Precambrian and Caledonian Tectonometamorphic Evolution of Northeastern Seiland, Finnmark, North Norway

JOHN AKSELSEN

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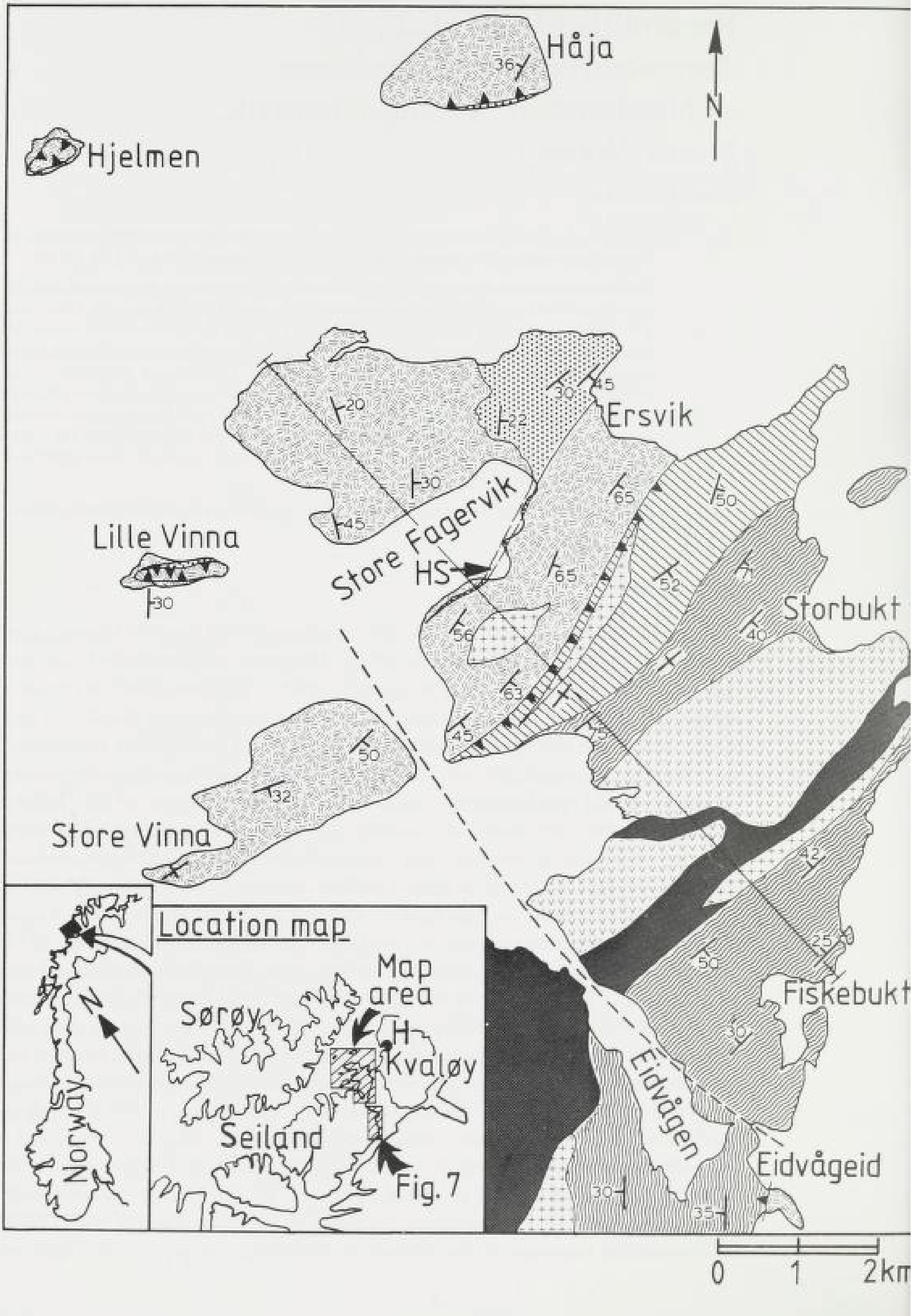
The metamorphic rocks of northeastern Seiland are predominantly Precambrian gneisses and schists. The Fagervik infracrustal complex, composed of tonalitic gneisses, constitutes a basement to the Late Precambrian-Cambrian Klubben Psammite Group, while the Precambrian Eidvågeid supracrustal sequence occurs as the uppermost allochthonous nappe. The Precambrian units contain evidence of Precambrian deformation and metamorphism. The subsequent Caledonian tectonism is characterized by two phases of deformation, D_1 and D_2. A metamorphic climax occurred in the interkinematic period. D_1 produced large isoclinal folds and large-scale translation of the nappes. The major D_2 structure is a large asymmetric synform, the Storbukt Synform, with a vergence towards the southeast.

John Akselsen, Norsk Hydro a.s., Research Center, Lars Hilles gate 30, 5000 Bergen, Norway

