Report on Field-work in the Repparfjord-Neverfjord District, July 1973.

The field activity of Summer 1973 was the initial exploration in a 3-4 years programme on the northern segment of the Komagfjord tectonic window. This exploratory study sought to resolve some general problems of the stratigraphy, structure and mineralisation and to establish a provisional tectono-stratigraphic framework. As a result limited systematic mapping was attempted, rather the study entailed mapping of traversing of a number of specific locations to obtain an overall perspective. The areas examined were selected on the basis of the previous study by Reitan (1963), and included:

Coastal zone from Neverfjord - Beritsfjord
Tappen and Kvalsundal
Faegfjord - Kvitbergstrand

Traverses: Djupelv - Ariselv
North shore Repparfjord to Klubben
Skaidi to Aisaroaivve
Skaidi to Russemes
Neverfjord to Kvernklubben

The geological report and accompanying map of Reitan highlighted a number of unresolved problems:

a. Stratigraphy - Age of the sedimentary sequence and orogenic structures.
Order of superposition.

b. Structure - The nature, pattern and geometry of the various tectonic elements and the number of discrete orogenic episodes.

c. Mineralisation - The pattern of mineralisation and its relationship to deformation history.

Stratigraphy

Reitan identified several major sub-divisions of the distinctive rock assemblages within the window, but the stratigraphical relations between them is not clear. In the eastern part of the window the superposition is unambiguous and the succession Holmvann-Lomvann-Doggelv groups appears to be a natural sequence. Problems arise in the stratigraphy of the western outcrop of the Holmvann gp. and the position and inter-relationship of the Holmvann and Saltvann groups.

The Saltvann gp. outcrops as a broad band in the central part of the area, flanked on either side by the Holmvann gp. Reitan effected a tripartite sub-division of the Saltvann gp. where the order of superposition Steinfjell-Djupelv-Fiskevann units is well established on the basis of sedimentary structures. The Holmvann group is a thick series of complex and diverse character. Lithologies include a variety of greenstone members, e.g. lavas, meta-tuffs, agglomerate and pelites. Other members of the suite include limestone and dolomite, quartzite and sand-stone, monomict and polymict conglomerates, and cherts. Reitan was unable to recognise a stratigraphy within this formation owing to the impersistence of individual lithologies resulting from sedimentary variation and tectonic processes. In the western outcrop he was unable to recognise top and bottom with any confidence.

In my studies of the western outcrop it appears that it may be possible to group lithologies into associations of distinctive character. Initial study suggests the following :

Volcanic association - greenbeds, chlorite schists and pelites.

Dolomite association - dolomite, quartzite, chert and siltstone.

Limestone association - limestone, shale, conglomerates.

In the coastal zone to the north of Neverfjord there appears to be a distinctive distribution of associations and within these an orderly repetition of lithologies. At one location I was able to determine 'way up' and from this I hope to extend the work eastwards and crack the problem of Holmvann gp stratigraphy.

The status of the Saltvann gp. is the key to the large-scale structural interpretation of the area and bears strongly on the genesis of the Ulveryggen mineralisation. Reitan regarded the Holmvann gp. as the oldest unit largely on the basis of greenstone pebbles in the Djupelv conglomerates. Within the broad band of the Saltvann gp., although there is an asymmetrical distribution of sub-divisions, sedimentary structures indicate younging towards either margin. Despite this anticlinal form and the axial situation of the band Reitan postulated that the contacts with the Holmvann gp. were steep faults. 2 km. south-west of Repparfjord however, the western contact of the Saltvann gp. swings to an east-west trend and this group patently dips beneath the Holmvann gp.

Reitan's proposals for fault contacts introduces a complex factor into the tectonic pattern. It is not easy to reconcile the tectonic conditions necessary for the development of the large D1 folds with the changes in the stress-field required to create steep faults. The faulting was succeeded by a recurrence of the conditions which generated the folds, and the faulted contacts themselves are folded. This problem has not yet been resolved.

Reitan's conclusion that the Saltvann gp. must be equated with the uppermost part of the Holmvann gp.is essentially a subjective one.

