Basement gneisses mapped as Valdres Sparagmite near Hermansverk, in Sogn, west Norway

JOHN L. ROBERTS

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The Njøs Formation near Hermansverk on the NW side of the Jotunheim Massif has been correlated with part of the Valdres Sparagmite. Evidence is presented from the type-section that these rocks are the deformed representatives of basement gneisses, affected by varying amounts of cataclasis and recrystallisation, similar to the blastomylonites developed at the base of the Jotunheim Massif. However, their original character as grey quartzo-felspathic gneisses, cut by basic sheets and pegmatite veins, can still be recognised wherever the intensity of the deformation is sufficiently low. The banding previously thought to represent bedding is produced by extreme deformation, which would obliterate the cross-cutting relationships between the various components in such a basement complex, while the felspar porphyroclasts previously considered as evidence for a sedimentary origin in the form of detrital grains are the product of differential cataclasis. It is suggested that the Jotun Nappe is underlain by one or more thrust-sheets of basement gneisses, separated from one another by supracrustal rocks of Caledonian age.

J. L. Roberts, Department of Geology, The University, Newcastle upon Tyne, NE1 7RU, England.

The 1:1,000,000 Geological Map of Norway (Holtedahl & Dons 1960) and the 1:1,500,000 International Geological Map of Europe (UNESCO 1966) show a narrow outcrop of rocks which have been mapped as Valdres Sparagmite along the NW margin of the Jotunheim Massif in southern Norway. They are overlain by plutonic rocks, affected by granulite-facies metamorphism (Battey & McRitchie 1973), which form the Jotunheim Massif to the SE, while they are underlain by the pelitic rocks of the Phyllite Formation to the NW. All these rocks lie on the NW side of the 'Faltensgraben', which is the name given to the synformal depression defined by the outcrop of the Jotunheim Massif (Goldschmidt 1916). This means that the contacts between the various formations dip moderately towards the SE, away from the Basal Gneisses which are exposed to the NW of the Phyllite Formation. Most of the contacts between the formations appear to be thrusts, even though the intense deformation of the rocks lying between the Jotunheim Massif and the Basal Gneisses has resulted in a structural concordance between these formations.

The main outcrop of the Valdres Sparagmite lies to the SE of the Jotunheim Massif, where Loeksche & Nickelsen (1967) have shown it to be an Eocambrian formation, and is older than the Cambro-Ordovician rocks now represented by the Phyllite Formation. However, it has been traced as a narrow band around the NE end of the Jotunheim Massif, where Strand (1964) considers it to separate a thin remnant of the Otta Nappe from the overlying Jotun Nappe. Beyond this point, it occurs along the NW margin of this massif, dying out some distance to the SW of Sognefjorden, as shown in Fig. 1. The rocks mapped as Valdres Sparagmite in this region are mainly light-coloured quartz-felspar gneisses, intercalated with darker rocks of a more basic composition. They show a pronounced banding which is thought to represent bedding. Although clastic textures have been described from these rocks, there are few records of sedimentary structures other than bedding.

Landmark (1948), Lacour (1969), and Skjerlie (1957) have described such rocks from various areas between Bøverdalen and Sognefjorden, where they occur immediately to the NW of the plutonic rocks forming the Jotunheim Massif, as shown on the small-scale maps of Norway. These rocks are evidently correlated with the Valdres Sparagmite according to their petrography, in that they have a mineral composition similar to the light and dark sparagmites which form the main components of this formation in its type-area. However, these arkoses and greywackes are formed by detritus, which is derived without much alteration from the physical disintegration of plutonic rocks. Thus, although these rocks have a mineral composition similar

