The type section of the Vikinghøgda Formation: a new Lower Triassic unit in central and eastern Svalbard

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Mørk, A., Elvebakk, G., Forsberg, A. W., Hounslow, M. W., Nakrem, H. A., Vigran, J. O. & Weitschat, W. 1999: The type section of the Vikinghøgda Formation: a new Lower Triassic unit in central and eastern Svalbard. *Polar Research 18(1)*, 51–82.

The Vikinghøgda Formation (250 m) is defined with a stratotype in Deltadalen-Vikinghøgda in central Spitsbergen. The Vikinghøgda Formation replaces the Vardebukta and Sticky Keep Formations of Buchan et al. (1965) and the lower part of the Barentsøya Formation of Lock et al. (1978) as extended geographically by Mørk, Knarud et al. (1982) in central Spitsbergen, Barentsøya and Edgeøya. The formation consists of three members: the Deltadalen Member (composed of mudstones with sandstones and siltstones), the Lusitaniadalen Member (dominated by mudstones with thin siltstone beds and some limestone concretions) and the Vendomdalen Member (composed of dark shales with dolomite interbeds and nodules). The Lusitaniadalen and Vendomdalen members replace the former Sticky Keep Formation/Member in the same area. The Vikinghøgda Formation can be followed through central and eastern Spitsbergen to Barentsøya and Edgeøya and includes all sediments between the chert-rich Kapp Starostin Formation (Permian) and the organic-rich shales of the Botneheia Formation (Middle Triassic). The subdivision into three members is also reflected in the organic carbon content and palynofacies. Upwards, each succeeding member becomes more distal, organic-rich and oil-prone than the one below.

The Vikinghøgda Formation is well-dated by six ammonoid zones, although the transitional beds between the Deltadalen and Lusitaniadalen members lack age diagnostic macrofossils. Corresponding palynozonation and magnetostratigraphy have also been determined. The overall stratigraphical development correlates well with other key Triassic areas in the Arctic, although intervals in the late Dienerian and early Smithian may be condensed or missing.

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Introduction

The Lower and Middle Triassic succession of Svalbard consists of fine-grained clastics. The dominant sediment supply from the west resulted in extensive deposits of coastal and shallow marine sandstones and shales in western Spitsbergen, whereas shales with minor siltstones and sandstones were deposited in a basinal setting in central and eastern Spitsbergen, Barentsøya and Edgeøya (Fig. 1). This sedimentary pattern continues southwards under the Barents Sea, with deposition of shales in basins and coarser grained clastics along the basin margins and on local highs.

The Vikinghøgda Formation, formally defined here, comprises Lower Triassic sediments in central and eastern Spitsbergen, Barentsøya and Edgeøya and has served as a practical mapping unit on the map series of the Norwegian Polar Institute (Major et al. 1992; Miloslavskij, Birjukov, Šlenskij, Hansen et al. 1993; Miloslavskij, Birjukov, Šlenskij & Dallmann 1998). The lithological and sedimentological description of the Vikinghøgda Formation type section is supplemented with biostratigraphical dating (macrofossils and palynology), magnetostratigraphy, and organic geochemical screening analyses.

Lithostratigraphical review: The Lower and Middle Triassic succession of Svalbard, the Sassendalen Group, was originally subdivided into the Vardebukta (Induan), Sticky Keep (Olenekian) and Botneheia (Anisian and Ladinian) formations by Buchan et al. (1965; Fig. 2). It was based on coastal and mountain exposures around Isfjorden. This nomenclature was followed

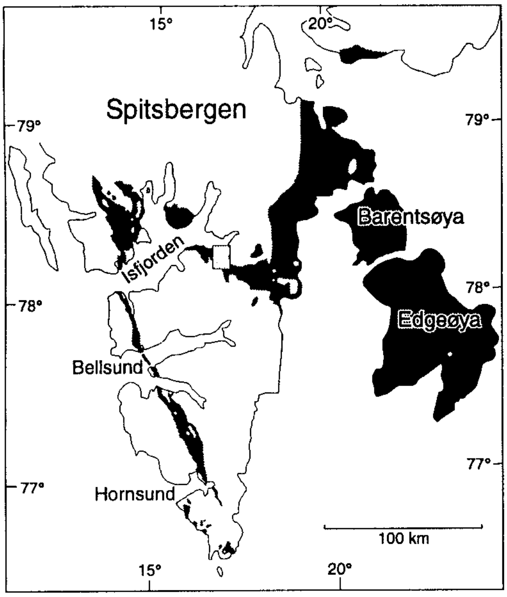


Fig. 1. Triassic exposures in Svalbard (black). Square indicates the detailed map of Fig. 3.

on the map sheets, although the Sticky Keep and Botneheia formations were grouped together as the Kongressfjellet Subgroup (Flood et al. 1971a; Major & Nagy 1972). Buchan et al. (1965) defined the Vardebukta Formation with a type section at Festningen in western Spitsbergen and the Sticky Keep Formation with a type section at Vikinghøgda in central Spitsbergen.

In the Hornsund area the local lithostratigraphy defined by Birkenmajer (1977) was later modified and incorporated into the general scheme erected for central Spitsbergen during the reappraisal of southern Spitsbergen by Worsley & Mørk (1978). Mørk & Worsley (1979) subsequently applied the stratigraphical scheme of Buchan et al. (1965) to the entire Svalbard archipelago.

In the eastern islands, Barentsøya and Edgeøya, extensive fieldwork by CASP (Cambridge Arctic Shelf Programme) and Norwegian Polar Institute geologists resulted in the preliminary map and stratigraphy of Flood et al. (1971b), adapting the principles used for Spitsbergen, although with lowered rank (i.e. Kongressfjellet Formation and Sticky Keep and Botneheia members). This nomenclature was followed on the published 1:500 000 map (Winsnes 1981). A more comprehensive description was given by the CASP group, with Lock et al. (1978) introducing a local nomenclature for the whole Triassic succession of Barentsøya and Edgeøya. These authors postulated that no subdivision was practical in these islands, and grouped all the sediments of the Sassendalen Group into the Barentsøya Formation, although they recognized the upper dark shales (the "oil shales member" of Falcon 1928), as forming a separate member. The shale-dominated Sassendalen Group sediments on eastern Spitsbergen, Barentsøya and Edgeøya show close similarities, that can be followed to central Spitsbergen and to the south-western part of Nordaustlandet, as shown by Mørk & Worsley (figure 7 in Mørk & Worsley 1979) and Pčelina (1983). Against this background, Mørk, Knarud et al. (1982) extended the Barentsøya Formation, as defined by Lock et al. (1978), to central and eastern Spitsbergen. In addition, they retained the units as defined by Buchan et al. (1965) as members, and they had to rename the lower unit the Deltadalen member as the Vardebukta Formation was retained for its type area in western Spitsbergen.

However, Pčelina (1983) retained the Vardebukta Formation for the central and eastern areas, but assigned the equivalent of the Sticky Keep Formation/Member to the Wichebukta Formation with a type section at Teistberget on eastern Spitsbergen. Pčelina also retained the Botneheia Formation with formational status in the same areas, although she followed Mørk, Knarud et al. (1982) and kept the Bravaisberget Formation for the equivalent beds in western Spitsbergen (Fig. 2).

The Committee on the Stratigraphy of Svalbard (Mørk, Dallmann et al. in press) suggests that the organic-rich phosphate-bearing shales defined as the Botneheia Formation by Buchan et al. (1965) should retain formational status, as suggested by Pčelina (1983). It will consequently replace the upper part of the Barentsøya Formation of Lock et al. (1978) and Mørk, Knarud et al. (1982), and prompt the need for a new formational unit for the underlying part of the Sassendalen Group.

The boundary between the two lower units of the Sassendalen Group has traditionally been regarded as corresponding to the Induan/Olenekian boundary. According to traditional western boreal terminology, this boundary corresponds to the Dienerian/Smithian transition (Lower and Upper Scythian: Buchan et al. 1965; Induan to Olenekian: Pčelina 1965, 1967, 1977, 1983; Korčinskaja 1982; Dienerian to Smithian: Tozer & Parker 1968; Mørk, Knarud et al. 1982; Mørk, Embry et al. 1989; Mørk, Vigran et al. 1993;

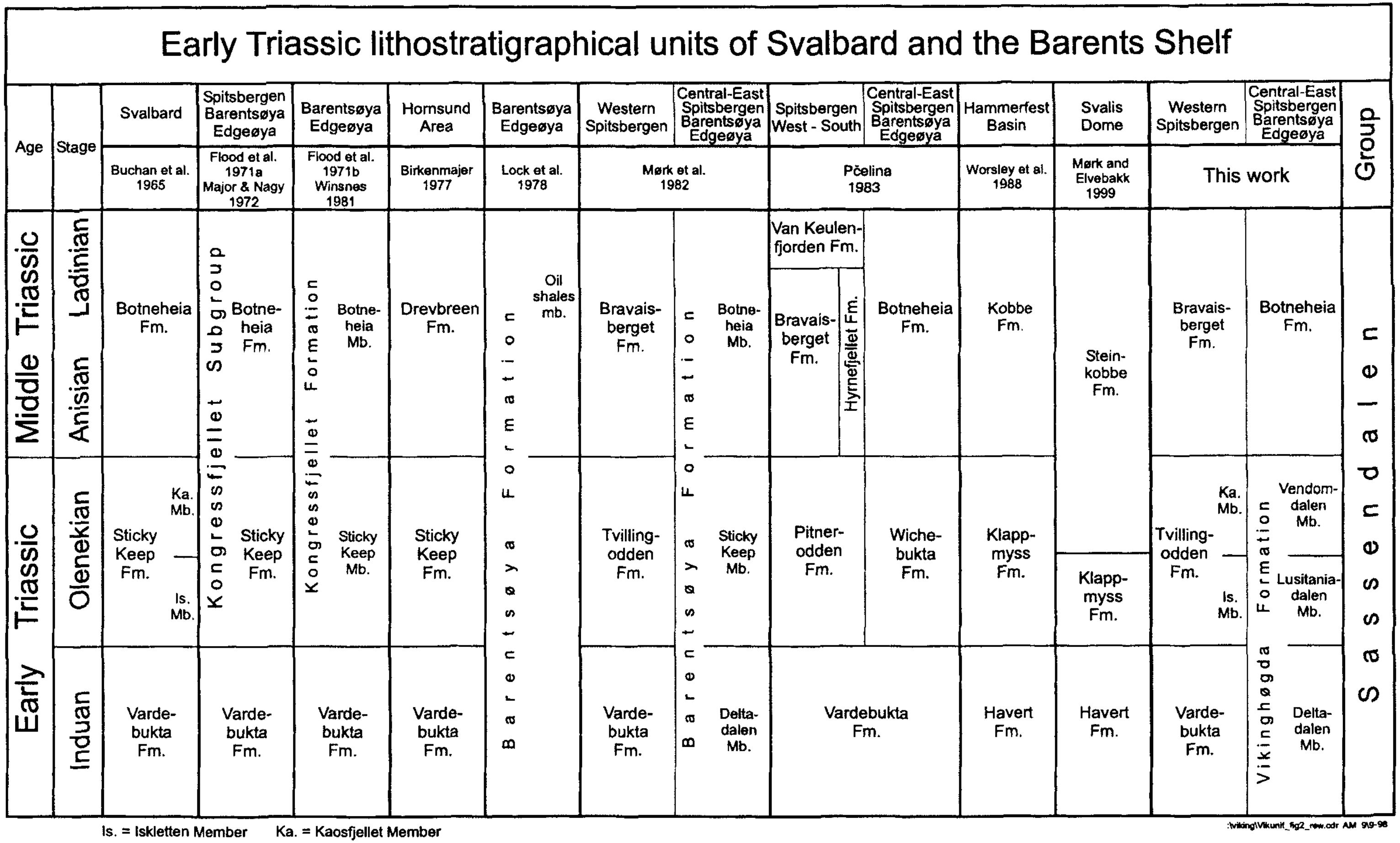


Fig. 2. Lithostratigraphical units used in the Lower and Middle Triassic succession.

Hochuli et al. 1989; and on numerous maps). The general description of these lower and upper units by all authors, has followed the same general principles, however the application of these definitions has not been straightforward, and misinterpretations have been inherited from paper to paper. Mørk, Embry et al. (1989), Mørk, Egorov et al. (1994) and Mørk (1994) interpreted a major circum-Arctic transgression as early Olenekian in age, and Vigran et al. (1998) and Van Veen et al. (1993) reported a pronounced transgression early in the Spathian in the western Barents Sea, similar to that reported by Embry (1988, 1997) in the Sverdrup Basin. These transgressions around the Dienerian–Smithian boundary have all been correlated with the change from the Deltadalen Member to the overlying unit.

In the type section at Vikinghøgda and the neighbouring mountain Sticky Keep, Buchan et al. (1965) defined the base of the Sticky Keep Formation at the first exposure above the scree-covered interval (i.e. at 115 and 129 m respectively). In the type section in Deltadalen, Mørk, Knarud et al. (1982) defined the boundary between the Deltadalen and Sticky Keep members 126 m above the base of the Triassic. This boundary is situated in the middle part of the well-defined Euflemingites romunderi Zone. No palaeontological study was carried out in the 1982 work and the boundary was partly based on the old interpretation of the nearby Sticky Keep section of Buchan et al. (1965). This misinterpretation was transferred to Stensiöfjellet where a correlative boundary was also drawn too high (figure 5 in Mørk, Knarud et al. 1982).

The new palaeontological evidence, and the improved understanding of the boundary criteria also indicate that the boundary at Høgrinden on Barentsøya and Veidebreen on Edgeøya are drawn too high. This interpretation is supported by the fauna reported from Krokå on central Edgeøya by Pčelina (1977) and by our fossil collection. An arctoceratid fauna occurs just above the Permian rocks, in a lithological setting similar to that occurring 20–40 m above the base at Høgrinden and about 50 m above the base at Veidebreen (figure 5 in Mørk, Knarud et al. 1982). Pčelina (1965, 1967, 1977, 1983) reported correctly that the basal Olenekian beds (the lower part of her Wichebukta Formation) consist of fossil-poor, dark, laminated mudstone.

A short distance (12 km) further west, at Botneheia, Buchan et al. (1965) reported the basal shore exposure as belonging to their Vardebukta Formation, and *Xenoceltites* sp. was reported from this exposure. We have also found numerous examples of *Arctoceras* sp. in limestone nodules in this sea cliff, which shows that the exposure should be included in the Lusitaniadalen Member as defined herein. However, at Tschermakfjellet, the situation is the reverse. Here the base of a cliff 60 m above the top of the Permian was regarded as the base of the former Sticky Keep Formation, an interpretation also followed by Mørk, Knarud et al. (1982). This cliff consists of fine-grained, hummocky laminated sandstone quite similar to that of the new type section, and the base of the Lusitaniadalen Member should accordingly be moved to the top of this cliff.

Buchan et al. (1965) subdivided their Sticky Keep Formation into the Iskletten and Kaosfjellet members with type sections on western Spitsbergen, and these are retained as subdivisions of the equivalent Tvillingodden Formation in the outer Isfjorden area (Mørk, Dallmann et al. in press). The Lusitaniadalen and Vendomdalen members, as defined below, are regarded as directly correlative to these members.

The establishment of the new Vikinghøgda Formation is warranted for several reasons:

1) The Vikinghøgda Formation is the natural mapping unit for the Lower Triassic sediment of central and eastern Svalbard.
2) Re-establishing the Botneheia unit as a formation demands a new name for the underlying part of the previous Barentsøya Formation.
3) The new name Vikinghøgda is introduced because the Vardebukta Formation is now restricted to the western areas. Other names used either comprise a larger rock volume (Barentsøya Formation), or a smaller or different volume (Sticky Keep, Kongressfjellet and Wichebukta units).

Vikinghøgda Formation

Type Area: The Sassendalen Group is well-exposed at the mountains Vikinghøgda and Sticky Keep in southern Sassendalen (Figs. 3, 4). The lower part (Deltadalen Member) is well-exposed in the river banks in Deltadalen (type section of Mørk, Knarud et al. 1982), the valley between Vikinghøgda and Sticky Keep. The middle part (Lusitaniadalen Member) is exposed in the

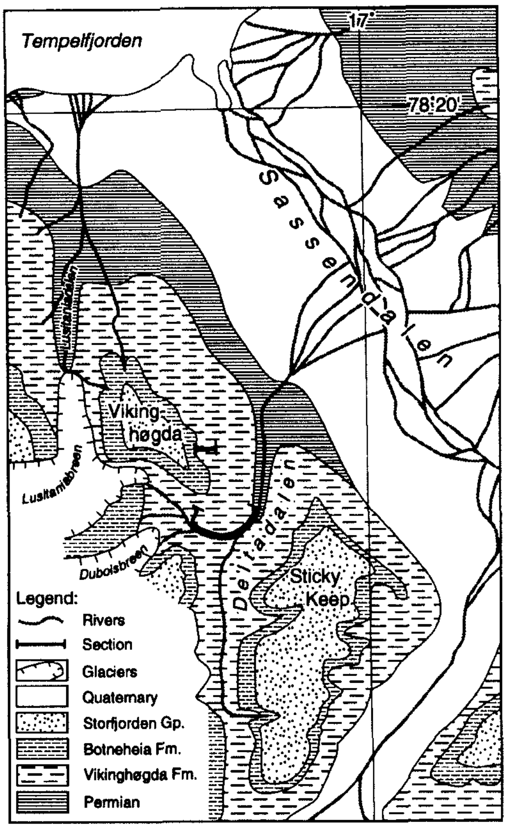


Fig. 3. Locality map.

riverbanks of the tributary continuing around the southern foot of Vikinghøgda, informally called the Duboisbreen tributary. The basal Vendomdalen Member is well-exposed in the same tributary and riverbanks, while the upper part of this member is best exposed in the surrounding mountain cliffs (Fig. 3). These river and mountain cliff sections of the Vikinghøgda Formation give better exposures than the original type section (Buchan et al. 1965) on the northern part of Vikinghøgda which is partly scree covered, and the base is not exposed. These sections combined give a continuous exposure from the Permian Kapp Starostin Formation through the Vikinghøgda Formation to the Middle Triassic Botneheia Formation which is found on both the Vikinghøgda and Sticky Keep mountains.

