

SPORE ASSEMBLAGES AND THEIR STRATIGRAPHICAL APPLICATION IN THE LOWER AND MIDDLE DEVONIAN OF NORTH AND CENTRAL VESTSPITSBERGEN

by K. C. ALLEN

ABSTRACT. Rock samples were collected from numerous stratigraphically measured sections throughout the Lower and Middle Devonian of North and Central Vestspitsbergen. An assessment has been made of the stratigraphical value of the dispersed spore content from over 250 rock samples which were prepared for microscopic investigation. Absence of spores from Andrée Land makes correlation less complete than was originally anticipated. Sections from North and Central Dickson Land have produced three distinct successive spore assemblages; the Culpa (lower) Assemblage, the Eximius (middle) Assemblage, and the Triangulatus (upper) Assemblage.

THE aim of this paper is to evaluate the stratigraphical use of the dispersed spores described earlier in this journal (Allen 1965). The author collected numerous stratigraphically placed rock specimens throughout the Lower and Middle Devonian of North and Central Vestspitsbergen, in the hope of working the complete succession for dispersed spores, and then correlating the formations on dispersed spore assemblages. Collections were made from the Red Bay Group on the east side of Raudfjorden, from the Wood Bay Formation of Andrée Land and Dickson Land, from the Grey Hoek Formation and Wijde Bay Formation of Andrée Land, and from the Mimer Valley Formation of Dickson Land (see map in Friend 1961, p. 86, fig. 2). Unfortunately spores were absent from the majority of samples collected from Andrée Land, and correlation was necessarily confined to Dickson Land. Place names in Dickson Land referred to in the text are given in text-fig. 1.

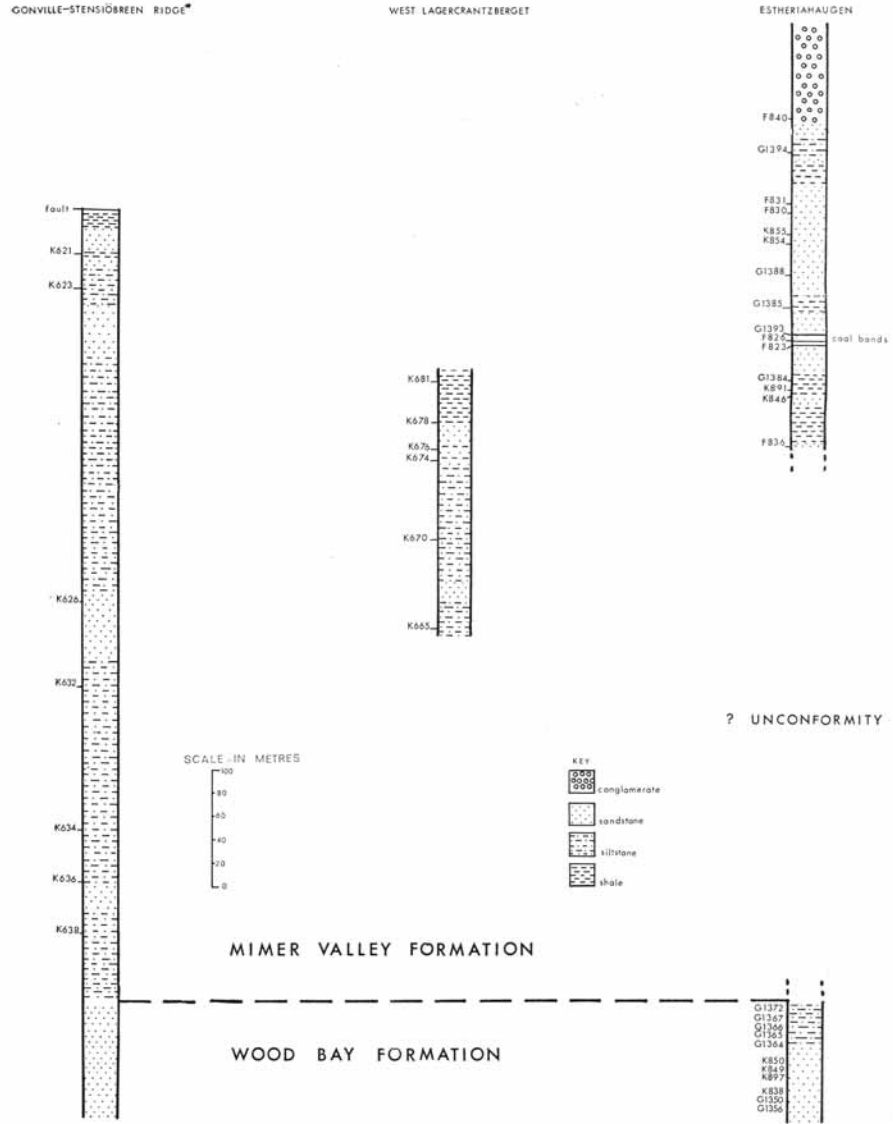
Sections collected over a wide area of Dickson Land (text-fig. 2) together represent the complete stratigraphical succession for that area. Detailed information is given in text-fig. 3, for three of these sections from Estheriahaugen, West Lagercrantzberget, and the Gonvillebreen–Stensiøbreen ridge (the top of this succession extends on to the Caiusbreen–Hoelbreen col).

Three distinct, successive, spore assemblages are distinguishable in Dickson Land, each characterized by a number of species of limited stratigraphical range, and therefore of importance for correlation within the area. To date, little work has been completed on Lower and Middle Devonian microfloras, and consequently the number of new species in Vestspitsbergen was large, and correlation with Lower and Middle Devonian spore floras from areas outside Vestspitsbergen was therefore limited. In addition to the three assemblages described from Dickson Land, productive samples were prepared from the Fraenkelryggen Formation of the Red Bay Group. Also recorded are a few ill-preserved samples from the Wijde Bay Formation, and from the highly deformed eastern portion of the Wood Bay Formation (Mimerbukta Sandstone of Friend 1961). For stratigraphical nomenclature I have followed Friend, Heintz, and Moody-Stuart (in press).

