From: ***Bryozoan Studes 2001***, Wyse Jackson, Buttler & Spencer Jones (eds)

A Moscovian (Carboniferous) bryozoan buildup from Svalbard

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ABSTRACT: A mid-Carboniferous (pre-latest Moscovian) buildup in central Spitsbergen is composed almost entirely of fenestrate bryozoans (13 of 18 species, which contribute almost 100% of bryozoan biomass). Identified species are generally of early to late Carboniferous age, but some have been reported from Permian strata. Fenestrate sheets acted as sediment traps, and fenestrules are in varying degree closed off by initial marine cementation. Buildup development (sedimentation, diagenesis) is like that described from adjacent basins in Canada and eastern North Greenland, but in Spitsbergen the buildups are smaller (20 m thick, 200 m wide).

1 MATERIAL

The material studied was collected during fieldwork in 1992 at the Nordströmfjellet locality, central Spitsbergen, Svalbard (Fig. 1). Around 400 samples were collected and more than 200 thin sections have been investigated. Very few acetate peels could be made due to extensive dolomitisation of the rocks. Conodonts were processed from a crinoid limestone above the bryozoan buildup for dating purposes. Illustrated material is catalogued and housed at the Palaeontological Museum, University of Oslo (PMO).

2 GEOLOGICAL SETTING

In Late Carboniferous through Early Permian time Svalbard was situated in a sub-tropical position and drifted northwards from 25°N to 35°N. Deposition of dominantly carbonates took place under warm and humid, and later arid, conditions. The Minkinfjellet Formation (Fig. 2), of Moscovian age, consists mainly of thinly bedded dolomites, shales and gypsum beds.

The bryozoan buildups are developed in the uppermost part of the Minkinfjellet Formation in central Bünsow Land (Fig. 1), in what is tectonically known as the Billefjorden Trough.

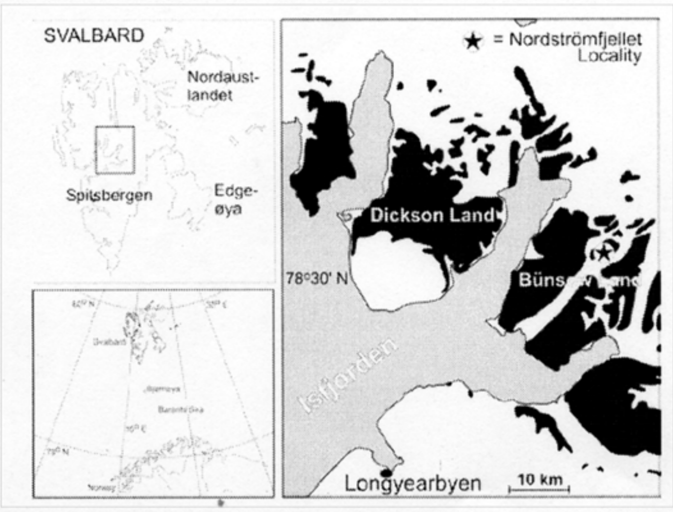

Figure 1. Locality map showing Svalbard's position in the Barents Sea and Carboniferous-Permian outcrops (black) in the investigated area.

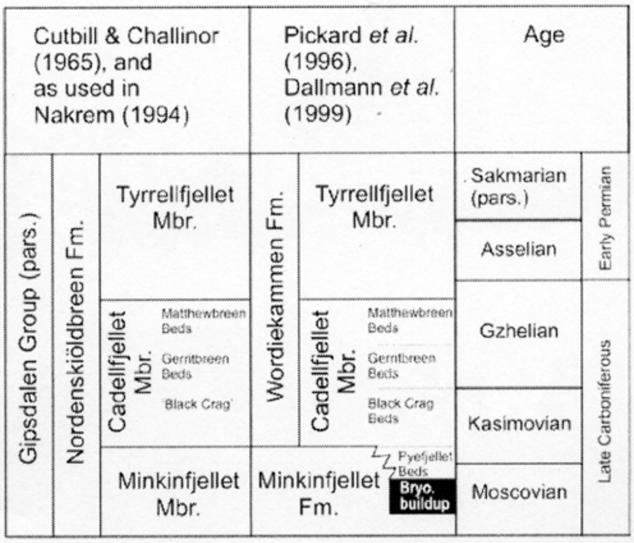

Figure 2. Lithostratigraphic units and corresponding ages in the investigated area.

