THE NAPPE COMPLEX IN THE TYIN-BYGDIN-VANG REGION, CENTRAL SOUTHERN NORWAY

MICHAEL HEIM, URS SCHÄRER & A. GEOFFREY MILNES

Heim, M., Schärer, U. & Milnes, A. G.: The nappe complex in the Tyin-Bygdin-Vang region, central southern Norway. *Norsk Geologisk Tidsskrift,* Vol. 57, pp. 171–178. Oslo 1977.

South of Jotunheimen, the main Caledonian thrust separates the overlying Jotun-Valdres nappe complex (mainly Precambrian basement rocks with some Eocambrian sparagmites) from a parautochthonous phyllite/quartzite mass (Lower Palaeozoic) lying on an autochthonous Precambrian crystalline fundament.

Events within the Jotun-Valdres complex predating the main thrust are: a Precambrian phase of regional metamorphism (amphibolite facies) and deformation, followed by heterogeneous shearing and sedimentation of sparagmites and an early Caledonian phase of intense, penetrative deformation effecting the lower part (sparagmites and some basement).

Main Caledonian movement was restricted to a thin basal thrust zone and accompanied by flow in the phyllite/quartzite mass below it (greenschist facies conditions).

A post-thrust NE-SW trending fault (Tyin-Gjende) is thought to mark the SE margin of the 'Faltungsgraben' in this region.

M. Heim, U. Schärer & A. G. Milnes, Geologisches Institut ETH, ETH-Zentrum, CH-8092 Zürich, Switzerland.

Our aim is to present briefly the results of a field study of the base of the Jotun-Valdres nappe complex in central southern Norway in the area south of Jotunheimen proper. Although not previously mapped in any detail (for early work, see Törnebohm 1896, Reusch 1901, Bjørlykke 1905), the region lends itself to the investigation of large-scale thrust tectonics. In the first place, deep glacial valleys provide a network of sections, through the nappe complex and the underlying parautochthonous series into the autochthonous fundament. Secondly, the main valleys are occupied by main roads (Fig. 1), providing easy access to all localities. On the basis of the mapping carried out up to now, mainly at a scale of 1:12.500 with the help of aerial photographs, a fairly clear structural history can be deduced, as summarized below. The field work is being followed up by isotopic studies in order to fix this relative sequence of events within the Caledonian and earlier time scale.

General Geology

The various tectonic units recognized in the area are composed of Precambrian crystalline rocks (basement) and/or late Precambrian to Lower Palaeozoic meta-sediments (cover) in varying proportions (Fig. 1). The main Caledonian thrust separates the units into two groups: the Jotun-Valdres

