

Palynology of the Permian succession of Spitsbergen, Svalbard

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

Palynological investigations of 16 sections from Spitsbergen, Svalbard, covering the uppermost Carboniferous, Permian and lowermost Triassic succession have been carried out. Because of general poor preservation and barrenness of the majority of the samples, it was not possible to establish a formal zonation for the Permian succession. The study resulted, however, in the recognition of three Permian palynological assemblages, restricted downwards by a Carboniferous assemblage and upwards by an earliest Triassic (Griesbachian) assemblage. The dating of these assemblages is based on palynological correlation with similar palynofloras elsewhere in the present Arctic region as well as dating by marine faunas, which in general give better stratigraphic resolution. The Permian assemblages recognised include (1) the *Vitulina* assemblage of late Gzhelian to early Asselian age recorded in the lower parts of the Tyrrellfjellet Member (Nordenskiöldbreen Formation), (2) the *Hamiapollenites tractiferinus* assemblage of late Asselian to Artinskian age recorded in the upper parts of the Tyrrellfjellet Member and in the Gipshuken Formation and (3) the youngest Permian *Kraeuselisporites* assemblage of late Artinskian to ?earliest Tatarian age recorded in the Kapp Starostin Formation.

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Introduction

Permian lithostratigraphy of Spitsbergen, Svalbard, was described by Cutbill & Challinor (1965), who also presented data on fusulinid zonation. Several papers concerning various fossil groups have been published subsequently, including Sosipatrova (1967), Ustritskii (1967, 1979), Czarniecki (1969), Federowski (1967, 1986), Szaniawski & Malkowski (1979), Morozova & Kruchinina (1986), Nakamura et al. (1987, 1992), Nakrem (1991a, b), Sakagami (1992), Ezaki & Kawamura (1992) and Igo & Okimura (1992). Except for one paper dealing with the palynology of Nordaustlandet (Mangerud & Konieczny 1991) and one paper giving a general overview of the biostratigraphy of the Permian succession of Svalbard (Nakrem et al. 1992), no work has been published on the palynology of the Permian in this region.

For several years IKU Petroleum Research carried out work in Svalbard through the IKU Arctic Geoprogram. The disciplines involved included sedimentology, organic geochemistry and paleontology. The material on which the present

study is based was collected by R. M. Konieczny in 1985 and 1986.

The purpose of this paper is to present palynological data and age discussions for the Permian succession of Spitsbergen based on several outcrop sections, mainly from the Isfjorden area (Fig. 1). Due to few productive samples and the generally poor preservation of the palynomorphs, no formal zonation has been established on Spitsbergen. From the Barents Shelf, however, well-preserved assemblages have proven valuable in dating the Permian succession (IKU in-house data).

Geological framework

On Spitsbergen, the main island of the Svalbard archipelago, Permian rocks are exposed in an area around Isfjorden, along the Tertiary fold-belt on the western coast and in the Lomfjord area on the north-eastern coast (Fig. 1). The Carboniferous and Permian lithostratigraphy published by Cutbill & Challinor (1965) divides the Permian into three formations in the study area (Fig. 2): The Nordenskiöldbreen Formation (Middle Carboniferous to Lower Permian), the Gipshuken Formation (Lower Permian), and the

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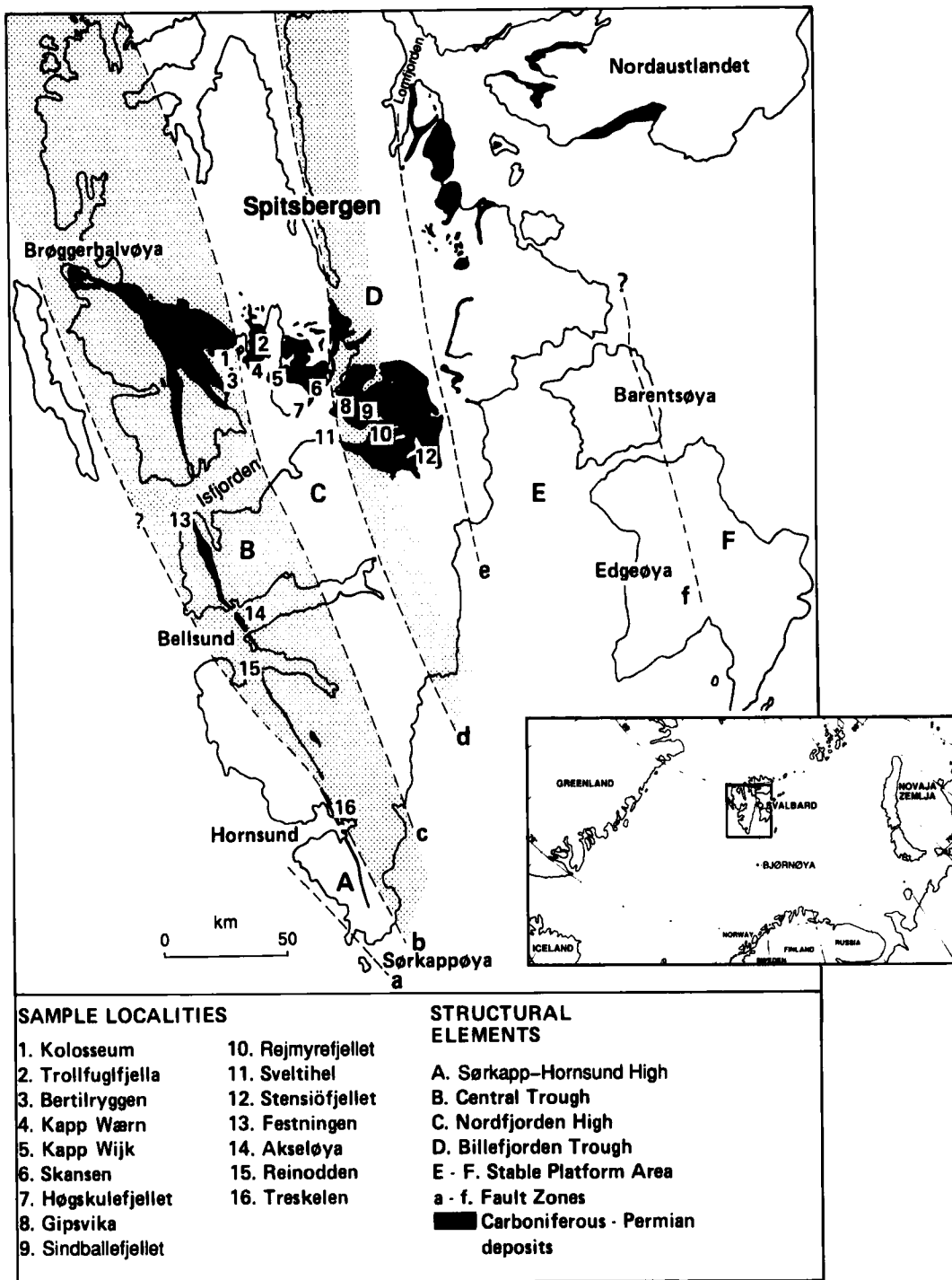


Fig. 1. Regional map of the central part of the Svalbard archipelago showing Carboniferous-Permian outcrops and sample localities. Base map from Steel & Worsley (1984).

Period	Epoch	Stage	UNITS, SPITSBERGEN		Palynological assemblages discussed				
Tr		Griesbachian	VARDEBUKTA FORMATION	DELTADALEN MEMBER	<i>Densosporites nejborgii</i>				
Permian	Zechstein	Lopingian	TEMPELF-JORDEN GROUP	KAPP STAROSTIN FORMATION	?				
						Longtanian (Djulfian)			
		Guadalupean				Capitanian			
						Wordian			
						Ufimian (Roadian)			
	Rotliegendes	Kungurian			VØRINGEN MBR.				
		Artinskian			GIPSDALEN GROUP	GIPSHUKEN FORMATION	<i>Hamiapollenites tractiferinus</i> assemblage		
		Sakmarian							
		Asselian						NORDEN-SKIÖLDBREEN FORMATION	TYRRELL-FJELLET MEMBER
C	Gze	Noginskian	KAP/CADEL MBR.	<i>Densosporites</i> assemblage					

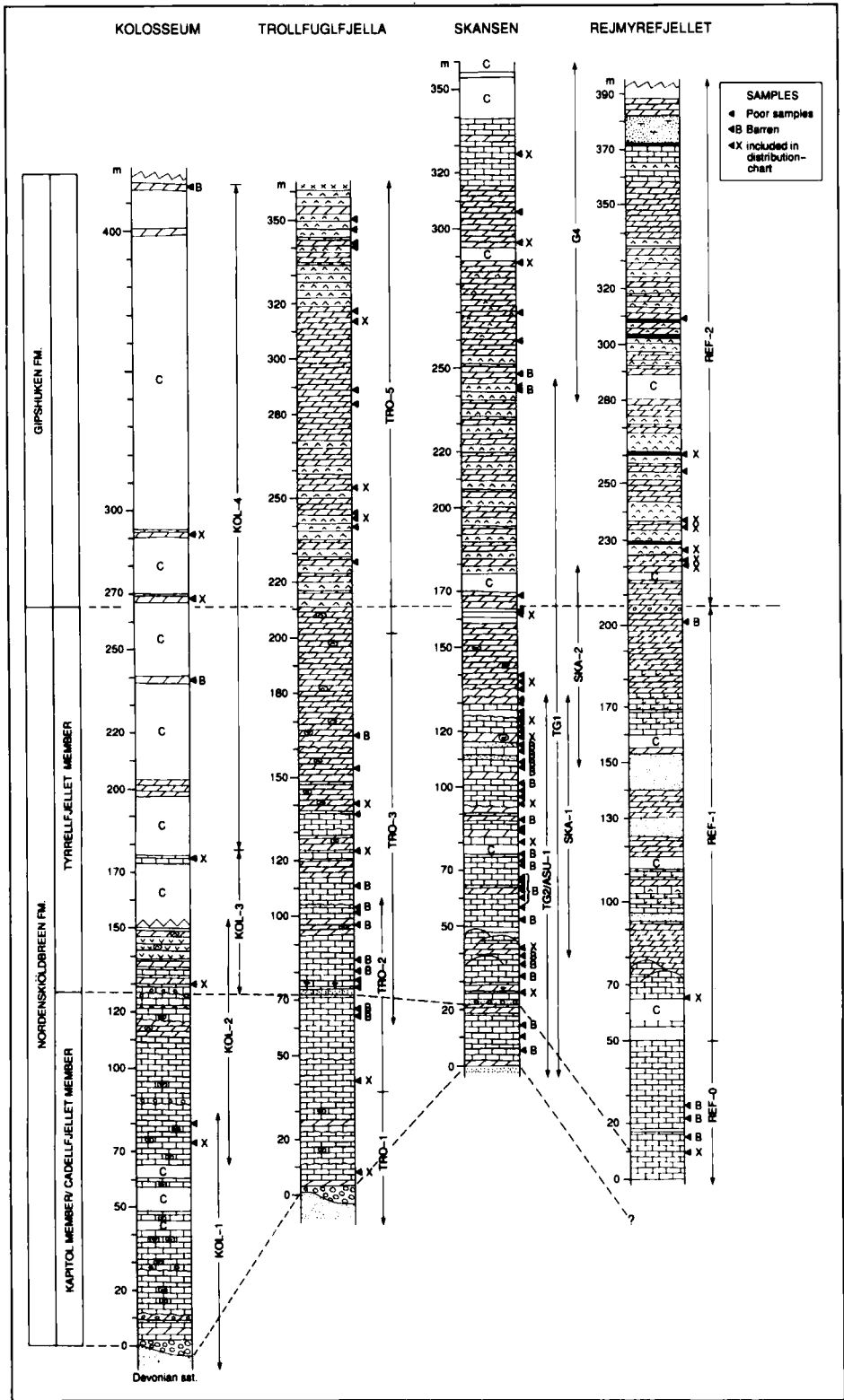
Fig. 2. Stratigraphic scheme for the Permian succession of Spitsbergen, Svalbard, including the position of the described palynological assemblages. Ages based on Harland et al. (1989).

Kapp Starostin Formation (upper Lower Permian to Upper Permian).

During the Late Paleozoic, the Svalbard Platform was part of a sedimentary basin covering most of the present day Barents Shelf. It was also connected westward to North Greenland and the Sverdrup Basin in the Canadian Arctic, and eastward to the Timan Pechora Basin in Russia. During the Carboniferous, sedimentation was controlled by the Nordfjorden High (Fig. 1) giving rise to a distinct block-and-basinal deposition on Spitsbergen. The Nordfjorden High acted as a barrier until it was transgressed during the latest Carboniferous/earliest Permian time period. More open marine conditions were gradually established during the period Asselian to Artinskian, as seen in this carbonate dominated succession. Gypsum/anhydrite units reflect the arid climate during this period (Steel & Worsley 1984). Shoals and bioherms seem to have been developed mainly along the earlier blocks, although no significant thickness variation can be seen in the

Lower Permian succession (Steel & Worsley 1984). A regressive trend is reflected in the lower parts of the Gipshuken Formation with sabkhas developing eastwards to the eastern margin of the Nordfjorden High (Steel & Worsley 1984). In the upper parts a more open marine environment is recognised (Keilen 1992).

