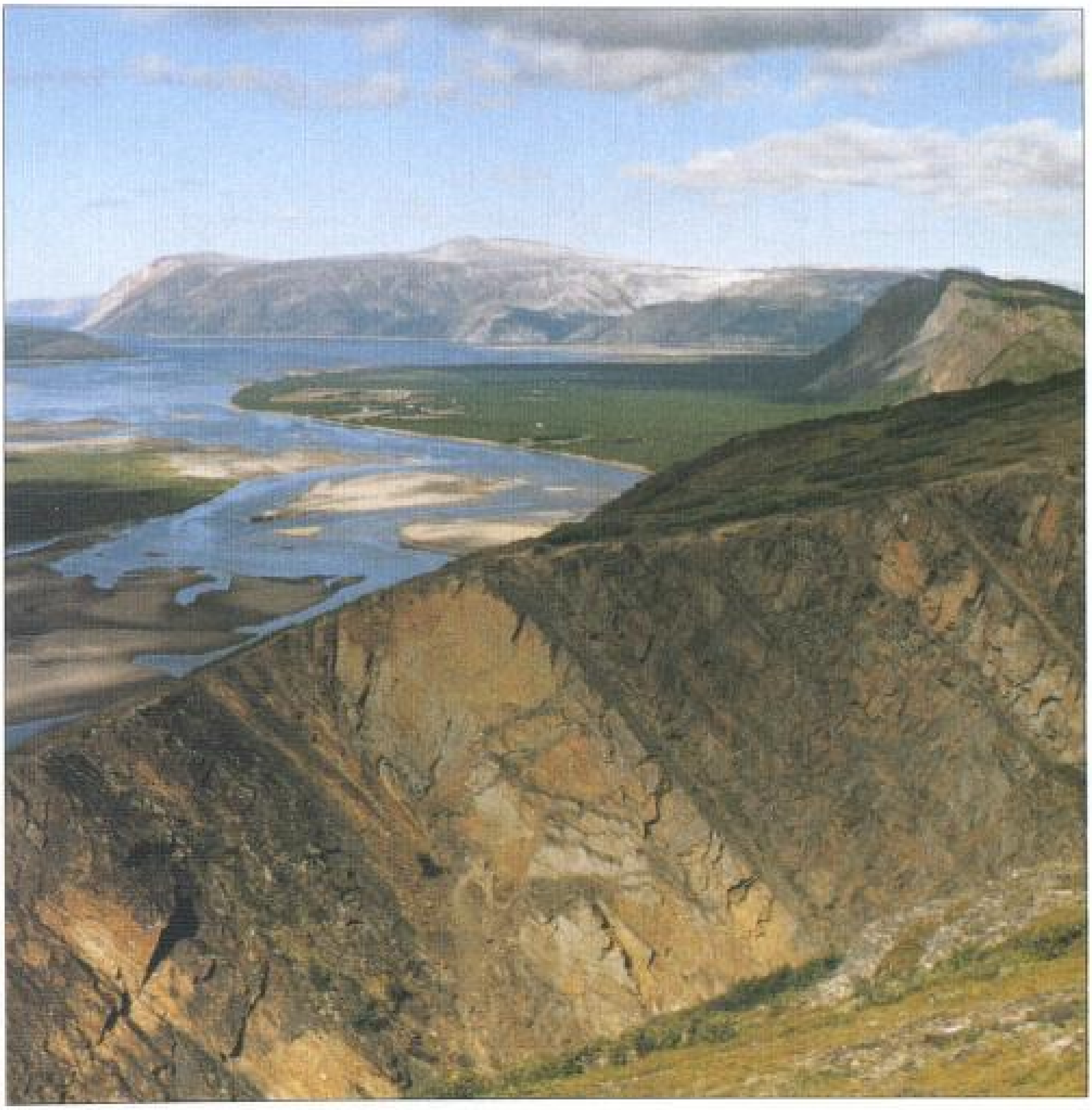
NORGES GEOLOGISKE UNDERSØKELSE

THE BEDROCK GEOLOGY OF VARANGER PENINSULA, FINNMARK, NORTH NORWAY: AN EXCURSION GUIDE

Anna Siedlecka & David Roberts

Special Publication 5



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Cover illustration: View towards the north from Ruossabak´ti on the eastern side of the Tana river.In the forground, from the left: Gamasfjellet Formation, Smalfjord Formation (tillite - the thick, pale brown unit) and Nyborg Formation. In the middle-ground to the right, Raudberget Mt. (Gamasfjellet Formation) and to the left the delta of the Tana river. In the background from the left to right: rocks of the Tanafjorden Group with Stangenestind, 725 m a.s.l., the highest point on the Varanger Peninsula; below, along the shore, the Vagge Section - the type section of the Tanafjorden Group.
Photo: Anna Siedlecka.

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Trondheim 1992

Preface

This excursion guide starts with a brief description of the bedrock geology of the Varanger Peninsula in the county of Finnmark, northern Norway. The development of geological research in this area and current understanding and interpretation of the geological history are presented. The main part of the guide consists of descriptions of 42 excursion localities with emphasis placed on stratigraphy and aspects of sedimentology; and in many cases with supplementary information on structural geology, metamorphic features and mafic dykes. The localities, with few exceptions, are situated along or close to the main roads and all have references to east and north coordinates and to the numbers and names of the 1:50,000 topographic maps produced by the former Norges geografiske oppmåling, now Statens Kartverk. Although a simplified map of the bedrock geology is included in the guide, it is recommended to have a copy of the 1:250,000 bedrock geological map-sheet Vadsø (Siedlecki 1980) on hand, as a supplement to the descriptions.

An early version of the excursion guide was written in connection with the collaboration programme between the former Soviet, now Russian Academy of Sciences, Kola Branch, and the Geological Survey of Norway, for the project 'Correlation of the Middle-Upper Proterozoic sedimentary successions of the northern coastal areas of the USSR and Norway'. Much of the actual data, including cited map-sheet compilations, are a result of several years' field and laboratory work that formed part of the Geological Survey of Norway's 'Finnmark Programme', which terminated in December 1991. The guide, purposely written in English and here revised, updated and partly enlarged from an earlier Xerox version (Siedlecka 1990), is thus designed for professional geologists with main interests in stratigraphy, sedimentology, basin development and subsequent tectonic deformation and metamorphism. However, the guide may also prove to be useful for field courses and for the training of geology students in stratigraphy, sedimentology and some aspects of tectonics and structure.

Descriptions of the localities are organised according to a fixed standard. In addition to the references to topographic maps, each locality comprises key words referring to lithostratigraphic units and important stratigraphic and tectonic boundaries which may be examined at this particular locality. In addition, the locality numbers are indicated on stratigraphic correlation tables, thus reminding the visitor at any time in which geological region and stratigraphic position the examined rocks are located. In some cases, references are given to papers in which may be found more detailed descriptions, interpretations and discussions on various topics relevant to the observed rocks.

The standardised way of describing localities leads to some unavoidable repetitions. However, the visitor may naturally choose to examine only a few of the 42 localities, depending on time and interest.

It has been decided to illustrate the excursion guide with several colour photographs which not only are a very valuable supplement to the text but also give a better impression of the excellent exposure of the colourful rocks, in particular along the coastal sections, the state of preservation of various structures and, finally, help to show the picturesque beauty of this northernmost part of Norway.

A guidebook to the type sections through the Upper Proterozoic geology of the Rybachi and Sredni Peninsulas and Kildin Island, along the coast of northern Kola, southeast of Varanger Peninsula, was prepared by our Russian colleagues in the early stages of our collaboration programme. This guide is currently being revised and extended, taking in the Upper Proterozoic sedimentary sequences along the southern coast of Kola, on the White Sea, with the aim of possible publication in the Special Publication series at some stage during the next year or two.

The bedrock geology of Varanger, Peninsula, Finnmark, North Norway: an excursion guide

ANNA SIEDLECKA & DAVID ROBERTS

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The Varanger Peninsula is underlain by weakly metamorphosed sedimentary rocks of Late Proterozoic to Early Cambrian age. The rocks occur in two regions: the Tanafjorden-Varangerfjorden Region (TVR) (southwestern half of the peninsula) and the Barents Sea Region (BSR) (northeastern half), juxtaposed along a complex NW-SE-trending fault zone, the Trollfjorden - Komagelva Fault Zone (TKFZ). The BSR is considered to have been brought to its present position largely by dextral strike-slip translation along the TKFZ.

The nature and thicknesses of the sedimentary facies in the TVR autochthonous basin suggest three main phases in basin development. In the Late Riphean, fluctuating fluvial to coastal marine conditions prevailed, testifying to instability of the Karelian substratum. The Early Vendian phase was characterised by fairly stable marine conditions and development of widespread coastal to shallow-marine facies. An intra-Vendian uplift and northward tilting resulted in erosion which deepened progressively towards the south and removed large parts of the Upper Riphean - Lower Vendian sedimentary pile. The final phase of sedimentation was characterised by two periods of glaciation followed by mainly shallow-marine conditions which continued into the Palaeozoic.

The development of the allochthonous basin was initiated by crustal rifting and spreading which may have commenced in Middle-Late Riphean time. The nature of the substratum and the character of the earliest sediments are unknown. The facies development of the exposed succession, which commences with a submarine fan, suggests gradually shallowing conditions of sedimentation along a stable continental margin. This sedimentation was disrupted by an intra-Vendian uplift, tilting and erosion followed by a new marine transgression. The Late Vendian shallow sea was affected by only minor fluctuations, apart from one clearly regressive episode, and lasted probably into the Early Palaeozoic, accumulating continuously terrigenous shelf sediments.

The sedimentary sequences in the two regions have been affected to different degrees by the main Caledonian deformation and metamorphism. In the BSR, mesoscopic, close to tight, asymmetric folds carrying an axial planar slaty cleavage are common, with deformation intensity at a maximum in the extreme northwest. The fold axial trend is generally NE-SW to ENE-WSW, swinging towards N-S in the southeast. Metamorphism occurred in epizone grade. In the TVR, cleavage-bearing NE-SW folds are common only in the northwest. These folds open out in central areas where there is a swing towards an ESE-WNW trend which dominates in the southeast. The rocks of the TVR have, on the whole, been affected only by diagenesis, though with a gradual prograde change to anchizone in the northwest.

Metadolerite and dolerite dykes intrude the rock successions in the two regions, with the former, carrying a metamorphic fabric, occurring in swarms in some areas but only in the BSR. Some have been K-Ar dated to c. 650 Ma. By comparison, post-Caledonian dolerite dykes are few in number but occur in both the BSR and the TVR. K-Ar dating on these dykes has yielded ages of around 360 Ma.

In this excursion guide, descriptions and interpretations of the sedimentary sequences of both basins are presented, together with information on the tectonic deformation and metamorphism. In the excursion itinerary 42 localities are described in which various parts of the stratigraphic section may be studied.

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Contents

BEDROCK GEOLOGY OF THE VARANGER PENINSULA

Introduction

The Varanger Peninsula of East Finnmark is underlain by predominantly terrigenous rocks which are extensively exposed in coastal sections. Early mapping (Holtedahl 1918, Føyn 1937) along the coast and in the southwestern areas provided the first detailed descriptions of the sedimentary sequences, in particular of tillites and associated formations. During this important early period of work the foundations of lithostratigraphy were also outlined. The suggested Late Precambrian age of these rocks was confirmed by the discovery of Cambrian fossils on the Digermulen Peninsula, west of Tanafjorden (Strand 1935), in formations which were later shown to be younger than the rock successions on Varanger Peninsula (Reading 1965).

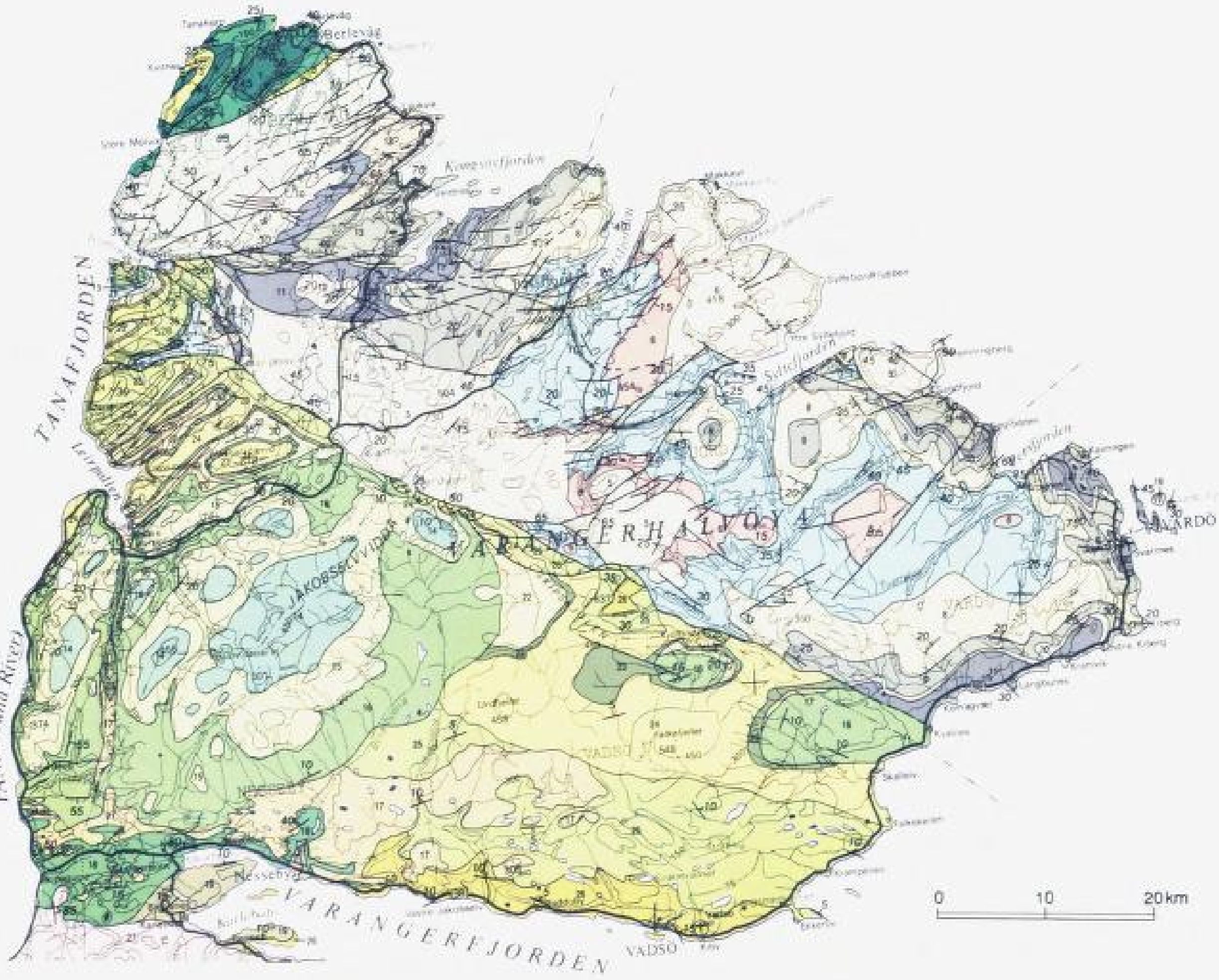
The discovery, in the mid-sixties, by Siedlecka & Siedlecki (1967) of a complex NW-SE-trending fault zone crossing the Varanger Peninsula was the next important step in the geological research of this area. This most prominent structural feature of the peninsula, the **Trollfjorden-Komagelva Fault Zone (TKFZ),** separates two geological regions, the **Tanafjorden-Varangerfjorden Region (TVR)** to the southwest of this major tectonic feature, and the **Barents Sea Region (BSR)** to the northeast. The fault zone separates sedimentary successions which, although roughly time equivalent, were accumulated under widely differing tectonic conditions. The TVR comprises sequences of mainly fluvial to shallow-marine sedimentary rocks close to 4 km in maximum thickness, and also includes two important tillite horizons. The main part of the BSR succession, on the other hand, consists of turbiditic submarine-fan deposits followed by deltaic sequences and then by shallow-marine, including tidal-flat sediments, some 9 km in total thickness. This is succeeded unconformably by a c. 5.7 km package of mainly shallow-marine sedimentary rocks.

The sedimentary sequence of the Tanafjorden-Varangerfjorden Region rests unconformably upon the Karelian metamorphic substratum and was thus accumulated in an *autochthonous* basin developed along the northern margin of the Fennoscandian Shield. The westernmost part of the TKFZ, which was interpreted by Johnson et al. (1978) as folded during the Caledonian deformation, has recently been reinterpreted by Rice & Townsend (1991) and Rice et al. (in prep.) as an unconformity between the rocks of the BSR and TVR. This interpretation, if correct, would imply (1) that the TKFZ continues uninterruptedly to the northwest without the southwesterly infold shown on several maps of Varanger Peninsula (e.g. Siedlecki 1980); and (2) that some of the sediments of the TVR were accumulated directly upon sequences of the BSR. Whatever the case, the bulk of the sedimentary succession of the BSR was accumulated in a basin whose original location remains uncertain; in consequence, the BSR rocks are considered as *allochthonous*. Siedlecka (1975), in an earlier stage of research, proposed a model in which the sequences of the TVR and BSR were deposited in different parts of one and the same basin; this was thought to have extended from the Timanian aulacogen of the Timan-Kanin region of NW Russia, along and offshore of the northern Kola Peninsula, and northwestwards into the Iapetus Ocean. Later, this model was modified by accepting the allochthonous nature of the BSR (Siedlecka 1985), following the interpretations of Kjøde et al. (1978). Also, Gayer & Rice (1989) proposed a model for the development of the Late Proterozoic basins in northern Norway by palinspastically restoring the Caledonian nappes. Recent work in neighbouring Russian territories (Siedlecka and Roberts, in progress) has refocused attention on this topic.

Based on palaeomagnetic data from mafic dykes, a minimum of 500 km of dextral strike-slip translation along the TKFZ was originally suggested for this basin and its sedimentary pile (Kjøde et al. 1978). The extent and sense of this strike-slip movement, however, has been questioned by Pesonen et al. (1989). Irrespective of the magnitude of the finite displacement, the rocks of the BSR were brought into juxtaposition with the TVR sequences during and/or subsequent to Caledonian deformation and metamorphism.

Rocks of both regions and of the fault zone were clearly affected by the Caledonian deformation, more strongly in the northwestern parts of the peninsula. While the rock units of the Tanafjorden-Varangerfjorden Region are, in the west, included in the lowermost part of the Caledonian nappe pile and parautochthon, no certain equivalents of the rocks of the Barents Sea Region have ever been recognised in the nappes of central Finnmark even though various correlations have been proposed (e.g. Føyn 1969, Laird 1972, Siedlecka & Siedlecki 1972). Rice et al.(1989a), however, have interpreted the rocks of the Barents Sea Region as a part of the Lower Allochthon, strike-slip emplaced along the TKFZ in a right-lateral sense over a distance of more than 400 km, although a smaller displacement has recently been suggested (Rice & Townsend 1991). More recent palaeomagnetic work on sediments from both sides of the TKFZ supports a dextral displacement along the fault zone of no more than 250 km (G. Bylund, in prep.).

Magmatic rocks on the Varanger Peninsula are represented only by mafic dykes. At least two episodes of dyke intrusion have been documented, Late Proterozoic and Mid to Late Palaeozoic, but there could be more. Isotopic dating work is in progress. In the BSR, cleaved metadolerite dykes reach swarm proportions in some areas. Such dykes are absent south of the TKFZ. Post-metamorphic dolerite dykes, on the other hand, are few in number and occur on both sides of the fault zone, mainly in eastern areas of the peninsula.



BARENTS SEA REGION

Berlevåg Formation (Tanahorn Nappe)

1 Phyllite
2 Metasandstone and phyllite
3 Metasandstone

Løkvikfjellet Group

4 Sandstone and mudstone
5 Feldspathic sandstone

Barents Sea Group

6 Tyvjofjellet Formation
7 Båtsfjord Formation
8, 9, 10, 11 Båsnæringen Formation
12, 13 Kongsfjord Formation

TANAFJORDEN-VARANGERFJORDEN REGION

Vestertana Group

14 Breivika Formation
15, 16 Stappogiedde Formation
17 Mortensnes Formation
18 Nyborg Formation
19 Smalfjord Formation
20 Mudstone, sandstone and tillite, undifferentiated

Tanafjorden Group

21 Grasdalen Formation
22 Hanglečærro Formation
23 Vagge Formation
24 Gamasfjellet Formation
25 Dakkovarre, Stangenes and Grønneset Formation
26 Vadsø Group
27 Proterozoic and Archaean crystalline basement

Fig. 1. Bedrock geology of Varanger Peninsula

Tanafjorden - Varangerfjorden Region

The Tanafjorden-Varangerfjorden Region is underlain by a c. 4000 m-thick sequence subdivided into three groups, the **Vadsø Group** (590-960 m), **Tanafjorden Group** (1448-1665 m) and **Vestertana Group** (1317-1665 m) (Fig. 1). There is a gradual transition between the Vestertana Group and the Cambro-Ordovician **Digermulen Group** which occurs on the Digermulen Peninsula, west of Tanafjorden (Figs. 2 and 3).

