

Correlation of the late Precambrian Ekkerøya Formation (Vadsø Group; E. Finnmark) and the Brennelvfjord Interbedded Member (Porsangerfjord Group; W. Finnmark), N. Norwegian Caledonides

HUGH RICE & CHRIS TOWNSEND

Rice, A. H. N. & Townsend, C.: Correlation of the late Precambrian Ekkerøya Formation (Vadsø Group; E. Finnmark) and the Brennelvfjord Interbedded Member (Porsangerfjord Group; W. Finnmark), N. Norwegian Caledonides. *Norsk Geologisk Tidsskrift*, Vol. 76, pp. 55–61. Oslo 1996. ISSN 0029-196X.

In the Caledonian Lower Allochthon, the 0–400 m thick Brennelvfjord Member at the base of the Porsangerfjord Group in W. Finnmark (correlated with the Tanafjorden Group in E. Finnmark) is similar to the < 200 m thick Ekkerøya Formation at the top of the Vadsø Group in the Autochthon and Lower Allochthon in E. Finnmark. Both units are lithologically very variable, with basal conglomerates/sedimentary breccias, dark shales, grey quartzites with intraformational mud-flake conglomerates and rust-spotting, yellow-green to red sandstones and siltstones and compressed triradiate 'mud-cracks' in siltstones and fine-grained sandstones. Further, these successions underlie quartz pebble conglomerates and grits at the base of both the Grønneset Formation, which is the unconformable base of the Tanafjorden Group in E. Finnmark, and its correlative, the Kikut Member, in W. Finnmark. Although the Brennelvfjord Member is essentially transgressive and the Ekkerøya Formation largely regressive, the two successions may be broadly chronostratigraphic (if not lithostratigraphic) correlatives. Such a correlation gives a greater continuity along the basin margin to the stratigraphic successions within the Lower Allochthon and Autochthon in Finnmark. An informal revision of the stratigraphic terminology is proposed in which the Ekkerøya Formation is renamed the Lille Molvik formation, the Brennelvfjord Member is upranked to the Brennelvfjorden formation and both these formations are combined into a new group, the Ekkerøya group.

A. H. N. Rice, *Institut für Geologie, Geozentrum, Universität Wien, Althanstraße 14, Vienna, Austria*; C. Townsend, *Den norske stats oljeselskap a.s., R&D Centre, Arkitekt Ebbellsveg 10, N-7005 Trondheim, Norway*.

Introduction

Over the past thirty years the Neoproterozoic to Tremadoc rocks of the Gaissa Thrust Belt (Lower Allochthon, Gaissa Nappe Complex) and East Finnmark Autochthon in northern Norway (Fig. 1) have been extensively studied, from both stratigraphical–sedimentological and structural viewpoints (see references below; Precambrian time-scale after Plumb 1991). In east Finnmark three stratigraphic groups have been recognized underlying the Neoproterozoic III tillites south of the Trollfjorden–Komagelva Fault (Fig. 1); the Vadsø and unconformably overlying Tanafjorden Groups (Røe 1970, 1975; Siedlecka & Siedlecki 1971; Banks et al. 1971, 1974; Siedlecka & Roberts 1992) and very locally the Barents Sea Group (Rice 1994). In the Gaissa Thrust Belt these rocks are weakly deformed, with 15% thrust-related shortening estimated by Chapman et al. (1985). Similarly, in west Finnmark the Airoaivi and Porsangerfjord Groups have been recognized underlying the Neoproterozoic III tillite rocks (White 1968, 1969; Roberts 1970, 1971a, b, 1974; Williams 1974, 1976a; Tucker 1976, 1977; Townsend et al. 1989), although there the deformation is greater, with ca. 55% thrust-related shortening (Townsend et al. 1986; Gayer et al. 1987). In central and west Finnmark the Lower Allochthon has

been thrust over the autochthonous Dividal Group (Føyn 1967; Townsend et al. 1989), a post-tillite sequence. All these rocks are thought to have been deposited on the subsiding flank of the approximately WNW–ESE trending late Precambrian Timanian Aulacogen (cf. Siedlecka 1975, 1985; Vidal & Siedlecka 1983).

This article outlines the evidence relating to an as yet unconsidered stratigraphic correlation between part of the sequences of eastern and western Finnmark. The intention here is to open the discussion on the topic, and thus the proposed revision to the stratigraphic nomenclature given here should be regarded as preliminary, and open for comments before any formal changes are made.

Late Proterozoic sediments of the Lower Allochthon and Autochthon

Tanafjorden and Porsangerfjord Groups

Williams (1974) and Føyn (1985) correlated the Porsangerfjord and Tanafjorden Groups, with the latter name taking precedence due to the thicker and less deformed sections preserved in the east. Although this correlation is now generally treated as being well estab-

