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# Eclogitic shear zones in a granulite-facies anorthosite complex: field relationships and an emplacement scenario – an example from the Bergen Arcs, Western Norway

by *Eva M. Klaper*[1]

**Abstract**

The Precambrian granulite-facies anorthosite complex, situated within the Bergen Arcs, is interpreted as a lower crustal tectonic unit from the western margin of Baltica. The anorthosites are locally transected by a network of Caledonian deformation structures like fractures, shear zones and mylonites which show eclogite-facies mineralogy.

These structures demonstrate impressively the importance of fluid infiltration as a trigger for mineral reactions and subsequent deformation-localization and the initiation of shearing. The large scale consequence of this process has been thrusting and possibly a decoupling of the anorthositic lower crust and its subsequent emplacement in the upper crust along major shear zones during the Caledonian orogeny.

Based on lithological similarities and the comparable tectonic position, it is suggested that the Bergen Arcs anorthosite complex and the Jotun nappe system can be interpreted as parts of the same slice of lower crustal material which had been subducted to variable depths. The anorthosite complex – Jotun nappe system, therefore, forms an exhumed and dismembered lower crustal section.

*Keywords:* Anorthosite, granulite facies, shear zone, lower crust, Caledonian orogeny, Bergen Arcs, Norway.

## Introduction

A unique segment of the lower continental crust is exposed in one of the thrust sheets within the Bergen Arcs system. This segment consists of a Precambrian granulite-facies complex of meta-anorthosites to gabbros and other mafic plutonic rocks which were partially transformed to eclogite-facies rocks during the Caledonian orogeny (COHEN et al., 1988). The transition of granulite-facies assemblages to eclogitic mineral parageneses is confined to localized zones of deformation such as veins, fractures with a metasomatic reaction zone and ductile shear zones of various scales (AUSTRHEIM, 1986/87).

The mineralogical transition from granulite- to eclogite-facies assemblages reduces the amount of feldspar in the rock. The growth of the dense phases omphacite and garnet and of the hydrous phases clinozoisite and phengite (AUSTRHEIM and GRIFFIN, 1985; AUSTRHEIM, 1986/87; KLAPER, 1990) can be observed. Because hydrated minerals are absent in the granulite-facies protolith it is obvious that the formation of eclogite-facies rocks requires access of an $H_2O$ bearing fluid phase. The subsequent mineralogical change must have a profound influence on the mechanical properties of the rocks and, therefore, on their behaviour under deformation.

The consequences of these mineralogical and textural changes following the fluid infiltration, can be studied in the anorthosites of the Bergen Arcs as an increase in ductility within localized high strain zones (KLAPER, 1990). This localized increase in ductility has been responsible for the initiation of shearing in these lower crustal rocks and, consequently, for thrusting and possibly decoupling and emplacement in the upper crust.

The aim of the first part of this paper is to show in detail the field relationships of the deformation zones in the anorthosite complex. The shear zone and fracture patterns will be used to help define the

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deformation characteristics and to assess the possible tectonic implications. In the second part of the paper a conceptual, but speculative emplacement model for the anorthosite complex will be discussed. The discussion is based on CUTHBERT et al.'s (1983) tectonic model for the Western Gneiss Region.

## General geology

The Bergen Arcs System (Fig. 1), centered around the city of Bergen, western Norway, constitutes a structurally unique feature within the Middle Allochthon of the Norwegian Caledonides (KOLDERUP and KOLDERUP, 1940). The structure contains two arcuate belts of Cambro-Silurian rocks (including ophiolites) with an intervening nappe complex of rocks of Precambrian age. The Bergen Arcs System is interpreted as a series of far travelled Caledonian nappes which were thrust onto a Precambrian gneiss complex, the Western Gneiss Complex (= WGC) including the Øygarden Gneisses, of probable para-autochthonous character (STURT and THON, 1978).

The island of Holsnøy (Fig. 2) is situated about 30 km northwest of the city of Bergen within the Precambrian nappe complex. The bedrock of Holsnøy is composed of a granulite-facies complex of intermediate to basic composition. Major lithologic units on the island are anorthositic to gabbroic rocks besides other mafic plutonic rocks (GRIFFIN, 1972). This anorthosite complex appears to have originated as a layered igneous body containing minor lenses of spinel lherzolite.

The anorthosite complex of the Bergen Arcs is interpreted as a slice of lower crust emplaced in the upper crust during the Caledonian orogeny (STURT and THON, 1978). The geological history of the anorthosite complex can be divided into two major polyphase events: the Precambrian (Grenvillian) orogeny which included extensive magmatic activity, deformation and granulite-facies metamorphism and secondly, a strong but localized Caledonian overprint associated with Caledonian nappe formation and transport (STURT and THON, 1978).

The granulite-facies complex is locally transected by Caledonian structures like fractures