Type section: The base of the type section (Figs. 3, 4) is located in Deltadalen (78°16′N, 16°53′E) with the section following up-river around the southern foot of Vikinghøgda. The upper part (ca. 80 m) is better exposed in a mountain cliff ca. 1.5 km to the north-east (78°16′7N, 16°52′0E). The two sections can be correlated by following a pronounced bivalve rich dolomite bed at a level 173 m above the base of the formation (Fig. 4).

Thickness: The Vikinghøgda Formation is 250 m thick in the type section. The thickness of the Deltadalen, Lusitaniadalen and Vendomdalen members are 68 m, 88 m and 94 m respectively. Buchan et al. (1965) reported the sum of these units to be 236 m on northern Vikinghøgda and 249 m at Sticky Keep. Mørk, Knarud et al. (1982) reported 250 m in the same section as studied here. At the western foot of Vikinghøgda (Lusitaniadalen, Figs. 3, 5), the formation is estimated to be 266 m thick, with the Deltadalen Member 67 m thick. The Vikinghøgda Formation has its thickest development in this area and the equivalent units in western Spitsbergen are ca. 500 m thick (Mørk, Knarud et al. 1982).

Equivalents: The Deltadalen Member is equivalent to the Vardebukta Formation in western Spitsbergen (Mørk, Knarud et al. 1982), the lower part of the Urd Formation on Bjørnøya (Mørk, Vigran & Hochuli 1990), and the Havert Formation in the southwestern Barents Sea (Worsley et al. 1988).

The Lusitaniadalen Member is equivalent to the Iskletten Member of the Tvillingodden Formation in western Spitsbergen (Buchan et al. 1965; Mørk, Knarud et al. 1982), and the lower part of the Sticky Keep Member/Wichebukta Formation in the same area (Mark, Knarud et al. 1982; Pčelina 1983). The Lusitaniadalen Member is also equivalent to the middle part of the Urd Formation on Bjørnøya (Mørk, Vigran & Hochuli 1990) and to the Klappmyss Formation in the south-western Barents Sea (Worsley et al. 1988).

The Vendomdalen Member is equivalent to the Kaosfjellet Member (of the Tvillingodden Formation) and the upper part of the Wichebukta Formation (Buchan et al. 1965; Mørk, Knarud et al. 1982; Pčelina 1983). The Vendomdalen Member is also equivalent to the upper part of the Urd Formation on Bjørnøya (Mørk, Vigran & Hochuli et al. 1990), the Klappmyss Formation in the south-western Barents Sea (Worsley et al. 1988) and the lowermost part of the Steinkobbe Formation in the Svalis Dome (Mørk & Elvebakk 1999).

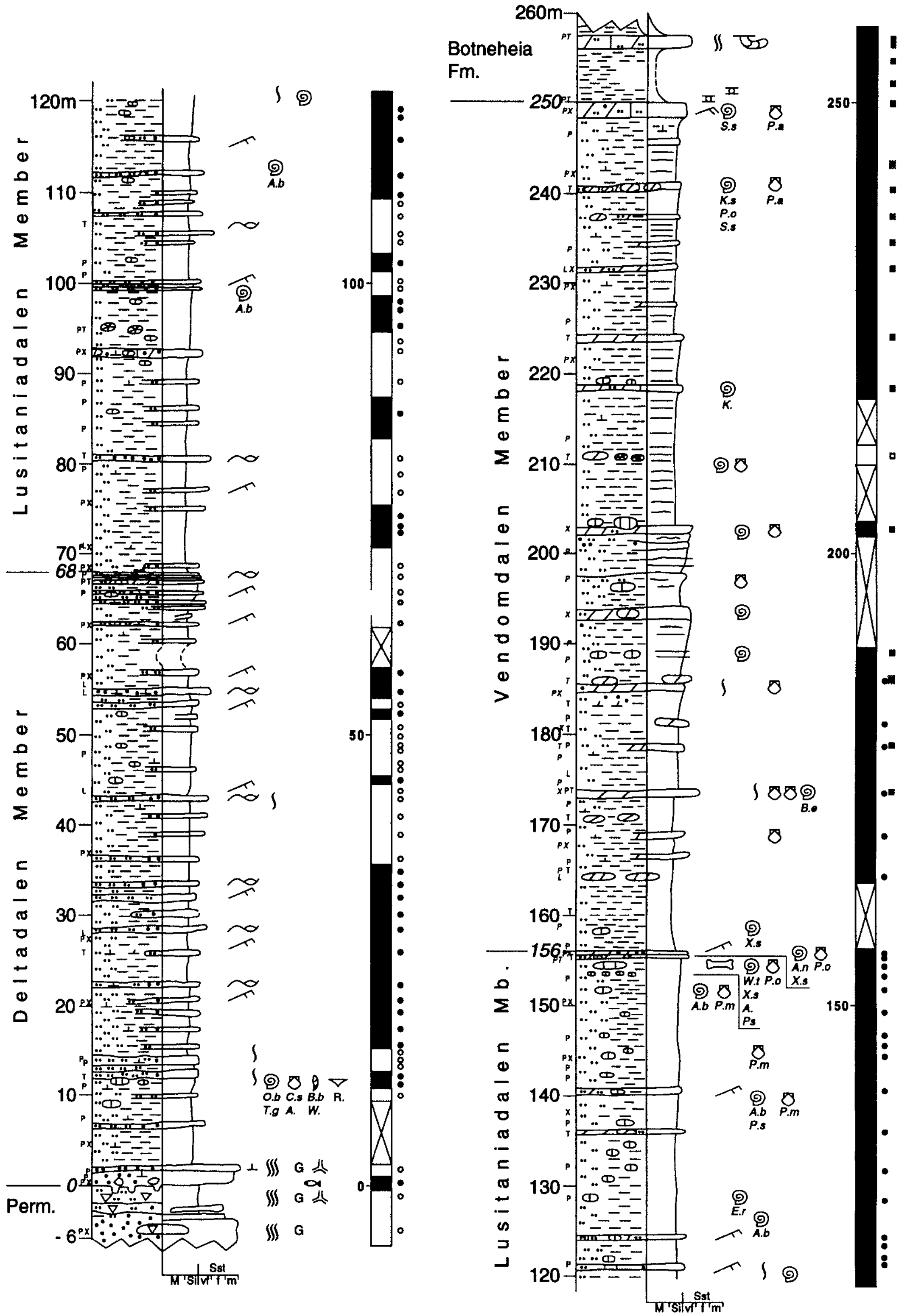

120m
110
100
90
80
70
68
60
50
40
30
20
10
0
Perm.
- 6
Lusitaniadalen Member
Deltadalen Member
Sst
M Si vf f m
A.b
O.b C.s B.b R.
T.g A. W.
G
100
50
0
260m
Botneheia
Fm.
250
240
230
220
210
200
190
180
170
160
156
150
140
130
120
Vendomdalen Member
Lusitaniadalen Mb.
S.s P.a
K.s P.a
P.o
S.s
K.
B.e
X.s
A.n P.o
X.s
W.t P.o
X.s
A.
Ps
A.b P.m
P.m
A.b P.m
P.s
E.r
A.b
250
200
150

Fig. 4. Vikinghøgda Formation type section. The letters to the left of the lithology column indicate position and nature of samples: P = Palynology, X = XRD, T = Thin-section, L = Lithology. Letters in italics are from the mountain section. See legend.

Legend

- Sandstone
- Siltstone
- Shale
- Limestone
- Dolomite
- Chert
- Nodule
- Septarian nodule
- Phosphate nodules
- Calcite cement
- Dolomite cement
- G Glauconite
- Intraformational conglomerate
- Erosional surface
- Planar lamination
- Irregular lamination
- Ripple lamination
- Hummocky bedding/lamination
- Fish remains
- Vertebrate bones
- Increasing bioturbation
- Rhizocorallium
- Thalassinoides

Ammonoids

A.	*Anasibirites* spp.
A.b	*Arctoceras blomstrandi*
A.n	*Arctoprionites nodosus*
B.e	*Bajarunia* ex gr. *euomphala*
E.r	*Euflemingites romunderi*
K.	*Keyserlingites* sp.
K.s	*Keyserlingites subrobustus*
O.b	*Otoceras boreale*
P.o	*Popovites occidentalis*
Ps	*Pseudosageceras* sp.
P.s	*Paranannites spathi*
S.s	*Svalbardiceras spitzbergense*
T.g	*Tompophioceras* cf. gracile
W.t	*Wasatchites tardus*
X.s	*Xenoceltites subevolutus*

Bivalves

A.	*Adontophora* sp.
C.s	*Claraia stachei*
P.a	*Posidonia aranea*
P.m	*Posidonia mimer*
P.o	*Pseudomonotis occidentalis*

Gastropod

B.b	*Bellerophon borealis*
W.	*Worthenia* sp.

Brachiopods

R.	Rhynchonellidae

- Presence
- Last occurrence
- First occurrence
- Normal polarity
- Reverse polarity
- Not measured

Magnetostrat. samples:

- river section, normal
- river section, reverse
- mountain section, normal
- mountain section, reverse
- mountain section, indeterm.

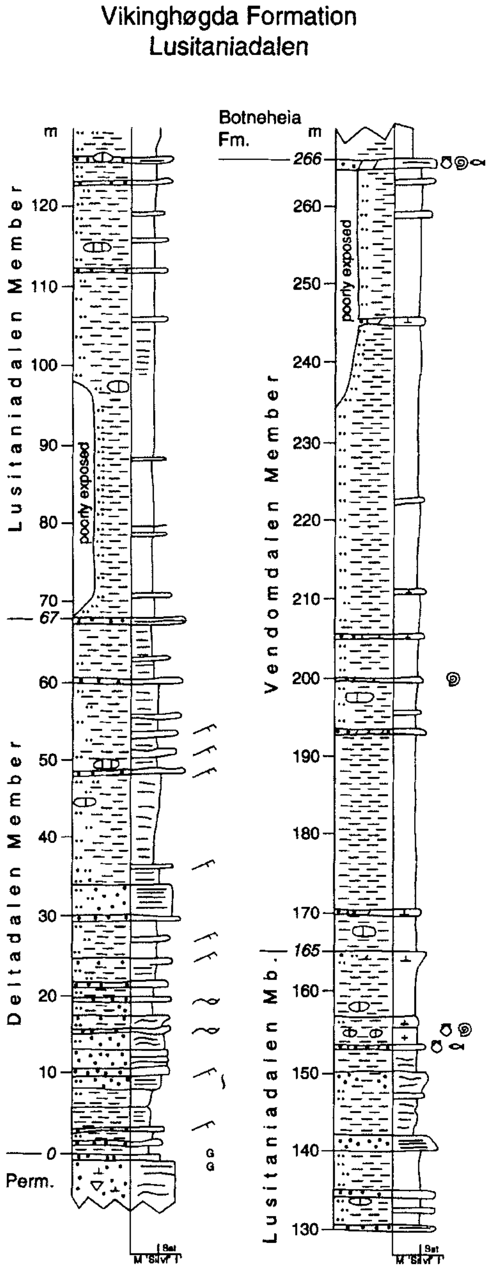


Fig. 5. Lusitaniadalen section. Legend with Fig. 4.

Lithology: The formation is dominated by silty shale. In the lower part of the Deltadalen Member sandstone and siltstone interbeds are abundant; siltstone and very fine-grained sandstone interbeds are less common in the Lusitaniadalen Member; whereas in the Vendomdalen Member dolomite beds and nodules are common, with few silty interbeds. Calcite concretions are most abundant in the upper part of the Lusitaniadalen Member, but also occur with different carbonate mineralogy in other parts of the formation.

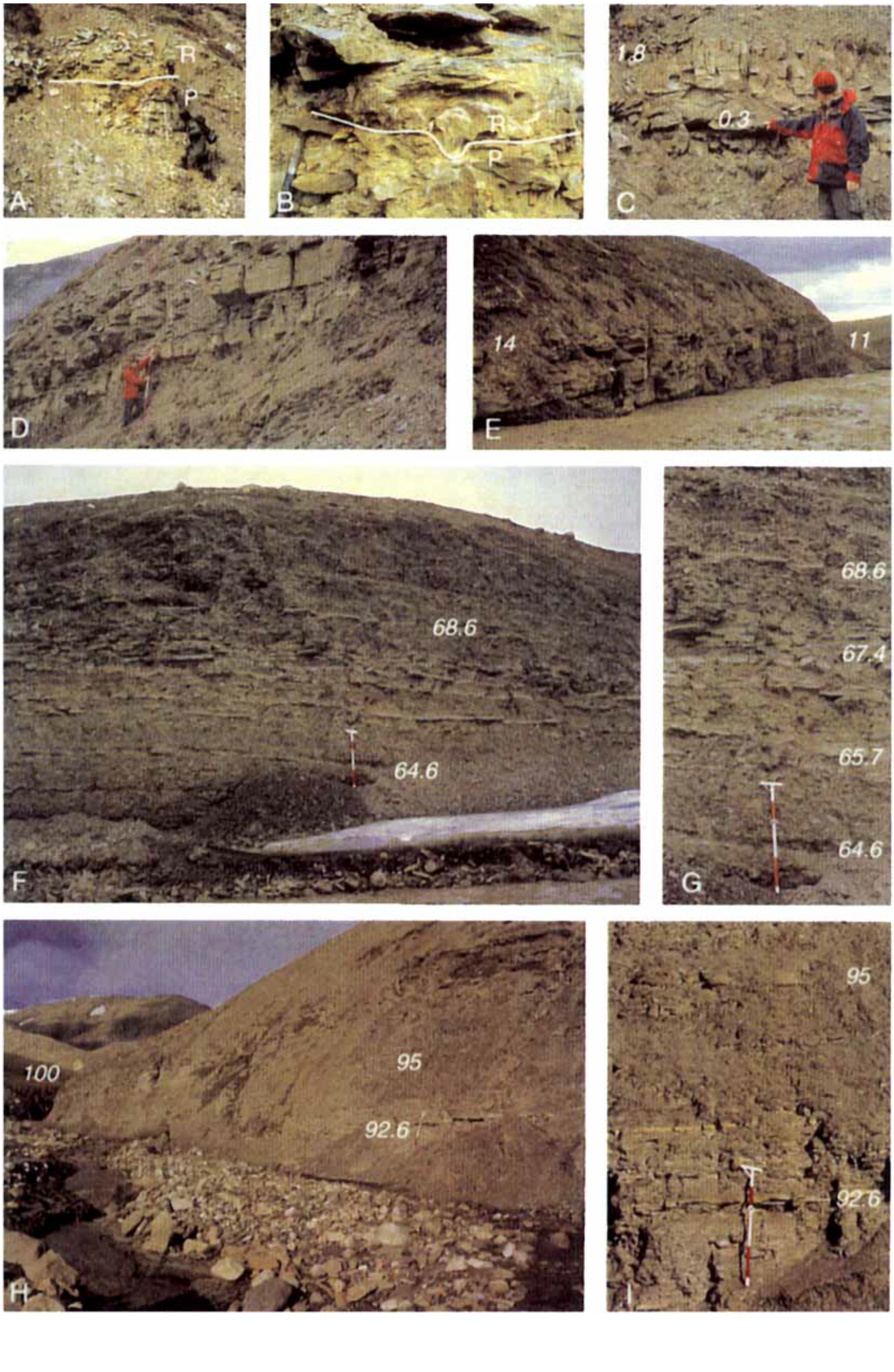
Deltadalen Member

The complete member is exposed in Deltadalen (68 m thick; Fig. 4), Lusitaniadalen (western side of Vikinghøgda; Fig. 3) and on the flank of the southern hill of Stensiöfjellet at its transition to Sassendalen. A development of more sandy (slightly thicker) beds transitional to the Vardebukta Formation occurs at Bertilryggen on Oscar II Land. The upper part of the member is exposed in several sections in the outcrop area of the unit, and a more condensed development (without the earliest Triassic beds) occurs at Barentsøya and Edgeøya.

The uppermost part of the Kapp Starostin Formation and the basal sandstone of the Deltadalen Member forms a cliff exposed on both sides of the Deltadalen River (Fig. 6A). It consists of 2–3 m of medium- to fine-grained glauconitic grey-green sandstone that occasionally shows faint cross-bedding. The sandstone is moderately bioturbated and has a patchy chert cement. *Thalassinoides* trace fossils are often filled by chert nodules.

