

CALEDONIAN TERRANES OF NORTHERN NORWAY AND THEIR CHARACTERISTICS

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Los Caledónides Escandinavos del norte de Noruega se caracterizan por una serie de mantos horizontales que fueron emplazados sobre el cratón Bastoscándico durante el cierre del Océano Japeto en el Paleozoico Inferior a Medio. Los mantos se agrupan en cuatro unidades principales denominadas respectivamente Alóctono Inferior, Medio, Superior y Terminal. Las rocas presentes en los alóctonos Inferior y Medio representan la sucesión miogeoclinal acortada depositada en el margen occidental, separada de Báltica en el Precámbrico Superior a Cámbrico Inferior. Los alóctonos Superior y Terminal, estructuralmente superpuestos, están constituidos por unidades estructurales con litologías exóticas respecto a la litostratigrafía baltoscándica. Las unidades estructurales que constituyen el Alóctono Medio en Troms son, de abajo arriba, el Terreno de Vaddas, el Manto de Kafjord, el Manto de Nordmannvik y el Terreno Compuesto de Lyngen. El Terreno de Vaddas representa una secuencia volcano-sedimentaria de edad Ordovícico Superior-Silúrico, mientras que los mantos suprayacentes de Kafjord y Nordmannvik contienen mármoles, cuarcitas y gneises micaceos de grado alto a medio, de edad y origen desconocidos. Un fragmento ofiolítico de gran tamaño (terreno oceánico), sobre el que se encuentra discordante una espesa secuencia metasedimentaria del Ordovícico Superior-Silúrico Inferior (Grupo de Balsfjord), constituye el Terreno de Lyngen. Las correlaciones regionales sugieren que el Grupo de Balsfjord representa una secuencia sobreimpuesta (over-stepping) entre un terreno oceánico y un terreno de arco de islas. Un resto aislado del Alóctono Medio en Finmark, el Terreno de Mageroy, se puede correlacionar bien con el Terreno de Vaddas o con el Grupo de Balsfjord.

El Alóctono Terminal en Troms, el Complejo de mantos de Tromsø, está constituido por tres unidades tectónicas, de las cuales el tercio superior está constituido por una secuencia carbonatada, intruida por doleritas transformadas en la actualidad en lentes de eclogitas dentro de mármoles. Las capas cuarzo-feldespáticas muestran asociaciones minerales relictas de alta presión. La edad y el origen de las rocas presentes en el Complejo de Mantos de Tromsø no se conocen bien.

El Terreno del Mar de Barents, una secuencia predominantemente turbidítica de 15.000 m de espesor que constituye la mitad norte de la Península de Varanger, está separada del autóctono Baltoscándico por una falla transcurrente del Precámbrico Superior.

Palabras clave: Escandinavia, Caledónides, Noruega Septentrional, terrenos, mantos, Vendense, estratigrafía, tectonoestratigrafía.

[Traducido por la revista]

The Scandinavian Caledonides of Northern Norway are characterized by a series of flat-lying nappes which were emplaced onto the Baltoscandian platform during closure of the Iapetus ocean in Early to Mid Palaeozoicum. The nappes are grouped into four main units named the Lower, Middle, Upper and Uppermost Allochthons. Rocks involved in the Lower and Middle Allochthons represents the shortened miogeoclinal sequence that developed along the rifted western margin of Baltica in Late Precambrian to Cambrian time. The structurally overlying Middle and Upper Allochthons are composed of structural units with lithologies that are exotic relative to the Baltoscandian lithostratigraphy. The structural units making up the Middle Allochthon in

Troms are in ascending order the Vaddas Terrane, the Kafjord Nappe, the Nordmannvik Nappe and the Lyngen Composite Terrane. The Vaddas Terrane represents a volcano-sedimentary sequence of Upper Ordovician-Silurian age, whereas the overlying Kafjord and Nordmannvik Nappes represents medium- to high-grade marbles, quartzites and mica-gneisses of unknown age and origin. A large ophiolite fragment (oceanic terrane), unconformably overlain by a thick Late Ordovician-Silurian metasedimentary sequence (Balsfjord Group) make up the Lyngen Composite Terrane. Regional correlations suggests that the Balsfjord Group represents an over-step sequence between an oceanic terrane and an island arc terrane. An isolated outlier of the Middle Allochthon in Finnmark, the Magerøy Terrane, correlates either with the Vaddas Terrane or the Balsfjord Group.

Uppermost Allochthon in Troms, the Tromsø Nappe Complex, is composed of three tectonic units, of which the upper third include a dolerite intruded carbonate sequence now transformed into eclogite-lenses in marble. Quartzo-feldspathic layers show relict high-pressure granulite mineral assemblages. Age and origin of rocks present in the Tromsø Nappe Complex is not well known.

The Barents Sea Terrane, a 15,000 m thick turbidite-dominated sequence making up the northern half of the Varanger Peninsula, is separated from the Baltoscandian autochthon by a Late Precambrian transcurrent fault.

Key words: Scandinavia, Caledonides, Northern Norway, terranes, nappes, Vendian, stratigraphy, tectonostratigraphy.

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One of the most valuable results of IGCP project-27, The Caledonide Orogen, was the compilation of a tectonic map covering the Caledonides in both Sweden and Norway, and a general subdivision of the allochthonous rocks or nappes into 4 main tectonic units (Roberts and Gee 1985). The four main nappe complexes are in ascending tectonic order: the Lower Allochthon, Middle Allochthon, Upper Allochthon and Uppermost Allochthon. It is now generally accepted that the various thrust-sheets and/or nappes present in the Lower and Middle Allochthons are derived from the rifted, and subsequently, passive continental margin that developed west of Baltica in Late Precambrian (Riphean to Vendian) to Cambrian time. The present arrangement of the individual thrustsheets are by most authors interpreted as being caused by tectonic telescoping due to crustal shortening in Ordovician through Early Devonian time. In most models dealing with the tectonics of the Lower and Middle Allochthons, the highest thrust sheet is considered to have travelled farthest, and the lowermost sheet the shortest distance (Gee 1975, Sturt *et al.* 1978,

Hossack *et al.* 1985, Nystuen 1981). The thrust distances suggested for the structurally highest sheets within the Middle Allochthon is of the order of 200-300 Km. Large scale transcurrent movement is generally not invoked.