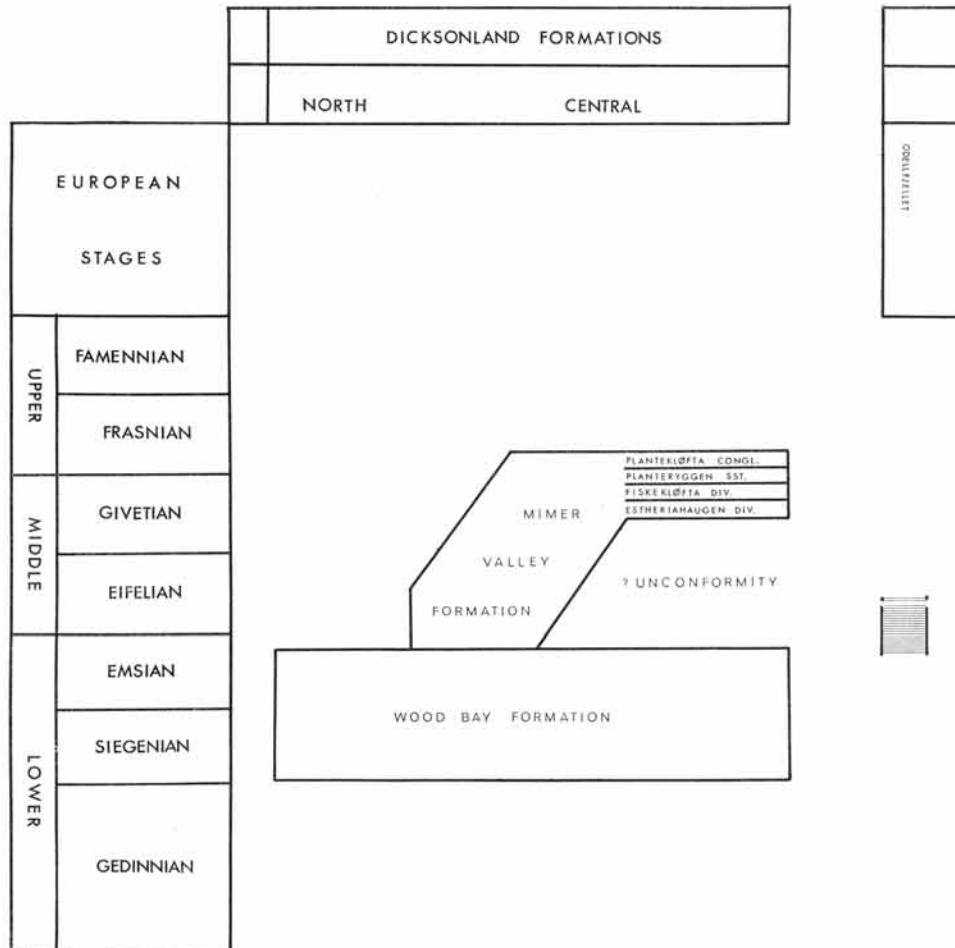
[Palaeontology, Vol. 10, Part 2, 1967, pp. 280–97.]



TEXT-FIG. 1. Place-names of Dickson Land referred to in the text.

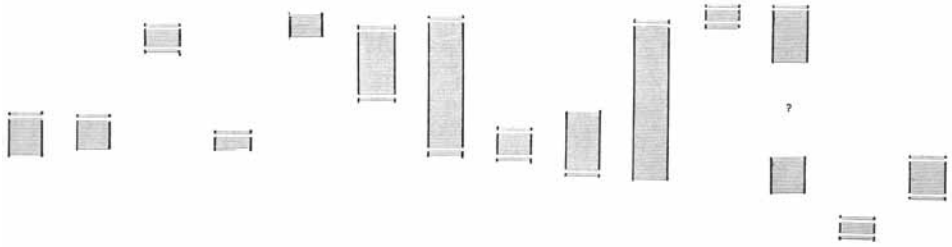


TEXT-FIG. 3. Sections represented in text-fig. 2 from Gonvillebreen-Stensiöbreen ridge (the top of the succession extends on to the Caiusbreen-Hoelbreen col), West Lagercrantzberget and Estheriahaugen, giving details of lithologies, and of horizons from which samples have been prepared for microscopic investigation.



TEXT-FIG. 2. Stratigraphical columns in Dick (Stratigraphic compar

DICKSONLAND LOCALITIES													
NORTH					CENTRAL								
OSLIVILLIET	MANDESTRØMSEN TUNN	NORTH BIRD OF PARADISEHILL	TRONDHØI	NORNE-DONUTBIRNEN OS	WEST LADEKAMPENHØI	GOVNETE-SINDSØEN HØI	NOJNØKALIN	SONDØEN	FISKEBERGA	NORTH-EAST SANDØKALIN	ETNØKAMPEN	SØEN AMØKALIN	KIRKEBERGØKALIN



is in Dickson Land from which collections were made for palynological investigation
 ic comparison with European stages taken from Friend 1961).

THE SUCCESSION OF SPORE ASSEMBLAGES

Red Bay Group

From the Red Bay Group rock specimens for palynological investigation were only collected by the author from the Fraenkelryggen Formation. This represents the lowest horizon from which dispersed spores were obtained. This formation consists mainly of red, grey, and green sandstones and siltstones, and especially selected were the darker grey siltstone bands. The age (see Friend 1961, p. 85, for references) based on Heterostracan and Cephalaspid faunas, suggests a probable equivalent to the Upper Downtonian and Dittonian in the Anglo-Welsh area (Lower and part of the Upper Gedinnian). No diagnostic species were present however, and the assemblage was not formally named. Spores were obtained from three samples; these were poorly preserved, and of simple morphology, none being confined solely to this assemblage. The following species were recorded, together with the percentage present in each case:

	per cent.
<i>Leiotriletes parvus</i> Naumova 1953	4.5
<i>Punctatisporites glaber</i> (Naumova) Playford 1962	80.5
<i>Punctatisporites laevigatus</i> (Naumova) Allen 1965	1.0
<i>Calamospora nigrata</i> (Naumova) Allen 1965	2.0
<i>Granulatisporites muninensis</i> Allen 1965	1.5
<i>Cyclogranisporites plicatus</i> Allen 1965	6.5
<i>Emphanisporites minutus</i> Allen 1965	4.0

Høeg (1942, pp. 14–25) records the following macroplants from the Fraenkelryggen formation: *Pachytheca* cf. *fasciculata* Kidston and Lang; *Prototaxites* sp.; *Zosterophyllum* sp.; *Taeniochrada*(?) *spitsbergensis* Høeg, and *Hostimella* sp.

