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Field relations of the Holt-Saurdal-
Tyssedalsvatnet mafic complex.
Field summary 1995-1996.

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RAPPORT

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Field relations of the Holt-Saurdal-Tyssedalsvatnet mafic complex - Field summary 1995-1996.

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NGU har i flere år foretatt undersøkelser av rutilførende eklogittbergarter i det aktuelle området, men uten å gå noe særlig inn på de detaljerte geologiske relasjoner. Geologien er kompleks med en serie proterozoiske felsiske og mafiske bergarter som har gjennomgått en omfattende kaledonsk deformasjon og metamorfose. Karakteristiske bergarter er granitoide gneiser og amfibolitter i forskjellige varianter, metagabbroer, kloritt-harzburgitter, pyroksenitter og eklogitter.

Formålet med den utførte kartleggingen har vært å få bedre kontroll på feltrelasjonene i Gjørlangerområdet med særlig henblikk på proterozoiske gabbroer, som tildels er Ti-rike, og deres eklogittiserte ekvivalenter.

Hovedpunktene i dette arbeidet oppsummeres som følger: Kontaktforholdene mellom gabbro, metagabbro, eklogitter og amfibolitter i det lagdelte gabbrokomplekset i området Holt - Saurdal - Tyssedalsvatn gjenspeiler prosesser som har foregått i de dypeste deler av kollisjonssonen under den kaledonske orogenesen og den påfølgende hevning. Det lagdelte gabbrokomplekset er tolket å være protolitt til de fleste eklogitter og amfibolitter i det øst-vest gående mafiske beltet som strekker seg fra Holt til Tyssedalsvatnet. De prosesser som danner eklogitter, amfibolitter og gneisser kan forstås ved å studere overgangene fra protolittene til både de delvise og de helt omvandlede bergarter. Disse prosessene kan endre bergartenes mineralogi og struktur fullestendig. Den kaledonske metamorfosen og deformasjonen har ikke vært fullstendig. Proterozoisk gabbro og rester av et lagdelt gabbrokompleks finnes bevart i det kartlagte området. Opptreden av eklogitter av forskjellig størrelse gjennom hele området, tyder på at eklogittiseringen var gjennomgripende. Den påfølgende amfibolittisering av eklogitter og andre mafiske bergarter dominerer bergartene i området og er strukturelt assosiert med en foldet Ø-V foliasjon. Denne amfibolittiseringen relateres til den sen-orogene ekstensjonskollapsen av Kaledonidene.

Emneord:		
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FIELD RELATIONS OF THE HOLT-SAURDAL-TYSSEDALSVATNET MAFIC COMPLEX.

FIELD SUMMARY, DALSFJORD AREA 1995-1996

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March 1997

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CONTENT

1: INTRODUCTION

One area south of Dalsfjorden was mapped at the 1:20 000 scale during fieldwork in June 1995 in connection with the NGU-project "Rutilprovinser i Norge". The purpose of this mapping was to produce a general geological map of the south side of Dalsfjorden, to follow up the geophysical maps of the area and to outline the geological history. Connections should be made to the fieldwork of E. Eide, L.P. Nilsson, Ø. Skår and M. Erambert in adjoining areas during 1995 and 1996. The mapped area is located east of Langesjøen, between Langesjøen and road 607, from the Holt farm in the north to the Ramsgrø farm in the south (UTM E29450-E29800, N679650-680060). In addition, more detailed mapping on the scale 1:5 000 was done in June 1996 in a smaller area SW of Tyssedalsvatnet (UTM E29770-29900, N680080-680160), for the purpose of obtaining better control of the metamorphic and structural transformations of the Precambrian layered metagabbro during Caledonian eclogitization and amphibolitization. Geological maps of the mapped area between Holt and Ramsgrø and the area SW of Tyssedalsvatnet are presented in the appendix, together with a geological overview map of the outer part of Dalsfjorden.

2: GEOLOGICAL FRAMEWORK OF THE DALSFJORD AREA

The Western Gneiss Region (WGR) of the Sunnfjord area was first described by Skjerlie (1969). In the Dalsfjord region, the dominant rocks of the WGR are mainly granitoid gneisses and amphibolites, in addition to metagabbros, chlorite-harzburgites, pyroxenites and different types of eclogites (Cuthbert 1985). The metamorphic assemblages and structure of these rocks are assumed to have formed mainly during Caledonian orogenesis and the subsequent extension (Andersen & Jamtveit 1990, Andersen et al. 1991). Some Precambrian rocks have, however, preserved their original mineralogies, textures and structures (Engvik 1995, Engvik et al. in prep.). Skjerlie & Pringle (1978) provided a Rb/Sr whole-rock isochron of 1625±75 Ma for gneisses in Sunnfjord. Gromet & Andersen (1994) have dated granitic rocks from Bårdsholmen in Dalsfjorden at 1000±10 Ma by the $^{207}Pb/^{206}Pb$ zircon evaporation method. Most of the rocks on the north side of Dalsfjorden are mylonites formed by penetrative top-to-the-west rotational deformation in the Nordfjord-Sogn-Detachment zone (Norton 1986, Andersen & Jamtveit 1990, Hveding 1993). An U-Pb zircon age of 1640.5±2.3 Ma (Skår et al. 1994) from a mylonitic quartz diorite in the detachment zone suggests that the protoliths

of the detachment mylonites originally were part of the WGR. The rocks in the hanging wall of the detachment constitute the Caledonian allocthons unconformably overlain by the Devonian sedimentary basins (Brekke & Solberg 1987, Andersen et al. 1990, Osmundsen 1996).

3: MAP DESCRIPTION

The regional map (appendix) shows on the south side of Dalsfjorden an E-W trending mafic belt of amphibolites, metagabbros and eclogites, interlayered with thin horizons of granodioritic gneiss. This mafic belt includes the rutile-rich Saurdal eclogite, the metagabbro of Holt and SW of Tyssedalsvatnet, in addition to many other smaller metagabbros and eclogites. The mafic complex is interpreted as an originally layered gabbroic complex based on field observations of preserved igneous layering, on cumulate textures in preserved metagabbros, and frequent occurence of mafic and ultramafic layers in the area. Rutile-rich eclogites are preserved in the area, especially the Saurdal eclogite (Korneliussen 1994), and some very garnet+rutile-rich layers occur in the hills SW of Tyssedalsvatnet (described below). This mafic E-W-trending belt is described as the Flekke unit by Cuthbert (1985), and interpretated as a basic-ultrabasic intrusive complex. The mapping work and the field report concentrate on this E-W-trending mafic belt with the purpose of establishing good control on the geological history of the original layered gabbroic complex.

The mapping of the Holt-Ramsgrø area was done at the 1:20 000 scale on a magnification of the 1:50 000 map M711, sheet 1117 I. In the Holt-Ramsgrø area, a metagabbro occurs around the Holt farm. The metagabbro is enveloped by amphibolites which dominate the northern part of the mapped region. The amphibolites are interlayered with horizons of granitoid gneiss of granodioritic/tonalitic composition. A folded E-W-trending foliation dominates the area and the thin horizons of gneiss appear folded into the amphibolites. Due to relatively poor exposure especially of the amphibolites, the trend/termination of the thin gneiss horizons are difficult to map. From Tempelet and southwards, a second type of granoitoid gneiss, also with an E-W-trending folded foliation, dominates. These latter granitoid gneisses are richer in K-feldspar while the granodioritic/tonalitic gneisses seem to be connected to the mafic Holt-Saurdal-Tyssedalsvatnet complex. The contact between the two granitoid gneisses is

uncertain, and could be drawn further to the north than indicated on the map. The southernmost mapped area around Ramsgrø, is part of the large Drøsdal eclogite. Smaller eclogite lenses (often too small to be mapped at this scale) are present throughout the area, both in the amphibolites and gneisses. Some ultramafic horizons are found in the amphibolites. The gneisses also contain amphibolite lenses.

The detailed mapped area SW of Tyssedalsvatnet was done on a 1:5 000 scale on economic map, sheet AG 077-5-3. This area is located inside the mafic Holt-Saurdal-Tyssedalsvatnet complex. Gabbro and metagabbro with preserved magmatic layering dominate the southern part, but also include some eclogite lenses. A shear zone of mylonites with interlayered eclogite and amphibolite divides the metagabbro from the foliated amphibolites. Horizons of granodioritic/tonalitic gneiss are found in the foliated amphibolites, in addition to small eclogite and ultramafic lenses. In the northern part, a shear zone divides an eclogite from the amphibolites. This eclogite is deformed, but shows clear textural relationships to the metagabbro (described below). The foliated amphibolites and gneiss are folded with dominantly E-W-trending fold axes and foliation. Structural data from the area SW of Tyssedalsvatnet will not be presented in this report, but will be addressed during further work.

4: ROCK DESCRIPTION

4.1: Layered, magmatic metagabbro

Preserved parts of a layered metagabbro occur different places in the mafic E-W-trending belt between Holt and Tyssedalsvatnet. The metagabbro is generally metamorphosed statically and contains mineral assemblages representative of both amphibolite and eclogite facies.

Gabbro

Gabbro with preserved magmatic minerals and textures occurs in a restricted part of the mapped area SW of Tyssedalsvatnet. The gabbro exhibits preserved magmatic layering and is an equigranular, medium-grained rock with a preserved subophitic texture. The gabbro is composed of plagioclase, clinopyroxene, orthopyroxene and olivine with spinel and Fe-oxide as accessory minerals. Plagioclase is the dominant mineral and appears in subhedral, lath-

shaped form and weaked laminated. The pyroxenes and olivine occur as interstitial aggregates between plagioclase crystals, and olivine sometimes occurs as rounded grains enclosed in pyroxenes.