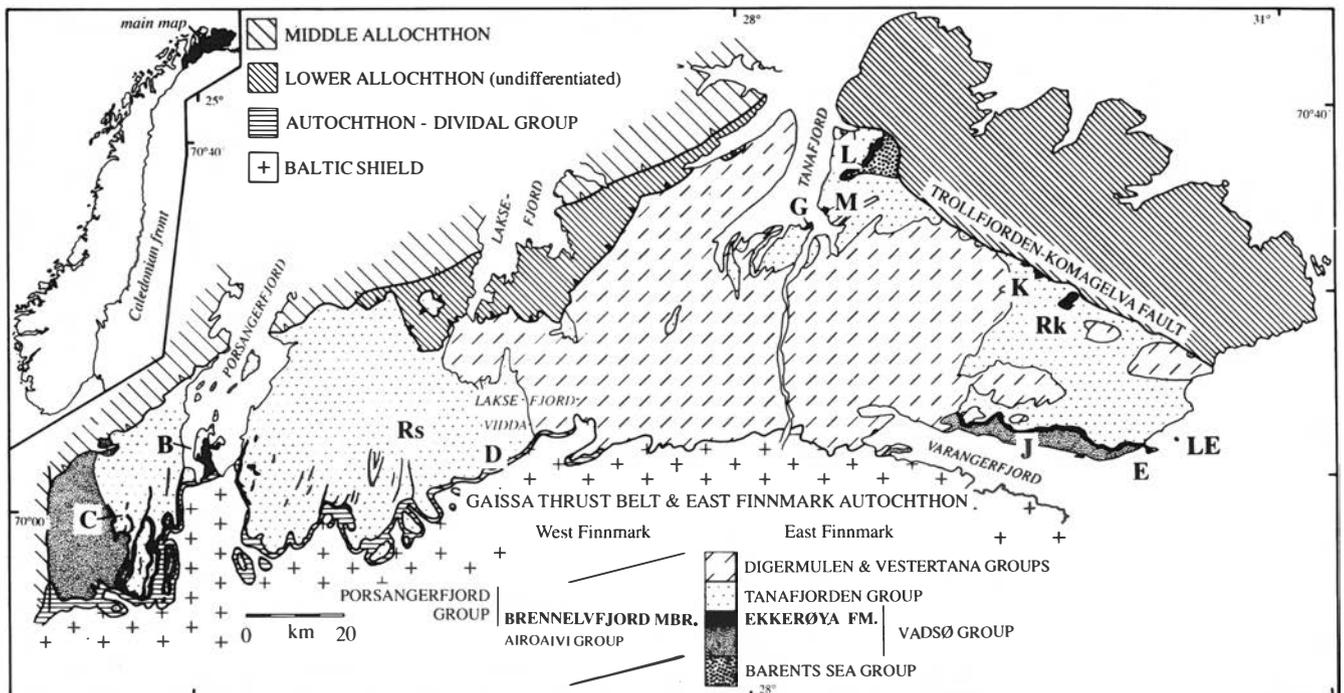


Fig. 1. Simplified geological map of N. Norway showing the distribution of the lithostratigraphic groups within the Gaissa Thrust Belt and East Finnmark Autochthon, using the existing stratigraphic nomenclature: B – Brennelvfjorden, C – Cäkkarassa, D – Doaresjävrít, E – Ekkerøya, G – Gavesluft, J – Jakobselv, K – Kjølstua, L – Lille Molvik, LE – Lille Ekkerøya, M – Marjavaggi, Rk – Ragnarokk, Rs – Rætkajåkskaidi.

lished, it should be noted that no detailed comparison has ever been made of either the lithostratigraphy or the sedimentology of the two sequences, and the correlation has not been demonstrated on a fine scale. A simplified form of the terminology of Williams (1976a) is used here for the rocks in the Porsangerfjord area; this is easier than having to refer to place names whenever a unit is discussed. Føyn (1985) showed in very simple form the generally agreed correlation of the complete sequences, with thicknesses. Although Føyn (1985) noted that correlation of the lower parts of the successions is uncertain, mapping in the area between Laksefjord and Porsangerfjord has resolved this problem (Rice et al. 1990; Roberts & Rice 1990); Fig. 2 shows the correlation of the lower parts of the successions.

Siedlecka & Siedlecki (1971) established the type lithostratigraphy of the Tanafjorden Group in East Finnmark, with a total thickness of 1.6 km. Williams (1976a) estimated the thickness of the Porsangerfjord Group at 880 m, partly based on earlier work by White (1968) and Roberts (1974). Note, however, that of the 880 m of the Porsangerfjord Group, 230 m consists of dolomites of the Porsanger Formation (Tucker 1977), the equivalent of which in the Tanafjorden Group is the upper 100 m of the Grasdal Formation (Siedlecka & Siedlecki 1971), although the western carbonate unit is somewhat older (Bertrand-Sarfarti & Siedlecka 1980). Further, no equivalent of the ca. 200 m of the Brennelvfjord Member at the base of the Porsangerfjord Group has been found in the Tanafjorden Group. Thus, the remaining 450 m thick siliclastic sequence in the west

is very significantly thinner than the correlated equivalent 1.5 km in the east. This thickness change reflects considerable differential subsidence between the two areas. The facies, however, are essentially the same in both groups, with dominantly shallow-marine facies and locally deltaic or sabkha facies (Roberts 1974; Tucker 1976; Williams 1976a; Johnson et al. 1978; Siedlecka 1978).