The Wood Bay Formation and Mimer Valley Formation of Dickson Land

In Dickson Land the lowest assemblage recorded was the Culpa Assemblage, represented only in a short section in South Mimerdalen (text-fig. 2). The Eximius and Triangulatus Assemblages, the middle and upper assemblages respectively, are best seen in sections collected from Estheriahaugen, West Lagercrantzberget, and Gonvillebreen–Stensiøbreen ridge; all the species present in these three sections are recorded in Tables 1 and 2, and wherever possible, a quantitative analysis based on 200 specimens per sample is included. Tables 3 and 4 list the species present in the Eximius and Triangulatus Assemblages from other productive, well-localized samples in Dickson Land. From a comparison of Tables 3 and 4 with text-fig. 2, it can be seen that over a wide area, the stratigraphical horizons from which these two assemblages are obtained, is extremely constant. More detailed collecting from the junctions between assemblages would probably show a more gradual change in spore composition. The assemblages are named after the most constantly occurring, easily recognizable, diagnostic species. Macroplants described by Høeg 1942 for the Wood Bay and Mimer Valley Formations of Dickson Land, are comprehensively listed in Friend 1961 (appendix, pp. 115–18).

The Culpa Assemblage. Although this assemblage is defined on the basis of only two samples from the Austfjorden Sandstone Member of the Wood Bay Formation (lower Light Member of the Reuterskiøldfjellet Sandstone of Friend 1961), it represents a more diverse assemblage than that recorded for the Fraenkelryggen Formation, and is clearly

TABLE 1. Spore distribution in samples containing the Eximius Assemblage, from a section exposed on Gönvillebreen-Stensiöbreen ridge, and from the lower portions of sections exposed on West Lagercrantzberget and Estheriahaugen. In well-preserved samples, constituent species are recorded as percentages, based on a count of 200 specimens. 'X' indicates samples in which there are too few well-preserved spores to permit a count, or where a species is present in a sample, but not in the actual count.

LOCALITY	GONVILLE-STENSIÖ- BREEN RIDGE					WEST LAGER- CRANTZBERGET				ESTHERIAHAUGEN													
	K638	K636	K634	K632	K626	K665	K670	K674	K676	G1356	G1350	K838	K897	K849	K850	G1364	G1365	G1366	G1371	G1372	F836		
<i>Leiotriletes pyramidalis</i>																							
<i>Leiotriletes parvus</i>												2	3		0.5		0.5						
<i>Punctatisporites glaber</i>	19.5			4.5	6.5						4.5	8	7.5	8.5	20.5	18			23.5				
<i>Punctatisporites laevigatus</i>			X			X			X	X	3	7.5	7.5		6.5								
<i>Punctatisporites flavus</i>	2.5		X	2.5	0.5																		
<i>Calamospora microrugosa</i>		X	X	2.5	6.5	X	X	X			7		9.5										
<i>Calamospora nigrata</i>	4	X			2.5	X				X	X	13.5	8	4.5	3	7	1.5	X	3.6		X		
<i>Calamospora witneyana</i>		X	X																X		X		
<i>Triletes oxfordiensis</i>		X		1.5		X	X	X	X	X													
<i>Granulatisporites muninensis</i>	1.5											1.5								0.5			
<i>Cyclogranisporites rotundus</i>					0.5																		
<i>Cyclogranisporites plicatus</i>	52.6	X	X	48.5	X	4.9	X	X	X	X	3.4	2.2	2.9	4.3	3.6	6.2	X	37.5	X	X			
<i>Geminospora svalbardiae</i>									X					4.5	5.5	1.5							
<i>Geminospora spinosa</i>				1.5	0.5						2												
<i>Acanthotriletes raptus</i>					X																		
<i>Ryaticosporites nitratu</i>	0.5				X						1.5			1.5		X							
<i>Bullatisporites bullatus</i>	0.5	X		8	X	2.5	X	X	X		7.5		3	3	1	1						X	
<i>Reticulatisporites emsiensis</i>	X			X	X		X			X	X	X	1	0.5									
<i>Reticulatisporites sp.</i>	0.5	X										0.5											
<i>Emphanisporites rotatus</i>										X	X		3.5		2.5	1	0.5	X	0.5				
<i>Emphanisporites neglectus</i>	4			3.5	0.5	X				X	X												
<i>Emphanisporites minutus</i>										X		0.5				1							
<i>Emphanisporites patagiatus</i>												X	0.5		1					0.5			
<i>Craspedispora craspada</i>						X				X		6.5											
<i>Stenozonotriletes furtivus</i>	X	X		X	X					X	X	X	0.5	0.5	X								
<i>Stenozonotriletes inaequalis</i>	3			X	2.5							1		1	1					0.5			
<i>Stenozonotriletes sp.</i>	0.5				1.5							1.5	2		0.5								
<i>Camptosonotriletes aliquantus</i>	0.5						X							X		X							
<i>Archaeozonotriletes seandricus</i>	0.5	X	2	X	0.5	X	X								X	0.5							
<i>Tholiasporites ancyclus</i>				X								X	0.5		0.5	1.5							
<i>Chelinospora perforata</i>	0.5			X											X								
<i>Perotriletes eximius</i>	6	X	X	1.2	X	1	X	X	X	X	14.5	33.6	18.5	12.5	1.6	3	X	1	X	X			
<i>Perotriletes ergatus</i>	2		X	1.5	X	1		X	X		X	7		3.5	1								
<i>Perotriletes pannosus</i>	1.5	X		1.5	1							0.5	4	10	1								
<i>Grandispora diamphida</i>			X	3.5		X	X				X	X	X										
<i>Rhabdosporites cymatulus</i>								X					3		1								
<i>Aulicosporites aulicus</i>		X		5.5	X			X	X	X			1	1	1.5								
<i>Ancyrospora trocha</i>									X					X									
<i>Ancyrospora reuta</i>	X	X		1.5	X	X	X	X			0.5	6.5	0.5	0.5	X	X							

separable from the succeeding assemblage. This assemblage is characterized by the presence of *Lycospora culpa* Allen 1965, comprising 3 per cent. of the total spores present, together with the following diagnostic species:

<i>Leiotriletes pagius</i> Allen 1965	per cent.
<i>Emphanisporites decoratus</i> Allen 1965	8.5
<i>Retialetes sp.</i> (not present in the spore count).	2.0

Apart from the diagnostic species, the percentages of other species are very different from those in the succeeding Eximius Assemblage. Particularly high, although not so high as in the Fraenkelryggen Formation, is the proportion of simple laevigate or apiculate forms, together with representatives of the genus *Emphanisporites* McGregor 1961. Those recorded were:

	per cent.
<i>Punctatisporites glaber</i> (Naumova) Playford 1962	46.5
<i>Punctatisporites laevigatus</i> (Naumova) Allen 1965	4.0
<i>Calamospora nigrata</i> (Naumova) Allen 1965	8.0
<i>Calamospora microrugosa</i> (Ibrahim) Schopf, Wilson, and Bentall 1944	3.0
<i>Trileites oxfordiensis</i> Chaloner 1963	0.5
<i>Granulatisporites muninensis</i> Allen 1965	2.5
<i>Cyclogranisporites plicatus</i> Allen 1965	7.0
<i>Emphanisporites neglectus</i> Vigran 1964	3.5
<i>Emphanisporites minutus</i> Allen 1965	6.0
<i>Emphanisporites patagiatus</i> Allen 1965	0.5

Other morphologically more complex species present were:

<i>Craspedispora craspeda</i> Allen 1965	0.5
<i>Stenozonotriletes furtivus</i> Allen 1965	0.5
<i>Stenozonotriletes incessus</i> Allen 1965	2.0
<i>Rhabdosporites cymatilis</i> Allen 1965	0.5
<i>Cirratiradites dissutus</i> Allen 1965	1.5

The last named species was very rare in the succeeding Eximius Assemblage. *Leiotriletes parvus* Naumova 1953, *Leiotriletes pyramidalis* (Luber) Allen 1965, *Calamospora witneyana* Chaloner 1963, and *Emphanisporites rotatus* McGregor 1961 were also present.