Sometime during the mid-Permian the general northwards drift led to a colder climate in the area, and carbonate deposition gradually decreased. Transition to stable platform environment was accompanied by a major transgression establishing new seaways also down to East Greenland (Doré 1991). No evidence of syn-sedimentary faulting is seen in the upper Permian succession on central Spitsbergen, while to the southwest the Sørkapp-Hornsund High (Fig. 1) acts as a positive structure. The basal bioclastic limestone (Vøringen Member) of the Kapp Starostin Formation deposited in central parts of Spitsbergen represents shoreface deposits. These were formed by the transgression that took place



across the restricted marine platform represented by the underlying Gipshuken Formation strata (Steel & Worsley 1984). There is a gradual development into the siliceous shales and siltstones derived from sponge spicules, which form the most characteristic feature of the Kapp Starostin Formation. Abundant trace fossils such as *Zoophycus* indicate low energy, but oxygenated, bottom environments, while organic sponge buildups are concentrated along the platform margins (Steel & Worsley 1984). In the Late Permian a cold water fauna replaced the Early Permian warm water fauna in the Spitsbergen area (Keilen 1992), contemporaneous with a change to a temperate, humid climate that persisted as the entire platform moved northwards during the Mesozoic.

Material

Palynological samples were collected from 16 sections, 4 sections (13–16, Fig. 1) in the western fold belt and 12 sections (1–12, Fig. 1) located in the inner Isfjorden area. Maps showing the localisation of the different composite sections are given in the Appendix. A total of 340 samples were analysed, approximately 65 from the Nordenskiöldbreen Formation, 50 from the Gips-

huken Formation and 225 from the Kapp Starostin Formation. The samples were given standard palynological treatment, and a large number proved to be barren. The preservation of the palynomorphs is in general poor. The palynomorphs are thin-walled, corroded and often folded, a phenomenon commonly seen in carbonate and evaporite sequences. The palynomorphs do not show much sign of pyrite growth, not even in samples from the deeper basinal facies within the upper part of the Kapp Starostin Formation. They seem to be extensively oxidised, but are in general not highly mature. Maturity indexes fall within the oil window, giving TAI values (on a fire-scale) between 2+ and 3 in the Isfjorden area, and around 4 in the south-western area. It is therefore difficult to evaluate why the preservation is so poor in the low maturity area and why a majority of the horizons are barren. The poor preservation in the highly silicified shales developed from sponge spicules in the Kapp Starostin Formation can be related to oxidation or perhaps microbial degradation in this depositional environment.

Lithological logs (Figs. 3 and 4) and distribution charts (Figs. 5–10) are included from all localities except the Gipsvika, Sindballefjellet, Reinodden and Treskelen localities, which were found to be nearly barren throughout. Semiquantitative results are given as percentages of the total assemblage and are based on counts of 200 specimens where this was possible. Only samples with more than 100 specimens are included (Fig. 11). Frequencies of each taxa are expressed as rare (<5%), common (5–10%) and abundant (>10%) on the legend added to each distribution chart. Lithological logs are simplified from the unpublished field-logs of Hellem (1980) (Festningen, Høgskulefjellet, Kapp Wijk, Kapp Wærn and Stensiöfjellet), Skaug (1982) (Skansen) and Dons (1983) (Kolosseum and Trollfuglfjella). With the exception of the Festningen and Akseløya localities, all distribution charts represent composites of two or three closely spaced sections giving the range through the Permian succession of each area. An alphabetical list of species is included (Table 1). To demonstrate the diversity, the best preserved specimens are illustrated (Figs. 12–17), but these are not typical for this material with regard to the quality of preservation. The palynological slides are housed in the type collection of the Paleontological Museum, Oslo, under the numbers PMO 139.075–139.096.

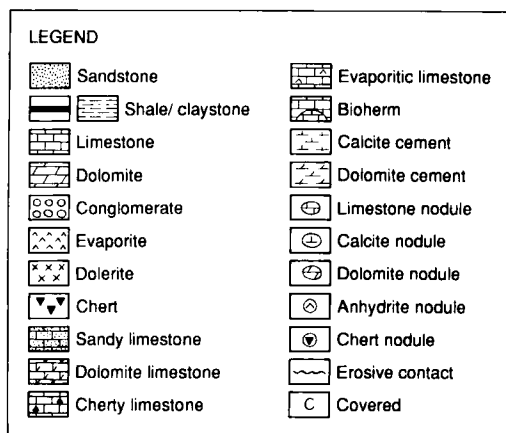


Fig. 3. Lithological columns for the investigated sections of the Nordenskiöldbreen and Gipshuken Formations on Spitsbergen. The simplified logs are based on Dons (1983) (Kolosseum and Trollfuglfjella), Skaug (1982) (Skansen) and unpublished field-logs and sample descriptions by Konieczny. Palynological sample levels are indicated.

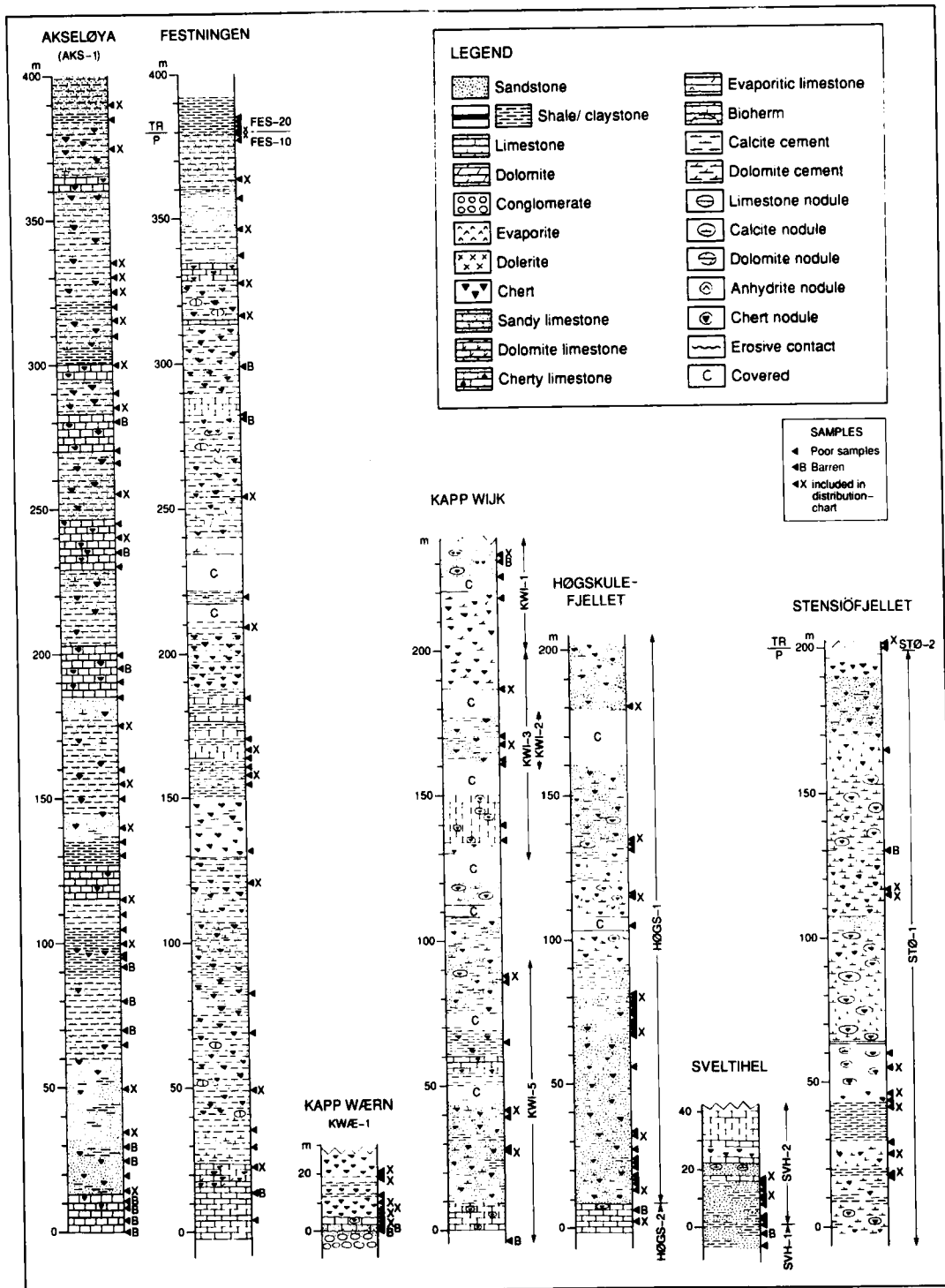


Fig. 4. Lithological columns for the investigated sections of the Kapp Starostin Formation on Spitsbergen. The simplified logs are based on Hellem (1980) (Festningen, Høgskulefjellet, Kapp Wijk, Kapp Wærn and Stensiøfjellet) and unpublished field-logs by Koniczny. Palynological sample levels are shown.

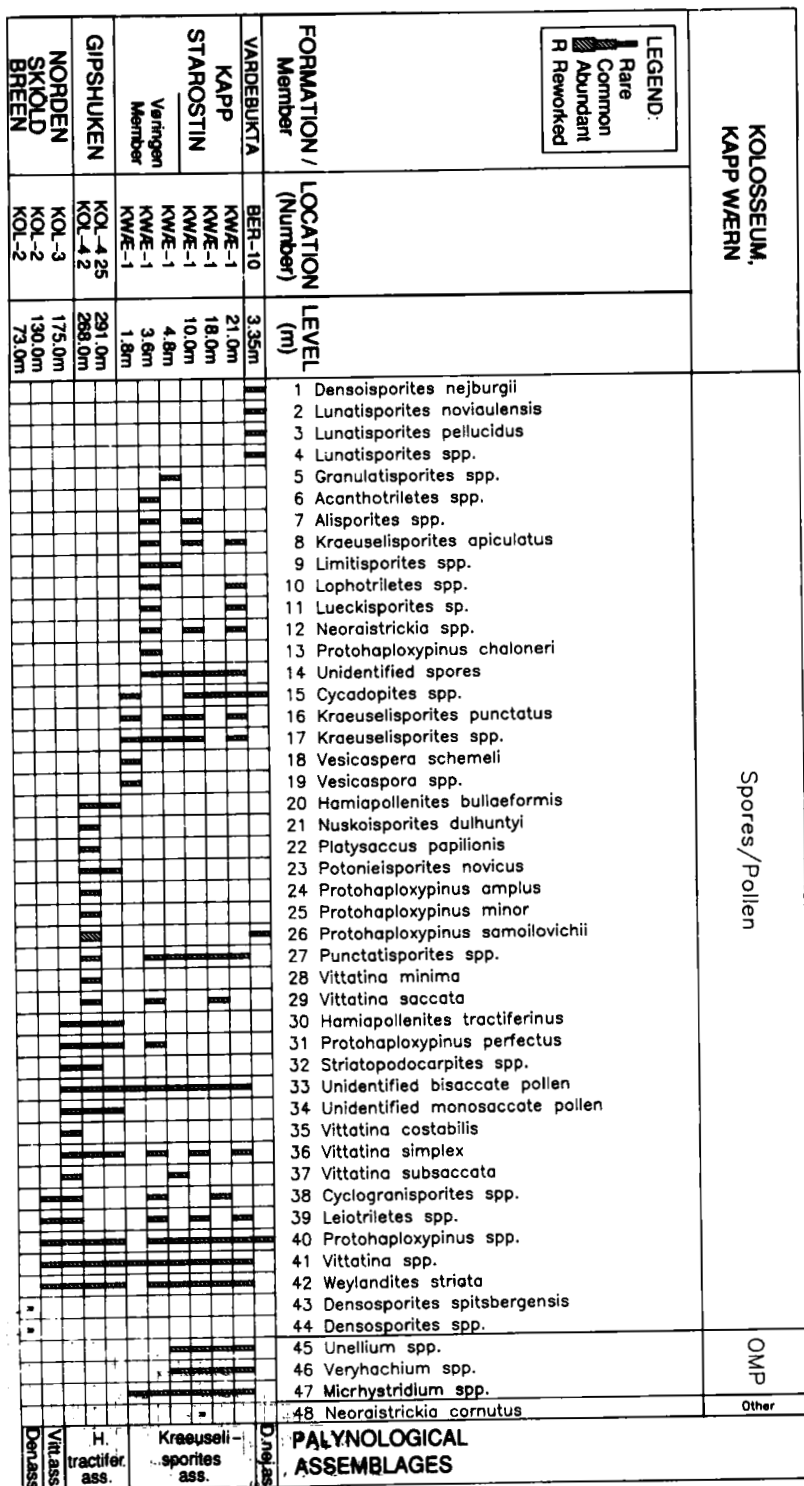


Fig. 5. Distribution chart for the Kolosseum and Kapp Wærn localities, representing the Permian succession of West-Mid Central Spitsbergen.

