The Tectonostratigraphy of the Velfjord-Region, Helgeland Nappe, Uppermost Allochthon, Nordland/Norway

Map sheet Velfjord 1:50 000, 1825-4

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1993 (unpublished)

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Abstract The southern Velfjord region is a key region to the understanding of the magmatic and tectonostratigraphic evolution of the Helgeland Nappe Complex (HNC). By comparing and interpreting different mappings it is possible to show that the sole thrust of the HNC, the Klapparfjell Thrust, is exposed in the investigated area. It divides the HNC into a lower and higher part. From the western parts of the HNC to its eastern ones the thrusting progressively becomes younger. Internal thrust divide the HNS into eight different nappes which are named and described.

In contrast to the Velfjord plutons (Brattåsfjell, Rödliheia and Sausfjell Pluton) which intruded into an internal thrust, the Lysingen Pluton intruded in the sole thrust itself. Thrusting after these plutons' emplacement initiated a renewed magmatism.

Contents

Preword

Some weeks before his death, Dr. Markwart Schönfeld wrote the following article, summarising most of the results he got while staying four summers in Norway.

During five years of being his student, colleague and friend I got to know Dr. Schönfeld as a person who liked to be perfect – in a positive sense, naturally. For this reason it is a pity that his first article on Norway to be published was not finished by the time he died. Some of Dr. Schönfeld's remarks in the hand-written-manuscript are indicated in angular brackets.

As I was one of the last persons to follow him to the Velfjord-Region I took over the job to compile his manuscript and to fill in the missing parts (e.g. the tables, figures and some dates). Hopefully this article will help further generations of researchers and geologists who will work within this region to understand their own results.

I think it is in the sense of Dr. Schönfeld to thank everybody, who made the field trips possible. Especially B.P.Norway, the N.G.U and the Technical University of Clausthal. Last – but not least – thanks to his wife, whose wish it was that this article had to be published.

Christian Wolkersdorfer

Introduction

It is the aim of this report to gather results of four field seasons (1987, 1988, 1989 and 1991) carried out by members of the Geological Institute of the University Clausthal/Germany in the region of the southern termination of the Velfjord.

The region under discussion with a total aerial extend of approximately 40 km^2 of land mass was mapped in the scale of 1:5 000 and part of the results are compiled on map sheet Sausvatnet 1:20 000, just in preparation.

Furthermore three diploma thesis are available (Adam 1988, Rüffer 1988, Fabian 1990), another three candidates have failed to finish their thesis. All these data, together with unpublished results of mappings and petrographical examinations of the author, prove that the region of the southern Velfjord is a clue region as far as the tectonostratigraphy and magmatic evolution of the Helgeland Nappe (HNC) of the Uppermost Allochthon is concerned.

A first interpretation of the tectonostratigraphy is given below and we will try to correlate our results with the data known from adjacent regions.

The thrust and nappe systems

On the basis of the different lithological content of the nappes, different attitudes of the thrust faults and other structural arguments a discrimination between a Western Nappe System (WNS) and an Eastern Nappe System (ENS) is made. As it can be evidenced at several localities, the ENS was thrust over the WNS. Uncertainties still exist about the tectonical positions of rock sequences at the top and on the base of the whole nappe pile (for descriptions and discussions see below).

The Western Nappe System (WNS)

The Western Nappe System consists of at least three nappes as tabulated below from up to down (see also table 1):

- Klapparfjell Nappe
- Sæterfjell Nappe
- Skomoviken Nappe

Below the Skomoviken Nappe homogeneous quartz dominated garnet-two mica-gneisses with layers of amphibolites occur. The rocks are throughout non-migmatitic and don't reoccur in any of the higher nappes. The fold axis of this so-called Salbuen-Unit strike NE-SW. A major fault zone, the Skomoviken Thrust, terminates those gneisses to the south-east. The outcrop of the thrust plane is marked clearly by

prominent morphological features and by mylonites of metasediments and of aphyric and porphyric granite gneisses.