Structure

The tectonic history of this region is characterised by two discrete phases of orogenic deformation, D1 and D2. Each of these phases displays episodes of ductile and brittle strain, an initial folding accompanied in some parts by brittle deformation, succeeded finally by phases of faulting and thrusting. The two deformation phases differ considerably in their development, scale, complexity and degree of penetration. D1 is the more profound deformation phase and the rocks display strong folding on small and large scales. Folds are also present in the second phase but their development is more localised and sporadic and confined in scale to relatively small structures. In addition to folding planar and linear structures are associated with both phases, cleavage and schistosity in the first phase and strain-slip cleavage in D2.

Reitan recognised a simple pattern of large-scale symmetrical to slightly asymmetrical folding within the window. This folding is associated with large, steeply inclined fractures causing abrupt and puzzling juxtapositions. The character of the deformation in his analysis changes in the north-west where thrusting associated with asymmetrical to overturned folding becomes dominant. Reitan however, made little attempt to integrate the various structural elements into a coherent kinematic model. Although his published map indicates a considerable degree of complexity he presented little on the geometrical relationships of the structures. His analysis leans heavily on the role of the features of brittle deformation, faults and thrust, in controlling the dispostion of the formations. The present study cannot yet confirm or modify the large scale model of Reitan.

My field-work, concentrating as it did in the north and west, identified several large to medium-scale folds. At Faegfjord, beneath the Eocambrian klippe and truncated by it, is a near upright tight synclinorium cored with Lomvann gp. and flanked by pelites and greenstones of the Holmvann gp. The plunge of this structure is gentle towards the north-east. At nearby Kvitberget the large outcrop of carbonate rock forms the core of a series of medium-sized asymmetrical folds overturned to the west. This lithology is flanked to east and west by mixed psephitic and pelitic lithologies of the Holmvann gp.

On the summit of Tappen the large elliptical area of dolomite is the core of a noncylindrical anticline varying in plunge from gentle in the centre to 45° in the south-west. This fold is enveloped by the distinctive slate gp. assigned to the Lomvann gp. by Reitan. The core of this structure reveals a sequence of sandstone, conglomerates and pelites beneath the thick dolomite sequence.

The traverses across the Saltvann formation revealed that the broad band, despite the asymmetrical distribution of its stratigraphic sub-divisions, is the core of large gently-plunging anticline. This fold has a simple profile and the competent psammitic-psephitic lithologies display a surprising lack of minor structures.

On the seaboard north of Neverfjord mapping revealed several medium-scale asymmetrical to overturned folds associated with pronounced thinning of long limbs and thrusting of lower limbs. A distinctive feature of this western outcrop of the Holmvann gp. is the lenticular outcrop pattern of the large dolomite-quartz bands. This pattern results from large-scale boudinage or pinch and swell rather than a primary stratigraphic variation or the result of small-scale thrusting as proposed by Reitan.

Small-scale Structures

The presence and character of small-scale structures in the region is closely tied to the physical nature of the participating lithologies. The pattern of structural development suggests that during the maximum orogenic compression the level of strain attained was close to the ductile-brittle transition. Thus in incompetent lithologies the rocks demonstrate greatest strain and maximum complexity in fold styles and patterns, while in the competent lithologies the patterns are less complex and in some rock types exhibit no obvious megascopic strain features. Despite the differences in style and orientation patterns the structures of each lithological type, resulting as they do from the same causal stress-field, can be integrated into an overall consistent framework.

In the competent Saltvann and Doggelv formations, conglomeratic horizons within the Holmvann gp. and thick quartzites of the Lomvann gp. at Faegfjord macroscopic and mesoscopic folds display homoaxial patterns with gentle plunge towards north-east or south-west. Where these are parasitic to large folds, as at Faegfjord, they are congruous with respect to style and orientation.

The common profile-style is concentric with local deviation towards similar, and axial surfaces vary in orientation between a vertical and steep north-westerly inclination. Within the less competent pelites and limestones of the Holmvann gp. the pattern of fold axes is much more complex. Folds are similar in style, plane to nonplane, with marked limb thinning and the axial surfaces generally fall into the same orientation as those of the folds in the competent lithologies. The minor fold axes are invariably noncylindrical, deviating markedly from the axial orientation of the large-scale folds, with an overall spread in orientation within a plane coincident with the modal axial surface. No single maximum in orientation occurs in a stereogram of axial orientation and they have all the characteristics of incongruous noncylindrical folds similar to those with the Eocambrian rocks on nearby Söröy. The minor folds in these lithologies therefore cannot be employed to deduce the orientation of allied larger structures.

