Stratigraphy and Caledonian structures in the area between the Atnsjøen and Spekedalen windows, Sparagmite Region, southern Norway

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Nystuen, J. P. & Ilebekk, S.: Stratigraphy and Caledonian structures in the area between the Atnsjøen and Spekedalen windows, Sparagmite Region, southern Norway. *Norsk Geologisk Tidsskrift*, Vol 61, pp. 17–24. Oslo 1981. ISSN 0029-196X.

The tectonostratigraphy in the area between the Atnsjøen and Spekedalen windows includes the crystalline basement with a thin discontinuous autochthonous sequence, overthrust by the Røa Nappe. The Røa Nappe consists of three thrust sheets and contains the Late Precambrian Hedmark Group. The Storskarven Sandstone is introduced as a new formation. Slaty cleavage and mineral elongation were formed early during the movement of the Røa Nappe, and a fracture cleavage originated during a late-Caledonian compressional phase, together with the basement domes exposed in the windows.

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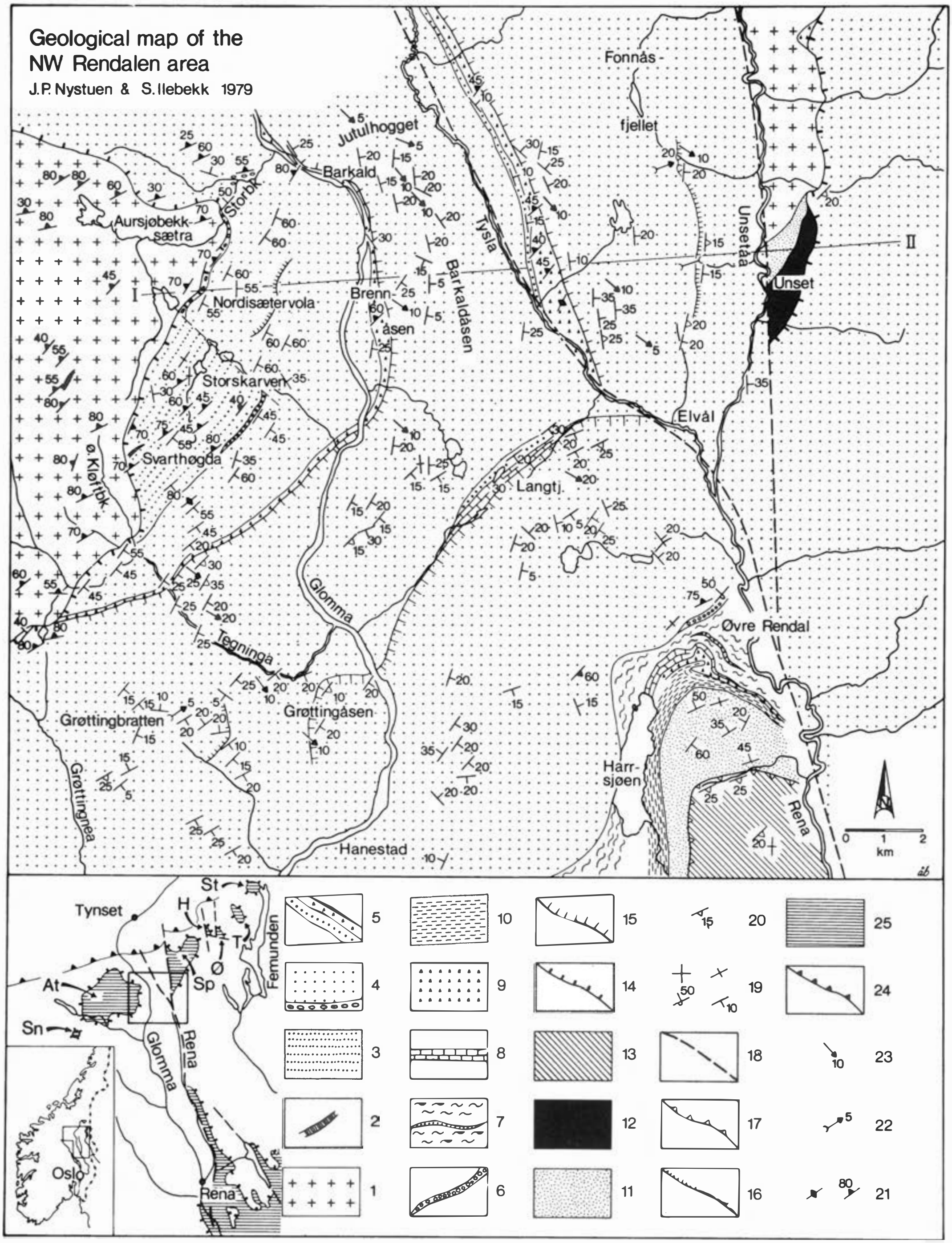
A basement antiform within the Caledonian nappe region in south Norway can be traced as a series of windows from Aurland in Sogn in the SW to Sylene at the Norwegian-Swedish border in the NE (Holtedahl & Dons 1960). The Atnsjøen and Spekedalen windows are among the largest windows along this anticlinal structure (Fig. 1). (The Spekedalen window has also been termed the 'Finstad window' (Oftedahl 1943, Oftedahl in Oftedahl & Holmsen 1952). However, Holmsen (1943:20) named this area 'Spekedalens grunnfjellsområde' (the Spekedalen area of Precambrian basement rocks); 'Spekedalen' is an appropriate name to the window as the valley Spekedalen crosses the window, whereas Finstad (a cluster of farms) is situated at the western margin of it).