Metamorphic overprinting - amphibolite and eclogite facies

The layered gabbro is converted to statically hydrated metagabbros in amphibolite or eclogite facies. At Holt and Tyssedalsvatnet the metagabbro is usually coronitic. The coronitic metagabbro is highly heterogranular, but has a coarse texture with almandine-rich red garnets constituting 0.1-0.5 mm thick coronas around mafic minerals (fig. 1). The mafic minerals inside the coronas are mainly amphibole, but also occur with talc. Minor calcite, rutile and apatite are also present inside the coronas. The pale green matrix which looks white on weathered surfaces, surrounds the coronas and is composed of very fine-grained amphibole, kyanite, paragonite, garnet and epidote. Large parts of the coronitic metagabbro have omphacite in the matrix instead of amphibole, and have reequilibrated under eclogite facies conditions. Omphacite replaces also locally amphibole inside the coronas. The two metamorphic facies (amphibolite and eclogite) of the metagabbro are difficult to distinguish in the field, and are therefore mapped together as "metagabbro".

Magmatic layering

The metagabbros show compositional layering on a scale that ranges from 0.1 m up to about 100 m or more. The layering is gradual and the compositions vary from dark gabbroic to lighter anorthositic layers; this layering is interpreted as original magmatic layering and is supported by preserved igneous textures in thin section. In the coronitic metagabbro at Holt, brown mafic layers of 0.5 m thickness occur frequently (fig. 2); these layers are strongly hydrated and composed of fine-grained relict orthopyroxene, talc, serpentine(?), chlorite, amphibole and a very high content of oxides (ilmenite/magnetite). In addition, pyroxenite layers of up to 10 m thickness also show a gradual transition to metagabbro (fig. 3). The pyroxenite comprises mainly pyroxene with large unoriented crystals usually 5-10 cm long, but which can be up to 40 cm x 50 cm in size; the pyroxenite also has locally high oxide contents (ilmenite/magnetite). The pyroxenite layers show minor metamorphic alteration via replacement of minor plagioclase by garnet, often adjacent to pale-green relics of the

originally black pyroxene. In the mapped area SW of Tyssedalsvatnet, gradual, rythmic layering on c. 0.1 m scale occurs in different places (fig. 4). As exhibited in figure 4 the layering can be clearly seen as a concentration of dark contra white minerals with a sharp contact in the lower part and gradual enrichments of white minerals upwards. Fine-grained, massive eclogite layers occur in the metagabbro east of Nipene. These 0.1-1 m thick layers are very garnet+rutile-rich in addition to lesser quantities of omphacite and amphibole. The massive eclogite layers appear parallel (N-S-trending) the magmatic layering of the gabbro and are interpreted as eclogitized versions of original mafic magmatic layers in the area.

Eclogite and amphibolite facies deformation

The coronitic appearance of parts of the metagabbro implies static metamorphism of the gabbro (Mørk 1985). Locally, deformation of the coronas can be linked to the eclogitization process. Figure 5, for example, shows a deformed LS-tectonite eclogite from Veslefjellet SW of Tyssedalsvatnet, which bears clear connections to the metagabbro assemblage via distinct domains of garnet, amphibole and omphacite.

An about 10 m thick shear zone which divides the metagabbro from the foliated amphibolite can be followed throughout the mapped area SW of Tyssedalsvatnet (see map of Tyssedalsvatnet area). This shear zone constitutes a mylonite that exhibits two strongly deformed lithologies in eclogite and amphibolite facies respectively. Preserved lenses of metagabbro inside the mylonite zone indicate derivation of the mylonites from metagabbro. The grain-size of the metagabbro is reduced from medium- to fine-grained and the intense deformation gives the mafic complex a new, strong, planar foliation fabric (fig. 6). The eclogite-mylonite is generally equigranular with strongly oriented omphacite, amphibole and clinozoisite in addition to garnet and minor rutile, pyrite, white mica and quartz. Observed shear-sense indicators such as shear-bands, rotated porphyroclasts and rotated boudins show both dextral and sinistral movement in the shear zone and indicate bulk non-rotational deformation. In addition to the main shear-zone, smaller eclogite shear zones also cut sharply through the metagabbro (fig. 7). These occurences of eclogite shear zones resemble the eclogite shear zones cutting the granulite anorthosites described from Holsnøy in the Bergen Arcs (Austrheim 1987).

Parts of the coronitic metagabbro suffered later amphibolite facies retrogression, documented by green amphibole replacements on the garnet coronas. The amphibolitization occurs both as restricted zones in the coronitic metagabbro and along the border of the mapped metagabbro at Holt. This younger amphibolite facies retrogression is characterized by foliated or LS-tectonite amphibolites that developed during deformation; the LS-tectonite amphibolites are the dominant rock types in the mafic E-W-trending complex between Holt and Tyssedalsvatnet. Both the rock fabric and the occurence of green amphibole in the amphibolites distinguish them from the black amphibole-bearing, statically hydrated metagabbro. The later amphibolitization of the metagabbro is described in sections 4.3 and 6.2.

4.2: Other eclogites

The eclogites of the Dalsfjord area are petrographically, texturally and structurally heterogenous. The eclogites occur throughout the Dalsfjord area, usually as lenses in amphibolites and gneisses with different mineral assemblages and sizes ranging from 1 dm up to more than 1 km^2. In addition to eclogitized shear zones and mylonites (described above), coronitic metagabbro (described above), very fine-grained eclogite dykes and "eclogite facies melange"-lithologies also occur in the region (described by Engvik 1995 and Engvik et al., in prep).

The Drøsdal eclogite

Only a small part of the Drøsdal eclogite was mapped on the south side of Ramsgrøheia, and was not studied in detail. The Drøsdal eclogite has some fine-grained, homogeneous, dark garnet-rich zones with minor omphacite and amphibole, but is dominantly a coarse-grained, lighter-coloured eclogite with the paragenesis garnet+omphacite+kyanite+quartz+white mica+amphibole+zoisite. This eclogite is foliated and has a distinct omphacite lineation. Veins up to 0.2 x 1 m wide occur frequently, and most contain the assemblage quartz and kyanite; however, veins with white mica, omphacite and amphibole are also present.

Fine-grained eclogite dykes in the coronitic metagabbro, Holt

Very fine-grained, light-coloured eclogite occurs as ≤7 m thick dykes cutting through the metagabbro of Holt. The eclogite dykes are composed of fine-grained garnet, omphacite, amphibole and some white mica. Rutile, apatite and zircon appear as very fine-grained accessory minerals, and rutile is more abundant than in the surrounding metagabbro. In the most fine-grained parts of these eclogites, the rock has a grey colour, and garnet and omphacite are indistinguishable in handspecimen. The contacts between the metagabbro and the eclogite dykes are usually straight and abrupt but locally, a bending of foliation in the metagabbro shows a shear-strain gradient over approximately 1 m in the direction of the dyke. Despite the general lack of deformation in the coronitic metagabbro, the fine-grained dykes have a locally strong fabric defined by strings and bands of garnet, rutile and apatite that run subparallel to aligned omphacite, amphibole and mica. The dykes have varying orientations, but show a preferred E-W trend.

Smaller eclogite lenses in amphibolites and gneisses

Eclogites occur as lenses in amphibolites and gneisses (e.g. locality 4.25). The lenses vary in size from dm to hundreds of m, but are usually about 0.5-2 m. The eclogite lenses occurring in the amphibolites and gneisses are fine-grained and dominated by garnet and omphacite. The fine-grained eclogites have both a foliation and a lineation fabric and the contact to the surrounding rock is usually sharp. The foliation of the gneisses and amphibolites bends around the eclogite lenses and the lens margins are often amphibolitized (fig. 8). On the SE part of Tempelet, eclogite and amphibolite lenses can be traced parallel to the foliation. Eclogite lenses also occur without tectonitized margins when they are observed as remains within amphibolite. The eclogite lenses of this latter type were identified in locality 4.08 and are 0.5-1 m in diameter. In the valley between Tempelet and Ramsgrøheia (loc. 5.14), a dark, massive eclogite lens of at least 50x300 m occurs. The grain size varies but is usually fine. A local foliation in the eclogite is defined by thin (< 1 cm) amphibolitic horizons, which are parallel the foliation in the surrounding gneiss.

4.3: Amphibolites

Amphibolites are the dominant rock type in the E-W-trending mafic belt south of Dalsfjorden, and occur together with eclogites and metagabbros (see above section 4.1:

Eclogite and amphiboilite facies deformation). In the mapped area between Holt and Ramsgrø, amphibolites appear north of Tempelet folded together with thin horizons of gneiss. South of Tempelet, amphibolites are found along margins of eclogites and as lenses and layers in gneiss. Amphibolites constitute also a large part of the area mapped in detail SW of Tyssedalsvatnet. The amphibolite consists of amphibole and plagioclase with varying amounts of white mica, chlorite, epidote and garnet. The foliation varies in intensity and is exhibited in outcrop as alternating green amphibole- and white plagioclase-rich layers with thicknesses from 1 to 10 cm (fig. 9). In areas with lesser developed foliation, amphibolite consists of coarse, flattened domains (< 5 cm) of respectively green amphibole and white plagioclase that constitute a lineated fabric (L>S-fabric). Shear-sense indicators like shearbands and rotated boudins show both sinistral and dextral movement. The outcrop structures and textures in the lesser deformed parts (L>S-fabric) of the amphibolites resemble the metagabbro and exposed transition from metagabbro to foliated amphibolite is preserved at several localities by Holt (locality 2.01, 3.03, 3.07, fig. 10). This leads to an interpretation of the amphibolites as amphibolitized and deformed metagabbros, as described and discussed in section 4.1 above and 6.2 below. Amphibolites can also occur more rarely as more homogeneous, foliated grey rocks with the assemblages quartz+plagioclase+amphibole+biotite±garnet, often banded with more felsic layers.

4.4: Ultramafic lenses and chlorite-schist in the amphibolites

Some ultramafic lenses and horizons up to 10 m in thickness are observed in the foliated amphibolites. SW of Tyssedalsvatnet, the ultramafics are rich in serpentinite and oxides, while in the Holt area horizons of chlorite-schist occur. Measurements of magnetic susceptibilities of the chlorite-schist are very high (see field data table, loc. 6003.04), and could be responsible for the high magnetic anomalies on the geophysical aeromagnetic map from the area. While the amphibolite is interpreted as the amphibolitized part of the metagabbro, the serpentine- and chlorite-rich schists are likely to be retrograded remnants of the ultramafic and pyroxenitic layers of the metagabbro complex.

