GRØNLANDS GEOLOGISKE UNDERSØGELSE
RAPPORT Nr. 78

The Geological Survey of Greenland
Report No. 78

Late Precambrian acritarchs from the Eleonore Bay Group and Tillite Group in East Greenland

A preliminary report

by

Gonzalo Vidal

KØBENHAVN 1976

Grønlands Geologiske Undersøgelse
(The Geological Survey of Greenland)
Øster Voldgade 10, DK-1350 Copenhagen K

Reports

No. 55 Report of activities, 1972. 1973. D.kr. 18.00

No. 56 A survey of the economic geology of Greenland (exclusive fossil fuels). 1973 *by* B. Leth Nielsen. D.kr. 12.00

No. 57 Structural and lithological divisions of the western border of the East Greenland Caledonides in the Scoresby Sund region between 71°00′ and 71°22′ N. 1973 *by* P. Homewood. D.kr. 10.00

No. 58 Report on the 1972 geological expedition to Scoresby Sund. East Greenland. 1973. D.kr. 20.00

No. 59 Radiocarbon dated shell samples from Nordre Strømfjord, West Greenland, with comments on models of glacio-isostatic uplift. 1973 *by* M. Kelly. D.kr. 7.00

No. 60 The uranium deposit at Kvanefjeld, the Ilímaussaq intrusion, South Greenland. Geology, reserves and benefication. 1974 *by* H. Sørensen *et al.* D.kr. 25.00

No. 61 The Precambrian geology of the Túngarnit nunât area, outer Nordre Strømfjord, central West Greenland. 1974 *by* J. Winter. D.kr. 8.00

No. 62 A dynamic model for a meniscus filled tunnel (*Ancorichnus* n. ichnogen.) from the Jurassic *Pecten* Sandstone of Milne Land, East Greenland. 1974 *by* C. Heinberg. D.kr. 9.00

No. 63 Offshore geology of northern West Greenland (69° to 75° N). 1974 *by* L. R. Denham. D.kr. 15.00

No. 64 The pollen stratigraphy of late Quaternary lake sediments of South-West Greenland. 1974 *by* M. Kelly & S. Funder. D.kr. 15.00

No. 65 Report of activities, 1973. 1974. D.kr. 21.00

No. 66 Geochronological studies in Greenland. 1974. D.kr. 19.00

No. 67 The Krummedal supracrustal sequence around inner Nordvestfjord, Scoresby Sund, East Greenland. 1974 *by* A. K. Higgins. D.kr. 19.00

No. 68 Estimates on the mass balance changes of the Inland Ice since Wisconsin-Weichsel. 1975. *by* A. Weidick. D.kr. 12.00

No. 69 Results of geological and geophysical work in central West Greenland in 1972. 1975. D.kr. 20.00

No. 70 Quaternary geology of the area between Frederikshåbs Isblink and Ameralik. 1975 *by* A. Weidick. D.kr. 12.00

No. 71 Mineralogy and geochemistry of two Amîtsoq gneisses from the Godthåb region, West Greenland. 1975 *by* B. Mason. D.kr. 6.00

No. 72 Tension structures related to gliding tectonics in the Caledonian superstructure of Canning Land and Wegener Halvø, central East Greenland. 1976 *by* R. Caby.

No. 73 Second progress report on the geology of the Fiskenæsset region, South-West Greenland. 1976. D.kr. 45.00

No. 74 Igneous stratigraphy of Archaean anorthosite at Majorqap qâva, near Fiskenæsset, South-West Greenland. 1975 *by* J. S. Myers. D.kr. 12.00

No. 75 Report of activities, 1974. 1975. D.kr. 38.00

No. 76 Radiometric survey between Scoresby Sund and Hold with Hope, central East Greenland. 1976 *by* B. Leth Nielsen & L. Løvborg.

No. 77 West Greenland coal deposits, distribution and petrography. 1976 *by* E. J. Schiener.

No. 78 Late Precambrian acritarchs from the Eleonore Bay Group and Tillite Group in East Greenland. A preliminary report. 1976 *by* G. Vidal.

GRØNLANDS GEOLOGISKE UNDERSØGELSE
RAPPORT Nr. 78

Late Precambrian acritarchs from the Eleonore Bay Group and Tillite Group in East Greenland

A preliminary report

by

Gonzalo Vidal

1976

Abstract

Thirty-five samples from the late Precambrian Eleonore Bay Group and Tillite Group in the Caledonian fold belt in East Greenland were investigated for acid-resistant microfossils. Eleven samples yielded acritarchs. As a rule the state of preservation of the recovered acritarchs is poor, as a result of slight metamorphism. Within the Eleonore Bay Group, identifiable acritarchs were recovered from four samples from the Limestone–Dolomite series, one sample from the Multicoloured series, one sample from the upper Quartzite series, two samples from the lower Quartzite series and one sample from the Argillaceous–Arenaceous series. Relatively well preserved acritarchs occur in two samples from the slightly disconformably overlying Tillite Group.

Some of the acritarchs recovered have a wide geographic distribution and apparently a narrow stratigraphic range in the upper Precambrian. Preliminary results indicate a Late Riphean age for the uppermost Eleonore Bay Group (Limestone-Dolomite series and Multicoloured series) and a Vendian age for at least the lower investigated parts of the Tillite Group.

Author's address:
New Zealand Geological Survey,
P.O.Box 30368, Lower Hutt,
New Zealand.

