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NOTES ON THE GEOLOGY AND MICROPALEONTOLOGY OF THE PROTEROZOIC THULE GROUP, ELLESMERE ISLAND, CANADA, AND NORTH-WEST GREENLAND

H.J. Hofmann and G.D. Jackson

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Cover description

Looking west at Paine Bluff (centre) and Goding Bay (left). The dark rocks on the left include the 1268 Ma gabbro underlain and overlain by basalt flows and associated sediments of unit 2 of the Wolstenholme Formation. The north-dipping dark-coloured unit at Paine Bluff is the middle subunit (Paine Bluff Member, Dawes, in press) of unit 5, from which fossiliferous samples 6-9 were obtained. GSC Photo 1994-735K.

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CONTENTS

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Abstract

An assemblage of organic-walled microfossils is described from macerates recovered from fine grained siliciclastic units of the Thule Group of southeastern Ellesmere Island and North-West Greenland. The Thule Group is up to 6 km thick, and considered to be correlative with the Bylot Supergroup of northwestern Baffin Island. Depositional environments include basinal, platform, and local deltaic environments, as well as coastal sabkhas on a carbonate shelf. The microbiota, between 1270 and 750 Ma old, comprises the following taxa, almost all of which have long stratigraphic ranges: Siphonophycus septatum, S. robustum, S. rugosum, S. kestron, Pellicularia? *sp.,* Obruchevella? *sp.,* Brachypleganon *sp.,* Navifusa majensis, Leiosphaeridia minutissima, L. tenuissima, L. crassa, L. jacutica, L. ternata, Valeria lophostriata, Pterospermopsimorpha insolita, Eomicrocystis malgica, Ostiana microcystis, Symplassosphaeridium. *sp.,* Synsphaeridium *spp.,* Satka *sp.,* Spumosina rubiginosa, *and* Fabiformis baffinensis*; two kinds of microdubiofossils are also present. This assemblage is less diverse than that in the Bylot Supergroup.*

Résumé

On décrit un assemblage de microfossiles à parois organiques tiré de macérats récupérés dans des unités silicoclastiques à grain fin du Groupe de Thule dans le sud-est de l'île d'Ellesmere et dans le nord-ouest du Groenland. Le Groupe de Thule qui mesure jusqu'à 6 km d'épaisseur est considéré corrélatif du Supergroupe de Bylot trouvé dans le nord-ouest de l'île de Baffin. Les milieux de sédimentation incluent des bassins, des plates-formes et des deltas locaux ainsi que des sabkhas littorales sur une plate-forme continentale carbonatée. La microbiote, qui remonte à entre 1 270 et 750 Ma, comprend les taxons suivants, qui ont presque tous un long intervalle stratigraphique : Siphonophycus septatum, S. robustum, S. rugosum, S. kestron, Pellicularia? *sp.,* Obruchevella? *sp.,* Brachypleganon *sp.,* Navifusa majensis, Leiosphaeridia minutissima, L. tenuissima, L. crassa, L. jacutica, L. ternata, Valeria lophostriata, Pterospermopsimorpha insolita, Eomicrocystis malgica, Ostiana microcystis, Symplassosphaeridium. *sp.,* Synsphaeridium *spp.,* Satka *sp.,* Spumosina rubiginosa *et* Fabiformis baffinensis*; deux types de microdubiofossiles sont également présents. Cet assemblage est moins diversifié que celui qui se trouve dans le Supergroupe de Bylot.*

INTRODUCTION

This paper provides a brief review of the geology of Thule Basin in northernmost Canada and North-West Greenland (Fig. 1, 2) and reports on an acritarch microbiota in fine grained siliciclastics and argillaceous limestones in the Thule Group. Microfossils had previously been reported from the Thule Group of Greenland (Vidal and Dawes, 1980; Strother et al., 1983; Dawes and Vidal, 1985), but not from the Canadian side of the Thule Basin. Samples used in the present study were collected by Jackson in 1982, T. Frisch in 1977, and R. Christie in 1961. Of the 28 shale and siltstone samples analyzed, 17 yielded identifiable remains. The microfossils include 22 taxa, and 2 kinds of microdubiofossils.

REGIONAL GEOLOGY

Mesoproterozoic to Neoproterozoic? Thule Group strata of Thule Basin outcrop in southeast Ellesmere Island and North-West Greenland (Fig. 1). The most comprehensive summaries of previous work are by Dawes and Christie (1982), and by Dawes (in press), who raised the group to supergroup status. Inasmuch as the new nomenclature awaits formal publication, we retain the old terminology, referring to Dawes' new nomenclature where appropriate to facilitate comparisons. Emphasis in the following descriptions is on the units sampled for this study in parts of the central basin and southeastern basin-margin successions. Information derives chiefly from Davies et al. (1963), Dawes et al. (1982), Frisch and Christie (1982), Jackson (1986), and Dawes (in press).

Thule strata nonconformably overlie a Paleoproterozoic crystalline basement, and onlap the basement to the north, east, and southeast (Dawes et al., 1982; Frisch, 1988; Frisch and Hunt 1988). Northern exposures of the group are overlain by Lower Cambrian strata; elsewhere Thule strata are capped by Pleistocene and Recent strata or by the present erosion surface. Preserved thicknesses range from a feather edge to at least 6 km.

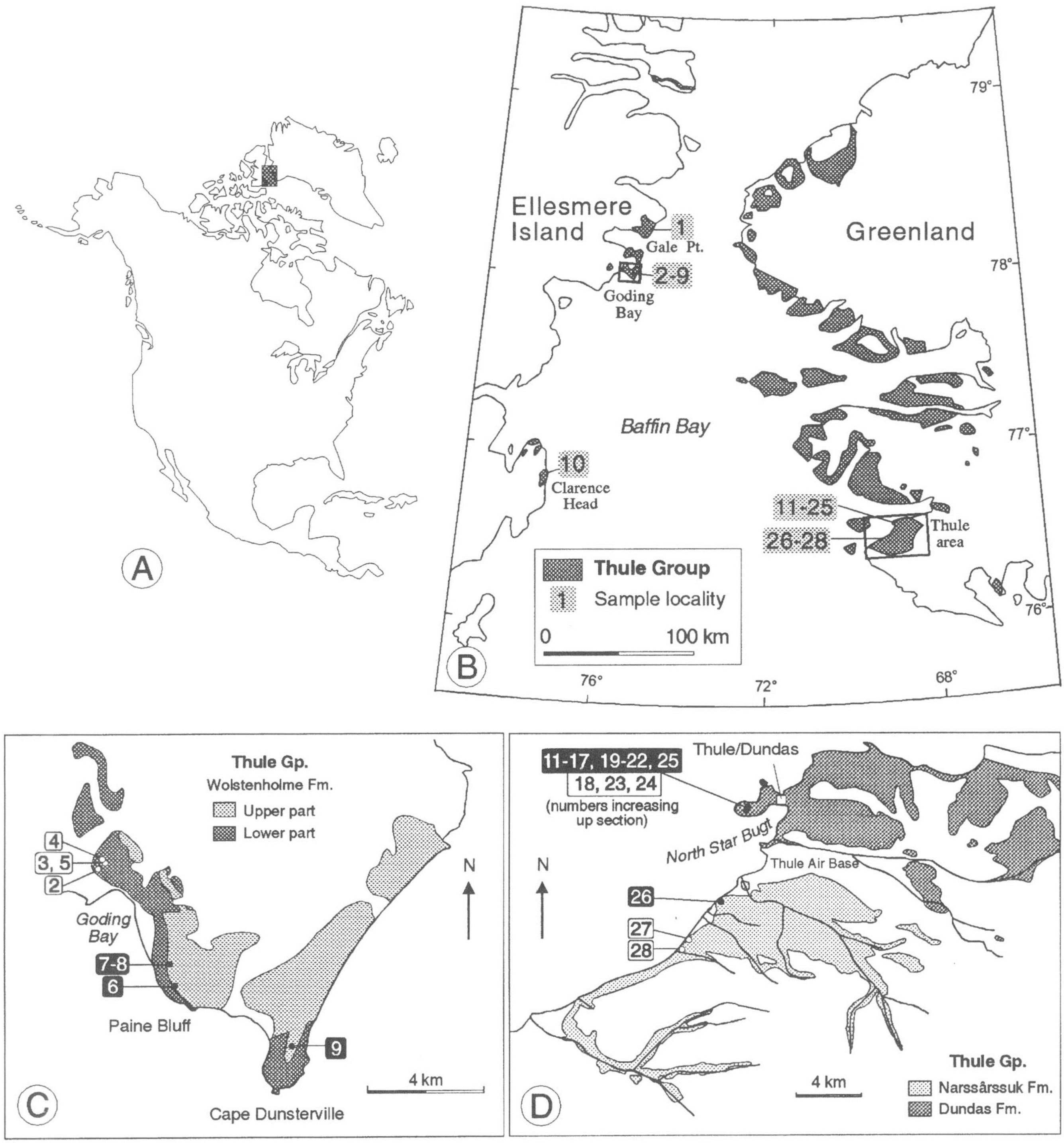


Figure 1. *A) Index map showing study area;* ***B)*** *Outcrop areas of Thule Group with sample localities; rectangles outlining Goding Bay and Thule areas enlarged in C and D;* ***C)*** *Sample localities in Goding Bay area;* ***D)*** *Sample localities in Thule area. In C and D, white numbers on black background represent samples with microfossils, black numbers on white background represent barren samples. B, C, and D are modified from figures 2, 107, and 142, respectively, in Dawes (in press).*

The Thule Group has been divided into lower and upper parts. The lower part (Wolstenholme Formation) comprises six units (Fig. 2), which Dawes (in press) has given formational status and assembled into new groups; in the region we report on here, Dawes' Nares Strait Group comprises the four lower units of the old Wolstenholme Formation and the two upper units are included in the Baffin Bay Group. The upper part of the Thule Group comprises the Dundas and overlying Narssârssuk formations (Fig. 2). Mesoproterozoic to Neoproterozoic gabbro intrusions (Mackenzie, and Franklin?) are probably most abundant in unit 2 of the Wolstenholme Formation and in the Dundas Formation. The boundary between the Dundas and Narssârssuk formations is covered, but is thought to be conformable because of concordant attitudes and an upward increase of carbonates and gypsum in the Dundas Formation toward the contact. Other contacts are sharply to gradationally conformable, although syndepositional faulting and uplift of fault blocks, and local disconformities within unit 2 have been reported (Dawes et al., 1982).

Wolstenholme Formation

The Wolstenholme Formation (Nares Strait and Baffin Bay groups of Dawes, in press) has a maximum composite thickness of 2.5 km in Greenland and comprises the entire 1 km or so of Thule strata preserved on southeastern Ellesmere Island (Frisch and Christie, 1982). Pale quartzarenites are the most abundant lithology in five of the six units of the formation. Varicoloured sandstones and shales (in units 1-3, 5), and thin stromatolitic and siliciclastic carbonates (in units 1-3) are also present. Unit 2 (cover photo) is chiefly interlayered tholeiitic plateau basalt flows and pyroclastics, gabbro sills, and red clastics.

The middle subunit (48 m) of unit 5 at Paine Bluff (Paine Bluff Member of the Goding Bay Formation of Dawes, in press) is predominantly green shale and siltstone that yield microfossils (Fig. 1, 2). Minor interbeds of off white very fine grained quartzarenite turbidite and sporadic, coarse, dark green carbonate lenses and concretions up to 25 cm thick are also present (cover photo; Fig. 3, 4).

Following early continental basalt volcanism, tide-dominated shelf-margin sedimentation prevailed in a wide range of marine subtidal to supratidal and terrestrial environments during Wolstenholme deposition (Dawes et al., 1982; Frisch and Christie, 1982; Jackson, 1986; Dawes, in press). Most of the sediments probably accumulated in response to repeated marine transgressions followed by progradational sedimentation, to account for thin stromatolitic carbonates followed successively by intertidal, lagoonal, and fluvial deposits (e.g. units 1, 3). Prodelta to offshore and localized basin deposits occur at the top of unit 2, and in the middle of unit 5 (Paine Bluff Member; Fig. 3, 4).

Dundas Formation

The Dundas Formation is at least 1 km thick and may attain 3 km locally. Black to dark grey fissile shale and siltstone predominate, show wide lateral variations in relative proportions, and are thinly interbedded, at least locally, with pale grey very fine- to fine-grained quartzarenite. Minor stromatolitic dolostone, limestone, chert, and gypsum are also present. Carbonates and gypsum increase in abundance upward. Most samples examined for microfossils are from the Dundas Formation, and all of these are from Dundas Fjeld (Fig. 1, 2, 5; Appendix), the most fossiliferous being from the lower part of the examined section.

Dundas strata mark a change from shelf margin sedimentation of the Wolstenholme Formation to intertidal and subtidal basinal deposition that, in places, was somewhat restricted and includes thin quartzarenite turbidite layers that may have been associated with faulting (Jackson, 1986). Some of the strata are interpreted as deltaic (Dawes et al., 1982; Dawes, in press).

