PERMIAN BIOSTRATIGRAPHY OF SVALBARD (ARCTIC NORWAY)—A REVIEW*

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Based on our records of bryozoans, conodonts, fusulinids and palynomorphs, as well as reviews of previously published data and unpublished sources, all biostratigraphically important fossil groups, except ammonoids, are present in Svalbard. A revision of the biostratigraphic framework for this area reveals that although there are small discrepancies between the individual fossil groups regarding the dating of some horizons, they broadly agree with each other. Uppermost Carboniferous as well as Lower Permian rocks (part of the Gipsdalen Group) contain abundant fusulinids, which together with conodonts date these rocks as Gzhelian through Sakmarian. At Bjørnøya the youngest fusulinids are of Artinskian age. The middle part of the Permian succession (of evaporitic nature) contains few fossils, but late Sakmarian through Artinskian palynomorphs and smaller foraminifera are present. The upper part of the succession (the Tempelfjorden Group) contains abundant brachiopod, bryozoan, and conodont faunas of latest Artinskian through Ufimian-Kazanian age. Exclusively Tatarian faunas or floras have not been detected. Basal Triassic strata at Spitsbergen are dated as early Griesbachian. A pronounced climatic shift from warm, through temperate dry and finally cooler conditions, took place during the Permian. This change is reflected in the sediments, and in the faunal composition and biostratigraphical usefulness of the biota.

The Svalbard Archipelago is located on the northwestern corner of the Barents Shelf (Fig. 1). The Upper Paleozoic succession is remarkably complete, apparently with few depositional breaks. New data have been acquired during recent fieldwork (1984-1990) regarding the sedimentological development as well as the biostratigraphy of this succession, notably on Spitsbergen, Nordaustlandet, and Bjørnøya [Bear Island].

The general geology, paleontology, and sedimentology have previously been described in several papers, but a comparative biostratigraphic review of Svalbard has not been compiled since the work by Forbes et al. and Cutbill and Challinor [13, 22] for Spitsbergen, and the work by Worsley and Edwards for Bjørnøya [84]. New contributions to our knowledge, including data on brachiopods [15, 42, 76, 77], bryozoans [39, 45], conodonts [44, 46, 74], corals [20, 21], foraminifera [68], fusulinids [48, 64, 65], and palynomorphs [37, 81] have been published.

*The present paper was selected from papers presented at the International Congress: Permian System of the World. This meeting was held August 5-10, 1991, in Perm', Russia, on the occasion of the 150th anniversary of Roderick Murchison's founding of the Permian System.

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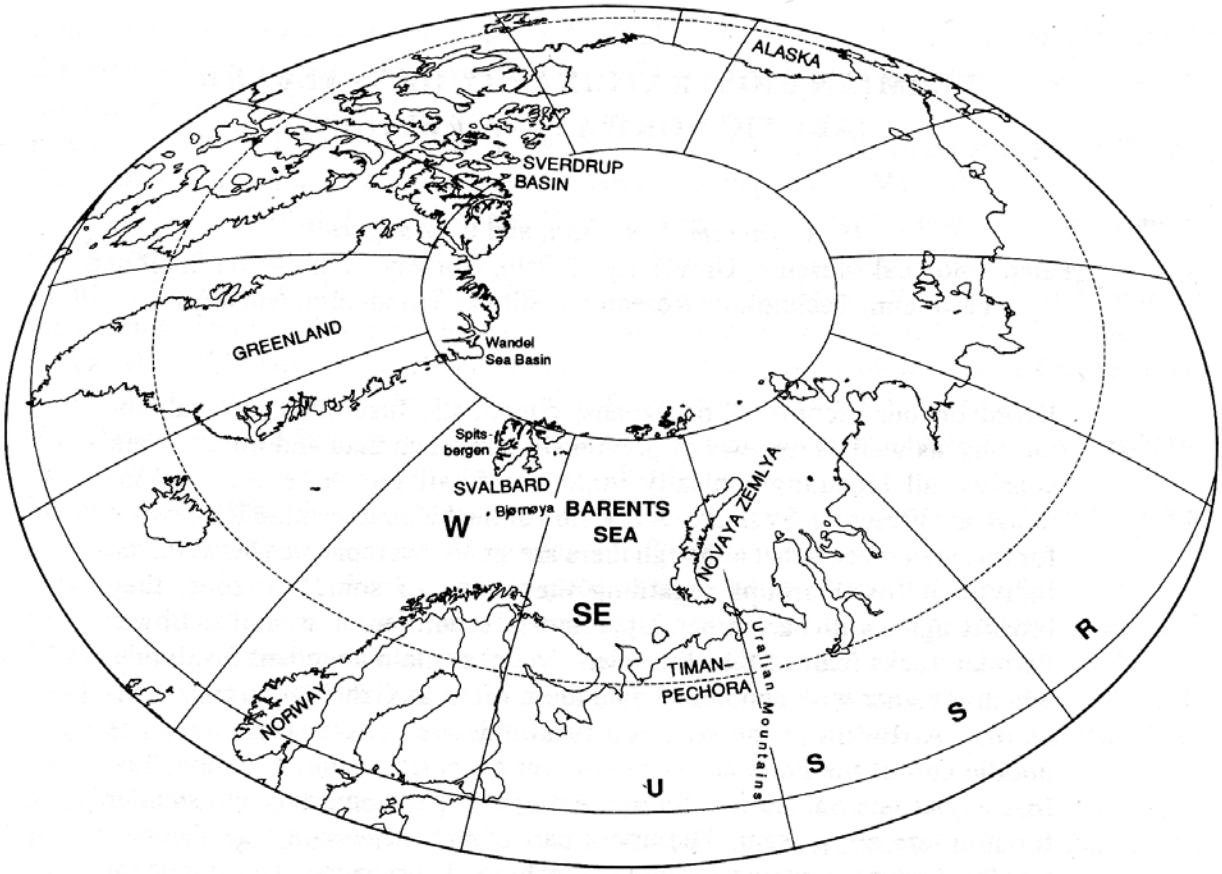

FIGURE 1. Locality map in north polar projection showing Svalbard's position on the western margin of the Barents Sea.

Several unpublished theses from Norwegian universities and released company reports have also been made available for our investigations.

The purpose of the present compilation is therefore to investigate previously described occurrences of all biostratigraphically significant fossil groups, and add our own data to provide a biostratigraphical framework for Svalbard. The fossils have been compared with faunas in well-known sections from adjacent regions: Canadian Arctic (the Sverdrup Basin), Greenland (Wandel Sea Basin), and the Western Arctic CIS (i.e., Novaya Zemlya, Timan-Pechora Basin and western Siberia).

Geological Framework

A lithostratigraphic scheme for the upper Paleozoic succession of Svalbard was proposed by Cutbill and Challinor [13] and revised by Worsley and Edwards [84] for Bjørnøya. The lithologic units discussed below are shown on Figures 2 and 3, with stratigraphical distributions of these units according to our revisions. A stratigraphic committee for Svalbard is, however, revising definitions of the units in current use (H. B. Keilen, pers. comm., 1991). The Permian paleogeography of Svalbard, with implications for the Barents Shelf, is dealt with in a number of studies [e.g., 26, 69], and data from these sources are also included in the present study.

Thickness and facies patterns of the sedimentary units of Spitsbergen are mainly related to a series of NNW-SSE-trending lineaments (Figs. 4, 5 and 6), which were active as a result of

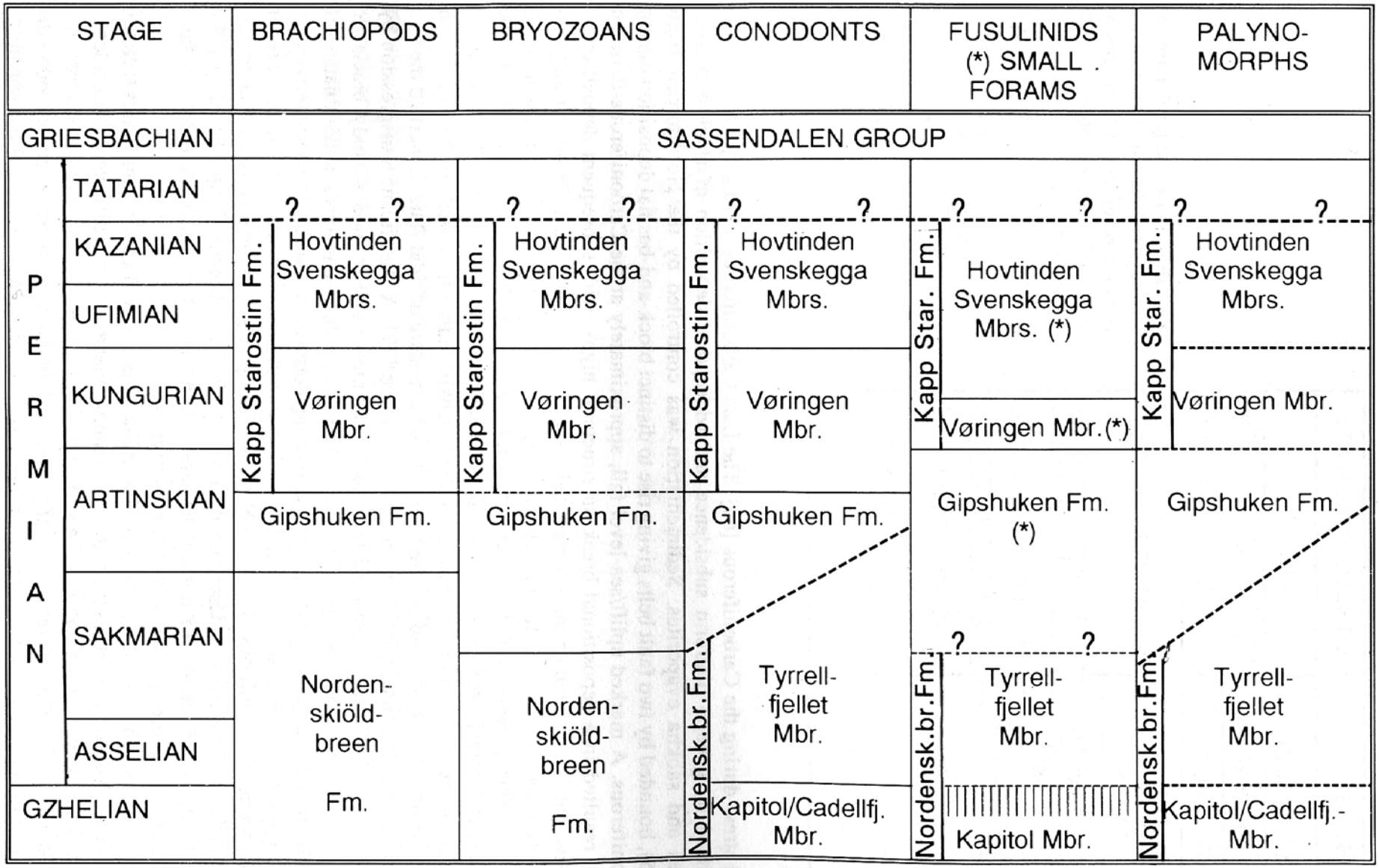

FIGURE 2. Lithological units of Spitsbergen and their stratigraphic distribution according to fossil groups discussed in the text. Ruled = break or lack of data.