3 BUILDUP DESCRIPTION

The buildup description is based on the material collected at Nordströmfjellet, as well as data in Pickard *et al.* (1994) and separate papers in Samuelsberg (2000) which cover buildups from Nordströmfjellet and Stenhousebreen.

The buildups are more than 20 m thick with a 200 m wide lateral development, and rest on dolostones with rare gypsum vugs which are generally devoid of bioclastic material. Core facies are composed mainly of a light grey, massive, fenestrate bryozoan wackestone that is commonly replaced by fabric-preserving dolomite. Locally fenestrate cementstone fabrics dominate, where initial porosity is replaced by pervasive calcite cement. Complex stromatactoid cavity systems are developed within the wackestones, and are often "roofed" by large fenestrate bryozoan sheets. This sediment trapping has resulted in visible macro-porosity in the rocks. Some cavities (now filled with sparry calcite) may have resulted from dissolved sponges, and spicules are commonly observed in thin sections. Sediment stabilisation was most probably a combination of marine cementation and binding algae (*Tubiphytes*).

Buildup flanks can occasionally be traced laterally. These flanks dip away from buildup cores (around 20°) and consist of coarse-grained crinoid-bryozoan grainstone and packstone. Intraclasts of fenestrate wackestone and crinoid particles are common in these detrital flank beds.

There is at least one palaeokarst surface near the top of the buildup indicating subaerial exposure (Fig. 3). The uppermost part of the buildup has also yielded phylloid algae in some thin sections, thus indicating that growth took place within the photic zone. The eroded top of the buildup is overlain by *c.* 15 m of barren dolostones marking the uppermost part of the Minkinfjellet Formation.

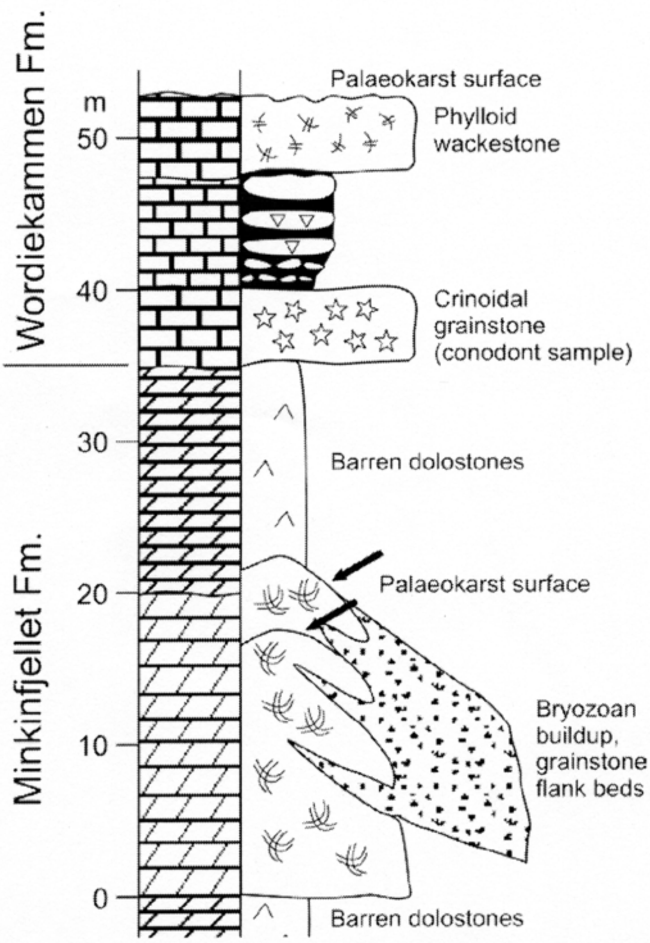

Figure 3. Lithological section through the Nordströmfjellet buildup. Arrows indicate palaeokarst surfaces.