The crystalline basement and its autochthonous cover of sedimentary rocks appearing in the windows are overthrust by the Røa Nappe which consists of the Late Precambrian Hedmark Group (Törnebohm 1896, Nystuen 1975, 1978 and 1981, Kjølberg 1980). Farther south, the Røa Nappe is succeeded by the Kvitvola Nappe. The Kvitvola Nappe, consisting of Late Precambrian metasediments and tectonic slices of crystalline basement rocks, will not be treated in this paper. The main objects here are to study the tectonic structures of the Røa Nappe, its lithostratigraphy and its tectonic relation to the crystalline basement and autochthonous strata, and the influence of Caledonian deformation on the whole tectono-stratigraphical succession. Among the lithostratigraphical units most emphasis is put on the lower part of the Hedmark Group, the Storskarven Sandstone and the Rendalen Formation.

Precambrian basement and autochthonous strata

The crystalline basement in the eastern part of the Atnsjøen window and in the Spekedalen window consists of granite, granite aplite, and some diabase dykes. The basement rocks occur up to an altitude of 1500 m a.s.l. in the central part of the Atnsjøen window and 1300 m a.s.l. in the Spekedalen window. The basement surface in the windows is dome-shaped and dips 40–60° at the eastern margin of the Atnsjøen window and 10–45° at the northern, eastern, and southeastern margin of the Spekedalen window (Nystuen 1978). The latter window is cut by the Rendalen – Unsetåa fault in the west (Figs. 1 and 2). The basement surface lies at a depth of about 1000 m b.s.l. in the area between the windows (Åm 1976, Åm in Nystuen 1981).

A discontinuous sequence of autochthonous sediments outcrops at the edges of the windows and beneath the allochthonous nappe rocks. This sequence has an original stratigraphical thickness of about 0–50 m at the southern and western margins of the Atnsjøen window (Siedlecka


