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UPPERMOST CAMBRIAN AND LOWER ORDOVICIAN ACRITARCHS AND LOWER ORDOVICIAN CHITINOZOANS FROM WILCOX PASS, ALBERTA

F. Martin

1992

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PREFACE

The microfossils described in this report were collected from the Upper Cambrian to Lower Ordovician Survey Peak, Outram, and Skoki formations of the southern Canadian Rocky Mountains. Several assemblages are recognized, and three new species of acritarch are described. The assemblages were dated mainly by using established trilobite zones as reference. The *Corallasphaeridium wilcoxianum* Zone is a useful stratigraphic marker near the Cambrian–Ordovician boundary. This new zone permits correlation between northern Laurentia and the Sino–Korean platform in northeastern China. In addition, two of the acritarchs described are known from Sweden, which formed part of Baltica in the Ordovician.

Detailed taxonomic and biostratigraphic studies such as this establish a framework for the precise dating and correlation of rock units, and are a vital tool in the assessment of resources in Canada's sedimentary basins. Correlation of rock units across international boundaries is also facilitated.

Elkanah A. Babcock
Assistant Deputy Minister
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PRÉFACE

Les microfossiles faisant l'objet du présent rapport ont été échantillonnés dans les formations de Survey Peak, d'Outram et de Skoki; ces formations varient en âge du Cambrien supérieur à l'Ordovicien inférieur et s'observent dans la partie sud des Rocheuses canadiennes. Plusieurs assemblages sont identifiés et trois nouvelles espèces d'acritarches sont décrites. Les assemblages ont été datés principalement à partir de zones à trilobites. La zone à *Corallasphaeridium wilcoxianum* proposée représente un repère stratigraphique utile à proximité de la limite entre le Cambrien et l'Ordovicien. Cette nouvelle zone permet d'établir une corrélation entre la Laurentia septentrionale et la plate-forme sino-coréenne du nord-est de la Chine. En outre, deux des acritarches décrits ont été observés en Suède qui faisait, durant l'Ordovicien, partie de la Baltica.

Des études taxonomiques et biostratigraphiques détaillées de cet ordre permettent d'en arriver à la datation précise et à la corrélation d'unités lithostratigraphiques; de plus, elles constituent un outil indispensable à l'évaluation des ressources dans les bassins sédimentaires du Canada. La corrélation d'unités lithostratigraphiques d'un pays à l'autre s'en trouve également facilitée.

Elkanah A. Babcock
Sous-ministre adjoint
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UPPERMOST CAMBRIAN AND LOWER ORDOVICIAN ACRITARCHS AND LOWER ORDOVICIAN CHITINOZOANS FROM WILCOX PASS, ALBERTA

Abstract

Organic-walled microfossils from Wilcox Pass, in the southern Canadian Rocky Mountains, are described from 651.9 m of mainly shallow water marine carbonate deposits belonging to the Survey Peak Formation, the Outram Formation, and the lowest 32 m of the Skoki Formation. Three new acritarch species are described: *Acrum*? *jasperense*, *Aryballomorpha albertana*, and *Athabascaella sunwaptana*. The species *Corollasphaeridium wilcoxianum* Martin *in* Dean and Martin, 1982 is emended. Six acritarch-based units (microfloras AU1-AU6), the second of which is proposed formally as the *Corollasphaeridium wilcoxianum* Zone, contain badly to moderately well preserved material, and range from uppermost Upper Cambrian to Lower Ordovician. Poorly represented chitinozoans from the Arenig are grouped in one unit (microfauna CU1). Fossil age control is determined mainly on the basis of the trilobite succession. Palynological data extend from 0.9 m below strata dated as *Corbinia apopsis* Subzone of the *Saukia* Zone to 30.3 m above strata belonging to trilobite zone J. In the lowest member of the Survey Peak Formation, two of the three conodont zones whose bases are being considered for defining the Cambrian–Ordovician systemic boundary are also used in dating. The *C. wilcoxianum* Zone, which is close to the Cambrian–Ordovician boundary, and microflora AU5b, from the upper Tremadoc, trilobite zones D to E, indicate correlation between the northern shelf of Laurentia and the northern border of the Sino-Korean platform, northeastern China. Two index acritarchs, *Aryballomorpha grootaertii* (Martin) emend. Martin and Yin, 1988 and *Athabascaella playfordii* (Martin) emend. Martin and Yin, 1988 occur in the Lower Ordovician of Laurentia and northeastern China and of Öland, Sweden, which was part of Baltica in the Ordovician.

Résumé

Les microfossiles à paroi organique du col Wilcox, des Rocheuses canadiennes méridionales, proviennent de 651,9 m de dépôts marins essentiellement peu profonds, carbonatés et appartenant à la formation de Survey Peak, à la formation d'Outram et aux 32 m inférieurs de la formation de Skoki. Trois nouvelles espèces d'acritarches sont décrites: *Acrum*? *jasperense*, *Aryballomorpha albertana* et *Athabascaella sunwaptana*. L'espèce *Corollasphaeridium wilcoxianum* Martin *in* Dean et Martin, 1982 est modifiée. Six unités à acritarches (microflores AU1-AU6), dont la seconde est proposée formellement en tant que zone à *Corollasphaeridium wilcoxianum*, contiennent du matériel mal à moyennement conservé. Elle sont étendues du sommet du Cambrien supérieur à l'Ordovicien inférieur. Les chitinozoaires sont pauvrement représentés dans l'Arénigien et groupés dans une unité (microfaune CU1). Les âges sont établis principalement par la succession des trilobites. Les données palynologiques vont de 0,9 m sous des dépôts contenant la sous-zone à *Corbinia apopsis* de la zone à *Saukia*, à 30,3 m au-dessus de ceux appartenant à la zone J à trilobites. En outre dans le membre inférieur de la formation de Survey Peak, il est fait usage de deux des trois zones à conodontes dont les bases sont prises en considération pour établir la limite entre le Cambrien et Ordovicien. La zone à *Corollaspharidium wilcoxianum*, proche de la limite cambro-ordovicienne, et la microflore AU5b, dans le Trémadocien supérieur, permettent des corrélations entre le versant nord du Laurentia et celui de la plate-forme sino-coréenne, du nord-est de la Chine. Deux acritarches de valeur stratigraphique détaillée, *Aryballomorpha grootaertii* (Martin) emend. Martin et Yin, 1988 et *Athabascaella playfordii* (Martin) emend. Martin et Yin, 1988 sont présents dans l'Ordovicien inférieur de ces deux dernières régions et aussi à Öland, en Suède, alors partie de la Baltica.

Summary

Two hundred and one palynological samples were examined from Upper Cambrian to Lower Ordovician deposits exposed opposite the Athabasca Glacier, in the southern Canadian Rocky Mountains. The productive samples were collected only at Wilcox Pass, from 651.9 m of mostly carbonate rocks that are well exposed, almost continuous, and unfaulted. The succession comprises, in ascending stratigraphic order: the Survey Peak Formation, 357.5 m thick and divided into four informal members (basal silty member, putty shale member, middle member, and upper massive member); the Outram Formation, 266 m thick; and the lowest 46.1 m of the Skoki Formation. In the absence of stratigraphically useful graptolites, the samples are dated by means of trilobites, known from almost the whole section and extending from the uppermost Upper Cambrian (Croixan Series, in part), *Corbinia apopsis* Subzone of the *Saukia* Zone, to the Arenig (Ibexian Series, in part), trilobite zone J. In addition, two conodont zones represented in the basal silty member are among those being considered internationally for defining the base of the Ordovician System. One hundred and thirty-two samples yielded determinable acritarchs, which are rare to moderately abundant and generally poorly preserved, except in the basal silty member, where their preservation is slightly better. Thirteen samples contained chitinozoans that could be identified approximately but are all very poorly preserved. No clear relationship was observed between the composition of acritarch assemblages and the distribution of Grand Cycles in the deposits and their subdivisions. The appearance of chitinozoans at the base of the Outram Formation is probably due more to its Arenig age than to its coinciding with the beginning of a Grand Cycle.

Three new acritarch species are described: *Acrum*? *jasperense*, *Aryballomorpha albertana*, and *Athabascaella sunwaptana*. The species *Corollasphaeridium wilcoxianum* Martin *in* Dean and Martin, 1982 is emended. Six acritarch-based units (microfloras AU1-AU6), the second of which is proposed also as the *Corollasphaeridium wilcoxianum* Zone, ranges from the uppermost Upper Cambrian to the Arenig Series (in part). Microflora AU1 (*Goniosphaeridium* sp. aff. *G. akrochodermum–Actinotodissus* sp. A assemblage) is found in the basal silty member, from 0.9 m below the *Corbinia apopsis* Subzone into the *Missisquoia* Zone; it is also dated as *Cordylodus proavus* Zone. Microflora AU1 belongs to the lowermost Ordovician, if the base of this system is drawn at the base of the *C. proavus* Zone; it belongs to the Upper Cambrian, if the systemic boundary is drawn at the base of the *Cordylodus intermedius* Zone. The *Corollasphaeridium wilcoxianum* Zone begins in the basal silty member, in the (questionably) upper part of the *Missisquoia* Zone and at a level close to the base of the *C. intermedius* Zone; it ends in strata containing trilobites of zone A. Microflora AU3 (consisting almost entirely of rare leiosphaerids) is recognized sporadically from the summit of the basal silty member up to the lower part of the middle member; it is dated as trilobite zones A and B. Microflora AU4 (with *Acrum*? *jasperense*) in the middle member corresponds to part of trilobite zones B and C. Microflora AU5 (with *Aryballomorpha albertana* in the lower part, microflora AU5a, and/or *A. grootaertii* in the upper part, microflora AU5b) occurs in the middle member, in trilobite zones C to E. Microflora AU6 (*Rhopaliophora pilata–R. palmata* and *Peteinosphaeridium* sp. cf. *P. breviradiatum* assemblage) begins at the summit of the upper massive member and continues throughout the Outram Formation into the basal 0.7 m of the Skoki Formation; it extends from trilobite zones F to J; that is, from the upper Tremadoc into the Arenig. Microfauna CU1 (with *Conochitina* sp. cf. *C. brevis* and/or *C.* sp. cf. *C. exilis*) occurs sporadically in the Outram Formation, from 10.7 m above its base, and in the lowest 32 m of the Skoki Formation. Of Arenig age, it extends from trilobite zone G to a level without macrofossils that lies 31.3 m above strata dated as zone J, and may also belong to that zone.

Among the seven palynological units above, the detailed stratigraphic value of the *Corollasphaeridium wilcoxianum* Zone, close to the Cambrian–Ordovician boundary, and of microflora AU5b, in the upper Tremadoc, is emphasized. The *C. wilcoxianum* Zone permits the establishment of a correlation between the northern part of Laurentia and the northern margin of the Sino–Korean platform in northeastern China. Two acritarchs, *Aryballomorpha grootaertii* (Martin) emend. Martin and Yin, 1988 and *Athabascaella playfordii* (Martin) emend. Martin and Yin, 1988 from microflora AU5b are known also from Lower Ordovician strata of the island of Öland, Sweden, which formed part of Baltica in the Ordovician.

Sommaire

L'auteur a examiné 201 échantillons palynologiques provenant de dépôts cambriens supérieurs à ordoviciens inférieurs exposés face au glacier Athabasca, dans les Rocheuses canadiennes méridionales de l'Alberta. Les échantillons productifs ont été récoltés uniquement au col Wilcox dans 651,9 m de strates, en majorité carbonatées, bien exposées, sans faille et presque continues. Dans l'ordre ascendant, elles sont formées par la formation de Survey Peak, épaisse de 357,5 m et divisée en quatre membres informels (le membre basal silteux, le membre de schiste d'aspect mastic, le membre moyen et le membre supérieur massif), par la formation d'Outram épaisse de 266 m et les 46,1 m inférieurs de la formation de Skoki. En l'absence de graptolithes stratigraphiquement utilisables, les datations reposent sur l'extension des trilobites, connue dans toute la section et allant du sommet du Cambrien supérieur (série Croixen en partie), sous-zone à *Corbinia apopsis* de la zone à *Saukia*, à l'Arénigien (série Ibexien en partie), zone J. En outre, les deux zones à conodontes du membre basal silteux sont parmi celles internationalement prises en considération pour fixer la base du système Ordovicien. Cent trente-deux échantillons ont fourni des acritarches déterminables, rares à modérément abondants et généralement mal conservés, sauf dans le membre silteux basal où leur préservation est un peu meilleure. Treize échantillons ont permis des déterminations approximatives de chitinozoaires, tous très mal conservés. Aucune relation claire et répétitive n'a été observée entre la composition des assemblages d'acritarches et la distribution des grands cycles de dépôts et leurs subdivisions. L'apparition de chitinozoaires à la base de la formation d'Outram est sans doute davantage en relation avec l'âge arénigien qu'avec le début d'un grand cycle.

Trois nouvelles espèces d'acritarches sont décrites, *Acrum*? *jasperense, Aryballomorpha albertana* et *Athabascaella sunwaptana*. L'espèce *Corollasphaeridium wilcoxianum* Martin *in* Dean et Martin, 1982 est modifiée. Six unités à acritarches (AU1-AU6), dont la seconde est formellement proposée en tant que zone à *Corollasphaeridium wilcoxianum*, s'étendent du sommet du Cambrien supérieur à l'Arénigien. La microflore AU1 (assemblage à *Goniosphaeridium* sp. aff. *G. akrochodermum*–*Actinotodissus* sp. A) est décrite dans le membre basal silteux, de 0,9 m sous la sous-zone à *Corbinia apopsis*, jusque dans la partie supérieure de la zone à *Missisquoia*; elle est aussi datée par la zone à *Cordylodus proavus*. La microflore AU1 appartient à la partie la plus inférieure de l'Ordovicien si la base de ce système est fixée à la base de la zone à *C. proavus*; elle date de la fin du Cambrien supérieur si cette limite est placée à la base de la zone à *C. intermedius*. La zone à *Corollasphaeridium wilcoxianum* débute dans le membre basal silteux, dans la partie supérieure et discutable de la zone à *Missisquoia* et à un niveau proche de la zone à *Cordylodus intermedius*; elle se termine dans des dépôts contenant la zone A à trilobites. La microflore AU3 (avec presqu'uniquement de rares leiosphaerides) est sporadiquement reconnue de l'extrême sommet du membre basal silteux jusqu'à la partie inférieure du membre moyen; elle est datée par les zones A et B à trilobites. La microflore AU4 (avec *Acrum*? *jasperense*) correspond, dans le membre moyen, à une partie des zones B et C à trilobites. La microflore AU5 (avec *Aryballomorpha albertana* dans la partie inférieure, AU5a, et/ou *A. grootaertii* dans la partie supérieure, AU5b) est datée dans le membre moyen par les zones C à E à trilobites. La microflore AU6 (assemblage à *Rhopaliophora pilata*–*R. palmata* et *Peteinosphaeridium* sp. cf. *P. breviradiatum*) débute au sommet du membre massif supérieur, continue dans toute la formation d'Outram et dans les 0,7 m à la base de la formation de Skoki; elle s'étend de la zone F à J à trilobites, soit de la partie supérieure du Trémadocien à l'Arénigien. La microfaune CU1 (avec *Conochitina* sp. cf. *C. brevis* et/ou *C.* sp. cf. *C. exilis*) est sporadiquement présente dans la formation d'Outram, à partir de 10,7 m au-dessus de sa base, et dans les 32 m inférieurs de la formation de Skoki. Dans l'Arénigien, elle va de la zone G à trilobites jusqu'à 31,3 m au-dessus de dépôts datés par la zone J à trilobites; il se peut que cette dernière séquence appartiennen aussi à la zone J.

Parmi les sept précédentes unités palynologiques, la valeur stratigraphique détaillée de la zone à *Corollasphaeridium wilcoxianum*, proche de la limite cambro-ordovicienne, et de la microflore AU5b, dans le Trémadocien supérieur, est soulignée. Elle permet d'établir une corrélation entre la partie septentrionale du Laurentia et le versant nord de la plate-forme sino-coréenne dans le nord-est de la Chine. Deux acritarches de la microflore AU5b, *Aryballomorpha grootaertii* (Martin) emend. Martin et Yin, 1988 et *Athabascaella playfordii* (Martin) emend. Martin et Yin, 1988 sont aussi connus dans l'Ordovicien inférieur de l'île d'Öland, Suède, faisant alors partie de la Baltica.

INTRODUCTION

This paper provides new data on the succession of acritarch assemblages, and some information on that of chitinozoans, in warm, mainly shallow water, marine carbonate deposits of the Canadian cratonic realm. The successions range in age from latest Late Cambrian to Early Ordovician. In North American chronostratigraphy, the strata extend from the uppermost Croixan Series (as the Sunwaptan Stage of Ludvigsen and Westrop, 1985 proved unacceptable to Robinson et al., 1985) to, in part, the Ibexian Series, a term introduced by Ross et al. (1982) to replace the Canadian Series. The work is based on the well exposed, almost continuous, unfaulted section at Wilcox Pass (Fig. 1), located about 2.5 km north of the Athabasca Glacier, between Banff and Jasper, in the southern Canadian Rocky Mountains. The succession (Fig. 2), is as follows: Survey Peak Formation (approximately 357 m thick), divided into four informal members: basal silty member (38 m thick), putty shale member (42 m thick), middle member (199 m thick), and upper massive member (78.5 m thick); Outram Formation (266 m thick), and the lowest 46 m (approximately) of the Skoki Formation. It was measured in detail by Dean (1978, 1989), who also reviewed the lithostratigraphic terms.

The Survey Peak Formation, with its subdivisions, and the Outram Formation were proposed by Aitken

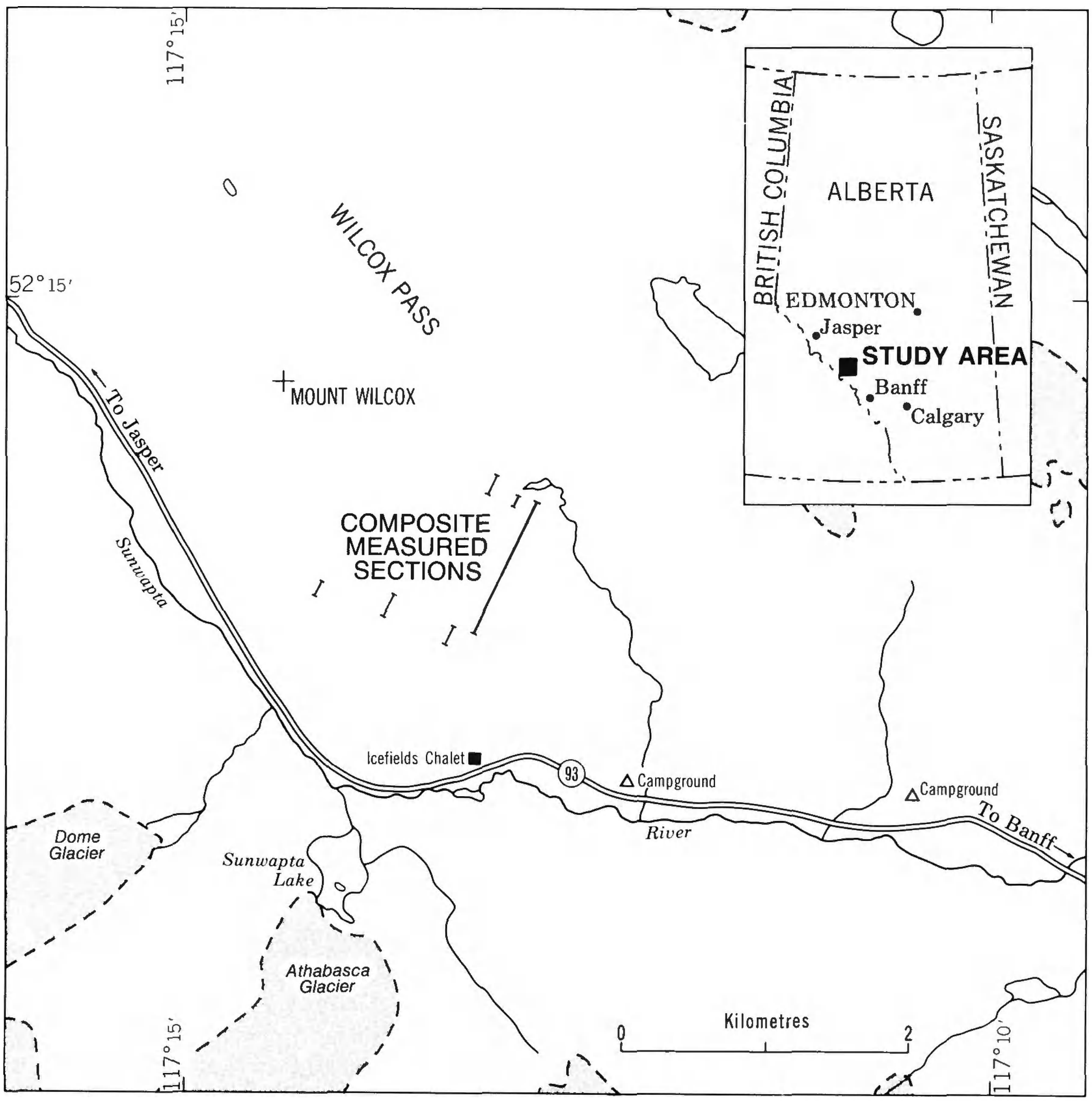

Figure 1. Outline maps showing the location of Wilcox Pass.

and Norford (1967, p. 160-179) on the basis of the cliff section on the south face of Mount Wilson, 35 km to the southeast. The Skoki Formation was proposed by Walcott (1928, p. 217, 218) for strata at Skoki Mountain, 14.5 km northeast of Lake Louise, and was revised by Norford (1969, p. 18-21). Fieldwork was carried out jointly with W.T. Dean in the summer of 1981, as part of GSC Project 500029, in order to extend and complete a preliminary palynological investigation from the Survey Peak Formation to the lowest Skoki Formation (Martin *in* Dean and Martin, 1982). This investigation had been based on samples obtained earlier in the course of work on the trilobite faunas (Dean, 1977, 1978). Further samples, all of which proved to be barren, were collected in 1981 from underlying Upper Cambrian rocks that outcrop lower on the hillside at the southeastern end of the west face of Wilcox Peak. These strata, which belong to the Mistaya Formation and the upper part of the Bison Creek Formation have been studied at Wilcox Peak by Westrop (1986) and extend from the *Illaenurus* to the *Saukia* trilobite zones. Lithostratigraphic terms were established by Aitken and Greggs (1967) at Mount Murchison, 45 km to the southeast.

The present acritarch data, obtained from 620.6 m of strata, range from uppermost Upper Cambrian (just below the *Corbinia apopsis* Subzone of the *Saukia* Zone), in the basal silty member of the Survey Peak Formation, to Lower Ordovician (trilobite zone J) in the lower part of the Skoki Formation. Chitinozoans were found in 287.3 m of Arenig strata, from trilobite zone G (in the Outram Formation) to 32 m above the base of the Skoki Formation, but 30.3 m above strata dated by means of trilobites as zone J. B.S. Norford (pers. comm., 1989) reported that the *Orthidiella* Zone, basal Whiterockian, is present in the Wilcox Pass section, but he did not give details. He recorded the brachiopod *Orthambonites marshalli* (Wilson) from levels in the uppermost Outram Formation and the

BRITISH SERIES	NORTH AMERICAN SERIES	FORMATION AND INFORMAL MEMBER (not to scale)		LITHOLOGY (From Aitken and Norford, 1967; Aitken, 1981; Dean, 1989)	PART OF UNIT SAMPLED (metres above base, except for Bison Creek Fm)	ACRITARCHS						CHITINOZOANS					
						No. of samples			Number in a gram	Percentage determinable	Range of acritarch-based unit	No. of samples			Number in a gram	Percentage determinable	Range of chitinozoan-based unit
						Barren	Undeter-minable	Deter-minable				Barren	Undeter-minable	Deter-minable			
ARENIG (part)	IBEXIAN (part)	SKOKI FM (lowest 46.10 m)		Mostly thick bedded dolomite, with well developed beds of nodular chert	0.70 – 46.10	8	1	1	25 – 100	2		8	0	2	1 – 3	5	CU1
		OUTRAM FM (266 m)		Characteristically nodular and clotted limestone in mudstone matrix; also calcarenite, limestone conglomerate, and impersistent chert horizons	156.20 – 265.65	0	14	8	25 – 100	1 – 5	AU6	17	5	0	1 – 5	0	
					3.65 – 152.50	0	0	50	25 – 100	1 – 10		37	3	11	1 – 5	5	
TREMADOC		SURVEY PEAK FM (357.50 m)	Upper massive mbr (78.50 m)	Calcarenite, dolomite, and subsidiary shale	72.85 – 78.15	0	0	2	5 – 15	5		2	0	0			
				Resistant, massive, thrombolitic limestone and biocalcarenite; subsidiary shale; occasional, impersistent chert beds	7.05 – 60.75	3	8	0	5 – 30	0		11	0	0			
			Middle mbr (199 m)	Mostly limestone, conglomerate, and thin bedded siltstone; subsidiary calcareous shale	188 – 198	0	0	4	5 – 30	1 – 5	AU5 b	4	0	0			
					19.40 – 183.15	0	3	41	5 – 2000	5 – 30	AU5 a; AU4	44	0	0			
					2.30 – 18.90	3	3	0	5	0		6	0	0			
			Putty shale mbr (42 m)	Mostly fissile, olive-grey, calcareous shale; numerous, commonly impersistent beds of flat-pebble conglomerate, calcarenite, and siltstone	0.05 – 40.45	14	0	3	5	50	AU3	17	0	0			
			Basal silty mbr (38 m)	Mostly silty shale, flat-pebble conglomerate, quartzitic and dolomitic silstone, calcarenite, and thrombolite	3.60 – 38	2	0	23	10 – 2000	75 – 95	AU2; AU1	25	0	0			
MERIONETH (part)	CROIXAN (part)	MISTAYA FM (129.40 m)		Mostly carbonate units, often dolomitized; biocalcarenite, and large masses of stromatolite and thrombolite; subsidiary hard shale	25.30 – 118.90	12	0	0				12	0	0			
		BISON CREEK FM (top 58.20 m)		Calcareous shale; thick beds of biocalcarenite; large masses of stromatolite and thrombolite	10 – 58.20 below top	3	0	0				3	0	0			

Figure 2. *Productivity of samples, and abundance and preservation of acritarchs and chitinozoans in relation to lithostratigraphic units at Wilcox Pass and on the hillside at the southeastern end of the west face of Wilcox Peak.*

lowermost Skoki Formation at Wilcox Pass. The same species is present in the *Orthidiella* Zone at Mount Wilson (Norford, 1969, p. 37). According to Dean (1989), the upper part of the Outram Formation contains trilobites that are found together in the lower and middle parts of zone J in Utah. The youngest chitinozoans at Wilcox Pass may be from the same zone, although this remains questionable. Graptolites are virtually absent from the section, and studies of macrofossils have been concerned mainly with trilobites, which have been systematically examined by Dean (1977) and Westrop (1986) for the basal silty member, and by Dean (1989) for the whole sequence. Correlations are proposed with the highest part of the Croixan Series and with the Ibexian trilobite zones A-J established in Utah and Nevada by Ross (1949, 1951), rather than the formally named zones of Hintze (1953). The faunal affinities between western U.S.A. and the southern Canadian Rocky Mountains, as exemplified by the Mount Wilson section, were first indicated by Aitken and Norford (1967).