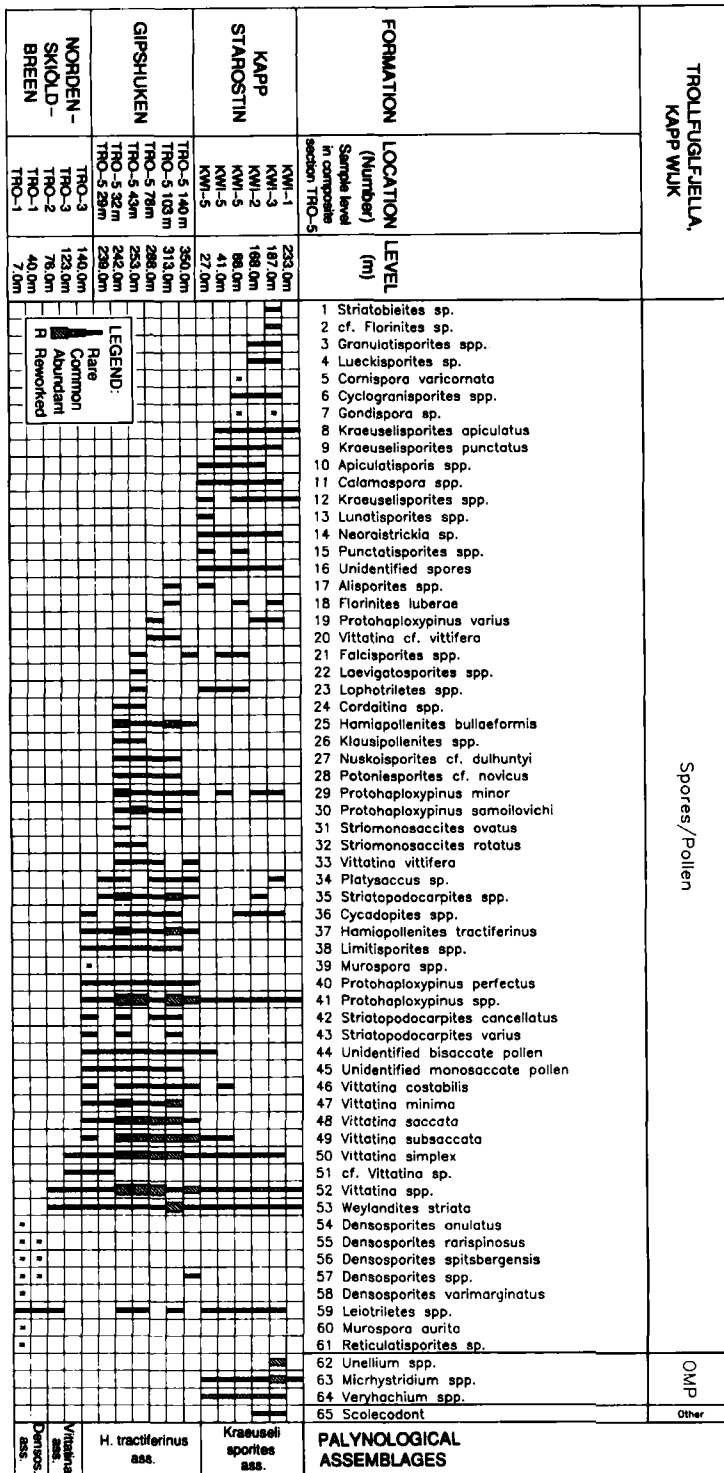


Fig. 6. Distribution chart for the Trollfuglfjella and Kapp Wijk localities, representing the Permian succession of Mid-Central Spitsbergen.

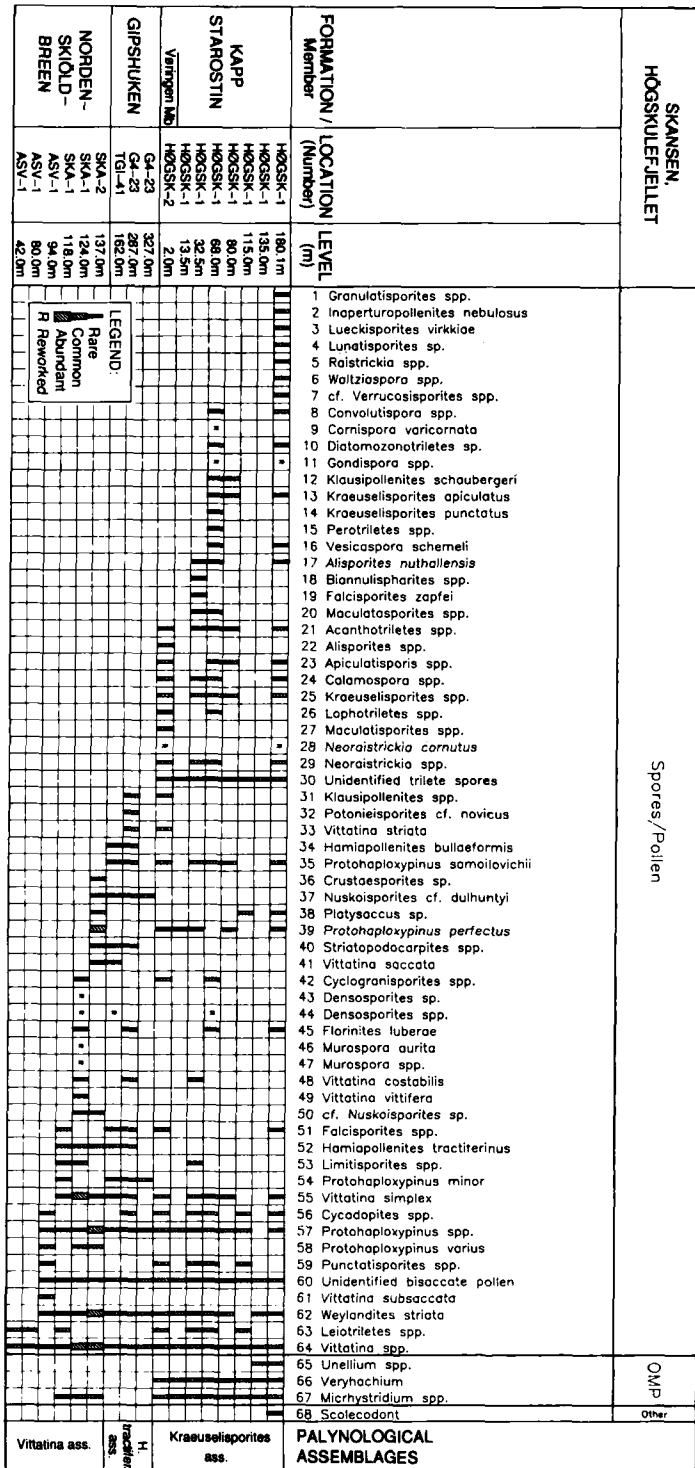


Fig. 7. Distribution chart for the Skansen and Høgskulefjellet localities, representing the Permian succession of East-Mid Central Spitsbergen.

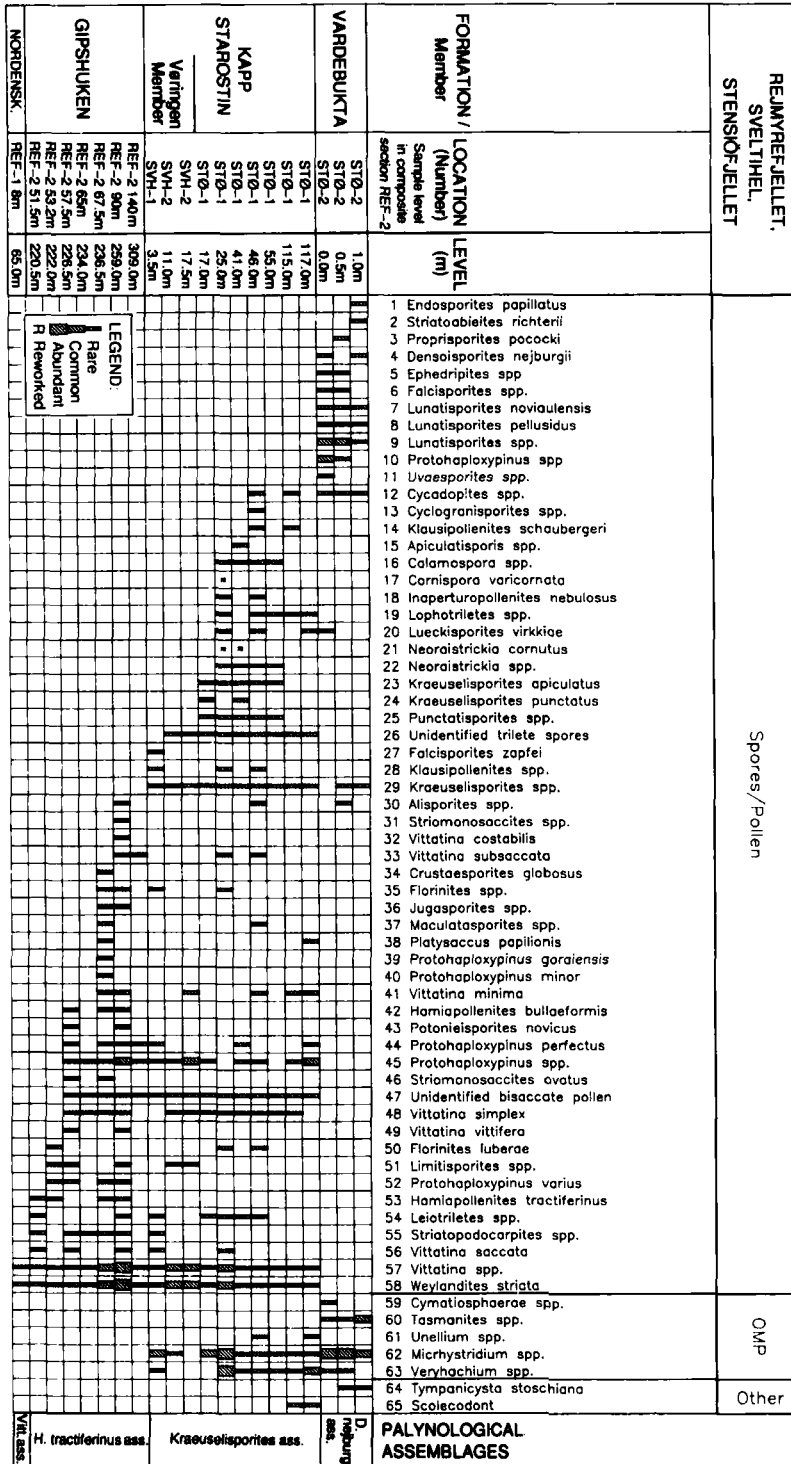


Fig. 8. Distribution chart for the Rejmyrefjellet, Sveltihel and Stensiøfjellet sections, representing the Permian succession of Eastern Central Spitsbergen.

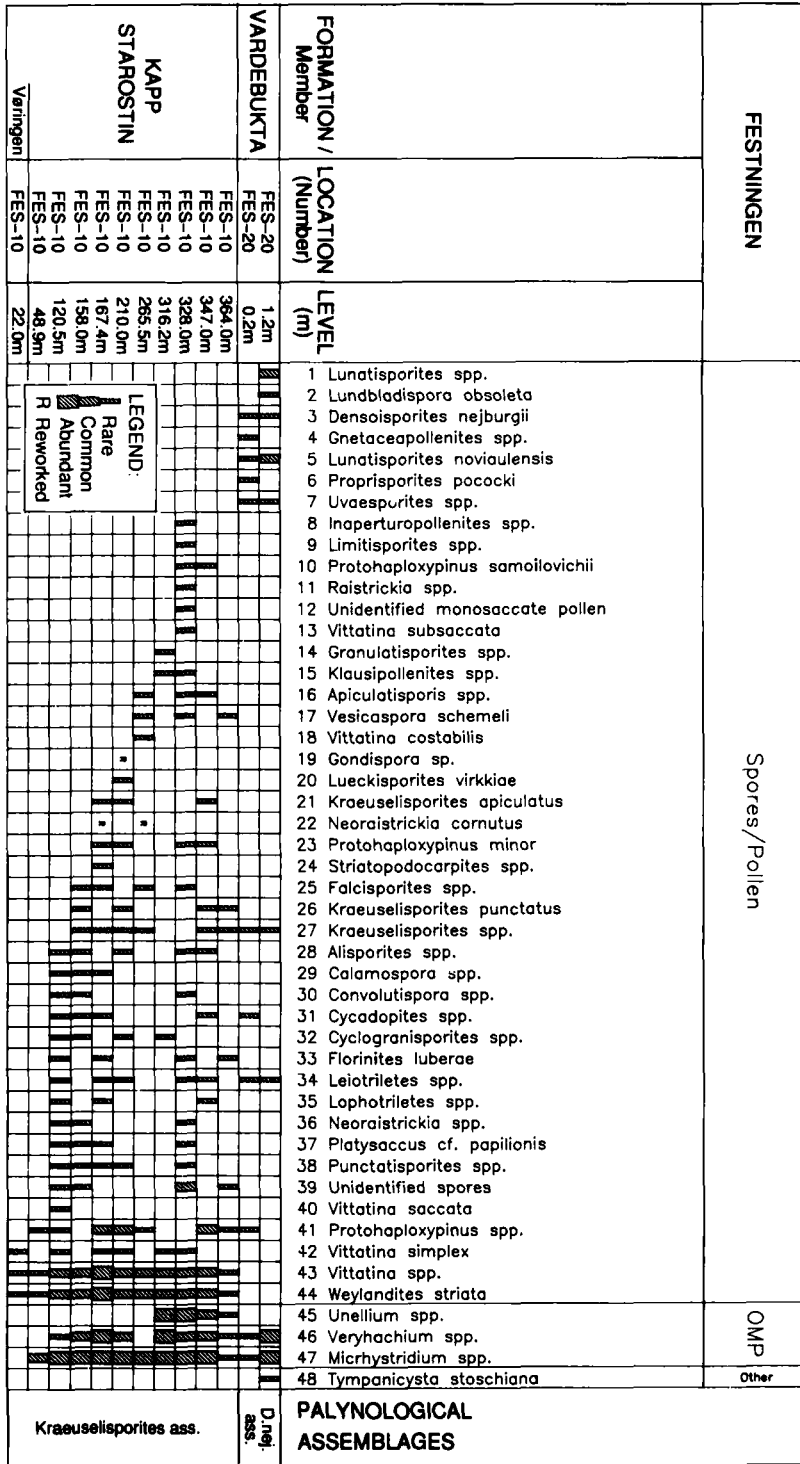


Fig. 9. Distribution chart for the Festningen locality, Western Spitsbergen.

