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The Tjørnseter Salient: A cartographic and structural curiosity in the outcrop pattern of the Otta Nappe

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REPORT

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Summary:

The Tjørnseterfjell salient is identified as part of the Otta Nappe. Structural analysis shows that the structuration of the salient is part of the movement plan of the nappe. The structure of the salient is of particular significance as the D2 folding can be demonstrated to be synchronous with the major thrusting at the base of the nappe. The report contains a number of details regarding the structure of the salient.

Keywords: Bedrock geology	Nappe-tectonics	Tectonostratigraphy
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The Tjørnseterfjell Salient : A cartographic and structural curiosity in the outcrop pattern of the Otta Nappe

By

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Abstract

The Tjørnseterfjell salient is identified as part of the Otta Nappe. Structural analysis shows that the structuration of the salient is part of the movement plan of the nappe. The structure of the salient is of particular significance as the D2 folding can be demonstrated to be synchronous with the major thrusting at the base of the nappe.

Introduction

The Tjørnseterfjell salient is a distinctive feature of the outcrop of the Upper Allochthon (Gee and Roberts 1985) where the latter meets the Jotun Nappe Complex , in the Gudbrandsdalen-Ottadalen district of Oppland Fylke. It has a NW-SE transverse orientation of the tectonic grain, differing by 60° from the regional trend within the main body of the Otta Nappe (=Trondheim Nappe) (Fig.1). The transverse trend is emphasized by a prominent, elongated prolongation of the Otta Nappe extending for some 20 km. over the Middle Allochthon on the southeastern side of the Mysuseter Fault (Fig.1).

On Strand's (1951) map of the Sel-Vågå area this salient comprises Heidal Gp. metasediments and a near axial band of Rudihø (= Høvringen) Gneiss Gp. As depicted on his map it is rather difficult to interpret and in the accompnying description (Strand 1951) he makes little reference to it.

In the provisional 1:50,000 map sheet Vinstra, which includes some 60% of the structure, Englund (1986) recorded a more detailed lithostratigraphy : A basal sequence of an orthogneiss complex comprising augen gneiss, gabbro, anorthosite, hornblendite and norite succeeded by a cover sequence of sandstone and mica schist with mappable horizons of calcareous sandstone and greenschist-serpentinite.

On the preliminary mapsheet these outcrop in an elongate, concentric pattern with an outer rim of gneiss and a core of sandstone and mica schist. The calcareous sandstone and greenstone-serpentinite occur as single bands in the cover sequence, to the gneisses, along the eastern and western sides of the salient respectively. A small klippen of gneiss with sedimentary cover occurs on the small knoll, Gneddin, to the west of the main salient (Fig. 2). The lower boundary is shown as a thrust plane. The gneiss member itself thins northwards along the eastern boundary and to the northwest of Sukkertoppen is completely missing.

Englund (1986) viewed this package as a flat-lying sequence with gentle limb dips and a shallow plunge to the NW. He named this the *Sjo Nappe* and assigned it to the uppermost level of the tectonostratigraphy, above the Jotun-Valdres Nappe Complex.

The present authors have remapped the salient as an extension of their studies in the main body of the Otta Nappe. This revision showed that the gneiss at the NW-end of the salient can be traced, as a narrow band, south-westwards across the River Lågen, to join up with the basal gneiss of the main Otta Nappe in the Sjoa valley. In a northeasterly direction the gneiss can be followed continuously, over a series of late, open folds to Mysuseter, then NW to Høvringen and on into Grimsdal. Thus the gneiss of the salient is clearly an extension of the basal unit of the Otta Nappe.

Revised tectonostratigraphy

As in the main outcrop of the Otta Nappe, the tectonostratigraphy of the Tjørnseterfjell salient comprises a basal orthogneiss, the Høvringen Gneiss Group (Sturt et al. 1997). The metasedimentary cover has been differentiated into two groups and correlated with the Heidal and Sel Groups of the main Otta Nappe.

