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A GEOLOGICAL REPORT ON THE REPPARFJORD-NEVERFJORD DISTRICT.

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A Geological Report on the Repparfjord - Neverfjord district.

The rock sequences which occur within the tract of ground extending some 30km. south from Repparfjord are part of the basement to the Caledonian nappe sequence of West Finnmark exposed in a large tectonic window.

This assemblage received some restricted or very specific attention in the past, much of it concerned with the copper mineralisation of the district. The first systematic map of the whole window was published by Reitan (1963). Although considerable progress was made in this and subsequent publications (Reitan 1965, Roberts and Fareth 1974) it was recognised that many structural and stratigraphical problems remained unresolved.

Reitan differentiated the major rock groups into a litho-stratigraphy which, by analogy and association, could be compared with that of the Alta Window. A major stratigraphical break was recognised within the sequence sub-dividing it into an older basement and a younger cover series. The basal Holmvann Formation was equated with the Raipas (= Karelian) suite of the adjacent window and the foreland. Aerially this constitutes the largest part of the window and despite its distinctive plurifacial character Reitan found no means of consistent sub-division. He mapped the group as a single unit, distinguishing only conspicuous carbonate and quartzite horizons, which he could not assign to any particular stratigraphic horizon.

The several members of the upper cover series are not only distinctive petrologically but contain sufficient sedimentary structures to ensure an order of superposition. In later publications (Reitan 1963, Roberts and Fareth 1974) this cover series was equated with the autochthonous Caledonian sediments of the Alta Window. As a result the 1:250 000 Hammerfest Sheet distinguishes the succession:

Komagfjord Window	Alta Window
Lomvann Fm. (tillite at base)	tillite
Doggelv Fm.	Bossekop Qtze.
Raipas Fm.	Raipas Fm.

The present author confirmed the major lithological sub-divisions but proposes some significant differences within this succession. The principal innovation is the recognition of a consistent lithostratigraphy within the western outcrop of the Holmvann Gp. (see Table of formations).

The overall distribution of formations is such that the broad axial band of Saltvann Gp. splits the outcrop of the Holmvann Gp. into two distinct parts. In the present study an insufficient area of the eastern basement was examined to enable meaningful correlation with the western outcrop.

It is also possible to be somewhat more forthcoming on the status of the Kvalsund Fm. which Reitan equated with the Lomvann Fm. This will be shown to be unlikely.

The structural framework presented by Reitan relied heavily on thrusting to account for the present outcrop pattern and any abnormal contacts. In large measure this was enforced by the absence of any detailed sub-division of the Holmvann Gp. together with the ubiquitous evidence of brittle deformation in the competent lithologies.

The present investigation recognises the major contribution made by folding in determining the outcrop pattern and a structural-metamorphic pattern which contrasts markedly with the allochthon.

Holmvann Gp. (= Raipas Gp.)

The Holmvann Gp. has been sub-divided into four distinctive members :

Langorvann Fm.	Upper clastic association
Vargsund Fm.	Carbonate association
Skinnfjell Fm.	Lower clastic association
Hogfjell Fm.	Volcanic association

The order of superposition outlined above and implied from the distribution of formations around eroded periclines was confirmed by sedimentary structures within several of the sedimentary sequences.

The particular development of these members is dependent on structural situation, as dramatic changes in thickness are associated with the large-scale folding. It is only in the crestal zones of the larger folds that one can obtain some indication of original thickness or can study little-modified sedimentary features within the rocks, although even here there has been some layer-parallel thickening.

Hogfjell Formation

This is primarily a metamorphosed volcanogenic assemblage comprising metabasites, greenbeds and pillow lavas; fine and coarse agglomerate; tuff; slate and phyllite of volcanic and normal marine character; vein-quartz and volcanic conglomerates; green sandstones.

The volcanic members predominate and form the thickest individual units. In consequence they exert a significant topographic control in the western part of the Window, with all the higher ridges and mountains composed of Hogfjell Fm. The periclinal nature of the folding exposes this formation in oval or linear upland masses with the younger metasedimentary formations confined to the intervening vales and depressions.

The volcanic suite and its metamorphic derivatives comprise massive schistose green beds, up to several hundred metres in thickness. These greenbeds range from crystalloblastic chlorite schist and phyllite to little recrystallised and highly fissile chlorite slate. Pillow lavas can be recognised sporadically throughout the western outcrop and individual developments can be thick or quite thin. Individual pillows range from sub-circular to ellipsoidal, regular to irregular, with sizes up to 30cm. in diameter.

The volcanic sequence is cut by numerous veins of irregular shape and trend. These veins include quartz, quartz-chlorite-epidote, quartz-carbonate, all of which display accessory chalcopyrite and magnetite. In the massive, coarse-grained metabasites spots of sulphide, chiefly pyrite, are locally conspicuous.

The metasediments associated with the volcanogenic material are frequently green in colour suggesting derivation from volcanic material, while those displaying other colours, e.g. cream, red, purple and black imply non-volcanic sediments.

Coarse clastic lithologies are distributed throughout the formation and include coarse to fine agglomerate and conglomerates. The agglomerates are generally massive to fairly massive rocks comprising angular blocks and large rounded pillows or fragments of pillows embedded in a fine agglomeratic matrix. In strongly deformed horizons pebbles become markedly ellipsoidal with consistent orientation of the principal dimensional axes. Fine agglomerate is generally more schistose, with small pebbles of chlorite schist and slate being flattened in the plane of schistosity. Volcanic conglomerates are widely distributed and are composed of elongated and flattened 'cigar-shaped' pebbles embedded in a chlorite-phyllite matrix.

The sporadic and restricted occurrence of many members of this group combined with the absence of sedimentary structures and the complexities of the high strains developed during the principal folding make it impossible to recognise consistent mappable units or to establish a succession within the formation.

The only part of the eastern outcrop of the Holmvann Gp which has been studied, i.e. at the head of Borsielv, is composed of massive chlorite schist and metabasite interlayered with fissile chlorite phyllite. This assemblage is lithologically compatible with the Hogfjell Fm.

On the eastern slopes of Nusseren a band of metasediments underlies the thick volcanogenic sequence of the mountain. This band is some 140-700 m. wide and is traceable from Gorradak west-southwest for 9km. It comprises dark and pale-grey slate, dark sandstones and local developments of fine to medium conglomerate with matrix of dark pelite or quartz sand. In one locality a few thin bands of pale-limestone were found within grey slate.

The status and full significance of this group is difficult to evaluate. The question of whether they represent the base of the volcanogenic sequence or merely a prominent sedimentary horizon within it cannot be answered. As far as is known the group is restricted to this one occurrence, where thrusting has brought up deeper rocks over the Saltvann Gp. and the Kvalsund Formation in the crest of the Skinnfjell anticline.

Skinnfjell Formation

This thin formation has a very restricted, non-systematic outcrop and merits separate identification only because it contrasts with the subjacent Hogfjell and overlying Vargsund Formations. The widespread omission of this member is by no means tectonic in origin. In the crests of large folds like the Langorvann and Tappen anticlines dolomite of the Vargsund Fm. rests directly on members of the Hogfjell Fm.

The Skinnfjell Fm. comprises sandstone, fine conglomerate and slate. Grain-size in the sandstones grades from fine into the conglomerate. At the north end of Skinnfjell there is a distinctive quartz conglomerate. This contains equidimensional rounded to angular pebbles of vein quartz up to 5cm in diameter embedded in a chlorite phyllite matrix. Schistosity is not always megascopically obvious.

A small pocket of distinctive character occurs in the core of the Wester Neverfjordbotn anticline at Neverfjord. In addition to cleaved siltstones, slates and sandstones there are two thin horizons of a coarse conglomerate containing cobbles of acid gneiss embedded in a pale psammitic matrix.

Vargsund Formation

Over most of the district the Hogfjell Fm. is succeeded by a predominantly carbonate sequence in which dolomite is the dominant lithology. The dolomite occurs as a thick single formation or thin repetitions of yellow, banded dolomite, 20-30cm. thick, and grey-green siltstone or slate (5-10cm).

Where the original sedimentary characteristics are preserved the dolomite is well-bedded in 10-20cm units with films of dark heavy-mineral layers emphasizing bedding planes. In some horizons there are thin, yellow-brown sandy lenses and layers in which ripple drift and small washout structures indicate the order of superposition. At two localities e.g. Kvitnes and Kvalsundal well-preserved examples of stromatolites were obtained. These primary structures are best preserved where the inclination is close to zero, as in the crestal areas of large anticlines.

In the limbs of the large folds where the dolomite becomes steeply inclined it experiences varying degrees of tectonic modification. Massive dolomite, highly cracked and filled with quartz gash veins exhibits large-scale boudinage or pinch and swell. This is especially well seen on the hillside immediately south-west of Kvalsund. Massive dolomite may also be sheared to a breccia or protomylonite with partings ranging from rudely elliptical to thin and regular.

In the massive facies which predominates in the Vargsund coastal strip it is difficult to recognise any sedimentary features. At Kvitnes and Klubben the lower and upper junctions of the Vargsund Fm. are somewhat transitional, dolomite interlayered with thin bands of siltstone, slate/phyllite and some bands of chert. In zones of high strain such as the limbs of the Langorvann anticline the basal facies of the Vargsund Fm exhibits intense flattening so that the phyllite is reduced to thin smears, giving the rock a striped or blotchy appearance.

Where these dolomite-slate sequences are folded the contrast in ductility of the lithologies leads to angular profiles and rupture of the dolomite in limbs and hinges. This can lead to penetration of such ruptures by the slate, effectively isolating blocks of dolomite. It is suspected that this may also occur locally on a large scale.

Langorvann Formation

The Langorvann Fm. is lithologically heterogeneous, the bulk of the members being of clastic origin. The thickest developments occur in Kvalsundal and in the envelope to the Langorvann Anticline. In the latter the lithologies comprise repetitions of green sandstone, fine conglomerate and dark pelite with individual beds ranging from a few centimetres to several meters.

In Kvalsundal the sequence is chiefly arenaceous with sporadic fine conglomerate. Slate may alternate with sandstones in thin repetitions or form more conspicuous bands. At least two blue-grey limestone horizons have been recorded, outcropping as thin, near continuous bands on both sides of the valley and in a prominent synclinal core in the bed of the river.