Introduction

The island of Seiland, is situated to the southwest of the town of Hammerfest, within the Kalak Nappe Complex of the Finnmark Caledonides of northern Norway (Fig. 1, Roberts 1974, Sturt et al. 1975). Worthing (1971 a) made a detailed study of the lithologies, structure and metamorphism of the eastern part of the island and described a conformable sequence of pelitic rocks sandwiched between psammite units (Worthing 1971 b). This sequence constitutes the eastern envelope of the predominantly basic and ultrabasic plutons of the Seiland Petrographic Province (Robins & Gardner 1974 and references therein). Worthing (op.cit.) attempted to correlate these units with the Late Precambrian-Cambrian metasedimentary succession on Sørøy (Holland & Sturt 1970, Ramsay 1971), but could not demonstrate an equivalence. Most of the rocks in the Kalak Nappe Complex had been interpreted as Caledonian in origin (Armitage et al. 1971, Ramsay 1971), but Rb-Sr studies on perthosite instrusions and surrounding rocks suggested that at least some of the rocks in the Øksfjord area had a Precambrian origin (Brueckner 1973). Although Pringle (1975) obtained the same Rb-Sr results from similar rocks on Seiland, he regarded them as spurious because the country rocks to the dated instrusions had been correlated with the Eocambrian Klubben Psammite Group. These correlations were, however, purely lithological and may have been in error. Subsequently Ramsey & Sturt (1977) found a sub-Caledonian unconformity on Kvaløy (Fig. 1) where the Klubben Psammite Group rests unconformably on granitic gneisses. Well preserved unconformable relationships were later discovered on the island of Hjelmsøy (Ramsay et al. 1980). Following the discovery of the Kvaløy unconformity, the pelitic lithologies on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Store Fagervik
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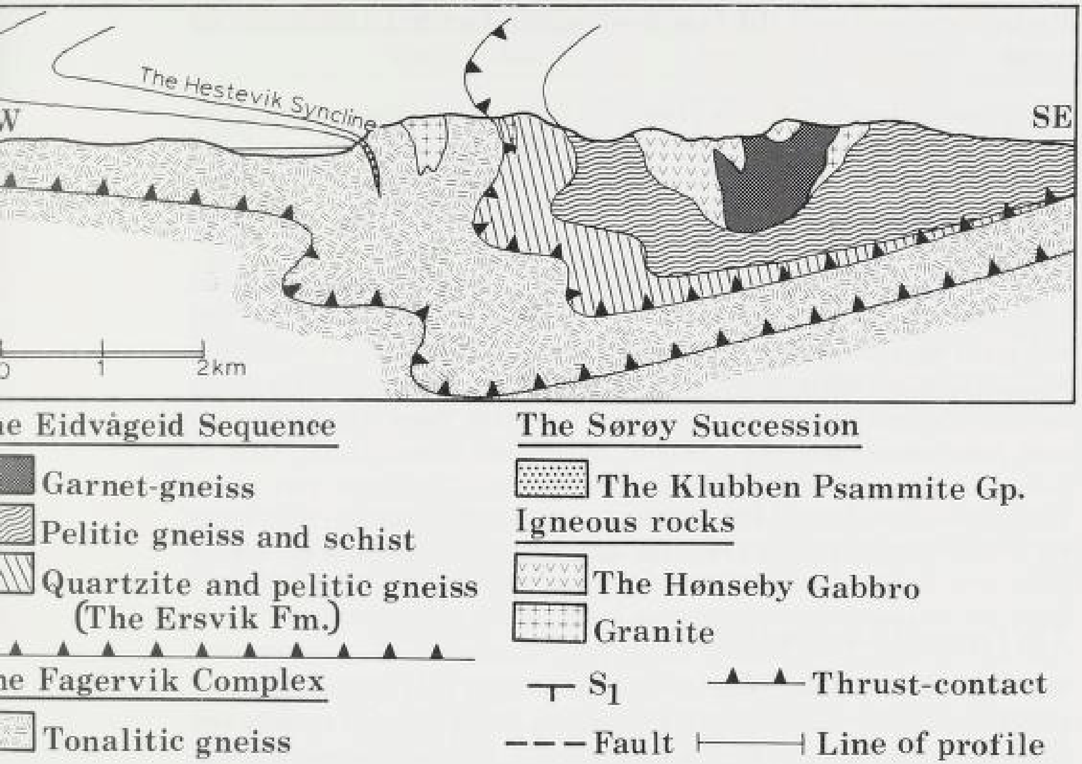


Fig. 2. Geological cross-section of Fig. 1 showing the Storbukt Synform and the refolded Hestevik Syncline.

Seiland were reinterpreted as mylonitic Precambrian gneisses (Ramsay & Sturt 1977), but the structurally lowermost and uppermost units were still correlated with the Klubben Psammite Group (Zwaan & Roberts 1978).

Mapping of northeastern Seiland by the present aothor has shown that Precambrian tectonometamorphic events are even more important on this island than was previously recognized.

Lithotectonic units

The metamorphic rocks of northeastern Seiland have been subdivided into three lithotectonic units:

1) Rocks correlated with the Late Precambrian-Cambrian metasedimentary succession on Sørøy.
2) The Precambrian Fagervik infracrustal complex.
3) The Precambrian Eidvågeid supracrustal sequence.

Fig. 1. Geological map of northern Seiland. Lithological boundaries southwest of Eidvågen are taken from Worthing (1971a). Geological cross-section with legend is shown in Fig. 2. H denotes Hammerfest in the location map and HS refers to the Hestevik Syncline.

Rocks correlated with the Late Precambrian-Cambrian succession on Sørøy

Rocks correlated with the Klubben Psammite Group occur as narrow strips in four areas on northeastern Seiland. They lie in a syncline around Store Fagervik (the Hestevik Syncline), while they occur in a series of thin thrust sheets on the neighbouring islands of Store and Lille Vinna, Hjelmen and Håja as well as on eastern Seiland (Figs. 1, 6 and 7).

The rocks of the Klubben Psammite Group are predominantly arkosic psammites and grey quartzites. The content of potash feldspar commonly is high and gives the rocks a characteristic buff colour. Locally there are semipelitic horizons up to one metre thick. Calc-silicate rocks occur along some of the thrusts on eastern Seiland (Worthing 1971a, Fig. 7) and Lille Vinna (Fig. 6); They are dark green schists containing actinolite, chlorite and biotite. Locally there are numerous quartz-lenses and thin marble horizons. The upper part of the imbrication-zone of eastern Seiland contains some rusty-weathering mica schists (Worthing 1971a). The age of the calc-silicates and mica schists is not known.

The Fagervik infracrustal complex

The Fagervik infracrustal complex is dominated by grey quartzo-feltspathic gneisses, commonly with a tonalitic composition. The gneisses are typically very homogeneous and probably have an igneous origin. They are intruded by granite to the south of Store Fagervik. Calc-silicate rocks and quartzite horizons in the gneisses on Store Vinna indicate, however, a sedimentary origin for some of the complex. The Fagervik complex thus appears to be composed of a series of ortho- and paragneisses, but a detailed subdivision has not been possible. The gneisses are lithologically similar to the gneisses which underlie the pre-Caledonian unconformity on the islands of Kvaløy and Hjelmsøy (Ramsay & Sturt 1977, Ramsay et al. 1980).

CONTACT RELATIONSHIPS WITH THE SØRØY SUCCESSION

The Klubben Psammite Group has an unconformable relationship to the Fagervik gneisses in certain areas and thrust-contacts in others. The lower boundary of the Klubben Psammite Group around the Hestvika Syncline is interpreted as a tectonized unconformity. The rocks along the contact are not generally mylonitic, but are considerably flattened, especially in long-limbs of asymmetric folds. The gneisses to the south of Store Fagervik are transformed into mylonites in a 10 m thick zone along the boundary with the Klubben Psammite Group, while they are coarse-grained with abundant cross-cutting pegmatites outside this zone.

The Eidvågeid Supracrustal sequence

A thick sequence of garnet-mica schists and gneisses, the Eidvågeid supracrustal sequence, occurs tectonically above and is separated from the Fagervik infracrustal

TABLE 1. Chemical analyses of pelitic rocks from the Eidvågeid sequence

	P44	P46	P50	P86	G48	E39a	E39b
SiO_2	60.11	64.42	60.26	57.74	61.43	60.93	60.04
Al_2O_3	19.91	18.02	16.92	22.16	18.26	20.16	20.53
TiO_2	1.12	1.07	1.36	1.26	1.13	1.07	1.01
FeO_t	7.05	6.06	8.68	7.95	7.14	7.13	6.70
MnO	0.10	0.10	0.14	0.18	0.12	0.17	0.18
MgO	3.55	2.53	2.78	2.67	3.54	3.28	3.11
CaO	2.04	1.54	2.40	1.35	2.32	1.17	1.22
Na_2O	2.79	2.21	2.16	1.74	2.68	1.59	1.44
K_2O	3.32	4.09	4.01	3.13	2.75	4.54	5.28
P_2O_5	0.27	0.13	0.17	0.33	0.16	0.29	0.29
H_2O	0.58	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sum	100.84	100.17	98.88	98.51	99.53	100.33	99.80

complex by a major thrust-contact. Quartzite and calc-silicate rocks occur in subordinate quantities in this sequence with the exception of a zone along the boundary against the Fagervik complex where quartzites dominate over pelitic rocks. The rocks within this zone will be referred to informally as the Ersvik Formation (Fig. 1). The quartzites contain less feldspar and mica than the arkosic Klubben Psammite. The garnet gneisses, which occur in the tectonically uppermost part of the Eidvågeid sequence, contain significantly less mica than the underlying pelitic gneisses and schists. The boundary is a transitional one with gradually decreasing biotite contents. Similar lithologies occur in the tectonically uppermost unit on eastern Seiland (The Olderfjord Group of Worthing 1971 a, b).