CONTENTS

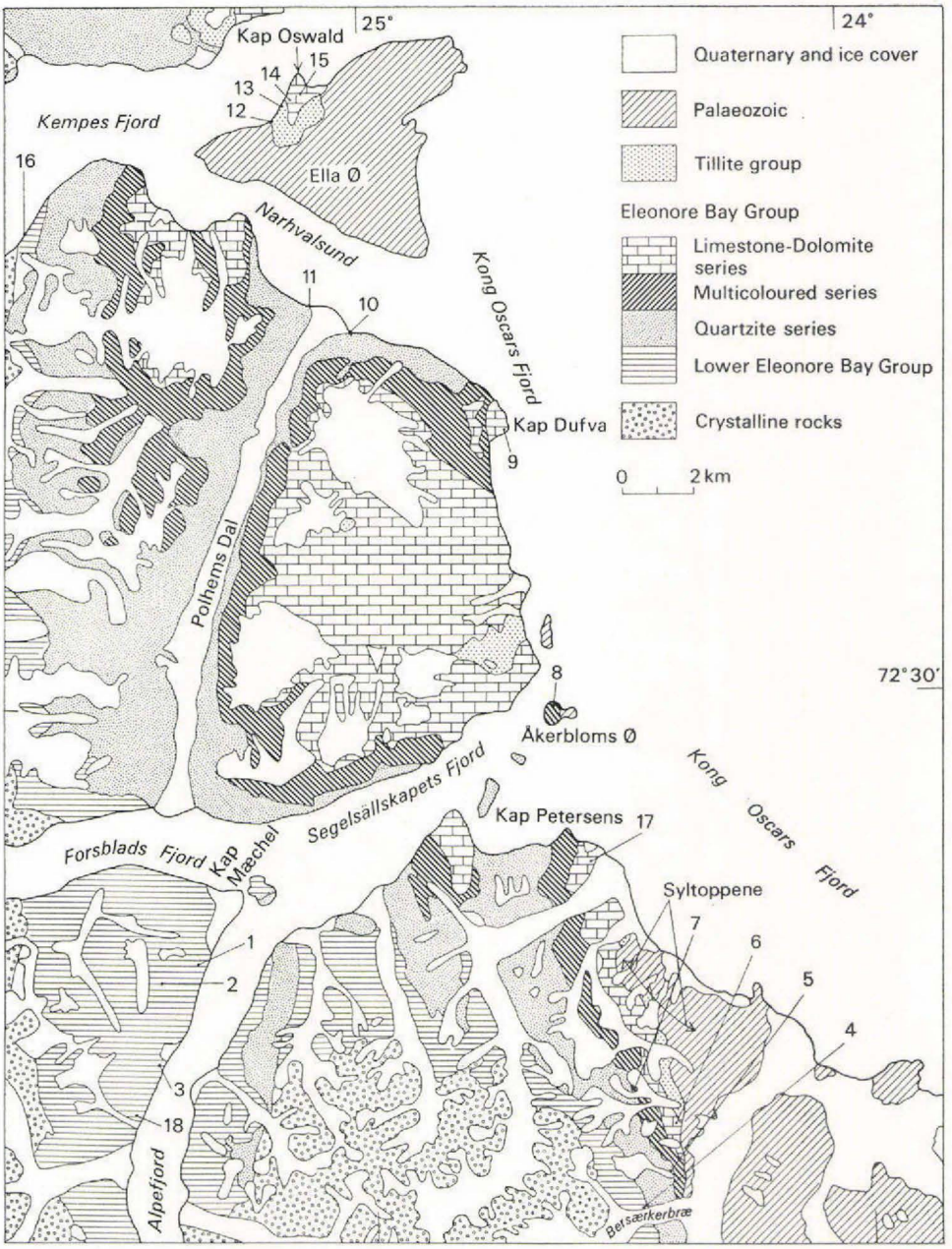


Fig. 1. Simplified geological map of the Kong Oscars Fjord region, showing the distribution of the investigated rock units (after Koch & Haller, 1971). The figures in the map indicate the location of sampled localities as follows: *1* GGU 136604; *2* GGU 142335; *3* GGU 142322; *4* GGU 136552, 136553, 136555; *5* GGU 136564; *6* GGU 136578; *7* GGU 142301, 142302, 142305, 142308; *8* samples G–1 to 5; *9* sample GA–1; *10* sample GB–1; *11* samples GC–1, 2; *12* samples GD–4, 5; *13* sample GD–3; *14* sample GD–2; *15* samples GD–1, 6; *16* sample G–6; *17* GGU 142343, 142339, 142340; *18* GGU 142315.

INTRODUCTION

The East Greenland Caledonian fold belt extends from latitudes 70°–82° N in East Greenland occupying most of the ice-free stretch between the coast and the Inland Ice. In central East Greenland the metamorphic crystalline complexes which form much of the fold belt are bordered to the east by thick successions of sedimentary rocks of late Precambrian to early Palaeozoic age. These rocks exhibit major folding with generally N–S axial trends, and towards the contacts with the metamorphic complexes show slight metamorphism. Regional descriptions of the fold belt are given in Haller (1971) and Henriksen & Higgins (1976), and the region between 72–76° N, from which most of the investigated samples derive, is covered by 1 : 250 000 geological maps (Koch & Haller, 1971).

The major part of the Caledonian geosynclinal sequence is made up of the upper Precambrian Eleonore Bay Group, whose thickness locally reaches up to 13 000 m, and which is divided from the top to bottom into the following series: Limestone–Dolomite series, Multicoloured series, Quartzite series, Upper Argillaceous–Arenaceous series, Calc–Argillaceous series, Lower Arenaceous–Argillaceous series, Basal series (Haller, 1971). The Eleonore Bay Group is overlain with slight disconformity by the Tillite Group, which contains a number of tillitic levels usually correlated with the widespread Eocambrian or Varangian (i.e. Vendian) glacial event. The Tillite Group is overlain, again usually with slight disconformity, by Cambro-Ordovician strata.

Thirty-five rock samples from the Eleonore Bay Group and Tillite Group were processed in order to make a preliminary investigation of acid-resistant microfossils. Seventeen samples were collected for this purpose from central East Greenland (fig. 1) during the summers 1971 and 1972 by Christian Hjort and Leif Bjelm of the Department of Quaternary Geology, University of Lund. A further 18 samples collected in the same general region were provided subsequently by A. K. Higgins and N. Henriksen of the Geological Survey of Greenland; these include two samples from tillitic sequences found beneath Caledonian thrusts in the western part of the Scoreby Sund region and speculatively correlated with the Tillite Group. In this report the 6-figure reference numbers refer to the samples from the collections of the Geological Survey of Greenland. The approximate location of all the samples investigated is given in the geological map in fig. 1.

MATERIAL AND RESULTS

Rock pieces with a weight of about 100 g were cut and chemically processed in the way fully described by Vidal (1976).

The samples processed are listed below in descending stratigraphic order, together with the results obtained.

Tillite Group (200–1000 m: Spiral Creek Formation, Canyon Formation, Upper Tillite, Inter-Tillite Beds, Lower Tillite)

GD–5 Two siltstone fragments from the Canyon Formation south of Kap Oswald, Ella Ø (fig. 1, locality 12). A red-grey siltstone was barren. The other siltstone, which comprised black and grey laminae was rich in organic debris which has apparently been reworked; the few microfossils recovered were corroded and showed irregular serrated edges. The colour of the organic residues is brown.