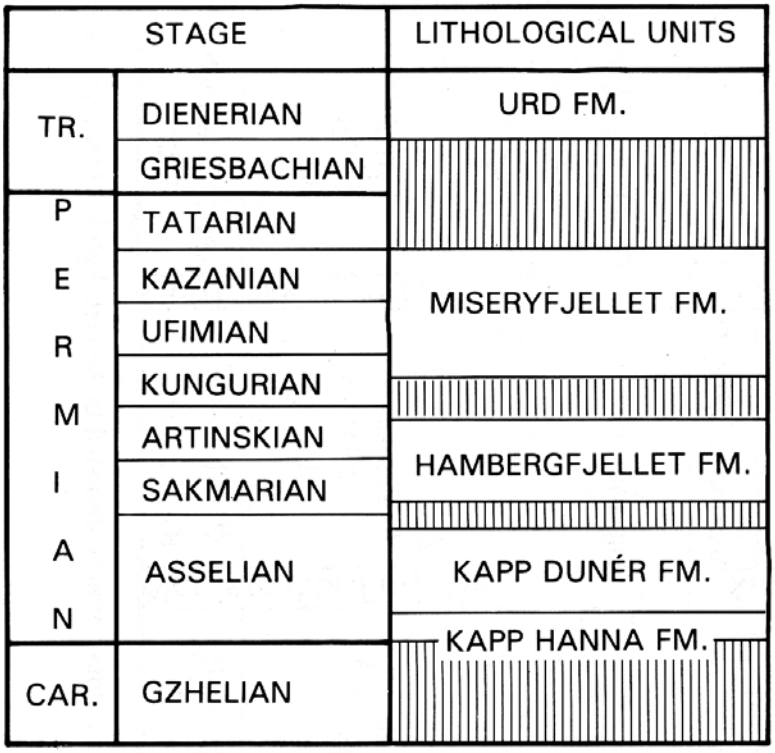

FIGURE 3. Lithological units of Bjørnøya and their stratigraphic distribution according to fossil groups discussed in the text. Ruled = break or lack of data.

tensional stress during the Carboniferous [69]. The Late Carboniferous and Early Permian was characterized by general platform subsidence and widespread deposition of shallow marine carbonates and sabkha evaporites. Sedimentation was controlled by the Nordfjorden High (Figs. 4, 5), bounded by two fault belts giving rise to distinct block-and-basinal deposition during the Carboniferous. A marked uplift/sea-level fall, approximately at the Carboniferous-Permian transition, resulted in a depositional break on structural highs, with subsequent deposition of transgressive sandstones and/or intraformational conglomerates. The Early Permian transgression led to shallow marine conditions, carbonate deposition, and reef development under warm climatic conditions, preserved in the upper part of the Nordenskiöldbreen Formation. Fusulinids, brachiopods, and corals were important faunal constituents in this environment. The regressive phase during more arid conditions produced thick sabkha units preserved in the Gipshuken Formation on structural highs and resulted in subaerial exposure of tidal flats; it marked the end of the Early Carboniferous-Early Permian major sequence [17]. A significant transgression by the end of the Early Permian drowned the sabkha sediments and formed a sandy bioclastic limestone barrier unit (the Vøringen Member). The fauna shifted towards a dominance of brachiopods, bryozoans, and sponges. The Early-Late Permian transition is characterized by increased deposition of dark spiculitic shales with local sandstones on an open marine, deeper platform under cooler conditions. The Tempelfjorden Group at Spitsbergen embraces the uppermost Paleozoic major sequence described by Embry [17] and Stemmerik and Worsley [71]. Glauconitic sandstones deposited during the latest Permian reflect uplift along active fault lineaments, as well as the "global" Late Permian regression.

The late Paleozoic history of Bjørnøya [83] was characterized by Late Carboniferous tectonic activity with north-south to northeast-southwest trending lineaments, and differential subsidence to the west. The Early Permian witnessed a shift from clastic deposition to reestablishment of a stable carbonate shelf and the development of paleoaplysinid buildups; these are preserved in the Kapp Dunér Formation. A mid to Late Permian phase of transtensional and flexuring uplift

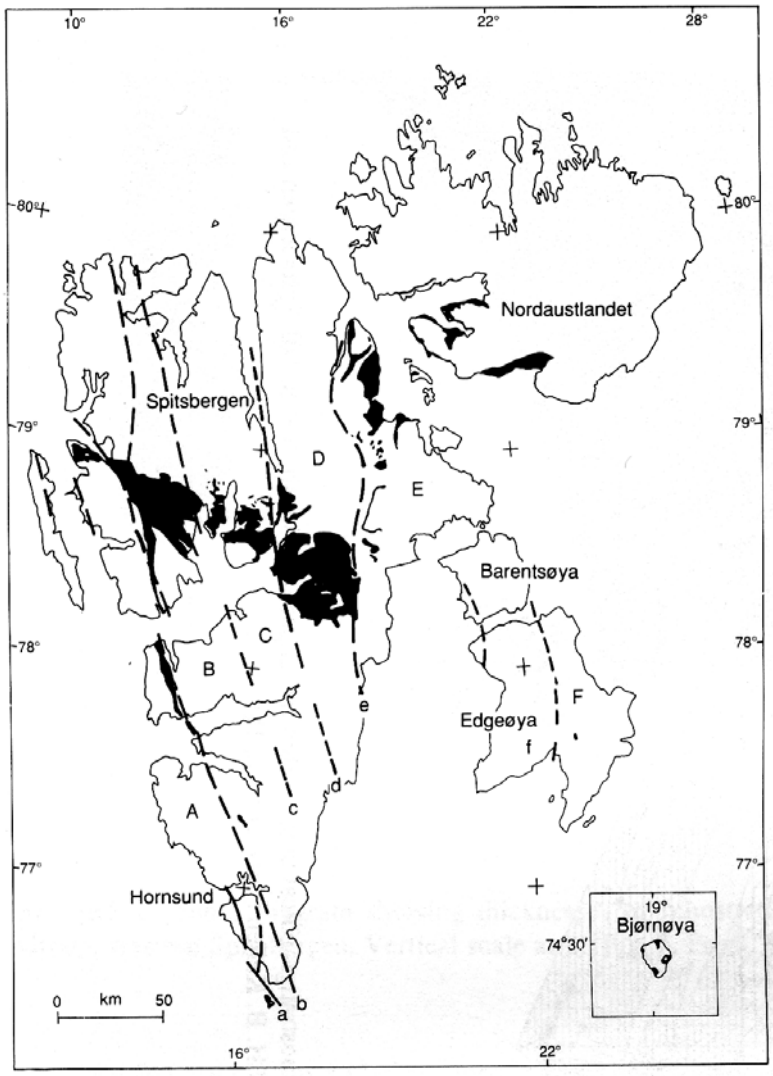

FIGURE 4. Map of Svalbard, with Carboniferous-Permian rocks in black. Structural elements; A: Sørkapp-Hornsund, B: Central Trough (St. Jonsfjorden Trough), C: Nordfjorden High, D: Billefjorden Trough, E-F: Ny Friesland Trough. a-f: Fault lineaments.

movements and episodes of peneplanation led to erosion and subsequent deposition of condensed mixed clastic/carbonate sequences through the Hambergfjellet and Miseryfjellet formations, progressively overstepping all older units in the area.

The biostratigraphy of these formations has previously been utilized in several paleontological contributions, and apart from ammonoids, all the typical Permian biota is present in the investigated successions of Svalbard. Ranges of selected fossils are presented in Figures 7-9 for Spitsbergen and Bjørnøya.

Lithological Units and Biostratigraphy, Spitsbergen

The distribution and revised age of lithological units are shown in Figure 2, and a brief description of each unit follows below. Unless otherwise mentioned, unit definitions are from Cutbill and Challinor [13]. Thickness of respective units in their type areas is in brackets.

Nordenskiölbreen Formation (Moscovian-Sakmarian)

The Nordenskiölbreen Formation is divided into the Carboniferous Scheteligfjellet (153 m), Morebreen (thickness unknown), Minkinfjellet (156 m), Cadellfjellet (106 m) and Kapitol (86 m) members, and the Permian Tyrrellfjellet Member (160 m).

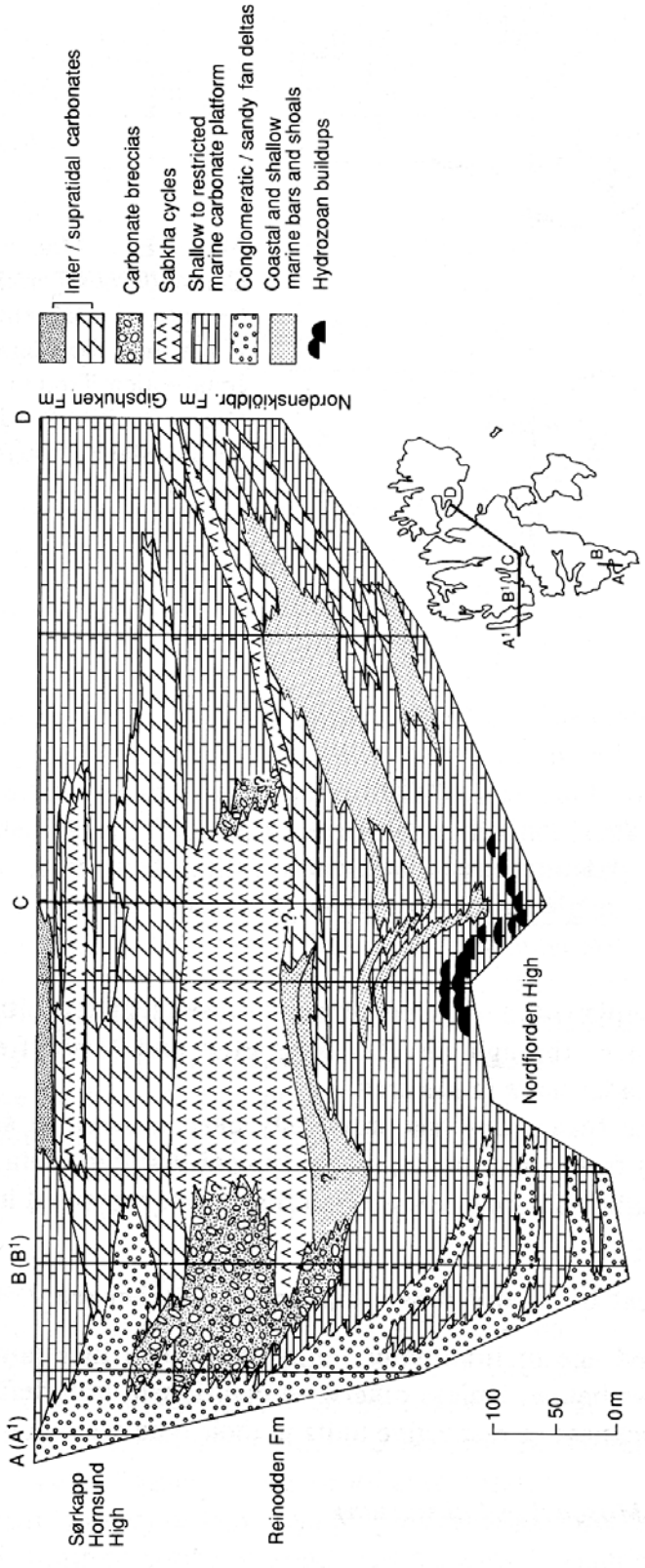

FIGURE 5. Fence diagram showing thicknesses of lithostratigraphical units within the Gipsdalen Group, SW to NE Spitsbergen and Nordaustlandet. Modified from Worsley et al. [83] and H. B. Keilen (pers. comm., 1991).