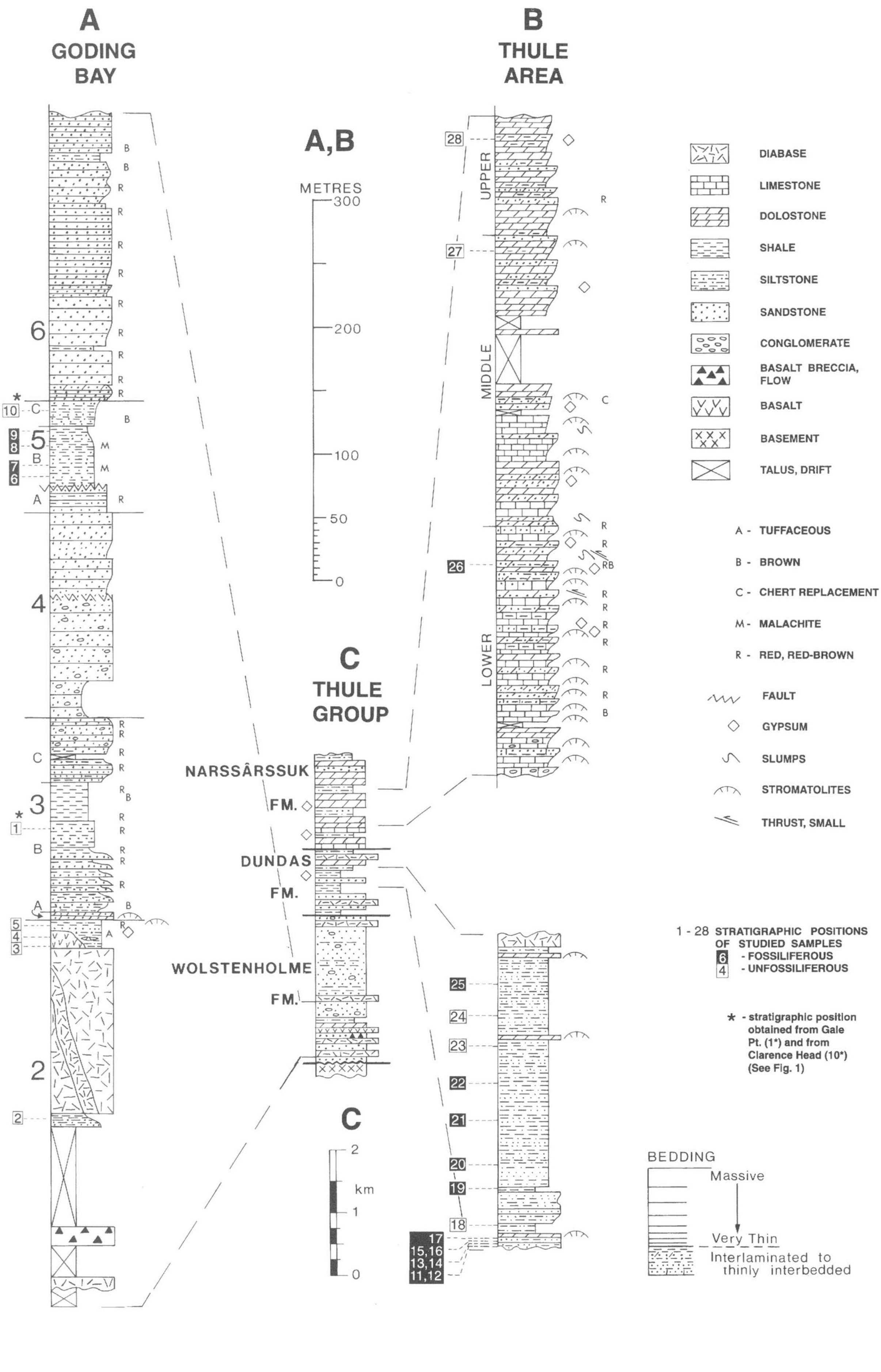
Narssârssuk Formation

This formation is restricted to an easterly trending graben in the Thule area (Fig. 1), and is probably 1-2.5 km thick. The strata are mostly well-bedded grey stromatolitic carbonates and interlayered variegated shales, siltstones, and sandstones. Most strata in the lower and upper red members define shallowing-upward cycles in which lithologies are laterally and vertically intergradational, and which include some coastal sabkha sequences. Limestone predominates in the lower red member (Fig. 6; Imilik Formation of Dawes, in press), but dolostone increases upward in abundance in the formation to dominate the upper part of the middle Aorfêrneq member (Aorfêrneq Formation of Dawes, in press), and the lower part of the upper red member (Bylot Sund Formation of Dawes, in press) which is otherwise similar to the lower red member. Siliciclastic strata are least abundant in the middle Aorfêrneq member, where they are rarely red (Fig. 2), but gypsum and chert are moderately abundant. The upper part of the upper red member is mostly red sandstone and siltstone, greyish-green sandstone and minor dolostone interbedded in relatively thick shallowing-up cycles (Davies et al., 1963).

The Narssârssuk Formation was deposited primarily in low energy, arid to semi-arid, protected marginal carbonate shelf environments such as lagoons and coastal embayments (Dawes et al., 1982; Jackson, 1986; Dawes, in press). Depositional environments within the cycles range upward from subtidal to intertidal and supratidal (Jackson, 1986). The upward increase of redbeds and greyish-green sandstones in the upper part of the upper red member may indicate increased syndepositional faulting and a change in environment to a more siliciclastic shelf at this time.

Age of the Thule Group

Most whole rock K-Ar ages for mafic igneous rocks within the Thule Group belong to one of two groups: 1284 - 914 Ma and 828 - 431 Ma (Dawes et al., 1973; Frisch and Christie, 1982; Dawes and Rex, 1986; Dawes, 1991; Dawes, in press). The older ages link only mafic igneous rocks in the Wolstenholme Formation, for which the most reliable age is a U-Pb baddeleyite age of 1268 Ma for the large sill near the top of unit 2 at Goding Bay (Fig. 2, 3). LeCheminant and Heaman (1991)


A
GODING
BAY
B
THULE
AREA
A,B
METRES
300
200
100
50
0
C
THULE
GROUP
NARSSÂRSSUK
FM.
DUNDAS
FM.
WOLSTENHOLME
FM.
C
2
km
1
0
UPPER
MIDDLE
LOWER
DIABASE
LIMESTONE
DOLOSTONE
SHALE
SILTSTONE
SANDSTONE
CONGLOMERATE
BASALT BRECCIA, FLOW
BASALT
BASEMENT
TALUS, DRIFT
A - TUFFACEOUS
B - BROWN
C - CHERT REPLACEMENT
M - MALACHITE
R - RED, RED-BROWN
FAULT
GYPSUM
SLUMPS
STROMATOLITES
THRUST, SMALL
1 - 28 STRATIGRAPHIC POSITIONS OF STUDIED SAMPLES
6 - FOSSILIFEROUS
4 - UNFOSSILIFEROUS
* - stratigraphic position obtained from Gale Pt. (1*) and from Clarence Head (10*) (See Fig. 1)
BEDDING
Massive
Very Thin
Interlaminated to thinly interbedded

considered this age to date a Middle Proterozoic (Neohelikian) Mackenzie igneous event. It probably approximates the age of at least the Wolstenholme Formation.

The younger K-Ar ages (828-431 Ma) were obtained on mafic igneous rocks throughout the Thule Group. For comparison, on northern Baffin Island whole-rock K-Ar ages for 33 Franklin dykes (23 intrude the Upper Mesoproterozoic Bylot Supergroup) range from 841-437 Ma (Fahrig et al., 1971; Jackson and Iannelli, 1981). However, 3 U-Pb baddeleyite ages of 723-729 Ma for Franklin dykes on Baffin Island (Heaman et al., 1990; Pehrsson and Buchan, in press) suggest that Franklin dykes are about 723 Ma. old. Generally, whole-rock K-Ar measurements for a particular igneous event yield a range of ages, the oldest of which approximates the age obtained by more reliable methods (Jackson and Iannelli, 1981). It seems likely that the younger Thule intrusions are of Franklinian age. If this is so, none of the Thule strata are as young as Sinian (Sturtian/Vendian, ca. 740-590 Ma).

Lack of precise radiometric dates for the upper part of the Thule Group led Dawes and co-workers to assign Late Proterozoic ages to these strata on the basis of contained microfossils (Vidal and Dawes, 1980; Strother et al., 1983; Dawes and Vidal, 1985; Dawes, in press), and a late Riphean age (ca. 1000-740 Ma) to the uppermost part of the Wolstenholme Formation and to most of the Dundas Formation, the uppermost part of which they regarded as possibly Early Vendian (ca. 670-630 Ma); the Narssârssuk Formation was interpreted as Early Vendian.

Not only has the age of the upper Thule Group not been closely constrained by radiometric methods, but the time ranges of microfossil taxa are also very poorly constrained, and new data commonly extend previously determined ranges considerably (e.g. Hofmann and Jackson, 1991, 1994). We

←

Figure 2. *Generalized stratigraphy of Thule Group (section C), and more detailed sections (A, B) showing source of samples with organic-walled microfossils. Modified from figures 65.2 and 65.6 in Jackson (1986).*

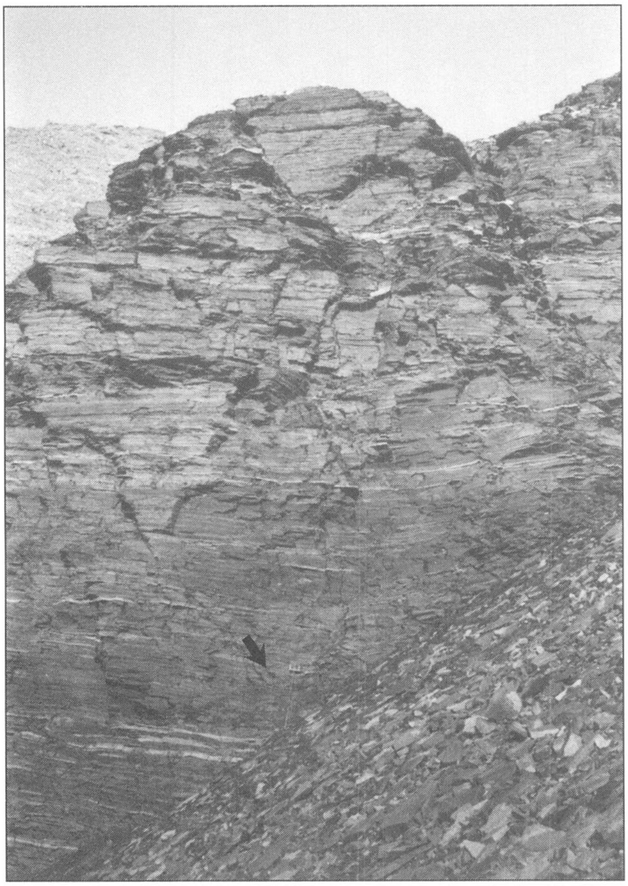


Figure 3. *Thinly interbedded green shale and siltstone and pale coloured quartzarenite turbidites in prodelta-type sediments of the middle subunit (Paine Bluff Member) of unit 5 at Goding Bay. A dark iron carbonate lens (black arrow) lies just left of the 1.5 m rod. Fossiliferous samples 7 and 8 were obtained from this site. GSC 1995-003.*

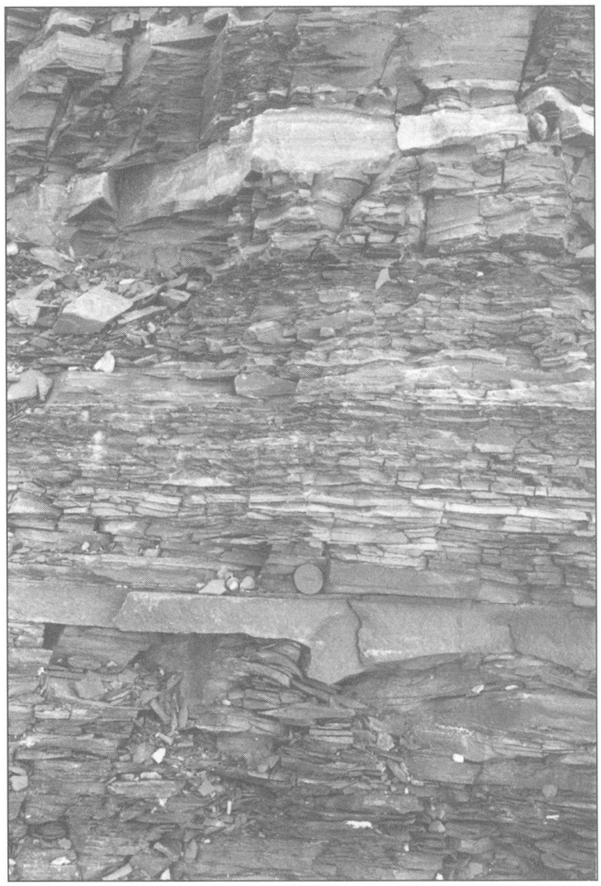


Figure 4. *A close-up view of the unit shown in Figure 3. The thick quartzarenite bed in the lower part of the photo is channelled into the underlying beds. The lens cap just above it is about 3.5 cm across. GSC 1995-054.*

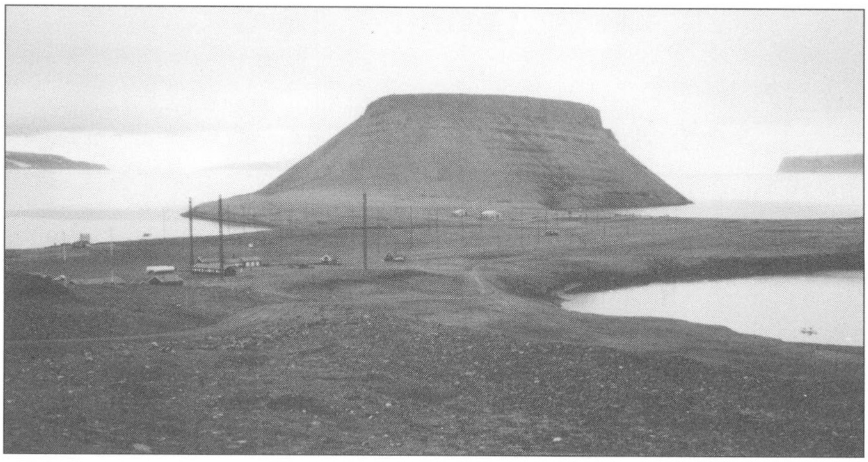


Figure 5. Dundas strata capped by a gabbro sill at Dundas Fjeld (elevation 220 m) in the Thule area. The section examined, and from which samples 19-22 and 25 were collected, occupies the dark strip on the right side of the mesa. Dark shales and siltstones are interbedded with minor light coloured turbidite quartzarenite and a few carbonate beds. GSC Photo 1994-735A.

