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F. Martin
W.T. Dean

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Critical readers

W.H. Fritz
J.A. Legault

Authors' addresses

F. Martin
Département de Paléontologie
Institut royal des Sciences naturelles de Belgique
rue Vautier 29, 1040-Bruxelles, Belgium

W.T. Dean
Department of Geology
University College
Cardiff CF1 1XL
United Kingdom

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PREFACE

This report contains detailed descriptions of acritarchs and trilobites found in the Cambrian strata of the Avalon Platform of eastern Newfoundland. One new genus and six new species of acritarchs are founded and a biostratigraphic zonation based on acritarchs is proposed. An analysis of seven previously described microfloras is refined and completed, enabling a more accurate correlation to be made with trilobite-bearing strata in Great Britain and Scandinavia, and with acritarch faunas in northern Norway, the Baltic area and the Gondwanaland region.

Detailed paleontological and stratigraphic studies such as this facilitate making more accurate correlations between strata of this age not only in other parts of the world, but also in other sedimentary basins in Canada. Such accurate dating is essential to the precise assessment of the economic potential of the eastern Canadian sedimentary basins.

R.A. Price
Assistant Deputy Minister
Geological Survey of Canada

PRÉFACE

Le présent rapport contient des descriptions d'acritarches et trilobites qui l'on rencontre dans les strates cambriennes de la plateforme d'Avalon, située dans l'est de Terre-Neuve. On a découvert un nouveau genre et dix espèces d'acritarches, et l'on propose une zonation stratigraphique basée sur les acritarches présents. On a affiné et complété une analyse de sept microflores déjà décrites, qui nous permettra d'établir une meilleure corrélation avec les strates à trilobites de Grande-Bretagne et de Scandinavie, et avec les faunes d'acritarches du nord de la Norvège, de la Baltique et de la région du Gondwana.

Des études paléontologiques et stratigraphiques détaillées comme celle-ci permettent d'établir des corrélations plus précises entre les strates de cet âge, non seulement dans d'autres parties du globe, mais aussi dans d'autres bassins sédimentaires du Canada. Cette datation précise est esssentielle, si l'on veut évaluer avec exactitude le potentiel économique des bassins sédimentaires de l'est du Canada.

R.A. Price, sous-ministre adjoint,
Commission géologique du Canada

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MIDDLE AND UPPER CAMBRIAN ACRITARCH AND TRILOBITE ZONATION AT MANUELS RIVER AND RANDOM ISLAND, EASTERN NEWFOUNDLAND

Abstract

Middle and Upper Cambrian lithostratigraphy and trilobite zonation, supported by a study of selected taxa at Manuels River and Random Island, eastern Newfoundland, are reviewed. Comparisons with macrofaunas in Scandinavia and the peri-Gondwanaland region are discussed. An acritarch zonation is proposed, based on the same trilobite-bearing deposits in eastern Newfoundland; the interval studied extends from the middle Middle Cambrian (lower part of *Paradoxides paradoxissimus* "Stage") to the Upper Cambrian (*Peltura* zones and, in part, *Acerocare* Zone).

Analysis of seven microfloras, A0-1, A0, A1 to A5, introduced earlier by Martin (in Martin and Dean, 1981, 1984) is completed. Two new medial Middle Cambrian acritarch zones – *Rugasphaera terranovana* Standard Zone and *Adara alea* Range Zone – replace microfloras A0 and A1, respectively. Upper Cambrian microfloras A3 (a, b), A4, and A5 (a, b) are redescribed; they occur successively in strata without trilobites below the *Parabolina spinulosa* Zone up to the *Peltura* zones and part of the *Acerocare* Zone. Acceptance of the formal acritarch zonation proposed by Vanguestaine and Van Looy (1983) on the basis of data from Morocco and eastern Newfoundland is here limited to their *Timofeevia pentagonalis – Vulcanisphaera turbata* Zone; the latter is equivalent to the upper part of Microflora A2 and extends from the highest Middle Cambrian (?*Lejopyge laevigata* Zone) into the Upper Cambrian, below the *P. spinulosa* Zone.

One new genus and six new species of acritarchs are founded: *Rugasphaera* gen. nov., type species *R. terranovana* sp. nov.; *Cymatiogalea aspergillum* sp. nov., *C. virgulta* sp. nov., *Dasydiacrodium obsonum* sp. nov., *Stelliferidium pingiculum* sp. nov. and *Vulcanisphaera lanugo* sp. nov. The acritarch taxa known from elsewhere are recorded principally from the Cambrian of the Sino-Korean Platform in northeastern China, northern Norway, the Baltic region and the peri-Gondwanaland region, and/or from the Tremadoc of the peri-Gondwanaland region.

Résumé

La lithostratigraphie et la zonation à trilobites, appuyée de l'étude de taxa selectionnés, sont revues pour le Cambrien Moyen et Supérieur à Manuels River et à Random Island, en Terre-Neuve orientale. Les comparaisons avec les macrofaunes de Scandinavie et du peri-Gondwanaland sont discutées. Une zonation à acritarches est proposée pour les mêmes dépôts contenant des trilobites en Terre-Neuve orientale; elle est étendue du début de la partie moyenne du Cambrien Moyen (partie inférieure de "l'Etage" à *Paradoxides paradoxissimus*) au Cambrien Supérieur (les zones à *Peltura* et, en partie, la Zone à *Acerocare*).

L'analyse de sept microflores (A0-1, A0, A1 à A5 de Martin dans Martin et Dean, 1981, 1984) est complétée. Deux nouvelles zones à acritarches, la Zone standard à *Rugasphaera terranovana* et la Zone d'extension à *Adara alea*, remplacent respectivement les microflores A0 et A1 de la partie moyenne du Cambrien Moyen. Les microflores A3 (a, b), A4 et A5 (a, b) sont redécrites; elles se succèdent dans le Cambrien Supérieur à partir de couches dépourvues de trilobites sous la Zone à *Parabolina spinulosa* jusqu'aux zones à *Peltura* et à une partie de la Zone à *Acerocare*. L'usage de la zonation formelle de Vanguestaine et Van Looy (1983), établie d'après des données au Maroc et en Terre-Neuve orientale, est ici limité à celui de leur Zone à *Timofeevia pentagonalis – Vulcanisphaera turbata* (= partie supérieure de la microflore A2) qui va de la fin du Cambrien Moyen (? Zone à *Lejopyge laevigata*) jusqu'au Cambrien Supérieur, sous la Zone à *Parabolina spinulosa*.

Un nouveau genre et six espèces d'acritarches sont fondés: *Rugasphaera* gen. nov., espèce-type *R. terranovana* sp. nov.; *Cymatiogalea aspergillum* sp. nov., *C. virgulta* sp. nov., *Dasydiacrodium obsonum* sp. nov., *Stelliferidium pingiculum* sp. nov. et *Vulcanisphaera lanugo* sp. nov. Les taxa connus sont principalement déterminés dans le Cambrien du nord de la plate-forme sino-coréenne, dans le nord-est de la Chine, de la Norvège septentrionale, de la Baltique et du peri-Gondwanaland et/ou dans le Tremadoc de cette dernière region.

Summary

In the Avalon Platform of eastern Newfoundland, Cambrian rocks occur in several basins. The strata considered here are of Middle (in part) and Late Cambrian age, and outcrop at sections in the valley of Manuels River, 20 km west of St. John's, and on the west coast of Random Island, 100 km to the northwest. The deposits are clastic sediments, mostly grey mudstone with minor beds of siltstone and sandstone, and belong to the highest part of the Chamberlains Brook Formation, the Manuels River Formation, and the Elliott Cove Formation. Although most of the strata lack macrofossils, some thin layers may be richly fossiliferous. The majority of the macrofossils are trilobites, which exhibit close affinities with corresponding faunas in Wales, England and Scandinavia. The trilobite (mainly agnostid and olenid) zones established in Sweden by Westergård (1922, 1944, 1946, 1953) were found to be applicable; in all cases the faunal diversity was low. The Swedish Middle Cambrian "Stages" named, in ascending order, for *Paradoxides oelandicus*, *P. paradoxissimus*, and *P. forchhammeri* refer to species not yet recorded in Newfoundland.

The highest part of the Chamberlains Brook Formation comprises green-grey mudstone and contains *Paradoxides (Eccaparadoxides) eteminicus* Matthew, 1883 associated with *Hartella* and *Badulesia*, genera found at a similar horizon in the Mediterranean region and Turkey. The strata are equated with the *Ptychagnostus gibbus* Zone, though the zonal index was not found. The Manuels River Formation comprises dark grey, pyritiferous mudstone with minor, concretionary siltstone and the rocks not only bear a marked resemblance to equivalent strata in Wales but also have several trilobites in common, including *Paradoxides (Hydrocephalus) hicksii* Salter, 1866 and *P. (Paradoxides) davidis* Salter, 1863. The two last-named species have been used as zonal fossils in eastern Newfoundland but the Manuels River Formation is better correlated with the Swedish agnostid zones (in ascending order) of: *Tomagnostus fissus* and *Ptychagnostus atavus*; *Hypagnostus parvifrons*; and *Ptychagnostus punctuosus*. *Solenopleuropsis variolaris* (Salter, 1864), from the *P. punctuosus* Zone both in Newfoundland and in Wales, belongs to a genus used as a zonal index in the Iberian Peninsula, the Mediterranean region and Turkey. The formation is much less fossiliferous at Random Island than at Manuels River.

At its type section on Random Island, the Elliott Cove Formation consists of grey, fissile mudstone in its lowest and highest parts; the middle portion contains both thinly and thickly bedded sandstone units that yielded no macrofossils. The base of the formation is marked by a thin conglomerate and succeeds the Manuels River Formation with minor disconformity. Evidence for the *Lejopyge laevigata* Zone, highest Middle Cambrian, is sparse and equivocal but trilobites of the *Agnostus pisiformis* Zone and *Olenus* Zone are well represented, the latter containing not only *Olenus* spp. but also *Homagnostus obesus* (Belt, 1867) and *Grandagnostus falanensis* (Westergård, 1947), species found in Britain and Scandinavia. In the highest, mudstone, part of the formation, the *Parabolina spinulosa* Zone contains both the index trilobite and the characteristic brachiopod *Orusia lenticularis* (Wahlenberg, 1821), the latter being useful in defining the base of the zone. Trilobites of the *Leptoplastus* Zone, including the eponymous genus, are uncommon. Evidence was found for the two lowest of the three Scandinavian *Peltura* zones at the type section of the formation, where characteristic trilobites included *Ctenopyge (Eoctenopyge) flagellifera* (Angelin, 1854) and *C. (Mesoctenopyge) similis* Henningsmoen, 1957. No trilobite of the uppermost of the *Peltura* zones, the *P. scarabaeoides* Zone, was found at the type section, but the zonal index fossil, *Ctenopyge (Ctenopyge) linnarssoni* Westergård, 1922 and *Sphaerophthalmus majusculus* Linnarsson, 1822 were collected from another section 4 km farther north on the west coast of Random Island. A few trilobite remains from the *Acerocare* Zone, highest zone of the Upper Cambrian, included *Westergaardia lata* (Matthew, 1891), known also from New Brunswick (its type area), Nova Scotia, and Norway. No strata higher than the *Parabolina spinulosa* Zone were found at Manuels River, and there is no evidence of the sandstone units that are so conspicuous at Random Island.

An acritarch-based zonation proposed for the same deposits extends from the base of the middle portion of the Middle Cambrian (lower part of the *Paradoxides paradoxissimus* "Stage") to the Upper Cambrian, *Parabolina spinulosa* Zone, at both Manuels River and Random Island. In the latter area it is extended to include the *Peltura* zones and, in part, the Zone *Acerocare*. The samples were intentionally collected both from beds dated by means of macrofossils and from sections sufficiently continuous to permit their relationship with the trilobite zones to be established. Fifty-five new samples, forty-three of them productive, are analyzed in the present work. The synthesis establishing the ranges of these Cambrian acritarchs in eastern Newfoundland incorporates also the results of previous work (Martin and Dean, 1981, 1983, 1984). A total of one hundred and forty-six palynological samples were investigated, eighty-eight of which yielded determinable microfossils. The acritarchs are usually abundant, but badly preserved. In the best samples, the identities of 20 to 50 per cent of the specimens were determined, and no account was taken of those specimens too incomplete for confident determination.

Analysis of the seven microfloras (A0-1, A0, A1 to A5) of Martin (in Martin and Dean, 1981, 1984) is completed. Microflora A0-1 (= *Eliasum jennessii* – Acritarch gen. et sp. nov. assemblage) is limited to the lower part of the *Paradoxides paradoxissimus* "Stage" (beds with

Hartella). The two index acritarchs are known only at Manuels River and Random Island. The stratigraphic continuity and close sampling of the middle portion of the Middle Cambrian ("*Paradoxides hicksi* Zone" and "*Paradoxides davidis* Zone") enable the *Rugasphaera terranovana* Standard Zone and the *Adara alea* Range Zone to be established, replacing microfloras A0 and A1, respectively. The two new zones are not known outside the Avalon Platform. The lower part of Microflora A2 (containing *Timofeevia phosphoritica* Vanguestaine, 1978, but lacking *Vulcanisphaera turbata* Martin, in Martin and Dean, 1981) begins below the *Paradoxides forchhammeri* "Stage" and extends almost to the top of it, into the ?*Lejopyge laevigata* Zone. The incomplete description of this microflora is due to the very poor preservation of the acritarchs. The formal zonation proposed by Vanguestaine and Van Looy (1983) is of limited use in eastern Newfoundland as it masks the successive appearance of the index species, as now established in the region, and does not take into account either hiatuses or uncertainties of observation. Use of the zonation is confined to the *Timofeevia pentagonalis – Vulcanisphaera turbata* Zone (= upper part of Microflora A2), which extends from uppermost Middle Cambrian (?*Lejopyge laevigata* Zone or the interval between that and the *Agnostus pisiformis* Zone) to the Upper Cambrian, below the *Parabolina spinulosa* Zone. Microfloras A3 (a, b), A4 and A5 (a, b), all in the Upper Cambrian, are redescribed. Microflora A3 (= *Cristallinium randomense* - *Veryhachium dumontii* assemblage) begins below the *Parabolina spinulosa* Zone and extends into the latter, excluding its uppermost part. The appearance of diacrodians is characteristic of Microflora A3b. Microflora A4 (= *Trunculumarium revinium – Dasydiacrodium caudatum* assemblage) begins in the uppermost part of the *Parabolina spinulosa* Zone and extends almost to the top of the *Leptoplastus* Zone. Microflora A5 (= *Arbusculidium rommelaerei – Vulcanisphaera turbata* assemblage) was found throughout the *Peltura* zones and also in one sample from the *Acerocare* Zone. *Saharidia fragilis* (Downie) Combaz, 1967, though rare, characterizes Microflora A5b.

One new genus and six new species are described: *Rugasphaera* and its type species *R. terranovana*, *Cymatiogalea aspergillum*, *C. virgultum*, *Dasydiacrodium obsonum*, *Stelliferidium pingiculum* and *Vulcanisphaera lanugo*. As far as is now known, the affinities of the eastern Newfoundland Middle and Upper Cambrian acritarchs lie especially with those of northern Norway, the Baltic area and the peri-Gondwanaland region, the palynology of the two last-named being the most documented. In addition, a partial comparison is made between the Upper Cambrian acritarchs of the Avalon Platform and those of the northern part of the Sino-Korean Platform in northeast China.

Sommaire

Des dépôts cambriens sont présents dans plusieurs bassins de la Plate-forme Avalon, en Terre-Neuve orientale. Les couches ici considérées appartiennent à une partie du Cambrien Moyen et au Cambrien Supérieur; elles affleurent dans la vallée de Manuels River, 20 km à l'ouest de St. John's, et le long de la côte occidentale de Random Island, 100 km au nord-ouest. Les roches sont formées de dépôts détritiques, principalement des pélites grises avec de petits bancs de microgrès et de grès; elles appartiennent à la partie la plus supérieure de la Formation de Chamberlains Brook, à la Formation de Manuels River et à celle d'Elliott Cove. Bien que la plupart des strates soient dépourvues de macrofossiles, certains lits peuvent être très fossilifères. La plupart des macrofossiles sont des trilobites qui présentent de nettes affinités avec les faunes du Pays de Galles, d'Angleterre et de Scandinavie. Les zones à trilobites (principalement des agnostides et des olénides) établies en Suède par Westergård (1922, 1944, 1946, 1953) sont utilisables en Terre-Neuve, bien que la diversité de la faune y soit faible. Les "Etages" à *Paradoxides oelandicus*, à *P. paradoxissimus* et à *P. forchhammeri* du Cambrien Moyen de Suède font référence à des espèces non trouvées en Terre-Neuve. La partie supérieure de la Formation de Chamberlains Brook comprend des pélites gris-vert et contient *Paradoxides* (*Eccaparadoxides*) *eteminicus* Matthew, 1883 avec *Hartella* et *Badulesia*, genres trouvés dans la région méditerranéenne et en Turquie. Les dépôts sont attribués à la Zone à *Ptychagnostus gibbus*, bein que l'espèce-guide de la zone fasse défaut. La formation de Manuels River comprend des pélites gris foncé, pyriteuses et des concrétions de microgrès; les roches montrent une nette ressemblance lithologique avec celles du Pays de Galles; en outre, elles ont plusieurs trilobites en commun, notamment *Paradoxides* (*Hydrocephalus*) *hicksii* Salter, 1866 et *P.* (*Paradoxides*) *davidis* Salter, 1863. Les deux dernières espèces ont été utilisées comme fossiles-guides en Terre-Neuve orientale; toutefois, la corrélation de la Formation de Manuels River est mieux établie avec des zones suédoises à agnostides, lesquelles sont les suivantes, dans l'ordre ascendant: *Tomagnostus fissus* et *Ptychagnostus atavus*; *Hypagnostus parvifrons*; et *Ptychagnostus punctuosus*. *Solenopleuropsis variolaris* (Salter, 1864), de la Zone à *P. punctuosus* tant en Terre-Neuve qu'au Pays de Galles, appartient à un genre-guide dans la Péninsule Ibérique, la région méditerranéenne et la Turquie. La Formation de Manuels River est moins fossilifère à Manuels River qu'à Random Island.

La Formation d'Elliott Cove, à la coupe-type de Random Island, est formée de pélites grises et fissiles à la partie inférieure et supérieure; la partie moyenne contient à la fois des lits gréseux minces ou épais et dépourvus de macrofossiles. La base de la formation est marquée par un petit conglomérat et est séparée de la Formation de Manuels River par une faible

discontinuité sédimentaire. Les indices de la Zone à *Lejopyge laevigata* sont rares et équivoques mais les trilobites de la Zone à *Agnostus pisiformis* et de la Zone à *Olenus* sont bien représentés. La dernière zone contient non seulement *Olenus* spp. mais aussi *Homagnostus obesus* (Belt, 1867) et *Grandagnostus falanensis* (Westerård, 1947), espèces connues en Grande-Bretagne et en Scandinavie. Dans les pélites les plus supérieures de la formation, la Zone à *Parabolina spinulosa* contient à la fois le trilobite-guide et le caractéristique brachiopode *Orusia lenticularis* (Wahlenberg, 1821), ce dernier étant utilisé pour définir la base de la zone. Les trilobites de la Zone à *Leptoplastus*, y compris le genre éponyme, sont rares. Les deux zones inférieures des trois zones scandinaves à *Peltura* ont été mises en évidence dans la coupe-type de la formation; les trilobites signalétiques comprennent *Ctenopyge (Eoctenopyge) flagellifera* (Angelin, 1854) et *C. (Mesoctenopyge) similis* Henningsmoen, 1957. Aucun trilobite de la Zone à *Peltura scarabaeoides*, la plus jeune des trois zones à *Peltura*, n'a été trouvé dans la section-type mais l'espèce-guide de la zone et *Ctenopyge (Ctenopyge) linnarssoni* Westergård, 1922 et *Sphaerophthalmus majusculus* Linnarsson, 1882 ont été recoltés dans une autre coupe, 4 km au nord, le long de la côte occidentale de Random Island. Quelques fragments de trilobites de la Zone à *Acerocare*, la zone la plus récente du Cambrien Supérieur, livrent *Westergaardia lata* (Matthew, 1891), également connu au New Brunswick (sa région-type), en Nouvelle-Ecosse et en Norvège. Aucun dépôt plus jeune que ceux contenant la Zone à *Parabolina spinulosa* n'affleure à Manuels River, ou manquent aussi les unités gréseuses si développées à Random Island.

Une zonation à acritarches est proposée pour ces mêmes dépôts. Elle va du début de la partie moyenne du Cambrien Moyen (partie inférieur de l' "Étage" à *Paradoxides paradoxissimus*) au Cambrien Supérieur (Zone à *Parabolina spinulosa*, tant à Manuels River qu'à Random Island. A ce dernier endroit, elle est étendue jusqu'aux zones à *Peltura* et, en partie, à la Zone à *Acerocare*. Les échantillons ont été intentionnellement récoltés dans des couches datées par la macrofaune, soit que celle-ci soit effectivement présente, soit que les strates suffisamment continues permettent d'établir leur relation avec les zones à trilobites. Cinquante-cinq échantillons, dont quarante-trois productifs, sont nouvellement analysés dans le présent travail. La synthèse établissant l'extension de ces acritarches cambriens en Terre-Neuve intègre les résultats de travaux antérieurs (Martin et Dean, 1981, 1983, 1984). L'ensemble représente l'investigation de cent quarante-six échantillons palynologiques dont quatre-vingts-huit ont livré des microfossiles déterminables. Les acritarches sont les plus souvent abondants et mal conservés. Dans les meilleurs échantillons, 20 à 50% des spécimens sont déterminés car il n'est pas tenu compte de ceux trop détériorés et entraînant une détermination douteuse.

L'analyse de sept microflores (A0-1, A0, A1 à A5 de Martin dans Martin et Dean, 1981, 1984) est complétée. La microflore A0-1 (= assemblage à *Eliasum jennessii* – Acritarche gen. et sp. nov.) est limitée à la partie inférieure de l' "Étage" à *Paradoxides paradoxissimus* (niveau à *Hartella*). Les deux acritarches désignant la microflore ne sont connus qu'à Manuels River et à Random Island. La continuité stratigraphique et l'échantillonnage dense de la partie moyenne du Cambrien Moyen (niveaux à "*Paradoxides hicksi*" et "*Paradoxides davidis*") permettent de définir la Zone standard à *Rugasphaera terranovana* et la Zone d'extension à *Adara alea*, remplaçant respectivement les microflores A0 et A1. Ces deux zones ne sont pas connues en dehors de la Plate-forme Avalon. La partie inférieure de la microflore A2 (avec *Timofeevia phosphoritica* Vanguestaine, 1978 et sans *Vulcanisphaera turbata* Martin dans Martin et Dean, 1981) débute sous l' "Étage" à *Paradoxides forchhammeri* et est étendue dans ce dernier, jusqu'à près du sommet et dans la ? Zone à *Lejopyge laevigata*. Le très mauvais état de conservation des acritarches rend fort incomplète la description de cette microflore. La zonation formelle de Vanguestaine et Van Looy (1983) est d'un usage limité en Terre-Neuve orientale car elle masque les apparitions successives d'espèces-guides, telles que présentement établies dans cette région, et ne met pas assez en évidence les hiatus ou incertitudes d'observations. Son utilisation est ici restreinte à celle de la Zone à *Timofeevia pentagonalis* – *Vulcanisphaera turbata* (= partie supérieure de la microflore A2) qui va de la fin du Cambrien Moyen (? Zone à *Lejopyge laevigata* ou intervalle compris entre cette dernière et la Zone à *Agnostus pisiformis*) jusqu'au Cambrien Supérieur, sous la Zone à *Parabolina spinulosa*. Les microflores A3 (a, b), A4 et A5 (a, b), toutes du Cambrien Supérieur, sont redécrites. La microflore A3 (= assemblage à *Cristallinium randomense* – *Veryhachium dumontii*) débute sous la Zone à *Parabolina spinulosa* et est étendue dans cette dernière, sommet exclu. L'apparition de diacrodiens est caractéristique de la microflore A3b. La microflore A4 (assemblage à *Trunculumarium revinium* – *Dasydiacrodium caudatum*) commence au sommet de la Zone à *Parabolina spinulosa* et se poursuit jusqu'à près du sommet de la Zone à *Leptoplastus*. La microflore A5 (= assemblage à *Arbusculidium rommelaerei* - *Vulcanisphaera turbata*) à la même extension que les zones à *Peltura*; elle est aussi trouvée dans un échantillon daté par la Zone à *Acerocare*. La présence, bien que rare, de *Saharidia fragilis* (Downie) Combaz, 1967 particularise la microflore A5b.

Une nouveau genre et six nouvelles espèces sont fondés: *Rugasphaera* et son espèce-type *R. terranovana*, *Cymatiogalea aspergillum*, *C. virgultum*, *Dasydiacrodium obsonum*, *Stelliferidium pingiculum* et *Vulcanisphaera lanugo*. Jusqu'à présent les acritarches du Cambrien Moyen et Supérieur de Terre-Neuve orientale présentent surtout des affinités avec ceux connus dans le nord de la Norvège, la Baltique et la péri-Gondwanaland, la palynologie de ces deux dernières régions étant la plus documentée. En outre, une comparaison partielle entre les acritarches du Cambrien Supérieur de la Plate-forme Avalon et ceux du nord de la Plate-forme sino-coréenne, au nord-est de la Chine, est indiquée.