These folds frequently develop a penetrative cleavage or schistosity and both this and bedding planes display a faint but persistent fibre-lineation. This lineation is a stretching lineation indicative of the direction of rock flow during formation.

In the competent formations schistosity is largely confined to thin pelitic layers or is sporadically developed in some sandstones. In the Fiskevann conglomerate and some conglomerates within the Holmvann gp. the schistosity is marked by alignment of the elliptical pebbles. This is especially prominent in conglomerates with fine grained matrices.

In the conglomerates which display significant strain the long axes of inequidimensional pebbles are oriented in a north-westerly direction, coincident with the fibre lineation on cleavage planes. This preferred orientation may be developed in strained pebbles with flattened cigar shape, or pebbles with no obvious distortion which have their present preferred orientation as a result of discrete physical rotation during deformation.

Such is the tight character of the folding in the incompetent lithologies of the Holmvann group that the cleavage is sub-parallel to the layering or makes an acute angle with it. Thus, in the N.W. zone, where the dolomites exhibit strong boudinage, it is obvious that strong flattening with marked layer-parallel extension characterises the first deformation phase.

A feature of the D1 deformation is the development of brittle cataclastic fabrics in the interfacial zones between rock types of highly contrasting competence. This is especially the case at junctions between dolomite and pelites or chlorite schists, where crush fabrics with polished and striated surfaces are developed. When the orientation of the slickenside lineations is plotted on a stereogram they group into a maximum coincident with the fibre lineation of the pelites and pebble lineation in the conglomerates, indicating a kinematic unity to the brittle and ductile deformation. Indeed as one traces away from a crushed interface with the incompetent lithology the signs of crushing rapidly diminishes and the rock gives way to lineated slate or greenschist, with the lineation parallel to the slickensides. This fabric results from differential shear at the interfaces due to the unequal response of the affected rocks to the deformation and does not necessarily imply significant displacement as in faulting or thrusting. The syn-D1 age of this brittle deformation is further confirmed by the frequent observation of

D2 folds affecting the polished and slickensided fabrics.

D2 deformation

In the northern area the second deformation episode is a minor phase, represented by small-scale folding and sporadic strain-slip schistosity. Folding was only observed on a mesoscopic scale and even then was not uniformly present even in the most susceptible lithologies. This phase is most conspicuous within the Holmvann group of the Vargsund district and is well displayed in the steep bluffs between Beritsfjord and Kvalsund Ferry. Small-scale angular folding with incipient strain-slip cleavage also affects the Caledonian rocks of the small Faegfjord Klippe. These structures have a similar orientation to the occurrences within the autochthon.

Thrusts and Faults

The principal fracture in the area is the boundary thrust of the Caledonian metamorphic nappe. In the area investigated the outcrop of the thrust can only be approached in the eastern part of the window and in the isolated patches of Faegfjord and Saraby. This summer the only observations on the thrust were in the Faegfjord district where the flat-lying Eocambrian psammites and schists rest discordantly on the folded rocks of the window. Megascopically the effect of the thrusting was the production of a diapthoritic fabric in schistose layers of the Eocambrian and a suite of extensive minor shear zones up to 3 cm. thick, sub-parallel to the parent fracture. In this area the thrust truncates some large folds of the autochthon dating therefore the development of the D1 fabric. The minor folds affecting the allochthonous rocks and shears have the geometry and pattern of D2 folds below the thrust and suggest at this stage, that the thrust is a late D1-pre D2 phenomenon.

Reitan invoked many minor thrusts to explain the stratigraphic relationships in the western part of the area but current work cannot substantiate or evaluate the existence of such structures.

Faults

As mentioned earlier brittle deformation occurred during the D1 pre-D2 interval throughout the western outcrop of the Holmvann gp. Small late-D2 faults, post-dating the minor folding of the phase, have been observed at several locations in the western Holmvann gp., usually marking the boundary of competent and incompetent rocks. These faults in the main strike with the northeast-southwest grain of the formations and served as important avenues for the latest mineralisation and were the site of early mineral prospects. The orientation of faults and allied shears together with the pattern of slickensides on polished surfaces tie in to the general orogenic pattern suggesting that, despite their late-stage occurrence, they result from the same orogenic stress-field as the earlier structures.