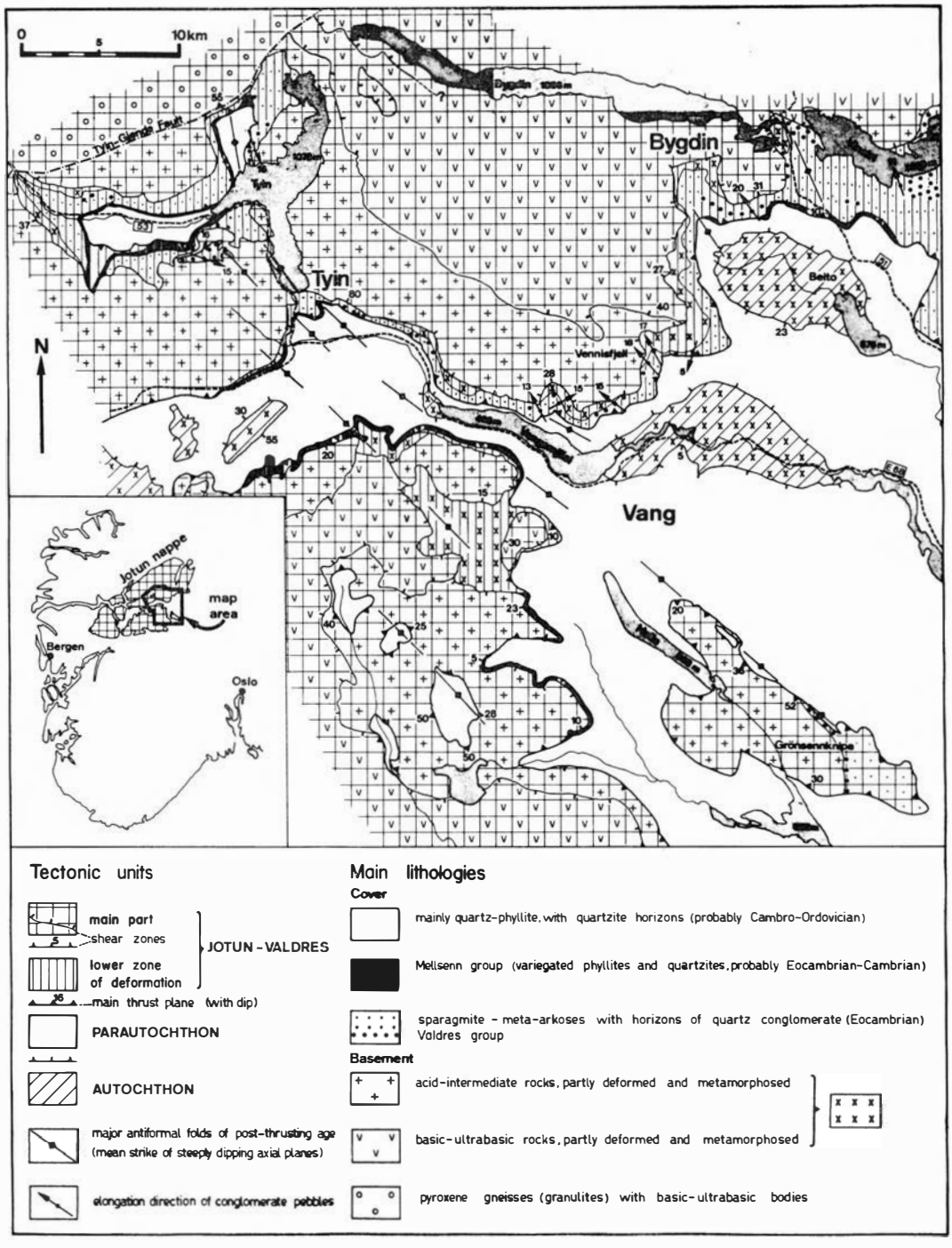

Fig. 1. Tectonic sketch map of the Tyin-Bygdin-Vang region. In part after: Bugge 1939, Strand 1950, Hossack 1967, 1976 and Battey 1973. [E 68], [51], [53]: main roads.

nappe complex above, and the Parautochthon-Autochthon below. The Jotun-Valdres nappe complex consists mainly of basement rocks, with some late Precambrian or Eocambrian cover (mainly sparagmites), subdivided by tectonic sutures generally of pre-main thrust age. Below the main thrust, the meta-sediments of the Parautochthon (probably Cambro-Ordovician) seem to represent an incompetent mass which deformed penetratively during the overthrusting, when it also suffered lower greenschist facies metamorphism. In contrast, the basement which makes up the Autochthon has remained almost unaffected by these events. In the following, the relations within these tectonic units will be first described and then set within a general sequence of events. It should already be noted, however, that the whole sequence is truncated to the northwest by a major zone of cataclasis (Tyin-Gjende fault, cf. Battey & McRitchie 1973) of post-main thrust age.

Relations within the tectonic units

Jotun-Valdres nappe complex

The Jotun-Valdres nappe complex can generally be divided into a main, higher part with little, and a lower part with strong Caledonian deformation. The former is composed of Jotun crystalline basement, the latter of a mainly sparagmitic metasedimentary sequence, the Valdres group, together with some basement.