It is now generally accepted that the Upper and Uppermost Allochthons contain a variety of exotic terranes which also have been thrust several hundred kilometers eastwards onto the Baltoscandian platform during the same Early to Mid Palaeozoic orogeny. Extensive structural, metamorphic and geochemical data dealing with their environment of formation and accretion onto Baltoscandian Craton have been presented from these outboard terranes from the central and southern parts of the orogen (Gee 1975, Roberts *et al.* 1985, Stephens *et al.* 1985, Dallmeyer *et al.* 1986). Considerably less is known about the geological history, including deposition, metamorphism, deformation and accretion, of the exotic terranes making up the Upper and Uppermost Allochthons in Northern Norway. It is the purpose of this paper to summarize existing knowledge on the Upper and Uppermost Allochthons in Northern Norway (Fig. 1), inc-

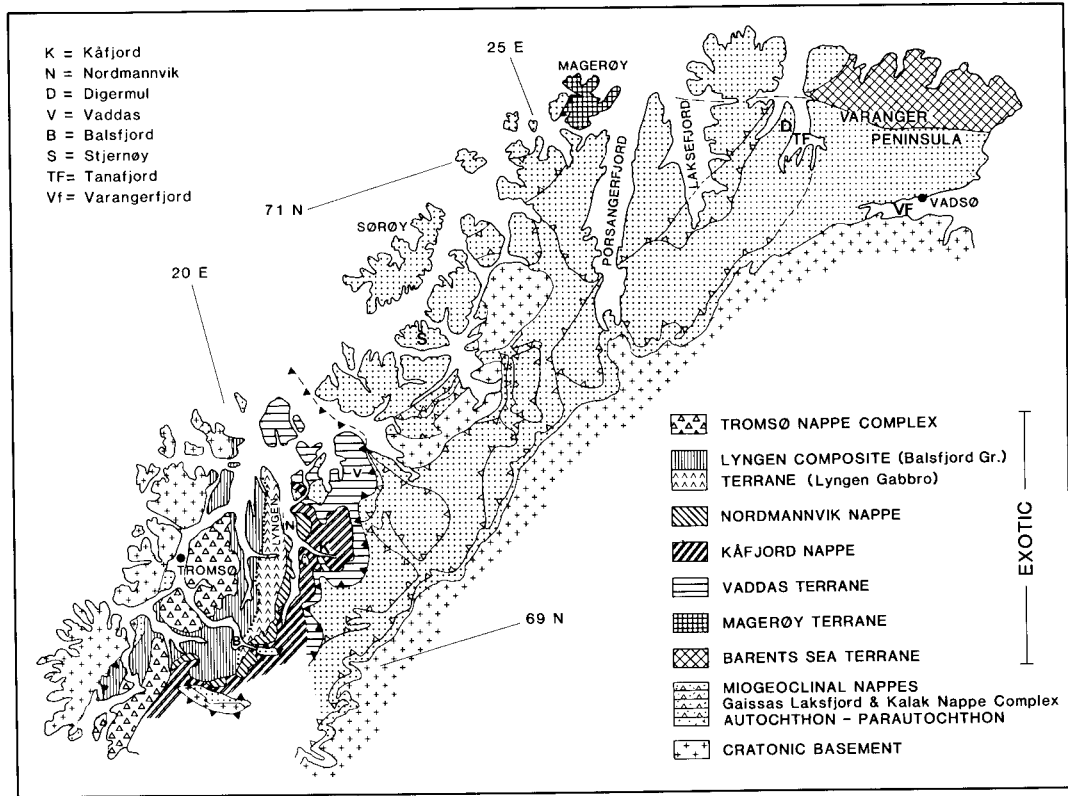


Fig. 1.—Simplified geologic map of the Scandinavian Caledonides in Finnmark and northernmost Troms, showing the main tectonic units and terranes.

cluding published as well as unpublished data. A summary dealing with the stratigraphy and structural history of the platform and miogeoclinal sequences present in the Autochthon, and Lower and Middle Allochthons, some of which may be of exotic origin, will also be presented.

BALTOSCANDIAN PLATFORM AND MIOGEOCLINAL SEQUENCES

Detailed stratigraphic and structural mapping the last 25 years have shown that the Late Precambrian platform and miogeoclinal sequences of the East-Finmark Caledonides represent a deeply exhumed section through a foreland thrust- and fold-belt (Gayer *et al.* 1985, Townsend *et al.* 1986), with well developed decollement zones, ramps, duplexes etc. The Late Precambrian metasedi-

ments, locally with their depositional basement preserved, occur in a series of thin faulting thrust-sheets or nappes, which thin towards the west and north-west. The main tectonic units overlying the autochthonous cover and making up the Lower and Middle Allochthons in this part of the orogen are the Gaissa Nappe, Laksefjord Nappe and the Kalak Nappe Complex (Ramsay *et al.* 1985) (Fig. 1). South of Finnmark other names are in use for the various nappes belonging to the Lower and Middle Allochthon (Andresen *et al.* 1985).

Precambrian Basement

Precambrian basement rocks are exposed in three structurally different settings, 1) as undisturbed crystalline foreland basement east of the orogen, 2) as large and small tectonic windows in the middle of the orogen, and 3) as a coastal basement region (Western Base-

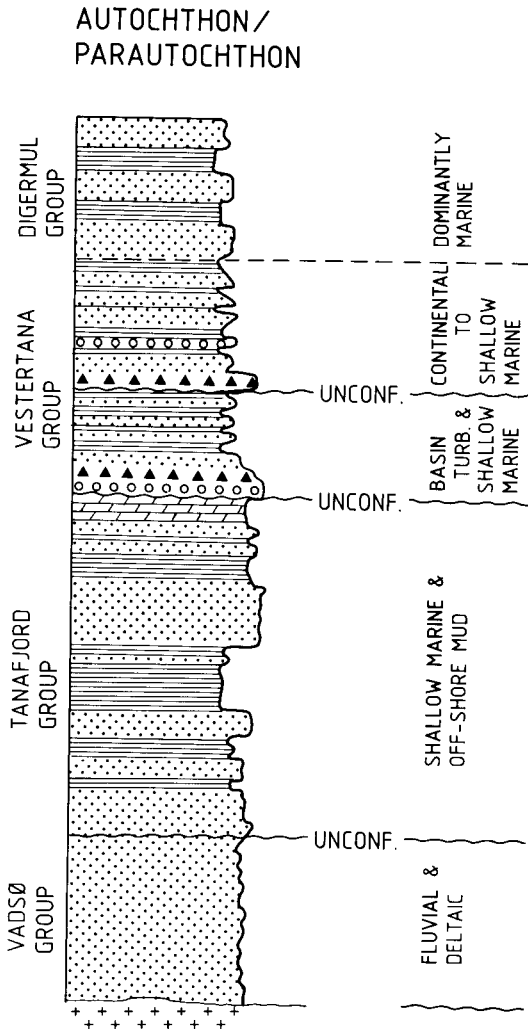


Fig. 2.—Simplified lithostratigraphic column, with inferred depositional environment, for the autochthonous-parautochthonous platform sequence. Modified from Føyn (1985).

ment Region) composed of Precambrian basement rocks showing variable degrees of superimposed Caledonian structures. Although various models have been proposed for the structural relationship between these three basement regions (Tull 1977, Hodges *et al.* 1982), most geologists consider all the basement rocks to be part of Baltica and not belonging to one or more suspect terranes.