In the Neverfjord district the Langorvann Fm. is more pelitic in character than the type locality. At Kvitnes the transitional facies of the Vargsund Fm. passes upwards into siltstone, soft black pyritous slate, dark grey limestone and calcareous slate.

A distinctive lithology occurring at different levels above the base of the formation is a dark grey pelitic conglomerate. In the crest of the Klubben anticline this succeeds calc slate and interbanded sandstone-siltstone. In the Neverfjordbotn area this pelitic conglomerate rests directly on the dolomite. This lithology is a soft and crumbly, dark grey pelite containing sparsely distributed pebbles ranging from 0.5cm. to 20cm. The cobbles include sandstone, igneous rock and metamorphic schists. The character of this lithology is indicative of a submarine flow.

In the Neverfjord area a few occurrences of greenbeds within the Langorvann Fm. testify to local recrudescence of volcanic activity after the main phase recorded in the Hogfjell Fm.

Way-up evidence in this formation was provided by sporadic occurrences of ripple drift and cross-bedding and in cleavage-bedding relationships.

Kvalsund Formation

The Kvalsund Fm. is restricted in outcrop to the north-western corner of the window. This is a lithologically distinctive formation exhibiting little variation in character across its outcrop. It is predominantly a lead-grey, rusty-weathering graphitic slate-phyllite, with occasional thin dark sandstones, and to the east of Trollvann one horizon of fine conglomerate. It is only in those outcrops where sandstone bands occur that one can distinguish original bedding. In most outcrops a penetrative cleavage marks bedding and makes large-scale structural deductions difficult.

Reitan equated this formation with the Lomvann Fm. despite its basic dissimilarity. Revision of his mapping however, indicates that in the envelope of the large Langorvann anticline typical rocks of the Kvalsund Fm. can be found within a few metres of the distinctively striped Lomvann Fm. There is no possibility therefore of lithological convergence in such a short distance and his correlation cannot be supported. On the basis of stratigraphical association the Kvalsund Fm. is regarded as the immediate successor to the Holmvann Gp. although the contact is one of unconformity.

Saltvann Gp.

The rocks of the Komagfjord Window are divided into three distinctive outcrops by the broad axial strip of psammites and psaphites which Reitan named the Saltvann Gp. This group he sub-divided into three distinctive members:

Fiskevann Fm.
Djupelv Fm.
Saltfjell Fm.

The lowest member, the Saltfjell Fm., is a somewhat variable psammite to fine conglomerate with occasional lenses of coarser conglomerate and a few thin pelitic layers. Throughout the northern part of the outcrop this formation is distinctly bedded and exhibits abundant cross-bedding and allied sedimentary structures. East of the Wester Ariselv the steeply inclined psammites exhibits strong flattening and sedimentary structures are difficult to detect. Schistosity varies in development, being most conspicuous in the fine grained lithologies.

The Djupelv Fm. is predominantly conglomeratic, although sizeable lenses of sandstone do occur. The passage from the Saltfjell Fm. is very rapid. The typical aspect of the Djupelv Fm. is a dark polymict conglomerate comprising pebbles of greenstone, chert, gabbro and vein quartz embedded in a matrix of dark, fine-grained sandstone. The pebbles are invariably flattened cigar-shaped with long axis aligned in the foliation, especially when the layering is steeply-inclined, e.g. along the western contact. The longest axes of pebbles exhibit a high degree of preferred orientation, plunging steeply north-west, congruous with the mineral and fibre lineation throughout the district.

The Fiskevann Fm. is a mixed sandstone-conglomerate formation with conglomerates occurring in bands and lenses from 0.3m - 5m thick. The sandstones are very similar to those of the Saltfjell

Fm. while the conglomerate is a very distinctive monomict lithology comprising angular blocks of dark-purple porphyrite set in a matrix of white quartzite. These cobbles range in size from 5-10cm. Throughout the area mapped this lithology remains constant. The clasts exhibit no trace of deformation in sharp contrast to the pebbles of the Djupelv Fm.

Doggelv Formation

In the eastern half of the window the Holmvann Gp. is unconformably overlain by the Doggelv Fm. This is a predominantly mature white quartzite, medium to coarse in grain-size, with strongly developed bedding-planes and numerous instances of cross-bedding. A few thin pebble horizons, ranging from pebble trails one pebble thick, to thin and impersistant lenses are developed. The pebbles include vein quartz, chert and occasional banded acid gneiss. Schistosity is only locally developed.

The thickness of this formation varies rapidly from west to east. In the Borsielv syncline the Doggelv Fm. is thin, a primary feature amplified in the tectonically-thinned limbs of the structure. In the folds east of the Rodfjell anticline the thickness increases but contact relations are obscured by the Rodfjell ultrabasic body.

From the observed tectonic pattern one cannot ascribe this variation in thickness simply to the folding affecting the Doggelv and the overlying Lomvann Fm., as the latter displays no such variability. It is held that the rapid westerly thinning is a consequence of pre-Lomvann faulting and erosion.

To the west, south-east of Faegfjord, a thin white quartzite with sporadic vein quartz conglomerate occurs on top of the Holmvann Gp. and beneath typical striped Lomvann Fm. In appearance this white quartzite could well be a truncated Doggelv sequence or alternatively a quartzite within the Lomvann Fm.

In the post-Holmvann Gp. succession of the window we have therefore two major sandstone horizons, the Saltvann and Doggelv Fms. The stratigraphical position of the Doggelv Fm. is unambiguous, lying as it does between the Lomvann and Holmvann Gps. The status of the Saltvann Gp. on the other hand is not so obvious. Reitan reasoned, on the basis of pebble composition within the Djupelv conglomerates, that it was younger than the Holmvann Gp. Two research students working in the southern and central areas of the window have described a contact between Saltvann and Holmvann Gps. as sedimentary, unlike the tectonic junctions in the north. If this is the case the Saltvann forms a faulted synclinorium, confirming Reitan's order of superposition. Thus from west to east across the area three different formations have sedimentary contacts with the Holmvann Gp., the Kvalsund, Saltvann and Doggelv Fms. The outcrop of Saltvann and Doggelv Formations is no more than 250m. apart across the Ariselv Fault. Two possibilities arise:

1. The two sandstones are equivalent. If this is the case then the difference in thickness across the Ariselv Fault implies that this fault is pre-Lomvann in age.

2. The Saltvann Gp. is older than the Doggelv Fm. In this case the Ariselv Fault must be pre-Doggelv in its inception and all trace of the Saltvann Gp. has been removed by erosion prior to the deposition of the Doggelv Fm. One feature against direct correlation is the difference in sedimentary character of the two quartzites. The Salfjell Fm. is an immature felspathic quartzite, frequently arkosic, while the Doggelv is a mature quartz sandstone.

It is hoped to perform some trace element studies to ascertain whether there are distinctive patterns in either formation which may help to resolve the problem. At present in the absence of new evidence the status of these formations must be left as before, e.g. the Saltvann Gp. grouped with the older Precambrian and the Doggelv Fm. with the Caledonian suite.

The Saltvann Gp. does not occur west of the main outcrop and the Kvalsund Fm. rests on the Holmvann Gp. There is no way of assessing the relative stratigraphic positions of these formations within the window. Acordingly both are grouped together as pre-Caledonian.

<u>Lomvann Gp.</u>

In the type area around Lomvann the diagnostic characteristic of the Lomvann is a regularly striped pelite-semi-pelite. Thin white, fine-grained quartzite less than 1cm. thick alternate with thicker pale to dark-grey slate bands. At certain horizons either component can disappear and thick quartzite or pelite horizons occur. One or two prominent quartzite layers occur just above the contact with the Doggelv Fm. in Borsielv.

In the Faegfjord district a distinctive three-fold sub-division of quartzite, striped schist and quartzite overlies the Langorsvann Fm. As stated earlier Reitan equated this with both Lomvann and Kvalsund Formations. The author has no hesitation in supporting the correlation with the Lomvann Gp. but not with the Kvalsund Fm.

Between Lomvann and Borsielv the base of the Lomvann Fm. transgresses horizons of the Doggelv Fm. At Faegfjord, as mentioned earlier, the Doggelv Fm. is probably missing and the Lomvann Fm. rests on the Langorsvann Fm. This supports the notion of pre-Lomvann faulting and erosion.

Structure

The rocks of the Window bear the imprint of polyphase deformation manifested in strong folding, thrusting, sliding and faulting. Despite the large time gap between the Raipas and Caledonian autochthon it is not possible in this northern area to differentiate with certainty the penetrative strain elements like folds, cleavage-schistosity and lineation etc. into pre-Caledonian and Caledonian phases. The symmetry, morphology and strain history of structures in both assemblages are compatible and indistinguishable with no indications of an overprinting.

Folding

Two cycles of fold formation have affected the autochthon, although the first (D1) is much more significant in terms of structure dimensions, pervasiveness of strain and effect on outcrop pattern. In the northern part of the Window the second deformation (D2) is often no more than a minor disturbance locally achieving mesoscopic dimensions. Nowhere are significant D2 megascopic folds produced.

a. First Deformation.

This phase of deformation produced folds ranging in wave-length from a few millimeters to 2km. and amplitudes up to 1km. The large folds are chiefly upright or slightly overturned with noncylindrical axes (see sections). The combination of stratigraphy, wave-length and fold style produce the distinctive topographic grain of the district. The pattern of regularly-spaced, rugged oval ridges flanked by smooth, vegetated valleys reflects the volcanic cores to periclines rimmed by the softer envelope. This pattern can only be appreciated when the distinctive lithostratigraphy of the Holmvann Gp. is understood. As Reitan did not recognise these stratigraphic markers all but the largest and most obvious folds went undetected. To explain anomalous juxtapositions which were dependent on the folding process he was forced to invoke thrusting as an explanation.

