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Results from a structural study in
Pasvik, North Norway

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

Geological Survey of Norway
P.O.Box 3006 - Lade
N-7002 Trondheim, Norway
Tel.: 47 73 90 40 11
Telefax 47 73 92 16 20

REPORT

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Title:
Results from a structural study in Pasvik, North Norway

Authors: Alvar Braathen		Client: KENOR	
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Summary:

This report describes results from structural investigations undertaken in Pasvik in 1996. The Early Proterozoic rocks of the Pasvik (Petsamo) and Kobbefoss Groups, and Archaean gneisses were deformed during three ductile to semiductile stages, designated D1, D2 and D3. Typical structures such as foliation, cleavage, lineations and folds support the structural subdivision, and place constraints on the structural position of the Gjedde Lake gold occurrence.
The deformation of the region evolved from a regime of N-S shortening during the D1 phase, leading to a penetrative foliation in all rocks, to continued shortening by N-directed thrusting during the D2 stage. The latter phase is seen as folds and discrete shear zones in the north, and a km-wide high-strain zone further south. This zone hosts the Gjedde Lake gold occurrence. The D3 stage resulted in regional N-S trending folds, and associated parasitic folds and shear zones.
Some important implications of the structural patterns in Pasvik are: (1) The Gjedde Lake gold deposit is located in a regional D2 shear zone, which may have similarities to the Poritash Fault in Russia. This fault zone seems to have formed from N-directed D2 thrusting of previously deformed (D1) and metamorphosed terranes to the south. (2) The gold-bearing rocks of the Gjedde Lake may be associated with fracture systems. These fractures relate to brittle to semibrittle deformation of competent rocks that suffered high strain rates in the regional, ductile, D2 shear zone. (3) Garnet occurs in the D2 shear zone and in overlying rocks, but not in underlying rocks. Thus, it may represent a potential marker for the location of this zone in Norway.

Keywords: Finnmark, Pasvik, structural geology, bedrock, tectonics, metamorphism, gold

Keywords: Berggrunnsgeologi	tektonikk	gull
strukturgeologi	omdanning	fagrapport

CONTENTS

FIGURES

1. INTRODUCTION

This report describes work undertaken during the gold exploration in the Pasvik valley in 1996. The aim of this work, which has been one of several tasks that were conducted during this year's exploration, was to study the deformation structures present in the Early Proterozoic rocks of the region, thereby addressing the relevance that this deformation has to potential targets for gold.

Structural investigations were conducted during one week of fieldwork in August 1996. The limited time in the field has restricted the work to areas that were easily accessible. Therefore, most time was spent in well exposed parts, i.e. in road sections and outcrops along lakes and rivers.

The work has established a preliminary understanding of the regional structural patterns and the deformation history in the area, and has thus provided a structural basis that could add to the interpretation of the possibly structurally controlled Gjedde Lake gold deposit. Another spin-off is the regional distribution of rocks that may have had a similar deformation history as the rocks at the Gjedde Lake.

The next section addresses the regional geology, thereafter follow several sections describing subjects related to the structural geology, i.e.: (1) structural introduction, (2) field observations and style of deformation, (3) structural orientations, and (4) some microscopical considerations. The final section discusses (i) the Gjedde Lake gold deposit in the light of the regional structural patterns, (ii) potential markers that can be followed in continued exploration, and (iii) suggestions for further structural work. A resume of the main observations and conclusions is presented as the last section in this report.

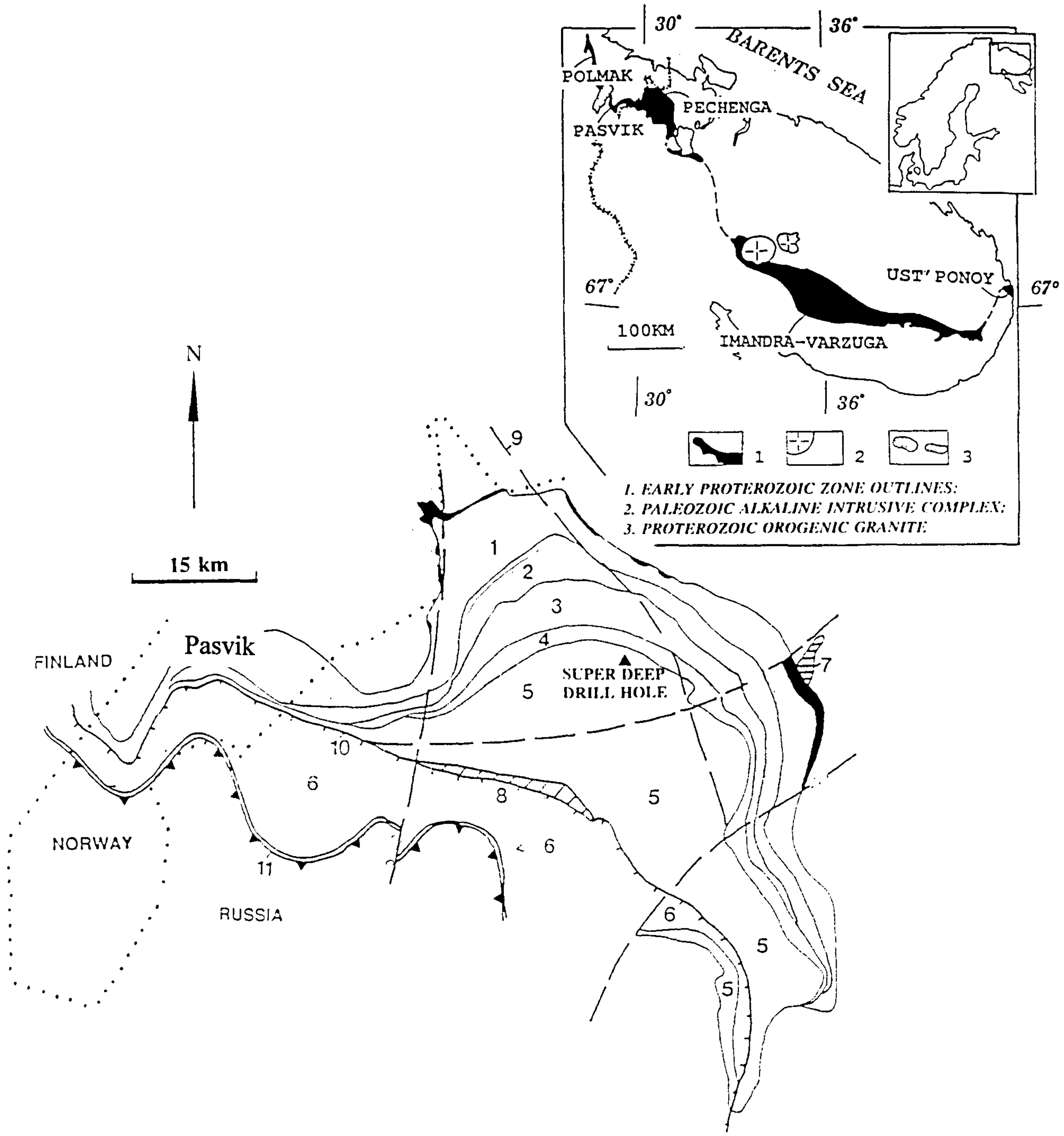


Fig. 1. *Sketch map of the study area. Legend:* ***North Pechenga/Pasvik Group****: *Black layers on base of the North Pechenga Group show abundance of the Akhmalahti/Neverskrukk basal conglomerate; 1, Akhmalahti Volcanic/Bålttjørna Formations; 2, Kuetsyarvi/Koivannet/ Skogfoss Formations; 3, Kolasyoki/Bergvannet/Skjelvannet Formations; 4, Pil'gujarvi Sedimentary Stallvannet Formations; 5, Pil'guyarvi Volcanic/Kiltjørnan Formation.* ***South Pechenga/Langvannet Group***: *6, Kollayvr, Mennel, Poroyarvi, Kasesyoki, Ansemyoki and Tal'ya Formations.* ***Intrusive complexes:*** *7, early Proterozoic gabbro-norite (Mt.General'skaya intrusive); 8, early Proterozoic subvolcanic andesite.* ***Faults:*** *9, long-lived syndepositional fault; 10, Poritash synvolcanic(?) fault; 11, early Proterozoic thrust. (*A first formational name is given for the Pechenga Zone, a second and third are given for the stratigraphic analogues of the Pasvik Zone–asterisks on the map mark the sections.)*

The figure is modified from Sturt et al. (1994). Note the location of Pasvik on the map.