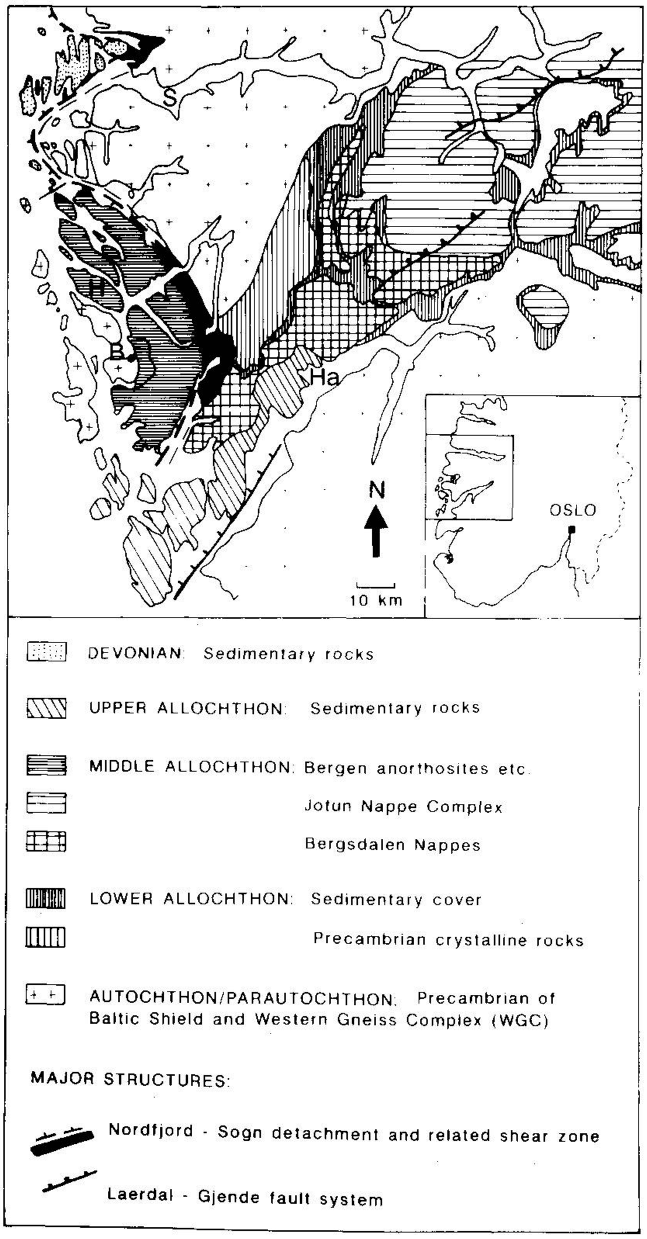


*Fig. 1* Location and geological map of the Bergen Arcs system with the Anorthosite Complex and the Jotun nappe complex. B: Bergen, H: Holsnøy, S: Sognefjord, Ha: Hardangerfjord.

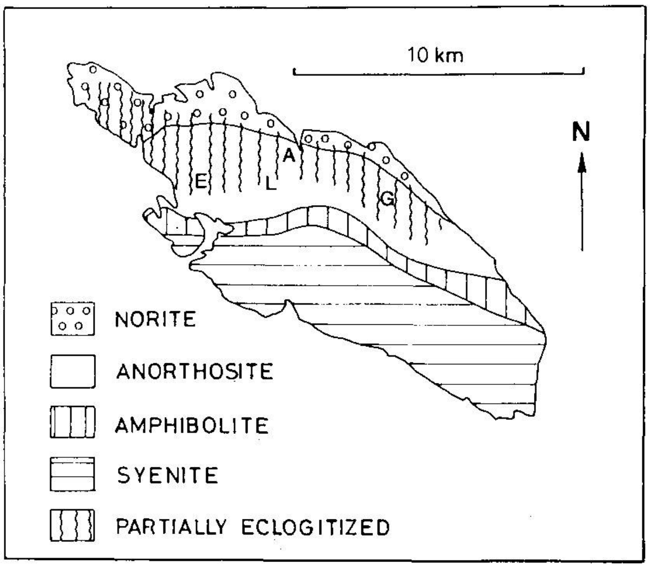


*Fig. 2* Geological sketch map of Holsnøy drawn after KOLDERUP and KOLDERUP (1940) and data from AUSTRHEIM (1987). Locality names used in text: A: Ådnefjellet, E: Eldsfjellet, G: Gaustadfjellet, L: Liafjellet.

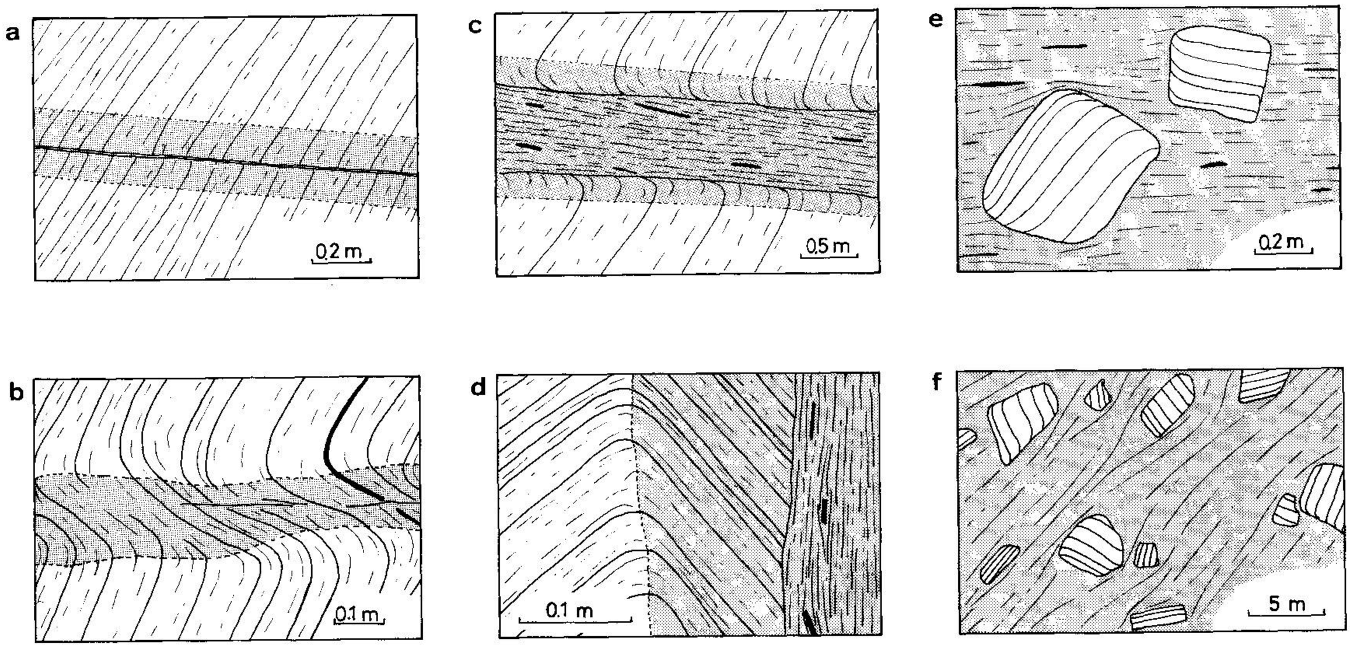


*Fig. 3* Sketches of several typical stages of Caledonian eclogite (shaded) formation in Precambrian anorthosite (white). For details see text.