Late-stage flattening has tightly appressed the limbs of folds with upright style, leading ultimately to strong layer-parallel thinning of the limbs. Where dolomite was involved the low ductility of this lithology leads to boudinage formation on all scales. Thinning in some cases leads to complete excision of one or more lithologies or whole lithostratigraphic groups and anomalous juxtapositions, e.g. sliding. In the western part of the Window slides develop most frequently, although not exclusively, on the western limbs of anticlines, e.g. Kvitnes, Asavann and Hogfjell Anticlines. The intensity of this flattening increases towards the west as indicated by a tightening of profiles and the pattern of intricate litho-stratigraphic repetitions in the Vargsund coastal zone. This contrasts with the outcrop pattern of the large Tappen, Langorsvann and Skinnfjell Anticlines, To the east of the Saltvann Gp. the large fold style is rather simple and the symmetry is closer to orthorhombic so that a conjugate pattern obtains, i.e. folds overturn to both east and west.

Within the Saltvann tract the structure is simple, namely a large, near symmetrical anticline with macroscopic parasitic folds. This structure is truncated on both its eastern and western sides by large north-south faults. Late movement on the Ariselv Fault was responsible for the asymmetrical distribution of formations within this belt.

In the central part of the Window it has been reported, as mentioned earlier, that the Saltvann Gp. rests with sedimentary contact on the Holmvann Gp. in a broadly synclinal structure. It is obvious therefore, that in the north the flanking faults have destroyed the true form of the major structure leaving only the central anticline.

Minor Folding

The distribution and interrelations of minor folds to each other and the larger associated structures in this region are complex. Synoptic district or specific outcrop patterns of mesoscopic folds indicate a high degree of axial variability consequent on primary noncylindrism. Individual axes can curve through angles of 90° or more in the axial surface, and if adjacent axes are out of phase it can be appreciated that in natural sections or outcrops the patterns may be highly complex. The short wave-length of axial curvature compared with that of the host fold indicates that minor folds can be incongruous to the host, i.e., the plunge of small folds differs from that of the large structures and cannot automatically be employed to deduce the attitudes of the major structures.

While the axes of major folds undulate in plunge up to 40° north or south the minor structures display much greater variability. In an evolving fold complex the later increments of strain cause any fold axes orientated oblique to the principal axes of strain to rotate towards the principal axis of finite strain (X), the amount of rotation governed by the level and pattern of strain. As will be described later X is delimited in these rocks by the orientation of the prominent lineation.

Minor folds in the highly thinned limbs of large folds are in regimes of high strain and the axial rotation can therefore be large, while in crestal zones highly divergent axes can only occur if they are very tightly appressed.

Some confirmation of this general thesis can be seen in synoptic or particular descriptions. Fig. 1 illustrates the orientation pattern of major axes from the area, while Fig. 2 [redacted] presents the spread of associated minor fold axes. Figs. 3 - 5 present specific examples of minor fold patterns and their relationship to the associated large structure. In each case the minor folds on the crest and each limb are differentiated and it can be appreciated that in the limbs where higher strains obtained axial variability is high. Confirmation of this rotation is perhaps best obtained from the strongly flattened Klubben Anticline. Rotation has carried minor fold axes into parallelism with the fibre lineation on schistosity surfaces (Fig. 6.)

Ulveryggen Fold

Because of the economic significance of the mineralisation associated with the Ulveryggen fold, this structure merits sperial consideration, although in the overall tectonic framework it is in no way distinctive.

The Ulveryggen structure is a medium to large scale coupled fold with inconstant profile diminishing in amplitude downwards (Fig. 7). In the vicinity of the open-casts it is a well-defined paired asymmetrical anticline and syncline. The anticlinal axis trends north-south and lies along the ridge below the access road, while the synclinal axis runs through the ridge immediately west of the mine. North and south of the mine the gentle plunge brings to the surface the deeper portions of the structure and demonstrates the diminution in amplitude. About 1400m. north of the mine the fold no longer exists. Projecting a line at the plunge angle from this point reveals that the fold dies out at 400m. depth. The total elliptical outcrop of the structure on the ground is 3.4km. long and 600m. wide.

The mineralised zone therefore, occurs in the common limb between the two folds. From the geometry of the outcrop pattern the axial surface is curviplanar, dipping steeply eastwards in the levels of the open-casts, steepening gradually with depth to a steep westerly inclination. The ore body therefore, in following the axial trace will exhibit a similar change in attitude. It is suggested that in permeating upwards the orebearing fluids followed the ease of emplacement direction, i.e. the axial surface.

From Mr. Hovland I understand that a geochemical anomaly has been obtained in the vicinity of a similar coupled fold on the western limb of the major fold. This fold pair faces eastwards, i.e. towards the anticlinal crest and is another large-scale parasitic structure to the major fold. If the mechanism of ore emplacement at Ulveryggen has been accurately identified the ore body in this second instance will be a structure dipping steeply westwards near the surface and changing gradually to an easterly inclination at a depth of approximately 200m.

It is suggested that geochemical scrutiny of similar folds if located could be a fruitful avenue in prospecting. Their location could be detected initially from a detailed photo-geological study.

Cleavage-schistosity

Slaty cleavage is well developed in pelitic lithologies although in many of the coarser fractions of siltsone sequences it may be absent. Cleavage is not developed in calcite marble, dolomite and pure quartzite. A less penetrative and more widely spaced schistosity develops in psammitic lithologies. In the steep limbs of upright folds the cleavage is orientated parallel to the bedding. In conglomerates the foliation may be marked by a preferred alignment of the XY planes of deformed ellipsoidal pebbles. The matrix on the other hand may or may not display schistosity.

Lineation

On cleavage surfaces in fine-grained rocks, e.g. slates, phyllites, there is a distinctive fibre lineation (Fig. 8). On some surfaces in mineralised slate this lineation is picked out by trains of idioblastic magnetite grains. In the interfacial zone between competent and incompetent rocks (e.g. dolomite-slate) the strong differential shear attending deformation is accompanied by a pronounced slickensiding, the fibres of which are orientated parallel to the fibre lineation of the slates.

In conglomerates which display pebble distortion it can be seen that the long axes of the pebbles have a similar distribution to the fibre lineation (Fig. 9). This lineation, when observed on cleavage planes (XY), denotes the direction of maximum finite elongation (X) in the rocks.

Second Fold Phase (D2)

D2 is a weakly expressed deformation phase in the northern part of the Window. Over much of the area it is a fine crumpling relating to conjugate strain-slip cleavage dipping north-west or south-east. Locally mesoscopic folds develop which exhibit a north-easterly plunge (Fig. 10).

Above the main thrust the mylonitic fabric is affected by angular conjugate folds with associated strain-slip schistosity. These are coaxial with D2 in the autochthon and may be comparable in age.

Thrusting and Sliding

Within the Window thrusting plays an important role in the evolution of the structural pattern. These thrusts fall into several distinctive types according to their relationship to the fold structures.

In some situations strain could not be achieved fully by the upright folding alone. As the fold tightened (i.e. inter-limb angle became small) there came a point when the profile could only amplify further by layer-parallel extension, parallel to the axial surface. As the participating lithologies demonstrate widely differing ductilities the response to this upward extension was not uniform. Pelite, greenschists and psephites with pelitic or semi-pelitic matrix extended by uniform flow, a fact reflected in the marked layer attenuation and strong development of fibre lineation. Dolomite, massive greenbed or quartzite on the other hand, displayed a more restricted flow resulting in large-scale boudinage or pinch and swell. The limit of this extension is sliding, i.e. total excision of one or more lithologies, leading to the anomalous juxtaposition of non-contiguous parts of the succession. These slide zones may exhibit no distinctive fabrics and could be overlooked unless the full stratigraphic succession was known.

The differential shear in the interfacial zone between ductile and rigid lithologies is high and in some cases the rigid layers become strongly crushed, leading to the development of rude lenticular partings on which there are prominent slickensides. Some of the quartzite horizons proved so rigid however, that the fabric yielded in brittle fashion to a structureless crush breccia.

In the slightly overturned folds of the coastal zone extension is most prominently concentrated in the trailing western limbs while the overturned eastern limbs may display similar sliding, or a more efficient horizontal shortening effected by gently-inclined break thrusts. These thrusts are attended by strong cataclasis, transecting structures and appearing to be independent of the folding. These thrusts vary from quite small and local to structures traceable for several kilometers. The mountain of Nusseren is composed of a thick slab of metavolcanic and metasedimentary sequences displaced on one of these thrusts over the crest of the Skinnfjell Anticline. The gently-inclined thrust plane is well exposed in the prominent escarpment along the southern border and can be traced for 9 km. to Gorradak. Within the overthrust slab another sub-parallel thrust displays a similar repetition with greenbeds thrust over highly sheared Kvalsund and Vargsund Fms.

On the hill north of Neverfjord another small breakthrust transgresses the tight syncline extending NNW from Neverfjordbotn (see sections). This thrust brings dolomite across the crest of an anticline and over the younger pelitic conglomerate of the complimentary synclinal core. This thrust can be traced for at least 1 km. The sole of the thrust slab contains large segregations of vein quartz and both this and the dolomite are strongly shattered with the development of a rude foliation and extensive quartz veining.

The largest of the thrusts is the boundary thrust (Kalak Thrust) on which high grade psammites from the orogenic interior moved over the autochthon, slicing through the upright structures in the process. In the psammites there is a thick development of blastomylonite and phyllonite, the latter in 2-5cm bands of coarse mica. This zone is characterised by strong layer-parallel attenuation and megascopically there is a gradual transition upwards into regional tectonites. Locally, as at Lomvann, thin streaks of pseudotachylite become conspicuous. Where the thrust transgresses greenbeds its effect is reflected in the subjacent fabric. For a depth of 50m. the massive greenbeds become chloritic phyllonites with strong schistosity parallel to the thrust. Elsewhere there are no obvious megascopic effects to be seen, even where one can approach to within a few centimetres of the thrust plane. Immediately north of Lomvann tight folding and pronounced sub-vertical cleavage produce a strong planar anisotropy sub-normal to the thrust and one would imagine, in thissituation, the Lomvann Fm. to be highly susceptible to thrust deformation.