2. REGIONAL GEOLOGY

The Precambrian geology of the northern Fennoscandian Shield is described in a number of publications, where the more recent ones are found in NGU Special Publication 7 (Roberts and Nordgulen, 1995). Rocks present in eastern Finnmark and the western Kola Peninsula include Archaean basement (e.g., Dobrzhinetskaya et al., 1995) along the northern coast line and as large-scale domes further south and west (Fig. 1). The Early Proterozoic Pechenga-Pasvik-Polmak Greenstone Belt (e.g., Marker, 1985; Melezhik et al., 1995) is sandwiched between two such Archaean blocks. It forms a 1000 km-long, discontinuous, southward dipping orogenic zone, where volcanigenic and sedimentary rocks were deformed and metamorphosed during several tectonic episodes. In the Pasvik region this greenstone belt is divided into northern and southern zones, which are separated by a major WNW-ESE-striking fault (Melezhik et al., 1994). The rocks of the northern zone on the Russian side of the border are located in a broad synformal basin, which reveals a primary depositional contact to the underlying Archaean basement along the northerly bounding margin (e.g., Sturt et al., 1994). Four cyclic units of rhythmic sediments followed by volcanic deposits fill the basin. The regional synformal structure is truncated to the south by a major SW-dipping reverse fault, the Poritash Fault, which defines the boundary towards the southern zone. In the southern zone, metamorphosed sedimentary and volcanigenic rocks dominate. In places, they are intruded by diorite and gabbro. Archaean gneisses occur at the top of the tectonostratigraphic succession of the southern zone.
In order to explain the repeated cycles of deposition, syn-sedimentary faulting, internal discordances, and geochemical composition of the volcanites, as found in the northern zone, a model involving two rift stages followed by major collision has been proposed (e.g., Melezhik and Sturt, 1994; Melezhik, 1996). Age constraints suggest that the entire evolution, from rifting to collision, occurred in the period between 2450 and 1800(?) Ma.

Early Proterozoic rocks of the south-central Pasvik valley, i.e. in the study area (Fig. 1), belong to the Pasvik-Polmak Greenstone Belt. Basement to the belt consists of Archaean granitic gneisses that are followed upward by metamorphosed volcanites and various sediments of the Båttjørn, Koievass, Skogfoss, Bergvass, Skjellvass, Stallvass and Kiltjørn formations of the Pasvik Group (terminology from Siedlecka and Nordgulen, 1996). Above a tectonic boundary (an extension of the Poritash Fault in Russia) there is a unit, called the Kobbfoss Group, which is composed of porphyric volcanites of rhyolitic to picritic composition, graphite-bearing phyllites, subordinate quartzite, a thick package of metavolcanic flows, and quartzite. A major high-strain zone separates these rocks from overlying para- and orthogneisses, some of probable Archaean age.

The Gjedde Lake gold occurrence was discovered by Melezhik in 1993, which led to further investigations (Melezhik, 1995; Ettner, 1995). In 1996 several investigations were started, beginning with a ground geophysical survey (Lauritsen, 1996). Accounts of the results of the subsequent drilling programme (Ihlen, 1996; Often, in prep.) are in progress, and these will describe the details of the gold occurrence. This contribution is a description of the regional deformation patterns, which may help to further understand the generation of this gold deposit.

3. Structural geology

3.1 Introduction

Four deformation stages can be separated in the greenstone belt of the Pasvik valley. The three oldest ones, designated D1, D2 and D3, reveal structures consistent with a progression from ductile to semiductile deformation, an evolution that is partly dependent on the competence of the rocks involved. These deformation episodes of regional extent were followed by late jointing and minor brittle faulting, probably related to several tectonic episodes, but herein described together and designated to a D4 stage.

This deformation sequence is based on numerous observations of superimposed folding, and cross-cutting fabrics and faults. One example of fold interference is shown in Fig. 2, where an F1 fold is clearly refolded around F2 and F3 folds. Other, similar relationships will be illustrated through descriptions and photographs in the following text. Specific documentation is thus available within the context of this chapter, and is not treated separately.

3.2 Field observations and style of deformation

The area studied in the greenstone belt of the Pasvik valley may be divided into four domains of characteristic deformation. Zone I (Figs. 3 and 4), the northern most part of the Pasvik Group, is characterised by an S1 foliation that, in most cases, is parallel to the primary layering, and dips moderately south to southeast. This foliation is used as the main reference surface in areas further south. Localised folds and discrete shear zones of D2 and D3 affinity are superimposed on this foliation in Zone I. In Zone II, the S1 foliation and primary layering is involved in two phases of folding; NW-SE (in the east), to E-W and NE-SW (in the west) trending folds of the D2 stage and N-S folds of D3 affinity, the later structures refolding the former folds. The F2 folds increase in intensity to the south, toward Zone III. In this zone, all lithological contacts are parallel, and the S1 foliation is more or less entirely erased, i.e., the S2 foliation dominates. In Zone IV, the rocks shows a well developed S1 foliation and are in places banded. In this zone, as well as further north, the foliation is folded in a regional, N-S-trending F3 synform, and in an F3 antiform in the southwestern part of the area.

Fig. 2. Photograph of mica-chlorite schist that is folded. Three fold-phases can be demonstrated; F1 isoclinal folds (dark, shaded rock-face), tight F2 folds, and upright, open

F3 folds. Fold-traces are outlined on the photograph. They document the relative age of the structures, i.e. the older folds (curved lines) are folded by the younger ones (straight lines).

As the above description shows all rocks in the Pasvik and Kobbfoss Groups display an S1 foliation, which varies in intensity through the (tectono-)stratigraphic section. In the lower part of the belt (Zone I of Fig. 3), the foliation is present as a L-S fabric (flattening 10-30%, stretching 2-10 times), which is well displayed in dark grey to black amygdaloidal, mafic volcanic flows. These flows are metamorphosed to fine-grained chlorite-biotite/mica-bearing rocks that reveal a weak foliation and stretched amygdales (Figs. 5 and 6). In ultramafic conglomerates of the overlying Kobbfoss Group, located to Zone II, the S1 foliation is well expressed in the hinge-zones of later folds (Fig. 7). In these folds, flattening, evident from disc-shaped conglomerate clasts that are only slightly stretched, was the dominant D1 deformation mechanism. Limbs of F2 and F3 folds reveal the S1 fabric that is transposed into later foliation(s).

Further south, near and in the D2 shear belt (Zone III), the S1 foliation is preserved in shear-lenses surrounded by high-strain rocks of the D2 fault zone (Figs. 3 and 4). In these lenses, within the S1 foliation there are isoclinal and hook-like folds of a layering which is possibly of sedimentary origin (Fig. 8). Above this level, i.e. south of the D2 shear belt, the S1 foliation is the dominant fabric in the rocks (Zone IV). In the southern area, the metamorphic conditions seem to be higher than further north, and there are minerals present such as garnet and amphibole together with mica; and in some locations with probable migmatitic orthogneiss. Minerals are generally medium grained, i.e. coarser than in areas further north. In the Kobbfoss Group, and in areas further south, most lithological contacts are interpreted as thrusts, which, besides the apparent high D1 strain in the rocks, is supported by the location of the oldest orthogneisses (Archaean?) in the highest part of the tectonostratigraphy (i.e., Lieungh, 1988a; 1988b; Siedlecka and Nordgulen, 1996; Siedlecka and Roberts, 1996).