The Culpa Assemblage was recorded only from the Austfjorden Member of the Wood Bay Formation, and it is probably equivalent to a Siegenian age (Friend 1961, Table 1). No spore assemblage yet described, compares with the Culpa Assemblage, but from an evolutionary viewpoint, it is interesting to note cingulate, zonate, and cavate species occurring in this low stratigraphical horizon.

The Eximius Assemblage. This assemblage (see Tables 1 and 3), was present in 77 samples, from 11 different areas in Dickson Land (those sections recorded in text-fig. 2 together with collections made by previous expeditions to West Dickson Land). The Eximius Assemblage is characterized by the presence of *Perotriletes eximius* Allen 1965, together with the diagnostic species recorded in Table 5. *Perforosporites sp.* is exclusive to this assemblage, but only two specimens have as yet been recorded. Common species which are also present in the Culpa Assemblage are recorded in Table 5.

The Eximius Assemblage is recorded from the Wood Bay Formation (the Dicksonfjorden Sandstone and Upper Reuterskiøldfjellet Sandstone of Friend 1961), Lower Mimer Valley Formation and from Vogt's bed '1' (the lowest part of the Estheriahaugen Division of the Mimer Valley Formation). The lowest beds containing the majority of species diagnostic of this assemblage, occur about 250 m. below the top of the Wood Bay Formation, probably equivalent to a Lower or Middle Emsian age (see text-fig. 2). One sample N383 from near Lykta, containing only *Bullatisporites bullatus* Allen 1965 of the diagnostic species, probably occurs slightly lower in the succession, in beds containing the 'Lykta fauna', which according to Dineley (1960, p. 31) is equivalent to

uppermost Siegenian or lowermost Emsian. The highest beds containing the Eximius Assemblage, occur in Vogt's bed '1' of the Estheriahaugen Division, which is probably equivalent to an Upper Eifelian or Lower Givetian age.

The Eximius Assemblage exhibits a marked increase in diversity of spore morphology from forms present in the Culpa Assemblage, with the presence of numerous cingulate, patinate, and cavate forms, together with the first appearance of species with grapnel-tipped spines. No other assemblage yet described resembles closely the Eximius Assemblage, but as the succeeding Triangulatus Assemblage compares at least in part with Lower Givetian assemblages from the Orcadian Basin (Richardson 1960), an Emsian/Eifelian age is provisionally suggested for the Eximius Assemblage.

The Triangulatus Assemblage. This assemblage (see Tables 2 and 4) was present in 51 samples from 8 different areas in Dickson Land (those areas recorded in text-fig. 2, together with rock specimens collected by previous expeditions from Watsontoppen).

The Triangulatus Assemblage is characterized by the presence of *Samarisporites triangulatus* Allen 1965, together with the diagnostic species recorded in Table 5. The following species appear to be confined to the Triangulatus Assemblage, but are of limited occurrence: *Geminospora tuberculata* (Kedo) Allen 1965, *Hystricosporites corystus* Richardson 1960, *Samarisporites praetervisus* (Naumova) Allen 1965, *Samarisporites inusitatus* Allen 1965, *Cirratriadites avius* Allen 1965, *Archaeozonotriletes sarus* Allen 1965, *Calyptosporites indolatus* Allen 1965, *Aulicosporites vitabilis* Allen 1965, *Nikitinsporites spitsbergensis* Allen 1965, and *Ancyrospora langii* (Taugourdeau-Lantz) Allen 1965. Species common to both the Triangulatus Assemblage and the Eximius Assemblage, or common to all three assemblages are recorded in Table 5.

The Triangulatus Assemblage marked by a further increase in the number and complexity of form species, extends from Vogt's bed '2' of the Estheriahaugen Division to the top of the Plantekløfta Conglomerate at the top of the Devonian succession in Vestspitsbergen. An age equivalent to the Middle and Upper Givetian and lowermost Frasnian as suggested by Friend (1961, pp. 95-97 and Table 1), based primarily on the correlation of the Fiskekløfta Division with the Nairn Sandstone in Scotland and the Oredesch and Podsnogor Stages of the Baltic sequence. However, Tarlo (1964, pp. 84, 85, Table 5) suggests that the Fiskekløfta Division Psammosteids are equivalent to the Tartu horizon of the Baltic sequence. This would indicate a probable Lower to Upper Givetian age equivalent for the Triangulatus Assemblage range. Evidence from the Psammosteids is supported by palynological correlation; for the Triangulatus Assemblage shows a marked similarity to an assemblage recorded by Richardson (1960), from the Eifelian-Givetian boundary in north-east Scotland. *Auroraspora macromanifestus* (Hauebard) Richardson 1960, *Calyptosporites microspinosus* Richardson 1962, and *Densosporites devonicus* Richardson 1960 occur in both assemblages, and *Samarisporites orcadensis* Richardson 1962 is very similar to *Samarisporites praetervisus* (Naumova) Allen 1965. Close comparison with Russian assemblages is more difficult, on the basis that the exact construction of the Russian species described are not always clear. The most interesting species is *Calyptosporites proteus* (Naumova) Allen 1965 which is recorded by Naumova (1953) from the Upper Givetian, and by Kedo (1955) as being an important component of the Lower and Middle Givetian, and may well prove to be an important Givetian zone fossil. Other Russian species of limited stratigraphical range

TABLE 5. Important constituent species of the three assemblages described from the Lower and Middle Devonian of North and Central Vestspitsbergen. The horizontal lines indicate the presence of a species in an assemblage, and not its stratigraphical range within that assemblage.