INTRODUCTION

Collecting of macrofossils from the Middle Cambrian, Upper Cambrian and lower Tremadoc Series of Random Island, Trinity Bay, eastern Newfoundland (Figs. 1, 5) was begun in the early 1970's by W.T. Dean as part of GSC project 690006. Sampling of upper Lower, Middle and Upper Cambrian strata in the same area and at Manuels River (Figs. 1, 2), 100 km to the southeast in Conception Bay, was carried out by us in 1981 as part of GSC project 500029. It represents a continuation of our earlier work (Martin and Dean, 1981, 1983, 1984), aimed at establishing a sequence of acritarch-based units, cross-dated by means of trilobites, that can be used for long distance correlation. As the use of palynological dating without independent macrofossil age control frequently, and inevitably, introduces uncertainties and/or anomalies with regard to the vertical ranges of guide taxa, the sampling for acritarchs was deliberately confined either to outcrops dated in terms of trilobite zones or to successions sufficiently continuous that an estimate of their relationship to trilobite zones could be made. The present work incorporates a review of the lithostratigraphy and trilobite zonation at Manuels River and Random Island, with particular reference to the Scandinavian zonal scheme, together with systematic comments on selected trilobites from the lower Middle Cambrian to the upper Upper Cambrian.

Acknowledgments

We are much indebted to J. Legault and W.H. Fritz for critically reading the manuscript and making suggestions for its improvement. Particular thanks are due to A.W.A. Rushton for advice on Upper Cambrian zonation and trilobite identifications, and to M. Lewis for providing unpublished results of his work on the Middle Cambrian of the St. David's area, southwest Wales. Joanne Dean is thanked for her help during fieldwork in summer, 1981. At the Institut royal des Sciences naturelles de Belgique, where processing of the acritarchs was carried out, H. de Potter is thanked for his technical help, P. Grootaert and J. Cillis for operating the scanning electron microscope, and G. Van der Veken for printing the photographs.

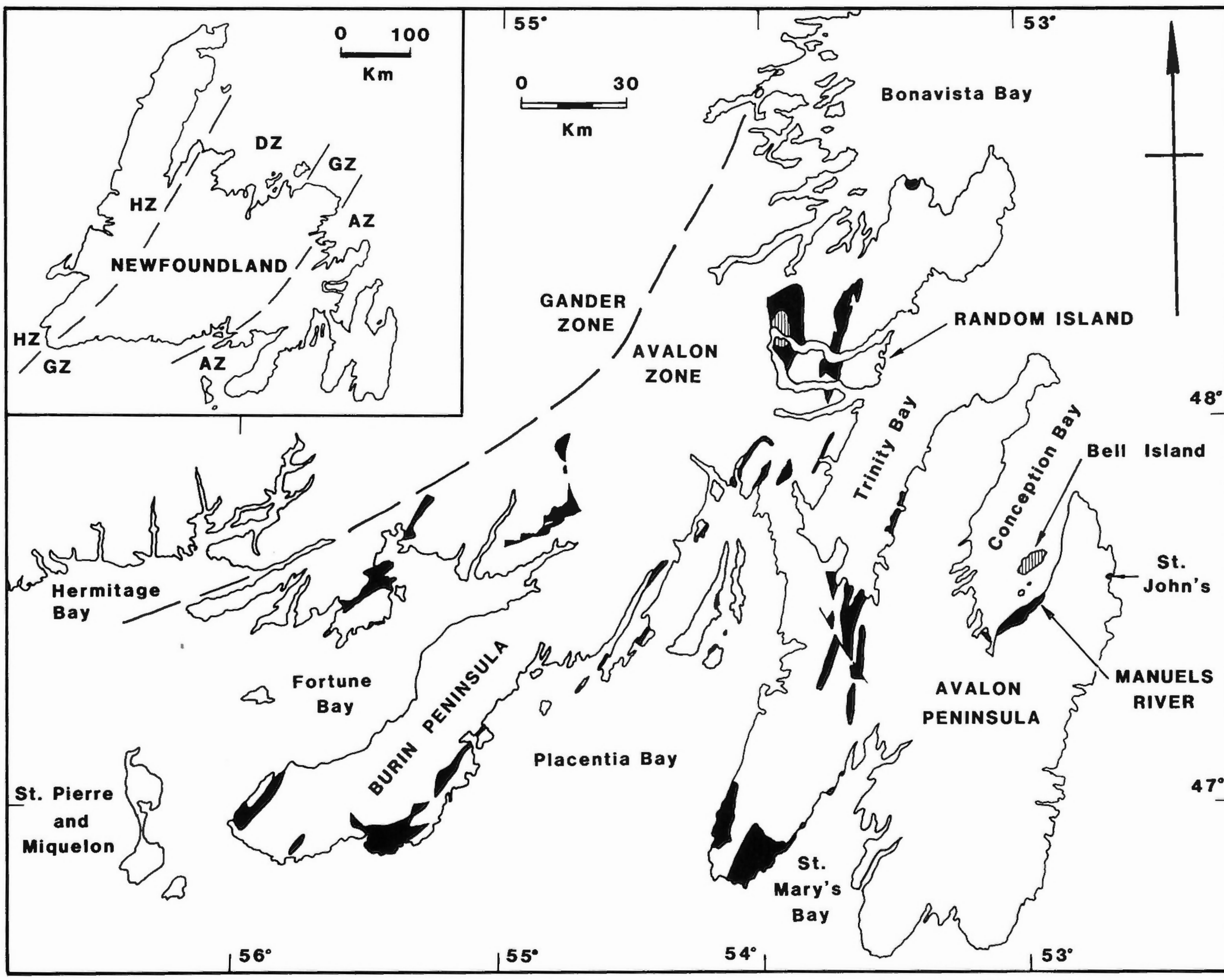

Figure 1. Regional map showing Cambrian (black) and Ordovician (shaded) outcrops on the Avalon Platform. Inset map shows principal structural subdivisions of Newfoundland (after Williams, 1964, 1979): HZ – Humber Zone; DZ – Dunnage Zone; GZ – Gander Zone; AZ – Avalon Zone.

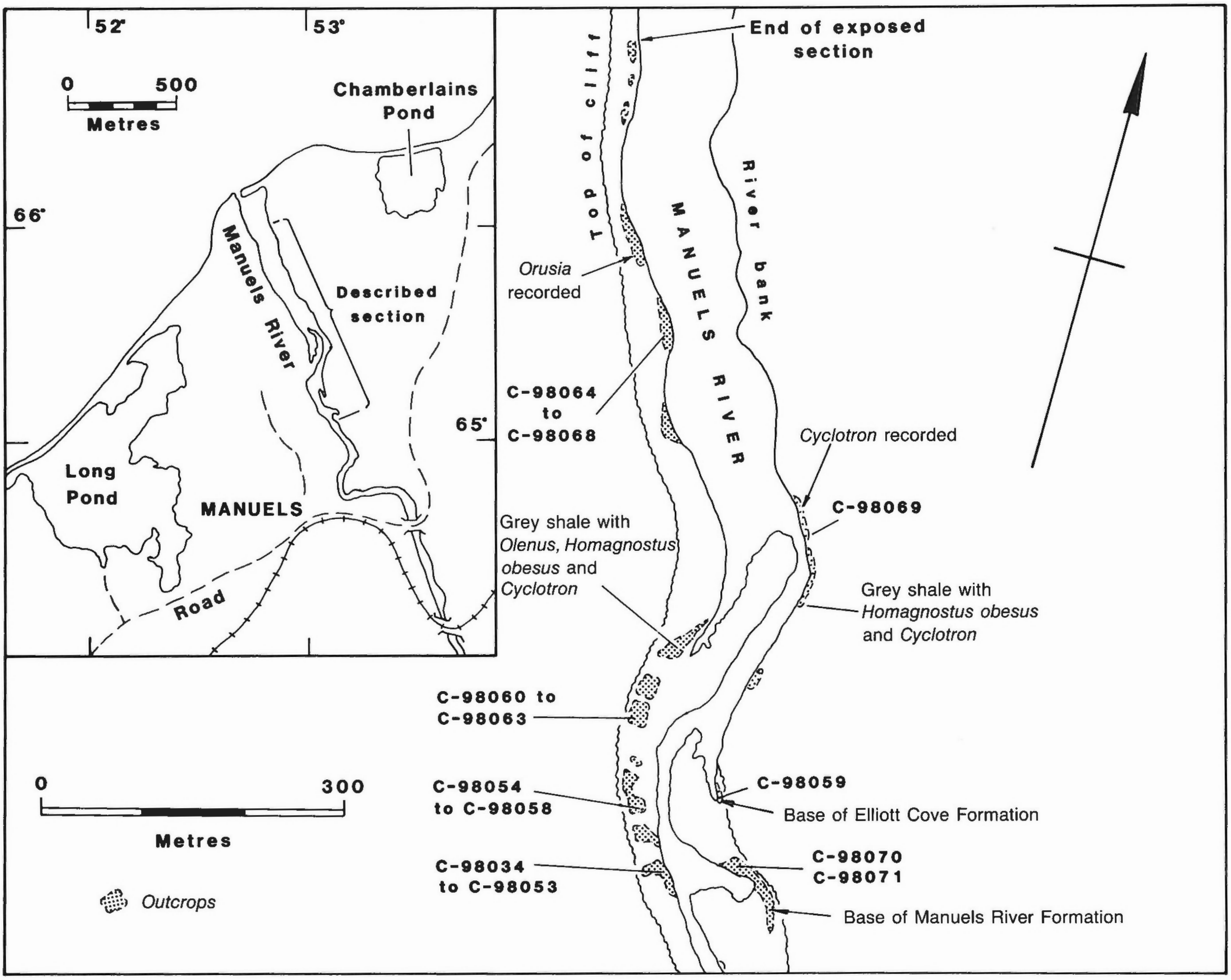

Figure 2. *Map showing position of GSC localities and lithostratigraphic boundaries near Manuels River. Inset map shows location of section.*

MACROFOSSIL ZONATION OF CAMBRIAN ROCKS

W.T. Dean

Present-day trilobite zonation of Middle and Upper Cambrian rocks in Scandinavia, England, Wales and easternmost North America is essentially the same as that proposed for Sweden by Westergård in 1922, 1944 (Upper Cambrian), 1946 and 1953 (Middle Cambrian). He divided the Middle Cambrian into three "stages" based on successive *Paradoxides* species: *P. oelandicus*, *P. paradoxissimus* and *P. forchhammeri*. The *P. paradoxissimus* "Stage" was divided into four zones, in ascending order: zone B1, *Ptychagnostus* (*Triplagnostus*) *gibbus*; zone B2, *Tomagnostus fissus* and *Ptychagnostus atavus*; zone B3, *Hypagnostus parvifrons*; and zone B4, *Ptychagnostus* (*Ptychagnostus*) *punctuosus*. The *P. forchhammeri* "Stage" was divided into three zones: zone C1, *Ptychagnostus* (*Triplagnostus*) *lundgreni* and *Goniagnostus nathorsti*; zone C2, *Solenopleura brachymetopa*; and zone C3, *Lejopyge laevigata*; the first of these has since been used as *G. nathorsti* Zone (for example, by Cowie and others, 1972). Of the index trilobites, the agnostids are proving increasingly important in wider, international correlation (Robison, 1984), but distribution of the paradoxidid species appears to be more restricted geographically.

The section at Manuels River provided the basis for the introduction by Howell (1925) of three successive zones, *Paradoxides bennetti*, *P. hicksi* and *P. davidis* zones, used by him to cover the whole of the Middle Cambrian; the correct spelling of the two former is *bennettii* and *hicksii*. These provided a standard for all of eastern Newfoundland (for example, in Hutchinson, 1962) but their continued use introduces inaccuracies because they do not reflect the true vertical ranges of the index species. In the present paper, the Scandinavian agnostid zones are used where possible. Certain of the "assemblages" introduced, but not defined, for the Middle Cambrian of the St. Mary's area, southeastern Newfoundland by Fletcher (in Bengtson and Fletcher, 1983) are noted. Where cited, Howell's *Paradoxides* zones, with their original spelling, are put in quotation marks.

Westergård (1922) divided the Swedish Upper Cambrian into the following zones, which were in turn subdivided into subzones:

1. *Agnostus pisiformis* Zone
2. *Olenus* Zone
3. *Parabolina* and *Orusia lenticularis* Zone
4. *Leptoplastus* and *Eurycare* Zone
5. *Peltura, Sphaerophthalmus* and *Ctenopyge* Zone
6. *Parabolina, Cyclognathus* and *Acerocare* Zone.

The first five of these were later used unchanged by Westergård (1947, p. 20, 21) but the sixth was modified by him to "*Acerocare* and *Parabolina* of the *heres* group Zone", and minor changes were made to the subzones of zones 4 and 5. Further small modifications of Westergård's zonal nomenclature by Henningsmoen (1957, p. 299, 300) included usage of: *Olenus* and *Agnostus obesus* Zone for zone 2; *Parabolina spinulosa* Zone for zone 3; *Leptoplastus* Zone for zone 4; *Peltura* zones for zone 5; and *Acerocare* Zone for zone 6. Although Henningsmoen (1957, p. 36, 302) used the terms *Olenus* zones (2a) and *Olenus* I-II to encompass Westergård's zones 1 and 2, elsewhere in the same paper he (*op. cit.*, p. 98) employed *Olenus* Zone for strata above the *Agnostus pisiformis* Zone. Subsequently Henningsmoen (1958, p. 191) reverted to the usage of an *Olenus* and *Agnostus obesus* Zone, 2aβ. It is preferred here to employ an *Agnostus pisiformis* Zone, succeeded in turn by an *Olenus* Zone, *Parabolina spinulosa* Zone, *Leptoplastus* Zone, *Peltura* zones and *Acerocare* Zone. Terminology used by Hutchinson (1962) for eastern Newfoundland is generally similar, except that his *Parabolina* Zone corresponds to the *P. spinulosa* Zone, and his *Peltura* Zone to Henningsmoen's *Peltura* zones; the last-named, composed of three zones and thirteen subzones, has been used also by Taylor and Rushton (1972, p. 28).

The so-called Acado-Baltic Province was considered by Westergård (1950, p. 4, 31) to include not only southern Scandinavia, England, Wales, eastern Newfoundland, Nova Scotia, southern New Brunswick and northeastern U.S.A. but also Spain and southern France, that is to say areas that would today be considered to have formed part of Gondwanaland in the Cambrian and Ordovician (review in Dean, 1985). Although some of the trilobites discussed here are not known outside eastern Canada, others occur in what Sdzuy (1971, p. 778) termed the Mediterranean subprovince, as well as in Scandinavia, and their significance is commented on where appropriate.

LITHOSTRATIGRAPHY AND TRILOBITE ZONES AT MANUELS RIVER

W.T. Dean

Chamberlains Brook Formation (upper part)

For the purposes of this study, only the topmost 3.7 m (12.14 ft), made up of Beds 25 to 35 of Howell's measured section were sampled. A convenient datum horizon (Fig. 3) is the top of Howell's Bed 24, a finely crystalline, nodular, grey limestone about 15 cm thick exposed low in the west bank of the river. Most of the 3.7 m consists of dark grey or green grey shale, with subsidiary nodular or lenticular bands of grey, fine grained limestone. Fossils occur sporadically, and Bed 32 (GSC loc. 101552) yielded numerous disarticulated trilobite fragments that are fairly well preserved though commonly dorsally compressed. Species noted and illustrated in the present account include: *Paradoxides* (*Eccaparadoxides*) *eteminicus* Matthew, 1883, *Hartella terranovica* (Resser, 1937), *Bailiella manuelensis* Hutchinson, 1962 and *Badulesia* aff. *B. tenera* (Hartt in Dawson, 1868). The fauna evidently corresponds in part to the *Hartella* assemblage of Fletcher (in Bengtson and Fletcher, 1983, p. 533), equivalent to the topmost part of Howell's "*Paradoxides bennetti* Zone", used also by Hutchinson (1962) but now redundant. No evidence of *Paradoxides* (s.l.) *bennettii* Salter, 1859 was found by us, and all the paradoxidid material collected from Bed 32 belongs to *P.* (*E.*) *eteminicus*, a species first described from the Middle Cambrian of New Brunswick and said by Hutchinson (1962, p. 115) to be common in the "*P. bennetti* Zone" throughout eastern Newfoundland. The species has not yet been reported outside Eastern Canada, where a *P. eteminicus* Zone was employed in New Brunswick (Hayes and Howell, 1937, p. 56; Rasetti, 1952, p. 450), but *Eccaparadoxides* is a widespread genus, found in Sweden (for example, *Paradoxides insularis* Westergård, 1936, p. 39, Pl. 7, figs. 1-9), Europe and the Mediterranean region.

Although *Hartella matthewi* (Hartt in Dawson, 1868) was recorded from Beds 21 to 35 in the highest Chamberlains Brook Formation at Manuels by Howell (1925, p. 110), the species present is *H. terranovica* (Resser, 1937), reported from various parts of eastern Newfoundland by Hutchinson (1962, p. 95). The occurrence of *Hartella* on the east side of the Atlantic was appreciated by Howell (1925, p. 118, 126), who noted *H. solvensis* (Hicks, 1871) in southwest Wales and *H. exsulans* (Linnarsson, 1879) in Sweden, eponymous fossil of the Exsulans Limestone, lower part of the *Ptychagnostus gibbus* Zone (Westergård, 1950, p. 31).

Both *Badulesia* and *Hartella* have a limited vertical range but wide geographic distribution and so are of potential significance in international correlations. *Badulesia* was introduced by Sdzuy (1968, p. 111) in Spain, where the *Badulesia* Zone (Sdzuy, 1971; Palmer, 1979) has been equated with the uppermost "*P. bennetti* Zone" and lower part of the "*P. hicksi* Zone" (Sdzuy, 1971, Table 2). *Badulesia tenera* has been described from shale facies in Germany (Schmidt, 1942, p. 370), Spain, Morocco and Turkey, and *Hartella* from both shales and limestones that extend from southern France to Turkey (see Dean, 1985 for review of literature).

The present table (Fig. 3) modifies an earlier one (Martin and Dean, 1984, Figs. 57.3), in which unpublished evidence from southwest Wales provided by M. Lewis extended the vertical range of *Paradoxides* (*Hydrocephalus*) *hicksii* through the *Tomagnostus fissus* and *Ptychagnostus atavus* Zone to include the upper part of the *Ptychagnostus gibbus* Zone. Mr. Lewis's subsequent work now shows that for practical purposes the vertical ranges of *Paradoxides* (*Hydrocephalus*) *hicksii* and *Tomagnostus fissus* almost coincide. No agnostid evidence was obtained for correlating the highest Chamberlains Brook Formation with part of the *Ptychagnostus gibbus* Zone at either Manuels River or Random Island, and *Ptychagnostus gibbus* was not recorded from eastern Newfoundland by Hutchinson (1962). Howell's listing of *Agnostus* cf. *A. gibbus* from Beds 88 and 90, in almost the topmost part of his "*P. hicksi* Zone", must be questioned.

Manuels River Formation

The formation, said by Hutchinson (1962, p. 22) to be 20.7 m (68 ft) thick at the type section on Manuels River, consists of the Long Pond Formation (Beds 36-92) and the Kelligrew Brook Formation (Beds 93-125) of Howell (1925, p. 59). In Hutchinson's (1962, p. 22) statement that "the type section on Manuels River is 68 feet thick and includes Beds 26 to 125 of Howell's 1925 section", 26 is clearly a misprint for 36. Following the interpretation of Martin and Dean (1981), Howell's Bed 125 is taken as the basal

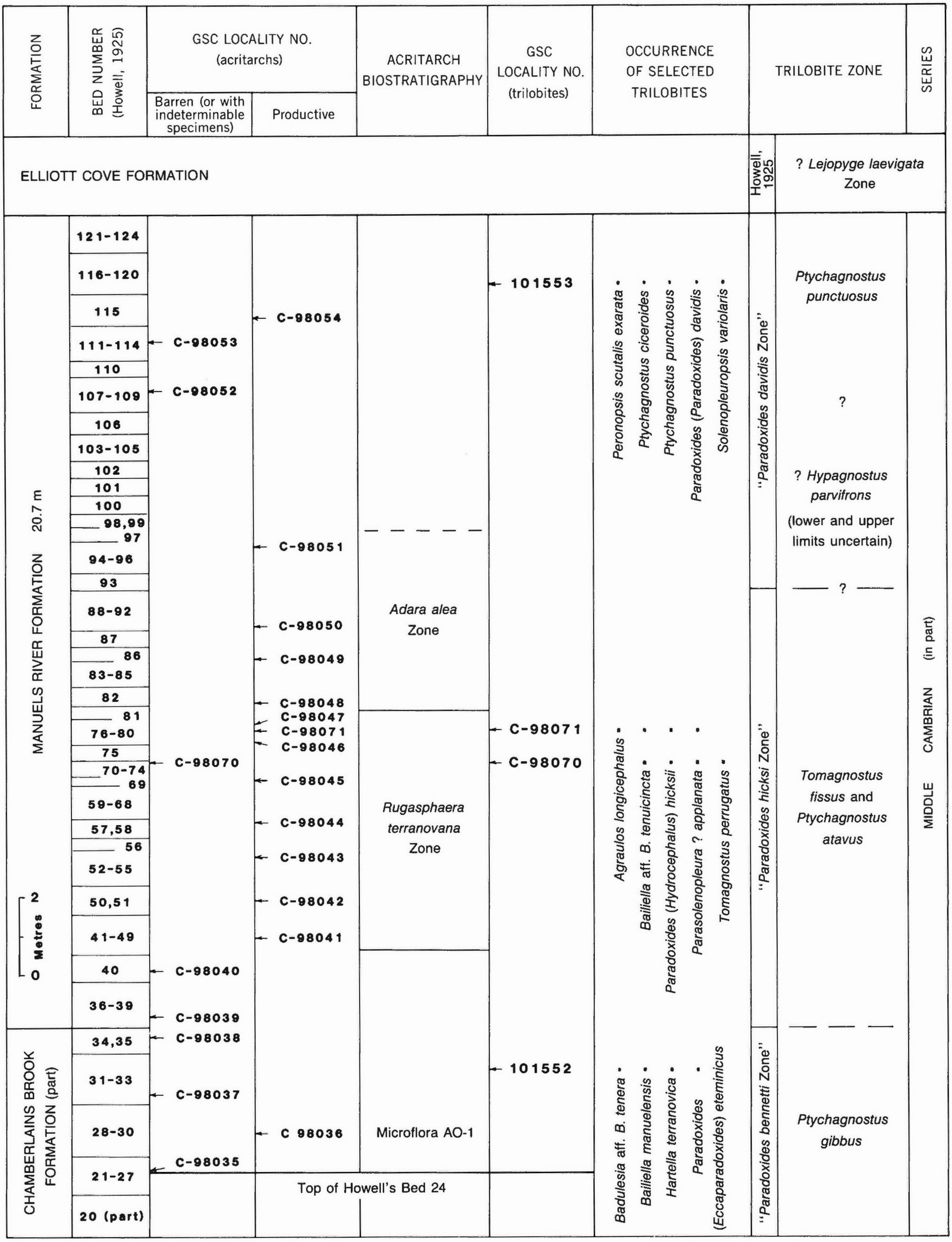

Figure 3. *Acritarch and trilobite zonation scheme for the Manuels River Formation and topmost Chamberlains Brook Formation at Manuels River. Column on the left shows stratigraphic succession of beds numbered by Howell (1925). GSC localities and corresponding acritarch and trilobite zones are shown opposite numbered beds.*

conglomerate of the Elliott Cove Formation; this is also in accordance with Hutchinson's (1962, p. 143) interpretation of the corresponding bed at Random Island. Howell described Bed 36 as "One-half inch of soft blue shale, underlain by one and a half inches of unctuous white clay. The clay, like the similar, but thinner ones, in the beds above, is probably the result of the weathering of a shale bed". The clay bed, one of four (Beds 36, 42, 60, 123) recorded by Howell, is apparently bentonitic; samples collected by us and examined at the Institute of Sedimentary and Petroleum Geology, Calgary, for the purpose of obtaining mineral grains suitable for fission-track dating (references in Ross, 1984, p. 317) proved fruitless. Evidence of volcanicity elsewhere in the Manuels River Formation was noted by Hutchinson (1962, p. 23), who recorded, without giving details, an interbedded volcanic rock in the area around the heads of Trinity Bay and St. Mary's Bay (Fig. 1).

Most of the formation at Manuels River comprises dark grey to black, often pyritous mudstone and shale with minor beds of dark grey limestone, generally impersistent and sometimes fossiliferous. Although Howell's faunal lists contain numerous genera and species, much of the rock thickness is unfossiliferous and macrofossils, particularly trilobites, tend to be concentrated in thin (up to 1 mm) layers.

Although both index species of Westergård's B2 *Ptychagnostus atavus* and *Tomagnostus fissus* Zone have been described from eastern Newfoundland, some published records of their stratigraphic ranges are anomalous. *Tomagnostus fissus* (Lundgren in Linnarsson, 1869) was stated by Hutchinson (1962, p. 77) to be one of the most common macrofossils in the "*P. hicksi* Zone", and was recorded (as *Agnostus fissus*) by Howell (1925, p. 115) from Beds 41 to 91 at Manuels River. On the other hand, *Ptychagnostus atavus* was recorded by Hutchinson (1962, p. 83) from both the upper part of the "*P. hicksi* Zone" and the lowest beds of the "*P. davidis* Zone". This is at variance with the evidence from both Scandinavia (Westergård, 1953, p. 36) and England and Wales (Lewis in Martin and Dean, 1984, p. 432; Thomas et al., 1984, p. 11), where *Paradoxides* (*Paradoxides*) *davidis* is recorded only from the *Ptychagnostus punctuosus* Zone. In the present study, *Tomagnostus perrugatus* (Gronwall, 1902), a species that ranges from the *Ptychagnostus gibbus* Zone to the *Hypagnostus parvifrons* Zone in Sweden (Westergård, 1946, p. 60), was found with *Paradoxides* (*Hydrocephalus*) *hicksii* at the level of Howell's Bed 73.