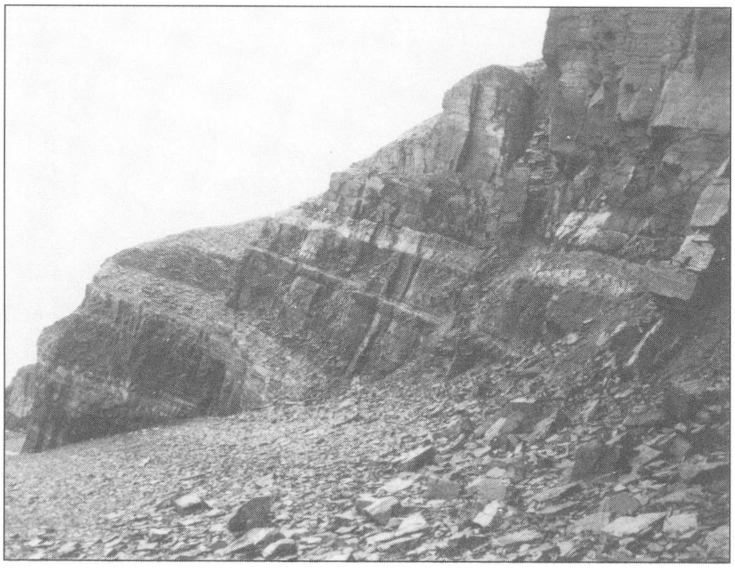


Figure 6.

A coastal section of the lower redbed member of the Narssârssuk Formation intruded by a 2.7 m thick vertical northeast-trending diabase dyke (right of middle) southwest of Thule Air Base. The dark units attain 10 m in thickness and are mostly limestone, but include a few units of red shale-arkose. Light coloured units are mostly dolostone with or without sandstone. Note the low broad domal structure in the light coloured dolostone bed near the base of the cliff just right of the dyke. The section in the foreground is about 40 m thick. Fossiliferous sample 26 was collected beyond the view about 90 m above the top of the section. GSC Photo 1994-735F.

suggest a minimum Middle Proterozoic age of about 1190 Ma is possible for upper Thule strata, based on several considerations, none of them conclusive:

1. Glaciogenic deposits, common in Neoproterozoic strata along the northwestern edge of the Canadian-Greenland Shield (e.g. Troelsen, 1956; Jepsen, 1971; Clemmensen, 1979; Eisbacher, 1978; Yeo, 1981), appear to be absent from both Thule strata and the nearby coeval Bylot Supergroup.
2. Considering the apparently uninterrupted nature of Wolstenholme and Dundas sedimentation, compaction of sediments (e.g. Potter et al., 1980), and sedimentation rates that commonly prevail in rifted and evaporitic basins and on carbonate shelves (e.g. Schwab, 1976; Kukal, 1990), it seems unlikely that sedimentation of the Thule Group occurred continuously for as long as six hundred million years (1270-670 Ma).
3. The age of the Bylot Supergroup on northwestern Baffin Island has been estimated to range from 1270 to 1190 Ma (Knight and Jackson, 1994; Jackson, in press). The estimate is based directly on paleomagnetic pole positions and Rb-Sr, K-Ar, and U-Pb baddeleyite ages, and indirectly on environmental sedimentation rates and on U-Pb baddeleyite ages and associated paleomagnetic poles for mafic intrusions elsewhere. If the correlations of Thule and Bylot strata as noted below are valid, Thule strata may not be younger than about 1190 Ma.

4. The present assemblage of microfossils does not contain any diagnostic Neoproterozoic acritarchs with prominent processes, or branching filamentous forms. The '*Peteinosphaeridium*' (= *Vandalosphaeridium varangeri* Vidal) reported by Vidal and Dawes (1980) from the upper part of the Dundas Formation and lower part of the Narssârssuk Formation were taken to indicate an early Vendian age (see also Dawes and Vidal, 1985), although its range may extend into older rocks in the light of geological correlations and geochronological data now available.

Basin evolution and correlations

Correlations and comparisons of Thule strata with other Mesoproterozoic sequences along the northwest edge of the Canadian-Greenland Shield (e.g. Blackadar, 1957; Jackson and Iannelli, 1981; Dawes et al., 1982) show that the closest and most similar sequence is the Bylot Supergroup of Borden Rift Basin on northwestern Baffin Island. Similarities range from nearly identical gross stratigraphy to internal similarities between formations and members. For instance, units one and two of the Wolstenholme Formation correlate with the Nauyat Formation, the rest of the Wolstenholme with the Adams Sound Formation, and the Dundas correlates with the Arctic Bay. Also, the lower red member of the Narssârssuk Formation is stratigraphically similar to lower Society Cliffs member (SC_1) on Bylot Island, and the middle Aorfêrneq member and the lower part of the upper red member are similar to the upper Society Cliffs member (SC_2) and the overlying Victor Bay Formation. In addition, the upward increase of redbeds and greyish-green siltstones-sandstones in the upper part of the upper red member of the Narssârssuk Formation, and at the top of the Uluksan Group and in the overlying Strathcona Sound Formation around Navy Board Inlet and on Bylot Island (Davies et al., 1963; Jackson and Iannelli, 1981; Jackson et al., 1985; Jackson, 1986), suggest that the upper red member may be correlative with the SS_6 member of the Strathcona Sound Formation and the lower part of the Elwin Subgroup. Also, although most of the microfossils in the present study are long-ranging, generalized types, the assemblages recovered from the Wolstenholme and Dundas formations compare with both the Arctic Bay and Society Cliffs formations of Baffin Island (Fig. 7; Hofmann and Jackson, 1994, Fig. 4).

Dawes and coworkers (Dawes et al., 1982; Dawes, in press) regarded the Bylot Supergroup and lower Thule Group as of similar age, the two basins to be separate, and Thule strata to represent a much longer period of time. Jackson and coworkers (Jackson and Iannelli, 1981; Jackson et al., 1985; Jackson, 1986, in press) considered that Thule and Bylot strata are probably correlative, that the two basins were interconnected during at least one stage, and that they were likely deposited in the same sedimentary basin as the Aston and Hunting formations on Somerset Island.

The Thule Basin is interpreted by Dawes et al. (1982) and Dawes (in press) as a "multicycle, polyhistory, interior fracture basin" formed in response to divergent plate movements as depicted by Kingston et al. (1983). It is characterized by syndepositional, mostly WNW-trending block faulting, subsidence, and basin sagging. Jackson and co-workers (Jackson and Iannelli, 1981; Galley et al., 1983; Jackson et al., 1985; Jackson, 1986) concluded that the Thule, Borden (aulacogen of Olson, 1977), and other penecontemporaneous Mesoproterozoic basins, that extend for 3200 km from the northern Cordillera to northern East Greenland along the northwestern edge of the Canadian-Greenland Shield, developed in response to rifting. The latter accompanied the opening of the Middle Proterozoic Poseidon Ocean and probably some separation of Greenland from Canada. Recent U-Pb baddeleyite ages for mafic rocks (e.g. LeCheminant and Heaman, 1991) support early basin formation and ocean opening at about 1270 Ma.

PREVIOUS MICROPALEONTOLOGICAL STUDIES

Acritarchs were reported from fine grained siliciclastic units throughout the Thule Basin of northwestern Greenland, but no descriptions or illustrations accompany the reports (Vidal and Dawes, 1980; Dawes and Vidal, 1985). Strother et al. (1983) analyzed thin sections of black carbonaceous cherts from the Aorfêrneq Member (Narssârssuq Formation) in a small area just south of the Thule/Pituffik air base, and described and illustrated 19 taxa occurring in four distinct microbial associations and one allochthonous assemblage. Table 1 summarizes previous taxonomic data. Based on the acritarch assemblage, a Neoproterozoic (late Riphean to early Vendian) age for the middle to upper parts of the Wolstenholme Formation and the Dundas Formation was suggested, and an early Vendian age for the Narssârssuq Formation. More recent data from the probably coeval Bylot Supergroup, including U-Pb radiometric dating (LeCheminant and Heaman, 1991), indicate that certain acritarchs may have ranges extending further back in time than previously thought (Hofmann and Jackson, 1994), into the late Mesoproterozoic. The chertified Narssârssuq microbiota is more indicative of a restricted paleoenvironmental setting (intertidal to supratidal, hypersaline) than it is of age.

METHOD OF STUDY

The microfossils in the present study were obtained by maceration, using HCl and HF on samples of about 30-50 g of rock (see Hofmann and Jackson, 1994 for description of procedure). The residues were washed, dried, and mounted on glass slides, which were systematically scanned at 250x, except for fine fractions which were scanned at 400x. Specimens of interest were further examined at 1000x, and photographed, chiefly at 500x.

DISCUSSION

A synopsis of the results is given in Figure 7, and details of the occurrences in the Appendix. Figures 1 and 2 show the geographic and stratigraphic positions of the fossiliferous samples under study.

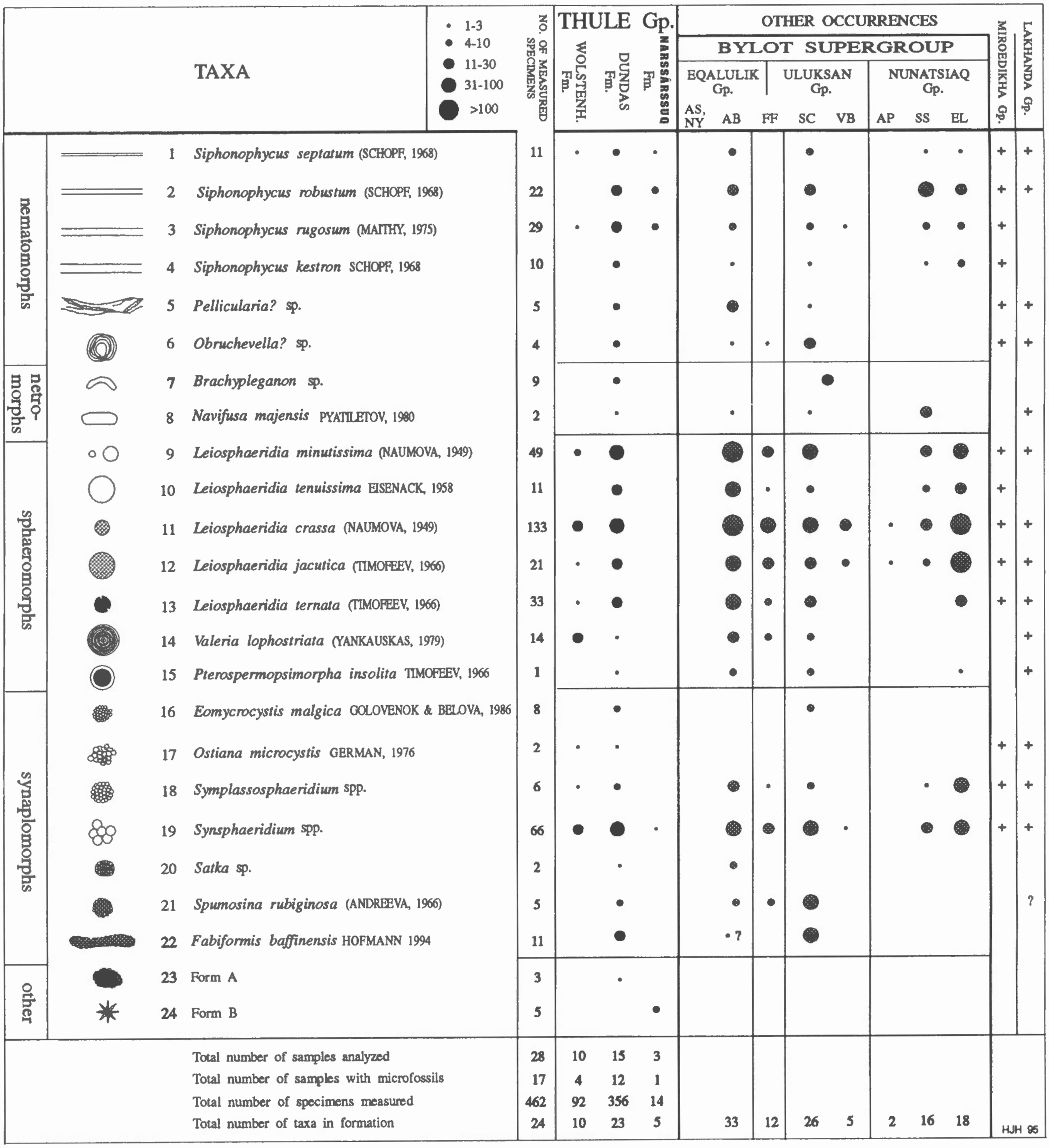


Figure 7. Synopsis of data of present study, compared with data from presumed coeval sequences. Data for Bylot Supergroup, and Lakhanda and Miroedikha formations (Siberia) extracted from Hofmann and Jackson (1994, Fig. 4). The cross-hatched circle for Brachypleganon *in the column for the Uluksan Group refers to specimens in a probable clast of Society Cliffs Formation within the Victor Bay Formation (sample G in Hofmann and Jackson, 1991, p. 363).*

Table 1. Previous reports of Thule Group microfossils.

