Regional foliation patterns in gneisses as an aid to the correlation of metasupracrustal units in the Western Gneiss Region, southern Norway

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Introduction

This contribution is a preliminary report from recent mapping in the area covered by the 1:250,000 map-sheets 'Ålesund' and 'Ulsteinvik'. These cover the major and central part of what Gjelsvik (1953) called the "North West Gneiss region of Southern Norway", hereafter abbreviated to 'WGR'. This regional project has provided an opportunity to carry out reconnaissance mapping in the area, extend or link different exotic rock units, and compare subareas investigated previously in detail by others, in the light of modern tectonic models and using computer-based methods for storing and retrieving data.

With few exceptions, most of the work in the WGR, after publication of an early regional map (Gjelsvik 1951), has concentrated on small areas where studies of special rock-types such as eclogites and garnet peridotites as well as metasupracrustal units could yield information on the petrogenesis of both the local rocks and the entire WGR.

In addition to this study, two other mapping projects with a similar basic methodology have been reported. These include mapping of the Trollheimen tectonostratigraphic sequence as far west as Vigra (Robinson & Krill in press), and the linking of the partly supracrustal Vikvatnet unit at Tafjord (Brueckner 1977) with metasupracrustals at Lesjaskog (Santarelli 1989). The present study incorporates information from these earlier regional studies.

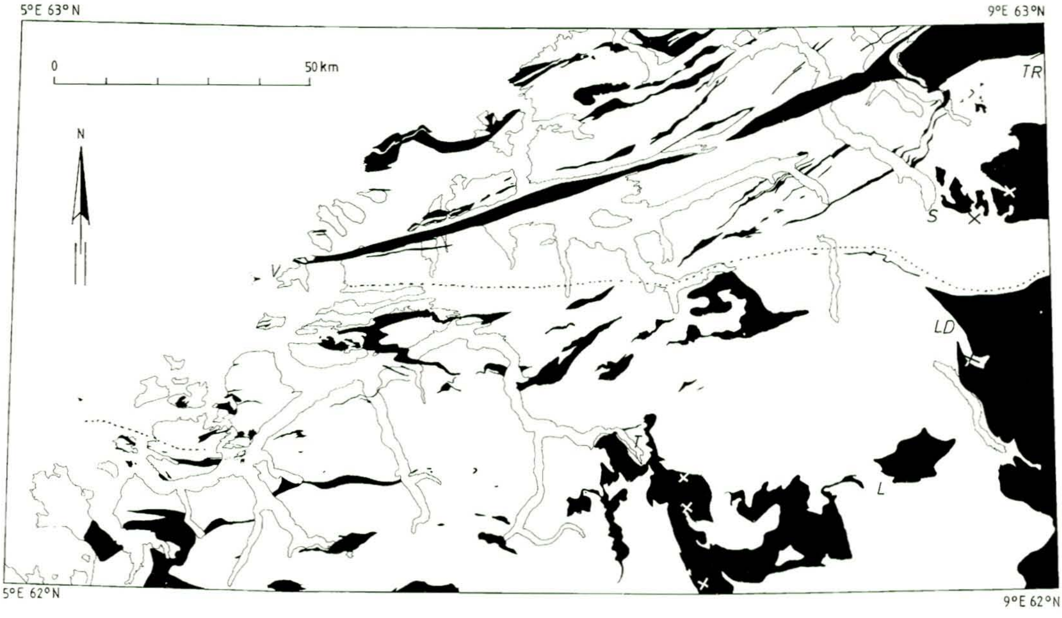

Fig. 1. The area covered by the two 1:250,000 scale map-sheets Ålesund and Ulsteinvik. The figure shows (in black) rocks with characteristics similar to the allochthonous units in the Trollheimen - Oppdal area. 'Basement' in white. See text for details about separation of the two categories. Localities where quartz pebble conglomerate is observed are marked with x. Some of the locations mentioned in the text are marked by capital letters: Grotli G, Lesja L, Litjdalen LD, Sunndalsøra S, Tafjord T, Trollheimen TR, Vigra V. Oppdal is located 50 km east of Sunndalsøra, outside the map area.

Methods

A map has been compiled for testing a basement/cover model where all possible 'paragneisses' or 'cover rocks' together with slices of transported Precambrian basement constitute one allochthonous group. A second group comprises 'basement' of intrusive gabbros, dioritic, quartz-dioritic and granodioritic orthogneisses with minor xenoliths of Precambrian paragneiss, and pockets of autochthonous meta-arkose and basal conglomerate (Fig.1). A field test for including a rock unit within the 'cover rocks' has been that it should have a petrographic and textural resemblance to one of the rock units found above the basal conglomerate that occurs along the eastern margin of the study area and in the Tafjord region. Anorthosites and ultramafic rocks are also included in the allochthon. This is justified by the fact that an increasing number of these rock-types have been observed within the sheared margins of allochthonous units, or in paragneisses of possible allochthonous origin.