((figure 1 should be placed here))

The Skomoviken Nappe nearly exclusively consists of metagranites, which are medium grained, leucocratic, tourmaline-bearing granites; locally porphyric varieties intrude the first-mentioned types. The granites are cut by numerous stripes of mylonites, mostly running in NE-SW-direction, thus delineating several mega-lenses with different tectonic fabrics, especially different attitudes of gneissic foliations. Some of the mylonites are folded (Schönfeld 1986).

At few outcrops an intrusive contact can be observed between the granites and biotite gneisses. The contact is pronounced by confirmable aplites, some decimetres thick which themselves seldom are intruded by pegmatites. The biotite gneisses show blastesis by contact metamorphism, overprinting migmatic textures. The tectonostratigraphical position of these gneisses is still enigmatic. All other boundaries between granite gneisses and metasediments are tectonic contacts along a fault plane dipping approximately 30° to the SE. The so-called Sæterfjell Thrust is a 300 m broad belt of intensive mylonitisation of granite gneisses, biotite gneisses and sometimes even marbles; it is also a zone of multiple imbricates between metasediments and granite gneisses. The Sæterfjell Nappe is made up of numerous repetitions of biotite gneisses and biotite schists, grey marbles, calcsilicates, amphibolites and seldom quartzites.

The internal structure of the nappe can be characterised as a duplex structure as evidenced by flats and ramps and by a horse with rocks of the footwall. Subdividing of the metasediments is not helpful because of the structural situation. Details on the metamorphic grade are not yet known but medium grade metamorphism is indicated, possibly [....-grade], anatectic phenomena have not been observed. Deformations initiated by the movement of the thrust mass have affected an already folded sequence, whose folds are strongly transposed and rotated to attitudes of the axial planes, parallel to the mylonitic foliations.

Large-scale folds originating from thrusting have NE-SW or NNE-SSW-axis; small-scale folds of that attitude are extremely seldom and possibly rotated towards the directions of thrusting.

Obviously there are two directions of displacements of the Sæterfjell Nappe. The first and most important direction, directed towards 135°, has been found from Dalbotn in the west towards the eastern termination of the Godvatnet, where it intersects with a younger 110° direction along the Sörfjorden. Here several small slices of metasediments of the Sæterfjell Nappe together with mylonites are present, dipping steeply towards 110° and being accompanied by granite-gneiss of the Skomoviken Nappe. This zone of imbrications is terminated to the south-southeast by a major thrust, which leads over to continuos outcrops of metasediments.

Another hint to a complex thrusting comes from the fact that the Skomoviken granite-gneisses show several attitudes of gneissic foliation, which can be grouped, according to Schönfeld (1986), into two sets. A renewal of movements on the faults of that system has to be taken into account, because they are intruded be diorites which seem to have their source in the Brattåsfjell pluton.

The obvious discrepancy between intrusive contacts on one side and the thrust contacts between granite-gneisses and metasediments on the other side demands for a special explanation and further research:

1. If the contact metamorphic gneisses belong to rock sequences of the Sæterfjell Nappe, than a tip point is located near the Sörfjord (Småklimpan), with the further consequence of a minimum thrust displacement at least in that region;

2. If the biotite-gneisses at the intrusive contacts don't belong to the thrust mass than considerable displacements must be assumed.

The Sæterfjell Nappe terminates to the SE at a thrust plane, the Klapparfjell Thrust, which is a 30° dipping fault with mylonites, tectonic melanges, half-windows and an obvious lithological contrast as well as a contrast in metamorphic conditions. Though

several times disrupted by dilatational faults, the thrust plane can be traced from the Sörfjord in the east to Dalbotn in the west. In the region of the Sörfjord, the Klapparfjell Thrust is cut near the boundary of the Brattåsfjell pluton by the sole thrust of the Eastern Nappe System [last sentence possibly later in the text].

Within the Klapparfjell Nappe a subdivision between gneisses at the base, the so-called Skogfjell Group, and marbles at the top, the Vasbygda Group, is proposed (Schönfeld 1987, 1989).