	TAXON	Source		Unit			
1	*Chuaria circularis* Walcott	V80	D85		W	D	
2	*Kildinella hyperboreica* Timofeev	V80			W	D	
3	*Kildinella sinica* Timofeev	V80			W	D	
4	*Kildinella* n.sp.	V80			W	D	
5	*Kildinella* spp.	V80				D	
6	*Kildinosphaera chagrinata* Vidal		D85		W	D	N
7	*Kildinosphaera granulata* Vidal		D85		W	D	
8	*Kildinosphaera lophostriata* (Yankauskas) Vidal		D85		W	D	
9	*Kildinosphaera verrucata* Vidal		D85		W		
10	*Leiosphaeridia asperata* (Naumova) Lindgren		D85		W	D	N
11	*'Peteinosphaeridium'* sp. (= *Vandalosphaeridium varangeri* Vidal)	V80	D85			D	N
12	*Protosphaeridium laccatum* Timofeev	V80				D	
13	*Satka colonialica* Yankauskas		D85		W	D	N
14	cf. *Stictosphaeridium* sp.	V80	D85		W	D	
15	cf. *Stictosphaeridium* spp.		D85		W		
16	*Symplassosphaeridium* sp.	V80			W		
17	*Synsphaeridium* sp.	V80	D85		W	D	N
18	*Tasmanites rifeicus* Yankauskas		D85		W	D	
19	*Trachysphaeridium* sp.	V80	D85		W		
20	*Trachysphaeridium* spp.	V80	D85		W	D	
21	*Trachysphaeridium timofeevi* Vidal	V80			W	D	
22	*Trematosphaeridium holtedahlii* Timofeev	V80				D	
23	Acanthomorph-like acritarch	V80				D	
24	Filamentous microfossils	V80	D85			D	N
25	Organic remains	V80	D85	R		D	N
26	*Avictuspirulina minuta* Strother et al.	S83					N
27	Chroococcoid Type A	S83					N
28	Chroococcoid Type B	S83					N
29	*Coleogleba auctifica* Strother et al.	S83					N
30	*Eoentophysalis* cf. *belcherensis* Hofmann	S83					N
31	*Eomycetopsis robusta* (Schopf)	S83					N
32	*Eosynechococcus amadeus* Knoll and Golubic	S83					N
33	*Eosynechococcus thuleensis* Strother et al.	S83					N
34	*Gloeodiniopsis* cf. *lamellosa* Schopf em. Knoll & Golubic	S83					N
35	*Gyalosphaera fluitans* Strother et al.	S83					N
36	*Myxococcoides* sp.	S83					N
37	*Oscillatoriopsis variabilis* Strother et al.	S83					N
38	*Siphonophycus kestron* Schopf	S83					N
39	*Siphonophycus* sp.	S83					N
40	*Sphaerophycus parvum* Schopf	S83					N
41	Spheroid Type A	S83					N
42	Spheroid Type B	S83					N
43	*Tenuofilum septatum* Schopf em. Knoll & Golubic	S83					N
44	*Tetraphycus* sp.	S83					N

Names of stratigraphic units and fossils as given in the original publications.
V80 = Vidal and Dawes (1980); S83 = Strother et al. (1983); D85 = Dawes and Vidal (1985)
R = Rensselaer Bay Fm.; W = Wolstenholme Fm.; D = Dundas Fm.; N = Narssârssuq Fm.

NOTE - These stratigraphic names are revised in Dawes (in press) as follows:
the Thule Group is raised to supergroup status; the Rensselaer Bay Formation is redefined and placed in the Smith Sound Group, a basin margin and platform sequence; strata formerly assigned to the Wolstenholme Formation are placed in the new Nares Strait Group and the Baffin Bay Group that make up the central basin sequence, and a new Wolstenholme Formation is defined within the Baffin Bay Group; the Dundas and Narssârssuq formations are each raised to group status.

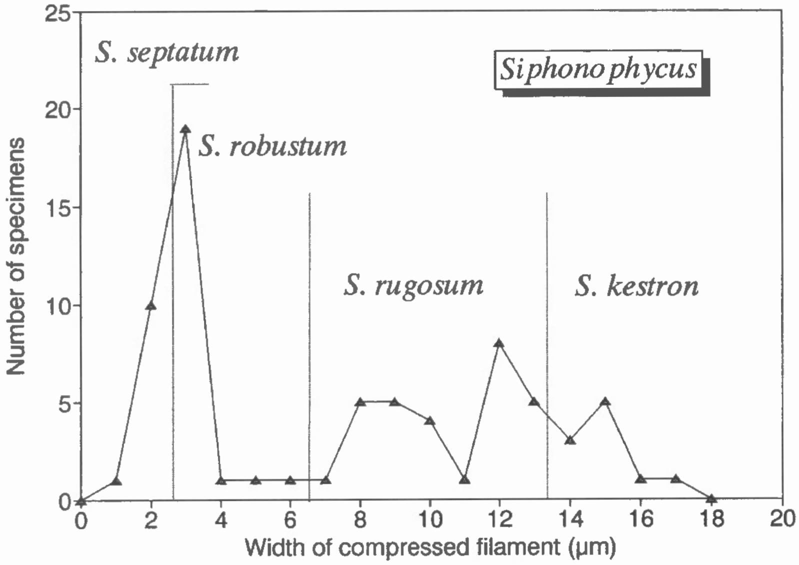


Figure 8.

Size distribution of filamentous taxa assigned to Siphonophycus*; species limits same as in Hofmann and Jackson (1994, Fig. 10).*

The microfossil assemblages recovered by maceration collectively comprise 22 species of organic-walled microfossils that include nematomorphs, netromorphs, sphaeromorphs, and synaplomorphs; two taxa are microdubiofossils. The microbiotas (Fig. 7) are dominated by cosmopolitan and long-ranging, planktonic leiosphaerids, with diameters of flattened cells ranging from 3 to more than 345 µm, the largest fragment observed. Filamentous forms are also widespread, but less abundant than the leiosphaerids.

Criteria used for paleobiological interpretations of similar material from Precambrian units (such as cell size, morphology, and similarity with Phanerozoic forms) indicate that the microfossils may include both procaryotes (cyanobacteria and other eubacteria) and eucaryotes (algae, and possibly fungi). However, such attributions to high level biological taxa are speculative due to the commonly inconclusive nature of the evidence, although cyanobacterial affinity of the nematomorphs is usually accepted.

The data tabulated in Figure 7 show 20 species of shale-facies microfossils in common between formations of the Thule Group and the Bylot Supergroup. The mostly generalized and long-ranging taxa in the Wolstenholme and Dundas formations compare best with those in rocks of similar facies in the Arctic Bay and Society Cliffs formations of Baffin Island, where the taxonomic diversity, however, is much greater (see Fig. 4 in Hofmann and Jackson, 1994), and specimens are better preserved. Comparison with shale-facies microfossils previously reported from the Thule Group (Vidal and Dawes, 1980; Dawes and Vidal, 1985) are not made, given the lack of descriptions and illustrations supporting the identifications in those preliminary reports.

The microbiotas reported here provide little support for dating the Thule units paleontologically, due to the absence of age-diagnostic taxa. The assemblages represent accumulation from source populations of widely distributed, simple spheroidal and filamentous photosynthesizers.

CONCLUSION

Fine grained siliciclastic sediments of the Thule Group, accumulated in shelf, shelf-margin, and basinal environments, have yielded microbiotas collectively comprising 22 generalized spheroidal and tubular types of widespread distribution and long stratigraphic range within the Meso- and Neoproterozoic. Though more depauperate, the assemblage of the Wolstenholme and Dundas formations contain about half the taxa known from units considered correlative in the lower and middle parts of the Bylot Supergroup on Baffin Island (On the basis of microfossil composition, the Dundas Formation most closely resembles both the Arctic Bay and Society Cliffs formations). As described more fully above, on lithostratigraphic grounds the Wolstenholme Formation correlates with the Nauyat and Adams Sound formations, the Dundas with the Arctic Bay, and the Narssârssuk with the Society Cliffs, Victor Bay and part of the Strathcona Sound formations. Consideration of the regional geology, lithostratigraphic correlations, available geochronology, and paleomagnetic data suggests that the Thule microbiotas are probably late Mesoproterozoic.

PALEONTOLOGY

The taxonomy of the most ancient organic-walled microfossils (acritarchs and cryptarchs) is still in a state of flux, despite recent progress in synthesizing large volumes of data (Yankauskas et al., 1989; Fensome et al., 1990; Mendelson et al., 1992; Mendelson and Schopf, 1992); some serious problems remain to be resolved. Although the affinities of most of the microbiota probably lie with the Cyanobacteria, particularly the filamentous and small spheroidal forms, evidence is not always conclusive as to the specific metabolic pathways utilized by the microbes. Therefore, as in our previous study (Hofmann and Jackson, 1994), we here basically follow morphological schemes proposed by Downie et al. (1963) for the Group Acritarcha (Evitt, 1963), and transferred by Diver and Peat (1979) to their Group Cryptarcha. The remains belong to the following subgroups, given in the order in which they are presented in this paper: filamentous forms (nematomorphs), long ellipsoid to rod-shaped forms (netromorphs), simple spheroids and short ellipsoids (sphaeromorphs), and spheroids and ellipsoids associated in globular aggregates (synaplomorphs).

All specimens illustrated in this paper are deposited in the National Type Fossil Collection at the Geological Survey of Canada in Ottawa, catalogued under the numbers 111204-111255. They are mounted on glass slides and can be relocated using the co-ordinates cited in the figure captions. The co-ordinates refer to orthogonal distances (in mm) from the upper (distal) right reference corner formed by the intersection of the distal (x = 0) and right (y = 0) edges of the slide, with the label positioned on the right.

NEMATOMORPHITAE Diver and Peat, 1979

Genus *Siphonophycus* Schopf, 1968, emend. Knoll, Swett, and Mark, 1991

Description. Fragmentary compressed, unbranched, tubular microfossils, nonseptate, without taper, commonly folded or wrinkled, and occurring in tangled aggregates; wall smooth; diameters (width of compressed specimens) polymodally distributed between 1 and 17 µm (Fig. 8).

Comments. Knoll et al. (1991) emended *Siphonophycus* to include two other genera of aseptate tubular microfossils (*Eomycetopsis* and *Tenuofilum*) originally recognized by Schopf (1968), as well as *Leiothrichoides* German. We here follow their practice and assign all our nonseptate filaments to *Siphonophycus*, and the species on the basis of the size limits given in Hofmann and Jackson (1994). The genus is cosmopolitan and ranges through all of the Proterozoic, and is commonly interpreted as representing cyanobacterial sheaths. The size distribution of the Thule *Siphonophycus* is different from that in the Borden Basin on Baffin Island (Hofmann and Jackson, 1994, Fig. 10) in that the latter contains filaments up to 37 µm, but the predominance of 2-4 µm filaments over other sizes is similar.

Siphonophycus septatum (Schopf, 1968) Knoll, Swett, and Mark, 1991

Figure 9 L (partim)

Tenuofilum septatum SCHOPF, 1968, p. 679, Pl. 86, fig. 10-12, Table 3; HOFMANN AND JACKSON, 1991, p. 367, Fig. 6 (partim), 7.1, 7.2 (see for further synonymy).

cf. *Archaeotrichion* spp. (partim) HORODYSKI, 1980, p. 656, Pl. 1, fig. 8.

Siphonophycus septatum (Schopf) KNOLL, SWETT, AND MARK, 1991, p. 565, Fig. 10.2; HOFMANN AND JACKSON, 1994, p. 10. Fig. 10, 11.1-11.4.

Comments. This is the species with the smallest filament width in the Thule assemblage: 1-2 µm (n=11); it occurs as individuals as well as bunched or tangled aggregates.

Siphonophycus robustum (Schopf, 1968) Knoll, Swett, and Mark, 1991

Figure 9 A, B

Eomycetopsis robusta SCHOPF, 1968, p. 685, Pl. 82, fig. 2, 3, Pl. 83, Fig. 1-4; HOFMANN AND JACKSON, 1991, p. 367-368, Fig. 5.1-5.3, 5.8, 6 (partim), 7.3, 7.4 (see for further synonymy).

Siphonophycus crassiusculum HORODYSKI, 1980, p. 656, Pl. 1, fig. 6,7; Text-fig. 6A.

Siphonophycus robustum (Schopf) KNOLL, SWETT, AND MARK, 1991, p. 585, Fig. 10.3, 10.5; HOFMANN AND JACKSON, 1994, p. 10, Fig. 10, 11.5.

Comments. With an observed size range between 2.5 and 6.0 µm (N = 22), this is a common species of *Siphonophycus* in the Thule Supergroup and probably represents detritus derived from benthic microbial mats.

Siphonophycus rugosum (Maithy, 1975) Hofmann and Jackson, 1994

Figure 9 C, D

Eomycetopsis rugosa MAITHY, 1975, p. 140, Pl. 4, fig. 25, 26.

Siphonophycus beltensis HORODYSKI, 1980, p. 654, 656, Pl. 1, fig. 4, Text-fig. 6B.

Siphonophycus inornatum ZHANG, 1981, p. 491-493, Pl. 1, fig. 1, 3-5; HOFMANN AND JACKSON, 1991, p. 368, Fig. 5.4, 5.6, 6 (partim) (see for further synonymy).