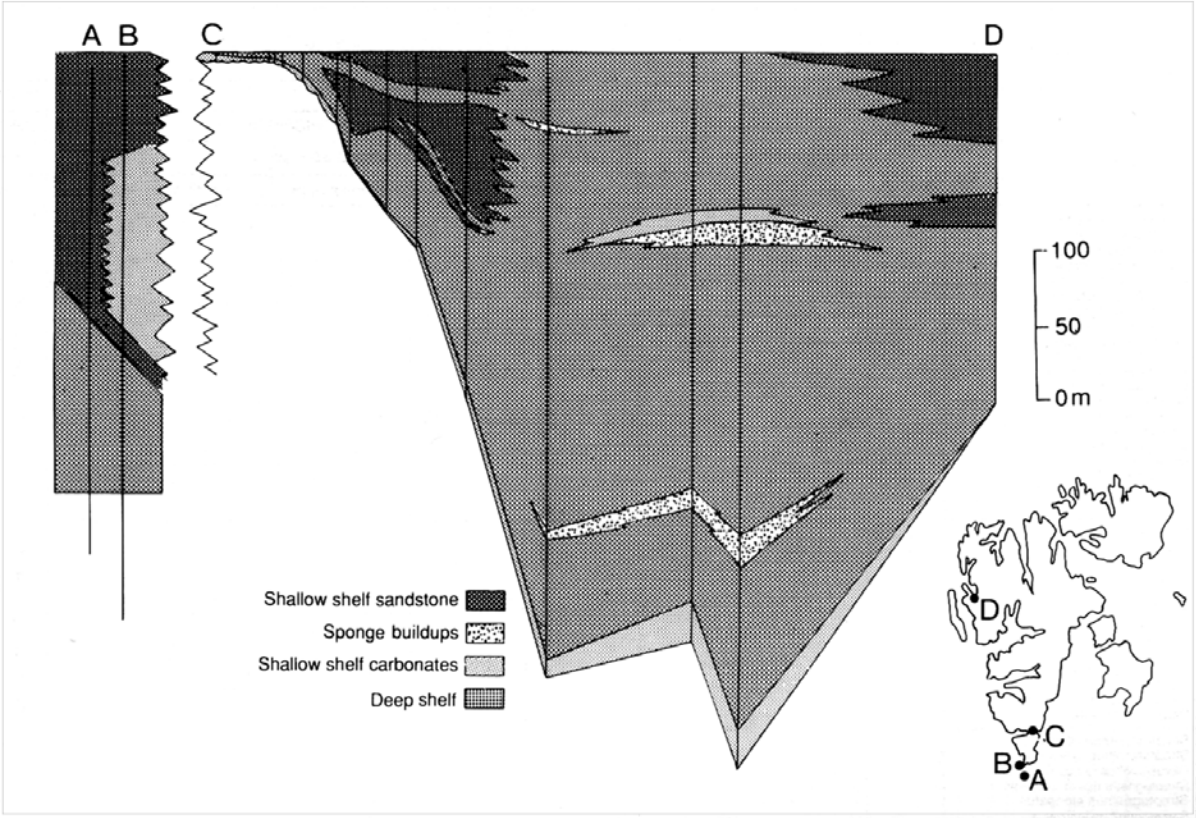

FIGURE 6. Fence diagram showing thicknesses of lithostratigraphical units within the Tempelfjorden Group, western Spitsbergen. Vertical scale as on Fig. 5. From Worsley et al. [83].

Data from the Upper Carboniferous Cadellfjellet and Kapitol members and the Lower Permian Tyrrellfjellet Member will be treated in detail below.

Kapitol and Cadellfjellet members (Moscovian-Gzhelian). These two members are in part lateral equivalents, of Middle-Late Carboniferous age. The Kapitol Member crops out on the Nordfjorden High, while the Cadellfjellet Member is developed within the Billefjorden Trough, east of the Billefjorden Fault Zone (Fig. 4). These units are dominantly carbonates with some minor clastics.

Brachiopods are abundant through the Kapitol and Cadellfjellet members. Most species have a long range; *Septacamera kutorgae* (Chernyshev), *Echinoconchus elegans* (M'Coy) and *Eomarginifera longispina* (Sowerby) have a reported middle to latest Carboniferous distribution in Great Britain, Novaya Zemlya, and the Moscow Basin [24]. Furthermore, *Krotovia pseudoaculeata* (Krotow) and *Choristites* cf. *supramosquensis* Nikitin are typical members of Gzhelian assemblages in the Moscow Basin [61]. Of the 24 brachiopod species known from these units, 11 range up into overlying units [24, 66].

Carboniferous bryozoan species (*Ascopora magniseptata* Shul'ga-Nesterenko and *A. muromsensis* Shul'ga-Nesterenko) present in these members have a Kasimovian through Gzhelian range in the Urals [62]. *Rhombotrypella invulgata* Trizna, *R. arbuscula* (Eichwald) and *Archimedes stuckenbergi* Nikiforova are recorded in several Spitsbergen sections; all occur through the Asselian-Artinskian of the Urals and Timan-Pechora [39].

Conodonts occur sporadically within the Cadellfjellet Member. *Streptognathodus excelsus*

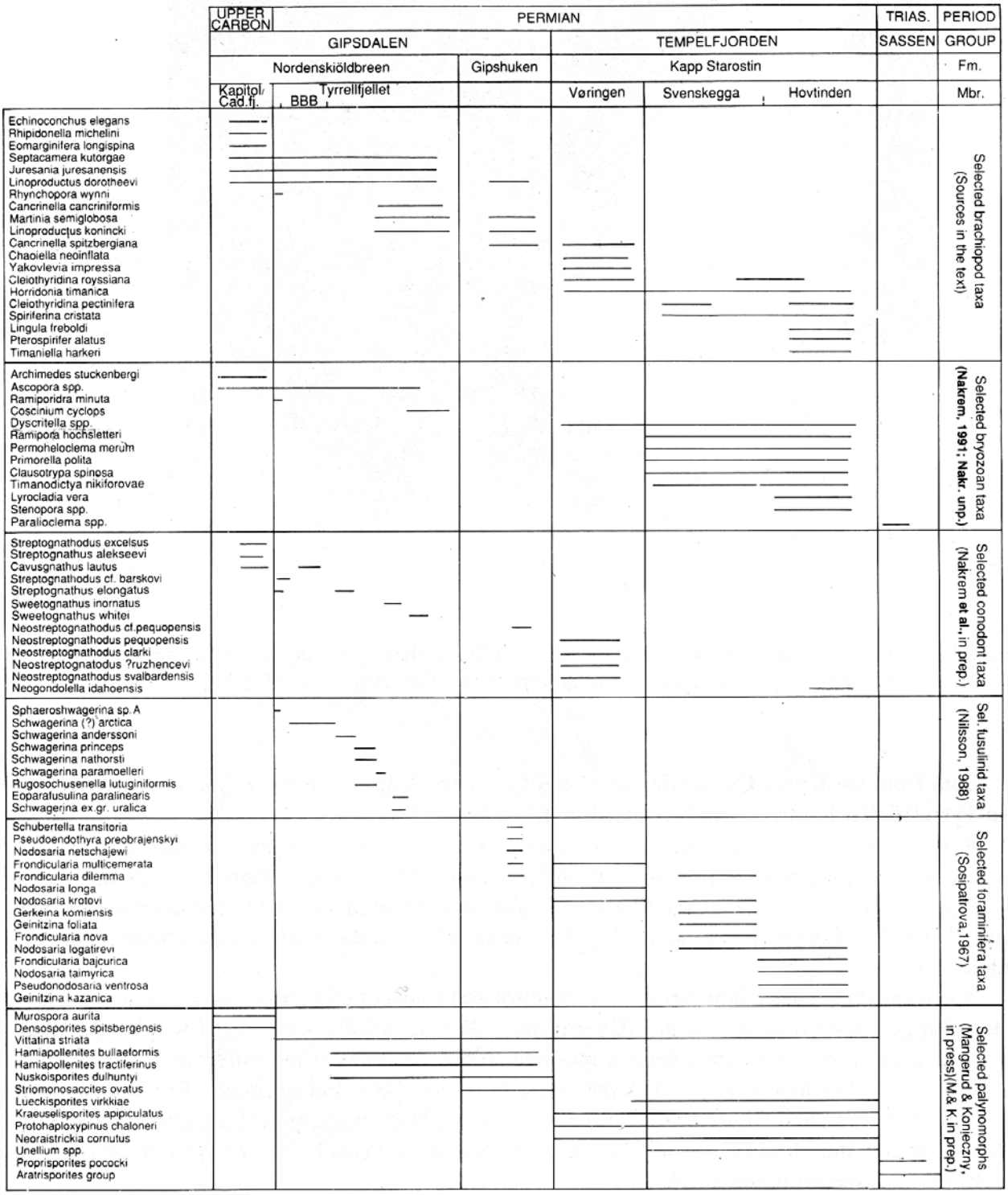

FIGURE 7. Ranges of selected fossils through the Permian of Spitsbergen. BBB = Brucebyen Beds, Sassen = Sassendalen Group.