Detailed faunal lists from the highest part of the formation at Manuels River were published by Bergstrom and Levi-Setti (1978), who introduced three new subspecies of *Paradoxides* (*Paradoxides*) *davidis*. They recorded, among others, *Ptychagnostus punctuosus* from Howell's Beds 115 to 121, in the upper part of their recorded range of *Paradoxides* (*Paradoxides*) *davidis*. Relatively uncrushed examples of the two forms, together with *Ptychagnostus ciceroides* (Matthew, 1896) and *Peronopsis scutalis* (Hicks, 1872) *exarata* (Gronwall, 1902) were collected by us from an impersistent bed of dark limestone, 11 cm thick (GSC loc. 101553) that corresponds to part of Bed 117 of Howell and served as a convenient datum for measurements of overlying strata.

Of particular interest in the trilobite fauna of the *Ptychagnostus punctuosus* Zone is *Solenopleuropsis variolaris* (Salter, 1864), listed by Howell only from Bed 115 but recorded by Bergstrom and Levi-Setti from Beds 115 to 120; a cranidium from GSC loc. 101553 (Bed 117) is figured herein (Pl. 4, figs. 7, 9). *Solenopleuropsis variolaris* occurs also with *Paradoxides* (*Paradoxides*) *davidis* in South Wales, where the species was first described, and in the English Midlands (Lake, 1931, p. 141). But the genus has a wide geographic distribution throughout the Mediterranean region, including southern France, as far as southeastern Turkey and is sufficiently limited in its vertical range to serve as an index for Sdzuy's (1971, 1972; see also Palmer, 1979) *Solenopleuropsis* Zone in the upper Middle Cambrian of Spain.

No evidence of the *Goniagnostus nathorsti* Zone or the *Solenopleura*? *brachymetopa* Zone is known from the uppermost Manuels River Formation.

Elliott Cove Formation

Although Howell (1925) documented the Manuels River Formation at Manuels in great detail, he wrote little on the overlying Elliott Cove Formation (Fig. 4), which he estimated as "probably some 400 to 500 feet thick". He did, however, record on a map (1925, Fig. 3), the occurrence of *Agnostus pisiformis*, *A. pisiformis obesus* (now *Homagnostus obesus*), *Olenus* and *Orusia lenticularis*; he also noted (1925, p. 27) the possible presence of the "*Paradoxides forchhammeri*" and "*Agnostus laevigatus*" zones. Subsequently Hutchinson (1962, p. 127) listed thirty-two numbered beds within the incomplete section of what he termed the Elliott Cove Group. His total thickness of 188 m (617 ft) corresponds closely to the present estimate of 190 m (623 ft) overall, though only about 155 m are exposed along the river. The section ends under a cover of Recent deposits at the mouth of Manuels River, where the rocks dip north-northwest beneath the waters of Conception Bay (Figs. 1, 2). Several fossil localities were cited by Hutchinson, but not all are to be found in his accompanying descriptions of fossils, and their age was not stated.

Hutchinson (1962, p. 24, 27) regarded the whole of the Elliott Cove Formation as Upper Cambrian, with the *Lejopyge laevigata* Zone unrepresented in eastern Newfoundland. His conclusion was not surprising in view of the paucity of significant trilobites, but prolonged collecting by Poulsen and Anderson (1975) yielded a small faunule, said to include, among others, the zonal index fossil, from the basal 1.5 m of the formation at Manuels River.

Rushton (1978, p. 249, 257) considered that most of, if not all, Poulsen and Anderson's specimens of "*Lejopyge laevigata*" belonged not to that species, but to *Grandagnostus falanensis* (Westergård, 1947), a longer-ranging form that extends upward from the *L. laevigata* Zone into the *Olenus* Zone (see later). Robison (1984, p. 44) also believed that Poulsen and Anderson's material did not belong to the genus *Lejopyge*, but might represent *Grandagnostus*. Three of the four specimens from Manuels River determined by Hutchinson (1962, p. 80) as *Oidalagnostus* cf. *O. trispiniger* (sic) Westergård, 1946 were confirmed by Rushton (1978, p. 249) as *O. spinifer*, recorded only from the upper part of the *L. laevigata* Zone (Westergård, 1946). Using Hutchinson's section, Rushton suggested that the base of the *Agnostus pisiformis* Zone (and of the Upper Cambrian) at Manuels River lies between 16.5 m (horizon with *O. spinifer*) and 21 m (horizon with *Cristagnostus papilio* Rushton, 1978, characteristic of the *A. pisiformis* Zone in England) above the base of the Elliott Cove Formation. The present work suggests that these figures are overestimates.

No distinctive fossils of the *L. laevigata* Zone were found in the present sampling and the zone is used with a question-mark in text and figures. *Agnostus pisiformis* was collected, though less well preserved than at Random Island, at GSC locs. 101554 and 101555, associated with *Grandagnostus falanensis*. The former is known as early as the *L. laevigata* Zone in Sweden (Westergård, 1946, p. 85, 102), and the latter ranges from the *L. laevigata* Zone to the *Olenus* Zone.

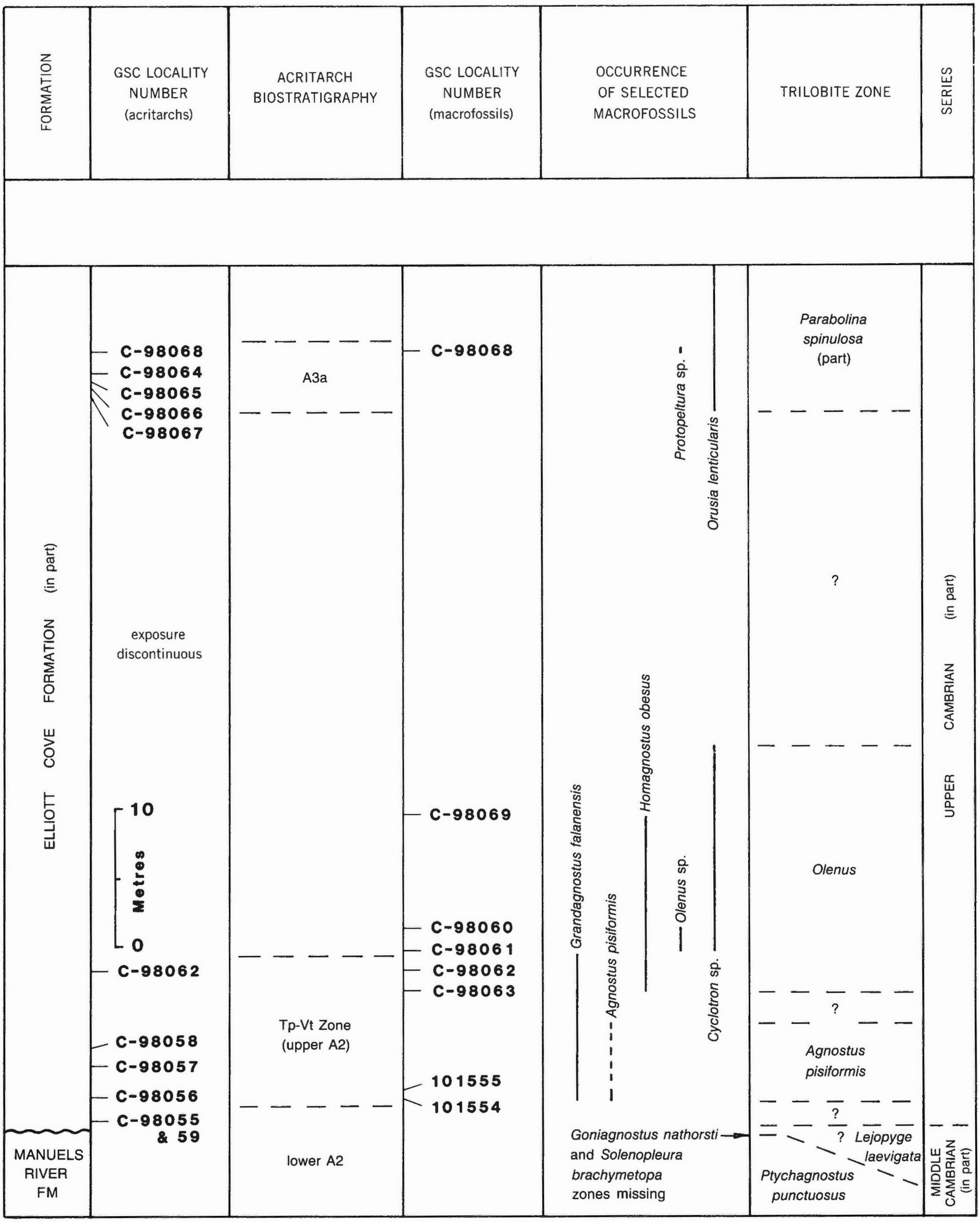

Figure 4. *Estimated stratigraphic position of samples collected from the lower part of Elliott Cove Formation at Manuels River. Vertical distribution of selected macro- and micro-fossils is also shown.*

Only a few specimens of *Olenus* were found (GSC locs. C-98060, C-98061) at Manuels River and, again, were less well preserved than at Random Island. No pygidia were seen and all the cranidia were compressed and distorted; the material is referred only to *Olenus* sp. *Homagnostus obesus* (Belt, 1867) was found in much greater abundance and is confined to the *Olenus* Zone (Henningsmoen, 1958, p. 183); the species is widespread, occurring in Wales (its type area), England and Scandinavia. The fauna of the *Olenus* Zone may contain locally abundant individuals, compressed in thin (1 mm) layers, but is of limited variety and the only other forms were *G. falanensis*, the upper limit of its range, and isolated valves of the bradoriid crustacean *Cyclotron* sp. The latter genus (Rushton, 1969), described first as *Polyphyma* Groom, 1902 (preoccupied) from the Midlands of England, occurs also in Scandinavia and has been found throughout the Upper Cambrian, though certain species have a restricted range.

Exposure of younger strata was discontinuous and an estimated 50 m of rock, from which no macrofossils were obtained, separated our highest record of the *Olenus* Zone and the first record of the *Parabolina spinulosa* Zone. The zonal olenid of the latter zone, though abundant at Random Island, was not found at Manuels River, where the only trilobites were two specimens assigned to *Protopeltura* sp. The small brachiopod *Orusia lenticularis* (Wahlenberg, 1821), found also in Scandinavia, England, Wales and New Brunswick, proved to be widely distributed through the section; according to Henningsmoen (1958, p. 187) the species is confined to the *P. spinulosa* Zone, here estimated to be at least 84 m thick.

LITHOSTRATIGRAPHY AND TRILOBITE ZONES, NORTHWEST COAST OF RANDOM ISLAND

W.T. Dean

Chamberlains Brook Formation (upper part)

On the northwest coast of Random Island, about 3 km south of Elliotts Cove (Fig. 5), Hutchinson (1962, p. 144) listed a continuous measured section 83.82 m (275 ft) thick of Chamberlains Brook Formation, underlain by still lower, but poorly exposed beds of the same formation that are faulted against Precambrian rocks to the southeast (map in Jenness, 1963). The highest strata (Hutchinson's Bed 8), comprising 26.5 m (87 ft) of green-grey, slaty shale that exhibits pencil cleavage, were said to be overlain conformably by dark, pyritous shale of the Manuels River Formation. Weathering of the highest Chamberlains Brook Formation is both conspicuous and distinctive, and produces a scree of long, almost pencil-like, splintery fragments. The underlying beds of the formation at this section comprise alternations of red and green shale and mudstone, the lower strata including minor pink and grey, nodular limestone. Acritarchs from the topmost 54 m (approx.) of the section were described by Martin (in Martin and Dean, 1984). The rock sequence exhibits many detailed differences from that at the type section at Manuels River, although the overall thickness may not differ much. At both sections, the greater part of the succession proved barren of macrofossils, but whereas the highest 4.1 m (13.5 ft) at Manuels River was relatively fossiliferous, the whole section at Random Island yielded no more than a few fossil fragments, including part of a large, distorted cranidium of *Paradoxides* (s.l.) sp. undet., 4.5 m below the top of the formation. No trilobites indicative of the *Hartella* assemblage of Fletcher (in Bengtson and Fletcher, 1983) were found at Random Island, though they were abundant at Manuels (see earlier); but it is evident that trilobite distribution in these strata is influenced by facies changes, and *Hartella terranovica* (Resser, 1937) was collected earlier by W.T. Dean from a bed of pink and grey limestone (GSC loc. 85218) on the mainland at Harcourt, 7 km north-northeast of Elliotts Cove (see Martin and Dean, 1981, Fig. 1 for map and place names).

Manuels River Formation

Rocks of this division succeed strata assigned by Hutchinson (1962, p. 144) to the uppermost Chamberlains Brook Formation. The boundary of the two may be conformable, but is affected by faulting (Martin and Dean, 1984). The succession, 29 m (95 ft) thick according to Hutchinson, is well exposed in the cliffs 1.5 km north of Weybridge (Fig. 5), and consists of dark grey to black shale and blocky mudstone, with minor beds of grey siltstone and, occasionally, calcarenite. The rocks are not only much less fossiliferous than at Manuels River, but are also well jointed. This made it difficult to extract trilobites that occurred in thin (1-2 mm) layers on bedding planes within the shales. The acritarchs contained in these beds were described by Martin (in Martin and Dean, 1984).

The lowest unit of the Manuels River Formation comprises grey silty shale about 2.7 m thick, cut by calcite veins and slightly contorted. These rocks, too, weather to form splinter-like fragments, though smaller than those of the Chamberlains Brook Formation, and mark a transition to the next higher unit. The latter, which comprises 2.6 m of massive, dark grey mudstone and shale, is more resistant to erosion than adjacent strata and forms a marked feature in the cliff and on the shore. The 2.6 m thick unit, which yielded no more than traces of macrofossils, is succeeded by 3.9 m of dark grey shale with brown weathering, thin beds of siltstone.

Tomagnostus fissus *and* Ptychagnostus atavus *Zone*

Up to this point in the formation, no recognizable macrofossils were observed, but at GSC loc. 89107 (Martin and Dean, 1984, Fig. 3), a conspicuous bed of silty, grey limestone 12 to 20 cm thick, yielded numerous trilobite fragments, particularly in the lowest few centimetres. The most abundant, well preserved form was *Eodiscus punctatus* (Salter, 1864) *scanicus* (Linnarsson, 1883), accompanied by agnostids including, among others, the zonal index *Tomagnostus fissus*. Broken fragments of *Paradoxides* were common and some were identified as *Paradoxides* (*Hydrocephalus*) *hicksii*. The stratum is probably Bed 11, GSC loc. 20477, of Hutchinson (1962, p. 144).

The succeeding part of the formation was shown diagrammatically in Martin and Dean (1981, Fig. 3). An impersistent bed of grey, silty limestone up to 15 cm thick (GSC loc. 89106, 14 m below the top of the formation) contained fragments of *P.* (*H.*) *hicksii* and a pygidium of *Clarella venusta* (Billings, 1874); the stratum is probably GSC loc. 20483 of Hutchinson, 1962, p. 112, 144). According to Hutchinson (1962, p. 111), *C. venusta* is both rare and confined to the "*P. hicksi* Zone" in eastern Newfoundland, though he described *Clarella* sp. from the "*P. davidis* Zone". *Clarella* cf. *C. venusta* is reported from southern France, possibly in strata containing *Solenopleuropsis* (Courtessole,

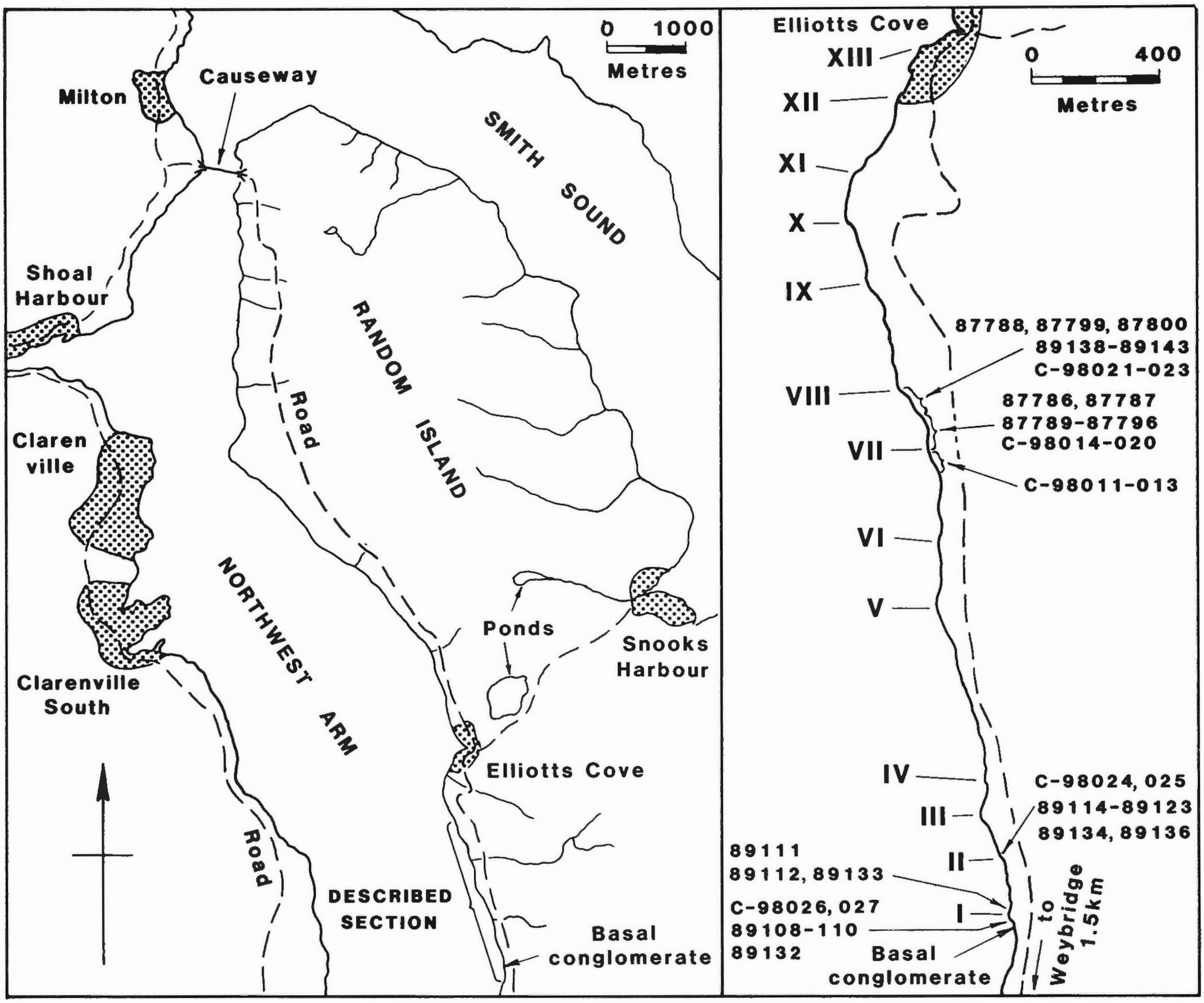

Figure 5. *Left: map of northwest half of Random Island and surrounding area showing location of stratigraphic section and fossil localities cited in text, but not listed in Martin and Dean (1981, 1984). Right: enlarged map of coast of Random Island, south of Elliotts Cove, showing additional detail of localities not listed in Martin and Dean (1981, 1984). Roman numerals I to XIII denote promontories used for locating samples cited in text.*

1975), though the age is uncertain; *C. impar* (Hicks, 1872) occurs in the *H. parvifrons* Zone of southwest Wales and the Midlands of England (Thomas et al., 1984, p. 11), and *C.* cf. *C. impar* in the *Ptychagnostus punctuosus* Zone of Sweden (Westergård, 1953, p. 36).

?Hypagnostus parvifrons *Zone*

The highest record of *Paradoxides* (*Hydrocephalus*) *hicksii* and the lowest record of *Paradoxides* (*Paradoxides*) *davidis* are separated by 2.4 m of dark grey shale. No macrofossils were found in this shale and the beds are equated only tentatively with the *H. parvifrons* Zone.

Ptychagnostus punctuosus *Zone*

No agnostids were found in the uppermost part of the formation, but at least the topmost 12.3 m fall within the range of *Paradoxides* (*Paradoxides*) *davidis* and so are assigned to the *Ptychagnostus punctuosus* Zone for reasons already discussed in the section on Manuels River.

Elliott Cove Formation

The strata making up the type section (Fig. 6) vary from dark, pyritous shale through grey, silty, micaceous shale to thinly and thickly bedded, grey siltstone and fine grained sandstone. The beds above the Manuels River Formation were measured in ascending order northwestward along the coast of Random Island toward Elliott's Cove settlement. Parts of the succession are straightforward, but others have local complications caused by both folding and small-scale faults, which could not be estimated either because of frequent cliff falls or the absence of suitable datum horizons. There are also a number of variations in both dip and strike. This part of the coast lacks both habitations and conspicuous topographic features, and suitable landmarks are difficult to find. In an earlier paper (Martin and Dean, 1981, Fig. 2), the first to give a description of acritarchs throughout the formation, it was found convenient to use the series of small promontories along the coast, north of the easily recognized conglomerate at the base of the formation; the promontories were numbered I to XIII from south to north, and the same convention is used here (Fig. 5).

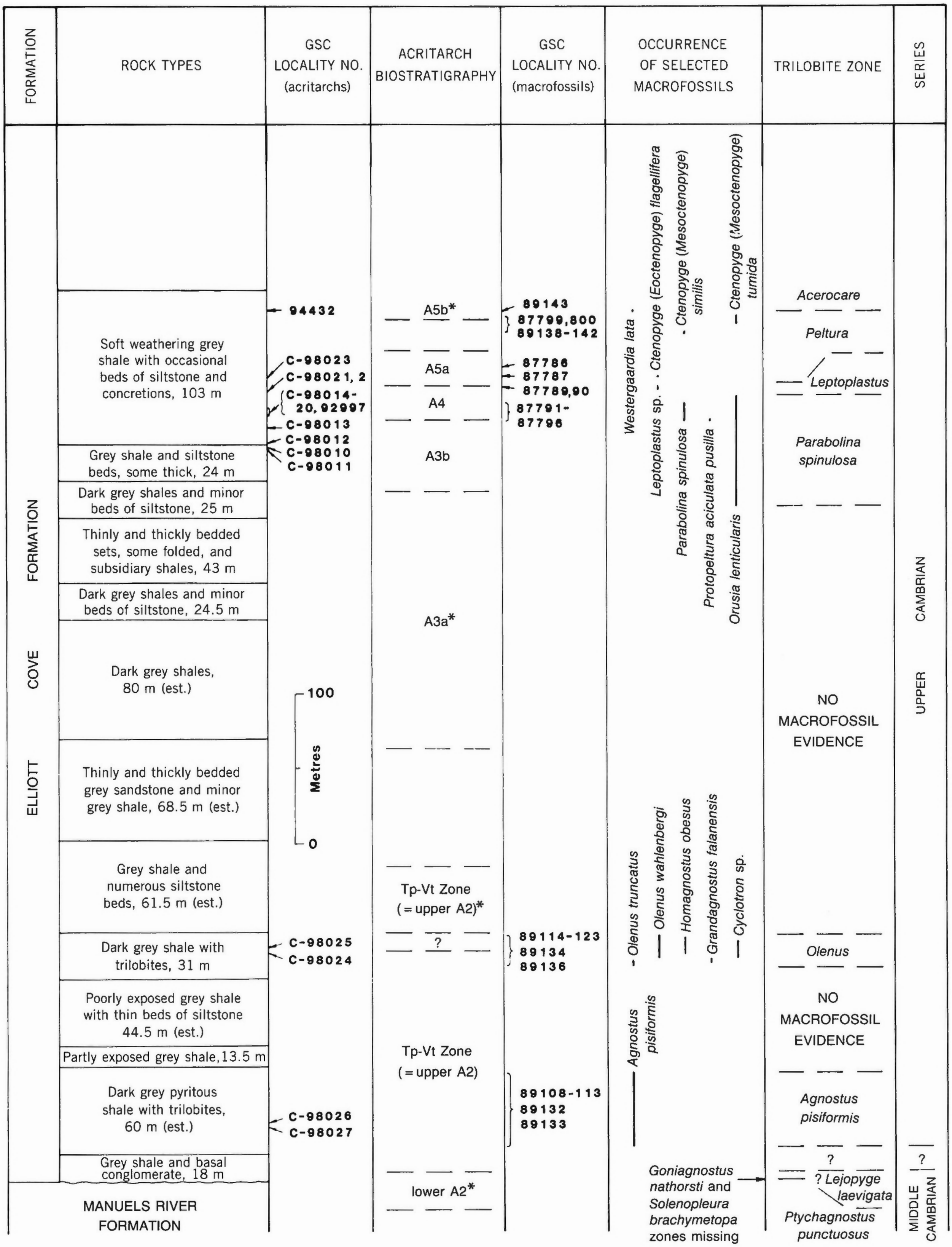

Figure 6. *Generalized stratigraphic section through the type Elliott Cove Formation showing estimated position of samples cited in text, vertical distribution of acritarch assemblages and trilobite zones, and occurrence of selected macrofossils. Ranges of microfloras established on the basis of data in Martin and Dean (1981), with appropriate nomenclatural modifications, are indicated by an asterisk (*). Vertical scale in part of the succession is exaggerated slightly in order to show closely-spaced stratigraphic levels and localities.*

As Hutchinson (1962, p. 50) pointed out, the Elliott Cove Formation as a whole is sparsely fossiliferous and detailed correlation with the established sequence of trilobite zones is, therefore, generally imprecise, though the zonal position of some levels can be determined with confidence. Rushton (in Taylor and Rushton, 1972, p. 21) noted the lithological resemblance of grey shale from the Elliott Cove Formation to rocks of approximately similar age in the English Midlands; such a comparison applies to the predominantly argillaceous lower and upper parts of the succession but does not take account of the substantial development of sandstone in approximately the middle third of the formation, which has not been found elsewhere.

In the lowest 4 m of the formation, Poulsen and Anderson (1975) found trilobites interpreted by them as indicative of the *Lejopyge laevigata* Zone, uppermost Middle Cambrian. These were said to include the zonal agnostid species, but Rushton (1978) has since considered the material to belong to *Grandagnostus falanensis* (Westergård, 1947), a species known from the *L. laevigata* Zone to the *Olenus* Zone. Because of this uncertainty, the *L. laevigata* Zone is indicated only questionably in our tables, as at Manuels River.