The basement rocks range in age from Archean to Mid Proterozoic. Archean rocks are found both within the Western Basement Region as well as on Finnmarksvidda east of the Caledonides (Griffin *et al.* 1978, Krill *et al.* 1985, Olsen and Nilsen 1985). A more complete description of the Archean and Proterozoic rocks and their evolutionary history is found in Griffin *et al.* 1978, Marker 1985, Krill *et al.* 1985, Olsen and Nilsen 1985.

Autochthon-Parautochthon

The autochthonous sequence is most extensively exposed on the south-eastern part of the Varanger Peninsula, south of the Trollfjord-Komagelv Fault Zone (Fig. 1). It also occurs as a thin zone below the allochthons further south-westwards along the front of the orogen. A thin autochthonous veneer is also found around some of the tectonic windows (Roberts and Fareth 1974). In the southwestern part of the Varanger Peninsula, the rocks are strongly folded (Siedlecki 1980) and are here considered parautochthonous. Cover rocks along the western edge of most windows are probably also parautochthonous.

The autochthonous sequence, which is composed of three groups (Vadsø Gr., Tanafjord Gr. and Vestertana Gr.) separated by minor unconformities, range in age from Late Riphean to (?) Early Cambrian (Fig. 2). It is composed entirely of sedimentary strata and includes at least two tillite horizons of Vendian age (Føyn 1985). The Vadsø Group, which is of Late Riphean age, is dominated by fluvial sandstones (Banks *et al.* 1974). A gentle, southerly dipping unconformity separates the shallow marine sediments of the Tanafjord Group (Siedlecka and Siedlecki 1971), which in its upper part contains dolomite layers, from the underlying Vadsø Group. A new angular unconformity of approximately 1-2 deg. separates the Tanafjord and Vestertana Groups. The latter, which contains two diamictite formations in its lower half, is composed of alternating sandstone, siltstone and some conglomeratic beds representing depositional environments varying from continental to deep water (Føyn 1985). The Lower Cambrian *Platysolenites antiquissimus* occurs in the upper part of the group (Breivik Formation) (Føyn 1967).

Gaissa Nappe

The location of the sole-thrust for the Gaissa Nappe against the parautochthon around Tanafjord is uncertain. Further south-westwards, however, a distinct thrust separates the Gaissa Nappe from the underlying autochthonous/parautochthonous sequence. The Gaissa Nappe has a rather discontinuous appearance south and west of Porsangerfjord (Fig. 1). Recent investigations (Føyn and Siedlecki 1980, Roberts 1985) have shown that both the upper part of the Tanafjord Group

and the entire Vestertana Group (Fig. 2) are present in the Gaissa Nappe. On Digermul Peninsula (Fig. 1), the Vestertana Group is succeeded by 1,500 m of folded and thrustured Cambrian to Lower Ordovician (Tremadocian) strata (Digermul Group). The Tremadocian fossils present in the Digermul Group (Reading 1965) place a lower age on the deformation and low-grade metamorphism in the area. Rare basic dykes, pre-dating the deformation, are observed locally.

Laksefjord Nappe

The Laksefjord Nappe differs from the Gaissa Nappe in that pieces of Proterozoic granitic and basic volcanic rocks are preserved at the structural base of the sedimentary sequence which make up the bulk of this tectonic unit. (Føyn *et al.* 1983). The Laksefjord Nappe is thus included in the Middle Allochthon on the tectonostratigraphic map published by Gee and Sturt (1985). The metasediments (Laksefjord Group) are dominated by metasandstones, schists and phyllites above a basal conglomerate (Føyn *et al.* 1983). A relatively thick dolomite sequence (Porsanger Dolomite Formation) occur in the upper part of the Laksefjord Nappe around Porsangerfjord. As no fossils have yet been recovered from the Laksefjord Group, the age of the group is unknown (Føyn 1985). Neither are there any obvious lithostratigraphic similarities between the Laksefjord Group and the autochthonous succession. Roberts (1985) prefers to correlate the Laksefjord Group with the Vestertana Group. Dolerite dykes occur locally in the Laksefjord Group.

Kalak Nappe Complex

The Kalak Nappe Complex, which is made up of 8 nappes or thrust sheets (Ramsay *et al.* 1985), differs markedly from the Autochthon as well as the Gaissa and Laksefjord Nappes (Fig. 3). The most prominent differences relative to the underlying units are: 1) a distinctly higher metamorphic grade, 2) a much more intense and complex deformational style, 3) mafic dikes occur more frequently, 4) includes intrusives other than mafic dikes, and 5) contains large volumes of basement rocks, locally with a well-preserved contact with the stratigraphically overlying cover-sequence.

MIDDLE ALLOCHTHON

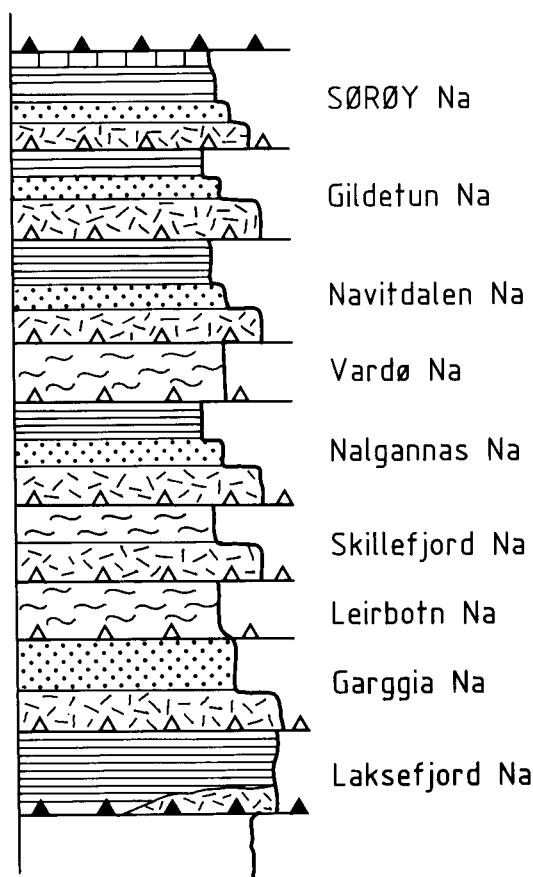


Fig. 3.—Tectonostratigraphy of the Kalak Nappe Complex after Ramsay *et al.* (1985). Ornamentation: random dashes — Precambrian basement rocks, dots — psammites; horizontal lines — schists with minor marble.