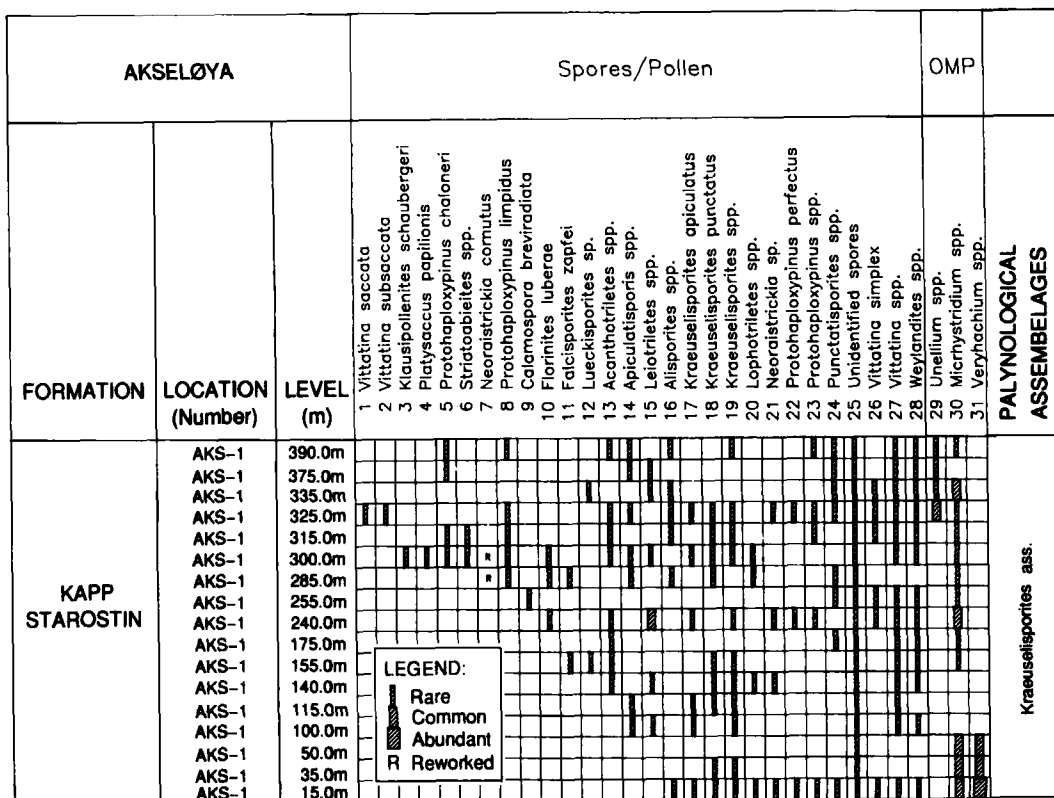


Fig. 10. Distribution chart for the Akseløya locality in Bellsund, Western Spitsbergen.

Palynological assemblages and age

In order to restrict the assemblages of the Permian succession downwards and upwards, a few samples were analysed from the Carboniferous Kapitol and Cadelfjellet Members as well as from the lowermost Triassic Vardebukta Formation.

The *Densosporites* assemblage

Palynological description. – This very low diversity assemblage is characterised by various spore genera *Densosporites*, *Reticulatisporites* and *Murospora*. Whether this assemblage is reworked or in situ is not certain due to the low diversity of palynomorphs.

Occurrence. – The assemblage is recorded in the Kapitol Member of the lowermost Norden-skiöldbreen Formation (Fig. 2) at localities Trollfuglfjella and Kolosseum (Figs. 5 and 6).

Palynological correlation and age. – This assemblage does not seem to correlate with other Late Carboniferous assemblages, although Clayton et al. (1977) reported various *Densosporites* from their Stephanian ST-Zone. This could indicate that the assemblage is reworked, and it appears similar to Playford's (1962a, b) assemblages from the Lower Carboniferous succession in Svalbard. However, this may not exclude that some of these species are in situ. The samples are recorded in beds dated as Moscovian to early Gzhelian based on fusulinids (Nilsson 1988). Brachiopods and conodonts give a general middle to latest Carboniferous (Gzhelian) age, while bryozoans suggest a Kasimovian to Gzhelian age based on correlation with the Urals (Nakrem et al. 1992), although some bryozoan species are also typical of the Asselian to Artinskian succession in the Timan-Pechora Basin, Russia (Nakrem et al. 1992).

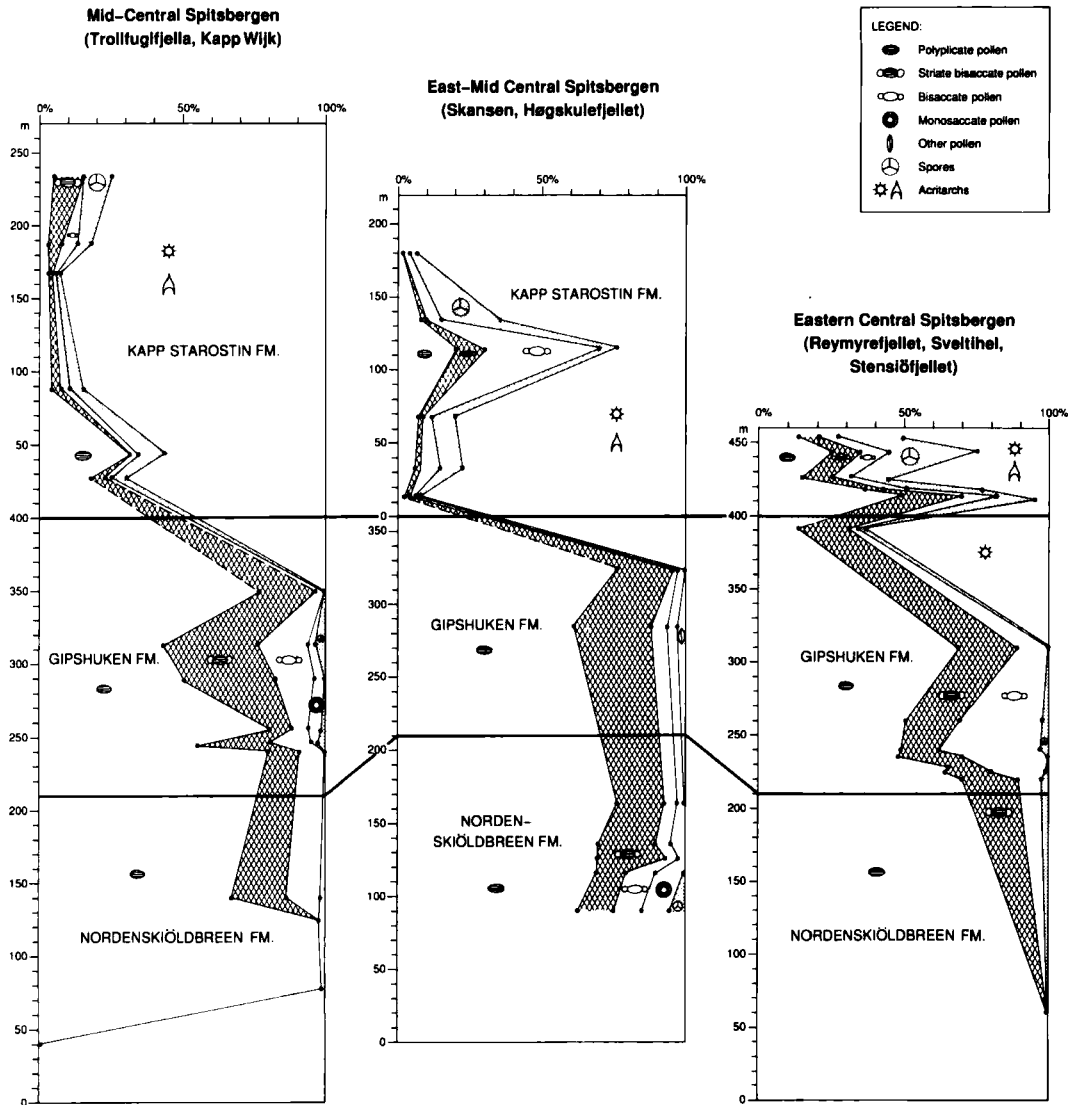


Fig. 11. Semiquantitative variations between some main palynomorph groups through the Permian succession in three areas on Spitsbergen, Svalbard.

The *Vittatina* assemblage

Palynological description. – The assemblage is characterised by having low diversity, and very few palynomorphs are recorded. In general, only poorly preserved *Vittatina* spp. and *Leiotriletes* spp. are present. However, specimens of the genera *Protohaploxypinus*, *Cycadopites* and *Cyclogranisporites* are recorded at two localities.

Occurrence. – This assemblage is recorded within

the lower part of the Tyrrellfjellet Member of the Nordenskiöldbreen Formation (Fig. 2) at all studied localities, including Kolosseum, Trollfuglfjella, Skansen and Reymyrefjellet (Figs. 5–8).

Palynological correlation and age. – Comparison with other assemblages is difficult due to the very poor recovery and low diversity. The assemblage mainly contains *Vittatina*, and based on fusulinids from the lower Tyrrellfjellet Member is given a

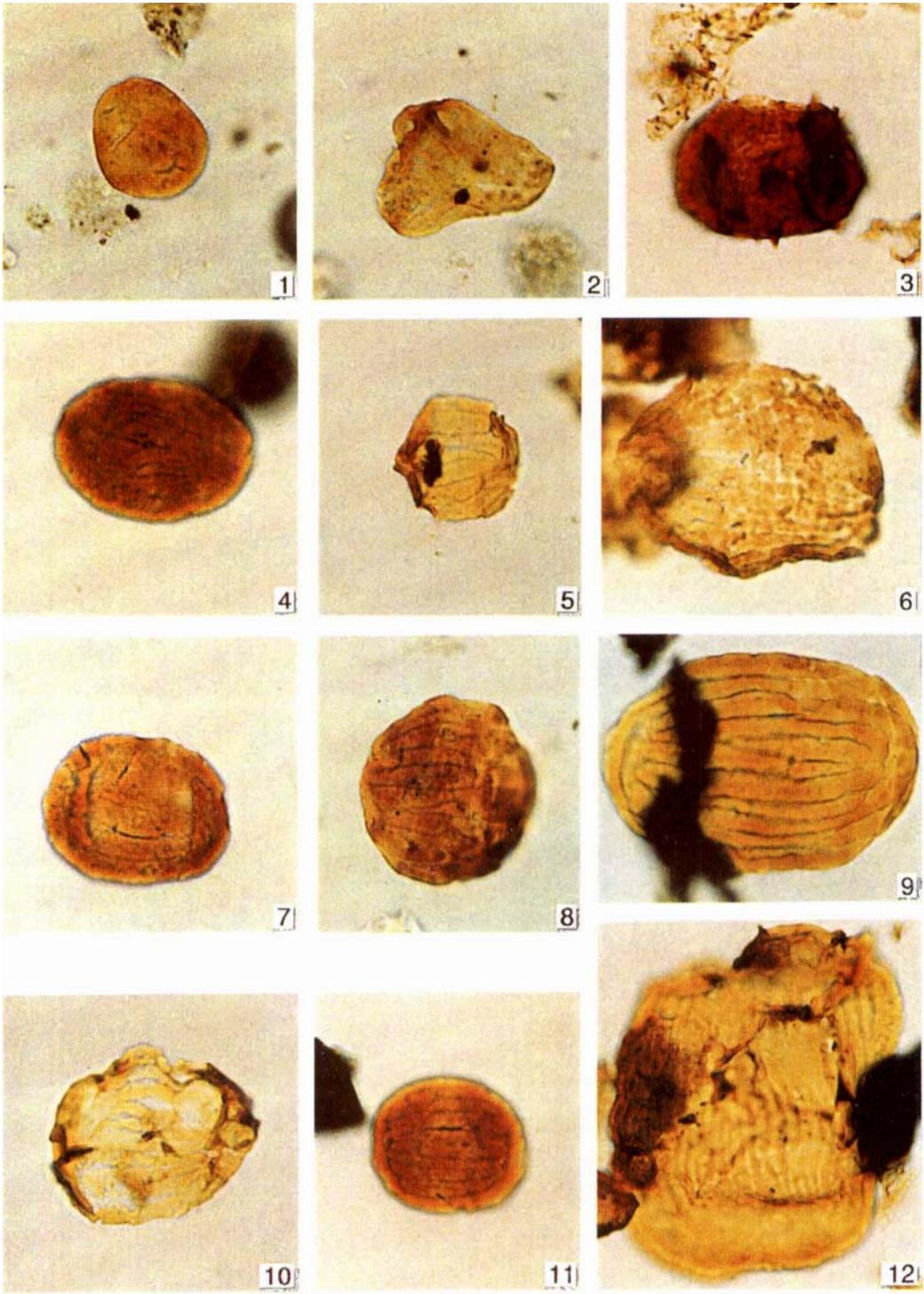
Table 1. Recorded palynomorphs from the Permian succession of Spitsbergen, Svalbard listed alphabetically