The Høvringen Gneiss Gp. is an orthogneiss complex, as described by Englund (1986) and Strand (1951). Over much of its crop it is a granitic augen gneiss which in the southern part of the salient has intrusive contacts into more ancient anorthositic, gabbroic, hornblendic and tonalitic orthogneisses. These older gneisses are generally in amphibolite facies, though relicts of granulite facies parageneses can be found. The thrust at the base of the gneiss group is marked by a conspicuous development of blastomylonites. The excision of the gneiss, observed by Englund in the vicinity of Sukkertoppen, persists only for ca. 4 km. then it reappears as a thin band which can be followed to the Mysuseter Fault (Fig.2).

The gneiss is overlain by a pale psammite-dominated sequence typical of the Lower Heidal Gp. of the main Otta Nappe. The mica-schists show low Amphibolite Facies metamorphic grade and are replete in garnet (often centimetric) and bearing sporadic staurolite. While the basal contact with the gneisses is not exposed the nature of the fabric of these metasediments, is not indicative of thrusting. In the Lågen valley 18 km. to the NW, Sturt et al.(1997) record an unconformable relationship between the Heidal Gp. and the gneiss.

In the tectonostratigraphy of the Otta Nappe the group of rocks suceeding the Heidal Gp. is the Vågåmo Ophiolite (Sturt et al. 1991), although as pointed out by these authors this unit is not always present, having been removed by pre-Sel Gp. erosion (Sturt et al 1997, Bøe et al. 1993). In a small disused opencast at Haugsætre and the small Klefstadlykkja mine, 2 km. along strike to the SE, talc-serpentine rich rock occurs (Fig.2). In the eastern wall of the opencast talc schist, talcose and dark garbenschiefer, serpentine sandstone, serpentine grits and fine conglomerate form a distinctive horizon in this lower part of the Sel Gp. The talc-rich deposit represents originally sedimentary material (Knutsen 1980), similar to that described by Strand (1951) and Bøe et al.(1993) from the Otta district. This horizon lies some 50m. up-sequence from the Sel Gp. - Heidal Gp. contact. In the lower levels of the Sel the rocks are predominantly silver-grey phyllites. As in a number of other areas in the Otta district the ophiolite is missing from the tectonostratigraphy. To the east of the ultramafic sediments, the typical lithologies of the Sel Gp. predominate, i.e. dark to black phyllites with varying developments of grey meta-sandstone. Locally the sands become grits and in a narrow belt on the NW shoulder of Sukkertoppen a thin band of conglomerate can be traced over a strike length of 2 km. This conglomerate is of the Skardshoi-type (Bøe et al. 1993), i.e. pebbles of quartzite and vein quartz in a quartz schist to grit matrix. This conglomerate facies is the most widespread of the three types recorded in the lower part of the Sel Gp. of the region.

STRUCTURE

The lateral extensions to the NE and SW of the main salient, together with the Gneddin klippen, suggest that the gneiss was originally an extensive one, and its preservation as an elongate prong on Tjørnsterfjell reflects some structural control rather than a mere accident of erosion.

Scandian Deformation

The effects of the Scandian Orogeny dominate the fabric in all members of the tectonostratigraphy, although within the thicker development of the gneiss on the western flanks of the salient, abundant relicts of the pre-Caledonian fabric are preserved. The rocks of the Heidal Gp. also preserve pre-Scandian metamorphic fabrics and parageneses, although these are often considerably over-printed.

In the main body of the Otta Nappe four phases of deformation involving folding can be identified i.e. D1-4 (Sturt and Ramsay 1997), but in the Tjørnseterfjell salient the effects of D2 and D3 are completely dominant.

SECOND DEFORMATION (D2)

As pointed out earlier, the assemblage of the Høvringen Gneiss with its metasedimentary cover is part of a nappe of the Upper Allochthon, and it has been argued that this is an extension of the Otta Nappe. This nappe was emplaced during the main Scandian deformation phase i.e. D2 (Sturt et al. 1991,1995,1997, Bøe et al. 1993). During nappe translation considerable reconstitution was effected with the formation of a conspicuous mylonite zone at the base, whose textures range from finely laminated to markedly porphyroclastic and augen gneiss. The mylonitic surfaces are generally decorated with a prominent mineral lineation. This, together with the mineral lineation in the less-deformed nappe interior all display a consistent north-westerly orientation (Fig.3 and 5c).