In terms of mineralisation potential one can distinguish between thrusts and slides. In thrusting the low to high temperature cataclasis on the thrust plane would have been accompanied by free permeation of hot water from the deeper levels penetrated by the thrust. As disseminated sulphide mineralisation is characteristic of the Karelian basement this could have yielded material for subsequent concentration along the thrust plane. While the boundary thrust is not associated with obvious mineralisation a number of the smaller thrusts which have steeper inclinations and penetrate down into the basement do contain minor concentrations, e.g. Nusseren Thrust and Kvitnes. In sliding on the other hand, the excision which reflects the limit of overall extension produces no avenues of easy access or source of abundant water flow.

FAULTS

A suite of small to medium-sized faults trending NNE-SSW are present through the Window. The two largest faults bound the Saltvann Gp. on its eastern and western margins. In both cases the faults are marked by prominent topographic depressions.

A number of smaller faults occur in the western Holmvann Gp. The throw on these faults cannot be determined and the faults trending parallel to the main outcrop can only be recognised by the belts of strong polish and striation or by occasional exposure of the fault breccia. Most of these faults were the site of late mineralisation, generally quartz-dolomite veins with sulphides. A number of these zones have been prospected in the past, and the old workings are the only sites where one can really study the brecciation.

MINERALISATION

Copper mineralisation has several expressions in the area. In the greenstones of the Hogfjell Gp. sulphides are widely disseminated in uneconomic concentrations. In most outcrops one can see small specks throughout the rock. Minor concentrations occur in quartz and quartz-carbonate veins emplaced at several times throughout the deformation history. These veins reflect concentration during the metamorphic reconstitution attending the several deformation episodes. The veins follow axial surfaces or transect D1 and D2 folds, and syn-D1 veins also bear the imprint of later D1 strain. The largest concentrations occur in thick quartz-carbonate veins emplaced along the site of late faults. These fault lodes mark the site of a number of old prospects e.g. Beritsfjord, Nusservannelv. Shearing along prominent stratigraphic interfaces may also mark the site of mineralisation as evidenced by the workings on Tappen and the vale south-west of Beritsfjord.

No significant mineralisation was observed in the meta-sedimentary sequences of the Holmvann or Kvalsund Gps.

The only significant sulphide mineralisation is that being exploited in the Saltvann Fm. This thick psammitic formation is held to overlie greenstones of the Holmvann Gp. and reworking during the D1 metamorphism probably reactivated the sulphides which migrated upwards along tectonic avenues, such as the steep layering or fracture zones in the eastern limb of the major anticline and axial surfaces of the parasitic folds.

The mineralisation therefore falls into two broad categories:

1. Synmetamorphic impregnation and redistribution during D1 deformation.

2. Late-tectonic emplacement in discrete and localised vein deposits along discrete shears and faults and associated with extensive gangue material.

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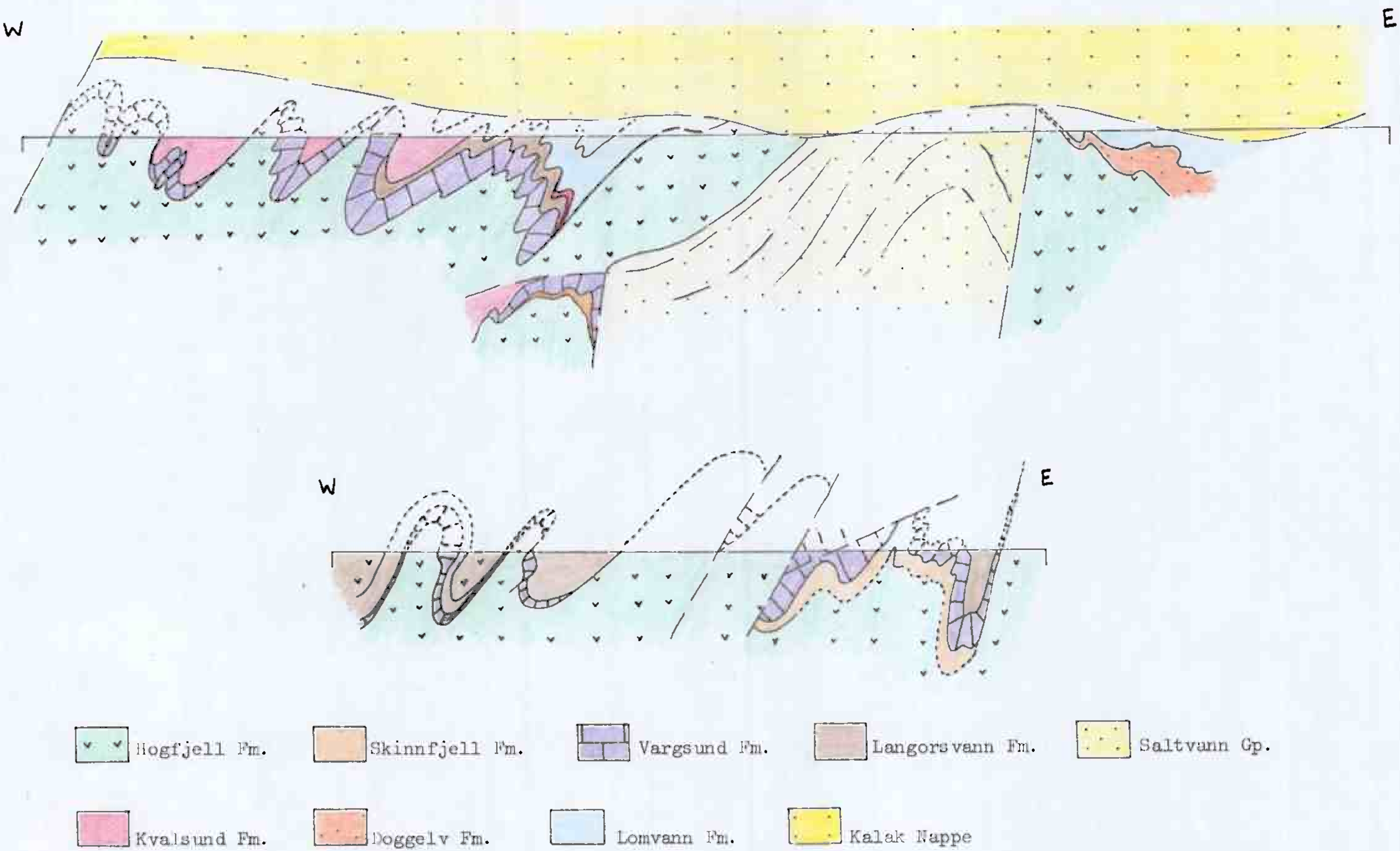

Cross-sections, a) From Trollvann to Lomvann b) North coast of Neverfjord from Klubben to W. Hogfjell.

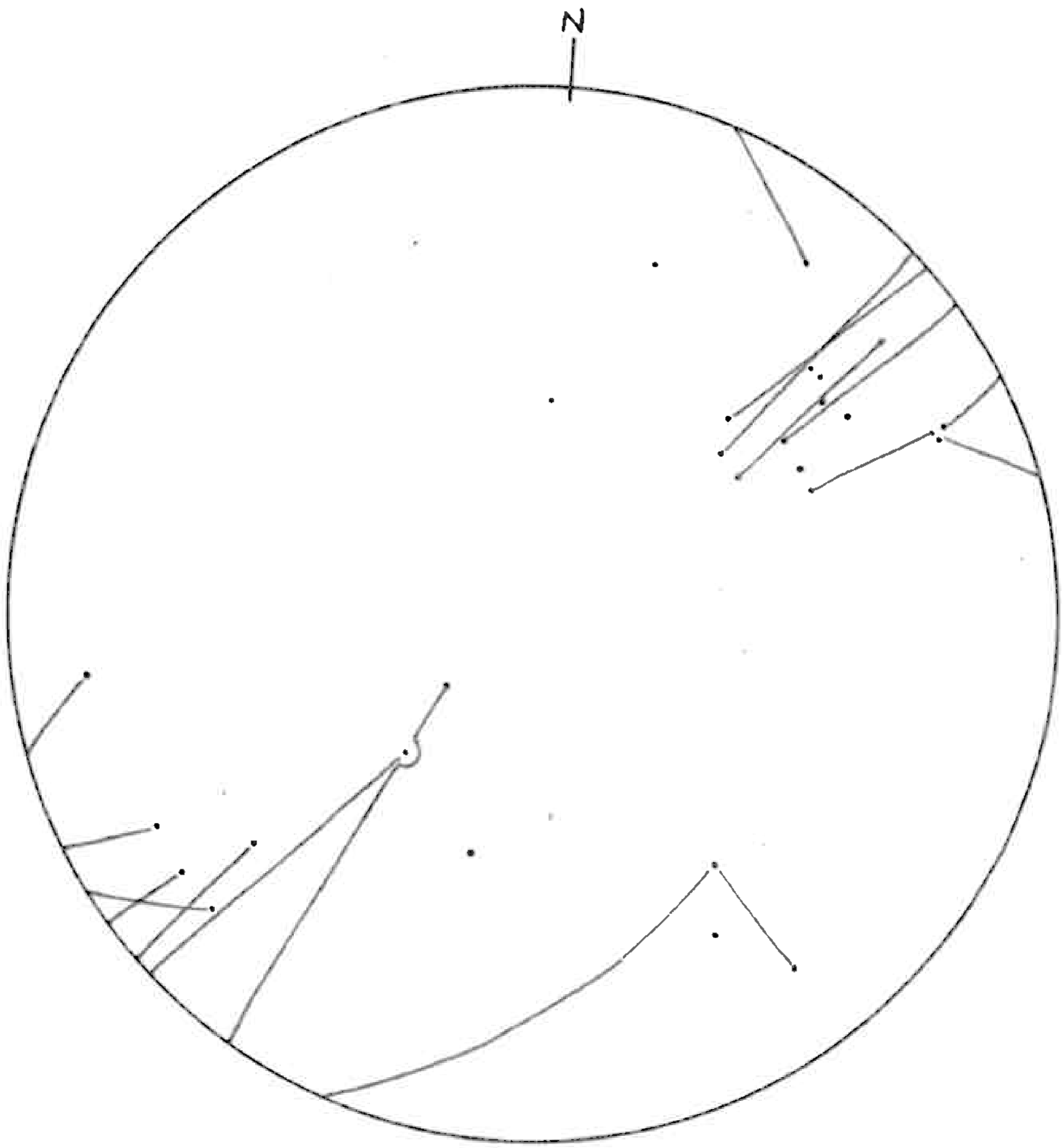

Fig. 1. Synoptic stereogram of axes to large folds within the Window. Lines link extremes of observed axial variation.