<p><i>Acanthotriletes</i> spp. <i>Alisporites nuthallensis</i> Clarke 1965 <i>Alisporites</i> spp. <i>Apiculatisporis</i> spp. <i>Biannulispharites</i> spp. <i>Calamospora</i> spp. <i>Calamospora breviradiata</i> Kosanke 1950 <i>Convolutispora</i> spp. <i>Cornispora varicornata</i> R! Staplin & Jansonius 1961 <i>Crustaesporites globosus</i> Leschik 1956 <i>Crustaesporites</i> spp. <i>Cycadopites</i> spp. <i>Cyclogranisporites</i> spp. <i>Cymatiosphaerae</i> spp. <i>Densoisporites neburgii</i> (Schulz) Balme 1970 <i>Densoisporites</i> spp. <i>Densosporites anulatus</i> R! (Loose) Smith & Butterworth 1967 <i>Densosporites rarispinosus</i> R! Playford 1962 <i>Densosporites spitsbergensis</i> R! Playford 1962 <i>Densosporites</i> spp. <i>Densosporites varimarginatus</i> R! Playford 1962 <i>Endosporites</i> spp. <i>Ephedripites</i> spp. <i>Falcisporites</i> spp. <i>Falcisporites zapfei</i> Potonié & Klaus 1954 <i>Florinites luberae</i> Samoilovich 1953 <i>Florinites</i> spp. <i>Gondispora</i> sp. <i>Gondispora</i> spp. <i>Granulatisporites</i> spp. <i>Hamiapollenites bullaeformis</i> (Samoilovich) Jansonius 1962 <i>Hamiapollenites tractiferinus</i> (Samoilovich) Jansonius 1962 <i>Inaperturopollenites nebulosus</i> Balme 1970 <i>Jugasporites</i> spp. <i>Klausipollenites schaubergeri</i> (Potonié & Klaus) Jansonius 1962 <i>Klausipollenites</i> spp. <i>Kraeuselisporites apiculatus</i> Jansonius 1962 <i>Kraeuselisporites punctatus</i> Jansonius 1962 <i>Kraeuselisporites</i> spp. <i>Laevigatosporites</i> spp. <i>Leiotriletes</i> spp. <i>Limitisporites</i> spp. <i>Lophotriletes</i> spp. <i>Lueckisporites</i> sp. <i>Lueckisporites virkkiae</i> (Potonié & Klaus) Clarke 1965 <i>Lunatisporites noviaulensis</i> Leschik 1956 <i>Lunatisporites pellusidus</i> (Goubin) Balme 1970 <i>Lunatisporites</i> spp. <i>Maculatisporites</i> spp. <i>Micrhystridium</i> spp. <i>Murospora aurita</i> R! (Waltz) Playford 1962 <i>Murospora</i> spp. R! <i>Neoraistrickia cornutus</i> R! (Andreyeva) Hart 1965 <i>Neoraistrickia</i> sp. <i>Neoraistrickia</i> spp. <i>Nuskoisporites dulhuntyi</i> Potonié & Klaus 1954 <i>Nuskoisporites</i> sp. <i>Peroitriletes</i> spp. <i>Platysaccus papilionis</i> Potonié & Klaus 1954 <i>Platysaccus</i> sp. <i>Potoniesporites novicus</i> Bharadwaj 1954</p>	<p><i>Propriisporites pococki</i> Jansonius 1962 <i>Protohaploxylinus amplius</i> (Balme & Hennelly) Hart 1964 <i>Protohaploxylinus chaloneri</i> Clarke 1965 <i>Protohaploxylinus goraiensis</i> (Potonié & Lele) Hart 1964 <i>Protohaploxylinus limpidus</i> (Balme & Hennelly) Balme & Playford 1968 <i>Protohaploxylinus minor</i> (Klaus) Clarke 1965 <i>Protohaploxylinus perfectus</i> (Naumova) Samoilovich 1953 <i>Protohaploxylinus samoilovichii</i> (Jansonius) Hart 1964 <i>Protohaploxylinus</i> spp. <i>Protohaploxylinus varius</i> (Bharadwaj) Balme 1970 <i>Punctatisporites</i> spp. <i>Raistrickia</i> spp. <i>Reticulatisporites</i> sp. <i>Scolecodont</i> <i>Striatoabieites</i> spp. <i>Striatopodocarpites cancellatus</i> (Balme & Hennelly) Hart 1965 <i>Striatopodocarpites</i> spp. <i>Striatopodocarpites varius</i> (Bharadwaj) Balme 1970 <i>Striomonosaccites ovatus</i> Bharadwaj 1962 <i>Striomonosaccites rotatus</i> (Bharadwaj) Hart 1965 <i>Striomonosaccites</i> spp. <i>Tasmanites</i> spp. <i>Unellium</i> spp. <i>Veryhachium</i> spp. <i>Vesicaspora schemeli</i> Klaus 1963 <i>Vittatina costabilis</i> Wilson 1962 <i>Vittatina minima</i> Jansonius 1962 <i>Vittatina saccata</i> (Hart) Jansonius 1962 <i>Vittatina simplex</i> Jansonius 1962 <i>Vittatina</i> spp. <i>Vittatina subsaccata</i> Samoilovich 1953 <i>Vittatina vittifera</i> (Luber & Waltz) Samoilovich 1953 <i>Waltziaspora</i> spp. <i>Weylandites striata</i> (Luber) Samoilovich 1953</p>
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Fig. 12. Selected spores and polyplaccate pollen from the Nordenskiöldbreen and Gipshuken Formations. Each figured palynomorph is located by abbreviated section name, sample level, PMO number and slide coordinates to an England Finder. Scale is added.

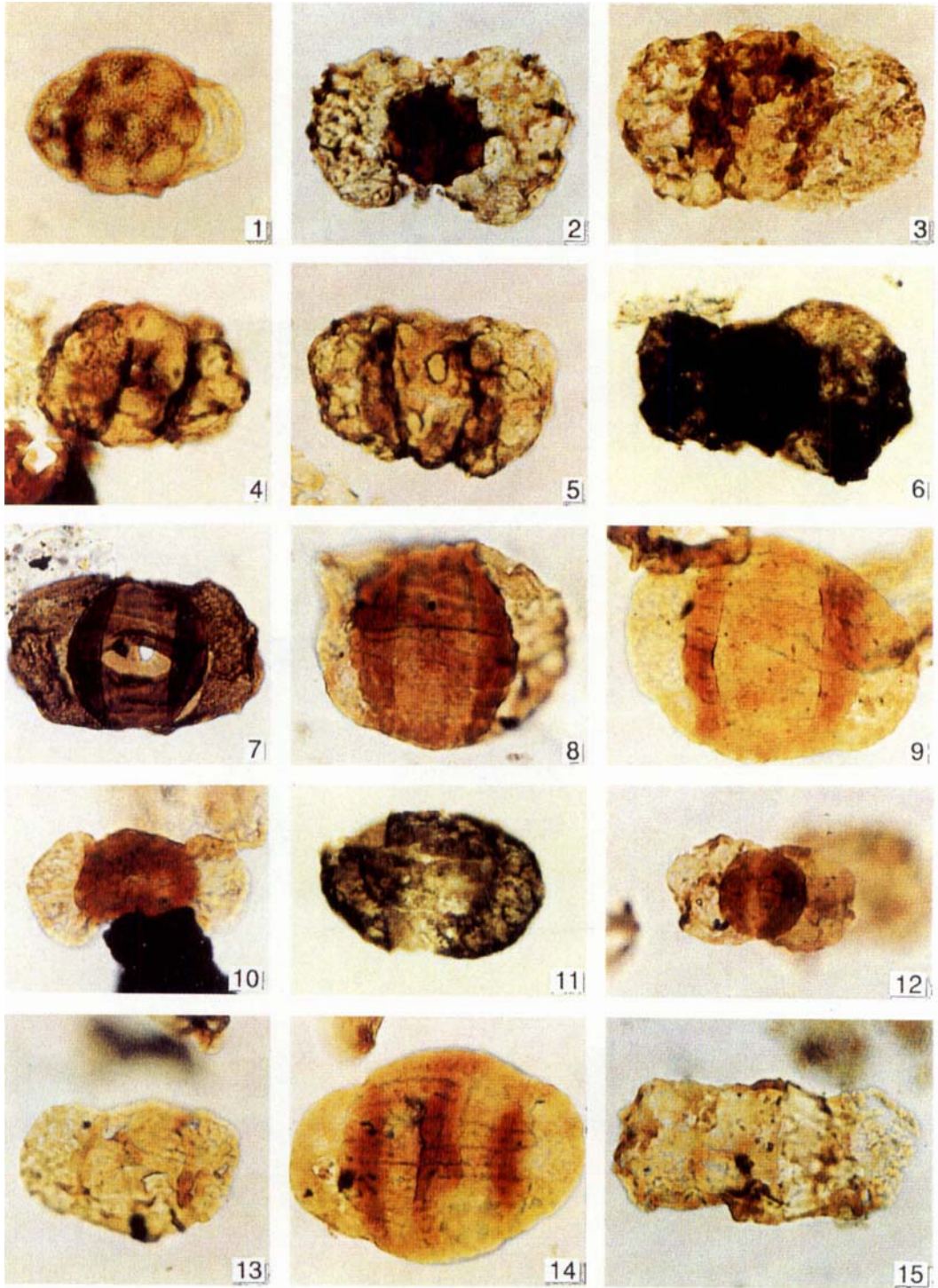
1. *Leiotriletes* sp. TRO-5, 43 m, PMO 139.075, H47
2. *Lophotriletes* sp. TRO-5, 43 m, PMO 139.075, T55/4
3. Cf. *Vittatina* sp. TRO-3, 130 m, PMO 139.076, R49
4. *Vittatina vittifera* TRO-5, 32 m, PMO 139.077, U49/2
5. *Vittatina simplex* TRO-3, 140 m, PMO 139.078, F52/4
6. *Weylandites striata*, TRO-5, 32 m, PMO 139.077, U47/3
7. *Vittatina saccata* TRO-5, 103 m, PMO 139.079, R55
8. *Vittatina* sp. TRO-5, 43 m, PMO 139.075, N55/1
9. *Vittatina* cf. *vittifera* TRO-5, 103 m, PMO 139.079, C54/4
10. *Vittatina* sp. TRO-3, 140 m, PMO 139.078, 060
11. *Vittatina vittifera* TRO-5, 103 m, PMO 139.079, C54
12. *Vittatina* sp. G4-16, 287 m, PMO 139.080, S29/4

NORDENSKIÖLDBREEN & GIPSHUKEN FORMATIONS



50 μ m

NORDENSKIÖLDBREEN & GIPSHUKEN FORMATIONS



50 μ m

late Gzhelian to early Asselian age (Nilsson & Davydov pers. comm. 1992). Few other age diagnostic fossil groups are recorded in this part of the succession. Palynomorphs as well as corals are inconclusive regarding the Carboniferous–Permian boundary (Ezaki & Kawamura 1992). The fusulinids have therefore been found to give the best dating to the present of these beds.

The Hamiapollenites tractiferinus assemblage

Palynological description. – This assemblage is dominated by different species of the polylicate genus *Vittatina* (Fig. 11), including *V. costabilis*, *V. saccata*, *V. saccifer*, *V. subsaccata*, *V. simplex* and *V. vittifera*. Striate bisaccate pollen include various *Protohaploxypinus* and *Striatopodocarpites* species, and *Hamiapollenites tractiferinus*, as well as *H. bullaeformis*. The latter appears somewhat higher in the succession compared with *H. tractiferinus*. Other bisaccate pollen include *Klausipollenites*, *Alisporites nuthallensis*, *A. spp.*, *Jugasporites*, *Platysaccus papilionis* and *Limitisporites*. Monosaccate pollen include *Nuskoisporites dulhuntyi*, *Cordaitina*, *Florinites luberae*, *Striomonosaccites* and *Potoniesporites*

novicus. Monosaccate pollen appear regularly in this assemblage, but never comprise more than about 5% of the total assemblage (Fig. 11). Spores occur also in low numbers, and include several genera such as *Cyclogranisporites*, *Leiotriletes*, *Maculatasporites* and *Punctatisporites*.

Occurrence. – The assemblage occurs in the upper parts of the Tyrrellfjellet Member of the Nordenskiöldbreen Formation and throughout the Gipshuken Formation (Fig. 2) at the localities Kolosseum, Trollfuglfjella and Skansen (Fig. 3). At Rejmyrefjellet the assemblage is only recorded in the Gipshuken Formation (Fig. 8). A similar assemblage was reported from Nordaustlandet, Svalbard (Mangerud & Konieczny 1991) in the upper part of the Nordenskiöldbreen Formation and the lower part of the Gipshuken Formation.

Palynological correlation and age. – The assemblage resembles the *Weylandites striatus* (syn. *Vittatina striata*) – *Protohaploxypinus perfectus* and the *Limitisporites monstruosus* – *Vittatina costabilis* Assemblage Zones in the Sverdrup Basin (Utting 1989). The first assemblage zone is of late Asselian to Sakmarian age based on fusulinids (Nassichuk & Wilde 1977), foraminifera (B. L. Mamet, in Utting 1989) and conodonts (A. C. Higgins, in Utting 1989), while the latter is of late Artinskian age based on conodonts (C. M. Henderson, in Utting 1989). Our assemblages differ in *H. tractiferinus*, being less common and *L. monstruosus* seeming to be absent. The latter feature could indicate a closer resemblance with the *Weylandites striatus* – *Protohaploxypinus perfectus* Assemblage Zone although our assemblages are more diverse.

In Svalbard the upper part of the Tyrrellfjellet Member is dated as middle Asselian to Sakmarian based on fusulinids (Nilsson pers. comm. 1993), while conodonts in the uppermost fusulinid zone indicate a late Sakmarian–Artinskian age (Nakrem et al. 1992). The Gipshuken Formation is in general poorly dated, and long-ranging forms have primarily been reported. Brachiopods have an Asselian–Artinskian affinity (Gobbett 1963) while a conodont recorded indicates an Artinskian–Kungurian age (Nakrem et al. 1992). In the upper part of the Gipshuken Formation, foraminifera indicate an Artinskian age (Sosipatrova 1967).