The stratigraphy of Siedlecka & Siedlecki (1971) is applicable to as far west as Laksefjordvidda (Fig. 1), although many formations are thinner, especially the Stangenes Formation, which thins out completely at Doaresjävrít (Edwards et al. 1973; Føyn et al. 1983; Føyn 1984, 1985; Føyn & Siedlecki 1981). West of Rætkajåkskaidi, however, where it has been found that the stratigraphy of Williams (1976a) is more applicable (Townsend et al. 1986, 1989; Rice et al. 1990; Roberts & Rice 1990; Roberts & Welbon 1992; Roberts & Davidson 1993), all the units are considerably thinner. For example, the Roddinesbukta Member is 25–40 m thick, compared to the 350 m of the equivalent Dakkavarre Formation in the type area (Fig. 2). Furthermore, the Brennelvfjord Member (0–400 m thick) comes in at the base of the Porsangerfjord Group, underlying rocks equated with the base of the Tanafjorden Group. For reasons outlined below, the Brennelvfjord Member, which is here informally upranked and, in line with modern geographic terminology, renamed the Brennelvfjord formation, is discussed separately below.

The basal unit of the Tanafjorden Group in E. Finnmark, the Grønneset Formation, has a distinctive 0.5–3 m thick basal conglomerate, consisting of quartz-pebbles with rare jasper clasts. At Gavesluft (Fig. 1),