Folding
The strong D2 deformation is the main foliation-generating event, as elsewhere in the Otta Nappe, and in the Tjørnseter salient effectively masks any traces of earlier Scandian deformation. The only exception being relicts of folded foliation in the hinges of D2 folds. This phase was characterised by folding on a range of scales. The largest structure is the coupled Kringseter Antiform and Synform, a Z-shaped coupled fold facing NE and involving the whole assemblage, including the Høvringen Gneiss (Fig. 4). The synformal member preserves an oval pattern of the Heidal and Sel Gps in the core, whose concentric arrangement is indicative of slight noncylindrism. The gneiss unit in the long lower limb of the synform and upper limb of the antiform shows the strong thinning anticipated for a fold-pair with this

type of profile (Fig.2 and 4). In the thick, recumbent common limb, strains are much lower and the pre-Scandian fabric is widely preserved.

The fold has a unique status among D2 folds in the southern sector of the TNC, in providing some evidence of the relative timing of the different deformational events. While, elsewhere the cover can become involve in the D2 recumbent folding, the Høvringen Gneiss Gp. does not participate and only later, open folds appear to affect its outcrop pattern. As it is folded by D2, in this area, the thrust obviously preceeded the folding, but this could be a local relationship during a protracted phase of deformation. Moving away from the thrust zone into the nappe interior, mineral lineation and minor fold axes remain coaxial with the mylonite lineation (Fig.3 and 5c). Thus the pervasive flow of the nappe interior and the discontinuous flow of the nappe base have congruous markers, i.e. X is constant throughout (Ramsay and Sturt 1973). The thrusting and folding, therefore, must have been broadly synchronous, although in detail one or other may appear to be older.

The orientation of minor folds is close to that for the mylonitic lineation maximum (Fig.5c), with less variability than is demonstrated for the rest of the nappe. For example, in a similarly orientated fold-pair, the Lalm Fold (Fig.1) which admittedly does not involve the Høvringen Gneiss, the parasitic folds display marked noncylindrism and a considerable spread in axial orientation (Ramsay and Sturt 1998). With only a statistical tendency to defining the region extension. In the Tjørnseterfjell area, therefore, the strain associated with the bulk flow must have been greater, so that fold axial attitudes were more tightly constrained. This finds support in the strong thinning which characterises the psammites of the Heidal Gp.

The NW-SE orientation of the axis of the main D2 Kringseter coupled fold is compatible with that of the Lalm Fold at Otta. Both of these are subsidiary to the major Jonndalen Syncline (Sturt et al. 1995, 1997, Sturt and Ramsay 1997) and both occur on what is the long, lower limb of that host structure. These folds are incongruous to the main host fold, a relationship frequently encountered on smaller scales (Ramsay and Sturt, 1973).

THIRD DEFORMATION D3

The third phase of folding was responsible for buckling the Kringseter coupled fold in a large open synform, flanked by several congruous intermediate-scale structures (Figs. 2; 5a,b, and d). These plunge NW (Fig. 5), broadly coaxial with D2. The effect on the large scale D2 fold is clearly displayed in the anticlinal member on Kringseterfjell and in the gentle attitude of the D2 synclinal hinge in the Sulsæter district (Fig. 3). The combined effect of D2 and D3 is responsible for the wide outcrop of the gneiss unit on the western side of the salient. The essentially coaxial relationship between D2 and D3 fold axes is comparable with that characterising the areas of Ottadalen between Tjørnseterfjell and Lake Tesse (Sturt and Ramsay 1997).

In the cover sequences the D3 deformation resulted in tighter, smaller amplitude, upright folds with marked transposition of D2 foliation and the development of axial-plane crenulation cleavage. This accounts for the prevailing steep attitudes encountered at outcrop level within the incompetent Sel Gp.

The effect of warping the large coupled Kringseter fold has resulted in a strong tectonic grain which has proved highly resistant to erosion in recent topographic development.