The distribution of conodonts and trilobites in the Bison Creek and Mistaya formations, as well as the lowest approximately 31 m of the basal silty member along the eastern ridge leading to Wilcox Peak, was discussed by Westrop et al. (1981) and compared with the distribution published by Derby et al. (1972) for the Mount Wilson section, from the upper part of the Mistaya Formation almost to the top of the putty shale member. At the Mount Wilson section, Kennedy and Barnes (1981) commented briefly on the typical upper Tremadoc conodont genera in the upper part of the middle member and in the upper massive member, both of which belong to trilobite zone E. Westrop et al. (1981) confirmed the opinion of Dean (1978) that the base of the Survey Peak Formation at Wilcox Pass is slightly younger than at Mount Wilson. Dean (1989) noted that other lithostratigraphic boundaries in the area may also be diachronous, and for this reason the present acritarchs and chitinozoans are dated exclusively using information from trilobites or conodonts at, or in the immediate vicinity of, Wilcox Pass.

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PALYNOLOGICAL METHODS, AND PRESERVATION OF MATERIAL

Of the 34 samples that formed the basis of the preliminary study (Martin *in* Dean and Martin, 1982), 19 proved to be productive; of these only two, from the basal silty member, are considered further here (see Appendix).

The 202 other samples (see Appendix), including three (GSC locs. C-97832, C-97833, C-97834) from the middle member that were partially described previously (Martin, 1984), come mainly from interbeds of silty, calcareous, or dolomitic mudstone, and to a lesser extent from almost dolomitic limestone and chert. Most of the available rocks appeared unsuitable for palynological study, an impression that was subsequently confirmed. Each sample of 40 to 60 g of rock was treated using routine laboratory techniques (Martin *in* Martin and Dean, 1988). In addition, most of the samples from near the Cambrian-Ordovician boundary (as interpreted from trilobite evidence) were treated twice. All organic-walled microfossils, including those coated with gold for SEM examination, were permanently mounted in Canada Balsam.

The state of preservation of acritarchs and chitinozoans, indicated by the percentage of determinable specimens, and an estimate of their abundance, are summarized in Figure 2. The acritarchs, rare to moderately abundant, vary from a few to 2000 in a gram of rock, and are generally poorly preserved, corroded, and abraded. As is often the case, the preservation may vary considerably according to the taxon and also, but relatively less frequently, within representatives of the same species. The colour is variably dark brown, with a tendency for the narrow bases of the processes to be opaque, to black. The determinable specimens from Wilcox Pass have a TAI (Thermal Alteration Index) (Staplin, 1969) of between 3 and 4, whereas the indeterminable specimens have a TAI of between 4 and 5. The frequent loss of detail in ornamentation may be due to conditions of sedimentation or to diagenesis. Chitinozoans, present from the base of the Outram Formation upward, are very rare, with a maximum of five in a gram of rock. They are black, and often incomplete, with a TAI of 4 to 5. The only available data concerning the state of preservation of conodonts from the palynologically productive strata are from the basal silty member. According to Westrop et al. (1981, p. 51), the euconodonts exhibit a Colour Alteration Index (CAI) of low 4, indicating, according to the scale of Epstein et al. (1977), a temperature rise of at least 200°C. The best preserved acritarchs from the Wilcox Pass section are from the basal silty member. After the specimens were lightly oxidized with pure nitric acid, 75 to 95 per cent of them were identifiable. The colour of the single-walled acritarchs (for example, leiosphaerids, *Goniosphaeridium*) that were not experimentally oxidized indicates a temperature not exceeding 160°C, according to the data provided by Correia (1967, Fig. 9), Epstein et al. (1977, Figs. 11, 12), Legall et al. (1982, Fig. 9), and Nowlan and Barnes (1986, Fig. 11.1). This slight difference in interpretation of temperature may reflect the paucity of experiments and published data concerning colour changes of acritarchs in relation to diagenesis and to the nature of the enclosing sediment; it may also indicate the variation induced in acritarchs by thermal alteration, as emphasized by Staplin (1969, p. 57) and Dorning (1986). Harris et al. (1988), using material from Lower Carboniferous limestone in Indiana, demonstrated similar anomalies between the TAI in palynomorphs, which showed a relatively large spectrum of thermal alteration within a single sample, and the CAI of associated conodonts. Whatever the reason, and on the basis of both acritarchs and conodonts, the organic metamorphic facies at Wilcox Pass is supramature, either at the limit of dry gas, or without associated hydrocarbons.

Acritarchs were absent from strata below the basal silty member, i.e., the Mistaya Formation and the upper part of the Bison Creek Formation. Above the basal silty member, the putty shale member, which appeared the most promising for yielding acritarchs, proved sterile or contained mainly rare leiosphaerids. The number of determinable specimens tended to diminish higher in the section where the organic matter no longer reacted to oxidation. This change, which became still more marked from the middle member upward, is as yet unexplained. It may partly depend on the properties of the acritarch membrane, which is eventually two-layered, the inner layer being more opaque. This could be the case in acritarch taxa that appear at 76 m above the base of the middle member (GSC loc. C-97815) and 72.85 m above the base of the upper massive member (GSC loc. C-97860). It may also be that this decrease in the number of determinable specimens bears some relationship to the nature of the enclosing sediment. For example, there is a greater proportion of thick beds of coarse, compact limestone in the upper massive member, development of a calcareous, nodular to clotted fabric in the Outram Formation, and a clear increase in dolomitization in the lower part of the Skoki Formation. In any case, there is no reason to suspect reworking in acritarch assemblages from any level within the Survey Peak, Outram, and basal Skoki formations.

The frequency values for the acritarchs (Figs. 3, 4) are estimates, apart from certain counts from the basal silty member. In most cases, the number of specimens identified represents less than 10 per cent of the assemblage. Apart from cases indicated by "cf." and "aff.", or taxa left in open nomenclature, ambiguous determinations have not been taken into account. The same applies to the chitinozoans, of which at most five per cent are determinable.

Figured specimens, accompanied by co-ordinates established with the England Finder graticule, are deposited in the National Type Collection of Plant and Invertebrate Fossils of the Geological Survey of Canada, Ottawa. Supplementary preparations are deposited in the Département de Paléontologie, Institut royal des Sciences naturelles de Belgique, Brussels. All the microfossils that were determined are illustrated, and all are described, except for three of the acritarchs, *Cymatiogalea* sp., *Goniosphaeridium* sp. cf. *G. pungens*, and the leiosphaerids. The processes of the first of these were always incomplete, preventing reliable determination at the species level. The other two have no stratigraphic value, because of their ubiquitous character.

LIST OF TAXA

Acritarchs

Acrum? *jasperense* n. sp.
Actinotodissus sp. A
Ammonidium sp. aff. *A. furtivum* Playford and Martin, 1984
Aryballomorpha albertana n. sp.
Aryballomorpha grootaertii (Martin) emend. Martin and Yin, 1988
Aryballomorpha n. sp. A
Athabascaella sp. cf. *A. penika* Martin and Yin, 1988
Athabascaella playfordii Martin, 1984 emend. Martin and Yin, 1988
Athabascaella rossii Martin, 1984 emend. Martin and Yin, 1988
Athabascaella sunwaptana n. sp.
Buedingiisphaeridium tremadocum Rasul, 1979

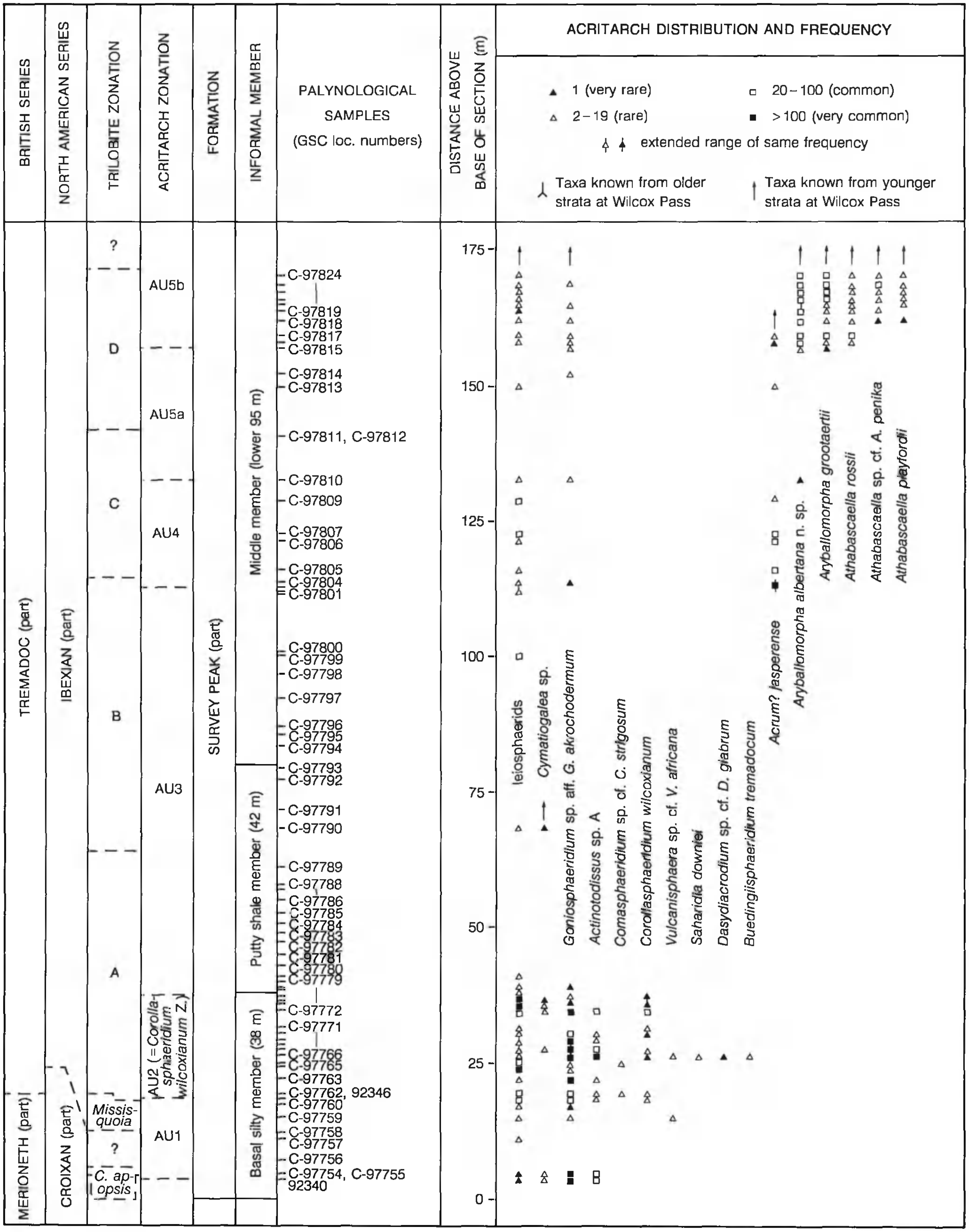

Figure 3. Range chart of acritarchs at Wilcox Pass.

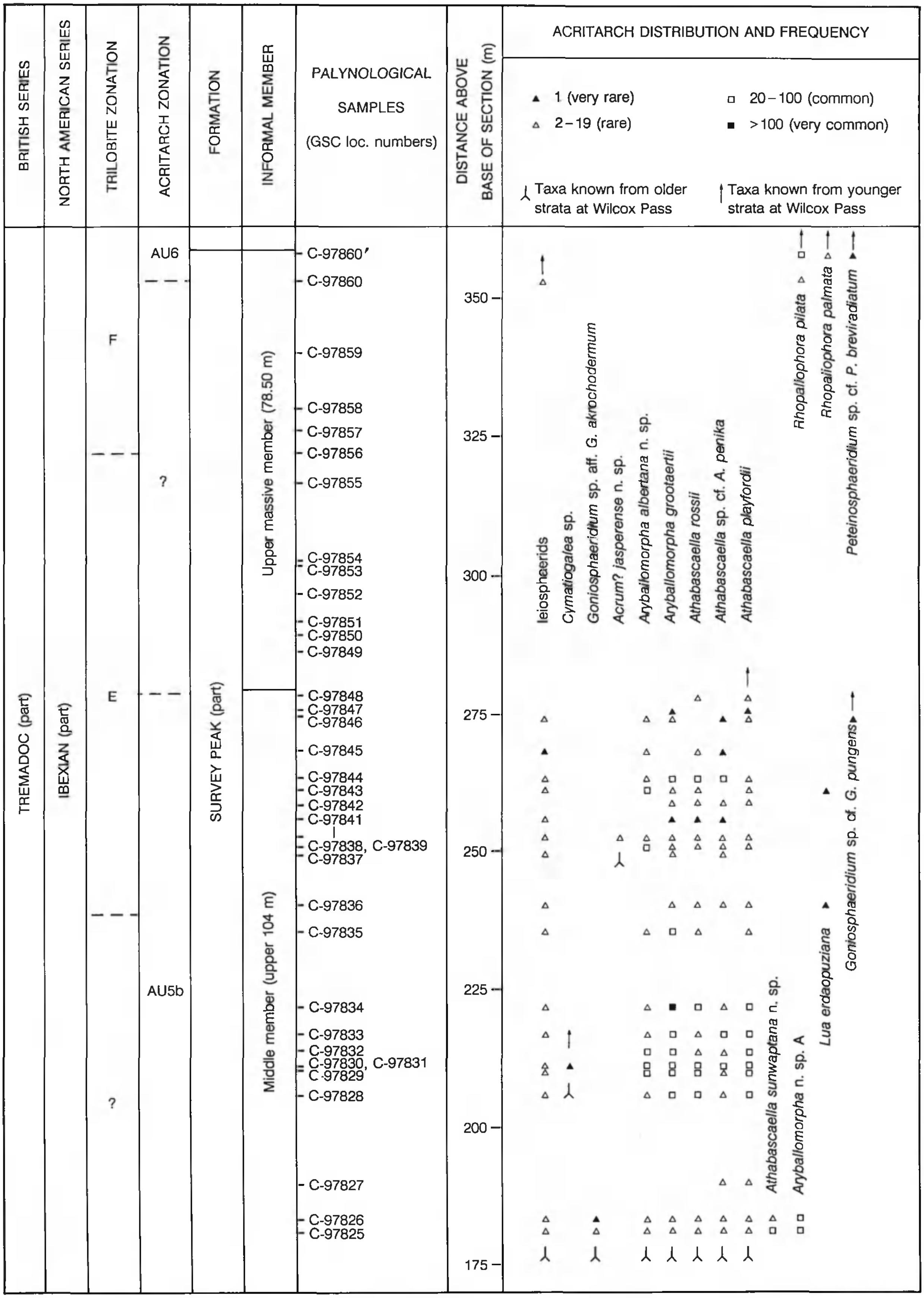

Figure 3. cont'd.

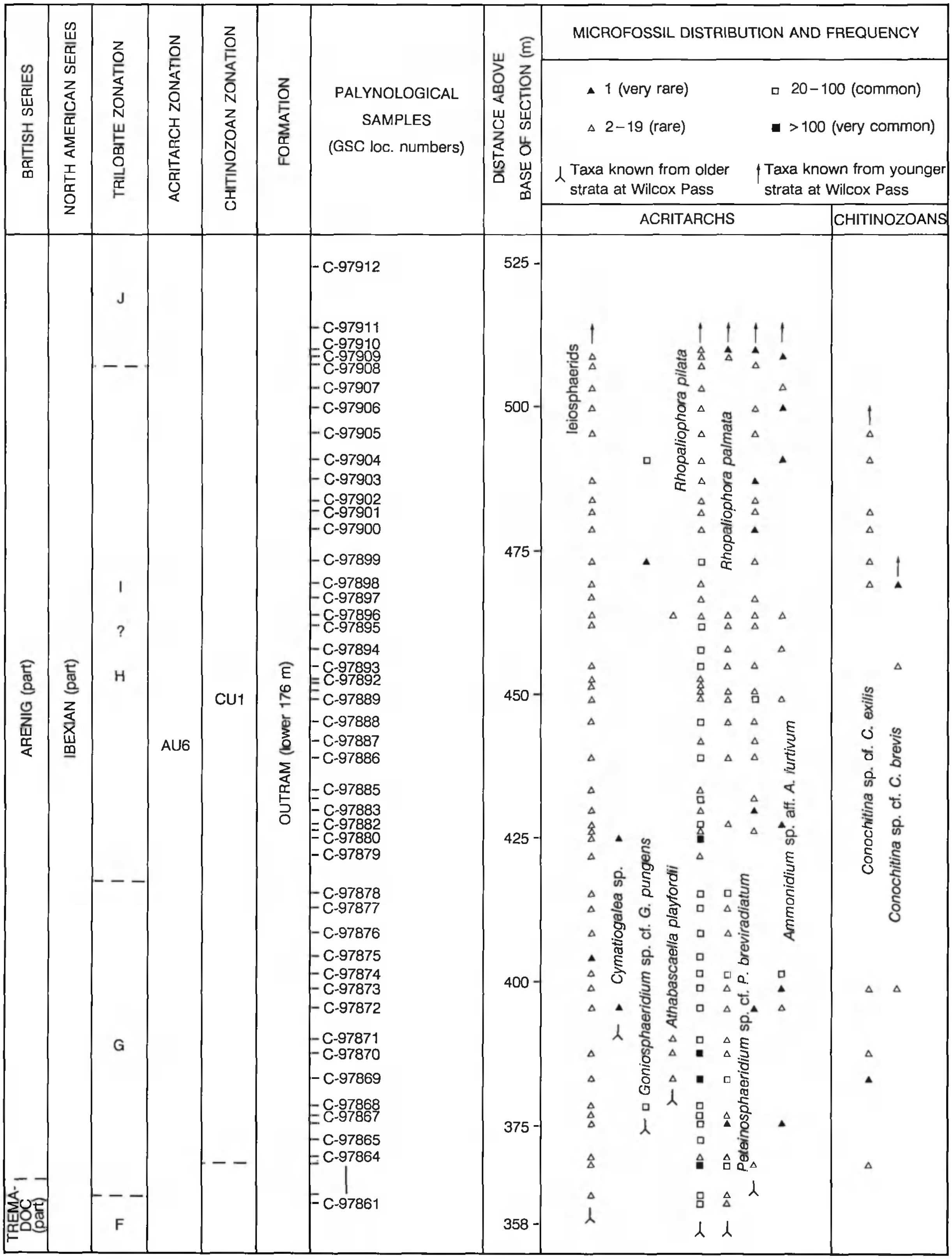

Figure 4. Range chart of acritarchs and chitinozoans at Wilcox Pass.

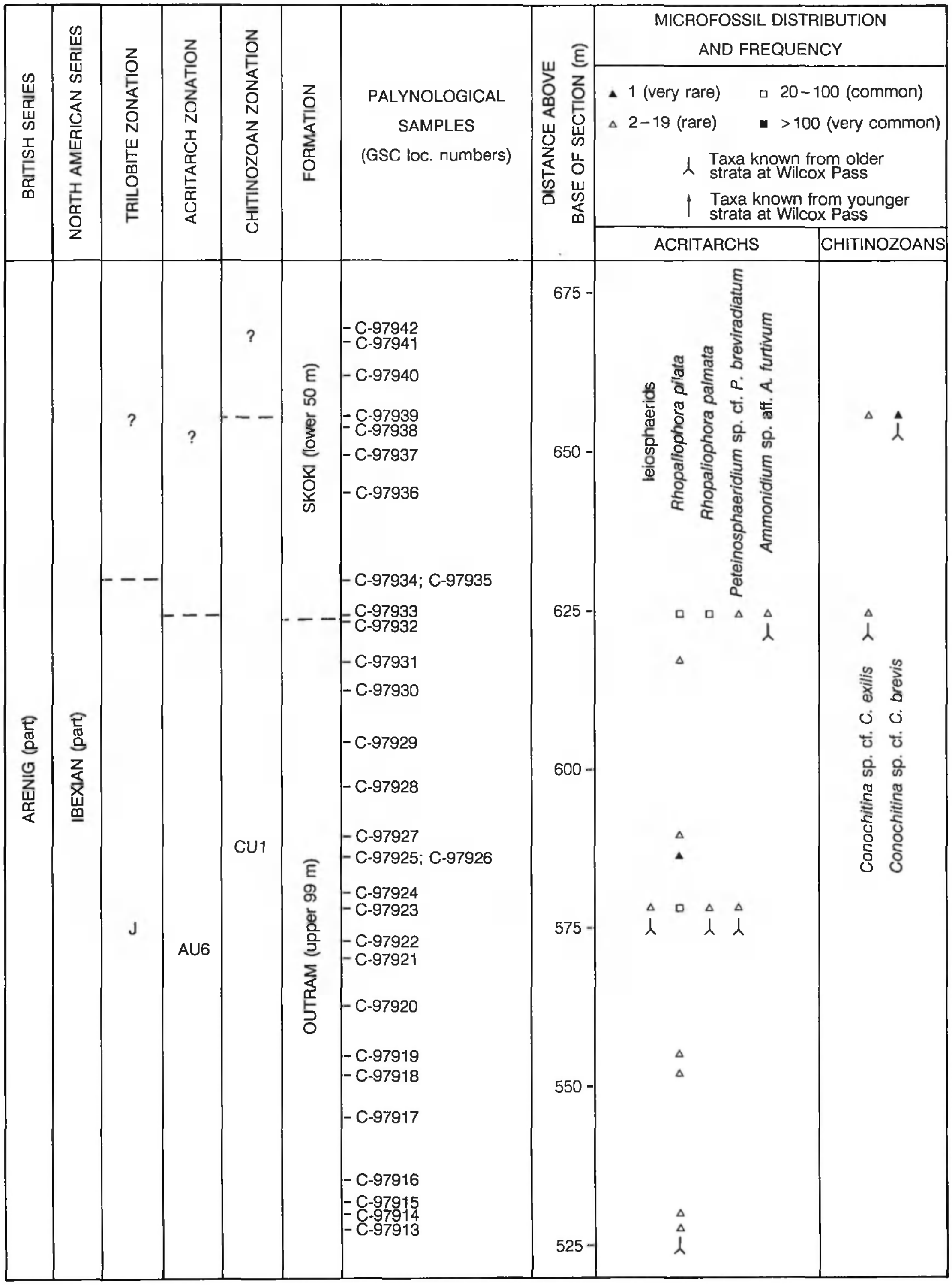

Figure 4. cont'd.

Comasphaeridium sp. cf. *C. strigosum* (Jankauskas) Downie, 1982
Corollasphaeridium wilcoxianum Martin *in* Dean and Martin, 1982 emend.
Cymatiogalea sp.
Dasydiacrodium sp. cf. *D. glabrum* Combaz, 1968
Goniosphaeridium sp. aff. *G. akrochodermum* (Rasul) Martin *in* Dean and Martin, 1982
Goniosphaeridium sp. cf. *G. pungens* (Timofeev) Rauscher, 1974
Leiosphaerids
Lua erdaopuziana Martin and Yin, 1988
Peteinosphaeridium sp. cf. *P. breviradiatum* (Eisenack) Eisenack, 1969
Rhopaliophora palmata (Combaz and Peniguel) emend. Playford and Martin, 1984
Rhopaliophora pilata (Combaz and Peniguel) emend. Playford and Martin, 1984
Saharidia downiei Combaz, 1968
Vulcanisphaera sp. cf. *V. africana* Deunff, 1961

Chitinozoans

Conochitina sp. cf. *C. brevis* Taugourdeau and de Jekhowsky, 1960
Conochitina sp. cf. *C. exilis* Bockelie, 1980

CONDITIONS OF DEPOSITION

In the Cambrian and Ordovician stratigraphic succession of the southern Canadian Rocky Mountains, Aitken (1966, 1978, 1981) defined a number of "Grand Cycles", involving lateral displacement of facies belts (Palmer, 1969). The somewhat atypical Grand Cycle (Aitken, 1981, p. 26) represented by the Survey Peak Formation is followed by that in the Outram and Skoki formations. Changes in rock type between adjacent units outcropping at Wilcox Pass are most often gradational; only the base of the basal silty member and of the upper massive member are sharp. No clear, repetitive relationship has been observed between the composition of the acritarch assemblages and the distribution of the grand cycles and their subdivisions. Five successive microfloras occur in the lower Grand Cycle, from the basal silty member to the top of the middle member. The sixth microflora appears at the top of the upper massive member, at its gradational contact with the Outram Formation, and extends upward into the lowermost Skoki Formation. The appearance of the single, though poorly represented, chitinozoan assemblage at the base of the Outram Formation is probably due more to the Arenig age of that unit than to its belonging to the beginning of a Grand Cycle.

The diversity of the acritarch assemblages in the Survey Peak Formation is low, even when the relatively low value of the specimen counts, due to the large number of undeterminable individuals, is taken into account. The most varied levels (GSC loc. C-97766 in the basal silty member; GSC locs. C-97825 and C-97826 in the middle member) contain nine taxa, including leiosphaerids. This low diversity may be related to the shallow-marine conditions under which, according to Aitken and Norford (1967, p. 172), the Survey Peak Formation was deposited. Leiosphaerids are generally uncommon in the whole of the Survey Peak Formation. They may be better represented in the basal silty member than other acritarchs, but their absolute numbers are moderate. If these low numbers are truly original, and not linked to a preferential oxidation of the acritarch membrane, this weak representation does not agree with the customary observations (see Jacobson, 1979 and Al-Ameri, 1983 for references) that the group attained its greatest abundance in a nearshore, shallow water environment. On the basis of the latter statement, the Survey Peak assemblage probably reflects deposition of strata relatively far from the continental margin.