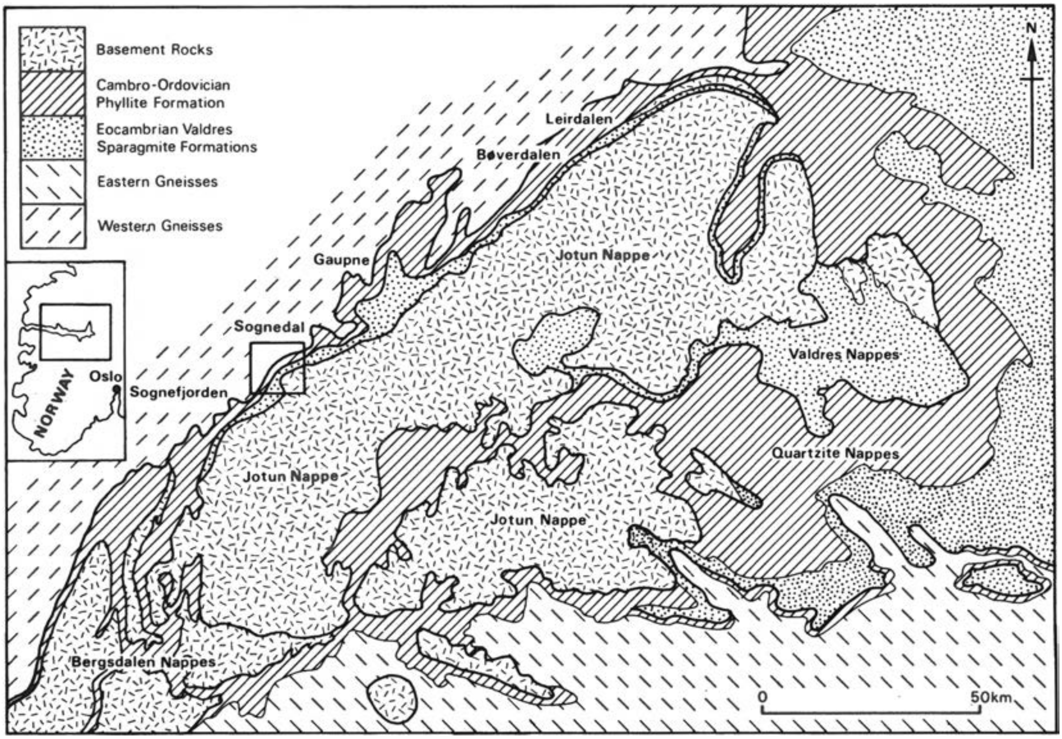

Fig. 1. Geological map of the Jotunheim Massif showing the rocks mapped as Valdres Sparagmite, according to the 1:1,000,000 Geological Map of Norway (Holtedahl & Dons 1960) and the 1:1,500,000 International Geological Map of Europe (UNESCO 1966). The area within the rectangle is shown in Fig. 2.

to the Valdres Sparagmite, they might represent the plutonic rocks from which the Valdres Sparagmite has been derived.

Banham & Elliot (1965) and Banham (1968) have also described rocks as belonging to the Valdres Sparagmite around Leirdalen, which lies midway between the areas considered by Strand (1964) and Landmark (1948). These rocks are thought to form thrust-sheets, associated with the rocks of the Phyllite Formation, which occur to the NW of the main outcrop of the Valdres Sparagmite. This work suggests that the NW margin of the Jotunheim Massif has a geological structure which is more complex than previously thought. However, it also implies that metasedimentary rocks are likely to occur stratigraphically below the Phyllite Formation, so that they could well have a lithological character similar to the Valdres Sparagmite in its type-area.

In fact, the evidence to be described in the present paper suggests that the rocks mapped by Skjerlie (1957) as the lower part of the Valdres Sparagmite near Hermansverk are the deformed representatives of basement gneisses. This evidence is sufficient to cast considerable doubt on the status of the rocks mapped as Valdres Sparagmite along the NW margin of the Jotunheim Massif. However, it does not preclude the possibility that the Valdres Sparagmite is also represented within this region, as suggested by the work of Banham & Elliot (1965) and Banham (1968).

General description

The present paper gives a detailed description of the rocks mapped as part of the Valdres Sparagmite along the northern coast-line of Sognefjorden, immediately to the east of Hermansverk. This area has been mapped by Skjerlie (1957), who divided the Valdres Sparagmite into two groups. These were subsequently by Skjerlie (1969) termed the Njøs Formation and the Fatlaberg Formation. Correlation