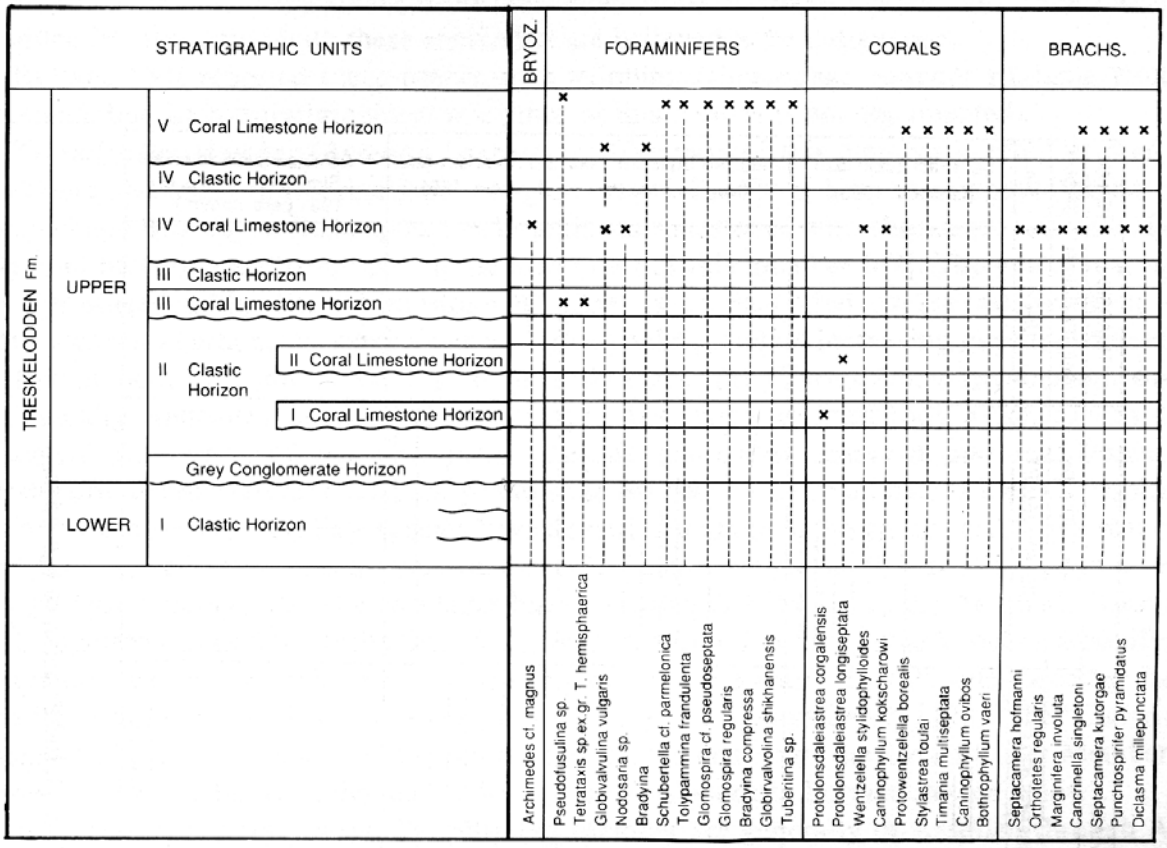

FIGURE 8. Ranges of selected fossils through the Treskelodden Formation, southern Spitsbergen. Based on Birkenmajer [6], Czarniecki [14, 15], Fedorowski [18, 19], and Liszka [33].

Stauffer and Plummer has a restricted Late Carboniferous (Virgillian) range in North America [55], and *S. alekseevi* Barskov, Isakova and Schastlivsheva has a restricted Gzhelian range in the Urals [40], whereas *Cavusgnathus lautus* Gunnell ranges into the Lower Permian in the Urals [40] and in the Canadian Arctic [27].

Corals from the Cadellfjellet Member have briefly been mentioned by Fedorowski (1986) and the genera *Heintzella, Fomichevella, Gshelia, Bothrophyllum*, and *?Arctophyllum* were considered to indicate a Late Carboniferous age for this unit, as well as for the lowermost part of the overlying Tyrrellfjellet Member.

Two fusulinid assemblages of Early Kasimovian (*Protriticites-Quasifusulinoides* zone) and Middle Kasimovian-Early Gzhelian (*Montiparus-Quasifusulina* zone) ages have been found in the uppermost part of the Kapitol Member [48]. These two zones appear to correspond partly to Cutbill and Challinor's [13] *Waeringella usvae* zone, to which they assigned a "Gzhelian" (= Kasimovian-Gzhelian) age. A similar fusulinid fauna has also been listed from the Cadellfjellet Member on Ny Friesland [12].

Palynomorphs are present throughout the Kapitol and Cadellfjellet members, but many are poorly preserved. Records include a typical Early Carboniferous palynomorph assemblage comprising various *Densosporites* species, including *D. rarispinosus* Playford [53], *D. spitsbergensis* Playford [53], and *D. anulatus* (Loose) Smith and Butterworth, 1967, as well as *Murospora aurita* (Waltz) [52]. Similar assemblages are reported from the Lower Carboniferous Billefjorden Group

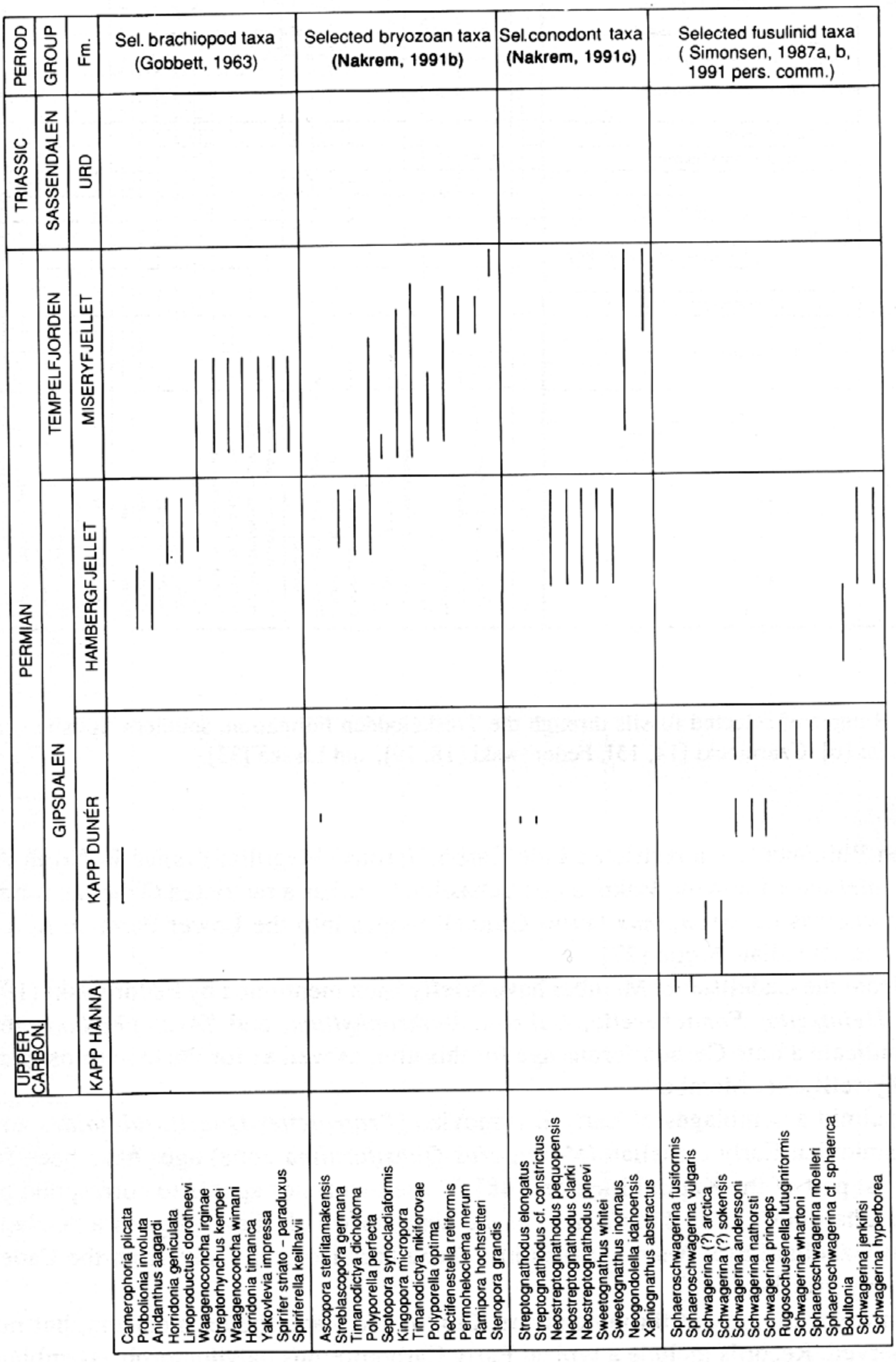

FIGURE 9. Ranges of selected fossils through the Permian of Bjørnøya.

by Playford [52, 53]. They are therefore considered to be reworked. Sphaeromorph acritarchs are recorded in association with these spores but are believed to be indigenous.

Ruitang [60] reported the presence of a trilobite, *Ditomopyge convexa* Ruitang, from Ny Friesland, but the biostratigraphical relevance of this species is not documented.

Tyrrellfjellet Member (Asselian-Sakmarian). The base of this member is often marked by a sandstone and/or an intraformational conglomerate [13]. From 5 to 15 m above the base, the conspicuous Brucebyen Beds appear as bituminous limestones with abundant fusulinids. Paleoaplysinid bioherms are developed in the lower part of this member [67]. The uppermost part of the Tyrrellfjellet Member ("Limestone B" [23]) is characterized by several fining upwards sequences with carbonates, sandstones with plant debris, and an increasing gypsum content.

Brachiopods are common throughout the carbonates of the Tyrrellfjellet Member, and distinct ecologically controlled brachiopod assemblages have been reported [66]. *Rhynchopora wynni* (Waagen), *Choristites* cf. *supramosquensis* Nikitin, and *Dictyoclostus* cf. *americus* Dunbar and Condra are representatives exclusively below the Brucebyen Beds; all have a Late Carboniferous to Early Permian affinity. Few species have a restricted range in the upper part ("Limestone B"): *Antiquatonica* cf. *serenensis* Sarycheva, *Cancrinella cancriniformis* (Chernyshev), and *Martinia semiglobosa* Chernyshev. The two latter have a limited distribution in the Asselian-?Sakmarian "Schwagerina Limestone" of the Urals [11], while the former occurs in the Middle Carboniferous. *Juresania juresanensis* (Chernyshev) ranging through the entire Tyrrellfjellet Member has an Asselian (Indiga Beds) distribution in Timan [4, 11] and Novaya Zemlya [28]. The "Cancrinella Limestone" fauna [8] is a lateral equivalent to the upper part of the Tyrrellfjellet Member and seems to be a link between the latter unit and the Treskelodden Formation (see below).