During the present sampling, *Agnostus pisiformis pisiformis* was found in abundance in dark grey shale at an estimated 22.7 m above the base of the formation (GSC loc. 89108) and at several levels through almost 50 m of rock, which are assigned to the *A. pisiformis* Zone.

No macrofossils were obtained between the beds containing *A. pisiformis* and a conspicuous unit of dark shale, almost 31 m thick, that crops out just south of Promontory II. As is so often the case in the area, fossils were found in thin (1 mm or less) layers, and although specimens were occasionally plentiful, they showed little variety. The section and samples from it were noted briefly in Martin and Dean (1981, p. 11). The most common trilobite was the zonal genus *Olenus*, including *O. truncatus* (Brünnich, 1781) and, slightly higher, *O. wahlenbergi* Westergård, 1922; these species indicate successive horizons in the middle part of the *Olenus* Zone (Henningsmoen, 1957, p. 300; 1958, p. 191). *Grandagnostus falanensis* was found at two levels in the lower half of the unit, and *Homagnostus obesus* (Belt, 1867) at three levels in the upper half. An uncommon component of the fauna was the bradoriid crustacean *Cyclotron* sp., and the assemblage is comparable with that of the *Olenus* Zone at Manuels River, though trilobites were more abundant.

From the top of the dark shale unit of the *Olenus* Zone there is a progressive increase of medium to thick, occasionally very thick bedded, fine grained sandstone units that weather light brown, but are commonly grey when fresh. Intervening shale beds are notably less well developed than in the lower part of the formation, and units rarely exceed 5 m in thickness; the shale is usually silty, or interbedded with thin beds of siltstone or fine grained sandstone, but is occasionally dark and pyritous. The sandstone beds, which are more resistant than the regressively weathering shale, sometimes form conspicuous features, a good example being a bed 80 cm thick at the base of Promontory III. They constitute an important part of the succession between Promontories II and VII, which makes up about one third of the thickness of the formation.

In the embayment between Promontories VI and VII is a prominent exposure of thin and medium bedded, brown to grey, fine grained sandstone, some beds of which show ripple marks; the unit, about 6.25 m thick, forms an anticlinal fold in the lower part of the cliff. At an estimated 14 m below the sandstone unit, and on the south side of Promontory VI, *Orusia lenticularis* was found in abundance in the upper half of a 6 m unit of grey, silty shale with occasional thin siltstone beds; no trilobites were found, but this level was taken as the base of the *Parabolina spinulosa* Zone. Strata above the folded sandstone unit become progressively more argillaceous and about 34 m of dark grey, brown weathering shale extend to Promontory VII. There are numerous thin beds of grey siltstone or fine grained sandstone in the lower half of the shale, but few in the upper half, where *O. lenticularis* was common. In the absence of other evidence, Taylor and Rushton (1972, p. 20) drew the boundary between the *Olenus* Zone and the *P. spinulosa* Zone in the English Midlands at "the appearance in force" of *O. lenticularis*, and the situation at Random Island is comparable.

The rocks in the uppermost part (approximately one third) of the Elliott Cove Formation consist mainly of soft, fissile, usually dark grey shale that weathers to produce screes of small fragments. Silty or sandy beds are apparently uncommon. Fallen and slumped masses of cliff obscure parts of the outcrop and thicknesses shown in Figure 6 are approximate. The bay between Promontories VII and VIII contains cliff exposures of commonly folded strata, in which were found several thin (1 mm or less) fossil bands. This is almost certainly the "small cove about one mile south of Elliott's Cove" where Hutchinson (1962, p. 28) found "a thin bed of black shale" with *Parabolina spinulosa*. It was difficult to measure these fossiliferous strata in detail due to folding and small-scale faulting, but the lowest third of a shale unit approximately 38 m thick on the north side of Promontory VII yielded trilobites of the *P. spinulosa* Zone. The specimens, though dorsally compressed, are well preserved and almost all belong to *Parabolina spinulosa* (Wahlenberg, 1821), used by Henningsmoen (1957, p. 128, 299; 1958, p. 191) as the subzonal index for the upper half of the zone. *Orusia lenticularis* was also found, sometimes locally abundant and occasionally covering bedding planes, not all of which were given formal locality numbers. A rare trilobite in the *P. spinulosa* Subzone at GSC loc. 87794 was *Protopeltura aciculata pusilla* (Westergård, 1922), found at the same horizon in Sweden and Norway (Henningsmoen, 1957, p. 223; 1958, p. 191). An unidentified species of *Protopeltura* was found at a similar horizon at Manuels River. Fragmentary evidence of *P. aciculata* was recorded from the *P. spinulosa* Zone in a borehole in central England by Taylor and Rushton (1972, p. 21). No evidence of the *Parabolina brevispina* Subzone, lower half of the *P. spinulosa* Zone, was found at Random Island, and the base of the *P. spinulosa* Zone there is drawn arbitrarily (Fig. 6) below the first record of *Orusia lenticularis*.

The strata with *Parabolina spinulosa* are apparently (there is an intervening small fault) succeeded by shale in which *Leptoplastus* sp. was occasionally found (GSC locs. 87789, 87790). Relationships of the strata containing *Leptoplastus* with the overlying beds are also affected by faulting, but GSC loc. 87787 yielded fragments of *Ctenopyge (Eoctenopyge) flagellifera* (Angelin, 1854), confined to the topmost subzone of the *Protopeltura praecursor* Zone, lowest of the three *Peltura* zones of Henningsmoen (1957, 1958). The succeeding dark shale (an estimated 12 m) yielded no macrofossils.

The highest part of the exposed section (Fig. 6) comprised grey shale, with minor, thin beds of siltstone, in which trilobites of the *Peltura* zones were numerous, though often fragmentary and poorly preserved. This part of the succession was much obscured by a large, slumped mass of cliff in which fossiliferous blocks (not considered here) were found; *in situ* specimens were collected from the upper part of the adjacent cliff face. During the collecting for this study, *Peltura* was not found there, but evidence of the remaining *Peltura* zones of Henningsmoen (1957) was provided by dorsally compressed specimens, mostly cranidia, at GSC loc. 87000. These are assigned, in some cases questionably, to *Ctenopyge* (*Mesoctenopyge*) *similis* Henningsmoen, 1957. Material slightly higher in the succession (GSC locs. 87799, 89138, and 89139) was identified, again questionably in part, as *Ctenopyge* (*Mesoctenopyge*) *tumida* Westergård, 1922. Lack of well preserved librigenae and pygidia proved to be a hindrance, but study of the material suggests that at least 5 m of shale belong to the *Peltura minor* Zone, second of Henningsmoen's three *Peltura* zones. No precise evidence of age was found in the succeeding 8 m of shale, which yielded trilobite fragments that were identifiable only at the generic level, including *Ctenopyge* (s.l.) sp. at GSC loc. 89140.

Elsewhere on the northwest coast of Random Island, *Peltura scarabaeoides scarabaeoides* (Wahlenberg, 1821), *Ctenopyge* (*Ctenopyge*) *linnarssoni* Westergård, 1922 and *Sphaerophthalmus majusculus* Linnarsson, 1882 were collected from GSC loc. 89793, about 1800 m southeast of the southeastern end of Bounds Mead, 3 km northwest of Elliotts Cove. Acritarchs were collected earlier from this locality (noted as GSC loc. 94435, A5a in Martin and Dean, 1981, p. 11). The trilobite assemblage indicates the lower half of the *Peltura scarabaeoides* Zone, highest of Henningsmoen's (1957, p. 299; 1958, p. 190) three *Peltura* zones.

The highest beds in the section (Fig. 6) produced only a few trilobite fragments and a cranidium of *Westergaardia lata* (Matthew, 1891), a species described first from New Brunswick and found also in Nova Scotia and Norway (Henningsmoen, 1957, p. 256). *Westergaardia* is the nominal genus for the third highest of the four subzones of the *Acerocare* Zone (Henningsmoen, 1957, p. 39; 1958, p. 190), uppermost Upper Cambrian, and the specimen is the only firm evidence of that zone found during the collecting for this study. Shale at GSC loc. 94432, 15 cm higher in the succession, was sampled for acritarchs (A5b, Martin in Martin and Dean, 1981) and is also considered to belong to the *Acerocare* Zone.

SYSTEMATIC DESCRIPTIONS OF TRILOBITES

W.T. Dean

The following pages are not intended as a comprehensive account of Middle and Upper Cambrian trilobites from Manuels River and Random Island. Several species were described by Hutchinson (1962), and Bergström and Levi-Setti (1978) documented variation in *Paradoxides davidis*, but illustrations of others from the region have not been published, and comments on their distribution are relevant to the present work. Specimens of three Middle Cambrian species from New Brunswick are illustrated for comparison. In the systematic descriptions, terminology follows that of the Treatise on Invertebrate Paleontology (Harrington, Moore and Stubblefield, in Moore, 1959, p. O117) and, where appropriate, that of Öpik (1961) for agnostids.

Family EODISCIDAE Raymond, 1913

Genus *Eodiscus* Hartt in Walcott, 1884

Type species. Eodiscus pulchellus Hartt in Walcott, 1884 (=junior subjective synonym of *Microdiscus scanicus* Linnarsson, 1883).

Eodiscus punctatus (Salter, 1864)
scanicus (Linnarsson, 1883)

Plate 1, figures 8, 9

Microdiscus scanicus Linnarsson, 1883, p. 29, Pl. 4, figs. 17, 18.
Eodiscus scanicus (Linnarsson). Rasetti, 1952, p. 447, Pl. 53, figs. 7-16; Pl. 54, figs. 10-16. Includes synonymy.
Eodiscus scanicus (Linnarsson). Hutchinson, 1962, p. 59, Pl. 2, figs. 1a-c, 2a-c.
Eodiscus punctatus (Salter) *scanicus* (Linnarsson). Thomas, Owens and Rushton, 1984, p. 11.

Figured specimens. GSC 83271 (Pl. 1, fig. 8), GSC 83272 (Pl. 1, fig. 9).

Occurrence and discussion. Although Howell (1925) recorded *Eodiscus punctatus* from both the "*Paradoxides hicksi* Zone" and "*Paradoxides davidis* Zone", Rasetti (1952, p. 449) noted that the species occurs only in the "*P. davidis* Zone" at Manuels. Hutchinson (1962) distinguished between *E. scanicus*, from the "*P. hicksi* Zone", and *E. punctatus*, from the "*P. davidis* Zone"; whether regarded as species or subspecies, the two appear to have discrete stratigraphic ranges.

Eodiscus punctatus scanicus, abundant in a bed of calcareous siltstone at GSC loc. 89107, Manuels River Formation, Random Island, was not found in adjacent shale at the same section. It proved to be more common, even in shale, at Manuels River; in both cases the strata contain *P.* (*H.*) *hicksii* and are assigned to the *Tomagnostus fissus* Zone.

Family AGNOSTIDAE McCoy, 1849

Subfamily AGNOSTINAE McCoy, 1849

Genus *Agnostus* Brongniart, 1822

Type species. Entomostracites pisiformis Wahlenberg, 1821.

Agnostus pisiformis pisiformis (Wahlenberg, 1821)

Plate 5, figures 1-4, 7, 9

Entomostracites pisiformis Wahlenberg, 1821, p. 42, Pl. 1, fig. 5.
Agnostus (*Agnostus*) *pisiformis* Linnaeus, 1757. Henningsmoen, 1958, p. 181, Pl. 5, figs. 1-12. Includes synonymy.
Agnostus pisiformis (Linnaeus). Hutchinson, 1962, p. 86, Pl. 12, figs. 2-6.
Agnostus pisiformis pisiformis (Wahlenberg, 1818). Rushton, 1978, p. 258, Pl. 24, figs. 15-19. Includes synonymy.

Figured specimens. GSC 32661 (Pl. 5, fig. 4), GSC 32662 (Pl. 5, fig. 1), GSC 32683 (Pl. 5, fig. 2), GSC 32684 (Pl. 5, fig. 7), GSC 32685 (Pl. 5, fig. 3), GSC 83305 (Pl. 5, fig. 9).

Occurrence. On the northwest coast of Random Island *A. pisiformis pisiformis* was found at nine localities ranging from 23 m to 73 m above the base of the Elliott Cove Formation (Fig. 6). Specimens were less common and less well preserved at Manuels River, being found at GSC loc. 101555 and, questionably, GSC loc. 101554, at an estimated 4.6 m and 5.75 m, respectively, above the base of the formation. Other questionable records were from unnumbered levels 12.7 m and 15.2 m above the base of the formation.

Discussion. Detailed accounts of this well known species were provided by Lake (1906, p. 9) and Westergård (1946, p. 85), and the present material adds nothing new. Occasional pygidia (Pl. 5, figs. 1, 4) exhibit traces of a mesh-like ornamentation of weakly developed ridges, but in others these parts are quite smooth (Pl. 5, fig. 7); similar differences in Scandinavian material were noted by Henningsmoen, 1958, p. 181). Very small differences in the proportions of both cephalic and pygidial axes may be the result of dorsal compression, though some intra-specific variation was noted by Westergård (1947, p. 4). The cephalon and pygidium of an immature dorsal exoskeleton (GSC 32683, Pl. 5, fig. 2) are both more quadrate in outline than those of large specimens; the pygidial axis of the same individual shows only weak segmentation.

Genus *Homagnostus* Howell, 1935

Type species. Agnostus pisiformis var. *obesus* Belt, 1867.

Homagnostus obesus (Belt, 1867)

Plate 5, figures 8, 14-16

Agnostus pisiformis var. *obesus* Belt, 1867, p. 295, Pl. 12, figs. 4a-d.
Agnostus pisiformis var. *obesus* Belt. Lake, 1906, p. 9, Pl. 1, figs. 13, 14.
Agnostus pisiformis obesus Belt. Westergård, 1922, p. 116, 193, Pl. 1, figs. 4a, b. (non figs. 5, 6 = *H. obesus laevis* Westergård, 1947).
Homagnostus obesus (Belt). Howell, 1935, p. 15, figs. 11, 12.
Agnostus (Homagnostus) obesus Belt. Westergård, 1947, p. 3, Pl. 1, figs. 10, 11.
Agnostus (Homagnostus) obesus Belt. Henningsmoen, 1958, p. 182, Pl. 5, figs. 13-16. Includes previous synonymy.
Homagnostus obesus (Belt). Palmer, 1960, p. 62, Pl. 4, figs. 7-9.
Homagnostus obesus (Belt). Howell in Hutchinson, 1962, p. 35.
Agnostus pisiformis obesus Belt. Hutchinson, 1962, p. 52.
Homagnostus obesus (Belt). Rushton, 1978, p. 259.

Figured specimens. GSC 32668 (Pl. 5, fig. 14), GSC 32670 (Pl. 5, fig. 15), GSC 32679 (Pl. 5, fig. 8), GSC 32681 (Pl. 5, fig. 16).

Occurrence. Elliott Cove Formation. GSC locs., in ascending order: 89114, 89116, 89117, 89120, 89121 and, questionably, 89122 at Random Island. Found uncommonly at GSC locs. C-98063, C-98062, C-98061 and C-98069, Manuels River.

Discussion. The present material adds nothing to the detailed accounts already available. According to Thomas et al. (1984, p. 13), *H. obesus* ranges through the whole of the *Olenus* Zone in England and Wales. During collecting for the present study, the species was found only in the upper half of the shale unit (Fig. 6) that yielded trilobites of the *Olenus* Zone at Random Island.

Subfamily QUADRAGNOSTINAE Howell, 1937

Genus *Grandagnostus* Howell, 1935

Type species. Grandagnostus vermontensis Howell, 1935.

Grandagnostus falanensis (Westergård, 1947)

Plate 5, figures 5, 6, 10-12

Ciceragnostus? *falanensis* Westergård, 1947, p. 7, Pl. 1, fig. 14.
Phalacroma bairdi Hutchinson, 1962, p. 90, Pl. 11, figs. 9-11.
Grandagnostus falanensis (Westergård, 1947). Rushton, 1978, p. 256, Pl. 24, figs. 6-14; Textfig. 3a. Includes synonymy.

Figured specimens. GSC 32687 (Pl. 5, fig. 6), GSC 32690 (Pl. 5, fig. 11), GSC 32694 (Pl. 5, fig. 5), GSC 83306 (Pl. 5, fig. 10), GSC 83307 (Pl. 5, fig. 12).

Occurrence. Elliott Cove Formation. Random Island, GSC locs. 89136, 89114, 89135 and 89134, in ascending order; all are in the *Olenus* Zone. Manuels River, GSC locs. 101554 (?*Lejopyge laevigata* Zone), 101555 (*Agnostus pisiformis* Zone), and C-98061 (*Olenus* Zone) in ascending order.

Discussion. Hutchinson's type material of *Phalacroma bairdi* came from the *Olenus* Zone at GSC loc. 21937, Manuels River; he stated that the species occurred only in the *A. pisiformis* and *Olenus* zones. In Sweden *G. falanensis* was recorded only from the *A. pisiformis* Zone by Westergård (1947, p. 22) but Rushton (1978, p. 258) showed it to extend from the *L. laevigata* Zone to the *Olenus* Zone in England and eastern Newfoundland. The present material agrees with published descriptions and demonstrates the difference in size between cephalon and pygidium (Pl. 5, figs. 6, 11); one compressed cephalon (Pl. 5, fig. 5) shows the impression of the inner margin of the doublure.

Genus *Peronopsis* Hawle and Corda, 1847

Type species. Battus integer Beyrich, 1845.

Peronopsis scutalis (Hicks, 1872) *exarata* (Grönwall, 1902)

Plate 4, figures 3, 8

Agnostus exaratus Grönwall, 1902, p. 77, 212; Pl. 1, fig. 17.
Agnostus exaratus Grönwall. Illing, 1916, p. 405, Pl. 28, fig. 1.
Peronopsis scutalis (Salter in Hicks, 1872). Westergård, 1946, p. 41, Pl. 4, figs. 4-11.
Peronopsis scutalis exarata (Grönwall, 1902). Rushton, 1979, p. 50.

Figured specimens. GSC 83295 (Pl. 4, fig. 3), GSC 83304 (Pl. 4, fig. 8).

Occurrence. Manuels River Formation, GSC loc. 101553, Manuels River; *Ptychagnostus punctuosus* Zone.

Description and discussion. Among the numerous fragmentary agnostids from a thin limestone bed with *Paradoxides (Paradoxides) davidis davidis* is a single pygidium referred to the Danish species. The pointed tip of the axis is slightly more distinct than in Grönwall's illustration, but otherwise agrees well with it. An associated cephalon (Pl. 4, fig. 8) compares closely with several assigned by Westergård (1946, Pl. 4, figs. 5, 6, 8) to *P. scutalis*, a species considered by him to be synonymous with *Agnostus exaratus*.

A cephalon (GSC 83282, Pl. 3, fig. 1) found in association with *Paradoxides (Hydrocephalus) hicksii* at GSC loc. C-98070, Manuels River, has a slightly wider, less cylindrical glabella than the above material, and is referred only to *Peronopsis* sp.

Subfamily PTYCHAGNOSTINAE Kobayashi, 1939

Genus *Ptychagnostus* Jaekel, 1909

Type species. Agnostus punctuosus Angelin, 1854.

Ptychagnostus ciceroides (Matthew, 1896)

Plate 4, figures 1, 2

Agnostus laevigatus ciceroides Matthew, 1896, p. 234, Pl. 17, figs. 3a, b.
Ptychagnostus ciceroides Matthew). Hutchinson, 1962, p. 85, Pl. 9, figs. 20-23; Pl. 10, figs. 1-8. Includes synonymy.

Figured specimens. GSC 83293 (Pl. 4, fig. 1), GSC 83294 (Pl. 4, fig. 2).

Occurrence and discussion. The species is represented by several fragmentary pygidia from the Manuels River Formation, GSC loc. 101553, Manuels River, in the *Ptychagnostus punctuosus* Zone. The largest example has a median length and maximum breadth of 5.2 mm and 4.9 mm, respectively; the rounded outline, swollen appearance, weakly defined axis and narrow border are particularly distinctive. Hutchinson (1962, p. 86) recorded *Ptychagnostus ciceroides* from the upper part of the "*Paradoxides hicksi* Zone" and the whole of the "*Paradoxides davidis* Zone" in eastern Newfoundland.

Ptychagnostus punctuosus (Angelin, 1851)

Plate 4, figures 5, 6, 10

Agnostus punctuosus Angelin, 1851, p. 8, Pl. 6, fig. 11.
Ptychagnostus (Ptychagnostus) punctuosus (Angelin, 1851). Westergård, 1946, p. 78, Pl. 11, figs. 34, 35; Pl. 12, fig. 1-7. Includes synonymy.
Ptychagnostus punctuosus (Angelin). Hutchinson, 1962, p. 84, Pl. 9, figs. 9-19 includes synonymy.
Ptychagnostus punctuosus. Bergström and Levi-Setti, 1978, p. 2.
Ptychagnostus punctuosus punctuosus (Angelin, 1851). Öpik, 1979, p. 89, Pl. 38, fig. 1; Pl. 39, figs. 1-7, 9, 10; Pl. 40, fig. 1; Textfig. 26.

Figured specimens. GSC 83300 (Pl. 4, fig. 5), GSC 83301 (Pl. 4, fig. 6), GSC 83302 (Pl. 4, fig. 10).

Occurrence and discussion. The present, well-preserved specimens are from the Manuels River Formation, GSC loc. 101553, Manuels River, where they are associated with *Paradoxides (Paradoxides) davidis*. The locality corresponds to Bed 117 (part) of Howell (1925), and Bergström and Levi-Setti (1978) recorded the species from Beds 115 to 121 at the same section.

Ptychagnostus sp.

Plate 3, figure 5

Figured specimen. GSC 83289.

Occurrence. Manuels River Formation, GSC loc. C-98071, Manuels River.

Discussion. A dorsally compressed exoskeleton from shale containing numerous fragments of *Paradoxides (Hydrocephalus) hicksii* at Manuels River is too compressed for specific identification. The outline of the pygidial axis generally resembles that of *Ptychagnostus atavus* (Tullberg, 1880) illustrated by Westergård (1946, Pl. 11, figs. 10, 17), but is wider posteriorly.

Family DIPLAGNOSTIDAE Whitehouse, 1936

Genus *Tomagnostus* Howell, 1935

Type species. Agnostus fissus Lundgren in Linnarsson, 1879.

Tomagnostus perrugatus (Grönwall, 1902)

Plate 3, figure 2

Agnostus fissus Lundgren MS., var. *perrugata* Grönwall, 1902, p. 50, Pl. 1, fig. 1.
Tomagnostus perrugatus (Grönwall, 1902). Westergård, 1946, p. 59, Pl. 8, figs. 1-10. Includes synonymy.

Figured specimen. GSC 83283.

Occurrence. Manuels River Formation, GSC loc. C-98070, Manuels River.

Discussion. The compressed cephalic fragment from shale with *Paradoxides (Hydrocephalus) hicksii* resembles material illustrated by Westergård (1946, Pl. 8, esp. figs. 1, 3), though the arcuate scrobicules (Öpik, 1961, p. 414) opposite the anterolateral angles of the frontal glabellar lobe are slightly smaller and narrower. The species was recorded from the *Ptychagnostus gibbus* to the *H. parvifrons* Zone in Sweden (Westergård, 1946, p. 100). Newfoundland examples were described by Hutchinson (1962, p. 77, Pl. 7, figs. 6-9), according to whom the species occurs mainly in the "*P. davidis* Zone" of eastern Newfoundland, and was found by him in the upper part of the "*P. hicksi* Zone" at only one locality.

Genus *Pseudagnostus* Jaekel, 1909

Type species. Agnostus cyclopyge Tullberg, 1880.

Pseudagnostus sp.

Plate 7, figure 3; Plate 8, figure 8

Figured specimens and occurrence. GSC 32643 (Pl. 7, fig. 3), GSC loc. 87792. GSC 32651 (Pl. 8, fig. 8). Elliott Cove Formation, GSC loc. 87796, Random Island.

Discussion. Both the cephala illustrated are from the *Parabolina spinulosa* Zone. Although insufficient for specific determination, they generally resemble a cephalon from the same zone in England assigned by Rushton (in Taylor and Rushton, 1972, p. 28, Pl. 8, fig. 1) to *P. cyclopyge* (Tullberg).

Family PARADOXIDIDAE Hawle and Corda, 1847

A number of genera introduced or reviewed by Šnajdr (1957, 1958) have been regarded either as synonyms of *Paradoxides* (for example C. Poulsen in Moore, 1959, p. 0213) or as subgenera of that genus (for example, Courtessole, 1973). The latter course is preferred here. Although the Chamberlains Brook Formation constitutes the basis of Howell's (1925) "*Paradoxides bennetti* Zone", no examples of that species were found in the highest beds at either Manuels River or Random Island. This accords with Fletcher's (in Bengtson and Fletcher, 1983, p. 533) positioning of an *Eccaparadoxides bennetti* assemblage in the lower middle part of the so-called "*P. bennetti* Zone". The species, more correctly termed *bennettii* (Salter, 1859, p. 552), was described from the St. Mary's Bay area of eastern Newfoundland (Fig. 1) and one of the syntypes, assigned to *Paradoxides* (*Paradoxides*), was illustrated by Morris and Fortey (1985, p. 110, Pl. 8, fig. 1).

Subfamily PARADOXIDINAE Hawle and Corda, 1847

Genus *Paradoxides* Brongniart, 1822

Type species. Entomostracites Paradoxissimus Wahlenberg, 1821.