(veins) and (mylonitic) shear zones, all of which show an eclogite-facies mineralogy. Within these zones the granulite-facies structures become transposed or completely obliterated and a new, Caledonian (COHEN et al., 1988), foliation may develop. Large parts of Holsnøy are overprinted by a regional amphibolite- to greenschist-facies metamorphism.

## Previous work

AUSTRHEIM and GRIFFIN (1985) and AUSTRHEIM (1986/87) describe in great detail the petrological transition from the more mafic parts of the granulites to their eclogite-facies equivalents in and close to shear zones. The textural changes and possible incomplete plagioclase breakdown reactions in the anorthositic rocks due to the infiltration of a hydrous fluid phase have been described by KLAPER (1990), the composition and origin of the fluid phase have been discussed by JAMTVEIT et al. (1990) while the nature and composition of the fluid inclusions have been examined by ANDERSEN et al. (1990).

The rocks contain two distinct metamorphic mineral assemblages. A Grenvillian (COHEN et al., 1988) granulite-facies assemblage which equilibrated at T = 800–900 °C, P = 8–10 kbar is defined by the minerals plagioclase, diopside (cpx I), orthopyroxene and garnet. The granulite-facies mineralogy is partially replaced by a Caledonian (COHEN et al., 1988) eclogite-facies mineralogy defined by omphacite (cpx II), garnet (II), kyanite, clinozoisite, phengite, quartz and amphibole. The equilibrium conditions for the eclogite-facies assemblage are estimated to be T = 700 °C (AUSTRHEIM and GRIFFIN, 1985; JAMTVEIT et al., 1990), P = 16–19 kbar (AUSTRHEIM and GRIFFIN, 1985) or P = 18–21 kbar (JAMTVEIT et al., 1990), respectively.

## The eclogitic shear zones – field relationships

The field relationships described in this section have been studied in the northwestern part of the island where the largest continuous mass of anorthosite occurs.

The anorthositic rocks possess a strong lithological banding defined by orientated disc-shaped coronas or centimeter-thick mafic bands with a granulite-facies mineralogy in alternation with plagioclase layers. In places this banding contains a lineation defined by orientated orthopyroxene (AUSTRHEIM and GRIFFIN, 1985). Three major stages of eclogite-facies reworking have been defined to aid in the description although gradual changes between the different stages occur (Fig. 3):

a) Initial stage (e.g. Liafjellet, Gaustadfjellet, Fig. 2)

Fractures forming a systematic pattern on outcrop scale occur in several localities on Holsnøy. Shear displacement is absent or small along these fractures. Some fractures may show a very fine grained leucocratic filling consisting of abundant quartz, phengite, clinozoisite and kyanite. Eclogitization commonly starts along such fractures, penetrating the wall rock with a metasomatic reaction front (Fig. 3a).

Small scale shear zones are exposed in the same outcrops. They are typically up to 0.5 meter wide and up to several meters long. Shear zones from this initial stage typically show a displacement of about 0.1 to 1.5 meters determined from the offset of mafic marker horizons in the outcrop plane. Conjugate shear zone systems developed occasionally (e.g. Liafjellet), but usually with one set of shear zones strongly dominant over the other. Again, eclogitization occurs along such shear zones which may or may not show a crack running along the center of the zone. In some shear zones the granulite banding can still be traced right across the zone (Fig. 3b). Mafic bands dragged into the developing shear zone break up into boudins which act as rotating rigid bodies in a flowing matrix. More common are shear zones which develop a new foliation subparallel to the shear zone boundaries (Figs 3 c and 3 d) and cut off the rotated anorthosite banding of the wall rock.

The first macroscopic sign of alteration along a profile towards a crack or shear zone is a decolourization of the dark plagioclase to pure white. Just outside a crack or shear zone an approximately 10 cm wide zone of mineralogical alteration is displayed and, within this zone as well as in the shear zone, the granulite facies mineral assemblage is replaced by an eclogitic assemblage locally developing a new foliation (Fig. 3).

b) Intermediate stage (e.g. parts of Ådnefjellet, Fig. 2)

In this intermediate stage, the area (volume) between the shear zone walls increases considerably. They show a width of 0.5–5 meters and a displacement of 1.0 to 10.0 meters determined from the offset of mafic marker horizons in the outcrop plane. Through the development of a system of crosscutting or anastomosing fractures and shear zones, blocks or lozenges of unaltered anorthosite are produced which swim in a matrix of eclogitic rocks (Figs 3 e and f). The almost rectangular shape of many of these blocks is ascribed to the initially perpendicular arrangement of fractures and shear zones. The compositional layering within the few remaining blocks of anorthosite is variably oriented due to rotation of the blocks.

In the intermediate stage eclogitic rocks are estimated to make up about 30–40% of the mapped area on northwestern Holsnøy.

The transition from the intermediate to the final stage of reworking can be described as a 'granulite breccia' in accordance with AUSTRHEIM and MØRK (1988). The eclogitic rocks usually show a compositional banding which bends around the remaining lozenges of preserved anorthosites (Figs 3 e and 3 f).

c) Final stage (e.g. southwest of Eldsfjellet, Fig. 2)

Major zones of eclogite-facies rocks without anorthosite remnants are typically 50 to 100 meters thick and usually can be followed for more than a kilometer along strike as zones of strongly foliated to mylonitic eclogite-facies rocks. Such major shear zones (see Fig. 8) occur along the northeastern coast of Holsnøy and southwest of Eldsfjellet. The shear zones may be bordered by wide zones of 'granulite breccia'. It is, however, difficult to determine the displacement in these shear zones due to the lack of good marker horizons. Integration of the displacement observed in small scale shear zones over the width of these major zones suggests displacements of at least several hundred meters to many kilometers.