Main part. – The Jotun crystalline complex southeast of the Tyin-Gjende fault is composed of a number of sub-units or thrust sheets, the structure of which has already been described in detail in an area east of Tyin (McRitchie 1965, Battey & McRitchie 1973, fig. 8). Only one of the shear zones recognized by McRitchie could be followed more or less continuously over the whole region (Fig. 1), and we have used this to distinguish two main sub-units of contrasting lithologies. The upper sub-unit consists of mainly basis rocks (e.g. the Mosaryggin sheared gabbro, McRitchie 1965), generally gneissified, sheared or mylonitized under amphibolite facies conditions, but occasionally occurring as undeformed igneous relics. It also includes ultramafic pods, pegmatitic veins and meta-dolerite dykes, all heterogeneously affected by the deformation. The lower sub-unit is mainly made up of intermediate rocks and their deformed and metamorphosed equivalents (e.g. the Amphibole-gneiss and the Tvindehaugen granite, McRitchie 1965). They generally show a marked gneissic structure, often steeply dipping and striking NW-SE. The gneisses are cut through discordantly by pegmatitic and aplitic veins and basic dykes, and both gneisses and minor intrusions are affected by later mylonitization. An even higher, third sub-unit of regional importance is probably to be distinguished in the extreme north of the area (Mjølkedola purple gabbro, Battey & McRitchie 1973).

At Grønsennknipa, Jotun crystallines seem to be associated with cover rocks in the form of sparagmites with an almost undeformed basal conglomerate lying in stratigraphic contact with gneissic basement (Hossack 1972).

This critical locality indicates that the main deformation in the unit is of Precambrian age. The age of the shearing into the above sub-units, and of the associated amphibolite facies metamorphism, is probably also of this age but certainly earlier than the development of the deformed lower zone.

Lower zone of deformation. – At the base of the main part, the shear zones between the sub-units described above are in places truncated by a mylonite zone which then marks the top of the deformed lower part. Although this contains some of the same lithologies as the main part (gabbros and intermediate gneisses) it is characterized by a much stronger and more penetrative deformation. The basement rocks are extremely heterogeneously laminated and sheared, and show greenschist facies mineral assemblages. The sparagmites, which are the main components of the Valdres group (Fig. 1), generally occur below this sheared basement, but in places they still retain a more or less stratigraphic relationship, with a well developed basal quartz-conglomerate (e.g. north of Vangsmjøsi and around Tyin). They show two main facies: a coarse-clastic, feldspar-rich type with a sericitic matrix ('Trikolorsparagmitt' or Rognslifjelltype, Loeschke 1967); and a more fine-grained, quartz-rich type with channel-like lenses of quartz-conglomerate and widespread cross-bedding (Rundemellen-type, Loeschke 1967). The whole sequence is intensely imbricated (e.g. around the Beito window, see Hossack 1976) or isoclinally folded (e.g. north of Vangsmjøsi), with the development of a penetrative foliation and concomitant intense elongation and flattening of conglomerate pebbles. The microstructure of these rocks shows that, with the exception of the feldspars, the deformation was accompanied or followed by recrystallization of the main minerals.

The main Caledonian thrust forms the base of the Jotun-Valdres nappe complex. It cuts discordantly through the above imbricate-fold structure (Fig. 2) and it is marked in some places by a mylonite, in others by heterogeneous and discontinuous horizons of greenish phyllites, dark and light quartzites and carbonate-bearing shales. A similar association of rock-types has been described to the east of the present region (Mellsenn group, Loèschke & Nickelsen 1968), where it is thought to lie stratigraphically above the Valdres sparagmites (lowermost Palaeozoic), although now in inverted position. In the present area, these Mellsenn group equivalents occur in tectonic slices along the thrust; some horizons within the sparagmites (e.g. north of Vangsmjøsi) seem to be in stratigraphic association.