3.1 *Bryozoan components*

The bryozoan constituents are dominated by different groups of fenestrates (Table 1). Fenestellids form the most important group, both as skeletal components in wackestones as well as sediment trappers and substrate for calcite cement growth. Large sheets of "*Ptylopora*" are also quite common, whereas fragments of *Penniretepora* and *Polypora* are only occasionally seen in thin sections. Encrusting cystoporates (*Fistulipora* cf. *incrustans*) are observed in more than 30 thin sections where they are encrusting both reverse and obverse side of fenestrate sheets. They occur also on brachiopod shells. Encrustation took place on both living and dead fenestrate colonies. Cryptostomes and hexagoneliid cystoporates (e.g. *Goniocladia*) are only subordinate faunal elements. In addition to fistuliporid encrustations fenestrate colonies are in varying numbers encrusted by foraminifera, e.g. *Archaegonus* (or the cyclostomatous bryozoan *Hederella*), worms and the enigmatic algae(?) *Tubiphytes*.

The crinoidal pack/grainstone above contains bryozoan fragments of a complete different nature. Fenestrates are present as abraded fragments, in addition to rare specimens of *Archimedes*, *Goniocladia*, cryptostomes and an encrusting trepostome, see Table 2.

Taxonomic characters of fenestellid bryozoans could be observed and measured from around 70 thin sections. Important taxonomic characters, e.g. internal zooecial geometry and dimensions were, however, often lost due to pervasive dolomitisation. Only a few species could therefore be determined to species level, and many remain in open nomenclature. The investigated fauna contains species which have a wide mid-Carboniferous to early Permian stratigraphic range. The time-equivalent bryozoan buildups of Greenland and Canada have not been systematically described, and a comparison on a detailed level is so far not possible.

The overlying crinoid pack/grainstone, defining the base of the overlying lithostratigraphic unit (the Cadellfjellet Member of the Wordiekammen Formation) contains a different bryozoan fauna with a

Table 1. Bryozoans in the buildup core and flanks

Taxon	Distribution
Fistulipora cf. *incrustans* (Phillips 1836), Figure 5D	Early Carboniferous of the British Isles, Russia and North America
Goniocladia sp.	
Rhombotrypella cf. *dvinensis* Shul'ga-Nesterenko 1955	Moscovian-Kasimovian of Russia
Indet. encrusting trepostome	
Clausotrypa cf. *ramosa* (Owen 1973)	Early Carboniferous of Ireland
Alternifenestella bifida (Eichwald 1860), Figure 4E, G	Late Carboniferous-Early Permian of Russia
A. pseudovirgosa (Nikiforova 1938)	Late Carboniferous of Russia, Early Carboniferous of Ireland
A. cf. *pulcherrima* (Shul'ga-Nesterenko 1941)	Late Carboniferous-Permian of Russia
A. cf. *basloensis* (Bassler 1929)	Permian
Exfenestella(?) sp. A, B, C, Figure 4C,D	
Flexifenestella cf. *foraminosa* (Eichwald 1860), Figure 4F	Late Carbonifeorus - Early Permian of Russia, Late Carboniferous of China
F. sp. A	
Laxifenestella(?) sp. A, B, C, Figure 4H	
Rectifenestella rudis (Cubifenestella by Snyder 1991a)	Early Carboniferous, North America and Ireland
Penniretepora spp.	
"*Ptylopora*" sp. A (?new genus, Figure 4A, 5A-C)	
Polypora cf. *sulaensis* Nikiforova 1938	Late Carboniferous and Early Permian, Russia
Polyporella cf. *gracilis* (Nikiforova 1938)	Early Carboniferous, North America
P. cf. *rhombocellata* (Nikiforova 1938)	Late Carboniferous and Early Permian, Russia
(?)*Hederella*	Mainly Carboniferous

distinct Moscovian affinity. This interval is composed of carbonates that are not affected much by dolomitisation, and the taxonomic characters of the bryozoa are more readily obtained from acetate peels.