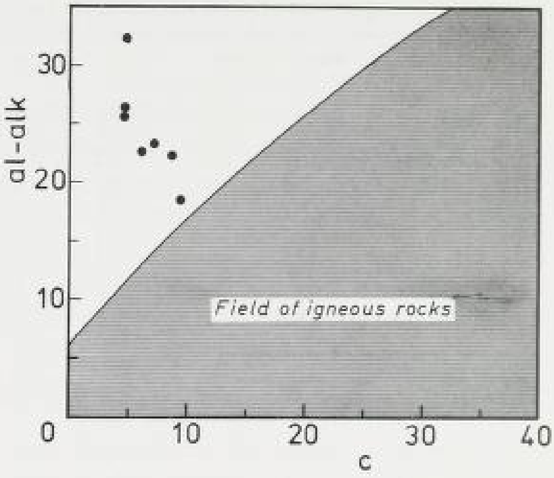
ORIGIN OF THE GNEISSES AND SCHISTS

The gneisses and schists in the Eidvågeid sequence have high contents of mica, garnet and kyanite indicative of peraluminous bulk compositions. They are also strongly corundum normative (Cor. $= 9.2 \pm 3.1$, $n = 7$, from CIPW norm). In a plot of the Niggli values al-alk against c (Fig. 3, Niggli 1954) all analyses in Table 1 fall outside the field of common igneous rocks, suggestive of a sedimentary origin. This is supported by the presence of quartzite and calc-silicate horizons and the common occurrence of graphite as an accessory mineral.

Stratigraphic correlations

The psammitic rocks correlated with the Late Precambrian-Cambrian Klubben Psammite Group are lithologically similar to the psammites described from Sørøy (Roberts 1968, Ramsay 1971). Distinctly arkosic horizons are common as they are in the psammites on Sørøy. The tectonometamorphic evolution is also similar. This correlation is further supported by the presence of an unconformity below the psammites. This unconformity is also good evidence for a Precambrian origin of the Fagervik infracrustal complex (Ramsay & Sturt 1977). The Eidvågeid sequence is also believed to be of Precambrian age based on metamorphic criteria (see below).

Fig. 3. Niggli plot of schists from the Eidvågeid sequence. The pl clearly shows that these rocks could not have had an igne origin.



It is frequently difficult to distinguish the gneisses of the Fagervik complex from the Klubben Psammites when they occur in zones of high strain. The presence of abundant feldspar porphyroclasts, the mylonite-foliation and tectonic lenses of less severely deformed gneiss indicate, however, that these rocks had a more coarse-grained parent.

The calc-silicate rocks described from the imbrication zones are similar to the lower calc-silicate unit in the Cambrian Falkenes Marble group on Sørøy (Ramsay 1971). They occur in association with the Klubben Psammite, and might be correlated with parts of the Sørøy succession. The rusty-weathering mica schists in the imbrication zone of eastern Seiland (Fig. 7) may be equivalent to the Storelv Schist group which overlies the Klubben Psammite on Sørøy (Ramsay 1971), but such lithological correlations can only be tentative.

Tectonic structures

CALEDONIAN STRUCTURES

The Klubben Psammite shows evidence for two phases of tectonic deformation, designated as D_1 and D_2. Their associated schistosities are termed S_1 and S_2, respectively. The correlation of these rocks with the Late Precambrian-Cambrian succession on Sørøy implies a Caledonian age for these deformational events.

D_1 minor structures in the Klubben Psammite Group

D_1 folds are uncommon in the Klubben Psammite. Those which have been observed have an isoclinal style with an axial-planar schistosity marked by parallel mica flakes, although in many cases the mica content is so low that no schistosity is visible. Because of the nature of the smooth weathering surfaces, it proved impossible to take accurate measurements of D_1 fold axes. However, they are believed to have an approximate N–S trend like the pre-D_2 lineation in the surrounding gneisses.

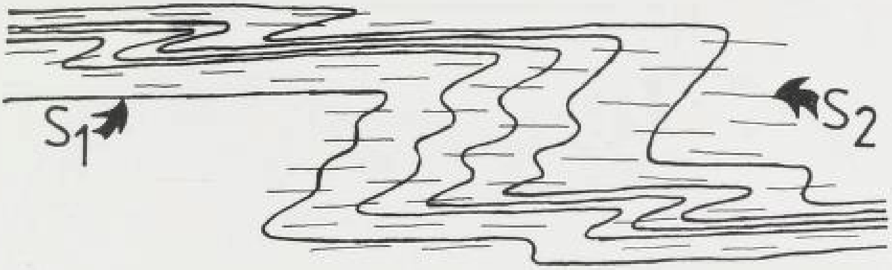


Fig. 4. Schematic figure showing typical style of asymmetric D_2 fold with strongly flattened long-limbs and open buckle-folds in the steep middle-limb.

D_1 minor structures in the Precambrian rocks

Isoclinal folds refolded by D_2 folds are very common in the Fagervik infracrustal complex. Owing to the high strain facies, however, it is impossible in most cases to distinguish Caledonian D_1 structures from possible Precambrian structures. Pre-D_2 linear fabrics have a N–S trend (Fig. 5c).

The main tectonic foliation in the Eidvågeid sequence is folded by D_2 and is considered to correspond to S_1 in the Klubben Psammite Group, but it probably represents a reactivated and transposed Precambrian foliation. It will, for convenience, be referred to as S_1

D_2 minor structures in the Klubben Psammite Group

D_2 folds are more common than D_1 folds. The style of the D_2 folds is variable and depends on their location in larger fold structures and on the intensity of deformation. They are generally asymmetric with steep middle-limbs which are overturned to varying degrees. Parasitic folds in middle-limbs of larger folds are open buckle folds while those in the long-limbs are asymmetric, tighter and show thickened hinge-zones and usually have a penetrative new schistosity (Fig. 4). The D_2 folds are cylindrical with a NNE-NE axial trend (Fig. 5b).