Parautochthon

The low grade metamorphic meta-sediments (lower greenschist facies) below the main Caledonian thrust are mainly phyllites and quartz-phyllites showing a penetrative E to SE dipping cleavage, in places discordant to the main thrust plane. These rocks are often strongly graphitic, with layers of dark quartzite and occasional lenses of fine-grained marble, and locally show an association similar to the Mellsenn group. In addition, there are

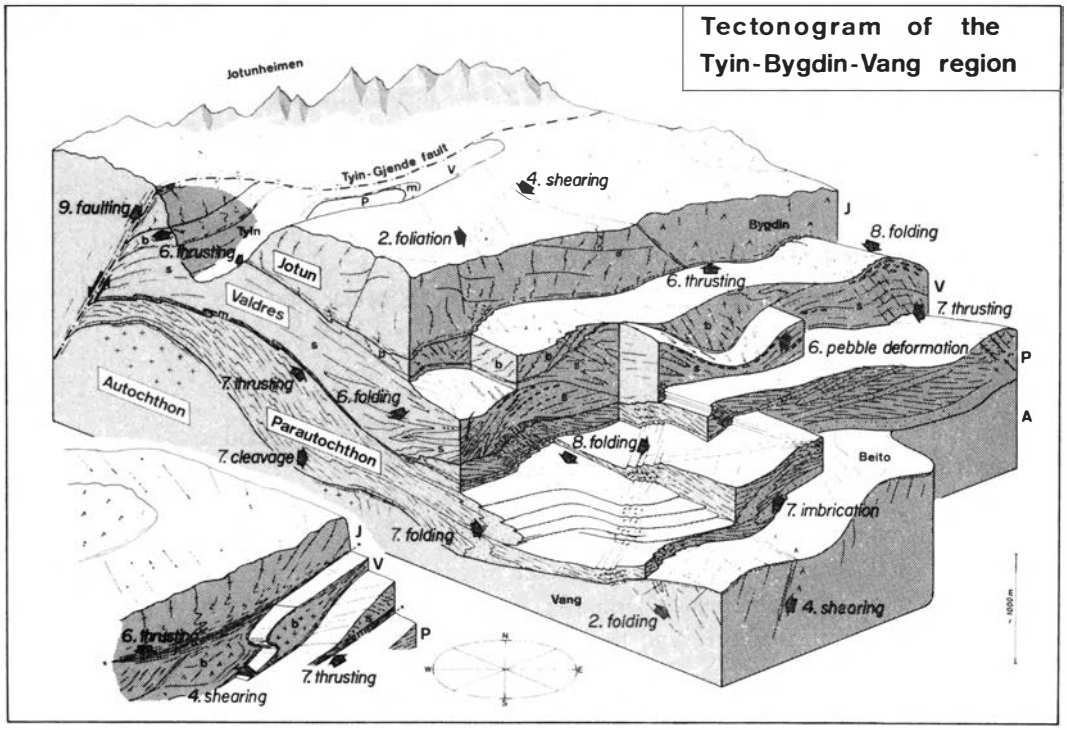

Fig. 2. Tectonogram of the Tyin-Bygdin-Vang region. The numbers refer to the corresponding events in the structural history, outlined in the text. Within the lower part of the Jotun-Valdres unit: b = basement, s = sparagmite, m = Mellsenn group equivalents.

thick, often basal horizons of a typical blue-grey quartzite or arkose, which are very similar to the quartz-sandstone or Synnfjell sandstone of Strand (1938) and to the Vangsås formation in the sparagmite region to the east (Bjørlykke et al. 1967). North of Vangsmjøsi, these quartzites delineate large recumbent isoclines, with axial planes parallel to the cleavage in the phyllites and fold axes trending E-W, sometimes imbricated, with flinty quartz-mylonite along the shear planes (Fig. 2, structures of event 7.). Throughout the phyllites, the cleavage is deformed and in part overprinted by sporadic zones of chevron or crenulation-type minor folds and cleavages, of several generations. Some of these are parasitic to major NW-SE trending folds with steep axial planes, which throw the main thrust into a series of tight antiforms (Fig. 1) and broad, intervening synforms.