Siphonophycus rugosum (Maithy) HOFMANN AND JACKSON, 1994, p. 10, Fig. 10, 11.6, 11.7.

Comments. This is a common *Siphonophycus* species in the assemblage, with a size ranging from 7 to 13 µm (N = 29; Fig. 8). The combination *Siphonophycus rugosum* was intoduced by Hofmann and Jackson (1994) to include the type assemblage of *Eomycetopsis rugosum* from the Bushimay Group (Maithy, 1975) as well as the type assemblage of *S. beltense*, described from compressed specimens in thin sections (Horodyski, 1980).

Siphonophycus kestron Schopf, 1968

Figure 9 E

Siphonophycus kestron SCHOPF, 1968, p. 671, Pl. 80, fig. 1-3, Table 5; HOFMANN AND JACKSON, 1991, p. 368, fig. 5.9, 5.10, 6 (partim) (see for further synonymy); 1994, p. 12, Fig. 11.8, 11.9.

Comments. Filaments with diameters in the range of 14-17 µm. As for other species of *Siphonophycus* in the assemblage, this species probably represents mostly detrital microbial mat material.

Genus *Pellicularia* Yankauskas, 1980

Pellicularia? sp.

Figure 9 F

Description. Large ribbon-like films with rugose, crumpled surface, twisted and bent; some specimens slightly tapering, with parallel, irregular, branching, or intersecting longitudinal folds. Ends broken off; fragments up to 0.5 mm long, 9-18 µm wide (N = 5).

Comments. These microfossils may represent deformed tubular sheaths. They appear to be more degraded than material assigned to *Pellicularia tenera* from the Bylot Supergroup.

Genus *Obruchevella* Reitlinger, 1948

Obruchevella? sp.

Figure 9 G-I

Description. Compressed microfossils with subcircular outline, 48-77 µm across (mean = 61.0 µm; N = 4), with more or less concentric lighter and darker bands uniformly 3-10 µm wide, central portion missing.

Comments. The real shape of the structures is not clear; they may be coiled filaments like *Obruchevella*, or flattened spheroids. Unlike specimens from the Bylot Supergroup (Hofmann and Jackson, 1994) that show transitional shapes from wound-up filaments to concentrically coiled forms, our material does not clearly demonstrate a curled, filamentous nature, and thus the generic assignment remains questionable. The forms resemble the "spiromorphs" in the Upper Vendian Blueflower Formation of the Mackenzie Mountains of northwestern Canada (Baudet et al., 1989, Pl. 2, fig. 20-25), and the unnamed specimen from the Vendian Baykibashev Formation in Bashkiria, illustrated by Yankauskas (in Keller, 1982, p. 93, Pl. fig. 22/6), later attributed to *Toromorpha* sp. (Yankauskas in Sokolov and Ivanovskiy, 1985, Pl. 61, fig. 4; Sokolov and Iwanowski, 1990, Pl. 61, fig. 4). Other possible examples for comparison are the *Dictyosphaeridium*? sp.

Figure 9. *Nematomorphs, netromorphs, and sphaeromorphs from Thule Basin. Magnifications for A-M shown by scale below B; part N has its own scale. For locality information, see Appendix; formation indicated in brackets following locality number: D = Dundas, N = Narssârssuk. GSC refers to National Type Fossil Collection, Geological Survey of Canada, Ottawa; x-y coordinates refer to distances (in mm) from the top (distal) right reference corner formed by the intersection of the top (distal) (x = 0) and right (y = 0) edges of the slide, with the label positioned on the right.*

A. *Siphonophycus robustum* (Schopf)
Loc. 11 [D], GSC 111204, 42.1 x- 7.8 y;

B. *Siphonophycus robustum* (Schopf)
Loc. 26 [N], GSC 111205, 45.9 x-18.8 y;

C. *Siphonophycus rugosum* (Maithy)
Loc. 17 [D], GSC 111206, 61.6 x- 7.6 y;

D. *Siphonophycus rugosum* (Maithy)
Loc. 12 [D], GSC 111207, 53.0 x-14.2 y;

E. *Siphonophycus kestron* (Schopf)
Loc. 11 [D], GSC 111208, 46.0 x- 7.5 y;

F. *Pellicularia?* sp.
Loc. 16 [D], GSC 111209, 71.8 x- 4.2 y;

G. *Obruchevella?* sp.
Loc. 17 [D], GSC 111210, 53.0 x- 3.3 y;

H. *Obruchevella?* sp.
Loc. 21 [D], GSC 111211, 65.8 x- 6.5 y;

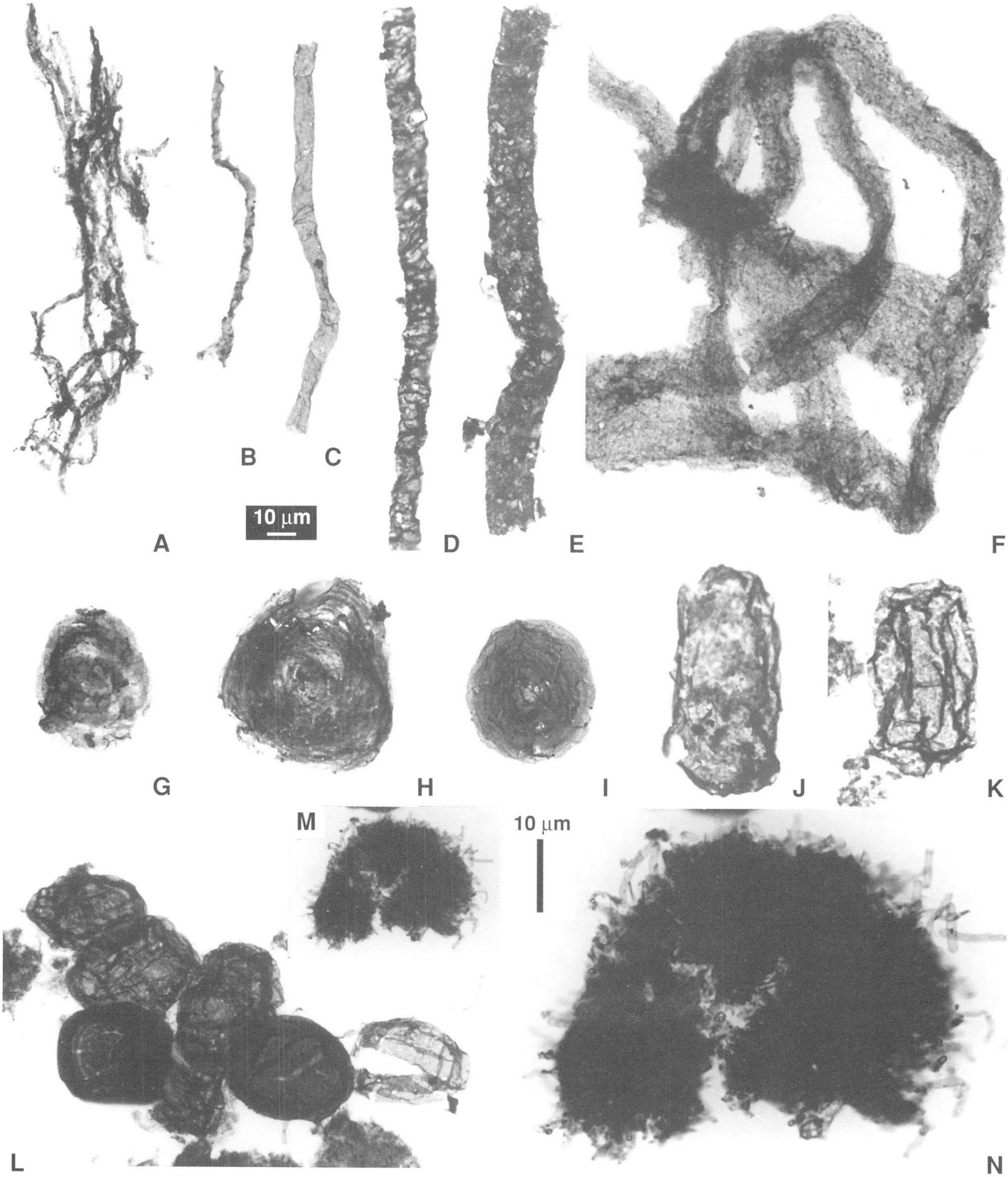
I. *Obruchevella?* sp.
Loc. 17 [D], GSC 111212, 52.4 x- 6.2 y;

J. *Navifusa majensis* Pyatiletov
Loc. 17 [D], GSC 111213, 56.5 x- 7.8 y;

K. *Navifusa majensis* Pyatiletov
Loc. 15 [D], GSC 111214, 40.8 x- 6.5 y;

L. *Siphonophycus septatum* (Schopf):
Loc. 15 [D], GSC 111215, 73.0 x-18.9 y;
(filaments)
Leiosphaeridia crassa (Naumov)
Loc. 15 [D], GSC 111216, 73.0 x-18.9 y;
(dark spheroids)
Leiosphaeridia minutissima (Naumov)
Loc. 15 [D], GSC 111217, 73.0 x-18.9 y;
(light spheroid)

M, N. *Brachypleganon* sp.
Loc. 21 [D], GSC 111218, 50.7 x-11.1 y



A
B
C
D
E
F
10 μm
G
H
I
J
K
L
M
10 μm
N

from the Vendian Volhyn Series of the Russian Platform (Shepeleva, 1974, p. 18, Pl. 4, fig. 4), and the *Spiromorpha* sp. reported by Vidal (1981, p. 39, Fig. 19, G,H) from the Vendian Dakkovarre Formation of northern Norway.

NETROMORPHITAE Downie, Evitt, and Sarjeant, 1963

Genus *Brachypleganon* Lo, 1980

Brachypleganon sp.

Figures 9 M, N, 10

Description. Short nonseptate rods, thin-walled, straight to curved, ends rounded, isolated or in loose clusters, 5.5-10.0 µm long, 1.0-2.5 µm wide (mean = 7.5 x 1.4 µm, N = 9).

Comments. The structures are similar to forms in the Society Cliffs Formation (Hofmann and Jackson, 1991, p. 368) and *Brachypleganon khandanum* in the Yudoma Group (Lo, 1980, p. 156), but are generally shorter and narrower than both of these forms (Fig. 10). In cell shape they resemble several modern rod-like bacteria such as *Rhodospirillum* as well as *Rhabdoderma*-like cyanobacteria.

Genus *Navifusa* Combaz, Lange, and Pansart, 1967

Navifusa majensis Pyatiletov, 1980a

Figure 9 J, K

Navifusa majensis PYATILETOV, 1980a, p. 144, fig. 1a-e; PYATILETOV, 1988, Pl. 1, fig. 7-9; HOFMANN AND JACKSON, 1994, p. 20, fig. 15.1-15.4.

Brevitrichoides bashkiricus YANKAUSKAS, 1980, p. 111, Pl. 12, fig. 4-6; YANKAUSKAS in Keller, 1982, p. 118, Pl. 37, fig. 10-12, 16, 17; YANKAUSKAS, MIKHAYLOVA, AND GERMAN, 1989, p. 102, Pl. 21, fig. 1? *Leiovalia tenera* PYATILETOV, 1986, Pl. 5, fig. 4.

Description. Short, cylindrical, nonseptate, smooth-walled vesicles with closed round tips, solitary; dimensions of two flattened specimens are 68 x 39 µm and 80 x 36 µm.

Comments. The taxonomy of the genera *Brevitrichoides* and *Navifusa* was discussed by Hofmann and Jackson (1994), who attributed similar fossils from the Bylot Supergroup on Baffin Island to *Navifusa majensis*. This species is also known from the Upper Riphean Zilmerdak Formation of the Urals foreland in Bashkiria (Yankauskas, 1980).

SPHAEROMORPHITAE Downie, Evitt, and Sarjeant, 1963

Genus *Leiosphaeridia* Eisenack, 1958 emend. Downie and Sarjeant, 1963, emend.

Turner, 1984

For synonymy and discussions, see Yankauskas et al. (1989) and Fensome et al. (1990).

Comments. Leiosphaerids are simple, usually flattened organic-walled spheroids with sizes ranging from a few micrometres to several hundred micrometres. They are the commonest microfossils in Proterozoic shale facies microbiotas, with species that are mainly differentiated on the basis of size, thickness of vesicle, and surface sculpture (texture). Their taxonomy is problematic. We follow here the taxonomy used by Hofmann and Jackson (1994), which is based on the revisions of Fensome et al. (1990) and Yankauskas et al. (1989, p. 24-25).

The Thule Basin leiosphaerids are isolated flattened spheroids ranging from 3 to 350 µm in diameter (Fig. 11), and thus extend to sizes resolvable by the unaided human eye. In all, five species of *Leiosphaeridia* were recognized in the Thule Group; all occur also in the Bylot Supergroup.

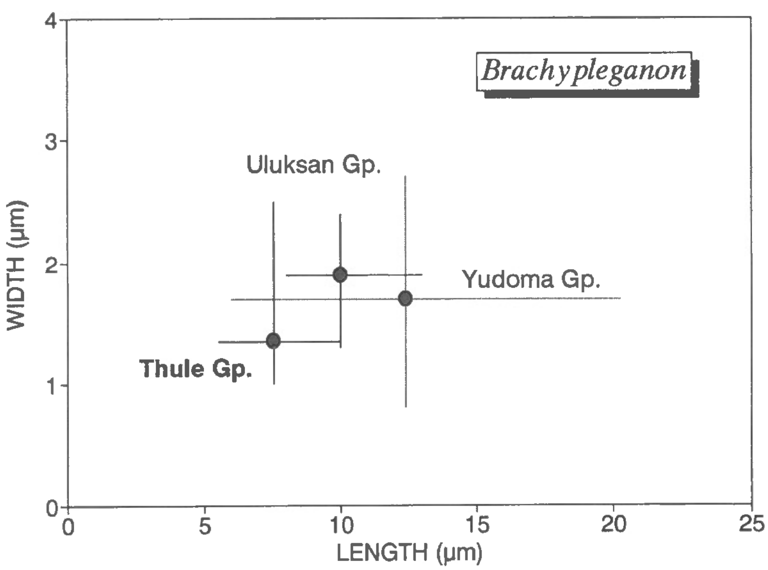


Figure 10.