Bryozoans occurring in the Tyrrellfjellet Member are generally of Asselian through Artinskian age. The faunas are most similar to those described from the Lower Permian of the Urals and Timan-Pechora [39]. *Coscinium cyclops* Keyserling, *Goniocladia tenuis* Shul'ga-Nesterenko, *Ramiporidra minuta* (Shul'ga-Nesterenko), *Rhombotrypella invulgata* Trizna, *Ascopora sterlitamakensis* Nikiforova, as well as abundant fenestrellids co-occur in the above regions. Their precise biostratigraphic significance is, however, not yet fully resolved.

Conodonts have been examined from throughout the Tyrrellfjellet Member. The lower part, including the Brucebyen Beds, contains *Streptognathodus elongatus* Gunnell and *Cavusgnathus lautus* Gunnell. These species have a Late Carboniferous through Asselian-Sakmarian distribution in North America [55], the Sverdrup Basin [27], and the Urals [40]. The occurrence of *S.* cf. *barskovi* Kozur in these beds may, however, indicate a more precise Middle Asselian age.

The upper part of this unit ("Limestone B") contains *Sweetognathus inornatus* Ritter and *Hindeodus minutus* (Ellison). *Sweetognathus* is characteristic of the Artinskian in the Sverdrup Basin [27] and in the Urals [40], whereas *S. inornatus* Ritter has a late Sakmarian-Artinskian range in North America [55].

Abundant corals are present at several distinct horizons within the Tyrrellfjellet Member. *Kleopatrina, Stylastrea, Thysanophyllum, Protowentzelella* and *Protolonsdaleiastrea* are common above the Brucebyen Beds. These faunas are indicative of a late Asselian to Sakmarian age [21]. A fauna of Artinskian age including the same taxa mentioned above, with the addition of *Clisiophyllum*? and, is recorded in the Canadian Arctic [58].

The Tyrrellfjellet Member on the Nordfjorden High comprises three fusulinid assemblages [48]. The two lower *Schwagerina*(?) *arctica* and *S. princeps* zones correspond to Cutbill and Challinor's *Schwagerina anderssoni* zone [13], and the upper *Eoparafusulina paralinearis* to their *Monodiexodina* zone. The *Schwagerina*(?) *arctica* zone in the lower part of this formation, including the Brucebyen Beds, is characterized by *S.*(?) *arctica* (Schellwien), *S.*(?) *pseudoarctica* (Rauser-Chernousova), *Schwagerina anderssoni* (Schellwien), *Sphaeroschwagerina*(?) sp. A.,

and *Quasifusulina compacta* (Lee). This assemblage indicates an Early Asselian age. The overlying *Schwagerina princeps* zone occurs in the middle part of the member. In addition to *S. princeps* (Ehrenberg) this assemblage includes *S. paramoelleri* (Rauser-Chernousova), *S. nathorsti* (Schellwien), *S. schwageriniformis* (Rauser-Chernousova), *Sphaeroschwagerina* sp. B., and *Rugosochusenella lutuginiformis* (Rauser-Chernousova). These faunas are similar to Middle-Late Asselian faunas of the Timan-Pechora Basin [25]. The appearance of *Eoparafusulina paralinearis* (Thorsteinsson) in the upper part of the member (although not in the uppermost part) indicates a younger age than the underlying *S. princeps* assemblage. *E. paralinearis* (Thorsteinsson) occurs together with *Schwagerina* ex. gr. *uralica* (Rauser-Chernousova), which is present in the Sakmarian of the Timan-Pechora Basin [25].

Palynomorphs in the Tyrrellfjellet Member are completely dominated by the distinct Permian palynomorph group *Vittatina*, together with the bisaccate pollen group *Protohaploxypinus*. Different species are present, including *Vittatina striata* Luber (Jansonius, 1962), *V. simplex* Jansonius, 1962, *V. subsaccata* Samoilovich, 1953, and *V. saccifer* Jansonius, 1962. In the upper parts of this member, monosaccate pollen, including *Nuskoisporites dulhuntii* Potonié and Klaus, 1954 and *Potoniesporites novicus* Bharadwaj, 1954 appear. *Hamiapollenites bullae-formis* (Samoilovich) Jansonius, 1962 and *Hamiapollenites tractiferinus* (Samoilovich) Jansonius, 1962, also make up a characteristic part of this assemblage. The assemblage recorded in the upper part of this member is similar to the Sakmarian-Artinskian assemblages recorded in the Sverdrup Basin [79, 80].

Treskelodden Formation (Gzhelian-Artinskian)

The Treskelodden Formation ("Treskelodden Beds" [6]) is approximately 170 m thick in its type area in inner Hornsund and consists mainly of conglomerates and sandstones with interbedded fossiliferous limestones in the upper parts. The Drevbreen Beds [49] are included in the Treskelodden Formation in this work, based on the similarities and lateral equivalence of these lithological units. Ranges of diagnostic fossils are shown in Figure 8.

In a large monograph on the brachiopods of the Treskelodden Formation Czarniecki [15] discussed their biostratigraphical value in the Gipsdalen Group. There is some faunal similarity between the upper part of the Tyrrellfjellet Member and the Treskelodden Formation, with *Juresania juresanensis* (Chernyshev), *Cancrinella singletoni* Gobbett, *Paeckelmannia forbesi* Gobbett, and *Linoproductus dorotheevi* (Fredericks) occurring in both units. *Aulosteges uralicus* Kulikov is a typical Sakmarian species, whereas several other taxa in Czarniecki's collection have a Late Carboniferous affinity. Czarniecki concluded with a correlation with the "Schwagerina Zone" of the Urals for the Treskelodden Formation, which he considered to be of Late Carboniferous age. The Uralian "Schwagerina Beds" in question are, however, included in the Permian Asselian stage by most workers.

A single occurrence of a bryozoan (*Archimedes* aff. *magnus* Condra and Elias) has been reported from this unit [14]. The genus *Archimedes* is most common through the Carboniferous elsewhere but is known to range into the earliest Artinskian. The conodont species *Cavusgnathus* cf. *lautus* Gunnell, of Carboniferous-Early Permian affinity (see above), was isolated from the coral limestones of the Treskelodden Formation.

The coral faunas of the Treskelodden Formation are well known from the works of Fedorowski [18-21] and Birkenmajer and Fedorowski [7]. Of special interest are species of *Thysanophyllum* and *Protowentzelella*, very similar to other Early Permian rugose corals from adjacent Arctic locations. Although a detailed zonation based on the rich coral faunas has not yet been presented for Spitsbergen, the corals suggest Artinskian affinities for the upper part of this unit.

Fusulinid-rich beds have been observed in the lower part of the Treskelodden Formation, i.e., the Drevbreen Beds [49]. No taxa were reported, but the recognized fauna is of Gzhelian to Asselian age, according to Lys [49].

Foraminifera have been found in the three higher Coral Horizons of the Treskelodden Formation [33]. The fauna contains no age diagnostic forms, but taken as a whole the assemblage resembles the faunas of the Artinskian stage.

Two trilobite species, *Paladin (Paladin) trigonopyge* Osmólska and *Ditomopyge spitsbergensis* (Osmólska) have been described from the upper part of the Treskelodden Formation [51], but their biostratigraphic value is uncertain.

Reinodden Formation (?Asselian-?Artinskian)

The Reinodden Formation crops out from Reinodden (south of Bellsund) and southwards to Kopernikusfjellet, is 200 m thick in its type area, and contains reddish conglomerates and sandstones with overlying limestones. The unit probably passes laterally into the Tyrrellfjellet Member (northwards) and the Treskelodden Formation (southwards).

Detailed biostratigraphic work has not been done, but based on local lithostratigraphic similarities (see above), the age of the formation is possibly Asselian (similar to the Tyrrellfjellet Member) to ?Artinskian (top Treskelodden Formation age).

Gipshuken Formation (?Sakmarian-Artinskian)

The Gipshuken Formation, 211 m thick at its type section on the southwestern ridge of Cowantoppen, reaches its maximum thickness (350 m) in the St. Jonsfjorden and Billefjorden troughs. The lower part of this formation consists of interbedded evaporites and dolomites, while breccias occur in some areas as lateral equivalents to evaporites [32]. In the upper part, more open marine to supratidal carbonates prevail, with evidence of subaerial exposure (caliche) [30]. The restricted depositional environment hosted a fauna of rare molluscs and brachiopods, while the upper parts in eastern areas yielded a richer marine fauna, including bryozoans, brachiopods, foraminifera, and molluscs (H. B. Keilen, pers. comm., 1991). The paleontology of these units has not yet been studied in any detail.

Brachiopods are poorly represented in the Gipshuken Formation; Gobbett [24] reported *Cancrinella spitsbergiana* Gobbett, *Cancrinella singletoni* Gobbett, *Linoproductus konincki* de Verneuil, *Linoproductus dorotheevi* (Fredericks), and *Linoproductus cora* (d'Orbigny) from this unit. This faunule has an Asselian-Artinskian affinity, but the individual species range both down into the Tyrrellfjellet Member, as well as up into the overlying Vøringen Member (Kapp Starostin Formation).

Bryozoans are represented by the Early Permian species *Polypora martis* Fisher, as well as some indeterminable fenestellids.

A single occurrence of the conodont *Neostreptognathodus* cf. *pequopensis* Behnken is recorded from the upper part of the Gipshuken Formation. Based on the range of *Neostreptognathodus*, an Artinskian-Kungurian age can be suggested for this part of the unit.

In the upper part of this unit foraminifera including *Frondicularia multicamerata* Zolotova, *F. dilemma* Gerke and *Nodosaria netschajewi* Cherdyntsev, considered to be of Artinskian age (Sosipatrova, 1967), are recorded. Long-ranging fusulinids, such as *Schubertella transitoria* Staff and Wedekind, *S. kingi* Dunbar and Skinner and *Pseudoendothyra preobrajenskyi* (Dutkevich) are also present in this assemblage.

Palynomorphs seem to be most frequent in the lowermost parts of the Gipshuken Formation,

where the assemblage recorded is similar to the assemblage recorded from the upper parts of the Tyrrellfjellet Member (see above). *Protohaploxypinus* and *Vittatina* dominate throughout the Gipshuken Formation, while monosaccate pollen seem to be less frequent and less diverse in the upper parts. The assemblage recorded in the lower part indicates a Sakmarian to Artinskian age based on correlation with the Sverdrup Basin (Mangerud and Konieczny, 1991).