Fig. 13. Selected bisaccate pollen from the Nordenskiöldbreen and Gipshuken Formations. Each figured palynomorph is located by abbreviated section name, sample level in composite section, PMO number and slide coordinates to an England Finder. Scale is added.

1. Unidentified bisaccate pollen TRO-3, 140 m, PMO 139.078, V42/2–4
2. *Platysaccus* sp. TRO-5, 32 m, PMO 139.077, C53/2
3. Unidentified bisaccate pollen, TRO-3, 140 m, PMO 139.078, V41/2–4
4. *Limitisporites* sp. TRO-3, 140 m, PMO 139.078, M62
5. *Limitisporites* sp. TRO-3, 140 m, PMO 139.078, R61/2
6. *Platysaccus* sp. SKA-2, 137 m, PMO 139.081, T43/2
7. *Protohaploxypinus samoilovichii* KOL-4, 2.0 m, PMO 139.082, D64
8. *Protohaploxypinus* sp. TRO-5, 103 m, PMO 139.079, K51/2
9. *Protohaploxypinus* sp. TRO-5, 103 m, PMO 139.079, A51/3–4
10. *Striatopodocarpites* sp. TRO-5, 103 m, PMO 139.079, 147/4
11. *Protohaploxypinus* sp. SKA-2, 137 m, PMO 139.081, C59/2
12. *Striatopodocarpites* sp. TRO-5, 103 m, PMO 139.079, T63/1
13. *Hamiapollenites bullaeformis* TRO-5, 32 m, PMO 139.077, N41/2
14. *Hamiapollenites bullaeformis* TRO-5, 103 m, PMO 139.079, D58/1
15. *Hamiapollenites tractiferinus* TRO-5, 32 m, PMO 139.077, F41/4

The *Kraeuselisporites* spp. assemblage

Palynological description. – The assemblage is totally dominated by acritarchs which at some levels account for up to 90% of the total palynomorph content (Fig. 11). The acritarchs mainly belong to the genera *Micrhystridium*, *Unellium* and *Veryhachium*. Polyplicate pollen are still common, but are less diverse compared to the underlying assemblages, mainly represented by *Weylandites striata* and *Vittatina simplex*. Striate bisaccate pollen are consistently present, but occur in low numbers, with the most common genus being *Protohaploxypinus*. *Lueckisporites virkkiae* is present but rare, and only a few *Lunatisporites* sp. (syn. *Taeniasporites* sp.) are recorded in the upper part. Other bisaccate pollen genera include *Klausipollenites*, *Falcisporites*, *Alisporites*, *Platysaccus* and *Vesicaspora*. *Florinites* occurs rarely. A characteristic feature is the income of several new spore genera including *Neoraistrickia*, *Leiotriletes*, *Maculatasporites*, *Waltziaspora*, *Calamospora*, *Convolutispora*, *Diatomozonotriletes*, *Apiculatisporites*, *Lophotriletes*, *Cyclogranisporites*, *Kraeuselisporites*, *Granulatisporites* and *Acanthotriletes*, as well as the pollen grain *Inaperturopollenites nebulosus*.

Occurrence. – This assemblage occurs in the Kapp Starostin Formation (Fig. 2), but palynomorphs from the uppermost part of the formation have not been recorded anywhere on Spitsbergen. The assemblage is recorded at localities Akxeløya, Festningen, Høgskulefjellet, Kapp Wijk, Kapp Wærn, Stensiöfjellet and Sveltihel (Figs. 5–8, 10).

Palynological correlation and age. – The assemblage resembles that from the lower part of the Kapp Starostin Formation on Nordaustlandet (Mangerud & Konieczny 1991) and from the Miseryfjellet Formation on Bjørnøya (Vigran & Mørk unpubl.). It is also similar to the *Dyupetalum* sp. – *Neoraistrickia* and *Scutasporites* – *Lunatisporites* zones from the Barents Shelf (Mangerud, unpubl. data). The latter zones have basically been dated by correlation with the Roadian and Wordian assemblages of the Sverdrup Basin (Utting 1985, 1989) where marine fauna control is well established. Utting (1989) defined an *Alisporites insignis*–*Triadispora* sp. Assemblage Zone of late Artinskian to Roadian age and a *Taeniasporites* sp. Assemblage Zone of Wordian age. Both these assemblages are similar

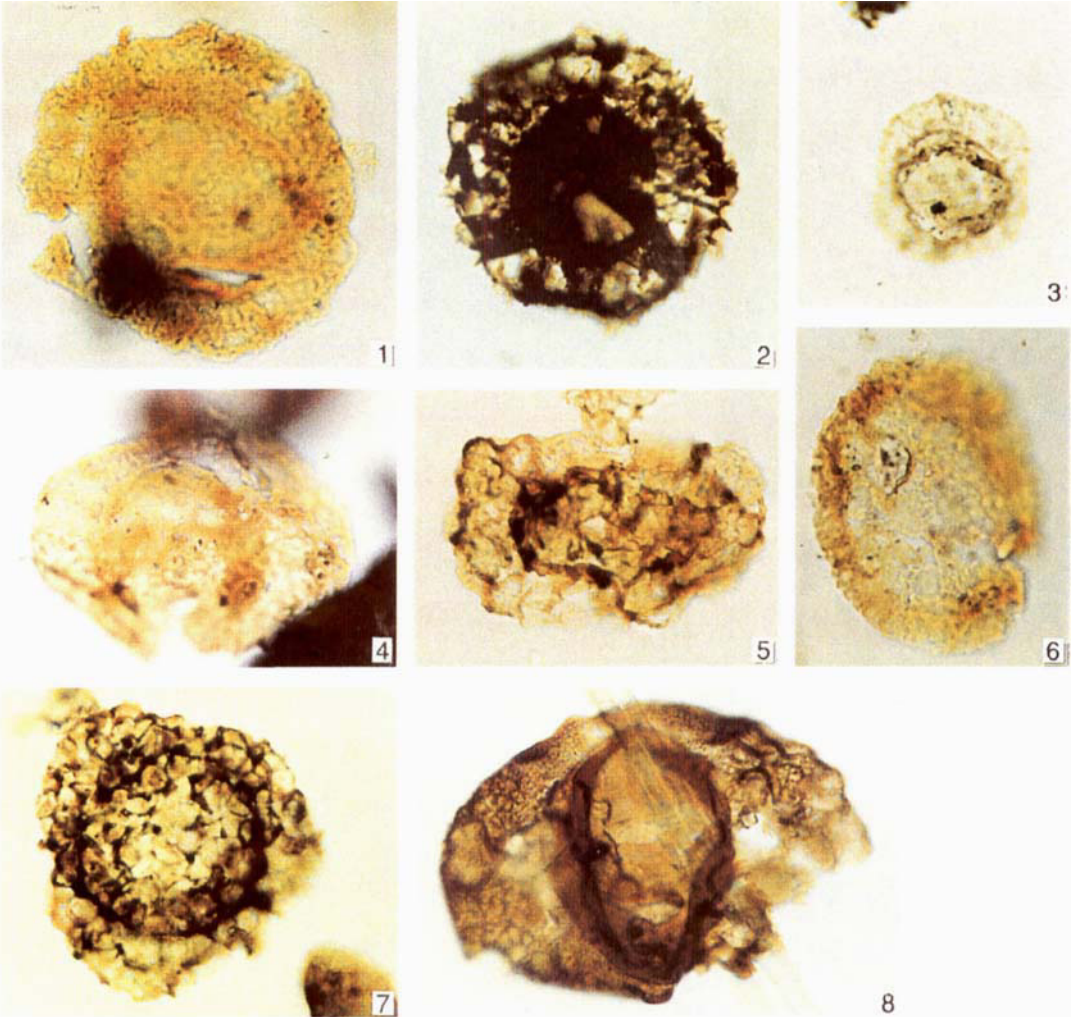
to the palynofloras from the Kapp Starostin Formation. The Late Permian *Vittatina* assemblages described from East Greenland (Balme 1980; Pia-secki 1984) are similar in the presence of *Lueckisporites virkkiae*, *Florinites luberae* and of spinose acritarchs in all samples (Balme 1980). They seem, however, to differ in quantitative composition and in very rare occurrence of spores. In the Timan-Pechora Basin, *Lueckisporites virkkiae* and *Taeniasporites noviaulensis* occur only in the Tatarian (Varyukhina 1971; Molin & Koloda 1972). However, both these species occur in beds dated to Wordian (= Kazanian) age in the Sverdrup Basin (Utting pers. comm. 1992). The Late Permian assemblages from Russia are in general similar to the assemblages from the Kapp Starostin Formation.

Due to the poor preservation and many barren samples, the Late Permian Svalbard assemblages cannot be dated precisely in terms of stages. In the Sverdrup Basin and in the Barents Sea area it is possible to distinguish the Ufimian and Kazanian on the presence of *Scutasporites* cf. *unicus*, *Ahrensisporites* and *Lunatisporites* sp. (syn. *Taeniasporites* sp.) which appear in the Kazanian (Utting pers. comm. 1992, IKU in-house data). Only a few poorly preserved *Lunatisporites* are recorded from the upper part of the Kapp Starostin Formation on Svalbard, but it is only possible on present data to indicate a general Ufimian

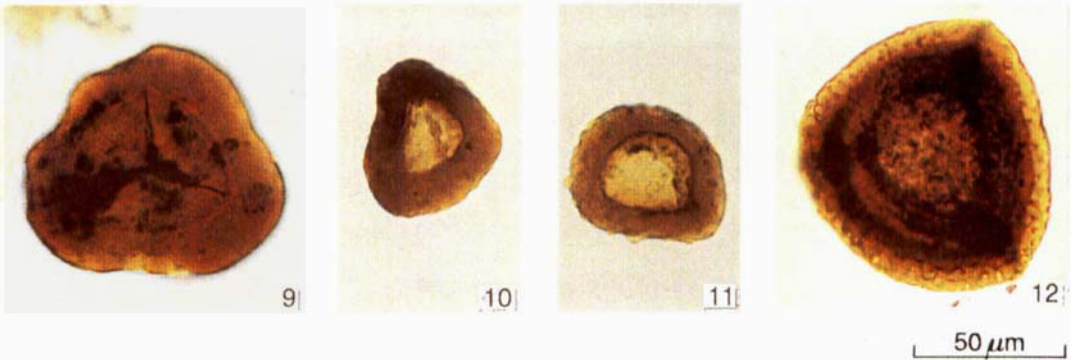
Fig. 14. Selected pollen from the Tyrrellfjellet Member of the Nordenskiöldbreen and Gipshuken Formations and spores from the Kapitoll and Cadellfjellet Members of the Nordenskiöldbreen Formation. Each figured palynomorph is located by abbreviated section name, sample level, PMO number and slide coordinates to an England Finder. Scale is added.

1. *Nuskoisporites* cf. *dulhuntyi* TRO-5, 43 m, PMO 139.075, S50
2. *Nuskoisporites* sp. SKA-2, 137 m, PMO 139.081, S29/4
3. Cf. *Florinites* sp. STØ-1, 25 m, PMO 139.087, T53/3
4. *Potoniesporites* cf. *novicus* TRO-5, 103 m, PMO 139.079, X49/2
5. Unidentified monosaccate pollen TRO-3, 140 m, PMO 139.078, L44/3
6. *Cordaitina* sp. TRO-5, 43 m, PMO 139.075, H46/1
7. *Crustasporites* sp. SKA-2, 137 m, PMO 139.081, M64/1
8. *Potoniesporites novicus* KOL-4, 2.0 m, PMO 139.082, W55/2
9. *Murospora aurita* SKA-1, 124.5 m, PMO 139.084, S32
10. *Densosporites* spp. SKA-1, 124.5 m, PMO 139.084, V32
11. *Densosporites* sp. SKA-1, 124.5 m, PMO 139.084, G52
12. *Densosporites spitsbergensis* TRO-1, 7.0 m, PMO 139.085, S17

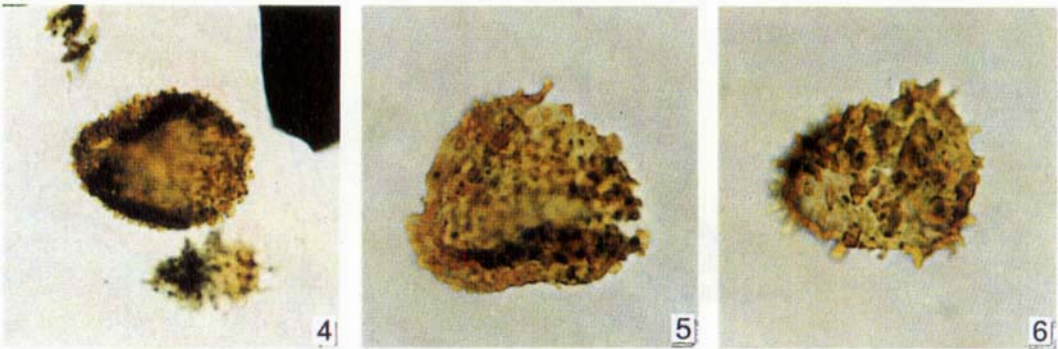
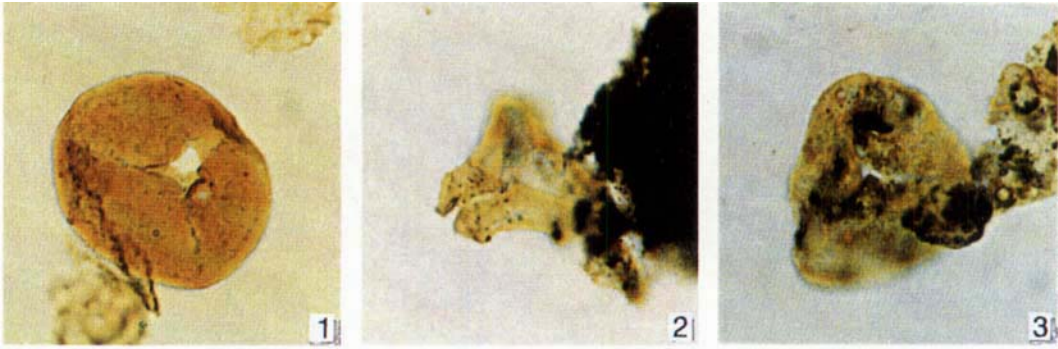
NORDENSKIÖLDBREEN & GIPSHUKEN FORMATIONS



Reworked:



KAPP STAROSTIN FORMATION



50 μ m

to Kazanian age. Probably due to low diversity and poor preservation, the palynoflora does not seem to differ significantly between the lower Vøringen Member and the overlying part of the formation.