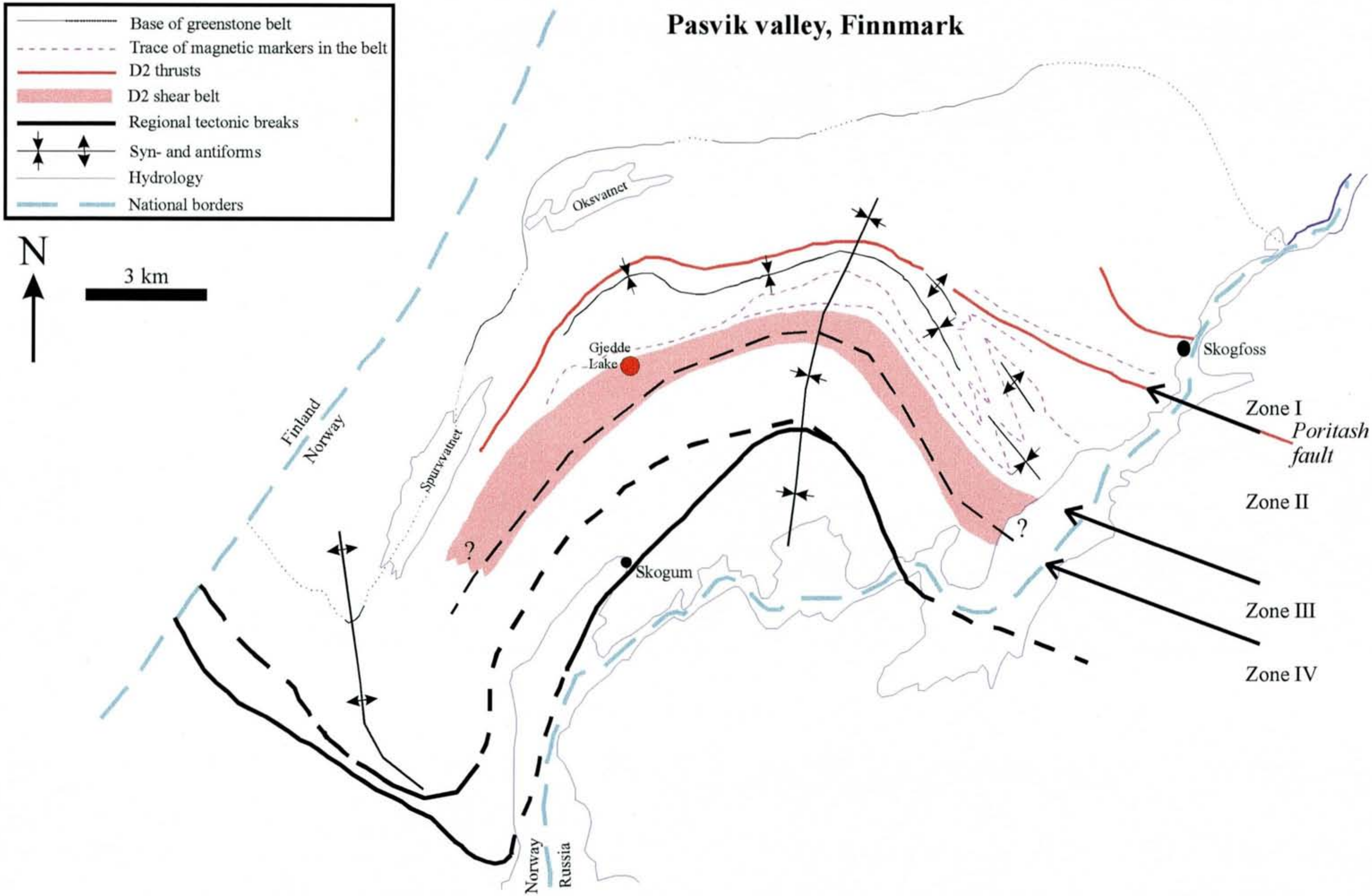
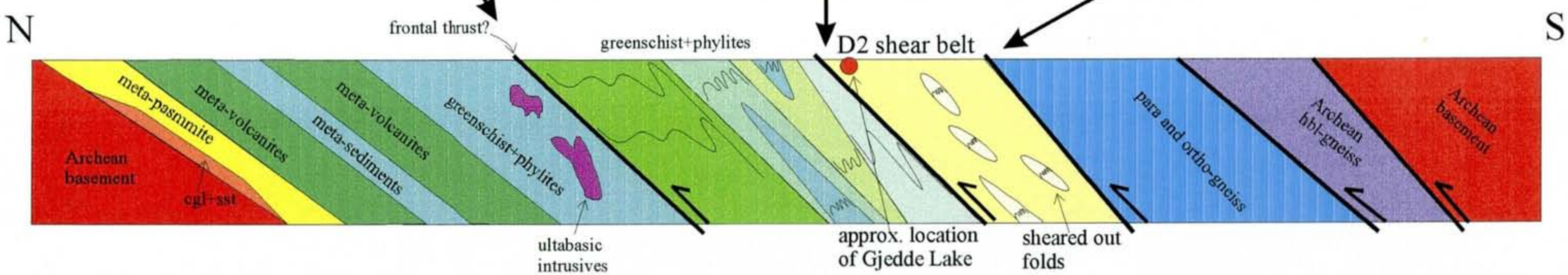


Fig. 3. Main structures of the Pasvik valley.

Fig. 4. Diagram illustrating pattern and style of deformation, and mineral parageneses in the Pasvik Greenstone Belt and nearby units. Abbrivations: amph, amphibole; gnt, garnet; hbl, hornblende; cgl, conglomerate; sst, sandstone..

	Zone I	Zone II	Zone III	Zone IV
D1	Moderate flatening (20-50%) and stretching (2-10 times). Foliation.	Foliation and streching lineation. Partly overprinted by D2.	Relict S1 in shear lenses.	Foliation and well developed stretching lineation.
D2	2-5 m wide shear zones. Open E-W folds with crenulation cleavage.	Shear zones in fold-limbs. Tight-isoclinal E-W folds with cleavage.	Ductile shear zones. Sheet-folds. S-plunging streching lineation.	not observed
D3	Open folds with N-S orientation. Local crenulation cleavage.	Shear zones in fold-limbs. Tight folds with crenulation cleavage.		Open folds with N-S orientation. Local crenulation cleavage.
M	M1 chlorite+mica, local amph, retrogradation to M2 and M3 chlorite+mica.	M1 amph to M2 and M3 chlorite+mica	M1 amph+gnt to M2 amph+gnt+mica to M3 mica+chlorite	M1 gnt+hbl+mica