On the slopes of Langvasfjell the contact between massive greenstone and pelite is a zone of crushing. In this zone one can recognise several prominent polished and slickensided shear surfaces cutting D2 minor structures. These shears trend north-north-east and dip steeply north-west while the slickensides pitch steeply down dip in the direction of the regional lineation.

At the site of the old prospect at Beritsfjord two fault zones are present, one trending north-east and dipping east, the other striking north-north-east and dipping to the north-west.

Where he didn't invoke thrusts Reitan employed faults to explain stratigraphic juxtapositions in the central and western part of the window, but it is not yet possible for me to confirm or dispute this.

The Allochthon

The rocks of the Caledonian nappe as seen at Faegfjord and on the north shore of Repparfjord are characteristic of the Eocambrian psammitic sequences observed on the offshore islands. They differ in character both lithologically and petrographically from the rocks of the window. Tectonic patterns, as revealed by minor structures, reflects the strong rotational strain of the interior orogenic locations and is characterised by tight recumbent folding and strong layer-parallel extension. This contrasts with the upright character of folds beneath the thrust where the only signs of translation are associated with minor thrusts.

A stereogram of minor fold axes reveals a distribution in two great circles, but the tectonic strike remains northeast-southwest, i.e. orogen-parallel. The fibre-lineation shows some tendency to concentrate in the north-west quadrant conforming in significance to that below the thrust.

At the present time the kinematic interpretation of the structural patterns above and below the thrust is one of integration into a single orogenic event, while the differences can be explained by the relative positions of the affected rocks at the time of initial deformation. This suggests that the deformation within the window is Caledonian. The geometry of the autochthon is compatible with this suggestion but it must be remembered that this could be coincidental. To substantiate this samples of slate with D1 cleavage were collected for radiometric dating by Dr. I. Pringle, University of Cambridge. If successful this should date the initiation of the cleavage and settle the question of the age of D1 deformation in the window. It will not of course settle the question of the absolute age of the rocks themselves.

The ultrabasic intrusive suite will be sampled by Mr. H. Fischer of Hamburg who is currently carrying out a comparative study of ore paragenesis in the ultrabasic rocks of the region. This may establish whether these rocks are part of the same suite as that featuring so prominently in the metamorphic nappe to the south-west and west.

Mineralisation

Sulphide minerals are widely but diffusely distributed throughout the northern part of the area, most conspicuous in the predominantly pelitic or greenstone formations and more restricted in the psammitic formations. Several characteristic modes of occurrence were recognised in the course of the present study. The minerals present include chalcopyrite, bornite and grey copper (? tetrahedrite) and pyrites. Significant development of secondary minerals like malachite and azurite are only conspicuous in the largest veins and minor lodes. Sulphide mineral growth is associated with each of the major orogenic episodes.

The earliest sulphide minerals appear to predate the D1 fibre lineation and develop streaks and trains of euhedral chalcopyrite and tetrahedrite in this tectonic direction. This was observed in the Holmvann gp. In some horizons of black slate, noticeably at Kvitnes there are abundant oxidised cubes of pyrite of a presumably sedimentary origin. The cubes of pyrite and irregular patches of chalcopyrite in some of the greenbed lithologies can be quite conspicuous although not to an economic level.

Pyrite and chalcopyrite also occur in quartz or quartz/dolomite veins folded or extended in the plane of schistosity by late D1-flattening. These synorogenic veins post-date the main generative phase of D1 folding, displaying only the late stage deformation. A later suite of sulphide-bearing quartz veins transects D2 folds and align parallel to axial surfaces.

The most conspicuous occurrence of sulphides is in thick quartz or quartz-dolomite-chalcopyrite veins up to 1 m thick emplaced along late post-D2 fault zones. Unfortunately these veins are laterally impersistent and the lodes came to nought, as evidence by the restricted nature of the old workings. The largest occurrence in the north-west is at Beritsfjord where the original lode was an inclined vein approximately 1 m thick cutting massive greenbeds. Only fragments of the vein remain at the top of an inclined stope extending down some 15 m from the surface. The ore in this case was chalcopyrite and malachite in a gangue of quartz-dolomite.

In the small pit on Langvasfjell a small shallow incline was driven for a few feet to explore several thin veins of quartz-dolomite containing bornite, malachite and grey copper.