Although the cover sequence varies from nappe to nappe due to intense post-depositional strain, a relatively complete cover sequence occurs on the island of Sørøy (Ramsay 1971, Roberts 1974). The five groups making up the cover sequence (Sørøy Sequence, Ramsay 1971) on Sørøy are the Klubben Psammite Group, the Storelv Psammite and Schist Group, the Falkenes Marble Group, the Aafjord Mica Schist Group and the Hellefjord Metagreywacke Group.

Fossils have not yet been found in the Sørøy sequence and its depositional age is therefore unknown. However, the sequence is intruded by a synorogenic alkaline plutonic complex (Sturt and Ramsay 1965, Robins and Gardner 1975), dated to 540-490 Ma (Sturt *et al.* 1978), which puts an upper age constraint on the depositional age of the Sørøy sequence.

Despite the lack of distinct lithostratigraphic units for correlation with underlying fossiliferous units, there is little doubt that the Kalak Nappe Complex is derived from the western margin of Baltica. In recent years it has been documented that the lithology and age of the basement slivers in the Kalak Nappe Complex match those of the autochthonous basement (Ramsay *et al.* 1985, Sturt and Austerheim 1985).

As already pointed out, there is a general upwards as well as westwards increase in metamorphic grade within the shortened miogeocline sequence represented by the Gaissa Nappe, Laksfjord Nappe and Kalak Nappe Complex. On a metamorphic map of Finnmark (Roberts 1985) it is easily seen that jumps in metamorphic grade or the location of various isograds coincide with major tectonic boundaries. The metamorphism seen in the rocks therefore has predated thrusting in the area. Rb/Sr and $^{40}\text{Ar}/^{39}\text{Ar}$ ages from intensely cleaved slates from both the parautochthon and the Gaissa Nappe (Pringle 1973, Dallmeyer 1984) indicate that folding and thrusting in this part of the orogen is of Late Cambrian to Early Ordovician age.

SUSPECT TERRANES OF THE NORTH NORWEGIAN CALEDONIDES

Suspect or exotic terranes occur in two distinctly different tectonic settings: 1) as a

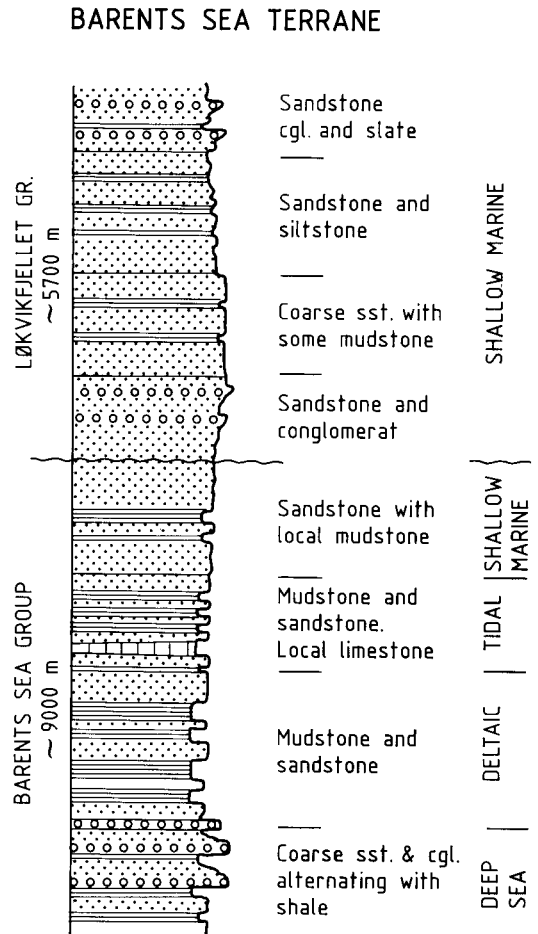


Fig. 4.—Simplified lithostratigraphic column, with interpreted depositional environment, for the Barents Sea Terrane. Data sources are Siedlecki (1980), Johnson *et al.* (1978), Siedlecki and Levell (1978) and Føyn (1985).

sequence of flatlying nappes on top of the Kalak Nappe Complex, and 2) as a distinct structural block making up the northeastern half of the Varanger Peninsula.

The latter block, which will be referred to as the Barents Sea Terrane, is separated from the autochthonous/parautochthonous sequence making up the southern half of the peninsula, by the Trollfjord-Komagelv Fault Zone. It is covered by water of the Barents Sea to the north and east, but has a thrust contact against the overlying Kalak Nappe Complex towards the west.

Barents Sea Terrane

The Barents Sea Terrane is composed of about 15,000 m of sediments divided into two groups, the Barents Sea Group and the Løkvikfjell Group, separated by a major angular unconformity (Fig. 4) (Siedlecka and Siedlecki 1967, 1971, Levell and Roberts 1977). Volcanics are not found interbedded with the sediments, but dyke swarms intrude the Barents Sea Group and the lower part of the Løkvikfjell Group. Time-diagnostic fossils have not yet been recovered from the Barents Sea Terrane, and the depositional age of the sediments is therefore uncertain. K/Ar dating of the dolerite dikes has given ages around 640 M.y (Beckinsale *et al.* 1975) indicating a Vendian to Riphean age for most of the two groups. Such an age is substantiated by recent micro-fossil investigations from the lowest formation of the Løkvikfjell Group (Vidal and Siedlecka 1983).

The Barents Sea and Løkvikfjell Groups show marked differences in lithofacies, thickness and interpreted depositional environment compared with the most likely time-stratigraphic units (Vadsø and Tanafjord Groups) of the autochthonous sequence (Siedlecka 1984).

The Barents Sea Group represents a regressive/off-lap sequence related to filling up of a deep sedimentary basin. It starts with a 3,000 m thick deep water turbidite sequence (Kongsfjord Fm) and continues with an almost equally thick sequence of offshore/delta front mud (Basnæringen Fm), followed by tidal dominated sediments before ending with shallow marine sandstone deposits with local fluvial incursions Johnson (Siedlecki 1980, *et al.* 1978, Siedlecki and Levell 1978). The unconformably overlying Løkvikfjell Group is more than 4,000 m thick, and is dominated by shallow water sandstone and mudstone, with minor conglomeratic deposits.