4.5: Granitoid gneisses

Together with the amphibolites, the granitoid gneisses are the dominant rock types areally in

the mapped area between Holt and Ramsgrø. In the area north of Tempelet, the gneisses have a granodioritic/tonalitic composition and usually occur as 10-20 m horizons folded together with the amphibolites in the E-W-trending mafic belt. In addition, a larger area just north of this mafic belt, from Hellevik to Tyssedalsvatnet consists of granodioritic/tonalitic gneiss. The gneiss which is intermediate- to coarse-grained, comprises quartz and feldspar with varying amounts of biotite which gives the gneiss a white to grey colour depending on the amount of biotite. A planar foliation, defined by biotite, has varying intensities and small folds are sometimes observed. Shearbands indicate both sinistral and dextral shear sense. An augen-gneiss protolith for the granodioritic/tonalitic gneiss was identified in several places, e.g. on the north side of Saurdalsvatnet by Hammerset. At this locality the coarse-grained augen-gneiss is deformed to the finer-grained, biotite-rich gneiss with the planar foliation characteristic of the granodioritic/tonalitic gneiss. Amphibolites and eclogites occur as lenses and layers in the gneiss, with thicknesses from cms up to 8-10 m thick, but usually < 0.5 m. The layers are folded in the gneiss, and the lenses occur as boudins and isoclinally folded layers. The mafic rocks are often in zones subparallel to the gneissic foliation (e.g. locality 5.19). One large eclogite lens was observed in the gneiss in the valley west of Liane (locality 5.14). This eclogite body can be followed for 300 m and is 50-100 m thick (section 4.2).

From Tempelet and southwards, the gneiss has a more granitic composition with the mineral assemblage quartz, K-feldspar, plagioclase and biotite. The granitic gneiss is also intermediate- to coarse-grained with a well-developed foliation defined by biotite. The biotite occurs locally in layers up to 10 cm thick. The K-feldspars occur often as coarse-grained augen or more rarely as < 20 cm-thick pegmatitic layers parallel to the foliation. The granitic gneiss show intense deformation, indicated by dense folds that refold the planar foliation (e.g. Ramsgrøheia). Shear-bands and asymmetrical boudins are also observed and show both sinistral and dextral shear-senses. Few lenses of eclogite and amphibolite are observed in the granitic gneiss, but towards the contact with the big Drøsdal eclogite, the content of mafic lenses, layers and mafic minerals increases.

5: SHORT STRUCTURAL DESCRIPTION

While original magmatic texture and layering locally are preserved in metagabbros, a folded

E-W-trending foliation dominates the Dalsfjord area. The foliation is dominating the amphibolites and gneisses, although with some differences in degree of development (described in section 4). As described in section 4 the structures of eclogites are heterogenous and exhibit as mylonitic, foliated and lineated fabric as well as a static coronitic texture.

Structural data collected between Holt and Ramsgrø are presented in stereographic projections in figure 11. The strike of the foliation is dominantly east-west oriented with rather steep dip (figure 11a). The best fit great circle to the foliation poles yielding a mean fold axis of 086/08. This accords with the main group of fold axes plotted in figure 11b. The measured mineral lineations on the foliation planes of the amphibolites and gneisses also have a similar orientation to the fold axes (fig. 11c). Measured mineral lineations of omphacite in eclogites have trends like the mineral lineations in the gneisses and amphibolites but with a preferred westward plunge (fig. 11d). Because the margins of the eclogite lenses are cut by the foliated amphibolites and gneisses, the fabric inside the eclogites is related to an earlier tectonic and metamorphic event than the foliation of the amphibolites and gneisses.

The foliated rocks in the mapped area are strongly folded, with flank width varying in size from some cm to larger folds of several hundreds of meters (e.g. locality 4.07-4.10). The smaller folds as shown in figure 12 can be described as parasitic folds, and occur frequently in the gneisses. Especially the granitic gneiss show intense folding, e.g. at Ramsgrøheia where dense folds refold the planar foliation. Shear-sense indicators as dextral and sinistral shear-bands, rotated boudins and porphyroclasts are observed both in foliated amphibolites and gneisses throughout the area, as well as in the mylonitic eclogite shear zone by Tyssedalsvatnet.

6: WHAT CAN BE CONSTRAINED ABOUT THE GEOLOGICAL HISTORY?

The rocks in the W and NW parts of the WGR have been through pervasive deformation and metamorphism through several phases of Caledonian orogenesis (Griffin et al. 1985, Andersen et al. 1991). The occurrence of eclogites indicates metamorphism of rocks at depths of more than 40 km, and implies that the W and NW part of WGR was formerly part of the

root zone of the Caledonian orogen (e.g. Griffin et al. 1985). The eclogites, amphibolites and the fabric of different gneisses in the Dalsfjord area are assumed to be the result of this event, but some parts of the pre-Caledonian protoliths have survived. The processes which generated the eclogites, gneisses and amphibolites can be understood by studying the transition from the protoliths to the enveloping rocks. The following examples are representative of processes within the root of the collision zone during Caledonian orogenesis and subsequent exhumation. To understand the complex metamorphic and deformational processes, it is necessary to establish a ground field understanding of the relationships between the metamorphic rocks of different facies and their preserved protoliths.

6.1: Precambrian protoliths and Caledonian eclogitization

In the mafic belt trending E-W from Holt to Tyssedalsvatnet, lenses of metagabbro occur with a preserved magmatic layering of pyroxenitic - gabbroic - anorthositic composition. Parts of the lenses consitute a gabbro with a primary mineralogy of plagioclase, pyroxene and olivine. The gabbro has suffered static metamorphism under both amphibolite and eclogite facies conditions. The amphibolitization proceeded via the hydration of the pyroxene to black amphibole and of olivine to talc, while the plagioclase was replaced by white mica, epidote, amphibole and garnet. This hydration process is interpretated to be a pre-eclogite facies amphibolitization, and can be distinguished from the later post-eclogite facies amphibolitization by lack of deformation and a black colour of the amphiboles in the older amphibolite facies metagabbro. The eclogitic facies part of the metagabbro is represented by the coronitic garnet around amphibole+talc, in addition to matrix omphacite white mica, kyanite and epidote in equilibrium with the garnet coronas. The mafic minerals inside the garnet coronas are also locally replaced by omphacite.

The coronitic appearance indicates a static eclogitization of the gabbro (Mørk 1985), but local deformation of the coronas did occur simultaneously with this eclogitization. The shear zone by Tyssedalsvatnet indicates a complete transformation of the metagabbro to amphibolite and eclogite with deformation marked by reduction in grain size and strongly planar foliation.

The occurrence of eclogites as layers and lenses in all the different rock types in the Dalsfjord

area indicates that the eclogitization in the area was regional and pervasive. The size of the Drøsdal eclogite shows that the eclogitization also completely transformed large rock bodies to eclogite. Variation in mineral parageneses and texture of different eclogites throughout the mapped area implies that the eclogites have different protoliths. The variations in fabric of different eclogites (e.g. coronitic texture of Holt metagabbro, lineation of Drøsdal eclogite and mylonitic fabric of shear zone by Tyssedalsvatnet), indicate that the strain regime during eclogitization was heterogeneous. A high degree of transformation of the rocks during eclogitization cause difficulties in recognizing the protolith of different eclogites, for example of the Drøsdal eclogite.

6.2: Late-Caledonian amphibolitization and formation of the E-W-oriented foliation

The most common rocks in the mapped area are amphibolites and gneisses with a folded E-W oriented foliation. Textures of the amphibolites and their contact relationships with the eclogites and metagabbros they enclose can be used to interpret retrograde processes in the area, and to conclude that a second amphibolitization episode followed the eclogitization.

Along its margin, the metagabbro at Holt was amphibolitized in a regime of flattening deformation. Transitions between coarse-grained coronitic metagabbro, amphibolite with textures resembling the coronitic metagabbro, amphibolites with flattened domains, and thinly banded amphibolites with a lineated and foliated (LS) fabric were observed at different localities. The pictures in figure 10, taken near the contact between the coronitic metagabbro and amphibolite, illustrate this metagabbro-amphibolite transition texture. These amphibolites also outcrop in the mapped area SW of Tyssedalsvatnet as characteristic LS-tectonite representing deformed and amphibolitized metagabbro. In more deformed parts, the amphibolites display a strong parallel foliation with alternating white and green horizons. The transitions at the margins of the Holt metagabbro and the texture of the amphibolites resembling the metagabbro in both the Holt-Ramsgrø and Tyssedalsvatnet areas imply that many of the mapped amphibolites in the area developed by deformation and metamorphism of coarse-grained metagabbro.

Numerous small eclogite lenses in the region are enveloped by amphibolite or amphibolite

facies gneisses. Usually the eclogites occur as lenses with tectonized and amphibolitized margins, but remnants of eclogite in amphibolite without movement on contacts is also observed. Both these occurences illustrate that a second amphibolite facies metamorphism postdates the formation of the eclogites. The amphibolite facies rocks are characterized by the dominant E-W trending foliation, while the fabric in the eclogites is cut by the amphibolite facies fabric. Amphibolite facies foliation which cuts an older eclogite facies fabric is also described by Andersen & Jamtveit (1990) in the Sunnfjord area. The present work shows that amphibolitization was fairly pervasive and that the gabbros, metagabbros and eclogites that survived the amphibolitization are preserved as small lenses. The pervasive amphibolitization in the coastal areas of WGR discussed by Andersen et al. (1991) was attributed to the late-orogenic extensional collapse of the Caledonian orogen.