GD–4 Finely laminated dark-grey shale from the central part of the Inter-Tillite Beds, south of Kap Oswald, Ella Ø (fig. 1, locality 12). This sample gave the acritarchs *Protosphaeridium laccatum* (Timofeev) Vidal (1974, 1976), *Trachysphaeridium timofeevi* Vidal (1976) (fig. 2, B) and *Bavlinella faveolata* (Shepeleva) Vidal (1976).

GD–3 Dark-grey tillitic shale, part of which contains clasts of siltstone and yellowish dolomite. The fine-clastic layers show convolute lamination. The sample comes from the upper part of the Lower Tillite, south of Kap Oswald, Ella Ø (fig. 1, locality 13). The sample gave the acritarchs *P. laccatum* and *B. faveolata* (fig. 2, M–O), and a number of large opaque unidentifiable fragments.

Eleonore Bay Group (up to *c.* 13 000 m)
Limestone–Dolomite series (1100 m: bed groups 14–20)

GD–2 Dark-grey shale with carbonaceous material on surfaces from the uppermost part of the series, probably bed 19. Collected at Tømmerbugt, Ella Ø (fig. 1, locality 14). The sample gave numerous well preserved acritarchs including: *Kildinella sinica* Timofeev, *Stictosphaeridium* cf. *sinapticuliferum* Timofeev (*sensu* Vidal, 1976), (fig. 2, C–D), *Synsphaeridium* sp., *Protosphaeridium laccatum* and *Trachysphaeridium laufeldi* Vidal (1976) (fig. 2, A). Moreover, the sample gave numerous very large (*c.* 0.5 mm or more in diameter), opaque, dish-shaped (compressed) acritarchs. Their opaqueness renders difficult a detailed study of these acritarchs, but they could possibly be *Chuaria circularis*.

GD–6 Fine-grained yellow and brown limestone from bed 19, collected in the cliff south of Storeelv, Ella Ø (fig. 1, locality 15). The sample is barren.

136578 Finely banded grey limestone from bed group 19, collected from north of Bersærkerbræ, Stauning Alper (fig. 1, locality 6). The sample gave only small black fragments.

GD–1 Dark-grey limestone with calcite veins from central part of the series, from north of Rundsø, Ella Ø (fig. 1, locality 15). Contains only carbonaceous material.

142339 Dark-grey thinly layered siltstone with fragments of light-coloured siltstone, from bed 17 south of Kap Petersens (fig. 1, locality 17). The sample contains *Synsphaeridium* sp. and cf. *Stictosphaeridium* sp. (*sensu* Vidal, 1976), and abundant large black fragments.

142340 Black, weakly bituminous limestone from bed group 17 south of Kap Petersens (fig. 1, locality 17). The sample gave *Synsphaeridium* sp. and black fragments.

142343 Grey bituminous limestone with calcite veins from bed 16, south of Kap Petersens (fig. 1, locality 17). The sample gave black circular objects (compressed sphaeromorphs ?).

GA–1 Black, highly bituminous limestone from bed group 15 collected in the southeast part of Kap Dufva (fig. 1, locality 9). The sample gave a number of black, fragmentary and complete, compressed sphaeromorphs. The largest ones, reaching 0.5 mm in diameter, could perhaps be referred to megaplanktic taxa (i. e. *Chuaria circularis*), but opaqueness prevents closer identification.

Multicoloured series (1000 m: bed groups 7–13)

G–5 Brown-red limestone with calcite veins from bed 12 on Åkerbloms Ø (fig. 1, locality 8). Barren.

G–4 Red-coloured limestone with calcite veins from bed 12 on Åkerbloms Ø (locality as above). Barren.

G–3 Red and grey dolomitic limestone from bed 12 on Åkerbloms Ø (locality as above). Barren.

G–2 Black bituminous limestone with calcite veins from bed 11 on Åkerbloms Ø (locality as above). Abundant carbonaceous material was recovered.

142308 Black bituminous limestone with calcite veins from bed 11, collected in the valley system between Syltoppene and Bersærkerbræ (fig. 1, locality 7). Large black fragments were isolated.

G–1 Yellowish marble from bed 10 collected on Åkerbloms Ø (fig. 1, locality 8). Barren.

142305 Finely banded grey siltstone with limey bands from bed 9, collected in the valley system between Syltoppene and Bersærkerbræ (fig. 1, locality 7). Contains small black fragments.

142302 Black bituminous limestone from bed 8, sampled in the valley system between Syltoppene and Bersærkerbræ (locality as above). Black compressed sphaeromorphs were found, but could not be identified.

142301 Black bituminous cherty limestone from bed 8, sampled at the same locality

as above between Syltoppene and Bersærkerbræ. The sample gave *Trachysphaeridium* cf *levis* (Lop.) Vidal (1974, 1976), cf. *Stictosphaeridium* sp. (*sensu* Vidal, 1976), *Synsphaeridium* sp., and abundant large black fragments.

Quartzite series (2100 m: bed groups 1–6)

GB–1 Shale comprising alternating grey and black laminae from the upper part of the series (beds 3–6) at the mouth of Polhems Dal (fig. 1, locality 10). The sample gave cf. *Stictosphaeridium* sp. (*sensu* Vidal, 1976) (fig. 2, K–L), *Kildinella* cf. *hyperboreica* Timofeev, *Protosphaeridium* cf. *patelliforme* Timofeev and *Synsphaeridium* sp. and abundant, large, compressed, opaque spaeromorphs which could perhaps be referred to *Chuaria circularis*.

136564 Grey limey siltstone comprising alternating grey and light coloured laminae from the upper part of the series (bed 3), north of the eastern side at the mouth of Bersærkerbræ (fig. 1, locality 5), Gave only large graphitic fragments.

GC–1 & 2 Black slates from the lower part of the series (bed groups 1–2) north-west of the delta in the valley mouth at Polhems Dal (fig. 1, locality 11). Both samples gave highly coalified, opaque, compressed sphaeromorphs of large dimensions, which could perhaps be referred to *Chuaria circularis*.