In an area (locality E on Fig. 2) of about 1 $km^2$ showing such a final stage of reworking, more than 60–70% of the rocks have been altered to eclogite-facies. The occurrence of lherzolite lenses is confined to this zone. These lherzolite occurrences may be mantle fragments* which mark a crustal scale shear zone.

## Shear zone geometry and distribution in the anorthosite complex

1) Shear zone strain

The only strain measurement technique which can be applied to quantify the deformation of the anorthosite complex during the eclogite-facies event, is based on an analysis of the variation of deflected marker lines across shear zones (RAMSAY, 1980).

In some of the exposed shear zones the topographic surface is close to a profile section with the (usually very weak) lineation subparallel to the intersection of the shear zone boundaries with this topographic surface. The wallrock of the shear zones selected for this study has not been visibly (macroscopically) strained during the Caledonian orogeny and the mineralogical alteration is minimal. The geometric features of such zones satisfy the boundary conditions of deformation by simple shear (RAMSAY and GRAHAM, 1970).

* However, new, yet unpublished data (pers. comm. H. Austrheim and anonymous referee) seem to suggest that the lherzolites were not related to the mantle, but formed a part of the same igneous body as the anorthosites.

For initial stage (a) shear zones (e.g. Liafjellet), values of $\gamma = 4$ to 8 have been deduced and can be interpreted as maximum values. However, since eclogitization is associated with growth of high density mineral phases a maximum volume decrease of up to about 8% during complete eclogitization has to be assumed (JAMTVEIT et al., 1990). If this volume decrease is estimated to be approximately 5% for an incomplete granulite to eclogite transition in shear zones of the initial stage, values of $\gamma = 3.5$ to 5 result for the eclogitized small scale shear zones (the displacement field being combined simple shear + homogeneous volume change). For shear zones from the intermediate stage (b) (e.g. Ådnefjellet), values of $\gamma = 6$ to 12 have been deduced for eclogitized shear zones (again 5% volume decrease taken into account). These values of $\gamma \leq 12$ can be taken as typical strain state in small scale shear zones within the anorthosite complex.

The application of this strain estimate technique is, however, limited to small scale features because the boundary conditions do only occasionally comply with the given constraints of simple shear (+ homogeneous flattening). The displacements measured from these small scale shear zones represent the internal deformation of the anorthosites. internal deformation was necessary to adapt the overall geometry of the anorthosite body to the bulk strain (see below and Fig. 7).

2) Termination of shear zones

The problem of how shear zones die out laterally has been discussed in several papers (e.g. RAMSAY and ALLISON, 1979). For the shear zone deformation to be a plane strain (no volume change, $e_2 = 0$: length of intermediate axis of strain ellipsoid is unchanged), the terminal displacements must be spread over an increasingly wider area until the strains are so low that no visible structure forms.

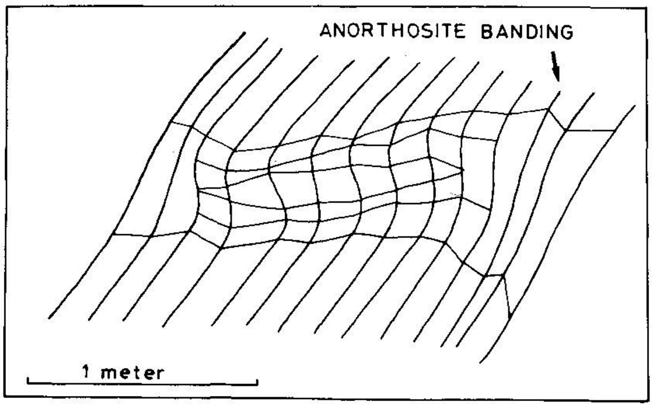


*Fig. 4* Diverging isogons drawn on the variation of the anorthosite banding at a shear zone termination.

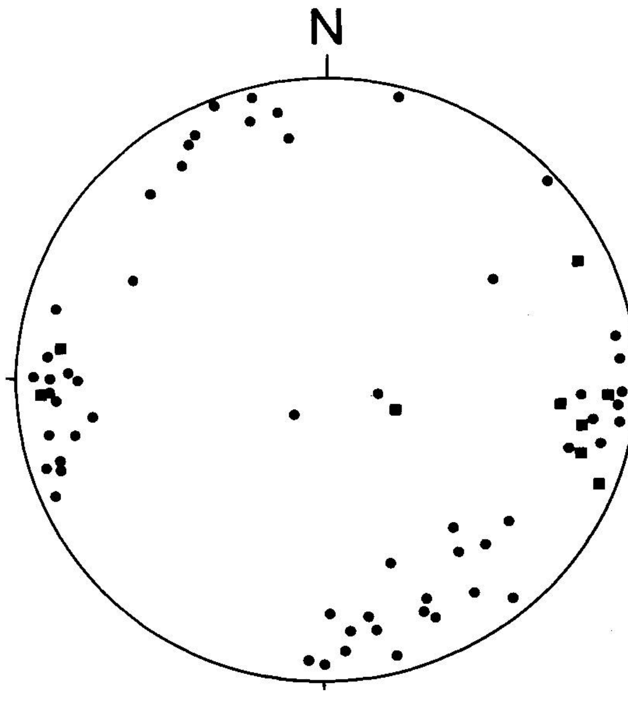


*Fig. 5* The stereogram gives the orientations (poles to shear zone boundaries) and displacement sense of shear zones from the three 'type areas'. Dots represent sinistral, squares dextral shear zones.

Isogons drawn on the banding trace at the end of a shear zone (Fig. 4) without macroscopically visible mineral transformations clearly show the increase in width of the zone. $\gamma$ decreases from 1.2 to 0.2 from the most deformed part of this small scale shear zone to its visible termination.