According to Aitken and Norford (1967, p. 179) the Outram Formation was deposited in more shallow water marine conditions that would now (Aitken, 1989; B.S. Norford, pers. comm.) be considered as having been located deeper on the middle to upper slope, outboard of a carbonate platform later represented by the Skoki Formation. Coincident with this increase in water depth, an increase in the abundance and diversity of the trilobites in the Outram Formation was noted by Dean (1989). In the Outram Formation, as in the Skoki Formation, the low diversity of the organic-walled microfossils may not be an original feature but may reflect, rather, their poor state of preservation, as a result of which only 1 to 10 per cent of acritarchs and no more than 5 per cent of chitinozoans were determinable.

SEQUENCE AND CORRELATION OF ACRITARCH AND CHITINOZOAN ASSEMBLAGES

Identifiable graptolites, absent in the Wilcox Pass section, are rare to extremely rare in the southern Canadian Rocky Mountains, and correlations with the British zonation are indirect and approximate (Fig. 5). In both Canada (Barnes et al., 1981) and U.S.A. (Hintze *in* Ross et al., 1982, p. 7) the Cambrian–

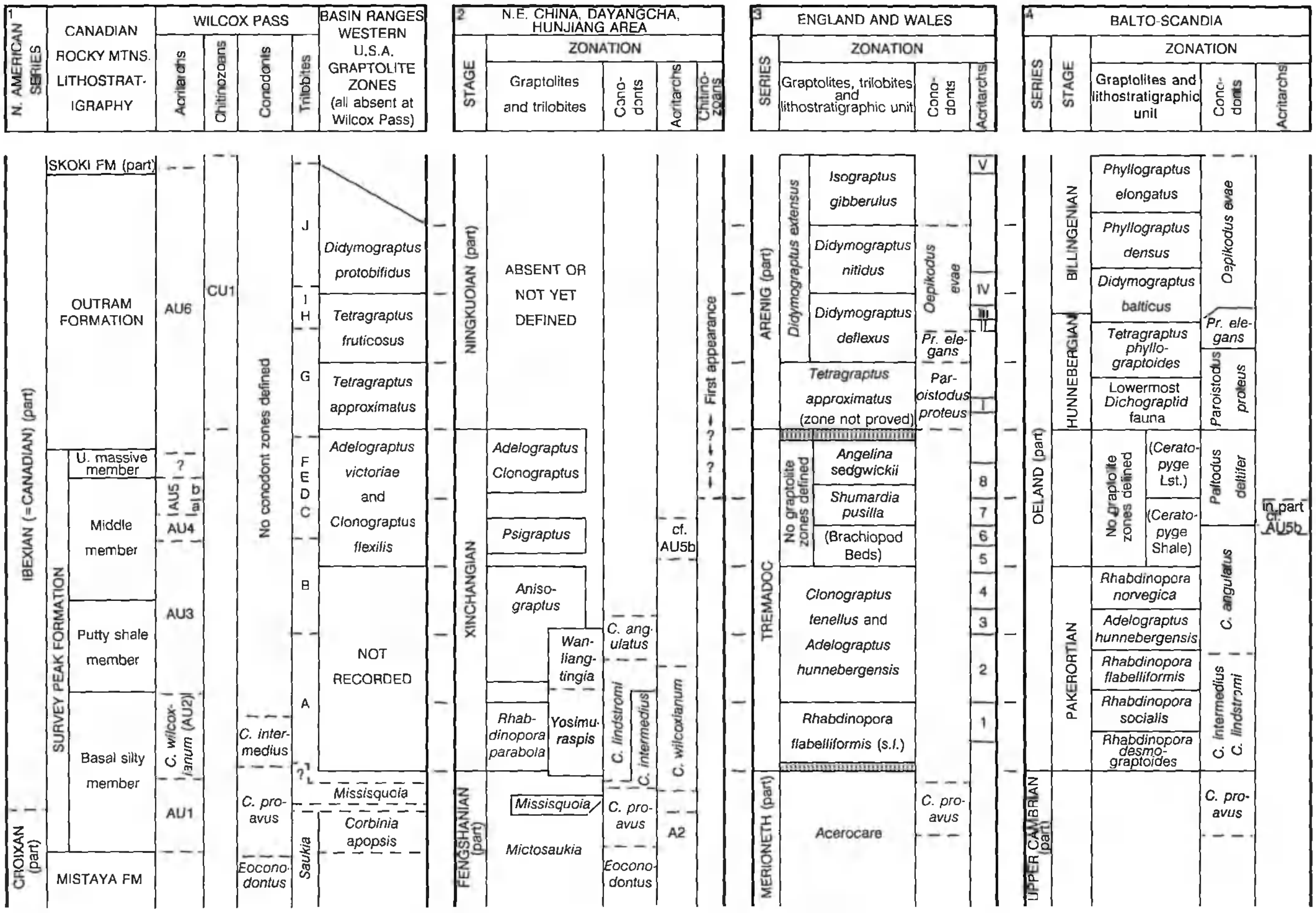

Figure 5. *Correlation of formations and microfossil and macrofossil successions at Wilcox Pass with North American and British series and zones, and with two selected sequences in northeast China and Balto-Scandia relevant for palynological comparison.*

Lithostratigraphic units in parentheses are not formal. The table is not to scale.

Column 1 (Basin Ranges and Western U.S.A.) modified from Ross et al., 1982.

Column 2 (N.E. China, Dayangcha, Hunjiang area) graptolites: Wang and Erdtmann, 1987; trilobites: Qian, 1986; Shergold, 1988; conodonts: Chen et al., 1988; acritarchs and chitinozoans: Yin, 1986; Martin and Yin, 1988; author's personal observation.

Column 3 (England and Wales) macrofossil zonation: Cowie et al., 1972; Whittington et al., 1984; conodonts: Bergström and Orchard, 1985; acritarchs: Rasul, 1979 (Arabic numerals); Molyneux, 1987 (Roman numerals).

Column 4 (Balto-Scandia) macrofossil zonation: Tjernvik and Johansson, 1980; Jaanusson, 1982; conodonts: Lindström, 1971; Bruton et al., 1988; acritarchs: Tongiorgi in Bagnoli et al., 1988.

Ordovician boundary (uppermost Croixan Series–lowermost Ibexian Series) based on trilobites has been placed conventionally at the base of the *Missisquoia* Zone, between the *Saukia* Zone and the *Symphysurina* Zone. For the Wilcox Pass area, Dean (1989) judged the material insufficient to subdivide the *Missisquoia* Zone, unlike Westrop (1986) for the adjacent section at Wilcox Peak; Dean preferred to use trilobite zone A (Ross, 1949) instead of the *Symphysurina* Zone (Hintze, 1953).

Since 1983 (Norford, 1988), the International Working Group on the Cambrian–Ordovician Boundary of the International Union of Geological Sciences has agreed to use conodonts as the principal guide fossils for defining the Cambrian–Ordovician boundary. The horizon eventually chosen is to be below, and as close as possible to, the first appearance of planktonic graptolites. The bases of three conodont zones have been considered; in ascending order they are: the *Cordylodus proavus* Zone; the *C. intermedius* Zone; and, less importantly, the *C. lindstromi* Zone, as reviewed by Miller (1987). Westrop et al. (1981, p. 52) showed that at Wilcox Pass the *C. proavus* Zone begins at least 2 m above the base of the basal silty member. J. Miller (pers. comm., 1988), reinterpreting the results of Westrop et al. (1981, Fig. 18) on the basis of the zonation proposed by Miller in 1987 and 1988, recognized the *C. intermedius* Zone higher in the basal silty member. In the sections studied by Miller, mainly in Oklahoma, Texas, Nevada, and Utah, this conodont zone appears in the lower part of the *Symphysurina brevispicata* Subzone of the *Symphysurina* Zone. At Wilcox Pass, the base of the *C. intermedius* Zone is located in the (questionably) upper part of the *Missisquoia* Zone, estimated at 0.5 m to 2 m above the certain record of the zonal trilobite. Miller considers also that the conodont fauna B found by Westrop et al. (1981) in the upper, but not uppermost, part of the basal silty member could possibly represent the *C. lindstromi* Zone. The reservations regarding this zonal attribution and its insufficiently precise location require additional stratigraphic data and will not be considered further in this paper. Until the Working Group makes its decision, the base of the Ordovician is taken here to coincide with the base of the *Missisquoia* Zone. The base of the Tremadoc is drawn at the top of the *Missiquoia* Zone, following Ross et al. (1982, sheet 1), who included the *Missisquoia* Zone in the Ibexian Series.

Correlation of trilobite zones G to J with the graptolite zones of the Arenig Series varies slightly according to author. Aitken et al. (1972, Fig. 13), summarizing the Ordovician succession in the southern Canadian Rocky Mountains, proposed the lower part of zone G (at a level slightly above the base of G1) as correlating with the base of the Arenig; they equated the lower part of zone J approximately with the upper part of the North American *Didymograptus protobifidus* Zone. The whole of the latter zone has been considered equivalent (Barnes et al., 1981) to the *D. nitidus* Subzone of the *D. extensus* Zone of the Anglo-Welsh area. Barnes et al. extended the correlation of zone J higher in the Arenig to include most of the overlying *D. gibberulus* Subzone. In the U.S.A., Ross et al. (1982) used the upper part of zone G (= G2) to establish an age coeval with the *Tetragraptus approximatus* Zone, currently admitted as the base of the Arenig Series, although its existence in the Anglo-Welsh area has not been proved (Fortey *in* Whittington et al., 1984). Ross et al. (1982) correlated zone J with part of the lower Arenig, within the base of the *D. nitidus* Subzone.

At Wilcox Pass, in the absence of positive evidence, most of the boundaries followed here between trilobite zones A–J (Dean, 1989) are drawn somewhat arbitrarily, notably between zones F and G, the latter not being divisible into G1 and G2. The base of the Arenig is drawn here approximately, a little below the base of zone G, and the palynological evidence does not permit a more precise correlation of the strata containing trilobite zones G to J; as noted earlier, there is no evidence from macrofossils that the youngest samples are younger than zone J.

A succession of six acritarch-based units (AU1 to AU6) is described, ranging in age from uppermost Upper Cambrian to lower or upper (but not uppermost) Arenig. A single chitinozoan assemblage is recognized in the Arenig. Composition and stratigraphic distribution of the assemblages, and their correlation with the trilobite zonation (Dean, 1989), are shown in Figures 3 and 4.

The poor state of preservation of the palynological material and the gaps in observations due to the thickness of deposits that are barren or lacking identifiable microfossils do not permit the introduction of formal zones, except for acritarch microflora AU2 (= *Corollasphaeridium wilcoxianum* Zone). The order of presentation of the palynologically based units is as follows: 1) description or definition; 2) stratigraphic position in relation to the trilobite zones and, in the two lowest cases, to the conodont zones as reinterpreted by J. Miller (pers. comm., 1988) in terms of his 1987 zonation from data in Westrop et al. (1981, Fig. 18); and 3) discussion, including range of separate taxa and correlation of assemblages (or part of them), using data from other regions.

Acritarch-based correlation of the uppermost Cambrian and Lower Ordovician epicratonic marine shelf deposits of Laurentia, as represented at Wilcox Pass, with those of other regions concerns mainly the Tremadoc and, to a lesser extent, the uppermost Tremadoc or lower Arenig of the northern border of the Sino-Korean platform in the south of Jilin Province, northeastern China (Yin, 1986; Martin and Yin, 1988). Data from the upper Tremadoc in Öland, Baltica (Tongiorgi *in* Bagnoli et al., 1988) indicate the possibility of partial comparison with southwestern Canada and northeastern China. Affinities of acritarch assemblages in the two last-named regions with those of approximately equivalent age in peri-Gondwanaland, including eastern Newfoundland (see references *in* Martin and Dean, 1988), western Europe (see references *in* Vavrdová, 1974; Vanguestaine, 1986; Molyneux and Rushton, 1988), North Africa (see references in Jardiné et al., 1974; Martin, 1982; Elouad-Debbaj, 1988) and northwestern Argentina (Volkheimer et al., 1980; Bultynck and Martin, 1982) are limited and of no detailed stratigraphic value. Comparisons with the Arenig of northwestern Australia (Combaz and Peniguel, 1972; Playford and

Martin, 1984) and northeastern Australia (Playford and Wicander, 1988) are of limited value and lack accurate index acritarchs. Chitinozoans from Wilcox Pass contribute nothing to correlation or regional relationships.

Microflora AU1

Microflora AU1 is characterized by the *Goniosphaeridium* sp. aff. *G. akrochodermum–Actinotodissus* n. sp. A assemblage.

Description

The most common taxa are the two index acritarchs. Leiosphaerids are variably represented and usually rare. *Cymatiogalea* sp. and *Vulcanisphaera* sp. cf. *V. africana* occur rarely and in small numbers.

Stratigraphic position at Wilcox Pass

Microflora AU1 is present in the basal silty member of the Survey Peak Formation from 3.6 m (GSC loc. 92340) to 17.45 m (GSC loc. C-97760) above its base. It ranges from 0.9 m below the *Corbinia apopsis* Subzone, *Saukia* Zone, to the *Missisquoia* Zone, 3.95 m above its questionable base and 0.25 m above the confirmed uppermost occurrence of the index trilobite. Microflora AU1 extends into the lower part of the *Cordylodus proavus* Zone. If the base of the Ordovician is drawn at the base of the *Cordylodus intermedius* Zone, microflora AU1 occurs entirely within the uppermost Cambrian. If the boundary is drawn at the base of the *C. proavus* Zone, microflora AU1 occurs from about 2 m above the systemic boundary.

Discussion

No detailed correlations are yet possible using microflora AU1. The stratigraphic value of *Goniosphaeridium* sp. aff. *G. akrochodermum* and *Actinotodissus* sp. A is diminished by the frequent deterioration of fine details of ornamentation and by the continuous variation of characters that are relatively little differentiated. Comparable acanthomorphids and diacrodians (see Systematic Paleontology), which differ mainly in having a better developed spinose ornamentation, are abundant in the Upper Cambrian of eastern Newfoundland (Martin *in* Martin and Dean, 1988), beginning in microflora A3b in the *Parabolina spinulosa* Zone, and in Jilin Province, northeastern China (microflora A2, Yin, 1986; author's personal observation). In northeastern China, Upper Cambrian strata are dated by means of conodonts (Chen and Gong, 1986) of North American affinity as belonging to the *Proconodontus muelleri* Subzone, and by trilobites (Qian, 1986) of Australian affinity, as the *Mictosaukia-Fatocephalus* Zone. The stratigraphically oldest records, with macrofossil age control, of *Cymatiogalea* and of *Vulcanisphaera africana*, to which *V.* sp. cf. *V. africana* herein may belong, are from microflora A3a (Martin *in* Martin and Dean, 1988) in the Upper Cambrian of eastern Newfoundland, in undated strata between the *Olenus* and *Parabolina spinulosa* zones. Both taxa have a long range and are widespread (references *in* Welsch, 1986) in the Tremadoc of peri-Gondwanaland and of northern Norway.

Microflora AU2

Microflora AU2 is equivalent to the *Corollasphaeridium wilcoxianum* Zone.

Definition

The lower boundary of the zone is defined by the first appearance of the eponymous taxon, in the absence of which no other taxon is considered characteristic of the zone. The upper boundary is not yet formally defined, due to the barren nature or poor palynological content of the overlying strata. *Actinotodissus* sp. A and *Goniosphaeridium* sp. cf. *G. akrochodermum* are often present and sometimes abundant. *Comasphaeridium* sp. cf. *C. strigosum* and *Cymatiogalea* sp. are rarely present. *Buedingiisphaeridium tremadocum*, *Dasydiacrodium* sp. cf. *D. glabrum*, *Saharidia downiei*, and *Vulcanisphaera* sp. cf. *V. africana* are rare.

Stratigraphic position at Wilcox Pass

In the reference section at Wilcox Pass, the zone has been recognized in 19.1 m of the basal silty member of the Survey Peak Formation, beginning 18.55 m above its base (GSC locs. C-97761 to C-97775). The lower limit of the zone is in the (questionably) upper part of the *Missisquoia* Zone, 0.55 m above the certain highest record and 0.65 m below the questionable highest record of the nominal genus. It is 1.1 m above the upper limit of microflora AU1, from which it is separated by strata that have not been investigated palynologically. The *C. wilcoxianum* Zone extends upward into trilobite zone A, to 18.25 m above its base. In terms of conodont zonation, the new acritarch zone at Wilcox Pass begins very close to (within less than 2 m of) the boundary between the *Cordylodus proavus* and *C. intermedius* zones.

Discussion

Corollasphaeridium wilcoxianum is known from Jilin Province, northeastern China, where it is present at the Xiaoyangqiao section, near Dayangcha, proposed as a candidate for the global Cambrian–Ordovician boundary stratotype by Chen, Qian et al. (1985). According to Yin (1986) and the author (personal observation) the species appears there in the upper part of Bed 12 of Zhang (1986), which contains the upper part of the *Cordylodus proavus* Zone and is close to the base of the *C. intermedius* Zone, reported by Chen and Gong (1986) from the base of Bed 14, about 5 m higher. Miller et al. (Cambrian–Ordovician Boundary Working Group Report, 1988, unpublished) found the latter zone a little lower, in Bed 13. Records of *Missisquoia* Shaw, 1951 (Qian, 1986) from Bed 12 of the same section have been accepted by Shergold (1988, p. 370, 371). Higher in the Xiaoyangqiao section *Corollasphaeridium wilcoxianum* extends (author's personal observation) into strata of the *Cordylodus lindstromi* Zone. About 50 km southwest of Dayangcha and close to Hunjiang city, the Cambrian–Ordovician boundary section at Muxiantougou (Chen, Zhou et al., 1985) contains (author's personal observation) *Corollasphaeridium wilcoxianum* at least between 1 and 2.5 m above the base of the *Cordylodus intermedius* Zone (Chen and Zhang, pers. comm., 1986). In Jilin Province, the strata with *C. wilcoxianum* contain mainly leiosphaerids and secondarily *Cymatiogalea* sp. (author's personal observation). *Goniomorpha rara* Yin, 1986 may be present, as at Wilcox Pass. These organic-walled fragments have been considered as acritarchs by Yin (1986) and Chen et al. (1988) but are probably eurypterids. Taxonomy of other acritarch taxa accompanying *Corollasphaeridium wilcoxianum* in China and quoted by the above Chinese authors needs to be revised and is not considered here.

Comments on the distribution of *Goniosphaeridium* sp. cf. *G. akrochodermum*, *Actinotodissus* sp. A., *Cymatiogalea* sp., and *Vulcanisphaera* sp. cf. *V. africana* are to be found in the discussion of microflora AU1. *Buedingiisphaeridium tremadocum* was described from the Tremadoc Series (*Clonograptus tenellus* Zone to *Shumardia pusilla* Zone) in the Shineton Shales of Shropshire, England (Rasul, 1979). In palynologically dated outcrops it is known from the Tremadoc of the Massif de Mouthoumet, Corbières, southern France (Cocchio, 1982), and the upper Arenig Solanas Formation, central Sardinia, Italy (Tongiorgi et al., 1984; Albani et al., 1985).

Dasydiacrodium sp. cf. *D. glabrum* is close to a species known only from strata dated palynologically as early Tremadoc in boreholes in the areas of Hassi-Messaoud (Combaz, 1968) and Oued Mya (Jardiné et al., 1974), in the Algerian Sahara. It forms part of assemblages that contain *Saharidia downiei*, but differ considerably from those at Wilcox Pass in the generic and specific diversity of diacrodians and in the presence of veryhachiids and leiofusids. The genus *Saharidia* is widespread in the Tremadoc of the Anglo-Welsh area (Rasul and Downie, 1974; Downie, 1984), southern France (Martin, 1973), northwestern Argentina (Bultynck and Martin, 1982), and in eastern Newfoundland, where the first appearance (Martin *in* Martin and Dean, 1981, 1988) occurs in microflora A5b, dated as Upper Cambrian, upper part of the *Peltura* Zone and, in part, *Acerocare* Zone. Fombella (1986, 1987) recorded the genus from palynologically dated Upper Cambrian and Tremadoc strata in northwestern Spain, and Combaz and Peniguel (1972) recorded it from the Arenig of Western Australia. *Comasphaeridium* sp. cf. *C. strigosum* is too incompletely preserved to be of stratigraphic value.

The taxa cited above, and either known from peri-Gondwanaland or having affinities with those known from around that supercontinent, occur at a level in the basal silty member where the acritarchs are the most numerous and relatively better preserved. The rock samples containing them were macerated three times in order to eliminate the possibility of contamination during palynological analysis. In peri-Gondwanaland the acritarch assemblages of an age approximately equivalent to those at Wilcox Pass always differ from the latter in their diversity of diacrodians and herkomorphids, and in the frequent presence of leiofusids, whose abundance is very variable.

Microflora AU3

Microflora AU3 is characterized by the sporadic occurrence of almost exclusively leiosphaerids.

Description

Microflora AU3 is poorly represented by very rare acritarch collections that contain almost exclusively leiosphaerids, though always in moderate numbers, and, in one case, very rare *Cymatiogalea* sp.

Stratigraphic position at Wilcox Pass

The microflora was recognized sporadically in 71.35 m of Tremadoc strata (GSC locs. C-97776 to C-97802) in the Survey Peak Formation, including the uppermost few centimetres of the basal silty member, the whole of the putty shale member, and the lowest 30.9 m of the middle member. It ranges from trilobite zone A, 18.6 m above its base, to trilobite zone B, 31.5 m above its arbitrarily drawn base.

Discussion

Microflora AU3 does not contain any index acritarch that is of use in detailed correlation.

Microflora AU4

Microflora AU4 is characterized by *Acrum*? *jasperense* n. sp.

Description

The microflora comprises a maximum of three taxa. *Acrum*? *jasperense* n. sp., the appearance of which indicates the base of the microflora, is variably present and sometimes abundant. *Goniosphaeridium* sp. aff. *G. akrochodermum* and leiosphaerids are rare and sporadic.

Stratigraphic position at Wilcox Pass

Microflora AU4 has been recognized in the middle member of the Survey Peak Formation from 31.55 m (GSC loc. C-97803) to 48 m (GSC loc. C-97809) above its base. Within the Tremadoc it ranges from trilobite zone B, 32.15 m above its base, to zone C, 12.1 m above its base; in each case the base of the zone is arbitrarily drawn.

Discussion

The stratigraphic value of microflora AU4 is not yet known, as *Acrum*? *jasperense* is a new species.

Microflora AU5

Microflora AU5 is characterized by the appearance of *Aryballomorpha albertana* n. sp. and/or *A. grootaertii*.

Description

All three taxa from microflora AU4 may be present in microflora AU5, but are always rare. The base of the lower part, microflora AU5a, is indicated by the appearance of very rare *A. albertana* n. sp. In the upper part, microflora AU5b, *A. grootaertii*, *Athabascaella rossii*, *A.* sp. cf. *A. penika*, and *A. playfordii* are commonly present and sometimes abundant, and *A. sunwaptana* n. sp., *Aryballomorpha* n. sp. A, and *Lua erdaopuziana* are very rare. *Goniosphaeridium* sp. cf. *G. pungens* is very rare in the upper part of microflora AU5b.

Stratigraphic position at Wilcox Pass

The microflora ranges through the upper 146.1 m of the middle member of the Survey Peak Formation. Microfloras AU5a and AU5b appear, respectively, at levels 51.9 m (GSC loc. C-97810) and 76 m (GSC loc. C-97815) above the base of the member. In the Tremadoc Series, microflora AU5 extends from trilobite zone C, 15.1 m above its arbitrarily drawn base, to zone E, 39.3 m above its base.

Discussion

A microflora closely resembling microflora AU5b is present in the Dayangcha and Hunjiang areas of Jilin Province, northeastern China. *Aryballomorpha grootaertii*, *Athabascaella penika* (to which *A.* sp. cf. *A. penika* is closely related), *A. playfordii*, and *A. rossii* range there from the Tremadoc, excluding lowermost Tremadoc, to uppermost Tremadoc or lowermost Arenig in terms of the graptolitic succession (see discussion *in* Martin and Yin, 1988). The latter interval, including the *Adelograptus-Clonograptus* Zone, would correspond, according to Wang and Erdtmann (1986, 1987), to the lower part of the Swedish "Hunneberg", at present of informal status and unrepresented in the Anglo-Welsh area, but which lies between the Tremadoc and Arenig Series. In the Chinese section at Xiaoliaohuangdi, *A. playfordii* and *A. rossii* extend a few metres higher into a stratum which, on the basis of a poorly diagnostic conodont fauna (Barnes, pers. comm., *in* Martin and Yin, 1988), may correspond to the base of the Whiterockian Series. The latter is equated in Canada (Barnes et al., 1981) with a level slightly below the base of the *Didymograptus hirundo* Zone, the uppermost zone of the British Arenig Series. *Lua erdaopuziana* appears in China a few metres below the *Psigraptus* Zone, probably upper Tremadoc, and, like *A. grootaertii*, is last recorded from some metres upward below the *Adelograptus–Clonograptus* Zone.

Goniosphaeridium sp. cf. *G. pungens* has no stratigraphic significance but is recorded here as the only simple, spinose acritarch in assemblages that are completely devoid of veryhachiids and diacrodians, just as in strata from the northern margin of the Sino-Korean platform (Martin and Yin, 1988) cited above.

In the Baltic region, *Aryballomorpha grootaertii* and *Athabascaella playfordii* have been determined (Tongiorgi *in* Bagnoli et al., 1988), together with herkomorphids and diacrodians in a condensed sequence (*Ceratopyge* Shale) in the upper Tremadoc of Öland, Sweden. *Aryballomorpha albertana* n. sp., *A.* n. sp. A, and *Athabascaella sunwaptana* n. sp. have not been recorded outside Wilcox Pass.

Microflora AU6

Mircroflora AU6 is characterized by the *Rhopaliophora pilata*, *R. palmata*, and *Peteinosphaeridium* sp. cf. *P. breviradiatum* assemblage.

Description

Microflora AU6 is distinguished from microflora AU5 mainly by the presence of *Rhopaliophora* and *Peteinosphaeridium*. *Rhopaliophora pilata* and *R. palmata* occur regularly and are sometimes very abundant, especially *R. pilata*. *Peteinosphaeridium* sp. cf. *P. breviradiatum* and *Ammonidium* sp. aff. *A. furtivum* also appear, but are rarer. *Athabascaella playfordii*, *Cymatiogalea* sp., and *Goniosphaeridium* sp. cf. *G. pungens* are very rare.