MICROFLORAL ASSEMBLAGE	TRIANGULATUS	EXIMIUS	CULPA
SUGGESTED AGE	GIVETIAN	EMSIAN, EIFELIAN	MIDDLE AND UPPER SIEGENIAN
<i>Hyaetriosporites porcatus</i>			
<i>Hyaetriosporites porrectus</i>			
<i>Hyaetriosporites monosaccus</i>			
<i>Raistrickia aratra</i>			
<i>Convolutispora disparilia</i>			
<i>Convolutispora mimerensis</i>			
<i>Convolutispora tegula</i>			
<i>Samarisporites senotus</i>			
<i>Samarisporites hesperus</i>			
<i>Samarisporites triangulatus</i>			
<i>Densosporites devonicus</i>			
<i>Camptozonotriletes samanthus</i>			
<i>Archaeozonotriletes variabilis</i>			
<i>Archaeozonotriletes columnus</i>			
<i>Chelinospora concinna</i>			
<i>Chelinospora ligurata</i>			
<i>Cymbosporites cyathus</i>			
<i>Cymbosporites catillus</i>			
<i>Grandispora inculca</i>			
<i>Calyptosporites microspinosus</i>			
<i>Calyptosporites proteus</i>			
<i>Calyptosporites optivus</i>			
<i>Rhabdosporites scamus</i>			
<i>Geminospora spinosa</i>			
<i>Geminospora avalbardiae</i>			
<i>Stenozonotriletes sp.</i>			
<i>Perotriletes ergatus</i>			
<i>Perotriletes pannosus</i>			
<i>Hyaetriosporites mitratus</i>			
<i>Bullatisporites bullatus</i>			
<i>Reticulatisporites emsiensis</i>			
<i>Camptozonotriletes aliquantus</i>			
<i>Archaeozonotriletes meandricus</i>			
<i>Tholisporites ancylus</i>			
<i>Chelinospora perforata</i>			
<i>Perotriletes eximius</i>			
<i>Grandispora diamphida</i>			
<i>Aulicosporites aulicus</i>			
<i>Ancyrospora trocha</i>			
<i>Ancyrospora reuta</i>			
<i>Emphanisporites neglectus</i>			
<i>Emphanisporites minutus</i>			
<i>Craspedispora craspeda</i>			
<i>Stenozonotriletes furtivus</i>			
<i>Stenozonotriletes inessus</i>			
<i>Cirratiradites dissutus</i>			
<i>Rhabdosporites cymatilus</i>			
<i>Leiotriletes pagius</i>			
<i>Emphanisporites decoratus</i>			
<i>Lycospora culpa</i>			
<i>Punctatisporites glaber</i>			
<i>Punctatisporites laevigatus</i>			
<i>Calamospora nigra</i>			
<i>Calamospora microrugosa</i>			
<i>Granulatisporites muninensis</i>			
<i>Cyclogmanisporites plicatus</i>			

the Fiskekløfta Division psammosteids, a Givetian age equivalent is provisionally suggested for the *Triangulatus* Assemblage.

Other productive samples

Wood Bay Formation—deformed eastern portion (Mimerbukta Sandstone of Friend 1961). Thirteen samples collected from Karnakfjellet, East Lagercrantzberget, and Mimerbukta were prepared, of which six produced a few poorly preserved, morphologically simple spores. These spores cannot be included within any one of the described assemblages. Spores present were *Punctatisporites glaber* (Naumova) Playford 1962, *Punctatisporites laevigatus* (Naumova) Allen 1965, and *Cyclogranisporites plicatus* Allen 1965.

Widje Bay Formation. Of the twenty-eight samples prepared, six produced a few ill-preserved spores. These were: *Leiotriletes parvus* Naumova 1953, *Punctatisporites glaber* (Naumova) Playford 1962, *Calamospora nigrata* (Naumova) Allen 1965, *Granulatisporites muninensis* Allen 1965, *Geminospora svalbardiae* (Vigran) Allen 1965, and *Cyclogranisporites plicatus* Allen 1965.

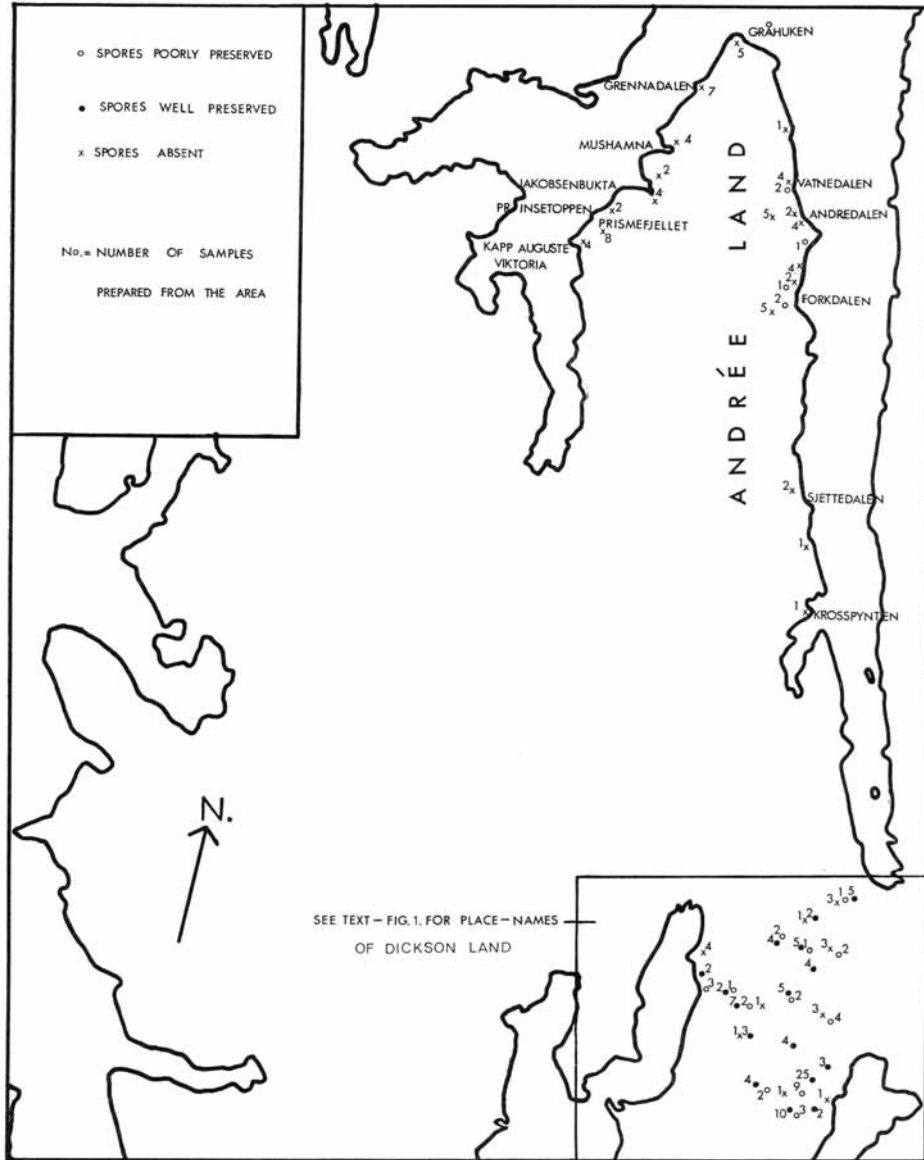
No diagnostic species were present, and the assemblage cannot be related to any one of the described assemblages. With 75 per cent. of the spores being *Punctatisporites glaber* (Naumova) Playford, and the rest of a very simple construction, this poorly preserved assemblage resembles most closely that of the Fraenkelryggen Formation, which is clearly considerably older.