Upper Argillaceous–Arenaceous series (1400–2000 m)

136555 Siltstone comprising alternating dark sandy and silty layers from near the top of the series at the north side of Bersærkerbræ (fig. 1, locality 4). Gave only small black fragments.

136553 Same as above. The sample gave *Synsphaeridium* sp. and black fragments.

136552 Grey thinly laminated limestone. Locality as above. Gave only black and grey organic fragments.

G–6 Green and red-coloured slate from the upper central part of the series collected at the southern shore at Kempes Fjord (fig. 1, locality 16). Gave only scattered carbonaceous fragments.

Lower Arenaceous–Argillaceous series (1200–8000 m)

136604 Grey fine-grained sandstone with dark silty laminae from the uppermost part of the series (bed o of Fränkl, 1951) south of Kap Mæchel (fig. 1, locality 1). Gave only black fragments.

142335 Laminated black and grey siltstone from the upper part of the series (bed m of Fränkl, 1951) at the western margin of Alpefjord (fig. 1, locality 2). Large graphitic fragments.

142322 Laminated siliceous siltstone from the central part of the series (bed f of Fränkl, 1951) at the western side of Alpefjord (fig. 1, locality 3). Barren.

142315 Dark-grey siltstone from the central part of the series (bed d of Fränkl, 1951) at the western margin of Alpefjord (fig. 1, locality 18). Gave only large black fragments.

Scoresby Sund region – tillite samples from foreland windows

103491 Grey bituminous tillite containing crystalline clasts from a *c.* 200 m thick tillite sequence on Tillit Nunatak, Charcot Land (71° 54′ N, 29° 46′ W), (Steck, 1971). The sample gave a few carbonaceous fragments.

168679 Red micaceous tillitic shale from pockets of tillite below a sedimentary sequence in Paul Stern Land (70° 21′ N, 29° 44′ W) (Phillips *et al.*, 1973). Barren.

The results can be summarised as follows: Highly coalified material was recovered from 22 of the processed samples. Five samples were completely barren. Eight samples gave indisputable acritarchs. Three samples gave flattened opaque (thermally altered) mega-acritarchs which could possibly be referred to known taxa. One sample gave uncoalified but unidentifiable microfossils. Unfortunately most of the recovered acritarchs are too poorly preserved for satisfactory reproduction as microphotographs.

STATE OF PRESERVATION OF ACRITARCHS

The best observed state of preservation was found in acritarchs from samples of the Tillite Group. The acritarchs recovered from two fossiliferous samples of this unit are light brown in colour, corresponding to Correia's stages N_2–N_3 (Correia, 1967), which may indicate that the samples have undergone heating to about 75–150° C.

The microfossils recovered from the Limestone–Dolomite series are very poorly preserved, with the notable exception of a sample from the upper part of the series at Ella Ø (GD–2), which gave acritarchs in a state of preservation comparable with those from the Tillite Group.

As a rule the acritarchs from the Limestone–Dolomite series and lower levels range in colour from opaque black for the largest specimens to grey for the smaller ones. This colouration representing alteration due to higher temperatures roughly corresponds to Correia's stages N_3–N_4, which could indicate that the rocks have been heated to about 150 to $\geqslant$ 180° C.

However, those temperatures should only be regarded as a rough guide, as comparable stages of preservation have been found by the author for late Precambrian acritarchs isolated from the Robertson Bay Group, Victoria Land, Antarctica; those rocks are known to have been metamorphosed in the prehnite-pumpellyite facies (> 300°C) (personal communication, A. Wodzicki).

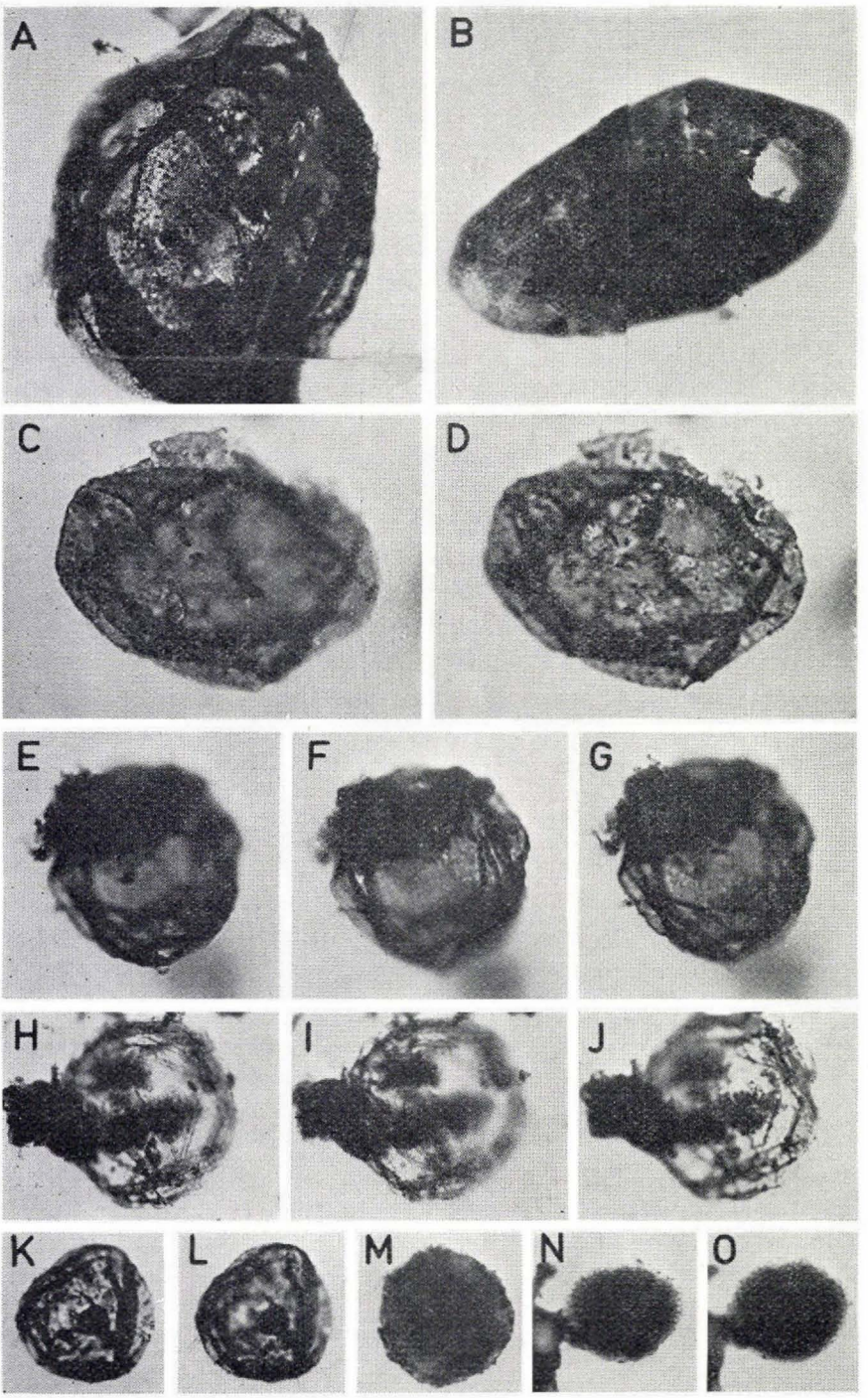
The state of preservation seems to be highly variable and to bear no relationship to stratigraphic levels. It seems unlikely to be related to depth of burial. In the case of the East Greenland material the likely cause of alteration seems to be the increase in the slight regional metamorphic grade westwards towards the metamorphic complexes.