6.3: Conclusions

- Contact relationships and metamorphic transitions between gabbros, metagabbros, eclogites and amphibolites in the layered metagabbroic complex of Holt-Saurdal-Tyssedalsvatnet represent processes active in the root of the collision zone during Caledonian orogeneses and subsequent exhumation.
- The layered gabbroic complex is interpretated as a protolith for most eclogites and amphibolites of the E-W-trending mafic belt from the Holt area to Tyssedalsvatnet.
- The processes making the eclogites, gneisses and amphibolitic rocks can be understood by studying the transition from the protoliths to partially or totally metamorphosed rocks.
- Processes that occured in the deep crust of the Caledonian orogen change sometimes completely the mineralogy and structure of the protoliths. The Caledonian eclogitization was pervasive but relics of preserved protoliths indicate that the eclogitization was not always complete. The eclogitization process is heterogenous, indicated by different structural states of the eclogite facies rocks.
- The development of the foliated or LS-tectonite amphibolites post-dates the eclogitization, and is distinct from an earlier pre-eclogite amphibolitization. The late amphibolitization is pervasive in the area and is structurally characterized by a folded E-W-trending foliation. These late pervasive amphibolitization is related to the late-orogenic extensional collapse of the Caledonian orogen (Andersen & Jamtveit 1990, Andersen et al. 1991).

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APPENDIX:

Geological regional map of the Dalsfjord area

Map over the Dalsfjord area

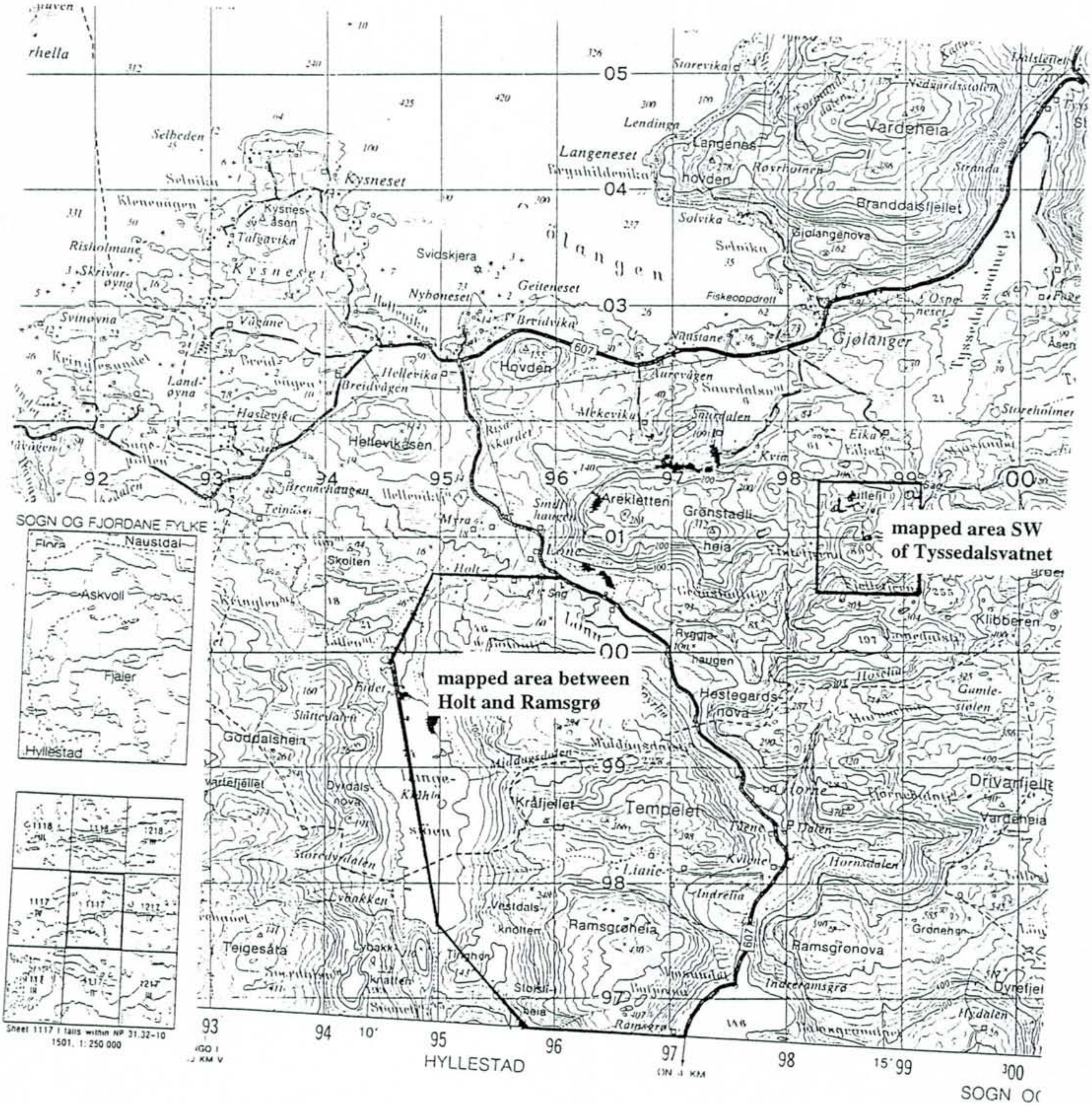
Geological map of the Holt-Ramsgrø area (1:20 000)

Locality map of the Holt-Ramsgrø area

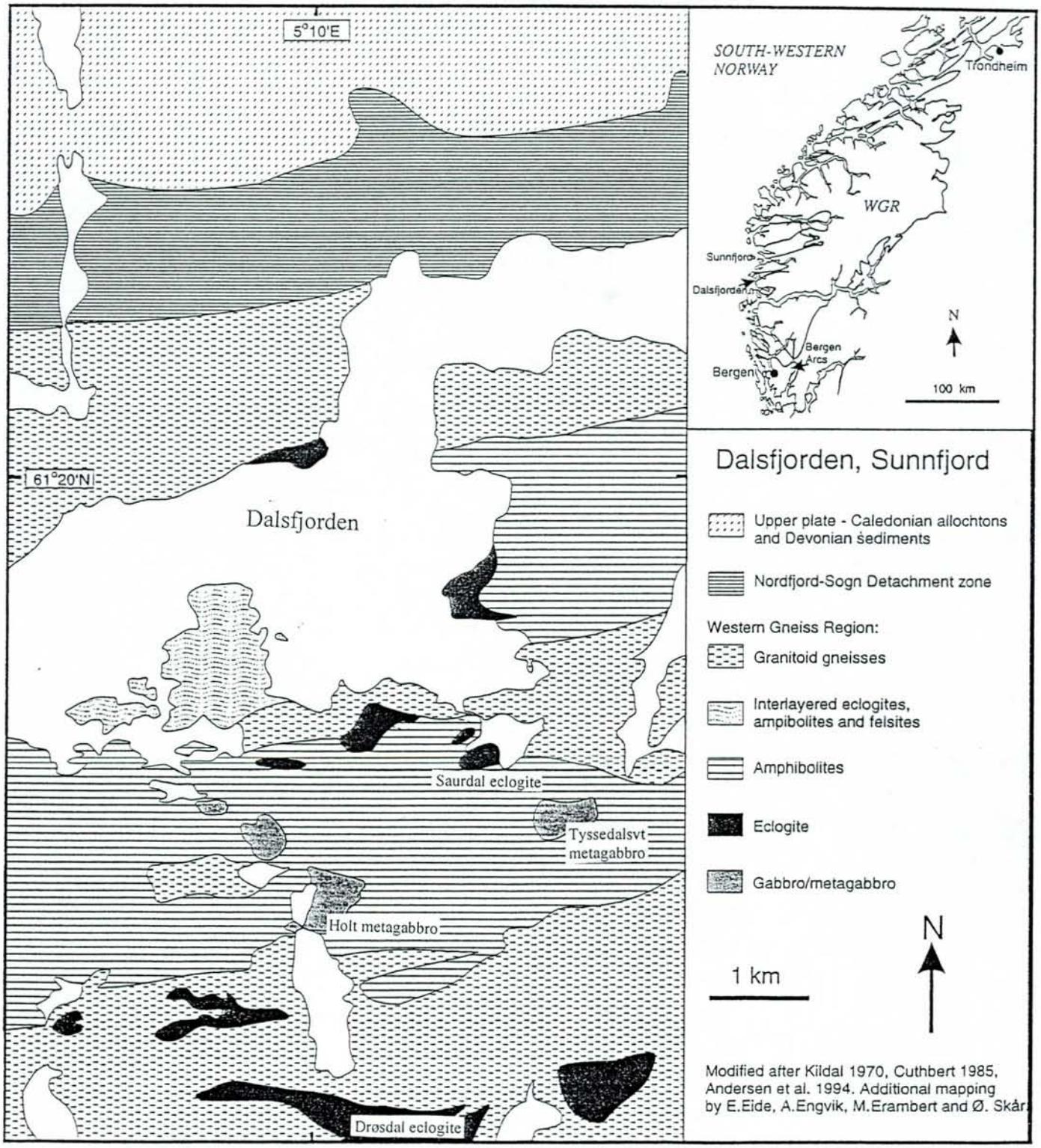
Geological map of the area SW of Tyssedalsvatnet (1:5 000)