Fenestrate bryozoans dominate in the buildup, with a composition largely of previously described taxa. There may, however, be a new taxon, - genus or species, denoted "*Ptylopora*" herein. Its colony form (Fig. 5C) is identical to *Ptylopora* as revised from type material from the Carboniferous of Ireland (Bancroft 1985). The zooecial features differ in that the Svalbard specimens have a clearly defined hemiseptum (Fig. B), which is also weakly developed in *Ptylopora* in Snyder (1991b). A systematic description of this fauna is in preparation by the author.

Additional faunal components in the buildup facies include algae, - *Bersella* sp. (cf. Mamet & Stemmerik 2000: fig. 5), *Stacheoides* sp. and "calcispheres", rare trilobites like *Ditomopyge* sp., rare ammonoids, tubular and other non-fusulinid foraminiferans like *Archaeogonus* sp. and *Tetrataxis*, crinoid grains (often strongly micritised and/or encrusted by marine cement), rare solitary corals, locally abundant ostracods and sponge spicules. The non-skeletal matrix is a mixture of mud, often with a clotted structure, porefilling cement (fibrous or sparry calcite) and peloidal grains (in the upper part of the buildup).

Table 2. Bryozoans in the basal Cadellfjellet Member (crinoid pack/grainstone)

Taxon	Distribution
Fistulipora sp.	
Goniocladia sp.	
Rhombotrypella cf. *rectangulata* Shul'ga-Nesterenko 1955	Late Carboniferous of Russia
Archimedes sp. A	
Rectifenestella cf. *veneris* (Fischer 1866)	Middle Carboniferous (Moscovian) to Early Permian of Russia, North America and China
Penniretepora cf. *longicellata* (Morozova 1955)	Early Carboniferous of Russia
Rhombopora sp.	
Ascopora cf. oblonga (Nikiforova 1933)	Moscovian of Russia

Samples were collected from the overlying crinoidal pack/grainstone above the bryozoan buildup for dating purposes. Fusulinid foraminiferans include *Wedekindellina dutkevichi* (Rauser-Chernousova 1951), *Fusuliniella* aff. *eopulchra* (Rauser-Chernousova 1951), *Ozawainella* sp. and *Quasifusulinoides*? spp. (I. Nilsson in Pickard *et al.* 1996), and a fairly rich conodont fauna was extracted. The latter includes:

Streptognathodus cancellosus (Gunnell 1933)
Neognathodus cf. *medexultimus* Merrill 1972
Neognathodus cf. *medadultimus* Merrill 1972
Idiognathodus delicatus Gunnell 1931
Idiognathodus obliquus Kossenko & Kozitskaya1978
Idiognathodus aff. *podolskensis* Goreva 1984
Idiognathodus aff. *sinuosus* Ellison & Graves 1941
Hindeodus sp.

This fauna places the investigated interval in the Myakhovian Horizon (uppermost Moscovian) of the Russian Platform and is correlative to Desmoinesian faunas of North America and Canada, see e.g. Beauchamp *et al.* (1989).

3.2 *Diagenesis*

Most of the diagenetic modifications seen in the buildup and flank depostits are believed to have taken place shortly after deposition. The most important phases include pervasive, porosity-