Sedimentation of the lithostratigraphical sequence of the Tanafjorden-Varangerfjorden Region was dominated by fluvial, coastal marine and shallow-marine conditions , and it is characterised by several erosional breaks. In general terms, the Vadsø Group consists mostly of deposits accumulated in braided streams, the Tanafjorden Group is primarily shallow-marine, while the Vestertana Group includes both fluvial and marine deposits and comprises two tillite horizons testifying to two periods of glaciation. The first major depositional break, detected by micropalaeontological work (Vidal 1981), occurs in the upper Vadsø Group between the Golneselva Formation and the Ekkerøya Formation. The most pronounced break is shown by the *pre-tillitic angular unconformity* at the base of the Vestertana Group. A slight pre-glacial tilting towards the north (discovered already by Holtedahl(1918)), resulted in a progressive southward removal of the Tanafjorden Group and the entire Vadsø Group. Thus, the uppermost formation of the Tanafjorden Group, the Grasdalen Formation, is preserved only in the northwest, close to the Trollfjorden-Komagelva Fault Zone, while on the southern side of Varangerfjorden the tillite-bearing Smalfjord Formation rests directly on the Veidnesbotn Formation, the lowermost formation in the Vadsø Group. West of the head of Varangerfjorden, a very thin tillite of the Smalfjord Formation, or even the Nyborg Formation, rests directly on the Karelian metamorphic substratum.

Three lines of evidence have been applied in establishing the chronostratigraphy of the rocks of the Tanafjorden-Varangerfjorden Region: (1) The presence of two tillite horizons in the lower Vestertana Group which were considered for a long time to be of Late Proterozoic (Varangerian) age and to represent the 'Varanger Ice Age'. (2) Findings of *Platysolenites antiquissimus* (Føyn 1967, Hamar 1967), trace fossils (Banks 1970), acritarchs (Vidal 1981) stromatolites (Bertrand-Sarfati & Siedlecka 1980) and, recently, Ediacaran fossils (Farmer et al. 1992), suggesting that the bulk of the Vadsø Group is Upper Riphean and that the Tanafjorden Group along with the bulk of the Vestertana Group originated in Vendian time. The Cambrian-Precambrian boundary was placed by Vidal (1981) within the Manndrapselva Member and by Farmer et al. (1992) in the lower Breivika Formation. (3) Radiometric ages: Rb-Sr whole-rock isochron ages of 654±7 Ma for the Nyborg Formation in the Vestertana Group, and 807±19 Ma for the Klubbnes Formation in the Vadsø Group (Sturt et al. 1975). (All Rb-Sr isochron dates reported here have been recalculated using the ^{87}Rb decay constant of 1.42 x 10^{-11}/yr (Steiger & Jäger 1977)).

Age	Lithostratigraphic units and their thicknesses		
		Formation	Member
VENDIAN	TANAFJORDEN GROUP 1448–1665 m	Grasdalen 280 m	Upper Lower
		Hanglečærro 200 m	
		Vagge 80 m	
		Gamasfjellet 280–300 m	
		Dakkovarre 273–350 m	Ferruginous sandstone 130 m "k" member 62 m "j" member 46 m "i" member 35 m Quartzitic sandstone 60–80 m
		Stangenes 205–255 m	
		Grønneset 130–200 m	
	VADSØ GROUP, 590–960 m	Ekkerøya 15–190 m	
RIPHEAN		Golneselva 50–135 m	
		Paddeby 25–120 m	
		Andersby 25–40 m	
		Fugleberget 125 m	
		Klubbnasen 50 m	
		Veinesbotn 300 m	

Fig. 2. Lithostratigraphy of the Tanafjorden Group and the Vadso Group in the Tanafjorden - Varangerfjorden Region (mainly after Siedlecka & Siedlecki 1971 and Banks et al. 1974).

Age	Lithostratigraphic units and their thicknesses		
		Formation	Member
VENDIAN – CAMBRIAN – ORDOVICIAN	DIGERMULEN GROUP 1510–1555 m	Berlogaissa 300 m	
		Kistedalen 710–735 m	Grey quartzite 200 m Black shale 200 m Black quartzite 10–35 m Sandstone and shale 200 m Quartzite and shale 100 m
		Duolbasgaissa 500–520 m	Massive bedded quartzite 300 m Thin-bedded quartzite 200–220 m
	VESTERTANA GROUP, 1317–1655	Breivika 600 m	
		Stappogiedde 505–545 m	Manndrapselva 190 m Innerelva 275 m Lillevatnet 40–80 m
		Mortensnes 10–60 m	
		Nyborg 200–400 m	
		Smalfjord 2–50 m	

Fig. 3. Lithostratigraphy of the Digermulen Group and the Vestertana Group (after Reading 1965).

Barents Sea Region

The Barents Sea Region comprises the following major lithostratigraphic units: (1) the **Barents Sea Group**; (2) the **Løkvikfjellet Group,** which rests on the Barents Sea Group transgressively and with an angular unconformity; and (3) the low-grade greenschist-facies **Berlevåg Formation,** which is thrust upon the rocks of the two former groups and has been suggested to be part of the Kalak Nappe Complex (Levell & Roberts 1977) (Fig. 1). This thrust unit of the Berlevåg Formation, inappropriately termed the Berlevåg Nappe by Rice et al. (1989a), is referred to informally as the Tanahorn Nappe (Roberts, in Siedlecka 1990).

The **Barents Sea Group** is c. 9000 m thick (basal parts and substratum unknown). It has been subdivided into four formations comprising sedimentary rocks which originated in different and gradually shallower environments of deposition (see Fig. 4 for lithostratigraphic names). The lowest unit is the **Kongsfjord Formation,** an up to c. 3500 m-thick sequence of graded-bedded, flysch-like sandstones and shales deposited by turbidity currents (Siedlecka 1972). In this formation there is an abundance of sedimentary structures and several facies associations which, together, were crucial for outlining the model of the Kongsfjord Submarine Fan. In this model, inner, middle and outer fan deposits were recognised as well as facies transitional to the upper basin slope/prodelta deposits of the next formation (Pickering 1981, 1982). In general terms the Kongsfjord Formation represents a thinning- and fining-upward sequence, retrogradational from inner through middle to outer fan, reflecting a decrease in the rate of growth of the submarine fan.

The **Båsnæringen Formation** which overlies the Kongsfjord Formation and commences with upper slope/prodelta deposits is generally interpreted as a major prograding delta (Siedlecka & Edwards 1980). This sequence, which is up to c. 3500 m thick, has a general coarsening-upward motif and comprises sediments interpreted as having accumulated in prodelta, delta front and braided delta-plain environments. Palaeocurrent directions in both the Kongsfjord Formation and the Båsnæringen Formation indicate transport of sediment towards the northeast and east-northeast across a NW-SE-oriented slope margin (Siedlecka & Edwards 1980, Pickering 1981).

The delta-plain braided stream deposits of the uppermost part of the Båsnæringen Formation are sharply overlain by an interbedded terrigenous-carbonate sequence: the **Båtsfjord Formation.** This c. 1500 m-thick unit starts with a 300 m-thick member of sandstones, mudstones, shales, dolomites and limestones, including stromatolite biostromes. This member has been interpreted as originating on tidal flats which developed on and in the marginal zone of the delta, possibly after a major switch of the prograding delta lobe (Siedlecka 1978, Siedlecka & Edwards 1980). Upwards in this formation, and in the overlying **Tyvjofjellet Formation,** purple and green beds appear and the number of carbonate beds decreases (they are present in the upper Båtsfjord Formation, but absent in the Tyvjofjellet Formation). At the same time there was a gradual increase in the sand supply. There is an abundance of sedimentary structures in this variegated sequence of the upper Båtsfjord and Tyvjofjellet Formations, testifying to a shallow-water sedimentation. A shallow-marine environment with increasing energy and possible fluvial incursions may tentatively be envisaged for this uppermost part of the Barents Sea Group.

Age	Lithostratigraphic units and their thicknesses		
		Formation	Member
RIPHEAN-VENDIAN?	LØKVIKFJELLET GROUP 5710–5810 m	Skidnefjellet > 800 m	
		Stordalselva 1200 m	
		Skjærgårdsneset 210 m	
		Styret 1500–1600 m	
		Sandfjorden 2000 m	
	BARENTS SEA GROUP 8900–>10 000 m	Tyvjofjellet 1500 m	
		Båtsfjord 1400–1600 m	Skovika 1100–1300 m
			Annijokka 300 m
		Båsnæringen 2500–3500 m	Hestman 600–1300 m
			Godkeila 490–1450 m
			Seglodden 100–350 m
			Næringselva 500–1200 m
		Kongsfjord > 3500 m	Nålneset 2000 m Risfjorden 1000–1500 m

Fig. 4. Lithostratigraphy of the Løkvikfjellet Group and Barents Sea Group in the Barents Sea Region (after Siedlecka 1978, 1989, Siedlecka & Edwards 1980, Siedlecka & Siedlecki 1967, Siedlecki & Levell 1978).

The rocks of the Barents Sea Group have yielded a varied assemblage of acritarchs, thus providing some more detailed information on the stratigraphic position of the group and its formations. The Båtsfjord Formation, in particular, has yielded several time-diagnostic taxa showing that the Riphean-Vendian boundary is located within the lower Båtsfjord Formation (Vidal & Siedlecka 1983).

The **Løkvikfjellet Group** rests upon various parts of the Barents Sea Group with a slight angular unconformity (about 12° according to Siedlecki & Levell 1978). This contact provides evidence of uplift and tilting of the Barents Sea Group prior to the Løkvikfjellet transgression. The Løkvikfjellet Group is c.5700 m thick. It is entirely terrigenous and has been subdivided into five formations (Siedlecki & Levell 1978) (Fig. 4). The lowermost **Sandfjorden Formation,** and the three highest, the **Skjærgårdnes Formation, Stordals-**

elva Formation and **Skidnefjellet Formation,** are shallow-marine deposits, while the intervening **Styret Formation** has been interpreted as fluvial (Levell 1978, 1980a). No breaks in deposition have been recorded.

The Sandfjorden Formation consists of pink and yellowish-grey arkoses and conglomerates and is the most widespread unit. The Styret Formation has been recognised in two separate areas (Siedlecki 1980), while the remaining formations are preserved only in the northwestern corner of the Varanger Peninsula. The Styret Formation is characterised by interbedded greenish-grey sandstones and mudstones. The sandstone beds are typically lenticular and erosively based, may be coarse to conglomeratic, and they decrease in number upwards. Paleocurrents in this formation, interpreted as fluvial, are dominantly towards the southeast (Siedlecki & Levell 1978). The Skjærgårdnes and Stordalselva Formations consist of interbedded grey sandstones and dark-grey mudstones and siltstones. The sandstone beds have a tabular geometry and are laterally fairly persistent. Grain size varies but is generally coarse, even conglomeratic. Cross-bedding is abundant and indicates transport of material mostly towards the northeast. Wave ripples are also common and orthogonal to the cross-bedding. Levell (1980b) emphasized the importance of wave- and current-generating storms in the transport and deposition of these shelf deposits. The Skidnefjellet Formation which terminates the Løkvikfjellet Group is strikingly similar to the Sandfjorden Formation, consisting of pale-coloured cross-bedded and wave-rippled sandstones and small-pebble quartz-quartzite conglomerate.

The Berlevåg Formation, occurring only in the extreme northwest of the BSR (Fig. 1), is thrust upon the Løkvikfjellet Group as the Tanahorn Nappe. The full sequence, c. 2650 m in exposed thickness (Levell & Roberts 1977), has been subdivided by Roberts (1988) into three mappable units: (1) a (lowermost) pelitic unit consisting of dark, greenish-grey phyllite interbedded with subordinate metasiltstone and fine-grained metasandstone; (2) a metasandstone unit consisting primarily of coarse to conglomeratic, grey, cross-bedded metasandstone with some phyllite interbeds; and (3) an interbedded metasandstone-phyllite series. In parts of this third unit graded bedding is abundant but thicker-bedded sandstones show cross-bedding. Many of the features of the metasediments of the Berlevåg Formation are comparable to those in parts of the rock successions of northern and northeastern Nordkinnhalvøya.

Levell & Roberts (1977) recognised both the tectonic contact between the Berlevåg Formation and the subjacent Løkvikfjellet Group, and the fairly significant differences in the structural and metamorphic histories of the two units. Results of studies of illite crystallinity have suggested, however, that the Berlevåg Formation suffered only a slightly higher grade of epizone metamorphism than the remaining units of the Barents Sea Region, and that it may possibly belong to the Lower Allochthon (Rice et al. 1989b).

Mafic dykes

Metadolerite and dolerite dykes are the only manifestation of magmatism on Varanger Peninsula. The terms were used in a descriptive and comparative sense (Roberts 1975) to distinguish a suite of dykes which are metamorphosed and cleaved from a younger set which post-date the cleavage and are relatively fresh. Both types of dykes occur in the Barents Sea Region while in the Tanafjorden-Varangerfjorden Region only a few dolerite dykes have been recorded. The metadolerite dykes are particularly abundant in the Kongsfjorden and Båtsfjorden areas, occurring in spectacular swarms. The metadolerite dykes in the outer Båtsfjorden area cut across the unconformity between the Barents Sea Group and the Sandfjorden Formation of the Løkvikfjellet Group. The K-Ar age of these dykes is around 650 Ma (Beckinsale et al. 1975; all K-Ar dates quoted here are recalculated according to Dalrymple 1979). K-Ar dating of the metadolerite dykes intruding the Kongsfjord Formation in the Kongsfjorden area gave ages ranging from 945 to 1945 Ma. The reliability of these dates, however, is uncertain because of very low potassium contents. Only one sample, which yielded an age of 1945±58 Ma, had a reasonable potassium content (Beckinsale et al. 1975). A cleaved metadolerite dyke in the Berlevåg Formation yielded a K-Ar age of 551±17 Ma. In general, the field relationships suggest that the metadolerite dykes were emplaced prior to and perhaps also during the initial stage of the fold deformation and cleavage development. Examples have been found, however, of metadolerites that cut across the prominent folds but also carry the penetrative axial surface cleavage to these same folds (D.Roberts, unpubl. data; also, Fig. 38).

The comparatively fresh dolerite dykes occur in both regions (they also cut the Cambrian to Tremadoc sediments on Digermul Peninsula), but they are not abundant. They post-date all the Caledonian structures. K-Ar ages of dykes which have so far been sampled and dated are around 360 Ma (latest Devonian to Early Carboniferous; Beckinsale et al. 1975). Major and trace element geochemistry of the metadolerites has shown them to be similar to magmas transitional between abyssal and continental tholeiites. The younger dolerites are comparable to continental tholeiites, and enrichment in some trace elements suggests magma generation at a greater depth than that at which the metadolerites originated (Roberts 1975). Current geochemical studies (D.R. in progress) are concentrating on sets of analyses obtained from metadolerites from the Båtsfjord, Kongsfjord and Berlevåg districts. Work is also advanced on further isotopic dating of selected mafic dykes employing the Sm-Nd, ^{40}Ar - ^{39}Ar and Rb-Sr methods; and oriented samples have been taken for a palaeomagnetic study.

Tectonic structure and metamorphism

The tectonic deformation and aspects of metamorphism of the rocks on the Varanger Peninsula have been described by Roberts (1972), though with emphasis on the Barents Sea Region. General features of local structural geology are contained in Siedlecka & Siedlecki (1971), Teisseyre (1972), Levell & Roberts (1977), Johnson et al. (1978) and Rice et al. (1989a), but the overall picture of folding and faulting is most readily seen from Siedlecki's (1980) 1:250,000 map compilation and geological profiles. Patterns of faulting, also offshore faults, have been discussed by Lippard & Roberts (1987). Most of the folding and metamorphism is ascribed to the *Caledonian* orogenesis in Early Palaeozoic time, although earlier Russian work, reviewed by Siedlecka (1975), suggested that structures related to the *Baikalian* orogeny of the Timanian Fold Belt may have extended as far west as the Varanger Peninsula. By comparison, faulting almost certainly covers a wider time span, from Late Precambrian in association with basin development through to the Cenozoic; and some possible neotectonic fault movements have also been reported (Olesen et al. in press).

As noted earlier, the Trollfjorden-Komagelva Fault Zone (Siedlecka & Siedlecki 1967) provides a natural division of the peninsula, and contrasts are seen in structural history, fold axial trends and metamorphic grade across this major fault zone. In the *Barents Sea Region* there is a general increase in intensity of assumed Caledonian deformation from southeast to northwest (Roberts 1972). In the southeast, prominent early mesoscopic and macroscopic, open to locally tight, concentric folds trend approximately N-S and verge towards the west; and they carry an axial plane slaty cleavage. In central areas, comparable early, open, upright folds with associated slaty cleavage vary in trend from N-S to NE-SW. In the extreme northwest, in the Berlevåg Formation of the Tanahorn Nappe, similar early folds carry a fine-grained, axial plane schistosity, are tight to locally sub-isoclinal, generally NE-SW trending, and overturned at moderate angles towards the southeast. Fold axial trends, however, may be extremely variable. In the Berlevåg district, second-generation folds deform the more common early folds and penetrative schistosity and carry a crenulation cleavage. Such folds and even younger kink folds and kink bands, are rarely encountered in central areas and have not been observed in the eastern part of the BSR. Later gentle folds with ENE-WSW axes occur throughout the region and help to produce spectacular fold interférence culminations and depressions (Roberts 1972, fig. 22, Siedlecki 1980). Extensional faults trending NE-SW to E-W with downthrows to the NW or N represent one of the latest phases of deformation (Lippard & Roberts 1987).

Thrusting is an important element in the tectonic deformation of the BSR (Roberts 1972). In particular, some of the minor thrust-faults can be seen to displace the early folds. In the footwall to the basal thrust of the Tanahorn Nappe, early major folds are truncated by the thrust-fault (Roberts 1988). Rice et al. (1989a) have suggested the possible presence of a major detachment beneath the folded sequences of the Barents Sea Region, which would conceivably have developed as a footwall propagation beneath the Kalak Thrust. In this, the basal Tanahorn Nappe thrust would represent an emergent imbricate thrust-fault. These same authors view the westward-facing fold structures in the southeastern BSR as having developed, as tip folds, by back-thrusting along the postulated sole detachment.

To the southwest of the TKFZ, in the *Tanafjorden-Varangerfjorden Region*, tectonic deformation as a whole is less intense than in the BSR. In the northwest, close to Tanafjorden, asymmetric, SE-facing folds and reverse-faults trend NE-SW, and an axial surface slaty cleavage is prominent. These particular rocks may form part of the Gaissa Nappe Complex (Townsend et al. 1986). Further southeast, in the parautochthon and autochthon, folds are more open and upright, trending both NNE-SSW and ESE-WNW (Siedlecki 1980), the NNE folds probably reflecting shortening above a blind décollement surface (Chapman et al. 1985, Townsend 1986). Mesoscopic folding along ENE-WSW to E-W axes is particularly prominent in the Nyborg Formation as far east as Mortensnes, with N-dipping axial surfaces and a locally developed crenulation cleavage. A more detailed structural assessment of this region has been presented by Rice et al. (1990 and in prep.).

Much has been written about the *Trollfjorden-Komagelva Fault Zone* and its significance in the pre-Caledonian, Caledonian and later structural history of this region (e.g., Siedlecka & Siedlecki 1967, Harland & Gayer 1972, Siedlecka 1975, Kjøde et al. 1978, Lippard & Roberts 1987, Rice et al. 1989a). Some information has already been given in the introduction to this text. Briefly, it will suffice here to note that there is abundant structural and metamorphic evidence favouring a major dextral strike-slip translation of the BSR along the TKFZ, and that this occurred at some stage, or stages, during the protracted Caledonian orogeny. Late-Caledonian strike-slip movements are clearly post-metamorphic and probably pre-360 Ma. Younger components of movement, extensional and/or strike-slip, almost certainly extend up into the Cenozoic (Gabrielsen 1984, Lippard & Roberts 1987, Gabrielsen & Færseth 1989) and there is also evidence of possible post-glacial reactivation along part of the fault zone (Olesen et al. in press). Ongoing studies involve both detailed field structural investigations along the fault zone, and an integration of digitally processed satellite images, geophysical data-sets and digital elevation data (Karpuz et al. 1992 and in press). The fault zone itself can probably be traced over a distance of 800-900 km from offshore West Finnmark (Gabrielsen & Færseth 1989) via Varanger and Rybachi-Sredni in Russia to the northern coastline of Kola Peninsula beyond Cape Teriberski (p. 13 and Fig. 5). The Rybachi-Teriberski segment of the fault zone is currently seismically active.

Metamorphic conditions prevailing in the various lithostratigraphic units on Varanger Peninsula during the time of early Caledonian folding and schistosity development have been determined from studies of illite crystallinity and lattice parameters (Bevins et al. 1986, Rice et al. 1989b). Results have indicated that whereas the rocks of the autochthonous/parautochthonous TVR have been affected only by diagenesis, the various units in the BSR have been metamorphosed in epizone grade, equivalent to lower greenschist facies. Within rocks of the BSR, a slight increase in grade can be detected from southeast to northwest, with a peak in the Berlevåg Formation of the Tanahorn Nappe (Rice et al. 1989b). In the westernmost TVR, illite crystallinity results indicate a prograde change to anchizone conditions of metamorphism directly beneath the sole thrust to the Gaissa Nappe Complex. This thermal inversion is considered to relate to the effects of the overriding nappe (Rice et al. 1989b).