Kapp Starostin Formation (Artinskian-?Kazanian)

The Kapp Starostin Formation is 381 m thick at its type section at Festningen, reaching 459 m farther north in the St. Jonsfjorden Trough, and thins to 5-6 m both north and south of Hornsund on the margins of the Hornsund-Sørkapp High. The formation is currently subdivided into the Vøringen, Svenskegga, and Hovtinden members, but as work is in progress to redefine the upper units (H. B. Keilen, pers. comm.), we have chosen to treat the faunas of the upper members as a single unit in the following faunal descriptions.

Vøringen Member (Late Artinskian-Kungurian). The Vøringen Member is 22 m thick at Festningen, with a maximum thickness of 39 m farther east. This unit consists of light-colored bioclastic limestones with rich brachiopod and bryozoan faunas.

The rich brachiopod faunas in the Vøringen Member (hence the unit's previous name "Spirifer Limestone") show a wide stratigraphic affinity. These faunas have a distinct Early Permian affinity as compared with faunas from the Canadian Arctic and eastern North Greenland. Typical Early Permian species include *Chaoiella neoinflata* (Licharew), *Cleiothyridina royssiana* (Keyserling), *Horridonia timanica* (Stuckenberg), and *Yakovlevia impressa* (Toula). In these faunas there are also several specimens in common with the Late Permian faunas of Novaya Zemlya and central East Greenland (e.g., *Spirifer striato-paradoxus* Toula, *Waagenoconcha payeri* Toula, and *Cancrinella cancrini* (Verneuil)). The *Horridonia timanica* Zone [42] spanning the Vøringen Member is believed to indicate a latest Early Permian or earliest Late Permian age for this unit, coeval with similar faunas in North Greenland [70]

Bryozoans occur in large numbers through the Vøringen Member. Biostratigraphically important species include *Tabulipora greenlandensis* Ross and Ross, *Rhombotrypella arbuscula* Trizna, *Streblascopora germana* Bassler, *Polyporella subcrotilla* (Trizna), and *P. borealis* (Stuckenberg). This fauna has elements similar to assemblages reported from the Kungurian of Timan-Pechora and the Artinskian reefs of the Urals [39] and the Mallemuk Mountain Group of eastern North Greenland [59].

Conodonts occur in fairly large numbers through the Vøringen Member. Szaniawski and Malkowski [74] described *Neostreptognathodus svalbardensis* from this unit, but some of their figured specimens of *Neostreptognathodus* are placed in synonomy with *N. pequopensis* Behnken, *N. clarki* Kozur, and *N. ?ruzhencevi* Kozur [46, 50]. Specimens figured as *Sweetognathus* sp. [74] are considered herein to be of *Sweetognathus whitei* (Rhodes). Taking the mentioned reassignments into consideration, this conodont fauna contains members of conodont zones P7-P9 of the Sverdrup Basin [5], also reported from North America [55] and the Urals (zones 9-11 [40]), indicative of a Baigendzhinian (Late Artinskian) to earliest Kungurian age.

A foraminifer assemblage with *Nodosaria longa* Morozova was identified in the Vøringen Member [68] considered to be of Early Kungurian age (Phillippovsky horizon) as compared with the zonation of Northern Timan [25] and the Urals [54]. Fusulinids are not recorded in these sediments.

The base of the Vøringen Member is characterized by the appearance of abundant spores including *Kraeuselisporites apiculatus* Jansonius, 1962 and *K. punctatus* Jansonius, 1962 and the bisaccate pollen *Protohaploxypinus chaloneri* Clarke, 1965 and *P. limpidus* (Balme and

Hennelly) Balme and Playford, 1968. Slightly higher in the unit, the distinct bisaccate pollen *Lueckisporites virkkiae* (Potonié and Klaus) Clarke, 1965 occurs. This species is regarded as a Late Permian marker and is also recorded in the Upper Permian succession on East Greenland [2] and in Barents Sea wells (Mangerud, unpubl. data).

Svenskegga and Hovtinden members (Kungurian-?Kazanian). The upper two members of the Kapp Starostin Formation, the Svenskegga and Hovtinden members [13], are here discussed as a single unit, but the original intermember boundary is pointed out in Figure 2. The brachiopod faunas described from the "Selander Suite" [76, 77] are included in the description of the upper part. The lithology of these units consists of spiculitic shales, partly silicified limestones, and glauconitic sandstones.

Brachiopods reached their acme in the Kapp Starostin Formation above the Vøringen Member, hence the previous name "Brachiopod Cherts" for this unit. Almost 60 species have been recorded in various publications, and attempts have been made to utilize their biostratigraphical value. The most recent scheme was presented by Nakamura et al. [42], who defined several brachiopod zones. This work was to a large extent based on the "zonation" of brachiopods through the Upper Permian of East Greenland; however, as stated by Dunbar [16] and commented on by Stemmerik [70], the distribution of brachiopods in East Greenland represents lateral facies variations and does not represent units of different ages. Occurring in the Kapp Starostin Formation, *Cleiothyridina pectinifera* (d'Orbigny), *Spiriferellina cristata* (Schlotheim), and *Pterospirifer alatus* (Schlotheim) are the only species in common with the Zechstein faunas of Great Britain, whereas more than 20 species are in common with the East Greenland faunas. The brachiopods recorded in East Greenland (Wegener Halvo Formation) are of Ufimian-Kazanian age [72], an age that is also applicable to the youngest Kapp Starostin faunas. Similar faunas are also recorded from other Arctic localities, e.g., the Tahkandit Limestone of east-central Alaska: *Lissochonetes spitzbergiana* (Toula), *Pterospirifer alatus* (Schlotheim), and *Spiriferella draschei* (Toula) [9]; the Assistance Formation of Ellesmere Island: *Timaniella harkeri* Waterhouse, *Lingula freboldi* Gobbett, and *Orbiculoidea winsnesi* Gobbett [75]; and Kazanian deposits of Novaya Zemlya with *Lingula freboldi* Gobbett [78].

Brachiopods from the upper part of the Kapp Starostin Formation suggest an Ufimian ("Pay Khoy Super Group") [77] to a Kazanian age [42]. The uppermost, locally developed glauconitic sandstones contain brachiopods resembling a "Novozemelsk" fauna of Kazanian age [77, 78] but are devoid of other fossils.

Bryozoans are widespread throughout this unit, especially in the limestone horizons but also in the spiculitic shales. There is, however, a barren interval up to approximately 60 m above the Vøringen Member. There seems to be little diagnostic change in the development of the bryozoan faunas throughout the upper part of the Kapp Starostin Formation. Typically Ufimian forms appear in the lower parts of this unit (*Ramipora hochstetteri* Toula, *Permoheloclema merum* Ozhgibesov, and *Timanodictya nikiforovae* Morozova), but these forms extend abundantly upwards. In the uppermost part there are some Kazanian species: *Stenopora timanensis* Morozova, *Dyscritella parallela* Morozova, *Polypora kossjensis* Ravikovich, and *Polypora* cf. *commutabilis* Morozova. Almost 30 bryozoan species occur in this unit [45]. An Ufimian age was assigned to the lower part of the "Starostinsk Group" based on similarities to faunas from Novaya Zemlya and the Canadian Arctic [39]. The presence of Kazanian species suggests, however, a younger age for the upper part of the Kapp Starostin Formation.

Conodonts have been extracted from a carbonate horizon high in this unit. A fauna comprising *Neogondolella idahoensis* (Youngquist, Hawley and Miller) and *Merrillina* sp. was recorded by Szaniawski and Malkowski [74] from some localities, dating this horizon within the upper part of the Kapp Starostin as latest Early Permian or earliest Late Permian if compared with the

Sverdrup Basin; Zone P11 from the lower part of the Assistance Formation [5]. In North America, *Neogondolella idahoensis* (Youngquist, Hawley and Miller) ranges through the upper Leonardian (Early Permian), whereas *N.* aff. *idahoensis* (Youngquist, Hawley and Miller) is reported from the Late Permian Zechstein of northern Great Britain [73]. Samples collected above this level were barren; thus the uppermost part of the Kapp Starostin Formation lacks conodont data.

Two foraminifer assemblages have been identified in the middle and upper parts of the Kapp Starostin Formation [68]. The lower *Gerkeina komiensis* assemblage is dominated by a Late Kungurian (Irensky horizon) fauna. The upper *Frondicularia bajcurica* assemblage includes both Early and Late Permian species, but the sharp influx of Late Permian elements indicates an Ufimian age for these deposits, when compared with the Urals succession [68].

Palynomorphs recorded in the basal Svenskegga Member are characterized by abundant acritarchs belonging to *Micrhystridium, Veryhachium*, and *Unellium*. Through the Svenskegga and Hovtinden members, acritarchs dominate together with striate, bisaccate pollen, and *Vittatina*. In general, the assemblage recorded is characterized by abundant striate pollen and consistent appearance of *Lueckisporites virkkiae* (Potonié and Klaus) Clarke 1965. A similar assemblage with high proportions of acritarchs is also recorded in the middle and upper parts of the Trold Fjord Formation in the Sverdrup Basin, in beds of Kazanian age based on conodonts [80].

A local occurrence of a trilobite fauna has been reported [31], but the stratigraphic range of the described species, *Neoproetus borealis* Kobayashi, is unknown. Additional trilobites from the Hovtinden Member are currently being described (D. L. Bruton, pers. comm., 1991).

Tokrossøya Formation (?Kungurian-?Kazanian)

This unit was originally defined by Siedlecki [64], then redefined by Siedlecki [35] and also commented on by Siedlecka [63]. The first definition distinguished between a "lower" and an "upper" unit which turned out to be inverted, and Siedlecka [63] redescribed these as the "Lower Tokrossøya beds" (oldest) of "impure, dark, carbonaceous and cherty rocks with a poor fauna," and the "Upper Tokrossøya Beds," with a richer fauna [35, 64, 43] in sandstones, siltstones, and cherty biocalcarenites. Total thickness is >425 m; neither the base nor the top of the unit is exposed. This unit occurs only on the small islands southwest of the southernmost point of Spitsbergen, i.e., southwest of the Sørkapp Hornsund High (Fig. 4). Brachiopods [64] are rare in the lower part of this formation, with the presence of *Horridonia* cf. *horrida* (Sowerby), whereas the upper part contains *Spirifer striatoparadoxus* Toula and *Spiriferella keilhavii* (von Buch).

Some horizons contain abundant bryozoans [35, 36], with the presence of *Dyscritella dickensi* (Ross), *D. bogatensis* Morozova and *?Tabulipora* cf. *gigantea* (Ross).

Other faunal elements from this formation remain undescribed, but the brachiopods and bryozoans are similar to those recorded in the Svenskegga and Hovtinden members of the Kapp Starostin Formation elsewhere.