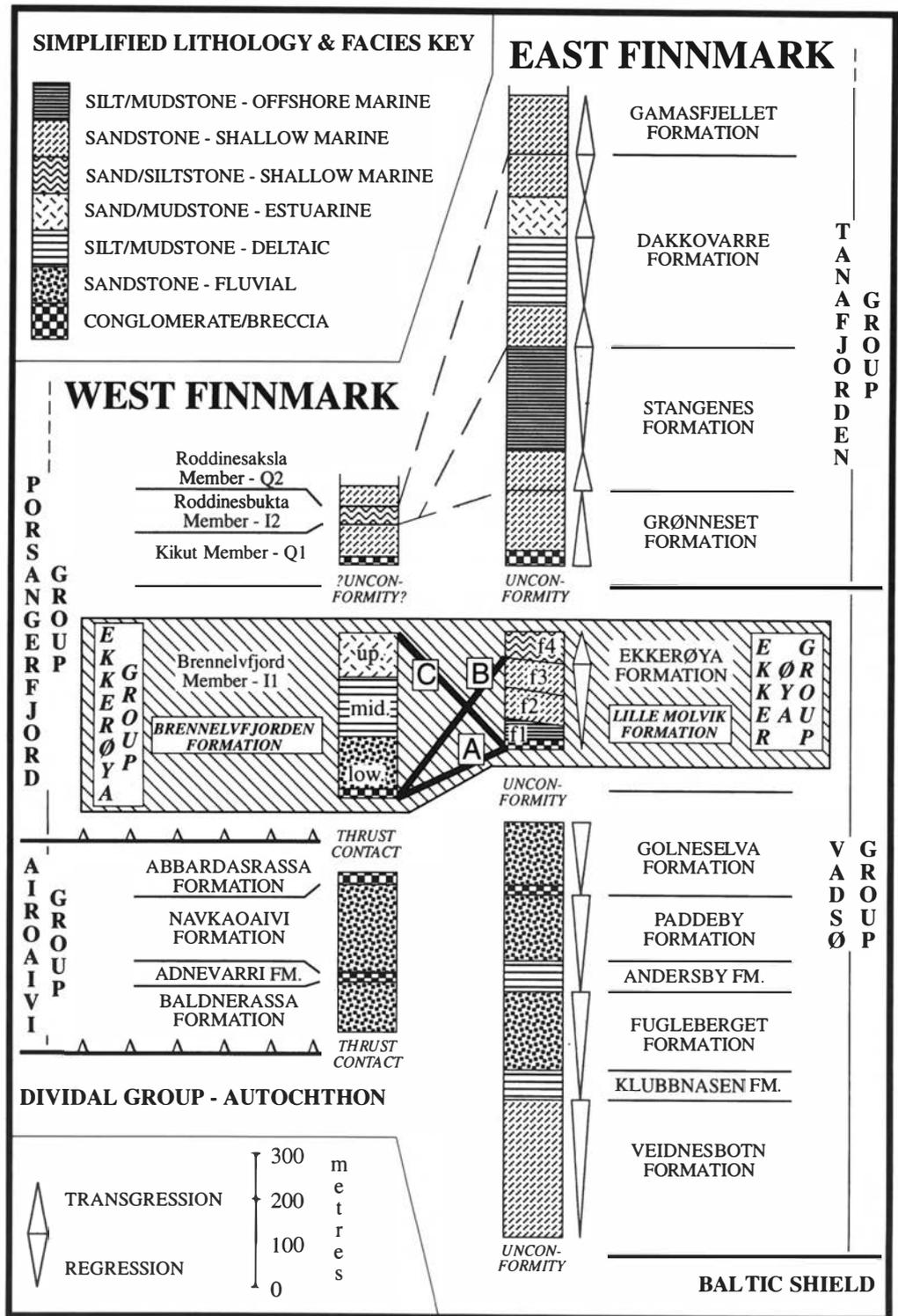


Fig. 2. Correlation of the successions above and below the base of the Grønnes Formation and Kikut Member in West and East Finnmark. Thicknesses, lithologies, facies and regression/transgression patterns simplified from Roberts (1974), Williams (1976a), Johnson (1978), Johnson et al. (1978) and Townsend et al. (1989). Note that not all the Tanafjorden and Porsangerfjord Groups are shown. Conglomerate/breccia thicknesses are exaggerated. The rocks of the correlation proposed in this article lie within the large shaded box encompassing both stratigraphic columns; within this box the informal new stratigraphic terminology is given in bold-italics within boxes. The *up.*, *mid.*, and *low.* refer to the three units in the Brennelfjord Member of Roberts (1974) and *f1 - f4* within the Ekkerøya Formation refer to the facies of Johnson (1978). Line A indicates correlation of the Brennelfjord formation with the Ekkerøya Formation; Line B correlates the Brennelfjord formation with the transgression in the upper part of the Ekkerøya Formation and Line C with the inferred transgression that must have occurred between the regression of the Golneselva Formation and the regression in the lower part of the Ekkerøya Formation.

where it can be seen easily, the contact is marked by cross-bedded, locally slumped, graded grits 1.5 m thick, with relatively thin quartz-pebble conglomerate bands and yellow-green sandstones similar to those in the underlying Vadsø Group. Further north, in the Lille Molvik area, the base of the Grønneset Formation is marked by conglomerates up to 2 m thick. In E. Finnmark the formation base has been recognized as a very slight unconformity, related to syn-sedimentary faulting (Johnson 1978). In W. Finnmark, the equivalent

Kikut Member has a gradational contact with the underlying Brennelfjord formation, marked by 2-3 m of thick-bedded grits comprising round to angular white quartz pebbles of up to 2 cm diameter (Roberts 1974).

Vadsø Group

The Vadsø Group falls into two parts; a 700 m thick lower unit comprising deltaic and fluvial facies, locally

with shallow-marine facies (Banks et al. 1974; Johnson et al. 1978) and an upper unit, the Ekkerøya Formation, which consists of dominantly regressive shallow-marine facies (Johnson 1978), up to 200 m thick, although Siedlecka & Siedlecki (1972) proposed a thickness of 250–300 m in the Lille Molvik area (Fig. 1).

Johnson (1978) divided the Ekkerøya Formation into four facies, forming a coarsening upwards, dominantly regressive, shallow-marine sequence, passing from distal offshore (facies 1) to proximal offshore (facies 2) and thence to coastal sand (facies 3), with lagoonal facies (facies 4) at the top of the succession. Isopachs show that the Ekkerøya Formation thins to the south–southwest, essentially normal to the Trollfjorden–Komagelva Fault (Johnson 1978). The thinning is interpreted to be a result of greater erosion along the unconformity at the base of the Grønneset Formation, such that the upper two facies are preserved adjacent to the Trollfjorden–Komagelva Fault (L, Rk & K, Fig. 1) and also further to the south at Gavesluft (G, Fig. 1). In the Ekkerøya area (E, Fig. 1) facies 3 and 4 are absent, although 6 km to the east–northeast, on Lille Ekkerøya (LE, Fig. 1), an 8 m thick succession of alternating facies 3 and 4 has been recorded by Johnson (1978).

According to Johnson (1978), facies (4) 'consists of well-sorted medium- to coarse-grained sandstone beds with dark-grey mudstones and siltstones ... They form laterally persistent beds which become lenticular due to small-scale channeling and are usually characterized by numerous rounded mudflakes which are concentrated along the bases of these beds. The intervening mudstones ... ubiquitous mudcracks and isolated ripple-sandstone lenses'. The underlying facies (3) was described by Johnson (1978) as '... cross-bedded, well-sorted medium-grained and rarely coarse-grained sandstones which usually contain more than 95% total quartz ... cross bedding commonly fills shallow troughs (30 cm deep) and foresets are frequently low-angled. Further characteristics ... are thin mud-drapes and abundant mud-flakes'.

Investigation of facies 3 at Gavesluft, where the base of the Grønneset Formation can be seen to cut down from facies 4 in the northeast to facies 3, revealed a sequence of grey, quartzitic sandstones and more common yellow-green to locally reddish sandstones/siltstones, sometimes with variably oriented ripples, and encompassing abundant impersistent thin lenses of grey sandstone. Thin conglomerates/breccias consisting of intraformational yellow sandstone clasts in a slightly darker and finer-grained matrix were seen. Sand-filled 'mud-cracks' are commonly developed in siltstones and fine-grained sandstones, sometimes cutting across ripples. The cracks, which have been flattened ptygmatically during sedimentary loading and tectonism, exhibit a radial cluster pattern, rather than polygonal shapes, on bedding surfaces. Pyrite nodules up to 3 cm in diameter were also found and rust-spotting is common in the grey sandstones.

Facies 2 was described by Johnson (1978) as a 'heterolithic facies (which) contains a complex array of

sedimentary structures ... characterized by alterations of laterally persistent sandstone beds with rippled sandstones and siltstones ... on a decimetre scale ...'. The underlying facies 1 consists of dominantly thin-bedded grey sandstones set within grey to grey-green siltstones; detrital micas are abundant. Ripple cross-laminations are common in the sandstones, which are often lensoid over short distances. Thicker sandstones, which are considerably more persistent and have sharp, planar bases, display parallel laminations, wave and ripple cross-lamination and grading. In the Manjunnas area thin conglomerates, with clasts up to 10 cm across, are locally present close to or at the base of the formation (Rice 1994).

