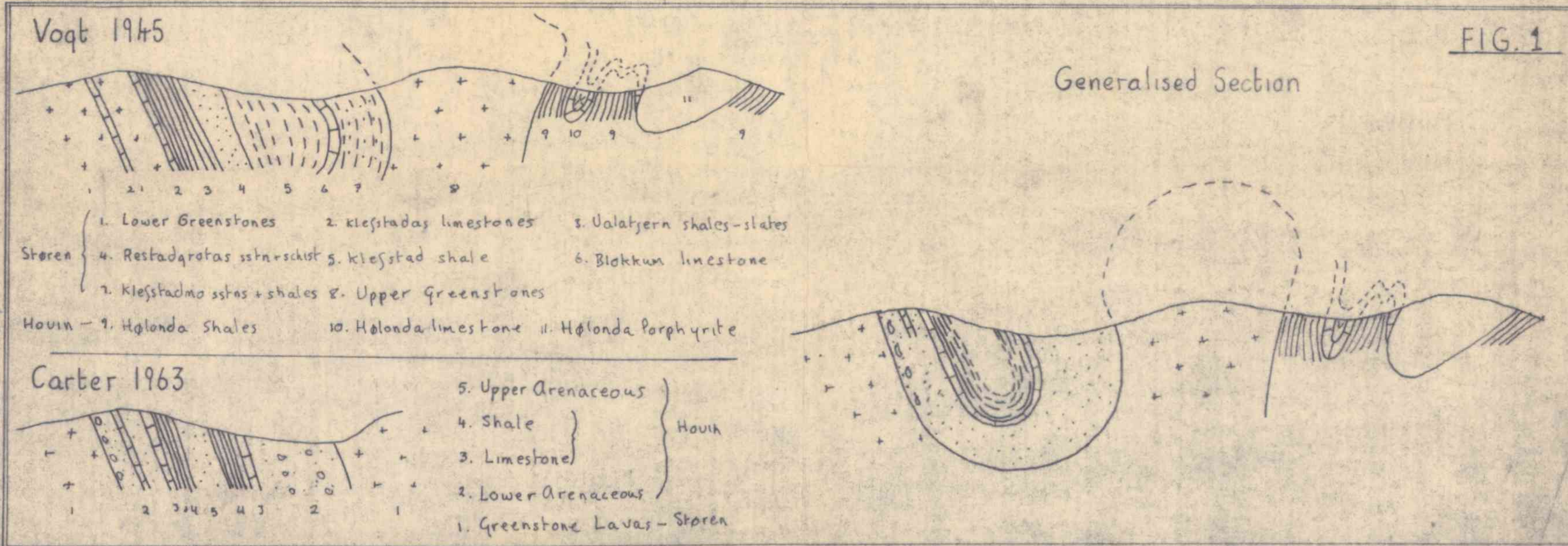

Vogt 1945
Generalised Section
Støren
1. Lower Greenstones
2. Klefstadas limestones
3. Valatjern shales-slates
4. Restadgrotas sstn + schist
5. Klefsstad shale
6. Blokkum limestone
7. Klefsstadmo sstns + shales
8. Upper Greenstones
Houin – 9. Hølonda Shales
10. Hølonda limestone
11. Hølonda Porphyrite
Carter 1963
5. Upper Arenaceous
4. Shale
3. Limestone
2. Lower Arenaceous
Houin
1. Greenstone Lavas – Støren

FIG. 1

TABLE I

Llandoilian		Absent
	LOWER	5. Hølonda Andesite
Vanuirnian		4. Hølonda Limestone
	HOVIN	3. Hølonda Shale
		2. Gaustadbakk Breccia + Almaas Mudstone
	SERIES	1. Venna Conglomerate
		Break
Skiddavian	Støren	3. Upper Støren Greenstone
(Arenigian)		2. Jåren Beds
	SERIES	1. Lower Støren Greenstone

Vogt's sequence for the Hølanda Area.