Conclusions

1. The Tjørnseter salient is a narrow, southward extension from the southern margin of the enlarged Otta Nappe. As such it is part of the Upper Allochthon and like that nappe complex, must have a tectonostratigraphic setting beneath the Jotun Nappe Complex.
2. The tectonostratigraphy and internal lithostratigraphy matches the main body of the Otta Nappe, although the Vågåmo Ophiolite is missing, but sediments derived from it are present, restricted to a single horizon.
3. Revision of the distribution of the Høvringen Gneiss at the northern end of the salient reveals extensions to the NE and SW which connect it to the main outcrop of the Otta Nappe. The outcrop of the gneisses clearly delineates the extent of the salient.
4. The overall structure of the salient in a large Scandian Z-fold (D2) with northwesterly axial trend and easterly gape.
5. The core of the syncline preserves the Heidal and Sel Gps. of the cover sequence, while the oval, concentric pattern of these indicates a measure of noncylindrism. The attitude of the western band of Høvringen Gneiss reveals the markedly overturned nature of the common limb of the structure. This recumbency, together with the level of erosion, accounts for the broard outcrop of the gneisses along the western margin of the salient.
6. The strong preferred orientation of the mylonitic lineation in the basal thrust zone, coaxial with minor fold axes and mineral lineation in the nappe interior, and the major fold axis suggest that thrusting and folding belong to the same movement plan.
7. The D2 deformation of the salient provides the only instance recorded, so far, from the southern end of the Otta (=Trondheim) Nappe, of the basal thrust and gneiss unit being involved in large D2 folds.
8. The Kringseter coupled fold, together with the Lalm Fold near Otta, have increased the scale on which incongruous folds occur in association with the major recumbent Jonndalen Syncline.
9. Later refolding of the Kringseter structure created a open D3 synform, while the thin lateral extensions of the gneiss are folded into a series of congruous medium-sized and open folds.
10. The near rectilinear D2 fold axes, reinforced by the coaxial D3 warping, have created a tectonic grain which has influenced subsequent erosion and landscape sculpting, leaving the structure as a significant salient.

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Figure Captions

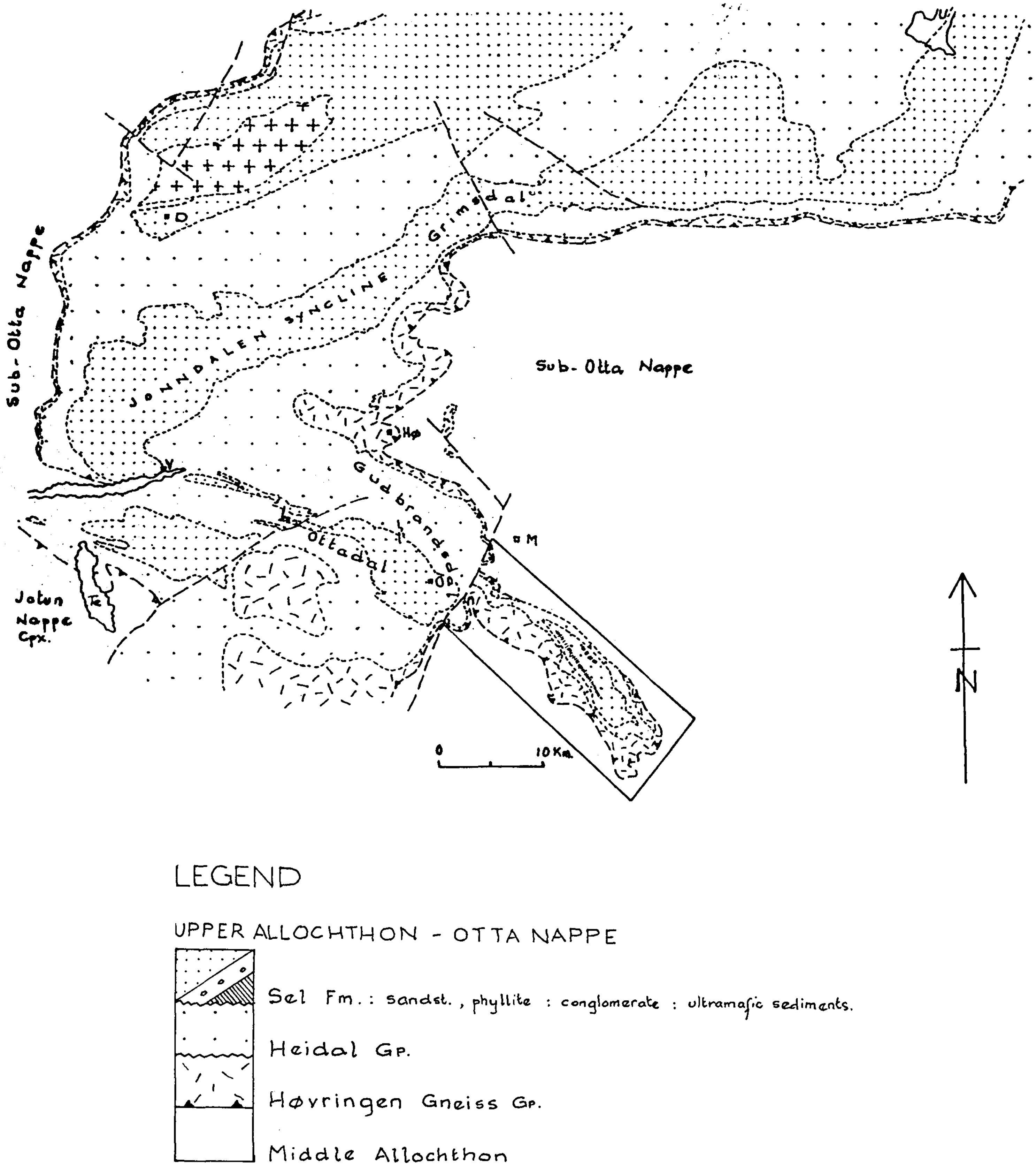
Fig. 1. Simplified geological map of the southern limits of the Otta Nappe. The location of the Tjørnseterfjell Salient is outlined in solid lines.
Localities : D - Dombås ; Hø - Høvringen ; L - Lalm ; M - Mysuseter ; O - Otta ; Te - Lake Tesse ; V - Vågåmo.