The rock types of the Skogfjell Group in the order of their frequency are:

- Sillimanite-staurolite-garnet-mica-gneisses
- Biotite-feldspar blast-gneisses
- Garnet-mica-gneisses
- Biotite-quartz-feldspar-gneisses
- (Quartz-feldspar-gneisses)
- (Quarzites)
- Amphibolites
- Calcsilicates

The gneisses are migmatitic, displaying various typical textures as for instance: [...], viscous shears.

Often separated from the Skogfjell Group by thin layers of biotite schists the Vasbygda Group commences with white to light-grey marbles, quartz-feldspar-gneisses, calcsilicates and seldom quartzites and amphibolites.

Additionally the nappe was intruded by various magmatites, occurring as stocks and dikes and ranging in mode from gabbros to granites.

The Skogfjell and Vasbygda Group have a common deformational history, resulting in older isoclinal megascoping NNE-SSW-folds, with axial planes dipping to the ESE. Secondary open folds are orientated ENE-SSW.

The Eastern Nappe System (ENS)

Tracing thrusts and nappes in the Eastern Nappe System is difficult, because in the region of Sörfjord, Heggefjord, Langvatn and Sausvatn they are intruded by the Velfjord plutons. So thrusts are deformed by the diapiric ascent of the plutons and thrusts and nappes are partly obliterated by the intruding magmatites.

The Sörfjord Thrust, as the sole thrust of the ENS can only be traced by the lithological contrast between the rocks of the WNS and that one of the ENS. The thrust plane is never directly exposed. Their curvilinear trace between the southern termination of the Velfjord and Hommelstø results from the integration of the thrust plane into the marginal synform of the Brattåsfjell pluton. West of Hommelstø a marginal antiform exposes rocks of the nappe, the thrust on the contrary again is not accessible, because it is intruded by late stage intrusions of the Brattåsfjell and Rödliheia plutons (as these plutons haven't been officially named by the time this manuscript had been written, M. Schönfeld 1989 Fig. 1, gave them the names Brattåsfjell, Rödliheia and Sausfjell Pluton. Barnes et al. 1992, differing from this naming, call them Hillstadfjellet, Akset-Drevli and Sausfjellet Plutons. In remembering the works of M. Schönfeld I suggest to use his names, C.W.). More to the south the approximate position of the thrust in the present erosional level can be reconstructed by delineating the south-western boundary of stopped blocks with rock types of the nappe. Directly north of the Sausvatn again a small area of a marginal synform was found and rocks of the Sörfjord Nappe occur as fragments in contactanatexites of the Rödliheia pluton. At the south-eastern beach of the Sausvatn again a small stripe of metasediments, within the marginal synform of the Sausfjell Pluton, is assigned to the ENS.

Assuming a general easterly dipping of the thrust faults in the ENS, which is locally affirmed by the attitudes of splay faults, the sole thrust of the ENS cuts off faults and nappes of the WNS.

Considering the fact that the rocks of the Sörfjord Nappe only occur as isolated folds or as small fragments within the plutons or in their diapiric marginal folds they are comprehended in one formation only, the Svanvatnet formation.

In an approximate order from up to down (E to W) there are:

- biotite gneisses with marbles,
- calcsilicate gneisses with marble clasts and intercalated marbles,
- quartzites, quartzites with calcsilicate minerals (*)
- marbles with quartzite clasts,
- calcsilicate gneisses with quartzite clasts,
- marbles with forsterite and locally marble clasts,
- granite-gneiss,
- marbles with calcsilicate layers.

At position indicated with (*) serpentinized dunites and harzburgites are present seemingly with tectonized contacts to the metasediments and to the rocks of the plutons. As a rarity the calcsilicate gneiss with quartzite clasts contains Cr-diopsid and Cr-garnet in the matrix (Prestvik 1974). This seems to be valid also for the calcsilicate-gneisses with marble clasts. The homogeneous distribution of the chromium-bearing minerals throughout these horizons points towards a clastic input of chromites to the sediments.