TABLE II

CARTER	VOGT	CHADWICK + CO	SYMBOL
UPPER ARENACEOUS (sandstones + grits)		NYPLASSEN BEDS (shales + sandstones)	
PORPHYRITES	HØLONDA ANDESITES	INTRUSIVE PORPHYRITES	
SHALE LIME-STONE SEQUENCE	HØLONDA LIMESTONE	FJELDHEIM BEDS	(shale)
	HØLONDA SHALE	shales	(limestone)
LOWER ARENACEOUS limestones, sandstones, grits, conglomerates	GAUSTADD BRECCIA + ALMAAS MUDSTONE	limestones sandstones	(Sandstone & grit)
	VENNA CONGLOMERATE	FJELDHEIM CONGLOM.	(conglom.)
STØREN	STØREN	STØREN	

Probable correlation of the successions noted in adjoining areas

TABLE III

VOGT	JÅREN BEDS	CARTER
klefstadmo Schist etc		Lower Arenaceous
Blokkum Limestone		Hølonda Limestone
klefstad Shale		Hølonda Shale
Restadgrotås Sandstone		Upper Arenaceous
Vålåtjern Shale etc.		Hølonda Shale
klefstadås Limestones		Hølonda Limestone

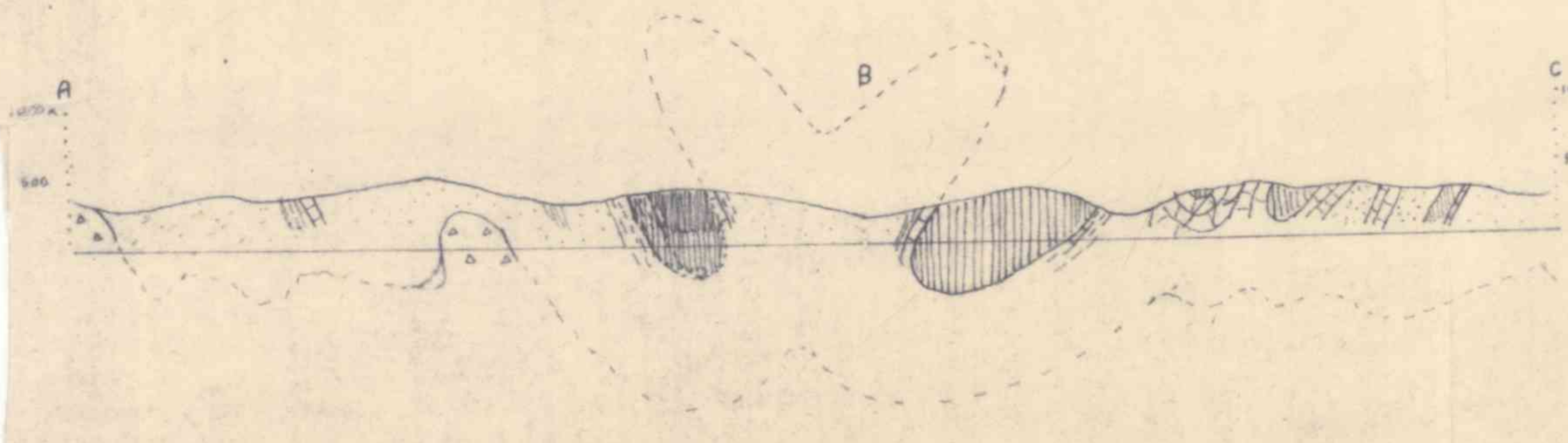
The Jåren Beds and their real stratigraphic position.

