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The Gaissa Nappe, Finnmark, North Norway: an example of a deeply eroded external imbricate zone within the Scandinavian Caledonides

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Abstract—The Lower Allochthon of the Caledonides of Finnmark, northern Norway, is represented solely by the Gaissa Nappe, which is composed of sub-greenschist facies sedimentary rocks of late Riphean to Tremadoc age. The lithostratigraphic sequence has been shortened by thrusting and folding in an ESE direction. Based on mapping and structural profiling east of Porsangerfjord, the Gaissa Nappe can be divided into four structural segments: the *Børselv duplex*, developed beneath the Kalak Nappe of the Middle Allochthon, is oblique to an imbricate fan, the *Munkavarri imbricate zone*, east of which is the *Guiverassa duplex zone* that is partly covered by the *Vuonjalrassa thrust sheet*. The sole thrust to the Gaissa Nappe is a flat planar surface which truncates the common N–S folds and associated cleavage in the rocks of the Gaissa Nappe. The Vuonjalrassa–Gaissa thrust cuts down section in the transport direction, possibly as a result of early tectonic downwarping.

A balanced cross-section and a hanging-wall diagram have been partially restored, indicating that the metasediments of the trailing edge of the Munkavarri imbricate zone have been displaced by 104 km in their ESE translation direction. Taking the sequence west of Porsangerfjord into consideration, an overall contraction of more than 150 km is possible. In the east, it is argued that the basal Gaissa décollement, formerly thought to die out and pass laterally into an unconformity, extends to the northeast beyond the head of Tanafjord. Folds that occur in front of the sole thrust on the Varanger Peninsula imply the presence of a blind thrust. In an orogenic context, the Gaissa Nappe forms a series of imbricated thrust sheets in the external part to the collision belt, produced during the Finnmarkian orogenic event in late Cambrian to early Ordovician time.

INTRODUCTION

The Caledonides of northernmost Norway consist of four major nappe complexes. These are the Magerøy Nappe, the Kalak Nappe, the Laksefjord Nappe and the Gaissa Nappe, all of which have been emplaced along thrust faults southeast and east-southeastwards onto the crystalline Baltic Shield with its thin autochthonous cover (Fig. 1).

Radiometric dating of synorogenically intruded igneous rocks and metasediments within the nappes has revealed two separate orogenic events. During an early, Finnmarkian event (Ramsay & Sturt 1976, Sturt *et al.* 1975, 1978) the three lower nappes were emplaced. The deformation moved diachronously from the northwest (540 ± 17 Ma) to the southeast (504 ± 7 Ma). The Magerøy Nappe was emplaced during a later Scandian event (411 ± 7 Ma) (Andersen 1981) which apparently had little effect on the underlying Finnmarkian nappes.

This paper describes and analyses the structures within the Gaissa Nappe (Holtedahl 1932, Rosendahl 1945), which is the lowest nappe of the Finnmarkian Caledonides. These sub-greenschist facies rocks have been studied previously by Gayer & Roberts (1971), Roberts (1974) and Williams (1976, 1979) all of whom concentrated on the interrelationships of minor fold phases and associated cleavages. They tended to overlook the internal thrusting which has since been acknowledged to have considerable significance (Roberts 1983, Chapman *et al.* 1986). These structures imply that the Gaissa Nappe east of Porsangerfjord has been deformed by thin-skinned compressional tectonics and that the termination of the Gaissa thrust at Andabaktoaivi (Fig. 1), as suggested by Føyn (1967), is not possible. It will be argued that the most internal part of the Gaissa Nappe may have been translated by up to 150 km from an area to the southwest of Sørøy (Fig. 1).

STRUCTURAL DIVISIONS WITHIN THE NAPPE

The Gaissa Nappe, bounded to the south and east by the Gaissa thrust, tectonically overlies the autochthonous Dividal Group in the south and the Nyborg Formation in the northeast. The Kalak Nappe overlies the Gaissa Nappe to the west, whilst the boundary is formed by the Kalak Nappe to the north, with the Laksefjord Nappe intervening to the east of Porsangerfjord (see Fig. 1).

The Gaissa Nappe is essentially a series of westerly dipping imbricate foreland thrust sheets, with a roof thrust (the Kalak and Laksefjord thrusts) and a sole thrust (the Gaissa thrust). Although the term nappe is no longer applicable to the structures present (thrust belt would be more suitable), we intend to retain the term for historical reasons.

The thrusting and folding within the Gaissa Nappe deforms the well-defined stratigraphic sequence of the Tanafjord Group (Table 1). However, no accurate estimates of thicknesses can be made in the Porsangerfjord