ENVIRONMENTAL COMMENTS

The occurrence of relatively well preserved acritarchs in a tillite sample (GD–3) is of particular interest. The rock contains also considerable amounts of bituminous matter, and shows convolute bedding. The acritarch taxa present are also found in shales of the Inter-Tillite Beds, but do not include those taxa recovered from the underlying Limestone–Dolomite series. The acritarchs do not appear to derive from eroded strata, and it may be surmized that the tillitic units of the Tillite Group on Ella Ø confirm these findings.

By contrast a completely different situation has been found for the Upper Tillite Formation in Finnmark (North Norway), where studies by the author have shown abundant acritarchs which are also found in the underlying Grasdal Formation.

Fig. 2. A: *Trachysphaeridium laufeldi* Vidal, × 320. Slide GD–2–1: Y/47–4. B: *Trachysphaeridium timofeevi* Vidal, × 800. Oil immersion. Slide GD–4–2: P/29–3. C–D: cf. *Stictosphaeridium* sp. Specimen at 2 focus levels, × 800. Oil immersion. Slide GD–2–1: X/32. E–G: *Stictosphaeridium* cf. *sinapticuliferum* Timofeev. Specimen at 3 different focus levels, × 800. Oil immersion. Slide GD–2–1: X/32–1. H–J: *Stictosphaeridium* cf. *sinapticuliferum*. Specimen at 3 different focus levels, × 1024. Oil immersion. Slide GD–2–1: R/35. K–L: cf. *Stictosphaeridium* sp. Specimen at 2 focus levels, showing internal structure, × 1024. Oil immersion. Slide GB–1–1: 0/43–4. M: *Bavlinella faveolata* (Shepeleva) Vidal. Specimen at a low focus level, × 1024. Oil immersion. Slide GD–3–1: R/24. N–O: *B. faveolata*. Specimen at 2 focus levels, × 800. Oil immersion. Slide GD–3–1: U/31. Specimens A, C–D, E–G and H–J come from sample GD–2, uppermost Limestone–Dolomite series at Tømmerbugt, Ella Ø. Specimen B comes from sample GD–4, Tillite Group, Kap Oswald, Ella Ø. Specimens K–L come from sample GB–1, upper Quartzite series, bed groups 3–6, northern valley mouth of Polhems Dal. Specimens M and N–O come from sample GD–3, Tillite Group, Kap Oswald, Ella Ø.


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

DISCUSSION

Tillite Group

The Tillite Group disconformably overlies the Eleonore Bay Group and is, also disconformably, overlain by the Kløftelv Formation which is apparently Lower Cambrian: the Kløftelv Formation is not necessarily lowermost Cambrian according to Cowie & Spencer (1970), who suggest the possibility of a Precambrian–Cambrian boundary somewhere between the Upper Tillite and the Bastion Formation.

So far, the Tillite Group has given three characteristic acritarch taxa (i.e. *Bavlinella faveolata, Protosphaeridium laccatum* and *Trachysphaeridium timofeevi*). *B. faveolata* is a diagnostic endosporulating blue-green alga (Moorman, 1974), which has been found in upper Precambrian rocks in many parts of the world (e. g. Canada, Russia, Czechoslovakia, France, Sweden and Antarctica; cf. Vidal, 1976) and is characteristic of the Vendian Stage (Vidal, 1976).

In the Visingsö beds in south Sweden the species occurs sporadically in the upper unit together with the Upper Riphean mega-acritarch *Chuaria circularis, T. timofeevi* and other taxa. The acritarch assemblage of this unit seems to be in agreement with a Vendian age and the co-occurrence of *B. faveolata* and *C. circularis* are interpreted as indicative of a Upper Riphean–Vendian transition (Vidal, 1976). No glacial deposits have been recorded in the upper unit of the Visingsö beds. However, boulder beds, believed to have been deposited at least in part under glacial conditions, occur in the middle unit of the beds, which has given a clearly Upper Riphean acritarch assemblage (Vidal, 1976).

The co-occurrence of *B. faveolata* and *C. circularis* is also noted in the Hector Formation (Late Proterozoic) in southern Canada. Moorman (1974) described from this unit a species later synonymized by Vidal (1976) with *B. faveolata* and Gussov (1973) recorded fossils very likely identical with *C. circularis*. It is therefore of interest to mention that the Hector Formation overlies the Toby Conglomerate (part of the Miette Group in Alberta), which is a possible equivalent of the diamictites of the Rapitan Formation in the Mackenzie Mountains (Gabrielse, 1967).

Acritarchs regarded as identical with *B. faveolata* have been reported from the Hsiamaling Formation in northern China (cf. Vidal, 1976). The Hsiamaling and Hunghsuichuang Formations are the youngest subdivisions of the Sinian Chingpaikou series in northern China. Notably, the first unit was considered by Sin & Liu (1973) as equivalent with the Valdai series in the Russian Platform. The Hunghsuichuang Formation has given acritarch taxa synonymized by Vidal (1976) with taxa recorded in the upper unit of the Visingsö beds and the Vendian Neminsky, Lyadovsky and Derlovskaya beds in Podolia and the Vendian–Lower Cambrian Motsk beds in Irkutsk.