Autochthon

The autochthonous basement, exposed in the windows of Vang and Beito as well as in some smaller ones further west (Øye, Fillefjell), consists of a wide range of igneous and highgrade metamorphic rock-types – coarse-grained granites (Fillefjell) intruding quartz-dioritic to amphibolitic gneisses (Øye, Vang) and anorthosites (Vang); gabbros, acid gneisses and metasediments (Beito, Hossack 1976). These are cut by pegmatitic veins, in

places parallel to shear zones showing medium-grade mineral assemblages, both these in turn crosscut by basic dykes. Except for local shearing, imbrication and retrograde metamorphism within a few metres of the contact with the overlying Parautochthon, no Caledonian effects could be distinguished.

Interpretation of the structural history

In the area southeast of the Tyin-Gjende fault, the general sequence of events in the various tectonic units is relatively clear (Fig. 2):

1. Formation of the basement intrusive complexes
The main process was probably magmatic differentiation but in general the primary relations are obscured by later events.

2. Regional deformation and metamorphism
Large parts of the intrusive complex were converted to gneiss with amphibolite facies mineral assemblages. Although a similar event can be recognized in both the Jotun-Valdres and the autochthonous basement, whether it was contemporaneous or not is uncertain, since at this time they may have been widely separated.

3. Minor intrusion
The inter-relationships of the pegmatitic and aplitic veins, the basic dykes, and the structural and metamorphic features vary from unit to unit, and it may be that minor intrusion took place at various times, some even coeval or later than event 4.

4. Shearing and mylonitization along narrow zones
In the Jotun basement-complex, this resulted in the formation of the various sub-units, under amphibolite facies conditions.

5. Uplift, erosion and sedimentation
The timing of this event, resulting in the deposition of the Eocambrian Valdres sparagmites in a western basin and the transgressive Lower Palaeozoic pelites and psammites, is uncertain with respect to event 4 in the Jotun basement complex. The relations on Grønsennknipa indicate that it is certainly later than event 2, and since no sparagmite is interleaved between the sub-units developed during event 4 we assume that the sedimentation came later (i.e. that the whole sequence 1 to 4 is Precambrian).

6. Early Caledonian thrusting
The mylonite zones in the lower Jotun-Valdres complex truncate the shear zones developed during event 4. In front of and below the advancing nappe a basement/cover slice underwent large-scale inversion, the basement was

intensely but heterogeneously sheared, and the cover (mainly sparagmite) was thrown into a series of large isoclinal folds, sometimes degenerating into multiple thrust slices. Most of the strain shown by the conglomerate pebbles developed during these movements (equivalent to the F_1 phase of Hossack 1967, 1972).

7. Main Caledonian overthrusting

The Jotun-Valdres complex seems to have been transported as a more or less rigid block over the more easterly Parautochthon and Autochthon. The main thrust plane at its base is sometimes sharply discordant, sometimes marked by thin imbricated slices of Valdres sparagmite, including Mellsenn-type meta-sediments. Below it lay a flowing cushion of mainly pelitic material (Parautochthon), separating the thrust block from an equally rigid fundament (Autochthon). Within the Parautochthon, a penetrative cleavage developed, accompanying or following the formation of large isoclinal folds and thrust slices. During the overthrusting, temperatures and pressures in the Parautochthon rose, eventually reaching a maximum at lower greenschist facies levels. As in other thrust belts (cf. Milnes & Pfiffner 1977) events 6 and 7 are probably the earlier and later parts of an essentially continuous process. The main thrust, however, truncates large recumbent folds of event 6 in the Valdres sparagmite, both in this area (Fig. 2) and further to the east (Nickelsen 1967).

8. Post-thrust fold phases

The main thrust plane, early structures in the Jotun-Valdres complex, and the cleavage and isoclinal folds in the Parautochthon are affected by various phases of later folding. The major structures seem to be sharp antiforms and broad synforms with steep axial planes and NW-SE trending axes (e.g. the Bygdin antiform, Hossack 1967). The analysis of these structures is not complete, but there are no major structures which can be related to a regional down-flexuring of the nappes into the 'Faltungsgraben', as has been described in the Hardanger area (Naterstad et al. 1973).