Stratigraphic position at Wilcox Pass

Microflora AU6 ranges from 5.65 m (GSC loc. C-97860) below the top of the upper massive member of the Survey Peak Formation, through the entire 266 m of the Outram Formation, where it is especially poorly preserved in the upper 113.5 m, into the basal 0.7 m of the Skoki Formation. It extends from the upper Tremadoc, in trilobite zone F, 42.45 m above its arbitrarily drawn base, to the Arenig zone J, 113.6 m above its base. It is separated from microflora AU5 by 72.85 m of strata belonging to the upper massive member that either were barren or contained undeterminable acritarchs.

Discussion

A palynologically barren interval of almost 77 m separates the upper limit of microflora AU5 from microflora AU6 where there is an abrupt, apparent renewal of acritarchs.

In northeastern China (Martin and Yin, 1988) *Rhopaliophora pilata*, unaccompanied by *Peteinosphaeridium* and with more specimens of *Athabascaella*, is known from the uppermost Tremadoc or lowermost Arenig to an unspecified level in the lower Arenig that is correlated indirectly and approximately with part of the *Didymograptus extensus* Zone. Poorly preserved specimens of *R. palmata*, determined as *R.* sp. cf. *R. palmata*, are present in the same samples from Jilin Province and also in the Arenig of Guizhou Province, southwestern China (Li, 1987). *Rhopaliophora palmata* has been described from the Arenig of western Hubei Province, central eastern China (Lu, 1987). However, the last two assemblages differ in containing taxa recorded from the peri-Gondwanaland region. Although microflora AU6 is particularly badly preserved, the absence of even fragments of, for example, veryhachiids (whether ornamented or not) is noteworthy. In mainly endemic assemblages from Australia, *R. pilata* and *R. palmata* have been recorded from the Arenig to at least Llanvirn in the Canning Basin (Combaz and Peniguel, 1972; Playford and Martin, 1984), and from probable Arenig strata in the Georgina Basin, Queensland (Playford and Wicander, 1988).

The long-ranging Ordovician genus *Peteinosphaeridium* is widely distributed in the lower Arenig strata of peri-Gondwanaland and the Baltic region (see references *in* Martin, 1982). In Australia, the oldest strata containing the genus are from an unspecified part of the Arenig in the Canning Basin (Combaz and Peniguel, 1972). In southwestern China (Li, 1987), they belong to the lowermost Arenig, correlated with the *Didymograptus deflexus* Subzone of the *D. extensus* Zone. *Ammonidium* sp. aff. *A. furtivum*, probably a new taxon, resembles a species known from the Arenig to at least the Llanvirn in the Canning Basin (Playford and Martin, 1984).

Microfauna CU1

Microfauna CU1 contains *Conochitina* sp. cf. *C. brevis* and/or *C.* sp. cf. *C. exilis*.

Description

The assemblage is very poorly preserved and may contain only either *Conochitina* sp. cf. *C. brevis* or *C.* sp. cf. *C. exilis*.

Stratigraphic position at Wilcox Pass

Microfauna CU1 has been found sporadically in 287.3 m of strata (GSC locs. C-97863 to C-97939), from 10.7 m above the base of the Outram Formation to 32 m above the base of the Skoki Formation. Within the Arenig Series it ranges from trilobite zone G, 6.5 m above its base, to a level (without macrofossils) 31.3 m above the highest beds with evidence of trilobite zone J. As noted earlier, this highest level may still be in zone J.

Discussion

The tentative determinations do not permit any correlation and their interest lies in the record of their appearance slightly above the base of the Outram Formation. Not a single, undoubted fragment was found in the Survey Peak Formation.

The first appearance of chitinozoans in the geological record is debatable. Supposedly oldest records in the Precambrian rocks of Arizona (Bloeser et al., 1977) and Saudi Arabia (Binda and Bokhari, 1980) have proved unacceptable to specialists. Tremadoc chitinozoans are absent from Quebec (Achab, 1986; author's personal observation), eastern Newfoundland, and Belgium (author's personal observation). They were reported from palynologically dated Tremadoc strata in the Algerian Sahara (Combaz, 1968; Poumot, 1968). Determinable chitinozoans have also been described (Elouad-Debbaj, 1988) in two samples from the Moroccan Anti-Atlas; the samples came from the debris from two water wells, and although they contained no macrofossils, they were attributed to the upper Tremadoc. The group may be present in the Tremadoc of the Russian Platform (Umnova, 1969), and has been described (Grahn, 1984) from Hunneberg strata in Estonia. Badly preserved chitinozoans have been noted from the uppermost Tremadoc or lowermost Arenig in northeastern China (Martin and Yin, 1988).

SYSTEMATIC DESCRIPTIONS OF ACRITARCHS

Genus *Acrum* Fombella, 1977

Type species. Acrum novum Fombella, 1977 by original designation.

Acrum? *jasperense* n. sp.

Plate 1, figures 1-8, 10, 11

Holotype. GSC 94580 (Pl. 1, figs. 5, 6). Diameter of almost spherical vesicle: 14.5 μm; length and basal width of baculae: 2 to 2.2 μm and 3 μm; diameter of lacunae: 1.4 to 2.5 μm; vesicle wall thickness: less than 0.1 μm.

Paratypes. GSC 94577 (Pl. 1, fig. 1), GSC 94578 (Pl. 1, figs. 2, 3), GSC 94579 (Pl. 1, fig. 4), GSC 94581 (Pl. 1, figs. 7, 8), GSC 94582 (Pl. 1, fig. 10), GSC 94583 (Pl. 1, fig. 11).

Type locality. GSC loc. C-97840, Wilcox Pass; middle member of the Survey Peak Formation.

Occurrence. Variably abundant in the middle member of the Survey Peak Formation from 31.55 m (GSC loc. C-97803) to 173.7 m (GSC loc. C-97840) above its base; ranges from the upper part of trilobite zone B to the lower part of zone E.

Etymology. After Jasper National Park.

Diagnosis. Based on 90 specimens. Vesicle originally spheroidal or almost so, and apparently single-layered. Outline circular to subcircular. Vesicle surface divided into numerous (about 50 to 60 on each side) polygonal lacunae, mainly hexagonal and pentagonal. Lacunae delimited on each edge by three to five small, baculate processes, joined by a membrane whose thickness is almost equal to that of the vesicle and forms the muri of the reticulum. Distal, evexate tips of baculae are slightly higher (to a maximum of 0.5 μm) than muri. Lacunae have psilate floors. No regular excystment opening observed.

Dimensions. Based on 30 specimens. Vesicle diameter: 10.5 to 21 μm; length and basal width of baculae: 0.7 to 3 μm, and 0.2 to 0.3 μm; diameter of lacunae: 1.2 to 2.5 μm; vesicle wall thickness: less than 0.2 μm.

Discussion. The attribution to this Cambrian genus is doubtful because the processes are regularly baculate and their distal extremities extend slightly beyond the height of the muri. The diagnosis of the genus *Sirius* Fombella, 1978 states that a concentric membrane surrounds the central body and that the short, numerous processes are formed by filamentous elements "interlaced like micropinules". Otherwise, the ornamentation of *Sirius punctatus* Fombella (1979, Pl. 3, figs. 49, 50), an undiagnosed, invalid species from the Cambrian of northern Spain, resembles that of *Acrum*? *jasperense* n. sp.

Genus *Actinotodissus* Loeblich and Tappan, 1978

Type species. Actinotodissus longitaleosus Loeblich and Tappan, 1978 by original designation.

Actinotodissus sp. A

Plate 1, figures 9, 13, 14, 16-22

Figured specimens. GSC 94584 (Pl. 1, fig. 9), GSC 94585 (Pl. 1, fig. 13), GSC 94586 (Pl. 1, fig. 14), GSC 94587 (Pl. 1, figs. 16, 18), GSC 94588 (Pl. 1, fig. 17), GSC 94589 (Pl. 1, figs. 19, 20), GSC 94590 (Pl. 1, figs. 21, 22).

Occurrence. Often present, and variably abundant, in the basal silty member of the Survey Peak Formation, from 3.6 m above base of member (GSC loc. 92340) to 34.85 m above base of member (GSC loc. C-97772). Ranges from the *Corbinia apopsis* Subzone of the *Saukia* Zone to the lower part of trilobite zone A.

Description. Based on 200 specimens. Outline of vesicle subcircular to ellipsoidal, slightly longer than wide, with two similarly shaped, virtually rounded poles. Equatorial zone very narrow, not obviously constricted and never longitudinally striated. Five to about 15 conical, hollow, originally similarly shaped processes on each pole. Their length varies between one fifth and one half that of the vesicle, and the interior of each communicates with that of the vesicle. Wall of both vesicle and processes thin, apparently single layered, varying from scabrous to spinose. Under the transmitted light microscope it appears most often spinose and does not exceed 0.3 μm; under the scanning electron microscope, certain spines have a slightly bulbous or flared extremity, which joins that of neighbouring spines. No definite excystment opening observed.

Dimensions. Based on 40 specimens. Length and width of vesicle: 20 to 35 (average 25) μm and 16 to 28 (average 18) μm; length and basal width of processes: 5 to 17 (average 8) μm and from 1 to 4 (average 2) μm; vesicle wall thickness: less than 0.3 μm.

Discussion. The anastomosed, spinose ornamentation is locally and incompletely preserved but it is probable that complete specimens were covered by a lattice formed by distally anastomosing spines. *Actinotodissus* sp. A differs from *A. achrasi* (Martin) Martin *in* Martin and Dean, 1988, from the Upper Cambrian and Tremadoc of peri-Gondwanaland (see references in Martin *in* Martin and Dean, 1988, p. 35) and the Upper Cambrian of northeastern China (Yin, 1986; author's personal observation), in having a less distinct equatorial zone, generally shorter processes, and coalescing, spinose ornamentation. See also remarks under *Goniosphaeridium* sp. cf. *G. akrochodermum*.

Genus *Ammonidium* Lister, 1970

Junior subjective synonym. Caiacorymbifer Tappan and Loeblich, 1971, p. 390, 391.

Type species. Ammonidium microcladum (Downie) Lister, 1970 by original designation.

Ammonidium sp. aff. *A. furtivum*
Playford and Martin, 1984

Plate 2, figures 1-4, 8

Figured specimens. GSC 94591 (Pl. 2, figs. 1, 2, 4), GSC 94592 (Pl. 2, fig. 3), GSC 94593 (Pl. 2, fig. 8).

Occurrence. Generally rare in the Outram Formation, from 17.65 m (GSC loc. C-97866) above its base. Rare in the Skoki Formation, 0.7 m above its base (GSC loc. C-97933). Ranges from trilobite zones G to J.

Description. Based on 40 specimens. Vesicle originally spheroidal or almost so, and apparently single-layered; outline circular to subcircular. Vesicle wall psilate to scabrate. Originally more than 150 small processes evenly distributed on each face. Proximal part of each process is subcylindrical to subprismatic, squat and hollow, though the relationship between process interior and vesicle cavity is obscure due to opacity; length of processes from one twentieth to one fifteenth of vesicle diameter. Distal extremities of processes variably flared; they are either divided into two or three short branches, each with two or three reduced filaments, or, most often, swollen, terminating in a small platform that carries four to six filamentous projections. Anastomosis of the distal parts of the filaments may be locally preserved. No regular excystment opening preserved.

Dimensions. Based on 25 specimens. Diameter of vesicle: 27 to 52 (average 34) μm; length and basal width of proximal part of processes: 1.5 to 2.5 μm; length of distal projections of processes: up to 2 μm; vesicle wall maximum thickness: 0.3 μm.

Discussion. The state of preservation is too poor to permit erection of a new species. In the general form of the central body and of most of the processes, the specimens resemble *A. furtivum*, from the latest Arenig to Llanvirn (? or Llandeilo) of the Canning Basin, Western Australia, in particular certain examples figured by Playford and Martin (1984, Figs. K-M), although in these the distal projections of the processes are only half as long.

Genus *Aryballomorpha* Martin and Yin, 1988

Type species. Aryballomorpha grootaertii (Martin) emend. Martin and Yin, 1988, by original designation.

Aryballomorpha albertana n. sp.

Plate 2, figures 5-7, 9-15

Holotype. GSC 94597 (Pl. 2, figs. 11, 13, 14). Diameter of almost spherical vesicle: 42 to 45 μm; length and basal width of tubular extension: 8 and 14 μm; length and basal width of proximal part of processes: 1.5 to 4 μm and 0.5 to 1 μm.

Paratypes. GSC 94594 (Pl. 2, figs. 5, 6) GSC 94595 (Pl. 2, figs. 7, 10), GSC 94596 (Pl. 2, fig. 9), GSC 94598 (Pl. 2, figs. 12, 15).

Type locality. GSC loc. C-97829, Wilcox Pass; middle member of the Survey Peak Formation.

Occurrence. Often present, in variable abundance, in the basal silty member of the Survey Peak Formation, from 51.9 m above the base of the member (GSC loc. C-97810) to 194.25 m above the base of the member (GSC loc. C-97846). Ranges from upper part of trilobite zone C to the middle part of zone E.

Etymology. After the Province of Alberta.

Diagnosis. Based on 200 specimens. Vesicle originally spherical or almost so; outline circular to subcircular in both polar and lateral views. Oriented laterally, most specimens show a variably protruding, hollow, tubular, apical extension with a distal, circular opening. No operculum observed. Length and basal diameter of tubular extension usually from one sixth to one fourth, and from one fifth to one third, respectively, of vesicle diameter. External surface of both vesicle and tubular extension psilate to variably echinate. Numerous slender processes, usually 120 or more on each face, are evenly distributed over the whole surface except that of the tubular extension, which tends to exhibit fine, longitudinal folds and, occasionally, rare, shorter processes. Processes originally hollow; interior of proximal parts presumably connected to interior of the vesicle. Proximal parts of processes sometimes linked by lateral trabeculae and have length between one twenty-fifth and one tenth of vesicle diameter. Distal extremity of each process divided into two or four straps that anastomose densely with those of neighbouring processes to form delicate, interwoven, peripheral meshwork.

Dimensions. Based on 80 specimens. Vesicle diameter: 30 to 51 (average 39) μm; length and basal width of tubular extension: 5.5 to 8 μm and 6 to 14 μm; length and basal width of proximal parts of processes: 1.2 to 4 μm and 0.3 to 1.0 (usually 0.7) μm; length of spines on vesicle wall: up to 0.5 μm; vesicle wall thickness: less than 0.3 μm.

Discussion. Vesicle and tubular extension apparently single layered with a membrane of uniform thickness, though that of the tubular extension is usually more transparent. Abrasion often eliminates the distal parts of processes and may also produce a fine, irregular pitting of the vesicle wall (Pl. 2, fig. 12). Vesicles and processes generally appear opaque and blackish but the same slide may also contain rare, light yellow-brown examples, in which the proximal parts of the processes are hollow and communicate with the internal cavity of the central body; most often the relationship between the interiors of the processes and the inner vesicle cavity is unclear. It has not been determined whether the distal ramifications are solid or not. *Aryballomorpha albertana* n. sp. differs from *A. grootaertii* in the form of the processes, the proximal part of which is finer and shorter.

Aryballomorpha grootaertii (Martin) emend. Martin and Yin, 1988

Plate 3, figures 6-13

Acritarch gen. et sp. nov. A. Martin *in* Dean and Martin, 1982, p. 138, Pl. 1, fig. 13.

Aremoricanium? *grootaertii* sp. nov. Martin, 1984, p. 442, Pl. 58.1, figs. 1-9; Pl. 58.2, figs. 1-4.

Aryballomorpha grootaertii (Martin) comb. nov. et emend. Martin and Yin, 1988, p. 113, 114, Pl. 13, figs. 1-11; Pl. 14, figs. 1, 2.

Aremoricanium? *grootaertii* Martin, 1984. Tongiorgi *in* Bagnoli et al., 1988, p. 185, Pl. 7, figs. 1-8; Pl. 8, figs. 1-5.

Figured specimens. GSC 94599 (Pl. 3, fig. 6), GSC 94600 (Pl. 3, figs. 7, 8), GSC 94601 (Pl. 3, figs. 9, 13), GSC 94602 (Pl. 3, figs. 10, 11), GSC 94603 (Pl.3, fig. 12).

Occurrence. Commonly present, in variable abundance, in the middle member of the Survey Peak Formation, from 76 m above the base of the member (GSC loc. C-97815) to 195.2 m above the base of the member (GSC loc. C-97847). Ranges from the middle part of trilobite zone D to the middle part of zone E.

Dimensions. Based on 200 specimens. Vesicle diameter: 28 to 62 (average 37) μm; length and basal width of tubular extension: 5 to 17 μm and 13 to 20 μm; length and basal width of proximal part of processes: 5 to 13 μm and 1 to 2 (usually 1.5) μm; length of spines on vesicle wall: up to 0.7 μm; vesicle wall thickness: less than 0.3 μm.

Remarks. The double membrane of the vesicle has been observed locally, at the base of the oral tube, in specimens not only from Wilcox Pass but also from Jilin Province, northeastern China (Martin and Yin, 1988). However, Tongiorgi (*in* Bagnoli et al., 1988, Pl. 8, fig. 4) has demonstrated that specimens from Öland, Sweden, possess two membranes, only the outer of which forms the oral tube and the processes. These morphological differences certainly depend in part on the preservation but may also be accentuated in a particular stage of the life cycle.

Aryballomorpha n. sp. A

Plate 3, figures 1-5

Figured specimens. GSC 94604 (Pl. 3, figs. 1, 5), GSC 94605 (Pl. 3, fig. 2), GSC 94606 (Pl. 3, fig. 3), GSC 94607 (Pl. 3, fig. 4).

Occurrence. Common in the middle member of the Survey Peak Formation at GSC locs. C-97825 and C-97826, 101.45 m and 103.85 m above its base, in strata not dated by macrofossil data between trilobite zones D and E.

Description. Based on 42 specimens. Vesicle originally spherical or almost so; outline circular to subcircular in both polar and lateral views. When oriented laterally, a few specimens show a prominent, hollow, tubular, apical extension with a distal circular opening. No operculum observed. Length and basal width of tubular extension about one quarter to one fifth, and one third of the vesicle diameter, respectively. Vesicle bilayered; hyaline external layer around the inner vesicle forms tubular extension and processes. All external surface is psilate. About 50 to 70 slender, flexuous processes evenly distributed on each face of the vesicle and rarely preserved on the tubular extension; processes are hollow, and separated from the internal cavity of the vesicle by the inner wall of the latter. Trunks of the processes variably conical, depending on their degree of turgescence, and their length is from one half to three quarters of the vesicle diameter; they ramify distally to form two elongate, narrow divisions of the first order, which may subdivide into straps up to the third order, with broken tips that anastomose with those of neighbouring processes.

Dimensions. Based on 38 specimens. Vesicle diameter: 26 to 46 (average 35) μm; length and basal width of tubular extension: 7 to 10 μm and 11 to 15 μm; length and basal width of trunks of processes: 5 to 12 μm and 0.7 to 5.5 μm; length of incomplete distal subdivisions: 3 to 12 μm; thickness of inner and external vesicle layers: about 0.5 μm and less than 0.3 μm.

Discussion. The preservation of the specimens is too poor for erecting a new species. The oral tube is always damaged, the processes are usually broken off at the base, and the distal ramifications are incomplete; the mode of division and anastomosis of the processes justify the attribution to *Aryballomorpha* rather than to *Aremoricanium* Deunff, 1955. *Aryballomorpha* n. sp. A differs from *A. grootaertii* in having relatively longer, more conical trunks of the processes, which may also be present on the oral tube, and by the obvious double membrane of the vesicle. It is distinguished from *Cymatiogalea messaoudi* Jardiné et al. 1974 as described (Jardiné et al., 1974, p. 123, Pl. 2, figs. 5, 6) from the Tremadoc of the Algerian Sahara, and from the uppermost Tremadoc or lowermost Arenig, pre-*Didymograptus deflexus* Subzone of the English Lake District (Molyneux and Rushton, 1988, p. 59, Figs. 5c, e, f) mainly by the absence of a polar opening closed by an operculum and of areas delimited by the process bases.

Genus *Athabascaella* Martin, 1984 emend. Martin and Yin, 1988

Type species. Athabascaella playfordii Martin, 1984 emend. Martin and Yin, 1988, by original designation.

Athabascaella sp. cf. *A. penika*
Martin and Yin, 1988

Plate 4, figures 1-8

Figured specimens. GSC 94608 (Pl. 4, figs. 1, 4), GSC 94609 (Pl. 4, figs. 2, 6), GSC 94610 (Pl. 4, fig. 3), GSC 94611 (Pl. 4, figs. 5, 8), GSC 94612 (Pl. 4, fig. 7).

Occurrence. Often present in variable abundance in the middle member of the Survey Peak Formation, from 80.9 m above the base of the member (GSC loc. C-97818) to 194.25 m above the base of the member (GSC loc. C-97846). Ranges from the middle of trilobite zone D to the middle of zone E.

Dimensions. Based on 50 specimens. Vesicle diameter: 24 to 64 (average 39) μm; length and basal width of processes: 5 to 15 μm and 0.5 to 2.2 μm; length of distal subdivisions up to the third order: 2 μm; height of baculate projections on vesicle wall: 0.5 to 1.7 μm; vesicle wall thickness: less than 0.3 μm.

Discussion. The specimens differ from *A. penika*, from the Tremadoc of northeast China (Martin and Yin, 1988), in having the central body with more strongly developed ornamentation, which is always incompletely preserved and made up of minute baculate projections. As in the Chinese material, a delicate, transparent, peripheral membrane, supported by the distal subdivisions of the processes, is sometimes locally preserved.

Athabascaella playfordii Martin, 1984 emend.
Martin and Yin, 1988

Plate 4, figures 9-13

Athabascaella playfordii gen. et sp. nov. Martin, 1984, p. 444, Pl. 58.3, figs. 1-9.
Athabascaella playfordii Martin, 1984 emend. Martin and Yin, 1988, p. 116, 118, Pl. 15, figs. 7-11.
Athabascaella playfordii Martin, 1984. Tongiorgi *in* Bagnoli et al., 1988, p. 186, Pl. 9, figs. 1-4.

Figured specimens. GSC 94613 (Pl. 4, figs. 9, 10), GSC 94614 (Pl. 4, figs. 11, 12), GSC 94615 (Pl. 4, fig. 13).

Occurrence. Commonly present in variable abundance in the middle member of the Survey Peak Formation from 80.9 m (GSC loc. C-97818) above its base, and rare in the Outram Formation, ranging up to 106.8 m (GSC loc. C-97896) above its base. Ranges from the middle part of trilobite zone D to zones H and I (undifferentiated).

Dimensions. Based on 60 specimens. Vesicle diameter: 32 to 70 (average 46) μm; length and basal width of trunks of processes: 5 to 13 μm and 1 to 2.5 μm; length of distal subdivisions of processes, including fourth order: up to 7 μm; vesicle wall thickness: about 0.3 μm maximum.

Athabascaella rossii Martin, 1984 emend.
Martin and Yin, 1988

Plate 5, figures 1-4

Athabascaella rossii gen. et sp. nov. Martin, 1984, p. 446, Pl. 58.2, figs. 5-12
Athabascaella rossii Martin, 1984 emend. Martin and Yin, 1988, p. 118, Pl. 15, figs. 1-6.

Figured specimens. GSC 94616 (Pl. 5, figs. 1-3), GSC 94617 (Pl. 5, fig. 4).

Occurrence. Commonly present in variable abundance in the middle member of the Survey Peak Formation from 77.1 m above the base of the member (GSC loc. C-97816) to 198 m above the base of the member (GSC loc. C-97848). Ranges from the middle part of trilobite zone D to the middle part of zone E.

Dimensions. Based on 90 specimens. Vesicle diameter: 32 to 73 (average 49) μm; length and basal width of trunks of processes: 2.5 to 6 μm and 1 to 2 μm; length of distal subdivisions, including fourth order: up to 1.5 μm; thickness of vesicle wall: less than 0.3 μm.

Athabascaella sunwaptana n. sp.

Plate 5, figures 5-13

Holotype. GSC 94619 (Pl. 5, figs. 6, 9, 12, 13). Diameter of spherical vesicle; 37 μm; length and basal width of processes: 8 to 12 μm and 0.8 to 1 μm; length of distal subdivisions of processes: up to 5 μm; height of baculate projections on vesicle wall: up to 1 μm.

Paratypes. GSC 94618 (Pl. 5, fig. 5), GSC 94620 (Pl. 5, fig. 7), GSC 94621 (Pl. 5, fig. 8), GSC 94622 (Pl. 5, figs. 10, 11).

Type locality. GSC loc. C-97825, Wilcox Pass; middle member of the Survey Peak Formation.

Occurrence. At two localities in the middle member of the Survey Peak Formation, in strata undated by macrofossils between trilobite zones D and E. Common at GSC loc. C-97825, rare at GSC loc. C-97826, 101.45 m and 103.85 m above base of member.

Etymology. After the Sunwapta River.

Diagnosis. Based on 26 specimens. Vesicle globular with circular outline; apparently single-layered. External surface covered with small baculate projections that may anastomose to form an interwoven, peripheral, fine meshwork. Originally about 80 to 100 well differentiated, evenly distributed processes on each face of the vesicle. The proximal part of each process is elongate, almost cylindrical, and was originally hollow, though the relationship between the interior and the vesicle cavity is unclear. The trunks of the processes have a narrow base and their length is between one fifth and one third of the vesicle diameter. The distal extremities of the processes ramify, generally from the same level, to form two to four subdivisions that themselves subdivide to the second or third order. Locally, both trunks and distal subdivisions may show lateral expansions that join with adjacent processes. A delicate, transparent, peripheral membrane, supported by the distal subdivisions of the processes, is sometimes present. The presence of an opening is uncertain.

Dimensions. Based on 17 specimens. Vesicle diameter: 24 to 43 (average 33) μm; length and basal width of trunks of processes: 6 to 12 μm and 0.7 to 1 μm; length of distal subdivisions: up to 5 μm; height of baculate projections on vesicle wall: 0.5 to 1.5 μm; thickness of vesicle wall: less than 0.3 μm.

Discussion. Athabascaella sunwaptana n. sp. differs from *A. playfordii* in having processes that are less subdivided distally, and in the ornamentation of the wall of the central body, which resembles that of *A.* sp. cf. *A. penika.* In the latter species, the baculate projections of the central body do not anastomose and the processes have distal ramifications that are much shorter and squat.

Genus *Buedingiisphaeridium* Schaarschmidt, 1963

Type species. Buedingiisphaeridium permicum Schaarschmidt, 1963 by original designation.

Buedingiisphaeridium tremadocum Rasul, 1979

Plate 6, figures 1, 5.

