Lithostratigraphy of the Late Precambrian Løkvikfjell Group on Varanger Peninsula, East Finnmark, North Norway

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The basal contact of the Løkvikfjell Formation of the former Raggo Group on Varanger Peninsula is an unconformity rather than a thrust as had been previously supposed. A new stratigraphy is formally proposed for this formation which is here upgraded to group status. This stratigraphy is based on new mapping and sedimentological work and allows a stratigraphic framework for the Løkvikfjell Group to be established for the northern part of Varanger Peninsula.

The unconformity is an angular one which implies a previously unrecognised deformation phase in the underlying Barents Sea Group rocks. It also helps to establish the age relations of the Løkvikfjell Group and bears on correlation problems.

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Introduction

Siedlecka & Siedlecki (1967) recognised that Varanger Peninsula is divided by a major fault (the Trollfjord–Komagelv fault) into two stratigraphically distinct geological regions. The northern (Barents Sea) region was thought to be underlain by a c. 9 km-thick succession (the Barents Sea Group, comprising in ascending order the Kongsfjord, Båsnæring, Båtsfjord and Tyvjofjell Formations) which was in turn overlain by the 9 km-thick Raggo Group. The contact between the two groups was interpreted as a thrust, although the actual contact was never observed in this stage of the investigations.

Work by Laird (1972a) and Teisseyre (1972) conformed with Siedlecka & Siedlecki's (1967) view that the Raggo Group was a continuous sequence from the sandstone dominated, cross-bedded, Løkvikfjell Formation at the base into the flysch-like Berlevåg Formation above. Laird also confirmed Siedlecka & Siedlecki's subdivision of the Løkvikfjell Formation into two members: the Sandfjord Member below and the Kjølnes Member above.

From regional mapping, Levell & Roberts (1977) showed that the Berlevåg Formation is thrust over the Løkvikfjell Formation, is of higher metamorphic grade than the latter and constitutes part of the Kalak Nappe Complex. Furthermore, the Kjølnes Member as described by Laird (1972a) was shown to have been partially measured upside-down. The term Raggo Group therefore became invalid.