Geological map of the
NW Rendalen area
J.P. Nystuen & S. Ilebekk 1979
Jutulhogget
Barkald
Fonnås-
fjellet
Aursjøbekk-
sætra
Storbk.
Nordisætervola
Brenn-
åsen
Barkaldåsen
Tysla
Unsetåa
Unset
Storskarven
Svarthøgda
ø. Kløftbk.
Elvål
Langtj.
Glomma
Tegningå
Øvre Rendal
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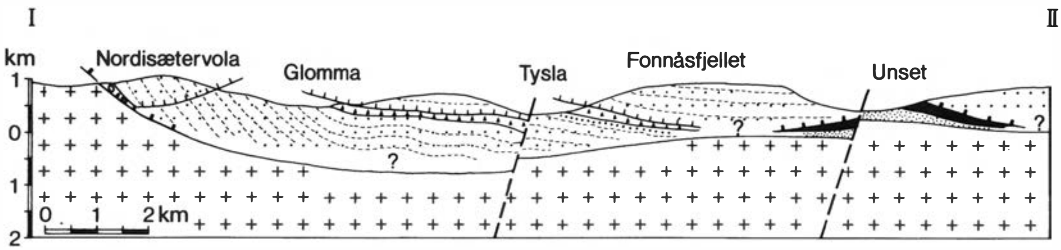

Fig. 2. Geological profile from Atnsjøen window to southern apex of the Spekedalen window. Position of section line I–II is shown on map in Fig. 1.

1979) and about 0–150 m on the Spekedalen window (Nystuen 1978). The autochthonous sequence includes the Moelv Tillite (basal till facies), the Vangsås Formation (complete with both the Vardal and Ringsaker Members at the Spekedalen window), and green and black Cambrian phyllite (Spekedalen). A grey arenaceous limestone at Unset (only seen as local erratic blocks) occurs at the southern apex of the Spekedalen window and is associated with grey, conglomeratic feldspathic sandstone and dark phyllite. The two last mentioned units are lithologically similar to the Vardal Sandstone Member and the overlying Cambrian phyllite at the northern edge of the Spekedalen window. This correlation favours the interpretation of Oftedahl (Oftedahl & Holmsen 1952) that the 'Unset limestone' corresponds to the Arenigian 'Orthoceras limestone' and not to the Biri Formation as suggested by Törnebohm (1896:42) and recently by Kjølberg (1980).

The Moelv Tillite is preserved as erosional remnants in several hundred metres wide and up to 30 m deep depressions in the crystalline basement surface (Nystuen 1976, 1978). The overlying Vangås Formation also rests directly on the crystalline basement; the granite beneath is weathered to a depth of 2–3 m at the northern part of the Spekedalen window (P. Holmsen 1943 and in Holmsen & Holmsen 1950). The degree of tectonic disturbance varies within short distances, from nearly no deformation to small-scale imbrications, development of cleavage and elongation and flattening of clasts and pebbles in tillite and conglomerates.

It has been suggested that the window structures in the northern part of the Sparagmite Region acted as topographic highs during the Late Precambrian and Cambro – Silurian (Skjeseth 1963). This suggestion is contradicted by the fact that the autochthonous strata are conformable (formation boundaries as well as lithofacies) with the dome structures displayed by the crystalline basement surface; a concentric pattern of onlap contacts and facies variations ought to have been present around the basement domes if they had existed as topographic highs when the sedimentation took place. In our opinion the window domes are late Caledonian structures, as also suggested and discussed by Nystuen (1981).

Fig. 1. Geological map of the northwestern Rendalen area. 1 Precambrian crystalline basement, 2 metamorphic diabase, 3 Storskarven Sandstone, 4 Rendalen Formation with basal conglomerate, 5 Atna Quartzite Member at Langtjern and east of Tysla, 6 conglomerate at Øvre Rendal, 7 Biri Formation; shale with sandstone unit, 8 Biri Formation; limestone and dolomite, 9 Moelv Tillite, 10 Ekre Shale, 11 Vangsås Formation, 12 Cambro-Ordovician shale and limestone, 13 Kvitvola Nappe, 14 Røa Nappe thrust plane, 15 thrust plane between thrust sheets in the Røa Nappe, 16 thrust plane in general, 17 Kvitvola Nappe thrust plane, 18 fault, 19 bedding plane (S_0), 20 slaty cleavage, (S_1), 21 fracture cleavage (S_2), 22 fold axis, 23 mineral elongation (L_1). I–II section line for profile in Fig. 2. Key map: 24 Trondheim Nappe thrust plane, 25 Precambrian basement. Windows: Sn = Snødøla, At = Atnsjøen, Sp = Spekedalen, H = Holøydalen, Ø = Øversjødalen, T = Tufsingdalen and St = Steinfjellet. Magnitude of dip 360° degrees.