The top of the Kapp Starostin Formation is fractured and cherty with an irregular brownish-weathering coloured surface. The base of the Deltadalen Member is defined at this weathering surface (Figs. 6A, B, C), which is irregular and has

Fig. 6. Photos from the type section. A) Triassic glauconitic sandstone rests sharply on cherty Permian sandstone. Measure rod is one metre long. B) Details of the PermianTriassic boundary beds. Note erosion surface with gutter cast at boundary. C) Basal Triassic sandstone. Note drillholes for magnetostratigraphy samples at base and top of bed. D) Sandstone interval between 12 and 14 m. The fossiliferous nodule with *Otoceras boreale* was located at the level of the geologist. E) Planar bedded thick sandstone/siltstone beds (12–14 m) in the lower part of Deltadalen Member. F) Thin sandstone beds in the upper part of the Deltadalen Member and the boundary at 68 m to the overlying silty mudstone of the Lusitaniadalen Member, however with one thin sandstone bed (68.6 m) in the lowermost part. G) Detail of 6F. H) The silty mudstone in the lower part of the Lusitaniadalen Member. Note marker horizons at 92.6 m, the flattened globular nodules at 95 m, and the double siltstone bed at 100 m which also appears in Fig. 7A. I) Detail of 6H.


A
R
P
B
R
P
C
1.8
0.3
D
E
14
11
F
68.6
64.6
G
68.6
67.4
65.7
64.6
H
100
95
92.6
I
95
92.6

small channels (gutter casts?) that are filled by medium-grained sandstone. The surface also contains irregularly shaped pits and grooves (maximum 7 cm deep and 8 cm wide) producing an angular shaped surface, resembling a karstic erosion surface. A thoroughly burrowed, greenish-grey, fine-grained sandstone (1.2 m thick), coarsening-up to medium-grained in the upper parts, rests on the erosion surface (Figs. 6B, C). Some chert clasts of the underlying lithology occur in this sandstone which splits into 10–30 cm thick beds.

Above the basal sandstone, the Deltadalen Member consists of silty shale with intervals dominated by siltstone or very fine-grained sandstone beds. Between 12 m and 14 m (Fig. 4) thickly bedded siltstones form a unit (Figs. 6D, E) which has a base containing calcareous nodules with a rich fauna of the Otoceras boreale Zone. Several intervals enriched in sandy siltstone beds occur throughout the member, and several show hummocky lamination, the upper parts of which are often rippled. Bioturbation is sparse. Calcite concretions (up to 30 cm in diameter) occur at a few levels higher in the member.

The top of the member consists of thin sandstone beds forming an upward-coarsening sequence (Figs. 6F, G). This part of the member is well-exposed on the southern side of the Duboisbreen tributary near its junction with the Deltadalen river. There is a minor gap in the section at the river junction creating some uncertainties in section correlation and thickness. The thickness of the member and the sandy uppermost beds are quite similar to the development seen in Lusitaniadalen on the western side of Vikinghøgda (Fig. 5).

Depositional environments: The weathering crust on the erosional surface at the base of the section indicates exposure of the top of the Permian Kapp Starostin Formation, prior to deposition of the Deltadalen Member. A similar erosion surface is reported from Edgeøya (Mørk, Knarud et al. 1982). At the equivalent boundary in Lusitaniadalen there is no erosion, but a yellow-weathering bed occurs at the boundary. Above the erosional surface, the basal beds contain fragments and debris of the underlying lithologies and palynomorphs (see below) related to those of the Kapp Starostin Formation. The extensive bioturbation, including *Thalassinoides* as a deep tier (cf. Bromley & Ekdale 1986) in the transgressive sandstone bed, indicates rapid establishment of conditions favourable for benthic colonization.

The repeated occurrences of siltstone and sandstone beds with hummocky lamination indicates storm influence on a shelf above storm wave base. Sediment supplied from the deltaic coast in the west (Mørk, Knarud et al. 1982) may have been built up above storm wave base, where sheet sand bodies were laterally spread out on the sea floor. This model is consistent with the distance of approximately 75 km to the coastal sequence present on the west coast of Spitsbergen, and the more distal, basinal shelf sediments further east on Spitsbergen and Edgeøya.

Lusitaniadalen Member

The unit is named after a valley on the northern side of Vikinghøgda (Fig. 3). The type section is well-exposed in the Duboisbreen tributary at the foot of Vikinghøgda (88 m thick; Figs. 3, 4). In other areas the transition from the underlying Deltadalen Member is often covered in scree.

The base is defined where dark grey laminated silty mudstone sharply overlies the hummocky laminated sandstone at the top of the Deltadalen Member (Figs. 4, 6F). This transition may give a break in slope which can be recognized in areas of poor exposure.

The lower part of the member is exposed on the southern side of the Duboisbreen tributary (Fig. 6F), while the remainder can be studied on the northern banks (Fig. 6H). There may be some minor uncertainties in correlations within this member partly due to scree cover. The upper part of the member is well-exposed in a small canyon on the mountain side (Figs. 7A, B).

Most of the mudstone is finely laminated and only sparse bioturbation is observed. The lower part is dominated by dark grey silty laminated mudstone. Some metres above the base sandstone

Fig. 7. A) The middle and upper part of the Lusitaniadalen Member. Level 100 m from Fig. 6H is indicated. Fig. 7B and C show detail of parts of this photo. B) Detail of A showing the upper part of the Lusitaniadalen Member. The boundary with the Vendomdalen member is at 156 m. C) Shaly nodular interval high in the Lusitaniadalen Mb. D) The base of the Vendomdalen Member is defined on top of the yellow weathering silty dolomite bed. The top of the section is represented by the bivalve-rich regional marker bed at 173 m. E) The upper part of the Vendomdalen Member on the eastern slopes of Vikinghøgda. The light-coloured levels represent dolomitic beds.


156
100
100
156
B
112
105
C
174
156
D
250
156
E

beds occur, arranged in faint coarsening-up sequences. Some of these display hummocky lamination and cross lamination. Small (20–30 cm in diameter) globular or flattened carbonate nodules occur in a few horizons from ca. 15 m above the base of the member (Fig. 6I), and a prominent horizon of large septarian concretions is found 25 m above the base. Calcite concretions are abundant in the middle and upper parts of the member (Fig. 7C). These concretions formed early in diagenesis, as is evident by deformation of the enclosing shales, and the fact that the enclosed fossils are not crushed. Abundant ammonoids and bivalves occur in a calcareous lens (154 m; Fig. 4) close to the top of the member. The Lusitaniadalen–Vendomdalen member boundary is placed at the top of a dolomite cemented sandstone (Fig. 7D).

Fossils occur throughout the member, except the lower 30 m, and are mostly concentrated in concretions. Ammonoids dominate, but bivalves are also common, often as imprints in sandstone/carbonate beds. Several levels with vertebrate remains are recognized.

Depositional environments: The lower part represents a transgressive development from the underlying member towards a distal shelf environment. The overall setting represents moderately deep shelf deposition, distal to the deltaic input from the west.

Vendomdalen Member

The Vendomdalen Member (94 m thick) is named after a valley 15 km south-east of Vikinghøgda where it is well-exposed in the surrounding mountain sides. The lower part of the type section is defined at the southern foot of Vikinghøgda where the basal beds are well-exposed (Figs. 3, 4, 7D). The major part of the member (and the upper boundary) is exposed in all outcropping areas of the Vikinghøgda Formation. The type section (except the basal beds) is defined on the eastern slope of Vikinghøgda (Figs. 3, 4, 7E). The two sections are correlated at a prominent bivalve-rich dolomite bed 18 m above the base of the member at 173 m (Figs. 4, 7D).

The member consists of silty, dark grey, laminated mudstone, thin- to medium-bedded, with more or less silty, yellow weathering, dolomite beds and nodules. A clear shift from grey to dark grey mudstone takes place at the lower boundary, and the yellow weathering dolomite beds are distinctive of the Vendomdalen Member throughout central Spitsbergen. The dolomitic beds may be up to 1.5 m thick, but most are 10–30 cm thick. Dolomitic nodules, some of them septarian, are up to tens of centimetres in diameter; flattened nodules may reach several metres in horizontal extent but generally only 0.5 m in thickness. Rare calcite concretions occur near the top of the member.

The type section continues ca. 1.5 km to the north-east where exposures from the bivalve bed (at 173 m; Fig. 4) upwards occur at ridges between melt water creeks. This section consists of several 3 to 12 m thick, faintly coarsening upward units, grading from laminated shale to silty mudstone, capped with dolomite beds, sometimes silty or sandy, or consisting of dolomite lenses. The dolomite beds consist of sucrose, ferrous dolomite (from SEM/microprobe analyses) and were formed relatively late in diagenesis. The upper 50 m consist of planar laminated silty grey mudstone with thin dolomite beds. At the top is a pronounced silty/sandy dolomite bed with abundant, though poorly preserved imprints of ammonoids. The bed shows some ripple lamination.

Above the top bed, very dark grey shale with small phosphate nodules is referred to the Botneheia Formation. Seven metres above the base of the Botneheia Formation there is a dolomitic siltstone bed, bioturbated by *Rhizocorallium*. This bed represents a local marker in the lowermost part of this formation in the Sassendalen area.

Depositional environments: The member represents distal shelf deposits, below wave base, with accumulation of marine derived organic material in a low oxic environment.

Palaeontology

Macrofossils which can be identified (Fig. 8) are restricted almost exclusively to concretions. Shales between the fossiliferous concretion-levels are either not fossiliferous or have only indeterminate fauna, so detailed ammonoid zones or distinctive biostratigraphical boundaries, cannot easily be defined. The fauna of a single concretion-layer represents a snapshot of the zone or higher biostratigraphical unit, consequently only comparison with ammonoid assemblages from other more fossiliferous boreal Triassic successions, such as in Siberia and the Canadian Arctic (Weitschat & Dagys 1989; Dagys & Weitschat 1993) allows a more precise biostratigraphical interpretation.

One sample from the Kapp Starostin Formation and five samples from the lower part of the Deltadalen Member have allowed recovery of conodonts. A single sample from a calcareous nodule was processed for conodonts using standard acetic acid technique. The remaining samples were taken from moderately lithified sandstones and shales and processed using a "freezing and thawing" technique (Pojeta & Balanc 1989). All samples produced small numbers of conodonts.

Deltadalen Member

The biostratigraphical control on this unit is poor. A single fossiliferous horizon occurs in the type section in a layer of carbonate concretions 11.5 m above the base of the member (Fig. 4), with the following fauna: ammonoids *Otoceras boreale* Spath (quite large, badly preserved specimens), *Tompophiceras* cf. *gracile* (Spath); bivalves *Claraia stachei* Bittner, *Adontophora* sp.; gastropods *Bellerophon borealis* Spath, *Worthenia* sp.; brachiopods Rhynchonellidae. The co-occurrence of *O. boreale* and ophiceratids indicates that this level represents the upper part of the Otoceras boreale Zone. *O. boreale* has also been described from the adjacent Lusitaniadalen (Korčinskaja 1986).

Throughout Svalbard there are few Induan strata with additional ammonoid-bearing horizons. From the upper part of the Griesbachian and the lower part of the Dienerian, Korčinskaja (1986) has found, *Proptychites* cf. *strigatus* and *P. rosenkrantzi* from both Lusitaniadalen and Dickson Land. From the upper Dienerian *Vavilovites* aff. *sverdrupi* was recorded from the Bellsund area (Gazdzicki & Trammer 1977) and *Vavilovites spitsbergensis* from Van Keulenfjorden and Lusitaniandalen (Korčinskaja 1986). *V. spitsbergensis* also occurs at Bertilryggen (Oscar II Land) about 40 m above the base of the Triassic (W. Weitschat's observation).

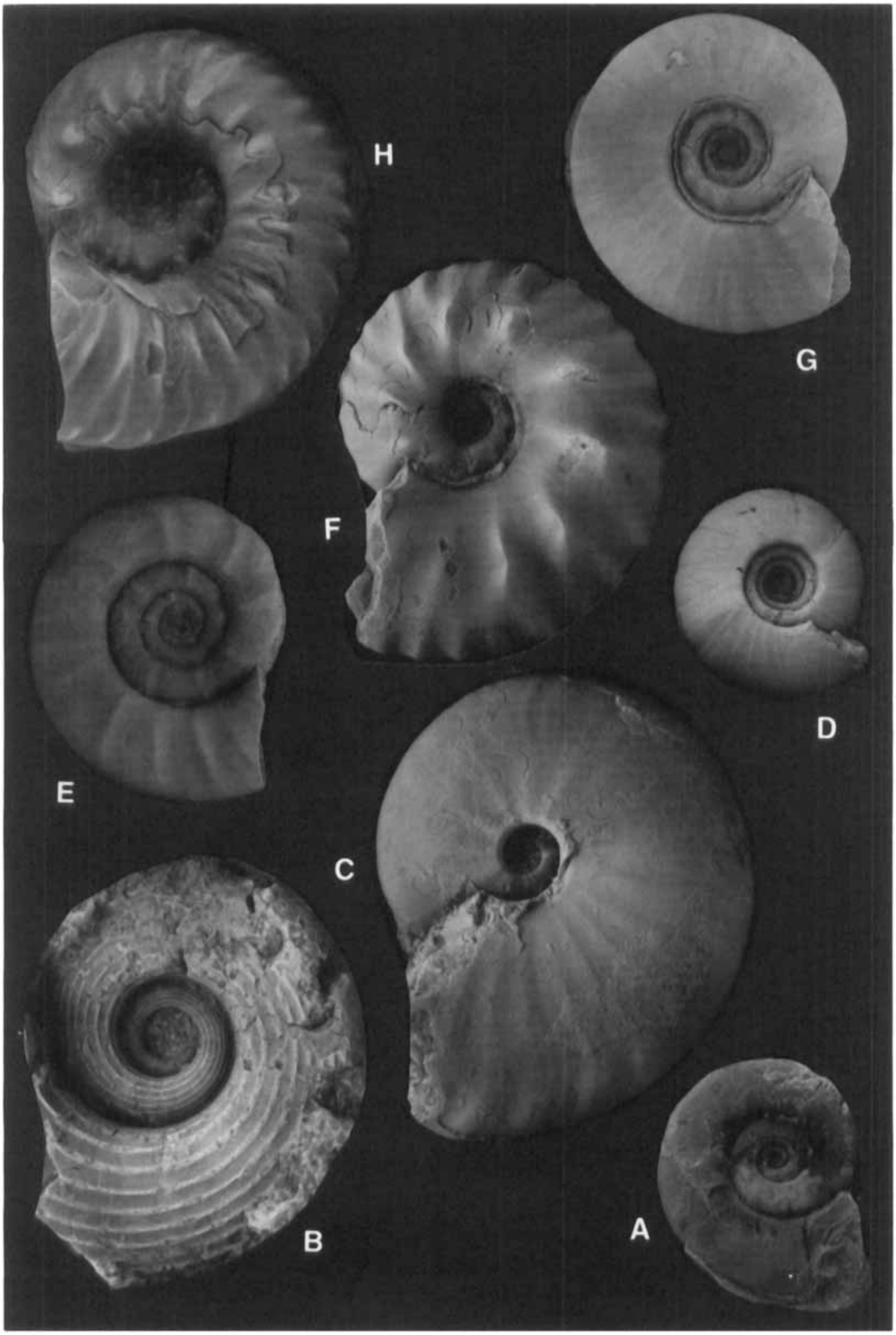
Conodonts from 5 m below the base of the section show 15 fragmented Pa-elements of *Mesogondolella* resembling *M. idahoensis*, previously described from Spitsbergen by Szaniawski & Malkowski (1979) and the Assistance Formation of the Sverdrup Basin (Beauchamp et al. 1989). Some fragments also resemble *M. bitteri*, which has a younger range (Wordian-Capitanian; see discussion in Henderson 1997). These conodonts provide no conclusive age for the sampled level. A similar fauna of *Mesogondolella* also occurs at the transition between the glauconitic sandstone and dark, soft shales, i.e. 0.5 m above the base of the section.

The samples at 5.0 m and 11.5 m contain preserved elements of *Neogondolella carinata*. The 11.5 m sample also contains large numbers of phosphatized gastropods and bivalves, while the sample at 47.0 m only contains a single broken ramiform element. The sample at 69.0 m (top of the Deltadalen Member) contains a single element of *Neospathodus* cf. *svalbardensis*, and indeterminate *Neogondolella* sp.

Discussion: Conodont faunas from the Lower Griesbachian Otoceras concavum and O. boreale zones are generally sparse in the Boreal Triassic. From the type section at Griesbach Creek (Arctic Canada) only a few indeterminate conodont fragments have been recovered from the O. concavum Zone (Orchard & Tozer 1997a, 1997b). From the Boreal lower Griesbachian succession (Siberia, Svalbard) several *Neogondolella* species have been reported from strata below the O. boreale Zone (Dagis 1984; Dagis & Korčinskaja 1987). Of the index species proposed by Yin et al. (1988) for the base of the Triassic, *Isarcicella parva* (= *Hindeodus parva*), only a single sample has been described from the lowermost Triassic of western Canada (Henderson 1993). These beds occur below the O. boreale Zone, but the lack of the index ammonoid *O. concavum* hampers the biostratigraphical correlation.