Two acritarch taxa synonymized with *B. faveolata* by Vidal (1976) have been recorded by Konzalová (1974) in an assemblage also including herkomorphic and acanthomorphic acritarchs, from the Upper Proterozoic of Bohemia. The assemblage was regarded as possibly Lower Cambrian (Konzalová, 1974), but the two species concerned (i.e. *Favososphaera conglobata* and *F. sola*) were originally reported from the Lusatian greywackes, apparently regarded as Upper Riphean and Vendian (Burmann, 1972). Acanthomorphic acritarchs occur also in the upper unit of the Visingsö beds (Vidal, 1976) and in the Lower Shale and Middle Sandstone Formations of the Torneträsk Group (northern Sweden), as well as in the Robertson Bay Group in Victoria Land (Antarctica) (unpublished data by the author), which are commonly regarded as Late Precambrian. Therefore, the presence of acanthomorphic taxa does not indicate *per se* an Early Palaeozoic age (Vidal, 1976).

In the Lower Shale Formation of the Torneträsk Group in northern Sweden *B. faveolata* occurs in great profusion associated with *Vendotaenia* algae (ribbon--like brown algae), scattered specimens of *T. timofeevi,* and, as mentioned above, scattered acanthomorphs. The overlying Middle Sandstone Formation contains *Vendotaenia* and acanthomorphs, and also *Spriggia annulata* (a medusoid) (Kulling, 1964, 1972) which is a component of the Vendian Ediacara fauna in South Australia. North of Lake Torneträsk, the above mentioned units are substituted or overlain by the widespread Vakkejokk Formation, regarded by Kulling (1972) as deposited under periglacial conditions and somewhat speculatively regarded as equivalent with the Upper Tillite in nearby Finnmark (northern Norway). The absence of the Vakkejokk Formation in the south could also indicate the presence of a stratigraphic gap between the Lower Cambrian (but not lowermost Cambrian) Middle Shale Formation and the underlying *Spriggia* beds, since the unit overlies the Vakkejokk Formation in the north (cf. Kulling, 1964, 1972).

The post-Ediacara position of the Vakkejokk glacial(?) event in Norrbotten is remarkable if compared with the Vendian sequence in the Russian Platform, where glacial deposits occur below the Mogilev-Podolian series (which contains an Ediacara-type fauna in the upper subdivision; Sokolov, 1974). Sokolov (1973) considers the Mogilev–Podolian series of the Dniester area as correlatable with the upper subdivision of the Volhyn series of the western and central Russian Platform. The Mogilev–Podolian and Volhyn series are both overlain by the fossiliferous Redkino series, Valdai series, and the uppermost Rovno horizon. The Redkino and Valdai series have both given *B. faveolata* (Volkova, 1968; Shepeleva, 1962), as well as *Vendotaenia* and *Tyrassotaenia* (Sokolov, 1973). The base of the Rovno horizon is the base of the Baltic Stage and is regarded as one of the two possible positions for the base of the Cambrian in the Russian Platform. This unit contains sabelliditids, shelly fossils and *Platysolenites* (Sokolov, 1974).

Comparisons with the Upper Precambrian sequences in north and south Norway are hardly permissible as most of the available data is of an incomplete

or preliminary character. However, it is of interest to note that acritarchs regarded as probably identical with *B. faveolata* have been reported by Manum (1967) from the Biri Conglomerate (Biskåpåsen Conglomerate in Bjørlykke *et al.*, 1967) and Biri Shale, which are partly equivalent (Spjeldnæs, 1967, cf. Vidal, 1976). No lower tillite horizon is recognized in the Mjøsa sequence, and Bjørlykke *et al.* (1967) apparently regard the Moelev Tillite (350–550 m above the *Bavlinella*-bearing Biri Shale; Bjørlykke, 1967) as equivalent with the Upper Tillite Formation in the Finnmark sequence. The Moelv Tillite is overlain in ascending order by the Ekre Shale and Vangås Formation (Bjørlykke, 1967). This latest unit, containing the first metazoan traces in the sequence, is regarded as Lower Cambrian.

In the Finnmark sequence, *B. faveolata* (and other Upper Precambrian acritarchs) have been sporadically found in the Upper Tillite Formation, and in great profusion in the Innerelv Member of the Stappogiedde Formation (unpublished data by the author). The Innerelv Member is the middle part of the Stappogiedde Formation, which overlies the Upper Tillite Formation, and is separated from the underlying Nyborg Formation by a sedimentation break (Banks, 1970). Simple vertical burrows appear in the Innerelv Member of the Stappogiedde Formation (Banks, 1970), but there is an unpublished record of trace fossils in the Nyborg Formation (Martinsson, 1974, p. 237). In the Breivik Formation (overlying the Stappogiedde Formation) *Russophycus* sp. (a trilobite resting burrow), evidently regarded by Bergström (1970) as an indicator of Early Cambrian age, is first recorded 70 m above the base of the unit (575 m above the Upper Tillite Formation) (Banks, 1970). *Platysolenites antiquissimus* occurs about 150 m above the base of the unit, 505 m above the top of the Upper Tillite; in Norrbotten this Lower Cambrian fossil occurs in the Middle Shale Formation, immediately above the Vendian *Spriggia* beds and the glacial(?) Vakkejokk Formation (cf. above), and the stratigraphic gap suggested by Kulling (1972) may therefore be in fact a major hiatus.

It remains to be noted that microfossils from the Middle Brioverian (upper Precambrian) in western France (cf. Roblot, 1961) are regarded by Vidal (1976) as probably identical with *B. faveolata.* This is of interest since the base of the Upper Brioverian contains tillites, the Brioverian being separated from overlying Lower Palaeozoic strata by the Cadomian unconformity.