The studies of low-grade metamorphism on the Varanger Peninsula, while by no means comprehensive, thus indicate that the TKFZ marks a significant metamorphic break between the two principal regions, and one which can be most readily explained by strike-slip juxtaposition of disparate metamorphic domains.

The age of the folding and associated slaty cleavage or schistosity development in the rocks of the Varanger Peninsula is still not fully resolved. Accepting a Caledonian nappe propagation from c. NW to SE and the results of illite crystallinity investigations, a relationship to the *Scandian* orogenesis, broadly mid-Silurian to Early Devonian, might be assumed. Radiometric data from the Gaissa Nappe Complex are not definitive. A K-Ar apparent age of 440±9 Ma has been interpreted as a maximum date for the slaty cleavage (Dallmeyer et al. 1989). An ultra-cataclasite from the sole thrust to the Gaissa Nappe has provided a date of 391±9 Ma (J.G. Mitchell, in Roberts & Sundvoll 1990); this is latest Early Devonian.

A Rb-Sr whole-rock isochron study from cleaved pelites of the Stappogiedde Formation, just beneath the Gaissa sole thrust, Tana, yielded an age of 504±7 Ma (Pringle 1973; recalculated in Sturt et al. 1975), which is earliest Ordovician. This was regarded as a metamorphic age, an interpretation which has been challenged by Dallmeyer & Reuter (1989) whose results rather point to a diagenetically related disturbance at c. 635 Ma.

The only relevant radiometric data so far available from the sequences in the BSR is that of a Rb-Sr isochron on Kongsfjord Formation pelites from near Hamningberg; 520±47 Ma, with an MSWD of 1.35 (Taylor & Pickering 1981). These authors interpret this date as the age of slaty cleavage formation, close to the Cambrian-Ordovician boundary; and signifying that the penetrative deformation in the BSR is associated with *Finnmarkian* orogenesis. Taking into account the regional picture, some doubt might perhaps be raised against this Rb-Sr isochron age. However, since Bylund (in prep.) has palaeomagnetic data suggesting that the rocks of the Gaissa Nappe Complex were possibly affected by an Early Ordovician magnetic overprint, and as the latest metamorphic event in the Baikalian orogenesis in the northern Timans occurred at c. 525-520 Ma (Siedlecka 1975), it is necessary to keep an open mind on the question of the age of folding and metamorphism until we have more isotopic dating work on which to base our conclusions.

Basin development

Unconformities, biostratigraphic data, sedimentary facies interpretation, thicknesses and thickness variations, and radiometric ages together provide information on the basis of which an interpretation of the development of the sedimentary basins may be attempted. Thus, there is evidence that sedimentation commenced in the *autochthonous basin* in Late Riphean time on an eroded, slightly subsiding Karelian basement of the northern and northeastern parts of the Fennoscandian Shield. Assuming that no sediments were deposited and subsequently removed prior to the Late Riphean, the period of erosion lasted some 700-1000 million years (Siedlecka 1985).

In the early phase, sedimentation was fluvial and the directions of sediment transport were variable; to the north, northeast or northwest, with a less common ESE direction (Banks et al. 1974). There were several marine incursions during the fluvial accumulation, perhaps the most prominent marine transgression being recorded in the uppermost Vadsø Group. This transgression, however, was preceded by a considerable non-depositional/erosional break, which straddles the Riphean-Vendian boundary (Vidal 1981). Banks et al. (1974) pointed out that the formations of the upper Vadsø Group thicken eastward, independently of sedimentary environment and transport direction, and suggested a higher rate of subsidence in the east.

Thus, in the early phase, the basin was shallow with a migrating coastline and there were varying conditions of sedimentation and periods of uplift and erosion, all testifying to instability of the substratum.

In the next phase, after the last transgression and the development of the regressive sequence of the Lower Vendian Ekkerøya Formation (Johnson 1978), a new transgression followed. This time a long-lasting marine sedimentation was in a fairly stable shallow-marine basin in which the whole of the Tanafjorden Group was accumulated. The formations of this group are typically widespread, sheet-like, sediment bodies which may easily be recognised also in the lowermost Caledonian nappes and imbricates, far to the west. Johnson (1975) has shown that this marine sedimentation occurred in tide-dominated environments and that there were several transgressive-regressive episodes. This resulted in sedimentation changing from an accumulation of near-shore, coastal and shallow-marine sands (sub-tidal to tidal sand bars, beaches and sheet sand complexes) to an offshore sand-mud facies of a continental shelf. There is a large variation in palaeocurrent directions, suggesting a complex shoreline configuration rather than any predominant direction of sediment transport. In the final stage, the transport of terrigenous material ceased and the basin was accumulating carbonates.

An uplift and northward tilting occurred in approximately mid-Vendian time, after the second phase of basin development was completed. This resulted in erosion becoming progressively deeper to the south and affecting the previously deposited Upper Riphean-Lower Vendian sequence of strata. The erosion in the south removed 2300 m of the sedimentary pile. The presence of palaeokarst (Siedlecka, unpubl. data) indicates a humid climate, while the striated pavement at Bigganjar'ga suggests that the final erosion was of glacial origin (Edwards 1984).

In the third and final phase, after the intra-Vendian break and climate deterioration, a new period of deposition started with the 'Varanger Ice Age' sediments, and continued almost uninterruptedly into Cambrian time. The older, glacially-influenced period of sedimentation resulted in the accumulation of glacial, fluvioglacial, fluvial and proglacial, probably marine sediments, recording several episodes of advance and retreat of the ice (Edwards 1984). The bulk of the Smalfjord Formation on the Varanger Peninsula was deposited in the Varanger paleovalley, in the present Varangerfjorden. The formation thins out towards the east and is absent east of Mortensnes.

The interglacial (post-Smalfjord) Nyborg Formation marks a marine transgression; it is thickest in the west (c. 300 m) and thins out eastwards. The formation is composed mainly of interbedded purple shale and brownish-grey sandstone deposited by turbidity currents. Tidal-flat dolomite and shallow-marine clastics are minor constituents. The second period of glaciation was heralded by a tillite which cuts down progressively southwards through the Nyborg Formation. This homogeneous glacial deposit is overlain by transgressive sediments and, with minor fluctations, the marine conditions continued throughout the time of deposition of the remainder of the Vestertana Group. There is evidence that the ice sheets during both glaciations advanced both from the south and from the north, while the water-transported sediments were mostly derived from southerly areas (Edwards 1984).

In summary, in spite of changes in sedimentary environments and directions of sediment transport and the presence of nondepositional/erosional breaks, the autochthonous basin may on the whole be characterised as shallow, with fairly slow and laterally varying subsidence rates and sediment influx, before permanent marine conditions were established. The intra-Vendian tilting and change of climate were the most important events that affected this basin, in which sedimentation also continued into Palaeozoic time.

The *allochthonous basin* is considered to have been located to the northwest of its present position, at most 250 km away. When this basin started to take form, the character of the earliest sediments, and the nature of the substratum upon which they accumulated are unknown. Several lines of evidence suggest that rifting and spreading of Lower/(?)Middle Proterozoic crust resulted in the formation of a NW-SE-oriented continental margin, and both an 'Atlantic type' margin and an aulacogen have been proposed (Siedlecka 1975, Pickering 1981, 1985). A combined model of normal and reverse faulting with subsequent lateral translation along the same fault line was suggested by Siedlecka (1985) for the developing basin. A >9000 m sedimentary wedge accumulated along the southwestern faulted margin of this basin during gradually shallowing conditions, in Late Riphean and Early Vendian time. This resulted in the development of a retrograding submarine fan overlain by a major deltaic complex followed by shallow-marine and fluvial strata. Thus, the basin margin, once formed, remained inactive over a long period of time. Subsequent uplift and tilting resulted in erosion of a part of the sequence. The eroded area was invaded by a shallow sea which persisted almost continuously, at least throughout the Late Vendian, and accumulated mainly terrigenous shelf deposits. Short-lived fluvial sedimentation with transport of material towards the southeast shows that the post-unconformity palaeogeography was different from that of the Barents Sea Group basin. Subsequent spreading and extension or transtension resulted in the emplacement of swarms of dolerite dykes, although in part this overlapped with compressional tectonism. After this phase of magmatism, the ancient buried fault line was reactivated as a major dextral strike-slip fracture and the basin was translated to its present position (cf. Kjøde et al. 1978).

Some aspects of correlation between Varanger Peninsula and the Rybachi - Sredni Peninsulas, Russia

A continuation of the stratigraphies of the BSR and TVR, and of the TKFZ, southeastwards on to the Sredni and Rybachi Peninsulas and Kildin Island in Russia (Fig. 5) was suggested by Siedlecka (1975) on the basis of data from earlier literature. Recent field studies in the Russian territories have clarified some of the correlation problems as well as the previously anticipated southeasterly extension of the TKFZ (D.Roberts and A.Siedlecka, unpubl.data). It became clear that the contact between the lithologies on Sredni and those of the Rybachi zone is everywhere faulted (Fig. 5), and it is reasonable to assume that this tectonic contact constitutes a continuation of the TKFZ. Although the precise nature of the displacements along this line is not clear, there is mesoscopic structural evidence of at least one significant component of

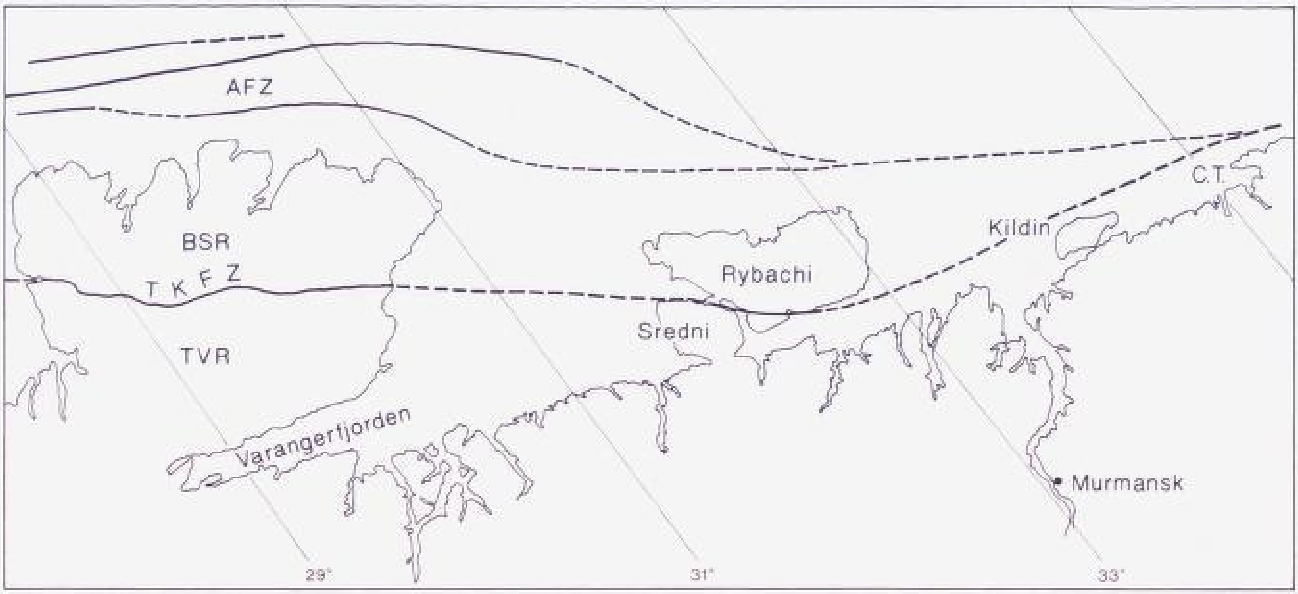


Fig. 5. The Trollfjorden-Komagelva Fault Zone (TKFZ) and its southeastward continuation. BSR – Barents Sea Region; TVR – Tanafjorden-Varangerfjorden Region, CT – Cape Teriberski; AFZ – Austhavet Fault Zone.

dextral strike-slip movement (D.Roberts, unpubl.data). It is also evident that the fault separating the Sredni and Rybachi Peninsulas marks a significant metamorphic break. The rocks on Rybachi are strongly folded and carry an axial planar slaty cleavage in pelites, whereas on Sredni the lithologies generally show only a diagenesis-grade, bedding-parallel, compactional cleavage.

It also became clear that the Rybachi succession is facially comparable to parts of the Barents Sea Group, and that the overall facies interpretation of the formations on Rybachi by Siedlecka (1975) was correct.

The relationship between the TVR and the Sredni zone, on the other hand, is more complex than earlier anticipated. The main similarities are that, in both areas, the Upper Proterozoic sedimentary rocks rest upon the crystalline substratum with an erosional contact and that they are primarily shallow-water deposits. The main difference is that in the Russian territories there are no tillites which are so typical and widespread on the Norwegian side. The existing stratigraphic data are insufficient for a more detailed correlation, and therefore any discussion on basin development on the Russian side, as compared with the Norwegian areas, would be premature.

EXCURSION ITINERARY

Southern part of the Tanafjorden - Varangerfjorden Region and eastern Barents Sea Region

This route takes us from the southern part of inner Varangerfjorden to Hamningberg, along the E6, highway 98 and a local dirt road (Fig. 6). The total driving distance, one way, is c. 173 km (starting c.100 km from Kirkenes). Localities 1 - 17 are located along this route (locality 2 requires a 45-minute walk, but it may also be reached by boat).

Locality 1. Highway E6, road-cut at 658 771, map-sheet 1:50,000 2335 III Varangerbotn.

Veinesbotn Formation, lower part (Fig. 7).

Sandstone, red, feldspathic, coarse- to medium-grained in medium-thick, cross-bedded, lenticular beds. Subordinate, 2-3 cm-thick mudstone beds are interbedded with the sandstone layers. Cross-bedding indicates a uniform flow direction towards north-northeast. The beds are flat lying with a few degrees dip towards the north.

The lower part of the Veinesbotn Formation has been interpreted as having accumulated in shallow interlocking channels in a braided stream environment (Hobday 1974).

Immediately southeast of this exposure there is a topographic depression, on the other side of which gneisses of Archaean age are exposed. The shortest distance between the exposures of the sedimentary rocks (the Veinesbotn Formation) and their crystalline basement is about 25 m.

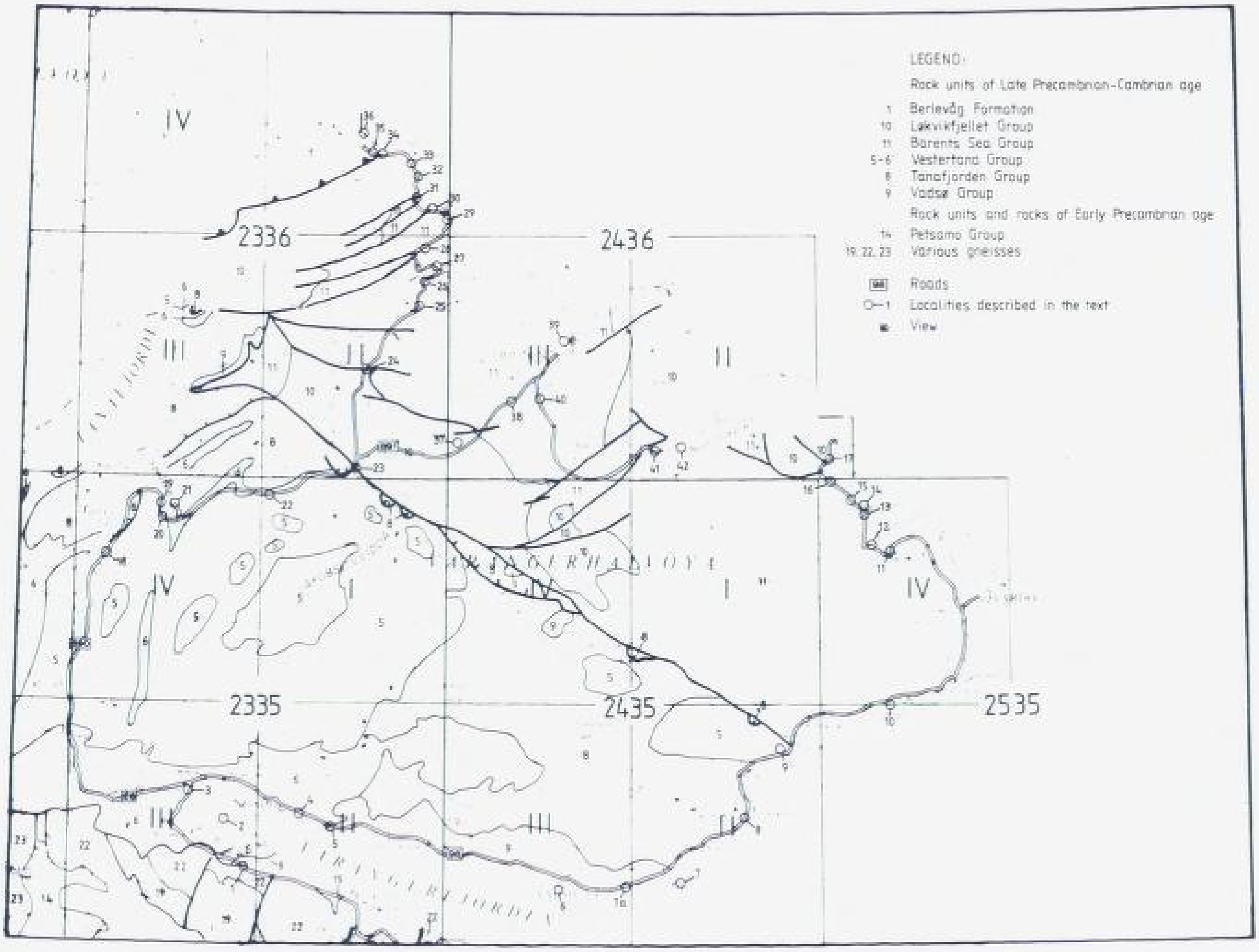


Fig. 6. Outline map of Varanger Peninsula showing the excursion localities. The 1:50,000 topographic map grid is also indicated.

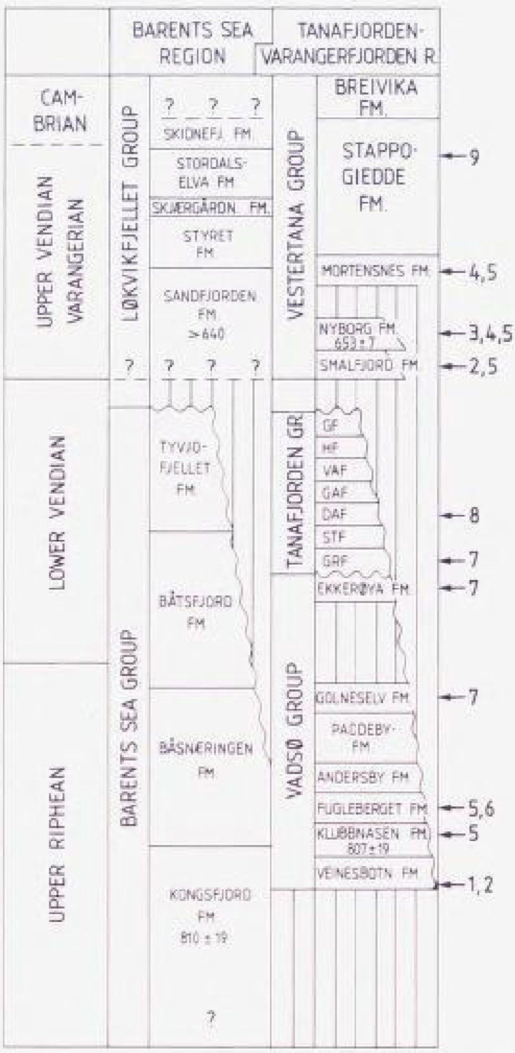


Fig. 7. Stratigraphic correlation chart showing the stratigraphic locations of excursion stops 1-9.

Locality 2. Oaibaččanjar'ga (Bigganjar'ga), coastal exposure at 632 816, map-sheet 1:50,000 2335 III Varangerbotn. A c. 45 min. walk from the school at Karlebotn. The locality is protected; sampling and hammering are not allowed.

Contact between the Veinesbotn Formation and the Smalfjord Formation. Unconformity and a major erosional hiatus.

A walk along the path paralleling the southern coast of Selešnjar'ga to the famous coastal exposure known in the geological literature either as 'Reusch's moraine' or as 'Bigganjar'ga tillite'.

Light-grey to pink-grey quartzitic sandstone of the middle part of the Veinesbotn Formation, interpreted by Hobday (1974) as a shallow-marine shelf accumulation, is sharply overlain by a c. 3 m-thick grey diamictite (Fig. 8). A unique striated pavement may be observed on the erosional surface of the sandstone (Fig. 9). The c. NW-SE trending striations are interpreted as glacial scours, and the overlying diamictite as a till left by a retreating glacier (Edwards 1984). The tillite contains fragments mainly of crystalline rocks. The bulk of the Smalfjord Formation on Selešnjar'ga (c.100 m) consists of medium-bedded sandstones interpreted as sediment flow deposits (Edwards 1984).