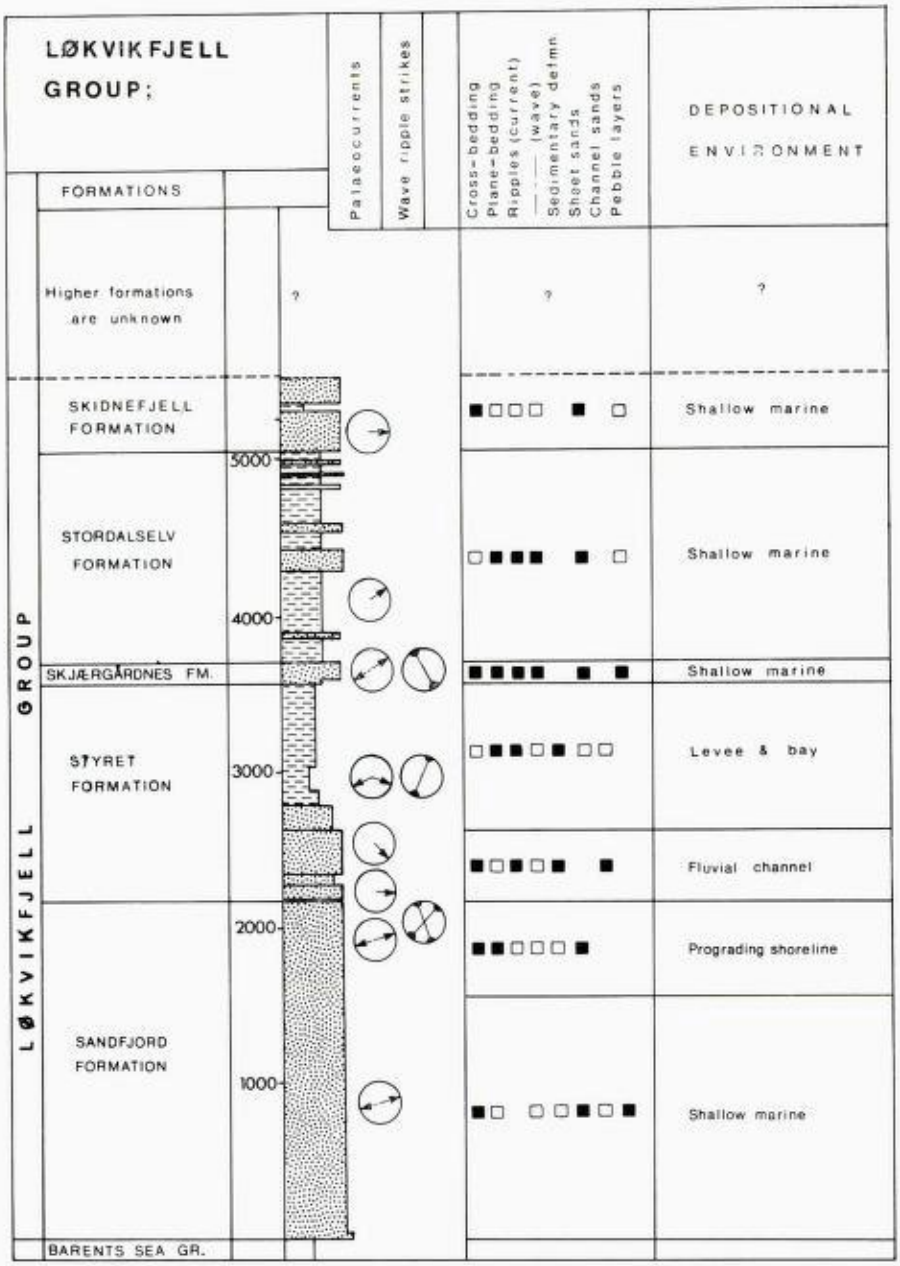

Fig. 1. Stratigraphic and sedimentological summary of the Løkvikfjell Group based on measurements of the type section (Sandfjord – lower Stordalselva Formations) and on estimated sections from the higher formations outcropping down-plunge in the core of the Kjølnes syncline. Solid squares indicate features that are common in the given formation, open squares those that are rare. Dotted arrows indicate the subordinate palaeocurrent directions. Lithologies: dots – sandstone and conglomerate; dashes – shale and siltstone.

The Løkvikfjell Formation in the type area near Berlevåg (Plate 1) has previously been carefully distinguished from similar rocks elsewhere on Varan-

ger Peninsula because no correlation has been established on grounds other than general similarity (Siedlecka & Siedlecki 1972). These rocks were referred to as possible Løkvikfjell Formation correlatives.

The purpose of the first part of this paper is to establish the correlation of all the outcrops of Løkvikfjell Formation and to reinterpret the sharp basal contact as an unconformity. In the second part the Løkvikfjell Formation is renamed the Løkvikfjell Group, and rigorously defined for the first time. It is subdivided into five formations, the Sandfjord, Styret, Skjærgårdnes, Stordalselva og Skidnefjell Formations (Fig. 1).

Løkvikfjell Group outcrops

Various outcrops of the old Løkvikfjell Formation and specifically of the old Sandfjord Member correlatives were roughly shown on Siedlecka & Siedlecki's (1967) map and are indicated with modifications in Plate 1. The main problem of correlation between these outcrops is that lithostratigraphic boundaries are scarce outside the Berlevåg area, where the group is folded into a southwest-plunging syncline, the Kjølnes syncline (Levell & Roberts 1977). Elsewhere, the folding of the Løkvikfjell Group is open or gentle, and facies are constant over large thicknesses (up to 2 km). Consequently, of the five formations erected in this paper, only two have been found to outcrop outside the type area, and one of these (the Styret Formation at Hamningberg) occurs at only one other locality. As a result, only the Hamningberg outlier can be correlated with the type section on the basis of lithostratigraphic *boundaries* (Fig. 2).

Sedimentological work by one of us (B. K. L.) allows *facies* correlation of an unconformity at the base of the group and allows some precision in this correlation.