Following the paper by Yin et al. (1988) many conodont studies have focused on the Permian–Triassic boundary beds (Dickins 1977; Kozur 1989, 1995; Zhang et al. 1995; Kozur et al. 1996; Lai 1997; Orchard & Tozer 1997a, 1997b; Yin 1997). However, the conodont occurrences in the basal Triassic beds are still not well understood, and the absence of *Isarcicella parva* in the lowermost part of the Deltadalen Member may have several reasons:

1) *I. parva* may not have been adapted to cool Boreal water temperatures.
2) The transgression at the base of the Deltadalen Member was rapid and the conditions may have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been too deep for *Isarcicella (Hindeodus)*, which Henderson (1997) regards as a near shore euryhaline form in contrast to the more open marine form *Neogondolella*.
3) At present it is not proven that sedimentation during the lowermost part of the Deltadalen Member is continuous.
4) Sampling may have been too sparse.

The lack of *I. parva* in Svalbard may thus be a facies or climatic effect as reported in Canada by Henderson (1997), similar to the general absence of *Hindeodus* in the Permian of Bjørnøya (Nakrem 1991). The general absence of *I. parva* in Boreal areas may thus indicate that the selection of this fossil may not be the best choice for defining the global P/T-boundary.

Neogondonella carinata is well-known from lowermost Triassic sections in western Canada (Henderson 1997), where a range through most of the Griesbachian is recorded. *N. carinata* has been previously recorded from Spitsbergen in association with *Otoceras* (Dagis & Korčinskaja 1987). *Neospathodus svalbardensis* as reported from southern Spitsbergen (Birkenmajer & Trammer 1975; Nakrem & Mørk 1991) is also known from the type locality of Diener Creek in Arctic Canada (Orchard & Tozer 1997b) and indicates the Protychites candidus Zone of early Dienerian age.

Fig. 8. Ammonoids from the Vikinghøgda Formation type section. A) *Tompophiceras* cf. *gracile* (Spath), Griesbachian, Otoceras boreale Zone, Deltadalen Member, 11.5 m above T/P boundary; Deltadalen, Spitsbergen, ×2. B) *Euflemingites romunderi* Tozer, Smithian, Euflemingites romunderi Zone; Vikinghøgda Formation, Lusitaniadalen Member, 128 m above P/T boundary; Duboisbreen tributary. C) *Arctoceras blomstrandi* (Oeberg), Smithian, Euflemingites romunderi Zone; Vikinghøgda Formation, Lusitaniadalen Member, 112 m above P/T boundary; Duboisbreen tributary. D) *Paranannites spathi* (Frebold), Smithian, Euflemingites romunderi Zone; Vikinghøgda Formation, Lusitaniadalen Member, 137 m above P/T boundary; Duboisbreen tributary. E) *Xenoceltites subevolutus* (Spath), Smithian, Wasatchites tardus Zone; Vikinghøgda Formation, Lusitaniadalen Member, 154.5 m above P/T boundary; Duboisbreen tributary. F) *Wasatchites tardus* (McLearn), Smithian, Wasatchites tardus Zone; Vikinghøgda Formation, Lusitaniadalen Member, 154.5 m above P/T boundary; Duboisbreen tributary. G) *Svalbardiceras spitzbergense* Frebold, Upper Spathian, Keyserlingites subrobustus Zone; Vikinghøgda Formation, Vendomdalen Member; 9 m below top of the formation; Vikinghøgda mountain cliff. H) *Keyserlingites subrobustsus* (Mojsisovics), Upper Spathian, Keyserlingites subrobustus Zone; Vikinghøgda Formation, Vendomdalen Member; 9 m below top of the formation; Vikinghøgda mountain cliff.

Lusitaniadalen Member

Except in the lowermost 30 m, fossils are common in the type section. Due to the abundance of early-formed calcite concretions, the higher part is the only unit within the Svalbard Triassic in which it is possible to separate faunal zones based on the ranges of ammonoids. This horizon was formerly known as the "Fish-Niveau" from which Stensiö (1921, 1925) described a rich fish fauna.

The lowest fossiliferous level (98 m; Fig. 4) contains only large arctoceratids which indicate the Euflemingites romunderi Zone of the Smithian Substage. The index ammonoid *Euflemingites romunderi* is quite rare and has its first occurrence in the type section at 128 m (Fig. 4), in a grey mudstone with numerous levels of nodules which contain a rich ammonoid and bivalve fauna.

Ammonoids from the E. romunderi Zone, apart from the index-species, are: *Arctoceras blomstrandi* (Oeberg), *Paranannites spathi* (Frebold) and *Anakashmirites* sp. The bivalve *Posidonia mimer* is also characteristic of this zone and occurs in the type section at several levels. In the type section the highest ammonoids from the E. romunderi Zone occur at 152 m (Fig. 4).

Ammonoids from the carbonate nodule layer above 152 m (at 154.5 m; Fig. 4) indicate the Upper Smithian Wasatchites tardus Zone, which extends upwards from this level. This zone is characterized by a typical prionitid ammonoid fauna (Frebold 1930; Spath 1934). This zone is known from all sections in central Spitsbergen (Dickson Land, Oscar II Land, Sassendalen area), the east coast of Spitsbergen, Barentsøya and Edgeøya. The fauna collected from the type section contains the following species: *Wasatchites tardus* (McLearn), *Xenoceltites subevolutus* (Spath), *Arctoprionites nodosus* (Frebold), *Anasibirites* spp. and *Pseudosageceras* sp. The bivalve *Pseudomonotis occidentalis* (Whiteaves) is also characteristic of this level and known from contemporaneous beds in the Canadian Arctic. The septarian carbonate nodular layer at 155 m contains, besides ammonoids, quite well-preserved skulls of stegocephalian amphibians (Wiman 1910, 1916, 1933). In the boundary beds of the Lusitaniadalen Member and the Vendomdalen Member *Xenoceltites subevolutus* is present, indicating the W. tardus Zone. This implies that the transition to the Vendomdalen Member probably takes place within the Upper Smithian W. tardus Zone.

Vendomdalen Member

Within this member carbonate concretions are rare and mainly restricted to the uppermost part of the unit. Most of the fossils in the dolomite beds and concretions are compressed and poorly preserved, hampering exact determination.

At 173 m (Fig. 4) a prominent dolomite bed contains abundant bivalves and some ammonoid imprints. These ammonoids have been compared with material from Siberia, and they belong to Bajarunia ex gr. *euomphala* (Keyserling 1845) indicating the Bajarunia euomphala Zone of the lowermost Spathian.

In the type section, a Spathian age is clearly demonstrated by the presence of the ammonoid *Keyserlingites* sp. upwards from ca. 219 m (Fig. 4). In the boreal Spathian ammonoid zonation the genus *Keyserlingites* is restricted to the latest Late Spathian zone (Dagys & Weitschat 1993).

The carbonate nodule layer at ca. 241 m (Fig. 4) contains a well-preserved latest Spathian fauna (Weitschat & Dagys 1989) which in the type section, includes: *Keyserlingites subrobustus* (Mojsisovics), *Svalbardiceras spitzbergense* (Frebold) and *Popovites occidentalis* (Tozer). The bivalve *Posidonia aranea* (Tozer), which is restricted to the Keyserlingites subrobustus Zone of the Boreal Triassic, also occurs at this level.

Field work at Milne Edwardsfjellet (about 15 km south-east of the type section) has produced additional biostratigraphical information concerning the Vendomdalen Member. From a dolomite nodule layer about 16 m above the "bivalve bed" (ca. 34 m above the base of the member) the ammonoid *Parasibirites* cf. *elegans* (Dagys & Ermakova 1988) was collected. This species is known from the upper Spathian of Siberia (Dagys & Ermakova 1988), indicating correlation to the Parasibirites grambergi Zone. Transferring this information to the type section indicates that the uppermost ca. 60 m are of Late Spathian age.

Palynology

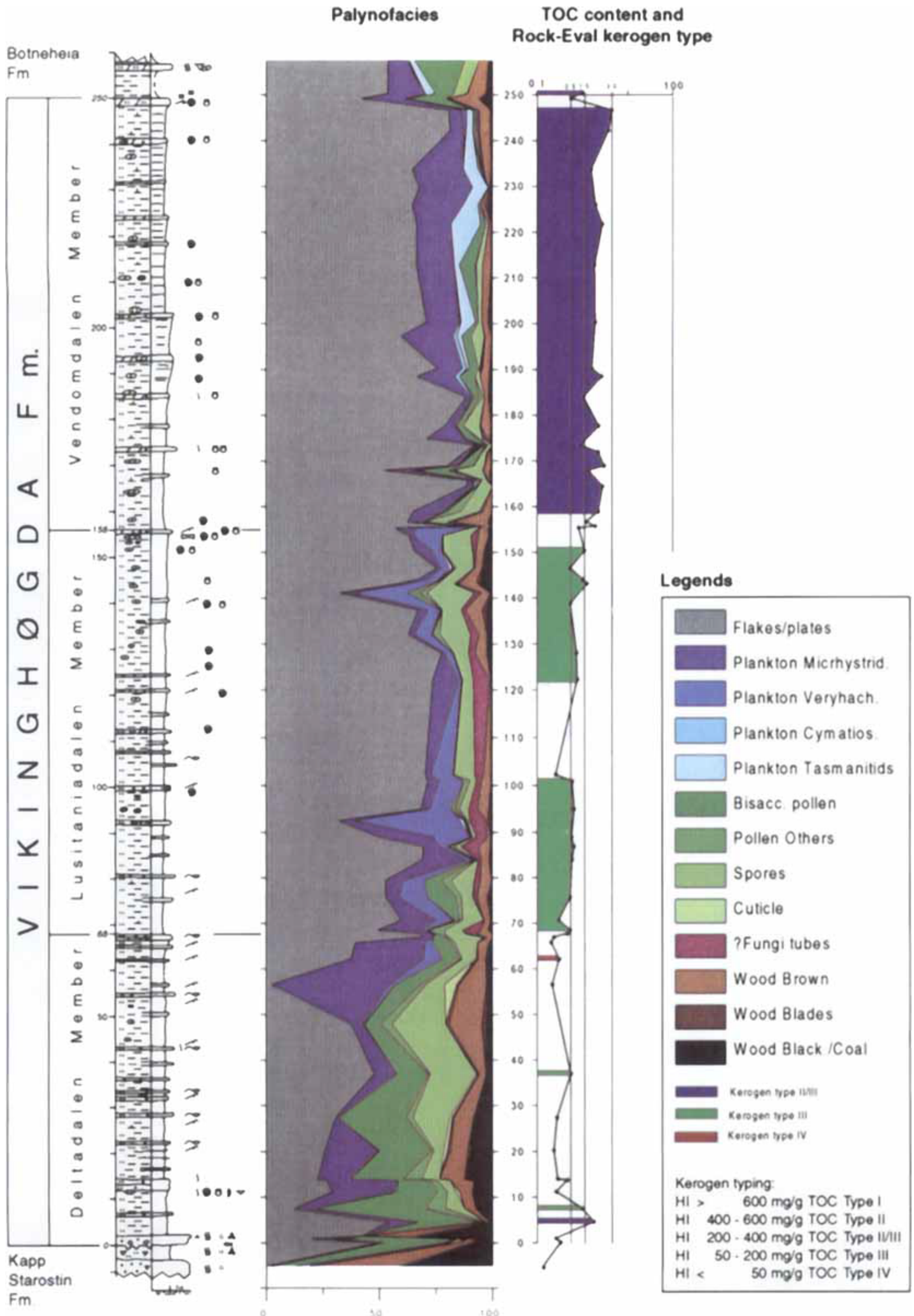
The acid insoluble remains from the Vikinghøgda type sections are generally badly preserved. The kerogen log (Fig. 9) shows that indeterminate palynodebris, often homogenized as sheets or flakes, dominates (Fig. 10). The original morphology is poorly defined and mostly allows identification only to major palynomorph groups. The changes in the morphological textures probably took place during early diagenesis with precipitation of pyrite (framboids and individual crystals) and recrystallization of carbonate.

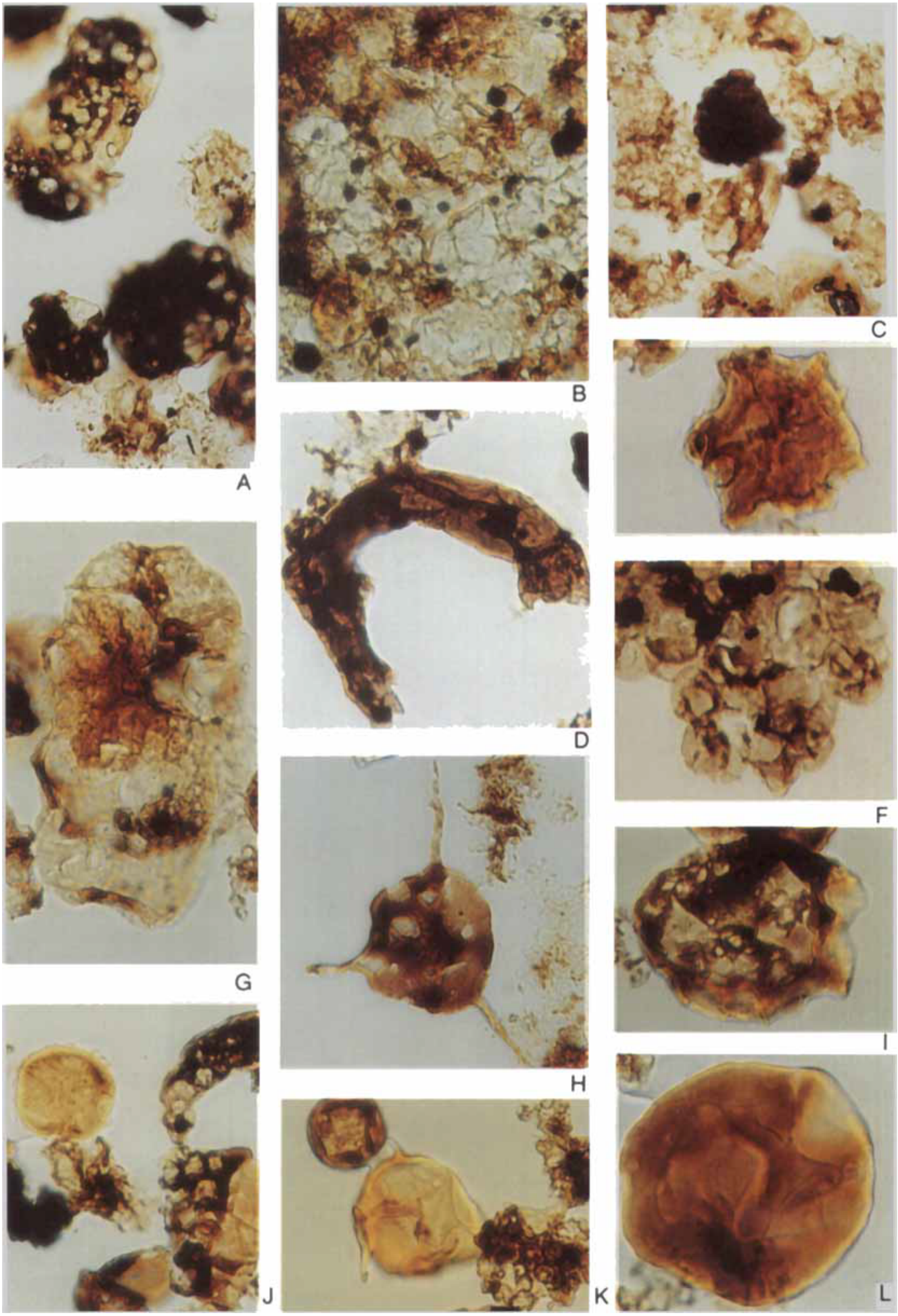
The kerogen log is based on particle counts, recognizing different stages of degraded woody material and palynomorphs. Plankton, pollen and spores were counted individually where preservation allowed. The categories were grouped for kerogen description and an extra group was added for homogenized sheets or flakes. The counting was carried out preferably on sieved residues, but also on slides from further stages of chemical processing. This was necessary to remove pyrite or to disintegrate the dense aggregates found in organic rich samples. The degraded woody particles are clearly affected by the oxidative treatment and therefore under-represented in many samples. The continued processing and sieving also cause large fragments to break into smaller pieces. Finely dispersed amorphous/degraded material has been evaluated as a percentage of the total residue and removed from the counting. The distribution chart for Vikinghøgda (Fig. 11) shows that there are few age diagnostic fossils and they have only scattered appearances.

Kapp Starostin Formation

One sample from 5 m below the top of the Kapp Starostin Formation yielded a residue with abundant woody material. The palynological assemblage comprises common *Vittatina* spp. besides *Apiculatisporis lanjouwii*, *Grebespora concentrica*, *Kraeuselisporites apiculatus*, *K. spinosus*, *Lueckisporites virkkiae*, *Neoraistrickia* spp., *Protohaploxypinus perfectus*, *P. samoilovichii* and *Vesicaspora* spp. The plankton comprises abundant *Cymatiosphaera* besides *Filisphaeridium setasessitante*, *Micrhystridium* spp. and *Unellium* spp. The assemblage correlates with the Scutasporites cf. unicus–Lunatisporites spp. Assemblage, described by Mangerud (1994) from the uppermost part of the Tempelfjorden Group on the Finnmark Platform. The equivalent Kraeuselisporites Assemblage documented from Svalbard (Mangerud & Konieczny 1991) regularly contains the same plankton.

Fig. 9. Palynofacies, TOC and RockEval data.