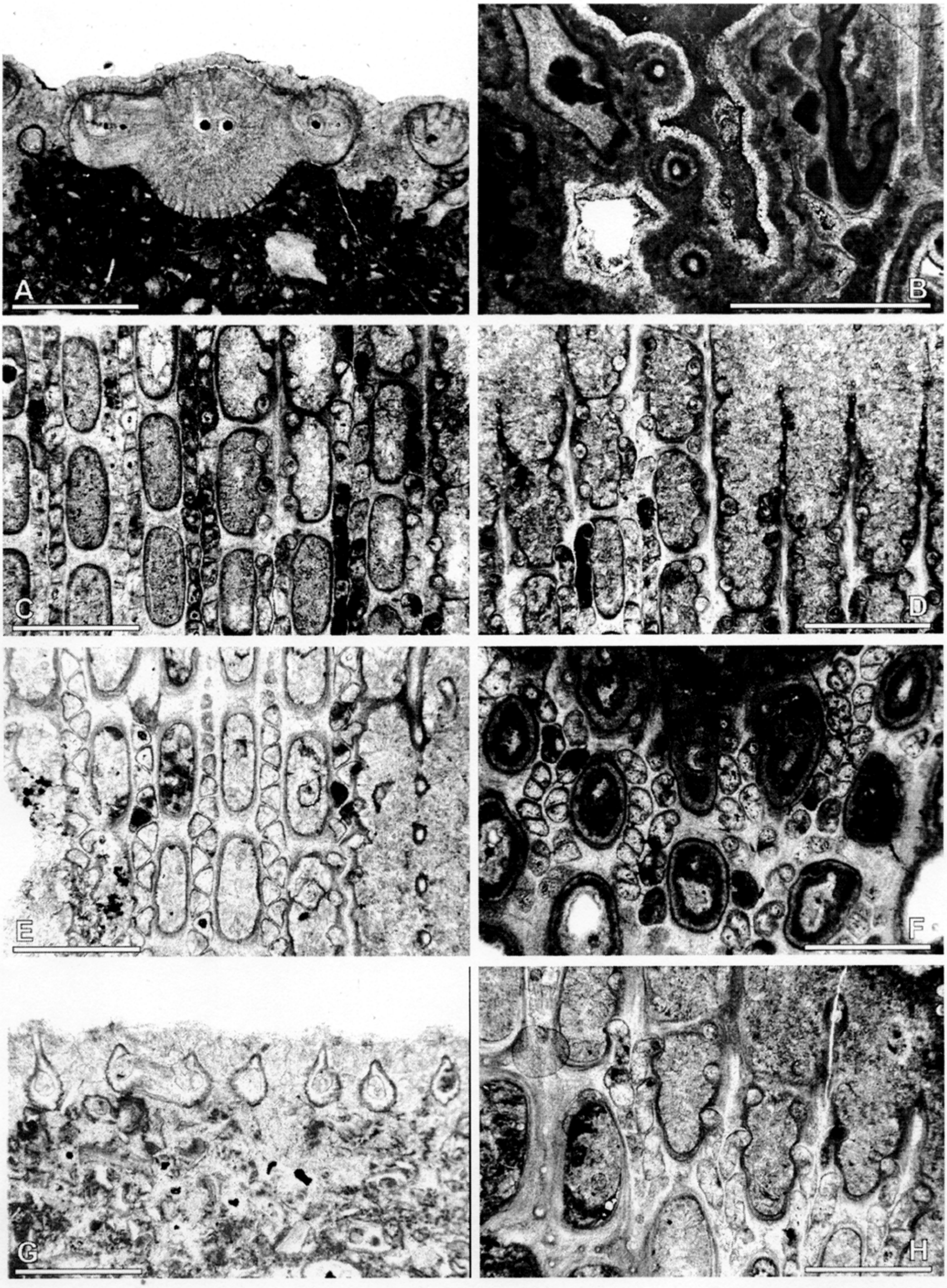
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Figure 4 (facing page).
A. "*Ptylopora*" sp., transverse section through main stem and lateral branches, PMO 136.507B. B. *Alternifenestella* sp., tangential section, with several generations of cement, PMO 136.596B. C. *Exfenestella*? sp., deep (left) to shallow tangential section, PMO 136.522B. D. *Exfenestella*? sp., shallow tangential section, PMO 136.522B. E. *Alternifenestella bifida*, deep (left) to shallow tangential section, PMO 136.623A. F. *Flexifenestella* cf. *foraminosa*, deep tangential section, PMO 136.646B. G. *Alternifenestella bifida*, transverse section PMO 136.623C. H. *Laxifenestella*? sp., deep (bottom) to shallow tangential section, PMO 136.636E. Scale bar 1 mm

destructive early cementation of the buildup cores and subsequent dolomitisation of the entire succession.

Epitaxial and radial-fibrous calcite growth into fenestrule openings was followed by entire filling of such porosity by microspar cement. This early cementation took place in varying degree, and some fenestrules seems to be unaffected (Fig. 5E). Multiple generations of cement, and local dissolution horizons are visible in some colonies (Fig. 4B), and may be after initial aragonite cements.