The Sandfjord Formation in all of the outcrops can be correlated on the basis of lithofacies. The lithologies are predominantly monotonous, thick-bedded, coarse-grained sandstones. These are notably feldspathic (5–25%) and pink or orange in colour. This colour is due to late diagenetic haematite or hydrated iron oxides, which have apparently been produced from the weathering of iron-rich clay minerals (mostly illites). Feldspar types are mostly microclines and perthite, but untwinned K-feldspar, microcline–microperthite and plagioclase (albite) also occur. Rock fragments are scarce but fragments of sheared quartzites, sandstone or metasandstone, quartz–mica rocks and granophyre can be found. Pebbles are predominantly siliceous; vein quartz and sheared quartzites dominate, with red sandstone, jasper and a few quartz–tourmaline rocks also occurring. Most heavy minerals are of stable type and include zircon, rutile, green tourmaline, ilmenite, leucoxene, garnet, epidote, zoisite, clinozoisite and sphene.

The sandstones are well sorted with very well rounded grains. The beds are notably parallel-sided as seen in several cliff exposures. Occasionally the bedding is defined by very thin pebble layers sometimes only a single grain diameter thick (about 5 cm); these layers are apparently derived by reworking from underlying pebble-rich beds. The principal structure is trough cross-bed-

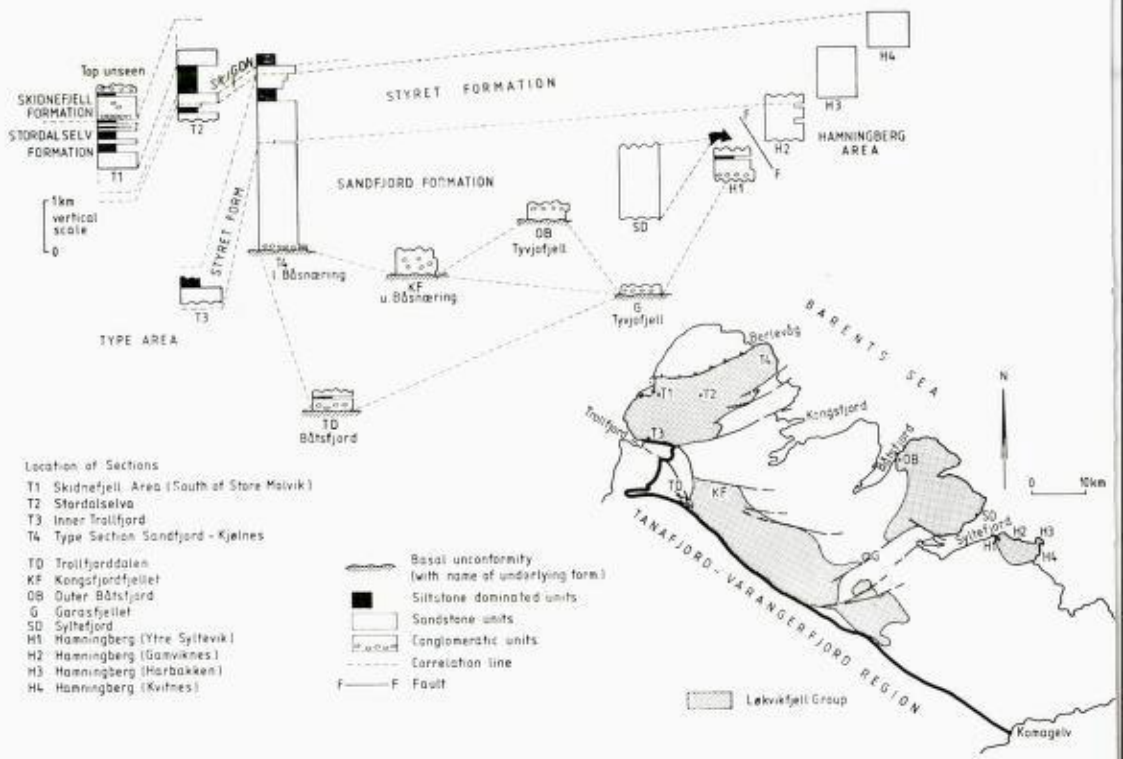

Fig. 2. Fence diagram showing the locations of measured (K2–4, KF, H1–4) and estimated (T1, TD, OB, G, SD) sections through the Løkvikfjell Group. Lithostratigraphical correlations are indicated by the dotted lines.

ding with subordinate tabular sets of planar or convex-upward cross-bedding, and rare wave ripples. Palaeocurrents from all outliers are uniformly towards the east or northeast which suggests that any tectonic rotation between the outcrops is small. There is generally more variability in palaeocurrents (with reversed sets fairly common) in the lower 400 m of the Sandfjord Formation.