Limestone–Dolomite series

A slight disconformity separates the Tillite Group from the Limestone–Dolomite series. The acritarchs recovered from this unit are as a rule too altered to render a close identification possible. However, those recovered from the topmost part of the unit (sample GD-2) deserve special mention, since *Trachysphaeridium*

laufeldi is included there. This very diagnostic spiny acritarch is very common in the argillites of the middle and upper units of the Visingsö beds, to which it is restricted (Vidal, 1976). Numerous opaque and compressed large acritarchs have also been recovered and it is regarded as possible that they could be *Chuaria circularis* (discussed above). The apparent absence of *Bavlinella faveolata* in the Limestone–Dolomite series, compared to its abundance in the Tillite Group, seems to be in agreement with a stratigraphic gap between the two units; this is also suggested by the slightly disconformable contact. There is only a single species common to both units, *(Protosphaeridium laccatum),* and this has an extremely long stratigraphic range (Lower Proterozoic to Ordovician) and is interesting only from the environmental point of view (cf. Vidal, 1974, 1976). The present evidence suggests a very late Riphean age for the Limestone–Dolomite series, although much data is required before a definitive age can be assigned to the unit on the base of acritarch evidence (further material is being processed). This is especially so as the suggested latest Riphean age disagrees with the Vendian age apparently indicated by algal stromatolites in the unit (cf. Bertrand-Sarfati & Caby, 1974).

Multicoloured series

Only one sample from this unit (142301) gave identifiable acritarchs. Two of these (cf. *Stictosphaeridium* sp. and *Synsphaeridium sp.*) are of very little diagnostic value. Only one species of some interest is found. *Trachysphaeridium* cf. *levis,* and this species and its synonyms (Vidal, 1974, 1976) are very diagnostic; however, *T. levis* seems to have a long stratigraphic range (Middle – Upper Riphean and Vendian?), (Vidal, 1974, 1976).

The opaque compressed sphaeromorphs recovered from one of the samples (142302) deserve some mention, since they could be *Chuaria circularis.* It is of interest that the acritarch taxa so far recovered from the Multicoloured series are also found in the Visingsö beds together with *C. circularis.* This could be an argument in favour of the suggested identity of the above mentioned sphaeromorphs with this species, and in that case the Multicoloured series could be tentatively referred to the Upper Riphean.

Quartzite series

Identifiable acritarchs were recovered from only one sample (GB-1). The specimens of cf. *Stictosphaeridium* sp. found are thin, small vesicles, more or less ornamented with an irregular meshwork, and are similar to *Stictosphaeridium* sp. noted from the Visingsö beds (Vidal, 1976). Internal bodies were observed in some of the specimens found (fig. 2, K–L), a circumstance also observed in the

material from the Visingö beds. The probably polyphylletic assemblage suggested by Vidal (1976) occurs apparently in both pre-Palaeozoic and Lower Palaeozoic rocks and has therefore no stratigraphic significance. *Synsphaeridium* sp. again lacks diagnostic features and has also a very long stratigraphic range (Vidal, 1976).

Kildinella cf. *hyperboreica* is of some interest, as the species is restricted to the Upper Riphean and Vendian (Timofeev, 1969). In the Visingö beds the species occurs in all the three units associated with other Riphean and Vendian taxa. It is therefore of some interest to mention the occurrence in two of the processed samples (GC–1 & 2) of large black and compressed acritarchs which could be *C. circularis*. This could also be in agreement with a Late Riphean age for the Quartzite series.

Upper Argillaceous–Arenaceous series

Only one acritarch taxa (*Synsphaeridium* sp.) was found in one of the processed samples from the Upper Argillaceous–Arenaceous series. As mentioned above the species is not diagnostic and therefore provides no further information about the age of this unit.

CONCLUSIONS

Eleven samples of the originally 35 processed from the Precambrian Eleonore Bay Group and Tillite Group proved to contain acid-resistant organic-walled microfossils (acritarchs). This may considered a fairly promising result, considering that the samples come from a folded area and that many of them are from rocks metamorphosed to some extent.

The state of preservation of the acritarchs indicates that most of the studied rocks were possibly heated to about 150 to 180° C. Exceptionally, the acritarchs in some of the samples from Ella Ø (Limestone–Dolomite series and Tillite Group) are much better preserved and indicate that these rocks were heated to no more than 150° C. It is expected that investigations in progress of more material from the Eleonore Bay Group and Tillite Group from areas little or unaffected by metamorphism will result in a higher percentage of fossiliferous samples.

The presence in the Quartzite series of acritarch taxa previously known from the Upper Riphean strata in south Sweden and elsewhere, together with the fact that the upper part of the Limestone–Dolomite series yielded acritarchs common to the middle and upper units of the Upper Riphean, Visingsö beds in south Sweden, seems to indicate that black, flattened large sphaeromorphs in these samples could possibly be referred to *Chuaria circularis*. The same conclusion is

valid for samples from the Multicoloured series. Bearing in mind the sligthty disconformable contact between the Limestone–Dolomite series and the Tillite Group, the very different assemblages recovered from these two units are tentatively interpreted as indicating slightly different ages for the two units: very Late Riphean for the Limestone-Dolomite series and Vendian for the Tillite Group.

The micropalaeontological evidence seems to indicate that, at least in part, the tillites of the Tillite Group are water-deposited sedimentary rocks, very likely glacial-marine deposits.

Acknowledgements

I wish to thank Christian Hjort and Leif Bjelm of the Department of Quaternary Geology, University of Lund, who collected a large part of the material included in this study. Niels Henriksen and A. K. Higgins of the Geological Survey of Greenland, Copenhagen, kindly provided material from their collections and contributed many suggestions for improvements to the manuscript. Their constructive criticism and interest are very much appreciated. The laboratory work involved in this study was undertaken at the Department of Historical Geology and Palaeontology, University of Lund. I would like to thank Professor Gerhard Regnéll, Director of the Department for providing excellent working conditions. Microphotography, draughting and typing of the manuscript were carried out at the New Zealand Geological Survey, Lower Hutt, during the early part of the tenure of a postdoctoral research fellowship. I wish to thank George H. Scott and Roger A. Cooper of the New Zealand Geological Survey, who kindly suggested linguistic improvements to the manuscript. Financial support was generously provided by Statens Naturvetenskapliga Forskningsråd (NFR Dnr. 080–019/580G) and the Geological Survey of Greenland.

The topographic outline of fig. 1 by courtesy of the Geodetic Institute, Copenhagen (A.649/72).

REFERENCES

Banks, N. L. 1970: Trace fossils from the late Precambrian and Lower Cambrian of Finnmark, Norway. *In* Crimes, T. P. & Harper, J. C. (edit.) Trace fossils. *Geol. J. Spec. Issue* **3,** 19–34.