Dolomitisation, including preservation of dolomite rhombs (Fig. 5I) apparently took place early in the post-depositional history. Karst surfaces are observed near the top of the buildup, and subaerial exposure and meteoric alteration most likely took place. Dolomitising fluids may have been a mixture of freshwater or evaporitic brines, as evidenced from presence of gypsum nodules in adjacent dolostones. Aragonite dissolution and dolomitisation may have regained some initial destroyed porosity. Silicification played a minor role, although some bryozoan skeletal microstructures are destroyed by silica growth. Chert nodules are present in layers in the overlying Cadellfjellet Member. Abundant sponge spicules as observed in thin sections may be the source for silicification.

4 DEPOSITIONAL ENVIRONMENT

The bryozoan buildup grew below fairweather wave base on the outer shelf or near the shelf edge. The water depth was sufficient for vertical aggregation, but presence of phylloid algae in the top of the buildup indicates growth into the photic zone. The presence of karst surfaces in the upper part indicates periods of very shallow water or even subaerial exposure. Growth into very shallow water most probably started laterally and can be followed in the flank deposits. Peloidal and clotted muds comprise parts of the buildup matrix similar to those present in other Carboniferous non-skeletal buildups or mud-mounds (Pickard 1992). There is no evidence that bryozoans or other skeletal elements, such as corals, formed a true reef framework, and the growth of the buildup was more controlled by sea level changes than an ecological succession in the sense of Walker & Alberstadt (1975)

5 REGIONAL COMPARISON

The investigated bryozoan buildups are time-equivalent to buildups reported from adjacent areas in the palaeo-Arctic. Reef-mounds more than 150 m in height and hundreds of metres in width are reported from the Canadian Arctic Sverdrup Basin (Beauchamp 1992). A succession of structures, from deeper distal bryozoan buildups, to proximal algal reefs is considered to reflect a depth-controlled biological gradient. Temperature is believed to control the large-scale presence of organisms, and warm-water biota disappeared successively in the Early to Late Permian as a reaction to the significant cooling that took place. Moscovian bryozoan-dominated buildups in eastern North Greenland are up to 40 m thick and several hundred metres wide (Stemmerik 1989, 1992, 2000, Stemmerik & Elvebakk 1994). Frequent occurrences of algae in both buildup cores and flanks indicate that the buildups formed in shallow water (more shallow than the Sverdup buildups) well within the photic zone. Buildups (mainly algal bioherms) are reported from the Moscovian Lavrovskaya Formation in Novaya Zemlya, but bryozoans occur abundantly in these strata as well (Sobolev & Nakrem 1997: p. 18). Time-equivalent buildups may be present in the Barents Shelf, between deeper basins (Stemmerik 2000, p. 109, fig. 9).

ACKNOWLEDGEMENTS

The material was collected during field work in 1992 together with Nils-Martin Hanken, Neil A. H. Pickard, and Tommy J. Samuelsberg. The project is part of a study of Upper Carboniferous - Lower Permian successions in Svalbard led by the "Carbonate Research Group" based at the University of Tromsø, and supported by several oil companies. I express my thanks to this group of people/ companies for making data and information available for the current study. Thin sections were prepared by Johny Skrårudseter at the Geological Museum, University of Oslo. Patrick Wyse Jackson is thanked for his constructive review.