In summary, the similar petrography and palaeocurrent pattern and the consistent appearance of the facies over the neighbouring outliers are regarded as sufficient grounds for suggesting that they all expose the same stratigraphic units. The details of the suggested correlations are shown in Fig. 2. The possible Løkvikfjell Formation correlatives are therefore all part of the new Sandfjord Formation.

The basal unconformity

In most localities the base of the Løkvikfjell Group is not exposed. However, in several places, notably Outer Båtsfjord, Trollfjorddalen and Inner Sandfjord it is possible to see the contact.

In Outer Båtsfjord (OB, Fig. 2), the contact is a sharply defined, planar surface (Figs. 3 and 4) between underlying, red and grey sandstones of the

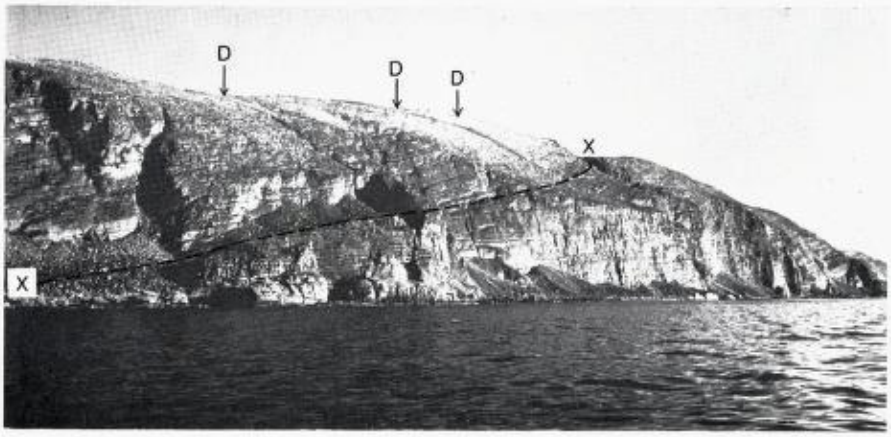

Fig. 3. The contact between the Tyvjofjell Formation (Upper Barents Sea Group) and the Løkvikfjell Group ,eastern coast of Båtsfjord. This contact (x-x) is cut by dolerite dykes (D) dated by Beckinsale et al. (1975) at 651 ± 19 ma. B.P. Photo: S. Siedlecki.