Palynofacies
TOC content and
Rock-Eval kerogen type
Botneheia Fm
VIKINGHØGDA Fm.
Vendomdalen Member
Lusitaniadalen Member
Deltadalen Member
Kapp Starostin Fm
Legends
Flakes/plates
Plankton Micrhystrid.
Plankton Veryhach.
Plankton Cymatios.
Plankton Tasmanitids
Bisacc. pollen
Pollen Others
Spores
Cuticle
?Fungi tubes
Wood Brown
Wood Blades
Wood Black /Coal
Kerogen type II/III
Kerogen type III
Kerogen type IV
Kerogen typing:
HI > 600 mg/g TOC Type I
HI 400 - 600 mg/g TOC Type II
HI 200 - 400 mg/g TOC Type II/III
HI 50 - 200 mg/g TOC Type III
HI < 50 mg/g TOC Type IV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Deltadalen Member

The organic residues from 0.2–1.7 m, representing the basal sandstone of the Deltadalen Member, are rich in woody material. Permian palynomorphs are relatively abundant (Fig. 11), represented by *Lueckisporites virkkiae*, *Vittatina* spp. and plankton, comprising *Cymatiosphaera*, *Filisphaeridium setasessitante*, *Micrhystridium* and *Unellium* spp. The assemblage is reminiscent of that from the Kapp Starostin Formation below. Mangerud (1994) described similar features from layers just below the base of the Havert Formation on the Finnmark Platform.

The organic residues from 4.7–14.0 m above the base of the Deltadalen Member are dominated by variably degraded palynomorphs. *Filisphaeridium*, *Micrhystridium*, *Densoisporites nejburgii* and *Lunatisporites* spp. dominate the palynological assemblage. *Crustaesporites globosus*, *Grebespora concentrica*, *Lueckisporites virkkiae*, *Maculatasporites* spp., *Proprisporites pocockii* and *Uvaesporites imperialis* represent subordinate age diagnostic forms (Figs. 10, 12). The stratigraphically significant *Tympanicysta stoschiana* is recorded as rare at the top of the interval. The assemblage is correlated to the equivalent Lundbladispora obsoleta–Tympanicysta stoschiana Assemblage Zone of Mangerud (1994) and to Assemblage P of Hochuli et al. (1989).

In Svalbard, Assemblage P is reported from the basal layers of the Vardebukta Formation, in which the index fossil *T. stoschiana* is sparsely represented (Mangerud & Konieczny 1993). There is no sign of an acme zone for this taxon; on the contrary the published evidence indicates that *T. stoschiana* is more regularly represented towards the upper part of its range. The palynology of the Vardebukta Formation, (apart from the base) has so far not been documented, and it is not known if Assemblage P is restricted to the Griesbachian in Svalbard. On the Finnmark Platform, Barents Sea, the Lundbladispora obsoleta–Tympanicysta stoschiana Assemblage is recorded throughout the lowest part of the Havert Formation. Here, the diverse assemblage comprises *T. stoschiana* and other fungal remains (Mangerud 1994). Equivalent assemblages from Greenland and the Canadian Arctic occur in the three lowest Griesbachian ammonoid zones (Balme 1980; Piasecki 1984; Utting 1985, 1989).

Organic residues from 20.3–48.0 m above the base of the Deltadalen Member comprise abundant plankton, pollen and spores and their degraded products. The mainly indeterminate palynomorphs have walls damaged by mineral growth (pyrite). *Micrhystridium* and *F. setasessitante*, *D. nejburgii*, *Cycadopites nitidus*, *Lunatisporites* spp. and *Pretricolpipollenites* spp. dominate the palynological assemblage (Fig. 11) and represent the basic elements also recovered from Assemblage O of Hochuli et al. (1989). Distinguishing features for this interval are the association of *Aratrisporites* spp., *Bharadwajispora labichensis*, *Cordaitina minor*, *Densoisporites complicatus*, *Kraeuselisporites apiculatus*, *K. hoofddijkensis*, *Lueckisporites virkkiae*, *Pechorosporites coronatus*, *P. intermedius* and *Proprisporites pocockii*. *Maculatasporites* sp. seems to be missing from the assemblage, but has been correlated to $Svalis_1$ that has been recovered from the Ophiceras commune Zone of the Svalis Dome (Vigran et al. 1998). Although the index fossil *T. stoschiana* is missing, the assemblage is considered as equivalent to Assemblage P of Hochuli et al. (1989), and possibly an equivalent of the L. obsoleta–T. stoschiana Assemblage Zone of Mangerud (1994).

The organic residues from 56.6–67.8 m are dominated by palynomorphs, mainly plankton. The palynological assemblage is distinguished from that of the interval below (20.3–48.0 m) by the lower proportion of bisaccate pollen, regular to abundant *Veryhachium* and abundant "Planktonic alga type A" (Fig. 10H, K). The distinctive taxa of

Fig. 10. Palynofacies and palynomorphs from Vikinghøgda Formation, Deltadalen. The metre level is followed by a letter code indicating progressive oxidation levels (X1–X5: Si = sieved residue) and slide coordinates. The exposures are through ×40 lenses, unless otherwise indicated. A) Palynofacies from the Deltadalen Member, 67 m, X1, 99.2-33.1 (×25). Pyrite damage. B) Palynofacies from the Lusitaniadalen Member, 141.2 m, Si, 103.2-33.5. Sheets/plates. C) Palynofacies from the Vendomdalen Member, 168 m, X2, 94.8-35.1. *Rewanispora foveolata*. D) "Fungal remains", a bent tube with partition from Lusitaniadalen Member, 137.5 m, Si, 100.6-26.4. E) *Cymatiosphaera* spp., Vendomdalen Member, 221.8 m, X5, 105.5-28.1. F) Algal colony, Vendomdalen Member, 200.4 m, Si, 107.1-40.3. G) *Tympanicysta stoschiana*, Deltadalen Member, 67 m, X1, 100.1-34.0. H) "Planktonic alga type A", Lusitaniadalen Member, 122.3 m, X1, 103.4-33.1. I) Tasmanitid, a degraded specimen damaged by pyrite crystals, Lusitaniadalen Member, 141.2 m, X1, 101.1-32.0. J) Palynofacies with *Filisphaeridium setasessitante*, Deltadalen Member, 65.8 m, X2, 103.5-36.4. K) *Micrhystridium* and "Planktonic alga type A", Lusitaniadalen Member, 144.2 m, Si, 99.3-30.7. L) *Tasmanites*, Vendomdalen Member, 168 m, X2, 107.6-27.9.

the Griesbachian assemblage are missing, and the assemblage resembles Dinerian Assemblage O (Hochuli et al. 1989) from Bertilryggen. The isolated specimen of *Tympanicysta stoschiana* at 67.0 m (Fig. 11) has been interpreted as due to reworking of Assemblage P.

Of note is the "Planktonic alga type A" comprising originally spherical, thick-walled smooth tests of rounded to triangular outline. The wall extends into 4 to 7 hollow cones, each of them continuing as a solid flexible whip-like projection that is often broken or missing (Fig. 10H, K). Compressional folds obscure a slit or an irregular hole in the wall. The opening suggests that the tests have germinated and emptied their living content. Spherical thick-walled specimens that are missing, or carrying poorly developed, conical bases resemble tasmanitids. Similar triangular specimens have been described as *Veryhachium subglobosum* Combaz, Peniguel and Vachey 1974. These algae occur in the upper part of the Deltadalen Member and the lower part of the Lusitaniadalen Member.

Discussion: The same palynomorphs occur in the basal beds (0.2–1.7 m) of Deltadalen Member and the top of the Kapp Starostin Formation at Vikinghøgda and indicate a Late Permian age. *Tympanicysta stoschiana* is absent, and it has no record from the top of the Kapp Starostin Formation at Vikinghøgda or elsewhere in Svalbard.

Within the 1.7–4.7 m interval of the Deltadalen Member, the organic residues change: the content of woody material decreases, while plankton, pollen, spores and their degraded products are dominant. The palynological assemblages change in the same interval from being dominated by bisaccates alone, to comprising equally dominant bisaccates, spores and plankton. The Permian–Triassic boundary therefore seems situated within the 1.7–4.7 m interval. The assemblages from 4.7–48.3 m at Vikinghøgda are restricted to the three lower of the Griesbachian ammonoid zones elsewhere in the Arctic. The palaeontogical evidence from the Barents Shelf and Svalbard supports the assumption that the L. obsoleta–T. stoschiana Assemblage (Mangerud 1994) and the Assemblage P (Hochuli et al. 1989) are partly time equivalents. Assemblage Svalis$_1$ (Vigran et al. 1998) seems to represent younger Griesbachian layers also within the range of Assemblage P. The deposits at 56.6–67.8 m, in the Deltadalen Member are correlated by palynology to be most likely Dienerian in age. The increased proportion of plankton and the increasing abundance of "Planktonic alga type A" in these layers mark an environmental change that continues into the Lusitaniadalen Member (Figs. 9, 11).

Lusitaniadalen Member

The residues of the Lusitaniadalen Member (68.6–156.8 m; Fig. 9) are distinguished from those of the Deltadalen Member by the presence of "Fungal remains" (Hochuli et al. 1989). The dominant plankton, as in the upper part of the Deltadalen Member, comprises *Micrhystridium* and "Planktonic alga type A" (Fig. 11). The low diversity assemblage comprises *Cycadopites*, *D. nejburgii*, *Pretricolpipollenites* sp. and *Punctatisporites fungosus*. The bisaccates of the *Lunatisporites* group are less well-represented than in the Deltadalen Member below. This assemblage, found throughout the Lusitaniadalen Member, is equivalent to Assemblage N of Hochuli et al. (1989), but it may be further subdivided based on relative assemblage criteria:

1) Palynological assemblages from the lower part of the member (68.6–89.0 m; Fig. 11) are distinguished by the lowest acme for "Fungal remains." The same palynomorphs and the relative assemblage composition are also recorded as Assemblage N by Mørk, Vigran & Hochuli (1990) from the Urd Formation on Bjørnøya.
2) Assemblages from the middle and higher parts (92.6–150.5 m; Fig. 11) of the Lusitaniadalen Member have relatively few "Fungal remains" but a regular representation of *P. fungosus*. The "Planktonic alga type A" dominates the interval that corresponds to the "Fish Niveau" of Stensiö (1921, 1925) and is dated by ammonoids to the Euflemingites romunderi Zone. A reduction of "Fungal remains" also occurs in the palynological assemblages from the romunderi Zone on Bjørnøya (figure 14a in Mørk, Vigran & Hochuli 1990).
3) Assemblages from the highest layers (153.8–156.8 m; Wasatchites tardus Zone) of the Lusitaniadalen Member are distinguished by a relative increase of *D. nejburgii*, *Cycadopites* and "Fungal remains." In the uppermost part of the Urd Formation on Bjørnøya, there is a second acme zone for "Fungal remains", an acme for *D. nejburgii* and a generally more diverse assem-

blage of pollen and spores (figure 14a in Mørk, Vigran & Hochuli 1990). The deposits of the W. tardus Zone from the Svalis Dome contain the diverse assemblage $Svalis_2$, with regular to common "Fungal remains", dominant cavate spores and an acme for *P. fungosus* (Vigran et al. 1998).

Discussion: The palynological results obtained for the Lusitaniadalen Member suggest that there may be a regional pattern of floral development related to the Smithian deposits on the Barents Shelf. The acme of "Fungal remains" (68.6–89.0 m; Fig. 11) lowest in Lusitaniadalen Member is probably correlated to the equivalent acme interpreted from the distribution chart for the Urd Formation, Bjørnøya (figure 14a in Mørk, Vigran & Hochuli 1990). In both areas above this acme, there are low diversity palynological assemblages with reduced input of "Fungal remains" that are dated by ammonoids to the Euflemingites romunderi Zone. Above the E. romunderi Zone in the Lusitaniadalen Member, palynological associations with increased input of "Fungal remains" are dated by ammonoids to the Wasatchites tardus Zone. The undated sediments above the *Euflemingites* horizons on Bjørnøya have a spore-dominated assemblage, with the lowest record of *P. fungosus*, and an increased proportion of 'Fungal remains'. These horizons on Bjørnøya are probably equivalents of the W. tardus Zone at Vikinghøgda. The equivalent ammonoid-dated horizons from the Svalis Dome comprise a diverse spore-dominated assemblage $Svalis_2$ with an acme of *P. fungosus*, *Densoisporites* spp. and *Lundbladispora* spp. There are only rare, but consistent "Fungal remains" (Vigran et al. 1998).

Vendomdalen Member

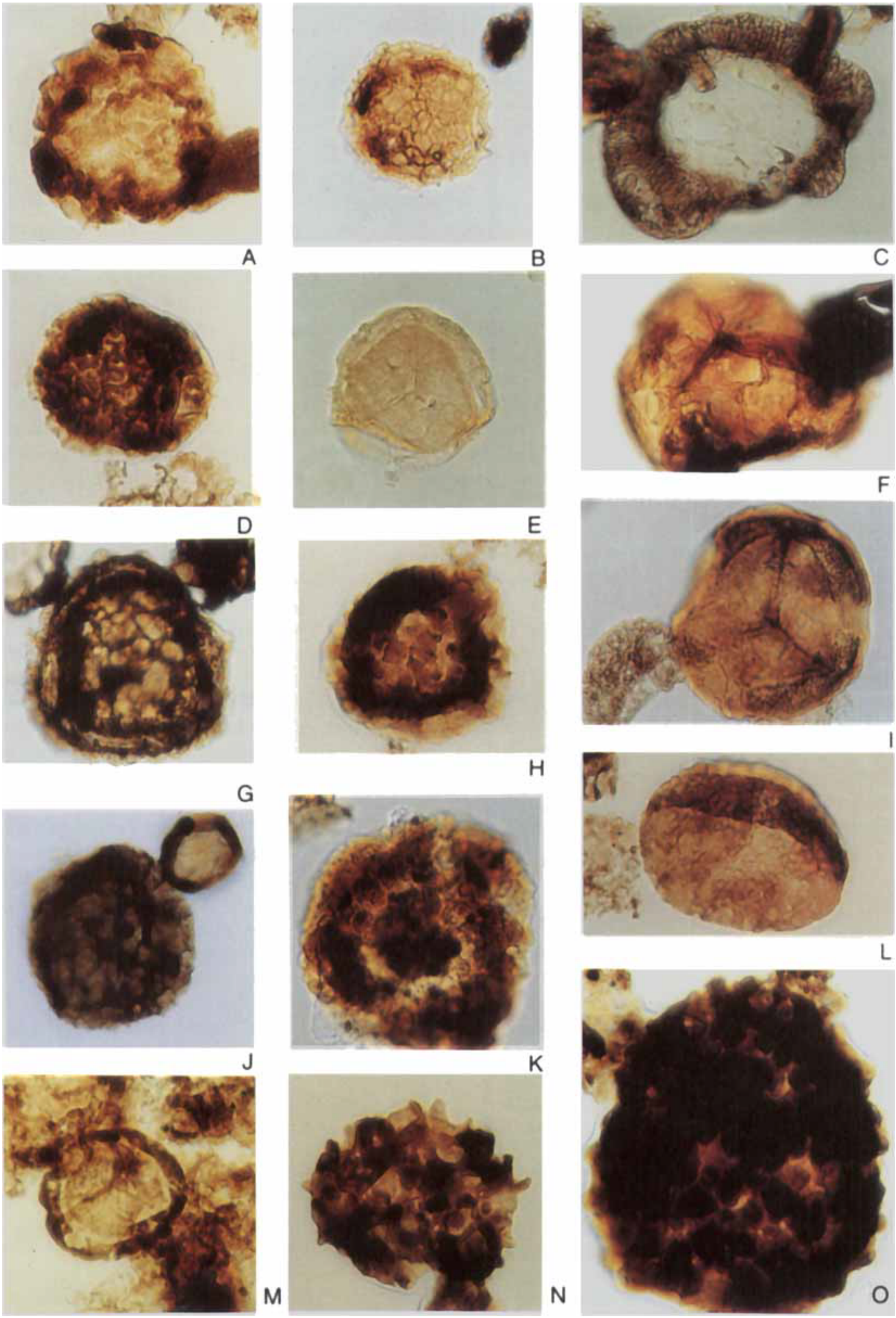
The residues in the lower part of the Vendomdalen Member (159.0–188.5 m; Fig. 9) predominantly comprise dense aggregates of degraded organic debris, which obscure the palynomorphs. The palynomorph taxa (Figs. 11, 12) are the same as in the Dienerian deposits of Lusitaniadalen Member, but occur in different proportions. Bisaccate pollen and *Micrhystridium* dominate, while "Fungal remains" and spores decrease. The poorly preserved, severely degraded specimens of *Tasmanites* (Fig. 10) are easily overlooked. *Lueckisporites junior* has its first occurrence at about 168 m in the mountain section and about 172 m in the Duboisbreen river section. The same residue (172 m; Fig. 11) is characterized by *Gordonispora fossulata*, *Pechorosporites disertus* and *Rewanispora foveolata*, an association that also occurs at 175 m in the mountain section. There are poorly preserved specimens of *P. disertus*. The assemblages are considered as equivalent to Assemblages M of Hochuli et al. (1989) and $Svalis_3$ (Vigran et al. 1998). The record of *L. junior* at this low level at Vikinghøgda contradicts the evidence from the Svalis Dome where this pollen has its first occurrence in the Anisian assemblage $Svalis_5$.