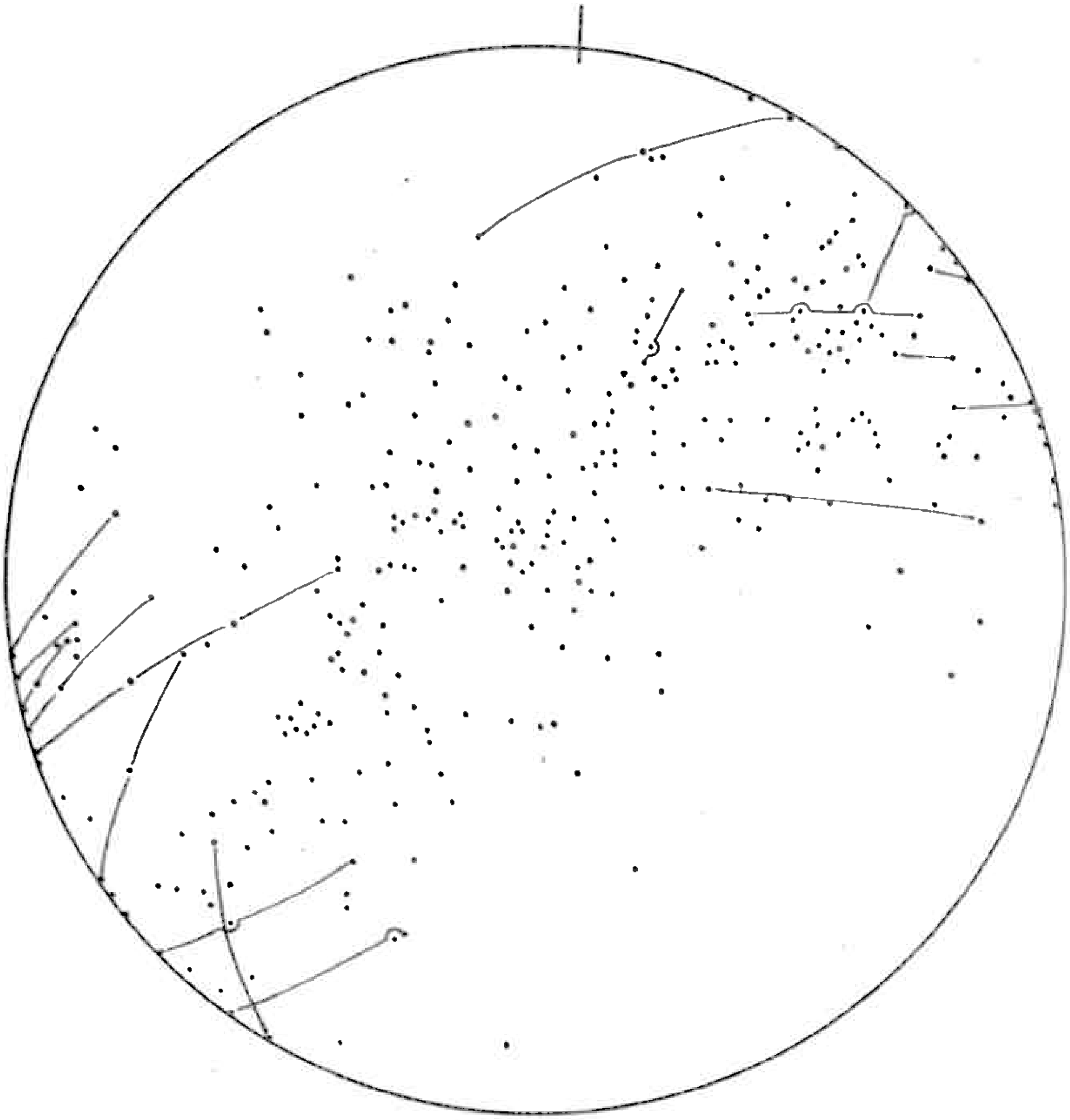

Fig. 2. Synoptic stereogram of axes to minor folds within the window.

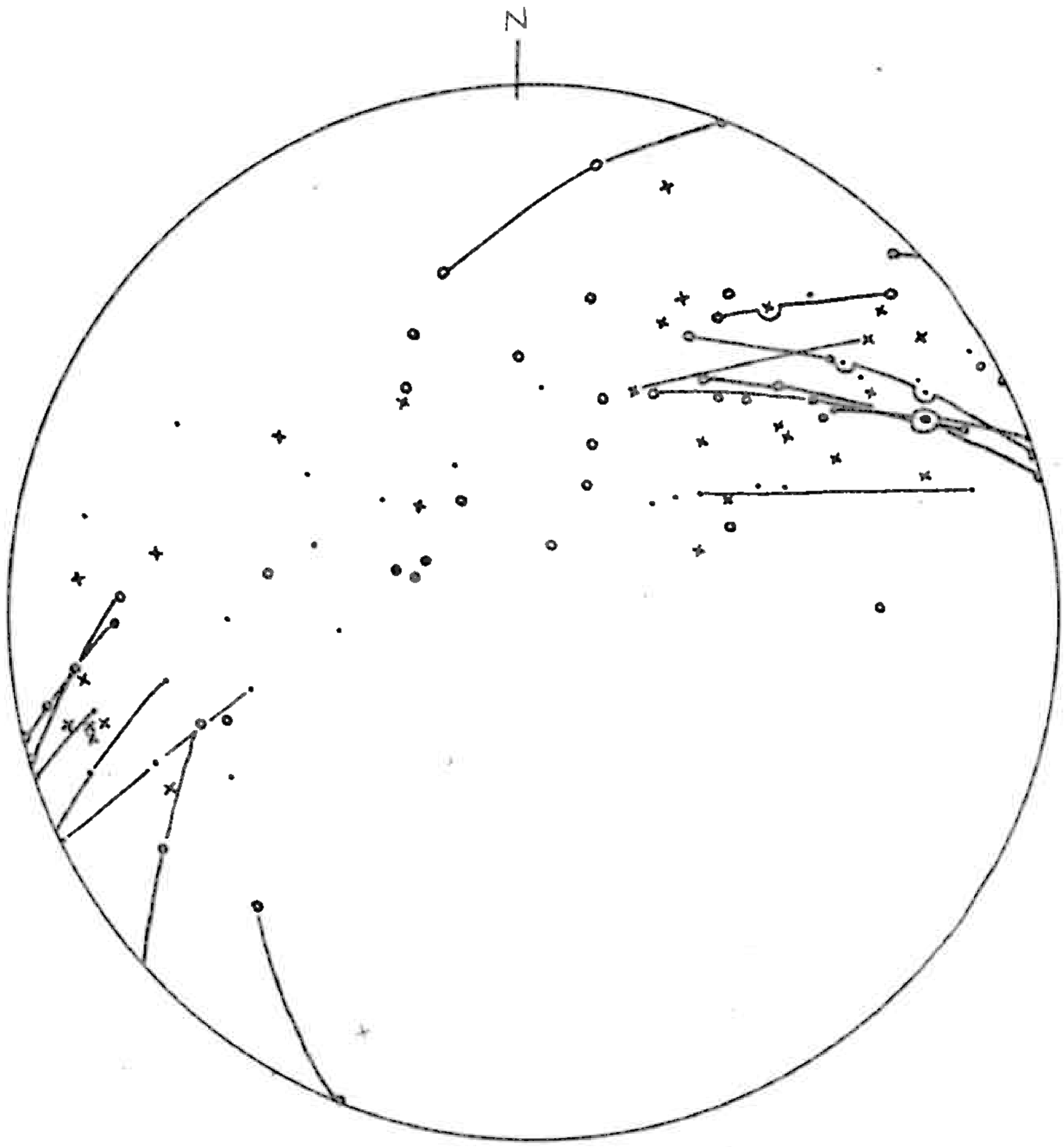

Fig. 3. Stereogram of minor folds on the Langorvann Anticline.
. - axes of minor folds from the crest of the large fold; o and x - axes of minor folds on the inverted lower limb and the upper limbs respectively.