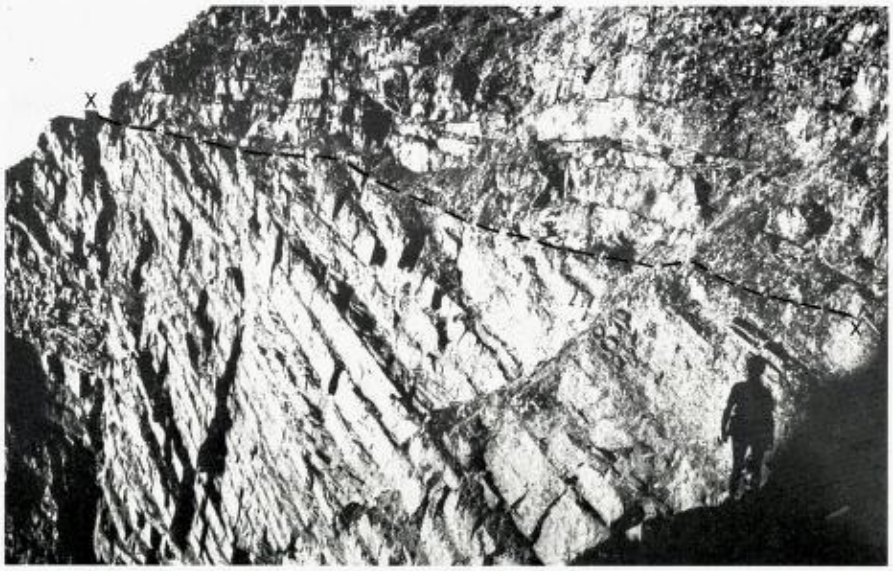

Fig. 4. Closer view of the sharp planar contact (Fig. 3), interpreted as an unconformity (x-x), between the underlying Tyvjofjell Formation dipping south-east and nearly flat-lying Løkvikfjell Group above. The figure (shadow) is approximately 2 m tall. Photo: S. Siedlecki.

Tyvjofjell formation (uppermost Barents Sea Group) and the pink, coarse, pebbly, feldspathic sandstones of the Sandfjord Formation. Pebbles near the contact, and the sandstone fabric, are unsheared, and there is no evidence of small-scale deformation in either unit. The contact is a simple angular junction. The Tyvjofjell Formation dips gently (20°SE) and the Sandfjord Formation even more gently (5°N). The contact can be observed for at least 2 km along the coast. The lack of evidence of tectonic disturbance along the contact suggests that it is an unconformity rather than a thrust.

Other exposures are less striking. In Trollfjorddalen (Fig. 2 – ID) at two localities, the Sandfjord Formation can be seen to rest abruptly, and without significant deformation, on the Båtsfjord Formation sandstones. In the Sandfjord area (T4, Fig. 2) the contact can be observed continuously for several hundred metres in inland exposures. It has been later folded along NE–SW axes, with the anticlines frequently being faulted out on the same trend. Stretched pebbles are found in the cores of the synclines. The contact, against the lower Båsnæring Formation, (middle Barents Sea Group) is sharp. The lowest unit of the Sandfjord Formation here is a 20 m-thick conglomeratic (cobble grade) horizon, and this can be traced along the contact without thickness variation for several kilometres. This contact may be either an unconformity or a bedding-parallel fault.

Generally, facies relations are not constant along the unconformity and there is no well defined conglomerate, although the lower 400 m of the Sandfjord Formation is usually pebble-rich. Also, the sharpness of the basal surface and the relative scarcity of clasts which can be directly matched with the underlying rocks are notable. Vein quartz is the dominant clast type, though a variable proportion of red or grey sandstone clasts similar in lithology to those of the Tyvjofjell and Båtsfjord Formations does occur (Fig. 5). The lack of channelling, the good sorting (both texturally and mineralogically) and the facies types in the Sandfjord Formation suggest that the unconformity is shallow marine in origin, rather than fluvial or subaerial. In no locality has weathering of the underlying rocks or any significant relief been found along the contact.

Significance of the unconformity

The unconformity implies that the Løkvikfjell Group is younger than the Barents Sea Group, for which a preliminary Rb/Sr whole rock isochron date on Kongsfjord Formation rocks gives an age of about 828 ± 60 m.y. B.P. (A. Råheim, pers. comm. 1977). Moreover, K/Ar dates (from the Båtsfjord dyke swarm; Beckinsale et al. 1975) suggest that the Løkvikfjell Group is older than 640 m.y. This brackets the Løkvikfjell Group within the late Precambrian age that was originally assigned to it (Siedlecka & Siedlecki 1967).

The attitude of lithologies above and below the unconformity surface suggests some tilting of the Barents Sea Group prior to Løkvikfjell Group deposition (Plate 1). This deformation may have been a simple south-eastward tilting resulting in the Løkvikfjell Group resting on progressively older formations westwards, hence it oversteps from Tyvjofjell to Båtsfjord to (?) Båsnæring Formation in this direction. The outcrops with definite unconformable contacts are too few to substantiate this conclusively.