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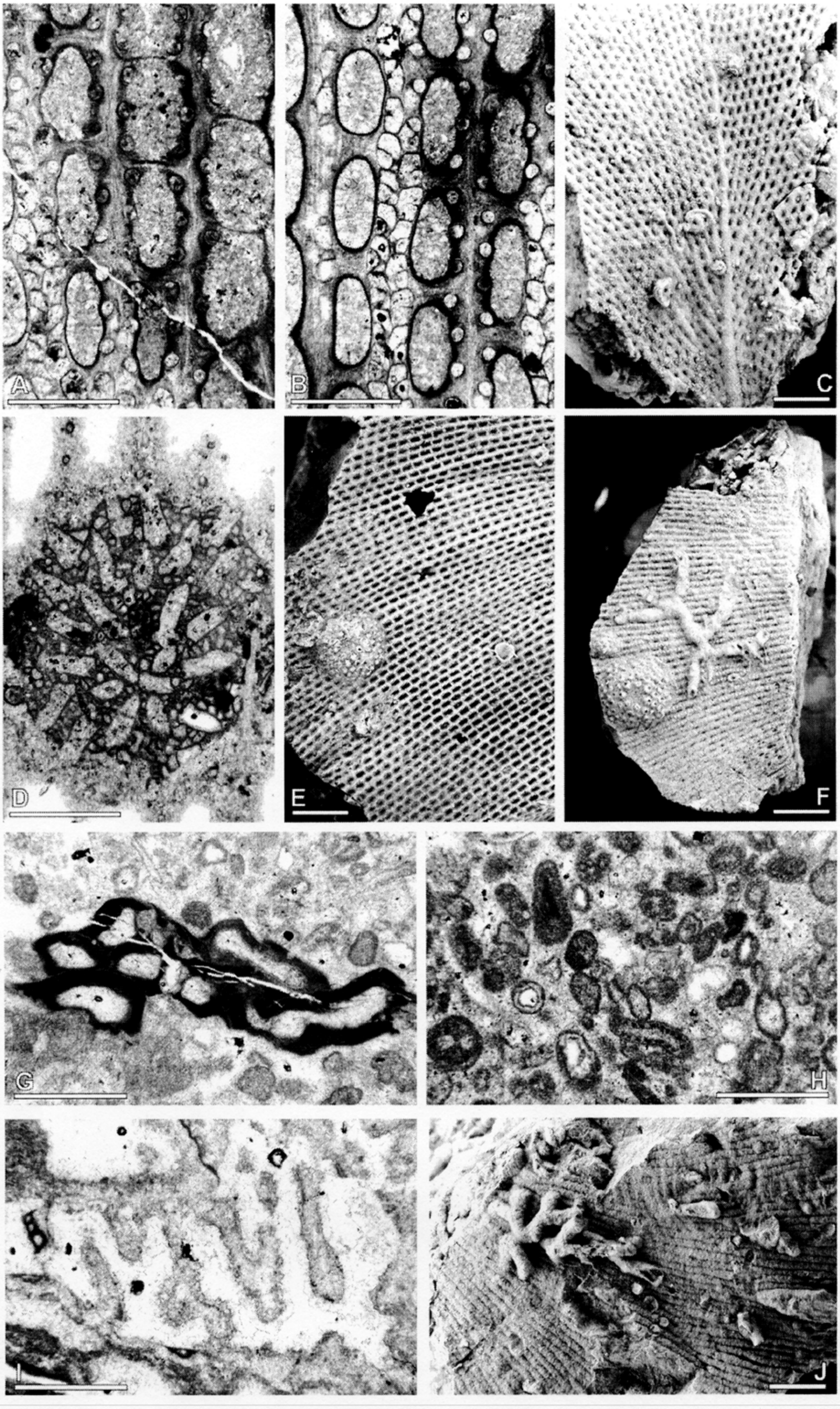
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Figure 5 (facing page). A. "*Ptylopora*" sp., deep (left) to shallow tangential section, PMO 136.292A. B. "*Ptylopora*" sp., deep (left) to shallow tangential section, note well developed hemisepta, PMO 136.292A. C. "*Ptylopora*" sp., external features, PMO 136.612. D. *Fistulipora* cf. *incrustans*, deep tangential section, PMO 136.345B. E. Colony of *Fistulipora* cf. *incrustans* encrusting a fenestellid sheet, PMO 136.333. F. Colony of *Fistulipora* cf. *incrustans* and *Archaeogonus* sp. (a tubular foraminifera) (or the cyclostomatous bryozoan *Hederella*) encrusting the reverse side of a fenestellid sheet, PMO 136.630. G. *Tubiphytes*, PMO 136.483A. H. Peloid grains and *Bersella* (an algae, central, lower) PMO 136.483A. I. Indet fossil, possibly phylloid algae or *Palaeoaplysina*, PMO 136.483C. J. A tubular foraminifera (or ?*Hederella*) encrusting a fenestellid sheet. Note intense calcification filling fenestellid fenestrules, PMO 136.661. Scale bar 1 mm; except C, E and F: 10 mm

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