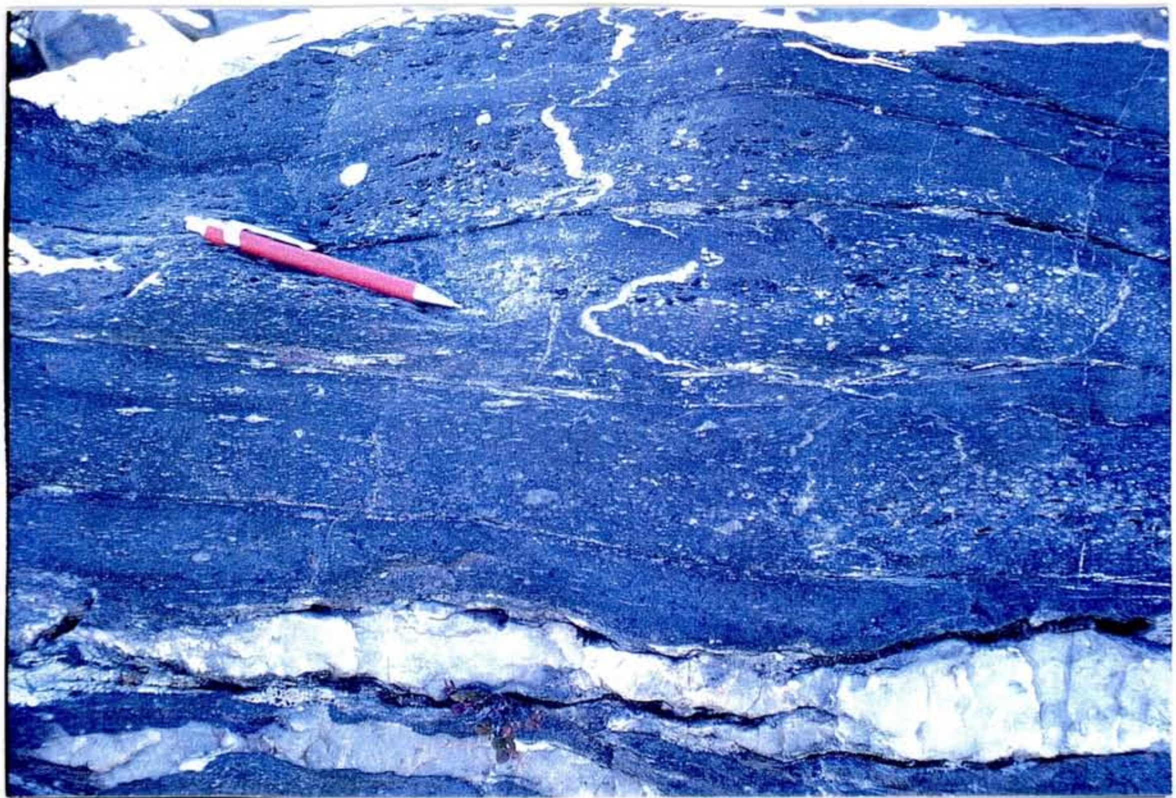


Fig. 5. Photograph of mafic flow in the Båttjørn Formation with amygdales and quartz veins. Note the vertical shortening of the quartz vein and the near horizontal S1 foliation in the rock.

D2 deformation varies in intensity through the four zones (Figs. 3 and 4). In Zone IV, no D2 structures have been found. However, when approaching Zone III the S2 foliation becomes the prominent fabric, and the S1 foliation is limited to inclusions or shear-lenses (Figs. 9). Such lenses consist of relatively competent rocks. Within and along the margin of these lenses there are indications of brittle deformation conditions, such as marginal breccias and quartz-filled shear and tensional fractures. Characteristic minerals along the S2 fabric are garnet, amphibole, quartz, mica, and subordinate carbonate, which, at some locations, are overgrown by late/post-S2 garnet and needle-shaped clusters of amphibole and biotite (Fig. 10). Some of the rocks are very fine grained and represent mylonitic counterparts to the schists and gneisses. Thin (<2 m) quartzite bands in most places show a mylonitic foliation, as is the case in the Gjedde Lake 'semi-outcrop'. Further north, in Zone II, folds near the D2 shear belt are tight to isoclinal, elliptical and asymmetric to the north, and the S2 foliation dominates in the foldlimbs. Here, S2 is defined by mica, chlorite and quartz. The intensity of folding as well as the appearance of the S2 foliation diminish towards Zone I, where D2 structures are found as open folds and discrete, 2-5 m-wide shear bands. In these bands the amphibolites are altered to chlorite and white mica schists The latter contain abundant quartz veins.

All four zones are affected by the F3 folding, as demonstrated by the two regional structures that are shown in Fig. 3, namely a synform in the central area and an antiform to the southwest. These structures involve both the northern Archaean basement, the overlying greenstone belt, and the overriding orthogneisses to the south, i.e., the greenstone belt is folded together with the underlying Archaean rocks. Numerous, S- and Z-shaped, parasitic folds on all scales are associated with the major F3 synform. They are well displayed in the road sections south of Skogfoss, where they vary in shape from elliptical to kink. Mesofolds reveal non-penetrative cleavages, varying from discrete to zonal crenulations dependent on the mica content (Fig. 11). Growth of mica and chlorite, and recrystallisation of quartz along the axial surfaces, are quite common.

Fractures formed mainly during the D2 event, but some relate to the D3 stage, as suggested by quartz veins that are associated with D2 and D3 shear bands. These episodes are followed by late joints, and in some cases by faults, which cross-cut all rocks and foliations of the greenstone belt. Some of the faults are filled with quartz (Fig. 12). These so-called D4 fractures are not the focus of this study.

3.3 Structural orientations

The S1 foliation dips moderately between SW and SE in the western part of the area, whereas the eastern domain generally shows SSW to SSE dips (Fig. 13). In both cases, later folding affects the orientation of the foliation. This is well displayed by the lack of clustering of the S1 foliation in the stereoplot, and by the spread of the foliation poles along great circles that define moderately S- to SSE-plunging fold axes. The mineral lineation, L1, which is oriented parallel to a stretching lineation in the rocks, varies from moderate S plunges in the east to SE plunges further west.

D2 data collected in the field show orientations that are in accordance with F2 folds on the regional map (Fig. 3). The F2 folds plunge moderately between E and SE, less commonly to the W (Fig. 14). Axial surfaces are steeply to moderately inclined to the SW, whereas a subordinate population is steeply inclined to the NE. In the D2 shear belt the L2 stretching lineation and folds plunge moderately to the south within the south-dipping S2 foliation (Fig. 14). In the same high-strain rocks, and in the underlying foldbelt, fracture systems of D2 affinity are quite common in competent rocks (see above). Two distinct orientations dominate (Fig. 15); (i) steep to moderately dipping, E-W striking, quartz-filled fractures, commonly partly folded or sheared out along the S2 foliation, and (ii) N-S to NNE-SSW-striking, vertical fractures, in many cases filled with quartz, but locally represented by open joints. The latter joints are common in the large blocks found near the Gjedde Lake (see below).

The spread of the D2 data can be explained by refolding around F3 folds. These F3 folds plunge moderately S to SSW (Fig. 16), whereas their axial surfaces strike NNE-SSW to N-S. Dips vary from steep to subvertical to the W and E; thus, the folds are more or less upright structures. When the D3 data set is compared with the other structural data (see Figs. 17 and 18), the consistent D3 orientations (clustering in the stereoplot, Fig. 15) in relation to the D1 and D2 data (Figs. 13 and 14) further document the structural chronology of the area; earlier structures vary more in orientation due to the effect of later folding.

Fig. 6. Photograph of metamorphosed (mica-chlorite rock) mafic flow in the Båttjørn Formation (same location as Fig. 5). Note the stretched amygdales within the S1 foliation.

Fig. 7. Conglomerate of the Kobbfoss Group. The clasts of this unit are disc-shaped from flattening in the S1 foliation, i.e. parallel to the surface of the outcrop. A new foliation, S3, is superimposed on S1. S3 is parallel to the pencil on the photograph.

Fig. 8. Isoclinal F1 fold and S1 foliation in mica schist of the upper Kobbfoss Group.

Fig. 9. Relict S1 foliation in the hinge of an isoclinal F2 fold. The S2 foliation dominates in the fold-limbs, where the S1 is entirely erased. The photograph is from the D2 shear belt (Zone III).

Fig. 10. Photograph of F2 fold-hinge that folds the S1-foliation. A new foliation, i.e. S2 crenulation cleavage, has formed along the axial surface. Note the late amphibole needles that grow on top of the S2 foliation. They have a random orientation.

Fig. 11. Photograph of mica-chlorite schist of the Kobbfoss Group. The rock shows two crenulation cleavages (S2 and S3).

Fig. 12. Photograph of quartz-filled late faults (D4) in the Båttjørn Formation. The foliation in the rock is the S1.

Fig. 13. Stereo plots (equal area, lower hemisphere) of D1 data. Poles to the foliation (dots) plot along great circles.