The diffuse and widespread nature of the mineralisation, the restricted extent of fault lodes and the repeated occurrence of the phenomena throughout the orogeny suggests that the pattern of mineralisation was one reworking and redistribution of material which was emplaced at an early stage, or which may have been part of the primary mineralogy of some of the rocks.

It should be pointed out that the largest development of copper, apart from Ulveryggen, is in the Porsa district and this has not yet been examined by the author.

A summary of mineralisation observed in the several rock groups is:-

Saltvann gp:	Apart from Ulveryggen sulphide minerals were not observed.
Kvalsund gp:	Sporadic traces of oxidised pyrite - probably original.
Doggelv gp:	Pyrite observed was confined to metabasite sheets.
Lomvann gp:	No observed mineralisation.
Holmvann gp:	Sulphides occur as disseminated minerals, in quartz and quartz-dolomite veins and gash fissures. Pyrite more abundant than chalcopyrite.

Finale

This report is based on a survey of reconnaissance rather than systemic nature but in the next few years it is intended that the northern part of the window will be remapped.

Donald Ramsay

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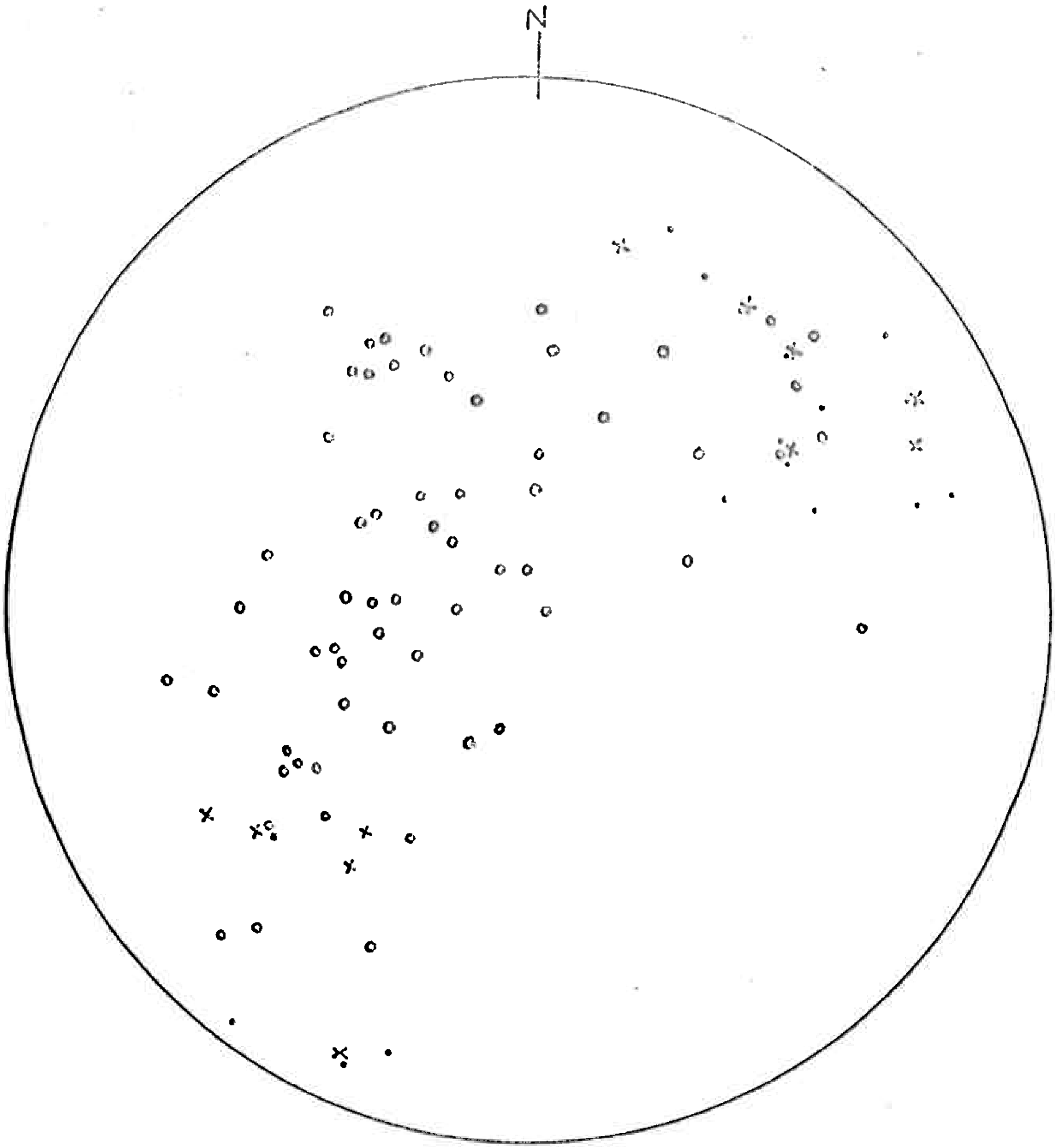
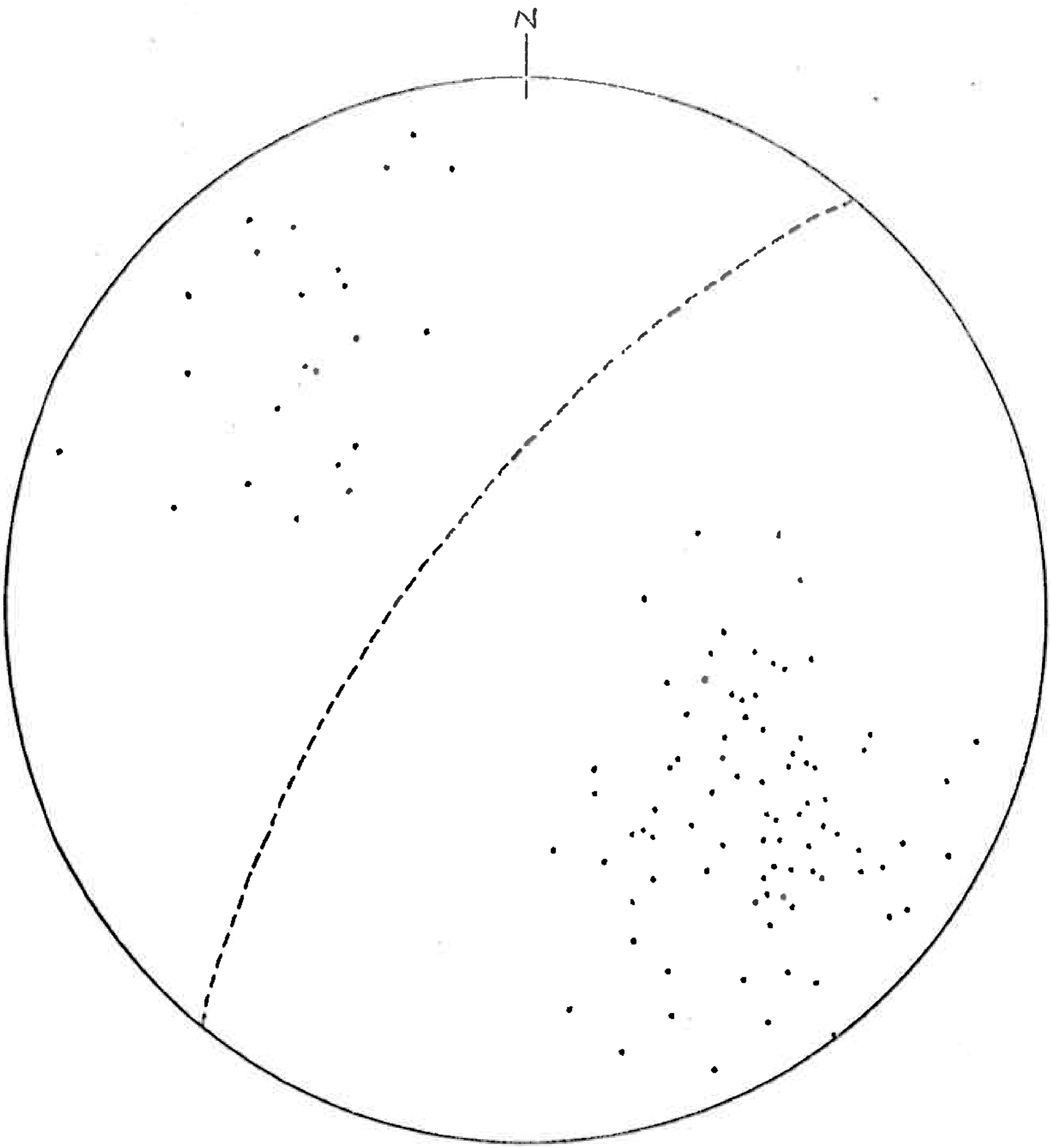
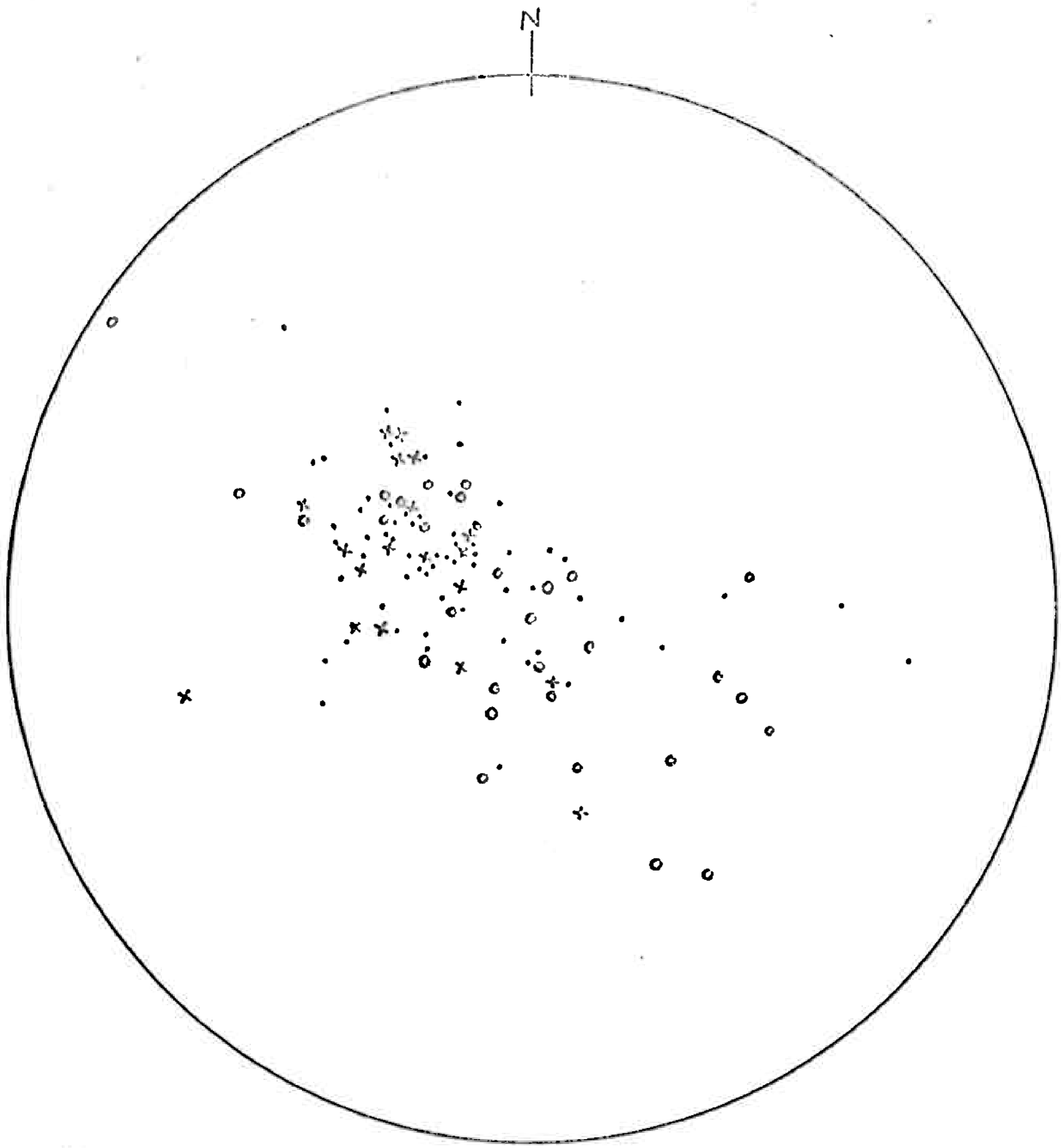