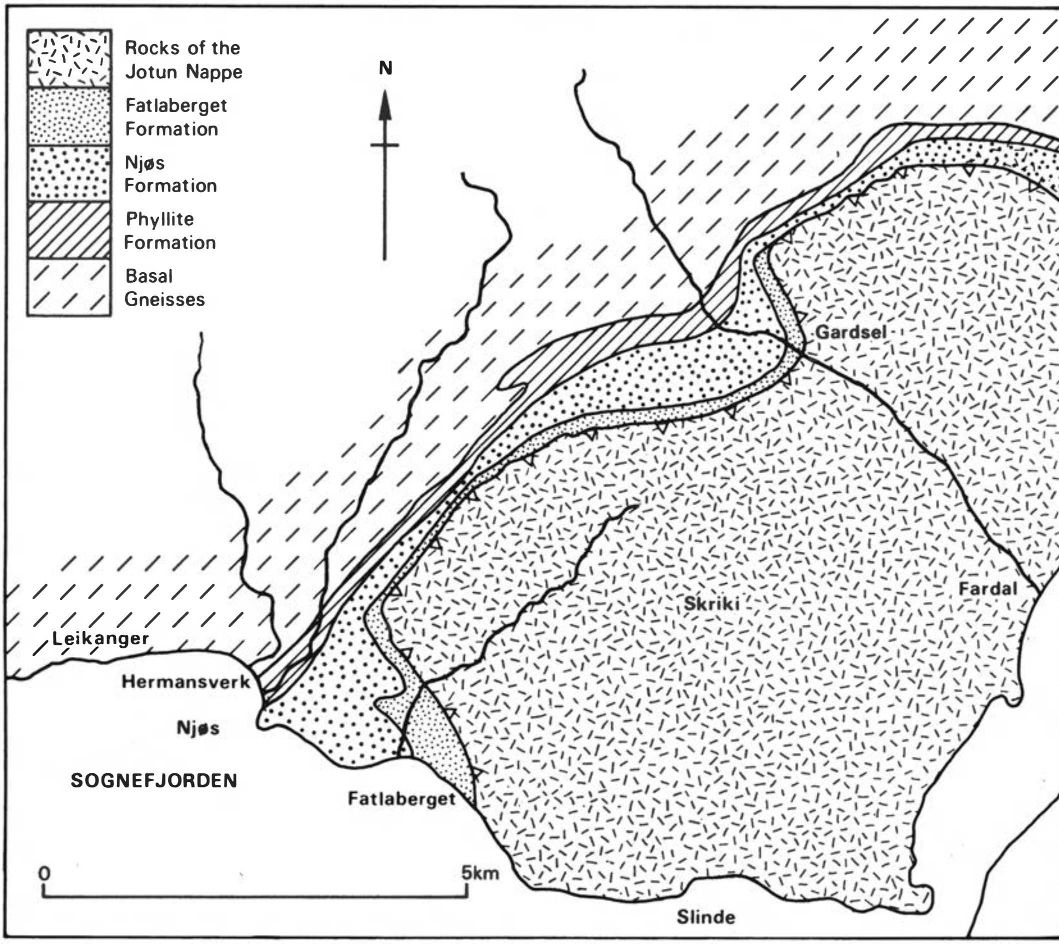

Fig. 2. Geological map of the Hermansverk district showing the outcrop of the Fatlaberg and Njøs Formations according to Skjerlie (1957, pl. 9, 1969, pl. 1).

with the rocks of the Askvoll–Gaular area in western Norway suggests that the underlying Njøs Formation is younger than the overlying Fatlaberg Formation, so that the whole sequence is inverted below the Jotun Nappe (Skjerlie 1969). It is the Njøs Formation which forms the subject of this paper. However, the Fatlaberg Formation is briefly described, for comparison with the Njøs Formation.

The Fatlaberg Formation has been studied in what may be regarded as its type-section at Fatlaberget. It lies immediately below the rocks of the Jotunheim Massif, as shown in Fig. 2. Although it has been traced eastwards towards Sogndal by Skjerlie (1957, pl. 9), rocks of a comparable character have not been reported further to the NE by Lacour (1969) or Landmark (1948).

The Fatlaberg Formation consists of uniform, fine-grained, dark, bluish-grey rocks which are finely-laminated and very compact. The lamination is caused by the presence of alternating quartzose and micaceous layers in the rock. It is likely to be a sedimentary lamination since the muscovite and biotite in the micaceous layers form a fine-grained fabric which cuts across the layering at the hinges of minor folds. Felspar occurs as rounded or angular grains of sodic plagioclase, microcline, and microperthite, much larger than the quartz grains which form the bulk of the rock. Skjerlie (1957) comments that the microperthite is similar to the mesoperthites which are found in the anorthosites of the Jotunheim Massif. There can be little doubt that these rocks were originally rather quartzose sediments incorporating detritus produced by the erosion of rocks which now form the Jotunheim Massif (Skjerlie 1957). However, it must be admitted that the stratigraphic position of the Fatlaberg Formation is rather uncertain.