Tectonostratigraphy of the Røa Nappe

The Røa Nappe lies directly on either the crystalline basement or the autochthonous strata. The nappe rocks are deformed by cataclasis and phyllonitization in the basal thrust zone (c. 20–200 m thick) and also along internal thrust planes (Fig. 1). A brecciation of the granite beneath the nappe at ø. Kløftbekken (Fig. 1) (Oftedahl 1943: 37) has been traced to a depth of about 150–200 m below the thrust plane. It is uncertain whether this brecciation merely is due to the nappe's overthrust or rather to an earlier or later phase of deformation.

The Røa Nappe in the investigated area con-

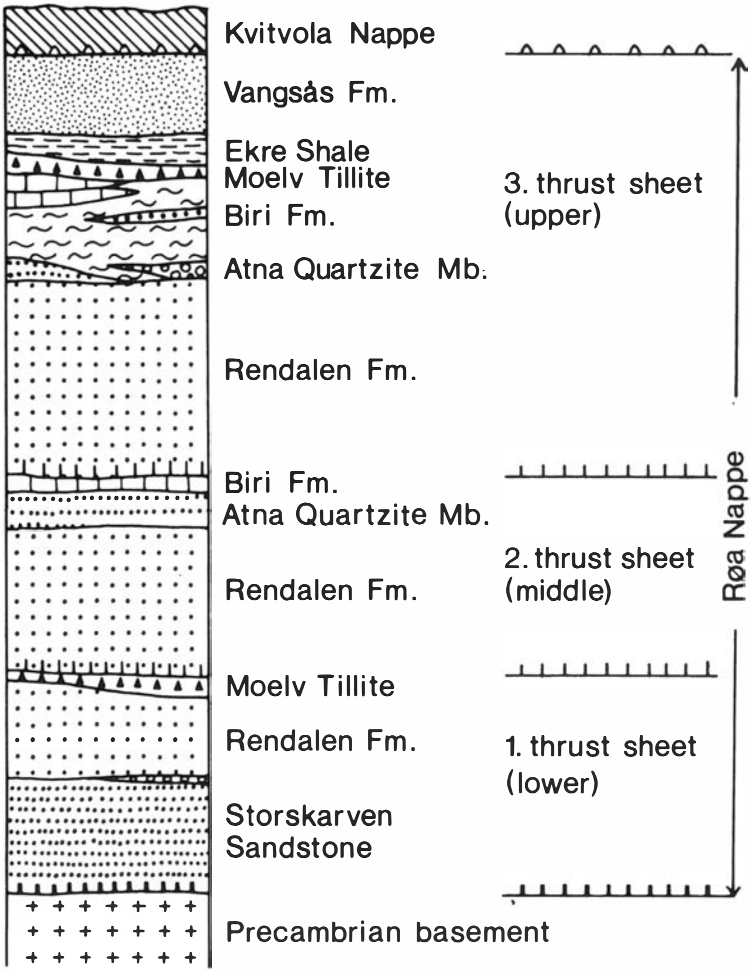

Fig. 3. Simplified tectono- and lithostratigraphical diagram from the Precambrian basement in the Atnsjøen window at the bottom through the Røa Nappe to the Kvitvola Nappe at the top.

sists of *three thrust sheets* or *subnappes* in which there is a repetition of lithostratigraphical units (Figs. 1, 2 and 3). In addition there are several tectonic shear zones along which differential movements have taken place within the thrust units (Oftedahl 1943). All thrust planes dip to the east or southeast.

The lower thrust sheet. – The basal thrust plane of the nappe cuts stratification and lithostratigraphical boundaries in the lower thrust sheet along the eastern margin of the Atnsjøen window (Fig. 1). This lower thrust sheet wedges out towards the southwest and is overlain by the middle subnappe in the east, whereas its northern extent is unknown. The lower subnappe consists of the Storskarven Sandstone, the Rendalen Formation, and the Moelv Tillite within a continuous stratigraphical sequence. The Storskarven Sandstone lies beneath the Rendalen Formation and is in this paper introduced as a new formation in the Hedmark Group. It is defined and described in a later chapter.