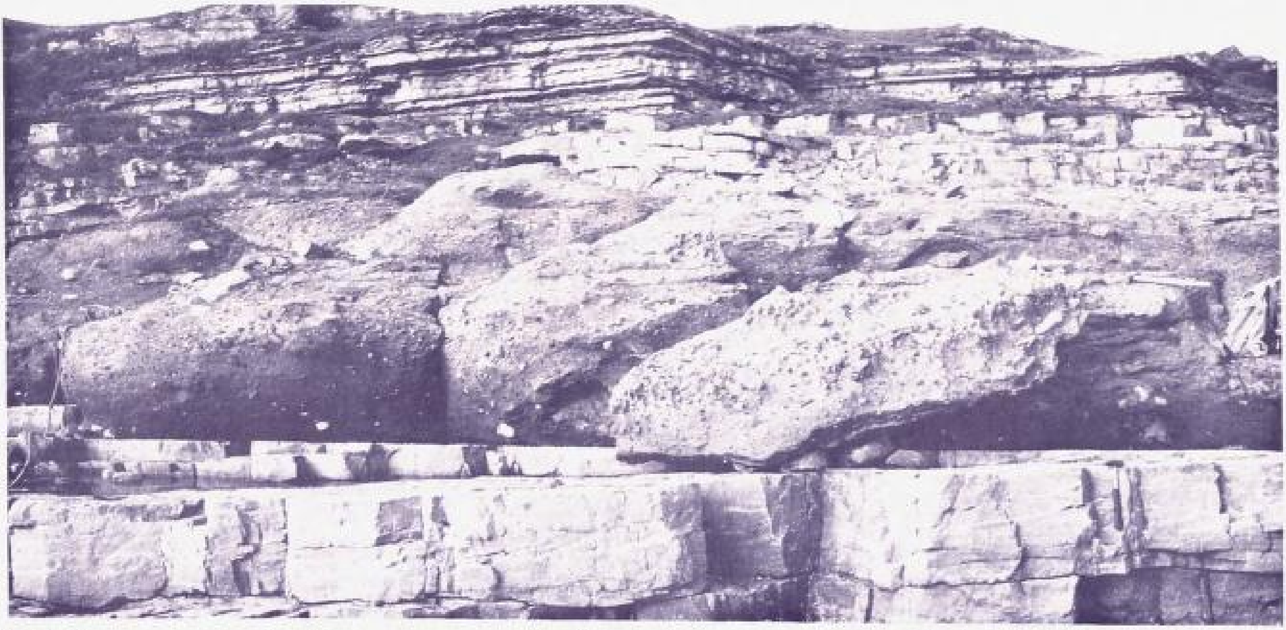


Fig. 8. Sharp erosional contact between sandstone of the Veinesbotn Formation and tillite at the base of the Smalfjord Formation; Oaibaččanjar'ga (Bigganjar'ga), locality 2. Note that 'Reusch's moraine' is overlain by predominantly massive sandstones which constitute the bulk of the formation at Selešnjar'ga.

Fig. 9. Glacially scoured top surface of a sandstone bed of the Veinesbotn Formation, beneath the Smalfjord Formation tillite; looking approximately west, locality 2.

Locality 3. Highway E6, road-cut at 596 847, map-sheet 1:50,000 2335 III Varangerbotn.

Nyborg Formation.

Thin to medium-thick beds of grey sandstone interbedded with purple clayey shale. The sandstone beds are parallel-sided, poorly sorted and massive to graded-bedded. This facies of the Nyborg Formation has been interpreted by Edwards (1984) as a relatively deep-water deposit of a submarine fan.

The Nyborg Formation as a whole is complex, consisting of various facies interpreted in terms of shallow-water to basinal deposition in a transgressive-regressive cycle (Edwards 1984). The lithology seen in this locality is particularly widespread and is well exposed along the highway.

The Nyborg Formation is a structurally incompetent unit resting on the competent Smalfjord Formation (and older competent rocks) and it is therefore usually tightly folded. The chevron or zig-zag folds (Fig. 10) are asymmetrical, close to tight, and have approximately E-W to ENE-WSW oriented axial planes which generally dip steeply to the north. A weakly developed axial planar slaty cleavage is present in pelitic layers. Minor faults, including small thrusts, can be seen in parts of the outcrop.

Locality 4. Highway 98, above the road on its northern side at 726 836, map-sheet 1:50,000 2335 II Nesseby.

Nyborg Formation overlain by the Mortensnes Formation.

Violet clayey shale interbedded with subordinate thin beds of grey sandstone is exposed in the lower part of the outcrop. This interbedded unit is overlain by a few metres of thick- and thin-bedded grey sandstone, poorly sorted and graded-bedded. This sandstone is, in turn, abruptly overlain by a massive, cliff-forming tillite (Fig. 11). The contact between the tillite and its substratum is planar. Mapping in the area, however, has shown that the Mortensnes Formation rests unconformably on an erosional surface, which in places cuts down to the Vadsø Group. In this locality the massive tillite marking the bottom of the Mortensnes Formation rests on the middle portion of the Nyborg Formation (member B of Edwards, 1984), the remainder of this formation having been removed by pre-glacial erosion.

Fig. 10. Chevron or zig-zag style asymmetrical folds deforming Nyborg Formation sandstones and shales; looking west, locality 3. Such folds are common in this structurally incompetent facies of the Nyborg Formation in many parts of this area.

Fig. 11. Contact between the sandstone and shale of the Nyborg Formation and tillite of the Mortensnes Formation. The contact marks a stratigraphic break where the youngest parts of the Nyborg Formation are missing.

The tillite contains fragments mainly of crystalline rocks, but chert, dolomite and other rock-types may be found. Edwards (1984) has interpreted this tillite as a lodgement till deposited by a large glacier or a continental ice sheet, because of its widespread occurrence, blanket geometry, and locally derived matrix material and clasts, some of which show striated and faceted surfaces.

Locality 5. Handelsneset (Mortensnes), section from c. 767 811 to 774 821, map-sheet 1: 50,000 2334 II Nesseby.

Klubbnasen Formation, Fugleberget Formation, Smalfjord Formation, Nyborg Formation and Mortensnes Formation (Fig. 7). Unconformity, pre-Smalfjord erosional surface with pronounced relief, major hiatus.

A short walk from highway 98 down to the coast, to the bottom of the section (Fig. 12). The Klubbnasen Formation is composed of grey, clayey shale and micaceous mudstone and sandstone, with the sandstone beds increasing upwards in number and thickness. There is a gradual transition into the cross-bedded or flat-bedded, grey, feldspathic sandstones of the Fugleberget Formation. The Klubbnasen - Fugleberget coarsening-upward sequence has been interpreted as an ESE-prograding delta (Banks et al. 1974).

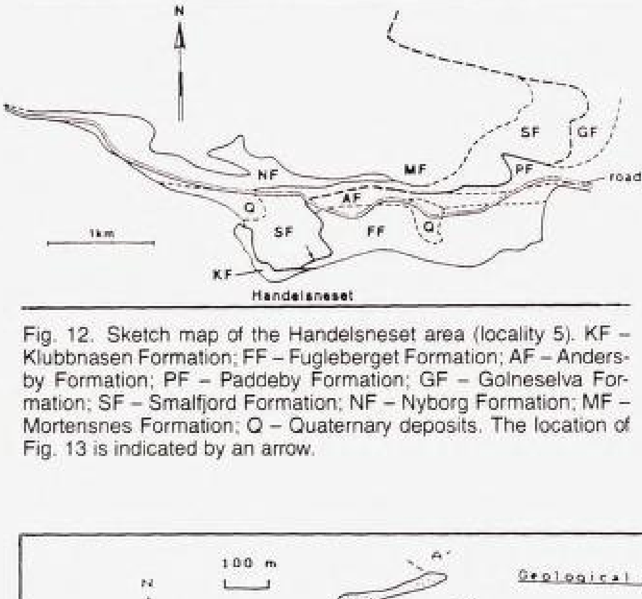


Fig. 12. Sketch map of the Handelsneset area (locality 5). KF – Klubbnasen Formation; FF – Fugleberget Formation; AF – Andersby Formation; PF – Paddeby Formation; GF – Golneselva Formation; SF – Smalfjord Formation; NF – Nyborg Formation; MF – Mortensnes Formation; Q – Quaternary deposits. The location of Fig. 13 is indicated by an arrow.

The Smalfjord Formation rests upon the eroded surface of this deltaic sequence (Fig. 13). The sharp contact and the topographic relief of the unconformity surface may be observed here. Diamictite, stratified conglomerates and pebbly sandstones (massive, parallel- or cross-bedded) constitute the rocks of the Smalfjord Formation at this locality. Pebbles of crystalline rocks, dolomite and chert are the most common. Edwards (1984) has interpreted the deposits observed here as glacial, glacideltaic, glacifluvial and coastal (Fig. 14). North of the highway the Smalfjord Formation is succeeded by the Nyborg Formation, a sequence consisting of interbedded purple clayey shale and sandstone. Hill slopes bordering the highway to the north are covered with the scree of these rocks and are partly vegetated. These slopes are capped by a several metres high cliff of reddish-brown diamictite of the Mortensnes Formation. At Handelsneset and on Fugleberget there are several interesting archaeological sites, including a sacrificial stone (1500 years old), house sites (3000 years old) and more than 250 graves (from before Christ to 1100 after Christ).

Fig. 13. Erosional contact between the Fugleberget Formation and the Smalfjord Formation. The contact marks a very low-angle regional unconformity, and the break in the stratigraphic record embraces the upper Vadsø Group and the entire Tanafjorden Group.

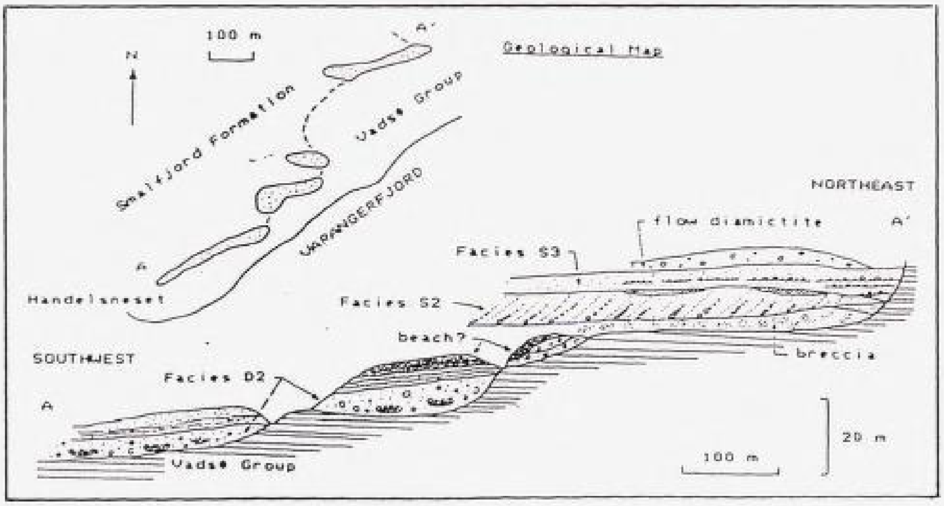


Fig. 14. Foreshortened section of the Smalfjord Formation resting with an erosional contact on the Vadsø Group, Handelsneset. From Edwards (1984).

Locality 6. St.Vadsøya, SW coast, c.039 760, map-sheet 1:50,000 2435 III Vadsø.

Fugleberget Formation

The Lower Member of the Fugleberget Formation is excellently exposed along the southwestern coast of the island (unfortunately close to a garbage dump and combustion stove). Fine- and very fine-grained feldspathic sandstone is the dominant lithology with subordinate thin siltstones. The sandstones show either large-scale cross-stratification (with sigmoidal and concave-up cross-stratal form), or horizontal to low-angle planar-stratification (with a prominent parting lineation on bedding surfaces). Massive sandstone is also common. Overturned cross-strata (Fig. 15) as well as reactivation surfaces are typical for the cross-bedded sedimentation units. The sandstone bodies of the Fugleberget Formation have, in general, sheet geometries but this locality also shows (to the west), a 100 m-wide and 5 m-deep channel-form filled with trough cross-stratified and massive sandstone.

The upper part of the Fugleberget Formation is best observed in an abandoned quarry nearby. Pebbly sandstones and conglomerates with fragments of mudstone and pebbles of sandstone may be seen interbedded with subordinate mudstone lenses. Carbonate concretions are abundant in some conglomerate and sandstone beds.

The Fugleberget Formation is interpreted as a product of a very wide, low-sinuosity, mainly braided fluvial system (Hobday 1974, Røe 1975, Røe & Hermansen 1991).

Locality 7. St.Ekkerøy, c. 900-905 764, map-sheet 1: 50,000 2435 II Ekkerøy.

Golneselva Formation, Ekkerøya Formation, Grønneset Formation. Disconformities and gaps between the formations are indicated by regional mapping and micropalaeontological work.

Dolerite dyke, K-Ar age 349±10 Ma (Beckinsale et al. 1975, recalculated).

Light-grey feldspathic sandstones of the Golneselva Formation are exposed in the southwestern part of the island, e.g. at the trenches from World War II. The brown film on the rock surface and sulphur-yellow spots may be weathering products of iron sulphides. The Ekkerøya Formation is best studied in S-facing cliffs c. 250 m northeast of the southwesternmost tip of the island, as well as in the coastal exposure at Flågan. The Ekkerøya Formation consists of grey-green mudstone and siltstone interbedded with greenish-grey sandstone and subordinate conglomerate. Mudstone beds predominate in the lower part of the formation, and there is an upward increase of sandstone beds in which 'ball-and-pillow' structures (Fig. 16) and

Fig. 15. Mudstone and sandstone of the Fugleberget Formation exposed along the coastal section of Vadsø Island, locality 6. Cross-bedding with overturned foresets is common in this coastal section.

slump folds may be observed. The Ekkerøya Formation is interpreted as starting with a transgression with a subsequent regressive development within a deltaic or interdeltaic coastal setting (Røe 1975, Johnson 1975, 1978). The boundary between the Ekkerøya and the Grønneset Formation is at the base of a transgressive quartz conglomerate (Røe 1970, Johnson 1978) exposed in the uppermost part of the cliff. An unconformity has been inferred at the base of the Grønneset conglomerate which occurs over a wide area in the TVR.

Fig. 16. 'Ball-and-pillow' structures in sandstones of the Ekkerøya Formation on the island of St. Ekkerøy, locality 7.

A vertical dolerite dyke cuts through the Ekkerøya Formation at Flågan and is clearly visible in the topography of the coastal cliffs. The dyke strikes almost N-S and dips at c. 75° to the east.

Flågan is a nature reserve with a rich and varied community of gulls and other sea-birds (Fig. 17).

Locality 7a. 137 765, map-sheet 1:50,000 Vadsø 2435 III (description provided by S.-L. Røe)

Golneselva Formation

The Golneselva Formation at this locality (as well as elsewhere) is characterised by large-scale trough cross-stratified, medium- to very coarse-grained sandstone with common evidence of soft-sediment deformation. A notable feature at the present locality is the presence of terraced channel margins exposed in a plan view over an area of 1500m^2 (Banks 1973a). These features compare closely to terraces formed during falling stages of discharge on exposed bars in modern rivers and support a fluvial interpretation for the Golneselva deposits (Banks & Røe 1974). The rivers which deposited the sediments of the Golneselva Formation flowed towards the northwest, in contrast to the eastward palaeoslopes inferred from the older fluvial deposits of the region (Paddeby and Fugleberget Formations). The lower and upper boundaries of the Golneselva Formation are interpreted as tectonically generated unconformities (Røe 1975) and the upper boundary towards the shallow-marine Ekkerøya Formation probably represents a significant time gap (Vidal 1981) (Fig. 7).

Fig. 17. Sandstones and interbedded siltstones and mudstones of the Ekkerøy Formation on the cliffs at Flågan, with a resident colony of kittiwakes. Locality 7.

Locality 8. Quarry at Skallnes, 980-985 836. map-sheet 1:50,000 2435 II Ekkerøy.

Dakkovarre Formation

The upper part of the Dakkovarre Formation (Fig. 7) is exposed in the quarry and also along the coast, east of the highway 98. The light-grey feldspathic sandstone is medium- to very thick-bedded and either massive or cross-bedded. Current and oscillation ripples are well exposed on the bedding surfaces. The sandstone contains spots of dark-brown iron oxide which are probably oxidation products of iron sulphide or siderite. The same brown coloration occurs as bands (weathering crust) along joints and bedding planes.

Hobday & Reading (1972) and Johnson (1978) interpreted these sandstones as shallow-marine storm deposits.

The sandstone was quarried for building stone for harbour constructions at Svartnes near Vardø.

Locality 9. Komagnes, c. 042 912, map-sheet 1:50,000 Ekkerøy.

Stappogiedde Formation, Innerelva Member.

Dolerite dyke, K-Ar age 360±10 Ma (Beckinsale et al. 1975).

The clayey and muddy shale, blue-green, in places reddish-grey, is typical of this member. The shale exhibits two kinds of sedimentary structures: parallel horizontal lamination and small ripple cross-stratification sets, both testifying to a very quiet environment of sedimentation, either from suspension or from weak bottom currents. The member is widespread in the Tanafjorden-Varangerfjorden Region (and in the Gaissa Nappe) without any important facies change. It is interpreted as a shelf deposit influenced by tidal currents (Banks 1973b).

A prominent dolerite dyke, up to 2.4 m in thickness and trending c. N-S, intrudes the shales at this locality. In the cliff section north of the road the 'composite' dyke dips at c. 75° to the east (Fig. 18) and really consists of two parallel dykes with a screen of baked sediment in between. In exposures between the road and the foreshore, and in the intertidal zone, the dyke is vertical or locally west-dipping and can be seen to split into several thinner dykes, some of which thin out either along the same N-S trend or curve into a bedding-parallel orientation. The shales and siltstones adjacent to the separate dyke offshoots are hornfelsed in zones of varying thickness, depending on the thickness of the actual dyke. These hornfelsed sediments also show a prominent spaced cleavage which is subparallel to the dyke margins.

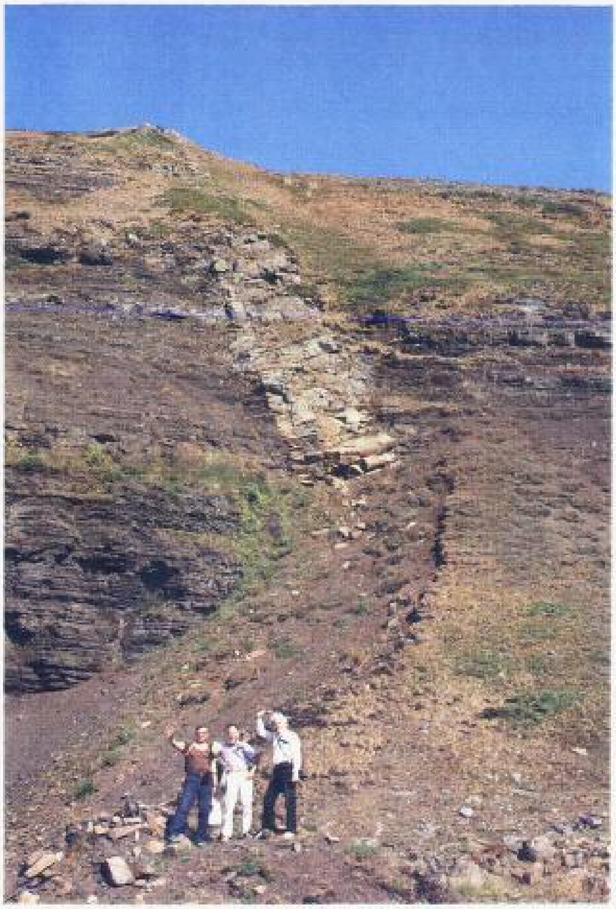


Fig. 18. Blue-green shale of the Stappogiedde Formation intruded by the Devono-Carboniferous dolerite dyke at Komagnes, locality 9.

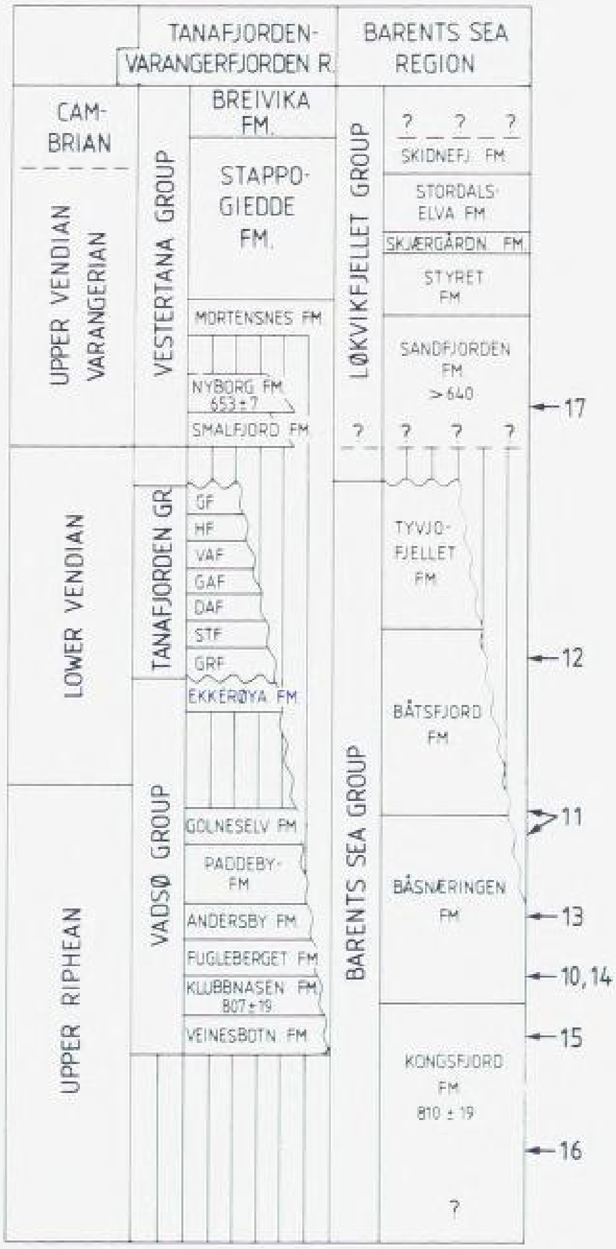


Fig. 19. Stratigraphic correlation chart showing the stratigraphic locations of excursion stops 10-17.