Previously it was argued that the principal fold-producing deformation of the Barents Sea Region was single phase and of Caledonian age (Roberts 1972). Subsequently Beckinsale et al. (1975) postulated a Precambrian deformation phase based on K/Ar ages of dolerite dykes which cut the supposedly thrust contact of the Løkvikfjell Group on the Barents Sea Group in outer Båtsfjord. However, as this contact is now thought to be unconformable, there is no reason

Fig. 5. Hand specimen from across the unconformity (x-x) of Løkvikfjell Group on Båtsfjord Formation some 11 km from the head of Trollfjord, in Trollfjorddalen. Rounded pebbles of sandstone in the conglomerate closely resemble the underlying lithologies. Thin-sections taken across the actual contact show no evidence of any deformation. Scale in millimetres. Photo: I. Aamo.

for accepting these dates as 'post-tectonic'. The angular unconformity does however imply some tilting of the Barents Sea Group prior to Løkvikfjell Group deposition, so a Precambrian deformation phase must have occurred.

The later folding of the Løkvikfjell Group and its basal unconformity is open or gentle in the east of the area. In the west, however, both the Løkvikfjell and Barents Sea Groups are folded into tight anticlines and synclines over a distance of several kilometres. Any evidence of gentle Precambrian tilting, is here destroyed by subsequent folding. The age of this later folding may be similar to that in the Kalak Nappe Complex (and the Berlevåg Formation) and hence be Caledonian.

Dyke dating of the syn-folding Kongsfjord dyke swarm has unfortunately been inconclusive (R. Beckinsale, pers. comm. 1976). The occurrence of a distinctive black siltstone in the Lower Sandfjord Formation in both the Hamningberg and the Trollfjorddalen areas suggests that these outcrops may possibly have been nearer each other than they are now. Within the Sandfjord Formation there is a general fining, and an increase in the proportion of siltstone to the east. The Trollfjorddalen outcrop would fit this facies pattern better if it were located south of Hamningberg along the main Trollfjord–Komagelv fault. This would be in line with the suggestions of Roberts (1972) and Johnson et al. (1978) that there had been dextral movement along this fault zone.

Numerous possible correlations have been proposed for the Løkvikfjell Group

with sequences in East Greenland, Svalbard and further west in Finnmark (Laird 1972a and b, Siedlecka & Siedlecki 1972). In the light of the recognition of the unconformable relationship with the Barents Sea Group, these ideas will need reassessment.

The Løkvikfjell Group: Lithostratigraphy

Following the work of Levell & Roberts (1977) the term Raggo Group is invalid and it is therefore proposed that the name Løkvikfjell Formation be upgraded to Løkvikfjell Group to allow the units into which it is divided (one of which is two kilometres thick) to be called formations. The stratigraphy of the group is given in Fig. 1.

Name of the group
Løkvikfjell is a hill to the west of Sandfjord some 10 km southeast of Berlevåg.

Type area
The type area is the northwestern outcrop of the Løkvikfjell Group, which extends from Sandfjord to Berlevåg on the Barents Sea coast, and from Store Molvik to Trollfjord on Tanafjord. Type profiles for all five formations are to be found in this area, which is the only one in which the three higher formations are exposed.

Thickness
The group is at least 5.6 km thick (Fig. 1).

Boundaries
The base of the group is taken at the unconformity, discussed above, on the underlying Barents Sea Group. The top is unknown.

SANDFJORD FORMATION
Name of the Formation
Sandfjord is a sandy bay some 9 km southeast of Berlevåg. The formation includes only the lower 2 km of Laird's (1972a) Sandfjord Member.

Type Profile
The only known continuous and possibly complete section through the formation is that on the west side of Sandfjord, along the coast and cliff to the west side of the bay Storsteinbukten. This is taken as the type profile (Fig. 1), see also Johnson et al. 1978).

Thickness
This formation is the most extensive of the Løkvikfjell Group with an inferred minimum areal extent of about 300 km^2. It is 2 kilometres thick.

Lithology
This is described on page 76. A largely shallow marine origin is proposed by Levell (thesis, in prep.).

Boundaries
The lower boundary is taken at the plane of unconformity on the Barents Sea Group which forms the base of the Løkvikfjell Group as discussed above. The upper boundary with the overlying Styret Formation is transitional and occurs as a coarsening-upward sequence of plane-laminated, fine- to medium-grained fawn sandstones. This lithofacies can be found both in the type section and in profiles at Hamningberg. The precise boundary is best taken at the base of the first, coarse-grained, thick-bedded sandstone above this sequence.