Size distribution of Brachypleganon *specimens from the Thule Group, and Baffin Island (Uluksan Group; Hofmann and Jackson, 1991) and Siberia (Yudoma Group; Lo, 1980); circles represent means, ranges displayed as orthogonal lines.*

Leiosphaeridia minutissima (Naumova, 1949) emend. Yankauskas, 1989

Figures 9 L (partim), 11, 12 A-C

Leiotriletes minutissimus NAUMOVA, 1949, p. 52-53, Pl. 1, fig. 1-2, Pl. 2, fig. 1-2.

Leiosphaeridia minutissima (Naumova) YANKAUSKAS, in Yankauskas, Mikhaylova, and German, 1989, p. 79-80, Pl. 9, fig. 1-4, 11 (see for further synonymy); HOFMANN AND JACKSON, 1994, p. 21, Fig. 15.9-15.15, 16.

Leiosphaeridia riphiana FENSOME, WILLIAMS, BARSS, FREEMAN, AND HILL, 1990, p. 284.

Description. Simple, compressed, thin-walled, spheroidal vesicles with smooth surface, and commonly with rectilinear or curvilinear folds. Diameters ranging from 6 to 69 µm (with bimodal distribution; N = 47). Some specimens with internal small, round, optically dense organic body.

Comments. Leiosphaeridia minutissima is a cosmopolitan and long-ranging species common in samples from the Thule Basin.

Leiosphaeridia tenuissima Eisenack, 1958

Figures 11, 12 E

Leiosphaeridia tenuissima EISENACK, 1958, p. 391-392, Pl. 1, fig. 2,3; YANKAUSKAS, MIKHAYLOVA, AND GERMAN, 1989, p. 81, Pl. 9, fig. 12, 13 (see for further synonymy); HOFMANN AND JACKSON, 1994, p. 22, Fig. 15.16-15.18, 16.

Description. Simple, compressed, thin-walled, spheroidal vesicles with smooth surface, and rectilinear or curvilinear folds. Diameters ranging from 74 to 345 µm (mean = 124.8 ± 85.9 µm; N = 11).

Comments. This is a long-ranging, cosmopolitan species.

Leiosphaeridia crassa (Naumova, 1949) emend. Yankauskas, 1989 Figures 9 L (partim), 11, 12 D, F-H

Leiotriletes crassus NAUMOVA, 1949, p. 54, Pl. 1, fig. 5,6, Pl. 2, fig. 5,6.

Leiosphaeridia crassa (Naumova) YANKAUSKAS in Yankauskas, Mikhaylova, and German, 1989, p. 75-76, Pl. 9, fig. 5-10 (see for further synonymy); HOFMANN AND JACKSON, 1994, p. 22, Fig. 13.3, 15.19-15.29, 16.

Description. Simple, compressed, thick-walled, spheroidal vesicles with smooth surface, and rectilinear or curvilinear folds. Diameters ranging from 3 to 69 µm (mean = 33.6 ± 16.9 µm; N = 133). Some specimens with internal small, round, optically dense organic body, others with medial split.

Comments. This is the most abundant microfossil species within the Thule Group.

Leiosphaeridia jacutica (Timofeev, 1966) emend. Mikhaylova and Yankauskas, 1989

Figures 11, 12 L, M

Kildinella jacutica TIMOFEEV, 1966, p. 30, Pl. 7, fig. 2.

Leiosphaeridia jacutica (Timofeev) MIKHAYLOVA AND YANKAUSKAS in Yankauskas, Mikhaylova, and German, 1989, p. 77-78, Pl. 12, fig. 3a,b, 7, 9 (see for further synonymy); HOFMANN AND JACKSON, 1994, p. 22, Fig. 16, 17.1-17.4.

Description. Compressed, thick-walled, spheroidal vesicles with smooth surface and rectilinear to curvilinear folds. Diameters 72-196 µm (mean = 103.9 ± 37.7 µm; N = 21).

Comments. The circumscription of the species as emended in Yankauskas et al. (1989) includes several specimens that had previously been described under *Chuaria circularis*. As mentioned in Hofmann and Jackson (1994), the lower size limit of *Chuaria* at 1 mm is artificial. Several specimens > 250 µm

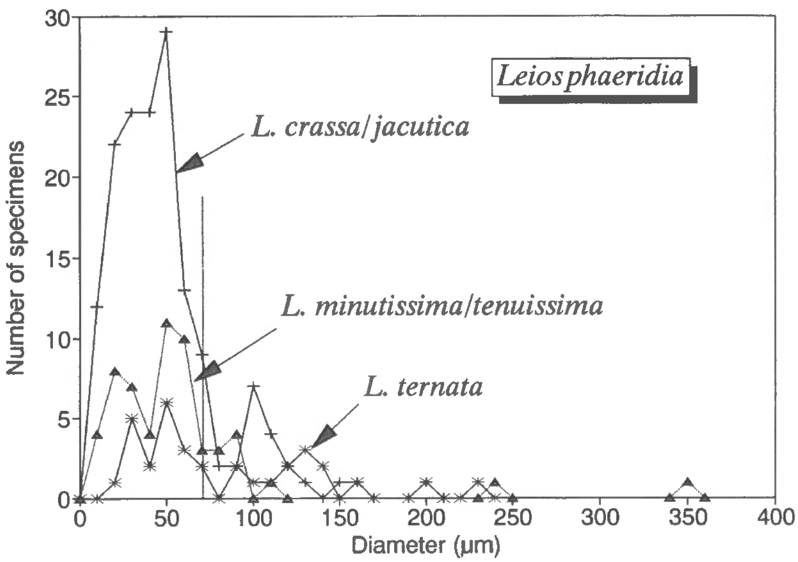


Figure 11.

Size distribution of sphaeromorph acritarchs in present collection; assignment to five species of Leiosphaeridia *is based on three levels of optical density of vesicle, and limiting diameter of 70 µm (vertical line) which separates* L. crassa *(< 70 µm) from* L. jacutica *(> 70 µm). and* L. minutissima *(< 70 µm) from* L. tenvissima *(< 70 µm).*

could be accommodated under *Chuaria circularis*, but are here considered to be the tail end of a distribution whose mode and mean lie well below this value and are thus included in *L. jacutica*.

Leiosphaeridia jacutica, a common constituent of Neoproterozoic microbiotas, is somewhat less abundant in the Thule samples than in formations in the Borden Basin.

Leiosphaeridia ternata (Timofeev, 1966) emend. Mikhaylova and Yankauskas, 1989

Figures 11, 12 I, J

Turuchanica ternata TIMOFEEV, 1966, p. 45, Pl. 9, fig. 8.

Leiosphaeridia ternata (Timofeev) MIKHAYLOVA AND YANKAUSKAS in Yankauskas, Mikhaylova, and German, 1989, p. 81, Pl. 11, fig. 2-4, Pl. 12, fig. 4, 5, 8 (see for further synonymy); HOFMANN AND JACKSON, 1991, p. 22, Fig. 17.8-17.9.

Description. Compressed, opaque to nearly opaque spheroids with very thick walls; compressed vesicles with radially oriented, acutely angled clefts. Diameter of compressed specimens ranging between 18 and 228 mm (mean = 76.6 ± 51.9 µm; N = 33).

Comments. This is a common constituent in the Thule samples. The thick walls are ruptured in compacted specimens to form the radial, acute-angled splits; little compressed specimens lack splits and have a smooth surface.

Genus *Valeria* Yankauskas, 1982

Valeria lophostriata (Yankauskas, 1979) Yankauskas, 1982

Figure 12 N-P

Kildinella lophostriata YANKAUSKAS, 1979, p. 192 (p. 53 in English version), Fig. 1.13-15; VOLKOVA, 1981, p. 71, Pl. 2, fig. 8a,b; VIDAL, 1981, p. 49, 50.

Agidelia reta PYATILETOV AND KARLOVA, 1980, p. 63, 65, 126, Pl. 2, fig. 11.

Agidelia lophostriata PYATILETOV, 1980c, p. 74, Pl. 5, fig. 1,2.

Valeria lophostriata YANKAUSKAS in Keller, 1982, p. 109-110, Pl. 39, fig. 2; SHENFIL', DIDENKO, KARLOVA, AND PYATILETOV, 1982, p. 67, Pl. 3, fig. 1,2; YANKAUSKAS, MIKHAYLOVA, AND GERMAN, 1989, p. 86, Pl. 16, fig. 1-5; BUTTERFIELD AND CHANDLER, 1992, p. 948-949, Text-fig. 5 A,B; HOFMANN AND JACKSON, 1994, p. 24, Fig. 17.14-17.15, 19.4.

Kildinosphaera lophostriata VIDAL AND SIEDLECKA, 1983, p. 59-61, Fig. 6A-G; VIDAL AND KNOLL, 1983, Fig. 1 D, E; VIDAL AND FORD, 1985, p. 361-363, 384, Fig. 4C, E, F.

? *Trachysphaeridium rugosum* var. *giganteum* XING et al., 1985 (partim), p. 51, Pl. 8, fig. 25; non Pl. 5, fig. 16.

Figure 12. *Sphaeromorphs from Thule Basin. Abbreviations same as for Figure 9. Magnifications for A-N shown in E, for O-P in P.*

A. *Leiosphaeridia minutissima* (Naumova) Loc. 17 [D], GSC 111219, 57.5 x- 9.2 y;

B. *Leiosphaeridia minutissima* (Naumova) Loc. 17 [D], GSC 111220, 43.2 x- 8.0 y;

C. *Leiosphaeridia minutissima* (Naumova) Loc. 16 [D], GSC 111221, 68.7 x- 4.5 y;

D. *Leiosphaeridia crassa* (Naumova) Loc. 15 [D], GSC 111222, 36.0 x- 8.9 y;

E. *Leiosphaeridia tenuissima* Eisenack Loc. 16 [D], GSC 111223, 51.9 x- 3.9 y;

F. *Leiosphaeridia crassa* (Naumova) Loc. 11 [D], GSC 111224, 44.1 x-18.0 y;

G. *Leiosphaeridia crassa* (Naumova) Loc. 12 [D], GSC 111225, 65.7 x- 7.6 y;

H. *Leiosphaeridia crassa* (Naumova) Loc. 15 [D], GSC 111226, 64.5 x- 9.8 y;

I. *Leiosphaeridia ternata* (Timofeev) Loc. 17 [D], GSC 111227, 57.7 x-10.7 y;

J. *Leiosphaeridia ternata* (Timofeev) Loc. 17 [D], GSC 111228, 64.2 x-13.1 y;

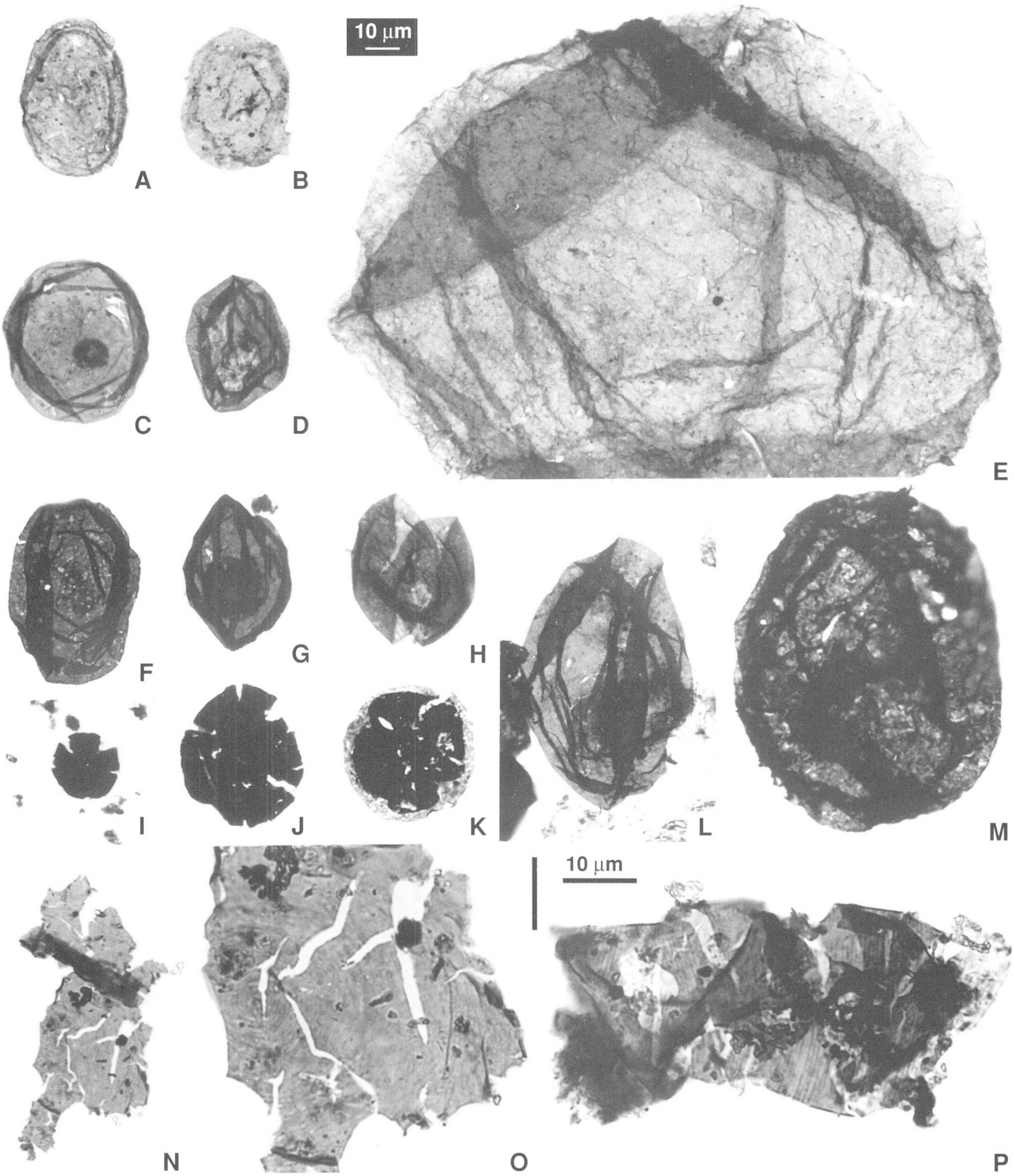
K. *Pterospermopsimorpha insolita* Timofeev Loc. 17 [D], GSC 111229, 53.0 x- 9.9 y;