Shear zones showing eclogitization may terminate abruptly or they may terminate by splitting up in smaller, divergent shear zones with or without (macroscopic) mineralogical changes. These small shear zones may again show an increase in width or terminate in a fracture without displacement. Occasionally it can be observed that shear zones curve as they die out.

3) Shear zone patterns on outcrop scale

An analysis of the spatial distribution of the shear zones and their displacement sense sheds some light on the behaviour of the anorthosite complex as a tectonic unit.

The Caledonian eclogite-facies deformation of the anorthosite complex on Holsnøy is characterized by shear zones of different orientations and with varying relative displacement, width and degree of reworking. The stereogram in figure 5 gives the orientation of shear zone boundaries and the displacement sense for the three 'type-outcrop' areas described above (Liafjellet, Ådnefjellet and

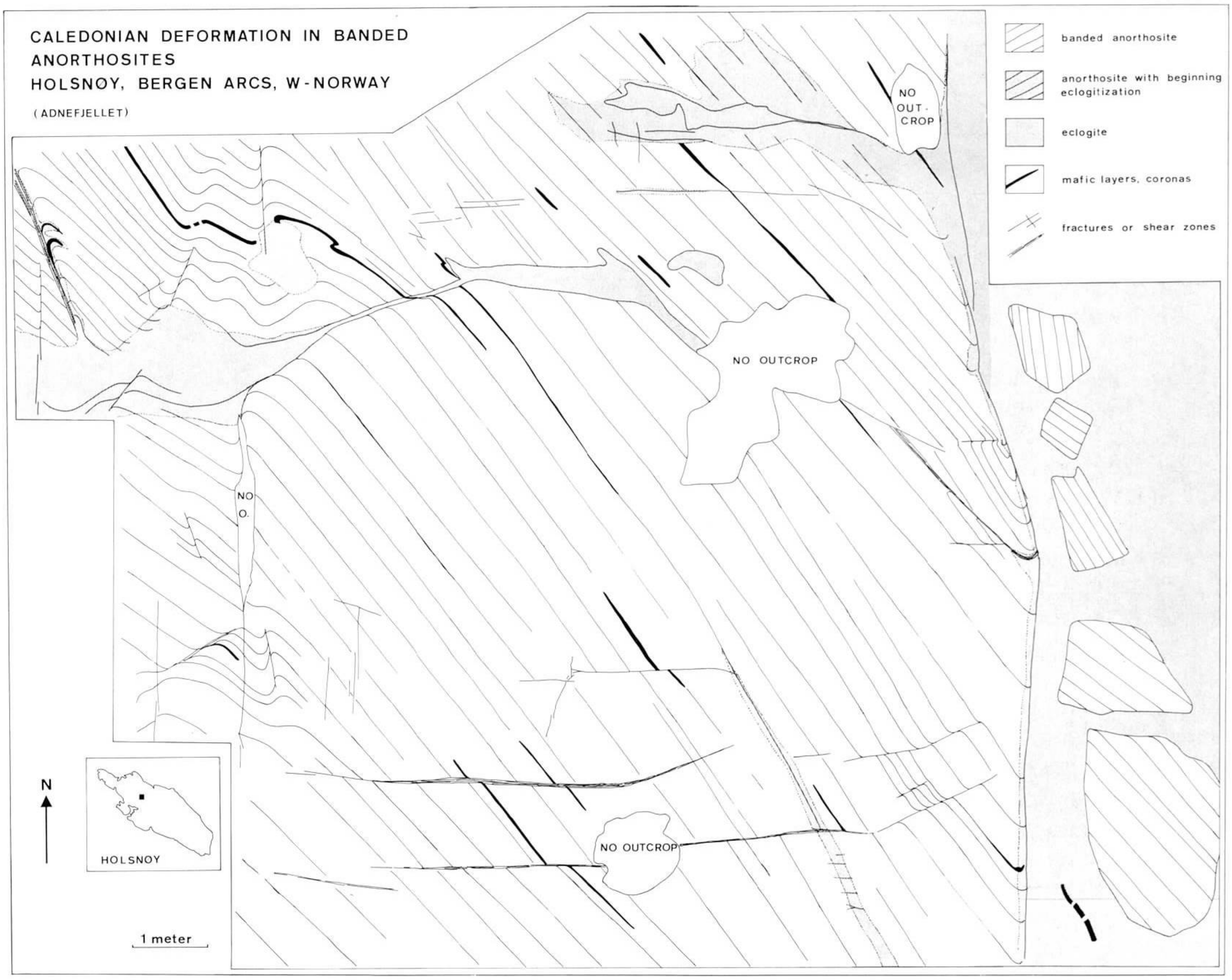


*Fig. 6* Map showing a typical outcrop of little affected anorthosite which is cut by fractures and shear zones and borders a zone of complete eclogite facies reworking.

Gaustafjellet). There are two dominant sets of shear zones; one running WSW–ENE with only sinistral shear sense and a second set running N–S with a large number of sinistral and only few dextral shear zones. Figure 6 shows an example of reworking with several small eclogitized shear zones and fractures bordering a zone of almost complete reworking. This outcrop (Ådnefjellet) clearly shows a distinctive trend of the shear zones to run N–S and of the fractures to run E–W. There is, however, no obvious control of the shear zone and fracture orientation by the old granulite facies structures. Most of the fractures show a sinistral displacement, while the shear zones also have a sinistral displacement. The fact that the shear zones often terminate just before the tip of a fracture suggests synchroneity.

In general, it can be argued that a framework of intersecting or anastomosing shear zones with the same, constant (here sinistral) displacement sense gives rise to a highly characteristic structural pattern whereby lozenge – shaped masses of undeformed rock are surrounded and separated from each other by shear zones. Simultaneous movement on such sets of anastomosing shear zones with the same displacement sense can more easily accomodate a bulk shape change in the rock than simultaneous movements along conjugate sets (RAMSAY and HUBER, 1987).