Fig. 20. Spectacular large 'ball-and-pillow' structures in the delta front sandstones of the Næringselva Member of the Båsnæringen Formation at Svartnes, locality 10. The encircled hammer is c. 30 cm long.

Locality 10. Svartnes, coastal exposure at 169 962, map-sheet 1:50,000 2535 IV Vardø.

Båsnæringen Formation, Næringselva Member (Fig. 19).

Thick-bedded grey to dark-grey sandstones crop out extensively in the coastal section at Svartnes, c. 1km SSE from the lake Svartnesvatnet. The sandstone beds exhibit large-scale trough cross-bedding and ripple marks on the bedding surfaces. Structures resulting from soft-sediment deformation are abundant, in particular large, spectacular 'ball & pillow' structures (Fig. 20).

The Båsnæringen Formation as a whole is interpreted as a major delta (Siedlecka & Edwards 1980, Siedlecka et al. 1989). In this context, the sandstones exposed at Svartnes are considered as shallow-marine delta-front accumulations.

Locality 11. Persfjorden, SE side, 177 150, map-sheet 1:50,000 2535 IV Vardø.

Båsnæringen Formation, Hestman Member, Båtsfjord Formation, Annijokka Member in mutual contact in the eastern limb of the Persfjorden syncline.

Thick-bedded, red to pink, feldspathic sandstone is typical for the Hestman Member. It may be observed from a distance in the steep slopes of the Hestman mountain and in road-cuts just before reaching locality 11 (Figs. 21, 22). The sandstone, c.800 thick in this area, is interpreted as a braided delta-plain deposit terminating the deltaic deposition of the Båsnæringen Formation (Siedlecka & Edwards 1980, Siedlecka et al. 1989).

The contact between the Båsnæringen and Båtsfjord Formations is exposed at the coast (Fig. 23); the exposure is best studied at low tide. The uppermost Båsnæringen Formation is represented by a few metres of pink and light-grey, quartz-rich, thick-bedded sandstone interbedded with thin sandstone beds and sandy shale. This is succeeded by a series of interbedded, blackish-grey, clayey shales, thin-bedded grey sandstones, greenish-grey mudstones and grey, yellow-weathering dolomite. In addition, there are subordinate, stromatolite-bearing limestone beds. These deposits contain an abundance of flaser and lenticular bedding, shrinkage cracks, desiccation cracks and intraformational breccias, and have been interpreted as tidal-flat deposits (Siedlecka 1975, 1980). Stromatolites, confined to a few horizons, vary from wavy to bulbous structures up to 0.5 m in size.

Fig. 21. Sandstones of the Hestman Member of the Båsnæringen Formation form cliffs on the southeastern side of Persfjorden close to locality 11. See also Fig. 22.

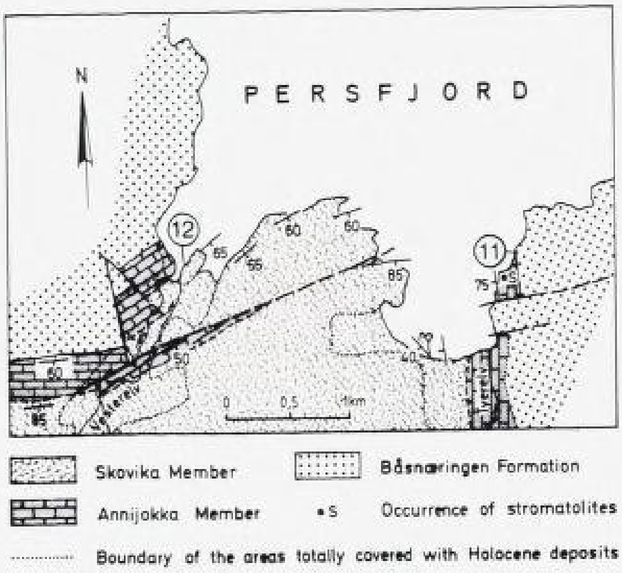


Fig. 22. Geological map of the inner Persfjorden area. Localities 11 and 12 are indicated.

The boundary between the Båsnæringen and Båtsfjord Formations is interpreted as marking a change in depositional regime resulting from an abandoning of the Båsnæringen delta lobe, and/or a transgression (Siedlecka & Edwards 1980).

The pelitic interbeds along this coastal traverse show a steeply eastward-dipping penetrative slaty cleavage; and the sandstone beds a convergent fracture cleavage. The intersection of cleavage and bedding produces a prominent S- to SSW-plunging lineation which is broadly parallel to the axes of large-scale folds in the region.

Fig. 23. Contact between sandstones of the Båsnæringen Formation, Hestman Member (to the right) and the sandstone-shale unit of the lower Båtsfjord Formation at locality 11 on the south-eastern side of Persfjorden.

Locality 12. Persfjord, coastal exposures, c.150 155, map-sheet 1:50,000 2535 IV Vardø.

Båtsfjord Formation, upper part (Skovika Member).

An interbedded multicoloured series of violet and green mudstone, grey and pink sandstone, yellow-grey dolomite and grey limestone is extensively exposed in coastal cliffs in the western part of the Persfjorden syncline (Figs. 22 & 24). Crinkled (?)algal lamination, desiccation cracks, 'birds eye' structures, intraformational breccias, ripple cross-lamination, (?)tepee structures, etc. may be observed. Shrinkage cracks deformed by compaction, and sealed with calcite, are a widespread structure.

Fig. 24. Multicoloured terrigenous – carbonate series of the upper Båtsfjord Formation in- inner Persfjorden close to locality 12.

The sequence shows a penetrative slaty cleavage (S1) paralleling the steeply SE-dipping axial surfaces of the SSW-plunging D1 folds (Roberts 1972).

Locality 13. Seglkollen, 152 194, map-sheet 1:50,000 2535 IV Vardø.

Båsnæringen Formation, Seglodden Member.

A section across the southern slope of Seglkollen shows medium- to thick-bedded, lenticular, erosively-based beds of violet and grey-green sandstone (Fig. 25). The sandstone is cross-bedded, mostly medium-grained and feldspathic and has been interpreted as having accumulated on a braided delta plain (Siedlecka & Edwards 1980). A short walk down to the coast at Seglodden provides a good opportunity to see an excellently exposed section at about 155 198 - 157 195.

Fig. 25. Thick, parallel-sided or lenticular, erosively-based sandstone beds of the Seglodden Member, Båsnæringen Formation at Seglodden, locality 13. Hammer (encircled) is c. 30 cm long. From Siedlecka & Edwards (1980).

In this general area, a prominent cleavage (S1) can be seen which dips steeply to the ESE; locally it may be vertical. The cleavage/bedding intersection lineation plunges at varying angles to the SSW.

In the small cove at Blåsenberg (153 187) c. 1 km south of Seglodden, there is a 5-6 m thick, unmetamorphosed dolerite dyke which dips at c. 80° to the southeast. This dyke has not been dated.

Locality 14. Road-cut at 149 202, map-sheet 1:50,000 2535 IV Vardø.

Båsnæringen Formation, Næringselva Member.

Medium-thick beds of greenish-grey, fine-grained sandstone and mudstone may be observed here. The beds are mostly parallel-sided and exhibit parallel horizontal lamination and graded-bedding in thin, 3 - 5 cm units. Current ripples are visible both in section and on bedding planes. Deformational structures resulting from loading of unconsolidated, water-saturated sediment are common.

A c. 1 km walk along the coast from Storflogdalen (c. 142 206) to locality 14 offers a very good section through the gradual transition between the Kongsfjord and the Båsnæringen Formations. The Kongsfjord Formation comprises up to several metres thick packages of thin 'overbank' turbidites and thick sandstone beds representing channel-fill deposits. Higher up in the section there appear greenish-grey laminated silt-claystones (the Næringselva Member). Several debrite beds 0.5 - 2 m thick occur in the higher parts of the section, testifying to instability of the depositional slope. Finally, a coarsening-upwards motif may be observed towards the mudstones and sandstones of locality 14. Several coarsening-upward sequences have been measured by S.-L. Røe (pers. comm. 1991). The Næringselva Member as a whole was deposited in a prodelta-delta front setting (Siedlecka & Edwards 1980; see also locality 10).

In this same area, the prominent S1 cleavage is readily seen in the pelitic and silty lithologies. In the sandstones it is developed as a convergent, spaced, fracture cleavage. Driving north and northwest from Storflogdalen, a complicated fold interference pattern can be seen in the steep slopes to the west of the road. Fold axial plunges show marked variations within a fairly consistently ESE-dipping S1 cleavage – plunging moderately steeply either to the NNE or to the SSW (Roberts 1972; fig. 22).

Locality 15. Road-cut at 139 214, map-sheet 1:50,000 2535 IV Vardø.

Kongsfjord Formation

Very thick-bedded, dark-grey turbidite beds can be seen in this road-cut and in several other exposures along the road towards Sandfjord. Graded-bedding in sets from a few centimetres to over 1 metre in thickness (in amalgamated beds) is present along with parallel horizontal lamination at the tops of the graded units.

The Kongsfjord Formation is interpreted as a flysch sequence which accumulated on a submarine fan (Siedlecka 1972, Pickering 1981). The beds observed at this locality are thought to represent outer fan deposits which accumulated rapidly on active lobes (Pickering 1981).

Locality 16. Exposures on the slopes of coastal cliffs and on both sides of the road at 108 237, mapsheet 1:50,000 2436 II Syltefjord.

Kongsfjord Formation. Dolerite dyke.

A steeply c. SE-dipping dyke of dolerite up to 10 m thick cuts through turbidites of the Kongsfjord Formation (Fig. 26). The turbidite units occur as thick, sandy and thin, muddy packages of graded-bedded and parallel-laminated beds. In the overall interpretation of the Kongsfjord Formation as a submarine fan, these beds are probably representing lateral margin fan deposits as suggested by Pickering (1981).

It is not clear whether this particular NE-SW trending dyke, uncleaved and little altered apart from its orange-brown weathering surface, has been dated because the precise map co-ordinates were not given by Beckinsale et al. (1975). However, it appears that it may well correspond with dyke no. R51 of Beckinsale et al. (1975), which yielded a K-Ar age (recalculated) of 363±10 Ma. In the exposures near the shore, the dyke shows a marked kink, transgressing the strata over several metres before resuming its bedding-subparallel trend. In the prominent exposure above the road, the southeastern contact surface of the dyke shows a concentriform to pseudohexagonal jointing pattern ascribed to cooling during crystallisation (see also locality 17, Fig. 27).

Fig. 26. Dolerite dyke intruding turbiditic greywacke-sandstones and pelites of the Kongsfjord Formation; looking c. southwest, locality 17.

Fig. 27. Columnar jointing in the structurally lower, marginal part of the dolerite dyke. The crudely hexagonal to concentrifrom pattern is considered to have developed during crystallisation and cooling. The photo was taken looking c. NNW, more or less perpendicular to the dyke margin. Near Ytre Steinsnes, north-northeast of locality 17.

Locality 17. Kvannvikbukta, road-cut at 107 259, map-sheet 1:50,000 2436 II Syltefjord.

Løkvikfjellet Group, Sandfjorden Formation.

Thick beds of pink, pale green and pale grey, coarse-grained, feldspathic sandstone with large-scale cross-bedding represent the typical development of the Sandfjorden Formation. The sandstones are interpreted as having accumulated in a shallow-marine environment strongly influenced by tidal currents (Levell 1980).

Just over 1 km further on (at c. 113 268), along the road to the picturesque, former fishing settlement and whaling station of Hamningberg, another dolerite dyke intrudes the sedimentary sequence. This orange-brown weathering dyke is up to 13 m in thickness; it dips at c. 70° to the NNW, in contrast to the sandstones which here dip at c. 40° towards ESE. A feature of the dyke, best seen along its margins above the road, is the development of a hexagonal 'columnar' joint pattern normal to the dyke margin, in places with a concentriform structure (Fig. 27).

This dyke has been K-Ar-dated to 361 ± 10 Ma (Beckinsale et al. 1975; recalculated).

Western Tanafjorden - Varangerfjorden Region and northwestern Barents Sea Region

This part of the excursion is from Varangerbotn to Berlevåg along the E6 and highway 890 (Fig. 6). The total driving distance, one way, is about 132 km. Localities 18 - 36 are situated along this route. Localities 18 - 22 are within the western part of the Tanafjorden - Varangerfjorden Region; localities 23 - 36 are situated in the northwestern Barents Sea Region.

Locality 18. Scenic view 458 103, map-sheet 1:50,000 2335 IV Tana.

Vestertana Group and Tanafjorden Group (Fig. 28).

The steep western slopes of Blåberget (Blue Mountain) on the eastern side of the road are covered with scree of blue-green and purple mudstones and clayey shales belonging to the Stappogiedde Formation (Innerelva Member) and Nyborg Formation, respectively. Both units are exposed in the upper portion of the slopes where, in addition, the Lillevatn Member, Mortensnes Formation and Smalfjord Formation are present. The tillites may be recognised from the road by their yellow coloration. All rocks are steeply dipping to vertical and are heavily cleaved because of proximity to a major reverse fault. Rocks of the Gamasfjellet Formation (Tanafjorden Group) are juxtaposed along this fault, and form the spectacular cliffs of Raudberget (Red Mountain) at a distance of several kilometres, starting about 3 km north of this stop (Fig. 29). In the far distance to the north, rocks of the Tanafjorden Group can be seen beyond the mouth of the Tana river, on the eastern side of the Tanafjorden.

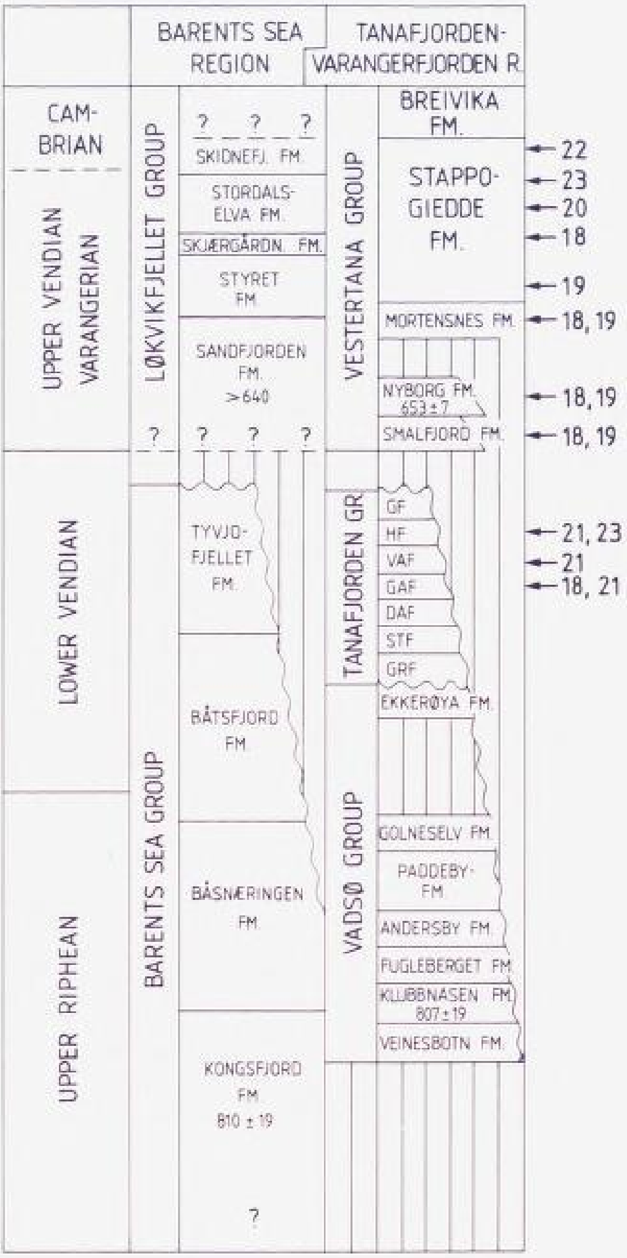


Fig. 28. Stratigraphic correlation chart showing the stratigraphic locations of excursion stops 18-23.

(Before reaching locality 19 it is recommended to make a short stop at 543 209 to view the stratigraphy of the upper Tanafjorden Group in the Giemaš anticline (Fig. 31), described further on as locality 21).

Fig. 29. View from just north of locality 18. To the right, the western slopes of Raudberget where quartzitic sandstones of the Gamasfjellet Formation are exposed; in the distance, various formations of the Tanafjorden Group crop out on the eastern side of the fjord.

Locality 19. Section c. 1 km long on the western side of the road, c.539 190, map-sheet 1:50,000 2335 IV Tana.

Smalfjord Formation, Nyborg Formation, Mortensnes Formation, Lillevatn Member, Stappogiedde Formation. The stratigraphic sequence crops out in a gentle anticline with the Smalfjord Formation in the core.

Fig. 30. Stromatolitic dolomite at the base of the Nyborg Formation, locality 19. Photo C.O. Mathiesen.

A light-grey, yellow-weathering dolomite, c. 1 m thick with stromatolitic structures, is conspicuous here (Fig. 30). It belongs to the lowermost part of the Nyborg Formation. Algal-laminated dolomite is a widespread facies at the bottom of the Nyborg Formation and has been interpreted by Edwards (1984) as a tidal-flat deposit which originated during a post-glacial transgressive episode. The dolomite rests on a grey mudstone, c. 1 m thick, which abruptly overlies a massive tillite containing a few dolomite fragments less than 1 cm in size (derived from erosion of the Grasdalen Formation). The dolomite is overlain by a violet and grey mudstone (Nyborg Formation) which, in turn, is followed by a grey tillite with fragments of crystalline rocks (Mortensnes Formation). This sequence can be seen over a distance of c. 400 m northwards, along the road (northern limb of an anticline). It is repeated southwards from the Nyborg dolomite where, after a distance of c. 500 m, there is also exposed dark-grey mudstone interbedded with coarse to conglomeratic feldspathic sandstone forming lenticular beds. These fluvial deposits form the basal part of the Stappogiedde Formation. The Nyborg Formation and the Mortensnes Formation are thin here compared with their thicknesses in neighbouring areas; this thinning may be a result of both facies development and interformational erosion.

Locality 20. Road-cut, c.800 m long, from 548 134 southwards, map-sheet 1:50,000 2335 IV Tana.

Stappogiedde Formation, Innerelva Member.

Blue-green mudstone, parallel-laminated due to separation of silt and clay. Siltstone with ripple cross-stratification occurs in subordinate layers. This is a typical development, widespread over large areas on Varanger Peninsula and west of the Tana river. The mudstone sequence has been interpreted by Banks (1973b) as a shelf deposit.

The mudstone is strongly cleaved along steep, NNE-SSW oriented slaty cleavage surfaces and dissected by a set of almost vertical, E-W-trending joints. It is typical that the rock splits along the joint and cleavage planes rather than along the bedding surfaces.

Locality 21. Quartzite quarry at 555 193 and the slope above it, map-sheet 1:50,000 2335 IV Tana.

Gamasfjellet Formation, Vagge Formation, Hanglečærro Formation.

Sections through all three formations may be conveniently studied along the roads of the quarry at various levels (Fig. 31). The Gamasfjellet Formation consists of red-violet (in the lower part of the formation) and pink quartzitic sandstone which is quarried mainly for ferro-silicium. The annual production is c. 600,000 tons of quartzitic sandstone containing less than 0.6 % Al_2O_3. The sandstone is mostly medium-bedded, massive or cross-bedded, and consists of rounded quartz grains cemented by quartz and haematite. At the top, the formation contains interbeds of arenaceous grey shale and grades into the Vagge Formation. This formation consists mainly of interbeds of grey, thin-bedded sandstone and arenaceous or muddy cleaved shale. The sandstones are rusty-brown on weathered surfaces. Symmetrical ripples and ripple cross-laminations and rippled bedding surfaces are abundant. Trace fossils and desiccation cracks may be found, but are uncommon. Close to the top, the Vagge Formation contains a few medium-thick beds of grey, cross-bedded quartzitic sandstone, and clastic dykes of sandstone, some over a metre in length, cut through the sequence.

The Hanglečærro Formation, overlying the Vagge, consists exclusively of medium- to thick-bedded quartzitic sandstone, blue-grey in the lower part and almost white higher up. The beds are mostly massive, locally cross-bedded, and the quartz grains are cemented by quartz overgrowths. None of the formations has been studied in detail. However, their blanket-like geometry without any facies change over large areas and the high textural and mineralogical maturity of the Gamasfjellet and Hanglečærro quartzitic sandstones suggest a shallow-marine environment. A wave-dominated environment has been proposed for the Hanglečærro Formation and tide-dominated for the Gamasfjellet Formation. For the Vagge Formation, an offshore setting influenced by storm processes has been suggested (Johnson et al. 1978).