Dating of the Kapp Starostin Formation based on brachiopods suggests a Kungurian to Midian (late Kazanian to early Tatarian) age (Nakamura et al. 1987, 1992). The Nakamura et al. zonation from 1987 was disputed as being controlled by environment rather than evolution (Stemmerik 1988), but the general age assignment of a latest Early Permian or earliest Late Permian to early Tatarian was also supported by Stemmerik. Conodonts from the lower Vøringen Member suggest a late Artinskian to early Kungurian age (Nakrem et al. 1992), while brachiopods suggest a Kungurian age for the Vøringen Member (Nakamura et al. 1992). Bryozoans suggest a Ufimian to Kazanian age for the overlying part of the formation (Nakrem 1991b).

The time-span of the proposed hiatus between youngest Permian and the ammonoid-dated Early Griesbachian succession on Spitsbergen has been debated for some time. Most publications based on fossil records suggest a hiatus spanning the uppermost Permian (Nakrem et al. 1992; Nakamura et al. 1987, 1992), but how much is missing is still a matter of discussion. The uppermost brachiopod faunas in Nakamura et al. (1992) suggest the lowermost part of the Tatarian to be present, implying that the Dzhulfian to Dor-

ashamian is missing. Dense sampling for palynology across the Permian-Triassic contact at Festningen and Stensiöfjellet (Fig. 3) does not give better resolution in the uppermost succession. Although fossil evidence is missing for the Tatarian, conformable lithological contacts between the Tempelfjorden and Sassendalen groups in some areas may indicate continuous, but very slow, sedimentation across the Permian-Triassic boundary in western Spitsbergen (Mørk 1989).

The *Densoisporites nejburgii* assemblage

Palynological description. – The assemblage is characterized by various *Lunatisporites* species, *Ephedripites*, *Densoisporites nejburgii*, *Uvaeisporites* spp., *Propriisporites pococki* and *Tympanicysta stoschiana*.

Occurrence. – The assemblage is recorded in the lowermost parts of the Vardebukta Formation (Fig. 2) at the Bertilyggen, Festningen and Stensiöfjellet localities.

Palynological correlation and age. – *Propriisporites pococki* and *Densoisporites nejburgii* are regarded as having their first occurrence from base Griesbachian, and are also reported from Griesbachian strata from the Barents Shelf (Hochuli et al. 1989) and East Greenland (Balme 1980). They occur in correlative beds where the Early Griesbachian ammonoid *Otoceras boreale* is reported (Tozer & Parker 1968, Korchinskaya 1986). *Tympanicysta stoschiana* is restricted to the Griesbachian succession in the Arctic region (Balme 1980; Utting 1989; Mangerud; IKU in-house data).

Fig. 15. Selected spores from the Kapp Starostin Formation. Each figured palynomorph is located by abbreviated section name, sample level, PMO number and slide coordinates to an England Finder. Scale is added.

1. *Leiotriletes* sp. KW1-5, 88 m, PMO 139.088, B60
2. *Waltziaspora* sp. HØGSK-1, 180 m PMO 139.089, E46/3
3. Unidentified, trilete spore STØ-1, 17 m, PMO 139.090, D44/1
4. *Apiculatisporis* sp. HØGS-1, 180 m, PMO 139.089, G54/2
5. *Neoraistrickia* sp. KWÆ-1, 3.6 m, PMO 139.091, T61/3
6. *Neoraistrickia* sp. HØGS-1, 180 m, PMO 139.089, G54/2
7. Cf. *Verrucosisporites* sp. HØGS-1, 180 m, PMO 139.089, V54/3
8. *Kraeuselisporites* sp. STØ-1, 115 m, PMO 139.092, C48/3
9. *Diatomozonotriletes* sp. HØGS-1, 68 m, PMO 139.093, L47
10. *Kraeuselisporites apiculatus* FES-10, 167.4 m, PMO 139.094, F55/1
11. *Maculatasporites* sp. aff. *Reticulatina* HØGS-1, 22 m, PMO 139.095, P56
12. *Inaperturopollenites nebulosus* STØ-1, 46 m, PMO 139.096, D39/2

Reworked material

Reworked palynomorphs are identified at several levels in the Permian succession. Reworking of Carboniferous palynomorphs as various *Densosporites* spp. and *Murospora* spp. is recorded sporadically throughout. Reworking of Upper Devonian spores, including various genera of *Ancyrospora* spp., *Grandispora* spp., *Samarisporites* spp. and the species *Cornispora varicornata* seems to be restricted to the Upper Permian. In general, the reworked palynomorphs are better preserved than the in situ palynofloras.

Paleoenvironment

The dominantly carbonate facies of the upper Nordenskiöld and the Gipshuken Formations are dominated by polylicate pollen (Fig. 11), reflecting the arid climate that existed during the late Carboniferous and early Permian in the Svalbard area. The extremely low number of acritarchs also suggests a restricted marine environment.

The significant increase in acritarchs across the Gipshuken/Kapp Starostin contact reflects a dramatic shift in depositional environment, allowing marine microplankton to become abundant. The decrease in polylicate pollen as well as the income of spores across the same formation contact (Fig. 11) reflect a change to more humid environmental conditions as suggested by Steel & Worsley (1984).

Conclusions

The generally very poor preservation and the low number of productive samples of palynomorphs reduce the potential for refined zonation of the Permian succession of Spitsbergen, Svalbard.

Three palynological assemblages are, however, recognised in the uppermost Carboniferous-Permian succession. These include the *Vittatina* assemblage of late Gzhelian to early Asselian age, the *Hamiapollenites tractiferinus* assemblage of late Asselian to Sakmarian/?Artinskian age and the *Kraeuselisporites* assemblage of late Artinskian to early Tatarian (Midian) age.

A Late Carboniferous *Densosporites* assemblage restricts the oldest Permian assemblage downwards, while an Early Griesbachian *Densosporites neburgii* assemblage restricts the youngest Permian assemblage upwards.

The Permian palynofloras of Spitsbergen closely resemble Permian palynofloras recorded from the Barents Shelf (IKU in-house data), Bjørnøya (Vigran & Mørk unpubl.), the Sverdrup Basin in Arctic Canada (Utting 1985, 1989) and from the Timan-Pechora Basin in Russia (for example Varyukhina 1971, 1980; Molin & Koloda 1972; and Dyupina 1987). In addition, similarities are seen with those palynofloras described from East Greenland (Balme 1980; Piasecki 1984), although the general quantitative composition is different.

In general, the Early Permian is dominated by polylicate pollen with abundant striate bisaccate pollen and regular appearance of monosaccate pollen, reflecting an arid climate. The Late Permian is dominated by acritarchs, while polylicate and bisaccate pollen commonly appear to association with various trilete spores, reflecting a change to more humid environmental conditions.

Acknowledgements. – The authors thank the IKU staff for assistance, in particular A. Mørk for critical reading of the manuscript. We would also like to thank C. E. Dons, T. Hellem and M. Skaug for making unpublished field-logs available.

We thank J. Utting, ISPG, Geological Survey of Canada in Calgary for hospitality during visits to ISPG, for fruitful discussions on Permian palynology of the Arctic and for making available comparative material from the Sverdrup Basin. One of the authors (G. Mangerud) also thanks ISPG, in particular B. Beauchamp, for making it possible to join a field-party to collect comparative material from Ellesmere Island.

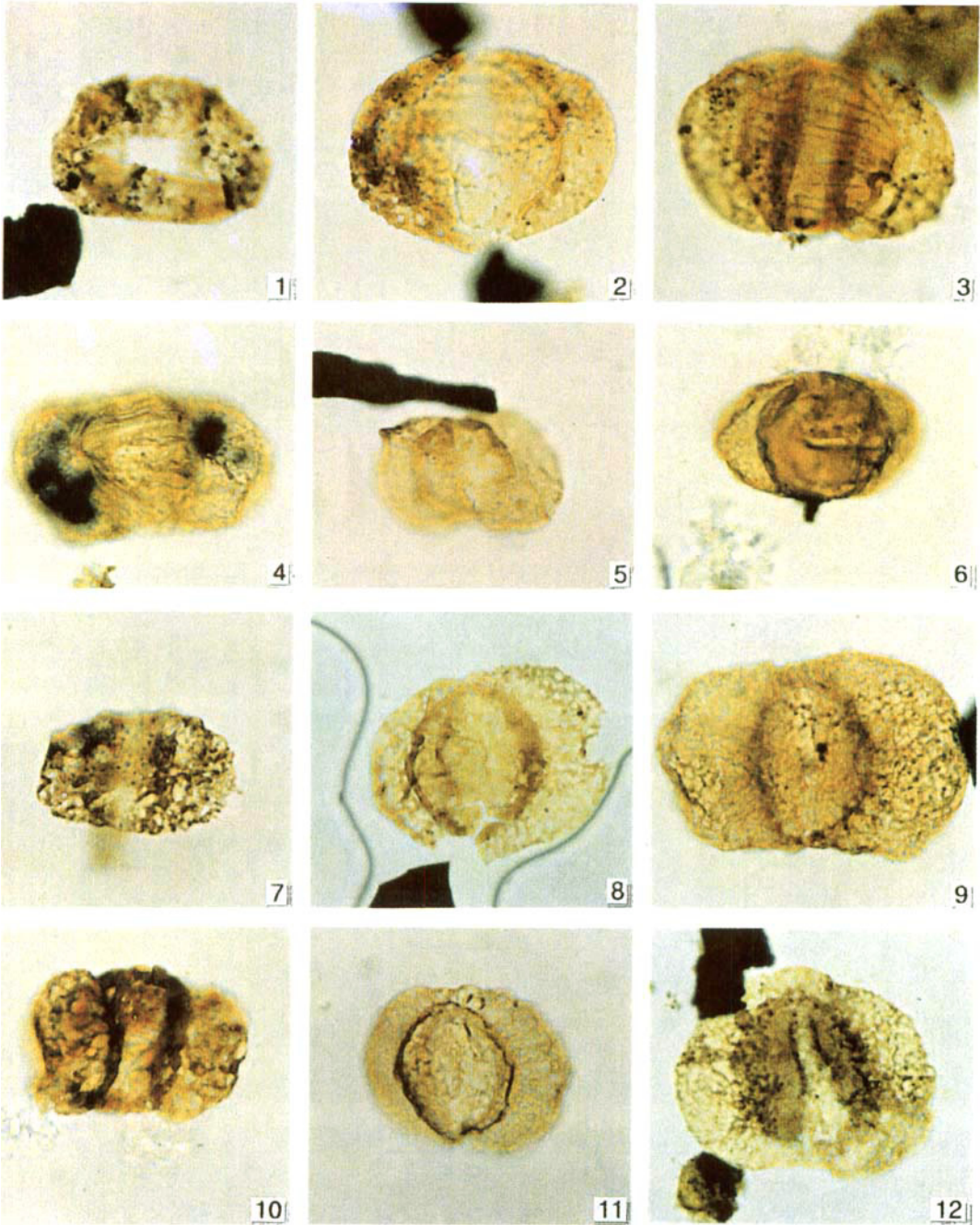
We thank S. Piasecki at the Geological Survey of Greenland (GGU) in Copenhagen for hospitality and for the opportunity to study material from Greenland.

We also gratefully acknowledge the companies who financially supported the Arctic Geoprogram and the Arctic Paleozoic project under the ongoing Arctic Correlation Program (A/S Norsk Shell, Amerada Hess Norge A/S, Amoco Norway Oil Company, BP Petroleum Development (Norway) Ltd., Elf Petroleum Norge A/S, Esso Norge a.s., Fina Exploration Norway, Mobil Exploration Norway, Norsk Agip A/S, Norsk Hydro a.s., Phillips Petroleum Company Norway, Saga Petroleum a.s. and Statoil).

Fig. 16. Selected bisaccate pollen from the Kapp Starostin Formation. Each figured palynomorph is located by abbreviated section name, sample level, PMO number and slide coordinates to an England Finder. Scale is added.