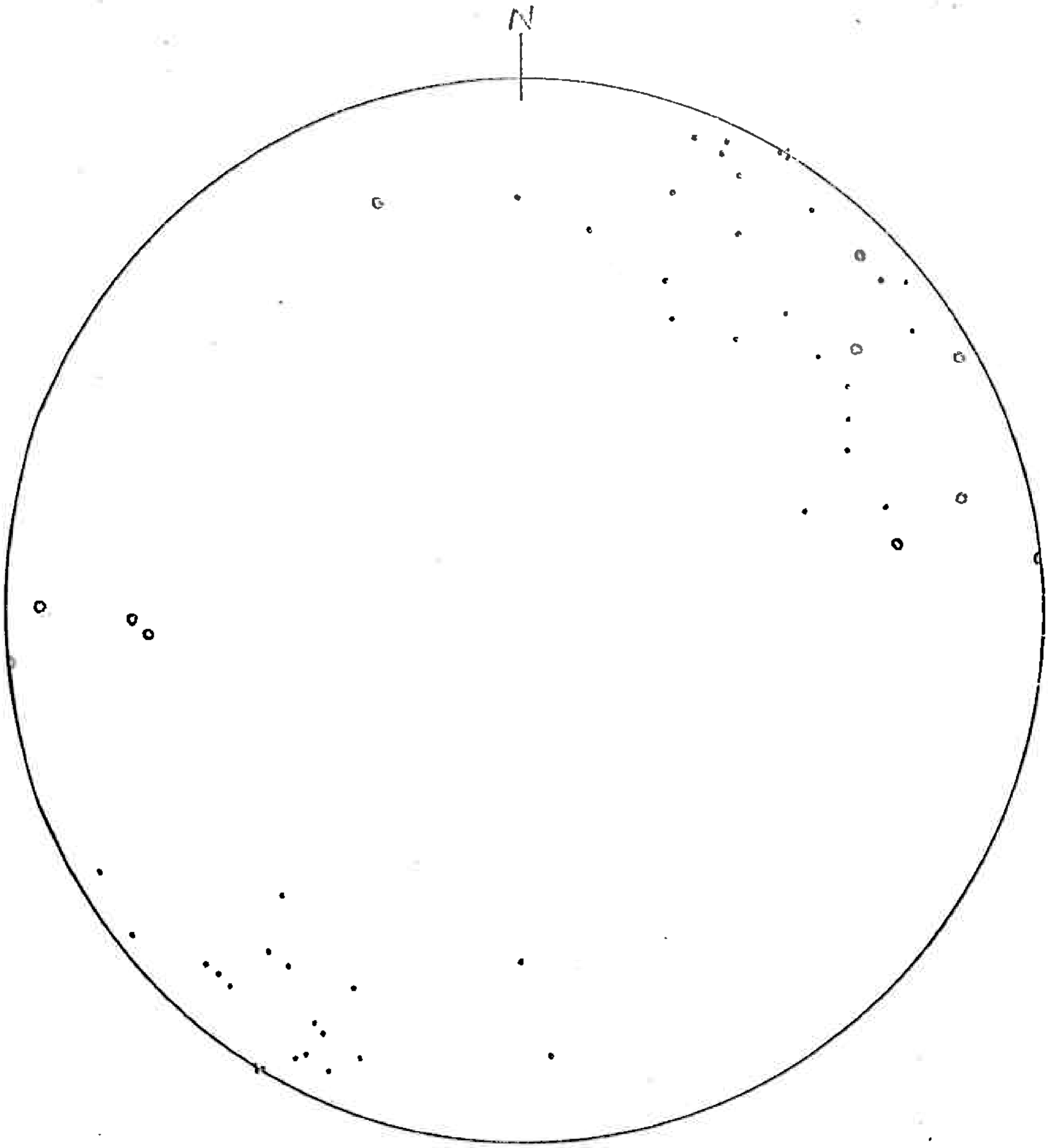
D1 fold axes. · - competent lithologies, o - incompetent lithologies
x - large folds



D1 axial-plane schistosity.



D1 stretching lineation. x - long axes of pebbles, o - slickensides, · - fibre lineation in pelites.



D2 fold axes. • - within autochthon, o - within allochthon.