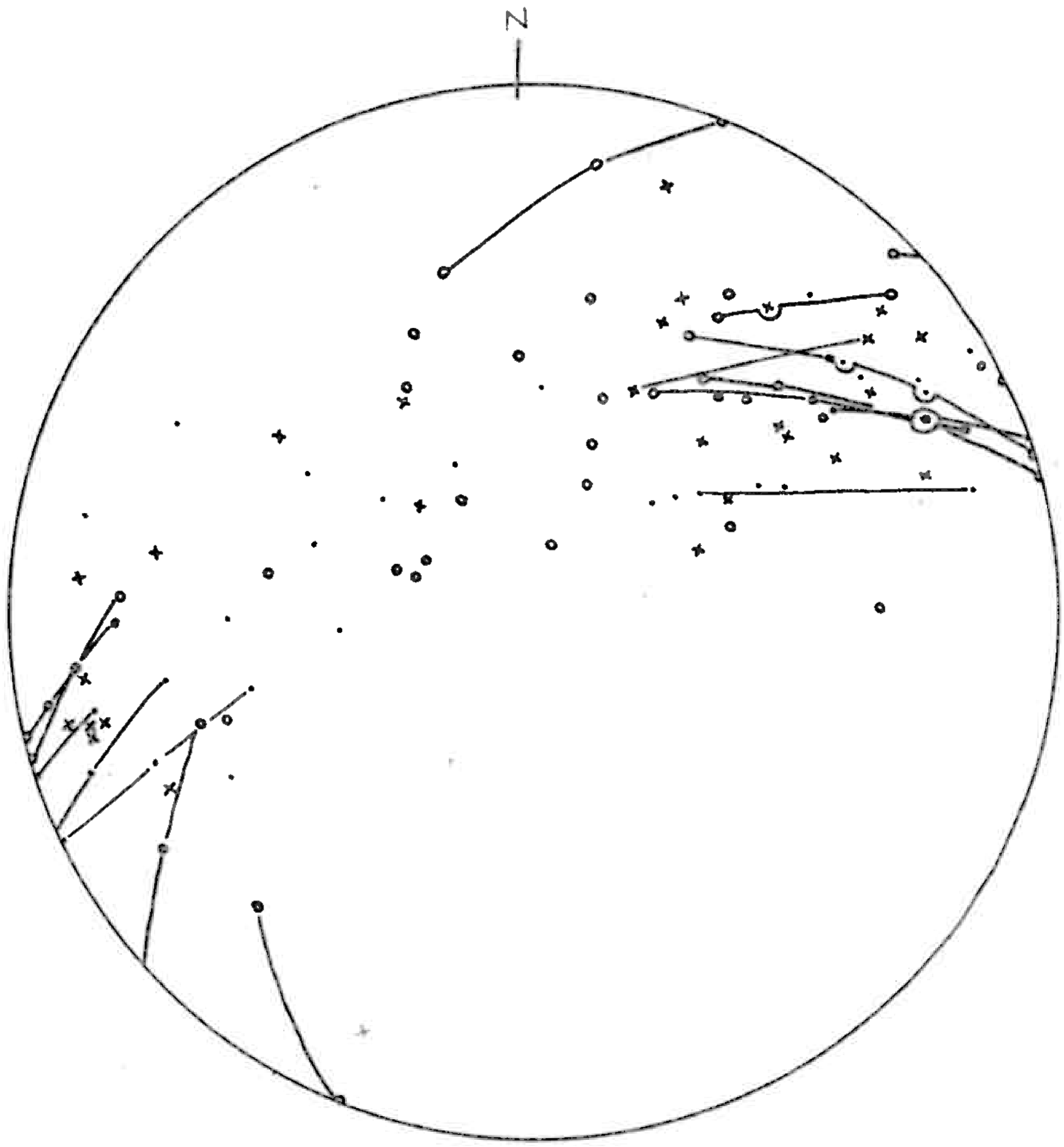

Fig. 3. Stereogram of minor folds on the Langorvann Anticline. · - axes of minor folds from the crest of the large fold; o and x - axes of minor folds on the inverted lower limb and the upper limbs respectively.

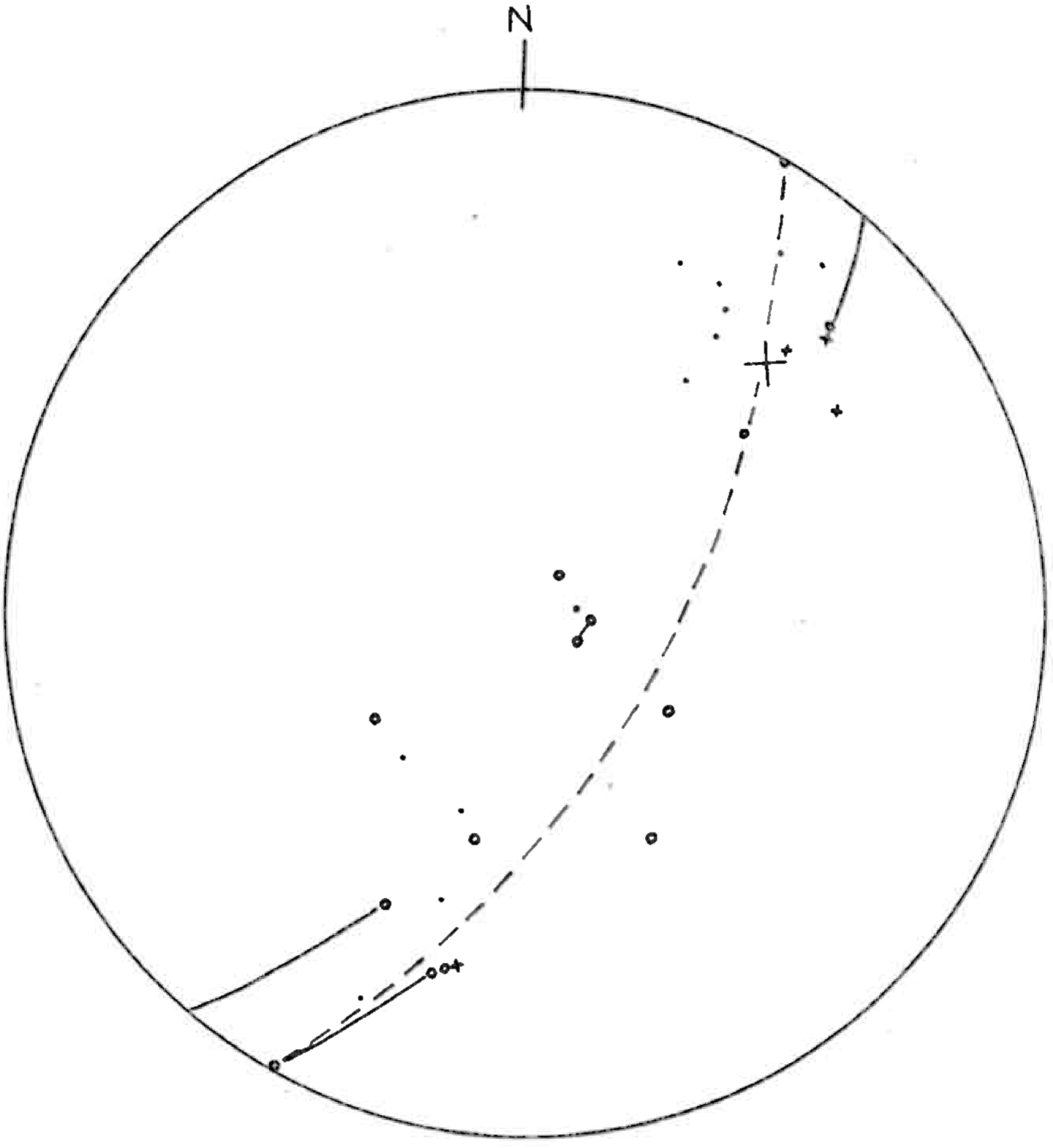

Fig. 4. Stereogram of minor folds on the Borselv Syncline. . o and x - axes of minor folds from the gently-inclined western limb, the crestal zone and the inverted eastern limb of the large fold respectively. + axis of the large fold.

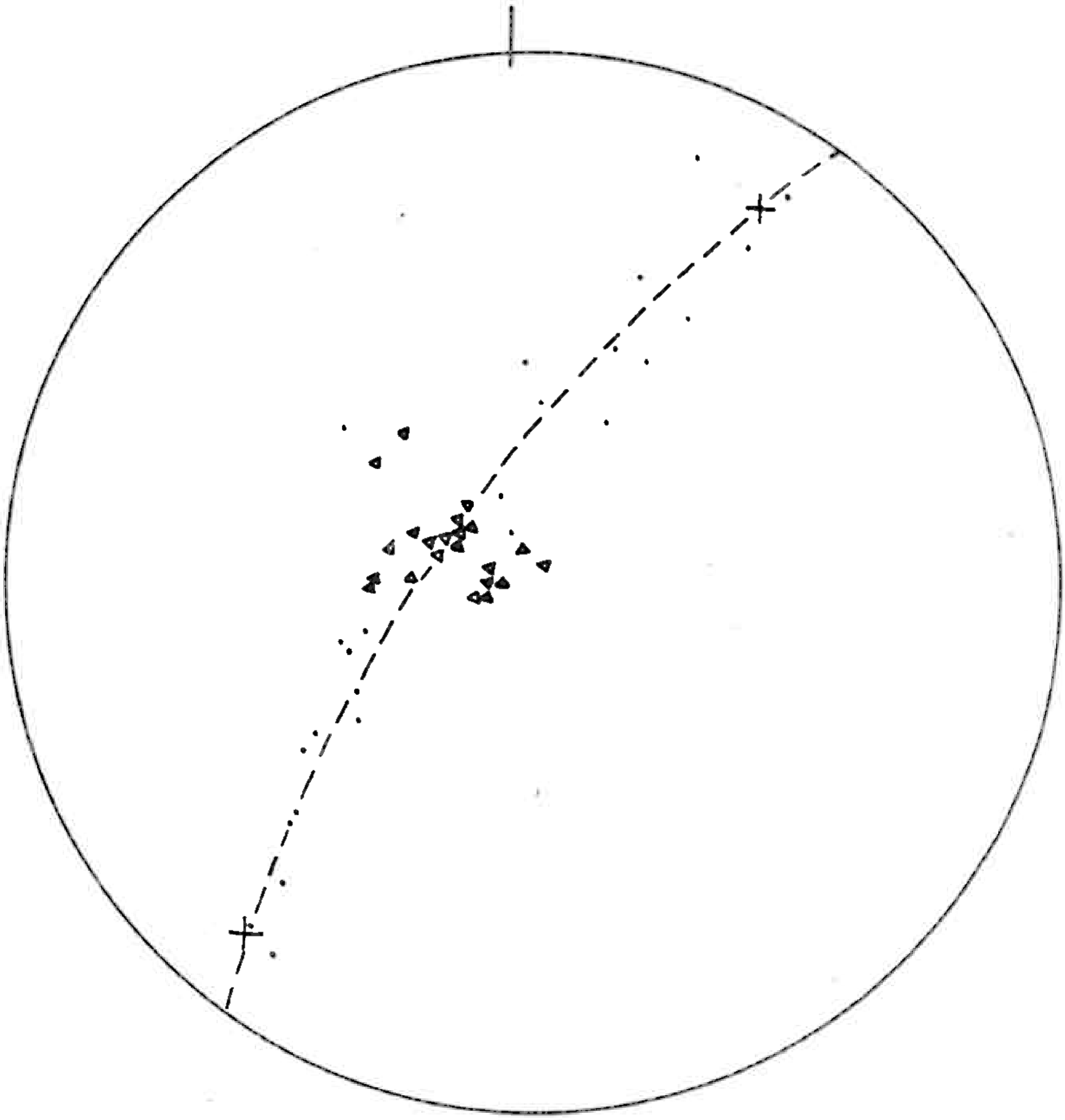

Fig. 5. Stereogram of minor folds on the Kvalsundal Syncline. . - axes of minor folds; Δ - fibre lineation; + large fold axis. The broken line is the trace of the mean axial surface.