The residues from the upper part of the Vendomdalen Member (190.3–249.3 m) are distinguished by dense aggregates of degraded organic debris and plankton, dominantly *Micrhystridium* and tasmanitids (Fig. 9). The palynological assemblage comprises *Cyclotriletes pustulatus*, *Illinites chitonoides* (226 m; Fig. 11), *Jerseyiaspora punctispinosa*, and an upwards increasing abundance of the *Verrucosisporites* group. There is a single occurrence of *Striatella seebergensis* (233.8 m; Fig. 11) that coincides with an increase of bisaccate pollen, including the *Striatoabieites* group. The assemblage from this interval is most likely correlated to Assemblage L that Hochuli et al. (1989) reported as ranging from Upper Spathian to Lower Anisian. Both *J. punctispinosa* and *S. seebergensis* have records in ammonoid-dated Upper Spathian deposits elsewhere in Svalbard.

Discussion: Most of the spore taxa in assemblages from the Vendomdalen Member are also present in the Dienerian deposits from Vikinghøgda and the Barents Shelf. However, these taxa are strikingly rare in the spore-dominated Smithian deposits (table 2 in Vigran et al. 1998). Hochuli et al. (1989) noted that Assemblages M and O are difficult to distinguish unless the intervening Assemblage N with "Fungal remains" is present. The influx in the upper part of the Vendomdalen Member of taxa defining the $Svalis_4$ (in the Keyserlingites subrobustus Zone) and $Svalis_5$ (early Anisian, Karangatites evolutus Zone) indicates that land plants developed different from the pattern seen on the Svalid Dome.

Botneheia Formation

The samples from the lowest beds of the Botneheia Formation have organic residues dominated by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degraded aggregates obscuring the embedded palynomorphs. The dominant palynomorphs are *Micrhystridium* and *Tasmanites* and bisaccate pollen, in particular those from the *Striatoabieites* group (Fig. 11). The low diversity assemblage is difficult to correlate with confidence to the late Spathian–early Anisian Assemblage L of Hochuli et al. (1989).

The general features of the Spathian–Anisian assemblage reflect deposition on a shallow shelf. The index fossil of $Svalis_4$, *J. punctispinosa*, and that of $Svalis_5$, *S. seebergensis* have not been found although both are represented in the Vendomdalen Member. The well-represented cavate spores seem out of place since this feature normally indicates the Spathian (Vigran et al. 1998). It may be that the lowest layers of the Botneheia Formation include reworked Spathian deposits.

Organic richness and facies

Hydrocarbon source rock screening analysis (total organic carbon [TOC] and RockEval pyrolysis) and kerogen evaluation were performed on samples from Vikinghøgda (Fig. 9, Table 1). The results show an overall upwards increase in organic content throughout the Vikinghøgda Formation and a characteristic pattern for the individual members.

Fig. 12. Palynomorphs from Vikinghøgda Formation, Deltadalen. The metre level is followed by a letter code indicating progressive oxidation levels (X1–X5; Si = sieved residue) and slide coordinates. The exposures are through ×40 lenses, unless otherwise indicated. A) *Uvaesporites* spp., Vendomdalen Member, 233.8 m, X2, 106.3-35.9. B) *Proprisporites pocockii*, Deltadalen Member, 11.2 m, X3, 106.8-25.8. C) *Crustaesporites globosus*, Deltadalen Member, 11.2 m, X2, 99.6-28.8. D) *Lycopodiacidites* sp. cf. *kuepperi*, Vendomdalen Member, 226.0 m, X5, 98.5-34.1. E) *Densoisporites playfordi*, Deltadalen Member, 11.2 m, X2, 99.0-36.6. F) *Perotrilites* spp., Lusitaniadalen Member, 92.6 m, X2, 100.0-26.0. G) *Pechorosporites* sp. cf. *intermedius*, Deltadalen Member, 27.5 m, X3, 105.1-22.1. H) *Kraeuselisporites apiculatus*, Vendomdalen Member, 213.0 m, X3, 103.5-29.6. I) *Densoisporites playfordi*, Deltadalen Member, 11.2 m, X3, 104.2-28.2. J) *Kraeuselisporites spinosus*, Lusitaniadalen Member, 144.2 m, Si, 100.2-21.4. K) *Pechorosporites coronatus*, Deltadalen Member, 62.2 m, Si, 96.4-33.1. L) *Verrucosisporites pustulatus*, Vendomdalen Member, 197.4 m, X3, 101.4-25.3. M) *Gordonispora fossulata*, Vendomdalen Member, 175.0 m, X2, 104.2-33.3. N) *Jerseyiaspora punctispinosa*, Vendomdalen Member, 190.3 m, X5, 99.5-24.1. O) *Cycloverrutriletes presselensis*, Vendomdalen Member, 190.3 m, X3, 96.5-27.9.

In the Deltadalen Member low TOC values (mostly <0.5%) were recorded. Higher values (1.0 and 1.8%) were found in samples from mudstones which directly overlie the basal bioturbated sandstone. These samples also show a significant content of pollen and marine plankton and the samples contain type II and mixed type II/III kerogen. The remainder of the Deltadalen Member shows a diverse palynofacies with wood fragments, cuticle, spores and marine plankton. However, due to the low content of total organic carbon the unit as a whole must be rated as having a poor hydrocarbon potential. The sediments, with abundant hummocky and current ripples, have been reworked under oxic depositional conditions, unfavourable for preservation of organic material.

In the Lusitaniadalen Member the organic carbon content ranges between 0.3 and 2.0%, which is a significant increase in organic richness relative to the underlying member. The kerogen is of type III. An upwards increasing trend in organic richness is also observed. The kerogen is dominated by organic flakes or plates, but there are also significant proportions of marine plankton (acritarchs), while pollen and wood fragments are reduced from the member below. Another characteristic feature of this member is the content of "Fungal remains" (see palynology section). This member has fair potential as a source rock for gas.

The Vendomdalen Member deviates from the underlying succession by having TOC content generally above 1% (mean around 2%) and mixed type II/III kerogen. Land-derived palynodebris (wood, cuticle and pollen) is significantly reduced and replaced by marine plankton, in particular tasmanitids and *Micrhystridium*. These changes are accompanied by a loss of sandstones and current indicators in the succession. This member has potential as a source rock for both gas and oil.

The abrupt improvement in organic carbon content and change in kerogen type from the Lusitaniadalen Member to the Vendomdalen Member was not noted by Mørk & Bjorøy (1984). Their data from the upper part of the former Sticky Keep Member show that there is a significant change in the content and properties of the organic matter, indicating that the interpretations from the Vikinghøgda area are regionally consistent. At the Svalis Dome in the southwestern Barents Sea excellent hydrocarbon source rocks are found from the Spathian upwards (Leith

Table 1. Organic richness (TOC) and RockEval pyrolysis data.

Level m	TOC %	Rock-Eval Pyrolysis S1	S2	Tmax °C	Hydrogen index	Production index
250.50	1.00	2.14	2.49	439	249	0.46
249.30	0.57	–	–	–	–	–
246.70	4.41	2.81	14.67	442	333	0.16
242.30	3.73	3.18	12.84	439	344	0.20
233.80	1.55	1.23	4.03	438	260	0.23
226.00	1.95	–	–	–	–	–
221.80	2.76	1.63	8.89	440	322	0.15
213.00	1.86	1.85	4.72	439	254	0.28
200.40	1.90	1.40	4.53	439	2389	0.24
190.30	1.62	–	–	–	–	–
188.50	2.69	1.63	7.71	442	287	0.17
184.00	1.06	–	–	–	–	–
177.70	2.28	1.59	6.47	441	284	0.20
173.60	0.91	–	–	–	–	–
172.00	2.26	1.76	6.51	442	288	0.21
169.00	3.04	4.83	10.80	445	355	0.31
168.00	1.34	–	–	–	–	–
164.50	2.78	3.26	9.33	443	336	0.26
159.00	2.23	2.24	6.29	441	282	0.26
156.80	1.23	–	–	–	–	–
155.80	1.96	1.67	5.51	444	281	0.23
155.50	0.84	–	–	–	–	–
150.50	1.12	0.98	2.14	442	191	0.31
146.70	0.54	–	–	–	–	–
144.20	1.02	–	–	–	–	–
143.20	1.27	1.39	2.15	440	169	0.39
138.90	0.55	0.52	0.65	439	118	0.44
128.20	0.75	0.56	1.01	438	135	0.36
122.30	0.78	0.86	1.16	437	149	0.43
102.30	0.26	–	–	–	–	–
101.00	0.60	0.36	0.76	438	127	0.32
95.00	0.66	0.59	1.29	437	195	0.31
89.00	0.58	0.71	1.11	436	191	0.39
87.00	0.66	–	–	–	–	–
84.00	0.59	0.58	0.90	439	153	0.39
75.80	0.54	0.31	0.79	438	146	0.28
70.80	0.30	–	–	–	–	–
68.60	0.54	0.32	0.69	439	128	0.32
67.80	0.476	–	–	–	–	–
67.00	0.24	–	–	–	–	–
65.80	0.21	–	–	–	–	–
62.20	0.31	0.15	0.11	439	35	0.58
56.60	0.22	–	–	–	–	–
37.00	0.56	1.34	1.12	439	200	0.54
27.50	0.28	–	–	–	–	–
20.30	0.24	–	–	–	–	–
14.00	0.29	–	–	–	–	–
13.80	0.47	–	–	–	–	–
11.20	0.27	–	–	–	–	–
7.60	1.00	1.08	1.68	438	168	0.39
4.70	1.78	2.49	4.33	444	243	0.37
1.10	0.26	–	–	–	–	–
0.20	0.33	–	–	–	–	–
–5.00	0.14	–	–	–	–	–

et al. 1993; Mørk & Elvebakk 1999), showing that the transition to environments with improved preservation potential of organic material is a regional phenomena.

The RockEval T_{max} values vary between 436 and 445°C, and the values are similar to those reported by Mørk & Bjorøy (1984) from the Middle Triassic succession of the same area, indicating that the whole succession lies within the oil window. The production index is mostly low, but several samples have values between 0.3 and 0.6, indicating that some hydrocarbon staining has occurred in the succession.

Magnetostratigraphy

Samples for magnetostratigraphy were collected mostly from siltstone and sandstone beds in the Deltadalen and lower Lusitaniadalen members, and from concretionary calcite and dolomite in the Vendomdalen Member and the upper part of the Lusitaniadalen Member. The samples were subjected to conventional thermal and alternating field (AF) demagnetization to isolate the characteristic remanence. Thermal demagnetization to 250°C, followed by AF demagnetization to 80 mT, proved effective in removing a present day-like overprint from the Triassic magnetization. The magnetization appears to be carried by a combination of magnetite and magnetic sulphide. The palaeomagnetic details will be presented elsewhere.

Stratigraphic height details differ slightly from those presented in Hounslow et al. (1996), because of stratigraphical re-evaluation made during fieldwork in 1997. The magnetozones have been numbered into reversed-normal polarity couplets, in the same way as marine magnetic anomalies are referenced (Cande & Kent 1992; Kent et al. 1995). The prefix V refers to the Vikinghøgda section. Using such a scheme the normal magnetozone V2n at 55 m (Fig. 13) is composed of submagnetozones in descending order V2n.n1 (normal), V2n.r1 (reversed) and V2n.n2. The work of Ogg & Steiner (1991) provides the most closely comparable Lower Triassic magnetostratigraphic study. In their study of the Sverdrup Basin sequences, magnetozones were numbered with codes GN, DN and SMN indicating normal polarity zones in the Griesbachian, Dienerian and Smithian respectively.

The two horizons sampled from the Kapp Starostin Formation (Fig. 4) show reversed polarity. This could indicate either a youngest Tatarian age, or a somewhat older age in the late Permian (Gialanella et al. 1997). The long normal polarity magnetozone (V1n) at the base of the Deltadalen Member is probably the GN1 magnetozone of Ogg & Steiner (1991), which has been identified in sequences in Asia and Europe (Haag & Heller 1991; Steiner et al. 1993; Nawrocki 1997) and characterizes the boreal lower Griesbachian ammonoid zones. In addition, within GN1, short reversed polarity magnetozones have been found in the Siberian traps (Gurevitch et al. 1995) and in China (Haag & Heller 1991), which may correlate to the short reversed intervals at 1.8 m, 10 m, and 13.3–14.8 m (Fig. 4). It is unclear, because of a sampling gap at the base of the Deltadalen succession, if the normal polarity continues through the basal transgressive shale of the Deltadalen Member.

The top part of the Deltadalen, and lower part of the Lusitaniadalen members (36–105 m; Fig. 4) contain reversed and normal polarity magnetozones. The overall mixed polarity character of this interval is the same as the mid Griesbachian to lower Smithian of Ogg & Steiner (1991) and Haag & Heller (1991), and less well-dated European sections (Nawrocki 1997). The overall mixed polarity of this interval indicates that most of the Dienerian and lower Smithian is probably present. If this were not so, more normal polarity would be evident in the upper parts of the Deltadalen and lower parts of the Lusitaniadalen members.

Over the interval 36–105 m the following correlations to the Ogg & Steiner (1991) results from the Sverdrup Basin are the most plausible:

1) V1r.n1 is the equivalent of GN2 of the Sverdrup Basin study. In the Sverdrup Basin GN2 is a thin normal zone, found only at the Creek of Embry locality. GN2 is late Griesbachian, based on ammonoid control.
2) V2n is equivalent to DN1, which was identified at the Creek of Embry and Griesbach Creek and is a relatively thick normal polarity zone, like V2n from the Vikinghøgda section. From the Sverdrup Basin study DN1 is early Dienerian.
3) VSn and V5r.n1 are equivalent to SMN1. Both at Vikinghøgda and in the Sverdrup Basin study, these polarity zones correspond to the basal part of the E. romunderi Zone.
4) V3n and V4n correlate with the interval

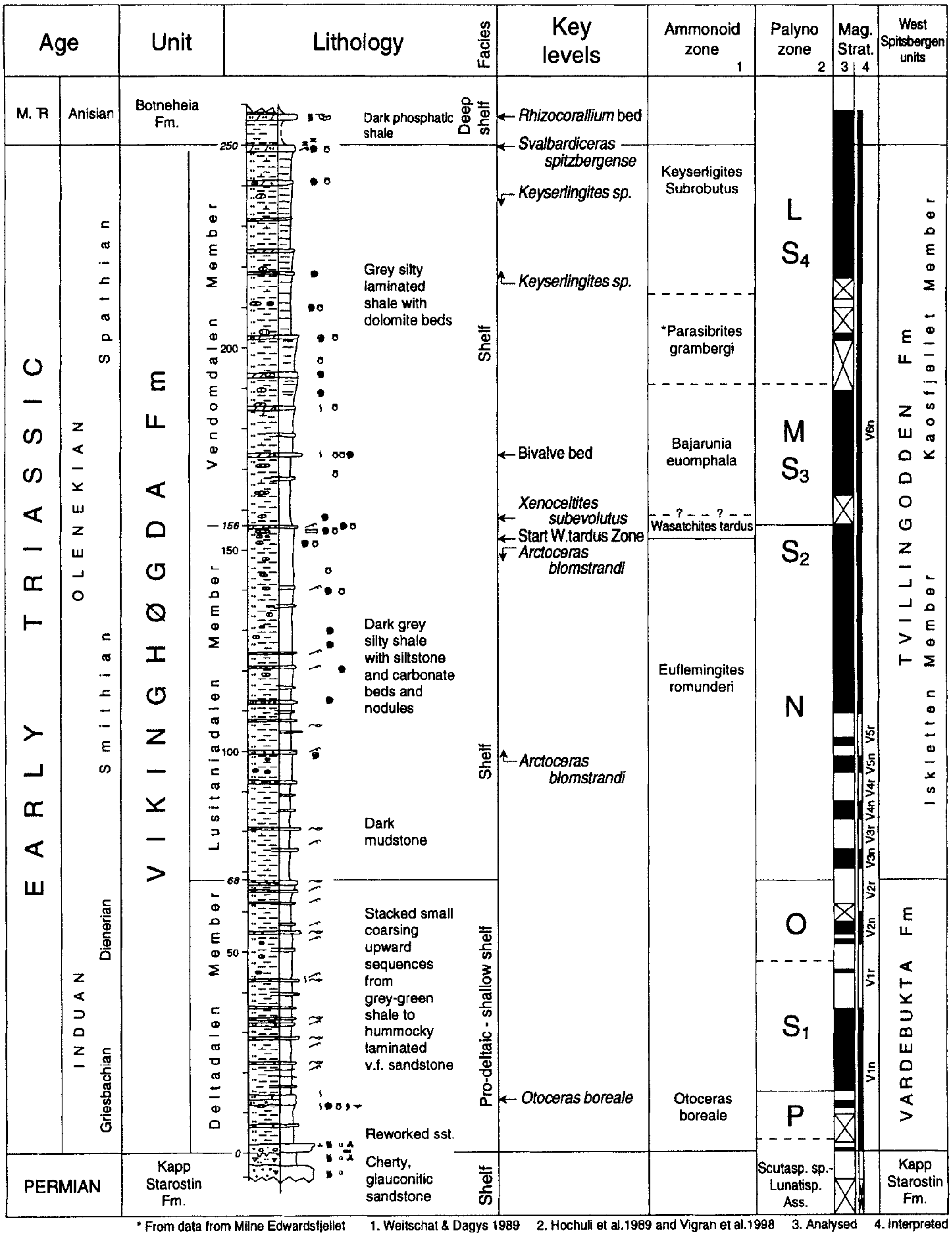

Fig. 13. Summary diagram from the type section. Legend with Fig. 4.

between DN1 and SMN1. In the Sverdrup Basin, the section with the largest sedimentation rate over this interval was Embry Creek. This section possessed two normal polarity zones between DN 1 and SMN 1 over this interval (DN2 and a lower unnumbered normal polarity zone). V4n may correlate with the upper (DN2), and V3n with the unnumbered lower magnetozone from Embry Creek. Biostratigraphic confirmation of the age of these magnetozones from the Sverdrup Basin was lacking, but they may occur in an interval between the upper Dienerian and lowest Smithian.