The Njøs Formation has also been studied along the northern coast-line of Sognefjorden, in what may be regarded as its type-section at Njøs. It lies immediately below the rocks forming the Fatlaberg Formation. There, it has been described by Skjerlie (1957), who traces this formation as far east as Sogndal. However, rocks of a comparable character have been described as Valdres Sparagmite further to the NE by Lacour (1969) and Landmark (1948).

The bulk of the Njøs Formation is formed by rocks which are here described as grey quartzo-felspathic gneisses of intermediate composition, grading into blastomylonites as the amount of deformation increases. The blastomylonites consist of porphyroclasts (<2 mm) of sodic plagioclase, microcline, and microperthite, set in a fine-grained matrix of quartz, felspar, epidote, muscovite, and biotite. Some of the microperthite porphyroclasts are formed by spindle mesoperthites similar to those found in the rocks of the Jotunheim Massif. A schistosity is developed in the matrix by the parallel arrangement of the muscovite and biotite flakes. The schistose character of the matrix is emphasised by the elongate form of the quartz and felspar grains, constrained by the parallel arrangement of the micas. The schistosity is deflected around the felspar porphyroclasts, while pressure shadows of recrystallised material are found at the sides of these grains. The porphyroclasts are rather angular in outline. They commonly show clear evidence of internal distortion and cataclasis which affects the twinning and microperthitic intergrowths of the felspars. This leads to the disruption of individual grains, forming angular fragments separated by areas of recrystallised quartz. These rocks show similar features where they are less deformed, except that a planar fabric or schistosity is not developed to any extent by the matrix minerals. However, the rock still shows larger grains of K and Na felspar set in a finer-grained matrix of quartz, felspar, epidote, muscovite and biotite. It is these rocks which are recognised to be grey quartzo-felspathic gneisses (cf. Skjerlie 1957). Relict grains of bluish-green amphibole are occasionally preserved in the more basic examples, replaced by varying amounts of brown biotite.

Basic rocks are found as amphibolite layers in the grey gneisses. These rocks are composed of relict grains of bluish-green amphibole, replaced by a felted mass of biotite flakes. It is possible that the amphibole has replaced pyroxene, since some grains have squarish outlines. Occasional grains of sodic plagioclase are found, riddled with epidote granules, while felspar also occurs as recrystallised grains in the matrix. These amphibolites grade into biotite-schists as the rocks become increasingly deformed. This is marked by the further replacement of amphibole by brown biotite, while the rock takes on a planar fabric in response to the parallel arrangement of the biotite crystals. Grains of sodic plagioclase are found in quartz-rich lenticles lying within the foliation formed by the biotite. Epidote granules are abundant throughout the rock.

Acid rocks are represented by sheared pegmatite veins which form pinkish layers in the rock. They consist essentially of quartz and alkali felspar. The quartz forms a mosaic of recrystallised grains, while the felspar is affected by internal distortion, fracturing, and disruption which results in angular porphyroclasts of sodic plagioclase, microcline, and microperthite lying in a very fine-grained matrix of quartz, felspar, epidote, and muscovite. These rocks show a blastomylonitic flow-banding formed by the differential response of the original quartz and felspar grains in the rock to cataclasis and recrystallisation.

Finally, there are some finely-banded siliceous rocks which form rather narrow zones in the grey gneisses. They are composed mainly of quartz, with small amounts of felspar, epidote, and muscovite. The banding is developed by thin films of muscovite, some 0.5 to 1.0 mm apart, between which the quartz is arranged as ribbons of recrystallised grains. The mica-films are deflected around the felspar, which appear to be the disrupted remnants of larger grains. The mica-films are often lined with epidote granules, formed in all probability by the breakdown of calcic plagioclase.

Most of these rocks are very deformed. However, there are some areas where the deformation is less intense so that the original features of the rocks can be discerned. Such an area is found on the shore at the western end of Fatlaberget (LN 858842). There, basic rocks occur as sheets in the grey gneiss, while folded and boudinaged pegmatite veins cut across the layering formed by these sheets. The discordance between the pegmatite veins and the lithological layering in the gneiss is gradually lost as the rocks become increasingly deformed. Thus, extreme deformation causes the pegmatite veins to rotate into parallelism with the layering, while a compositional banding is developed on a fine scale by the progressive attenuation of the pegmatite veins and the basic layers in the rock. This process is accompanied by the development of a blastomylonitic flow-banding or schistosity, which forms in response to the differential cataclasis and recrystallisation undergone by the various rock-types.