D_2 minor structures in the Precambrian rocks

The D_2 deformation was stronger to the north of Store Fagervik and to the south of the garnet gneisses (Fig. 1) as compared to the area between. This is a consequence of the location of these two areas in flat-lying long-limbs of a major asymmetric D_2 fold, while the area between is situated in a steep middle-limb (Fig. 2).

The D_2 folds in the Fagervik complex have morphologies similar to the D_2 folds in the Klubben Psammite Group (fig. 4). Crenulation folds are frequently developed in the schists of the Eidvågeid sequence. To the south of Store Fagervik the D_2 fold axes have a shallow plunge towards the NE (Fig. 5b) parallel to the axes of D_2 folds in the Klubben Psammite Group. To the north of Store Fagervik the attitudes of the D_2 folds show a large variation within their mean axial surface (Fig. 5a). The variable attitudes of the axes is at least partly caused by noncylindrical folding which frequently can be seen on a small scale (Ramsay &

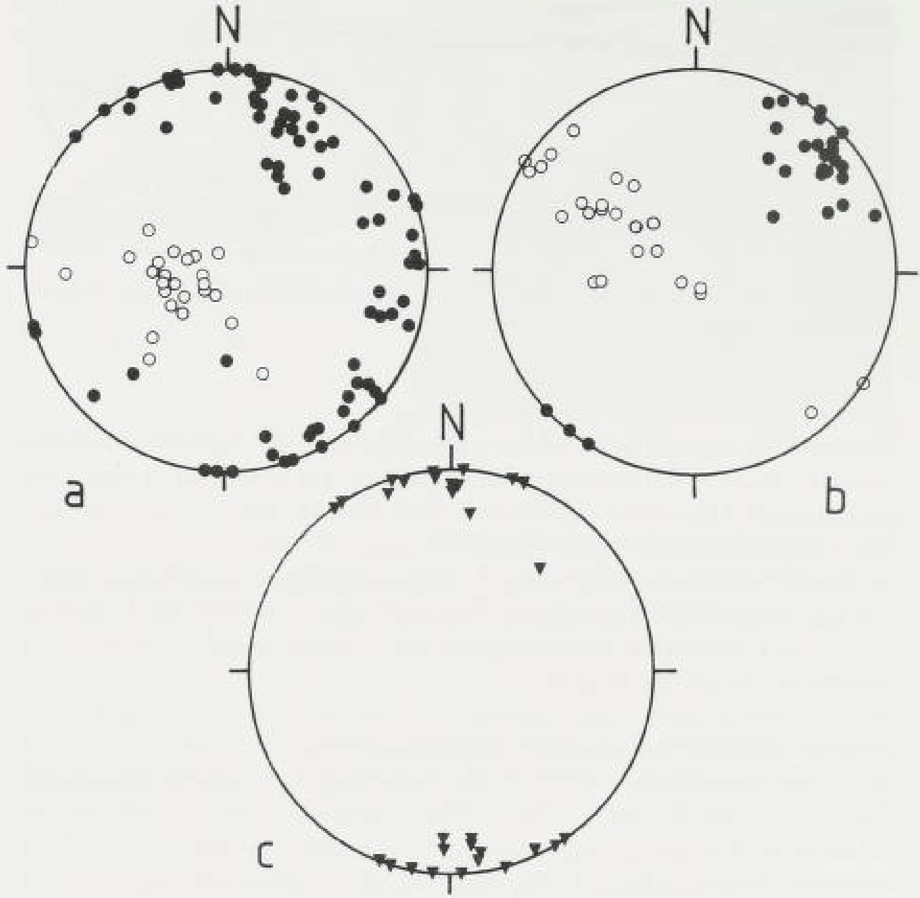


Fig. 5. Stereographic plots (equal area) of D_2 fold axes (filled circles) and axial surfaces (open circles) from (a) the gneisses to the north of Store Fagervik and (b) the Klubben Psammite in the Hestevik Syncline and the gneisses to the south of Store Fagervik. (c) D_1 lineation to the north of Store Fagervik.

Sturt 1973), but some of the folds shown in Fig. 5b might be of an older generation.

MAJOR STRUCTURES

Thrusts

A major thrust-contact occurs on the islands of Lille Vinna, Hjelmen and Håja (Fig. 6). On Lille Vinna it is underlain by seven, thin, discontinuous thrust sheets of the Klubben Psammite, calc-silicate schists and gneisses with a total thickness of 30–80 metres (Fig. 6). The thrust sheets are sandwiched between two thick units of mylonite-gneisses. The mylonite foliation and a NNE-trending linear fabric along the thrusts are folded by small-scale D_2 folds, suggesting that thrusting occurred during D_1.

Worthing (1971a) mapped rocks from eastern Seiland as correlative with the

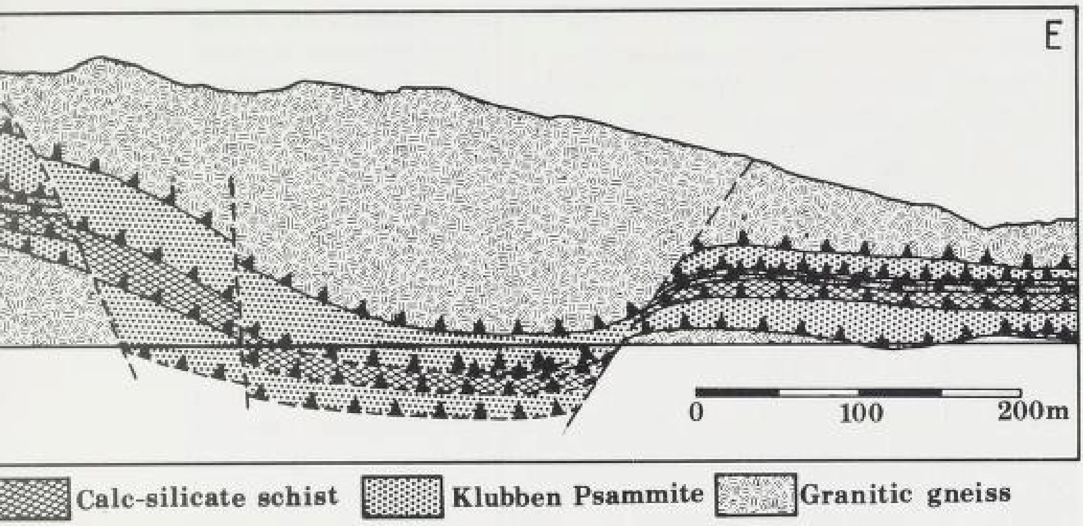


Fig. 6. Geological cross-section of the central part of Lille Vinna, showing the imbrication sheets of Klubben Psammite, calc-silicate schists and gneisses sandwiched between Fagervik gneiss.