Lithological Units and Biostratigraphy, Nordaustlandet

Very little detailed biostratigraphical information is available from Nordaustlandet, and only correlations based on conodonts and palynomorphs will be discussed below.

Nordenskiölbreen Formation (Moscovian-?Artinskian)

The Nordenskiölbreen Formation, 150 m thick on Nordaustlandet, is divided into the lower

Harbardbreen Member (Moscovian age) (15 m) and the upper Idunfjellet Member of Moscovian-?Artinskian age (134 m) [32]. Middle Carboniferous fusulinids are known from the Harbardbreen Formation [32]; new data from the upper part of the Idunfjellet Member will be discussed below.

The base of the Idunfjellet Member, of Late Moscovian-?Artinskian age, is defined by the first occurrence of carbonates in the sedimentary succession on Nordaustlandet. The lithology consists mostly of dolomitic carbonates, and some partly silicified limestones [32]. Palynomorphs occur in the upper parts of the Idunfjellet Member, comprising a well-preserved assemblage dominated by *Protohaploxypinus* and *Vittatina*, and together with characteristic monosaccate pollen. The assemblage contains *Hamiapollenites tractiferinus* (Samoilovich) Jansonius and is correlated with the *Weylandites striatus-Protohaploxypinus perfectus* assemblage zone in the Sverdrup Basin [37]. The assemblage resembles those recorded in the upper part of the Nordenskiölbreen and lower part of the Gipshuken Formation on Spitsbergen of Sakmarian-Artinskian age (see above).

Gipshuken Formation (?Sakmarian-Artinskian)

The Gipshuken Formation (121 m) is here mainly developed as carbonates. A lower Zeipelodden Member (8 m) was defined as comprising limestone breccias [32].

Palynomorphs are present throughout this unit, and as on Spitsbergen (see discussion above) the assemblage recorded in the lower parts is similar to the one recorded in the upper part of the Nordenskiölbreen Formation [37] of ?Sakmarian to Artinskian age.

Kapp Starostin Formation (Kungurian-?Kazanian)

The Kapp Starostin Formation (141 m) is divided into the basal Vøringen Member (9 m) and the Palanderbukta Member (17.5 m), a limestone unit 46.5 m above the base of this formation [32]. Lithologies include sandy carbonates and silicified shales (cherts); rich but undescribed brachiopod and bryozoan faunas are known. Data from the Palanderbukta and Vøringen members are discussed below.

Vøringen Member (Kungurian). Palynomorphs are recorded in the basal beds, comprising an assemblage completely dominated by acritarchs assigned to the genus *Micrhystridium*. Several spore genera not recorded below, appear at the same level, including *Kraeuselisporites, Granulatisporites trisinus* Balme and Hennelly, *Lophotriletes, Cyclogramisporites* and *Neoraistrickia cornutus* (Andreyeva) Hart. The assemblage characteristics are very similar to the assemblages recorded in the Kapp Starostin Formation on Spitsbergen. A similar assemblage with high proportion of acritarchs are also noted in Wordian (Ufimian) beds in the Sverdrup Basin [81].

Palanderbukta Member (Ufimian). Conodonts recorded from this member (for example *Neogondolella idahoensis* (Youngquist, Hawley and Miller) are of latest Early Permian to earliest Late Permian age (see discussion above).

Lithologic Units and Biostratigraphy, Bjørnøya

The distribution and revised age of lithological units are shown in Figure 3, and a brief description of each unit follows below.

Kapp Hanna Formation (Late Moscovian-Early Asselian)

The Kapp Hanna Formation (150 m) consists of sandstones, conglomerates, and dolomitic carbonates. Apart from several fusulinids, few fossils have been reported from this unit [85].

The lowermost part of this formation includes fusulinids of Late Moscovian age (B. T. Simonsen, pers. comm., 1991). The uppermost beds contain *Sphaeroschwagerina vulgaris* (Sherbovich) and *S. fusiformis* (Krotow), which indicate an Early Asselian age. Fusulinids of Gzhelian age have not yet been found on Bjørnøya [65].

Palynomorphs are recorded in the uppermost part and are dominated by *Vittatina* and *Weylandiella*. An Early Asselian age is suggested based on correlation with standard European miospore zones [82].

Kapp Dunér Formation (Asselian)

The lower part of this unit is dominated by dolomitized palaeoaplysinid buildups [34] interbedded with limestones rich in fusulinids; the upper part is dominated by fusulinid-rich limestones and dolomitized mudstones. The composite maximum thickness is close to 80 m, with a fauna of fusulinids, large coral colonies, and rare bryozoan thickets.

Brachiopods are not abundant in the Kapp Dunér Formation. The only published record is *Camerophoria plicata* Kutorga [29], which was originally described from the Asselian "Schwagerina Horizon" [11].

Bryozoans are rare in the Kapp Dunér Formation, except for a single horizon with abundant specimens of *Ascopora sterlitamakensis* Nikiforova. This species is well known from the Sakmarian of Timan-Pechora and the Urals [47].

A small conodont faunule in the middle part of the Kapp Dunér Formation has yielded specimens of *Streptognathodus elongatus* Gunnel and *Streptognathodus* cf. *constrictus* Chernykh and Reshetkova. The former species has a fairly long range through the Late Carboniferous-Early Permian, whereas *Streptognathodus constrictus* Chernykh and Reshetkova is restricted to the Middle Asselian in the Sverdrup Basin (Zone P3 [5]) and in the Urals [10].

A colonial rugose coral fauna suggests an Asselian age for this formation [21].

The Kapp Dunér Formation comprises three fusulinid faunas [65]. The lower *Schwagerina*(?) *arctica-S. sokensis* assemblage is not older than Early Asselian, based on the occurrence of *Sphaeroschwagerina* stratigraphically below (in the Kapp Hanna Formation). The *Schwagerina anderssoni-S. nathorsti* assemblage in the middle part of the formation includes species as *Rugosochusenella paragregaria* (Rauser-Chernousova), *R. lutuginiformis* (Rauser-Chernousova), *Schwagerina anderssoni* (Schellwien), *S. nathorsti* (Schellwien), *S. subnathorsti* (Lee), *S. princeps* (Ehrenberg), *Sphaeroschwagerina* cf. *pavlovi* (Rauser-Chernousova), and *S. moelleri* (Schellwien). The age of this zone is Middle-Late Asselian. The upper part of the formation is also characterized by a fauna of Middle to Late Asselian age (*Sphaeroschwagerina moelleri-Schwagerina warthoni* assemblage) [65].

Badly preserved palynomorphs with mostly long ranging Permian species (*Vittatina*, saccate pollen) are recorded [82]. This assemblage is similar to that recorded from the upper part of the Nordenskiölbreen Formation and the lower parts of the Gipshuken Formation on Nordaustlandet and Spitsbergen.

Hambergfjellet Formation (?Sakmarian-Artinskian)

This formation consists of a basal yellowish dolomite with *Microcodium*, otherwise devoid of fauna. The middle part consists of grayish calcareous sandstone, and an upper reddish medium-bedded limestone with shaly and sandy partings; it has a maximum thickness of 50 m. Colonial corals are preserved in the middle unit, while the upper part has a more diverse fauna, with brachiopods, bryozoans, and fusulinids. Both lower and upper boundaries of the unit are unconformable.

Brachiopods occur in fairly high numbers in this unit, hence the previous name "Cora Limestone." A common species is *Linoproductus dorotheevi* (Fredericks), which was originally described as *Productus cora* [1]. Gobbett assigned the brachiopod faunas to the Sakmarian, after comparing them with similar faunas from Spitsbergen [24]. The fauna contains, however, several incompletely described taxa: *Chaoiella* cf. *gruenewaldti* (Krotow), *Spiriferella* cf. *saranae* (Verneuil), and *Neophricadothyris asiatica* (Chao), and these brachiopods require further study. The brachiopods have, however, a Sakmarian-Artinskian affinity, compared with those from parts of Canada [3].

A limited number of bryozoan taxa in this unit allow correlation with the Artinskian of Ellesmere Island, and the Sakmarian-Kungurian of Timan-Pechora and the Urals [39]. Typical Artinskian species include *Timanodictya dichotoma* (Stuckenberg), *Polyporella orientalis* (Eichwald), and *Polyporella perfecta* Kruchinina, whereas *Dyscritella narjanmarica* Kruchinina and *Streblascopora germana* (Bassler) occur in the Kungurian of Timan-Pechora, and in the Vøringen Member of Spitsbergen.

The upper calcareous part of the Hambergfjellet Formation has yielded rich conodont faunas [46], with a dominance of *Neostreptognathodus clarki* Kozur, *N. pequopensis* Behnken, *N. pnevi* Kozur and Movshovich, *Sweetognathus whitei* (Rhodes), and *Sweetognathus inornatus* Ritter. Compared with the Sverdrup Basin [5], North America [55], and the Urals [40], these species indicate a distinct Late Artinskian age for the upper part of this unit.

Corals from the middle part of the Hambergfjellet Formation have been described [21]. Typical genera are *Kleopatrina, Stylastrea, Thysanophyllum, Protowentzelella*, and *Protolonsdaleiastrea*, indicative of a Late Asselian to Sakmarian age [21].

A fusulinid assemblage in the middle part with species of *Boultonia* have been observed (B. T. Simonsen, pers. comm., 1991), of Late Asselian to Artinskian affinity. A fauna characterized by *Schwagerina jenkinsi* Thorsteinsson and *S. hyperborea* (Salter) is present in the upper calcareous part of the Hambergfjellet Formation [66], and this fauna corresponds well to Early-Middle Artinskian faunas of Arctic Canada [56, 57, 76].

Badly preserved palynomorphs comprising an assemblage similar to the one recorded from the Kapp Dunér Formation have been reported [82], but the flora contained no age-diagnostic species.

Miseryfjellet Formation (Kungurian-?Kazanian)

This unit unconformably overlies the Hambergfjellet Formation and is itself overlain disconformably by Triassic shales. The thickness is approximately 115 m, with basal sands and conglomerates grading into yellowish sandy, partially silicified limestones. A sandstone unit up to 20 m thick occurs in the middle part of the formation. The top of this formation is marked by a reddish, partly phosphatic limestone unit.

Brachiopods have been described from only the lowermost 20 m of the Miseryfjellet Formation [24], although present throughout the entire formation. The occurrence of *Waagenoconcha wimani* (Fredericks), *Horridonia timanica* (Stuckenberg), *Waagenoconcha irginae* (Stuckenberg), *Waagenoconcha wimani* (Fredericks), and *Yakovlevia impressa* (Toula) resembles the mixed fauna of the Vøringen Member and the upper part of the Kapp Starostin Formation on Spitsbergen. Compared with faunas from adjacent regions, the brachiopods of the Miseryfjellet Formation show a complete mixture of Early and Late Permian forms.