Figures 1-12

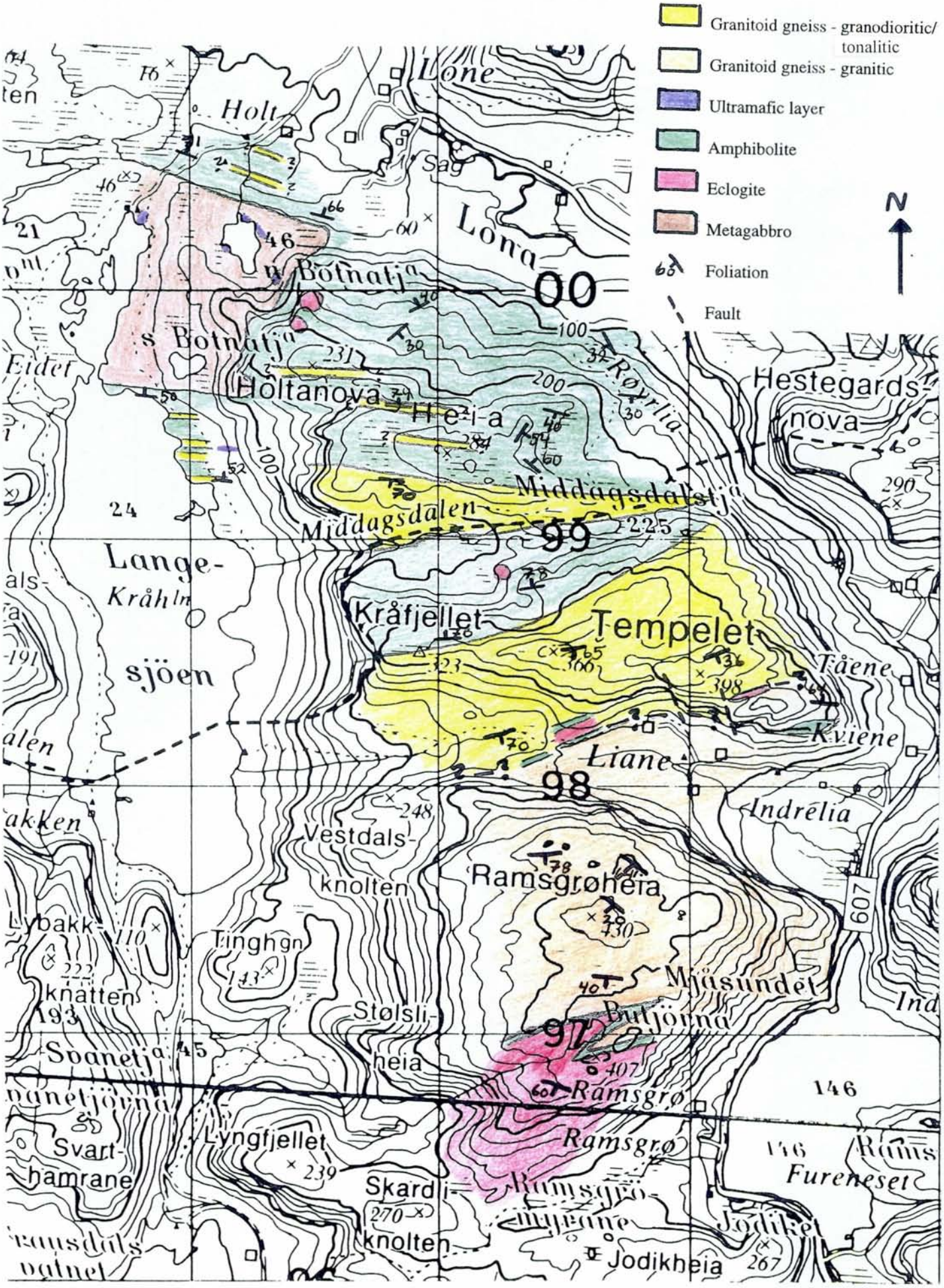
Field data table



Map over the Dalsfjord area. 1:50 000



Geological regional map of the Dalsfjord area.



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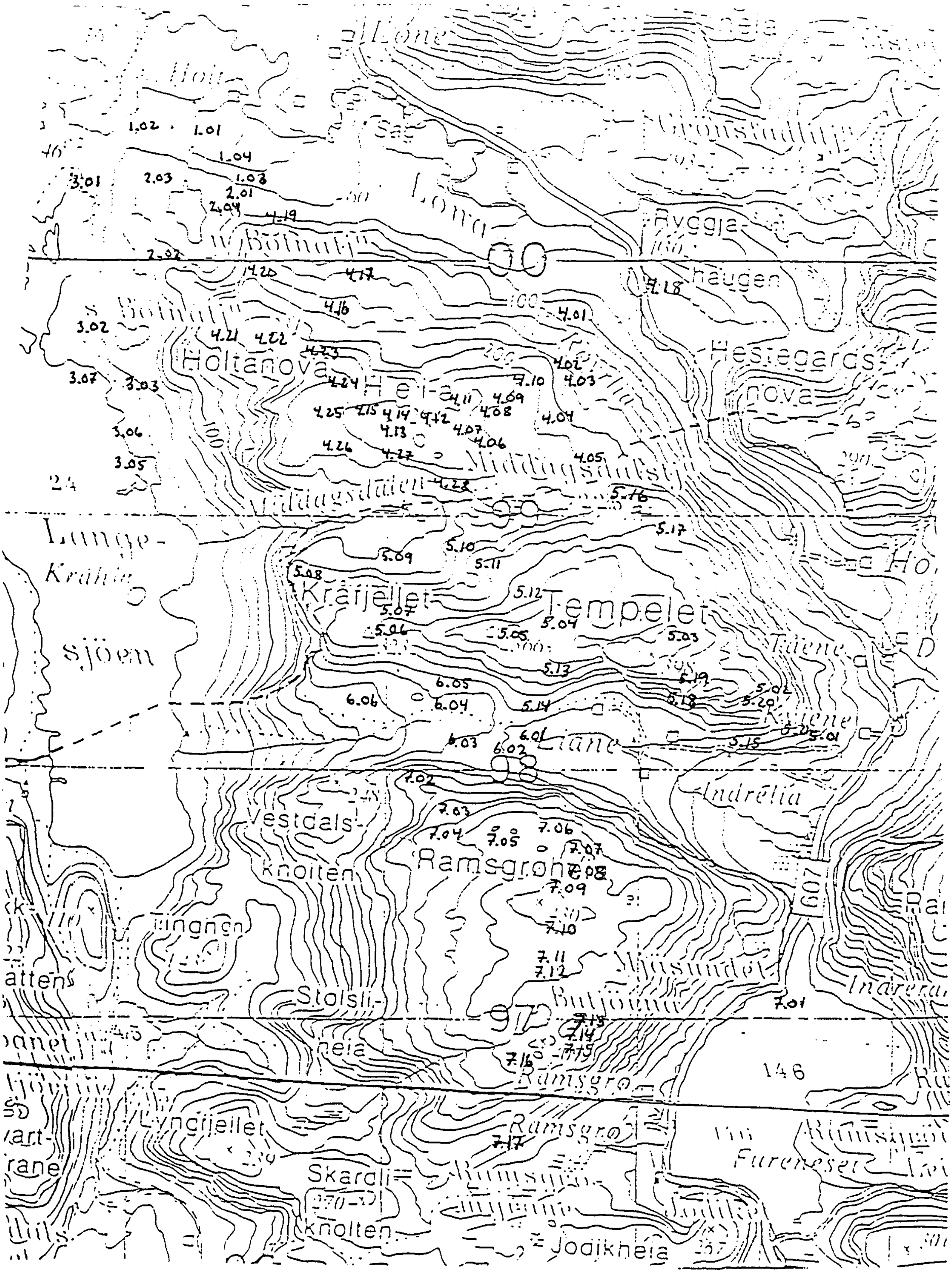
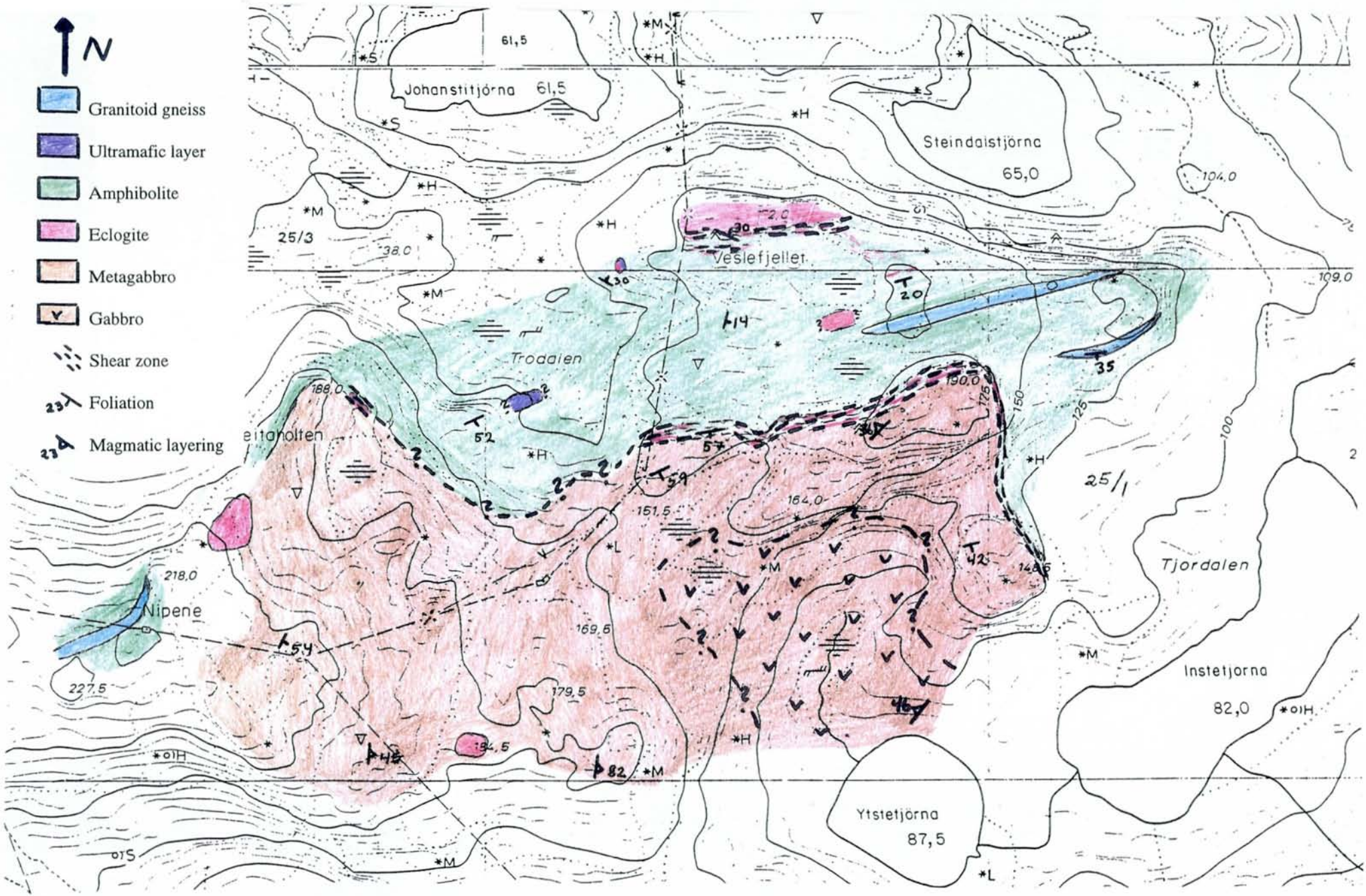


Locality map of the Holt-Ramsgrø area.