ABSENCE OF SPORES IN ANDRÉE LAND

From numerous localities and horizons within Andrée Land (text-fig. 4), 73 rock specimens were macerated from which only 6 (all from the Wijde Bay Formation) produced spores. These were ill-preserved, few in number, and of a simple morphographic nature. Many of these samples did, however, produce poorly preserved tracheids and cuticle fragments. This compares with 138 rock specimens prepared for microscopic examination from Dickson Land, of which only 18 failed to produce any spores, and of the remainder 93 produced moderately well preserved and diverse species.

Of the Andrée Land specimens prepared, 42 were from the Grey Hoek Formation, 28 from the Wijde Bay Formation, and 3 from the Wood Bay Formation. From the palaeo-ecological aspect, samples from every lithology present in Andrée Land were prepared; these included black shales, dark grey-green and red siltstones and sandstones, and ferruginous nodules. From the depositional aspect, specimens were selected for their high or low micaceous and calcareous contents, and for size of plant remains, from specimens with very large plant fragments down to those with only carbonaceous specks. Specimens with well-preserved plant or fish fragments were especially selected, and badly weathered material was not used. Much experimentation in timing and concentration of chemicals in the preparation of samples, suggests that the preparation technique was not at fault.

Absence of spores from the red beds in the Wood Bay Formation in both Andrée Land and Dickson Land, is probably the result of depositional or post-depositional lateritic and oxidizing conditions, whereas their absence from non-red Wijde Bay and Grey Hoek Formations is more surprising. If, as Friend (1961) suggests, these beds



TEXT-FIG. 4. Localities in Andrée Land and Dickson Land giving details of spore presence and absence.

represent a marginal marine area, then it is unlikely that they would produce spores in the same quantity, or of the same diverse morphology, as those from the Mimer Valley Formation, which probably represents an area of inland rivers and stagnant lakes (Friend 1961). However, abundant plant fragments are present throughout the Wijde Bay and Grey Hoek Formations, and it seems very probable that spores were commonly deposited within this sequence. Sub-aerial weathering has some effect, but unweathered samples were carefully selected, and specimens from Andrée Land are certainly no more weathered than productive Dickson Land samples. Two possibilities would appear to remain; either there has been an increase in thickness of post-Devonian sediments northwards, the greater overburden causing disruption of the spore exine, or there has been increased tectonic activity in Andrée Land. There is no evidence for greater thickness of post-Devonian deposits to the north in Andrée Land (Orvin 1940), and during Carboniferous and Permian times, the main basins of deposition were to the south of Andrée Land (Cutbill and Challinor 1965, pp. 425–31). A tectonic cause seems more probable; absence of spores from the deformed eastern part of the Wood Bay Formation in Dickson Land (Mimerbukta Sandstone of Friend 1961), is certainly due to their deformed state, and although the Wijde Bay and Grey Hoek Formations have not suffered deformation to the same extent, there have frequently been small movements along the bedding planes. It may be a certain type of deformation that destroys spores, for in Dickson Land spores have been obtained from vertical and slightly overturned beds. Before a more definite hypothesis can be put forward, further sampling must be carried out in the critical, rather inaccessible, area of North Dickson Land and South Andrée Land.

CONCLUSIONS

The Spitsbergen succession is particularly important as a spore assemblage/stratigraphical study, in that it represents one of the few Devonian continental successions extending from Lower Devonian into Middle Devonian without a stratigraphical break. According to Vogt (1941) there is an unconformity between the Wood Bay and Mimer Valley Formations in Mimerdalen, but neither Friend (1961, p. 95) nor the author could find any evidence of this within the Estheriahaugen section. Further more detailed subdivision of the Eximius Assemblage may help to solve this problem.

Of the three successive assemblages described herein, the *Triangulatus* Assemblage is compared in part with assemblages from the Lower Givetian of Russia, and with the Upper Eifelian and Lower Givetian of Scotland. The *Culpa* and *Eximius* Assemblages cannot be closely compared with previously described Devonian assemblages. The diversity of spore forms particularly in the *Eximius* Assemblage, suggests that during Lower Devonian times, Spitsbergen supported a relatively advanced land flora.

The vertical distribution of dispersed spores provides a useful means of correlation within Dickson Land. This is particularly important in an area where fish fragments may be sparse or only locally abundant.

Acknowledgements. The author especially thanks Mr. N. F. Hughes for his advice and encouragement throughout this study, and Dr. P. F. Friend whose help with the stratigraphy has been invaluable. He also thanks Professor O. M. B. Bulman, F.R.S. for the use of research facilities at the Sedgwick Museum, Cambridge, and the Shell International Petroleum Company Limited, for financial assistance during the tenure of one of their Postgraduate Studentships.

APPENDIX I

A note on the geographical position of Plantekløfta and Planteryggen

Plantekløfta was named by Høeg (1942, p. 69), for a 'small ravine in the east side of the plateau, between Fiskekløfta and Torfjellet'. This is shown as position A in text-fig. 1. Planteryggen was also named by Høeg (1942, p. 69), being 'somewhat further north on the sloping side of the terrace at the foot of Torfjellet', position B in text-fig. 1. These localities were checked in a private communication with Professor O. A. Høeg.

Prior to Høeg's publication, however, Vogt (1941, pp. 2, 3 and fig. 1) referring only to Plantekløfta, recorded its position as being a ravine on the south-eastern slopes of Odinfjellet (see text-fig. 1).

Orvin (1958, p. 85) in Supplement I to *The Place Names of Svalbard*, records Planteryggen as the 'ridge in the extreme south-eastern part of Odinfjellet' (see text-fig. 1), and Plantekløfta as the 'brook ravine in the south-eastern slope of Odinfjellet', which is the same location as that recorded by Vogt.