Besides the differences in lithofacies and thicknesses pointed out above between the Barents Sea Terrane and the Baltic miogeocline, other observations also indicate that the Trollfjord-Komagelv Fault Zone represents a terrane boundary. Kjode *et al.* (1978) concluded on the basis of paleomagnetic data that the Barents Sea Terrane was displaced a distance of 500 to 1,000 Km in a right lateral manner

after emplacement of the dolerite dikes (640 mill. Ma.). Such a displacement distance and direction is supported by the lithostratigraphic similarities of the Barents Sea and Løkvikfjell Groups with the Eleonore Bay Group along the east coast of Greenland (Siedlecki 1975). If 500 to 1,000 Km of displacement has taken place across the Trollfjord-Komagelv Fault Zone, most of this displacement must have been completed prior to emplacement of the Kalak Nappe Complex during the Finnmarkian orogeny (530-490 Ma.).

Suspect terranes within the Upper and Uppermost Allochthons

Most suspect terranes within the Scandinavian Caledonides are found within the Upper and Uppermost Allochthons. It is important to emphasize that the Upper and Uppermost Allochthons are composite tectonic complexes and that every nappe need not be a separate terrane, nor do all existing thrusts represent terrane boundaries. On the other hand, some of the nappes appear to be composed of more than one terrane. In the following, I will first describe the main tectonic units, and then discuss their characteristics in relation to the terrane concept (Coney *et al.* 1980).

Andresen and Bergh (1985), following Binns (1978) and Zwaan and Roberts (1978), divided the Upper allochthon into three, locally four, major lithotectonic units. Based on new data (Bergh and Andresen 1985), the terminology of Andresen and Bergh (1985) has been somewhat modified, and this modified terminology will be used in the further description and discussion (Fig. 5). An isolated klippe of Upper Allochthon also occur on Magerøy (Fig. 1). The Uppermost Allochthon in Northern Norway is represented by the Tromsø Nappe Complex (Fig. 5 & 6).

The three main tectonic units within the Upper Allochthon in Troms are from the base and upwards: Vaddas, Nappe, Nordmannvik Nappe and Lyngen Nappe (Zwaan and Roberts 1978, Andresen and Bergh 1985). A fourth nappe, the Kafjord Nappe, occurs between the Vaddas Nappe and the Nordmannvik Nappe east of Lyngen (Fig. 1). Of these four nappes, fossils are found only in the Vaddas and Lyngen Nappes (Olausen 1976, Binns and Gayer 1980, Bjørlykke and Olaus-

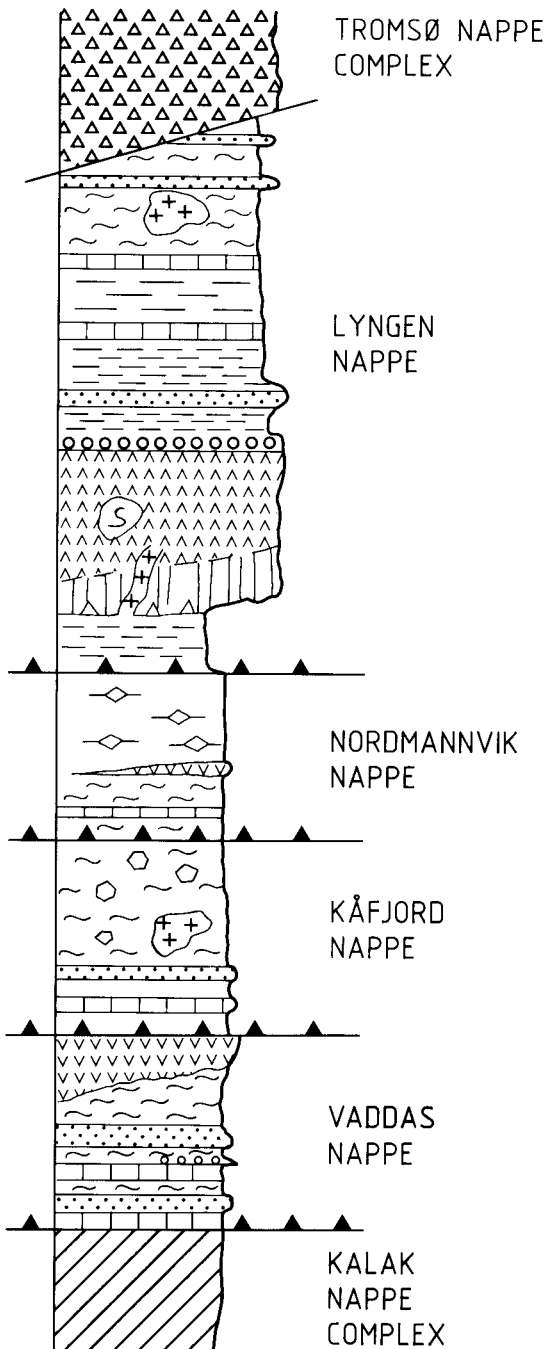


Fig. 5.—Tectonostratigraphy and terminology for the Upper and Uppermost Allochthons (suspect terranes) in northern Troms.

sen 1981, and Binns and Matthews 1981), as well as the Magerøy Nappe. In the following description these three lithotectonic units are considered as terranes for reasons given below.

Vaddas Terrane

The only comprehensive description of rocks present in the Vaddas Nappe is by Padget (1955). He grouped the rocks now included in the Vaddas Nappe as «the non-granitized Birtavarre Series» in contrast to the «granitized» rocks structurally below, now considered part of the Middle Allochthon (Zwaan and Roberts 1978, Binns and Gayer 1980). A simplified columnar section through the metasediments and metavolcanics making up the Vaddas Nappe around Kafjord, hereafter named informally the Birtavarre group, is given in Fig. 6. Interbedded marble and schists («Big Limestone») overlain by a quartzite dominated unit (Nitsimvarre series/Vaddas Quartzite) make up the lower two formations of the Birtavarre group. These lithologies are succeeded by the «Goulas Limestone Series» composed of marble and variable amounts of volcanics, including pillow lavas and volcanoclastic deposits. In addition to the basaltic volcanics described by Padget (1955), Binns and Gayer (1980) have recently reported horizons of intermediate and acid lavas. The fossils recently described from the Vaddas Nappe by Binns and Gayer (1980), halysitides with ordinary lacunae and elliptical corallites of Silurian or possibly Late Ordovician age, were recovered from these marbles. An almost monomict quartzite conglomerate marks the start of the Ankerlia series (Padget 1955). The bulk of the Ankerlia series is composed of various types of schist, often with biotite and amphibole porphyroblasts, and impure psammities with a total structural thickness of 1.5 Km. Amphibolite layers and lenses occur locally. Some of the psammities show graded bedding and well developed flame structures indicating that parts of the Ankerlia series represents distal turbidites. The uppermost part of the Vaddas Nappe is composed of a relatively thick sequence of green schists and more massive amphibolites («Green Beds») interpreted as lava flows by Padget (1955).