L. *Leiosphaeridia jacutica* (Timofeev) Loc. 16 [D], GSC 111230, 60.0 x-14.1 y;

M. *Leiosphaeridia jacutica* (Timofeev) Loc. 17 [D], GSC 111231, 61.1 x-11.3 y;

N,O. *Valeria lophostriata* (Yankauskas) Loc. 9 [W], GSC 111232, 41.4 x- 3.1 y;

P. *Valeria lophostriata* (Yankauskas) Loc. 9 [W], GSC 111233, 69.2 x- 9.3 y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Description. Fragments of large, medium-walled flattened spheroids with distinct, narrow folds, ornamented with fine, parallel, very closely and evenly spaced, concentric (or possibly planispiral) striations resembling fingerprints or grooves of a phonograph record; maximum dimension of fragments 35-153 µm (N=14); striations uniformly about 0.9 µm wide, about 1 µm apart. Fragments crossed by tapering splits up to several micrometres wide.

Comments. This is a readily recognizable taxon in Proterozoic acritarch assemblages due to its striking and distinct ornamentation. The specimens in the present assemblage are all fragmentary and the fragments are commonly crossed by several cracks. These cracks are post-depositional and appear to control the shape of the fragments, suggesting strong desiccation of the vesicle wall, possibly as a result of contact with the atmosphere along a strand line. The species is known from at least 18 widely separated localities in North America and Eurasia, with dimensions in the range of 55-450 µm, and was previously known from the Thule Group (Dawes and Vidal, 1985), as well as from the correlative Fury and Hecla, Eqalulik, and Uluksan Groups of western Baffin Island (Butterfield and Chandler, 1992; Hofmann and Jackson, 1994).

Genus *Pterospermopsimorpha* Timofeev, 19696 emend. Mikhaylova and Yankauskas,1989

Pterospermopsimorpha insolita Timofeev, 1969 emend. Mikhaylova, 1989

Figure 12 K

Pterospermopsimorpha insolita TIMOFEEV, 1969, p. 16-17, Pl. 3, fig. 8; MIKHAYLOVA, in Yankauskas et al., 1989, p. 49, Pl. 3, fig. 5, 6; HOFMANN AND JACKSON, 1994, p. 24, Fig. 17-10-17.13.

Pterospermopsimorpha wolynica KIRJANOV, 1974, p. 234-235 [English version], Pl. 8, fig. 7, 8.

? *Nucellosphaeridium zonatum* MAITHY, 1975, p. 144, Pl. 6, fig. 48.

***Figure 13. Sphaeromorphs and incertae sedis. Abbreviations same as in Figure 9. Magnification shown by** scale in R.*

A. *Eomicrocystis malgica* Golov. & Bel.
Loc. 17 [D], GSC 111234, 42.8 x-11.6 y;

B. *Eomicrocystis malgica* Golov. & Bel.
Loc. 17 [D], GSC 111235, 41.2 x-12.7 y;

C. *Symplassosphaeridium* sp.
Loc. 6 [W], GSC 111236, 63.4 x-10.2 y;

D. *Synsphaeridium* sp.
Loc. 6 [W], GSC 111237, 52.4 x- 7.5 y;

E. *Synsphaeridium* sp.
Loc. 17 [D], GSC 111238, 49.0 x-10.5 y;

F. *Synsphaeridium* sp.
Loc. 6 [W], GSC 111239, 40.5 x-20.8 y;

G. *Synsphaeridium* sp.
Loc. 17 [D], GSC 111240, 43.4 x-16.1 y;

H. *Synsphaeridium* sp.
Loc. 12 [D], GSC 111241, 62.3 x-14.8 y;

I. *Ostiana microcystis* German [Hermann]
Loc. 6 [W], GSC 111242, 43.4 x- 7.7 y;

J. *Ostiana microcystis* German [Hermann]
Loc. 17 [D], GSC 111243, 51.5 x- 5.2 y;

K. *Satka* sp.
Loc. 15 [D], GSC 111244, 55.0 x-15.5 y;

L. *Satka* sp.
Loc. 16 [D], GSC 111245, 61.0 x-15.5 y;

M. *Spumosina rubiginosa* (Andreeva)
Loc. 12 [D], GSC 111246, 37.6 x- 9.9 y;

N. *Spumosina rubiginosa* (Andreeva)
Loc. 12 [D], GSC 111247, 54.0 x-18.4 y;

O. *Fabiformis baffinensis* Hofmann
Loc. 12 [D], GSC 111248, 46.5 x- 9.5 y;

P. *Fabiformis baffinensis* Hofmann
Loc. 17 [D], GSC 111249, 61.2 x- 4.0 y;

Q. *Fabiformis baffinensis* Hofmann
Loc. 12 [D], GSC 111250, 50.2 x-15.4 y;

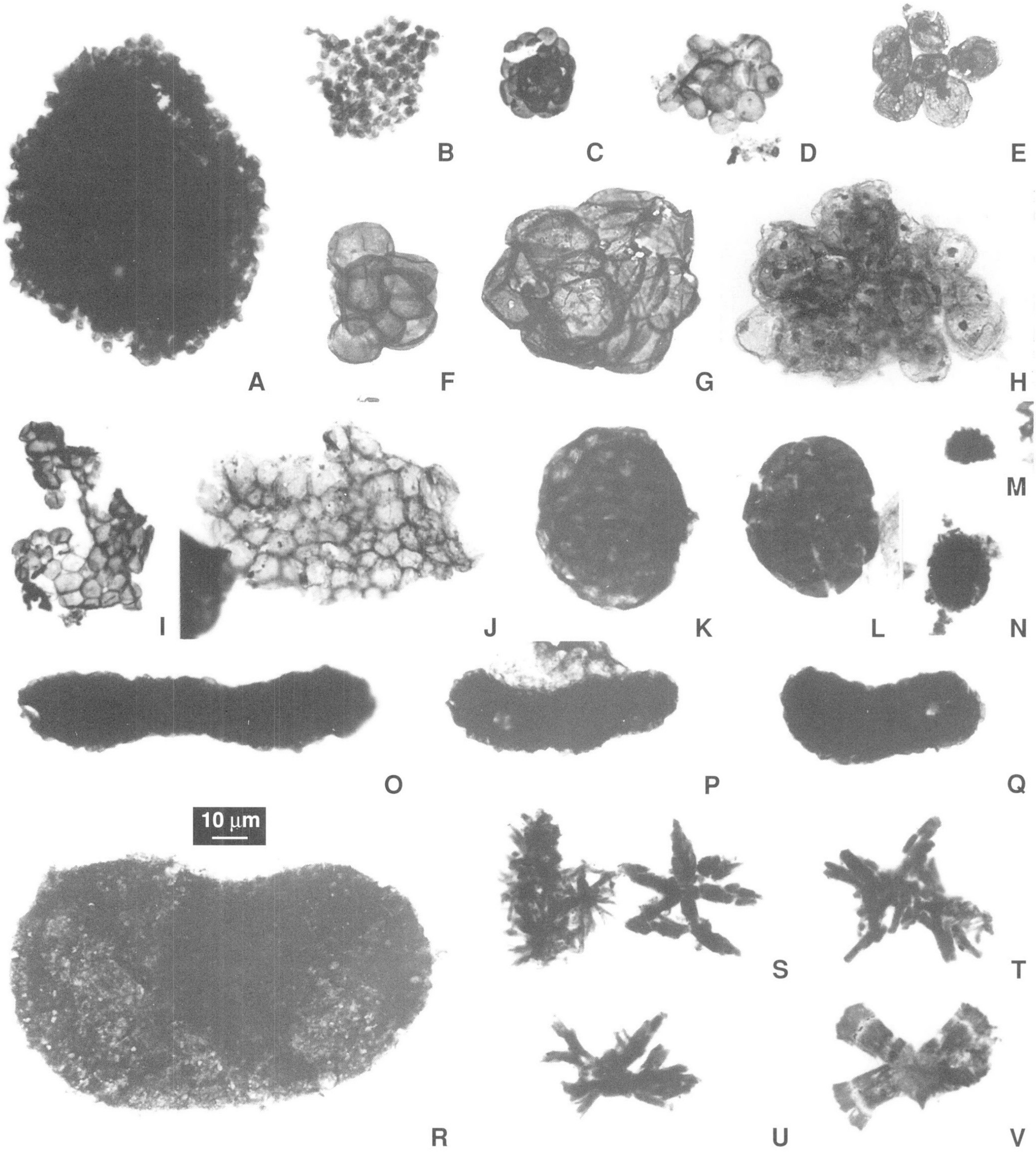
R. Form A
Loc. 15 [D], GSC 111251, 67.0 x-19.0 y;

S. Form B, acicular aggregates
Loc. 26 [N], GSC 111252, 65.6 x- 8.1 y;

T. Form B, acicular aggregates
Loc. 26 [N], GSC 111253, 43.9 x-10.7 y;

U. Form B, acicular aggregates
Loc. 26 [N], GSC 111254, 69.1 x-12.0 y;

V. Form B, acicular aggregates
Loc. 26 [N], GSC 111255, 53.4 x-12.3 y



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? Pterospermopsimorpha pileiformis PYATILETOV, 1980b, Fig. 11, 12, 14.

Pterospermopsimorpha capsulata YANKAUSKAS in Keller, 1982, p. 101, Pl. 41, fig. 6, 8; PYATILETOV, 1988, Pl. 6, fig. 3, 4.

Description. Single specimen of spheroidal microfossil composed of two flattened spheroids of contrasting transparency and slightly differing diameters, arranged concentrically; inner disk dark, almost opaque, with or without folds, more than 2/3 diameter of outer body (envelope) which is optically less dense and has no ornamentation. Outer diameter 48 x 48 µm, inner spheroid 42 x 39 µm.

Comments. In the most recent monographic treatment of the genus, Yankauskas et al. (1989) recognized only 5 species based mainly on the sculpture of the envelope. Our material with a smooth envelope best fits the concept of *P. insolita*.

SYNAPLOMORPHITAE Diver and Peat, 1979

Genus *Eomicrocystis* Golovenok and Belova, 1984

Eomicrocystis malgica Golovenok and Belova, 1986

Figure 13 A, B

Eomicrocystis malgica GOLOVENOK AND BELOVA, 1986, p. 95-96 (English translation, p. 89), Pl. 7, fig. 5-7; YANKAUSKAS, MIKHAYLOVA, AND GERMAN, 1989, Pl. 19, fig. 7, HOFMANN AND JACKSON, 1994, p. 25, Fig. 18.5-18.7.

Description. Round to irregular clusters of loosely packed, flattened, globoidal cells of uniform size; clusters 15-108 µm across (mean = 59.6 µm; N = 8), without apparent envelope; dimensions of flattened cells between 3 and 4 µm.

Comments. The loose clustering and the round shape of some colonies suggest that the cells were embedded in a mucilaginous matrix when alive. The species has previously been reported from the Middle Riphean Malgin Formation in the Uchur-Maya region of eastern Siberia where it occurs as three-dimensionally preserved spheroidal colonies (Golovenok and Belova, 1986), and from the Borden Basin (Hofmann and Jackson, 1994).

Genus *Ostiana* German, 1976

Ostiana microcystis German, 1976

Figure 13 I, J

Ostiana microcystis GERMAN, in Timofeev et al., 1976, p. 43-44, Pl. 12, fig. 5, 6, 8, Pl. 17, fig. 8; YANKAUSKAS, MIKHAYLOVA, AND GERMAN, 1989, p. 83, Pl. 14, fig. 1, 2, 6; BUTTERFIELD, KNOLL, AND SWETT, 1994, p. 74, Fig. 5F-I.

Ostiana TIMOFEEV AND GERMAN, 1979, Pl. 25, fig. 1-4.

Ostiania [sic] *microcystis* PYATILETOV, 1988, p. 54, 61, Pl. 9, fig. 11.

Description. Irregular aggregates (fragments; N=2) of 1-cell-layer-thick, sheet-like colonies of closely packed, compressed spheroidal cells; each cell 5-10 µm across.