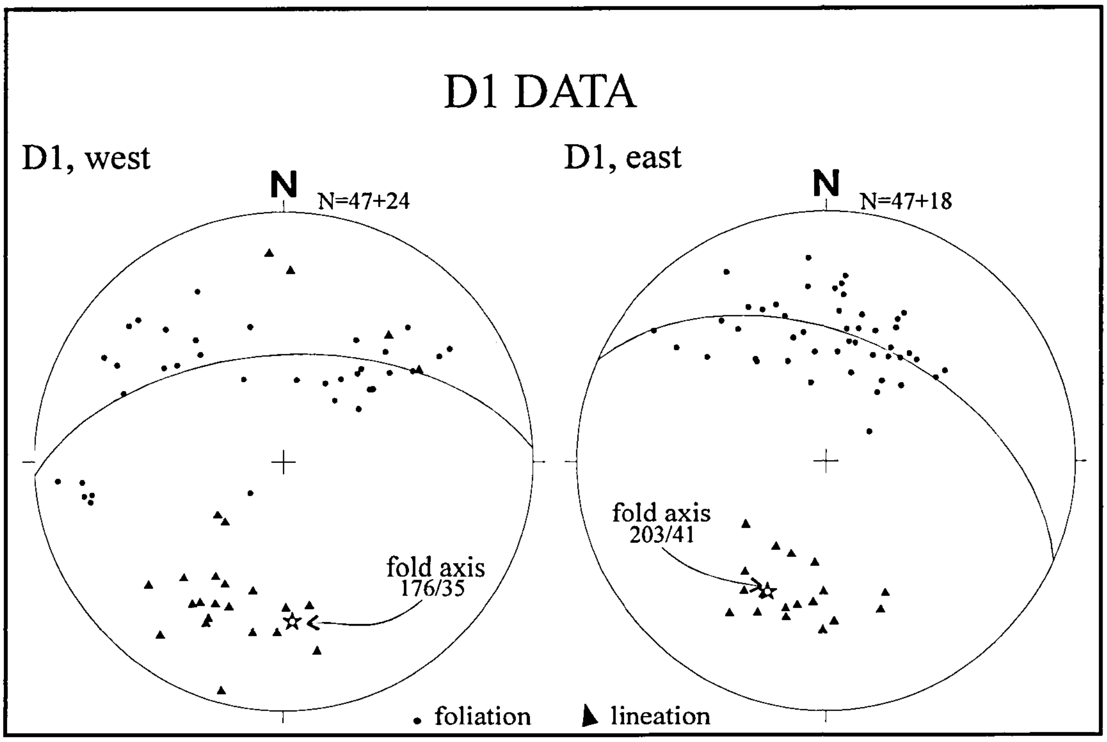


Fig. 14. Stereo plots (equal area, lower hemisphere) of D2 data.

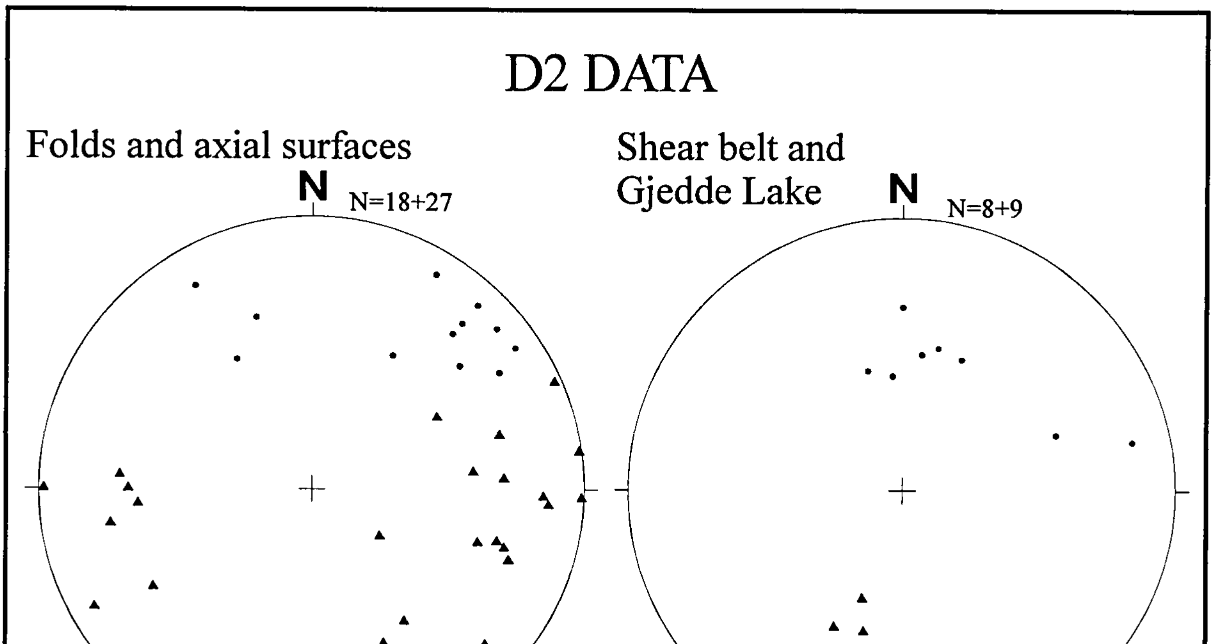


Fig. 15. Stereo plot of poles to fractures (equal area, lower hemisphere).

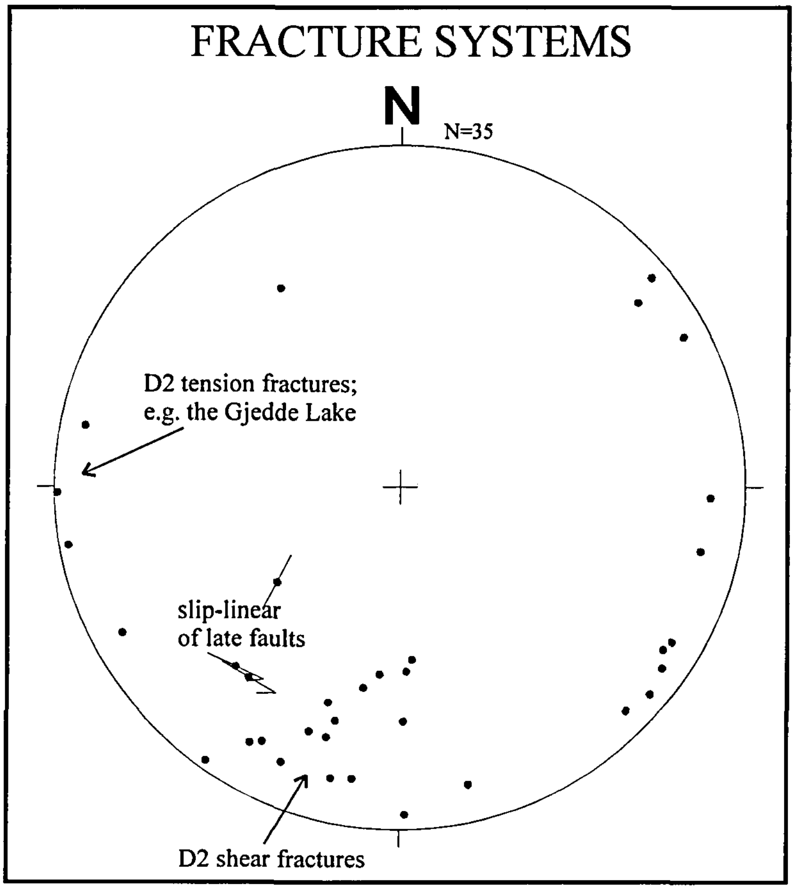
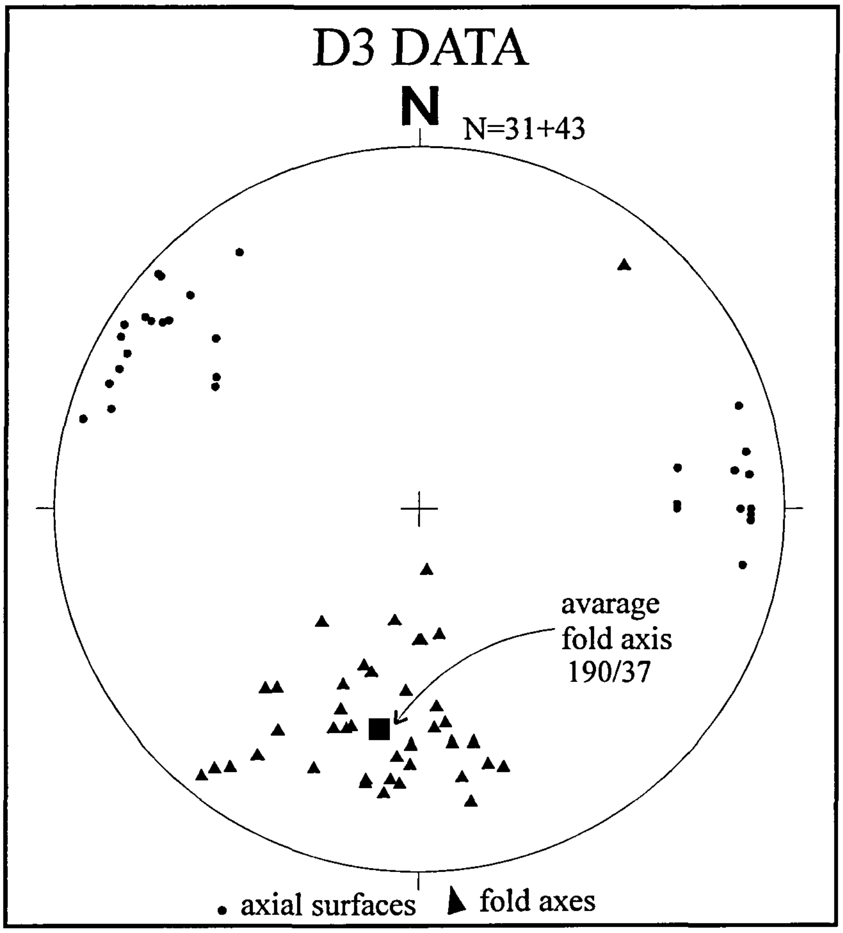