Fig. 2. Geology of the Tjørnseter Salient. Ornament as in Fig. 1- Symbols are strike and dip of layering and regional foliation.
Localities : Gn - Gneddin ; HS - Haugeseter ; Kl - Klefstadslykka ; K - Kringseterfjell ; S - Sukkertoppen ; Su - Sulseter ; Tj - Tjørnseterfjell.

Fig. 3. Structural Geology of the Tjørnseter Salient.
D-2 structures : fold axes - arrows with two coss-bars in tail ; lineation: intersection type-cross with bar, mylonitic striping- triangle with bar ; mineral lineation - circle with bar ; pebble elongation - oval with bar.
D3 structures : fold axes - arrows with three cross-bars in tail.

Fig. 4. Vertical cross-section through Tjørnseter Salient.

Fig. 5. Stereograms summarising structural data :
a) Poles to layering and regional foliation in main body of the salient.
b) As in a) from the flanking subordinate folds.
c) D2 linear features: dots - mineral lineation ; open circles - mylonitic striping ; crosses - fold axes and intersection lineation.
d) D3 fold axes.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Grimsdal
JONNDALEN SYNCLINE
Sub-Otta Nappe
Hø
Gudbrandsdal
M
Ottadal
Jotun Nappe Cpx.
0
10Km
N
LEGEND
UPPER ALLOCHTHON - OTTA NAPPE
Sel Fm.: sandst., phyllite : conglomerate : ultramafic sediments.
Heidal Gp.
Høvringen Gneiss Gp.
Middle Allochthon