STYRET FORMATION

Name of the Formation
Styret is a point on the coast midway between Kjølnes and Sandfjord.

Type profile
The type section is that on the coast between Storsteinbukten and Styrelven.

Thickness
Approximately 1.5 km at the type profile. The maximum thickness of 1.6 km occurs at Hamningberg where the top of the formation is unseen. These two sections are some 60 km apart.

Lithology
Thick-bedded, green or grey sandstone interbedded with thick units (up to 20 m) of dark siltstone form the main lithologies. The sandstone to siltstone ratio is very variable, in the type section the lower half is dominantly sandstone (70%), and the upper half dominantly siltstone with medium-bedded sandstone. At Hamningberg where the formation is thicker, the lower half is mostly (70%) sandstone and the upper half is almost completely (95%) sandstone.

Characteristically, the sandstones are lenticular and have erosional bases which down cut as much as 9 m. In laterally extensive exposures several channel sequences can be mapped; the sandstone bodies filling these are up to 700 m wide and 10–20 m thick. The sandstones are, as a rule, slightly more feldspathic than those of the Sandfjord Formation, but are still sub-arkosic with mixed quartz/calcite cements. Pebbles occur but are generally less than 5 cm in diameter. They include vein quartz, red sandstone and feldspar, and are generally less abundant than in the Sandfjord Formation. Sedimentary structures in the sandstones are principally through cross-bedding, with ripple cross-lamination, wave ripples and plane-lamination characterising the silt units. Soft sediment deformation is abundant in the form of type B pillars (Lowe 1975) up to 3 m high and over-steepened cross bedding. Palaeocurrents are dominantly towards the southeast, though the variance is large. A largely fluvial origin is suggested for the formation by Levell (in prep).

Boundaries

The lower boundary of the formation is placed at the base of the first, coarse, green-grey, thick-bedded sandstone above the thin-bedded, plane-laminated lithofacies at the top of the Sandfjord Formation. The upper part of the formation is a siltstone-dominated, thin-bedded facies and is transitional over about 300 m with a slightly more sandy, silty and sandy streak facies (de Raaf et al. 1965) above. The best mapping boundary is probably the last occurrence of the silty and sandy streak facies beneath the thick, planar-based sheets of cross-bedded sand belonging to the overlying Skjærgårdnes Formation. The boundary in the type area between the silt-dominated lithologies in the upper half of the formation and the sand-dominated lithologies in the lower half is a good mapping boundary and was used by Laird (1972a) as the boundary between his Kjølnes and Sandfjord Members. It enables the formation to be divided (in the type area only) into two informal members: an upper siltstone member and a lower sandstone member. A predominantly fluvial environment of deposition is proposed by Levell (in prep.).

SKJÆRGÅRDNES FORMATION

Name of the formation

Skjærgårdnes is a point on the coast near Berlevåg some 2 km southeast of the lighthouse at Kjølnes.

Type profile

The best exposed section through the formation is that along the coast around the point at Skjærgårdnes.

Thickness

The formation is 210 m thick and maintains this thickness throughout its outcrop.

Lithology

Within the type area the formation shows a remarkably constant facies pattern, and is characterised by medium- to thick-bedded, coarse-grained, sandstone unts interbedded with siltstones and mudstones. The sandstones are tabular in geometry and can be traced up to 300 m along strike. Internally they are cross-bedded with occassional tabular herringbone sets, and abundant wave ripple cross-lamination. Synaeresis cracks are common. The tops of sandstone units frequently have concentrations of small pebbles and granules, sometimer only a single grains thick, composed chiefly of quartz. Petrographically the sandstones are moderately sorted sub-arkoses. Palaeocurrents from the abundant cross-bedding are predominantly towards the northeast, with wave ripple strikes almost exactly orthogonal to this. A shallow marine origin is proposed by Levell (in prep.).

Boundaries

The lower boundary is taken as the first occurrence of planar-based sandstones above the silty and sandy streak facies of the upper part of the Styret Formation. The upper boundary is transitional into the Stordalselva Formation over about 20 m, but can be taken as the top of the last sandstone unit which is greater than 1 m thick. Generally, the proportion of sandstone to siltstone decreases rapidly at the top of the formation.