Fig. 16. Stereo plots (equal area, lower hemisphere) of D3 data.



3.4. Microscopic relationships

A limited number of samples were collected during fieldwork, all aiming to confirm the field observations of mineralparageneses along the various foliations and cleavages. Twelve thin-sections were made from the samples. They form the basis for the observations that are summarised below.

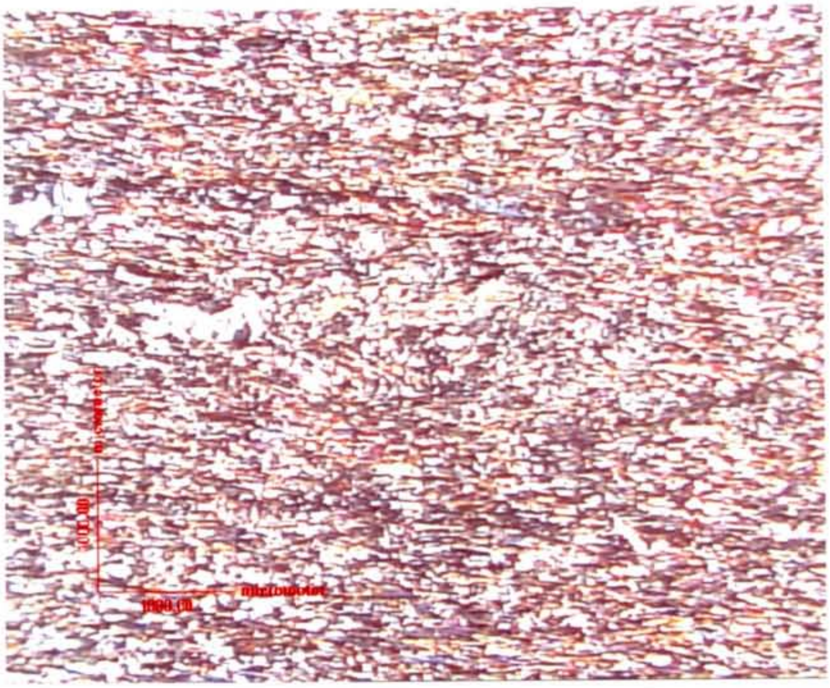


Fig. 17. Photomicrograph (crossed nicols, 25x, see scale bar) of biotite-chlorite rock (meta-volcanic flow) of the Båttjørn Formation. Note the well developed foliation.

Thin-sections from rocks in the lower part of the greenstone belt (Zone I) confirm that the S1 foliation is dominated by very fine- to fine-grained, oriented chlorite and mica in mafic, volcanic flows (Fig. 17). The same dominant mineral paragenesis has been found in rocks of Zone II. However, relics of partly retrograded amphibole occur in one thin-section. In Zone IV the S1 foliation reveals medium-grained, oriented minerals such as amphibole, mica and quartz in combination with garnet (Fig. 18). Coarse porphyroblasts of biotite and amphibole are found along the foliation; however, they also occur together with garnet as post-S1 porphyroblasts. In the latter case they are present as non-oriented clusters (see below).

Within the D2 high-train zone (Zone III) the dominant S2 foliation contains shear-lenses of quartz in a fine-grained matrix consisting of white mica and subordinate chlorite-biotite-carbonate (Fig. 19), which, in places contains syn-tectonic garnet. Similar garnet has been found in more mafic rocks, which are characterised by an amphibole-biotite matrix. Relics of the S1 foliation indicate that a similar mineralogy existed in the rocks prior to the D2 shearing (Fig. 20).

Coarse, randomly oriented porphyroblasts of biotite and amphibole have been found on top of the S2 foliation. They occur together with post/late-S2 garnet, i.e., mineral associations that have been found for the S1 foliation in Zone IV.

In Zones I and II the S2 cleavage is defined by chlorite and mica (Fig. 20), whereas quartz was dissolved and concentrated in lenses. The mica-chlorite-graphite schists and meta-volcanogenic rocks of zones I and II differ from the overlying rocks of Zone III by their lack of garnet and amphibole.

The S3 foliation shows a similar mineralogy throughout all the zones. Typical minerals that recrystallised along this foliation are chlorite and mica, and in some cases quartz (Figs. 20 and 21).

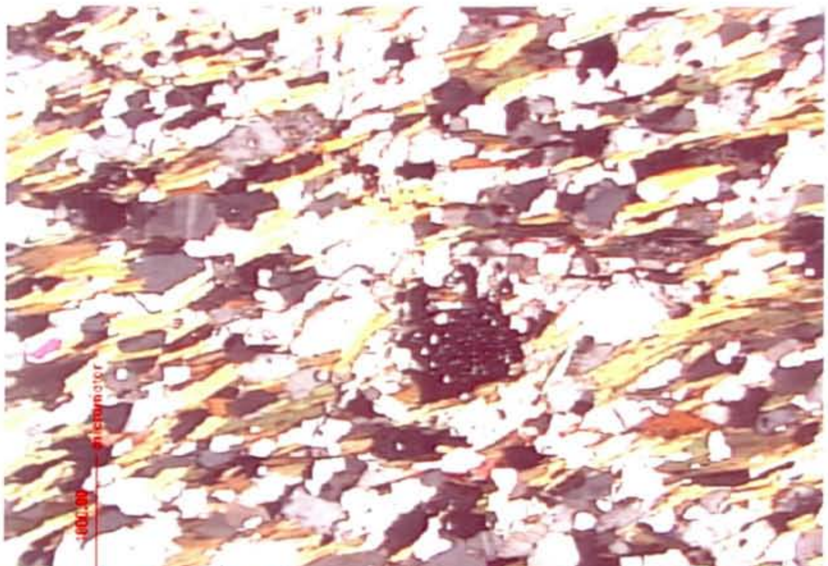


Fig. 18. Photomicrograph (crossed nicols, 25x, see scale bar) of foliated, garnet-bearing mica-gneiss of the Kobbfoss Group. Rocks in higher tectonostratigraphic positions are coarser grained than rocks in lower positions. See Fig. 17 for comparison.