Besides pyroxene diorites and gabbros of the Brattåsfjell-, the Rödliheia- and the Sausfjell Pluton the rocks of the Svanvatnet formation SE of Hommelstø are intruded by different hornblende diorites, monzodiorites and granites, which cannot be linked with certainty to any of the plutons mentioned above (Anuet monzonite after Barnes et al. 1992).

Fold structures in the Svanvatnet formation strike NW-SE, clearly different from fold structures in the WNS. Several other characteristics of the Svanvatnet formation contrast clearly to rock types of the WNS:

1. marbles with forsterite, educts from dolomite limestones never occur in the WNS,

2. also chromium-bearing minerals have never been observed,

3. calcsilicates and quartzitic rocks with calcsilicate minerals are underrepresented in the WNS, whereas they are abundant in the ENS,

4. regional migmatization as in the Klapparfjell Nappe don't occur in rocks of the Sörfjord Nappe.

5. The abundance of dunite fragments in the Svanvatnet formation is striking; only one fragment is known NW of the Klapparfjell summit in the WNS, which has a position directly on the Klapparfjell Thrust, but the emplacement mechanism – whether tectonical or intrusional – is not yet known.

In contrast to the petrographical and structural differences between the Sörfjord Nappe and the WNS there are similarities between the former and the Heggefjord Nappe, as demonstrated below.

The Heggefjord Thrust Fault is exposed nowhere in the area of Fig. 1, but is mapped by Løseth (1985) E of Hommelstø as the base of an ultramafic complex (Neverness ultramafics), which is interpreted by the author as a dismembered ophiolite. Further prolongations of the thrust fault to the north and south are less certain, but they seem to be expressed correctly by the trace given in Fig. 1 (instead of this figure, that has never been drawn, an older one was used, on which the Heggefjord Thrust Fault can be seen, C.W.)

The Heggefjord Nappe is made up of the Neverness ultramafics (Velfjord Group) at the base and a sequence of metasediments, the Tosenfjord Group at the top, as described by Løseth (1985).

According to Løseth the Tosenfjord Group is subdivided into several formations and even members, they consists of metapsammites, calcareous schists, marbles and conglomerates. As described in detail by the author mentioned above the metap-

sammites contain among others detrital chromites and pyrrhotite with pentlandite flames; the conglomerates contain for instance clasts of gabbro and ultramafics. These findings led the author to the assumption that the Tosenfjord Group is an unconformable cover-sequence of the Neverness Group, containing clasts of the dismembered ophiolite and deposited in a shallow marine environment.

Several common phenomena, which cannot be accidental, exist between the Svanvatnet formation [group?], below the Neverness ultramafics and the Tosenfjord Group, above the Neverness ultramafics:

1. The frequent conglomerate horizons,

2. the fine-grained structure of the metapsammites, together with the millimetre layering,

3. the remarkable, colourful appearance of the metapsammites, ranging from white to red brown (biotite) and green (tremolite/actinolite), alternating in layers of cm to dm thickness,

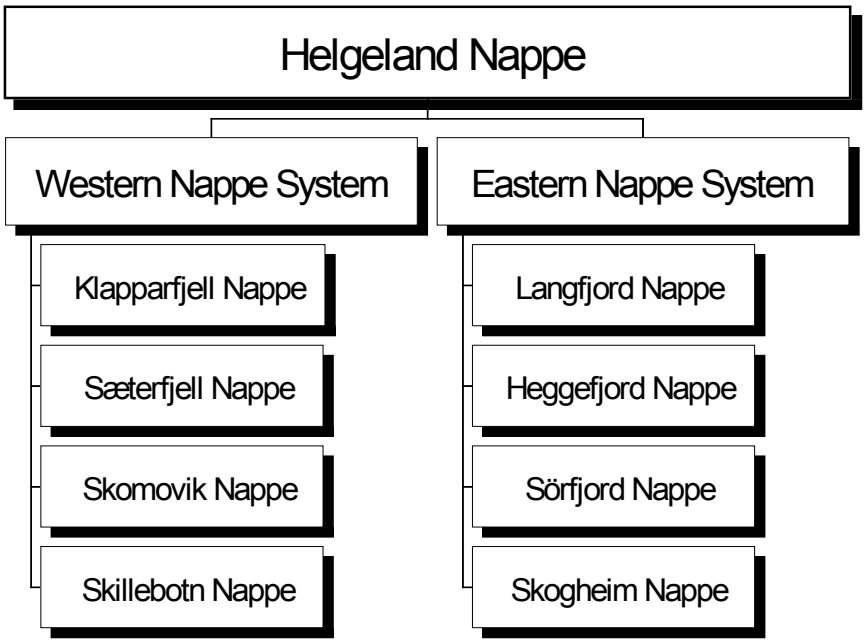
4. the high quartz content often grading to pure quartzites,