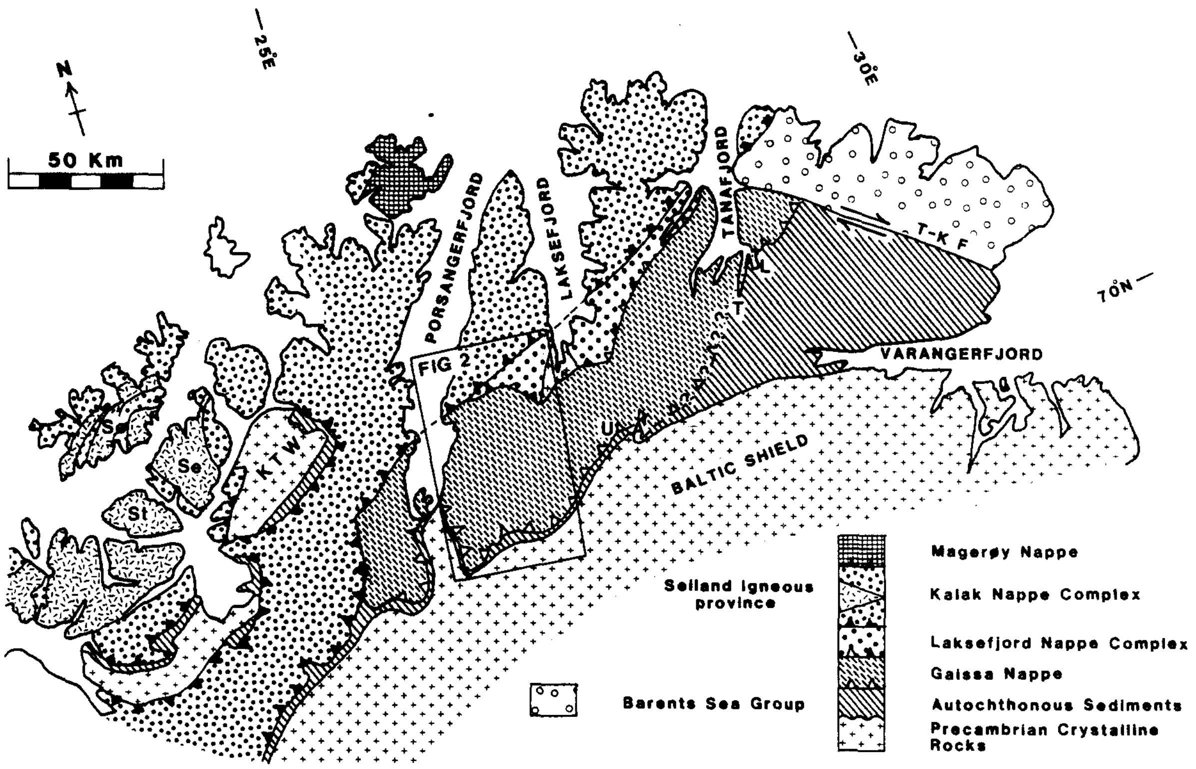

Fig. 1. Simplified map of the Finnmark Caledonides showing the area of the Gaissa Nappe detailed in Fig. 2. KTW, Komagfjord tectonic window; A, Andabaktoaivi; L, Leirpollen; Se, Seiland; Sø, Sørøy; St, Stjernøy; T, Tana river; T–KF, Trollfjord–Komagelv fault; U, Ullugaisa.

region, as no undeformed sections are present through any of the Tanafjord Group formations. Original stratigraphic thicknesses can only be measured in southern Varangerhalvøya (Siedlecka & Siedlecki 1971). Føyn *et al.* (1983) and Williams (1976) present stratigraphic thicknesses in the Adamsfjord/Ullugaisa and Porsangerfjord regions, respectively, but they have been measured within the allochthon and must therefore be considered as deformed thicknesses. It is also apparent from the estimated thicknesses (deformed or undeformed) and the mapped formation outcrops, that the Tanafjord Group formations thin westwards. In constructing balanced cross-sections and accurate sections normal to the transport direction, these two problems must be taken into account.

The Gaissa Nappe has been divided into four main structural zones within the area of the present study (see Fig. 2). *The Børselv duplex* lies in the immediate footwall to the Kalak thrust, deforming the Porsanger and Stabbursdal Formations by thrusting and, rarely, folding. The thrust faults and bedding have an ENE–WSW strike, parallel to that of the Kalak thrust and highly oblique to the structural grain within the remainder of the Gaissa Nappe.

Table 1. Lithostratigraphy of the Late Riphean to Vendian Tanafjord Group present in Eastern Porsangerfjord, modified from Williams (1976) & Føyn *et al.* (1983)

	Eastern Porsangerfjord
Formations	Lithologies
Porsanger Fm.	stromatolitic dolomite
Stabbursdal Fm.	red and green siltstone and mudstone
Hanglecærro Fm.	thin-bedded white quartzite
Vagge Fm.	brown mudstone
Gamasfjell Fm.	pink and maroon quartzite
Dakkovarre Fm.	brown mudstones and thin-bedded sandstone
(?) Stangenes Fm.	grey, red and green mudstone
Grønnes Fm.	pale grey quartzite
Brennelvfjord Fm.	grey–brown mudstone and rusty quartzite

The remaining zones (Fig. 2) crop out to the south and southeast of the Børselv duplex: the *Munkavarri imbricate zone* occupies the area immediately east of Porsangerfjord; the *Vuonjalrassa thrust sheet* forms an extensive outcrop to the east of the Munkavarri imbricate zone, continuing beyond the eastern limits of Fig. 2; whilst the *Guiverassa duplex zone* underlies the Vuonjalrassa thrust sheet, cropping out in antiformal cores and over a wider area in the south of the Gaissa Nappe.

The Munkavarri imbricate zone

No major thrust dominates the overall structure of this zone, in which the stratigraphy is constantly repeated by thrust faults. All formations except the Porsanger Formation are involved within the imbricated W-dipping thrust sheets. The structures of the Gaissa Nappe plunge gently north, so that the stratigraphically lowest formations crop out in the south. The stratigraphic repetitions are a consequence of an intricate network of thrust faults which are characteristically spaced between 0.5 and 1 km. They have variable strike length and commonly form branch lines with adjacent thrusts. More rarely they die out into a tip line.