Subgenus *Paradoxides* Brongniart, 1822

Paradoxides (*Paradoxides*) *davidis davidis* Salter, 1863

Plate 4, figures 4, 11-17

Paradoxides Davidis Salter, 1863, p. 274, Textfigure.
Paradoxides davidis Salter. Howell, 1925, p. 35-41, 65, 121, 130.
Paradoxides davidis Salter. Lake, 1935, p. 203, Pl. 27, figs. 1, 2; Pl. 28, figs. 1-3; Pl. 29, figs. 1-3. Includes synonymy.
Paradoxides davidis Salter. Hutchinson, 1962, p. 115, Pl. 19, fig. 10; Pl. 20; Pl. 21; Pl. 22, figs. 1-5.
Paradoxides davidis Salter, 1863 (senu lato, including four subspecies). Bergström and Levi-Setti, 1978, p. 6-11, Pl. 2-10, Textfigs. 7a-c.
Paradoxides (*Paradoxides*) *davidis davidis* Salter, 1863. Morris and Fortey, 1985, p. 110, Pl. 7, fig. 3; Pl. 8, fig. 4.

Figured specimens. GSC 83296 (Pl. 4, fig. 4), GSC 83297 (Pl. 4, figs. 11, 12, 17), GSC 83298 (Pl. 4, figs. 13-15), GSC 83299 (Pl. 4, fig. 16).

Occurrence. Manuels River Formation, GSC locs. 89104, 89105 and 89131, Random Island; GSC loc. 101553, Manuels River.

Description and discussion. Long, detailed descriptions are available elsewhere and the present material adds little new information. All the specimens from Random Island are indifferently preserved in jointed, dark mudstone, but those illustrated herein are from a thin bed of dark limestone (GSC loc. 101553) at Manuels River and show clearly the facial suture and details of surface ornamentation. In particular, the fixigenae are covered with closely-spaced granules, a form of ornamentation said by Courtessole (1973, p. 132) to be rare in *Paradoxides*, but probably widespread, though not always preserved. A large pygidium (Pl. 4, figs. 13-15) shows the relatively short pair of posterolateral border spines; most of each apparent "side" of the pygidium is occupied by a very long (exsag.) anterolateral facet that articulated with the posteriorly directed, subparallel pleura of the hindmost thoracic segment.

Subgenus *Eccaparadoxides* Šnajdr, 1957

Type species. Paradoxides pusillus Barrande, 1846.

Paradoxides (*Eccaparadoxides*) *eteminicus* Matthew, 1883

Plate 1, figures 1-7, 11, 12, 15

Paradoxides eteminicus Matthew, 1883, p. 92, Pl. 1, figs. 7-12.
Paradoxides eteminicus Matthew. Walcott, 1884, p. 27, Pl. 3, figs. 1, 1a-g.
Paradoxides eteminicus Matthew. Howell, 1925, p. 50-53, 126.
Paradoxides eteminicus Matthew. Hayes and Howell, 1937, p. 70-72, 88.
Paradoxides eteminicus Matthew. Hutchinson, 1962, p. 114, Pl. 19, figs. 3-9.

Figured specimens and occurrence. GSC 83263 (Pl. 1, fig. 1), GSC 83264 (Pl. 1, figs. 2, 3, 6), GSC 83265 (Pl. 1, fig. 4), GSC 83266 (Pl. 1, fig. 7), GSC 83267 (Pl. 1, fig. 11), GSC 83268 (Pl. 1, fig. 15). All from Chamberlains Brook Formation, GSC loc. 101552, Manuels River.

Discussion. The species is adequately described in the works of Matthew (1883) and Hutchinson (1962), and the present material adds no new information. Cranidium GSC 83269 (Pl. 1, fig. 5) and pygidium GSC 83270 (Pl. 1, fig. 12) from Saint John, New Brunswick, are figured here for comparison. The cranidia from Manuels River, though dorsally compressed, share several characters, such as glabellar outline and lobation, large eyes and very short posterior branches of the facial suture, with a number of species of *P.* (*Eccaparadoxides*) from western Europe, the Mediterranean region and the Near East (examples in Šnajdr, 1958; Courtessole, 1973; Dean, 1982).

Subgenus *Hydrocephalus* Barrande, 1846

Type species. *Hydrocephalus carens* Barrande, 1846.

Paradoxides (Hydrocephalus) hicksii Salter, 1866

Plate 3, figures 4, 7

Paradoxides Hicksii Salter, 1866, p. 299, Pl. 4, fig. 12.
Paradoxides Hicksii Salter. Salter and Hicks, 1869, p. 55, Pl. 3, figs. 1-10.
Paradoxides hicksi Salter. Lake, 1934, p. 196, Pl. 25, figs. 4-9; Pl. 26, figs. 1, 2. Includes synonymy.
Paradoxides hicksi Salter. Howell, 1925, p. 42-49, 119.
Hydrocephalus hicksi hicksi (Salter). Šnajdr, 1958, p. 130.
Paradoxides hicksi Salter. Hutchinson, 1962, p. 113, Pl. 18, figs. 4-12; Pl. 19, figs. 1, 2.
Hydrocephalus hicksi (Salter). Bergström and Levi-Setti, 1978, Textfig. 10.
Paradoxides (Paradoxides) hicksii Salter, 1866. Morris and Fortey, 1985, p. 110, Pl. 7, fig. 2.

Figured specimens. GSC 83287 (Pl. 3, fig. 4), GSC 83288 (Pl. 3, fig. 7).

Occurrence. Paradoxides (H.) hicksii was reported from numerous localities in the lower part of the Manuels River Formation by both Howell (1925) and Hutchinson (1962, p. 114). Relevant localities in the present account are GSC localities C-98070 and C-98071 at Manuels River, and GSC localities 89107 and 89106 at Random Island; the two last correspond, respectively, to localities 20477 and 20483 in Hutchinson's (1962, p. 144) measured section.

Description and discussion. The species has been described in detail, particularly by Lake, and the present material adds nothing new. Particularly distinctive are the relatively short palpebral lobes, the narrow preocular portion of the cranidium, in which the anterior border becomes conspicuously wider (exsag.) abaxially, and the long frontal glabellar lobe. The last-named has an almost pointed anterior margin in compressed examples (Pl. 3, fig. 4) from shale, but appears either bluntly pointed or rounded in uncrushed specimens illustrated by Hutchinson (1962, Pl. 18, figs. 8-11). The original of Pl. 3, fig. 7 has details of surface ornamentation preserved that comprise fine, undulating, anastomosing ridges, approximately transverse in direction.

Subfamily CENTROPLEURINAE Angelin, 1854

Genus *Clarella* Howell, 1933

Type species. *Anopolenus venustus* Billings, 1874.

Clarella venusta (Billings, 1874)

Plate 1, figure 13

Anopolenus venustus Billings, 1874, p. 73, fig. 42.
Clarella venusta (Billings). Hutchinson, 1962, p. 111, Pl. 17, figs. 7-10. Includes synonymy.

Figured specimen. GSC 83274.

Occurrence and discussion. Hutchinson noted the species as being "rather rare" and during collecting for this study, only a single pygidium was obtained, from limestone in the Manuels River Formation at GSC loc. 89106, Random Island. The stratum probably corresponds to GSC locality 20483 of Hutchinson (1962, p. 112, 153), whose figured pygidium is indistinguishable from the present specimen.

Family CONOCORYPHIDAE Angelin, 1854

Genus *Bailiella* Matthew, 1885

Type species. *Conocephalites baileyi* Hartt in Dawson, 1868.

Bailiella aff. *B. tenuicincta* (Linnarsson, 1879)

Plate 2, figures 7, 12

Figured specimen. GSC 83279.

Occurrence. Manuels River Formation, GSC loc. C-98070, Manuels River.

Description and discussion. The present specimen is typical of several found at Manuels River in the "*Paradoxides hicksi* Zone", approximately equivalent to the *Tomagnostus fissus* and *Ptychagnostus atavus* Zone of Sweden. It is almost identical to an uncrushed cranidium from the same horizon figured by Hutchinson (1962, Pl. 15, fig. 3). Both show minor differences from the type and other material illustrated by Westergård (1950, p. 26, Pl. 5, figs. 6-8, 9?) from the *Ptychagnostus gibbus* Zone, to which the species was said to be restricted in Sweden (Westergård, 1953, p. 38). The glabella in the Newfoundland specimens has straighter sides and is slightly narrower than that of the Swedish cranidia, and the fixigenae are proportionately wider. A conspicuous feature is the presence of a pair of protuberances immediately outside the glabellar furrows and opposite the anterolateral angles of the glabella. From these, a pair of gradually diminishing, curved ridges turn posterolaterally and mark the posterior margin of an area covered by genal caeca that extends from the ridges to the border furrow.

Bailiella manuelensis Hutchinson, 1962

Plate 2, figure 13

Bailiella manuelensis Hutchinson, 1962, p. 106, Pl. 15, figs. 5-7.

Figured specimen. GSC 83281.

Occurrence. Highest part of Chamberlains Brook Formation, GSC loc. 101552, Manuels River.

Description and discussion. The species was described by Hutchinson as "the commonest *Bailiella* in Newfoundland" and was recorded by him from only the "*Paradoxides bennetti* Zone".

Genus *Hartella* Matthew, 1885

Type species. *Conocephalites matthewi* Hartt in Dawson, 1868.

Since its introduction, *Hartella* has had a chequered career, frequently misspelt as *Harttella*, for example in the Treatise on Invertebrate Paleontology (C. Poulsen in Moore, 1959, p. 0242), and considered variously as either a junior subjective synonym or a subgenus of *Ctenocephalus* Hawle and Corda, 1847, though less often as a genus. The original spelling appears to have been a printing error, as the genus was clearly named for C.F. Hartt, whose name appears elsewhere in Matthew's paper, but as this was not specifically stated by Matthew, *Hartella* must stand. Matthew's (1885, p. 103) original account pointed out that *Ctenocephalus* sensu stricto (type species by original designation *C. barrandii* Hawle and Corda, 1847, a junior subjective synonym of *Conocephalus coronatus* Barrande, 1846) had a "wall-like front to the cheeks and frontal lobe" (of the glabella), whereas *Hartella* had "a sloping front to the cheeks and frontal lobe". The value of this character is debatable, as uncrushed cranidia of both genera have the genal region steeply declined or near vertical immediately inside the border furrow. In *Ctenocephalus*, the change in convexity is marked by a pair of conspicuous ridges that curve posterolaterally from opposite the preglabellar furrow to the abaxial ends of the border furrow. Ornamentation differs on either side of the ridges, with tubercles and granules more densely grouped on the outer side. In *Hartella*, the inner part of the genal region is commonly, if not always, more strongly convex than in *Ctenocephalus* and the paired ridges are absent or very weakly developed.

Hartella terranovica (Resser, 1937)

Plate 2, figures 1, 2, 4-6, 8, 10

Harttella matthewi (Hartt) in part. Howell, 1925, p. 110.
Ctenocephalus terranovicus Resser, 1937, p. 41, Pl. 7, figs, 13, 16, 17.
Ctenocephalus bucculentus Resser, 1937, p. 41, Pl. 7, figs. 22, 23.
Ctenocephalus (*Harttella*) *terranovicus* Resser. Hutchinson, 1962, p. 95, Pl. 12, figs. 13-17.

Figured specimens. GSC 83276 (Pl. 2, figs. 1, 5, 8, 10), GSC 83277 (Pl. 2, figs. 2, 4, 6).

Occurrence. Chamberlains Brook Formation, GSC loc. 101552, Manuels River.

Description and discussion. Resser's account of species of *Hartella* and *Ctenocephalus* from Manuels River was confusing and gave the impression that the two genera and several species occurred together at the same locality. The situation was clarified by Hutchinson, who showed that the type material of *H. terranovica* probably came from Bed 23 of Howell (1925, p. 53). According to Hutchinson the species is one of the commonest in the "*Paradoxides bennetti* Zone" and is confined apparently to the upper part of that subdivision, where "*Harttella matthewi*" was recorded by Howell (1925, p. 110) from Beds 21 to 35, a thickness of 4.27 m. During the present work, several fragments of *H. terranovica*, including the specimens now figured, were found 1 m below the top of the Chamberlains Brook Formation, in a faunule corresponding at least in part to Fletcher's (in Bengtson and Fletcher, 1983, p. 533) *Hartella* assemblage.

In addition to the large tubercles ornamenting most of the cranidial surface, there is a conspicuous pair of isolated tubercles sited near the adaxial posterolateral angles of the fixigenae and apparently within the axial furrows; their position corresponds to that of a pair of alar lobes, though there is only slight evidence of lobation. Similar tubercles are evident in Resser's original illustrations and may also be seen on the holotype cranidium of *Hartella exsulans* (Linnarsson, 1879) figured by Westergård (1950, Pl. 6, fig. 9a), as well as in Sdzuy's (1961, Pl. 30, fig. 7) illustration of a Spanish cranidium of *Conocoryphe* (*Conocoryphe*) *heberti* Munier-Chalmas and Bergeron, 1889. In *H. exsulans*, from the *Ptychagnostus gibbus* Zone of Sweden, the glabella is proportionately longer, larger and less tapered than that of *H. terranovica*, the preglabellar field is less conspicuous, and the higher part of the fixigenae is covered with fewer, widely spaced tubercles. *Hartella matthewi* (Hartt in Dawson, 1868), from the Fossil Brook Formation of New Brunswick and figured here for comparison (Pl. 2, fig. 3), is distinguished from *H. terranovica* by its narrower, less tapered glabella and smaller, less convex preglabellar field; the cephalic surface of *H. matthewi* is finely granulate with sparse tubercles, in marked contrast to the more coarsely granulate surface of *H. terranovica*.

Family SOLENOPLEURIDAE Angelin, 1854

Subfamily SOLENOPLEURINAE Angelin, 1854

Genus *Parasolenopleura* Westergård, 1953

Type species. Calymene aculeata Angelin, 1851.

Parasolenopleura? *applanata* (Salter in Salter and Hicks, 1869)

Plate 1, figure 14;
Plate 3, figures 3, 6, 8, 14, 15

Conocoryphe applanata Salter, 1866, p. 285. Nomen nudum.
Conocoryphe applanata Salter in Salter and Hicks, 1869, p. 53, Pl. 2, figs. 1, 2, 4, 5.
Solenopleura cf. *S. applanata* (Salter). Howell, 1925, p. 120.
Solenopleura applanata (Salter). Lake, 1931, p. 137, Pl. 17, figs. 2-12. Includes synonymy.
Parasolenopleura applanata (Salter). Thomas, Owens and Rushton, 1984, p. 11.

Figured specimens. GSC 83275 (Pl. 1, fig. 14), GSC 83284 (Pl. 3, figs. 3, 6), GSC 83285 (Pl. 3, figs. 8, 14), GSC 83286 (Pl. 3, fig. 15).

Occurrence. Manuels River Formation. Uncommon at GSC loc. 89107, Random Island. Abundant at GSC locs. C-98070 and C-98071, Manuels River, where Howell (1925) recorded *Solenopleura* cf. *S. applanata* from Beds 48 to 112. Specimens illustrated here are from the *Tomagnostus fissus* and *Ptychagnostus atavus* Zone, but the species was recorded intermittently from the *T. fissus* Zone to the *Ptychagnostus lundgreni* and *Goniagnostus nathorsti* Zone in Britain (Thomas et al., 1984, p. 11), where Lake (1931, p. 139) listed several locations.

Description and discussion. Little need be added to Lake's detailed description. The surface of the cephalon is ornamented with both fine granules and large tubercles, the distribution of which exhibits some variation. In certain specimens (Pl. 1, fig. 14; Pl. 3, fig. 14) the tubercles have a regular, paired arrangement, whereas in others (Pl. 3, fig. 6) this is not developed. An internal mould (Pl. 3, fig. 15) from the same beds shows almost no trace of granulation. Particularly distinctive is the outward curvature of the librigenal spine in front of the very small genal notch, as illustrated by Lake (1931, Pl. 17, fig. 6).

Whether the species belongs to *Parasolenopleura* is debatable. *Parasolenopleura aculeata*, redescribed by Westergård (1953, p. 23) from the *Ptychagnostus gibbus* Zone of Sweden, has a trapezoidal glabellar outline, truncated frontally; the low anterior border and distinct preglabellar field are weakly differentiated and there is no median preglabellar depression as seen here. The last-named structure, the median widening (sag.) of the anterior border and the coarse granulation are all seen in *Solenopleura canaliculata* (Angelin, 1851), from the *Solenopleura brachymetopa* Zone (Westergård, 1953, p. 19, Pl. 5, figs. 1-5).

Subfamily SOLENOPLEUROPSINAE Thoral, 1947

Genus *Solenopleuropsis* Thoral, 1947

Type species. Conocoryphe rouayrouxi Munier-Chalmas and Bergeron, 1889.

Solenopleuropsis variolaris (Salter, 1864)

Plate 4, figures 7, 9

Conocoryphe? variolaris Salter, 1864, p. 236, Pl. 13, figs. 6a, b, 7a, b.
Solenopleura variolaris (Salter). Howell, 1925, p. 122, 131.
Solenopleura variolaris (Salter). Lake, 1931, p. 139, Pl. 18, figs. 1-5.
Solenopleuropsis variolaris (Salter). Bergström and Levi-Setti, 1978, p. 2.
Solenopleuropsis variolaris (Salter). Thomas, Owens and Rushton, 1984, p. 11.
Solenopleuropsis variolaris (Salter, 1864). Morris and Fortey, 1985, p. 138, Pl. 2, fig. 5.

Figured specimen. GSC 83303.

Occurrence and discussion. Manuels River Formation, GSC loc. 101553, Manuels River. The species has not received a modern revision, but was described in detail by Lake (1931); the present specimen agrees with his account except that the tubercles are slightly coarser, and some may represent the broken bases of short spines as illustrated for certain Spanish species by Sdzuy (1961, Pls. 25-27). All records of *S. variolaris* at Manuels River are from the *Ptychagnostus punctuosus* Zone; the species has not yet been found at Random Island. In England and Wales, *S. variolaris* occurs in the upper part of the *Hypagnostus parvifrons* Zone and the lower part of the *Ptychagnostus punctuosus* Zone, according to Thomas et al. (1984, p. 11).

Genus *Badulesia* Sdzuy, 1968

Type species. Liostracus granieri Thoral, 1935.

Conocephalites tener Hartt in Dawson (1868, p. 652) and *C. ouangondianus* Hartt in Dawson (1868, p. 651) from the Middle Cambrian of New Brunswick were considered congeneric and referred to *Andrarina* (Howell in Shimer and Shrock, 1944, p. 605); they are now conventionally referable to *Badulesia* (Sdzuy, 1968, p. 111, 112). More recently Fletcher (in Bengtson and Fletcher, 1983, p. 533) assigned *C. tener* to *Braintreella*, and listed a *B. tenera* assemblage below his *Hartella* assemblage in the St. Mary's area, southeastern Newfoundland. *Braintreella* Wheeler, 1942 was founded on *Ptychoparia rogersi* Walcott, 1884, from the Braintree Formation of Massachusetts, northeastern U.S.A. and was illustrated in the Treatise on Invertebrate Paleontology (C. Poulsen in Moore, 1959, p. O233, Fig. 170, 1). Evidence for considering *Badulesia* a junior subjective synonym of *Braintreella* is not yet published, and for present purposes *Badulesia* is retained provisionally.

Badulesia aff. *B. tenera*
(Hartt in Dawson, 1868)

Plate 2, figs. 9, 11

Figured specimen. GSC 83280.

Occurrence. Chamberlains Brook Formation, GSC loc. 101552, Manuels River.

Description and discussion. Badulesia tenera has been described in detail, sometimes under different generic and specific names (see Sdzuy, 1968, p. 112 for review), but *Conocephalites ouangondianus* and *C. neglectus* Hartt in Dawson (1868, p. 654), the latter placed in synonymy with *C. tener* by Walcott (1884, p. 41) are in need of revision. Hartt's original line drawing of *C. ouangondianus*, though schematic, suggests that the glabella may be wider and more rounded frontally than that of *B. tenera*. This is the case for the specimen now figured; the preglabellar field is also wider (sag., exsag.) and flatter than in any of the Spanish cranidia of *B. tenera* figured by Sdzuy (1968). Two cranidia illustrated as *Andrarina tenera* by Howell (in Shimer and Shrock, 1944, Pl. 276, fig. 25) show the characteristic two pairs of sharply angulate ridges, one composed of continuous eye ridges and palpebral lobes, the other close to the adaxial and posterior margins of the fixigenae. Similar pairs of ridges occur in the present specimen. A cranidium of *Andrarina ouangondiana* (Howell in Shimer and Shrock, 1944, Pl. 276, fig. 26) differs in having: less conspicuous eye ridges; no posterior pair of ridges; shorter preglabellar field; more rounded frontal glabellar lobe; and the anterior cranidial margin more convex forwards. A cranidium (GSC 83273, Pl. 1, fig. 10) in an old collection from Seely Street, Saint John, New Brunswick, made by G.F. Matthew and labelled as *Conocephalites tener*, differs from specimens of *B. tenera* figured by Sdzuy (1968) in having a parabolic glabellar outline with convex sides, and three pairs of glabellar furrows. For the present this specimen is referred only to ?*Badulesia tenera*. At Manuels River, Howell (1925) recorded *Liostracus ouangondianus* (including *L.* cf. *L. ouangondianus*) from Beds 15 to 31, and *Liostracus tener* from Beds 25 to 40.

Family AGRAULIDAE Raymond, 1913

Genus *Agraulos* Hawle and Corda, 1847

Type species. Arion ceticephalus Barrande, 1846.

Agraulos longicephalus (Hicks, 1872)

Plate 3, figures 9-13

Arionellus longicephalus Hicks, 1872, p. 176, Pl. 5, figs. 20-26.
Agraulos longicephalus (Hicks). Lake, 1932, p. 157, Pl. 19, fig. 10; Pl. 20, figs. 1-10.

Agraulos longicephalus (Hicks, 1872). Szudy, 1961, p. 338, Pl. 23, figs. 7-17, textfigs. 32, 33. Includes synonymy.
Agraulos longicephalus (Hicks). Thomas, Owens and Rushton, 1984, p. 11.

Figured specimens. GSC 83290 (Pl. 3, figs. 9, 11), GSC 83291 (Pl. 3, figs. 10, 13), GSC 83292 (Pl. 3, fig. 12).

Occurrence. Manuels River Formation, GSC locs. C-98070 and C-98071, Manuels River. GSC loc. 89107, Random Island. In each case the species occurs with *Paradoxides (Hydrocephalus) hicksii.*

Description and discussion. Hick's original material came from southwest Wales and the species is now being revised by Mr. M. Lewis, who kindly provided additional data. Published descriptions by Lake and Sduzy used tectonically distorted material and the present specimens show some features that are not clear in their illustrations. In particular a median, axial ridge may be present on the glabella of both small and large cranidia (Pl. 3, figs. 9, 10), and the development of eye ridges varies. Lake noted that "at least three pairs of glabellar furrows are sometimes visible", and a fourth pair is seen here in Pl. 3, figs. 9, 12. One cranidium (Pl. 3, fig. 10) retains the occipital spine, which is slim, short, and directed posteriorly upward.

Family OLENIDAE Burmeister, 1843

Subfamily OLENINAE Burmeister, 1843

Genus *Olenus* Dalman, 1827

Type species. Entomostracites gibbosus Wahlenberg, 1821 (see Henningsmoen in Moore, 1959, p. 0262).

Olenus truncatus (Brünnich, 1781)

Plate 5, figure 13, Plate 6, figures 1-4, 7, 13

Trilobites truncatus Brünnich, 1781, p. 391.
Olenus truncatus (Brünnich). Lake, 1908, p. 52, Pl. 5, figs. 1-7.
Olenus truncatus (Brünnich). Westergård, 1922, p. 126, Pl. 3, figs. 18, 19; Pl. 4, figs. 1-4. Includes synonymy.
Olenus truncatus (Brünnich). Henningsmoen, 1957, p. 109, Pl. 3. Includes synonymy.
Olenus truncatus Henningsmoen, 1958, p. 191, 192, Pl. 1.

Figured specimens. GSC 32615 (Pl. 5, fig. 13), GSC 32616 (Pl. 6, fig. 3), GSC 32617 (Pl. 6, fig. 7), GSC 32618 (Pl. 6, fig. 13), GSC 32664 (Pl. 6, fig. 2), GSC 32692 (Pl. 6, fig. 4), GSC 32693 (Pl. 6, fig. 1).

Occurrence. Elliott Cove Formation. GSC locs. (in ascending order) ?89137, 89136 and 89114 at Random Island.

Description and discussion. For convenience all the specimens of *Olenus* now described are discussed together, at the end of the section.

Olenus wahlenbergi Westergård, 1922

Plate 6, figures 6, 8, 9, 12, 16?, 17

Olenus Wahlenbergi Westergård, 1922, p. 128, Pl. 4, figs. 5-14.
Olenus wahlenbergi Westergård, 1922. Henningsmoen, 1957, p. 110, Pl. 3. Includes synonymy.
Olenus wahlenbergi Henningsmoen, 1958, p. 191, 192, Pl. 1.

Figured specimens. GSC 32619 (Pl. 6, fig. 12), GSC 32666 (Pl. 6, fig. 8), GSC 32667 (Pl. 6, fig. 9), GSC 32671 (Pl. 6, fig. 6), GSC 32672 (Pl. 6, fig. 17), ?GSC 32620 (Pl. 6, fig. 16).

Occurrence. Elliott Cove Formation. GSC locs. (in ascending order) 89134, 89115, 89117, 89121 and ?89123, Random Island.

Olenus cf. *O. transversus* Westergård, 1922

Plate 6, figures 5, 14

Figured specimens and occurrence. Elliott Cove Formation, GSC 32621 (Pl. 6, fig. 5), GSC loc. 89134; GSC 32682 (Pl. 6, fig. 14), GSC loc. 89121, Random Island.