This evidence suggests that the rocks of the Njøs Formation are the deformed representatives of a basement complex formed by grey gneisses, basic sheets, and pegmatite veins. This is contrary to the views of Skjerlie (1957), who attributed a sedimentary origin to these rocks since he considered the felspar porphyroclasts to be detrital grains. However, these porphyroclasts are found in the more deformed rocks, where they have been formed by the processes described by Higgins (1971) as typical of differential cataclasis. Moreover, these rocks have a plutonic aspect where they are least deformed, showing no evidence for a sedimentary origin. Thus, the banding and lamination of the rocks developed in response to deformation, affecting rocks which originally showed intrusive relationships. It is clear that this banding and lamination does not represent bedding, as implied by Skjerlie (1957).

It is emphasised that the rocks of the Njøs Formation show many features in common with the rocks forming the base of the Jotunheim Massif. These rocks are exposed along the roadside at Fatlaberget, where they lie above the fine-grained sediments of the Fatlaberg Formation. The contact between the Jotunheim Massif and the Fatlaberg Formation is a major thrust, above which the rocks of the Jotunheim Massif are extremely deformed. However, the intensity of the deformation declines upwards so that the original features of the rocks may be seen only a short distance above the basal thrust. There, the rocks are grey quartzo-felspathic gneisses cut by basic sheets and pegmatite veins. It is possible to match these rocks individually, as they become increasingly deformed towards the base of the Jotunheim Massif, with the rocks which have already been described from the Njøs Formation. Any differences which exist between the two groups are simply the result of differences in the proportions of the various lithologies which were originally present.

The only rocks which cannot be matched in this way are the finely banded siliceous rocks described from the Njøs Formation. However, it is likely that these are the deformed representatives of quartz veins. Skjerlie (1957) describes rocks with a similar mineralogy from the interior of the Jotunheim Massif, where they form cross-cutting dykes and veins.

Conclusions

The evidence described in this paper suggests that the rocks of the Njøs Formation are the deformed representatives of basement gneisses. Since these rocks are similar in character to the deformed rocks forming the base of the Jotunheim Massif, it seems likely that it was the presence of the Fatlaberg Formation which allowed the Njøs Formation to be recognised as a separate entity by Skjerlie (1957). This implies that rocks of a similar character, which have previously been correlated with the Valdres Sparagmite (Skjerlie 1957, Lacour 1969, Landmark 1948, Strand 1964), may also represent basement gneisses where they occur elsewhere along the NW margin of the Jotunheim Massif. However, this is not proved by any means, so that rocks equivalent to the Valdres Sparagmite may also occur within this region, stratigraphically below the Cambro-Ordovician rocks of the Phyllite Formation (Banham & Elliot 1965, Banham 1968). Further work is evidently required to distinguish these formations from one another, wherever they might occur along the NW margin of the Jotunheim Massif. The convergence in lithological character which would affect these rocks as they become increasingly deformed means that such a distinction is very difficult to make in the field.

Even so, certain conclusions can be drawn concerning the structural features shown by the NW margin of the Jotunheim Massif. It is clear that the Njøs Formation forms a thrust-sheet which can be termed the Njøs Nappe. This nappe is separated from the Jotun Nappe by the sedimentary rocks of the Fatlaberg Formation. These rocks would form another nappe if the sharp contact reported by Skjerlie (1957) between the Njøs and Fatlaberg Formations is a thrust-plane, as seems likely. Although it is not certain that the underlying rocks of the Phyllite Formation are allochthonous, the evidence from elsewhere along the NW margin of the Jotunheim Massif would support such an interpretation. Thus, the rocks of the Phyllite Formation exposed at Gaupne, some 40 km to the NE of Sognefjorden, are divided into three parts by two sheets of deformed gneisses, similar in most respects to the rocks of the Njøs Formation. This suggests that the Jotun Nappe is underlain by thrust-sheets of deformed gneisses, separated from one another by supracrustal rocks of Caledonian age. These basement rocks would correspond in tectonic position to the Precambrian rocks of the Bergsdalen Nappes described by Kvale (1960) from the region to the SW of Sognefjorden.

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