Locality 22. Slope on the NW side of the road, 679 196, map-sheet 1:50,000 2335 I Ourdujav'ri.

Stappogiedde Formation, Manndrapselva Member.

Sandstone beds, almost horizontal, interbedded with red, clayey, cleaved shale may be observed on a low

Fig. 31. The Giemaš anticline exposed on the eastern side of Leirpollen, locality 18. From left to right: pink quartzitic sandstones of the Gamasfjellet Formation overlain by brownish-grey sandstones and shales of the Vagge Formation and grey to whitish-grey quartzitic sandstones of the Hanglečærro Formation. The Dakkovarre Formation occurs in the core of the anticline – the area with vegetation close to sea-level. The uppermost part of the Gamasfjellet Formation is quarried for ferro-silicium.

slope near an unnamed creek. The sandstone is thin- or medium-bedded, pink, greenish-grey or reddish-brown; it is fine-grained, and haematite- and clay-rich. Desiccation cracks occur on the bedding planes of shale. Ripple cross-stratification may be seen in the sandstone and in some beds there are abundant horizontal and vertical burrows (cf. Banks 1970). These beds were interpreted as shallow-marine accumulations (Reading 1965, Banks 1971).

The strata of the Manndrapselva Member very probably represent the terminal part of Precambrian sedimentation and, as suggested by Vidal (1981), the Precambrian-Cambrian boundary may be located within this unit.

(About 2 km further to the northeast there is a particularly fine scenic view: in the foreground, a 300-350 m high plateau, partly vegetated and underlain by rocks of the upper Vestertana Group and, in the background, a white, barren, c.300 m high 'wall' of quartzites of the Hanglečærro Formation.).

Locality 23. Gædnjajav'ri, southern side of the lake at c.772 235 and northeastern side of the lake at c.770 255, map-sheet 1:50,000 2336 II Kongsfjord (topographic map and map of bedrock geology, Siedlecka 1989).

Stappogiedde Formation and Hanglečærro Formation in tectonic contact, Trollfjorden-Komagelva Fault Zone, Sandfjorden Formation (Fig. 28).

Blue-green mudstones of the Innerelva Member of the Stappogiedde Formation crop out, but mostly as scree, on the sides of the road. A small hill, 271 a.s.l., northwest of the road, consists of quartzitic sandstone of the Hanglečærro Formation, separated from the subjacent mudstones of the Innerelva Member by a thrust fault. Folded and fairly poorly exposed rocks of the upper Tanafjorden Group may be seen along the ridge bordering the lake to the southwest. White quartzitic sandstone can be examined in a small quarry on the slope of this ridge at 766 242.

The Trollfjorden-Komagelv Fault Zone extends from the southeast, beneath the Gædnjajav'ri lake, towards the northwest and is clearly marked in the topography. Exposure along the fault zone in this area is generally very poor.

Approximately 500 m northwest of the quarry, breccia and cataclastic fault rocks associated with the TKFZ are locally exposed. Further northwest (755 265), one of the main segments of the TKFZ defines a NW-SE trending valley along which slickensided and brecciated rocks can be observed. The deformation is more intense in the strongly fractured quartzitic sandstones of the Dakkovarre Formation, whereas the coarse-grained sandstones and conglomerates of the Sandfjorden Formation are less deformed but contain a series of well developed quartz vein arrays. This locality can be reached in a 20-30 minutes walk from the northwestern tip of lake Gædnjajav'ri.
(The text to this paragraph has been contributed by Ridvan Karpuz).

The rocks exposed on the northeastern side of the lake belong to the Sandfjorden Formation. The coarse-grained to conglomeratic, reddish-yellow arkoses of this formation may be observed in the slope northwest of the road (c.770 255). The Sandfjorden Formation rests transgressively on various formations of the Barents Sea Group and covers a large area in the central part of Varanger Peninsula.

Locality 24. Tranga, road-cuts over a distance of more than 1 km, 778 351-785 356, map-sheet 1:50,000 2336 II Kongsfjord (topographic map and map of bedrock geology, Siedlecka 1989).

Sandfjorden Formation, Båtsjord Formation, Båsnæringen Formation (Fig. 32).

The Gædnja river crosses a NW-SE ridge underlain by arkoses of the Sandfjorden Formation, which rests unconformably on the Båtsfjord Formation. Road-cuts provide a good section through the thick-bedded, cross-stratified, pink and yellowish-grey, medium- to coarse-grained and conglomeratic arkoses. Sand grains and small pebbles of white quartz and red jasper are well-rounded and cemented with quartz and carbonate cement and subordinate sericite and chlorite. Zircon, tourmaline, rutile and garnet are the principal heavy minerals (Siedlecki & Levell 1978).

The Sandfjorden Formation is interpreted as a shallow-marine deposit accumulated in an area dominated by strong tidal currents (Levell 1980).

The Båtsfjord Formation crops out north of the ridge in small road-cuts. The unconformity is not exposed. Grey and yellowish-grey carbonate-bearing sandstone interbedded with blackish-grey clayey shale and red muddy shale is best seen on the eastern side of the road. Current ripples and desiccation cracks (Fig. 33) are common on the bedding surfaces of these beds, providing evidence of shallow-water sedimentation with temporary exposure above water level.

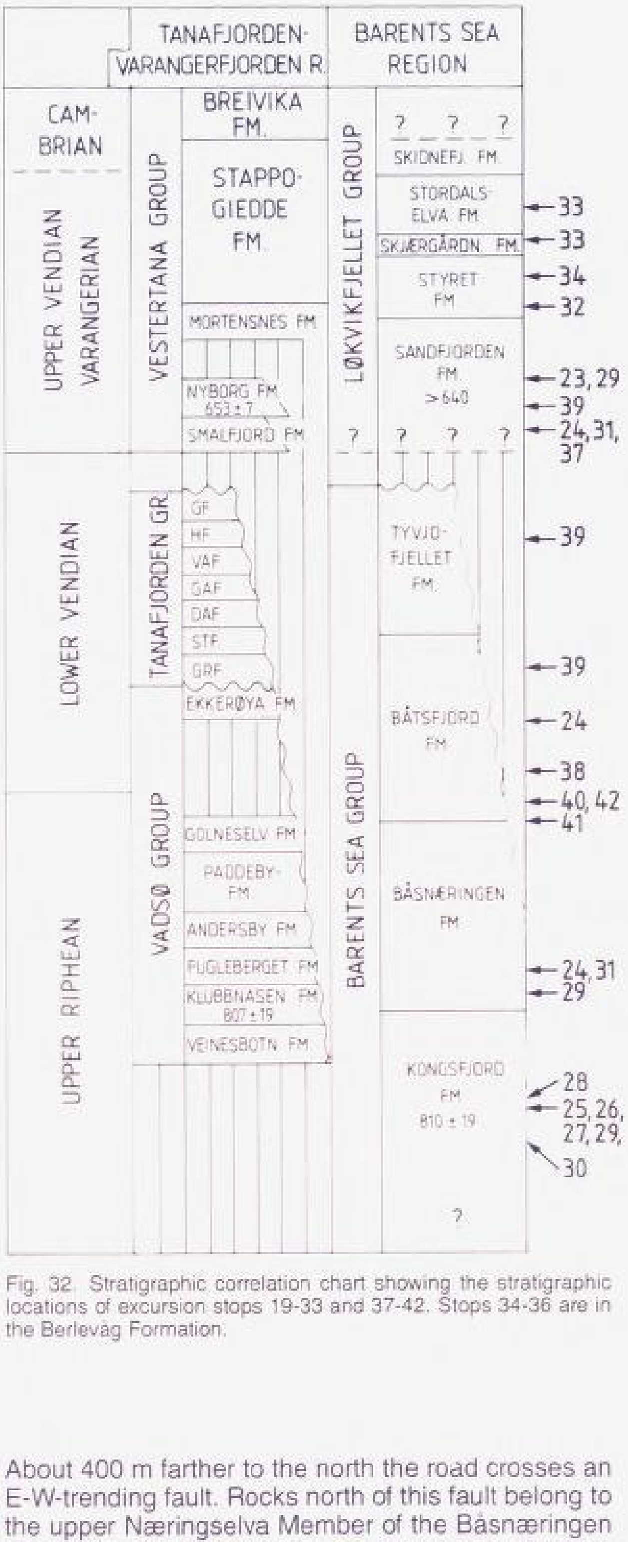


Fig. 32. Stratigraphic correlation chart showing the stratigraphic locations of excursion stops 19-33 and 37-42. Stops 34-36 are in the Berlevåg Formation.

About 400 m farther to the north the road crosses an E-W-trending fault. Rocks north of this fault belong to the upper Næringselva Member of the Båsnæringen Formation. Medium-thick to very thick beds of a dark-grey, fine-grained to medium-grained sandstone are exposed in a c.300 m long road-cut. The sandstone beds are mostly massive, but some exhibit parallel lamination. These beds have probably originated in a prodelta environment of the Båsnæringen deltaic system (Siedlecka & Edwards 1980).

The rocks are dissected by a tightly spaced system of steep joints, oriented approximately E-W to WNW-ESE.

Fig. 33. Desiccation cracks in the sandstone-mudstone interbedded series of the Båtsfjord Formation, locality 24.

Locality 25. Rundvatnet, road-cuts at 842 443, map-sheet 1:50,000 2336 II Kongsfjord (topographic map and map of bedrock geology, Siedlecka 1989).

Kongsfjord Formation, Risfjorden Member (Fig. 32).

Thin beds of grey sandstone interbedded with dark-grey muddy shale are exposed in high road-cuts on both sides of the road (Fig. 34). Medium-thick and thick beds of sandstone are subordinate. The sandstone beds show some graded bedding, and parallel

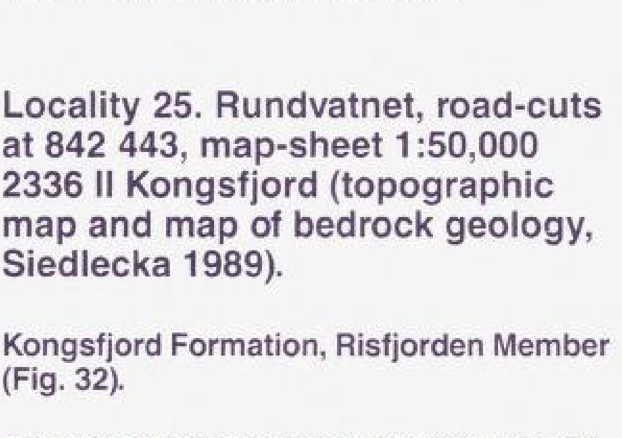


Fig. 34. Turbidites of the submarine fan of the Kongsfjord Formation, Risfjorden Member, exposed in road-cuts at Rundvatnet, with thick-bedded channel deposits in the middle of the picture. Locality 25. The hammer for scale, bottom right, is c. 30 cm long.

lamination may be observed in the upper parts of some graded beds. The sandstone beds are sharply and erosively based and their lowermost portions may contain fragments of shale. This flysch-like turbidite sequence is interpreted as having accumulated on a submarine fan, possibly in its middle to lower part (Siedlecka 1972, Pickering 1981).

The beds are inclined steeply towards the northwest and are folded, the folds carrying an axial plane slaty cleavage, S1. In places there are good examples of cleavage refraction; from slaty cleavage in the pelites into a shallower dipping fracture cleavage in the sandstones. Two, pale green-grey, strongly cleaved metadolerite dykes, c. 0,5 m thick, lie subparallel to the near-vertical, penetrative, S1 cleavage.

Locality 26. Kongsfjorden, Djupbukta, cliffs at c.844 466, map-sheet 1:50,000 2336 II Kongsfjord (topographic map and map of bedrock geology, Siedlecka 1989).

Kongsfjord Formation, Risfjorden Member, metadolerite dykes.

Coastal cliffs in the inner part of Kongsfjorden, cut by the road, provide excellent exposure of turbidites of the Kongsfjord Formation dissected by a swarm of metadolerite dykes.

The Kongsfjord Formation is represented here by thin-bedded and fine-grained turbidites in which graded bedding and parallel lamination are ubiquitous, and various sole marks may be observed (Siedlecka 1972). These turbidites were interpreted by Pickering (1981) as having accumulated mostly as unchannelled, distal deposits in an outer fan.

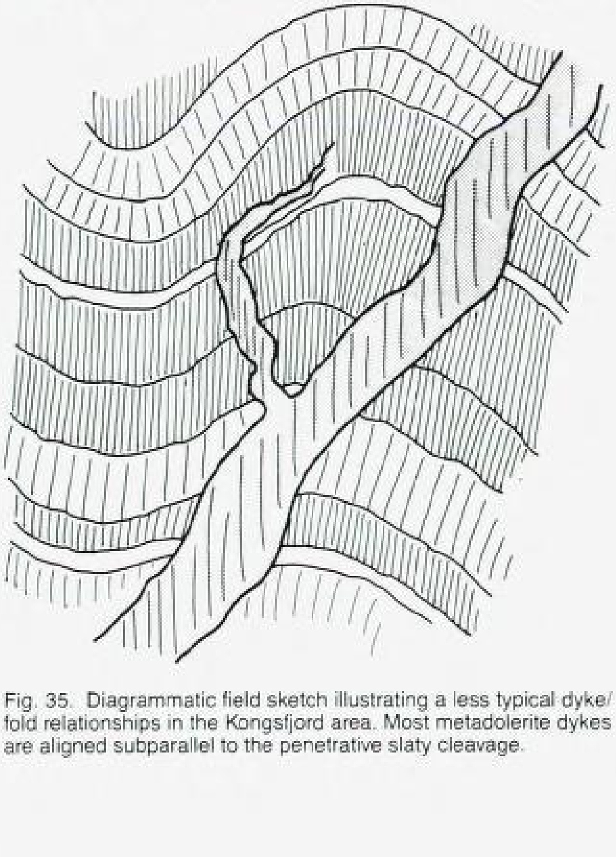


Fig. 35. Diagrammatic field sketch illustrating a less typical dyke/fold relationships in the Kongsfjord area. Most metadolerite dykes are aligned subparallel to the penetrative slaty cleavage.

The ENE-WSW-trending metadolerite dykes, brown- to green-weathering and generally a few metres in thickness, are almost vertical and are prominent in the coastal landscape, standing out as ribs. They are generally cleaved, though to varying degrees, with the cleavage oriented at a variable, low angle to the margins of the dykes (Roberts 1972, fig. 14). Thin dykes, only a few centimetres in thickness, are pale green-grey in colour, penetratively cleaved and commonly boudinaged; and many such dykes or offshoots from larger dykes thin out either along or at varying angles to the S1 cleavage. The dykes as a whole have clearly been subjected to strike-parallel extension. Quartz and calcite veins are abundant in many dykes and commonly arranged in a 'fiederspalten' pattern (an en échelon array of veins), or in conjugate sets of vein arrays.

The metadolerites consist mainly of strongly altered plagioclase and chloritised clinopyroxene. Relict ophitic to subophitic texture is present in the central parts of many dykes. Geochemical data indicate that the metadolerites are representative of magmas transitional to those producing abyssal tholeiites and continental basalts (Roberts 1975).

One dyke along this section (precise location unknown) was dated by the K-Ar method to 1193±36 Ma (Beckinsale et al. 1975, recalculated). However, the value of this determination is uncertain because of the very low potassium content.

The metadolerite dykes have been interpreted as broadly 'syntectonic', though pre-dating the prominent cleavage which is axial planar to the common open to tight folds (Roberts 1972). Although it is tempting to consider the dykes as wholly pre-tectonic, related to a phase of rifting (Roberts 1975), the fact that some of them cut obliquely across folds but are themselves penetratively cleaved (Figs. 35 & 38) argues against this interpretation, at least for these particular dykes. Another possibility is that we are dealing with more than one generation of pre-cleavage mafic dykes.

Locality 27. Kongsfjorden, Hergevika, 854 489, map-sheet 1:50,000 2336 II Kongsfjord (topographic map and map of the bedrock geology, Siedlecka 1989).

Kongsfjord Formation, Risfjorden Member, metadolerite dyke.

Turbidites of the Kongsfjord Formation are well exposed on the southern side of the bay, along the coast below the road. These outer fan deposits (Pickering 1981) exhibit sedimentary structures such as graded bedding, parallel lamination, load casts, pseudonodules and clastic dykes. Intraformational mud-chip breccias may also be observed. Sedimentary structures are, in general, abundant in the Kongsfjord Formation and spectacular examples may be observed in several places (Figs. 39, 40).

Fig. 36. Relationship between folds and slaty cleavage in a multilayered, turbiditic, sandstone-pelite sequence, Kongsfjord Formation, Hergevika. The outcrop is in the hinge zone of a large-scale anticline; from Roberts (1972).

Pelitic layers and the clay-rich portions of mud-chip beds display the usual penetrative S1 cleavage, which is axial planar to local mesoscopic folds (Fig. 36). In some outcrops a second, spaced, crenulation cleavage is developed. Elsewhere in the Risfjorden area this second cleavage can be shown to have an axial planar attitude to small-scale close to open folds.

A bifurcating metadolerite dyke crops out in the northern part of the bay. In several places, the contacts between the cleaved metadolerites and the host rocks are well exposed. Networks of white quartz-calcite veins transect the dykes. Although the metadolerite dykes are generally oriented subparallel to the penetrative S1 cleavage (Fig. 37), there are many examples where they cut across the folds (Fig. 38) yet carry the same S1 cleavage as in the host rocks. Such dyke/fold relationships are particularly well seen at low tide along the foreshore of Aust Risfjorden between c. 849 494 and 839 488.

Fig. 37. A rather common dyke/fold relationship in the Kongsfjord Formation, Risfjord, Kongsfjorden; looking northeast. From Roberts (1972).

A metadolerite dyke exposed in the vicinity of Hergevika (precise location unknown) has been dated by the K-Ar method to 945±28 Ma. The reliability of this date, however, is in doubt because of a very low potassium content (Beckinsale et al. 1975).

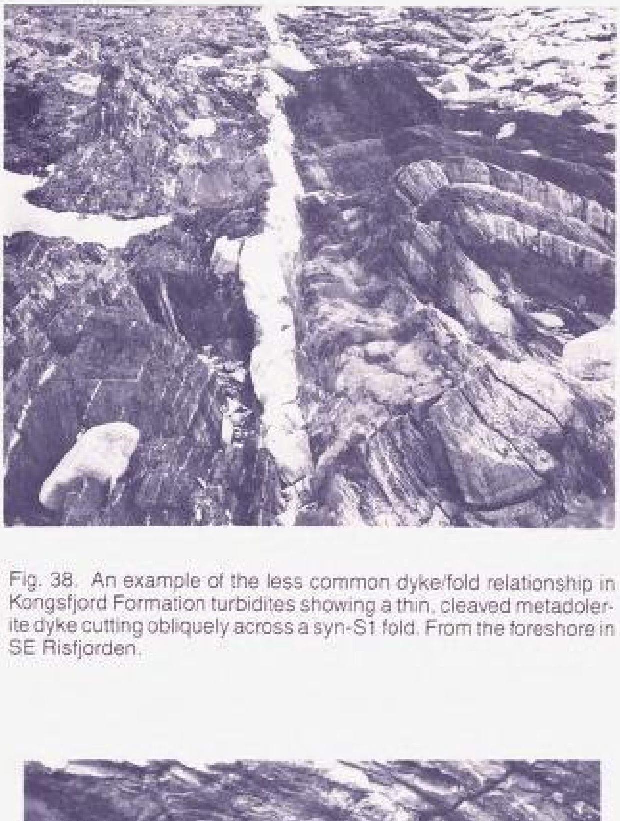


Fig. 38. An example of the less common dyke/fold relationship in Kongsfjord Formation turbidites showing a thin, cleaved metadolerite dyke cutting obliquely across a syn-S1 fold. From the foreshore in SE Risfjorden.

Fig. 39. Frondescent casts in turbidites of the Kongsfjord Formation. Southeastern coast of Veines Peninsula in Kongsfjorden. Photo S. Siedlecki.