Friend (1961) follows Vogt's and Orvin's localities, in naming the Planteryggen Sandstone and Plantekløfta Conglomerate.

Since the publication of *The Place Names of Svalbard* (edit. Hoel 1942) and Supplement I to that publication (edit. Orvin 1958), most authors (including the present writer) have followed the well-documented place-names as recorded therein. It would be less confusing if in future Orvin's (1958) recordings of Plantekløfta and Planteryggen were always followed.

APPENDIX II

Macroscopic information on samples studied

Macroscopic information on the samples recorded in Tables 1–4, is listed below. The collector is referred to in the Cambridge Spitsbergen Specimen number; (B) B. Moore, (C) M. J. Collins, (F) P. F. Friend, (G) D. J. Gobbett, (K) present author, (N) N. F. Hughes. All samples referred to were prepared by the author (KA).

Caiusbreen–Hoelbreen col.

- F800 sandstone, grey-green, with plant fragments; KA18.
- F799 mudstone, grey-green, micaceous, with plant fragments; KA15.
- K621 siltstone, dark grey, micaceous, with plant fragments; KA190.
- K623 sandstone, grey, micaceous with plant fragments; KA227.

Gonvillebreen–Stensiöbreen ridge

- K626 siltstone, grey, with plant fragments; KA294.
- K632 sandstone, grey-green, slightly micaceous, with plant fragments; KA226.
- K634 siltstone, grey-green, with plant fragments; KA284.
- K636 sandstone, grey-green, fine-grained, with plant fragments; KA194.
- K638 sandstone, grey-green, fine-grained, micaceous, with plant fragments; KA230.

West Lagercrantzberget

- K678 shale, black, slightly micaceous; KA254.
- K681 shale, black, slightly micaceous; KA290.
- K676 siltstone, grey-green, micaceous, with plant fragments; KA 289.
- K674 sandstone, grey-green, micaceous, with plant fragments; KA232.
- K670 sandstone, grey-green, micaceous, with plant fragments; KA264.
- K665 siltstone, grey-micaceous, with plant fragments; KA267.

Estheriahaugen

- F840 conglomerate, siltstone lenses, ferruginous; KA130.
- G1394 siltstone, dark grey, with plant fragments; KA122.
- F831 sandstone, grey, with plant fragments; KA14.
- F830 siltstone, grey with plant fragments; KA128.

- K855 siltstone, grey-green, micaceous, with plant fragments: some movement along the bedding planes; KA278.
 K854 shale, grey-green, with plant fragments; KA282.
 G1388 siltstone, grey, micaceous, with plant fragments; KA123.
 G1385 siltstone, black and red, with fish fragments; KA133; KA270.
 G1393 cannel coal; KA35, KA41.
 F826 cannel coal; KA31, KA127.
 F823 cannel coal; KA29.
 G1384 sandstone, dark grey; KA132, KA151.
 K891 shale, black; KA261.
 K846 shale, dark grey, with plant fragments; KA287.
 F836 fine sandstone, light grey, with plant fragments; KA131.
 G1372 siltstone, green, micaceous, with plant fragments; KA77.
 G1371 siltstone, grey, calcareous; KA100.
 G1366 siltstone, grey, calcareous, with plant fragments; KA124.
 G1365 mudstone, grey-green, with carbonaceous specks; KA275.
 G1364 mudstone, grey-green, with plant fragments; KA147.
 K850 shale, grey; KA281.
 K849 siltstone, grey-green, micaceous, with plant fragments; KA188.
 K897 siltstone, grey-green, with lamellibranchs; KA249, KA271.
 K838 sandstone, grey, with plant fragments; KA204.
 G1350 marl, grey-green, with plant fragments; KA167.
 G1356 pellet conglomerate, micaceous, calcareous, with fish fragments; KA162.

Watsontoppen

- B652 sandstone, yellow-grey, with plant fragments; KA149.
 B661 sandstone, yellow, with plant fragments; KA104.

North ridge of Kinanderfjellet

- K530 siltstone, grey-green, slightly micaceous, with plant fragments; KA185.
 K558 shale, grey-green, with plant fragments; KA269.
 K550 siltstone, grey-green, micaceous, with plant fragments; KA229.
 K555 siltstone, grey, with plant fragments; KA203.
 K556 shale, grey; KA293.
 K559 sandstone, grey-green, fine-grained, micaceous, with plant fragments; KA228.

Gonvillebreen-Hörbybreen col

- F793 nodular ironstone, with fish fragments; KA136.
 F798 nodular ironstone; KA135.
 F790 shale, green, micaceous, with plant and fish fragments; KA101.
 F788 siltstone, green, micaceous, with plant and fish fragments; KA121.
 K590 siltstone, grey, ferruginous, micaceous, with plant fragments; KA235.

Odindalen

- K816 siltstone, grey, ferruginous, micaceous, with plant fragments; KA276.
 K815 siltstone, grey-green, micaceous, with well-preserved plant fragments; KA179.
 K808 sandstone, grey, fine-grained, micaceous, with plant fragments; KA288.
 K806 sandstone, grey, fine-grained, micaceous, with plant fragments; KA183.
 K801 sandstone, grey, fine-grained, micaceous, with plant fragments; KA186.
 K782 sandstone, grey, with plant fragments; KA193.

North and East Munindalen

- K773 siltstone, grey-brown, with plant fragments; KA286.
 K772 siltstone, grey-brown, with plant fragments; KA242.
 K767 mudstone, grey-brown, with plant fragments; KA243.
 K760 siltstone, grey-green, micaceous, with plant fragments; KA255.

Fiskekløfta

- K745 siltstone, dark grey, with plant fragments; KA252.
K738 shale, grey, slightly micaceous, with plant fragments; KA283.
F1529 siltstone, grey, micaceous, with plant fragments; KA110.
K737 siltstone, grey, micaceous, with plant fragments; KA245.
K728 sandstone, grey-green, fine-grained, with well-preserved plant fragments; KA241.
K721 siltstone, grey, micaceous, with plant fragments; KA244.
K720 shale, dark grey, with carbonaceous specks; KA279.
K753 siltstone, black, micaceous, with plant fragments; KA292.
K914 siltstone, grey-green, micaceous, with plant fragments; KA268.
K920 fine sandstone, grey-brown, micaceous, poorly preserved plant fragments; KA285.
K922 bright coal; KA258.
K716 siltstone, grey-purple, micaceous, with plant fragments; KA178.
K829 siltstone, dark grey, micaceous, with plant fragments; KA223.