The base of the Ekkerøya Formation is an unconformity thought to represent a lengthy period of either non-deposition or deposition and subsequent erosion (Røe 1975; Vidal 1981). No angular discordance has been found between the Ekkerøya Formation and the underlying Golneselva Formation, although at the base of the Ekkerøya Formation in southern Varangerhalvøya there is a < 2.5 m thick polymict conglomerate forming the matrix to a proximally derived coarse sedimentary breccia (Banks et al. 1974; Johnson 1978; Rice, unpubl. data). In northwestern Varangerhalvøya, where the Ekkerøya Formation rests with a slight angular discordance on the Barents Sea Group, there is also a mixed conglomerate and sedimentary breccia, typically < 50 cm thick, at the base (Rice 1994).

Airoaivi Group

The Airoaivi Group (Townsend et al. 1989; Rice & Siedlecka 1994), which crops out in the southwest part of the Gaissa Thrust Belt (Fig. 1), has not been studied in detail. The unit comprises ca. 200 m of sandstones and conglomerates with a high feldspar content and sub-angular grain shapes (Townsend et al. 1989). Since the rocks were deposited on the flank of a rift basin (Timanian Aulacogen) with no contemporary active volcanic feldspar source, the feldspar is inferred to have been derived from the Fennoscandian Shield. The textural immaturity suggests a short transport distance and thus *perhaps* a fluvial depositional environment, although it should be noted that this interpretation is very tentative. For this reason the Airoaivi Group has been loosely correlated with the Vadsø Group (cf. Gayer & Rice 1989). However, no correlative of the Ekkerøya Formation has been identified at the top of the Airoaivi Group.

Brennelvfjorden formation

The Brennelvfjorden formation crops out at the base of the numerous imbricates in the Gaissa Thrust Belt in the Cåkkarassa–Porsangerfjord–Rætkajåkskaidi area of central and western Finnmark, directly underlying the Kikut Member, with a gradational contact (see above; Roberts 1974; Fig. 1). A variety of thicknesses have been

proposed for the unit; White (1968) estimated a thickness of 293 m, Roberts (1974) suggested a minimum of 200 m and Townsend et al. (1989) a thickness of 0–400 m, the last one adjacent to syn-depositional faults which were later inverted. The base of the formation is always marked by a thrust; no stratigraphic base is known.

Roberts (1974) divided the Brennelvfjorden formation into three informal units and provided extensive descriptions and a log section. All three units appear to be lithologically variable and detailed correlations of sections from different areas are not possible. In the sections described by Roberts (1974), the lower unit, 36–40 m thick, comprises poorly sorted conglomerates of either intraformational shales/silty pebbles set in siltstones or extraformational rounded pebbles set in sandstone (or locally both), yellow unconsolidated grits with normal grading to sandstones, thin- to medium-bedded dark sandstones and quartzites with variably oriented ripples, rust-spotted quartzites and red-purple and green-buff siltstones. The middle unit, 64–71 m thick, is characterized by mudcracks, which usually form triradiate sets rather than polygons, sometimes contorted by subsequent compaction. Light quartzitic sandstones with green silts, black homogeneous siltstones to fine-grained sandstones, massive quartzites, locally mottled purple, intraformational black-mudflake conglomerates and rippled sandstones with pebbly lenses in the troughs, are all present. The upper unit, 59 m thick, comprises fine-grained quartzites with persistent green siltstones overlain by interbedded thin quartzites and dark-grey to black siltstones and thence by 2–3 m yellow-green interbedded siltstones and sandstones. Mud-cracks and mud-flake conglomerates are common.

In the area southwest of Lakselv, Townsend et al. (1989) found that most exposures of the Brennelvfjorden formation are dominated by quartzites, grey-coloured grits and yellow-green sandstones, although purple, yellow-green and grey sandstones and shales are also present. Rust-spotting is locally abundant. A sharp contact with the overlying Kikut Member was not observed.

Although Roberts (1974) noted that his work was of a preliminary nature, he interpreted the sequence to reflect braided fluvial facies (lower unit) overlain by meandering river facies, in which crevasse splays imply deltaic conditions, although not directly stated so by Roberts (1974), possibly with beach facies (middle unit), to beach facies (upper unit). Overall, therefore, the formation forms a *broadly* transgressive sequence.

Discussion

Correlations of lithologies in the absence of precise chronostratigraphic data are always rather speculative. However, although we cannot make a detailed facies correlation, our extensive work in the Lower Allochthon in Finnmark (see references above) enables us to note the lithological similarities between the Ekkerøya Formation

in East Finnmark, particularly facies 3 and 4 as seen in the Gavesluft area and at the mouth of Marjavaggi (Fig. 1), and the Brennelvfjorden formation in the Porsangerfjord region. The units are similar in the very variable nature of their lithologies, which include dark shales, grey quartzites with abundant intraformational mud-flake conglomerates, rust-spotting, yellow-green to locally reddish/purple sand- and siltstones, and compressed triradiate mud-cracks. Furthermore, both units underlie grits and quartz conglomerates at the base of the previously correlated Grønneset Formation and Kikut Member and themselves have basal conglomerates/breccias. Clearly, however, there are also differences between the units, in particular the greater thickness of dark siltstones and mudstones in the Ekkerøya Formation.