These correlations would place the age of the top of the Deltadalen Member as mid-Dienerian. This is compatible with the Griesbachian-Dienerian palynology age of the upper part of the member, and the conodont fauna.

Above 108 m, up to the last occurrence of *Wasatchites tardus*, the polarity is normal (V6n), which corresponds closely with the normal polarity in the Sverdrup Basin sequences, covering the same ammonoid zones.

Samples from the Vendomdalen Member have a steeper mean inclination (entirely normal polarity) magnetization than the underlying units. It has not proved possible to test the age of this magnetization because of the low bedding dips. Combined with the reverse polarity in the Spathian identified by Ogg & Steiner (1991) and Muttoni et al. (1995), these data suggest the Vendomdalen Member samples have been remagnetized. The cause of the remagnetization is unclear – possibilities include weathering and freeze-thaw action – but may be causally connected with the following features:

1) The total dominance of an unidentified magnetic sulphide as the carrier of the remanence in the Vendomdalen Member.
2) The exclusive collection of samples in the Vendomdalen Member from the yellow weathering dolomite beds, of late diagenetic origin. Samples from other units were collected from siltstone units, or early diagenetic calcite concretions.
3) The relatively high organic carbon content of the Vendomdalen Member, which has probably acted to modify the diagenetic processes responsible for the sulphides, in comparison to the underlying, less organic-rich units.

The remagnetization is not a local phenomenon; recent work from the same unit at Milne Edwardsfjellet 15 km further south-east displays the same remagnetization.

Discussion

Using a multidisciplinary approach to establish this new type section highlights the dangers of erecting type sections based on restricted information. Although the conceptual definitions by Buchan et al. (1965) and Mørk, Knarud et al. (1982) are still valid, wrong correlations to other areas (i.e. western Svalbard), resulted from poor exposures in the previously defined type section, and the erection of succeeding type sections in different geographical areas (i.e. Tvillingodden Formation was defined in the western outcrop area, while Sticky Keep Formation/Member was defined in the central areas). It should be noted that the Russian researchers (e.g. Pčelina 1983) presented correlations compatible with those made during the present study.

The new Vikinghøgda Formation type section is located in the same area as the earlier type section of the Sticky Keep Formation/Member, but in a well-exposed river section which permits both palaeontological, sedimentological and magnetostratigraphic control. The palaeontological control (i.e. the presence of *Arctoceras blomstrandi* at 98 m above base Triassic) clearly demonstrates the erroneous member boundary indicated by Mørk, Knarud et al. (1982), and represents a clear improvement in relation to the type section of Buchan et al. (1965).

Conodonts, palynomorphs and mineral grains typical for the Kapp Starostin Formation are also recorded from the basal sandstone of the Deltadalen Member, indicating reworking at the boundary.

The Deltadalen Member is dated by the early Griesbachian *Otoceras boreale* in the lower part of the unit. The layers from 4.7–48.3 m are correlated by palynology to be of Griesbachian age. The age is supported by magnetostratigraphy, which indicates that sedimentation continued through the Griesbachian into the Dienerian. Wignall et al. (1997) have suggested that the presence of *Tympanicysta stoschiana* in the Vardebukta Formation as recorded by Mangerud & Konieczny (1991), could be associated with a Late Permian "fungal spike" (Visscher et al. 1996). According to the results presented by Mangerud & Konieczny (1993) and Mangerud (1994), a Permian acme zone for *T. stoschiana* has so far not been recognized in Svalbard or on the Finnmark Platform. At Vikinghøgda the single specimen of *T. stoschiana* was discovered above the level of the *Otoceras boreale* fauna. Therefore in Svalbard *T. stoschiana* is only recorded well above the highest records of Permian indicators like *Vittatina* spp. and *Unellium* spp.

Biostratigraphical control in the Dienerian deposits in Svalbard is poor with one observation of *Vavilovites* cf. *sverdrupi* (upper Dienerian) from the Vardebukta Formation (Gazdzicki & Trammer 1977) and one from Lusitaniadalen (Korčinskaja 1986). Palynology of the same level reflects a change in the marine environment, which continues into the Lusitaniadalen Member. Throughout Svalbard no ammonite fauna has been found in the lowest part of the Lusitaniadalen Member or in the lowermost part of the Tvillingodden Formation. Classically an "undated ammonoid zone" is suggested at the base of the Smithian on most correlation diagrams (Mørk, Embry et al. 1989; Weitschat & Dagys 1989; Dagys & Weitschat 1993). The base of both the Lusitaniadalen Member and the Tvillingodden Formation have been interpreted as a major transgressive episode resulting in deposition of undated basal mudstones. This transgression has been regarded as earliest Smithian in age, partly based on comparisons with other Arctic areas (Embry 1988; Mørk, Embry et al. 1989; Mørk, Egorov et al. 1994). The conodont *N. svalbardensis* at 69 m suggests an early Dienerian age. The magnetostratigraphic data indicate that the Deltadalen–Lusitaniadalen member boundary is located within the mid-Dienerian, and that the basal parts of the Lusitaniadalen Member thus may be of Dienerian age. The palynological investigations allow recognition of the Assemblage N of (Hochuli et al. 1989), with abundant "Fungal remains" below the first *Arctoceras blomstrandi* at 98 m; and the present data show that Assemblage N starts already in the Dienerian. The well-developed overlying faunas document the E. romunderi and W. tardus zones (Fig. 13) which also fits the magnetostratigraphy compared with the Sverdrup Basin.

The Smithian–Spathian transition occurs between the Wasatchites tardus Zone and the bivalve-rich bed with *Bajarunia* ex gr. *euomphala* of the lowermost Spathian. This interval contains the palynological assemblages correlated with $Svalis_3$ (Vigran et al. 1998) or Assemblage M (Hochuli et al. 1989) predating the late Spathian palynozone $Svalis_4$ recorded in upper part of the Vendomdalen Member.

The marked reduction in abundance of silt/sandstones and the transition into dark grey mudstones, which characterize the Vendomdalen Member, occur just above the sandstone bed with a W. tardus Zone fauna. This transition correlates with transgressions in the latest Smithian in the Sverdrup Basin (Embry 1988, 1997) and in the earliest Spathian in Siberia (Egorov & Mørk in press), and also correlates with a pronounced transgression in the Barents Sea (Van Veen et al. 1993). It should be noted that the change in abundance and type of organic material at the Lusitaniadalen–Vendomdalen member boundary indicates a change in sedimentary regime at this level. This change is accompanied by a minor reduction in sedimentation rate and a bloom in marine plankton resulting in deposition of mixed kerogen type II/III. At the Svalis Dome, in the western Barents Sea, this transition is more prominent, resulting in the deposition of excellent hydrocarbon source rock; a transition which is delayed until the Anisian Botneheia Formation in central Spitsbergen (Mørk & Bjory 1984).

Acknowledgements. – We wish to thank Reinhardt Veit for ammonoid collecting, Clare Peters for co-work in the field and laboratory, and the technical staff at IKU/SINTEF Petroleum Research, mainly Jan H. Johansen, for help with the illustrations. Discussions with Algirdas S. Dagys has clarified biostratigraphical problems. The project has been supported by Saga Petroleum ASA and Norsk Hydro ASA. The manuscript benefits from comments by Geoffrey Warrington and Ashton F. Embry.

References

Balme, B. E. 1980: Palynology of Permian–Triassic boundary beds at Kap Stosch, East Greenland. *Meddelelser om Grøland 200(6)*, 37 pp.

Beauchamp, B., Harrison, J. C. & Henderson, C. 1989: Upper Paleozoic stratigraphy and basin analysis of the Sverdrup Basin, Canadian Arctic Archipelago. Part 1: Time frame and tectonic evolution. *Current Research, Part G, Geological Survey of Canada, Paper 89-16*, 105–113.

Birkenmajer, K. 1977: Triassic sedimentary formations of the Hornsund area, Spitsbergen. *Studia Geologica Polonica 51 (pt. 8)*, 7–74.

Birkenmajer, K. & Trammer, J. 1975: Lower Triassic conodonts from Hornsund, South Spitsbergen. *Acta Geologica Polonica 25(2)*, 299–307.

Bromley, R. G. & Ekdale, A. A., 1986: Composite ichnofabrics and tiering of burrows. *Geological Magazine 123(1)*, 59–65.

Buchan, S. H., Challinor, A., Harland, W. B. & Parker, J. R. 1965: The Triassic stratigraphy of Svalbard. *Norsk Polarinst. Skrifter 135*, 94 pp.

Cande, S. C. & Kent, D. V. 1992: A new geomagnetic polarity time scale for the late Cretaceous and Cenozoic. *J. Geophys. Res. 97*, 13,917–13,951.

Dagis, A. A. 1984: Early Triassic conodonts of northern central Siberia. *Trans. Inst. Geol. Geophys. Acad. Sci. (USSR Siberian Branch) 554*, 1–69.

Dagis, A. A. & Korčinskaja, M. 1987: The first discoveries of conodonts in the Otoceras beds of Svalbard. *Trudy Instituta Geolog i Geofiziki (Novosibirsk) 689*, 110–113.

Dagys, A. S. & Ermakova, S. P. 1988: Boreal Late Olenkian Ammonoids. *Trans. Inst. Geol. Geophys. Acad. Sci. (USSR Siberian Branch) 714*, 132 pp.

Dagys, A. S. & Weitschat, W. 1993: Correlation of the Boreal Triassic. *Mitteilungen Geologisch-Paläontologisches Institut Universität Hamburg 75*, 249–256.

Dickins, J. M. 1997: Comment – The Permian–Triassic boundary: recent developments, discussion and proposals. *Albertiana 19*, p. 8.

Egorov, A. Y. & Mørk, A. in press: The East Siberian and Svalbard Triassic successions and their sequence stratigraphical relationships. In Lerche, I. & Bachmann, G. B. (eds.): *Proceedings of the Epicontinental Triassic International Symposium, Halle/Saale 1998*. Springer.

Embry, A. F. 1988: Triassic sea level changes: evidence from the Canadian Arctic archipelago. In Wilgus, C. K. et al. (eds.): Sea level changes: an integrated approach. *SEPM Special Publication 42*, 249–259.

Embry, A. F. 1997: Global sequence boundaries of the Triassic and their identification in the Western Canada sedimentary basin. *Canadian Petroleum Geology Bulletin 45(4)*, 415–433.

Falcon, N. L. 1928: Geology; Appendix III in Watkins, H. G.: The Cambridge expedition to Edge Island. *Geographical Journal 72*, 134–139.

Flood, B., Nagy, J. & Winsnes, T. S. 1971a: Geological map of Svalbard 1:500,000, sheet IG, Spitsbergen, southern part. *Norsk Polarinst. Skrifter 154A*.

Flood, B., Nagy, J. & Winsnes, T. S. 1971b: The Triassic succession of Barentsøya, Edgeøya, and Hopen, Svalbard. *Norsk Polarinst. Medd. 100*, 20 pp.

Frebold, H. 1930: Die Altersstellung des Fischhorizontes, des Grippian niveaus und des unteren Saurierhorizontes in Spitsbergen. *Skr. Svalb. og Ishavet 28*, 1–36.

Gazdzicki, A. & Trammer, J. 1977: The Sverdrupi zone in the Lower Triassic of Svalbard. *Acta Geologica Polonica 27(3)*, 349–356.

Gialanella, P. R., Heller, F., Haag, M., Nurgaliev, D., Borisov, A., Burov, B., Jasonov, P., Kasanov, D., Ibragimov, S. & Zharkov, I. 1997: Late Permian magnetostratigraphy on the eastern Russian Platform. *Geologie en Mijnbouw 76*, 145–154.

Gurevitch, E., Westphal, M., Daragan-Suchov, J., Feinberg, H., Pozzi, J. P. & Khramov, A. N. 1995: Paleomagnetism and magnetostratigraphy of the traps from western Taimyr (northern Siberia) and the Permo-Triassic crisis. *Earth Planet. Sci. Lett. 136*, 461–473.

Haag, M. & Heller, F. 1991: Late Permian to early Triassic magnetostratigraphy. *Earth Planet. Sci. Lett. 107*, 42–54.

Henderson, C. M. 1993: Are Permian–Triassic boundary events diachronous? Evidence from the Canadian Arctic. P. 136. *Carboniferous to Jurassic Pangea: program and abstracts*.

Henderson, C. 1997: Uppermost Permian conodonts and the Permian–Triassic boundary in the western Canada sedimentary basin. *Bulletin of Canadian Petroleum Geology 45(4)*, 693–707.

Hochuli, P. A., Colin, J. P. & Vigran, J. O. 1989: Triassic biostratigraphy of the Barents Sea area. In Collinson, J. D. (ed.): *Correlation in hydrocarbon exploration*. Pp. 131–153. London: Norwegian Petroleum Society/Graham & Trotman.

Hounslow, M. W., Mørk, A., Peters, C. & Weitschat, W. 1996: Boreal Lower Triassic magnetostratigraphy from Deltadalen, central Svalbard. *Albertiana 17*, 3–10.

Kent, D. V., Olsen, P. E. & Witte, W. K. 1995: Late Triassic-earliest Jurassic geomagnetic polarity reference sequence from cyclic continental sediments of the Newark Rift Basin (eastern North America). *Albertiana 16*, 17–26.

Keyserling, A. von 1845: Beschreibungen einiger von Dr. A. Th. v. Middendorff mitgebrachten Ceratiten des arctischen Sibiriens. *Bulletin de l'Academie Imperiale des Sciences de St. Petersbourg 5*, 161–174.

Korčinskaja [Korchinskaya], M. V. 1982: Ob'jasnitel'naja zapiska k stratigrafičeskoj scheme mezozoja (trias) Sval'barda. (Explanatory note to the stratigraphic scheme of Mesozoic (Triassic) of Svalbard.) PGO "Sevmorgeologija", Leningrad. Pp. 40–49.

Korčinskaja, M. V. 1986: Biostratigrafija indskogo jarusa Špicbergena. (Induan Stratigraphy of Spitsbergen.) In: *Geologija osadočnogo čechla archipelaga Špicbergena. (Geology of the sedimentary cover of Spitsbergen.)* PGO "Sevmorgeologija", Leningrad. Pp. 77–93.

Kozur, H. 1989: Significance of events in conodont evolution for the Permian and Triassic stratigraphy. *Cour. Forsch. Inst. Senkenberg 117*, 85–408.

Kozur, H. 1995: Some remarks on the conodonts *Hindeodus* and *Isarcicella* in the latest Permian and lowermost Triassic. *Palaeoworld 6*, 64–77.

Kozur, H., Ramovs, A., Wang, C. Y. & Zakharov, Y. D. 1996: The importance of *Hindeodus parvus* (conodonta) for the definition of the Permian–Triassic boundary and evolution of the proposed sections for a global stratotype section and point (GSSP) for the base of Triassic. *Geologija 37-38*, 173–213.

Lai, X. 1997: A discussion on Permian–Triassic conodont studies. *Albertiana 20*, 25–30.

Leith, T. L., Weiss, H. M., Mørk, A., Århus, N., Elvebakk, G., Embry, A. F., Brooks, P. W., Stewart, K. R., Pčhelina, T. M., Bro, E. G., Verba, M. L., Danyushevskaya, A., Borisov, A. V. 1993: Mesozoic hydrocarbon source-rocks of the Arctic region. In Vorren, T. O. et al. (eds.): Arctic geology and petroleum potential. *Norwegian Petroleum Society (NPF) Special Publication 2*, 515–538.

Lock, B. E., Pickton, C. A. G., Smith, D. G., Batten, D. J. & Harland, W. B. 1978: The geology of Edgeøya and Barentsøya, Svalbard. *Norsk Polarinst. Skrifter 168*, 7–64.

Major, H. & Nagy, J. 1972: Geology of the Adventdalen map area. (Accompanies Major & Nagy 1964: Geological map of Svalbard 1:100,000, sheet C9G, Adventalen.) *Norsk Polarinst. Skrifter 138*, 58 pp.

Major, H., Nagy, J., Haremo, P., Dallmann, W. K., Andresen, A. & Salvigsen, O. 1992: Geological map of Svalbard 1:100,000, sheet C9G, Adventdalen. (Preliminary edition, colour plot; revised after Major & Nagy 1964.) *Norsk Polarinst. Temakart*.

Mangerud, G. 1994: Palynostratigraphy of the Permian and lowermost Triassic succession, Finnmark Platform, Barents Sea. *Review of Palaeobotany and Palynology 82*, 317–349.