With almost 40 species present, the bryozoans constitute an important element of the fauna throughout this unit. The species composition reveals a succession from Early to Late Permian forms, but the mixing of certain species makes it difficult to construct a distinct zonation. In the lower part there are few typical Early Permian forms: e.g., *Kingopora micropora* (Stuckenberg)

and *Rectifenestella lunaris* (Shul'ga-Nesterenko) but also taxa known from the Zechstein Basin, e.g., *Rectifenestella retiformis* (Schlotheim) and from the Kazanian of the Soviet Union [38], e.g., *Polypora barabashensis* Morozova, *Reteporidra atarensis* Morozova, and *Stenopora grandis* Morozova. There are faunal similarities with the Assistance Formation (latest Early Permian-earliest Late Permian) of Ellesmere Island, and the Kazanian deposits of Novaya Zemlya [39]. The upper part of the Miseryfjellet Formation has a distinct fauna similar to the upper part of the Kapp Starostin Formation of Spitsbergen [45].

Small foraminifera have been found in conodont samples but are, as yet, undescribed.

Apart from the lowermost conglomeratic horizon, conodonts are present throughout most of this unit. The species composition is uniform, with *Neogondolella idahoensis* (Youngquist, Hawley and Miller) and *Xaniognathus abstractus* (Clark and Ethington) and a single occurrence of *Neogondolella* cf. *serrata* (Clark and Ethington) in a sample from high in the unit [46]. The age of this unit, based on the occurrence of *Neogondolella idahoensis* (Youngquist, Hawley and Miller), is latest Early Permian to earliest Late Permian; see discussion above (Kapp Starostin Formation). Furthermore, only the uppermost 7 m of the Miseryfjellet Formation is devoid of conodonts. With *Neogondolella idahoensis* (Youngquist, Hawley and Miller) ranging so high in this unit, it becomes inevitable that a significant part of the uppermost Permian is missing on Bjørnøya.

The palynomorphs recorded in the Miseryfjellet Formation are badly preserved [82] but are very similar to the assemblages recorded in the Kapp Starostin Formation on Nordaustlandet and Spitsbergen. The high proportion of acritarchs seems to be a feature that can be traced in Upper Permian beds here and also in the Sverdrup Basin [81].

Biostratigraphic Conclusions

The fossil groups recorded through the Permian succession on Svalbard suggest the need for revising the ages of the lithologic units (Figs. 2 and 3). In the following paragraphs, the significance of our new information is discussed, and relevant ages for the units mentioned on Spitsbergen and Bjørnøya are given.

Spitsbergen

The upper parts of the Cadellfjellet Member are characterized by conodonts and fusulinids of Late Carboniferous Gzhelian age; the Kapitol Member, on the other hand, lacks distinct Late Gzhelian fusulinid fauna. The palynomorphs recorded are badly preserved and include reworked Early Carboniferous spores. The brachiopod and bryozoan faunas are composed of long-ranging species of Late Carboniferous to Early Permian age which also occur in the overlying Tyrrellfjellet Member. We prefer a latest Carboniferous age for this interval.

The Carboniferous-Permian boundary on Spitsbergen is traditionally placed at a transgressive sandstone/conglomerate in the transition between the Kapitol/Cadellfjellet Member and the Tyrrellfjellet Member. The conglomerate, which occurs only rarely in the Billefjorden Trough, marks the initial phase of the Early Permian transgression after the minimum sea level/maximum regression around the Carboniferous/Permian transition.

In the uppermost parts of the Cadellfjellet Member, there are conodonts of latest Carboniferous (Gzhelian) age, whereas in the Kapitol Member, the uppermost fusulinid faunas are of Middle Kasimovian-Early Gzhelian age. A depositional break in the latter member is thus possible. In the lowermost part of the overlying Tyrrellfjellet Member, conodonts and fusulinids of earliest Asselian age are present.

It seems appropriate, based on current records of conodonts and fusulinids, to continue to

regard the transition between the Cadellfjellet/Kapitol and the Tyrrellfjellet members as representing the Carboniferous-Permian boundary on Spitsbergen.

The lower beds of the Tyrrellfjellet Member contain conodonts, fusulinids and palynomorphs of earliest Permian (Asselian) age, whereas brachiopod and coral faunas contain both Late Carboniferous and Early Permian elements. Based on fusulinids the Tyrrellfjellet Member can be divided into three assemblage zones of Early Asselian, Middle-Late Asselian, and Sakmarian ages. Conodonts and palynomorphs within the uppermost fusulinid zone suggest a Sakmarian to Artinskian age.

A similar palyno-assemblage occurs in the lower part of the overlying Gipshuken Formation. Conodonts in the upper part of this unit have an Artinskian-Kungurian affinity. Foraminifera, however, are of definite Artinskian age in this part of the succession. Brachiopods and bryozoans reported from these beds have an Early Permian affinity. With reference to units above and below, as well as the fossils discussed above, we conclude a Late Sakmarian to Late Artinskian age is most probable for the Gipshuken Formation.

Fusulinids in the lower part of the Treskelodden Formation are of Gzhelian to Asselian age, whereas foraminifera, corals, and conodonts from the upper part of the formation show Artinskian affinities. The brachiopods are similar to both those in the upper part of the Tyrrellfjellet Member and in the "Schwagerina Horizon" of Asselian to ?Sakmarian age in the Urals. We consider a latest Carboniferous to Early Permian (Gzhelian-Artinskian) age appropriate for the fossil-bearing beds of the Treskelodden Formation.

The basal beds of the Vøringen Member of the Kapp Starostin Formation contain rich brachiopod and bryozoan faunas of late Early Permian age. Conodonts and foraminifera are of more distinct Late Artinskian to Kungurian age, and we prefer such an age for this unit. In the upper part of the Kapp Starostin Formation, through the Svenskegga and Hovtinden members, Late Permian palynomorphs and brachiopods and bryozoans of Ufimian to Kazanian affinities are recorded, whereas a conodont fauna high in this unit is not younger than Ufimian. The topmost approximately 50 m in the type area is devoid of diagnostic fossils. We therefore suggest a Late Artinskian to Kazanian age for the entire Kapp Starostin Formation.

The Permian-Triassic boundary in Svalbard is traditionally placed between the Tempelfjorden and Sassendalen groups (Fig. 2), where there is a change from silicified shales and sands of Permian age to the softer Triassic shales. Fossil evidence is, however, lacking in the uppermost beds of the Tempelfjorden Group. Brachiopods, conodonts, bryozoans, and palynomorphs recorded in the uppermost part of the Kapp Starostin Formation suggest an Ufimian-Kazanian age, and no undisputable faunal evidence of latest Permian (Tatarian) rocks has been recorded. The amount of missing uppermost Permian sediment is therefore unknown. The presence of conformable lithological contacts between the Tempelfjorden and Sassendalen groups in some areas (A. Mørk pers. comm) may indicate a condensed Late Permian succession in western Spitsbergen, a feature also noted in the Sverdrup Basin [5]. The basal beds of the Sassendalen Group at Spitsbergen are dated as Early Griesbachian based on ammonoids (*Otoceras boreale* Spath), palynomorphs (e.g., *Proprisporites pococki* Jansonius, 1962), and conodonts (*Neogondolella carinata* (Clark)).

Bjørnøya

On Bjørnøya the Carboniferous-Permian transition is placed herein in the uppermost part of the Kapp Hanna Formation (Fig. 3). Traditionally this boundary was placed between the Kapp Hanna and Kapp Dunér formations, but new fusulinid- and palyno-elements in the uppermost part of the Kapp Hanna Formation contain distinct Asselian forms.

Conodonts and fusulinids of Asselian age are present throughout the Kapp Dunér Formation,

with close similarities to those in the Tyrrellfjellet Member on Spitsbergen. Furthermore, the Kapp Dunér Formation can be subdivided into Early Asselian and Middle to Late Asselian fusulinid zones. Brachiopods, bryozoans, and corals occur in low numbers in this unit, and the reported faunas have Asselian affinities. Palynomorphs contain mostly long-ranging Permian species, an assemblage resembling those recorded in the upper part of the Nordenskiölbreen and the lower part of the Gipshuken formations on Spitsbergen and Nordaustlandet. To conclude, the age of the Kapp Dunér Formation is Asselian based on the fossils discussed above.

Corals have been reported from the middle part of the Hambergfjellet Formation, and this fauna is of Late Asselian to Sakmarian age. The fusulinid assemblage in the middle part of the unit has a reported long Late Asselian to Artinskian range, while the assemblage in the upper part contains fusulinids of Early-Middle Artinskian age. The middle and upper parts of this unit contain brachiopods with Sakmarian to Artinskian affinities, which is in accord with the fusulinids that have been identified. Conodonts in the same beds indicate a definite Late Artinskian age. The palynomorphs in this part of the succession lack age diagnostic species. To conclude, when excluding data from long-ranging fusulinids, the lowermost fossil-bearing horizons of the Hambergfjellet Formation are probably of Sakmarian age, while the upper part is Artinskian.

Brachiopods, bryozoans, and palynomorphs in the Miseryfjellet Formation contain generally long-ranging taxa, with both Early (Artinskian) and Late Permian (Ufimian-Kazanian) affinities. Conodonts are of more diagnostic value in this unit, giving a latest Early to earliest Late Permian age. Undisputable latest Permian (Tatarian) fossils have not been recorded.

The youngest conodont species in the Permian of Bjørnøya, of Late Kungurian (Late Leonardian) to Early Ufimian age, has been recorded in a sample from 7 m below the contact between the Urd and Miseryfjellet formations. This implies that the uppermost 7 m may represent a younger condensed interval, or more likely, that there is a significant hiatus in the top of the Permian on Bjørnøya. On palynological evidence [41] the lowermost Triassic beds are Dienerian in age, and a hiatus spanning the latest Permian and Griesbachian is suggested.

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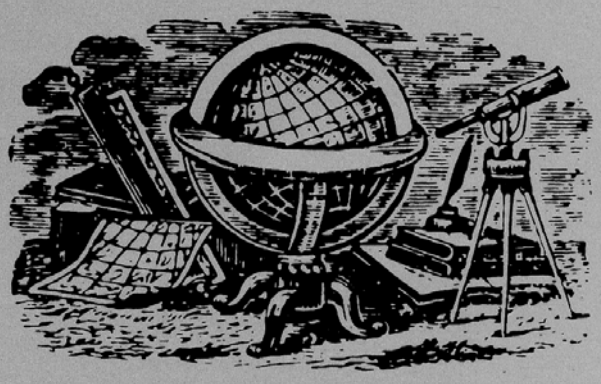

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