Store Bjørndalen (Fig. 3a) is a river gorge, up to 400 m deep, whose north face is completely exposed for 5.5 km

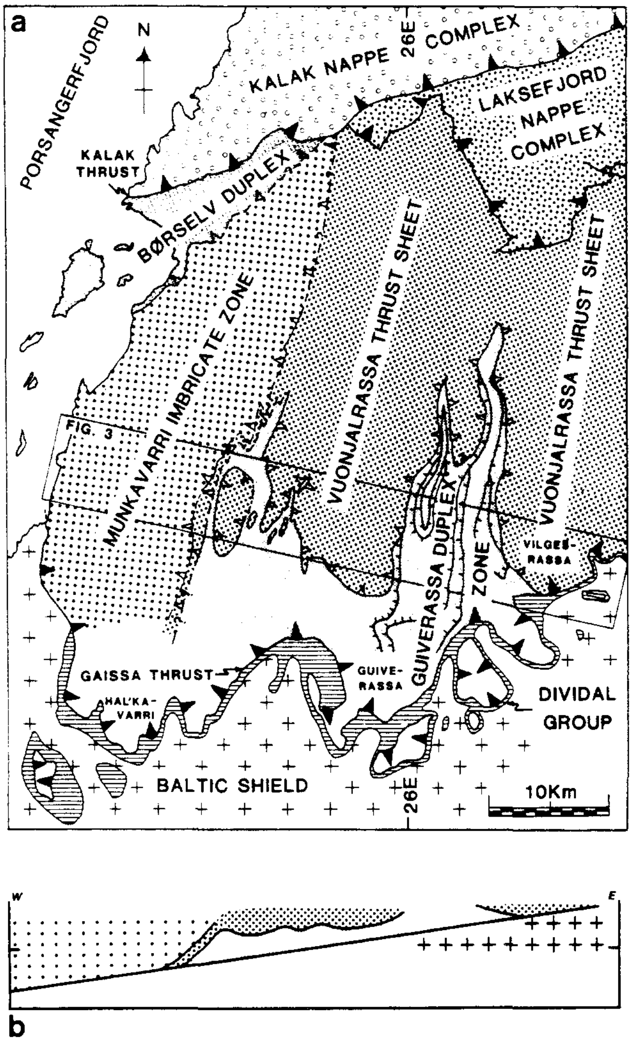

Fig. 2. (a) Map showing the structural zones of the Gaissa Nappe described in the text and the area detailed in Fig. 3. The undifferentiated area in the southern part of the Gaissa Nappe has not been mapped in detail. (b) Simplified cross-section showing the structural zones detailed in Fig. 3. The section has a 3× vertical exaggeration.

in an E–W direction, giving an insight into the third dimension of the Munkavarri imbricate zone. Several classical structures are exposed. A leading imbricate fan (Boyer & Elliott 1982) is developed where the Brennelvfjord and Grønnes Formations are repeated several times (Fig. 4), with the leading thrust having the greatest displacement, emplacing the imbricate fan on to the Vagge and Gamasfjell Formations. Two tip-line anticlines crop out (Figs. 4 and 5), both having been displaced from their respective synclines by the propagating thrust which produced them. Both of these anticlines fold the Brennelvfjord and Grønnes Formations. A duplex is exposed (Fig. 4) within the Grønnes Formation, doubling the thickness of the quartzite at the base of the cliff. Ramps and flats are clearly observed in all parts of the section (Figs. 4 and 5), and ramp-bedding angles tend to vary from as little as 15° up to 90° (Figs. 4 and 5).

The Vuonjalrassa thrust sheet

The Vuonjalrassa thrust sheet is large and extensive (Fig. 2). It presumably extended further south, but has been removed by erosion. The thrust sheet is underlain by the Vuonjalrassa thrust, which combines with the sole thrust (the Gaissa thrust) in a leading branch line east of grid line 473 (Fig. 3). The rock units of the Vuonjalrassa thrust sheet consist of the Gamasfjell, Vagge and Hanglecærro Formations. The Gamasfjell Formation at the base of the thrust sheet becomes thicker eastwards, which may be due to sedimentary thickening or possibly a result of the Vuonjalrassa thrust cutting down section in the transport direction. At Vilgesrassa, the Gaissa thrust, east of the leading branchline with the Vuonjalrassa thrust, cuts down section in the transport direction into the Dakkovarre Formation.

The Vuonjalrassa thrust sheet has been folded by several N–S trending open folds, generally symmetric or facing eastwards. Erosion through the major antiforms has exposed a large duplex below the Vuonjalrassa thrust sheet. These folds may be culminations above duplexes at depth (see Fig. 3b). A culmination in the area between Salgutoaivi and Vilgesrassa has been eroded, exposing the Guiverassa duplex zone beneath it (Fig. 3). This is similar to the culmination produced by the duplex within the Grandfather Mountain Window (Boyer & Elliott 1982). On Salgutoaivi a far-travelled (?) klippe of Gamasfjell Formation overlies the Vuonjalrassa thrust sheet, which has also been folded by these N–S open folds. Although no thrust sheet is exposed to which this klippe could be connected, its origin must lie west of the Vuonjalrassa thrust sheet and possibly west of the Munkavarri imbricate zone.

The Guiverassa duplex zone

The Guiverassa duplex zone crops out below the Vuonjalrassa thrust sheet in the southern and central part of the Gaissa Nappe, due to the slight regional northward tilt. There are four thrust sheets exposed (Fig. 3b), consisting of the Gamasfjell and Dakkovarre Formations. These have subsequently been folded into two major antiforms with an intervening synform. These N–S trending folds may also be culminations formed over underlying duplexes at depth, like the N–S trending folds in the Vuonjalrassa thrust sheet. The roof thrust to the Guiverassa duplex zone is the Vuonjalrassa thrust, but the floor thrust is unexposed. It is thought, however, to be near the base of the Dakkovarre Formation and may well be the Gaissa thrust.