Mangerud, G. & Konieczny, R. M. 1991: Palynological investigations of Permian rocks from Nordaustlandet, Svalbard. *Polar Res. 9(2), 155–167.*

Mangerud, G. & Konieczny, R. M. 1993: Palynology of the Permian succession of Spitsbergen, Svalbard. *Polar Res. 12(1)*, 65–93.

Miloslavskij, M. Ju., Birjukov, A. S., Šlenskij, S. N., Hansen, S., Larsen, B. T., Dallmann, W. K. & Andresen, A. 1993: Geological map of Svalbard 1 : 100,000, sheet D9G, Agardhfjellet. (With description by Miloslavskij, M. Ju., Dallmann, W. K., Dypvik, H., Krasil'sikov, A. A., Birkeland, Ø. & Salvigsen, O.) *Norsk Polarinst. Temakart 21.*

Miloslavskij, M. Ju., Birjukov, A. S., Šlenskij, S. N. & Dallmann, W. K. 1998: Geological map of Svalbard 1 : 100,000, sheet DBG, Negribreen. (With description by Miloslavskij, M. Ju., Dallmann, W. K. & Salvigsen, O.) *Norsk Polarinst. Temakart 25.*

Mørk, A. 1994: Triassic transgressive-regressive cycles of Svalbard and other Arctic areas: a mirror of stage subdivision. In Guex, G. & Baud, A. (eds.): *Recent developments on Triassic Stratigraphy, Mémoires de Géologie (Lausanne) 22*, 69–82.

Mørk, A. & Bjorøy, M. 1984: Mesozoic Source Rocks on Svalbard. In Spencer et al. (eds.): *Petroleum geology of the North European Margin.* Pp. 371–382. London: Norwegian Petroleum Society/Graham & Trotman.

Mørk, A. & Elvebakk, G. 1999: Lithological description of subcropping Lower and Middle Triassic rocks from the Svalia Dome, Barents Sea. *Polar Res. 18(1)*, 83–104.

Mørk, A. & Worsley, D. 1979: The Triassic and Lower Jurassic succession of Svalbard: a review. *Norwegian Sea Symposium NSS 29*, 1–22

Mørk, A., Dallmann, W. K., Dypvik, H., Johannessen, E. P., Larssen, G. B., Nagy, J., Nøttvedt, A., Olaussen, S., Pčhelina, T. M. & Worsley, D. in press: Mesozoic lithostratigraphy. In Dallmann, W. K. (ed.): *Lithostratigraphic lexicon of Svalbard.* Tromsø, Norway: Norwegian Polar Institute.

Mørk, A., Egorov, A. Y. & Embry, A. F. 1994: Base Olenekian and base Anisian sequence boundaries produced by Triassic circumpolar "synchronous" transgressions. In Thurston, D. K. & Fujita, K. (eds.): *International Conference on Arctic Margins 1992 Proceedings. OCS Study MMS 94-0040.* Alaska OCR Region. Pp. 9–14. U.S. Department of the Interior, Mineral Management Service.

Mørk, A., Embry, A. F. & Weitschat, W. 1989: Triassic transgressive-regressive cycles in the Sverdrup Basin, Svalbard and the Barents Shelf. In Collinson, J. D. (ed.): *Correlation in hydrocarbon exploration.* Pp. 113–130. London: Norwegian Petroleum Society/Graham & Trotman.

Mørk, A., Knarud, R. & Worsley, D. 1982: Depositional and diagenetic environments of the Triassic and Lower Jurassic succession of Svalbard. In Embry, A. F. & Balkwill, H. R. (eds.): *Arctic Geology and Geophysics, Canadian Society of Petroleum Geologists Memoir 8*, 371–398.

Mørk, A., Vigran, J. O. & Hochuli, P. A. 1990: Geology and palynology of the Triassic succession of Bjørnøya. *Polar Res. 8*, 141–163.

Mørk, A., Vigran, J. O., Korchinskaya, M. V., Pčhelina, T. M., Fefilova, L. A., Vavilov, M. N. & Weitschat, W. 1993: Triassic rocks in Svalbard, the Arctic Soviet islands and the Barents Shelf: bearing on their correlations. In Vorren, T. O. et al. (eds.): Arctic geology and petroleum potential. *Norwegian Petroleum Society (NPF) Special Publication 2*, 457–479.

Muttoni, G. Kent, D. V. & Gradstein, M. 1995: Magnetostratigraphy of the Lower-Middle Triassic boundary section from Chios (Greece). *Phys. Earth Planet Interiors 92*, 245–260.

Nakrem, H. A. 1991: Conodonts from the Permian succession of Bjørnøya (Svalbard). *Norsk Geologisk Tidsskrift 71*, 235–248.

Nakrem, H. A. & Mørk, A. 1991: New early Triassic bryozoa (Trepostomata) from Spitsbergen, with some remarks on the stratigraphy of the investigated horizons. *Geological Magazine 128(2)*, 129–140.

Nawrocki, J. 1997: Permian and early Triassic magnetostratigraphy from the central European basin in Poland: implications on regional and worldwide correlations. *Earth Planet. Sci. Lett. 152*, 37–58.

Ogg, J. G. & Steiner, M. B. 1991: Early Triassic polarity timescale: integration of magnetostratigraphy, ammonite zontation and sequence stratigraphy from stratotype sections (Canadian Arctic Archipelago). *Earth Planet. Sci. Lett. 107*, 69–89.

Orchard, M. J. & Tozer, E. T. 1997a: Triassic conodont biostratigraphy, its calibration with the ammonid standard, and a biostratigraphic summary for the western Canada sedimentary basin. *Bulletin Candian Petroluem Geology 45*, 675–692.

Orchard, M. J. & Tozer, E. T. 1997b: Triassic conodont biochronology and intercalibration with the Canadian ammonoid sequence. *Albertiana 20*, 33–44.

Pčelina [Pčhelina], T. M. 1965: Stratigrafija i sostav mezozojskich otloženij srednych rajonov Zapadnogo Špicbergena. (Stratigraphy and composition of the Mesozoic deposits of central Vestspitsbergen.) In Sokolov, V. N. (ed.): *Materialy po stratigrafii Špicbergena. (Data on the stratigraphy of Spitsbergen.)* NIIGA, Leningrad. (English translation: The National Lending Library for Science and Technology, Boston Spa, Yorkshire, England, 1970.)

Pčelina, T. N. 1967: Stratigrafija i nekotorye osobennosti veščestvennogo sostava mezozojskich otloženij južnych i vostočnych rajonov Zapadnogo Špicbergena. (Stratigraphy and some compositional features of the Mesozoic deposits of the southern and eastern areas of Vestpitsbergen.) In Sokolov, V. N. (ed.): *Materialy po stratigrafii Špicbergena. (Data on the stratigraphy of Spitsbergen.)* NIIGA, Leningrad. 121–158. (English translation: The British Library Board 1977, Stratigraphy of Spitsbergen, pp. 64–205.)

Pčelina, T. M. 1977: Permskie i triasovye otloženija ostrova Edž (Sval'bard). (Permian and Triassic deposits on Edgeøya, Svalbard.) In: *Stratigrafija i paleontologija dokembrija i paleozoja severa Sibiri. (Stratigraphy and palaeontology of the Precambrian and Palaeozoic of northern Siberia.)* Sbornik naučnych trudov (Collection of scientific papers), NIIGA, Leningrad. Pp. 59–71. (Unpublished English translation by Norwegian Polar Institute.)

Pčelina, T. M. 1983: Novye dannye po stratigraf mezozoja archipelaga Špicbergen. (New data on the Mesozoic stratigraphy of the archipelago of Spitsbergen.) In: *Geologija Špicbergena. (Geology of Spitsbergen.)* Pp. 121–141. PGO "Sevmorgeologija", Leningrad.

Piasecki, S. 1984: Preliminary palynostratigraphy of the Permian–Lower Triassic sediments in Jameson Land and Scoresby Land, East Greenland. *Geological Society of Denmark Bulletin 32*, 139–144.

Pojeta, J. Jr. & Balanc, M. 1989: Freezing and thawing of fossils. In Feldmann, R. M., Chapman, R. E. & Hannibal, J. T. (eds): Paleotechniques. *Paleontological Society Special Publication 4*, 223–226.
Steiner, M., Morales, M. & Shoemaker, E. M. 1993: Magnetostratigraphic, biostratigraphic and lithologic correlations in Triassic strata of the Western United States. In Aissaouui, D. M. et al. (eds.): Applications of paleomagnetism to sedimentary geology. *SEPM Special Publication 49*, 41–58.
Stensiö, E. A. 1921: *Triassic fishes from Spitzbergen*. Part I. Vienna. 307 pp.
Stensiö, E. A. 1925: *Triassic fishes from Spitzbergen*. Part II. *K. Svenska Vetensk. Akad. Handl. Ser. 3, 2(1)*, 1–261.
Spath, L. F. 1934: *The catalogue of the fossil cephalopoda in the British Museum (Natural History). Part 4: The ammonoidea of the Trias (I)*. London. 521 pp.
Szaniawski, H. & Malkowski, K. 1979: Conodonts from the Kapp Starostin Formation (Permian) of Spitsbergen. *Acta Palaeontologica Polonica 24(2)*, 231–264.
Tozer, E. T. & Parker, J. R. 1968: Notes on the Triassic biostratigraphy of Svalbard. *Geological Magazine 105(6)*, 526–542.
Utting, L. 1985: Preliminary results of palynological studies of the Permian and lowermost Triassic sediments, Sabine Peninsula, Melville Island, Canadian Arctic Archipelago. *Current Research, Part B. Geological Survey of Canada Paper 85(1b)*, 231–238.
Utting, J. 1989: Preliminary palynological zonation of surface and subsurface sections of Carboniferous, Permian and lowest Triassic rocks, Sverdrup Basin, Canadian Arctic Archipelago. *Current Research, Part G. Geological Survey of Canada Paper 89(1g)*, 233–240.
Van Veen, P. M., Skjold, L. J., Kristensen, S. E., Rasmussen, A., Gjelberg, J. & Stølan, T. 1993: Triassic sequence stratigraphy in the Barents Sea. In Vorren, T. O. et al. (eds.): Arctic geology and petroleum potential. *Norwegian Petroleum Society Special Publication 2*, 515–538.
Visscher, H., Brinkhuis, H., Dilcher, D. L., Elsik, W. C., Eshet, Y. Looy, C. V., Rampino, M. R. & Traverse, A. 1996: The terminal Paleozoic fungal event: evidence of terrestrial ecosystem destabilization and collapse. *Proceedings of the National Academy of Sciences of the USA 93*, 2155–2158.
Vigran, J. O., Mangerud, G., Mørk, A., Bugge, T. & Weitschat, W. 1998: Biostratigraphy and sequence stratigraphy of the Lower and Middle Triassic deposits from the Svalis Dome, central Barents Sea, Norway. *Palynology 22*, 89–141.
Weitschat, W. & Dagys, A. S. 1989: Triassic biostratigraphy of Svalbard and a comparison with NE-Siberia. *Mitteilungen Geologisch-Paläontologisches Institut Universität Hamburg 68*, 179–213.
Wignall, P. B., Morante, R. & Newton, R. 1997: The Permo-Triassic transition in Spitsbergen: $\delta^{13}C_{org}$ chemostratigraphy, Fe and S geochemistry, facies, fauna and trace fossils. *Geological Magazine 135*, 47–62.
Wiman, C. 1910: Ichthyosaurier aus der Trias Spitzbergens. *Bull. Geol. Inst. Univ. Upsala 10*, 124–148.
Wiman, C. 1916: Neue Stegocephalenfunde aus dem Posidonomyaschiefer Spitzbergens. *Bull. Geol. Inst. Univ. Upsala 13(8)*, 209–222.
Wiman, C. 1933: Über *Grippia longirostris*. *Nova Acta Soc. Sci. Upsala Ser. 4*, p. 9.
Winsnes, T. S. 1981: Geological map of Svalbard 1:500,000, sheet 2G, Edgeøya. *Norsk Polarinst. Skrifter 154B*.
Worsley, D. & Mørk, A. 1978: The Triassic stratigraphy of southern Spitsbergen. *Norsk Polarinst. Årbok 1977*, 43–60.
Worsley, D., Johansen, R. & Kristensen, S. E. 1988: The Mesozoic and Cenozoic succession of Tromsøflaket. *NPD Bull. 4*, 42–65.
Yin, H. 1997: Permian–Triassic boundary – a discussion on *Hindeodus parvus* and the Meishan section. *Albertiana 20*, 19–24.
Yin, H. F., Yang, F. Q., Zhang, K. X. & Yang, W. P. 1988: A proposal to the biostratigraphy criterion of Permian/Triassic boundary. *Mem. Soc. Geol. Ital. 34*, 329–344.
Zhang, K. X., Lai, X. L., Ding, M. H. & Liu, Y. H. 1995: Conodont sequences and its global correlation of Permian–Triassic boundary in Meishan section, Changxing, Zhejiang province. *Earth Science, J. China Univ. Geosci. 20*, 669–676.

Appendix

Taxa, including species recorded under open nomenclature, in the text, text figures and distribution diagram.

"*Acanthotriletes* sp. F" Vigran et al. 1998
Algal colony
Anapiculatisporites spiniger (Leschik 1955) Reinhardt 1961
Angustisulcites klausii Freudenthal 1964
Apiculatisporis lanjouwii Jansonius 1962
Aratrisporites macrocavatus Bjærke & Manum 1977
Aratrisporites scabratus Klaus 1960
Aratrisporites spp.
Aratrisporites tenuispinosus Playford 1965
Bharadwajispora labichensis Jansonius 1962
Circumstriatites spp.
Cordaitina minor (Pautsch 1971) Pautsch 1973
Crustaesporites globosus Leschik 1956
Cycadopites spp.
Cycadopites spp.
Cyclotriletes oligogranifer Mädler 1964
Cyclotriletes pustulatus Mädler 1964
Cycloverrutriletes presselensis Schulz 1964
Cymatiosphaera spp.
Densoisporites complicatus Balme 1970
Densoisporites nejburgii (Schulz 1964) Balme 1970
Densoisporites playfordi (Balme 1963) Playford 1965
Densoisporites spp.
Dictyotidium spp.
Endosporites papillatus Jansonius 1962
Ephedripites steevesii (Jansonius 1962) de Jersey & Hamilton 1967

Filisphaeridium setasessitante (Jansonius 1962) Staplin et al. 1965
Foram linings
"Fungal remain sp. B" Mangerud 1994
"Fungal remains" Hochuli et al. 1989
Gordonispora fossulata (Balme 1970) Van der Eem 1983
Granulatisporites spp.
Grebespora concentrica Jansonius 1962
Illinites chitonoides Klaus 1964
Inaperturopollenites nebulosus Balme 1970
Jerseyiaspora punctispinosa Kar, Kieser & Jain 1972
Klausipollenites schaubergeri (Potonié & Klaus 1954) Klaus 1963
Kraeuselisporites apiculatus Jansonius 1962
Kraeuselisporites hoofddijkensis Visscher 1966
Kraeuselisporites spinosus Jansonius 1962
Kraeuselisporites spp.
Leeches cocoons
Leiospheres
Lueckisporites junior Klaus 1960
Lueckisporites virkkiae Potonié & Klaus 1959
Lunatisporites acutus (Leschik 1955) Scheuring 1970
Lunatisporites noviaulensis (Leschik 1955) Scheuring 1970
Lunatisporites pellucidus (Goubin 1965) Balme 1970
Lunatisporites spp.
Lunatisporites transversundatus Jansonius 1962
Lundbladispora obsoleta Balme 1970
Lundbladispora spp.
Lycopodiacidites spp.
Maculatasporites spp.
Micrhystridium spp.
Neoraistrickia spp.
Pechorosporites coronatus Yaroshenko & Golubeva 1984
Pechorosporites disertus Yaroshenko & Golubeva 1989
Pechorosporites intermedius Yaroshenko & Golubeva 1989
Pilasporites spp.
"Planktonic alga type A"
Podosporites amicus Scheuring 1970
Polycingulatisporites spp.
Pretricolpipollenites spp.
Proprisporites pocockii Jansonius 1962
Protodiploxypinus gracilis Scheuring 1970
Protodiploxypinus spp.
Protohaploxypinus microcorpus (Schaarschmidt 1963) Clarke 1965
Protohaploxypinus perfectus (Naumova ex Kara-Murza 1952) Samoilovich 1953
Protohaploxypinus samoilovichii (Jansonius 1962) Hart 1964
Protohaploxypinus spp.
Pterospermella spp.
Punctatisporites fungosus Balme 1963
Retusotriletes hercynicus (Mädler 1964) Schuurmann 1977
Retusotriletes spp.
Rewanispora foveolata de Jersey 1970
Staplinisporites caminus (Balme 1957) Pocock 1962
Striatella seebergensis Mädler 1964
Striatoabieites balmei (Klaus 1964) Scheuring 1978
Striatoabieites multistriatus (Balme & Hennelly 1955) Hart 1964
Striatoabieites spp.
Tasmanites
Triadispora spp.
Tympanicysta stoschiana Balme 1980
Unellium spp.
Uvaesporites argentaeformis (Bolkhovitina 1953) Schulz 1967
Uvaesporites imperialis (Jansonius 1962) Utting 1994
Verrucosisporites spp.
Veryhachium subglobosum Combaz, Peniguel & Vachey 1974
Veryhachium spp.
Vesicaspora spp.
Vitreisporites pallidus (Reissinger 1938) Nilsson 1958
Vittatina spp.