Fig. 1

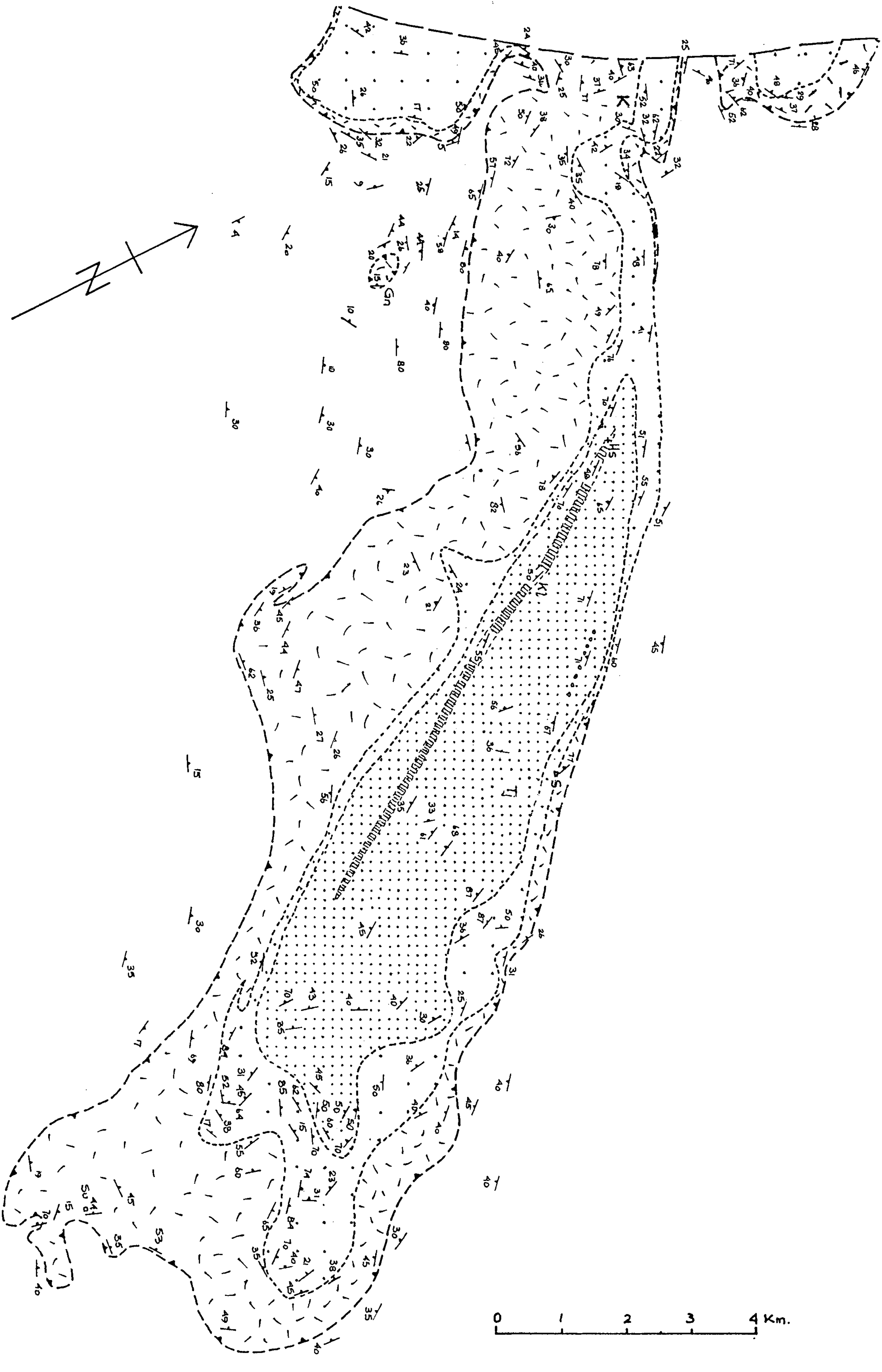

Fig. 2