ASPECTS OF REGIONAL STRUCTURE

The tectonic strike of the Gaissa Nappe is dominantly NNE–SSW. Fold axes, with shallow, dominantly northward plunges, trend subparallel to the strike with up to 20° deviation (Fig. 6). This northward plunge is a consequence of northward regional tilt. The fold-related cleavage planes have a similar strike, dipping predominantly towards the west, consistent with an eastward fold vergence. Thrust fault surfaces have a similar

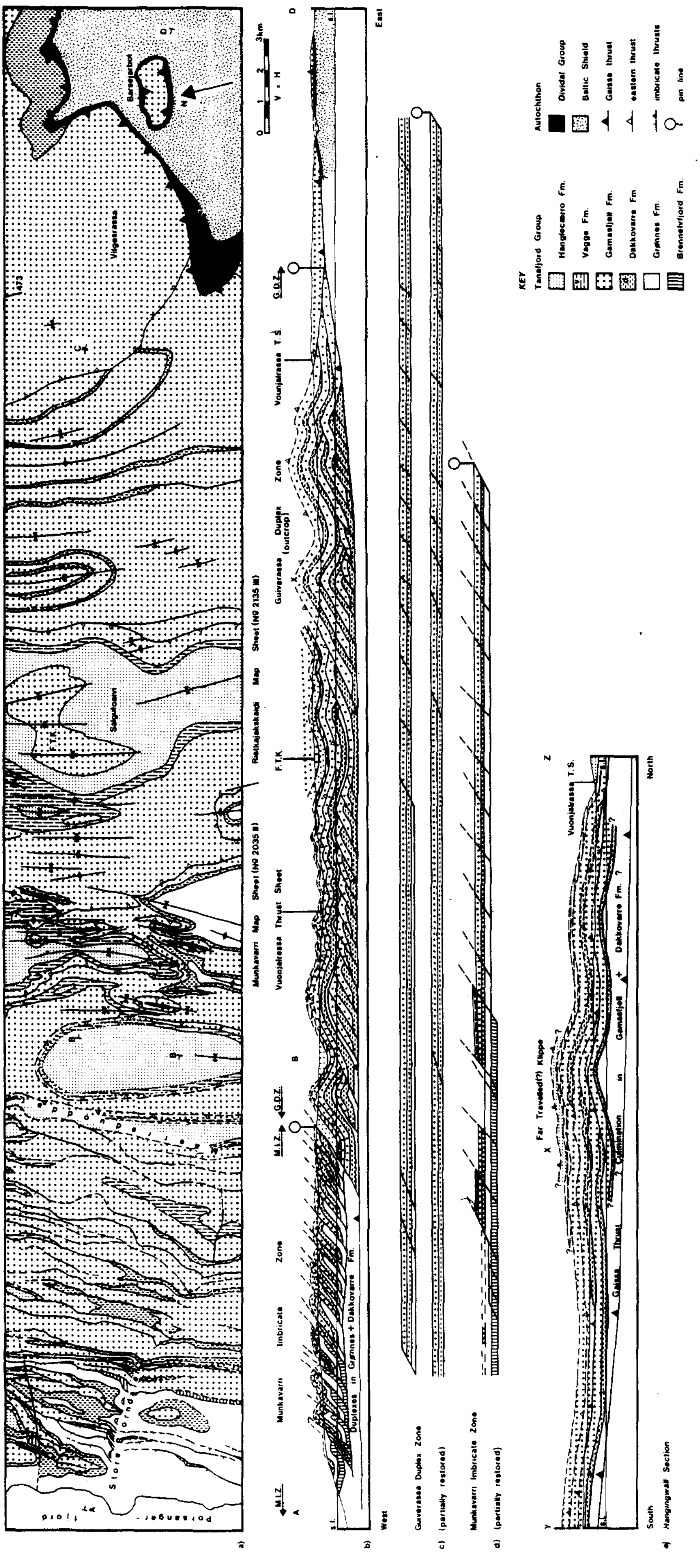

Fig. 3. (a) Map showing the geology along the line of section A–B–C–D, based on the mapping by D. Roberts in the west and H. Rice, K. Harrington & S. Føyn in the east. (b) Balanced section along the line A–B–C–D. MIZ, Munkavarri imbricate zone; GDZ, Guiverassa duplex zone; Vuonjalrassa T.S., Vuonjalrassa thrust sheet. (c) Partially restored section within the Munkavarri imbricate zone. (e) Hangingwall section through X (shown on b).