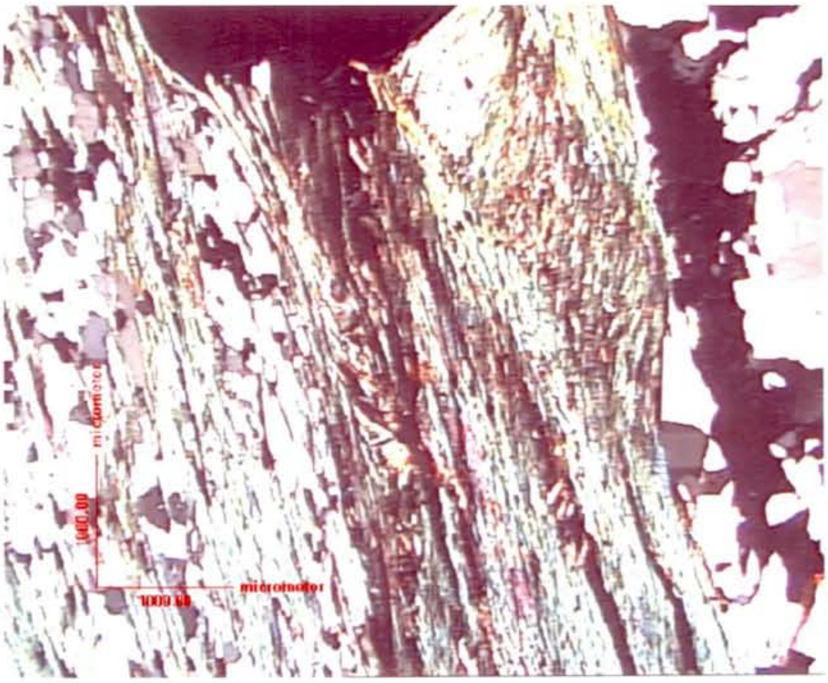


Fig. 19. Photomicrograph (crossed nicols, 25x, see scale bar) of thin-section of the D2 high-strain zone. This quartz-rich white mica(-biotite-chlorite)-schist reveals two foliations; the S1 fabric occurs in lenses that are surrounded by the S2 foliation, as displayed in the upper central-left part of the photograph.

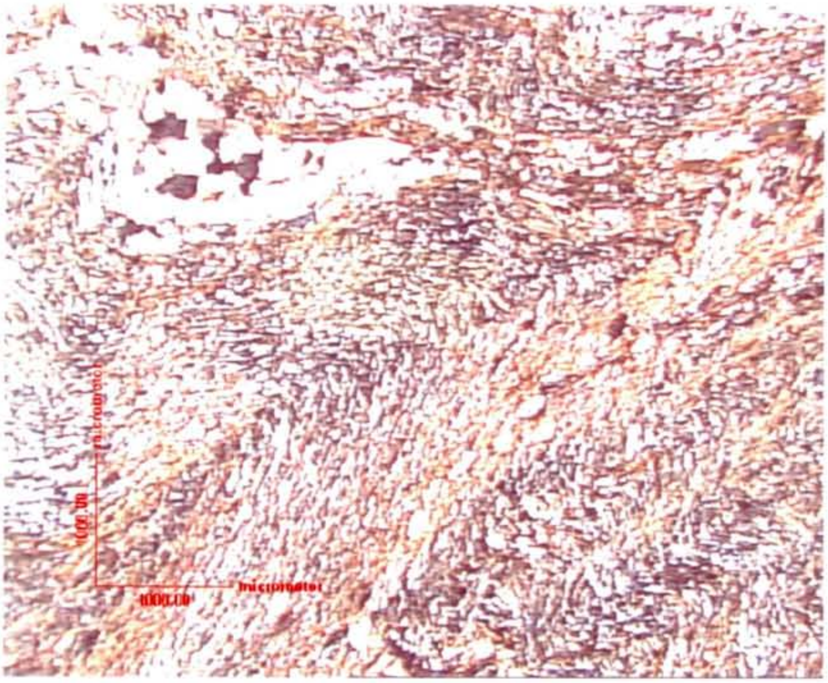


Fig. 20. Photomicrograph (crossed nicols, 25x, see scale bar) of a chlorite-mica-carbonate-schist in Zone II. Two fold-phases is evident in this thin-section: (i) Isoclinal folds with an axial plane that is parallel to the S1 foliation. One such fold is illustrated by the wedge-shaped carbonate band in the upper left corner. (ii) The S1 foliation is folded, as shown by the S2 crenulation cleavage in central parts of the photograph.

4. DISCUSSION

4.1 Regional considerations

The deformation sequence that is described herein has not been reported in the literature, which has focused on the stratigraphy and depositional environments of the Petsamo Supergroup (e.g., Melezhik et al., 1994; Sturt et al., 1994; Melezhik et al., 1995; Melezhik 1996). The main collisional phase and its implications have been discussed by Marker (1985) and Melezhik and Sturt (1994).

The most prominent structural feature in the greenstone belt is the large-scale (Figs. 3 and 4). Strain increases to the south; from the northern low-strain zone via the fold-belt to the D2 shear belt, and finally to the thick units of S1 foliated, garnet-, amphibole- and mica-bearing nappes. This development indicates either an inverted metamorphic gradient or, which is more in accordance with the M1 and M2 mineralparageneses, emplacement of higher M1 metamorphic grade rocks on top of lower M1 grade rocks during D2 thrusting (see model in Fig. 21). In the latter case the thrust-sheet, which probably contains several internal D1 thrust slices, was emplaced as a hot package of rocks upon colder rocks along the D2 shear belt, as suggested by the presence of the late/post-D2 garnet, biotite and amphibole porphyroblasts. In front of the D2 thrust-sheet the volcano-sedimentary package, already metamorphosed under lower P-T conditions, was shortened by folding and low-angle thrusts. In the lower part of the greenstone belt, low-grade metamorphic conditions prevailed throughout all the deformation episodes, as indicated by the common presence of mica and chlorite. Thus, the metamorphic conditions seem to range from greenschist to amphibolite facies from north to south in the Pasvik Greenstone Belt of northern Norway.

The kinematics of the D1 and D2 events are suggested by lineations and folds. The S1 foliation contains a stretching lineation - a lineation which is generally suggested to be aligned parallel to the direction of tectonic transport (see Fig. 13 for orientation). Although this lineation is deformed around F3 folds, the impression remains that the D1 deformation relates to a phase of shortening where rocks were transported from south to north. A similar stretching lineation is also evident along the S2 foliation of the D2 shear belt. In this case the lineation plunges to the south (Fig. 14), as is also the case for L1. Furthermore, most F2 folds in front of the D2 shear belt verge to the north. Thus, continued transport towards the north seems to be a reasonable conclusion for the D2 event. This is further supported both by the tectonostratigraphy, where older rocks are emplaced on younger units, and by shear-sense indicators along the S1 and S2 foliations. This consistency in movement pattern may be explained by a progressive evolution from the D1 to D2 stage.

The D2 shear belt of the Pasvik Greenstone Belt may correlate with a significant tectonic break on the Russian side of the border, i.e. the Poritash Fault Zone (e.g., Moralev et al., 1995). In the northern zone of the Pechenga Greenstone Belt rocks are located in a regional synform. This structure is abruptly truncated to the S-SW by the WNW-ESE-striking Poritash Fault, which separates the northern and southern parts of the greenstone belt. No detailed structural studies from this area have yet been published; thus information on this important fault is so far minimal, at least in the available western literature (e.g., Moralev et al. 1995).

The D3 deformation produced the large-scale folding of the entire package of D1 and D2 thrust-sheets and folds, and even affected the underlying basement. The S3 foliation/cleavage is defined by a mineral paragenesis of mica and chlorite, which is present throughout the area. In order to explain such equal conditions the P-T state in the entire greenstone belt and overlying nappes had to be homogenised before the D3 event. This suggests that there may have been a gap in time between the D1-D2 and the D3 stages.