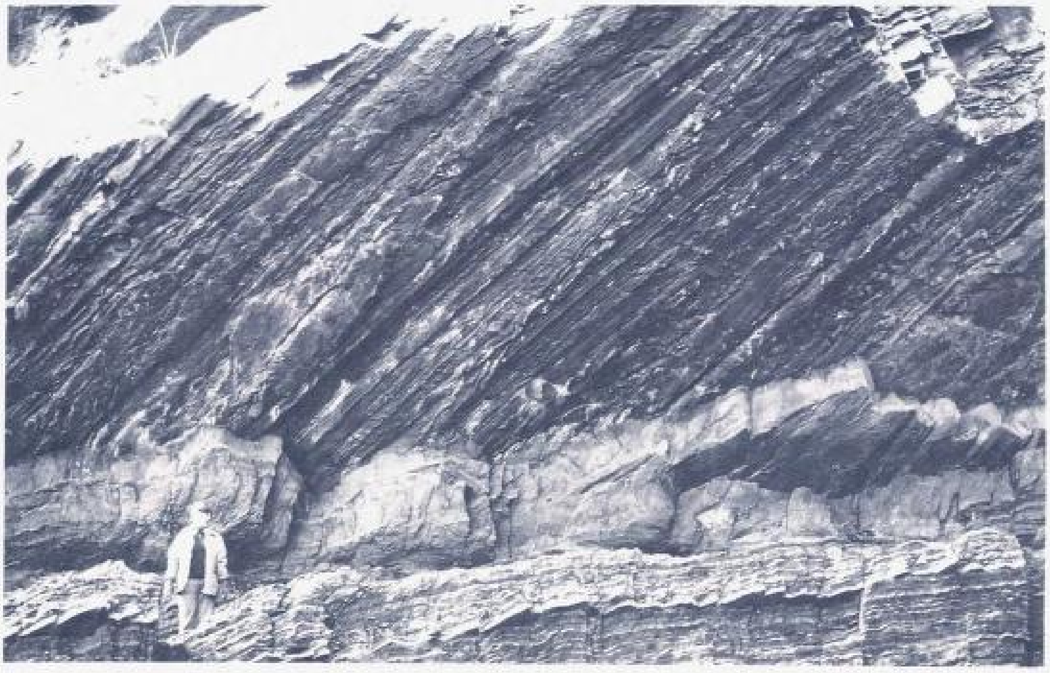


Fig. 40. Large groove casts in turbidites of the Kongsfjord Formation exposed in Veines Peninsula (Riš'šančilanjar'ga) in Kongsfjorden.

Locality 28. Western part of Risfjorden, near the mouth of the Meresjåkka river, 842 510, mapsheet 1:50,000 2336 II Kongsfjord (topographic map and map of the bedrock geology, Siedlecka 1989).

Kongsfjord Formation, Nålneset Member

Thick, graded-bedded, turbidite beds crop out on the northern side of the road. These beds represent deposits accumulated in large channels of the middle fan environment of Pickering (1981).

The predominantly thick-bedded sequence exposed here is dissected by a system of joints oriented N-S and E-W with easterly and southerly dips, respectively. Folds which carry the S1 cleavage along their axial surfaces – as a divergent slaty cleavage in siltstones and pelites, and a convergent, fanning, fracture cleavage in thick sandstones – are seen nearby in cliff-like roadside exposures (Fig. 41).

Dykes of metadolerite may be observed along the northwestern coast of Risfjorden. However, they are noticeably fewer in number compared with the Kongsfjorden area further to the southeast.

Fig. 41. Thick-bedded channel deposits and thin-bedded interchannel accumulations in the middle fan turbidite series of the Kongsfjord Formation, Risfjorden Member; close to locality 28 on the northestern side of Risfjorden. The convergent, fanning, fracture cleavage is well developed in the sandstones.

Locality 29. Stop between Kongsfjorden and Sandfjorden at c. 861 550, map-sheet 1:50,000 2336 I Berlevåg. View towards locality 31.

Contact between the Barents Sea Group (Kongsfjord Formation and Båsnæringen Formation) and the Løkvikfjellet Group (Sandfjorden Formation).

Excellent view towards northwest (Fig. 42). The coastal plain to the right of the road and the low hill to the left in the foreground are underlain by the Kongsfjord Formation (inner fan of Pickering 1981). A somewhat higher hill in the middleground is underlain by the Næringselva Member of the Båsnæringen Formation, Næringselva Member. Finally, the high, light-coloured ridge on the opposite side of Risfjorden and the plateau in the background consist of the Sandfjorden Formation of the Løkvikfjellet Group.

The unconformable contact between the Barents Sea Group and the Løkvikfjellet Group in this coastal area is dissected by faults. It is rather poorly exposed in a few places inland.

Locality 30. Laukvika, stop at the bridge at 844 556, map-sheet 1:50,000 2336 I Berlevåg.

Kongsfjord Formation, Nålneset Member

A few hundred metres walk towards the outer parts of Laukvika and Tarevika provides an opportunity to examine a section through the proximal part of the Kongsfjord submarine fan (Pickering 1981). The section contains medium- to coarse-grained sandstones and fine quartz conglomerates. Graded turbidite beds are interbedded with erosively based, lenticular conglomerate and coarse-grained sandstone beds which accumulated in channels. The conglomerates are either sandy and grain-supported, i.e. water-transported and deposited as bed load, or matrix-supported and unstratified (Fig. 43), and accumulated by subaqueous debris-flow. The interbedded, parallel-sided turbidites were probably deposited in the interchannel areas.

The regional S1 cleavage can be seen in the thin, pelitic interbeds, here dipping steeply to the south. A cleavage/bedding intersection lineation plunges at 20-30° towards the west.

Fig. 42. View towards the contact between the Barents Sea Group and the Løkvikfjellet Group at Sandfjorden. In the foreground and left-middleground – Kongsfjord Formation. Right-middleground and left-background – Båsnæringen Formation. Pinkish-coloured rocks in the middle- and right-background – Sandfjorden Formation. The low-angle unconformity is faulted and poorly exposed in this coastal area.

Fig. 43. Matrix-supported conglomerate – a subaqueous debris flow in the proximal part of the Kongsfjord Formation submarine fan. Note large angular fragments of soft sediment. The hammer is c. 30 cm long.

Locality 31. Sandfjorden, NW side, c.831 572, map-sheet 1:50,000 2336 I Berlevåg.

Båsnæringen Formation, Næringselva Member, in tectonic contact with the Sandfjorden Formation (Fig. 32).

The road crosses strongly cleaved and jointed, blue-green, laminated mudstone and muddy shale. The same rocks, belonging to the Næringselva Member, are also well exposed in the low cliffs nearby.

A few tens of metres further to the northeast the road crosses medium- to thick-bedded pink arkose and conglomerate of the Sandfjorden Formation. These rocks are particularly well exposed just below the road. The Sandfjorden Formation can be seen along the road over a distance of several kilometres as pink, greenish-grey arkoses and grey sandstones. The arkoses and sandstones are well-sorted with well-rounded grains. The conglomerate pebbles consist primarily of milky quartz, quartzite, black chert and red jasper. The beds are parallel-sided, and commonly trough cross-bedded. The feldspars are mostly microcline and perthite. Heavy minerals include zircon, rutile, tourmaline, garnet and other stable minerals (Siedlecki & Levell 1978).

The Sandfjorden Formation has been interpreted as a shallow-marine deposit which accumulated under the influence of tidal currents (Levell 1980).

There is a fault separating the Båsnæringen Formation and the Sandfjorden Formation at this locality. This is believed to continue westward along the scree-covered slopes. The actual contact, however, is not exposed.

Locality 32. Styret, c.831 599, map-sheet 1:50,000 2336 I Berlevåg.

Styret Formation, lower part.

Thick beds of greenish-grey, in places reddish-grey, trough cross-bedded sandstone crop out in road-cuts. Typically, the sandstone beds are lenticular and erosively based, in places with considerable relief (Levell & Siedlecki 1978). Pebbles and feldspar are less common than in the Sandfjorden Formation. There is a gradual transition between the Sandfjorden and the Styret Formations and the boundary was placed on the basis of studies of sedimentary structures rather than on overall lithological appearance. The Styret Formation was interpreted by Levell (1980) as largely of fluvial origin.

Upwards in the sequence assigned to the Styret Formation there is a gradual increase of clayey and muddy shale beds interbedded with the sandstone, and at the same time the thickness of the sandstone beds decreases. This gradual change in lithological composition is clearly visible in the cliffs bordering Styrsletta from the southwest. The upper Styret Formation may also be examined at c.828 604 (western side of the road) about 200 m south of the Styrelva river.

A cleavage, of very tightly spaced solution cleavage type, is developed in the pelitic layers of this formation. In the sandstone beds it is seen as a widely spaced fracture cleavage. A cleavage/bedding intersection lineation plunges at a low angle to the ENE.

A dolerite dyke, c. 4 m thick and c. E-W trending, cuts the sediments c. 100 m north of this locality. This has been K-Ar dated to 362±10 Ma (Beckinsale et al. 1975, recalculated).

Locality 33. Skjærgårdnes, 823 611, (optional: Mellanes c.822 620) map-sheet 1:50,000 2336 I Berlevåg.

Skjærgårdneset Formation, Stordalselva Formation.

Dark-grey, thick-bedded sandstone interbedded with muddy shale (the Skjærgårdneset Formation) crops out along the road and in the coastal section. Typical for the sandstone is tabular, herring-bone cross-bedding, reflecting varying palaeocurrent directions. The sandstones are moderately well sorted and sub-arkosic in composition and were interpreted by Levell (1980) to be of shallow-marine origin.

Between Skjærdgårdnes and Kjølnes Fyr further to the northwest, the road crosses a syncline with rocks belonging to the Stordalselva Formation in its core, and with the Skjærgårdneset Formation reappearing at Kjølnesaksla and Kjølnes Fyr.

There are no road-cuts in the Stordalselva Formation, but good coastal exposures occur close to Mellanes. The axial zone of the syncline is located about 150 m south of the tip of Mellanes. The uppermost part of the Stordalselva Formation visible in the Mellanes section, consists of thick trough cross-bedded, coarse-grained sandstones underlain by dark-grey, laminated mudstone interbedded with rippled arenaceous shale and ripple cross-stratified, thin- to medium-bedded sandstone. Interbeds of thick, coarse sandstones with mixed mudstone-sandstone units are typical of this formation, interpreted as a shallow-marine deposit (Levell 1980).

From Skjærgårdnes to Mellanes, mesoscopic folds increase markedly in number, and in the axial zone of the major syncline they show rapid plunge variations, locally up to 75-80°, within the S1 cleavage. The spaced cleavage is very prominent here, with the development of quartz- and mica-rich domainal ribs ascribed to pressure solution processes ('spaced solution cleavage') (Fig. 44).

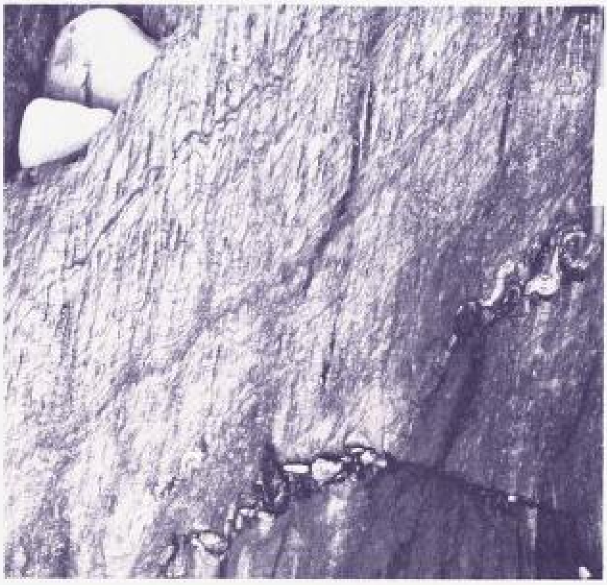


Fig. 44. Spaced S1 cleavage in the Stordalselva Formation, near Mellanes, showing quartz-rich ribs developed parallel to the near-vertical cleavage, at a moderately high angle to bedding. Locality 33.

Locality 34. Vargvika, c. 794 622, map-sheet 1:50,000 2336 I Berlevåg.

Tectonic contact between the Styret Formation of the Løkvikfjellet Group and the phyllite-metasandstone interbedded unit of the Berlevåg Formation (Tanahorn Nappe).

The high-angle thrust-fault separating the Løkvikfjellet Group from the Berlevåg Formation was mapped and described by Levell & Roberts (1977). The NE-SW-trending thrust-plane is not exposed along the road but it may be observed in the cliffs towards the southwest. There, a 7-10 m thick mylonite zone marks the contact, and the Styret Formation sandstones are partly vitrifred in a narrow, partly brecciated zone below the mylonite. A chloritic rock type present here is probably a deformed and retrogressed dolerite dyke. Small-scale, SE-facing asymmetric folds deform the mylonitic foliation. Immediately to the southeast of the Vargvika thrust, a second spaced cleavage (S2) is developed in Styret Formation rocks; this SE-dipping crenulation cleavage produces a marked kinking of the S1 spaced cleavage. Quartz veins occur along both the S1 and the S2 cleavages. In the Berlevåg phyllites, a NW- to NNW-dipping strain-slip (extensional) cleavage is well developed, indicating a top-to-the-SE shear movement.

In this northwestern part of Varanger Peninsula, the metasandstones and phyllites of the Berlevåg Formation form three mappable units, and at locality 34 an interbedded unit of blackish-grey phyllite, metasiltstone and thin-bedded metasandstone is thrust upon the coarse sandstones of the (lower) Styret Formation.

There is a perceptible difference in metamorphic grade between the very weakly metamorphosed rocks of the Løkvikfjellet Group and the greenschist-facies metasediments of the Berlevåg Formation (Levell & Roberts 1977). In the Berlevåg Formation the penetrative S1 is a true, fine-grained schistosity (transitional from slaty cleavage), whereas in the Løkvikfjellet Group it is a spaced solution cleavage. In terms of illite crystallinity (Rice et al. 1989b), the difference in metamorphic grade appears to be less marked (Berlevåg, high epizone grade; Løkvikfjellet, epizone). However, the Berlevåg Formation has suffered a more complex deformational history than the Løkvikfjellet Group and, in contrast to the latter, contains abundant metadolerite dykes.

Locality 35. Road-cuts at c. 784 621, map-sheet 1:50,000 2336 I Berlevåg.

Berlevåg Formation, coarse-grained metasandstone unit.

Steeply NW-dipping beds of metasandstone interbedded with subordinate phyllite are exposed in high road-cuts on both sides of the road. The metasandstone is coarse-grained, thin- to medium-bedded and exhibits a weakly developed graded-bedding and good examples of load casts and flute-casts.

The rocks in this area are strongly cleaved, the slaty cleavage or schistosity being axial planar to tight to isoclinal F1 folds which plunge steeply to the northwest. Three sets of folds and/or cleavages deform these early structures. The shear-band crenulation cleavage noted near locality 34 is less conspicuous here. On the other hand, small-scale asymmetric folds plunging NNW are common (Fig.45), and are well developed on the foreshore immediately to the east of the road-cut where they are clearly seen to deform flattened F1 folds and S1 slaty cleavage. A steeply dipping crenulation cleavage axial planar to these folds varies in development from a very weak structure to a prominent, semi-penetrative, tectonic banding. A third generation of post-S1 structures is represented by kink bands and small kink folds.

In the road-cut, a curious ribbing or groove lineation (Fig. 46) on bedding surfaces is of tectonic origin, produced by the intersection of the strain-slip, shear-band cleavage with the bedding.

Rocks belonging to the same unit may be conveniently examined in a quarry about 0.5 km south of the main road (776 618). Here, in addition to the coarse-grained sandstone (and subordinate semipelitic rocks), fine-grained quartz conglomerate is exposed. Pebbles are lineated within S1 and show a steep plunge to the northwest.

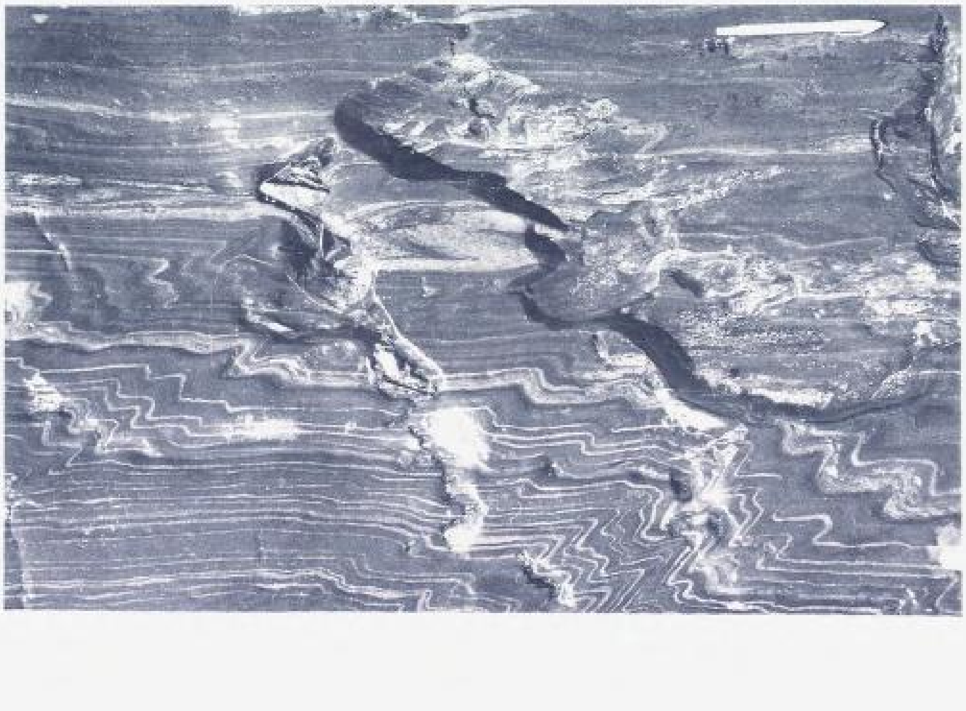


Fig. 45. Small-scale asymmetric folds deforming the bedding and S1 schistosity. A partly flattened F1 fold near the centre of the photograph shows an opposite vergence to that of the later, more open, asymmetric folds. Berlevåg Formation, on the foreshore just east of the road-cuts, locality 35; looking approximately northwest.

Fig. 46. Tectonic, rib-like, linear structure on bedding surfaces in interbedded sandstones and phyllites of the Berlevåg Formation, locality 35. From Roberts (1972).

Locality 36. Valen, coastal section north of the road at c.763 647, map-sheet 1:50,000 2336 I, Berlevåg.

Berlevåg Formation, upper metasandstone-phyllite interbedded unit.

The steeply westward-dipping rocks of this turbidite unit (Laird 1972) crop out in a low, partly vegetated coastal area. The sequence consists of thin- to medium-bedded, grey metasandstone beds, each bed sharply based and with an upward gradual transition into blackish-grey phyllite. Thin-bedded metasandstone beds are usually ripple cross-stratified while the medium-thick layers show graded bedding. Sporadic, thicker, white-weathering metasandstone beds display cross-bedding. Other primary structures present in the thinner bedded sequence include convolutions, ball-and-pillow, load casts and slump units (Fig. 47). Segregations of carbonate (siderite) are present in some sandstone beds.

Mesoscopic folds are common, generally plunging NNE, and carry a penetrative axial planar slaty cleavage or schistosity, S1. A faint 'fibre' lineation on schistosity surfaces, equivalent to a stretching fabric, can be seen in many places. This plunges at a moderately steep angle to the NNW-NW, which is quite oblique to the axial trend of mesoscopic folds in this particular area. Minor folds and kink bands which post-date the schistosity are also present.

Many metadolerite dykes, trending NE-SW to NNE-SSW, are exposed along the foreshore west from Valen. They vary in thickness from a few centimetres to 15 m in the case of one composite dyke. One of these cleaved dykes (exact location unknown) has been dated by the K-Ar method to 551±17 Ma (Beckinsale et al. 1975; recalculated).

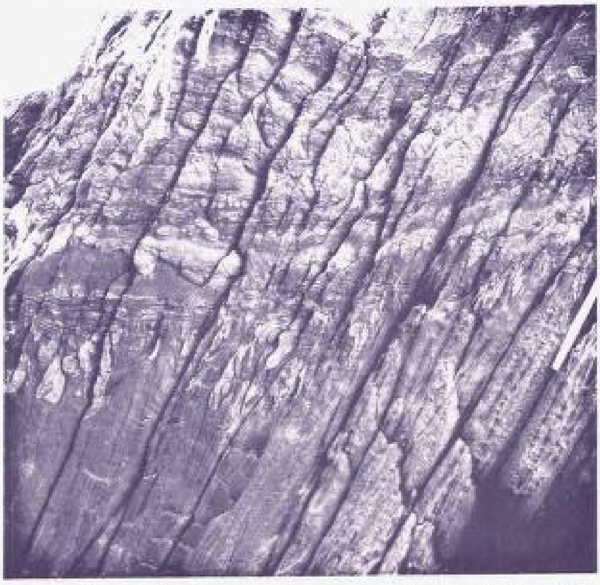


Fig. 47. Interbedded metasandstone and phyllite, Berlevåg Formation, showing small load casts and other associated primary structures partly transposed into the steeply dipping S1 schistosity. Coastal exposures just west of Valen, looking approximately north-northeast.

Central part of the Barents Sea Region

Drive from Berlevåg to the road junction on the mountain plateau near Gædnjajav'ri; then from Gædnjajav'ri to Båtsfjord along highway 891 and further on to Syltefjord along a local dirt road (Figs. 6 & 32). The total driving distance from the road junction, one way, is about 60 km. Localities 37 - 41 are located along this route. Locality 42 requires c. 35 minutes walking.

Locality 37. Adamsvatnet, c. 910 288, map-sheet 1:50,000 2436 III Båtsfjord (topographic map and map of bedrock geology, Siedlecka 1987).

Løkvikfjellet Group, Sandfjorden Formation.

Medium-thick and thick beds of pink arkose crop out in the hillslope about 50 m northwest of the road. This arkose, coarse-grained to conglomeratic, with quartz, quartzite and red jasper granules and pebbles, is a typical rock of the lower Sandfjorden Formation. The roundness of grains, good sorting, stable heavy minerals (e.g. zircon, tourmaline, rutile, garnet) and the quartz-quartzite dominated composition of the pebbles are characteristics which led to the interpretation of this unit as a shallow-marine deposit (Levell 1980a).