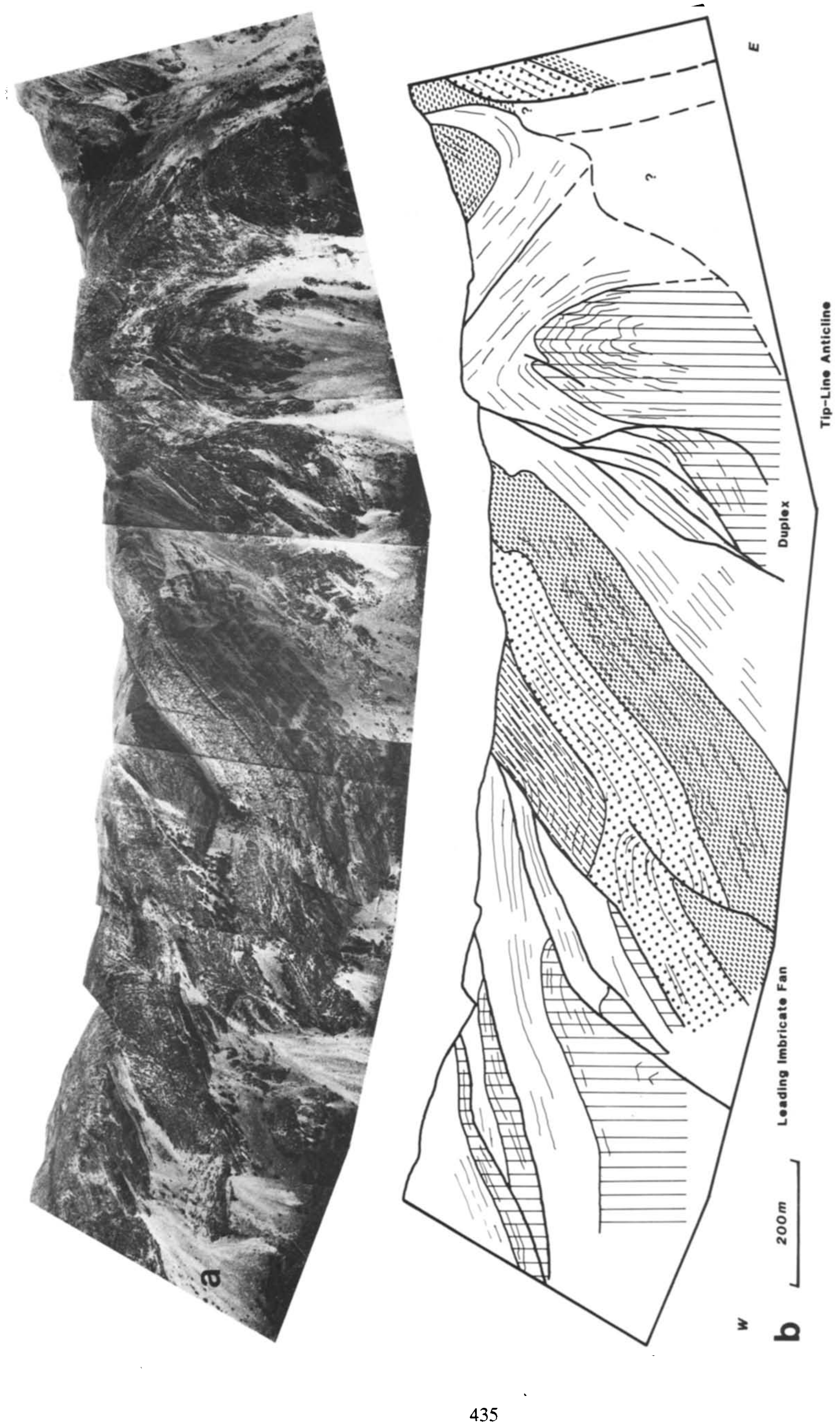

Fig. 4. (a) Photomosaic of the western part of the Munkavarri imbricate zone exposed in the Store Bjørndalen section. (b) Geological interpretation of (a), showing a leading imbricate fan, a tip-line anticline and a duplex. The heavier lines indicate thrusts and the ornamentation is that used in Fig. 3.

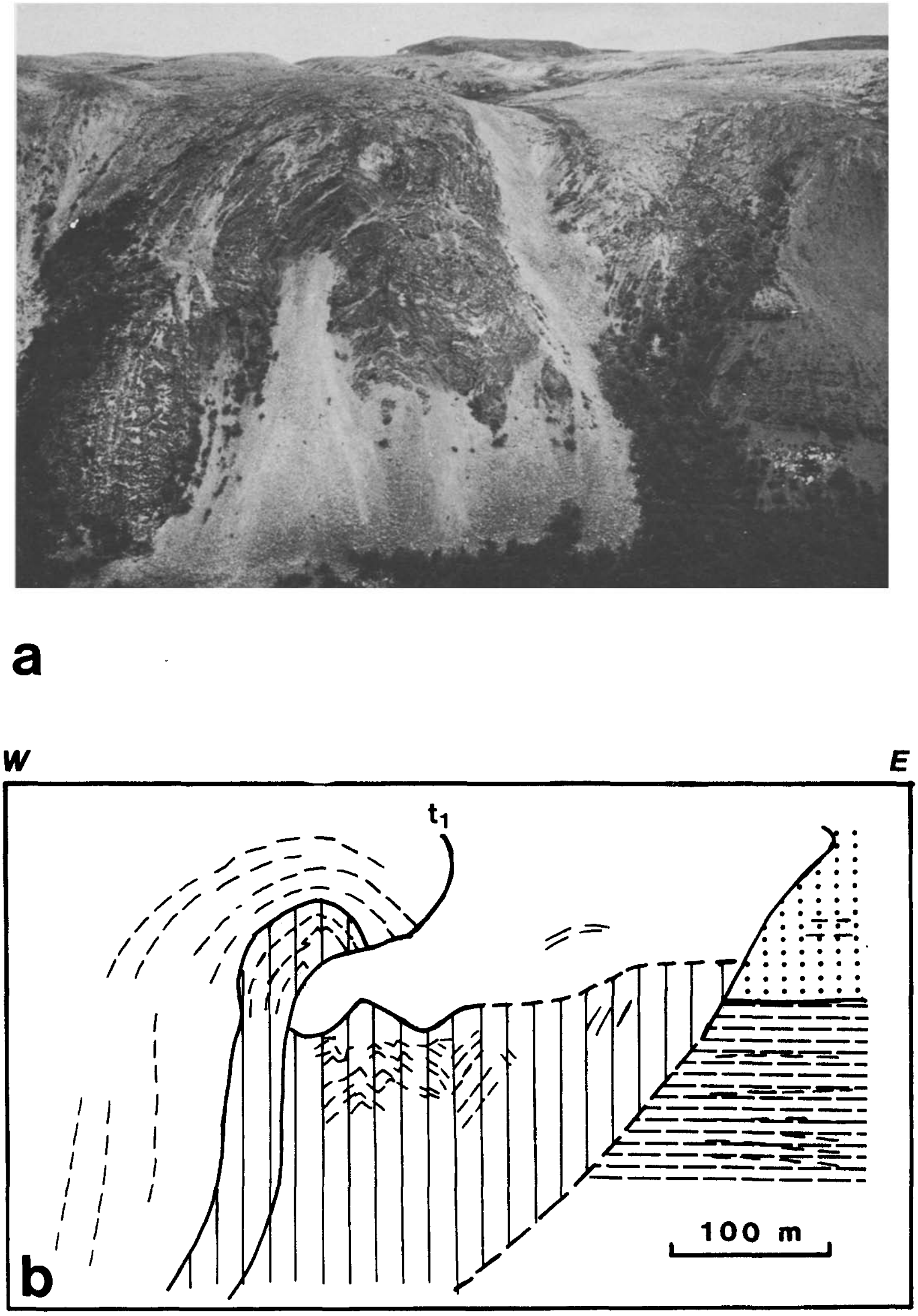

Fig. 5. (a) Photograph of part of the Munkavarri imbricate zone exposed in the Store Bjørndalen section to the east of Fig. 4. (b) Geological interpretation of (a), showing a tip-line fold above the western thrust (t_1) and intraformational folds within the Brennelvfjord Formation within the footwall to t_1. The heavier lines indicate thrusts.