Lithologies younger than the Skjærgårdnes Formation have been found only in coastal exposures in the core of the Kjølnes syncline where they are affected by tight, mesoscopic folding and cut by a spaced cleavage (Levell & Roberts 1977). This tectonic deformation hinders the establisment of a precise stratigraphy. It is probably advisable at our present state of knowledge to regard all the units occurring between the easily recognisable Skjærgårdnes and Skidnefjell Formations as constituting a single major unit (the Stordalselva Formation).

STORDALSELVA FORMATION

Name of the formation

Stordalselva is a river entering the sea at Berlevåg and which breaches the Kjølnes syncline some 10–12 km southwest of Berlevåg. The valley Stordalen contains the best exposures of the greater part of the formation.

Type profile

No continuous section was measured for the formation but sections were estimated from the Stordalen valley and from the area immediately north of outer Trollfjorden, on the southeast limb of the Kjølnes syncline. Little detailed work has been done on this unit.

Thickness

The total thickness is estimated as 1.2 km.

Lithologies

The formation consists of several, 20–200 m-thick sandstone units interbedded with 100–500 m-thick, medium-bedded, mixed sandstone and siltstone units. The sandstone members form good, traceable mapping horizons which allow some of the mesoscopic and macroscopic folding in the axial region of the syncline to be determined. They consist of coarse, white, pebble-bearing, sandstones. The beds have a tabular geometry and contain tabular, decimetre-scale sets of cross-bedding, with palaeocurrents to the northeast. Occasional sandstone units within this facies are granular and resemble those of the Skjærgårdnes Formation.

The heterolithic units are dominated by wave ripple cross-laminated or plane-laminated, medium-grained sandstones and siltstones, with synaeresis cracks. Beds are generally less than a metre thick and tabular. The vertical variation in facies is much greater than that in the underlying formation. A shallow marine origin is proposed by Levell (in prep.).

Boundaries
The lower boundary is taken at the last metre-thick sandstone at the top of thick-bedded sandstones assigned to the Skjærgårdnes Formation. The upper boundary is taken as the base of the first, thick, pebble-bearing, coarse sandstone of the Skidnefjell Formation. This latter boundary is generally marked by the geomorphological change from the frost-scattered blockfields of Skidnefjell Formation sandstones, to the grassed slopes of the mixed lithologies beneath. It is an easily mappable contact although actual exposures are scarce.

SKIDNEFJELL FORMATION

Name of the formation
Skidnefjell is a flat-topped, blockfield-covered hill north of Trollfjord.

Thickness
The top of the formation is unknown, and the thickness is estimated as greater enn 800 m.

Type profile
The best exposed section, although difficult of access, is the coastal section from outermost Trollfjord to Fugleviken.

Lithology
The formation bears a remarkable similarity to the Sandfjord Formation and consists of monotonous, white, creamy white or buff, medium- to thick-bedded, coarse sandstones, locally feldspathic, and occasional thin layers of granule conglomerate, with abundant small pebbles of white and pink vein quartz and quartzite, and sometimes of red sandstone. These may occur as only one pebble thick lags on bedding planes. A basal conglomerate on the south side of Skidnefjell is 40–45 cm thick and consists of pebbles mostly of quartz or quartzite up to 4 cm across in a sandy matrix but also fragments of the subjacent siltstone (D. Roberts, pers. comm. 1977).

Cross-bedding is the predominant structure in the sandstones, generally in decimetre-thick trough sets but also in planar sets up to 2 m thick. Wave ripples are the only other recorded primary structure in the sandstones. Two siltstone units (each less than 50 m thick) characterised by occur within the formation and can be used as convenient mapping horizons, although folding and sliding have resulted in local repetition of the sequence.

Boundaries
The lower boundary of the formation is transitional over 20 m with a thin coarsening-upward sequence from the mixed lithologies below; however, the first occurrence of pebble-rich beds is abrupt and forms an easily mappable horizon. The top of the formation, and thus of the group, is nowhere exposed.

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