Description and discussion. Specific identification of *Olenus* is often difficult when librigenae and pygidia are not available, and the majority of the present sample consists only of cranidia. A pygidium (Pl. 6, fig. 2) and left librigena (Pl. 6, fig. 13) from GSC loc. 89114 agree with descriptions of *Olenus truncatus* by Westergård (1922) and Henningsmoen (1957); associated cranidia show minor differences in glabellar proportions, possibly due to compression, and the curvature of the posterior branches of the facial suture. Cranidia found slightly higher in the sequence (GSC loc. 89134 upward) have a proportionately shorter preglabellar field and when the specimens are uncrushed (Pl. 6, fig. 17), the front of the glabella is more rounded. In these respects, the material agrees with *Olenus wahlenbergi* rather than *O. truncatus* (compare Henningsmoen's 1957, Pl. 3 reconstruction of the two species).

A single cranidium (Pl. 6, fig. 5) from GSC loc. 89134 in the lower part, and another (Pl. 6, fig. 14) from GSC loc. 89121 near the top, of the *Olenus* bearing strata at Random Island have the posterior halves of the fixigenae strikingly long (tr.) and narrow (exsag.) and are compared here to *Olenus transversus* Westergård (1922, p. 125, Pl. 3, figs. 11-17; Henningsmoen, 1957, p. 108, Pl. 3). In Scandinavia (Henningsmoen, 1958, p. 191) *O. transversus* is found below *O. truncatus*, the oldest species recorded at Random Island. The present material is insufficient for a positive identification and it may be noted that cranidia of *Olenus*, including *O. truncatus*, illustrated by Westergård (1922) show some variation in the length and direction of the posterior branches of the facial suture.

Cranidia from GSC locs. C-98060 and C-98061 at Manuels River (Pl. 6, figs. 15, 18) are compressed and distorted. The preglabellar field is much shorter than in either *O. truncatus* or *O. wahlenbergi* and the material is identified simply as *Olenus* sp.

Genus *Parabolina* Salter, 1849

Type species. Entomostracites spinulosus Wahlenberg, 1821.

Parabolina spinulosa (Wahlenberg, 1821)

Plate 7, figures 1, 2, 4, 7-13
Plate 8, figures 1-3, 6

Entomostracites spinulosus Wahlenberg, 1821, p. 38, Pl. 1, fig. 3.

Parabolina spinulosa (Wahlenberg, 1821). Henningsmoen, 1957, p. 126, Pl. 1, fig. 2; Pl. 3, Textfig. 12. Includes full synonymy.
Parabolina spinulosa Henningsmoen, 1958, p. 191, 192, Pl. 1.
Parabolina spinulosa (Wahlenberg). Taylor and Rushton, 1972, p. 26, Pl. 8, figs. 4, 5.

Figured specimens. GSC 32602 (Pl. 7, fig. 12), GSC 32604 (Pl. 7, fig. 2), GSC 32605 (Pl. 7, fig. 7), GSC 32606 (Pl. 7, fig. 8), GSC 32608 (Pl. 8, fig. 2), GSC 32611 (Pl. 8, fig. 6), GSC 32612 (Pl. 7, fig. 13), GSC 32637 (Pl. 7, fig. 10), GSC 32638 (Pl. 7, fig. 9), GSC 32640 (Pl. 7, fig. 1), GSC 32642 (Pl. 7, fig. 4), GSC 32644 (Pl. 7, fig. 11), GSC 32647 (Pl. 8, fig. 1), GSC 32649 (Pl. 8, fig. 3).

Occurrence. Elliott Cove Formation, GSC locs. (in ascending order) 87794, 87793, 87796, 87795, 87792 and 87791, Random Island. No examples of the species have yet been reported from corresponding strata at Manuels River.

Description and discussion. The present material adds little to the descriptions by Westergård (1922, p. 134) and Henningsmoen, but it does confirm that specimens with either three or four pairs of pygidial border spines may occur in the same assemblage. Although most specimens consisted of disarticulated fragments, a few nearly complete exoskeletons were collected (Pl. 7, figs. 8, 9, 13) and a pair of united librigenae similar to Norwegian examples described by Henningsmoen (1957, p. 91, Fig. 12).

An incomplete cranidium, GSC 32652 from GSC loc. 87796, is figured here as *Parabolina* sp. (Pl. 8, fig. 4). It differs from *P. spinulosa* in having the glabella more strongly tapered and narrower posteriorly, while the posterior branches of the facial suture are shorter (tr.). In these respects it may be compared with *Parabolina brevispina* Westergård (1922, p. 133, Pl. 6, fig. 9-13) but the latter has the 2p glabellar furrows and the eyes set slightly farther forward, so that the posterior branches of the facial suture are notably shorter. The Newfoundland specimen occurs within the stratigraphic range of, though not accompanied by, *P. spinulosa*; in Scandinavia, *P. brevispina* is found in the lower of the two subzones of the *P. spinulosa* Zone.

Subfamily LEPTOPLASTINAE Angelin, 1854

Genus *Leptoplastus* Angelin, 1854

Type species. Leptoplastus stenotus Angelin, 1854.

Leptoplastus sp.

Plate 8, figures 13, 14

Figured specimens and occurrence. Elliott Cove Formation. GSC 32632 (Pl. 8, fig. 14) from GSC loc. 87789; GSC 32634 (Pl. 8, fig. 13) from GSC loc. 87790, Random Island.

Description and discussion. Specimens of *Leptoplastus* were found at only two localities. Cranidium GSC 32632, though not quite complete and slightly compressed laterally, may be compared with *Leptoplastus raphidophorus* Angelin, 1854 (see Henningsmoen, 1957, p. 175, Pl. 13, fig. 2, 5, 6). GSC 32634, still less well preserved, retains part of the left librigena; the position of the librigenal spine and the form of the genal notch resemble particularly a Norwegian example of *L. raphidophorus* illustrated by Henningsmoen (1957, Pl. 13, fig. 1). The material is insufficient for the specific identification to be made with certainty.

Genus *Ctenopyge* Linnarsson, 1880

Type species. Olenus (Sphaerophthalmus) pecten Salter, 1864.

Subgenus *Eoctenopyge* Henningsmoen, 1957

Type species. Sphaerophthalmus flagellifer Angelin, 1854.

Ctenopyge (Eoctenopyge) flagellifera (Angelin, 1854)

Plate 8, figures 5, 7, 10, 15?

Sphaerophthalmus flagellifer Angelin, 1854, p. 49, Pl. 26, fig. 7.
Ctenopyge (Eoctenopyge) flagellifera (Angelin, 1854). Henningsmoen, 1957, p. 189, Pl. 2, fig. 17; Pl. 5; Pl. 18, figs. 1-4. Includes synonymy.
Ctenopyge (Eoctenopyge) flagellifera Henningsmoen, 1958, p. 191, 192, Pl. 3.
Ctenopyge (Eoctenopyge) flagellifera (Angelin). Rushton in Taylor and Rushton, 1972, p. 32.

Figured specimens. GSC 32624 (Pl. 8, fig. 7), GSC 32626 (Pl. 8, fig. 5), GSC 32628 (Pl. 8, fig. 10), ?GSC 32629 (Pl. 8, fig. 15).

Occurrence. Elliott Cove Formation, GSC loc. 87787, Random Island.

Description and discussion. Identification of the species is facilitated by a left librigena (Pl. 8, fig. 10) that shows the markedly anterior position of the librigenal spine and resembles illustrations by Westergård (1922, Pl. 10, fig. 20) and Henningsmoen (1957, Pl. 5; Pl. 18, figs. 2-4). Two associated cranidia (Pl. 8, figs. 5, 7) match published illustrations of the species; a third (Pl. 8, fig. 15) is questionable, though the eye ridges and form of the fixigenae agree with those of a Swedish cranidium figured by Westergård (1922, Pl. 11, fig. 1).

Subgenus *Mesoctenopyge* Henningsmoen, 1957

Type species. Ctenopyge spectabilis Brögger, 1882.

Ctenopyge (Mesoctenopyge) similis Henningmoen, 1957

Plate 9, figures 1?, 5, 7?, 11?

Ctenopyge (Mesoctenopyge) similis Henningsmoen, 1957, p. 195, Pl. 5; Pl. 20, figs. 10-14.
Ctenopyge (Mesoctenopyge) similis Henningsmoen, 1958, p. 192, Pl. 3.

Figured specimens. ?GSC 32623 (Pl. 9, fig. 1), ?GSC 32656 (Pl. 9, fig. 7), GSC 32658 (Pl. 9, fig. 5), ?GSC 83312 (Pl. 9, fig. 11).

Occurrence. Elliott Cove Formation, GSC loc. 87800, Random Island.

Description and discussion. Combined with that of *Ctenopyge (Mesoctenopyge) tumida*.

Ctenopyge (Mesoctenopyge) tumida Westergård, 1922

Plate 9, figures 2-4, 6?, 8?, 10, 13?

Ctenopyge tumida Westergård, 1922, p. 155, Pl. 11, figs. 15-18 only.
Ctenopyge (Mesoctenopyge) tumida Westergård, 1922. Henningsmoen, 1957, p. 198, Pl. 5; Pl. 20, fig. 16. Includes synonymy.
Ctenopyge (Mesoctenopyge) tumida Henningsmoen, 1958, p. 190, 193, Pl. 3.
Ctenopyge (Mesoctenopyge) tumida Westergård. Rushton in Taylor and Rushton, 1972, p. 32, Fig. 8a.

Figured specimens. ?GSC 32654 (Pl. 9, fig. 8), GSC 32655 (Pl. 9, fig. 3), ?GSC 32697 (Pl. 9, fig. 6), GSC 32698 (Pl. 9, fig. 4), ?GSC 32699 (Pl. 9, fig. 13), GSC 32700 (Pl. 9, fig. 2), GSC 32701 (Pl. 9, fig. 10).

Occurrence. Elliott Cove Formation, GSC locs. (in ascending order) 89138, 87799 and 89139, Random Island.

Description and discussion. The left librigena now figured from GSC loc. 87800 (Pl. 9, fig. 5) matches that of *Ctenopyge (Mesoctenopyge) similis* in having a deep genal notch with the posterior margin of the librigenal spine meeting the cephalic margin at less than ninety degrees. Associated cranidial fragments are less convincing, but in one (Pl. 9, fig. 11) the posterior border appears to curve only gently forward abaxially. By contrast, in cranidia slightly higher in the succession, at GSC locs. 89138, 87799 and 89139 (Pl. 9, figs. 3, 4, and, especially, 10), the distal portions of the posterior border turn forward sharply and closely resemble illustrations of *Ctenopyge (Mesoctenopyge) tumida* given by Henningsmoen (1957, Pl. 5; Pl. 20, fig. 16; 1958, Pl. 3).

Subgenus *Ctenopyge* Linnarsson, 1880

Ctenopyge (Ctenopyge) linnarssoni Westergård, 1922

Plate 9, figure 19

Ctenopyge linnarssoni Westergård, 1922, p. 162, Pl. 13, figs. 2-5.
Ctenopyge (Ctenopyge) linnarssoni Westergård, 1922. Henningsmoen, 1957, p. 207, Pl. 5; Pl. 22, fig. 8.
Ctenopyge (Ctenopyge) linnarssoni Henningsmoen, 1958, p. 193, Pl. 3.

Figured specimen. GSC 38971.

Occurrence. Elliott Cove Formation, GSC loc. 89793, Random Island.

Discussion. The two figured cranidia have the glabellar breadth and 1p transglabellar furrow slightly exaggerated by dorsal compression, but otherwise agree well with published illustrations.

Genus *Sphaerophthalmus* Angelin, 1854

Type species. *Trilobites alatus* Boeck, 1838.

Sphaerophthalmus majusculus Linnarsson, 1880

Plate 9, figure 20

Sphaerophthalmus majusculus Linnarsson, 1880, p. 11, Pl. 1, figs. 11, 12.
Sphaerophthalmus majusculus Linnarsson, 1880. Henningsmoen, 1957, p. 218, Pl. 5; Pl. 22, figs. 16, 17.
Sphaerophthalmus majusculus Henningsmoen, 1958, p. 190, 193, Pl. 3.

Figured specimen. GSC 38978.

Occurrence. Elliott Cove Formation, GSC loc. 89793, Random Island.

Discussion. The single available cranidium, even though incomplete and compressed, shows well developed eye ridges that are directed strongly backward. Of comparable species, *S. humilis* (Phillips, 1848) (Henningsmoen, 1957, p. 215, Pl. 22, figs. 7, 15) has the eye ridges more weakly developed and directed less strongly backward; in *S. alatus* (Boeck, 1838) (Henningsmoen, 1957, p. 212, Pl. 5; Pl. 22, figs. 21, 24-26), the eyes are set notably farther forward.

Subfamily PELTURINAE Hawle and Corda, 1847

Genus *Peltura* Edwards, 1840

Type species. *Entomostracites scarabaeoides* Wahlenberg, 1821.

Peltura scarabaeoides scarabaeoides (Wahlenberg, 1821)

Plate 9, figures 12, 14, 16-18

Entomostracites scarabaeoides Wahlenberg, 1821, p. 41, Pl. 1, fig. 2.
Peltura scarabaeoides (Wahlenberg). Lake, 1919, p. 97, Pl. 11, figs. 9-12.
Peltura scarabaeoides (Wahlenberg). Westergård, 1922, p. 173, Pl. 15, figs. 12, 13, 18. Includes synonymy.
Peltura scarabaeoides scarabaeoides (Wahlenberg, 1821). Henningsmoen, 1957, p. 237, Pl. 2, fig. 1; Pl. 6; Pl. 25, figs. 6, 13, 14; Pl. 26, figs. 1, 2. Includes synonymy.
Peltura scarabaeoides scarabaeoides. Henningsmoen, 1958, p. 190, 193, Pl. 4.

Figured specimens. GSC 38972 (Pl. 9, fig. 12), GSC 38973 (Pl. 9, fig. 14), GSC 38974 (Pl. 9, fig. 17), GSC 38975 (Pl. 9, fig. 16), GSC 38979 (Pl. 9, fig. 18).

Occurrence. Elliott Cove Formation, GSC loc. 89793, Random Island.

Discussion. The Newfoundland specimens, all preserved in shale and dorsally compressed, agree closely with Norwegian material preserved in limestone and illustrated by Henningsmoen.

Genus *Protopeltura* Brögger, 1882

Type species. *Peltura praecursor* Westergård, 1909 (see discussion in Henningsmoen, 1957, p. 220).

Protopeltura aciculata (Angelin, 1854) *pusilla* Westergård, 1922

Plate 7, figures 5, 6

Protopeltura aciculata pusilla n. var. Westergård, 1922, p. 171, Pl. 14, figs. 14-17.

Protopeltura aciculata pusilla Westergård. Henningsmoen, 1957, p. 223, Pl. 3; Pl. 23, figs. 1-6.
Protopeltura aciculata pusilla Henningsmoen, 1958, p. 191, 193, Pl. 4.

Figured specimens. GSC 32645 (Pl. 7, fig. 6), GSC 32646 (Pl. 7, fig. 5).

Occurrence. Elliott Cove Formation, GSC loc. 87794, Random Island.

Discussion. GSC 32646 is slightly compressed laterally, so that the glabella appears to be narrower than in Westergård's illustrations, and the eye ridges are more weakly developed, but it otherwise resembles the Swedish type material. GSC 32645, though a little abraded, shows the short, outwardly curved librigenal spine (Westergård, 1922, fig. 15) as well as the narrow doublure. The Newfoundland material was found in association with *Parabolina spinulosa*, indicative of the *P. spinulosa* Subzone, and its age is similar to that recorded in Norway and Sweden.

Protopeltura sp.

Plate 8, figures 9, 11, 12

Figured specimens. GSC 83310 (Pl. 8, fig. 9), GSC 83311 (Pl. 8, figs. 11, 12).

Occurrence. Elliott Cove Formation, GSC loc. C-98068, Manuels River.

Description and discussion. GSC 83310 (Pl. 8, fig. 9) has the glabella abraded, but the left librigena and the front of the cranidium are like those of *P. aciculata pusilla*. In GSC 83311 (Pl. 8, figs. 11, 12) the outlines of the glabella and fixigenae are appropriate, but the preglabellar field is narrower (sag.), the anterior border is slightly curved forward rather than transversely straight and is broader (exsag.) abaxially; there is only slight evidence of glabellar furrows and a median occipital tubercle. A closer comparison may be made with *Protopeltura intermedia* Westergård (1922, p. 171, Pl. 14, figs. 18-22; see also Henningsmoen, 1957, p. 228), but in the Newfoundland specimens the anterior border is wider (sag.), the evidence for 2p lateral glabellar furrows is equivocal, and the posterior halves of the fixigenae are slightly smaller, owing to the more posterior position of the eyes. *Protopeltura intermedia* is recorded only from the *Leptoplastus* Zone of Sweden; the Manuels River specimens are from the *Parabolina spinulosa* Zone as they lie within the range of *Orusia lenticularis*.

Genus *Westergaardia* Raymond, 1924

Type species. *Boeckia scanica* Westergård, 1909.

Junior subjective synonym. *Sphaerophthalmoides* Hutchinson, 1952.

Westergaardia lata (Matthew, 1891)

Plate 9, figure 15

Leptoplastus lata n. sp. Matthew, 1891, p. 462, Textfigs. 1-3.
Boeckia? illaenopsis Westergård, 1909, p. 49, Pl. 1, figs. 14-20.
Westergårdia illaenopsis (Westergård). Westergård, 1944, p. 44, Pl. 3, figs. 15-22.
Westergårdia lata (Matthew, 1891). Henningsmoen, 1957, p. 254, Pl. 7; Pl. 28, figs. 7-10. Includes synonymy.
Westergårdia lata Henningsmoen, 1958, p. 190, 193, Pl. 4.

Figured specimen. GSC 32703.

Occurrence. Elliott Cove Formation, GSC loc. 89143, Random Island.

Discussion. The single available cranidium lacks the anterior border and is slightly crushed, but shows the wide fixigenae, rounded glabellar outline, posterior location of the eyes, granular ornamentation and long (tr.), narrow eye ridges that are clearly indicated in a Norwegian cranidium illustrated by Henningsmoen (1957, Pl. 28, fig. 7).

MICROPALEONTOLOGY

F. Martin

Materials and methods

All the samples analyzed were shale. In each case approximately 30 g of rock were treated successively in cold 70% HF and cold ±30% HCl. Filtration of the organic residue using a metallic filter (53 μm mesh) and a nylon filter (10 μm mesh preferred) was carried out in denatured alcohol with ether to minimize flocculation. Where flocculation remained significant in spite of ultrasonic treatment, the acritarchs were concentrated using a nylon filter with 20 μm mesh. Treatment with zinc bromide (density 2.1 to 2.2) followed the filtration. Acritarchs were neither coloured nor oxidized. Preparations for the SEM were made using the method described by Playford and Martin (1984); this included, in part, the technique for mounting chitinozoans on aluminium foil described by Paris (1981, p. 67) as well as innovations developed by H. De Potter of the Institut royal des Sciences naturelles de Belgique. All specimens, including those coated with gold for SEM examination, were mounted permanently in Canada balsam.

Organic matter is very abundant in the majority of samples from both Random island and Manuels River. Rocks described here as "barren" may possibly contain undeterminable acritarchs; chitinozoans and scolecodonts are always absent. The acritarchs, which number from some tens to about four thousand per gram of rock, are variably and usually badly preserved. They are commonly irregularly corroded and blackish, except in the lower part of the Manuels River Formation at Manuels River (GSC locs. C 98041 and C-98042), where they are generally light brown. The latter state of preservation is similar to that found at the top of the Brigus Formation and at the base of the Chamberlains Brook Formation at the same river section (Martin and Dean, 1983). Specimens from the lower part of the Elliott Cove Formation are better preserved at Random Island than at Manuels River, but preservation in a single assemblage may vary considerably either between species or within a species. In the most favourable cases only 20 to 50 per cent of the acritarchs were identified; apart from cases indicated by cf., or taxa left in open nomenclature, ambiguous determinations have not been taken into account. The value of the frequency tables (Figs. 7, 8) is obviously only relative; certain species (e.g., *Trunculumarium revinium* and *Rugasphaera terranovana*) that are easily determined from a

Acritarchs from Manuels River Formation

- ∘ 1 (very rare)
- • 2-19 (rare)
- ○ 20-100 (common)
- ● >100 (very common)

GSC LOCALITY NUMBER	C-98036	C-98041	C-98042	C-98043	C-98044	C-98045	C-98046	C-98071	C-98047	C-98048	C-98049	C-98050	C-98051	C-98054	C-98055	C-98059	C-98056	C-98057	C-98058	C-98062	C-98067	C-98066	C-98065	C-98064	C-98068
Series	MIDDLE CAMBRIAN (in part)																UPPER CAMBRIAN (in part)								
Formation	C* B FM	MANUELS RIVER FORMATION													ELLIOTT COVE FORMATION (in part)										
ACRITARCH ZONATION	AO-1	*Rugasphaera terranovana* Zone								*Adara alea* Zone				?	lower A2		Tp-Vt Zone (upper A2)				A3a				
Leiosphaeridia sp.	•	•	•	•	•	•	•	•	∘	•	○										•	•			
Kildinella sp.							∘			∘	•														
Eliasum jennessii	•																								
Eliasum llaniscum	•	•	○	•	•			∘	∘	•	•			∘											
Acritarch gen. et sp. nov.	○	●	○					○			●														
Retisphaeridium dichamerum	•	○	○				•			•	•														
Retisphaeridium howellii	•	•	•								•														
Cristallinium cambriense		•	•	•	•	•	•	•	•	•	○	•	∘							•					
Rugasphaera terranovana		○	•																						
Vulcanisphaera lanugo		•	●	•																					
Adara alea										∘	○	•	∘												
Eliasum cf. *E. asturicum*											•	•													
Timofeevia lancarae															○	•	•	•	○	•			•		
Timofeevia phosphoritica															•	•	○	•	•	•	•			•	
Timofeevia pentagonalis																	•	∘	•						
Vulcanisphaera turbata																	∘	∘	∘	•	•	•	•	•	•
Vulcanisphaera turbata — V. africana																				∘	•	○	○	○	•
Timofeevia microretis																			∘	•					
Stelliferidium pingiculum																				○	•			•	
Cristallinium randomense																					•	•	•	○	•
Vulcanisphaera africana																					•	•	•	•	•
Cymatiogalea aspergillum																					○	○	○	○	○
Cymatiogalea cf. *C. cylindrata*																					•		∘	•	
Cymatiogalea virgulta																					•	•	•	•	
Leiofusa stoumonensis																					•	•	•	•	•
Veryhachium dumontii																					•	•	•	•	•
Impluviculus sp. A																							∘	∘	
Acritarch count per sample	50	400	400	20	10	8	10	46	40	400	240	10	2	1	25	12	30	20	50	100	200	60	150	300	150

* CHAMBERLAINS BROOK FORMATION

Figure 7. *Acritarch distribution in the uppermost Chamberlains Brook Formation, Manuels River Formation and lower part of Elliott Cove Formation at Manuels River.*

Acritarchs from Random Island o 1 (very rare) • 2-19 (rare) ○ 20-100 (common) ● >100 (very common)	UPPER CAMBRIAN (in part)																	
	ELLIOTT COVE FORMATION (in part)																	
	GSC LOCALITY NUMBER																	
	C-98027	C-98026	C-98024	C-98025	C-98011	C-98010	C-98012	C-98013	C-98020	C-98019	C-98018	C-98017	C-98016	C-98015	C-98014	C-98022	C-98021	C-98023
	Tp-Vt Zone (= upper A2)			?	A3b				A4									A5a
Leiosphaeridia sp.	•	•			•	•	•	•	o			•		•			•	o
Cristallinium cambriense	•	•	•				o											
Timofeevia lancarae	●	●	•	•			•											
Timofeevia microretis		o																
Timofeevia phosphoritica	•	○		•	•	•	•	•	o	•	•	•	o	•	•		•	
Timofeevia pentagonalis	•	•	•		•			○										
Vulcanisphaera turbata	•	○	•		•	•	○	•	•	•	•	•		•				
Vulcanisphaera turbata → *V. africana*					○	○	•	•		•		o			o		o	
Cristallinium randomense					●	●	○	○	•	•	•	○	•	•	•	•	o	o
Stelliferidium pingiculum			•			•												
Vulcanisphaera africana					•	•	•	•	•	•	•	•		•	•	•	•	o
Cymatiogalea aspergillum					○	○	○	•		•		•	o		•		•	o
Cymatiogalea cf. *C. cylindrata*					o	•	o				•					•	•	
Cymatiogalea virgulta		•			•	•	•	•	•	•		•		•	•	○	○	
Leiofusa stoumonensis					○	○	○	•	•	•	•	•		•		•		
Veryhachium dumontii					●	○	●	○	•	○	○	○	•	○	○	○	•	•
Impluviculus sp. A					•	•	•					o					•	o
Dasydiacrodium caudatum					•	•	•	•		•	•	•		•	•	o	o	o
Dasydiacrodium obsonum					•	•	•	•	o	•	•	•	o	○	○	•	•	
Stellichinatum uncinatum					•	•	•		•	•	•	•	o	•	•		•	•
Veryhachium sp. A						o				o				•	•	•	•	o
Actinotodissus achrasi								•	•	•	•	•	•	•	•	•	○	o
Trunculumarium revinium									●	○	●	●	○	○	●	o		o
Actinotodissus cf. *A ubui*																•	○	•
Arbusculidium rommelaerei																		o
Acritarch count per sample	200	300	50	9	400	400	400	300	200	300	150	150	50	300	300	100	300	30

Figure 8. *Acritarch distribution in part of the Elliott Cove Formation at Random Island. Locality numbers identify places where samples have been collected since those reported by Martin and Dean in 1981.*

single fragment will appear more numerous than those (e.g., species of *Cymatiogalea*) that require a complete specimen in order to be determined. The frequency of taxa in Figures 7 and 8 indicates the number of specimens determined in any one sample as follows: very rare = 1; rare = 2-19; common = 20-100; very common = more than 100. Figured specimens, accompanied by coordinates established with the England Finder graticule, are deposited in the type fossil collection of the Geological Survey of Canada, Ottawa; supplementary preparations are deposited in the Département de Paléontologie, Institut royal des Sciences naturelles de Belgique, Brussels.