Geological map of the area SW of Tyssedalsvatnet (1:5 000).

Figure 1: Metagabbro (coronitic eclogite) with garnet coronas around amphibole and omphacite. The white (weathered surface) is composed of omphacite, kyanite, epidote, white mica and garnet. Locality 2.02 - Holt.

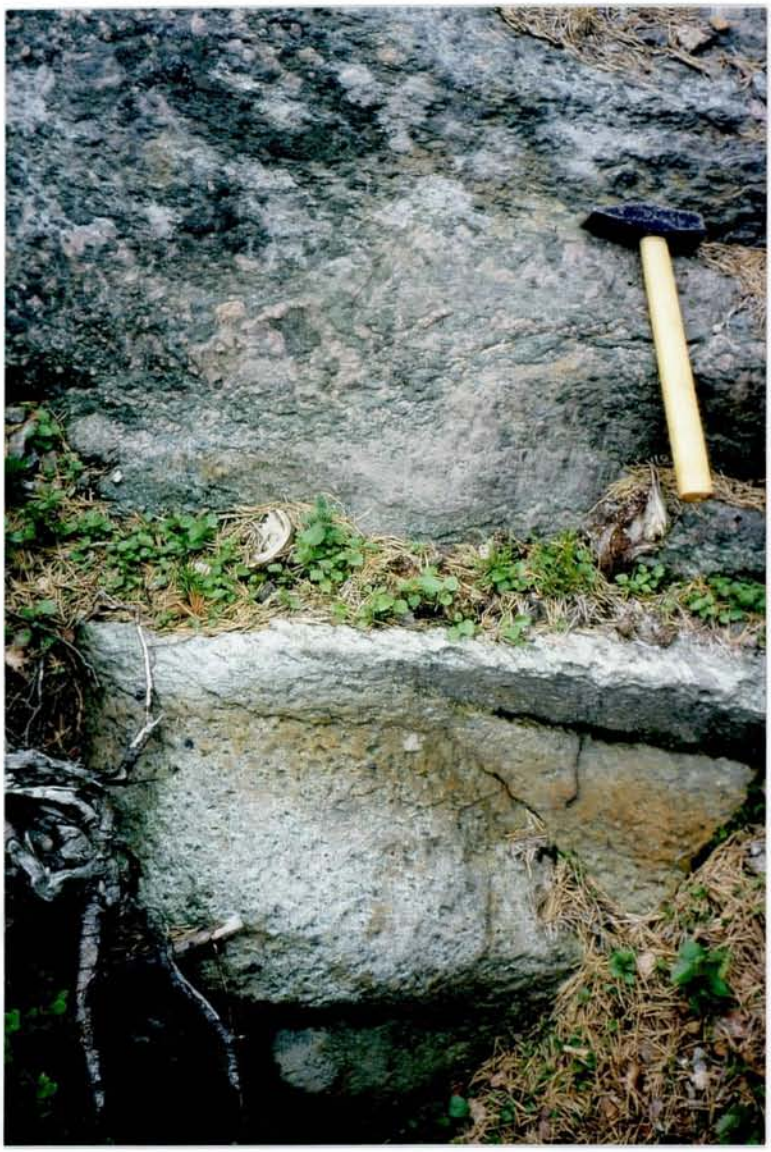


Figure 2: Hydrated mafic (lower part) layer in the coronitic metagabbro at Holt.

Figure 3: Very coarse-grained pyroxenite with minor plagioclase-replacement containing garnet, locality 2.04 - Holt.

Figure 4: Cumulative magmatic layering in metagabbro, SW of Tyssedalsvatnet.

Figure 5: Deformed coronitic eclogite with LS-fabric. Veslefjellet - SW of Tyssedalsvatnet.

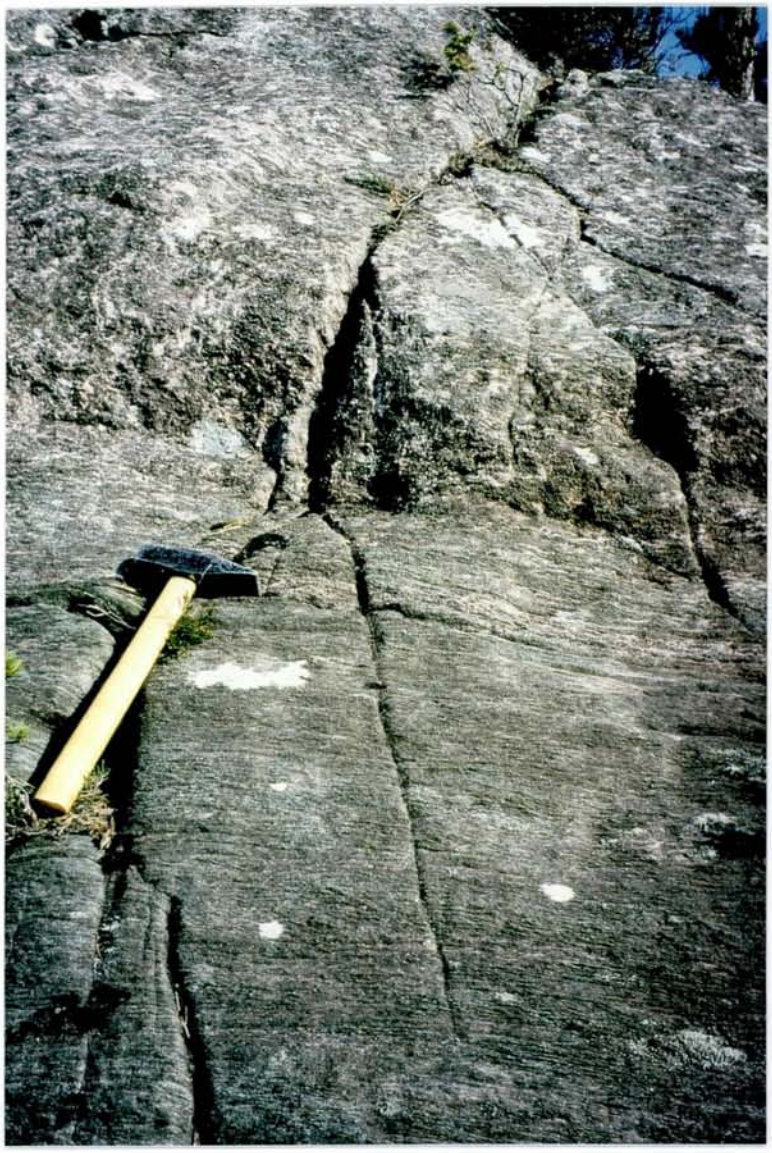


Figure 6: Eclogite and amphibolite mylonite cutting the metagabbro, SW of Tyssedalsvatnet.

Figure 7: Small eclogite shear-zone cutting through coronitic metagabbro, SW of Tyssedalsvatnet.

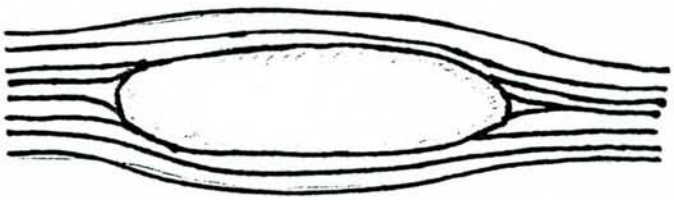


Figure 8: Schematic sketch of eclogite lense with tectonized and amphibolitized margins in foliated amphibolites or gneisses. The lenses varies in size from 0,1-2m, but occur also much larger.

Figure 9: Foliated amphibolite with green amphibole- and white plagioclase+mica-rich layers. Locality 3.03 - Holt.

a)

b)

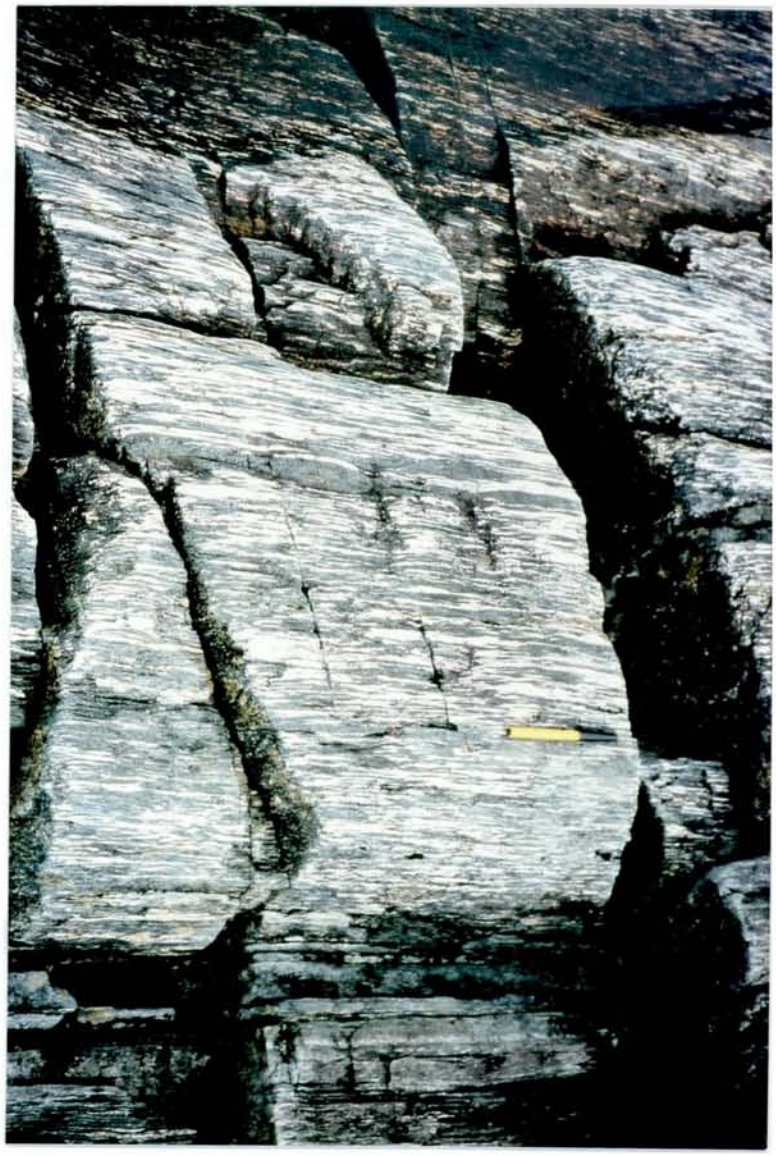


Figure 10: Pictures illustrating amphibolitization and deformation of coronitic metagabbro.
The pictures are taken 3 from each other.
Locality 3.07 - Langesjøen.
a) Amphibolite with textures resembling coronitic metagabbro. **b)** Amphibolite with green amphibole and white plagioclase bands constituting an LS-tectonite.