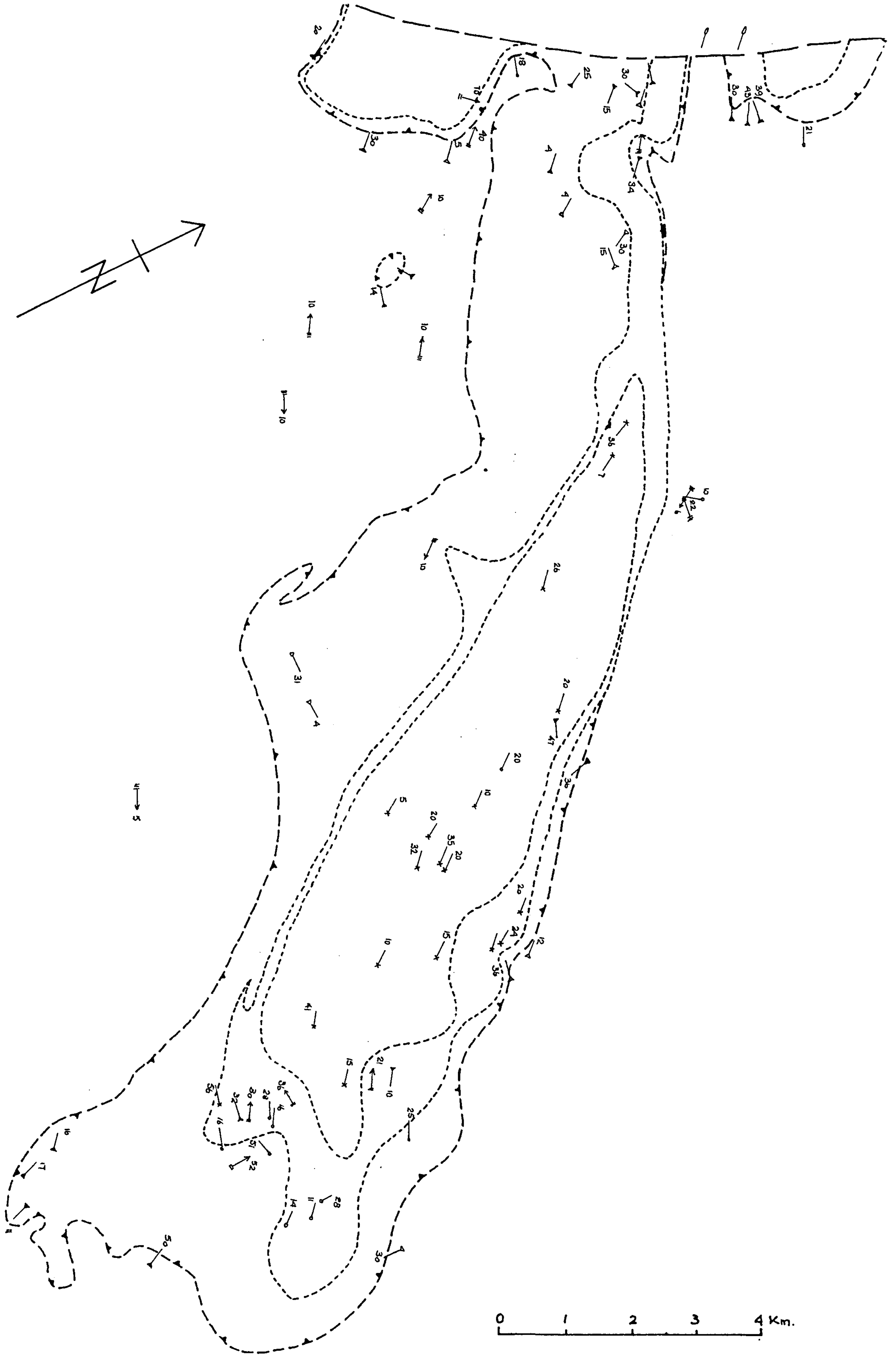

Fig. 3

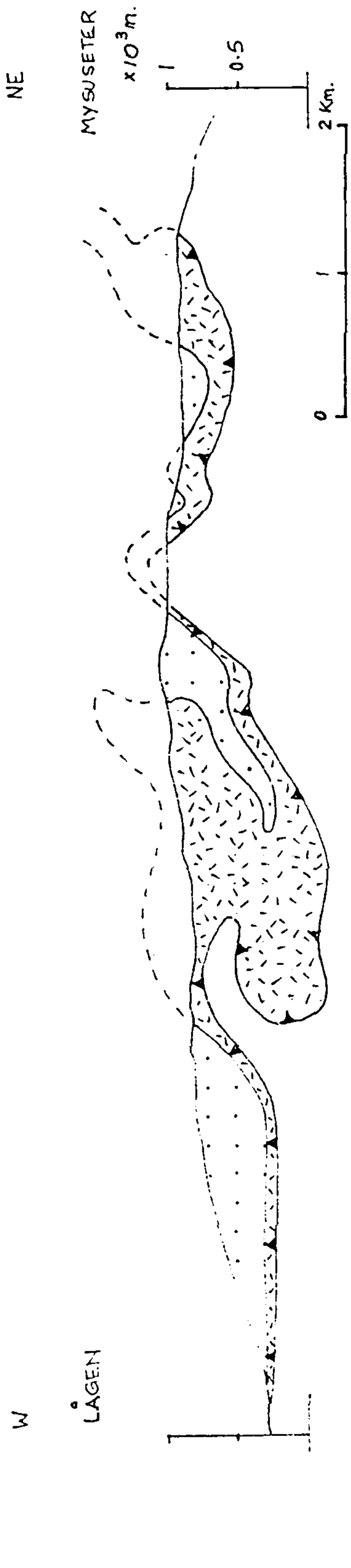