## Amphibolite-facies overprint

Some of the major shear zones in the anorthosite complex show, besides the eclogite-facies overprint, amphibolite to greenschist-grade mineral assemblages and even brittle, cataclastic features. Regional amphibolite-grade metamorphism prevails in the southeastern part of Holsnøy where the pro-

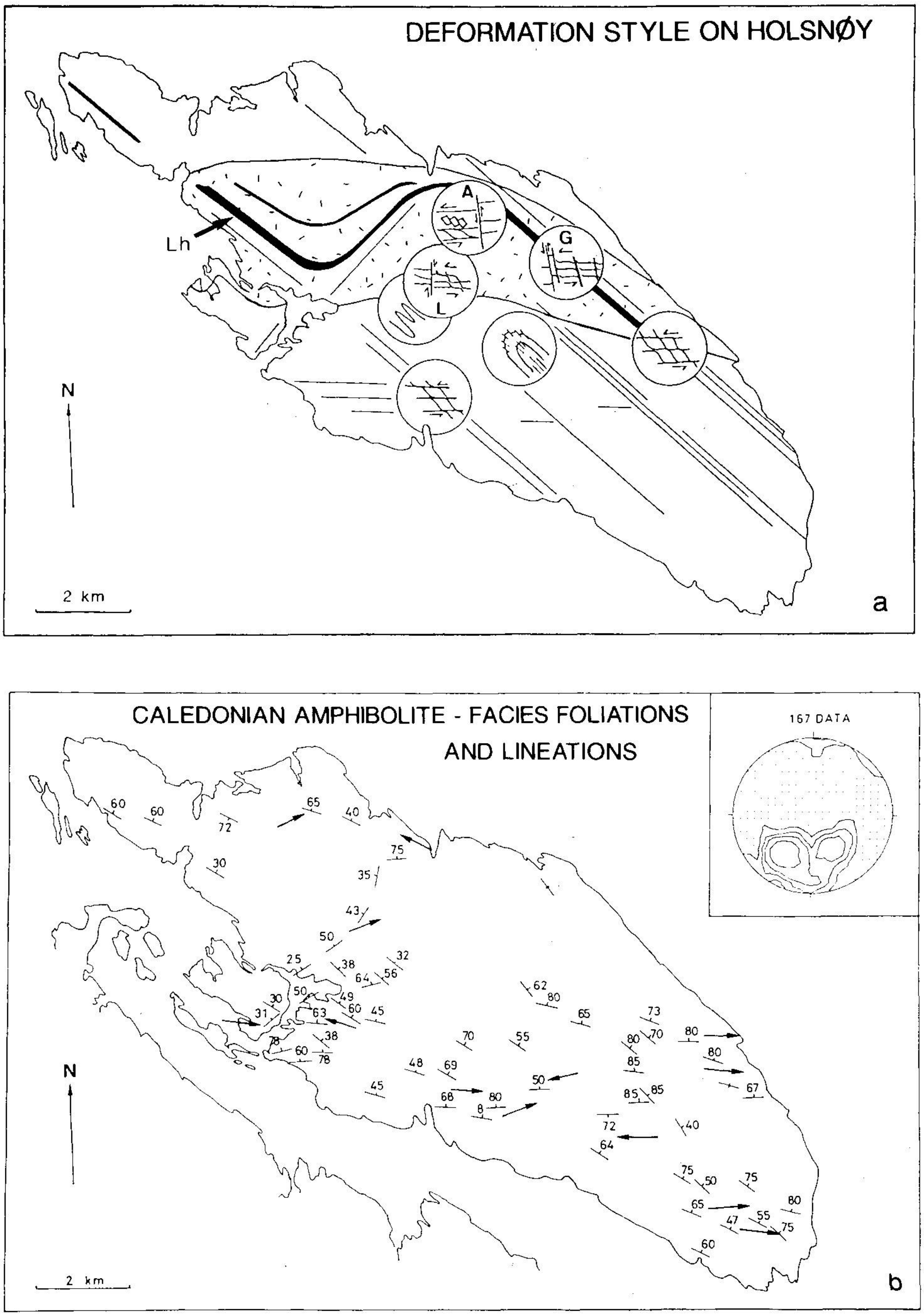


*Fig. 7* a) Sketch map showing major eclogite-facies shear zones and details (blown up from outcrop scale) of the Caledonian shear zone and foliation patterns. Heavy black lines and localities A, G, L: eclogite-facies structures, thin black lines and blow ups without locality names: asymmetric amphibolite-facies foliations. Stippled area: anorthosite protolith. Lh: major eclogite-facies shear zone containig lherzolite lenses.
b) Caledonian foliation and lineation map and foliation orientation diagram. Plotting and contouring (contoured at 1.0, 2.0, 3.0, 5.0, 10.0 times) is in the lower hemisphere, using a FORTRAN computer program described by Starkey (1979).

tolith consisted predominantely of mangerosyenites and banded granulites.

The map given in figure 7a shows the most important eclogite- and amphibolite-grade structures observed on Holsnøy during reconnaissance structural mapping. Two major eclogite-facies structures are given in figure 7 a in heavy black lines. The 'blow ups' of type-localities A (Ådnefjellet), G (Gaustafjellet) and L (Liafjellet) which have already been discussed above show small scale eclogite-facies structures. The thin black lines indicate amphibolite-facies foliation trends with 'blow ups' of four additional localities showing typical outcrop patterns.

The amphibolite-facies foliation and lineation data and the stereographic projection of the foliation data are given in figure 7 b. The map clearly shows that a major NW–SE striking and steeply NE dipping foliation orientation dominates the island. This foliation strongly varies in intensity. Locally, there is a shallow west or (north-)east dipping lineation associated with this foliation. This lineation is usually parallel to small scale fold axes and is formed by the preferred orientation of biotite.