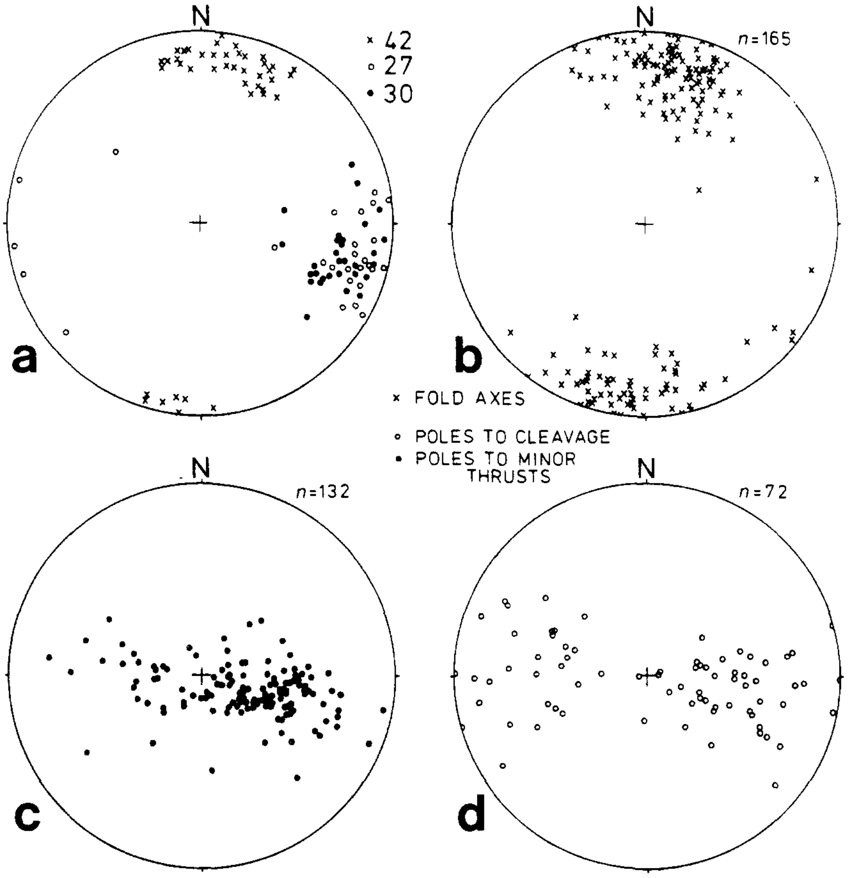

Fig. 6. Lower hemisphere stereographic projections of structures of the Gaissa Nappe. (a) Fold axes and poles to cleavages and minor thrust planes in Munkavarri imbricate zone. (b) Fold axes in the Vounjalrassa thrust and Guiverassa duplex zone. (c) Poles to minor thrust planes in the Vounjalrassa thrust sheet and Guiverassa duplex zones. (d) Poles to cleavages in the Vounjalrassa thrust sheet and Guiverassa duplex zones.

attitude and crop out parallel to the regional strike. They cut up and down section in the direction of strike along lateral ramps. These observations suggest that to the east of Porsangerfjord the tectonic transport direction was dominantly towards the ESE.

Folds

The folds produced during the compressional tectonics can be classified into three types, based on scale and process of formation. These are intraformational, interformational and ramp folds. The intraformational folds occur only within the interbedded sandstone and shale formations, where there is a strong competence contrast. They occur on a scale of 1–2 m and are generally symmetrical open to close chevron folds. They are the product of layer-parallel shortening prior to the displacement along the underlying thrust. The interformational folds deform one or more formations and deactivated thrusts as tip-line folds. They are generally ESE verging asymmetric, close folds which occur with a wavelength of up to several hundreds of metres. The ramp folds deform the thrust sheets and their underlying thrust faults, forming culminations and depressions which can only be detected by regional mapping. These folds are gentle to open and have been formed by movements along later, underlying thrust-faults.

The fold mechanism in all cases is a flexural process, resulting in bedding-surface slip lineations, slickensides and quartz-filled tension gashes perpendicular to bedding in the competent sandstone beds (see Williams 1979, fig. 6).

Layer-parallel shortening

Layer-parallel shortening in association with thrusting has been described by Fischer & Coward (1982), who consider the shortening to be due to sticking on the floor thrust prior to the development of a ramp. This would cause a component of layer-parallel shortening leading to and accompanying buckling of the layers by flexural processes in the production of tip-line folds. It is evident that layer-parallel shortening has occurred within the Gaissa Nappe, to a variable degree. The intraformational folds formed within the interbedded sandstone and shale formations may have resulted from this mechanism. The shortening produced by these intraformational folds has only been measured at a few localities, where values in the region of 16% have been obtained. Cleavage is well developed in the interbedded sandstone and shale formations and it is possible that it could also have accommodated a certain amount of shortening. As the cleavage has not been studied in detail no estimate of the shortening by this process has been made.

The strain within the quartzite formations should approximate to that in the interbedded formations. The resulting thickening of the quartzites may have been achieved by movement along the many minor thrusts forming thrust wedges or by pure shear. The pure shear was accommodated by crystal plastic deformation, grain scale cracking, and cataclasis of the quartzites, all of which have been noted by previous workers (Roberts 1971, White 1967). Cleavage, however, is poorly developed in the quartzites and has produced little or no shortening. Strains within the quartzites have not been studied quantitatively, although it should be possible to derive strain estimates from studies of grain shapes or nearest neighbour clast distribution (see e.g. Ramsay & Huber 1983).