Klubben Psammite Group. However, there is a complicated imbrication-zone in eastern Seiland (Fig. 7). The major part of the lowermost 'psammite' unit of Worthing (1971a, b), the Komagnes Group, is composed of grey gneisses similar to those described from the Fagervik infracrustal complex. This area has therefore been remapped and reinterpreted by the present author (Fig. 7) as largely Fagervik equivalent. The Klubben Psammite Group does occur in several thin thrust sheets. Worthing (1971a) mapped one of these and called it the 'pink psammite', but considered it to be an integral part of the surrounding gneisses, all of which he correlated with the Klubben Psammite Group. Some of the sheets shown in Fig. 7 are composed of a series of extremely thin units of alternating psammites and mylonitic and phyllonitic gneisses well below mappable thickness. It thus appears that this imbrication zone consists of a series of thin nappes with large lateral extensions.

The D_1 Hestevik Syncline

The Klubben Psammite Group around Store Fagervik occurs in the core of a large D_1 syncline, the Hestevik Syncline (Fig. 1). The hinge can be seen in a steep cliff to the south of Store Fagervik where the sedimentary layering in the psammite and its contact with the gneisses are isoclinally folded. The hinge zone has been dramatically thinned and refolded by D_2 folds.

The D_2 Storbukt Synform

The Storbukt Synform is the largest D_2 structure on northeastern Seiland (Fig. 2). It has a fold axis with a shallow plunge towards the NE. Several independent observations indicate the presence of this large synform. There is a two-sided areal

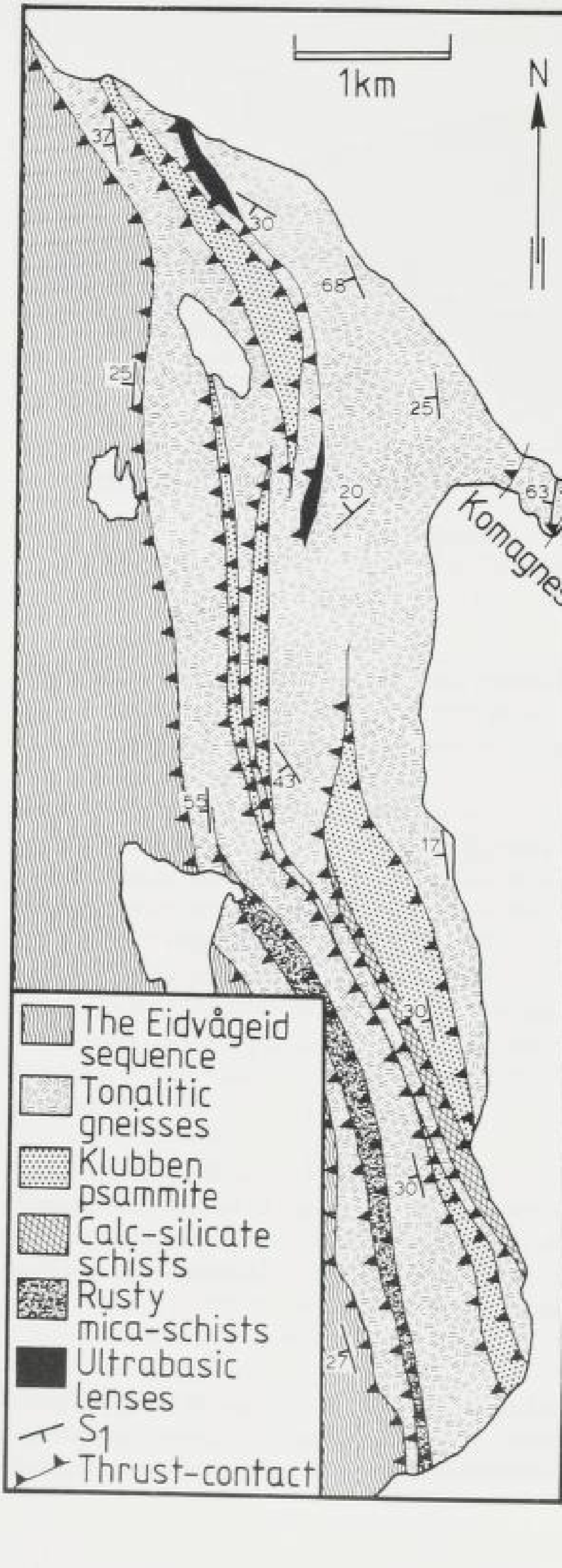


Fig. 7. Geological map of eastern Seiland showing the imbrication sheets. Location map shown in Fig. 1.

distribution of the gneisses of the Fagervik infracrustal complex with the Eidvågeid sequence located between. The northern boundary between these has a steep southeastward dip, while the southeastern boundary has a shallow dip towards the west and northwest where the variation is caused by a strike-swing across Eidvågen (Fig. 1).

The D_2 folds in the area between Ersvika and Store Vinna commonly have an open style and near horizontal axial surfaces as one would expect in a steep middle-limb of an asymmetric fold (Fig. 4). The geometry of the D_2 folds in the area around Fiskebukt and to the north of Store Fagervik indicate, on the other hand, a much stronger flattening and have a vergence towards the SE. All these observations suggest the presence of a large asymmetric synform (Fig. 2). The folds of assumed D_2 age to the south of Eidvågen have, however, a vergence towards the west. This might be a result of different orientations of the layering to the north and south of Eidvågen prior to D_2 (Ramsay 1967, p. 538), which could also explain the strike-swing. Alternatively these folds could be of a younger generation.

PRECAMBRIAN STRUCTURES

Ramsay & Sturt (1977) and Ramsay et al. (1980) described tectonic foliations in gneisses from Kvaløy and Hjelmsøy that are cut by granite dykes which are in turn truncated by the unconformity below the Klubben Psammite Group. This relationship gives evidence for Precambrian deformation. The granitic intrusion to the south of Store Fagervik appears to be younger than much of the deformation and migmatization in the surrounding gneisses, but is affected by the D_1 deformation, especially along its margins. The earliest deformation in the surrounding gneisses is therefore probably of Precambrian age. The deformation of a gneissic layering cut by granitic pegmatites around the D_1 Hestevik Syncline also indicates Precambrian deformation. Internal foliations in garnet and orthoclase porphyroblasts (Fig. 8) give evidence for deformation which predated a high-grade Precambrian metamorphism in the Eidvågeid sequence (see below).

Metamorphism

METAMORPHISM IN THE KLUBBEN PSAMMITE GROUP

Biotite and muscovite have crystallized or recrystallized parallel to the axial surfaces of D_1 and D_2 folds in semipelitic horizons in the Klubben Psammite Group. Xenoblastic garnets have overgrown S_1 while S_2 bends around them suggesting post-D_1/pre- or syn-D_2 garnet growth. The garnet/biotite geothermometer gives temperatures around 585°C from the calibrations of Thompsom (1976) and Ferry & Spear (1978). This temperature must, however, be regarded as only a minimum temperature since the garnets contain up to 37 mole percent grossular + spessartine (Kretz 1958, Albee 1965). From these observations it appears that the P–T conditions increased from D_1 and reached a climax in pre- or syn-D_2 time. This metamorphism must be of Caledonian age based on the correlation with the Late Precambrian-Cambrian Klubben Psammite Group. The tectonometamorphic evolution is similar to that described from Sørøy (Roberts 1968).