The Ekkerøya Formation is predominantly regressive, whilst the Brennelvfjorden formation has an overall transgressive aspect, although sea-level changes might well have been more complex in detail. Thus a direct correlation of the two units is not strictly valid, although the sequences may still be chronostratigraphic equivalents; this possibility is shown in Fig. 2 by line A. An alternative is to regard the Brennelvfjorden formation as equivalent to either the transgressive/aggradational sedimentation which occurred with facies 4 of the Ekkerøya Formation (fig. 2 in Johnson 1978), shown as line B in Fig. 2, or the transgression which must have occurred after deposition of the Golneselva Formation and prior to the regression of the Ekkerøya Formation (line C, Fig. 2). Sedimentation in central and west Finnmark seems to have been almost continuous from the Brennelvfjorden formation into the Kikut Member, with only a relatively thin, or perhaps not developed, basal conglomerate, whilst in East Finnmark sedimentation was markedly non-continuous during Ekkerøya–Grønneset Formation times.

The lack of evidence for an unconformity between the Brennelvfjorden formation and the overlying quartzites of the Kikut Member should not be regarded as being particularly significant. Since subsidence/uplift rates vary considerably between *adjacent* areas of basins, invoking differential subsidence between Porsangerfjord and East Finnmark creates no conceptual difficulties. Indeed, such variations in subsidence rate are *already* implicit in the widely accepted correlation of the Tanafjorden and Porsangerfjord Groups.

Johnson (1978) invoked syn-sedimentary faulting as a controlling feature of sedimentation within the Ekkerøya Formation, consistent with the location of the Vadsø Group close to the Trollfjorden–Komagelva Fault, an active sedimentation controlling structure in the late Precambrian (Siedlecka 1985). Although the Brennelvfjorden formation lies considerably further south of the inferred WNW projection of the Trollfjorden–Komagelva Fault, Townsend et al. (1989) recorded evidence of thickening of the Brennelvfjorden formation towards syn-sedimentary faults. Other evidence of late Proterozoic syn-sedimentary faulting/deformation in the Por-

sangerfjord area has been noted by Williams (1976a, b) and Roberts & Rice (1990) in late- to post-Porsangerfjord Group times.

There can be no objection, in principle, to a westwards increase in the areal extent of the Ekkerøya Formation or a correlative thereof; indeed, such an enlargement simplifies the overall geology of the area by increasing the across-strike lithostratigraphic continuity of the area. Although the Ekkerøya Formation thins to the south and west on Varangerhalvøya, this is a result of later erosion prior to sedimentation of the Grønneset Formation, and does not, therefore, affect the validity of the proposed correlation. In a palinspastic reconstruction the outcrop area of the Brennelvfjorden formation would be larger than the known outcrop area of the Ekkerøya Formation in East Finnmark (see Townsend et al. 1986, 1989, for restorations). Note that although this is an across-strike correlation, it is, much more significantly, broadly an along-basin-margin correlation (Siedlecka 1985; Gayer & Rice 1989), the difference resulting from the Caledonian tectonic activity in the area.

Finally, such a correlation implies that the lithostratigraphic terminology of the region should be revised, since it is illogical to have correlated formations lying within different groups. Four possibilities are (1) placing the Ekkerøya Formation in the Tanafjorden Group; (2) placing the Brennelvfjorden formation in the Vadsø Group; (3) combining the two formations into a new group; and (4) separating the two units from both the Vadsø and the Tanafjorden Groups, but not creating a new group.

Arguments for and against any one of these possibilities can be made. The most satisfactory, however, seems to be to create a new group lying between the Tanafjorden and Vadsø Groups, and thus probably between the Tanafjorden and Airoaivi Groups. For this the term *Ekkerøya group* is here informally proposed, consisting of two formations – the *Brennelvfjorden formation* and the *Lille Molvik formation*, the latter being the informally renamed Ekkerøya Formation. The advantages of this revision are, first, that the major hiatus/unconformity at the base of the Ekkerøya Formation in East Finnmark becomes a significant lithostratigraphic boundary and is thus more readily recognized, both in lithostratigraphic columns and on maps; this is lost in proposal 2. Second, the unconformity at the top of the Ekkerøya Formation, and possibly also at the top of the Brennelvfjorden formation, is retained as a major lithostratigraphic boundary and the along-strike significance of the correlation is enhanced; these are both lost in proposal 1. Third, it enables the Ekkerøya Formation rocks to be named after the area where the thickest succession has been described (250–300 m according to Siedlecka & Siedlecki (1972), although Johnson (1978) indicates only 130 m), containing all four facies, with an unstrained stratigraphic top and base to the succession in a well-exposed and relatively accessible area. Finally, it emphasizes the correlation between the two units by placing them in the same group.

Acknowledgements. – AHNH thanks Arild and Jorunn Pettersen for hospitality in Tana; Christa Hofmann, Rafael Herrgoß and Charlie Offenbecher for field assistance; Rainer Zühlke and Thomas Rüffer for computer graphics assistance. Both authors thank Norges Geologiske Undersøkelse for the opportunity to work in the remoter parts of the Gaissa Thrust Belt; Unn & Per-Øle Gjøvik for hospitality in Lakselv; Rod Gayer, David Roberts, Signe-Line Røe and Reidulv Bøe for reviewing the manuscript.