The lower thrust sheet is probably also present east of the Tysla fault (Figs. 1 and 2) in a continuous sequence comprising the Rendalen Formation with the Atna Quartzite Member in the upper part and the Moelv Tillite at the top.

The middle thrust sheet. – It starts with the Rendalen Formation lying above the Moelv Tillite. This tectonic repetition was already suggested by Oftedahl (in Oftedahl & Holmsen 1952: 23). Phyllonitization has taken place in the top of the Moelv Tillite, and the slaty cleavage (S_1) is well developed in the lower part of the overlying arkoses of the Rendalen Formation (east of Tysla, at Brennåsen and north of Tegninga). Kjølberg (1980) correlated the red arkose in Barkaldåsen with the Vangsås Formation, but its position is within the Rendalen Formation, as shown by a transition upwards into the Atna Quartzite Member at Langtjern. At this locality the middle thrust sheet is terminated by a dolomite which here is correlated with the Biri Formation.

The upper thrust sheet. – This is the third thrust sheet ('Harrsjø Nappe' of Kjølberg 1980) and is defined by the repetition of the Rendalen Formation above the Biri Formation (dolomite) west of Elvål (Fig. 1). The thrust zone west of Elvål is 200 m thick (Kjølberg 1980), and the arkose of the Rendalen Formation is altered to a quartz-sericite schist. A similar thick deformation zone is present in Grøttingåsen west of Glomma, and though the dolomite is lacking here, it is considered that the quartz – sericite rock represents the continuation of the thrust zone beneath the upper subnappe. This is the westernmost recorded exposure of the thrust. It is possible that the zone of tectonic movement is hinged in the area west of Glomma, and that the middle and upper tectonic units are joined in this area. A zone of strong tectonic deformation in the eastern side of Fonnåsfjellet (Fig. 1) may separate Rendalen Formation sandstones belonging to the middle thrust sheet in the west and to the upper thrust sheet in the east. The upper thrust sheet includes a continuous sequence through the Hedmark Group in the area west of Øvre Rendal (Figs. 1 and 3).

Only one major thrust unit has been identified so far on the eastern side of the Rendalen – Unsetåa fault (Figs. 1 and 2).

Hedmark Group in the Røa Nappe

The Hedmark Group stratigraphy in the studied area differs in several ways from that of the 'type' area at Mjøsa (e.g. Bjørlykke 1978). The Brøttum and Ring Formation are not developed, but instead the Rendalen Formation is the dominating unit beneath the Moelv Tillite. *Storskarven Sandstone* is introduced as a new formation beneath the Rendalen Formation. The most complete sequence through the Hedmark Group is preserved in the upper thrust sheet (Figs. 1 and 3). In the hillside west of Øvre Rendal sedimentary contacts have been observed at all stratigraphical boundaries. This section, embracing the upper part of the Hedmark Group, has recently been discussed by Kjølberg (1980) and Sæther & Nystuen (1981). An inverted sedimentary contact is here present between the Rendalen Formation and the overlying conglomerate and dark shale of the Biri Formation. The Moelv Tillite rests with erosional contact upon a local limestone in the upper part of the Biri Formation and is succeeded conformably by the Ekre Shale. The Ekre Shale passes upwards into the Vardal Sandstone Member of the Vangås Formation, and this unit comprises variously coloured greywackes and feldspathic sandstones. The sequence at Øvre Rendal occurs within a complex fold structure which extends southwestwards for 40 kilometres (Sæther & Nystuen, 1981).

Storskarven Sandstone

This is a new formation of the Hedmark Group and is the lowest known unit of the group in the northwestern and eastern part of the Sparagmite Region in southern Norway.