Known taxa from eastern Newfoundland described by Martin in Martin and Dean (1981, 1983, 1984), for which no new observations are made here, are not discussed in the Systematic Descriptions. With the exception of *Saharidia fragilis* (Downie) Combaz, 1967, which is not variable and has already been illustrated by Martin (1982; in Dean and Martin, 1978; in Martin and Dean, 1981), all the acritarchs considered in the present stratigraphic synthesis of eastern Newfoundland (Fig. 10) are illustrated.

List of acritarch taxa

Genera and species are listed below in alphabetical order and according to their stratigraphic appearance in Figures 7, 8 and 10. Taxa marked with an asterisk (*) are described in the text.

Acritarch gen. et sp. nov. Martin in Martin and Dean, 1984.

**Actinotodissus achrasi* (Martin, 1973) Martin comb. nov.

**Actinotodissus* cf. *A. ubui* (Martin, 1969) Martin comb. nov.

Adara alea Martin in Martin and Dean, 1981.

**Arbusculidium rommelaerei* Martin in Martin and Dean, 1981.

**Cristallinium cambriense* (Slavíková) Vanguestaine, 1978.

**Cristallinium randomense* Martin in Martin and Dean, 1981, emend.

**Cymatiogalea aspergillum* Martin sp. nov.

Cymatiogalea cf. *C. cylindrata* Rasul, 1974, as described by Martin in Martin and Dean, 1981.

**Cymatiogalea virgulta* Martin sp. nov.

Dasydiacrodium caudatum Vanguestaine, 1973.

**Dasydiacrodium obsonum* Martin sp. nov.

Eliasum cf. *E. asturicum* Fombella, 1977 as described by Martin in Martin and Dean, 1981.

Eliasum jennessii Martin in Martin and Dean, 1984.

Eliasum llaniscum Fombella, 1977.

**Impluviculus* sp. A.

Kildinella sp.

Leiofusa stoumonensis Vanguestaine, 1973.

Leiosphaeridia sp.

Retisphaeridium dichamerum Staplin, Jansonius and Pocock, 1965.

Retisphaeridium howellii Martin in Martin and Dean, 1983.

**Rugasphaera terranovana* Martin gen. et sp. nov.

Saharidia fragilis (Downie) Combaz, 1967.

**Stellichinatum uncinatum* (Downie) Martin comb. nov.

**Stelliferidium pingiculum* Martin sp. nov.

Timofeevia lancarae (Cramer and Diez de Cramer) Vanguestaine, 1978.

Timofeevia microretis Martin in Martin and Dean, 1981.

Timofeevia pentagonalis (Vanguestaine) Vanguestaine, 1978.

Timofeevia phosphoritica Vanguestaine, 1978.

**Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976.

**Veryhachium dumontii* Vanguestaine, 1973.

Veryhachium sp. A Martin in Martin and Dean, 1981.

Vulcanisphaera africana Deunff, 1961.

**Vulcanisphaera lanugo* Martin sp. nov.

**Vulcanisphaera turbata* Martin in Martin and Dean, 1981.

Sequence and correlation of acritarchs

The new palynological data in the present work refer to rocks of middle Middle Cambrian (*Paradoxides paradoxissimus* "Stage") to Late Cambrian (*Parabolina spinulosa* Zone) age at Manuels River and Random Island. At the latter location they are extended to include the *Peltura* zones and part of the *Acerocare* Zone, highest zone of the Upper Cambrian, which is inadequately documented there. The results are integrated with those that permitted the establishment by Martin (in Martin and Dean, 1981, 1984) of seven acritarch microfloras (A0-1, A0 and A1 to A5) at Random Island. The stratigraphic continuity and close, productive sampling of the middle part of the Middle Cambrian at Manuels River and Random Island now permit the definition of a *Rugasphaera terranovana* Standard Zone and an *Adara alea* Range Zone to replace, respectively, microfloras A0 and A1. Three (A3 to A5) of the other five microfloras are revised. A table of synthesis (Fig. 9), showing also the correlation with the trilobite zones present at Manuels River and/or Random Island, compares the acritarch-based units from eastern Newfoundland with the formal palynological zonation of Vanguestaine and Van Looy (1983), established by them in part on the basis of their personal observations on the Middle Cambrian of the Tacheddirt valley, Moroccan High-Atlas, and in part on the basis of data for the Middle and Upper Cambrian of Random Island published by Martin and Dean (1981). With the single exception of their *Timofeevia pentagonalis* – *Vulcanisphaera turbata* Zone (= upper part of microflora A2, beginning at the end of the Middle Cambrian, ?*Lejopyge laevigata* Zone, or between the latter and the *Agnostus pisiformis* Zone),

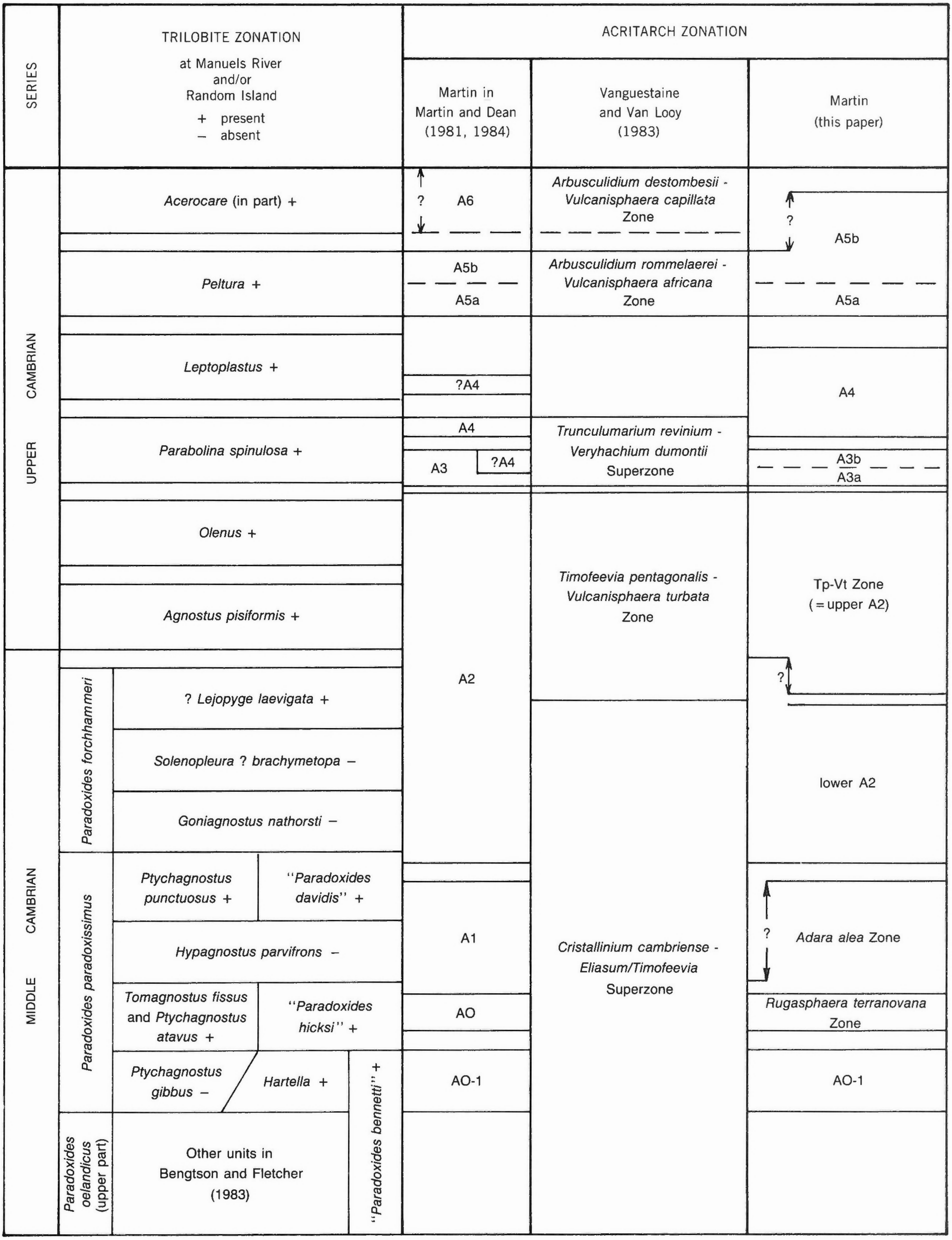

Figure 9. *Trilobite and acritarch zonation in the Middle and Upper Cambrian at Manuels River and/or Random Island.*

Vanguestaine and Van Looy's generalized zonation has been found inappropriate for use in eastern Newfoundland. In practice it hides the successive appearances of guide-taxa, such as are now established, and does not emphasize sufficiently the hiatuses present or the uncertainties of observation. The present, more flexible use of informal microfloras is justified for the following reasons:

1. In the case of microflora A0-1, further sampling is required from the "*Paradoxides bennetti* Zone", Middle Cambrian at Manuels River

2. In the lower part of microflora A2, acritarchs are very badly preserved in Middle Cambrian strata dated as the uppermost part of the *Paradoxides paradoxissimus* "Stage" and the lower part of the *Paradoxides forchhameri* "Stage" at Manuels River and Random Island

3. In microflora A3a, the levels at which guide taxa appear in the Upper Cambrian, between the *Olenus* Zone and the *Parabolina spinulosa* Zone, at Manuels River and Random Island are insufficiently known

4. Microfloras A3b, A4 and A5 from the upper part of the Upper Cambrian at Random Island cannot be reproduced or verified at Manuels River, where the youngest strata exposed are dated as low in the *P. spinulosa* Zone.

The microfloras and zones are based on selected taxa whose range at Manuels River and Random Island is indicated (Fig. 10). The order of presentation of the acritarch-based units is as follows:

a. Description or definition

b. Stratigraphic position in relation to macrofaunal subdivisions in the eastern Newfoundland sections

c. Discussion, including range of separate taxa and correlation of assemblages (or parts of them), using data from other regions. The distribution of the acritarchs outside Newfoundland, discussed by Martin (in Martin and Dean, 1981, 1983, 1984) is summarized, and the details of newly published references are given.

Palynological correlation of the Newfoundland Middle and Upper Cambrian with other areas concerns principally the following: the Middle Cambrian of Czechoslovakia (Slavíková, 1968; Vavrdová, 1976), western U.S.S.R. (Jankauskas, 1976), southeastern Turkey (Erkmen and Bozdoğan, 1981) and the Moroccan High Atlas (Vanguestaine and Van Looy, 1983); the Middle and Upper Cambrian of the Franco-Belgian Ardennes (Vanguestaine, 1973, 1974, 1978), and Anglo-Welsh area (Potter, 1974 and unpublished thesis cited by Vanguestaine, 1974, 1978; Vanguestaine and Van Looy, 1983; and Downie, 1984), northeastern Spain (Cramer and Diez de Cramer, 1972; Fombella, 1977, 1978, 1979, 1982) and northern Norway (Welsch, 1984); and the Upper Cambrian of Sardinia (Albani et al., 1985) and the northeastern part of the east European platform (Volková, 1983; Volková and Goloub, 1984. Successions of Middle and Upper Cambrian acritarch assemblages dated directly by means of trilobites relate especially to Czechoslovakia, the Anglo-Welsh area (for which no acritarch mongraph has been published) and, in part, Morocco.

Until now, it has been suggested that the affinities of the eastern Newfoundland Middle and Upper Cambrian acritarchs are mainly with those of northern Norway, the Baltic, and the perimeter of Gondwanaland, the palynology of the last two regions having been documented the most. Further, partial comparisons are made here between the Upper Cambrian of the Avalon Platform and that of the northern Sino-Korean Platform on the basis of acritarchs from Dayangcha, Jilin Province, northeastern China (Yin in Chen et al., 1985; and writer's personal observations).

Microflora A0-1* (Eliasum jennessii *and* Acritarch gen. et sp. nov. *assemblage) Martin* in *Martin and Dean, 1984

Description. At Manuels River, as at Random Island, the characteristic taxa are: *Eliasum jennessii*, Acritarch gen. et sp. nov., *Retisphaeridium dichamerum*, *R. howellii* and *Eliasum llaniscum*. *Cymatiosphaera crameri* Slavíková, 1968 is found only at Random Island, where it is rare.

Stratigraphic position in eastern Newfoundland. On the west side of Manuels River, this microflora has been recognized at one level (GSC loc. C-98036) in the uppermost part of the Chamberlains Brook Formation. The age is middle Middle Cambrian, upper part of the "*Paradoxides bennetti* Zone" (= *Hartella* assemblage). At Random Island (Martin and Dean, 1984) it is present in the upper part of the Chamberlains Brook Formation, in 16 m of Bed 8 of Hutchinson (1962), strata that lack macrofossils and are assigned that to the "*P. bennetti* Zone".

Discussion. Eliasum jennessii and Acritarch gen. et sp. nov. are known only from eastern Newfoundland. The stratigraphic range of the former coincides with that of microflora A0-1. In eastern Newfoundland (Martin and Dean, 1983) *Retisphaeridium dichamerum* and *R. howellii* are known from the uppermost Lower Cambrian and *Eliasum llaniscum* from the base of the Middle Cambrian. The distribution of these three species outside Newfoundland, compiled by Martin (in Martin and Dean, 1983, p. 357, 359; 1984, p. 440), may be summarized as follows. The first two extend from the topmost Lower Cambrian almost to the top of the Middle Cambrian. However, according to Downie (1984) *Retisphaeridium dichamerum* has been determined in the Upper Cambrian (*P. spinulosa* Zone) of the Anglo-Welsh area. *Eliasum llaniscum* is especially characteristic of the Middle Cambrian; records of it in the Upper Cambrian - Tremadoc of northeast Spain (Fombella, 1978, 1979, 1982) are considered with reserve in the absence of verifiable stratigraphic data. Vanguestaine and Van Looy (1983) also expressed doubts regarding the latter record, and illustrated the species from Middle Cambrian strata in the High Atlas of Morocco that contain also *Retisphaeridium dichamerum*. Smith (1981) and Welsch (1984) cited and Erkmen and Bozdoğan (1981) illustrated *Eliasum llaniscum* from the Middle Cambrian (dated palynologically) of, respectively, southeastern Ireland (Booley Bay Fm.), northern Norway (Digermul Group) and southeastern Turkey (boreholes in the Sosink Fm.). Downie (1984) recorded the species from the uppermost Lower Cambrian (Protolenid-Strenuellid Zone) to the middle Middle Cambrian (*Hypagnostus parvifrons* Zone) of the Anglo-Welsh area.

Microflora A0-1, from its stratigraphic position, equated with the lowest part of the *Paradoxides paradoxissimus* "Stage", should fall within the *Cristallinium cambriense* - *Eliasum* and/or *Timofeevia* Superzone (= Cc - ET Superzone) proposed by Vanguestaine and Van Looy (1983). The latter was stated to extend from the upper part of the *Paradoxides oelandicus* "Stage" to the lower part of the *Paradoxides forchhammeri* "Stage", and its reference section is situated in the Tacheddirt Valley, in the Moroccan High Atlas. The Cc - ET Superzone contains the

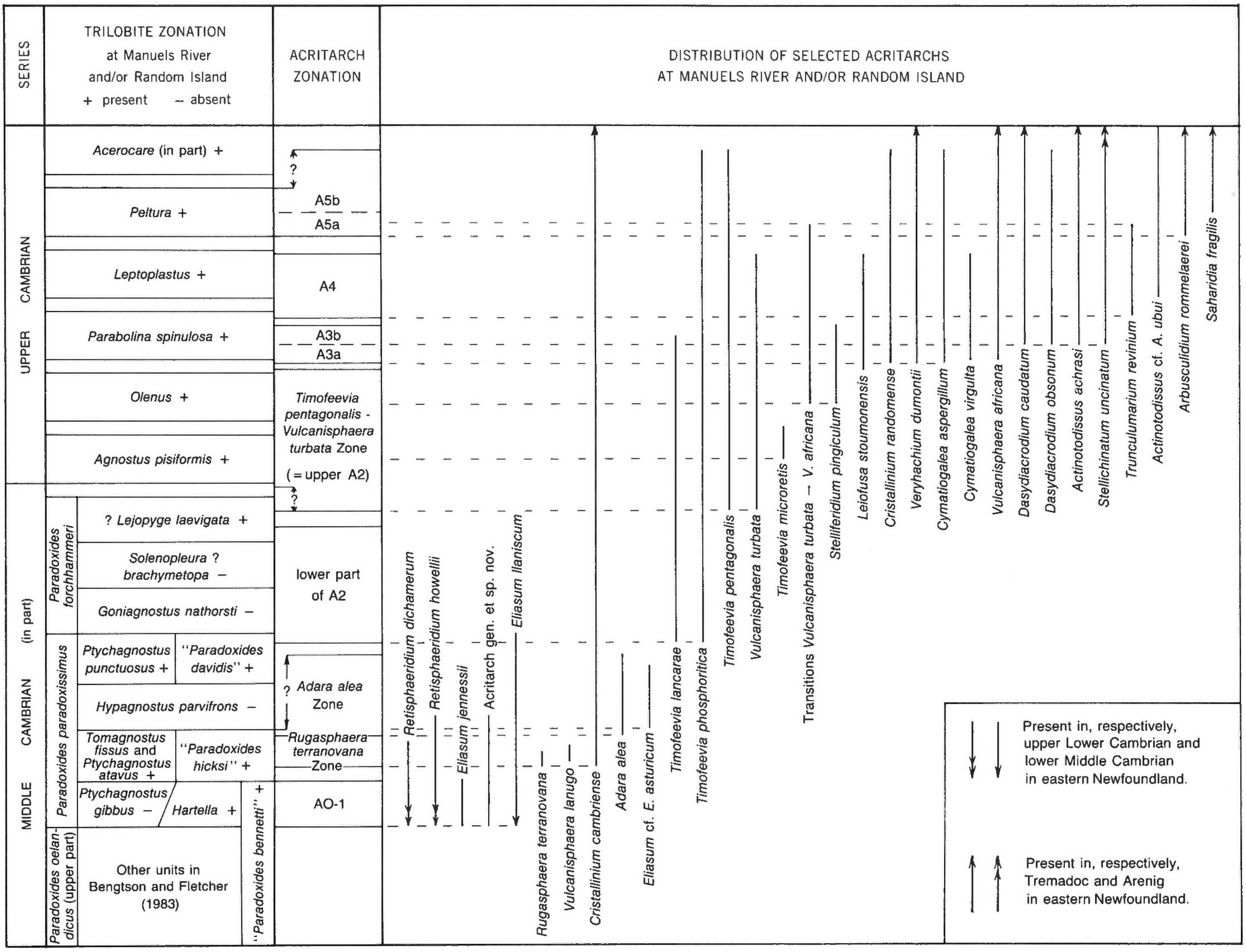

Figure 10. *Ranges of Middle and Upper Cambrian acritarchs at Manuels River and/or Random Island.*

first nominal species and one or both of the index genera. Such a definition limits its application in the Avalon Platform, where the index taxa appear successively in the following order: *Eliasum* at the base of the "*Paradoxides bennetti* Zone" (Martin and Dean, 1983); *Cristallinium cambriense* a little above the base of the "*Paradoxides hicksi* Zone" (Martin and Dean, 1984); and *Timofeevia* in the "*Paradoxides davidis* Zone" (Martin and Dean, 1981).

Rugasphaera terranovana *Standard Zone, Martin herein (= microflora A0 of Martin in Martin and Dean, 1984)*

Definition. Lower and upper boundaries of the zone are defined by the first appearances of, respectively, *R. terranovana* and *Adara alea*. The accompanying acritarchs characteristic of this zone are mainly *Vulcanisphaera lanugo* and *Cristallinium cambriense*, both of which make their first appearance here. *Eliasum jennessii* and *Cymatiosphaera crameri* are absent. Other taxa of microflora A0-1 may be present in variable abundance. *Eliasum*? *hutchinsonii* Martin (in Martin and Dean, 1984), rare at Random Island, is absent at Manuels River.

Stratigraphic position in eastern Newfoundland. The reference section is on the west side of Manuels River, where it has been recognized in 5.5 m of the Manuels River Formation (GSC locs. C-98041 to C-98047); its lower limit is 5 m above the upper limit of microflora A0-1, from which it is separated by palynologically barren strata. Its age is middle Middle Cambrian; lower, but not lowermost part of the "*Paradoxides hicksi* Zone". At Random Island, further examination of localities in the lower part of the Manuels River Formation permitted recognition of the *R. terranovana* Zone in 3.5 m of rock dated as "*Paradoxides hicksi* Zone" (GSC locs. C-97982 to C-97975 in Martin and Dean, 1984); the stratigraphic range of the zone coincides with microflora A0 of Martin (in Martin and Dean, 1984).

Discussion. *Rugasphaera terranovana* and *Vulcanisphaera lanugo* are known only from eastern Newfoundland, where they are confined to the "*Paradoxides hicksi* Zone". *Cristallinium cambriense* is particularly widely known from the Middle and Upper Cambrian (see references in Martin and Dean, 1981, p. 17; 1984, p. 440). Downie (1984) showed that the species extended from the upper part of the Middle Cambrian (*S.*? *brachymetopa* Zone) to the Upper Cambrian (*P. spinulosa* Zone) in the Anglo-Welsh area. According to

Vanguestaine and Van Looy (1983) the species appears earlier in the Middle Cambrian in Morocco than in Newfoundland, and they identified it in beds situated below a limestone conglomerate that contains trilobites possibly belonging to the lower part of the *Paradoxides oelandicus* "Stage". Smith (1981) and Erkmen and Bozdoğan (1981) recorded the species in southeastern Ireland and southeastern Turkey, respectively, from strata dated as Middle Cambrian from palynological studies. Welsch (1984) recorded the species, also without illustration, from strata in northern Norway dated as Middle and Upper Cambrian after comparison with the zonation of Vanguestaine and Van Looy (1983). From its stratigraphic position, the *R. terranovana* Zone lies within the Cc - ET Superzone of Vanguestaine and Van Looy (1983), from which, however, its nominal species has not been recorded.

Adara alea *Range Zone, Martin herein (= microflora A1 of Martin in Martin and Dean, 1981, 1984)*

Definition. The zone is defined by the range of the eponymous taxon. *Eliasum* sp. cf. *E. asturicum*, though always very rare, is considered characteristic and has not been found outside the zone. *Eliasum llaniscum* and *Cristallinium cambriense* are commonly present. Rare specimens of *Retisphaeridium dichamerum* and *R. howellii* are subsidiary components, found only at Manuels River.

Stratigraphic position in eastern Newfoundland. The reference section is on the west side of Manuels River, where it has been recognized in 4 m of strata of the Manuels River Formation (GSC locs. C-98048 to C-98051), and the age is middle Middle Cambrian. The lower limit of the zone, in the upper part of the "*Paradoxides hicksi* Zone", is 50 cm above the upper limit of the *R. terranovana* Zone, from which it is separated by strata that have not been investigated palynologically. The upper limit lies questionably within the "*Paradoxides davidis* Zone". On the west coast of Random Island, the range of the *Adara alea* Zone within the Manuels River Formation coincides with that of microflora A1 of Martin (in Martin and Dean, 1981, 1984) and it extends from 15.5 m to 10 m below the basal conglomerate of the Elliott Cove Formation. Its lower limit, in the upper part of the "*Paradoxides hicksi* Zone", is 1 m above the upper limit of the *R. terranovana* Zone, from which it is separated by palynologically barren strata. Owing to the lack of macrofossils at Random Island, the upper limit there is dated only as lying either between the "*Paradoxides hicksi* Zone" and the "*Paradoxides davidis* Zone", or within the lower part of the "*Paradoxides davidis* Zone".

Discussion. Adara alea and *Eliasum* cf. *E. asturicum* are known only from eastern Newfoundland. Extension of the zone's other taxa outside the Avalon Platform is considered in the two previous discussions. Stratigraphically, the *Adara alea* Zone lies within the Cc - ET Superzone of Vanguestaine and Van Looy (1983), from which the index species is not recorded.

Lower part of microflora A2 (with Timofeevia phosphoritica *and without* Vulcanisphaera turbata*) Martin in Martin and Dean, 1981*

Description. Timofeevia lancarae and *T. phosphoritica* appear. *Eliasum llaniscum* is rare in the basal part of the microflora (GSC loc. 95155 in Martin and Dean, 1981), and *Cristallinium cambriense* occurs sporadically throughout. The acritarchs are very poorly preserved and no other species was recorded.

Stratigraphic position in eastern Newfoundland. The microflora was recognized on both the west side (GSC loc. C-98055) and east side (GSC loc. C-98059) of Manuels River, in the lower part of the Elliott Cove Formation, strata dated as ?*L. laevigata* Zone. At Random Island (Martin and Dean, 1981) it was present in the uppermost 4.3 m of the Manuels River Formation, assigned to the "*Paradoxides davidis* Zone", and in the basal conglomerate of the Elliott Cove Formation, which is provisionally included in the ?*L. laevigata* Zone. The lower part of microflora A2 is of late Middle Cambrian age, and its lower limit is 4 m above the top of the *Adara alea* Zone, from which it is separated by palynologically barren strata.