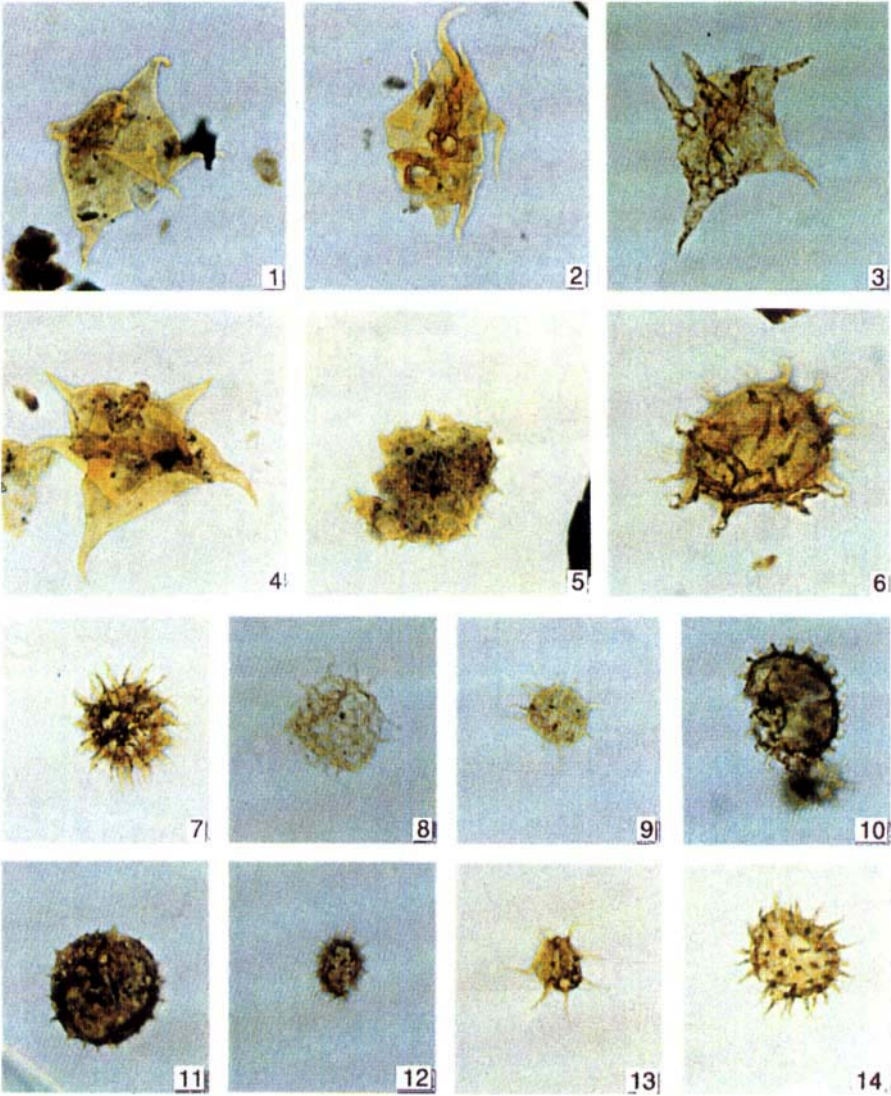
1. *Lueckisporites virkkiae* STØ-1, 25 m, PMO 139.083, Q46/1
2. *Protohaploxylinus samoilovichii* HØGS-1, 180 m, PMO 139.089, H61/1
3. *Protohaploxylinus perfectus* KWÆ-1, 3.6 m, PMO 139.091, T61
4. *Protohaploxylinus* sp. HØGS-1, 180 m, PMO 139.089, E53/1
5. *Klausipollenites* sp. STØ-1, 46 m, PMO 139.096, B40/1
6. Cf. *Limitisporites* sp. KWÆ-1, 3.6 m, PMO 139.091, Q44/3
7. *Falcisporites* sp. HØGS-1, 180 m, PMO 139.089, E51/2
8. *Alisporites* spp. KWÆ-1, 3.6 m, PMO 139.091, B40
9. *Vesicaspora* sp. KWÆ-1, 3.6 m, PMO 139.091, E53
10. Unidentified bisaccate pollen, KWÆ-1, 3.6 m, PMO 139.091, T58/4
11. *Vesicaspora schemeli* KWÆ-1, 3.6 m, PMO 139.091, T52/2
12. Cf. *Florinites* sp. KWI-3, 187 m, PMO 139.086, R56/2

KAPP STAROSTIN FORMATION

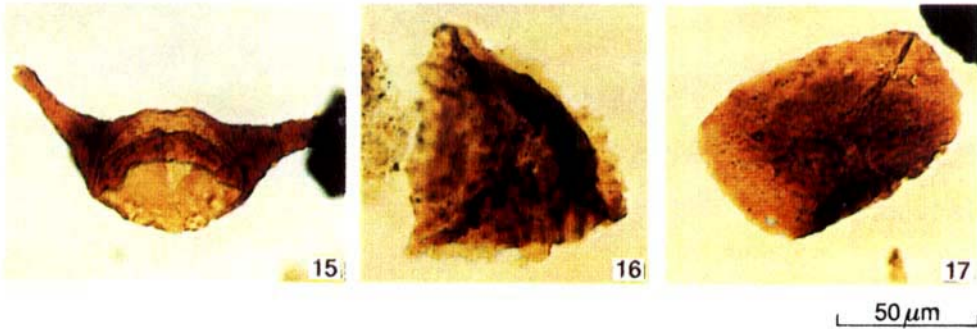


50 μ m

KAPP STAROSTIN FORMATION



Reworked:



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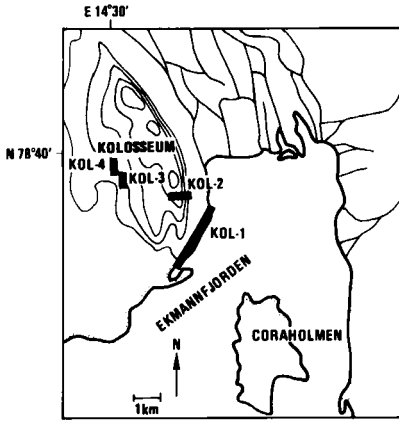
Fig. 17. Selected acritarchs and representative reworked spores from the Kapp Starostin Formation. Each figured palynomorph is located by abbreviated section name, sample level, PMO number and slide coordinates to an England Finder. Scale is added.

1. *Unellium* sp. KWI-3, 187 m, PMO 139.086, E54/2
2. *Unellium* sp. KWI-3, 187 m, PMO 139.086, D53/4
3. *Unellium* sp. KWI-3, 187 m, PMO 139.086, E46/2
4. *Unellium* sp. KWI-3, 187 m, PMO 139.086, J40/3
- 5–14 are all *Micrhystridium*s from sample KWI-3, 187 m, PMO 139.086.
15. *Cornispora varicornata* (reworked) KWI-5, 88 m, PMO 139.088, A49/1
16. ?*Gondispora* sp. (reworked) KWI-5, 88 m, PMO 139.088, G51
17. ?*Gondispora* sp. (reworked) KWI-5, 88 m, PMO 139.088, D59/1

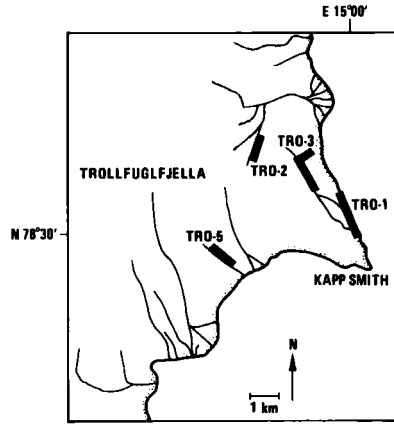
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Appendix

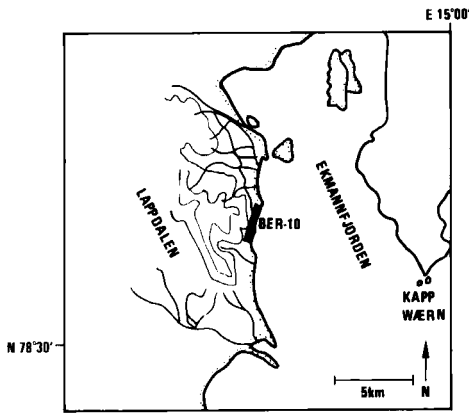
Maps showing the localisation of the 16 different Permian sections and composite sections sampled for this study. The sections are arranged in the same order as in Fig. 1 (see Loc. number).



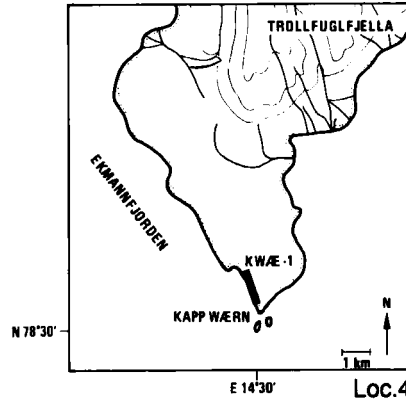
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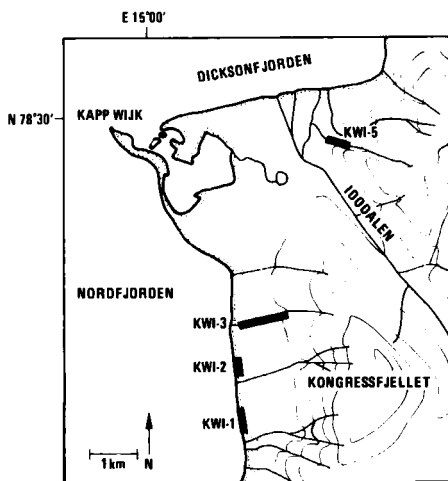
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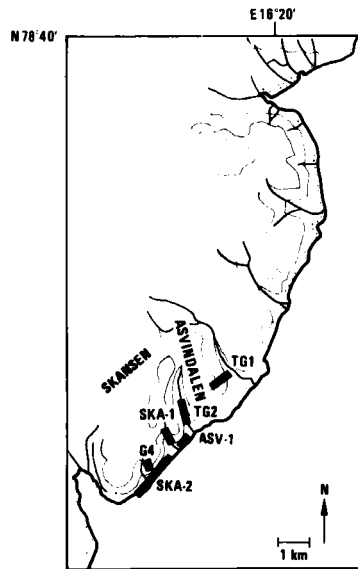
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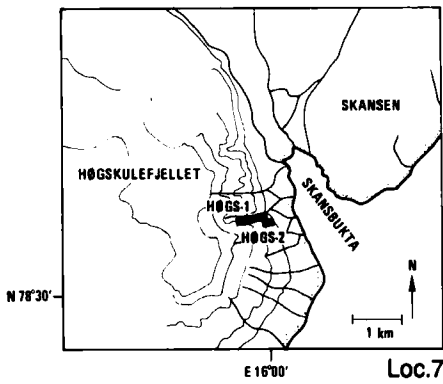
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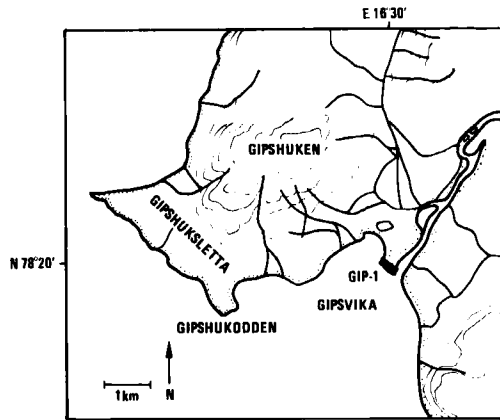
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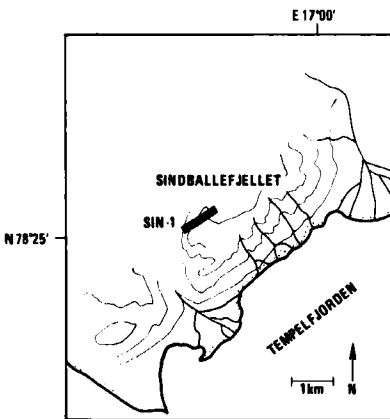
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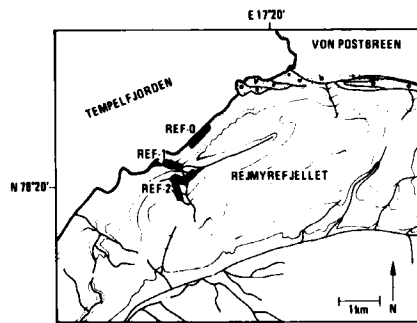
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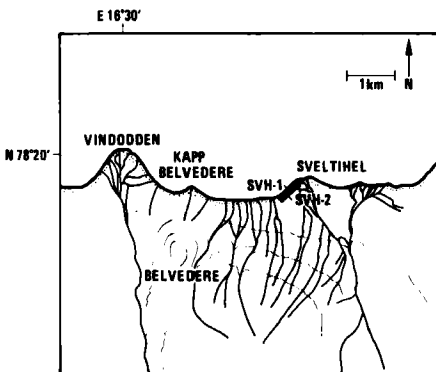
Loc.8



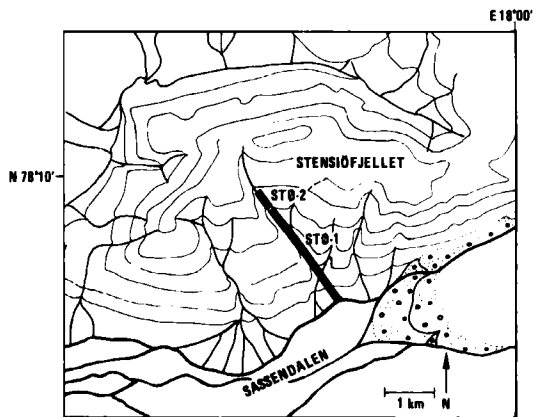
Loc.9



Loc.10



Loc.11



Loc.12