The significant deformation structures that have been found for the D3 event, as well as for the older deformations, suggests that all episodes are regional in scale. It therefore seems reasonable to assume that similar deformation events may be found in other, age-equivalent greenstone belts of the northern Baltic Shield, e.g., the Karasjok Greenstone Belt (e.g., Often 1985). This belt shows a three-stage ductile to semi-ductile evolution, where the latest D3 stage is represented by an E-W shortening due to folding and localised thrusting (Braathen and Davidsen, in prep). This is a strikingly similar situation to that recorded in the Pasvik Greenstone belt.

4.2 The Gjedde Lake gold deposit in the light of the regional structures

Exposures of rocks near the Gjedde Lake are sparse, and, in actual fact, the outcrops next to the lake turned out to be blocks that had been slightly transported during the last glaciation (Ihlen, 1996). However, these blocks, as well as the drillcores, show structures which are consistent with those of the D2 shear belt (see location in Fig. 4). Typical rocks are well S2 foliated, carbonate-amphibole-biotite-chlorite-bearing schists and gneisses, and metre-wide quartzite bands. Quartzveins are common in all rocks. These veins occur in different structural positions related to a progressive path of shear-strain in the rocks, i.e., ranging from well preserved straight shear fractures, through slightly folded, tightly folded, to sheared out, foliation-parallel quartz bands. Another type of quartz-filled fracture is align parallel to the stretching lineation and probably formed as tensile fractures during deformation. These fractures are common in the quartzites and other competent rocks and lenses, and are commonly seen to be associated with brecciation along the margins of these bodies. The breccias and the quartz veins, which reflect more brittle deformation in otherwise ductilely sheared rocks, suggest either that the style of deformation was controlled by competence contrasts, or that the strain rate was high in the D2 shear belt. These quartz veins, and especially the ones aligned parallel to the tectonic transport direction, i.e. parallel to the hydrostatic gradient, probably formed good channelways for transportation of fluids. It thus seems reasonable to assume that dissolved gold could have entered the deforming rocks along such fractures and been deposited in the wall rocks.

If the above reasoning is valid, and a regional gold source has been available, then the location of the Gjedde Lake gold deposit within the D2 shear belt point towards a regional potential for similar gold occurrences. This shear belt can be followed from the Gjedde Lake both to the SW and to the east (see Fig. 3). One good marker mineral that may help to target potentially prospective areas in further exploration is that of garnet; the D2 shear belt in Norway separates garnet-bearing rocks from underlying rocks without garnet. One has to keep in mind, however, that this pattern may not necessarily have a tectonic origin. It may be geochemically controlled.

4.3 Suggestions for further structural work

Several aspects of the regional geology and deformation history seems to be important in order to gain a better knowledge of the gold potential in the Pasvik Greenstone Belt. Some suggestions are listed below:

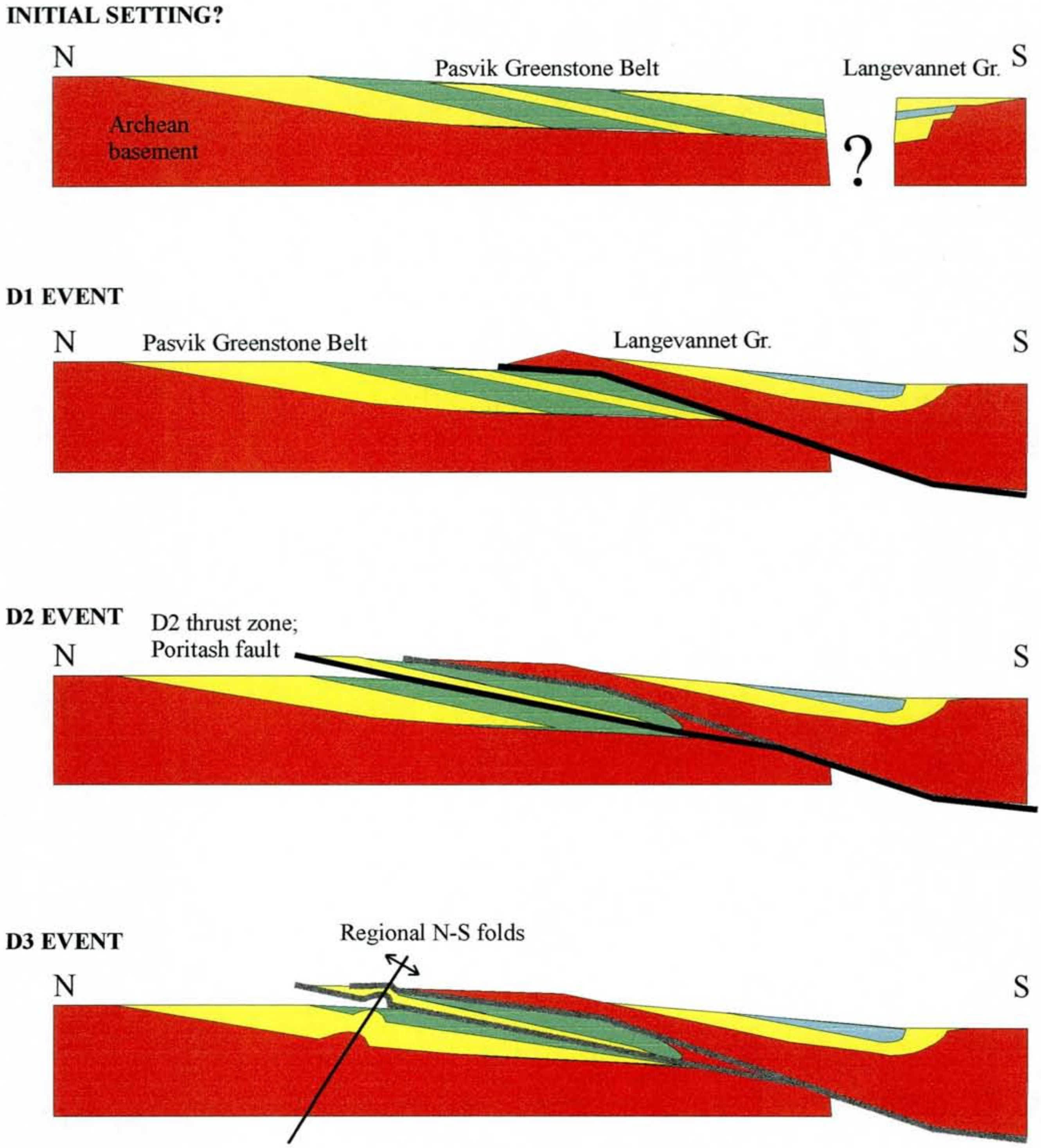
1. A study that combines structural field observations and regional geophysics. This would help in further interpretations of the regional geology and in outlining the locations of D2 structures.
2. Fieldwork that focuses on mapping the D2 shear belt further to the SW in Norway, across the F3 antiform in this area, and all the way to the Finnish border. In this area a regional E-W-striking structure, which appears to be late in the deformation sequence, affects the map pattern. This structure has not yet been studied or explored. The eastward extent of the D2 high-strain belt, i.e. on the Russian side of the border, may also deserve similar considerations.

5. SUMMARY AND IMPLICATIONS

1. The Gjedde Lake gold deposit is located in a regional D2 shear zone. This fault zone formed from N-directed thrusting of previously deformed (D1) and metamorphosed terranes in the south.
2. The gold-bearing rocks of the Gjedde Lake area may be associated with fracturesystems. These fractures relate to brittle to semibrittle deformation of competent rocks that suffered high strain rates in the regional, ductile, D2 shear zone.
3. Garnet occurs in the D2 shear zone and in overlying rocks; however, it is not present in the underlying rocks. Thus, it represents a potential marker for the location of this zone.
4. Further exploration for gold should focus on the D2 shear zone and its associated structures.

Fig.21. Tectonic model for formation of the Pasvik Greenstone Belt and associated allochthonous Archean terranes.

TECTONIC MODEL FOR THE PASVIK GREENSTONE BELT



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