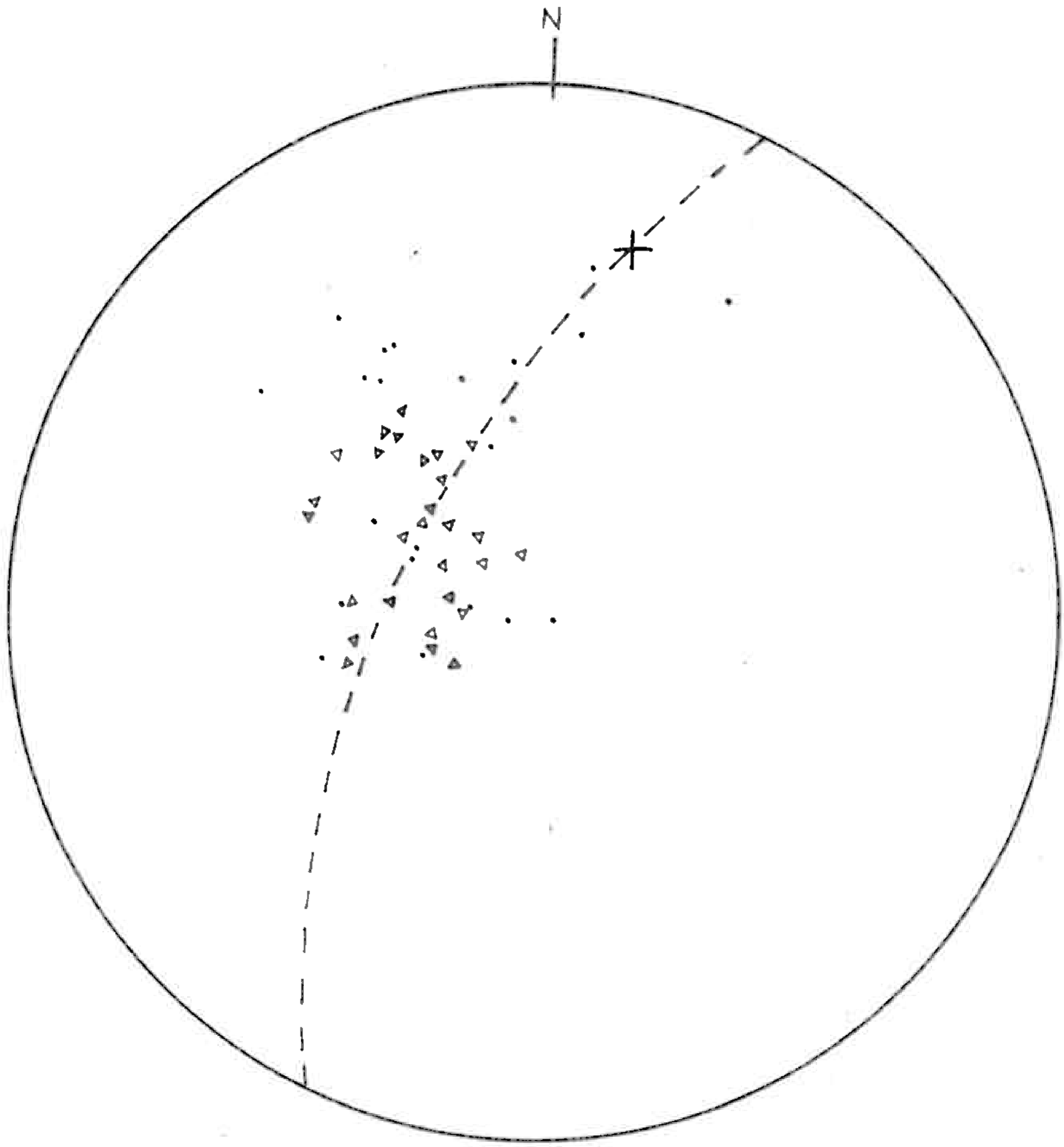

Fig. 6. Stereogram of minor folds on the Klubben Anticline.
Symbols as in Fig. 5.

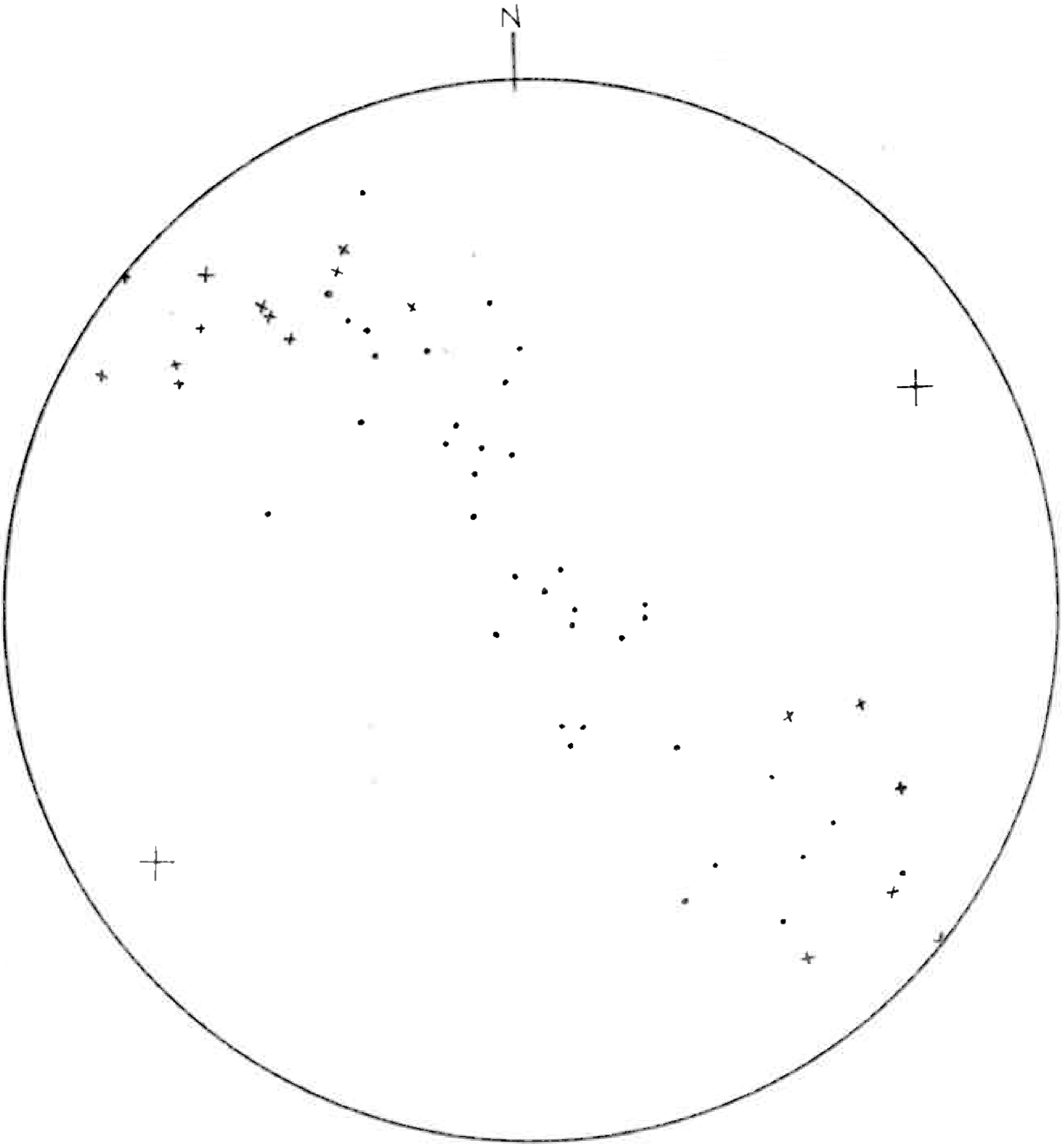

Fig. 7. Stereogram of poles to planar elements in the Ulveryggen fold. . - bedding; x - schistosity.