Manuscript received January 1994

References

- Banks, N. L., Edwards, M. B., Geddes, W. P., Hobday, D. K. & Reading, H. G. 1971: Late Precambrian and Cambro-Ordovician sedimentation in East Finnmark. *Norges geologiske undersøkelse* 269, 197–236.
- Banks, N. L., Hobday, D. K., Reading, H. G. & Taylor, P. N. 1974: Stratigraphy of the Late Precambrian 'Older Sandstone Series' of the Varangerfjord area, Finnmark. *Norges geologiske undersøkelse* 303, 1–15.
- Bertrand-Sarfati, J. & Siedlecka, A. 1980: Columnar stromatolites of the terminal Precambrian Porsanger Dolomite and Grasdalen Formation of Finnmark, north Norway. *Norsk Geologisk Tidsskrift* 60, 1–27.
- Chapman, T. J., Gayer, R. A. & Williams, G. D. 1985: Structural cross-sections through the Finnmark Caledonides and timing of the Finnmarkian event. In Gee, D. G. & Sturt, B. A. (eds.): *The Caledonide Orogen – Scandinavia and Related Areas*, 593–609. J. Wiley & Sons, Chichester.
- Edwards, M. B., Baylis, P., Gibling, M., Goffe, W., Potter, M. & Suthren, R. J. 1973: Stratigraphy of the 'Older Sandstone Series' (Tanafjord Group) and Vestertana Group north of Stallogaissa, Lakesfjord District, Finnmark. *Norges geologiske undersøkelse* 294, 25–41.
- Føyn, S. 1967: Dividal Gruppen ('Hyolithus Zonen') i Finnmark og dens forhold til de eokambriske-kambriske formasjoner. *Norges geologiske undersøkelse* 249, 1–84.
- Føyn, S. 1984: Vendian-Cambrian stratigraphy and Caledonian tectonics in the area between Laksefjorden and Guor'gabmir, Finnmark, North Norway. *Norges geologiske undersøkelse Bulletin* 395, 39–46.
- Føyn, S. 1985: The Late Precambrian in northern Scandinavia. In Gee, D. G. & Sturt, B. A. (eds.): *The Caledonide Orogen – Scandinavia and Related Areas*, 233–245. J. Wiley & Sons, Chichester.
- Føyn, S. & Siedlecki, S. 1981: Glacial stadials and interstadials of the late Precambrian Smalfjord Tillite on Laksefjordvidda, Finnmark, North Norway. *Norges geologiske undersøkelse* 358, 31–45.
- Føyn, S., Chapman, T. J. & Roberts, D. 1983: Adamsfjord and Ut lugaisa. Description of the geological maps 2135I and II–M 1:50,000. *Norges geologiske undersøkelse* 381, 1–78.
- Gayer, R. A., Rice, A. H. N., Roberts, D., Townsend, C. & Welbon, A. 1987: Restoration of the Caledonian Baltoscandian margin from balanced cross-sections: the problem of excess continental crust. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 78, 197–217.
- Gayer, R. A. & Rice, A. H. N. 1989: Palaeogeographic reconstruction of the pre-to syn-Iapetus rifting sediments in the Caledonides of Finnmark, N Norway. In Gayer, R. A. (ed.): *The Caledonide Geology of Scandinavia*, 127–139. Graham & Trotman, London.
- Johnson, H. D. 1978: Facies distribution and lithostratigraphic correlation in the late Precambrian Ekkerøya Formation, East Finnmark, Norway. *Norsk Geologisk Tidsskrift* 58, 175–190.
- Johnson, H. D., Levell, B. K. & Siedlecki, S. 1978: Late Precambrian sedimentary rocks in East Finnmark, north Norway and their relationship to the Trollfjord–Komagelva fault. *Journal of the Geological Society of London* 135, 517–533.
- Plumb, K. A. 1991: New Precambrian time scale. *Episodes* 14, 139–140.
- Rice, A. H. N. 1994: Stratigraphic overlap of the late Proterozoic Vadsø Group and Barents Sea Group and correlation across the Trollfjord–Komagelva Fault, Finnmark, N. Norway. *Norsk Geologisk Tidsskrift* 74, 48–57.
- Rice, A. H. N. & Siedlecka, A. 1994: Berggrunnskart CAKKARASSA 2035 3, M 1:50,000, foreløpig utgave. *Norges geologiske undersøkelse*.
- Rice, A. H. N., Harrington, K. & Roberts, D. 1990: RÆTKAJAKSKAIDI, berggrunnsgeologisk kart 2135 3–M 1:50,000, foreløpig utgave. *Norges geologiske undersøkelse*.
- Røe, S.-L. 1970: Correlation between the Late Precambrian Older Sandstone Series of the Varanger and Tanafjord Areas: Preliminary Report. *Norges geologiske undersøkelse* 266, 230–245.
- Røe, S.-L. 1975: Stratification, sedimentary processes and depositional environments of part of the Late Precambrian Vadsø Group, Varangerfjord area, Finnmark. Unpublished Cand.Real. thesis, University of Bergen, Norway.