Within these NW–SE trending structures a relic eclogite-facies mineral assemblage is preserved locally in some of the major amphibolite-facies shear zones and indicates that the eclogite-facies was a precursor to the amphibolite grade (during either reactivation of older structures or continuous deformation). Small bands within such major shear zones may, on the other hand, show complete chloritization and late cataclastic deformation, indicating a long and complex history.

A second foliation orientation occurs as shown in figure 7 b. This foliation is steeply N dipping and strikes W–E, also locally showing a weak and moderately east or west dipping biotite lineation. This second foliation shows the same critical mineral assemblage of amphibolite-grade and is seen to develop as a kind of C–S fabric ('blow ups' in Fig. 7 a).

The amphibolite grade S planes, representing the NW–SE striking foliation, form the regionally dominant foliation of the northern segment of the Bergen Arcs nappe system. The C planes, however, indicate sinistral (northern block to the west) shearing. The observation of such S–C fabrics emphasizes that a noncoaxial progressive deformation history lead to such asymmetric foliation patterns.

The amphibolite-facies deformation event itself seems to be a complex, possibly polyphasal event as indicated by the regional deformation history described by Sturt and Thon (1978) and Thon (1985). Further structural mapping will show whether S–C fabrics are common in the rest of the Bergen Arcs nappe system and whether or not they are related to the arc shape.

## The anorthosite complex as an example of a lower crustal slab emplaced within the upper crust – a tectonic model

The second part of this study considers a possible tectonic model for the emplacement of the anorthosite complex to its present position in the upper crust. The model agrees with the observed small scale structures and with the few data points on a P–T–t path which are known for the study area on Holsnøy. It is obvious from previous work (e.g. Austrheim and Griffin, 1985; Jamtveit, 1990; Klaper, 1990) and from this study that the transition from granulite- to eclogite facies assemblages was essential to enable shearing within the anorthosite complex. Such movements along eclogite facies shear zones may well have been responsible for thrusting and possibly also for the decoupling of a lower crustal slab, a process which is required to emplace lower crustal rocks in the upper crust. Although only few major shear zones have been identified (cf. Fig 7 a) on Holsnøy, a (speculative) emplacement scenario which is based on Cuthbert et al.'s (1983) model for the Western Gneiss region will be discussed.

Eclogitization of lower crustal material must be associated with an active large scale tectonic regime such as subduction or continent-continent collision because the eclogitization process requires pressures higher than in continental crust of normal thickness. During the Caledonian orogeny large parts of the western continental margin of Baltica were disrupted and partially subducted after a rifting phase (Kumpulainen and Nystuen, 1985) which is, however, badly constrained within the study area. The mafic granulites and meta-anorthosites, occurring in the Bergen Arcs terrane, represent subducted lower crustal material because metamorphic pressures of around 20 kbar can be read from the rocks.

The regional geological context shows a close similarity between the rock types (Goldschmidt, 1916) and the tectonic position (Gee and Sturt, 1985) of the Bergen Arcs anorthosite complex and the Jotun nappe to the northeast of the Bergen Arcs. Cohen et al. (1988 and references therein) could show similar patterns of the granulite-facies metamorphism at around 900 my for the Bergen Arcs anorthosites and the Jotun nappe. The present day relative tectonic position of the Jotun nappe and the anorthosite complex in the middle Allochthon (Gee and Sturt, 1985) (Fig. 1) as well as the lithological resemblence may suggest that