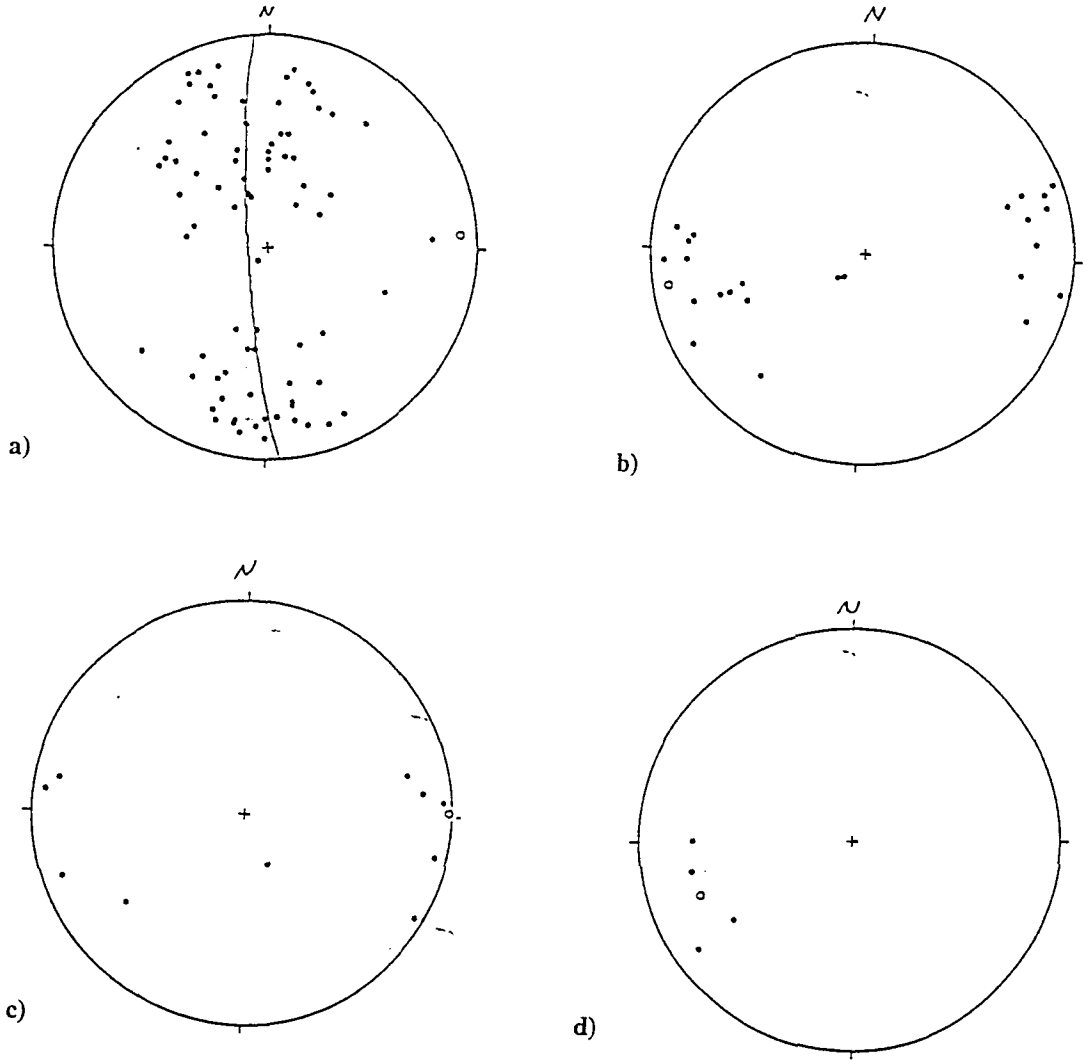
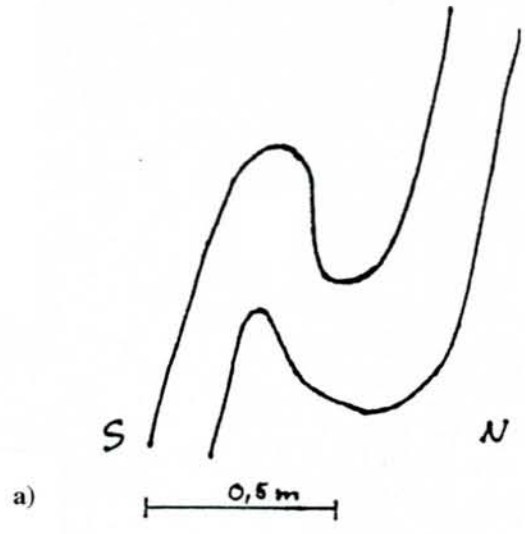


Figure 11: Stereographic projections of structural data from the Holt-Ramsgrø area. **a)** Measured foliations of amphibolites and gneisses. Pole to the best fit great circle (open circle): 086/08. **b)** Measured fold axis in the amphibolites and gneisses. Mean lineation vector (open circle): 258/08. **c)** Measured lineations in amphibolites and gneisses. Mean lineation vector (open circle): 089/01. **d)** Measured lineations in eclogite. Mean lineation vector (open circle): 250/25.

b)



a)

Figure 12: a) Small folds in granitoid gneiss. Tempelet. **b)** Sketch of parasitic fold in granitoid gneiss. Locality 5.20 - Tempelet.