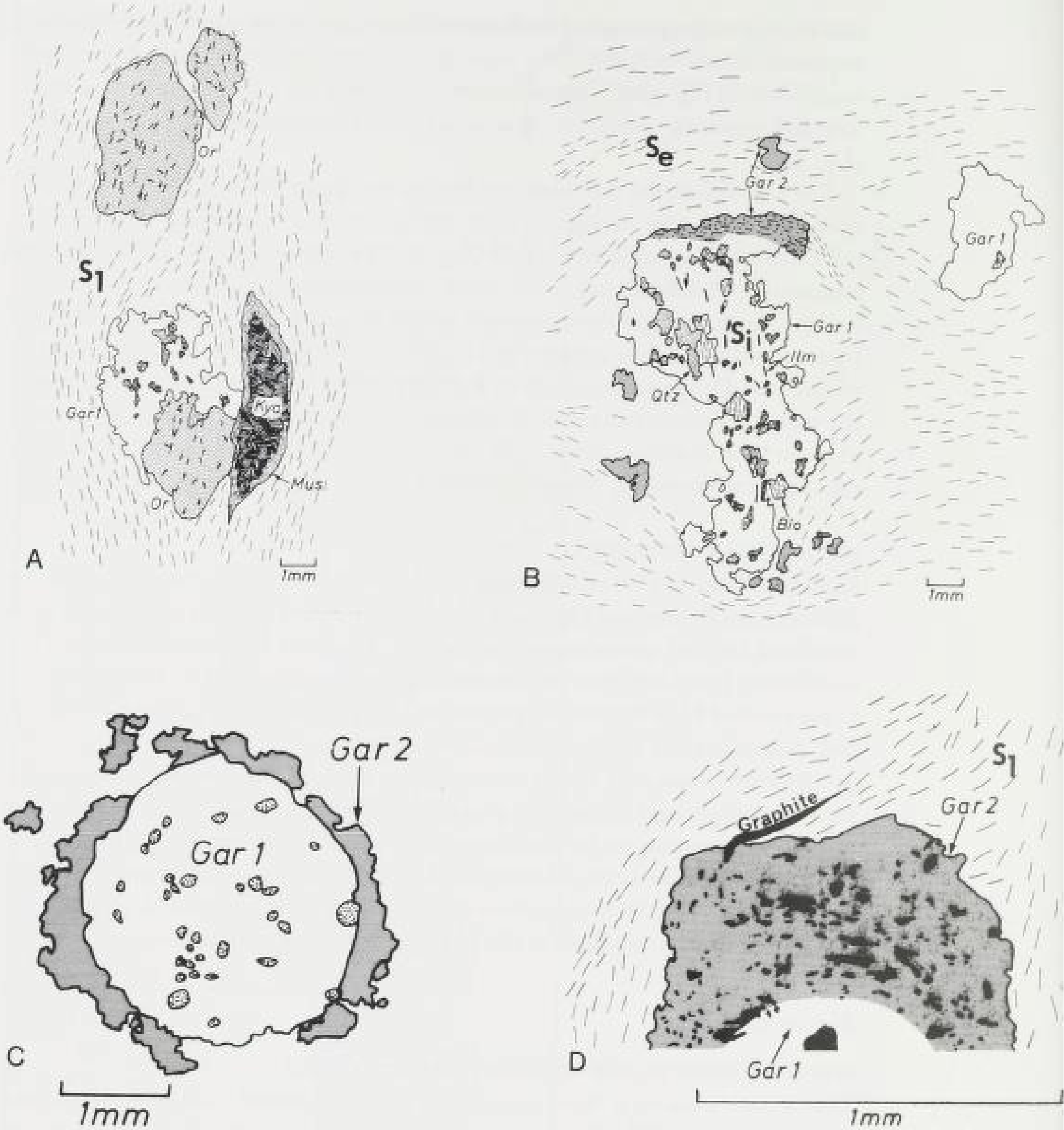


Fig. 8. Textures in pelitic schists from the Eidvågeid sequence. The distinction between garnet 1 and garnet 2 based on textural features and microprobe-analyses (Akselsen 1980 and in prep.).
A) S_1 deflected around pre-D_1 porphyroblasts in the Ersvik formation.
B) Garnet 1 with planar, internal schistosity, S_i, overgrown by interkinematic D_1–D_2 garnet 2.
C) Garnet 1 overgrown by garnet 2.
D) Graphite crystal partly overgrown by garnet 2 and subsequently bent during D_2

METAMORPHISM IN THE EIDVÅGEID SEQUENCE

The Eidvågeid sequence has been affected by two distinct phases of metamorphism which are believed to be of Precambrian and Caledonian age, respectively.

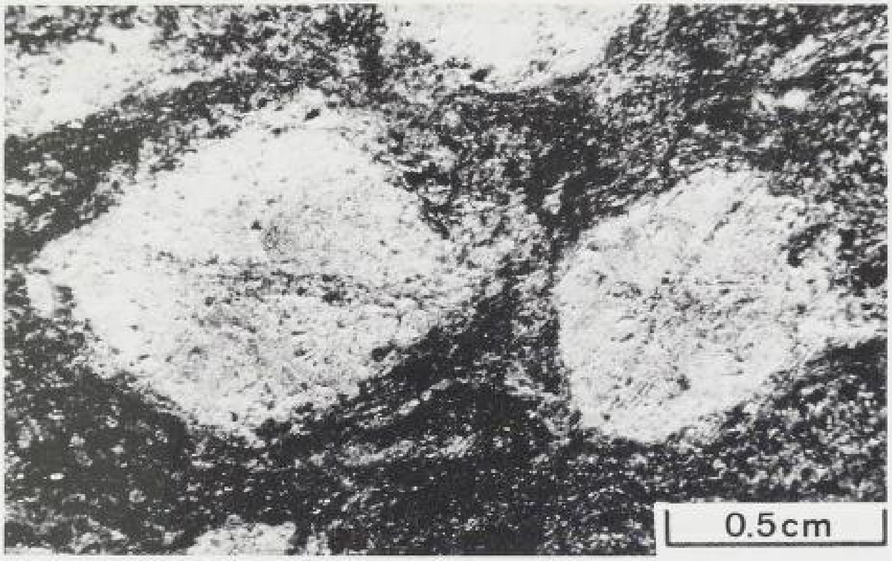


Fig. 9. Kyanite crystals from pelitic schists in the Eidvågeid sequence possibly representing pseudomorphed andalusite.