Comments. The cell dimensions of the Thule specimens are similar to those in material originally described from the Miroedikha and Lakhanda formations in Siberia (7-10 µm; Timofeev and German, 1976), but smaller than specimens reported later from the Lakhanda Formation (15-25 µm as measured in Fig. 11 of Pyatiletov, 1988) and the Svanbjergfellet Formation of Spitsbergen (11-27 mm, Butterfield et al., 1994, p. 74). Small clusters of only a few cells are difficult to assign to this taxon, as they look also like *Synsphaeridium* specimens, and such clusters are here referred to the latter. *Ostiana microcystis* may be more abundant in the assemblage than indicated, because only large fragments, in which a monolayered structure is readily demonstrated, were assigned to this taxon.

Genus *Symplassosphaeridium* Timofeev, 1959 ex Timofeev, 1969

Symplassosphaeridium sp.

Figure 13 C

Description. Isolated, compact, globular aggregates of small spheroidal cells; compressed aggregates 19-44 µm across (mean = 33.7 mm; N = 6); flattened cells 6-12 mm across (mean = 7.7 µm); spheroids smooth, most with few or no folds; light brown to dark brown.

Comments. This is another cosmopolitan genus with a long stratigraphic range, from the Paleoproterozoic into the Paleozoic.

Genus *Synsphaeridium* Eisenack, 1965

Synsphaeridium spp.

Figure 13 D-H

Description. Irregular, nonlinear aggregates composed of a few or many flattened, contiguous, spheroidal vesicles with smooth walls and commonly with folds; some specimens with internal opaque body several micrometres across; diameter of compressed vesicles generally uniform within each aggregate, observed size 15-105 µm (mean = 50.1 ± 22.4 µm, N = 49 aggregates), though some colonies contain cells of various sizes, 3-35 µm (mean = 14.5 ± 6.7 µm).

Comments. Following the practice of Yankauskas et al. (1989), and of most other authors, the fossils are left in open nomenclature. As mentioned under *Ostiana*, many of the clusters with few cells here assigned to *Synsphaeridium* may be fragments of *Ostiana*.

Genus *Satka* Yankauskas, 1979

Satka sp.

Figure 13 K, L

Description. Collapsed elliptical bodies; 2 specimens with dimensions of 64 x 45 µm and 62 x 52 µm, consisting of network of contiguous, angulate, cellular compartments with dimensions of 15 and 11 µm, respectively.

Comments. The specimen illustrated in Figure 13K resembles *Satka squamifera*, a species common in the lower part of the Bylot Supergroup.

Genus *Spumosina* Naumova, 1968 emend. Yankauskas and Medvedeva, 1989

Spumosina rubiginosa (Andreeva, 1966) Yankauskas and Medvedeva, 1989

Figures 13 M, N, 14

Orygmatosphaeridium rubiginosum ANDREEVA, 1966, p. 126, Pl. 3, fig. 3-6.

For synonymy, see Hofmann and Jackson (1994, p. 30).

Description. Dark to semitransparent, kerogenous, discoidal masses with spongy appearance; peripheral region slightly more transparent than central portion; aggregates 17-40 µm across (mean = 27.6 µm, N = 6) (left side of Fig. 14); outline circular to slightly ovate or elliptical. Spongy appearance due to cell-like elements that are uniformly about 3-4 µm across.

Comments. Microfossils of this type have previously been reported under a variety of names, mainly from rocks of Late Riphean and Vendian age, but also in the Mesoproterozoic Bylot Supergroup (Hofmann and Jackson, 1994).

As with the Bylot specimens, it is of interest to note that the spongy structure of *Spumosina rubiginosa* is comparable to that of the co-occurring *Fabiformis baffinensis*, which is characterized by elongate shapes. However, the size distribution of each taxon is distinct, as shown in Figure 14.

Genus *Fabiformis* Pyatiletov, 1988

Fabiformis baffinensis Hofmann, in Hofmann and Jackson, 1994

Figures 13 O-Q, 14

Description. Short to slender, rod-like, club-like, or curved, dark, dense, parallel-sided, kerogenous masses of spongy appearance; outline uneven to granular at high magnification, without distinct envelope; margins more translucent in most thicker specimens; ends semicircular; most specimens elongate and slightly curved, some more irregular; long dimensions 60-120 µm, width 18-42 µm (mean = 92 x 27 µm; N = 11); length-to-width ratios from 1.7 to 5.8 (mean = 3.7; N = 11); structures composed of compact aggregates of spheroidal to ellipsoidal units uniformly about 2.5 µm across, seen most clearly at uneven margins.

Comments. Specimens are slightly smaller than those in the Bylot Supergroup on Baffin Island, the only other known occurrence of the species. The elongate masses are aggregates of cells, most likely coccoid bacterial colonies, possibly in an amorphous matrix reminiscent of the modern *Zoogloea*. The colonies appear to be composed of the same kind of micrometric organism that built spheroidal colonies described under *Spumosina*, and the two genera may represent different habits of aggregation assumed by a bacterium , as suggested by Hofmann and Jackson (1994).

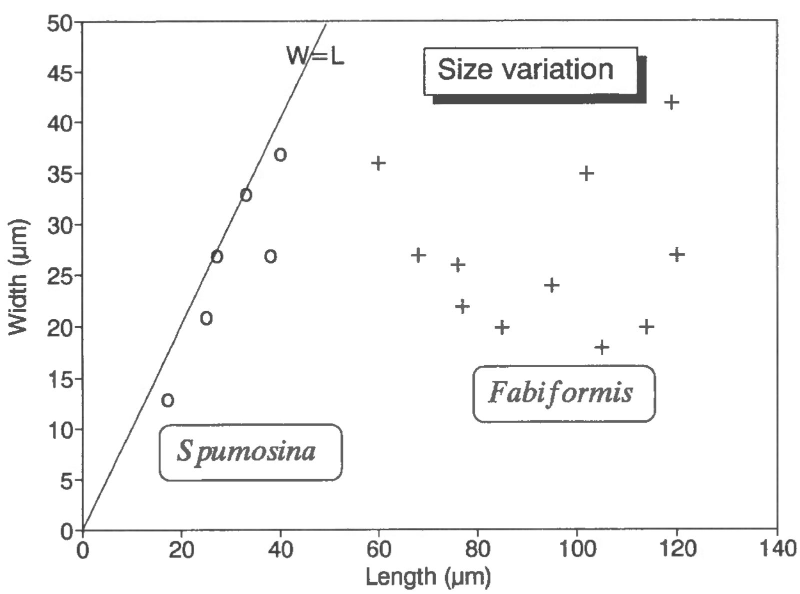

Figure 14.

Size distribution of aggregates of minute spheroids assigned to Spumosina *and* Fabiformis.

Other remains

Form A

Figure 13 R

Description. Round carbonaceous films with granulose texture, dimensions up to 12x70 μm (N = 3).

Comments. These nondescript round films appear to be similar to the somewhat larger pear-shaped and ovate remains illustrated from the Derlov Formation of Podolia, also of undetermined affinities (Yankauskas et al., 1989, Pl. 50, fig. 8).

Form B

Figure 13 S-V

Description. Loose stellate aggregates 25-60 μm across (N=5), comprising a series of individual radiating, rodlike packets 3-4 μm wide, 5-13 μm long, each composed of filamentous or tapering acicular elements 0.5-1.5 μm wide.

Comments. The origin and affinity of these structures is enigmatic. They somewhat resemble organic coatings on Paleoproterozoic aragonite fans (e.g. Hofmann and Jackson, 1987, Fig. 4B), as well as the problematic aggregates of spinose forms described by Timofeev et al. (1976, Pl. 24, fig. 13, 14) from the Vendian Derlov Formation in Podolia (Ukraine).

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APPENDIX

Sample information

Locality	GSC Field No.	Micro-fossils	Stratigraphy old	Stratigraphy Dawes (in press)	Envrion-ment	Geographic area	Latitude north	Longitude west	Lithology[1]
1	CB 61-1-33/2		W 3	NS Nu	2	Gale Point	78.212	75.556	bn gy sts
2	FS 77-123		W 2	NS Jh sg	1	Goding Bay	78.017	76.136	dk bn gy lam ironst ss
3	82 JD 16/ 6B		W 2	NS Cc ek	1	Goding Bay	78.017	76.135	dk gy sts
4	82 JD 16/18		W 2	NS Cc ek	1	Goding Bay	78.017	76.135	dk gn gy mudst
5	CB 61-1-42/4		W 2	NS Cc ek	1	Goding Bay	78.014	76.138	dk gn gy mudst
6	CB 61-3-17/3	*	W 5	BB Gb pb	3	Goding Bay	77.986	76.021	med to fi gr lt olive gy ss, micaceous
7	82 JD 11/ 7	*	W 5	BB Gb pb	3	Goding Bay	77.991	76.056	med gy vy fi gr ss, micaceous
8	82 JD 11/ 8	*	W 5	BB Gb pb	3	Goding Bay	77.991	76.056	med gy med to fi gr ss with shaly partings
9	CB 61-3- 5/3	*	W 5	BB Gb pb	3	Goding Bay	77.969	75.875	gn gy lam fi gr ss
10	FS 77-120		W 5	BB Gb tr	3	Clarence Head	76.803	77.807	dk bn gy lam ironst ss
11	82 JD 36/ 1	*	D	D	4	Dundas Mtn.	76.563	68.871	dk gy lam shaly fi gr ss, micaceous, nod
12	82 JD 36/ 3	*	D	D	4	Dundas Mtn.	76.563	68.871	dk gy lam shaly fi gr ss/sts
13	82 JD 36/ 4	*	D	D	4	Dundas Mtn.	76.563	68.871	dk gy fi gr ss, lam with shaly seams, micaceous
14	82 JD 36/ 5	*	D	D	4	Dundas Mtn.	76.563	68.872	dk gy shaly fi gr ss, micaceous
15	82 JD 36/ 6	*	D	D	4	Dundas Mtn.	76.562	68.872	bk phos? vy fi gr ss
16	82 JD 36/ 7	*	D	D	4	Dundas Mtn.	76.562	68.872	fi gr gn gy ss with bk sh lam
17	82 JD 36/ 8	*	D	D	4	Dundas Mtn.	76.562	68.873	dk gy sts
18	82 JD 36/ 9		D	D	4	Dundas Mtn.	76.562	68.873	gn gy fi gr ss/sts w olive sh stringers
19	82 JD 36/10	*	D	D	4	Dundas Mtn.	76.561	68.873	gn gy fi gr ss w dk gy sh lay & clasts, syneresis cracks
20	82 JD 36/13	*	D	D	4	Dundas Mtn.	76.561	68.874	fi gr med gy arg ss, like locality 25
21	82 JD 36/14	*	D	D	4	Dundas Mtn.	76.561	68.874	gn gy fi gr ss w sh partings
22	82 JD 36/16	*	D	D	4	Dundas Mtn.	76.561	68.874	dk gy mudst
23	82 JD 36/17		D	D	4	Dundas Mtn.	76.560	68.875	gn gy lam fi gr ss
24	82 JD 36/18		D	D	4	Dundas Mtn.	76.560	68.875	fi gr olive gy ss, lam
25	82 JD 36/20	*	D	D	4	Dundas Mtn.	76.560	68.875	fi gr med gy arg ss/sts
26	82 JD 31/14	*	N	N Im	5	Aorfêmeq Dal	76.551	68.959	ss/sts, gn gy, fi gr, micaceous
27	82 JD 33/10		N	N Ao	6	Aorfêmeq Dal	76.491	69.016	med gy shy fi gr ss
28	82 JD 34/14		N	N Bs	5	Aorfêmeq Dal	76.486	69.038	olive gy mudst

Key: * - microfossils present

ENVIRONMENTS (numbered in approximate order of development):
1 - Prodelta to offshore in localized basins partially restricted by plateau basalt flows, on siliciclastic shelf margin
2 - Intertidal to supratidal and alluvial plains, on siliciclastic shelf
3 - Prodelta and offshore semirestricted basin, on siliciclastic shelf
4 - Transgressive semirestricted intertidal to subtidal turbiditic muddy shelf and basin
5 - Low energy protected intertidal to subtidal environment in a semiarid to arid climate (sabkha deposits), on carbonate shelf margin
6 - Intertidal to subtidal stable carbonate shelf in a semiarid to arid environment (evaporites)

STRATIGRAPHY

Old terminology (Dawes et al., 1982)	New terminology (only sampled units are listed; Dawes, in press)
N = Narssârssuk Fm.	N = Narssârssuk Gp.
ur = upper red mem.	Bs = Bylot Sound Fm.
ao = Aofêmeq mem.	Ao = Aofêmeq Fm.
lr = lower red mem.	Im = Imilik Fm.
D = Dundas Fm.	D = Dundas Gp.
W = Wolstenholme Fm.	BB = Baffin Bay Gp.
unit 6	
unit 5	Gb = Goding Bay Fm.
	tr = Troelsen mem.
	pb = Paine Bluff mem.
	NS = Nares Strait Gp.
unit 4	
unit 3	Jh = Josephine Headland Fm.
	sg = Sparks Glacier mem.
unit 2	Cc = Cape Combermere Fm.
	ek = Ekblaw mem.
unit 1	Nu = Northumberland Fm.

[1]ABBREVIATIONS

w	=	with	fi	=	fine	arg	=	argillaceous
bk	=	black	med	=	medium	ironst	=	ironstone
bn	=	brown	gr	=	grained	mdst	=	mudstone
gn	=	green	vy	=	very	phos?	=	phosphatic?
gy	=	grey	lam	=	laminated/laminae	sh	=	shale
dk	=	dark	lay	=	layers	shy	=	shaly
lt	=	light	nod	=	nodular	ss	=	sandstone
						sts	=	siltstone