- Roberts, D. & Rice, A. H. N. 1990: MUNKAVARRI, berggrunnsgeologisk kart 2035 2—M 1:50,000, foreløpig utgave. *Norges geologiske undersøkelse*.
- Roberts, D. & Welbon, A. 1992: BØRSELV, berggrunnsgeologisk kart 2035 1—M 1:50,000, foreløpig utgave. *Norges geologiske undersøkelse*.
- Roberts, D. & Davidson, B. 1993: LAKSELV, berggrunnsgeologisk kart 2035 3—M 1:50,000, foreløpig utgave. *Norges geologiske undersøkelse*.
- Roberts, J. D. 1970: Geology of South Porsanger, Finnmark. Unpublished Ph.D. thesis, University of Wales, Cardiff.
- Roberts, J. D. 1971a: Preliminary notes on the sedimentology in South and East Porsanger, Finnmark. *Norges geologiske undersøkelse* 269, 237–241.
- Roberts, J. D. 1971b: Geology of South and East Porsanger, Finnmark. *Norges geologiske Undersøkelse* 269, 307–313.
- Roberts, J. D. 1974: Stratigraphy and correlation of Gaissa Sandstone Formation and Børslev Subgroups, (Porsangerfjord Group), South Porsanger, Finnmark. *Norges geologiske undersøkelse* 303, 57–118.
- Siedlecka, A. 1975: Late Precambrian stratigraphy and structure of the northeastern margin of the Fennoscandian Shield (East Finnmark—Timan Region). *Norges geologiske undersøkelse* 316, 313–348.
- Siedlecka, A. 1978: Late Precambrian tidal flat deposits and algal stromatolites in the Båtsfjord Formation, East Finnmark. *Sedimentary Geology* 21, 277–310.
- Siedlecka, A. 1985: Development of the Upper Proterozoic sedimentary basins of the Varanger peninsula, East Finnmark, North Norway. *Geological Survey of Finland, Bulletin* 331, 175–185.
- Siedlecka, A. & Siedlecki, S. 1971: Late Precambrian sedimentary rocks of the Tanafjord—Varangerfjord region of Varanger Peninsula, northern Norway. *Norges geologiske Undersøkelse* 269, 246–294.
- Siedlecka, A. & Siedlecki, S. 1972: Lithostratigraphical correlation and sedimentology of the Late Precambrian of Varanger Peninsula and neighbouring areas of East Finnmark, northern Norway. *24th International Geological Congress, Section 6*, 349–358.
- Siedlecka, A. & Roberts, D. 1992: The bedrock geology of Varanger Peninsula, Finnmark, North Norway. An excursion guide. *Special Publication No. 5, Norges geologiske Undersøkelse*.
- Townsend, C., Roberts, D., Rice, A. H. N. & Gayer, R. A. 1986: The Gaissa Nappe, Finnmark, north Norway: an example of a deeply eroded external imbricate zone. *Journal of Structural Geology* 8, 431–440.
- Townsend, C., Rice, A. H. N. & Mackay, A. 1989: The structure and stratigraphy of the southwestern portion of the Gaissa Thrust Belt and the adjacent Kalak Nappe Complex, Finnmark, N. Norway. In Gayer, R. A. (ed.): *The Caledonide Geology of Scandinavia*, 111–126. Graham & Trotman, London.
- Tucker, M. 1976: Replaced evaporites from the late Precambrian of Finnmark, Arctic Norway. *Sedimentary Geology* 16, 193–204.
- Tucker, M. 1977: Stromatolite biostromes and associated facies in the late Precambrian Porsanger Dolomite Formation of Finnmark, Arctic Norway. *Palaeogeography, Palaeoclimatology, Palaeoecology* 21, 55–83.
- Vidal, G. 1981: Micropalaeontology and biostratigraphy of the Upper Proterozoic and Lower Cambrian sequence in East Finnmark, northern Norway. *Norges geologiske undersøkelse* 362, 1–53.
- Vidal, G. & Siedlecka, A. 1983: Planktonic, acid-resistant microfossils from the Upper Proterozoic strata of the Barents Sea Region of Varanger Peninsula, East Finnmark, northern Norway. *Norges geologiske undersøkelse* 382, 45–79.
- White, B. 1968: The Porsanger Sandstone Formation and subjacent rocks in the Lakselv Valley District, Finnmark, North Norway. *Norges geologiske undersøkelse* 255, 59–86.
- White, B. 1969: The Stabburnes Formation and Porsanger Dolomite Formation in the Kolvik District, northern Norway: the development of a Precambrian algal environment. *Norges geologiske undersøkelse* 258, 79–115.
- Williams, D. M. 1974: The geology of the northern parts of the Gaissa Nappe, Finnmark, North Norway. Unpublished Ph.D. thesis, University of Wales, Cardiff.
- Williams, D. M. 1976a: A revised stratigraphy for the Gaissa Nappe, Finnmark, Norway. *Norges geologiske undersøkelse* 324, 63–78.
- Williams, D. M. 1976b: Clastic dykes from the Precambrian Porsangerfjord Group, North Norway. *Geological Magazine* 113, 169–176.