9. Major faulting

The Tyin-Gjende zone of cataclasis truncates the nappe structure in the northwest and may be associated with some of the minor folding included in event 8, as well as with widespread jointing. It seems to mark the southeast margin of the so-called 'Faltungsgraben' here, and also the southeast edge of the prominent gravity high reported by Smithson et al. (1974). The downthrow to the northwest of the fault is likely to have been several kilometres.

It is hoped that the on-going isotopic studies will enable us to place more precise time limits on the various events in this sequence, in particular, on the intrusion history, on the phases of mylonitization, and on the Caledonian low-grade metamorphism.

March 1976, revised February 1977

REFERENCES

Battey, M. H. & McRitchie, W. D. 1973: A geological traverse across the pyroxene-granulites of Jotunheimen in the Norwegian Caledonides. *Nor. Geol. Tidsskr. 53,* 237–265.

Bjørlykke, K. O. 1905: Den centrale Norges fjeldbygning: Valdres, Hemsedal, Lærdal. *Nor. Geol. Unders. 39,* 461–542.

Bjørlykke, K., Englund, J. O. & Kirkhusmo, L. A. 1967: Studies on the latest Precambrian and Eocambrian rocks in Norway. No. 3. Latest Precambrian and Eocambrian stratigraphy of Norway. *Nor. Geol. Unders. 251,* 5–17.

Bugge, C. 1939: Hemsedal og Gol: Beskrivelse til de geologiske gradteigskarter E32V og E32Ø. *Nor. Geol. Unders. 153,* 84 p.

Hossack, J. R. 1967: Structural history of the Bygdin area, Oppland. *Nor. Geol. Unders. 247,* 78–107.

Hossack, J. R. 1972: The geological history of the Grønsennknipa nappe, Valdres. *Nor. Geol. Unders. 281,* 1–26.

Hossack, J. R. 1976: Geology and structure of the Beito window, Valdres. *Nor. Geol. Unders. 327.*

Loeschke, J. 1967: Zur Stratigraphie und Petrographie des Valdres-Sparagmites und der Mellsenn-Gruppe bei Mellane/Valdres (Süd-Norwegen). *Nor. Geol. Unders. 243,* 5–66.

Loeschke, J. & Nickelsen, R. P. 1968: On the age and tectonic position of the Valdres sparagmite in Slidre (southern Norway). *Neues Jb. Geol. Pal. Abh. 131,* 337–367.

Milnes, A. G. & Pfiffner, O. A. 1977: Structural development of the Infrahelvetic complex in eastern Switzerland. *Eclog. Geol. Helv. 70,* 83–95.

Naterstad, J., Andresen, A. & Jorde, K. 1973: Tectonic succession of the Caledonian nappe front in the Haukelisæter-Røldal area, southwest Norway. *Nor. Geol. Unders. 292,* 1–20.

Nickelsen, R. P. 1967: The structure of Mellene and Heggeberg, Valdres. *Nor. Geol. Unders. 243,* 99–121.

McRitchie, W. D. 1965: Structure and geochemistry of layered metamorphic rocks near Eidsbugarden, Jotunheimen, Norway. Unpublished Ph. D. thesis, Univ. Durham, 177 p.

Reusch, H. 1901: Højfjeldet mellem Vangsmjøsen og Tisleia (Valdres). *Nor. Geol. Unders. 32,* 45–88.

Strand, T. 1938: Nordre Etnedal: Beskrivelse til det geologiske gradteigskart. *Nor. Geol. Unders. 152,* 71 p.

Strand, T. 1950–51: Geologisk kart 1:100,000. Slidre: Beskrivelse til det geologiske gradteigskart. *Nor. Geol. Unders. 180,* 54 p.

Smithson, S. B., Ramberg, I. B. & Grönlie, G. 1974: Gravity interpretation of the Jotun nappe of the Norwegian Caledonides. *Tectonophys. 22,* 205–222.

Törnebohm, A. E. 1896: Grunddragen af det centrala Skandinaviens bergbygnad. *Kgl. Sv. Vet. Akad. Förh. 28/5,* 210 p.