The name is taken from the 1024 m high mountain Storskarven west of Glomma (map sheet Hanestad, 1918 IV, UTM co-ordinates NP953689), and the type area includes this mountain and the adjacent Svarthøgda to the southwest. There is no complete stratigraphical section through the unit, but the dip is towards the southeast (30–80°) throughout the whole outcrop area, and sedimentary structures show the strata to be orientated the right way up. There are no indications of tectonic repetition of strata, and the preserved thickness is at least 2000 m.

The dominating lithology is a pink or white, well-sorted and fine- to medium-grained feldspathic sandstone. The bed thickness varies from about 10 cm to 200 cm. Very thin dark laminae form a plane-parallel stratification, but a massive appearance is common. Some beds reveal tabular cross-bedding, and graded bedding has been observed in 10–20 cm thick coarse- to fine-grained beds. A lensoid body of a strongly deformed polymict conglomerate, 3–4 m thick, with rounded clasts (max. diameter 10–15 cm) of granite, porphyry, and various quartzites occurs in the central part of the sandstone.

The lower stratigraphical boundary is not preserved because the formation is truncated downwards by the Røa Nappe thrust plane. The upper boundary is exposed at the south-eastern side of Storskarven (map sheet Hanestad, 1918 IV, UTM co-ordinates NP966690). The rocks are here only moderately deformed. The upper boundary of the formation is drawn along the top surface of the uppermost fine-grained bed beneath the overlying conglomerate of the Rendalen Formation (see below). There is no evidence of erosion beneath the conglomerate.

Southwards the Storskarven Sandstone is cut by the Røa Nappe thrust plane. A fault terminates the formation towards the northeast. The fault does not penetrate the basement in the window and is probably of pre- or syn-thrust origin.

The interpretation of depositional environment for the Storskarven Sandstone is uncertain due to lack of diagnostic sedimentary structures. However, the bulk lithology and the association with the overlying braided-river facies Rendalen Formation may indicate deposition on the distal parts of an alluvial plain.

On the western side of Svarthøgda a strongly foliated *greenstone* is exposed within the sandstone. The boundaries and foliation of the 4–5 metres thick rock body are conformable with the penetrative cleavage in the sandstone. The rock has been observed for only some few metres in the direction of strike. It is most probably a tectonically deformed and metamorphosed diabase dyke and would be the first rock recognized to be intrusive in the Hedmark Group. The rock was compared with the Palaeozoic greenstones in the Trondheim Region by Oftedahl (1943: 34–35).

Rendalen Formation

The stratigraphical position of the 'red and light sparagmite' in the area west of the Rendalen fault has been much disputed. Oftedahl (1943 and in Oftedahl & Holmsen 1952) correlated the unit with a lithologically similar formation beneath the Moelv Tillite at Mjøsa (Ring Formation), Prost (1975) and Bjørlykke et al. (1976) with the Vangås Formation, and Kjølberg (1980) in part with the pre-tillite Rendalen Formation east of the Rendalen fault, in part with the Vangsås Formation.

The bulk of the Rendalen Formation is a red or light grey, coarse-grained arkose with the bed thickness c. 20–300 cm. Trough cross-bedding and plane parallel stratification are common, and the beds are lenticular, usually organized in fining-upwards sequences of varying thickness and restricted, wedge-shaped extent. This and discontinuous conglomerate beds also occur. This facies dominates within the formation in all three thrust sheets and is similar to the facies of the Rendalen Formation in the area east of the Rendalen–Unsetåa fault zone. A braided-river origin has been suggested for this facies (Nystuen 1981).

The basal conglomerate which lies above the Storskarven Sandstone in the eastern hillside of Storskarven, is a 20 m thick coarsening-upwards sequence, starting at the bottom with an arkosic granule bed. The grain size decreases in the uppermost 0.5 m, and the conglomerate grades into the overlying arkose. The conglomerate has a plane parallel stratification and a clast-supported framework of rounded clasts with maximum diameter up to 20 cm. The clasts consist of various porphyries, felsites, granite, grey and red quartzite, and quartz.