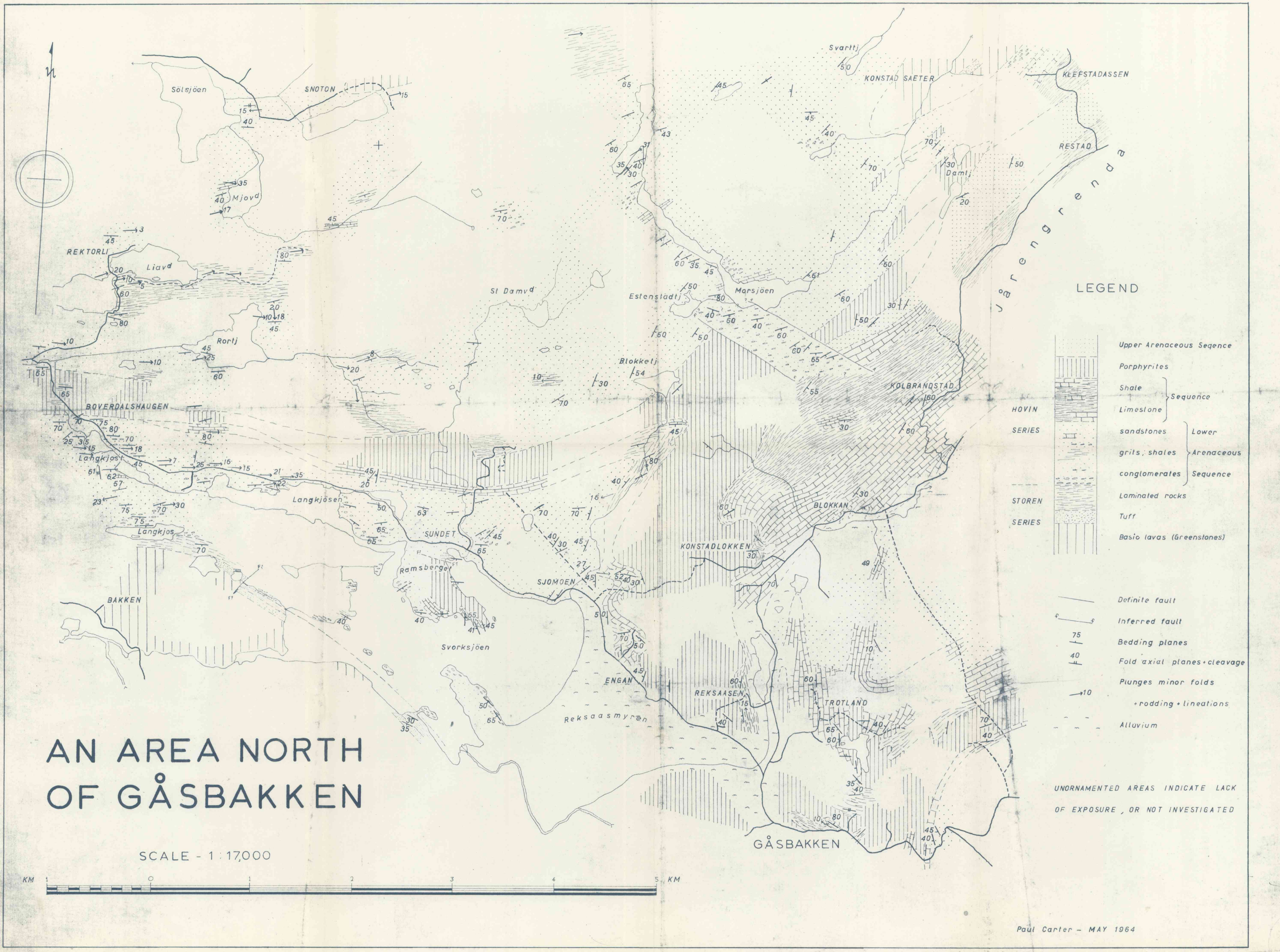
CARSTENS

	Hovin
	Støren
	Röros

0 1 2 3 km

GENERAL MAP TO SHOW CORRELATION WITH VOGT, CARSTENS, AND CHADWICK + CO.
the limits of the field areas of the previous workers are shown, the present author extended his mapping 0·5 - 2 km into the previously mapped areas for purposes of correlation.




AN AREA NORTH OF GÅSBAKKEN
SCALE - 1 : 17,000
KM 1 0 1 2 3 4 5 KM
LEGEND
HOVIN SERIES
STOREN SERIES
Upper Arenaceous Seqence
Porphyrites
Shale
Limestone
Sequence
sandstones
grits, shales
conglomerates
Lower Arenaceous Sequence
Laminated rocks
Tuff
Basic lavas (Greenstones)
Definite fault
Inferred fault
Bedding planes
Fold axial planes + cleavage
Plunges minor folds + rodding + lineations
Alluvium
UNORNAMENTED AREAS INDICATE LACK OF EXPOSURE, OR NOT INVESTIGATED
Paul Carter - MAY 1964
Sölsjöen
SNOTON
Mjovd
REKTORLI
Liavd
Rortj
BOVERDALSHAUGEN
Langkjost
Langkjösen
Langkjos
BAKKEN
St Damvd
Estenstadtj
Blokketj
Marsjöen
Svarttj
KONSTAD SAETER
KLEFSTADASSEN
RESTAD
Damtj
Jårengrenda
KOLBRANDSTAD
BLOKKAN
KONSTADLOKKEN
SUNDET
Ramsberget
SJOMOEN
Svorksjöen
ENGAN
Reksaasmyren
REKSAASEN
TROTLAND
GÅSBAKKEN