5. the chromium content in the conglomerate horizons and metapsammites,

6. the existence of small fragments of ultramafics also in the Svanvatnet formation.

Though a stratigraphical correlation between the Svanvatnet formation and the Tosenfjord Group is not yet possible it is assumed that the Svanvatnet formation also is a part of the cover-sequence of the Neverness ophiolite.

A further tectonic break is indicated along the Langfjord, but whether this is a thrust fault or a SW dipping dilatational fault is not known. Nevertheless, the petrographical contrast is striking, because east of the Langfjord gneisses, which resemble the migmatitic, staurolit-sillimanite-garnet-mica-gneisses of the Klapparfjell Nappe are found (Ø. Nordgulen, pers. comm., 1991).



Tab. 1: Nappe System of the Helgeland Nappe (compiled according to the manuscript, handwritten remarks of Schönfeld's estate and after Wolkersdorfer 1993).

The results – an extended summary

The area at the southern termination of the Velfjord seems to be a clue-region in deciphering various unanswered questions concerning the structural and magmatic evolution of the Helgeland Nappe Complex (HNC).

Indeed, the information on the magmatic aspect of the region under discussion is not reported in full, but the results in structural developments provides the frame to fit further phenomena in time and space as plutonism, metamorphism, vertical tectonics and so on.

The most important question, whether the sole thrust of HNC (Uppermost Allochthon of the Scandinavian Caledonides) is exposed in the Velfjord region can be answered now comparing the nappe stratigraphy of the Velfjord region with results of mappings in the south-west, south and west. The trace of the sole thrust is well known between Grong and the Bindalfjord, south-west of the Velfjord map sheet, Nordgulen

et al. (1990) and references cited there. The HNC at the Bindalfjord is thrusted upon the so-called Vestranden sequence:

The thrust itself is an imbricate zone containing tectonic lenses of metasediments and intrusive rocks amongst them also mafic and ultramafic fragments with unconformable cover-sequences are found.

Monotonous migmatitic gneisses above this imbricate zone are assigned to the HNC; they are by all means comparable with rocks of the Skogfjell Group of the Klapparfjell Nappe.

West of the Bindalsfjord the fault between the Vestranden sequence and the HNC is intruded by the Heilhornet pluton, but reappears north of the pluton in a N-S-direction to disappear in the Bindalsfjord (Nordgulen et al. 1987, 1989, 1990, 1992).

A continuation of the thrust to the north is indicated; here it is intruded by the Lysingen pluton, but continues north of the pluton to cut the Klapparfjell thrust of the Velfjord region [to be checked].

From that structural correlation the following statements can be deducted:

1. The Klapparfjell Thrust is the sole thrust of the Helgeland Nappe Complex. It divides the WNS of the Velfjord region into a lower part, which belongs to the Vestranden sequence and a higher part of migmatitic gneisses typical for the HNC.

Within the Vestranden sequence the rocks of the Sæterfjell Nappe seems to be unique, because of the high content of amphibolites, whereas the tourmaline-bearing granite-gneisses of the Skomoviken Nappe have striking similarities with granite-gneisses near Holm (Nordgulen 1987). Furthermore the quartz-dominated garnet-two mica-gneisses below the Skomoviken Nappe resemble the quartz-rich two mica schists west of the Velfjord map sheet (Heldal 1987).