Buedingdisphaeridium (sic) *tremadocum* n. sp. Rasul, 1979, p. 64, Pl. 1, figs. 12, 13.
Buedingdisphaeridium (sic) *tremadocum* Rasul, 1979. Cocchio, 1982, p. 28, Pl. 2, fig. 12.
Buedingisphaeridium (sic) aff. *B. tremadocum* Rasul, 1979. Tongiorgi et al., 1984, p. 670, Pl. 1, figs. 1, 2.
Buedingisphaeridium (sic) aff. *B. tremadocum* Rasul, 1979. Albani et al., 1985, p. 5, Pl. 3, figs. 11-13.

Figured specimens. GSC 94623 (Pl. 6, fig. 1), GSC 94624 (Pl. 6, fig. 5).

Occurrence. Rare in the basal silty member of the Survey Peak Formation at GSC loc. C-97766, 38 m above its base. Trilobite zone A.

Description. Based on three specimens. Vesicle originally spherical with circular outline; apparently single-layered. About 40 verruca-like processes on each side of vesicle. The proximal part of each process is hollow, its interior communicating with that of the vesicle; the rounded distal end is solid. No excystment observed.

Dimensions. Based on two specimens. Vesicle diameter: 14 to 17 μm; length and basal width of processes: 1 to 1.8 μm and 0.6 to 1.3 μm.

Genus *Comasphaeridium* Staplin, Jansonius, and Pocock, 1965

Type species. Comasphaeridium cometes (Valensi) Staplin, Jansonius, and Pocock, 1965, by original designation.

Comasphaeridium sp. cf. *C. strigosum* (Jankauskas) Downie, 1982

Plate 6, figures 6, 7

Figured specimens. GSC 94625 (Pl. 6, fig. 6), GSC 94626 (Pl. 6, fig. 7).

Occurrence. Rare in the basal silty member of the Survey Peak Formation, between 19 m (GSC loc. C-97762) and 24.7 m (GSC loc. C-97765) above its base. Trilobite zone A.

Description. Based on 41 specimens. Vesicle originally spherical, entirely covered with abundant, juxtaposed, apparently solid, hair-like processes; the latter are always incomplete distally, with length between one fifth and one third of the vesicle diameter. No excystment observed.

Dimensions. Based on 21 specimens. Vesicle diameter: 20 to 33 (average 25) μm; basal width of processes: 0.3 to 0.6 μm.

Discussion. Although the specimens have broken processes, they bear some resemblance to *C. strigosum*, particularly to its representatives from the Fucoid Beds, Lower Cambrian, of northwest Scotland (Downie, 1982, Figs. 6k, i) and from palynologically dated Upper Cambrian strata in northwest Spain (Fombella, 1987, Pl. 2, fig. 20).

Genus *Corollasphaeridium* Martin *in* Dean and Martin, 1982 emend. Yin, 1986

Type species. Corollasphaeridium wilcoxianum Martin *in* Dean and Martin, 1982 by original designation.

Corollasphaeridium wilcoxianum Martin *in* Dean and Martin, 1982 emend. herein

Plate 6, figures 2-4, 8, 10-16

Corollasphaeridium wilcoxianum gen. et sp. nov. Martin *in* Dean and Martin, 1982, p. 136, Pl. 1, figs. 15, 16.

Corollasphaeridium normalisum sp. nov. Yin, 1986, p. 337, Pl. 88, figs. 1, 2, 4, 6, 9, 15; Textfig. 123.

Corollasphaeridium wilcoxianum Martin, 1982. Yin, 1986, p. 338, Pl. 88, figs. 12, 14.

Figured specimens. GSC 94627 (Pl. 6, fig. 2), GSC 94628 (Pl. 6, fig. 3), GSC 94629 (Pl. 6, figs. 4, 8), GSC 94630 (Pl. 6, figs. 10, 11), GSC 94631 (Pl. 6, fig. 12), GSC 94632 (Pl. 6, fig. 13), GSC 94633 (Pl. 6, fig. 14), GSC 94634 (Pl. 6, fig. 15), GSC 94635 (Pl. 6, fig. 16).

Occurrence. Of variable and often reduced frequency in the basal silty member of the Survey Peak Formation, from 18.55 m above the base of the member (GSC loc. C-97761) to 37.65 m above the base of the member (GSC loc. C-97775). Ranges from the uppermost, questionable part of the *Missisquoia* Zone (recorded with certainty between 17.2 m and 18 m above the base of the basal silty member) to the lower part of trilobite zone A. The species first appears close to the base of the *Cordylodus intermedius* Zone.

Emended diagnosis. Based on 52 specimens. Vesicle originally cylindrical, or almost so. Outline originally elongate in lateral view and circular to slightly polygonal in transverse view. One extremity (apical pole) of vesicle progressively prolonged by a collarette that is always open distally, relatively transparent, lacks an operculum, and has a length approximately equal to that of central body. The other extremity (antapical pole) carries six to ten simple, conical, hollow processes whose internal cavity communicates with that of the vesicle. Five to nine (generally five or six) processes arranged more or less regularly around a more developed central process that prolongs the longitudinal axis of the vesicle and may be as long as the latter. The smallest processes carry two to four longitudinal fibrils; the best developed processes carry four to ten. The most strongly marked of these ridge-like thickenings extend into the vesicle as far as the distal extremity of the collarette, the opening of which is bordered by a thickening of similar type. The principal fibrils of the vesicle, including those on the collarette, may be secondarily anastomosed. The membrane, excluding fibrils, is smooth and apparently single layered.

Dimensions. Based on 25 specimens. Total length, from base of vesicle to distal extremity of collarette: 34 to 73 (average 55) μm; basal width of vesicle: 19 to 50 (average 38) μm; length and basal width of the most developed process: 13 to 37 μm and 6 to 24 μm; length and basal width of smallest processes: 10 to 29 μm and 3 to 16 μm; thickness of principal fibrils: 0.5 to 0.7 μm; vesicle wall thickness: 0.2 to 0.3 μm.

Discussion. Additional observations justify modification of the original diagnosis, which was based on incompletely preserved specimens lacking the collarette. In particular, the holotype (Martin *in* Dean and Martin, 1982, Pl. 1, fig. 16) is compressed in apical view, the more transparent central part corresponding to the detached collarette. From personal observation of about 60 specimens from the Cambrian–Ordovician section at Xiaoyangqiao, northeast China, I determined that Yin (1986) attributed to *C. normalisum* those specimens seen in lateral view, and to *C. wilcoxianum* those compressed in transverse view. The appearance of the species varies, depending on its orientation in a palynological preparation, the degree of swelling of the central body and processes, and the preservation of the collarette. Although the collarette wall had a thickness approximately equal to that of both the base of the central body and of the processes, it is often more oxidized and its texture is more fragile.

Genus *Dasydiacrodium* Timofeev, 1959 ex and emend. Deflandre and Deflandre-Rigaud, 1962

Type species. Dasydiacrodium eichwaldi Timofeev, 1959 by subsequent designation of Deflandre and Deflandre-Rigaud, 1962.

Dasydiacrodium sp. cf. *D. glabrum* Combaz, 1968

Plate 7, figure 14

Figured specimen. GSC 94638.

Occurrence. Very rare in the basal silty member of the Survey Peak Formation at GSC loc. C-97766, 26.6 m above its base. Trilobite zone A.

Dimensions. Based on one specimen. Length and equatorial width of vesicle: 31 μm and 25 μm; thickness of vesicle wall: approximately 0.3 μm.

Discussion. The single specimen has an abraded surface; the more inflated pole carries five incomplete spines, 0.3 μm long, but the other pole is smooth. The general shape of the vesicle is close to that of *D. glabrum* as originally described from the palynologically dated Tremadoc of the Algerian Sahara by Combaz (1968, p. 16, Pl. 3, fig. 77).

Genus *Goniosphaeridium* Eisenack, 1969 emend. Kjellström, 1971

Type species. Goniosphaeridium polygonale Eisenack, 1969 by original designation.

Goniosphaeridium sp. aff. *G. akrochodermum* (Rasul) Martin *in* Dean and Martin, 1982

Plate 7, figures 2-13, 18-20

Goniosphaeridium aff. *G. akrochodermum* Rasul, 1979) comb. nov. Martin *in* Dean and Martin, 1982, p. 138, Pl. 1, figs. 8, 12, 14.

Figured specimens. GSC 94639 (Pl. 7, figs. 2, 3), GSC 94640 (Pl. 7, fig. 4), GSC 94641 (Pl. 7, figs. 5, 6), GSC 94642 (Pl. 7, fig. 7), GSC 94643 (Pl. 7, fig. 8), GSC 94644 (Pl. 7, fig. 9), GSC 94645 (Pl. 7 fig. 10), GSC 94646 (Pl. 7, fig. 11), GSC 94647 (Pl. 7, fig. 12), GSC 94648 (Pl. 7, fig. 13), GSC 94649 (Pl. 7, fig. 18), GSC 94650 (Pl. 7, fig. 19), GSC 94651 (Pl. 7, fig. 20).

Occurrence. Common in the basal silty member of the Survey Peak Formation, from 3.6 m above the base of the member (GSC loc. 92340). The species is rare in a few samples from the middle member of the same formation up to 103.85 m above its base (GSC loc. C-97826). Ranges from the *Corbinia apopsis* Subzone of the *Saukia* Zone to an interval not dated by macrofossil data, between trilobite zones D and E.

Description. Based on more than 2000 specimens. Vesicle apparently single-layered, with subcircular to polygonal outline. Seven to 30, usually 15 to 20, conical, variably inflated processes, with interior opening into that of vesicle; length of processes between one quarter and one tenth of vesicle diameter; tips are closed, usually simple, and less than 0.1 per cent of specimens have one or two distally divided processes. Wall surface smooth, weakly granulose, pilose, or spinose. No regular excystment opening observed.

Dimensions. Based on 200 specimens. Vesicle diameter: 15 to 35 (average 24) μm; length and basal width of processes: 3 to 20 (average 7) μm and 0.7 to 6 (average 1.5) μm; length of wall surface ornamentation: up to 0.5 μm; thickness of vesicle wall: less than 0.3 μm.

Discussion. See also discussion by Martin *in* Dean and Martin, 1982. The diagnosis of *Goniosphaeridium akrochodermum*, from the Shineton Shales, Brachiopod Beds (Tremadoc) of England (Rasul, 1979, p. 56, Pl. 1, fig. 6), does not indicate the variability of the species, the membrane of which is ornamented with "tubercles too small to be measured" that are invisible on the transmitted light microscope photograph of the holotype. In each of the assemblages determined as *G.* sp. aff. *G. akrochodermum*, about 5 per cent of the specimens show a bipolar tendency, the extremes of which are attributed to *Actinotodissus* sp. A (see above). Some rare specimens with one process more inflated at its base (Pl. 7, figs. 7, 9) are included here within the variability of *G.* sp. aff. *G. akrochodermum*. If seen individually, the specimens could be attributed to *Tectitheca prima* Rasul, 1979, from the Tremadoc of Shropshire, or to *T. multispinula* Yin, 1985 emend. Yin, 1986, from the Upper Cambrian of northeast China. Other specimens, whose spinose ornamentation is preserved, have a shape that is either spherical (Pl. 7, fig. 8) or polygonal (Pl. 7, figs. 13, 18); these could alternatively be assigned to *Uncinisphaera* Wicander, 1974 or *Stellechinatum* Turner, 1984. The significant variability in a few distinct morphographic characters and the uneven but generally important abrasion of the wall ornamentation justify the determination adopted here.

Smooth specimens of *G.* sp. aff. *G. akrochodermum* differ essentially from *G.* sp. cf. *G. pungens* (Timofeev) Rauscher, 1974 (Pl. 7, fig. 1 herein), which is rare in the upper part of the middle member of the Survey Peak Formation and in the Outram Formation, in having shorter, less numerous, and less sharply outlined processes.

Genus *Lua* Martin and Yin, 1988

Type species. Lua erdaopuziana Martin and Yin, 1988 by original designation.

Lua erdaopuziana Martin and Yin, 1988

Plate 7, figure 15

Lua erdaopuziana sp. nov. Martin and Yin, 1988, p. 120, 122, Pl. 16, figs. 1-6.

Figured specimen. GSC 94654.

Occurrence. Very rare in the middle member of the Survey Peak Formation at GSC locs. C-97836 and C-97843, 159.85 m and 181 m above its base. Trilobite zone E.

Dimensions. Based on three specimens. Vesicle diameter: 35 to 59 μm; length and basal width of tubular extension: 9 μm and 12 μm; length and basal width of trunks of processes: 3.7 to 5 μm and 0.7 to 3 μm; length of distal divisions of processes: up to 3 μm; height of echinate ornamentation of vesicle wall: up to 1.5 μm; vesicle wall thickness: 0.3 μm.

Genus *Peteinosphaeridium* Staplin, Jansonius, and Pocock, 1965

Type species. Peteinosphaeridium trifurcatum (Eisenack) Staplin, Jansonius, and Pocock, 1965, originally designated as *P. bergstromii* Staplin et al., 1965, which Eisenack (1969) considered to be a junior subjective synonym of *P. trifurcatum.*

Peteinosphaeridium sp. cf. *P. breviradiatum* (Eisenack) Eisenack, 1969

Plate 8, figures 5, 8, 11, 12

Peteinosphaeridium cf. *P. breviradiatum* (Eisenack) Eisenack, 1969. Martin *in* Dean and Martin, 1982, Pl. 1, fig. 3.

Figured specimens. GSC 94655 (Pl. 8, fig. 5), GSC 94656 (Pl. 8, figs. 8, 11), GSC 94657 (Pl. 8, fig. 12).

Occurrence. Rare in the upper massive member of the Survey Peak Formation, the species occurs first at 0.35 m (GSC loc. C-97860′) below the top of the member. The species is also found in the Outram Formation, and is rare in the Skoki Formation, at GSC loc. C-97933, 0.7 m above its base. Ranges from the upper part of trilobite zone F to zone J.

Dimensions. Based on 25 specimens. Vesicle diameter: 35 to 75 (average 44) μm; length of processes: 7.5 to 16.5 μm; width of longitudinal lists of processes: 3 to 9 μm.

Discussion. Based on 70 specimens. Poor preservation of the specimens permits only tentative specific assignment. Outer and free margins of the transparent lists may be entirely or locally echinate. One pylome without lip-like rim is rarely present; its diameter is about one quarter of that of the vesicle.

Genus *Rhopaliophora* Tappan and Loeblich, 1971 emend. Playford and Martin, 1984

Type species. Rhopaliophora foliatis Tappan and Loeblich, 1971 by original designation.

Rhopaliophora palmata (Combaz and Peniguel) emend. Playford and Martin, 1984

Plate 8, figures 4, 13

Peteinosphaeridium palmatum n. sp. Combaz and Peniguel, 1972, p. 136, Pl. 2, figs. 4, 9-12.
Rhopaliophora palmata (Combaz and Peniguel) comb. nov. et emend. Playford and Martin, 1984, p. 210, 212, Figs. 9A-N (includes further synonymy).
Peteinosphaeridium palmatum Combaz and Peniguel var. *dilatum* Combaz and Peniguel, 1972. Lu Li-Chang, 1987, p. 95, 96, Pl. 1, fig. 13; Pl. 2, figs. 13, 14.
Rhopaliophora palmata (Combaz and Peniguel) emend. Playford and Martin, 1984. Playford and Wicander, 1988, p. 25, Figs. 13 G-L.

Figured specimens. GSC 94658 (Pl. 8, fig. 4), GSC 94659 (Pl. 8, fig. 13).

Occurrence. Commonly present in variable abundance in the upper massive member of the Survey Peak Formation, where it first appears at 0.35 m (GSC loc. C-97860′), below the top of the member, and in the Outram Formation; common in the Skoki Formation at GSC loc. C-97933, 0.7 m above the base of the formation. Ranges from the upper part of trilobite zone F to zone J.

Dimensions. Based on 30 specimens. Vesicle diameter: 22 to 61 (average 41) μm; length and basal width of processes: 3 to 16 μm and 2 to 9 μm; vesicle wall thickness: 0.3 to 0.8 μm.

Discussion. Based on 300 specimens. One pylome without lip-like rim is rarely observed; its diameter is between one quarter and one fifth of that of the vesicle. Operculum not observed. Vesicle wall psilate.

Rhopaliophora pilata (Combaz and Peniguel) emend. Playford and Martin, 1984

Plate 8, figures 1-3, 6

Peteinosphaeridium pilatum n. sp. Combaz and Peniguel, 1972, p. 136, 137, Pl. 2, figs. 1-3.
Rhopaliophora pilata (Combaz and Peniguel) comb. nov. and emend. Playford and Martin, 1984, p. 212-214, Figs. 10 A-E, G-M (includes further synonymy).
Rhopaliophora pilata (Combaz and Peniguel) emend. Playford and Martin, 1984. Martin and Yin, 1988, p. 122, 123, Pl. 16, figs. 9, 11, 12.
Rhopaliophora pilata (Combaz and Peniguel) emend. Playford and Martin, 1984. Playford and Wicander, 1988, p. 25-27, Figs. 14 D-K.

Figured specimens. GSC 94660 (Pl. 8, fig. 1), GSC 94661 (Pl. 8, figs. 2, 3), GSC 94662 (Pl. 8, fig. 6).

Occurrence. Often present in variable abundance in the upper massive member of the Survey Peak Formation, from 6.65 m (GSC loc. C-97860) below its summit, and in the Outram Formation; common in the Skoki Formation 0.7 m above its base (GSC loc. C-97933). Ranges from the upper part of trilobite zone F to zone J.

Dimensions. Based on 50 specimens. Vesicle diameter: 20 to 55 (average 38) µm; length and basal width of processes: 1 to 4 µm and 1.5 to 4 µm; vesicle wall thickness: 0.3 to 0.8 µm.

Discussion. Based on more than 500 specimens. One pylome, without lip-like rim, is sometimes present. The operculum, its diameter about one fifth of that of the vesicle, was observed in five cases; two of these, partially displaced into the vesicle cavity, show three and five processes, respectively, of the same type as those observed on the central body. The vesicle wall is psilate or, infrequently and irregularly preserved, echinate to pilate.

Genus *Saharidia* Combaz, 1968

Type species. Saharidia downiei Combaz, 1968 by original designation.

Saharidia downiei Combaz, 1968

Plate 7, figures 16, 17, 21

Saharidia downiei n. sp. Combaz, 1968, p. 13, Pl. 2, figs. 35, 36.
non Saharidia downiei Combaz, 1967(?). Combaz and Peniguel, 1972, p. 129, Pl. 1, figs. 11, 12.
?*Saharidia downiei* Combaz, 1967. Fombella, 1987, Pl. 1, fig. 6.

Figured specimens. GSC 94663 (Pl. 7, fig. 16), GSC 94664 (Pl. 7, fig. 17), GSC 94665 (Pl. 7, fig. 21).

Occurrence. Rare in the basal silty member of the Survey Peak Formation at GSC loc. C-97766, 26.6 m above its base. Trilobite zone A.

Description. Based on 20 specimens. Vesicle outline circular to subcircular, probably lenticular or discoidal originally. Specimens always compressed with one to three circular, continuous, concentric, well marked folds located toward the periphery. Supplementary, discontinuous, irregular folds commonly present. Membrane thin, fragile, and smooth. Abrasion may produce numerous cracks and fine irregular pitting. Circular excystment opening in the middle of one side of the vesicle has a diameter between one third and one quarter of that of the central body. No operculum observed.

Dimensions. Based on eight specimens. Vesicle diameter: 53 to 65 (average 58) µm; opening diameter: 13 to 15 µm; vesicle wall thickness: 0.1 to 0.2 µm.

Remarks. Because of their shagreenate ornamentation and larger dimensions (80 to 90 µm), the rare specimens determined by Combaz and Peniguel (1967) from the Arenig (palynological zone 02) in the Nambeet Formation of the Canning Basin, Western Australia, are not retained here in the species. Fombella (1987) determined *Saharidia downiei* in beds of the Oville Formation, León Province, northwestern Spain, that she dated palynologically as Upper Cambrian and Tremadoc. Her illustration is insufficient to judge whether the specific determination is well founded.

Genus *Vulcanisphaera* Deunff, 1961 emend. Rasul, 1976

Type species. Vulcanisphaera africana Deunff, 1961 by original designation.

Vulcanisphaera sp. cf. *V. africana* Deunff, 1961

Plate 8, figures 7, 9, 10

Figured specimens. GSC 94666 (Pl. 8, figs. 7, 10), GSC 94667 (Pl. 8, fig. 9).

Occurrence. Rare in the basal silty member of the Survey Peak Formation at GSC locs. C-97759 and C-97766, 15.15 m and 26.6 m above its base. Ranges from the *Missisquoia* Zone to the lower part of trilobite zone A.

Dimensions. Based on four specimens. Vesicle diameter: 30 to 39 μm; length of filament-like processes: 5 to 9 μm; vesicle wall thickness: about 0.2 μm.

Remarks. Based on eight specimens. The poor state of preservation makes specific attribution uncertain. The specimens resemble *V. africana*, originally described (Deunff, 1961, p. 42, Pl. 2, fig. 1) from unspecified Tremadoc strata in the Sahara, in having on each face about forty "tufts", the polygonal disposition of which is obscure; each "tuft" has two or three anastomosed processes.

SYSTEMATIC DESCRIPTIONS OF CHITINOZOANS

Genus *Conochitina* Eisenack, 1931 emend. Paris, 1981

Type species. *Conochitina claviformis* Eisenack, 1931 by original designation.

Conochitina sp. cf. *C. brevis* Taugourdeau and de Jekhowsky, 1960

Plate 8, figure 14

Figured specimen. GSC 94668.

Occurrence. Rare in the Outram Formation, the species first appears at 41.35 m (GSC loc. C-97873) above the base of the formation, and rare in the lowest Skoki Formation, up to 32 m above its base (GSC loc. C-97939). Ranges from the lower part of trilobite zone G to a little above strata dated by means of trilobites as zone J; although the highest level lacks macrofossils, it possibly belongs to zone J.

Description. Based on six specimens. Vesicle squat and conical, its base flat with rounded margins. Chamber and oral tube little differentiated. Vesicle surface smooth.

Dimensions. Based on two specimens. Vesicle length: 150 to 190 μm; vesicle maximum width: 105 to 120 μm; oral opening width: 65 to 72 μm.

Discussion. The lack of diagnostic characters and the poor state of preservation make specific identification uncertain. *Conochitina brevis* was originally described (Taugourdeau and de Jekhowsky, 1960, p. 1222, Pl. 4, figs. 47-49) from the Upper Ordovician and Lower Silurian (chitinozoan zones 2 and 3) of the Algerian Sahara.

Conochitina sp. cf. *C. exilis* Bockelie, 1980

Plate 8, figures 15-17

Figured specimens. GSC 94669 (Pl. 8, fig. 15), GSC 94670 (Pl. 8, figs. 16, 17).

Occurrence. Rare in the Outram Formation, the species first appears at 10.7 m (GSC loc. C-97863) above the base of the formation, and is rare in the lowest Skoki Formation, up to 32 m above its base (GSC loc. 97939). Ranges from the lower part of trilobite zone G to a little above strata dated by means of trilobites as zone J; although the highest level lacks macrofossils, it possibly belongs to zone J.

Description. Based on 30 specimens. Vesicle elongate and slender. Flanks of chamber taper progressively toward the oral tube. Aboral pole flat or rounded, depending on compression and distortion; maximum width just above basal edge. Surface of vesicle originally smooth but here abraded.

Dimensions. Based on seven specimens. Vesicle length: 400 to 605 (average 482) μm; vesicle maximum width: 85 to 150 (average 118) μm; oral opening width: 65 to 91 (average 85) μm.

Discussion. Unobserved prosome and mucro limit comparison with *C. exilis*, described (Bockelie, 1980, p. 10, Pl. 1, figs. 2, 5-7, 11, 13; Textfig. 7B) from the Arenig and, possibly, Llanvirn of Spitsbergen.

REFERENCES

Achab, A.
1986: Assemblages de Chitinozoaires dans l'Ordovicien inférieur de l'est du Canada. Canadian Journal of Earth Sciences, v. 23, p. 682-695.

Aitken, J.D.
1966: Middle Cambrian to Middle Ordovician cyclic sedimentation, southern Rocky Mountains of Alberta. Bulletin of Canadian Petroleum Geology, v. 14, p. 405-441.

1978: Revised models for depositional Grand Cycles, Cambrian of the southern Rocky Mountains, Canada. Bulletin of Canadian Petroleum Geology, v. 26, p. 515-542.

1981: Cambrian stratigraphy and depositional fabrics, southern Canadian Rocky Mountains, Alberta and British Columbia. *In* The Cambrian System in the Southern Canadian Rocky Mountains, Alberta and British Columbia, M.E. Taylor (ed.); Guidebook for Field Trip 2, Second International Symposium on the Cambrian System, August 14-20, 1981, p. 1-27. (compiled by J.D. Aitken)

Aitken, J.D. and Greggs, R.G.
1967: Upper Cambrian formations, southern Rocky Mountains of Alberta, an interim report. Geological Survey of Canada, Paper 66-49, 91 p.

Aitken, J.D. and Norford, B.S.
1967: Lower Ordovician Survey Peak and Outram formations, southern Rocky Mountains of Alberta. Bulletin of Canadian Petroleum Geology, v. 15, p. 150-207.

Aitken, J.D., Fritz, W.H., and Norford, B.S.
1972: Cambrian and Ordovician biostratigraphy of the southern Canadian Rocky Mountains. 24th International Geological Congress, Montreal, Field Excursion A-19, Guidebook, 57 p.

Al-Ameri, T.
1983: Acid-resistant microfossils used in the determination of Paleozoic palaeoenvironments in Libya. Palaeogeography, Palaeoclimatology, Palaeobiology, v. 44, p. 103-116.

Albani, R., Di Milia, A., Minzoni, N., and Tongiorgi, M.
1985: Nuovi dati palinologici e considerazioni geologiche sull'eta delle Arenarie di Solanas (Cambro-Ordoviciano-Sardegna Centrale). Atti della Società Toscana di Scienze Naturali, Memorie, Serie A, v. 92, p. 1-20.

Bagnoli, G., Stouge, S., and Tongiorgi, M.
1988: Acritarchs and conodonts from the Cambro-Ordovician Furuhäll (Köpingsklint) section (Öland, Sweden). Rivista Italiana di Paleontologia e Stratigrafia, v. 94, p. 163-248.

Barnes, C.R.
1984: Early Ordovician eustatic events in Canada. *In* Aspects of the Ordovician System, D.L. Bruton (ed.); Palaeontological Contributions from the University of Oslo, no. 295, p. 51-64.

Barnes, C.R., Norford, B.S., and Skevington, D.
1981: The Ordovician System of Canada. Correlation chart and explanatory notes. International Union of Geological Sciences, Publication no. 8, 26 p.