A similar conglomerate, and probably the same stratigraphical unit, is found at the base of the Røa Nappe at Nordisætervola. It is strongly deformed in its lower part and passes upwards into the red, fluvial arkose. Oftedahl (1943 and in Oftedahl & Holmsen 1952) interpreted the conglomerate as an autochthonous Moelv Tillite. However, this basal conglomerate of the Rendalen Formation probably marks progradation of coarse-clastic alluvial fan(s) onto the alluvial plain.

The arkose of braided-river facies in the Rendalen Formation is directly overlain by the Moelv Tillite (basal till facies) in the lower thrust sheet. The erosional contact is well exposed at Glomma in the waterfall Barkaldfossen 2 km south of Barkland and in the western slope of Brennåsen (Fig. 1). East of Tysla (lower thrust sheet) and at Langtjern south of Barkaldåsen (middle thrust sheet) the arkose grades into a light grey quartzite. The quartzite is 90 m thick in the section east of Tysla and is here overlain with erosional contact by the Moelv Tillite. At Langtjern the quartzite is conformably succeeded by a light grey dolomite which is correlated with the Biri Formation. In the upper thrust sheet both arkose and quartzite are overlain by dark shales of the Biri Formation (Sæther & Nystuen 1981).

The upper quartzite member of the Rendalen Formation increases in thickness westwards, west of Glomma and south of the map area of Fig. 1 (Sæther & Nystuen 1981). West of Glomma the quartzite is again overlain by carbonate rocks and was originally named Atna Quartzite in a lithostratigraphical sense by Prost (1970). Later it was renamed the 'Hira Quartzite

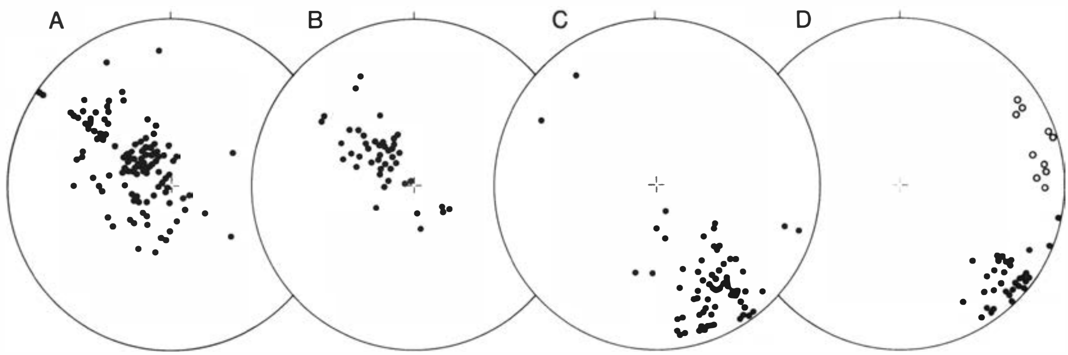

Fig. 4. Stereodiagrams showing orientation of structural elements in the Storskarven, Rendalen and Moelv Formations.
A: poles to bedding plane (S_0),
B: poles to slaty cleavage (S_1),
C: poles to fracture cleavage (S_2) and
D: mineral elongation (L_1) (dots) and fold axes (open circles). Schmidt net, lower hemisphere.

Formation' (Prost 1975), while the name 'Unité d'Atna' was introduced for a supposed tectonic unit correlative to the Osen Nappe in front of the Sparagmite Region (Prost 1975, 1977). The stratigraphical position of the quartzite at the top of the Rendalen Formation and beneath the Moelv Tillite is also well established in the area east of the Atna railway station (Sæther & Nystuen 1981). It is here proposed to retain the name 'Atna' for this upper member of the Rendalen Formation and introduce a formal unit: the *Atna Quartzite Member*.

The maximum thickness of the Rendalen Formation in the area is at least 2–3000 m.

Caledonian deformation

Structural elements within the Røa Nappe and the crystalline basement of the Atnsjøen window are shown in Fig. 4.

The bedding plane – S_0 defines a very broad and wavy fold style in the thick competent Rendalen Formation. There is a general tendency of S_0 to dip in the same direction as the basement surface.