The sole thrust

The regional sole thrust, the Gaissa thrust, is exposed at several localities which have been recorded by Føyn (1967). In all cases the thrust has tectonically emplaced the metamorphosed and deformed Tanafjord Group sediments, along a flat planar surface, over the unmetamorphosed Dividal Group (Føyn 1967).

The thrust is usually a 15–30 cm thick deformed zone, affecting both the hangingwall and footwall rocks. Within this zone, there is a 2–3 cm-thick band of ultracataclasite, along which most of the displacement has been accommodated. Otherwise, deformation in the footwall is rare. Only occasionally are NW–SE trending folds present and a weak bedding-parallel fabric or compaction cleavage is present. The rocks of the hangingwall are always extensively deformed.

The Gaissa thrust has been mapped as a planar fault (Føyn 1967), with a constant dip of 3° towards 335°. This agrees with the aeromagnetic interpretations of Åm (1975), who calculated the depth to basement. His results show the basement-cover contact dipping northwards, to a depth of 1 km below the outcrop of the Kalak thrust in Porsangerfjord and Laksefjord. This gives a dip to the sole thrust of 2.5° to the north, assuming that the décollement lies just above the unconformity, as it does at outcrop in the southern part of the Gaissa Nappe.

As the map trace of the Gaissa thrust is followed eastwards, it cuts down section in both the hangingwall and footwall stratigraphies. In the hangingwall it cuts down from the Gamasfjell Formation at Vilgesrassa (Fig. 2) into the Grønnes Formation at Ullugaisa (Fig. 1) in the transport direction (see Føyn *et al.* 1983). In the footwall the thrust cuts down from above member IV into member III of the Dividal Group east of Halkevarre (see Føyn 1967), although this structure is probably an oblique ramp.

BALANCED CROSS-SECTION

A balanced cross-section has been constructed through part of the Gaissa Nappe, approximately parallel to the direction of thrusting (Fig. 3b). Displacements have been kept to a minimum, except where surface geology suggests the presence of underlying imbrication to explain culminations and depressions, for example, the extension of the Guiverassa duplex zone beneath the Vuonjalrassa thrust sheet to explain the culminations in the latter. Thus the resulting section shows an overall minimum shortening. Although the section as a whole cannot be restored, the Munkavarri imbricate zone and the Guiverassa duplex zone have been partially restored, by using the line length balance technique (Hossack 1979) (Figs. 3c & d). An area restoration is not possible, because accurate estimates of undeformed formation thicknesses are unavailable. If it were possible to restore the areas of the different tectonic zones, the total calculated displacement would be increased.

The Munkavarri imbricate zone has no exposed roof thrust but a roof thrust was probably once present. Three possibilities are the Kalak thrust, the Vuonjalrassa thrust or the thrust below the far-travelled (?) klippe. The floor thrust is unexposed and its depth has been kept to a minimum. The small scale of the section does not allow all of the considerable detail of the Munkavarri imbricate zone exposed in the Store Bjørndalen profile to be represented, but all the important structures are shown. It has a deformed length of 11 km and an undeformed length of 25 km, giving a displacement of 14 km, or a total shortening of 55.6%.

Three thrust sheets within the Guiverassa duplex zone have been folded and exposed towards the eastern part of the section. The two antiforms have been explained by imbrication of the Grønnes and Dakkovarre Formations, producing two culminations. This hypothesis gives a minimum estimate of the shortening, but it requires a fourth thrust sheet consisting entirely of the Gamasfjell Formation to balance the section. A hangingwall section (Elliott & Johnson 1980) has been constructed across the exposed portion of the duplex, with the aid of branch lines and lateral cut-offs (Fig. 3e). The folding of the exposed thrust sheets again becomes apparent. The leading edge of the duplex zone is buried east of grid-line 473, as indicated by the northward extension of the exposed leading branch point.

We interpret the thrusts underlying the Vuonjalrassa thrust sheet as part of a duplex, although other interpretations, such as the presence of blind thrusts, would be equally valid. The highest thrust sheet in this part of the duplex zone extends eastwards to a point east of Vilgesrassa, as indicated by the northward extension of a leading branch point. The floor thrust has been kept within the Dakkovarre Formation so that the Gaissa thrust does not cut down section in the transport direction.

The Guiverassa duplex zone has a deformed length of 22.5 km and a restored length of 77 km, giving a displacement of 51.5 km, or a total shortening of 67%.

We interpret the western end of the Vuonjalrassa thrust sheet as connecting with a thrust sheet in Maerraduoddar, which is a very poorly exposed area. Although it is possible that it continued westwards over the Munkavarri imbricate zone, such an interpretation would considerably increase the displacement along the Vuonjalrassa thrust. The displacement along the Vuonjalrassa thrust can be demonstrated to be greater than 38.5 km. The Gamasfjell Formation hangingwall cut-off must lie east of the klippe at Borsejarbot, which is a minimum of 38.5 km from the corresponding footwall ramp.

The Vuonjalrassa thrust is within the Gamasfjell Formation, but the floor thrust to the central duplex zone is within the Dakkovarre Formation. Unless the floor thrust cuts down section, the Dakkovarre Formation must have been deformed either as one or several thrust sheets, the cumulative bed-length of which must be at least 38.5 km. Our interpretation has been to deform the Dakkovarre Formation into a duplex, which conveniently fits into a hole beneath the Munkavarri imbricate zone.

The total displacement estimated from the balanced cross-section is a minimum of 104 km. This estimate does not account for any of the displacement along the Gaissa thrust east of the leading edge of the Guiverassa duplex zone which is probably considerable. No feasible minimum displacement estimates are possible for the far-travelled klippe of Gamasfjell Formation, which rests on the Vuonjalrassa thrust sheet.