Bergström, S.M. and Orchard, M.J.
1985: Conodonts of the Cambrian and Ordovician systems from the British Isles. *In* A Stratigraphical Index of Conodonts, A.C. Higgins and R.L. Austin (eds.); British Micropalaeontological Society Series, Chichester, p. 32-67.

Binda, P.L. and Bokhari, M.M.
1980: Chitinozoanlike microfossils in a Late Precambrian dolostone from Saudi Arabia. Geology, v. 8, no. 2, p. 70-71.

Bloeser, B., Schopf, J.W., Horodyski, R.J., and Breed, W.J.
1977: Chitinozoans from the Late Precambrian Chuar Group of the Grand Canyon, Arizona. Science, v. 195, no. 4279, p. 676-679.

Bockelie, T.G.
1980: Early Ordovician Chitinozoa from Spitsbergen. Palynology, v. 4, p. 1-14.

Bruton, D.L., Koch, L., and Repetski, J.E.
1988: The Naernes section, Oslo Region, Norway: trilobite, graptolite and conodont fossils reviewed. Geological Magazine, Cambrian-Ordovician Boundary Issue, v. 125, p. 451-455.

Bultynck, P. and Martin, F.
1982: Conodontes et Acritarches de l'Ordovicien inférieur et Acritarches du Silurien inférieur de la partie septentrionale de la Cordillère argentine. Institut royal des Sciences naturelles de Belgique, Bulletin, Sciences de la Terre, v. 53, no. 4, 21 p.

Chen Jun-yuan (ed.)
1986: Aspects of Cambrian-Ordovician Boundary in Dayangcha, China (Contributions to Dayangcha International Conference on Є/O Boundary). China Prospect Publishing House, Beijing, 410 p.

Chen Jun-yuan and Gong We-li
1986: Conodonts. *In* Aspects of Cambrian-Ordovician Boundary in Dayangcha, China (Contribution to Dayangcha International Conference on Є/O Boundary), Chen Jun-yuan (ed.); China Prospect Publishing House, Beijing, p. 93-223.

Chen Jun-yuan, Qian Yi-yuan, Lin Yao-kun, Zhang Jun-ming, Wang Zhi-hao, Yin Lei-ming, and Erdtmann, B.-D.
1985: Study on Cambrian-Ordovician Boundary and its biota in Dayangcha, Hunjiang, Jilin, China (Contribution to the Calgary Cambrian-Ordovician Boundary Meeting). China Prospect Publishing House, Beijing, 138 p.

Chen Jun-yuan, Zhou Zhi-yi, Lin Yao-kun, Wang Zhi-hao, Xu Jun-tao, Zhang Jin-lin, Peng Yi-jing, and Shi Xin-zeng
1985: The Ordovician of the southern Jilin. Journal of Stratigraphy, v. 9, p. 21-27. (in Chinese)

Chen Jun-yuan, Qian Yi-yuan, Zhang Jun-ming, Lin Yao-kun, Yin Lei-ming, Wang Zhi-hao, Wang Zong-zhi, Yang Jie-dong, and Wang Ying-Xi
1988: The recommended Cambrian-Ordovician global boundary stratotype of the Xiao-yangqiao section (Dayangcha, Jilin Province), China. Geological Magazine, v. 125, Cambrian-Ordovician Issue, p. 415-444.

Cocchio, A.-M.
1982: Données nouvelles sur les acritarches du Trémadoc et de l'Arenig dans le Massif de Mouthoumet (Corbières, France). Revue de Micropaléontologie, v. 25, p. 26-39.

Combaz, A.
1968: Un microbios du Trémadocien dans un sondage d'Hassi-Messaoud. Actes de la Société Linéenne de Bordeaux, Série B, v. 104 (dated 1967), no. 29, 26 p.

Combaz, A. and Peniguel, G.
1972: Étude palynostratigraphique de l'Ordovicien dans quelques sondages du Bassin de Canning. Centre de Recherches de Pau, SNPA, Bulletin, v. 6, p. 121-167.

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. Revue de l'Institut français du Pétrole, v. 22, p. 1285-1306.

Cowie, J.W., Rushton, A.W.A., and Stubbefield, C.J.
1972: A correlation of Cambrian rocks in the British Isles. Geological Society of London, Special Report no. 1, 42 p.

Dean, W.T.
1977: The Early Ordovician trilobite genus *Missisquoia* Shaw, 1951 in the southern Canadian Rocky Mountains of Alberta and British Columbia. Geological Survey of Canada, Paper 76-33, 7 p.

1978: Preliminary report on the stratigraphy and trilobites of the Survey Peak and Outram formations at Wilcox Pass, Jasper National Park, Canada. Geological Survey of Canada, Paper 76-34, 10 p.

1989: Trilobites from the Survey Peak, Outram and Skoki formations (Upper Cambrian-Lower Ordovician) at Wilcox Pass, Jasper National Park, Canada. Geological Survey of Canada, Bulletin 389, 141 p.

Dean, W.T. and Martin, F.
1982: The sequence of trilobite faunas and acritarch microfloras at the Cambrian-Ordovician boundary, Wilcox Pass, Alberta, Canada. *In* The Cambrian-Ordovician Boundary: Sections, Fossil Distributions, and Correlations, M.G. Bassett and W.T. Dean (eds.); National Museum of Wales, Geological Series no. 3, Cardiff, p. 131-140.

Deflandre, G. and Deflandre-Rigaud, M.
1962: Nomenclature et systématique des Hystrichosphères (sensu lato); observations et rectifications. Revue de Micropaléontologie, v. 4, p. 190-196.

Derby, J.R., Lane, H.R., and Norford, B.S.
1972: Uppermost Cambrian-basal Ordovician faunal succession in Alberta and correlation with similar sequences in the western United States. 24th International Congress, Montreal, Proceedings, Section 7, p. 503-512.

Deunff, J.
1955: *Armoricanium*, genre nouveau d'Hystrichosphères du Silurien breton. Compte rendu sommaire des Séances de la Société géologique de France, p. 227–229.

1961: Un microplancton à Hystrichosphères dans le Tremadoc du Sahara. Revue de Micropaléontologie, v. 4, p. 37-52.

Dorning, K.J.
1986: Organic microfossil geothermal alteration and interpretation of regional tectonic provinces. Journal of the Geological Society of London, v. 143, p. 219, 220.

Downie, C
1982: Lower Cambrian acritarchs from Scotland, Norway, Greenland and Canada. Transactions of the Royal Society of Edinburgh: Earth Sciences, v. 72 (for 1981), p. 257-285.

1984: Acritarchs in British stratigraphy. Geological Society of London, Special Report, no. 17, 26 p.

Eisenack, A.
1931: Neue Mikrofossilien des baltischen Silurs. I. Paläontologische Zeitschrift, v. 13, p. 74-118.

1969: Zur Systematik einiger paläozoischer Hystrichosphären (Acritarcha) des baltischen Gebietes. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 123, p. 245-266.

Elouad-Debbaj, Z.
1988: Acritarches et Chitinozoaires du Tremadoc de l'Anti-Atlas central (Maroc). Revue de Micropaléontologie, v. 31, p. 85-128.

Epstein, A.G., Epstein, J.B., and Harris, L.D.
1977: Conodont color alteration — an index to organic metamorphism. United States Geological Survey, Professional Paper 995, 27 p.

Fombella, M.A.
1977: Acritarcos de edad Cámbrico Medio-Inferior de la Provincia de León. Revista Española de Micropaleontologia, v. 9, p. 115-124.

1978: Acritarcos de la Formación Oville, edad Cámbrico Medio-Tremadoc, Provincia de León, España. Palinología, Número Extraordinario, p. 245-261.

1979: Palinologiá de la Formación Oville al Norte y Sur de la Cordillera Cantábrica, España. Palinologiá, v. 1, p. 1-16.

1986: El transito Cámbrico-Ordovicico, palinologiá y diacronismo, Provincia de León, NO de España. Revista Española de Micropaleontologia, v. 28, p. 165-179.

1987: Resemblances and differences between the palynological associations of Upper Cambrian age in the NW of Spain (Vozmediano) and north of Africa. Revue de Micropaléontologie, v. 30, p. 111-116.

Grahn, Y.
1984: Ordovician Chitinozoa from Tallinn, northern Estonia. Review of Palaeobotany and Palynology, v. 43, p. 5-31.

Harris, A.G., Rexroad, C.B., Lierman, R.T., Gordon, J., and Askin, R.
1988: Evaluation of CAI anomaly, Putnam County, central Indiana, U.S.A. *In* First International Senckenberg Conference (ECO V), Contributions 1, W. Ziegler (ed.); Courier Forschungsinstitut Senckenberg, v. 102, p. 240, 241.

Hintze, L.F.
1953: Lower Ordovician trilobites from western Utah and eastern Nevada. Utah Geological and Mineralogical Survey, Bulletin 48, p. 1-249. (dated 1952)

Jaanusson, V.
1982: Introduction to the Ordovician of Sweden. *In* Field Excursion Guide IV, International Symposium on the Ordovician System, Oslo-

Norway 1982, D.L. Bruton and S.H. Williams (eds.); Palaeontological Contributions from the University of Oslo, p. 1-9.

Jacobson, S.R.
1979: Acritarchs as paleoenvironmental indicators in Middle and Upper Ordovician rocks from Kentucky, Ohio and New York. Journal of Paleontology, v. 53, p. 1197-1212.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G., and Vachey, G.
1974: Distribution stratigraphique des Acritarches dans le Paléozoïque du Sahara algérien. Review of Paleobotany and Palynology, v. 18, p. 99-129.

Kennedy, D.J. and Barnes, C.R.
1981: Conodont biostratigraphy of the Survey Peak Formation, southern Rocky Mountains, Alberta. *In* Geological Association of Canada and Mineralogical Association of Canada, Program with Abstracts, v. 6, p. A-31.

Kjellström, G.
1971: Ordovician microplankton (Baltisphaerids) from the Grötlingbo borehole no. 1 in Gotland, Sweden. Sveriges Geologiska Undersökning, C, no. 665, 75 p.

Legall, F.D., Barnes, C.R., and Macqueen, R.W.
1982: Thermal maturation, burial history and hotspot development, Paleozoic strata of southern Ontario-Quebec, from conodont and acritarch colour alteration studies. Bulletin of Canadian Petroleum Geology, v. 29 (dated 1981), p. 492-539.

Li Jun
1987: Ordovician acritarchs from the Meitan Formation of Guizhou Province, south-west China. Palaeontology, v. 30, p. 613-634.

Lindström, M.
1971: Lower Ordovician conodonts of Europe. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.G. Bergström (eds.); Geological Society of America, Memoir 27, p. 21-62.

Lister, T.H.
1970: The acritarchs and chitinozoa from the Wenlock and Ludlow series of the Ludlow and Millichope areas, Shropshire, Part I. Palaeontographical Society (Monographs), v. 124, 100 p.

Loeblich, A.R., Jr. and Tappan, H.
1978: Some Middle and Late Ordovician microphytoplankton from central North America. Journal of Paleontology, v. 52, p. 1233-1287.

Lu Li-chang
1987: Acritarchs from the Dawan Formation (Arenigian) of Huanghuachang in Yichang, western Hubei. Acta Micropalaeontologica Sinica, v. 4, p. 87-105. (in Chinese with English abstract)

Ludvigsen, R. and Westrop, S.R.
1985: Three new Upper Cambrian stages for North America. Geology, v. 13, p. 139-143.

Martin, F.
1973: Les acritarches de l'Ordovicien inférieur de la Montagne Noire (Hérault, France). Institut Royal des Sciences Naturelles de Belgique, Bulletin, Sciences de la Terre, v. 48 (dated 1972), no. 10, 61 p.

1982: Some aspects of Late Cambrian and Early Ordovician acritarchs. *In* The Cambrian–Ordovician Boundary: Sections, Fossil Distributions, and Correlations, M.G. Bassett and W.T. Dean (eds.); National Museum of Wales, Geological Series no. 3, Cardiff, p. 29-40.

1984: New Ordovician (Tremadoc) acritarch taxa from the middle member of the Survey Peak Formation at Wilcox Pass, southern Canadian Rocky Mountains, Alberta. *In* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 441-448.

Martin, F. and Dean, W.T.
1981: Middle and Upper Cambrian and Lower Ordovician acritarchs from Random Island, eastern Newfoundland. Geological Survey of Canada, Bulletin 343, 43 p.

1988: Middle and Upper Cambrian acritarch and trilobite zonation at Manuels River and Random Island, eastern Newfoundland. Geological Survey of Canada, Bulletin 381, 91 p.

Martin, F. and Yin Lei-ming
1988: Early Ordovician acritarchs from southern Jilin Province, north-east China. Palaeontology, v. 31, p. 109-127.

Miller, J.F.
1987: Upper Cambrian and basal Ordovician conodont faunas of the southwest flank of Llano Uplift, Texas. *In* Early and Late Paleozoic Conodont Faunas of the Llano Uplift Region, Central Texas—Biostratigraphy, Systemic Boundary Relationships, and Stratigraphic Importance, R.C. Grayson (ed.); Guidebook for Field Trip 1, 1987 Meeting of South-Central Section, Geological Society of America, p. 1-22.

1988: Conodonts as biostratigraphic tools for redefinition and correlation of the Cambrian-Ordovician boundary. Geological Magazine, Cambrian-Ordovician Boundary Issue, v. 125, p. 349-362.

Miller, J., Kennedy, D., and Repetski, J.
1988: Conodonts from the Dayangcha section, Jilin Province, China. *In* International Working Group on the Cambrian-Ordovician Boundary, circular 24, June 1988, Appendix II, p. 1-4.

Molyneux, S.G.
1987: The Arenig Series in South Wales: stratigraphy and palaeontology. II. Appendix. Acritarchs and Chitinozoa from the Arenig Series of south-west Wales. Bulletin of the British Museum (Natural History), Geology, v. 41, p. 309-364.

Molyneux, S.G. and Rushton, A.W.A.
1988: The age of the Watch Hill Grits (Ordovician), English Lake District: structural and palaeogeographical implications. Transactions of the Royal Society of Edinburgh. Earth Sciences, v. 79, p. 43-69.

Norford, B.S.
1969: Ordovician and Silurian stratigraphy of the southern Rocky Mountains. Geological Survey of Canada, Bulletin 176, 90 p.

1988: Introduction to papers on the Cambrian-Ordovician boundary. Geological Magazine, Cambrian-Ordovician Issue, v. 125, p. 323-326.

Nowlan, G.S. and Barnes, C.R.
1986: Application of conodont colour alteration indices to regional and economic geology. *In* Conodonts: Investigative Techniques and Applications, R.L. Austin (ed.); British Micropalaeontological Society Series, p. 188-202.

Palmer, A.R.
1969: Cambrian trilobite distributions in North America and their bearing on Cambrian paleogeography of Newfoundland. American Association of Petroleum Geologists, Memoir 12, p. 139-144.

Paris, F.
1981: Les Chitinozoaires dans le Paléozoïque du sud-est de l'Europe (Cadre géologique—Étude systématique). Mémoires de la Société Géologique et Minéralogique de Bretagne, no. 26, 412 p.

Playford, G. and Martin, F.
1984: Ordovician acritarchs from the Canning Basin, Western Australia. Alcheringa, v. 8, p. 187-223.

Playford, G. and Wicander, R.
1988: Acritarch palynoflora of the Coolibah Formation (Lower Ordovician), Georgina Basin, Queensland. Association of Australasian Palaeontologists, Memoir 5, p. 5-40.

Poumot, C.
1968: *Amphorachitina, Ollachitina, Velachitina;* trois genres nouveaux de chitinozoaires de l'Erg Oriental (Algérie-Tunisie). Centre de Recherches de Pau-SNPA, Bulletin 2, p. 45-55.

Qian Yi-yuan
1986: Trilobites. *In* Aspects of Cambrian-Ordovician Boundary in Dayangcha, China (Contributions to the Dayangcha International Conference on Ꞓ/O Boundary), Chen Jun-yuan (ed.); China Prospect Publishing House, Beijing, p. 255-313.

Rasul, S.M.
1976: New species of the genus *Vulcanisphaera* (Acritarcha) from the Tremadocian of England. Micropaleontology, v. 22, p. 479-484.

1979: Acritarch zonation of the Tremadoc Series of the Shineton Shales, Wrekin, Shropshire, England. Palynology, v. 3, p. 53-72.

Rasul, S.M. and Downie, C.
1974: The stratigraphic distribution of Tremadoc acritarchs in the Shineton Shales succession, Shropshire, England. Review of Palaeobotany and Palynology, v. 18, p. 1-9.

Rauscher, R.
1974: Recherches micropaléontologiques et stratigraphiques dans l'Ordovicien et le Silurien en France. Étude des Acritarches, des Chitinozoaires et des Spores. Sciences Géologiques, Mémoire 38 (dated 1973), 224 p.

Robison, R.A., Rowell, A.J., Fritz, W.H., Kurtz, V.E., Miller, J.F., Norford, B.S., Palmer, A.R., Repetski, J.E., Stitt, J.H., Taylor, J.F., and Taylor, M.E.
1985: Comment on "Three new Upper Cambrian Stages for North America" by R. Ludvigsen and S.R. Westrop. Geology, v. 13, p. 666, 667.

Ross, R.J.
1949: Stratigraphy and trilobite faunal zones of the Garden City Formation, northeastern Utah. American Journal of Science, v. 247, p. 472-491.

1951: Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas. Peabody Museum of Natural History, Yale University, Bulletin 6, 161 p.

Ross, R.J., Adler, F.J., Amsden, T.W., Bergström, D., Bergström, S.M., Carter, C., Churkin, M., Cressman, E.A., Derby, J.R., Dutro, J.T., Ethington, R.L., Finney, S.C., Fischer, D.W., Fischer, J.H., Harris, A.G., Hintze, L.F., Ketner, K.B., Kolota, D.L., Landing, E., Neuman, R.B., Sweet, W.C., Pojeta, J., Potter, A.W., Rader, E.K., Repetski, J.E., Shaver, R.H., Thompson, T.L., and Webers, G.F.
1982: The Ordovician System in the United States of America. Correlation chart and explanatory notes. International Union of Geological Sciences, Publication no. 12, 73 p.

Schaarschmidt, F.
1963: Sporen und Hystrichosphaeriden aus dem Zechstein von Büdingen in der Wetterau. Palaeontographica, Abt. B, v. 113, p. 38-91.

Shaw, A.B.
1951: The paleontology of northwestern Vermont. I. New Late Cambrian trilobites. Journal of Paleontology, v. 25, p. 97-114.

Shergold, J.H.
1988: Review of trilobite biofacies distributions at the Cambro-Ordovician boundary. Geological Magazine, Cambrian-Ordovician Issue, v. 125, p. 363-380.

Staplin, F.L.
1969: Sedimentary organic matter, organic metamorphism, and oil and gas occurrence. Bulletin of Canadian Petroleum Geology, v. 17, p. 47-66.

Staplin, F.L., Jansonius, J., and Pocock, S.A.J.
1965: Evaluation of some acritarchous hystrichosphere genera. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 123, p. 167-201.

Tappan, H. and Loeblich, A.R., Jr.
1971: Surface sculpture of the wall in lower Paleozoic acritarchs. Micropaleontology, v. 17, p. 385-410.

Taugourdeau, P. and de Jekhowsky, B.
1960: Répartition et description des chitinozoaires siluro-dévoniens de quelques sondages de la C.R.E.P.S., de la C.F.P.A. et de la S.N. Repal au Sahara. Revue de l'Institut Français du Pétrole, v. 15, p. 1199-1260.

Timofeev, B.V.
1959: La plus ancienne flore des régions de la Baltique et sa signification stratigraphique. VNIGRI, no. 129, Traduction B.R.G.M. no. 4686, 142 p.

Tjernvik, T.E. and Johannson, J.V.
1980: Description of the upper portion of the drill-core from Finngrundet in the South Bothnian Bay. Bulletin of the Geological Institutions of the University of Uppsala, n.s., v. 8, p. 173-204.

Tongiorgi, M., Albani, R., and Di Milia, A.
1984: The Solanas Sandstones of central Sardinia; new paleontological data (acritarchs) and an attempt of geological interpretation (a "post-sardinian" molasse?). Bulletin de la Société Géologique de France, v. 26, p. 665-680.

Turner, R.E.
1984: Acritarchs from the type area of the Ordovician Caradoc Series, Shropshire, England. Palaeontographica, Abt. B, v. 190, p. 87-157.

Umnova, N.I.
1969: Distribution of Chitinozoa in the Ordovician of the Russian Platform. Palaeontological Journal, Academy of Sciences of the U.S.S.R., no. 3, p. 45-62. (in Russian)

Vanguestaine, M.
1986: Progrès récents de la stratigraphie par Acritarches du Cambro-Ordovicien d'Ardenne, d'Irlande, d'Angleterre, du Pays de Galles et de Terre-Neuve orientale. Société Géologique du Nord, Annales, v. 105, p. 65-76.

Vavrdová, M.
1974: Geographical differentiation of Ordovician acritarch assemblages in Europe. Review of Palaeobotany and Palynology, v. 18, p. 171-175.

Volkheimer, W., Melendi, D.L., and Aceñolaza, F.G.
1980: Una microflora ordovicica de la Formacion Mojotoro, Provincia de Salta. Asociación Geológica Argentina, Revista, v. 35, p. 401-416.

Walcott, C.D.
1928: Pre-Devonian Paleozoic formations of the Cordilleran provinces of Canada. Smithsonian Miscellaneous Collections, Washington, v. 75, no. 5. (edited by C.E. Resser)

Wang Xiao-feng and Erdtmann, B.D.
1986: The earliest Ordovician graptolite sequences from Hunjiang, Jilin Province, China. Acta Geologica Sinica, v. 3, p. 226-236. (in Chinese with English abstract)

1987: Zonation and correlation of the earliest Ordovician graptolites from Hunjiang, Jilin Province, China. Geological Society of Denmark, Bulletin 35, p. 245-257.

Welsch, M.
1986: Die Acritarchen der höheren Digermul-Gruppe, Mittelkambrium bis Tremadoc, Ost-Finmark, Nord-Norwegen. Palaeontographica, Abt. B, v. 201, 109 p.

Westrop, S.R.
1986: Trilobites of the Upper Cambrian Sunwaptan Stage, southern Canadian Rocky Mountains, Alberta. Palaeontographica Canadiana, v. 3, 179 p.

Westrop, S.R., Landing, E., and Ludvigsen, R.
1981: Upper Cambrian and Lower Ordovician trilobite and conodont biostratigraphy, Wilcox Peak, Jasper National Park, Alberta. *In* Guidebook for Field Trip no. 2, M.E. Taylor (ed.), Second International Symposium on the Cambrian System, August 14-20, 1981, p. 45-53. (compiled by Aitken, J.D.)

Whittington, H.B., Dean, W.T., Fortey, R.A., Rickards, R.B., Rushton, A.W.A., and Wright, A.D.
1984: Definition of the Tremadoc Series and the series of the Ordovician System in Britain. Geological Magazine, v. 1, p. 17-33.

Wicander, R.
1974: Upper Devonian-Lower Mississipian acritarchs and prasinophycean algae from Ohio, U.S.A.. Palaeontographica, Abt. B, v. 148, p. 9-43.

Yin Lei-ming
1985: Acritarchs. *In* Study on Cambrian-Ordovician Boundary and its Biota in Dayangcha, Hunjiang, Jilin, China, Chen Jun-yuan, Qian Yi-yuan et al.; China Prospect Publishing House, Beijing, p. 101-112.

1986: Acritarchs. *In* Aspects of Cambrian-Ordovician Boundary in Dayangcha, China, Chen Jun-yuan (ed.); China Prospect Publishing House, Beijing, p. 314-373.

Zhang Jun-ming
1986: Description of sections. *In* Aspects of Cambrian-Ordovician Boundary in Dayangcha, China, Chen Jun-yuan (ed.); China Prospect Publishing House, Beijing, p. 7-14.

APPENDIX

LOCATION OF SAMPLES

Samples from locality numbers with prefix C- are catalogued at the Geological Survey of Canada, Institute of Sedimentary and Petroleum Geology, Calgary. Thirty-four previously collected samples from Wilcox Pass with numbers that lack a prefix are catalogued at the Geological Survey of Canada, Ottawa. The latter numbers were published in Dean and Martin, 1982 and are omitted here, except for two from the basal silty member of the Survey Peak Formation: GSC loc. 92340, the oldest sample collected from the recessively weathering, lowest unit, and GSC loc. 92346 (see Pl. 6, fig. 6). Most of the appendix refers to the principal section at Wilcox Pass: a subsidiary section in the Mistaya Formation and uppermost Bison Creek Formation on the hillside at the southeastern end of Wilcox Peak yielded no microfossils. The samples are listed at the end of the appendix.

WILCOX PASS

Sampling and trilobite zones are based on the measured section described by Dean (1978, 1989). Localities are listed in descending stratigraphic order and their position is expressed in metres above the base of the appropriate lithostratigraphic unit. The organic-walled microfossil content of each sample is denoted by the following symbols: A, at least some determinable acritarchs, possibly including leiosphaerids; L, exclusively leiosphaerids; C, at least some determinable chitinozoans; B, barren; UndA, all acritarchs undeterminable; UndC, all chitinozoans undeterminable.

Skoki Formation (lowest 46.10 m)

All samples are from interbedded dolomitic mudstone, except where indicated otherwise.

Trilobite zone uncertain

C-97942, 46.10 m above base of fm.; B
C-97941, 43.65 m above base of fm.; B (chert).
C-97940, 38.40 m above base of fm.; B.
C-97939, 32.00 m above base of fm.; C (chert).
C-97938, 30.10 m above base of fm.; B.
C-97937, 26.00 m above base of fm.; B.
C-97936, 20.20 m above base of fm.; B.
C-97935, 6.35 m above base of fm.; B.
C-97934, 6.00 m above base of fm.; UndA.

Trilobite zone J

C-97933, 0.70 m above base of fm.; A, C.

Outram Formation (266 m)

All samples are from calcareous mudstone associated with nodular limestone, except where indicated otherwise.