Precambrian metamorphism

The most pervasive mineralogical and textural reconstitution of the Eidvågeid sequence can be related to a Precambrian metamorphism when coarse-grained and pegmatite-veined lithologies were produced, especially in the tectonically intermediate and upper parts of the sequence. Many of the pegmatites have been disrupted during subsequent deformation which has impressed a cataclastic fabric on the rocks. The Ersvik Formation contains porphyroblastic orthoclase. Unlike the K-feldspar porphyroclasts from the disrupted pegmatites, the porphyroblasts contain numerous inclusions of biotite which define a planar, internal schistosity (Fig. 8a). This schistosity is truncated by S_1 in the surrounding matrix, showing that the orthoclase overgrew a schistosity prior to or possibly at an early stage in the Caledonian D_1 deformation. These porphyroblasts co-existed with pre- or possibly early-D_1 alumino-silicates (Fig. 8a) implying high-grade conditions (Winkler 1979) during this metamorphism. Kyanite locally occurs in prismatic pseudomorphs with rounded, square and diamond-shaped cross-sections (fig. 9). Within the prisms it has recrystallized with (100) in random orientations in the prismatic zone. Many of the diamond-shaped pseudomorphs contain a diagonal zone of quartz grains and in a few cases two such zones have been seen to form a cross (Fig. 9). Bechennec & Herve (1973, 1974) have described similar pseudomorphs from the islands of Arnøy and Laukøy in north Troms and interpreted them as pseudomorphs after andalusite. This is supported by the diagonal cross in some of them, which resembles chiastolite. Alternatively, they may represent pseudomorphed prismatic sillimanite.

Early garnets (garnet 1) in the tectonically intermediate and upper parts of the

Eidvågeid sequence formed pre- or possibly early-D_1 as shown by the deflected S_1 foliation. An internal, planar schistosity defined by parallel biotite and ilmenite has only been observed in one garnet (Fig. 8b). The largest garnets are generally surrounded by felspar-rich mantles.

Caledonian metamorphism

Garnets of a second generation (garnet 2) contain numerous tiny inclusions, mainly quartz and rutile, rather than the coarser inclusions in garnet 1. In many cases they have grown on the first generation garnets (Fig. 8c). Fig. 8b shows an early garnet (garnet 1) with an internal foliation, S_i, overgrown by a later garnet (garnet 2). The latter contains a planar internal schistosity which is discordant to S_i and parallel to the external foliation, S_e, except where S_e is locally deflected around the garnets. S_e is polyphasal due to coincidence of S_1 and S_2 in a long-limb of a D_2 fold (Fig. 4). These relationships show that the two generations of garnets grew during two distinct phases separated by a period when the external foliation was rotated relative to garnet 1. Muscovite which formed simultaneously with garnet 2 (Akselsen 1980 and in prep.) has overgrown S_1, suggestive of post-D_1 growth of garnet 2. Fig. 8D shows a graphite crystal parallel to S_1 partly overgrown by garnet 2. After cessation of garnet growth, the graphite was bent by a D_2 crenulation, which is the only D_2 structure seen in the schists to the north of the Hønseby gabbro where this specimen was collected. This shows that at least this garnet ceased growing prior to the main D_2 deformation in this area. It thus appears that the second generation of garnet grew in the interkinematic D_1–D_2 period.

The major difference in the metamorphic evoluton of the Eidvågeid sequence and the Klubben Psammite Group is the high-grade pre- or possibly early-D_1 metamorphism in the former. This early event is unlikely to be a contact-metamorphic effect of the basic and ultrabasic intrusions in central Seiland, as high-grade assemblages formed in the gneisses as far as 5 km from the intrusions. Such high-grade conditions can also be found on the island of Kvaløy where igneous intrusions only occur in subordinate amounts (Jansen 1979). The post-D_1 tectonometamorphic evolution of the Eidvågen sequence is similar to that described from the Klubben Psammite Group on Seiland and from the island of Sørøy (Roberts 1968). This must, therefore, be of Caledonian age (Sturt et al. 1978), while the early (pre-D_1) metamorphism is considered to be of Precambrian age. This supports the hypothesis of a Precambrian origin for the Eidvågeid sequence, despite its tectonic position above the Klubben Psammite Group.

The presence of kyanite pseudomorphs after andalusite or sillimanite suggests that the Precambrian metamorphism was of a lower pressure type than the Caledonian metamorphism. The detailed evidence supporting this observation will be published elsewhere.

The Hønseby gabbro

The Hønseby Gabbro south of Eidvågen was briefly described by Worthing (1971a). The gabbro also extends northeast of Eidvågen slightly offset by a fault

(Fig. 1). Further to the northeast the gabbro thins and is only found as minor boudins on Kvaløya (Ø. Jansen pers.comm. 1979). Worthing (1971a) concludes from structural relationships that the gabbro is of Caledonian syn-D_1 age. It therefore has been regarded as one of the oldest intrusions in the Seiland Petrographic Province (Robins & Gardner 1975). However, the Hønseby Gabbro on NE Seiland is surrounded by metasediments of the Eidvågeid sequence which have suffered Precambrian deformation and metamorphism. There is consequently no a priori reason to reject Precambrian ages for some of the intrusions on Seiland as argued by Pringle (1975).

The Hønseby Gabbro has a granoblastic texture and contains pyroxenes, plagioclase, hornblende, biotite, quartz and Fe-Ti oxides. Locally it appears to contain two generations of garnet. The largest garnets contain coarse inclusions while the second generation garnets contain numerous tiny inclusions and have grown, together with quartz, as coronas between orthopyroxene and plagioclase. Texturally this is somewhat similar to the garnets described from the surrounding metasediments and may indicate an early (Precambrian) medium-pressure granulite-facies metamorphism followed by a Caledonian metamorphism at lower temperatures and/or higher pressure (Green & Ringwood 1967). Similar textures have been ascribed to polymetamorphic evolution by Wagner & Crawford (1975). However, Griffin & Heier (1973) regarded the formation of such coronas as retrograde features solely due to cooling during uplift.

Conclusions

Northeast Seiland provides a typical example of cover-basement relationships in the Kalak Nappe Complex. The youngest metasediments, correlated with the Vendian-Cambrian Sørøy succession (Holland & Sturt 1970, Ramsay 1971), were affected by two phases of Caledonian deformation, D_1 and D_2 The metamorphic climax was reached in the D_1–D_2 interkinematic period. In some places these rocks rest unconformably on a Precambrian basement complex, and in others occur as thin thrust sheets in complex imbrication zones. It is possible to subdivide the Precambrian basement into two lithotectonic units: The Fagervik infracrustal complex, generally composed of tonalitic gneisses, and the Eidvågeid supracrustal sequence, dominated by pelitic gneisses and schists. Structural, textural and mineralogical relationships indicate that the Eidvågeid sequence suffered a high-grade Precambrian metamorphism prior to a weaker Caledonian metamorphism. This metamorphic evolution clearly suggests a Precambrian age for these metasediments. The main overthrusting event in this area occured during D_1 and the nappes were subsequently folded into a large asymmetric synform, the Storbukt Synform. The latest deformation involved faulting with brecciation and associated diaphthoresis.