Fig. 4

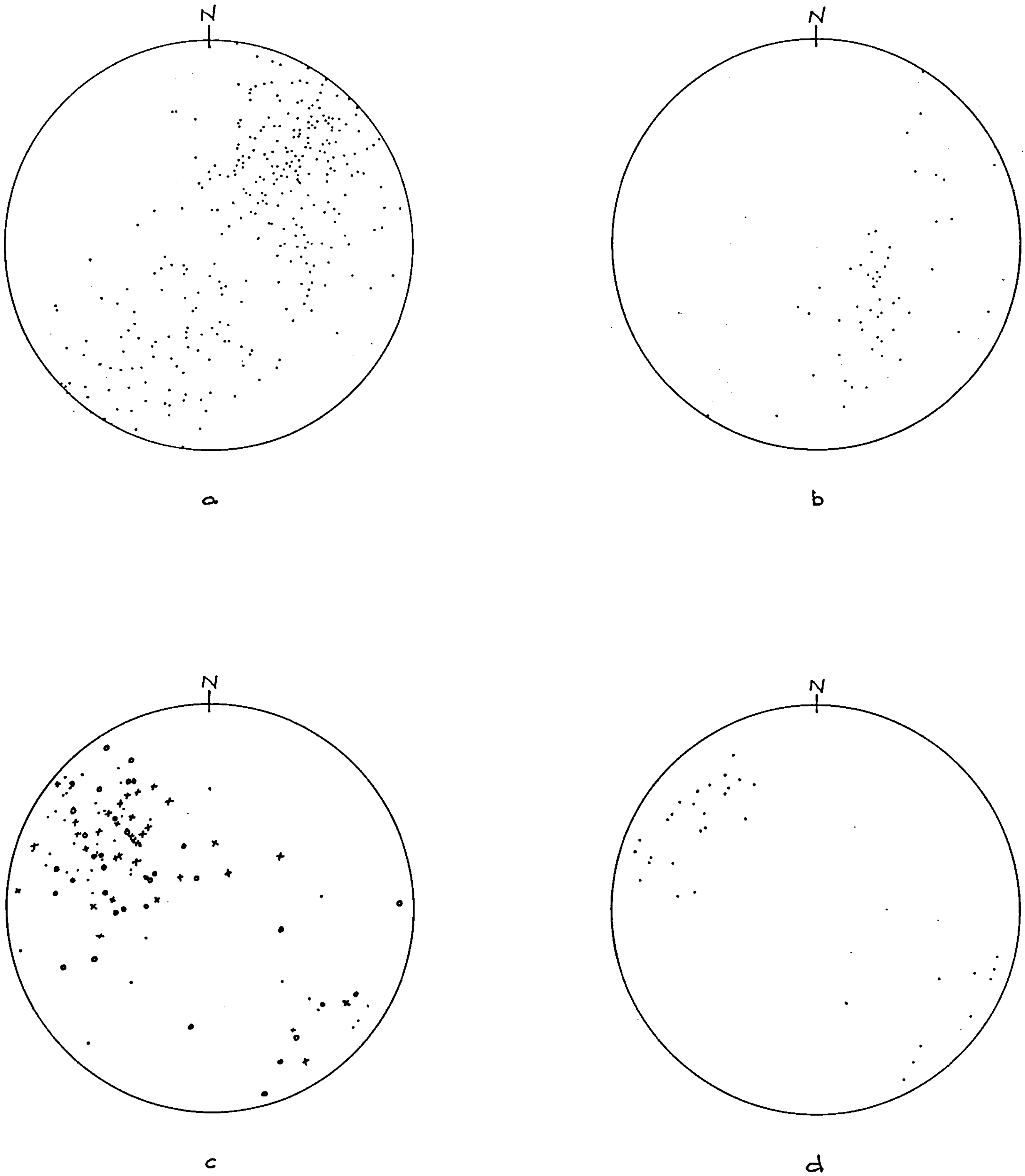

Fig. 5