Trilobite zone J

C-97932, 265.65 m above base of fm.; UndA (dol.).
C-97931, 259.45 m above base of fm.; A.
C-97930, 255.00 m above base of fm.; UndA.
C-97929, 246.60 m above base of fm.; UndA.
C-97928, 239.50 m above base of fm.; UndA, UndC.
C-97927, 231.60 m above base of fm.; A, UndC.
C-97926, 228.50 m above base of fm.; UndA.
C-97925, 228.10 m above base of fm.; A.
C-97924, 222.80 m above base of fm.; UndA.
C-97923, 220.30 m above base of fm.; A.
C-97922, 215.20 m above base of fm.; UndA, UndC.
C-97921, 212.50 m above base of fm.; UndA.
C-97920, 205.00 m above base of fm.; UndA.
C-97919, 197.30 m above base of fm.; A.
C-97918, 193.90 m above base of fm.; A.
C-97917, 187.30 m above base of fm.; UndA.
C-97916, 177.90 m above base of fm.; UndA, UndC.
C-97915, 174.00 m above base of fm.; UndA.
C-97914, 172.00 m above base of fm.; A, UndC.
C-97913, 169.55 m above base of fm.; A.
C-97912, 166.90 m above base of fm.; UndA.
C-97911, 156.20 m above base of fm.; UndA.
C-97910, 152.50 m above base of fm.; A.
C-97909, 151.30 m above base of fm.; A.

Trilobite zones H and I, undifferentiated

C-97908, 148.15 m above base of fm.; A.
C-97907, 145.80 m above base of fm.; A.
C-97906, 142.20 m above base of fm.; A.
C-97905, 137.90 m above base of fm.; A, C.
C-97904, 133.90 m above base of fm.; A, C.
C-97903, 130.50 m above base of fm.; A.
C-97902, 126.85 m above base of fm.; A.
C-97901, 125.00 m above base of fm.; A, C.
C-97900, 121.70 m above base of fm.; A, C.
C-97899, 115.60 m above base of fm.; A, C.
C-97898, 112.30 m above base of fm.; A, C.
C-97897, 109.50 m above base of fm.; A.
C-97896, 106.80 m above base of fm.; A.
C-97895, 104.80 m above base of fm.; A.

C-97894, 100.50 m above base of fm.; A.
C-97893, 97.20 m above base of fm.; A, C.
C-97892, 95.30 m above base of fm.; A.
C-97891, 94.30 m above base of fm.; A.
C-97890, 93.20 m above base of fm.; A.
C-97889, 91.60 m above base of fm.; A.
C-97888, 87.90 m above base of fm.; A.
C-97887, 84.45 m above base of fm.; A.
C-97886, 81.45 m above base of fm.; A.
C-97885, 76.15 m above base of fm.; A.
C-97884, 74.45 m above base of fm.; A.
C-97883, 72.10 m above base of fm.; A.
C-97882, 70.45 m above base of fm.; A, UndC.
C-97881, 69.15 m above base of fm.; A.
C-97880, 67.35 m above base of fm.; A.
C-97879, 64.05 m above base of fm.; A.

Trilobite zone G

C-97878, 58.00 m above base of fm.; A. (lst.)
C-97877, 55.50 m above base of fm.; A.
C-97876, 51.00 m above base of fm.; A.
C-97875, 47.00 m above base of fm.; A.
C-97874, 43.60 m above base of fm.; A.
C-97873, 41.35 m above base of fm.; A, C.
C-97872, 37.60 m above base of fm.; A.
C-97871, 31.95 m above base of fm.; A.
C-97870, 29.80 m above base of fm.; A, C.
C-97869, 25.45 m above base of fm.; A, C.
C-97868, 20.85 m above base of fm.; A.
C-97867, 19.05 m above base of fm.; A.
C-97866, 17.65 m above base of fm.; A, UndC.
C-97865, 14.75 m above base of fm.; A, UndC.
C-97864, 11.70 m above base of fm.; A. (lst.)
C-97863, 10.70 m above base of fm.; A, C. (nod. lst.)

Trilobite zone F

C-97862, 5.25 m above base of fm.; A. (nod. lst.)
C-97861, 3.65 m above base of fm.; A. (nod. lst.)

Survey Peak Formation

Upper massive member (78.50 m)

All samples are from interbedded, calcareous, silty mudstone, except where indicated otherwise.

Trilobite zone F

C-97860', 78.15 m above base of mbr.; A.
C-97860, 72.85 m above base of mbr.; A.
C-97859, 60.75 m above base of mbr.; B.
C-97858, 50.90 m above base of mbr.; UndA.
C-97857, 47.05 m above base of mbr.; UndA.

Trilobite zone E

C-97856, 43.15 m above base of mbr.; UndA.
C-97855, 37.50 m above base of mbr.; B.
C-97854, 23.55 m above base of mbr.; UndA.
C-97853, 22.65 m above base of mbr.; UndA. (lst.)
C-97852, 17.35 m above base of mbr.; UndA.
C-97851, 12.50 m above base of mbr.; UndA.
C-97850, 9.90 m above base of mbr.; B.
C-97849, 7.05 m above base of mbr.; UndA.

Middle member (199 m)

All samples are from interbedded calcareous, silty mudstone, except where indicated otherwise.

Trilobite zone E

C-97848, 198.00 m above base of mbr.; A.
C-97847, 195.20 m above base of mbr.; A. (lst.)
C-97846, 194.25 m above base of mbr.; A. (lst.)
C-97845, 188.00 m above base of mbr.; A.
C-97844, 183.15 m above base of mbr.; A.
C-97843, 181.00 m above base of mbr.; A.
C-97842, 178.50 m above base of mbr.; A.
C-97841, 175.70 m above base of mbr.; A.
C-97840, 173.70 m above base of mbr.; A.
C-97839, 171.10 m above base of mbr.; A.
C-97838, 170.80 m above base of mbr.; A. (lst.)
C-97837, 169.30 m above base of mbr.; A. (lst.)
C-97836, 159.85 m above base of mbr.; A.

Trilobite zone uncertain

C-97835, 155.20 m above base of mbr.; A.
C-97834, 141.80 m above base of mbr.; A.
C-97833, 136.90 m above base of mbr.; A.
C-97832, 134.60 m above base of mbr.; A.
C-97831, 132.20 m above base of mbr.; A.
C-97830, 131.90 m above base of mbr.; A. (lst.)
C-97829, 130.70 m above base of mbr.; A.
C-97828, 126.30 m above base of mbr.; A. (lst.)
C-97827, 110.10 m above base of mbr.; A. (lst.)
C-97826, 103.85 m above base of mbr.; A.
C-97825, 101.45 m above base of mbr.; A.

Trilobite zone D

C-97824, 89.20 m above base of mbr.; A.
C-97823, 87.20 m above base of mbr.; A.
C-97822, 86.00 m above base of mbr.; A. (lst.)
C-97821, 84.65 m above base of mbr.; A.
C-97820, 83.90 m above base of mbr.; A.
C-97819, 83.10 m above base of mbr.; A. (lst.)
C-97818, 80.90 m above base of mbr.; A.

C-97817, 78.20 m above base of mbr.; A.
C-97816, 77.10 m above base of mbr.; A.
C-97815, 76.00 m above base of mbr.; A.
C-97814, 71.00 m above base of mbr.; A.
C-97813, 69.10 m above base of mbr.; A. (lst.)

Trilobite zone C

C-97812, 60.25 m above base of mbr.; UndA. (lst.)
C-97811, 60.10 m above base of mbr.; UndA.
C-97810, 51.90 m above base of mbr.; A.
C-97809, 48.00 m above base of mbr.; L.
C-97807, 41.50 m above base of mbr.; A. (lst.)
C-97806, 40.40 m above base of mbr.; A.
C-97805, 35.15 m above base of mbr.; A.

Trilobite zone B

C-97804, 32.55 m above base of mbr.; A. (lst.)
C-97803, 31.55 m above base of mbr.; A. (lst.)
C-97802, 30.90 m above base of mbr.; L.
C-97801, 30.55 m above base of mbr.; UndA.
C-97800, 19.40 m above base of mbr.; L.
C-97799, 18.90 m above base of mbr.; B.
C-97798, 15.60 m above base of mbr.; UndA.
C-97797, 11.00 m above base of mbr.; UndA.
C-97796, 5.80 m above base of mbr.; B.
C-97795, 4.30 m above base of mbr.; B. (lst.)
C-97794, 2.30 m above base of mbr.; UndA.

Putty shale member (42 m)

All samples are from calcareous mudstone.

Trilobite zone B

C-97793, 40.45 m above base of mbr.; B.
C-97792, 38.45 m above base of mbr.; B.
C-97791, 32.45 m above base of mbr.; B.
C-97790, 29.45 m above base of mbr.; A.

Trilobite zone A

C-97789, 22.45 m above base of mbr.; B.
C-97788, 19.00 m above base of mbr.; B.
C-97787, 18.00 m above base of mbr.; B.
C-97786, 16.00 m above base of mbr.; B.
C-97785, 14.00 m above base of mbr.; B.
C-97784, 12.00 m above base of mbr.; B.
C-97783, 10.00 m above base of mbr.; B.
C-97782, 8.00 m above base of mbr.; B.
C-97781, 6.00 m above base of mbr.; B.
C-97780, 4.00 m above base of mbr.; B.
C-97779, 2.00 m above base of mbr.; L.
C-97778, 1.00 m above base of mbr.; B.
C-97777, Basal 5 cm of mbr.; A.

Basal silty member (38 m)

All samples are from interbedded calcareous, silty mudstone.

Trilobite zone A

C-97776, 38.00 m above base of mbr.; A.
C-97775, 37.65 m above base of mbr.; A.
C-97774, 36.35 m above base of mbr.; A.
C-97773, 35.95 m above base of mbr.; A.
C-97772, 34.85 m above base of mbr.; A.
C-97771, 31.50 m above base of mbr.; A.
C-97770, 30.55 m above base of mbr.; A.
C-97769, 29.50 m above base of mbr.; A.
C-97768, 28.55 m above base of mbr.; A.
C-97767, 27.55 m above base of mbr.; A.
C-97766, 26.60 m above base of mbr.; A.
C-97765, 24.70 m above base of mbr.; A.
C-97764, 24.45 m above base of mbr.; A.
C-97763, 22.00 m above base of mbr.; A.

Missisquoia *Zone*

The *Missisquoia* Zone is recorded with confidence only from 17.20 to 18 m.

92346, 19.20 m above base of mbr.; A.
C-97762, 19.00 m above base of mbr.; A.
C-97761, 18.55 m above base of mbr.; A.
C-97760, 17.45 m above base of mbr.; A.
C-97759, 15.15 m above base of mbr.; A.

Trilobite zone uncertain

C-97758, 12.35 m above base of mbr.; B.
C-97757, 11.15 m above base of mbr.; L.
C-97756, 7.35 m above base of mbr.; B.

Corbinia apopsis *Subzone,* Saukia *Zone*

C-97755, 4.80 m above base of mbr.; A.
C-97754, 4.60 m above base of mbr.; A.

Trilobite zone uncertain

92340, 3.60 m above base of mbr.; A.

SECTION AT SOUTHEAST END OF WEST FACE OF WILCOX PEAK

The preliminary samples taken from a measured section through the Mistaya Formation and the upper part of the underlying Bison Creek Formation on the hillside approximately 1 km northwest of the Icefields Chalet (Fig. 1) proved to be palynologically barren. According to Westrop (1986, Textfig. 21) the upper part of the Bison Creek Formation and approximately the lowest third of the Mistaya Formation belong to the *Illaenurus* Zone, and approximately the upper two thirds of the latter formation are in the *Saukia* Zone. Samples are from interbeds of calcareous mudstone unless stated otherwise. Localities in the Mistaya Formation are listed with reference to the base of the formation; those in the Bison Creek Formation with reference to the top of the formation.

Mistaya Formation (129.40 m)

C-97943, 118.90 m above base of fm.; (dol. lst.)
C-97944, 118.70 m above base of fm.
C-97945, 99.90 m above base of fm.; (dol. lst.)
C-97946, 94.20 m above base of fm.; (lst.)
C-97947, 73.20 m above base of fm.; (nod. lst.)
C-97948, 60.80 m above base of fm.; (lst.)
C-97949, 45.60 m above base of fm.
C-97950, 40.30 m above base of fm.
C-97951, 25.50 m above base of fm.
C-97952, 15.10 m above base of fm.; (lst.)
C-97953, 8.20 m above base of fm.
C-97954, Basal 0.05 m of fm.; (chert)

Bison Creek Formation (uppermost 58.20 m)

C-97955, 10.00 m below top of fm.
C-97956, 28.30 m below top of fm.
C-97957, 58.20 m below top of fm.

PLATES 1–8

PLATE 1

Magnification x1000, except where stated otherwise.

Figures 1-8, 10, 11. *Acrum*? *jasperense* n. sp.

1. GSC 94577, GSC loc. C-97803; x3000.

2, 3. GSC 94578, GSC loc. C-97803; figure 2, x7000, central part of figure 3; figure 3, x3000.

4. GSC 94579, GSC loc. C-97804.

5, 6. Holotype, GSC 94580, GSC loc. C-97840.

7, 8. GSC 94581, GSC loc. C-97803; figure 7, x3000; figure 8, x7000, upper right part of figure 7.

10. GSC 94582, GSC loc. C-97803.

11. GSC 94583, GSC loc. C-97817.

Figures 9, 13, 14, 16-22. *Actinotodissus* sp. A.

9. GSC 94584, GSC loc. C-97766.

13. GSC 94585, GSC loc. C-97766.

14. GSC 94586, GSC loc. C-97766.

16, 18. GSC 94587, GSC loc. C-97766; figure 16, x750, opposite face of gold-coated specimen in figure 18.

17. GSC 94588, GSC loc. C-97766; x750.

19, 20. GSC 94589, GSC loc. C-97766; figure 19, x4000, right part of figure 20.

21, 22. GSC 94590, GSC loc. C-97766; figure 22, x4000, left part of figure 21.

Figures 12, 15. *Cymatiogalea* sp. (Not described in text.)

12. GSC 94636, GSC loc. C-97772.

15. GSC 94637, GSC loc. C-97772.

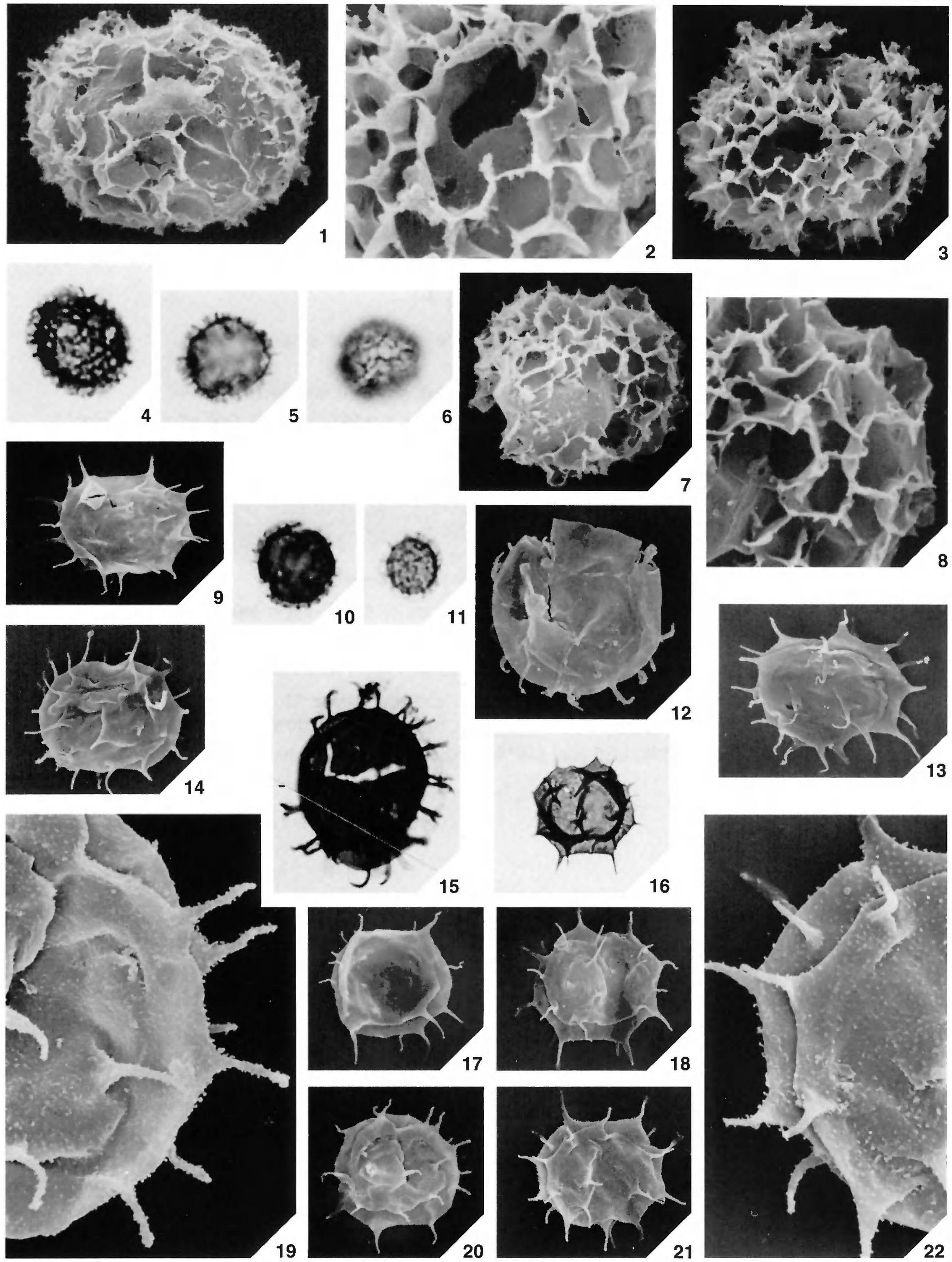
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PLATE 2

Magnification x1000, except where stated otherwise.

Figures 1-4, 8. *Ammonidium* sp. aff. *A. furtivum* Playford and Martin, 1984.

1, 2, 4. GSC 94591, GSC loc. C-97874; figure 2, x500, opposite face of gold-coated specimen in figure 1; figure 4, x4000, lower right part of figure 1.

3. GSC 94592, GSC loc. C-97874.

8. GSC 94593, GSC loc. C-97874.

Figures 5-7, 9-15. *Aryballomorpha albertana* n. sp.
All lateral views, except figures 12, 15, which are antapical.

5, 6. GSC 94594, GSC loc. C-97825; figure 6, x3000, upper left part of figure 5.

7, 10. GSC 94595, GSC loc. C-97829; figure 10, x4000, lower central part of figure 7.

9. GSC 94596, GSC loc. C-97829.

11, 13, 14. Holotype, GSC 94597, GSC loc. C-97829; figure 11, x500, opposite face of gold-coated specimen in figure 14; figure 13, x3000, lower left part of figure 14.

12, 15. GSC 94598, GSC loc. C-97843; figure 12, x5000, upper right part of figure 15.

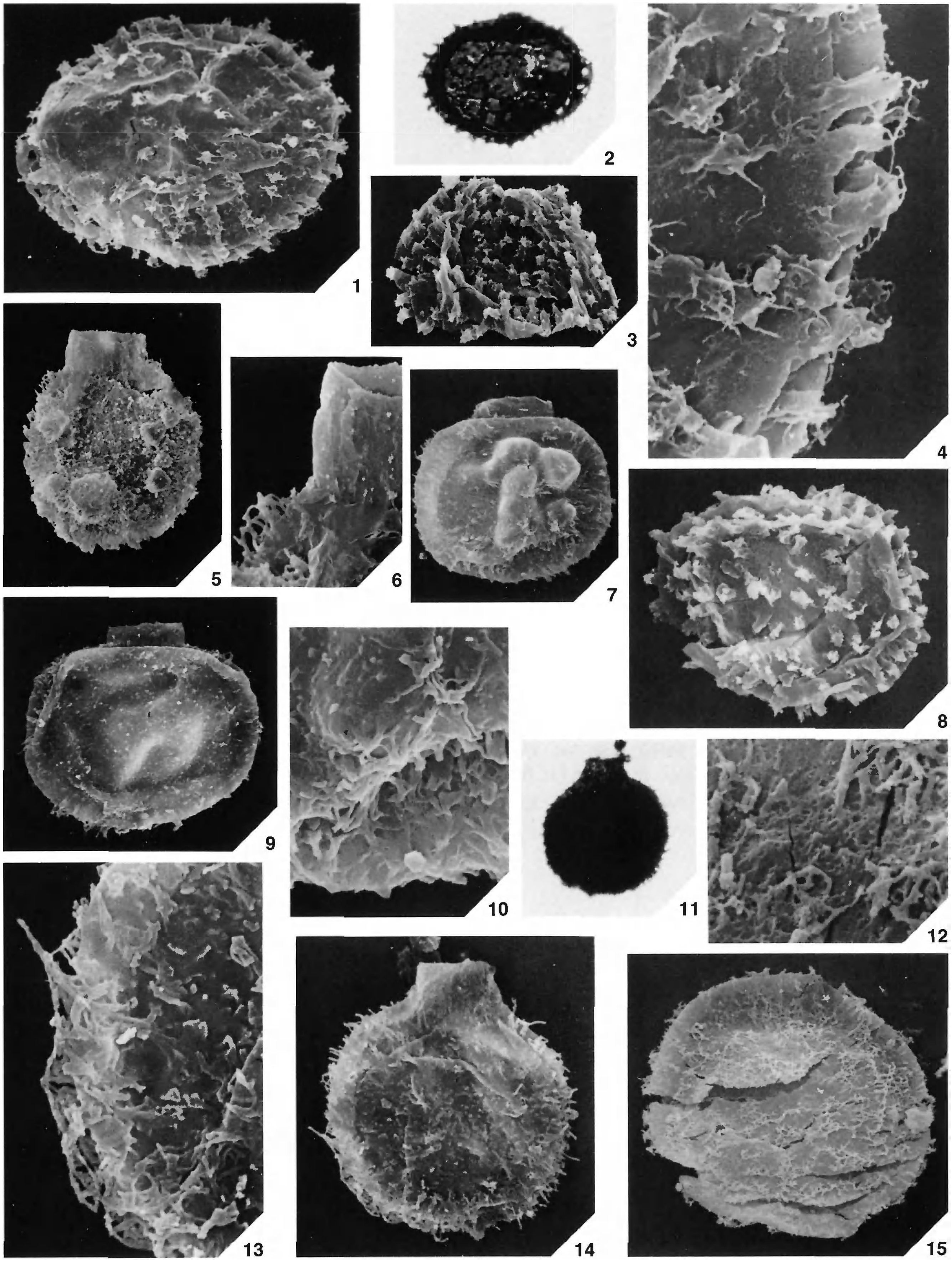
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PLATE 3

Magnification x1000, except where stated otherwise.

Figures 1-5. *Aryballomorpha* sp. nov. A.
All lateral views except figure 3, which is a broken specimen.

1, 5. GSC 94604, GSC loc. C-97826; figure 5, x2000, right part of figure 1.

2. GSC 94605, GSC loc. C-97825.

3. GSC 94606, GSC loc. C-97825.

4. GSC 94607, GSC loc. C-97825, x750.

Figures 6-13. *Aryballomorpha grootaertii* (Martin) emend. Martin and Yin, 1988.
All lateral views except figure 6, which is sublateral and has a very deformed and compressed antapical pole.

6. GSC 94599, GSC loc. C-97826.

7, 8. GSC 94600, GSC loc. C-97826; figure 8, x5000, left central part of figure 7.

9. GSC 94601, GSC loc. C-97826.

10, 11, 13. GSC 94602, GSC loc. C-97826; figure 10, x500, opposite face of gold-coated specimen in figure 11; figure 13, x5000, right part of figure 11.

12. GSC 94603, GSC loc. C-97834, x500.

PLATE 3

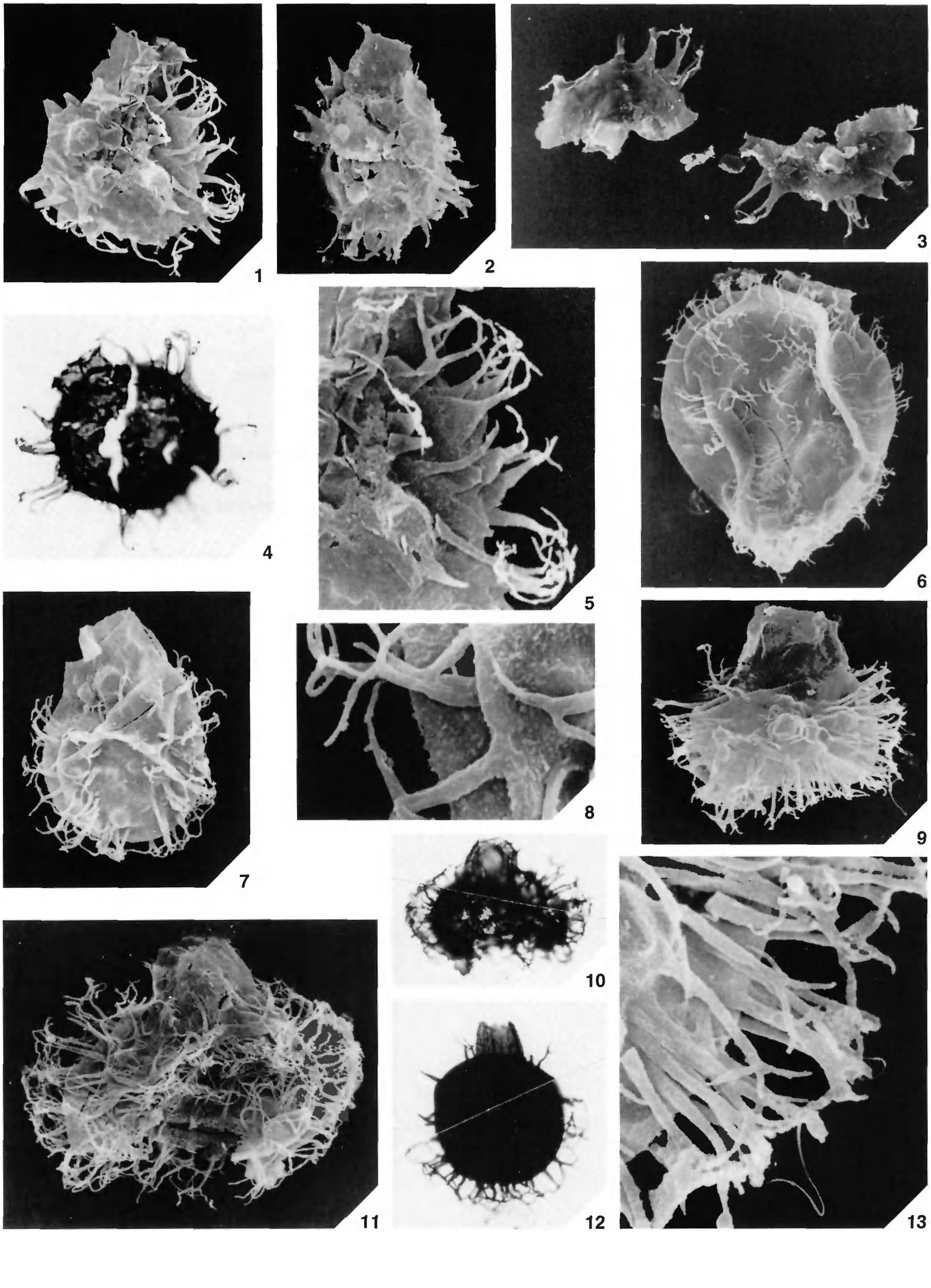

PLATE 4

Magnification x1000, except where stated otherwise.