Locality 38. Annejåkka, section in a c. 2 km long road-cut (middle at c.970 330), map-sheet 1:50,000 2436 III Båtsfjord (topographic map and map of bedrock geology, Siedlecka 1987). (The old road is marked on the maps: the new road with the exposed section has a different location !).

Båtsfjord Formation, transition between the Skovika Member and the Annijokka Member.

This multicoloured sequence, composed of purple mudstone interbedded with grey, pink or red sandstone beds and sporadic yellowish-grey dolomitic layers, is typical of the upper Båtsfjord Formation. Although the uppermost (westernmost) part of the exposure is rather poor, sedimentary structures such as, e.g., rippled surfaces, ripple cross-lamination and desiccation cracks may be observed, testifying to a shallow-water deposition. Eastwards, and stratigraphically downwards in the section, there is a gradual transition into an interbedded sequence of greenish-grey mudstone, pink and greenish-grey carbonate-bearing and clayey sandstone and greenish-grey dolomite, bright-yellow on weathered surfaces. This sequence, typical of the Annijokka Member, is exposed in the lower (eastern) c. 600 m-long part of the road-cut. The beds are typically medium-thick, parallel-laminated and wavy laminated or rippled. Mud-chip breccias and desiccation cracks may be observed.

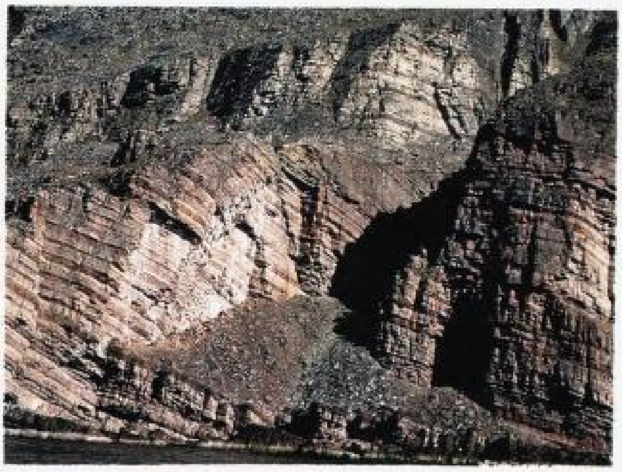


Fig. 48. The angular unconformity between the Tyvjofjellet Formation of the Barents Sea Group and the Sandfjorden Formation of the Løkvikfjellet Group exposed on the southeastern side of outer Båtsfjorden.

The Annijokka Member has been interpreted as having accumulated in a marine coastal area, largely on tidal flats (Siedlecka 1978).

In the upper part of the section there are two metadolerite dykes, one c. 4 m thick with a green epidote-quartz vein and the other c. 60 cm in thickness.

Locality 39. View-point, NW side of Båtsfjorden, northeast of Båtsfjord settlement, c. 017 405, map-sheet 1:50,000 2436 III Båtsfjord (topographic map and map of the bedrock geology, Siedlecka 1987).

Unconformity between the Sandfjorden Formation of the Løkvikfjellet Group and the Tyvjofjellet Formation and the Båtsfjord Formation of the Barents Sea Group (Fig. 32). Dolerite dykes.

In clear weather the view towards the cliffs on the southeastern side of Båtsfjorden shows the angular unconformity between the Barents Sea Group and the Løkvikfjellet Group. The purple and yellowish-pink banded mudstone and sandstone sequence of the Tyvjofjellet Formation and the uppermost Båtsfjord Formation (the latter seen best in the NW-cliffs of the inner Båtsfjorden) are sharply overlain by a homogeneous, pink sandstone sequence of the Sandfjorden Formation (Fig. 48).

The unconformity is cut by a swarm of steeply dipping to vertical, metadolerite dykes (Fig. 49). The greenish weathering dykes are also numerous in the general vicinity of Båtsfjord, and many can be seen and studied by walking northeastwards from here along the shore. The NE-SW to NNE-SSW trending dykes are less pervasively metamorphosed and cleaved than those occurring in the Kongsfjord and Berlevåg areas. In some cases only the dyke marginal zones are cleaved. In the host metasediments the S1 cleavage may be oblique (by as much as 30°), but generally curves into subparallelism with the dyke margins.

Three of these dykes were dated by the K-Ar method to around 650 Ma (Beckinsale et al. 1975). Further isotopic dating work and a geochemical study are nearing completion.

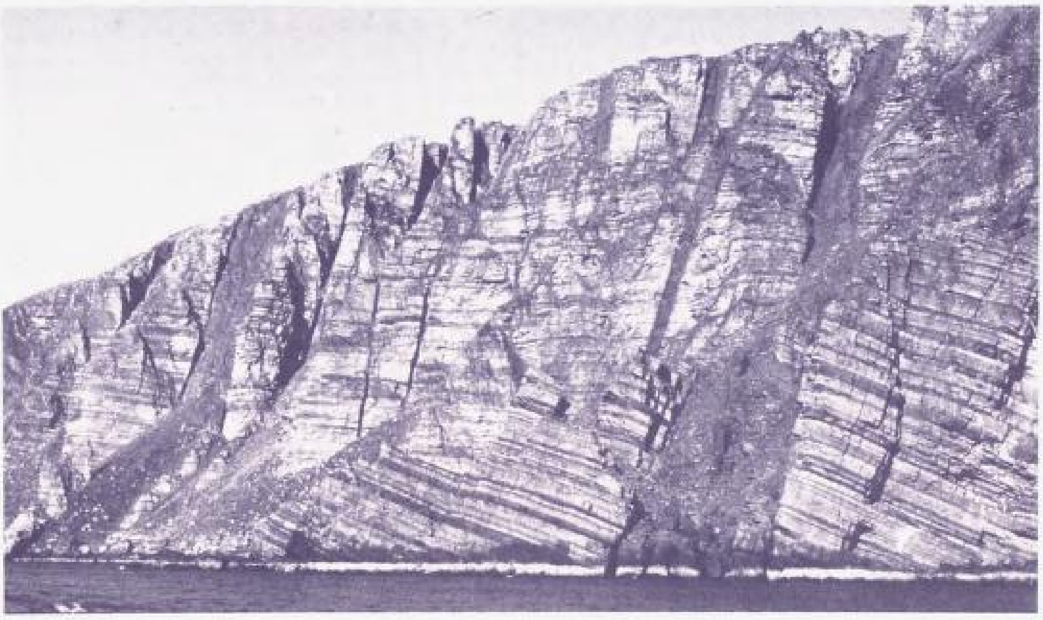


Fig. 49. Metadolerite and dolerite dykes intruding rocks of the Barents Sea Group and Løkvikfjellet Group. Southeastern coast of outer Båtsfjorden.

Locality 40. Arusjåkka, road-cut at c. 987 327, map-sheet 1:50,000 2436 III Båtsfjord (topographic map and map of the bedrock geology, Siedlecka 1987).

Båtsfjord Formation, Annijokka Member.

A section through the (upper) Annijokka Member is exposed in a c.400 m-long road-cut, along a marked bend in the road to Syltefjord. The section consists of interbeds of blue-green to greenish-grey, thick-bedded, banded mudstone, dark-grey clayey shale and yellowish-grey arenaceous dolomite. These rock-types form recurrent sandstone-shale-mudstone-dolomite cycles. The cycles are particularly well-exposed in the eastern part of the road-cut. At the same time there appear purple-coloured mudstones and reddish-grey sandstones typical of the upper Båtsfjord Formation. There is an abundance of sedimentary structures preserved in these beds: parallel horizontal lamination, ripple cross-stratification, ripple marks, desiccation cracks, intraformational mud-chip breccias and 'birds eye' structures (Fig. 50). Pseudomorphs after salt have been found in this locality by S. Siedlecki (personal comm.).

The Annijokka Member was interpreted by Siedlecka (1978) as a coastal marine deposit accumulated mainly on tidal flats, with the terrigenous-carbonate sequences reflecting shallowing-up conditions.

The weakly metamorphosed sedimentary sequence carries a fairly penetrative, SE-dipping, S1 slaty clea-

Fig. 50. Many sedimentary structures, in particular birds-eye structures (filled with calcite) and intraformational breccias, common in the Båtsfjord Formation, may be studied in the road-cut labelled as locality 40.

vage. In a part of the road-cut, two mafic dykes, 50 cm and c. 35 cm thick, merge into one composite dyke and are oriented subparallel to the cleavage. Quartz-calcite veins are prominent in the dykes; and they also extend out into the hornfelsed aureole zone and transect S1.

Locality 41. Straumen, road-cuts and exposure in the hillslope of Veineset, map-sheet 1:50,000 2436 II Syltefjord.

Stratigraphic contact between the Båsnæringen Formation and the Båtsfjord Formation, section of the Annijokka Member, stromatolites.

The local dirt road to Hamna in Syltefjord crosses the stratigraphic contact between the Hestman Member of the Båsnæringen Formation and the Annijokka Member of the Båtsfjord Formation (Figs. 51 & 52). The contact is clearly visible from a distance in the southwestern slope of Hamnefjellet, and the rocks of both units may be examined along the road.

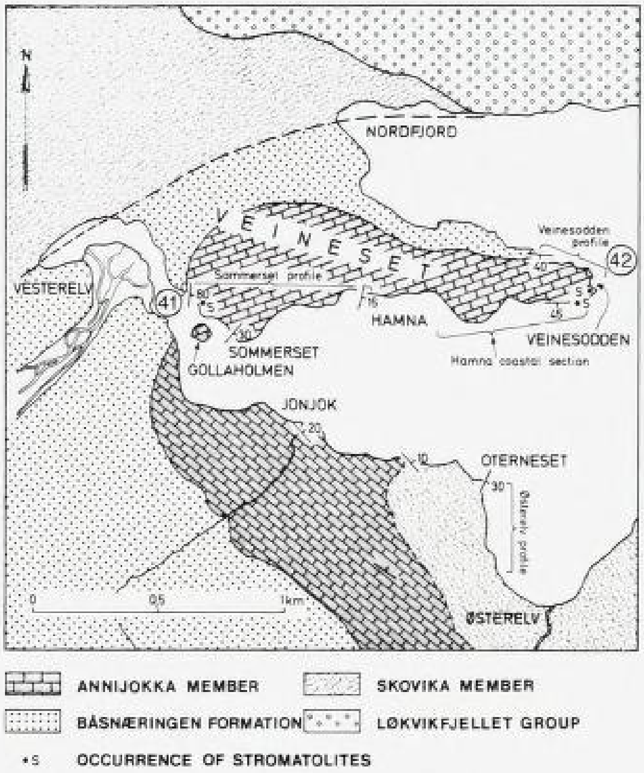


Fig. 51. Geological map of the area around the head of Syltefjorden. Localities 41 and 42 are indicated.

A c. 200 m-thick section of the Annijokka Member is exposed along the road and coast over a distance of more than 4 km (the Sommerset profile of Siedlecka, 1978). The section consists of siliciclastic and carbonate rocks arranged in recurrent cycles each a few metres thick. The cycles start with sandstone grading into siltstone, followed by claystone and dolomite with limestone. At the same time there is, in the section, a gradual upward increase in carbonate rocks at the expense of terrigenous beds, testifying to a gradual transition from terrigenous to carbonate deposition. There is, in these rocks, an abundance of sedimentary structures such as cross bedding, ripple cross-stratification, flaser and lenticular bedding (Fig. 53), parallel lamination, desiccation cracks, mud-chip breccias and 'birds eye' structures in dolomite. In addition,

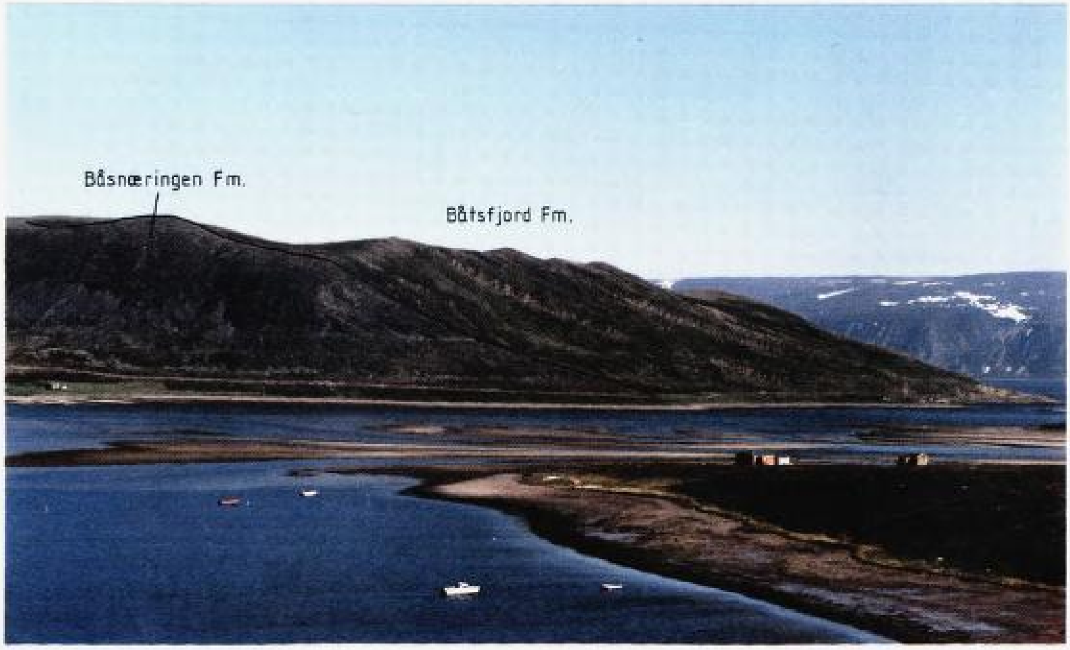


Fig. 52. View towards Veineset in inner Syltefjorden. The contact between the Båsnæringen Formation and the Båtsfjord Formation is visible in the slopes, and the section is partly exposed along the coastal road. Locality 41 is close to the road at the far right.

there are at least two stromatolite biostromes containing non-columnar stromatolites.

A terrigenous-carbonate tidal flat environment of sedimentation for this succession has been proposed by Siedlecka (1978). The stromatolites were interpreted as having formed in supratidal, fresh-water to schizohaline ponds (Siedlecka 1982).

Calcareous concretions, developed and superimposed on rippled and laminated terrigenous-dolomitic sediment, may also be observed in this section (Fig. 54).

Fig. 53. Dolomitic sandstone and mudstone beds with flaser and lenticular bedding in the Annijokka Member of the lower Båtsfjord Formation at locality 41.

Locality 42. Veinesodden, section at c.936 283, map-sheet 1:50,000 2436 II Syltefjord.

Hestman Member of the Båsnæringen Formation in stratigraphic contact with the Annijokka Member of the Båtsfjord Formation; section of the Annijokka Member, stromatolites.

From the end of the road at Hamna (922 281), a c. 35 min. walk over the hill towards the east, to the northern coastal section of Veinesodden (last part of the walk along a rather steep sheep path !). The section is continuously exposed and it is recommended to examine it at low tide.

In this Veinesodden profile of Siedlecka (1978) (Fig. 51), several interesting features may be observed. The red feldspathic sandstone marking the top of the Båsnæringen Formation is overlain by a series of interbedded greenish-grey claystone and siltstone, grey sandstone and shaly sandstone and siltstone, blackish-grey claystone and carbonate rocks in which six stromatolite biostromes have been recorded. As in the Sommerset profile, the rocks are arranged in recurrent terrigenous fining-up to carbonate cycles. There is an abundance of sedimentary structures such as cross-bedding, ripple cross-stratification, flaser- and lenticular bedding, parallel lamination, desiccation cracks and intraformational mud-chip breccias. The structures testify to shallow-water sedimentation and a tidal-flat environment of deposition was sugges-

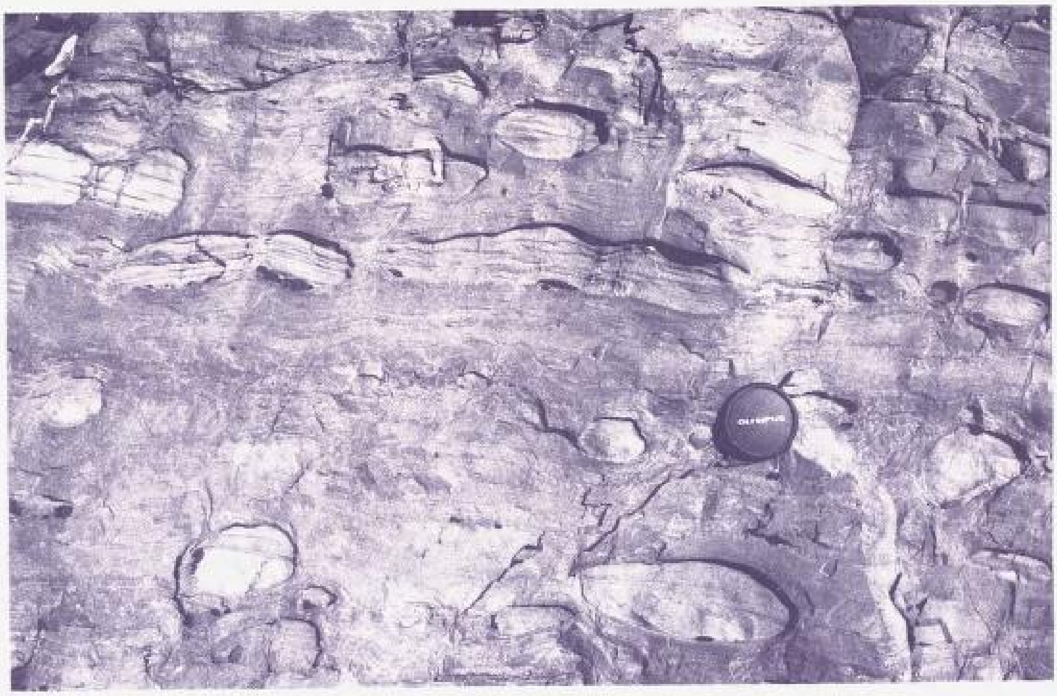


Fig. 54. Calcareous concretions in terrigenous-dolomitic beds of the Annijokka Member, Båtsfjord Formation, at locality 41. Parallel lamination and ripple cross-stratification (and other structures not visible here) are essentially undeformed, testifying to a late stage of formation of the concretions.

ted by Siedlecka (1978), with the cycles reflecting repeated shallowing-up events. Particularly interesting are synæresis cracks which occur in abundance and penetrate deeply into clay-rich beds. The stromatolites have unusual 'wash-bowl' shapes (Fig. 55), form calcareous horizons within terrigenous and dolomitic beds within the upper parts of the cycles, and were interpreted by Siedlecka (1982) as having originated in supratidal, fresh-water to shizohaline ponds.

As an alternative to this locality, a walk along the Hamna coastal section, east of Hamna (Fig. 51) can be recommended. Structures resulting from sediment desiccation and brecciation are particularly well exposed here. Some of the microspar-sealed pores have sub-cubic shapes and may represent pseudomorphs after salt crystals.

Fig. 55. Stromatolite-bearing, terrigenous-carbonate series of the Annijokka Member, Båtsfjord Formation, exposed at Veinesodden in inner Syltefjorden. Note the block with stromatolites, known as 'Holtedahl's block', which was pictured for the first time by Olaf Holtedahl in his 1918 memoir.

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Finnmark, in northern Norway, has long been a magnetic attraction to geologists. At the time of Everest`s and von Buch`s excursions in that county over one and a half centuries ago, the North Cape then served as the principal goal for our geo-forefathers. At about the same time Keilhau provided the first descriptions of the geology of East Finnmark; and later, Reusch established the glacial origin of a curious conglomerate - the now famous Reusch moraine" in Varangerfjorden. Over the past 2-3 decades emphasis has focused on the detailed geological mapping of the entire county, directed from the Geological Survey of Norway. The Varanger Peninsula in particular has figured prominently in this research effort, which has been coordinated by Anna Siedlecka and Stan Siedlecki.

In 1989, a collaboration programme was launched between the former Soviet, now Russian Academy of Sciences, Kola Branch, and the Geological Survey of Norway and included the project "Correlation ot the Middle-Upper Proterozoic sedimentary successions of the northern coastal areas of the USSR and Norway". Essentially, this involves the very low grade sedimentary rocks of Varanger Peninsula and the nearby peninsulas of Rybachi and Sredni, and Kildin island, in the Russian Federation. For the very first time specialists from both countries have together been able to visit neighbouring territories and examine the stratigraphy, sedimentology and tectonic structures of these excellently preserved successions. The excursion guide forming this Special Publication has been written in connection with this joint fieldwork.

The excursion guide is laid out in two parts. In a lengthy but concise introduction, the lithostratigraphical successions occurring throughout the peninsula are briefly described. A geological map in colour is also included. Short chapters are presented on basin development, tectonic structures and metamorphism, dolerite dykes, and aspects of correlation between Varanger and the Rybachi and Sredni Peninsulas. Descriptions of the excursion localities, 42 in number, form the main part of the guide. Precise locations and grid references are given for each stop, and the localities are also indicated on stratigraphic correlation tables. The excursion guide is illustrated with over forty field photographs, many of which are in colour, thus reminding one of the picturesque beauty ot this northeasternmost part of Finnmark.

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THE BEDROCK GEOLOGY OF VARANGER PENINSULA, FINNMARK, NORTH NORWAY: AN EXCURSION GUIDE

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