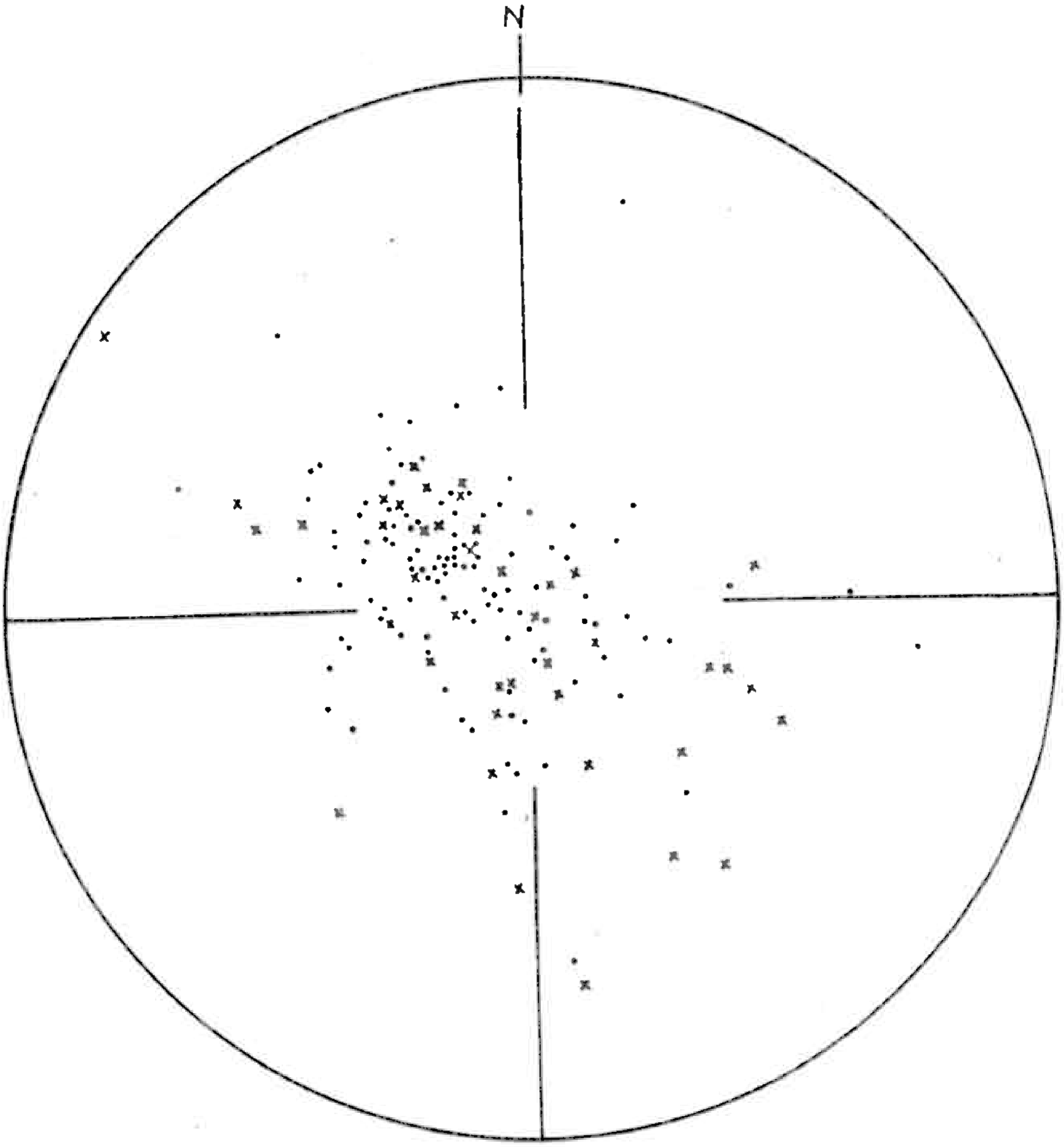

Fig. 8. Synoptic stereogram of poles to the stretching lineation within the Window. . - fibre lineation in pelites etc. x - slickenside fibres.

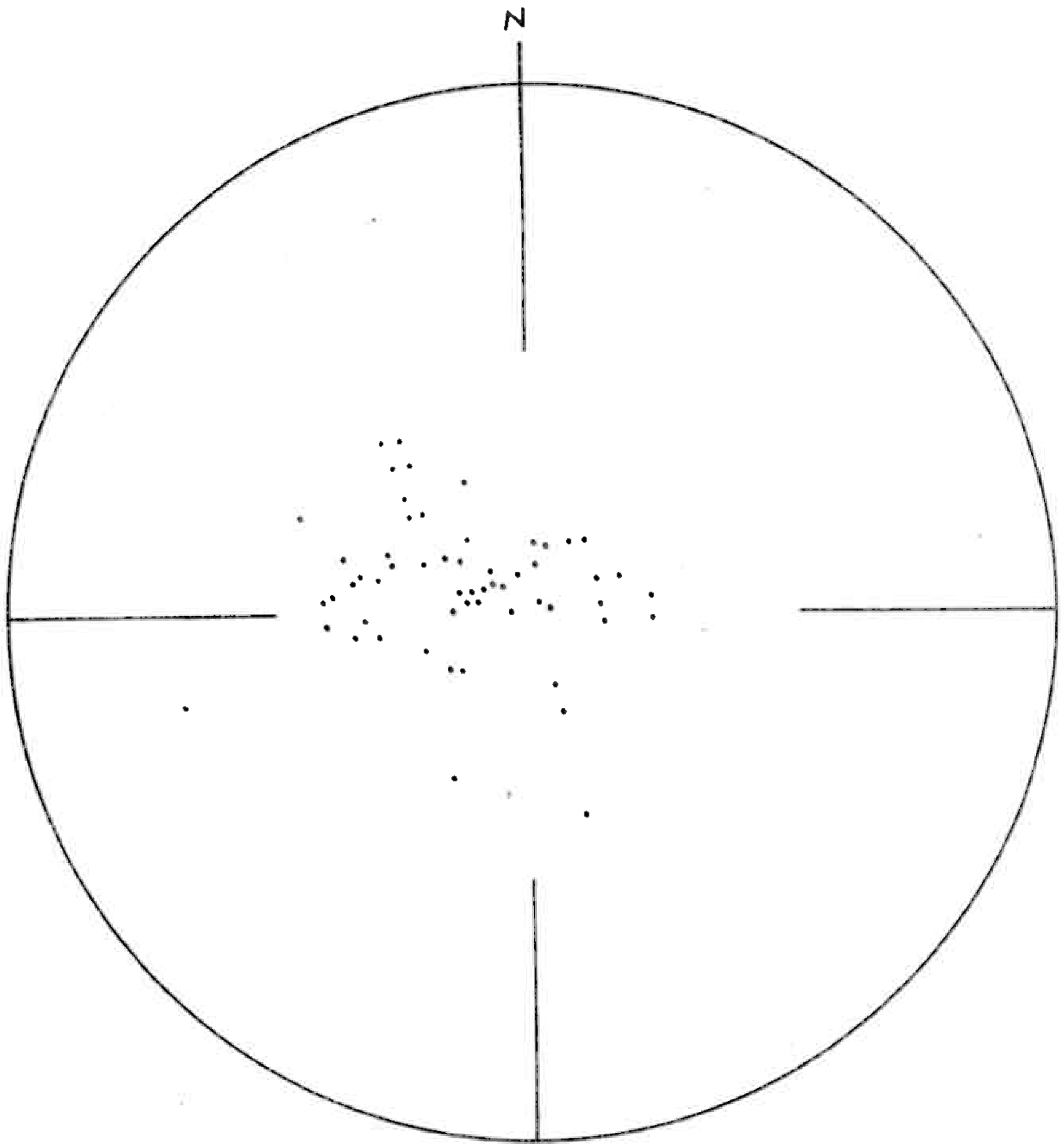

Fig. 9. Synoptic stereogram of poles to the pebble lineation, i.e. long axes of ellipsoidal pebbles.

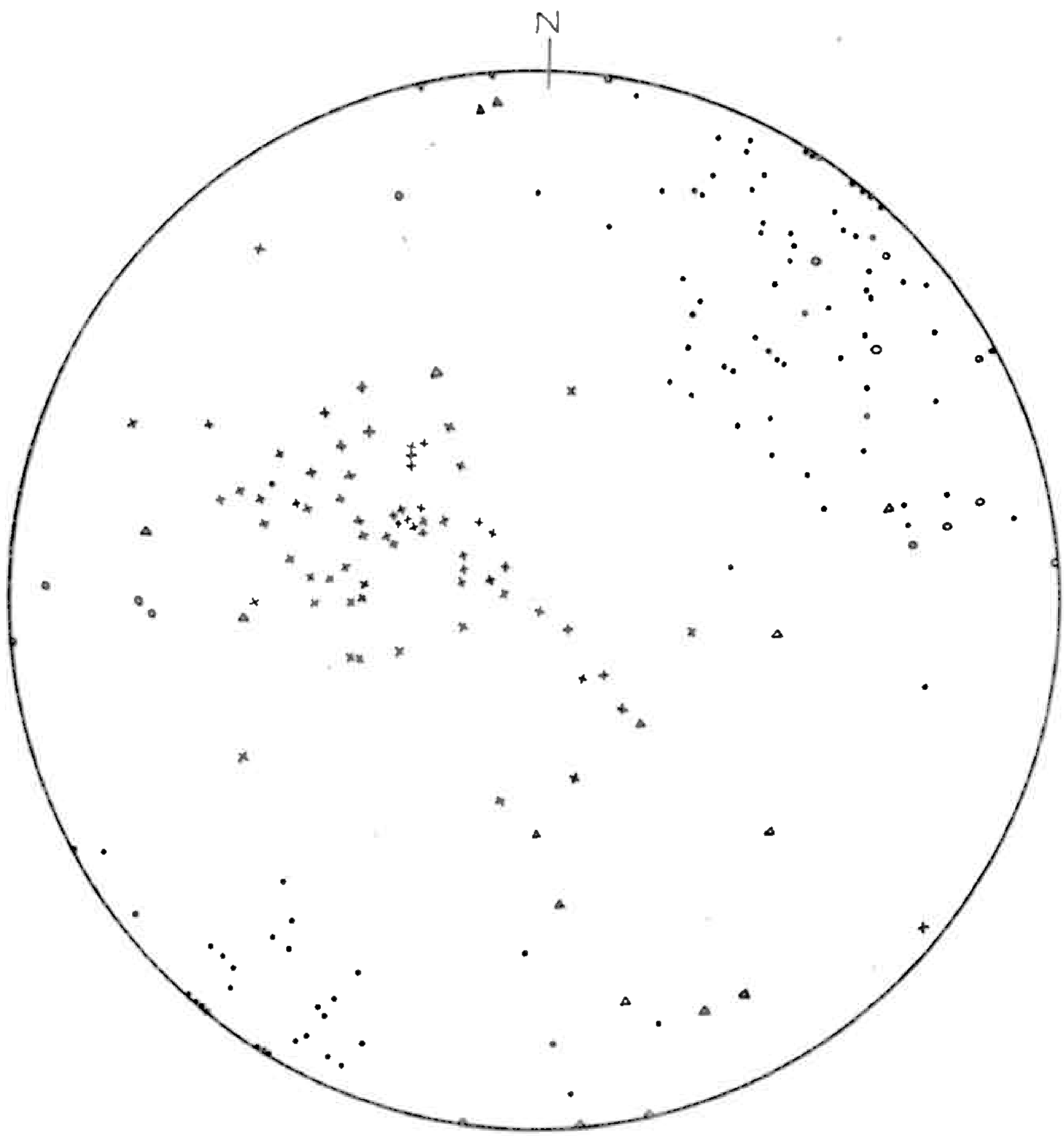

Fig. 10. Synoptic stereogram of axes to D2 minor folds. . - folds within the Window; o - axes in the Kalak Nappe; x - poles to axial planes.

KOMAGFJORD WINDOW

TABLE OF FORMATIONS