2. The Sörfjord Thrust is an internal thrust of the HNC; it cuts thrusts and nappes of the WNS and therefore is younger than the former mentioned tectonic elements. By

this relation the Sörfjord Thrust appears as a relative independent tectonic element within the HNC.

3. As an unique element in the tectonostratigraphy of the whole region between Velfjord, Tosenfjord and Bindalfjord the Sörfjord Nappe represents an equivalent of the cover-sequence of the Neverness ophiolite, now occurring tectonostratigraphically below the ophiolite.

Though the similarities between the Svanvatnet Group and the Tosenfjord Group are striking a direct correlation seems to be difficult to establish. Therefore a different source of the cover-sequences within the [...]-basin might be assumed.

A stratigraphic sequence is difficult to be established, because sections to a certain extent are rare and fragments of ultramafics occur, which might be linked to nappe internal imbricates.

4. The Sörfjord Nappe was emplaced prior to the intrusion of the three Velfjord plutons: the Sausfjell-, Rödliheia- and Brattåsfjell Pluton. This relation clearly is demonstrated by parts of the Svanvatnet Group, which are transposed to be incorporated in the diapiric marginal synforms and diapiric antiforms of the plutons. This structural situation also clearly demonstrates that the three Velfjord plutons are intruded at the place and are not transported together with the nappes.

5. In contrary to the relation between the time of emplacement of the Sörfjord Nappe and the time of the intrusion of the Velfjord plutons the emplacement of the Heggefjord Nappe post-dates this magmatic event.

The conclusion is made by the facts that:

a) no dykes originating from the plutons were found *in* the Velfjord and Tosenfjord Groups of the Heggefjord Nappe and the dykes below the Heggefjord thrust display continuous deformation, where traced towards the base of the nappe (Løseth 1985),

b) the marginal synform of the Rödliheia diapir at the eastern end of the of the Sausvatn terminates below the Heggefjord Thrust,

c) strongly deformed, folded and mylonitisized pyroxene diorites are found at the north-eastern margin of the Rödliheia pluton and

d) even very late stage magmatites of the Rödliheia pluton are cut by subordinate thrust planes dipping at low angles to the north-east.

6) A distinct time interval therefore exists between the thrusting of the Sörfjord and the Heggefjord Nappe.

7) Thrust movements, which post-dates the solidification of the Velfjord pluton – as the emplacement of the Heggefjord Nappe – seemingly have caused a renewed magmatic activity expressed by half-moon-shaped marginal plutonic facies at the western borders of at least the Sausfjell and Rödliheia Plutons. The space for that secondary intrusions was possibly achieved by an eastward moving of the solidified core complexes of the plutons and/or by rotation of the plutons core complexes.

To sum up the results it can be stated that it was possible to define the sole thrust of the HNC by correlation with already mapped regions in the south and south-west. Additionally it was demonstrated that the Vestranden sequence below the HNC as well as the HNC itself were affected by thrust faults. Thrusting within the HNC becomes progressively younger to the east, intermittent by a period of plutonism.

While the Velfjord plutons intruded an internal thrust of the HNC, the Lysingen granite/diorite intruded the sole thrust. This spatial relation is comparable with the intrusion of the Heilhormet granite through the sole thrust. Nordgulen et al. (1990), reported crystallisation ages of this granite of 444 ± 11 Ma, which corresponds to the late Ordovician.

It seems to be possible that the Lysingen magmatites and that of the Velfjord plutons intruded at the same time (Nordgulen & Sundvoll 1992, report intrusion ages of 440 Ma, which state this suspicion, C.W.).

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Figures

Fig. 1: Prominent thrusts, nappes, vertical faults and intrusions in the Velford area (results of different authors from the geological institute of the Technical University Clausthal). Areas east of Langfjord are unmapped.