Odellfjellet

- K519 siltstone, grey, micaceous, with plant fragments; KA209.
K515 sandstone, grey-green, fine-grained, micaceous, with plant fragments; KA211.
K509 sandstone, grey-green, micaceous, with plant fragments; KA195.
F632 siltstone, grey, slightly calcareous, with ostracods; KA164.
K507 siltstone, grey, micaceous, with plant fragments; KA263.
K501 siltstone, grey-green, micaceous, with plant fragments; KA266.

Manchesterbreen spur

- K571 shale, grey-green, with plant fragments; KA265.
K572 siltstone, grey-green, very micaceous, with plant fragments; KA234.
K584 sandstone, grey-green, with plant fragments; KA233.
K577 sandstone, light grey; KA236.
K579 sandstone, grey-green, micaceous, with plant fragments; KA198.
K582 siltstone, grey-green, with plant fragments; KA240.

Triungen

- K649 siltstone, grey-green, fine-grained, micaceous, with plant fragments; KA291.
K648 siltstone, grey-green, with plant fragments; KA231.
K645 siltstone, grey, micaceous, with plant fragments; KA202, KA237.

Hugindalen

- C626 siltstone, grey, with plant fragments; KA272.
F1598 siltstone, dark grey; KA148.
F1597 siltstone, grey-green, with plant fragments; KA145, KA154.

Lykta

- N372 sandstone, grey-purple, fine-grained, micaceous; KA117.
N383 sandstone, grey, fine-grained, micaceous; KA106, KA166.
G1442 pellet conglomerate, calcareous, with fish fragments; KA176.
G1440 sandstone, grey, micaceous, slightly calcareous; KA78.

Reuterskioldfjellet

- K870 sandstone, grey-green, fine-grained, micaceous, with plant fragments; KA181.
K872 siltstone, grey, micaceous, with plant fragments; KA274.
K876 sandstone, grey, fine-grained, micaceous, with plant fragments; KA250.

South Mimerdalen

- K908 siltstone, black; KA262.
K905 siltstone, black; KA251.
-

REFERENCES

- ALLEN, K. C. 1965. Lower and Middle Devonian Spores of North and Central Vestspitsbergen. *Palaeontology*, **8**, 687–748, pl. 94–108.
- BALME, B. E. and HASSELL, C. W. 1962. Upper Devonian spores from the Canning Basin, Western Australia. *Micropaleontology*, **8**, 1–28.
- CHALONER, W. G. 1963. Early Devonian spores from a borehole in Southern England. *Grana palynologica*, **4**, 100–10.
- CHIBRIKOVA, E. V. 1959. Spores of the Devonian and older deposits of Bashkir. *Akad. Nauk SSSR, Materials on Palaeont. and Strat. of Devonian and older deposits of Bashkir*, 3–116 (in Russian).
- CUTBILL, J. L. and CHALLINOR, A. 1965. Revision of the Stratigraphical Scheme for the Carboniferous and Permian rocks of Spitsbergen and Bjørnøya. *Geol. Mag.* **102**, 418–39.
- DINELEY, D. L. 1960. The Old Red Sandstone of eastern Ekmanfjorden, Vestspitsbergen. *Geol. Mag.* **97**, 18–32.
- FORBES, C. L., HARLAND, W. B. and HUGHES, N. F. 1958. Palaeontological evidence for the age of the Carboniferous and Permian rocks of Central Vestspitsbergen. *Geol. Mag.* **95**, 465–90.
- FRIEND, P. F. 1961. The Devonian stratigraphy of North and Central Vestspitsbergen. *Proc. Yorks. Geol. Soc.* **33**, 77–118.
- HEINTZ, N., and MOODY-STUART, M. (In press). New Unit Terms for the Devonian of Spitsbergen and new Stratigraphical Scheme for the Wood Bay Formation.
- HØEG, O. A. 1942. The Downtonian and Devonian flora of Spitsbergen. *Skr. Svalb. og Ishavet Unders.* **83**, 77–146.
- HORN, G. 1941. Petrology of a Middle Devonian cannel coal from Spitsbergen. *Norsk Geol. Tidsskr.* **21**, 13–18.
- KEDO, G. I. 1955. Spores of the Middle Devonian of the north-east of Belorussia SSR. *Palaeont. i stratig. B.S.S.R. I. Minsk. Akad. Nauk B.S.S.R.* 5–47 (in Russian).
- 1957. Spores from salt deposits of the Pripiat depression and their stratigraphic significance. *Ibid.* 3–43 (in Russian).
- MCGREGOR, D. C. 1961. Spores with proximal radial pattern from the Devonian of Canada. *Bull. geol. Surv. Canada*, **76**, 1–12.
- NAUMOVA, S. N. 1953. Sporo-pollen complexes of the Upper Devonian of the Russian Platform and their stratigraphical value. *Tr. Inst. Geol. Nauk Akad. SSSR.* **143** (Geol. Ser. no. 60), 1–204 (in Russian).
- ORVIN, A. K. 1940. Outline of the geological history of Spitsbergen. *Skr. Svalb. og Ishavet*, **78**, 1–57.
- 1958 (edit.). Supplement I to the Place Names of Svalbard. *Skr. Norsk. Polarinst.* **112**, 1–133.
- PLAYFORD, G. 1962. Lower Carboniferous microfloras of Spitsbergen, Part I. *Palaeontology*, **5**, 550–618. Part 2 (1963). *Ibid.* **5**, 619–78.
- RICHARDSON, J. B. 1960. Spores from the Middle Old Red Sandstone of Cromarty, Scotland. *Ibid.* **3**, 45–63.
- 1962. Spores with bifurcate processes from the Middle Old Red Sandstone of Scotland. *Ibid.* **5**, 171–94.
- TARLO, L. B. H. 1964. Psammosteiformes (Agnatha). A Review with description of new material from the Lower Devonian of Poland. I. General Part. *Palaeontologia Polonica*, **13**, 135 pp.
- TAUGOURDEAU-LANTZ, J. 1960. Sur la microflore du Frasnian Inferieur de Beaulieu (Boulonnais). *Rev. de Micropaléontologie*, **3**, 144–54.
- VIGRAN, J. 1964. Spores from Devonian deposits, Mimerdalen, Spitsbergen. *Skr. Norsk. Polarinst.* **132**, 1–30.
- VOGT, T. 1941. Geology of a Middle Devonian cannel coal from Spitsbergen. *Norsk Geol. Tidsskr.* **21**, 1–12.
- WINSLOW, M. R. 1962. Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio. *Prof. Pap. U.S. geol. Surv.* **364**, 1–93.

K. C. ALLEN,
43 April Close,
Horsham,
Sussex