VADDAS TERRANE

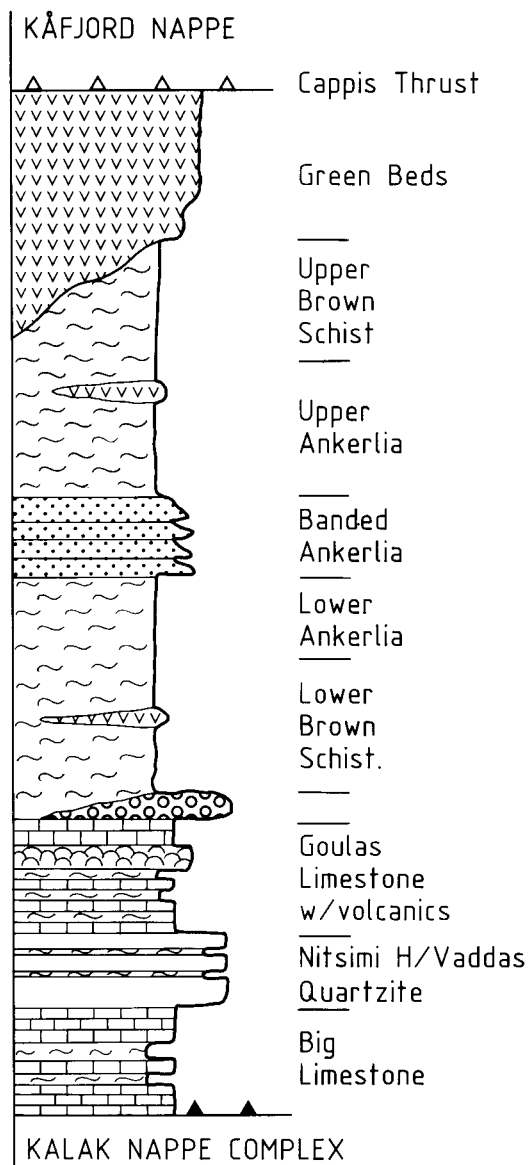


Fig. 6.—Simplified lithostratigraphic column of the Vaddas Terrane. Based on data from the Birtavarre area (Padget 1955).

The Birtavarre group is intruded by a large mafic complex (Vaddas Gabbro) just north of Kafjord (Vogt 1927, Lindahl 1974). A large deformed felsic intrusive (Rappesvarri Granitic

Gneiss) also occurs in the same area (Lindahl 1974, Lindahl *et al.* in prep.). No absolute age-dates have so far been obtained from igneous rocks within the Vaddas Nappe. The Scandian metamorphism recorded in the Vaddas Nappe is somewhat variable but reached at least low amphibolite facies over most of the area (Padget 1955).

Kafford Nappe

The Cappis Thrust separates the Vaddas Nappe/terrane from the structurally overlying Kafford Nappe. High strain, combined with extensive mylonitization and development of several internal thrusts, make it difficult to establish a lithostratigraphy/tectonic stratigraphy for this unit which can be mapped over wide areas. Marbles, meta-psammities and garnet mica-schists dominate the lower part of the Karjord Nappe. Mylonitic gneisses, often with boudinaged amphibolite layers and some granite bodies dominate the upper part (Padget 1955, Quarnardel 1978).

The metamorphic grade (middle to upper amphibolite facies) is higher than in the Vaddas nappe, and anatexis is associated with some of the granites. The latter has yielded a Rb-Sr whole rock age of ca. 440 Ma (Dangla *et al.* 1978).

Nordmannvik Nappe

This is another high grade tectonic unit sandwiched between the Kafford Nappe and the Lyngen Nappe (Zwaan and Roberts 1978, Andresen *et al.* 1985). The Nordmannvik Nappe is dominated by polymetamorphic mylonite micaceous gneisses, with minor garnet amphibolite, marble, dolomitic marble, calc-silicate and ultramafic lenses (Andresen and Bergh 1985, Bergh and Andresen 1985). Thin psammitic layers occur locally. Metamorphic grade is middle/upper amphibolite facies, although relict granulite facies mineral assemblages are found in some mega-porphyroclasts (Bergh and Andresen 1985). Neither fossils nor absolute age dates exist from this tectonic unit.

Lyngen Composite Terrane

The Lyngen Nappe (Andresen *et al.* 1985) is composed of three lithotectonic units, the

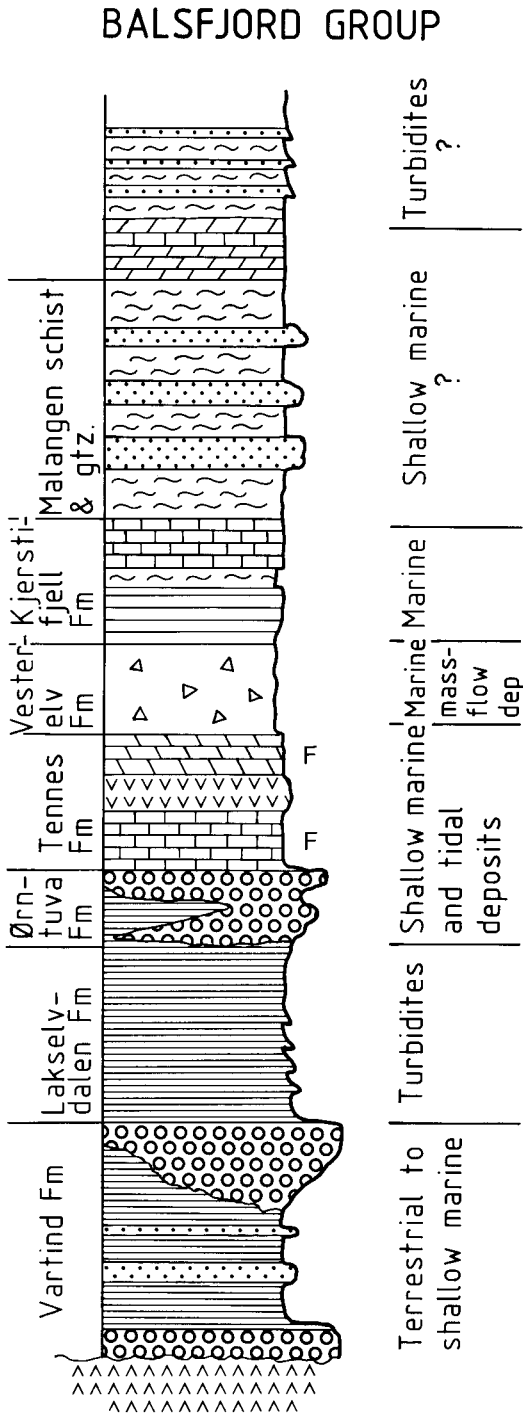


Fig. 7.—Simplified lithostratigraphic column of the Balsfjord Group After Andresen and Bergh (1985).