Field data table, Holt-Ramsgrø-area, june 1995												
locality no.	area	UTM-north	UTM-east	rock-type	foliation	lineation	fold axe	sample	density	remanence	magn.susc.	
6001.01	Holt	680060	29530	gneiss	096/45							well foliated; small lenses with amphibolite and eclogite parallell foliation
6001.02	Holt	680050	29500	amphibolite	286/74							foliated, textures after coronittic gabbro, dextral shearbands
6001.03	Holt	680030	29540	amphibolite	106/66			6001.031				foliated, dextral shearbands
6001.04	Holt	680040	29535	gneiss								weakly foliated
6002.01	Holt/Botnatjern	680020	29540	amphibolite	116/34							textures after the coronittic metagabbro, dextral and sinistral shearbands
6002.02	Holt/Botnatjern	680000	29510	metagabbro				6002.021	3.367	0.00	0.00070	homgenous rock, some layering with varing amount of px-plag
				metagabbro				6002.024	3.424	0.00	0.00050	
				eclogite				6002.022	3.451	56.60	0.00126	< 6m thick dikes of very finegrained eclogite cutting straight trough the coronittic gabbro
				eclogite				6002.023	3.520	170.27	0.00120	
6002.03	Holt/Botnatjern	680030	29510	eclogite	250/84							eclogite facies foliation, completely eclogitized part of the metagabbro
6002.04	Holt/Botnatjern	680020	29535	pyroxenite				6002.041	3.384	430.92	0.03365	<10 m layer, px with some plag + grt domains, grainsize of px up to 20 cm
6003.01	Langesjøen E	680030	29470	metagabbro								
				pyroxenite								
6003.02	Langesjøen E	679970	29420	chl-schist	200/50							chlorite + biotite-rich rock with oxides
				amphibolite	290/56							deformed coronittic metagabbro, dextral shearband
6003.03	Langesjøen E	679950	29500	amphibolite	300/60; 280/74							well-foliated, horizons with more mafic minerals
6003.04	Langesjøen E	679940	29515	chl-schist	280/72			6003.041	2.788	6903.07	0.35553	well-foliated schist, locally with garnets
6003.05	Langesjøen E	679925	29500	gneiss	288/52			6003.051	2.634	9.67	0.00683	with amphibolitic lenses
6003.06	Langesjøen E	679935	29495	amphibolite	286/64							
6003.07	Langesjøen E	679960	29470	amphibolite	300/50	120/04		6003.071				amphibolite facies deformed coronittic metagabbro, L<S tectonite
								6003.072	2.8	79.42	0.00394	Transition can be followed from the metagabbro to this amphibolite
6004.01	Heia	679980	29670	amphibolite	140/32			6004.011	2.753	809.80	0.00794	well-foliated, banded horizons with amphibole-rich and felsic horizons (mm-dm thick), locally with garnet
6004.02	Heia	679965	29670	amphibolite	290/34			6004.021	2.798	45.85	0.00454	
6004.03	Heia	679960	29680	amphibolite	090/30							
6004.04	Heia	679945	29670	amphibolite	248/58							isoclinal folded amphibolittic lense, quartz veins
6004.05	Heia	679925	29670	gneiss	260/72							weak foliation of biotite
6004.06	Heia	679925	29640	amphibolite	276/60							well-foliated, banded horizons with amphibole-rich and plagioclase-rich layers (mm-cm thick)
6004.07	Heia	679930	29635	amphibolite	320/66							
6004.08	Heia	679945	29640	grt-amphibolite	015/30							weaker foliation, amph-rich and plag-rich domains, eclogite lenses (0,5-1 m)
6004.09	Heia	679950	29645	grt-amphibolite	100/36							weak foliation, amph-rich and plag-rich domains
6004.10	Heia	679955	29650	grt-amphibolite	030/40			6004.101				
6004.11	Heia	679950	29630	amphibolite	036/54							
6004.12	Heia	679940	29615	gneiss	094/58							weak foliation of biotite
6004.13	Heia	679935	29600	grt-amphibolite	276/40							well-foliated, banded horizons amphibole-rich and plagioclase-rich layers (mm-cm thick)
6004.14	Heia	679940	29600	gneiss	100/45							
6004.15	Heia	679945	29590	gneiss/amphibolite	288/70							contact between amphibolite and gneiss, coherent foliation in the rock types and contact
6004.16	Holtenova	679985	29590	amphibolite	050/30							well-foliated, banded horizons with amphibole and plagioclase (mm-cm thick)
6004.17	Holtenova	679995	29590	amphibolite	250/40							
6004.18	road 607	679990	29700	amphibolite	260/55							
6004.19	Holtenova	680020	29555	grt-amphibolite	072/20	102/06		6004.191				foliated with domains of amphibole and plag+grt; large shearzone (060/40); little sinistral shearzone (020/56)
				eclogite								fine-grained eclogite partly retrograded along cracks (360/80) and contact (100/62)
6004.20	Holtenova	680000	29550	grt-amphibolite	046/58; 050/20		110/16	6004.201	2.875	69.30	0.03520	finegrained amphibolite (retrograded eclogite) foliateted with qtz-horizons (<cm) and lot of small isoclinal folds; >6m thich
6004.21	Holtenova	679970	29540	grt-amphibolite	070/22		068/04					foliated with amphibole and felsic layers, with white mica
6004.22	Holtenova	679970	29550	gneiss	266/70							
6004.23	Holtenova	679960	29570	grt-amphibolite	098/74	276/06	074/10					foliated, with small folds
6004.24	Heia	679950	29585	gneiss	273/74							
6004.25	Heia	679945	29580	grt-amphibolite	177/68	154/68						foliated, with domains of amphibole and plagioclase
				eclogite	177/68	234/12						small lenses of eclogite (0,5 and 1m) surrounded by foliated amphibolite, parallell foliation in eclogite and amphibolite
6004.26	Heia	679930	29585	gneiss	096/70							with < 5 cm thick amphibolite layers, deformed to lenses with sinistral shearsense, also eclogite lens
6004.27	Heia	679925	29600	gneiss	270/80			6004.271				gneis and amphibolite deformed together making a grey gneiss with qtz+fld+bt+grt+amph
6004.28	Heia	679920	29615	gneiss	006/32; 090/34		076/20					with amphibolite layers
6005.01	Tempelet	679820	29770	gneiss	256/76							well-foliated, layered K-fld-rich and bt-rich horizons, locally blue quartz, lenses and layers (<0,5m thick) with amphibolite and sometimes eclogite
6005.02	Tempelet	679850	29750	gneiss	080/60; 260/64							
6005.03	Tempelet	679850	29710	gneiss	069/36		266/06					foliated, lenses and layers with amphibolite, some eclogite-lenses
6005.04	Tempelet	679855	29660	gneiss	040/54; 065/80							foliated, sinistral shearband, lenses and layers with amphibolite, some eclogite-lenses
6005.05	Tempelet	679850	29650	gneiss	070/65			6005.051	2.613	0.00	0.00028	
				amphibolite				6005.052	2.836	0.00	0.00049	foliated, small folds
6005.06	Tempelet	679850	29595	gneiss	070/70		240/10					foliated, lenses and layers with amphibolite and garnet-amphibolite
6005.07	Tempelet	679855	29600	amphibolite	270/70							well-foliated, amph and plag-rich layers, sinistral and dextral shearbands, 1x0,5m eclogite lens enclosed
6005.08	Tempelet	679880	29570	amphibolite	276/32							
6005.09	Tempelet	679885	29600	amphibolite	303/06							
6005.10	Tempelet	679890	29620	grt-amphibolite	250/78		070/10					foliated, domains of amph and plag+grt
				eclogite				6005.101	3.445	4.36	0.00099	6x30 m lens of homogenous finegrained eclogite enclosed in the foliated grt-ampibolite

6005.11	Tempelet	679880	29640	grt-amphibolite	260/64							
				eclogite								1x5 m eclogite exposure, homogenous fine-grained eclogite enclosed in grt-amphibolite
6005.12	Tempelet	679870	29660	gneiss	244/76							
6005.13	Tempelet	679840	29660	gneiss	045/40							
6005.14	Tempelet	679830	29655	eclogite	260/80			6005.141				massiv, dark eclogite >50x300m, enclosed in gneiss; <1 cm thick retrograded layers parallell foliation in the gneisses
				eclogite				6005.142	3.512	18.25	0.00131	varyating grainsize, usually fine-grained, but also more coarse
				amphibolite				6005.143	2.864	35.71	0.00053	
6005.15	Tempelet	679810	29760	gneiss	260/65		252/34	6005.151	2.608	11.15	0.00409	well-foliated, layered K-fld-rich and bt-rich horizons
6005.16	Tempelet	679910	29690	amphibolite	236/40							
6005.17	Tempelet	679900	29700	gneiss	072/40							
6005.18	Tempelet	679825	29720	gneiss	278/78	280/12		6005.181	2.791	19.92	0.00035	deformed zone in hanging-wall of brittle fault
								6005.182	2.673	10.32	0.00658	
6005.19	Tempelet	679830	29720	eclogite	058/70			6005.191	3.176	56.01	0.00085	about 5m thick layer of eclogite in K-fld gneiss, amphibolitized margins; can be followed along strike for about 30-40 m.
												Light eclogite with qtz+mica layers defining foliation, parallell foliatiobn in gneisses around.
								6005.192	3.215	7.00	0.00071	A zone in the gneisses around is containing abudant amphibolite and eclogite layers and lenses.
6005.20	Tempelet	679830	29750	gneiss	280/40	083/14	085/18					Small fold in the gneisses
6005.21	Tempelet	679820	29750	gneiss			100/04					Zone with eclogite lenses and layers can be folloved along strike
				eclogite/amphibolite								
6006.01	Liane	679815	29650	grt-amphibolite	110/60		246/40					grt-amphibolite and eclogite together (1-2m thick lens) and in contact to the gneiss
				eclogite								
				gneiss	080/50							with amphibolite layers and lenses, a lot of small folds, sinitral shearband
6006.02	Liane	679810	29645	gneiss	120/28			6006.021	2.557	21.71	0.01015	
6006.03	Liane	679815	29630	grt-amphibolite	070/70							gneiss and amphibolite deformed together, sinistral shearbands and boudins, a lot of small folds
				eclogite								eclogite with ky, qtz and mica
6006.04	Liane	679825	29625	gneiss	070/70			6006.041	2.668	5.79	0.00031	weak foliation defined of bt
6006.05	Liane	679835	29635	gneiss	106/36			6006.051	2.630	32.46	0.00667	weak foliation
				gneiss				6006.052	2.696	0.00	0.00027	biotite-rich
6006.06	Liane	679830	29590	gneiss		086/04		6006.061	2.628	34.08	0.01856	massif rock, K-fld as eyes
6007.01	Ramsgrøvatnet	679710	29750	gneiss	070/28	250/10		6007.011	2.629	11.84	0.00630	well-developed foliation defined of biotite, fine-grained biotite og more coarse-grained to pegmatittic horizons up to 10 cm thick, frequently small folds
6007.02	Ramsgrøheia	679800	29615	gneiss	042/50		218/26	6007.021	2.599	0.00	0.00015	
6007.03	Ramsgrøheia	679780	29625	gneiss	147/24;064/75		272/18	6007.031	2.569	6.07	0.00335	
6007.04	Ramsgrøheia	679770	29620	gneiss	074/78		252/30	6007.041	2.665	0.00	0.00801	asymmetric boudins show both sinistral and dextral shearsense
6007.05	Ramsgrøheia	679770	29640	qtz-rich gneiss	074/78		096/24	6007.051	2.685	0.00	0.00072	20-30 m thick layer of very qtz-rich well-foliated gneiss, high density of small "kinck"folds; small lenses (cm) with bt+ep+amph
								6007.052	2.614	16.56	0.00055	
6007.06	Ramsgrøheia	679775	29660	qtz-rik gneiss	068/78		068/20					contact to the granittic gneiss is folded together
6007.07	Ramsgrøheia	679765	29675	gneiss	128/64		226/76					with K-fld eyes
6007.08	Ramsgrøheia	679760	29675	gneiss	060/52		219/78					
6007.09	Ramsgrøheia	679755	29670	gneiss	124/20		252/18					
6007.10	Ramsgrøheia	679740	29665	gneiss	116/60	232/30						
6007.11	Ramsgrøheia	679725	29660	bt+ep-rich gneiss	092/40		276/12	6007.111	2.761	7.05	0.00057	5-10 m thick layer in granittic gneiss, with epidot-rich lenses
6007.12	Ramsgrøheia	679720	29660	eclogite/gneiss								eclogite-lenses (<3 m) in granittic gneiss, surrounded by qtz+white mica rock
6007.13	Ramsgrøheia	679705	29675	amphibolite/eclogite	104/69							eclogite and amphibolite layers and lenses with felsite
6007.14	Ramsgrøheia	679700	29675	bt+ep-rich gneiss	090/37							gneiss with variations in mineral content of bt and epidot; with lenses and layers of amphibolite and eclogite
6007.15	Ramsgrøheia	679695	29675	eclogite	086/74	259/24	254/40					variating petrography with darker (grt+omph+amph) fine-grained layers, but dominating of light (grt+omph+ky+qtz+white mica) coarser grained layers
6007.16	Ramsgrøheia	679680	29655	eclogite	112/60	270/26	274/20					light eclogite
6007.17	Ramsgrøheia	679650	29650	eclogite	100/87	236/33	266/17	6007.171	3.303	8.18	0.00055	veins <0.2x1 m with qtz, ky, white mica, amph, omph <0.2x1m

chl = chlorite	px = pyroxene
grt = garnet	plag = plagioclase
amph = amphibolite	fld = feldspar
omph = omphacite	ky = kyanite
qtz = quartz	ep = epidote
bt = biotite	