In the preparation of the map of gneissic banding and concordant foliation (Fig. 2), about 8,000 measurements taken during the mapping project have been used. Plotting these directly, however, gave a map of very poor clarity due to an uneven data distribution. 'Averaging' of data over grid areas of convenient size was necessary. The most useful method in this case proved to be that involving the calculation of eigenvectors from the 3 x 3 matrix of the sums of cross products of the direction cosines (Woodcock 1977). A computer program by Vollmer (1990) has been used in this connection. The map (Fig.2) is composed of 712 equally spaced strike/dip symbols with dip-dependent tick length. Each represents the 'average' orientation of gneissic banding within a rectangle measuring 3.6 km N-S by 6.6 km E-W.

Discussion

A detailed stratigraphic comparison would admittedly be the most powerful method to find if rocks can be correlated. In this area, however, field observations have indicated several early tectonic disturbances of the original nappe pile succession. Field relations for a few serpentinites found close to amphibolites and garnet-mica schists, which are their most common host rocks, are probably best explained by separation of rocks with strongly different rheologies during deformation. It is also conceivable that the nappe pile has been isoclinally folded and imbricated both prior to and during the main intercalation between crustal mega-lenses. A rigorous stratigraphic correlation of rocks seems, therefore, to be impossible, except in the coastal areas from the northeastern corner of the map to Vigra ('V' in Fig. 1). Here, a remarkable consistency in sequential order may be demonstrated, although the thicknesses in the western part are only fractions of what they are further northeast (Robinson & Krill in press). This dramatic attenuation seems to be restricted to this area, following a penetrative, sinistral, simple-shear deformation. In the southern and southeastern parts of the map area, open folding and an alternating shear sense prevail as products of the last ductile deformation, whereas the possible cover rock units usually show a map pattern of irregular rootless and recumbent folds. These contrasting deformational styles call for structurally founded methods as an aid to correlation.

During the period of this study, the tectonostratigraphic sequence of Trollheimen (Krill 1985) has been traced southwestwards to Sunndalsøra (Fig. 1). Here, the strata are more or less horizontal and are separated from orthogneissic basement by mylonites and discontinuous occurrences of basal conglomerate and meta-arkose. Based on arguments from Rb-Sr dating of metasupracrustals, Bryhni and Aas rejected Krill's correlation (Krill 1985) of the Trollheimen rocks with the Fjordane complex that lies further to the southwest of Sunndalsøra (Aas 1986, Bryhni 1989). Observation of metasediments occurring beneath allochthonous rocks in Sogn supports the view of Aas and Bryhni.

Santarelli (1989, p.219) correlated the metasupracrustals of Tajord, Grotli and Lesja (TGL) with the Fjordane complex and agreed with Aas and Bryhni's objection to correlating the TGL and the Trollheimen tectonostratigraphic sequence.

In this study a model is discussed where most of the Fjordane complex (as defined in Bryhni 1989, p. 227), the TGL and the westernmost part of the Trollheimen allochthonous pile are delineated (black in Fig. 1). Both alternative correlations mentioned above are thus accepted in this context. Grouping of the cover units and basement units in this way implies that at some advanced stage in the development of a thickened crustal collision zone, the thin-skinned allochthonous units formed imbricated and complexly folded units trapped between thicker, parautochthonous/autochthonous wedges of more homogeneous, plutonic basement.

This model is similar to that proposed by Bryhni (1989, fig.5) but with the addition that nappes formed early in the collision and translated onto the rigid foreland were subsequently

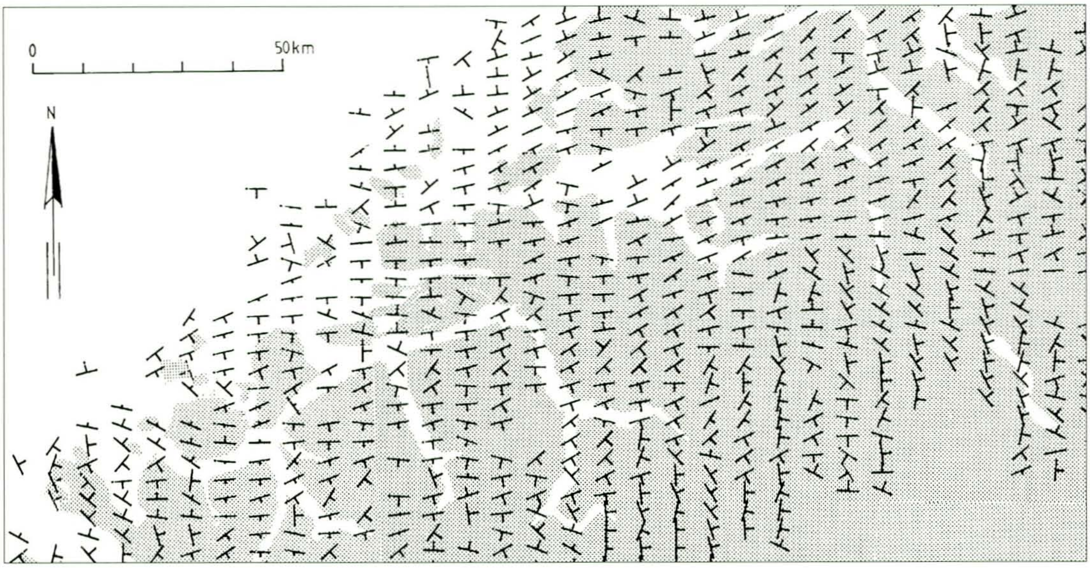

Fig. 2. The strike and dip symbols display the 'average' trend of gneissic banding within rectangular cells of 24 km². There are 712 such cells with 7,900 single measurements. A short tick length reflects a steep dip of the banding. See text for details about calculating the 'average' values of orientation data.