Koppangen formation, the Lyngen Gabbro and the Balsfjord Group, and most probably represents a composite terrane. A thrust separates upper greenschist facies metapelites, locally with thin metaconglomerate and meta-sandstone layers, of the the Koppangen Formation, from the underlying Nordmannvik Nappe. Structurally above the Koppangen Formation is an intensely deformed dolerite dikeswarm followed by deformed meta-gabbro. The gabbro becomes less deformed away from the contact with the Koppangen Formation, and a layered gabbro makes up most of the Lyngen Peninsula. Large and small serpentized ultramafic bodies occur throughout the gabbro. Plagiogranites are common along the lower, tectonized portion of the gabbro, as well as in the dike complex. The Lyngen Gabbro, the largest layered mafic complex within the Scandinavian Caledonides, most probably represents the cumulate portion of an ophiolite complex. The Balsfjord Group, which lies west of the Lyngen Gabbro (Fig. 1), has a depositional contact against the latter (Minsaa and Sturt 1985). Schists, quartzites, conglomerates and various types of carbonate deposits make up the bulk of the Balsfjord Group (Fig. 7) (Andresen and Bergh 1985). Lithologic thickness variations as well as clast size variations within the conglomerates indicate deposition in a fault controlled basin. Depositional environments were locally favourable for subtidal to supratidal carbonate depositis (Bjørlykke and Olausen 1981). Volcanic rocks are not common, but pillow lavas and pyroclastics, with within plate geochemical characteristics, are present at some stratigraphic levels. The few poorly preserved fossils found and described by Bjørlykke and Olausen (1981) indicate a Late Ordovician to Silurian age for the group. The Balsfjord Group is intruded by pre-tectonic dikes. A few syn-tectonic trondhjemite and granite bodies occur locally (Andresen and Bergh 1985, Velvin 1985). One of the granites has been dated to 430 Ma (Andresen in prep.) by the Rb-Sr whole rock method.

Three episodes of deformation are recognized in the Balsfjord Group, all of which took place under middle to upper greenschist facies conditions. The metamorphic grade varies both along and across strike. The thrust separating the Lyngen and Nordmannvik

Nappe was most probably established during the first deformational event as it is deformed by the two subsequent episodes (Bergh and Andresen 1985).

Steltenpohl *et al.* (1984) and Tull *et al.* (1985) have recently argued that the Balsfjord Group correlates with the Salangen Group, which occurs approximately 100 Km south of Balsfjord and has many of the same lithologies as in the Balsfjord Group. The substratum on which the Salangen Group is deposited is, however, not a piece of oceanic crust as in the Balsfjord area, but mica schist and minor amphibolite, intruded by numerous trondhjemites. Trondjemite and amphibolite clasts are common in the basal conglomerate of the Salangen Group. There is thus ample evidence to suggest that the southern correlative of the Balsfjord Group was deposited on an eroded island arc, or island arc related rock sequence. Based on this long range correlation it seems likely that the Balsfjord-Salangen Group represents a Late Ordovician-Silurian overstep sequence that was deposited after amalgamation of an oceanic terrane (Lyngen Ophiolite Terrane) and an island arc dominated terrane. This amalgamation is most probably related to ophiolite obduction associated with the Finnmarkian orogeny.

Magerøy Terrane

The Magerøy Nappe constitutes the major part of Magerøy (Fig. 1). It has a tectonic contact against the underlying Gjesvær Migmatite Complex according to Ramsay and Sturt (1976) and Andersen (1981). These authors have further argued that the protolith to this migmatite complex was the Sørøy Sequence (Ramsay and Sturt 1976, Andersen *et al.* 1982). The Magerøy Supergroup comprises a sequence of Lower Silurian and possibly Upper Ordovician metasediments (Henningsmoen 1961, Føyn 1967) with a minimum stratigraphic thickness of more than 5.5 Km (Andersen 1984). The lower part of the sequence (Kjelvik Group) is characterized by distal and proximal turbidites, which upwards are succeeded by a shelf sequence (Nordvåg Group) dominated by sandstone, siltstone, conglomerates and some metalimestones with a shelly fauna. The uppermost group (Juldagnes Group) comprises flysch-type turbidites (An-

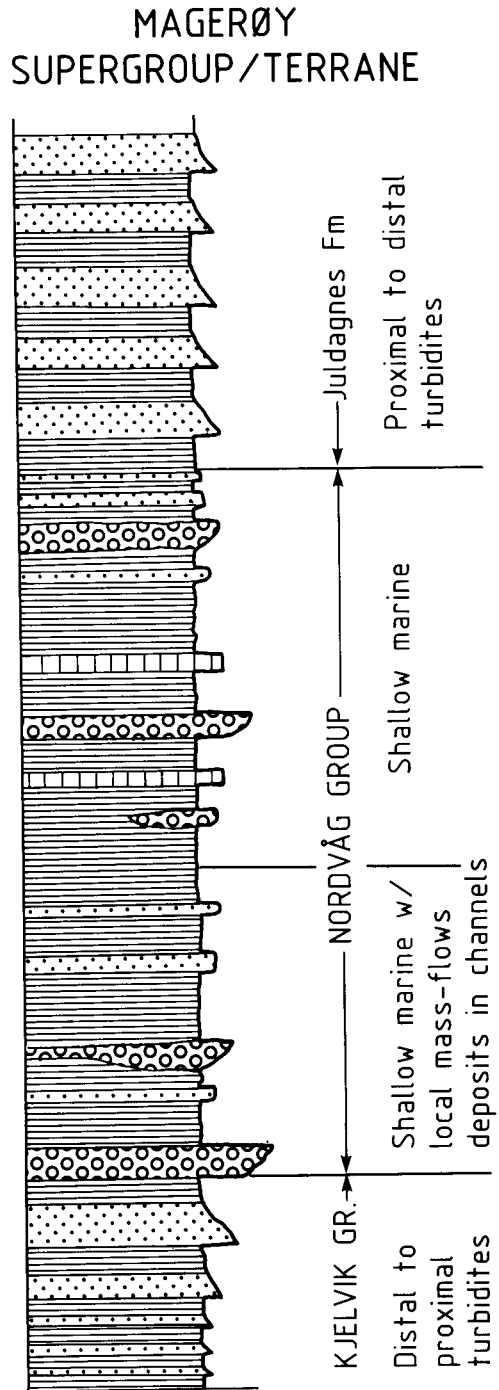


Fig. 8.—Simplified lithostratigraphic column, with inferred depositional environment, of the Magerøy Terrane. After Andersen (1984).

dersen 1984) (Fig. 8). Volcanics have not been found, but syntectonic igneous rocks occur, including a large layered mafic-ultramafic complex (Curry 1975) and a series of granites and granitoids). A Rb-Sr whole rock isochron from one of the granites yielded an age of 411 ± 7 Ma (Andersen *et al.* 1982). The metamorphism within the Magerøy Supergroup is variable but reached amphibolite facies prior to emplacement of the granites.