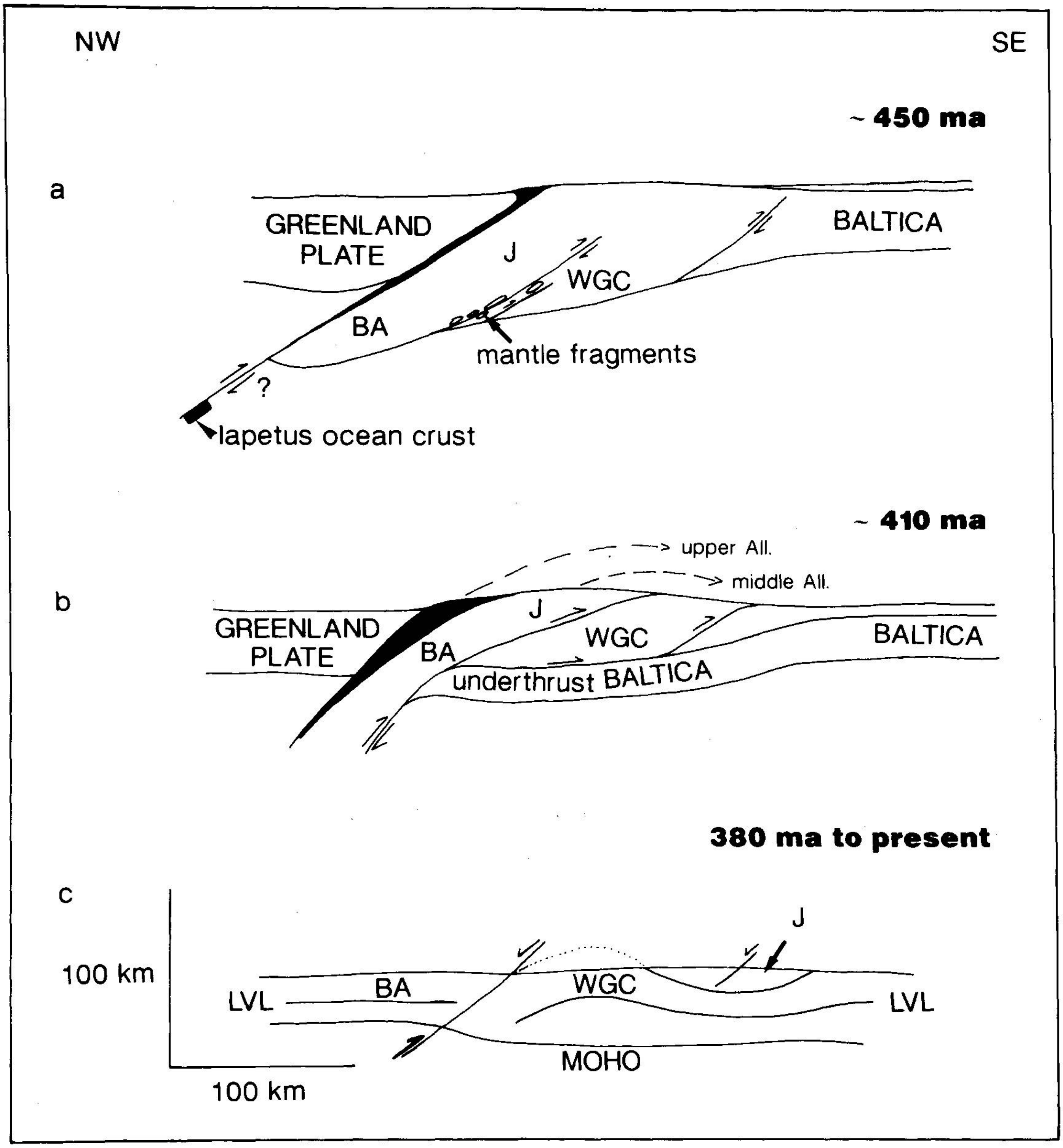


*Fig. 8* Tectonic model for the emplacement of a lower crustal section in the middle (or upper) crust: the Bergen Arcs system and Jotun nappe as an example (after CUTHBERT et al., 1983). For details see text. BA: Bergen Arcs, J: Jotun nappe, WGC: Western Gneiss Complex, LVL: Low velocity layer.

the two tectonic units originally may have been one continuous slice of Proterozoic lower crustal material. The fact that there are no eclogites known from the Jotun nappe but occurrences of eclogites in the Bergen Arcs anorthosite complex and also in the Western Gneiss Complex (= WGC), underlying the Jotun nappe, are numerous, suggests the following (Fig. 8): During convergence of Baltica in the East and the Greenland plate in the West and subduction of the Iapetus ocean floor it came to a partial subduction of the anorthosite complex + Jotun unit. The high-pressure overprint affected the anorthosite complex but not the less deeply subducted Jotun nappe. This eclogite-facies overprint of the anorthosites occurred between 509 ± 109 my (phengite Sm–Nd ages) and 421 ± 68 my (phengite Rb–Sr ages, 443 ± 5 my phengite K–Ar ages) according to COHEN et al., (1988). The lower crustal slab consisting of the anorthosite complex and the Jotun nappe was then obducted and thrust onto higher crustal levels, overriding part of the western continental margin of Baltica, the Western Gneiss Complex (Fig. 8a). The enormous crustal thickening (> 16 kbar or 50 km) which was a consequence of this collisional stage, was responsible for depressing the Western Gneiss Complex (CUTHBERT et al., 1983) to a depth where eclogite formation (around 425 my, Sm–Nd mineral ages, GRIFFIN and BRÜCKNER, 1980) was possible and occurred roughly at the same time or shortly after eclogitization in the Bergen Arcs anorthosite complex.

A major problem with such a model is to find rheologically and mechanically meaningful mechanisms by which crust which has been buried to depths of 50 to 60 km can be restored to the earth surface and can still have a crust of near normal thickness beneath it. The rheological aspects can not be treated here. But following CUTHBERT et al. (1983) it is suggested that after an early phase of collision and the formation of eclogite-facies assemblages in the Bergen Arcs and the Western Gneiss Complex an underplating of Baltica (Fig. 8b) below these eclogite-bearing units provided the isostatic impetus for the necessary rapid (isothermal?) uplift.

During the early Devonian buoyancy forces in the thickened crust initiated a period of extension (NORTON, 1986) which led to the formation of a westerly dipping extensional fault, the Nordfjord-Sogn detachment. This extensional detachment (Fig. 1) seems to truncate the compressional base of the Bergen Arcs-Jotun system around the back of the Bergen Arcs (MILNES et al., 1988; NORTON, 1986). Such Devonian extensional structures (e.g. HURICH and KRISTOFFERSEN, 1988; MILNES and KOESTLER, 1985; Fig. 8c) considerably modified the collision zone on the edge of Baltica to its present geometry.

## Conclusions

Detailed mapping of the structural features of a part of the Precambrian anorthosite body on Holsnøy helped to establish the deformation characteristics of the Caledonian orogeny associated with this tectonic unit:

1. The 'syn-eclogite' deformation is localized in cracks and small and major ductile shear zones (AUSTRHEIM and GRIFFIN, 1985 among others). Cracks and shear zones form a pattern of anastomosing or intersecting high strain zones and predominantely strike N–S or WSW–ENE within the anorthosite body. A prevailing sinistral displacement sense can be observed on steeply dipping shear zones of both orientations.

2. The overprinting regional amphibolite-facies deformation reactivated and/or produced major shear zones. Some of the amphibolite-facies shear zones show remnants of an eclogitic precursor mineralogy indicating a protracted deformation history.

3. The amphibolite-facies pattern of macro- and meso-structures corresponds to a planar composite fabric in the form of S–C planes.

Similarities between the anorthosite complex and the Jotun nappe lead to a conceptual model for the emplacement of a lower crustal 'anorthosite complex + Jotun nappe system' based on CUTHBERT et al. (1983).

4. The initiation of shearing within the anorthosite body as a consequence of the granulite- to eclogite-facies transition is important for the subsequent thrusting of this slab of lower crustal material. A decoupling of the anorthosites and emplacement of this lower crustal slab in the upper crust is assumed.

5. CUTHBERT et al.'s (1983) model for the Western Gneiss Region is consistent with the assumption that the anorthosite complex and the Jotun nappe formed originally one single slab of lower crust. The tectonic emplacement model indicates partial subduction of the anorthosite complex + Jotun nappe system to variable depth followed by a pronounced, polyphase, compressional event and rapid uplift.


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