A slaty cleavage – S_1 – is penetrative in large parts of the middle and upper thrust sheets. It is very pronounced at certain zones in the Rendalen Formation and was most likely produced by intense differential movements within the nappe pile (Oftedahl 1943). Clastic grains are flattened and light mica has grown at the expense of alkali feldspar. The slaty cleavage is generally coincident with S_0 (Figs. 1 and 4), but the bedding plane is in some places cut by the slaty cleavage at an angle of 5–10°.

A mineral elongation – L_1 – is formed by the flattening (in S_1) and elongation NW–SE of clastic grains. This lineation is also most frequent in zones of higher deformation. The intersection between the S_0 and S_1 forms another type of lineation (L_2) which may be orientated NE–SW or E–W.

A fracture cleavage – S_2 – penetrates S_0, S_1, and L_1, and is orientated about 45° E with mostly steep dips to the NW (Fig. 4). This cleavage is penetrative in the granite basement of the Atnsjøen window (Fig. 1) and is also observed within basement and autochthonous strata of the Spekedalen window. It is a common tectonic structure in the Røa Nappe and is very prominent in the lower thrust sheet. Clasts in the Moelv Tillite may be deformed and orientated parallel with the S_2-plane; this feature is very well developed in the south-eastern part of the tillite outcrop east of Tysla. An incipient growth of light mica parallel with the S_2-cleavage has also occured in some places. The age relation between S_2 and folds running NE–SW has not been determined, but axial planes of some folds are orientated parallel with the S_2 fracture cleavage.

Conclusion

The Late Precambrian Hedmark Group in the area between the Atnsjøen and Spekedalen windows was deposited in a basin lying northwest of the windows. During the Caledonian orogeny the sedimentary sequence was thrust as the Røa Nappe towards the SE and now rests directly upon crystalline basement rocks or a thin autochthonous sequence. The Røa Nappe was sliced into three local subnappes which are characterized by a tectonic repetition of one or more stratigraphical units. The Storskarven Sandstone, which is established as a new formation within the Hedmark Group, was probably lain down on the distal parts of an alluvial plain whereas the overlying Rendalen Formation introduced a period of coarse-clastic braided-river deposition. The *Atna Quartzite Member* terminates the Rendalen Formation and may again represent a distal alluvial plain or a shallow marine environment. The conformably overlying Biri Formation (dolomite and shale) marks a marine transgression, whereas the Moelv Tillite has been deposited as a basal till upon an erosional surface which cuts down into the Atna Quartzite Member and the fluvial arkoses of the Rendalen Formation. The Moelv Tillite is conformably succeeded by the Ekre Shale and the Vangsås Formation in the upper thrust sheet.

The greenstone in the Storskarven Sandstone is probably a diabase dyke. It may have been a feeder to the Svarttjørnkampen Basalt (or corresponding lava flow) which occurs above the Atna Quartzite Member south of the map area (Sæther & Nystuen 1981).

Slaty cleavage (S_1) and mineral elongation (L_1) were formed in the early phase of the Røa Nappe's translation towards the SE. Regional and minor folds trending NE–SW probably originated during a late stage in the nappe's movement. The typical fracture cleavage (S_2) was formed during a late Caledonian phase of crustal compression. The S_2-cleavage acts as an axial plane cleavage of the Atnsjøen and Spekedalen basement domes and indicates, together with the steep basement-cover interface, that the anticlinal ridge is of late Caledonian origin. Caledonian nappes and the basement antiform have been cut by the post – Caledonian Rendalen – Unsetåa and Tysla faults.

Acknowledgement. – The field studies were financed by Norges geologiske undersøkelse. We thank Jens-Olaf Englund and Anna Siedlecka for their critical comments on an earlier draft of the manuscript, Åslaug Borgan for drawing the figures, Marie-Louise Falch for typewriting, and Adrian Read for correction of the English text.

International Geological Correlation Programme
Norwegian Contribution No. 42
to Project Caledonide Orogen

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