enclosed between thicker imbricating crustal segments in the late phase of collision, together with deposited supracrustals. Most of the banding and the migmatites have subsequently been rotated into concordance with major lithological units, also during the extensional collapse of the orogenic welt.

Comparing the map of strikes and dips of gneissic banding and foliation (Fig. 2) with the 'cover rock map' (Fig. 1), one may conceive three possible situations based on the simple idea that each phase of major regional deformation greatly increases the degree of apparent dismemberment of an originally continuous layer as displayed on a map. In the first case, folding and shearing during deformation could have preserved the remains of 'cover rocks' as elongated patches aligned parallel to the banding and foliation over considerable distances, even if the 'cover rocks', at the late stage of collision, were discontinuously distributed. This would support the correlation between the individual 'cover rock' patches as shown in Fig. 1. Secondly, a regional distribution, which is totally independent of the mesoscopic banding, may indicate a longer co-residence related to the deformational history. In this case, the 'cover rocks' would have been involved in regional folding and deformation prior to the last phase of major banding and foliation development; or intrusions may have broken the connection between the spatially separated 'cover rocks'. A third possibility is that certain groups of 'cover rocks' align along the foliation while others do not; this would tend to support the apparent lack of correlation between these groups as argued by Aas, Bryhni and Santarelli.

It is the opinion of the present author that the alignment of most 'cover rocks' along the banding and foliation is so strong that the first of the three alternatives is considered the most likely. Some discrepancies may possibly be explained by the effects of a later, extensional deformation along discrete zones.

In the eastern and southeastern part of the map area, a gentle easterly dip prevails, yielding several larger outcrops of 'cover rocks' exposed mainly on high mountain ridges. The situation is different west of a line NNW-SSE along Sunndalsfjorden and Litjdalen where a major system of faults may have been active during an extensional phase. The rocks on the western side of these faults are mostly of 'basement' type.

The fault along Sunndalen and Litjdalen may be genetically related to an anomalous zone, apparent on both maps, trending E-W and located north of the centre of the map. In Fig. 1 this zone is marked by a conspicuous corridor devoid of any 'cover rocks'. In Fig. 2 the foliations are always steep and more consistently E-W trending along this zone. One interesting working hypothesis to explain this structure is the mechanism proposed by Séranne (1992) whereby folding parallel to a low-angle 'top-to-the-southwest' shear movement promotes disruption along steep shear zones parallel to one set of fold limbs. In the area south of Sunndalsøra, the shear zone curves towards north and back towards west about 10 km further west. Combined with a sinistral movement, this would have set up a compressional stress, possibly released by faulting along horst-like structures along the west side of Litjdalen (Tveten & Lutro, map-sheet 'Ålesund', in prep.). The lack of 'cover rock' observations in the shear zone may have been brought about by a more effective tectonic homogenisation in the extensional simple shearzones than elsewhere in the WGR.

Concluding remarks

There still seems to be a possibility that the majority of the paragneiss, together with some orthogneiss, anorthosite and serpentinite, may be correlated with the allochthonous pile in Trollheimen - Oppdal, even in those cases where isotopic evidence is indicating a different history. The isotopic evidence seems to be partly in conflict with both the observation of striking petrographic similarities and the regional structural pattern as reported in this study.

If one assumes that nappe translation occurred at some distance from the initial suture, the presented data support the idea that crustal imbrication took place elsewhere and independently of the suture, so that allochthonous cover rocks could have been brought in between crustal mega-lenses. This conforms with the ideas of Cuthbert et al. (1983, fig. 5), except that they indicate that the main phase of nappe translation was late in the development of the orogen, whereas this study supports translation prior to the last phases of crustal imbrication or formation of discordant extensional shearzones . Finally, it is considered that late ductile shear related to the exstensional collapse of the orogen must be regarded as an important mechanism for producing a consistently steep foliation along certain discrete zones trending E-W.

Further work

To extend this work, a more comprehensive subdivision into structurally cylindrical subdomains is necessary. This will involve detailed mapping of some key areas with supplementary measurements of structural elements. Hopefully, it will be possible to separate late shear domains (and gneissic textures ?) related to extensional deformation from the earlier compressional phases. More petrographic and petrochemical work on existing sample material will probably make it possible to include more of the 'common gneisses' in the group of 'cover rocks', and to subdivide the 'cover rocks' into at least three units. The study area should be expanded to include the remainder of the WGR towards the southeast.

With a regional model of this kind available, future workers in petrology, geochronology and geophysical modelling in the actual area will be able to classify their sample material in a more meaningful manner.

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