Figures 1-8. *Athabascaella* sp. cf. *A. penika* Martin and Yin, 1988.

1, 4. GSC 94608, GSC loc. C-97823; figure 4, x750, opposite face of gold-coated specimen in figure 1.

2, 6. GSC 94609, GSC loc. C-97823; figure 6, x5000, upper central part of figure 2.

3. GSC 94610, GSC loc. C-97823.

5, 8. GSC 94611, GSC loc. C-97826; figure 5, x5000, upper left part of figure 8.

7. GSC 94612, GSC loc. C-97821.

Figures 9-13. *Athabascaella playfordii* Martin, 1984 emend. Martin and Yin, 1988.

9, 10. GSC 94613, GSC loc. C-97833; figure 9, x5000, lower right part of figure 10.

11, 12. GSC 94614, GSC loc. C-97843; figure 12, x750, opposite face of gold-coated specimen in figure 11.

13. GSC 94615, GSC loc. C-97843.

PLATE 4

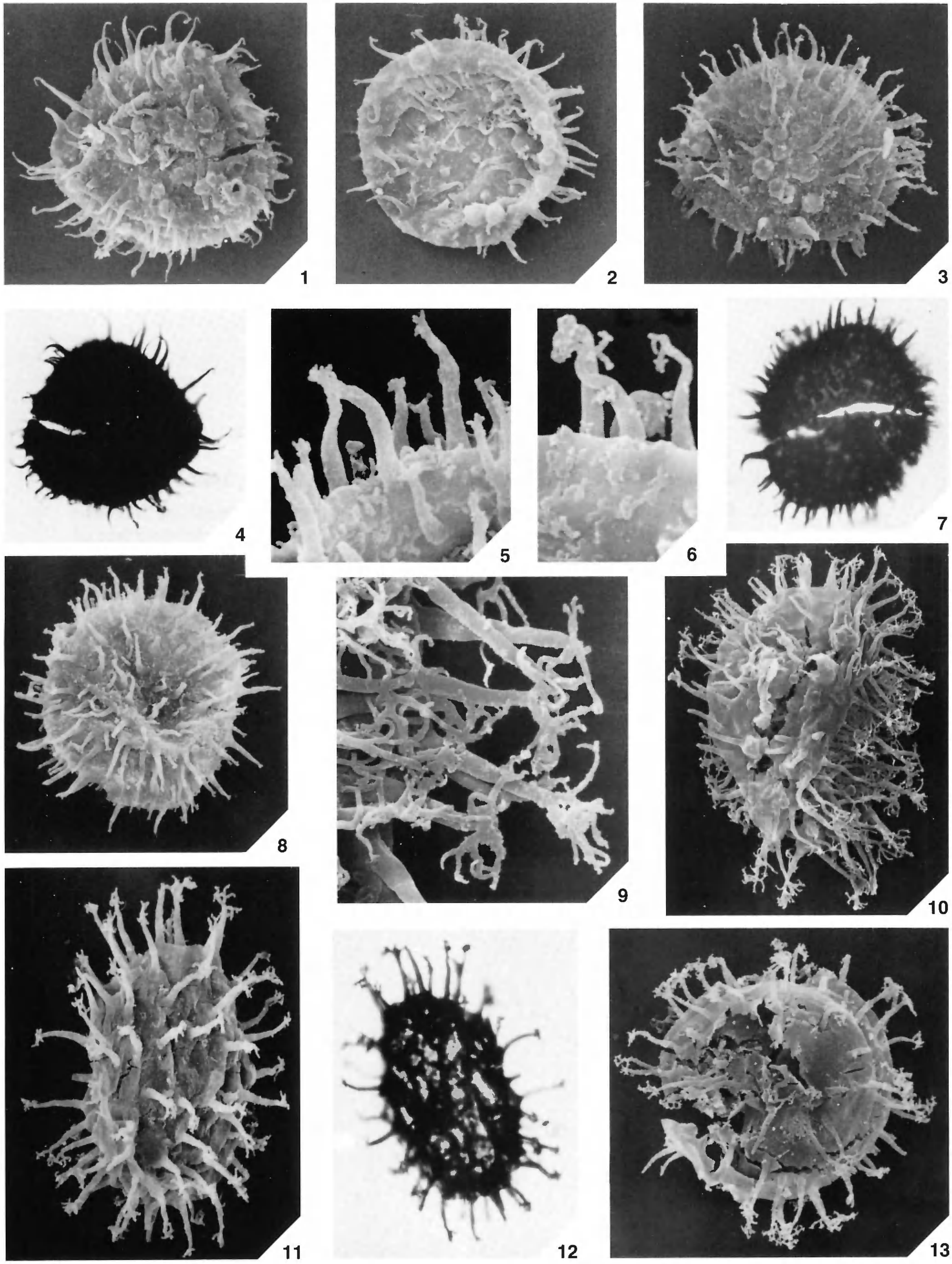

PLATE 5

Magnification x1000, except where stated otherwise.

Figures 1-4. *Athabascaella rossii* Martin, 1984 emend. Martin and Yin, 1988.

1-3. GSC 94616, GSC loc. C-97826; figure 2, x2500, processes supporting fragment of peripheral membrane in left part of figure 1; figure 3, x500, opposite face of gold-coated specimen in figure 1.

4. GSC 94617, GSC loc C-97826.

Figures 5-13. *Athabascaella sunwaptana* n. sp.

5. GSC 94618, GSC loc. C-97825.

6, 9, 12, 13. Holotype, GSC 94619, GSC loc. C-97825; figure 6, x750, opposite face of gold-coated specimen in figure 12; figure 9, x5000, right part of figure 12; figure 12, x1000; figure 13, x5000, left part of figure 12, including some processes supporting fragment of peripheral membrane.

7. GSC 94620, GSC loc. C-97825; x1500.

8. GSC 94621, GSC loc. C-97825.

10, 11. GSC 94622, GSC loc. C-97825; figure 10, x500, opposite face of gold-coated specimen in figure 11.

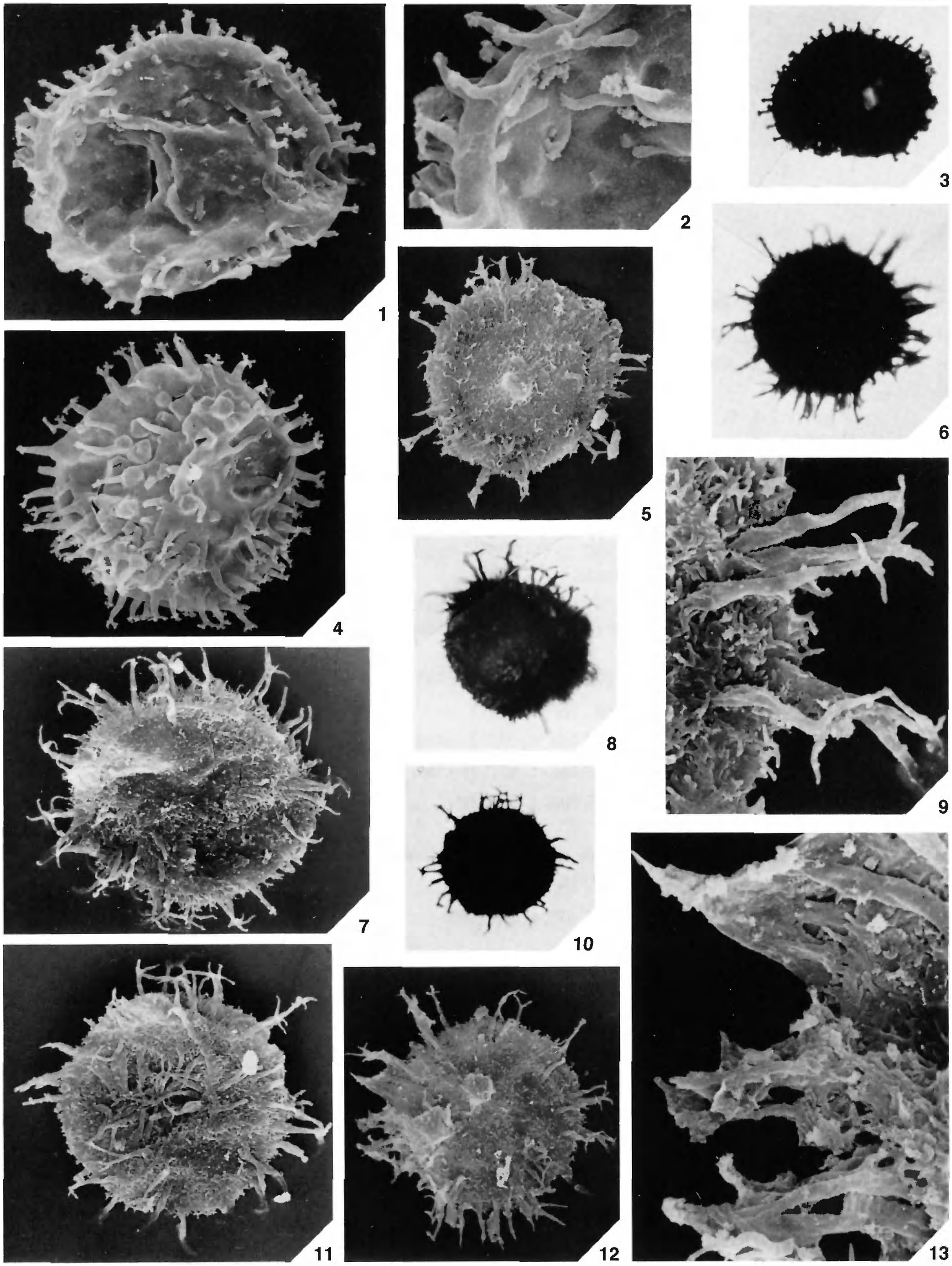
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PLATE 6

Magnification x1000, except where stated otherwise.

Figures 1, 5. *Buedingiisphaeridium tremadocum* Rasul, 1979.

1. GSC 94623, GSC loc. C-97766; x3000.
5. GSC 94624, GSC loc. C-97766; x 1500.

Figures 2-4, 8, 10-16. *Corollasphaeridium wilcoxianum* Martin *in* Dean and Martin, 1982 emend.
All lateral or sublateral views, except figure 11, which is antapical.

2. GSC 94627, GSC loc. C-97772; x750.
3. GSC 94628, GSC loc. C-97767; collarette broken at its base.

4, 8. GSC 94629, GSC loc.C-97772; figure 8, x500, opposite face of gold-coated specimen in figure 4.

10, 11. GSC 94630, GSC loc. C-97772; figure 10, x7000, right processes in figure 11; figure 11, contracted specimen with one upwardly directed process broken at its base.

12. GSC 94631, GSC loc. C-97767; x750.
13. GSC 94632, GSC loc. C-97772.
14. GSC 94633, GSC loc. C-97772; x750.
15. GSC 94634, GSC loc. C-97772; x750.
16. GSC 94635, GSC loc. C-97772.

Figures 6, 7. *Comasphaeridium* sp. cf. *C. strigosum* (Jankauskas) Downie, 1982.

6. GSC 94625, GSC loc. 92346.
7. GSC 94626, GSC loc. C-97765.

Figure 9. Leiosphaerid. GSC 94653, GSC loc. C-97774; x750. (Not described in text.)

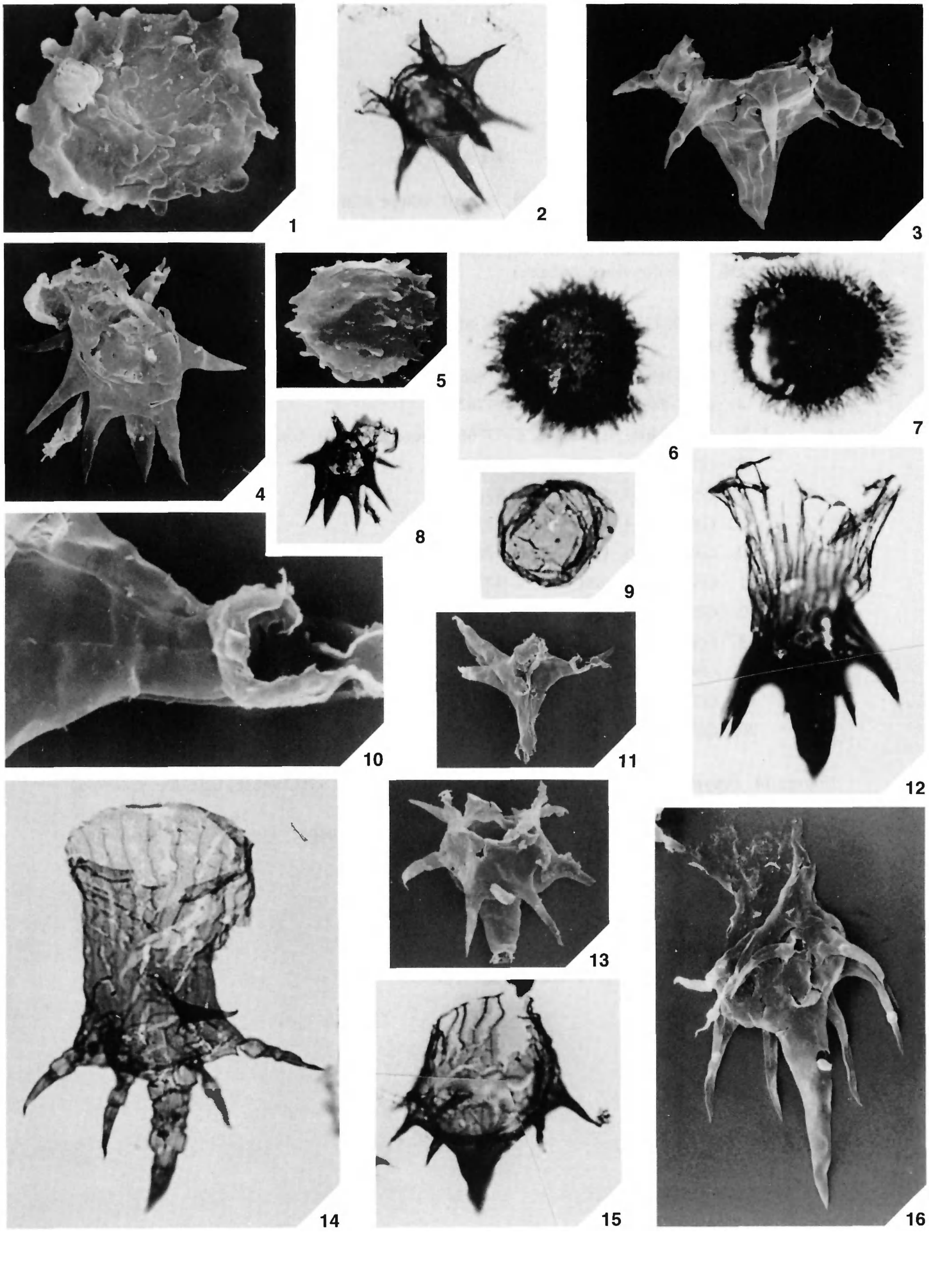
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PLATE 7

Magnification x1000, except where stated otherwise.

Figure 1. *Goniosphaeridium* sp. cf. *G. pungens* (Timofeev) Rauscher, 1974. GSC 94652, GSC loc. C-97904. (Not described in text.)

Figures 2-13, 18-20. *Goniosphaeridium* sp. aff. *G. akrochodermum* (Rasul) Martin *in* Martin and Dean, 1982.

2, 3. GSC 94639, GSC loc. C-97766; figure 3, x3000, upper right part of figure 2.

4. GSC 94640, GSC loc. C-97767.

5, 6. GSC 94641, GSC loc. C-97766; figure 6, x3000, lower part of figure 5.

7. GSC 94642, GSC loc. C-97767.

8. GSC 94643, GSC loc. C-97766.

9. GSC 94644, GSC loc. C-97754.

10. GSC 94645, GSC loc. C-97766.

11. GSC 94646, GSC loc. C-97767.

12. GSC 94647, GSC loc. C-97766.

13. GSC 94648, GSC loc. C-97767.

18. GSC 94649, GSC loc. 92340.

19. GSC 94650, GSC loc. C-97766.

20. GSC 94651, GSC loc. C-97766.

Figure 14. *Dasydiacrodium* sp. cf. *D. glabrum* Combaz, 1968. GSC 94638, GSC loc. C-97766.

Figure 15. *Lua erdaopuziana* Martin and Yin, 1988. GSC 94654, GSC loc.C-97836; x500.

Figures 16, 17, 21. *Saharidia downiei* Combaz, 1968.

16. GSC 94663, GSC loc. C-97766; x500.

17. GSC 94664, GSC loc. C-97766; x500.

21. GSC 94665, GSC loc. C-97766; x750.

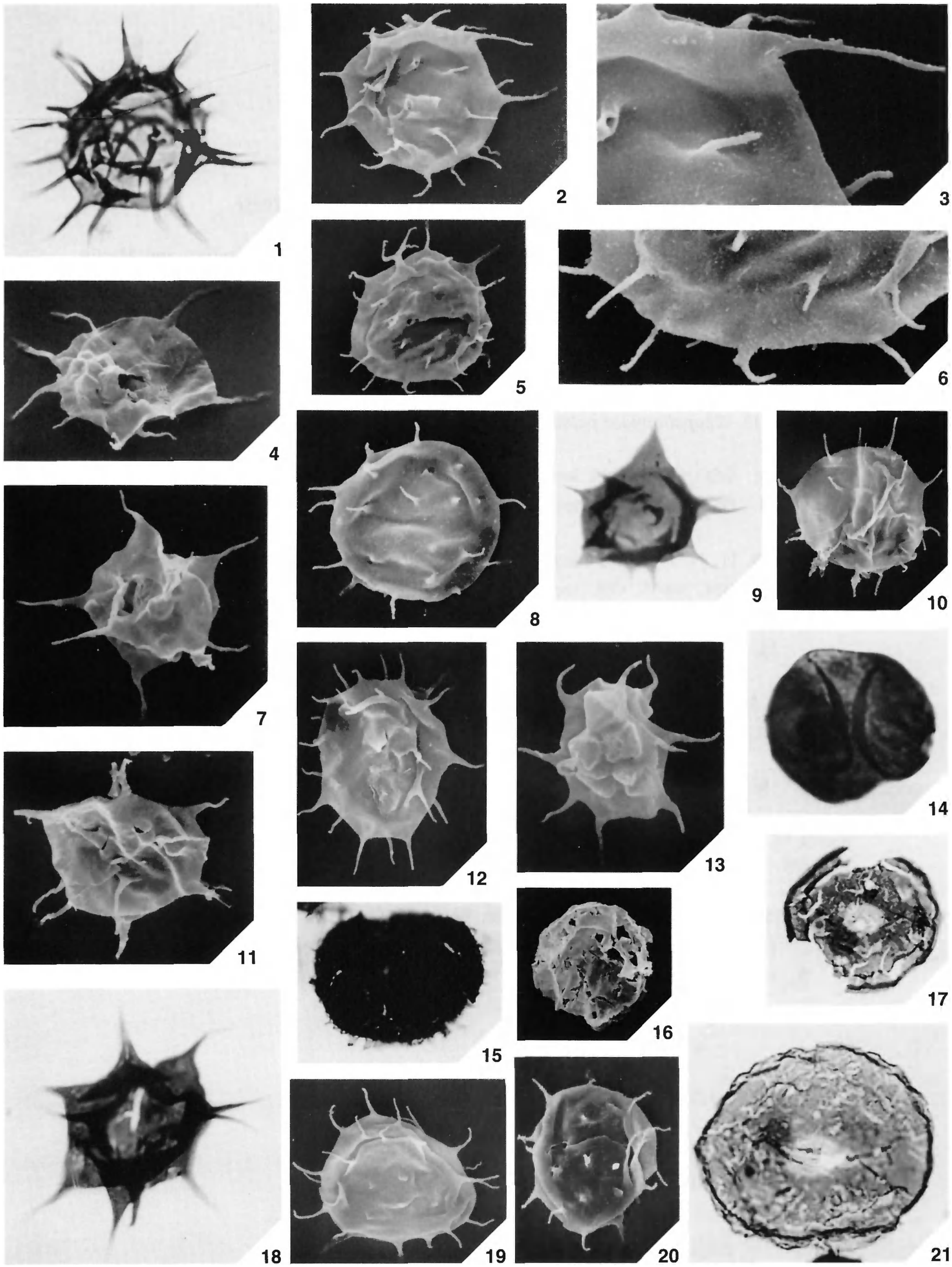
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PLATE 8

Magnification x1000, except where stated otherwise.

Figures 1-3, 6. *Rhopaliophora pilata* (Combaz and Peniguel) emend. Playford and Martin, 1984.

1. GSC 94660, GSC loc. C-97878.

2, 3. GSC 94661, GSC loc. C-97878; figure 3, x4000, central part of figure 2.

6. GSC 94662, GSC loc. C-97860; x750.

Figures 4, 13. *Rhopaliophora palmata* (Combaz and Peniguel) emend. Playford and Martin, 1984.

4. GSC 94658, GSC loc. C-97863.

13. GSC 94659, GSC loc. C-97863; x750.

Figures 5, 8, 11, 12. *Peteinosphaeridium* sp. cf. *P. breviradiatum* (Eisenack) Eisenack, 1969.

5. GSC 94655, GSC loc. C-97895; x500.

8, 11. GSC 94656, GSC loc. C-97889; figure 8, x4000, lower part of figure 11.

12. GSC 94657, GSC loc. C-97889.

Figures 7, 9, 10. *Vulcanisphaera* sp. cf. *V. africana* Deunff, 1961.

7. 10. GSC 94666, GSC loc. C-97766; figure 7, x750; figure 10, x4000, right part of figure 7.

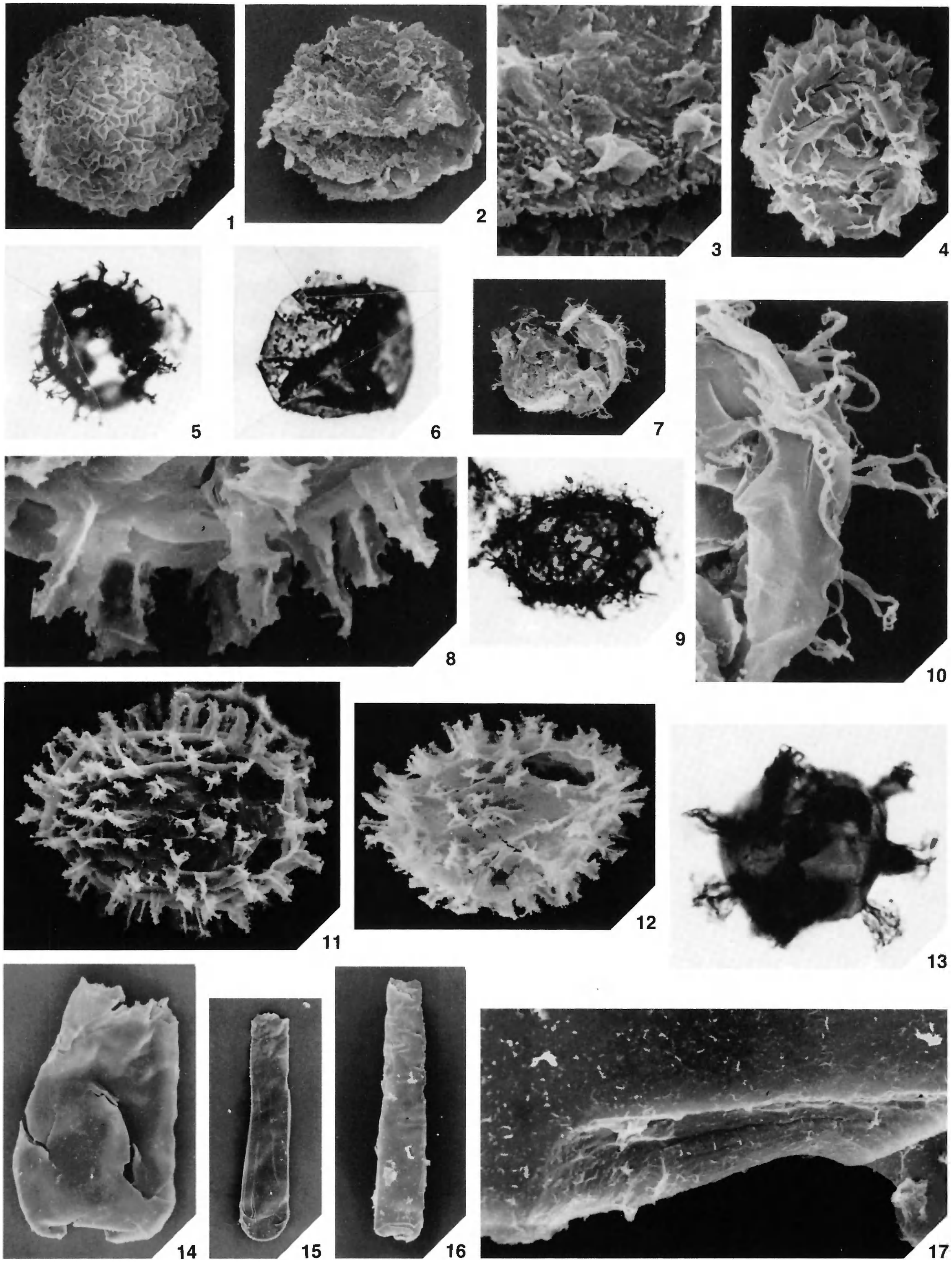
9. GSC 94667, GSC loc. C-97766; x750.

Figure 14. *Conochitina* sp. cf. *C. brevis* Taugourdeau and de Jekhowsky, 1960. GSC 94668, GSC loc. C-97873, x300.

Figures 15-17. *Conochitina* sp. cf. *C. exilis* Bockelie, 1980.

15. GSC 94669, GSC loc. C-97873; x100.

16, 17. GSC 94670, GSC loc. C-97873; figure 16, x100; figure 17, x4000, lower part of figure 16.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