Bergström, J. 1970: *Rusophycus* as an indication of early Cambrian age. *In* Crimes, T. P. & Harper, J. C. (edit.) Trace fossils. *Geol. J. Spec. Issue* **3,** 35–42.

Bertrand-Sarfati, J. & Caby R. 1974: Précisions sur l'âge précambrien terminal (vendien) de la série carbonatée à stromatolites du groupe d'Eleonore Bay (Groenland oriental). *C. r. hebd. Séanc. Acad. Sci., Paris* **278,** 2267–2270.

Bjørlykke, K. 1967: The Eocambrian "Reusch moraine" at Bigganjargga and the geology around Varangerfjord; northern Norway. *Norges geol. Unders.* **251,** 18–44.

Bjørlykke, K., Englund, J. O. & Kirkhusmo, L. A. 1967: Latest Precambrian and Eocambrian stratigraphy of Norway. *Norges geol. Unders.* **251,** 5–17.

Burmann, G. 1972: Problematika aus der Lausitzer Grauwackenformation. *Jb. Geol.* **1968** (4), 387–423.

Correia, M. 1967: Relations possibles entre l'état de conservation des éléments figurés de la matière organique (microfossiles palynoplanctologiques) et l'existence de gisements d'hydrocarbures. *Rév. Inst. fr. Pétrole* **22,** 1285–1306.

Cowie, J. W. & Spencer, A. M. 1970: Trace fossils from the late Precambrian/Lower Cambrian of East Greenland. *In* Crimes, T. P. & Harper, J. C. (edit.) Trace fossils. *Geol. J. Spec. Issue* **3,** 91–100.

Fränkl, E. 1951: Die untere Eleonore Bay Formation im Alpefjord. *Meddr Grønland* **151,** 6, 15 pp.

Gabrielse, H. 1967: Tectonic evolution of the northern Canada. Cordillera. *Can J. Earth Sci.* **4,** 271–293.

Gussow, W. C. 1973: *Chuaria* sp. cf. *C. circularis* Walcott from the Precambrian Hector Formation, Banff National Park, Alberta, Canada. *J. Paleont.* **47,** 1108–1112.

Haller, J. 1971: *Geology of the East Greenland Caledonides.* 413 pp. Interscience.

Henriksen, N. & Higgins, A. K. 1976: East Greenland Caledonian fold belt. *In* Escher, A. & Watt, W. S. (edit.) *Geology of Greenland* 182–246. Copenhagen: Grønlands geol. Unders.

Koch, L. & Haller, J. 1971: Geological map of East Greenland 72°–76° N lat. (1:250,000). *Meddr Grønland* **183,** 26 pp.

Konzalová, M. 1974: Acritarchs from the Bohemian Precambrian (Upper Proterozoic) and Lower Cambrian. *Rev. Palaeobot. Palynol.* **18,** 41–56.

Kulling, O. 1964: Översikt över Norra Norrbottensfjällens Kaledonberggrund. *Sveriges geol. Unders.* Ba. **19,** 116 pp.

Kulling, O. 1972: The Swedish Caledonides. *In* Strand, T. & Kulling, O. *Scandinavian Caledonides.* 149–285. Wiley-Interscience.

Manum, S. 1967: Microfossils from the Late Precambrian sediments around Lake Mjøsa, southern Norway. *Norges geol. Unders.* **251,** 45–52.

Martinsson, A. 1974: The Cambrian of Norden. *In* Holland, C. H. (edit.) *Cambrian of the British Isles, Norden, and Spitsbergen.* 185–283. Wiley-Interscience.

Moorman, M. 1974: Microbiota of the Late Proterozoic Hector Formation, south-western Alberta, Canada. *J. Paleont.* **48,** 524–539.

Phillips, W. E. A., Stillman, C. J., Friderichsen, J. D. & Jemelin, L. 1973: Preliminary results of mapping in the western gneiss and schist zone around Vestfjord and inner Gåsefjord, south-west Scoresby Sund. *Rapp. Grønlands geol. Unders.* **58,** 17–32.

Roblot, M.-M. 1961: L'etage à niveux charbonneux du Briovérien normand (X^{2a}). *Bull. Soc. géol. France* (7) **3,** 27–32.

Shepeleva, E. D. 1962: Plant(?) fossils of unknown taxonomic position from the deposits of the Bavlinskaya series in the Volga-Urals oil province. *Dokl. Acad. Sci. USSR, Earth Sci. Sect.* **142,** 170–171. (*Dokl. Akad. Nauk SSSR. Geol.* **142,** 2, 456–457).

Sin Yu-sheng & Liu Kui-zhih 1973: [On Sinian micro-flora in Yenliao region of China and its geological significance.] *Acta geol. Sinica* **1973,** 1–64. (In Chinese with English abstract).

Sokolov, B. S. 1973: Vendian of northern Eurasia. *In* Pitcher, M. G. (edit.) Arctic Geology. *Mem. Am. Ass. Petrol. Geol.* **19,** 204–218.

Sokolov, B. S. 1974: [Problem of Precambrian-Cambrian boundary.] *Geologiya Geofiz. Novosibirsk* **1974,** 2, 3–29. (In Russian).

Spjeldnæs, N. 1967: Fossils from pebbles in the Biskopåsen Formation in southern Norway. *Norges geol. Unders.* **251,** 53–82.

Steck, A. 1971: Kaledonische Metamorphose der praekambrischen Charcot Land Serie, Scoresby Sund, Ost-Grönland. *Bull. Grønlands geol. Unders.* **97** (also *Meddr Grønland* **192,** 3) 69 pp.

Timofeev, B. V. 1969: [*Proterozoic sphaeromorphs.*] Leningrad (Inst. Geol. Geokhron. Dokembr.): Nauka. (In Russian).

Vidal, G. 1974: Late Precambrian microfossils from the basal sandstone unit of the Visingsö beds, South Sweden. *Geol. Palæont.* **8,** 1–14.

Vidal, G. 1976: Late Precambrian microfossils from the Visingsö beds, South Sweden. *Fossils Strata* **9.**

Volkova, N. A. 1968: [Acritarcha of Precambrian and Lower Cambrian deposits of Estonia.] *In* [Problemetics of Riphean and Cambrian layers of the Russian Platform, Urals and Kazakhstan.] *Trudy geol. Inst. Leningr.* **188,** 8–36. (In Russian).

ANDELSBOGTRYKKERIET I ODENSE