The Eidvågeid supracrustal sequence is separated from the Fagervik infracrustal complex by a thrust, and hence the age relationships between these two units is unknown. Ramsey & Sturt (1977) reported preliminary Rb/Sr isochrons of 1469 ± 70 my. and 2660 ± 150 my for granitic dykes that cut a high-grade migmatitic gneiss complex in the Skillefjord Nappe on the mainland to the south of Seiland. An Archaean age for these gneisses appears to be conformed by further Rb/Sr isocrons of approximately 3000 my from similar granitic dykes (Austerheim & Sturt pers. comm. 1981), but it is possible that several Precambrian age-provinces are represented in the gneisses of the Kalak Nappe Complex. Further more detailed geochronological work is obviously necessary to solve this problem.

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REFERENCES

Akselsen, J. 1980: Tectonic and metamorphic development of the Precambrian and Caledonian rocks of NE. Seiland, Finnmark. Unpubl. Cand. Real. thesis, Univ. of Bergen, 351 pp.

Albee, A.L. 1965: Distribution of Fe, Mg and Mn between garnet and biotite in natural mineral assemblages. *J. Geol. 73,* 155–164.

Armitage, A.H., Hopper, R.R., Lewis D. & Pearson, D.E. 1971: Stratigraphic correlation in the Caledonian rocks of southwest Finnmark and North Troms. *Norges geol. Unders. 269,* 318–322.

Bechennec, F. & Herve, A. 1973: Etude des batis cristallophylliens des iles d'Arnøy et de Laukøy (Troms, Norvege septentionale), analyse structurale et petrographique. Unpubl. thesis, Orsay.

Bechennec, F. & Herve, A. 1974: Metamorphism.-Decounverte d'un metamorphisme general precoce de type basse pression dans les Caledonides du Nord, Iles d'Arnøy et de Laukøy (Troms, Norvege). *C.R. Acad. Sc. Paris, 279 (D),* 239–242.

Brueckner, H.K. 1973: Reconnaissance Rb-Sr investigation of salic, mafic and ultrabasic rocks in the Øksfjord area, Seiland Province, northern Norway. *Norsk geol. Tidsskr. 53,* 11–23.

Brueckner, H.K. 1975: A. reply. Reconnaissance Rb-Sr investigation of salic, mafic and ultramafic rocks in the Øksfjord area, Seiland Province, N. Norway. *Norsk geol. Tidsskr. 55,* 101–103.

Ferry, J.M. & Spear, F.S. 1978: Experimental calibration of the partitioning of Fe and Mg between biotite and garnet. *Contrib. Mineral. Petrol.* 66, 113–117.

Green, D.H. & Ringwood, A.E. 1967: An experimental investigation of the gabbro to eclogite transformation and its petrological applications. *Geochim. Cosmochim. Acta, 31,* 767–833.

Griffin, W.L. & Heier, K.S. 1973: Petrological implications of some corona structures. *Lithos, 6,* 315–335.

Holland, C.H. & Sturt, B.A. 1970: On the occurence of archaeocyathids in the Caledonian metamorphic rocks of Sørøy, and their stratigraphic significance. *Norsk geol. Tidsskr. 50,* 345–355.

Jansen, Ø. 1979: Kvaløy, Vest-Finnmark – Et typisk eksempel på den tektonometamorfe utvikling i Kaladekkekomplekset. *Abstract, 14. Nordiske geol.v.møte 1980, Norsk geol. Forening, Geolognytt, 13, 34.*

Kretz, R. 1958: Chemical study of garnet, biotite and hornblende from gneisses of southwestern Quibec, with emphasis on distribution of elements in coexisting minerals. *J. geol. 67,* 371–402.

Niggli, P. 1954: Rocks and mineral deposits. Freeman, San Francisco, 559 pp.

Pringle, I.R. 1975: A comment. Reconnaissance Rb-Sr investigation of salic, mafic and ultramafic rocks in the Øksfjord area, Seiland province, northern Norway. *Norsk geol. Tidsskr. 55,* 97–99.

Ramsay, D.M. 1971: Stratigraphy of Sørøy. *Norges geol. Unders. 269,* 314–317.

Ramsay, D.M. & Sturt, B.A. 1973: An analysis of non cylindrical and incongrous fold patterns from Eocambrian rocks of Sørøy, Northern Norway. *Tectonophysics, 18,* 81–107.

Ramsay, D.M. & Sturt, B.A. 1977: The significance of the sub-Caledonian unconformity within the nappe sequence of the Finnmarkian belt. *Norges geol. Unders. 334,* 107–116.

Ramsay, D.M., Sturt, B.A. & Andersen, T.B. 1980: The sub-Caledonian unconformity on Hjelmsøy – New evidence for primary basement/cover relations in the Finnmarkian nappe sequence. *Norges geol. Unders. 351,* 1–12.

Ramsay, J.G. 1967: *Folding and fracturing of rocks.* McGraw Hill, 568 pp.

Roberts, D. 1968: The structural and metamorphic history of the Langstrand–Finnfjord area of Sørøy, North Norway. *Norges geol. Unders. 253,* 160 pp.

Roberts, D. 1974: Hammerfest. Description of the 1:250 000 geological map. *Norges geol. Unders. 301*, 66 pp.

Robins, B. & Gardner, P.M. 1974: Synorogenic Layered basic instrusions in the Seiland Petrograhic Province, Finnmark. *Norges geol. Unders. 312*, 91–130.

Robins, B. & Gardner, P.M. 1975: The magmatic evolution of the Seiland Province and Caledonian Plate boundaries in northern Norway. *Earth and Plan. Schi.Let. 26*, 167–178.

Sturt, B.A., Pringle, I.R. & Roberts, D. 1975: Caledonian nappe sequence of Finnmark, Northern Norway, and the timing of orogenic deformation and metamorphism. *Geol. Soc. Am. Bull., 86*, 710–718.

Sturt, B.A., Pringle, I.R. & Ramsay, D.M. 1978: The Finnmarkian phase of the Caledonian Orogeny. *J. Geol.Soc.Lond. 135*, 597–610.

Thompson, A.B. 1976: Mineral reactions in pelitic rocks: II Calculations of some P–T–X (Fe-Mg) phase relations. *Am.J.Sci., 276*, 653–682.

Wagner, M.E. & Crawford, M.L. 1975: Polymetamorphism of the Precambrian Baltimore Gneiss in southeastern Pennsylvania. *Am.J.Sci. 275*, 653–682.

Winkler, H.G.F. 1979: *Petrogenesis of metamorphic rocks.* Springer–Verlag, 334 pp.

Worthing, M.A. 1971a: Studies in the structure and metamorphic petrology of the Eocambrian rocks of Eastern Seiland, North Norway. Unpubl. Ph.D.thesis, Univ. of London.

Worthing, M.A. 1971b: The stratgraphy of part of eastern Seiland, West Finnmark. *Norges geol. Unders. 269*, 323–327.

Zwaan, K.B. & Roberts, D. 1978: Tectonostratigraphic succession and development of the Finnmarkian nappe sequence, North Norway. *Norges Geol. Unders. 343*, 53–71.