DISCUSSION

Intraformational folds are common in the pelitic formations of the Gaissa Nappe, and probably constitute the bulk of the ubiquitous cleavage-related folds than one sees in outcrop. These folds have formed as a consequence of layer-parallel shortening, but due to uncertainties about formation thickness, they cannot be restored. Other folds, which have been restored, were associated with thrust displacement, forming first at thrust tips, as well as later ramp folds. The implication of this variety of fold-forming process is that it is unwise to attempt any strict nappe-wide classification of folds on an age basis.

Previous investigations of the Gaissa Nappe highlighted the fold pattern (e.g. Gayer & Roberts 1971, 1973, Williams 1979), with little attention paid to contractional faulting. Estimates of shortening were based on these upright folds and on a restoration of the Gaissa Nappe rocks along their basal thrust. This yielded a figure of 35–40 km in south Porsangerfjord. Recent work used the regional lithostratigraphy from the less strongly deformed Tanafjord–Varangerfjord district (Siedlecka & Siedlecki 1971) enabling thrust repetition to be recognized. The presence of a series of imbricate sheets and duplexes means that estimates of shortening have been revised, and for the section shown in Fig. 3 a cumulative minimum shortening of about 104 km along an ESE–WNW trend has been calculated for the Tanafjord Group rocks by constructing and partially restoring a balanced cross-section.

The shortening of over 100 km indicates that the deformed rocks now exposed at the western end of the cross-section (Fig. 3) derive from the vicinity of the islands of Stjernøy and Seiland (Fig. 1), west of the Komagfjord tectonic window of Precambrian basement rocks (Reitan 1963, Pharoah *et al.* 1983). When detailed maps of the Gaissa Nappe have been prepared for the area west of Porsangerfjord, this may well increase the overall shortening estimate to more than 150 km, placing the provenance area into the Norwegian Sea just SW of Sørøy.

No Gaissa Nappe rocks are known from the vicinity of the Komagfjord window; but the Dividal Group equivalents are present, though in a partly deformed and cleaved condition (Roberts & Fareth 1974, Pharoah *et al.* 1983), more strongly deformed in the northwest. Either the Svecokarelian rocks in the window are part of a thrust sheet, or the Gaissa Nappe has travelled across this presently exposed basement. Chapman *et al.* (1986) favoured the former solution in their true-scale profiles, showing these basement rocks as a horse accreted to the base of the Kalak Nappe Complex; but the available geophysical data, particularly aeromagnetic anomalies that can be traced southwestwards into the Alta–Kvaenangen area without any disruption, appear not to support this notion. The alternative, however, that the weakly metamorphosed Gaissa rocks passed across an essentially autochthonous (perhaps parautochthonous in the northwest) and only very gently upwarped Precambrian basement surface, and that the prominent antiformal window and deformed Kalak thrust are expressions of later Scandian deformation, also has its difficulties. The thin sequence of autochthonous cover sediments which unconformably overlie the Svecokarelian basement of the window are of Vendian age and there are no representatives of the distinctive Riphean stratigraphy of the Gaissa Nappe. There is no record in the Gaissa Nappe of a stratigraphy transitional to that of this Vendian cover, which should be present had the more internal parts of the Gaissa Nappe moved across the window. We feel that the solution to this problem requires further study of the Caledonian structure of the window rocks and of the aeromagnetic data.

In general, the geometry of the thrust structures in the Gaissa Nappe is typical of thin-skinned compressional tectonics (e.g. Elliott & Johnson 1980). There is, however, evidence that the thrust beneath the Vuonjalrassa thrust sheet cuts down section in its hangingwall in the transport direction. This may be due to syn-depositional or early tectonic downwarping of the sedimentary basin prior to thrust propagation.

There are problems associated with the eastward extent of the Gaissa Nappe, as delimited by the outcrop of its sole thrust. Føyn (1967) terminated the thrust south of the hill Andabaktoaivi (Fig. 1) in an overturned fold, east of which the Vendian tillites lie unconformably upon Archaean and Proterozoic crystalline rocks. Føyn (1967) suggested that the Gaissa Nappe was hinged in this area and that the tectonic translation involved a component of anticlockwise rotation, with displacements increasing westwards.

The present study indicates that a thrust termination at Andabaktoaivi, where there is still some 14 km of displacement according to Føyn's mapping, is quite unlikely (see Chapman *et al.* 1986). This part of the Gaissa Nappe is one of the poorest exposed tracts of eastern Finnmark, but there are features of the geology that suggest where the extension of the thrust may be located. Føyn (1976) mapped a 3 km segment of a NE–SW trending thrust northeast of the Andabaktoaivi termination, and we consider it likely that this may be traced northeastwards along strike as a flat within the Nyborg Formation (Table 1). Further northeast the thrust may link with the easternmost thrust fault occurring near the estuary of the Tana river and across Leirpollen (Siedlecki 1980), eventually being truncated by the major Trollfjord–Komagelv Fault (Siedlecka & Siedlecki 1967) (Fig. 1). Faults further east on Varanger Peninsula are in fact extensional, cutting a folded sequence. The shortening expressed by these folds, which die out southeastwards (Siedlecki 1980), can be compensated by inferring the presence of a blind thrust. Further southeast the Riphean–Vendian sediments are truly autochthonous.

CONCLUSIONS

The present study has four main conclusions, as follows.

(1) In agreement with Chapman *et al.* (1986), it is possible to apply a thin-skinned tectonic model to the external part of the Finnmarkian Caledonides.

(2) Thrusting was the dominant deformation process in the Gaissa Nappe.

(3) Thrusting occurred with an ESE translation direction, with the deformation dying out eastwards.

(4) A minimum shortening of 104 km occurs in the area to the east of Porsangerfjord.

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