The rocks within the Magerøy Nappe have been correlated with both the Vaddas Terrane and the Balsfjord Group based on lithologic similarities, particularly the development of fossiliferous Lower Silurian carbonate deposits (Andersen 1984). Existing data make a direct litho- and chrono-stratigraphic correlation between these Upper Ordovician/Silurian sequences difficult. Until such data exist I suggest that the Magerøy Supergroup with its intrusives is considered a separate terrane, the Magerøy Terrane.

Tromsø Nappe Complex

The Tromsø Nappe Complex is a non-fossiliferous tectonic unit (Andersen *et al.* 1985, Krogh *et al.* in press) composed of three lithotectonic units. A distinct structural and metamorphic break characterizes the contact against the underlying Balsfjord Group. Garnet-mica schists and quartzo-feldspathic gneisses, intruded by various types of felsic intrusives, dominate the lowermost part of the Tromsø Nappe Complex. The quartzo-feldspathic gneisses show a gradual transition into amphibole gneisses and foliated amphibolites, which northeast and east of Tromsø (Fig. 1) are crosscut by numerous anorthositic dikes. This mafic, dike-intruded amphibolite complex, named the Skattøra Gneiss (Binns 1978), reaches a structural thickness of almost 1,000 m. The anorthositic dikes are almost monomineralic (An_{30-40}), but some dikes contain up to 20 % of amphibole phenocrysts.

Structurally on top of the Skattøra Gneiss, and separated from it by a late thrust, is the Tromsdalstind Sequence. This is a heterogeneous, pre-dominantly supracrustal sequence, composed of garnet-amphibolites, calc-silicate rocks, marbles, amphibole gneisses, fine-grained biotite-microcline gneisses, kyanite- and sillimanite-bearing garnet schists and

gneisses, and a few thin quartzite layers. Eclogites, partly retrogressed, occur together with omphacite-bearing high-pressure granulites as boudins and lenses within impure marbles in the lower part of the Tromsdalstind Sequence (Andersen *et al.* 1985, Krogh *et al.* in press). The Tromsdalstind Sequence also contains several ultramafites, some of which are altered to serpentinites, whereas others occur as rather fresh dunites or saxonites. Several generations of equilibrium mineral assemblages are recognized in the Tromsdalstind Sequence indicating a complex geologic history at deep crustal levels. The presence of eclogites and high-pressure granulites indicates that deformation and metamorphism took place in a subduction zone (Krogh *et al.* in press). The lack of high pressure mineral assemblages in the underlying Skattøra Gneiss testify that emplacement of the Tromsdalstind Sequence on top of the former, post-dates the high-pressure metamorphism.

At present little is known about the timing of the structural and metamorphic development seen in the Tromsø Nappe Complex. A Rb-Sr whole rock isochron on a biotite microcline gneiss within the Tromsdalstind Sequence has yielded an age of 433 Ma (Krogh *et al.* in press). K-Ar dating of amphiboles from the Skattøra Gneiss and Tromsdalstind Sequence all gave ages around 420 Ma. The significance of these ages in terms of terrane identification is unclear and further isotope work is in progress. The presence of two, and possibly three, distinct lithotectonic units, each with its own lithologic, igneous and metamorphic history indicate, however, that several terranes may be present in the Tromsø Nappe Complex/Uppermost Allochthon. The dolerite-intruded (?) shelf carbonates, now transformed into eclogite lenses in marble, as seen in the Tromsdalstind Sequence, combined with its structural position high in the nappe pile, may indicate deposition in proximity to the Laurentian Craton.

SUMMARY

The Caledonian nappes of North Norway can be grouped into a lower nappe stack representing a shortened miogeoclinal sedimentary prism, and a higher nappe sequence com-

posed of several suspect terranes. The miogeoclinal rocks were deposited along the passive continental margin that developed after rifting in Late Riphean/Early Vendian time. A major east-west trending transform/transcurrent fault system was active across the Varanger Peninsula in Late Precambrian time. Movement along this presumably steeply-dipping fault emplaced the exotic Barents Sea Terrane next to the autochthon of Northern Norway in Vendian time. This event was followed by deformation and emplacement of the miogeoclinal sequence onto the craton during the Late Cambrian/Early Ordovician Finnmarkian orogenic phase (530-490 Ma).

Palaeontological and geochronological data indicate that the upper nappe stack including the exotic terranes was emplaced on top of the miogeoclinal nappes in Silurian – (?) Early Devonian time. The individual nappes or thrust units making up the upper nappe stack are composed of one or more terranes. On the basis of lithostratigraphy, tectonostratigraphy and structural and metamorphic evolution the following suspect terranes/tectonic units are recognized from the base upwards in the upper nappe pile: The Vaddas Terrane, the Kafjord tectonic unit, the Nordmannvik tectonic unit, the Lyngen Composite Terrane, and the Tromsø Nappe Complex. The structurally isolated Magerøy Terrane is by most people correlated with the Vaddas Nappe (Andersen

1984), but it could also correlate with the Balsfjord Group.

The Lyngen Composite Terrane is composed of an oceanic terrane (Lyngen Gabbro/Ophiolite), unconformably overlain by the Balsfjord Group. The latter represents most probably an overstep sequence between oceanic and island arc terranes (Steltenpohl *et al.* 1984). Minsaas and Sturt (1985) believe that obduction of the Lyngen Gabbro/Ophiolite was related to the Finnmarkian orogeny.

The Tromsø Nappe Complex is most probably composed of two or more terranes, separated by faults. The high-grade metamorphism (eclogite/granulite-facies) typical for parts of the Tromsø Nappe Complex indicate that amalgamation of the various tectonic units took place in a continental collision/subduction zone environment, possibly along the eastern margin of Laurentia. The intense deformation typical of the Kafjord and Nordmannvik Nappes makes it at present difficult to say much about their age and origin.

The Vaddas, Balsfjord and Magerøy Terranes all represent fragments of sedimentary basins of Upper Ordovician/Silurian age. Data from the Lyngen Composite Terrane indicate that at least one of these basins developed after a period of ophiolite obduction. Whether the Vaddas and Magerøy Terranes are derived from the same basin is at present unknown but should be a target for future research.

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