Discussion. The description of the lower part of microflora A2 is very incomplete owing to the particularly bad state of preservation of the assemblage; nevertheless the unit may be included within the Cc - ET Superzone as defined by Vanguestaine and Van Looy (1983). In eastern Newfoundland, *Eliasum* and *Timofeevia* are found together only in the upper part of the "*Paradoxides davidis* Zone". According to the data of Potter cited by Smith (1981) and Downie (1984), the vertical ranges of *Eliasum* and *Timofeevia* do not overlap in the Anglo-Welsh area. The two genera have been recorded together by Smith (1981), Welsch (1984) and Erkmen and Bozdoğan (1981) from palynologically dated Middle Cambrian strata in, respectively, southeastern Ireland, northern Norway and southeastern Turkey. The appearance of *Timofeevia*, in particular of *T. lancarae*, at the end of the Middle Cambrian is relatively late in Newfoundland compared with that in Czechoslovakia (*Eccaparadoxides pusillus* Zone according to Vavrdová, 1976) and Morocco (probably at the beginning of the *Paradoxides oelandicus* "Stage" according to Vanguestaine and Van Looy, 1983). In Great Britain (Downie, 1984) *T. lancarae* and *T. phosphoritica* appear in the upper part of the Middle Cambrian (*S.? brachymetopa* Zone). In the Franco-Belgian Ardennes (Vanguestaine, 1974, 1978), northeastern Spain (Fombella, 1978, 1979) and the northwest of the East European Platform (Jankauskas, 1980, non 1976; Volková, 1980, non Volková et al., 1979), the appearance of *T. lancarae* is dated palynologically as being from the early part of the Middle Cambrian. In Sardinia, Albani et al. (1985) illustrated *T. lancarae* and *T. phosphoritica* from deposits assigned to the Upper Cambrian on the basis of acritarch evidence, and Pittau (1985) considered *T. phosphoritica* to have been reworked when it was found in palynologically dated Tremadoc deposits in Sardinia.

Timofeevia pentagonalis – Vulcanisphaera turbata *Zone (Tp - Vt Zone) Vanguestaine and Van Looy, 1983 (= upper part of microflora A2 of Martin and Dean, 1981)*

Description. Timofeevia pentagonalis and *Vulcanisphaera turbata*, whose respective order of appearance has not been established, are present together from the base of the zone. *Timofeevia lancarae* and *T. phosphoritica* are variably abundant and *Cristallinium cambriense* is rare. Taxa enter successively in the assemblage; however, neither sampling in Newfoundland nor data from elsewhere permit the establishment of new units within the acritarch zone. *Timofeevia microretis* extends from the *A. pisiformis* Zone into strata without trilobites that underlie the *Olenus* Zone. All the other taxa that appear subsequently are present at least in the upper part of microflora A3 (= A3b). *Stelliferidium pingiculum* and transitional forms *Vulcanisphaera turbata* → *V. africana* were determined from the *Olenus* Zone onward and *Leiofusa stoumonensis* enters between the latter zone and that of *P. spinulosa*.

Stratigraphic position in eastern Newfoundland. The reference section on the western coast of Random Island is in the Elliott Cove Formation; it begins (GSC loc. 94431 in Martin and Dean, 1981) possibly within the ?*L. laevigata* Zone (and certainly below the *A. pisiformis* Zone), 3.3 m above the conglomerate that contains the lower part of microflora A2, and it ranges upward into strata without macrofossils (GSC loc. 92993 in Martin and Dean, 1981) between the *Olenus* Zone and the *P. spinulosa* Zone. The age is late Middle Cambrian to Late Cambrian, and the total thickness at Random Island is estimated to be approximately 200 m. On the west bank of Manuels River, the zone was recognized in 11 m (GSC locs. C-98056 to C-98062) of the Elliott Cove Formation extending from between the ?*L. laevigata* and *A. pisiformis* zones to the lower part of the *Olenus* Zone.

Discussion. Timofeevia pentagonalis and *Leiofusa stoumonensis* are recorded from the *Olenus* Zone to the *P. spinulosa* Zone in the Anglo-Welsh area (Downie, 1984). All the following quotations refer to deposits dated palynologically. In the Upper Cambrian of Belgium, the Tp-Vt Zone is recognized in the Revinian (Rn2a) of the Massif of Stavelot (Vanguestaine in Vanguestaine and Van Looy, 1983). *Vulcanisphaera turbata* and *Leiofusa stoumonensis* have been illustrated from, respectively, a level within the Solanas Formation of central Sardinia (Albani et al., 1985) and the Ulgaz Horizon in Estonia (Volková, 1983). Welsch (1984) recorded *Timofeevia microretis*, *T. pentagonalis* and *Vulcanisphaera turbata* from the Middle and Upper Cambrian in the Digermul Group, northern Norway.

Microflora A3 (= Cristallinium randomense – Veryhachium dumontii *assemblage) Martin in Martin and Dean, 1981, revised herein*

Revised description. Microflora A3 is divided into a lower (A3a) and an upper (A3b) part. *Cristallinium randomense*, *Veryhachium dumontii*, *Cymatiogalea aspergillum* and *C.* cf. *C. cylindrata* are present together from the beginning of A3a; *C. virgulta* and *Vulcanisphaera africana* appear a little higher. All were found in variable abundance in most samples. *Stelliferidium pingiculum*, *Vulcanisphaera turbata* and transitional forms *V. turbata* → *V. africana* were found frequently. Minor components include *Veryhachium* sp. A and *Impluviculus* sp. A. Species of *Timofeevia* are rare.

The appearance of diacrodians is characteristic of microflora A3b. *Dasydiacrodium caudatum*, *D. obsonum* and *Actinotodissus achrasi* appear. *Stellichinatum uncinatum* enters and its variability here includes specimens whose shape resembles that of *Tectitheca* sp.

Stratigraphic position in eastern Newfoundland. Microflora A3 is of Late Cambrian age, and on the west coast of Random Island it ranges through more than 150 m (estimated) of the Elliott Cove Formation, from rocks lacking macrofossils between the *Olenus* Zone and the *P. spinulosa* Zone, to the lower part of the *P. spinulosa* Zone.

The lower limit of microflora A3a (GSC loc. 92994 in Martin and Dean, 1981) is an estimated 76 m above the upper limit of the *Timofeevia phosphoritica* – *Vulcanisphaera turbata* Zone, from which it is separated by strata that have not been investigated palynologically and are discontinuous because of faulting. Microflora A3b, the upper part of the microflora, occurs within the *P. spinulosa* Zone and has been found in the interval between GSC locs. C-98011 and 87793 (in Martin and Dean, 1981). The base of microflora A3b is separated from the top of microflora A3a by 3.1 m of strata that have not been sampled palynologically. On the west side of Manuels River, microflora A3a has been recognized in 5.9 m (GSC locs. C-98067 to C-98068) of the Elliott Cove Formation belonging to the *P. spinulosa* Zone.

Discussion. See under discussion of microflora A4.

Microflora A4 (= Trunculumarium revinium - Dasydiacrodium caudatum *assemblage) Martin in Martin and Dean, 1981, revised herein*

Revised description. Microflora A4 is distinguished from microflora A3b mainly by the appearance of *Trunculumarium revinium*, which ranges upward into the *Peltura* zones. Of the other taxa in microflora A3, *Stelliferidium pingiculum* is the only one that is characteristically absent; *Leiofusa stoumonensis*, though commonly present, is less abundant; *Vulcanisphaera turbata* and transitional forms *V. turbata* → *V. africana* are found more rarely, and the genus is represented mainly by *V. africana*. *Dasydiacrodium caudatum* is commonly found, but had appeared earlier, in microflora A3b. *Actinotodissus* cf. *A. ubui* enters later, in microflora A4, in strata belonging to the *Leptoplastus* Zone.

Stratigraphic position in eastern Newfoundland. On the west coast of Random Island, microflora A4 is present in the Elliott Cove Formation, in 3 m of strata (GSC locs. C-98014 to C-98020) belonging to the upper part of the *P. spinulosa* Zone and in 0.3 m (GSC loc. C-98022, and GSC loc. 87789 in Martin and Dean, 1981) belonging to the *Leptoplastus* Zone. The base of microflora A4 is separated from the top of microflora A3b by 3.1 m of strata not yet investigated palynologically.

Discussion. Vanguestaine and Van Looy (1983), combining microfloras A3 and A4, introduced a *Trunculumarium revinium* – *Veryhachium dumontii* Superzone (Tr-Vd Superzone). They cited as the reference section, strata of the Elliott Cove Formation at Random Island, extending from beds without trilobites between the *Olenus* Zone and the *P. spinulosa* Zone up to the summit of the latter zone. The lower limit of the Tr-Vd Superzone was established on the joint presence of *Cristallinium randomense*, a species not yet illustrated from outside Newfoundland, and *Veryhachium dumontii*; the upper limit was defined by the disappearance of *Trunculumarium revinium*. No interregional correlation of the superzone was furnished by its authors. This definition of the superzone is confusing in view of the composition of the assemblage and the vertical range of the guide taxa in eastern Newfoundland as they are now understood. In particular, its usage masks the successive appearance of: *Vulcanisphaera africana*, known especially from the Tremadoc Series (see references in Martin, 1982, p. 37), between the *Olenus* Zone and the *P. spinulosa* Zone; diacrodians toward the middle of the *P. spinulosa* Zone; and *Trunculumarium revinium* in the upper part of the *P. spinulosa* Zone. In a generalized sequence comparable to that in the Avalon Platform, Downie et al. (1979) noted that the first appearances of *Dasydiacrodium* sp., *Polygonium* sp. and *Tectitheca* sp. (tentatively considered here as close to the variability of *Stellichinatum uncinatum*, which ranges from microflora A3b) succeed those of *Vulcanisphaera* sp., *Stelliferidium* sp. and *Cymatiogalea* sp. in the Merioneth Series of Great Britain. In the Anglo-Welsh area (Downie, 1984) *Veryhachium dumontii* ranges from the *Olenus* Zone to the *P. spinulosa* Zone; *Trunculumarium revinium* ranges from high in the *P. spinulosa* Zone to the lower Tremadoc; and *Stellichinatum uncinatum* enters higher, in the *Acerocare* Zone.

The badly preserved assemblage from the Niarbyl Flags, Manx Group of the Isle of Man, which Molyneux (1979) attributed tentatively to the Tremadoc Series, contains *Cristallinium cambriense*, *Timofeevia phosphoritica*, *Stelliferidium* sp., *Vulcanisphaera* sp. and "?*Acanthodiacrodium* sp.". In view of Molyneux's determinations, it could belong to the uppermost Upper Cambrian (from *P. spinulosa* Zone upward).

Veryhachium dumontii, *Leiofusa stoumonensis*, *Dasydiacrodium caudatum* and *Trunculumarium revinium* on the one hand, and the appearance of diacrodians on the other, are characteristic (Vanguestaine, 1974) of the palynologically dated Zone 5 and Zone 6, respectively, in the Upper Cambrian of the Franco-Belgian Ardennes. Vanguestaine and Van Looy (1983) correlated Zone 5 with the *P. spinulosa* Zone and Zone 6 with the *Peltura* Zone.

Cristallinium randomense, which, with *Veryhachium dumontii*, marks the base of microflora A3, was illustrated by Volková (1983) from Estonian strata that she attributed, on the basis of acritarch evidence, to the early part of the Upper Cambrian. From the same Ulgaz Horizon, she figured *Veryhachium dumontii* and emphasized the absence of diacrodians. The assemblage that she illustrated may correspond to that of microflora A3a. Welsch's (1984) record of *Cristallinium randomense* in the lower part of the Berlogaissa Formation of northern Norway is considered here with reserve; the deposits said to contain the species were attributed to the beginning of the Tremadoc for palynological and sedimentological reasons in the absence of *Rhabdinopora flabelliformis*, found for the first time 100 m higher in the section.

In addition to its occurrence in the Upper Cambrian and Tremadoc of eastern Newfoundland, *Actinotodissus achrasi* is known from the Tremadoc of Belgium (Martin, 1977) and of Hérault (Martin, 1973) and Corbières (Cocchio, 1982), both in France. The species occurs in the Upper Cambrian of Dayangcha, northeastern China (Section A, Bed 4, Yin in Chen et al., 1985; Bed 3 of same section, author's personal observation), in strata dated (Chen et al., 1985) as *Cambroistodus minutus* Subzone, the youngest Cambrian subzone with protoconodonts in Utah (Miller et al., 1982). At Dayangcha, *Actinotodissus achrasi* occurs with *Dasydiacrodium obsonum* and with *Stellichinatum uncinatum*, the variability of which overlaps with that of *Tectitheca* sp. In addition to these three taxa and the relative abundance of *Cymatiogalea* sp., this Dayangcha assemblage is partly comparable to those of the Upper Cambrian at Random Island, from microflora A3b onward. However, the latter contains distinctive taxa (see Figure 10), which are absent from this section on the north margin of the Sino-Korean Platform.

Microflora A5 (= Arbusculidium rommelaerei – Vulcanisphaera africana *assemblage) Martin in Martin and Dean, 1981, revised herein*

Revised description. Microflora A5 is distinguished from microflora A4 mainly by the appearance of *Arbusculidium rommelaerei*. *Vulcanisphaera africana* is known to range from microflora A3a; *Stellichinatum uncinatum* and *Actinotodissus achrasi* from microflora A3b; and *Actinotodissus* cf. *A. ubui* from microflora A4. *Leiofusa stoumonensis*, *Vulcanisphaera turbata* and *Cymatiogalea virgulta* are not found. *Cymatiogalea*? *membranula* Martin (in Martin and Dean, 1978) and *Stelliferidium cortinulum* (Deunff) Deunff et al., 1974 first appear in the lower part (A5a) of the microflora. In the upper part, A5b, *Saharidia fragilis* and *Stelliferidium gautieri* (Martin) Pittau, 1985 are very rare.

Stratigraphic position. On the west coast of Random Island, microflora A5 is present in the upper part of the Elliott Cove Formation, in strata assigned to the *Peltura* Zone and, in part, *Acerocare* Zone. The age is Late Cambrian. Assemblage (microflora) A5a was found 3.4 m (GSC loc. C-98023) above the upper limit of microflora A4 and also in one sample from an unmeasured section (GSC loc. 94435 in Martin and Dean, 1981). Assemblage A5b was found in 7.7 m of rock at GSC locs. 92298 and 94432 (in Martin and Dean, 1981), the latter being in the *Acerocare* Zone; the section is an estimated 42 m above GSC loc. C-98023, but is separated from it by faulted strata.

Discussion. Vanguestaine and Van Looy (1983) introduced an *Arbusculidium rommelaerei* - *Vulcanisphaera africana* Zone, its type section coinciding with the *Peltura* zones in the Elliott Cove Formation at Random Island. For the same region they also proposed an *Arbusculidium destombesii* – *Vulcanisphaera capillata* Zone (= microflora A6 Martin and Dean, 1981) that, according to them, questionably begins in the ?*Acerocare* Zone of the Elliott Cove Formation and extends into the Tremadoc of the Clarenville Formation. The last-named may also be, in part, of uppermost Cambrian age and has not been systematically investigated palynologically. This formal treatment is not justified by the discontinuity of the outcrops and the sporadic sampling.

Preliminary analogies between the Late Cambrian acritarchs of Newfoundland and those of the Baltic region have already been suggested by Volková and Goloub (1984). The assemblage that they described from the lower part of the *Obolus* Sandstone (Ladoga Suite) in the Leningrad area is linked to that of microflora A5 by the appearance of *Arbusculidium* sp.

Arbusculidium rommelaerei and *Cymatiogalea*? *membranula* are recorded only from the Upper Cambrian and Tremadoc in eastern Newfoundland (Martin, 1982). *Stelliferidium cortinulum* has been determined in the Tremadoc of England (Rasul, 1974), southwestern France (Martin, 1973; Cocchio, 1982), Belgium (Martin, 1977), Celtiberia, Spain (Wolf, 1980), southwest Sardinia (Pittau, 1985) and the Algerian Sahara (Deunff, 1961). *Stelliferidium gautieri* is present in the Tremadoc of the Montagne Noire, southern France (Martin, 1973), Belgium (Martin, 1977) and Sardinia (Pittau, 1985). *Saharidia fragilis*, recognized also in the Tremadoc of eastern Newfoundland (Martin, 1982), is reported from the Tremadoc of the Anglo-Welsh area (Rasul and Downie, 1974), southwestern France (Martin, 1973), the Algerian Sahara (Combaz, 1967; Jardiné et al., 1974) and northwestern Argentina (Martin in Bultynck and Martin, 1982).

SYSTEMATIC DESCRIPTIONS OF ACRITARCHS

Genus *Actinotodissus* Loeblich and Tappan, 1978

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

Actinotodissus achrasi (Martin) comb. nov.

Plate 10, figures 1-5

Acanthodiacrodium achrasi n. sp. Martin, 1973, p. 30, Pl. 5, fig. 11; Pl. 6, figs. 8, 11, 19; Pl. 8, figs. 1, 2, 4.
Acanthodiacrodium achrasi Martin, 1973. Martin in Dean and Martin, 1978, Pl. 3, fig. 9.
Acanthodiacrodium achrasi Martin, 1973. Martin in Martin and Dean, 1981, p. 26.
p.p. *Acanthodiacrodium uniforme* Burmann, 1968. Yin in Chen et al., 1985, Pl. 28, fig. 1 (non fig. 24).

Figured specimens. GSC 83124 (Pl. 10, figs. 1, 2), GSC 83125 (Pl. 10, fig. 3), GSC 83126 (Pl. 10, fig. 4), GSC 83127 (Pl. 10, fig. 5).

Description. Based on eighty specimens. Outline of vesicle elliptical with two polygonal to rounded poles that are originally symmetrical, but are often modifed by compression. Each pole has an almost equal number – five to fifteen – of similarly shaped processes. If the number of processes does not exceed ten, there can be a difference of one or two processes between the two poles; if the number is more than ten, the difference can be up to three.

The processes are conical, distally tapered with simple tip, are hollow, and communicate with the interior of the vesicle; their lengths vary from one half to the full length of the vesicle. The wall of the vesicle and processes is thin and apparently single-layered, covered with reduced spines, each of which has a granulose base and hair-like tip. No definite excystment opening observed.

Dimensions. Based on twenty-five specimens. Length and width of vesicle from 22 to 37 (average 27) µm and 14 to 27 (average 20.5) µm, respectively; length and basal width of processes from 12 to 19 µm and from 1.5 to 3 µm, respectively; wall thickness about 0.4 µm; length of spines on processes from 0.3 to 1.5 µm.

Discussion. The poles are similarly shaped, each provided with an approximately equal number of elongated processes; each of the latter has a simple distal extremity and its internal cavity communicates with that of the central body, features that justify placing the species in *Actinotodissus*.

Loeblich and Tappan (1978, p. 1237, 1238), in their detailed review of the confusing taxonomy of the diacrodians, pointed out that *Lophodiacrodium* Timofeev, 1958 is very similar to, if not identical with, *Acanthodiacrodium* Timofeev, 1958. The type species by monotypy of these two genera are, respectively, *Lophodiacrodium obtusum* Timofeev, 1958 and *Acanthodiacrodium dentiferum* Timofeev, 1958. In each case the holotype is a half specimen, it being assumed that the absent pole is similar to the one present; the latter is ornamented with short, conical knobs, as seen in Timofeev's (1958, Pl. 1, figs. 1, 2; Pl. 3, figs. 1, 2) illustrations. It is suggested here that usage of these genera should be restricted to the type species and that, contrary to the opinion of Deflandre and Deflandre-Rigaud (1962), *Diornatosphaera* Downie, 1958 should be used for diacrodians in which the similarly shaped poles are covered with short, solid spines or protuberances in approximately equal numbers. One of the Late Cambrian specimens from Dayangcha, northeastern China, attributed to *Acanthodiacrodium uniforme* by Yin (in Chen et al., 1985) has eight processes at one pole, six at the other, and reduced, hair-like spines locally preserved on some of the processes. From personal observation, this specimen, which is from Bed 4, belongs to *Actinotodissus achrasi*, as do others from Bed 3.

Occurrence. In eastern Newfoundland *Actinotodissus achrasi* appears in the Upper Cambrian (upper part of the *Parabolina spinulosa* Zone); it extends into the Tremadoc and is commonly present in the upper part of the Elliott Cove Formation and in the Clarenville Formation at Random Island (Martin in Martin and Dean, 1981), and in the Bell Island Group at Bell Island (Martin in Dean and Martin, 1978; for review of lithostratigraphy, see Ranger et al., 1984).

Actinotodissus cf. *A. ubui* (Martin) comb. nov.

Plate 11, figures 1, 2

p.p. *Acanthodiacrodium ubui* Martin, 1969. Martin in Martin and Dean, 1981, p. 16, Pl. 4, figs. 2, 4.

Figured specimens. GSC 83128 (Pl. 11, fig. 1), GSC 83129 (Pl. 11, fig. 2).

Description. Based on fifty specimens. Vesicle outline elliptical and squat with two similarly shaped, almost rounded poles. About twenty to thirty processes on each pole; the equatorial area without processes is relatively short. The processes are conical, slender with a narrow base that is hollow and communicates with the interior of the vesicle; they taper distally towards the usually broken tip. The wall of both vesicle and processes is thin and apparently single-layered; spinose ornamentation, often damaged, is present only on the process wall. No definite excystment mechanism observed.

Dimensions. Based on twenty specimens. Length and width of vesicle from 25 to 38 (average 30) µm and 18 to 30 (average 21) µm, respectively; length and basal width of processes from 9 to 20 µm and from 1.5 to 3 µm, respectively; wall thickness about 0.4 µm; length of spines on processes from 0.5 to 1.5 µm.

Discussion. The change of generic attribution is justified for the same reasons as for *A. achrasi* (see p. 35). *Actinotodissus* cf. *A. ubui* represents a new species that is not introduced here, because the specimens are insufficiently well preserved. It differs from *A. ubui* in having generally more numerous processes and an equatorial zone that is shorter and lacks longitudinal wrinkles. *Actinotodissus spinum* (Rasul, 1979) comb. nov., from the Tremadoc of Shropshire, has smooth, more tapered processes, and its central body is completely covered with fine, longitudinal striae. *Actinotodissus achrasi* prossesses less numerous processes and a longer equatorial zone; in addition, ornamentation of the membrane is not limited to the processes and consists of more delicate, hair-like spines.

Occurrence. Variably abundant at Random Island in the upper part of the Elliott Cove Formation (*Leptoplastus*, *Peltura* and *Acerocare* zones); the last-named is based on additional observations for material from GSC loc. 94432 in Martin and Dean (1981).

Genus *Arbusculidium* Deunff, 1968

Type species. Arbusculidium destombesii Deunff, 1968 by original designation.

Arbusculidium rommelaerei Martin <u>in</u> Martin and Dean, 1981

Plate 11, figures 7, 9-13

Arbusculidium rommelaerei sp. nov. Martin <u>in</u> Martin and Dean, 1981, p. 16, Pl. 3, figs. 6, 8, 21, 23; Pl. 5, fig. 1.

Figured specimens. GSC 83134 (Pl. 11, fig. 7), GSC 83135 (Pl. 11, figs. 9, 11), GSC 83136 (Pl. 11, figs. 10, 12), GSC 83137 (Pl. 11, fig. 13).

Dimensions. Based on ninety specimens. Length and width of vesicle from 22 to 40 (average 29) µm and 17 to 30 (average 22) µm, respectively; length of processes from 2 to 5 µm on the more ornamented pole, and from 5 to 10 µm on the less ornamented pole; wall thickness about 0.3 µm.

Discussion. Based on four hundred specimens. *Arbusculidium rommelaerei* differs from *Dasydiacrodium cilium* Rasul, 1979 from the Tremadoc of Shropshire, in having echinate, as opposed to smooth, processes on the less ornamented pole. The more ornamented pole has numerous, more slender processes interconnected along their length by fine, anastomosing, net-like ramifications. *Dasydiacrodium cilium* has numerous conical processes that are both wider and hair-like, as does *Arbusculidium* sp. figured by Volková and Goloub (1984, Pl. 2, fig. 12) from the Upper Cambrian of western U.S.S.R., which may be conspecific.

Occurrence. Recorded only from Random Island. Appears in the upper part of the Elliott Cove Formation (*Peltura* zones). Variably abundant in the Clarenville Formation (Martin <u>in</u> Martin and Dean, 1981), which is of early Tremadoc and perhaps, in part, latest Cambrian age.

Genus *Cristallinium* Vanguestaine, 1978

Type species. Cristallinium cambriense (Slavíková) Vanguestaine, 1978 by original designation.

Cristallinium cambriense (Slavíková) Vanguestaine, 1978

Plate 12, figures 1, 2

Dictyotidium cambriense sp. nov. Slavíková, 1968, p. 201, Pl. 2, figs. 1, 3?.
Cristallinium cambriense (Slavíková) Vanguestaine, 1978. Martin <u>in</u> Martin and Dean, 1981, p. 17, Pl. 3, figs. 4, 5, 9, 11; Pl. 5, figs. 3, 5, 8, 11 (includes previous synonymy).
Cristallinium cambriense (Slavíková) Vanguestaine, 1978. Vanguestaine and Van Looy, 1983, p. 72, Pl. 1, figs. 7, 8.
Cristallinium cambriense (Slavíková) Vanguestaine, 1978. Martin <u>in</u> Martin and Dean, 1984, p. 433, Pl. 57.1, figs. 1-7, 9, 13.
Cristallinium cambriense (Slavíková) Vanguestaine. Volková, 1983, Pl. 2, fig. 3.
Cristallinium cambriense (Slavíková) Vanguestaine, 1978. Pittau, 1985, p. 180, Pl. 4, fig. 12; Pl. 7, fig. 3.

Figured specimens. GSC 83138 (Pl. 12, fig. 1), GSC 83139 (Pl. 12, fig. 2).

Dimensions. Based on one hundred specimens. Vesicle diameter from 25 to 49 (average 30) µm; wall thickness from 0.3 to 0.4 µm; height of spines or reduced rod-like projections up to 1 µm.

Discussion. Based on approximately five hundred specimens. The type material of *C. cambriense* came from a level within the Jince Formation dated as Middle Cambrian, *Ellipsocephalus hoffi* Subzone, from a borehole in the Brdy Mountains, Czechoslovakia. Judging from the photograph by Slavíková (1968, Pl. 1, fig. 3), the paratype appears to have incomplete processes and could be a damaged specimen of *Timofeevia* sp. Vavrdová (1976, Pl. 1, figs. 1, 3, 5, 8) figured the species from several Middle Cambrian trilobite zones in the Jince Formation. Examination of a sample from the *Eccaparadoxides pusillus* Zone at Vinice, near Jince, kindly provided by Milada Vavrdová, indicates that well preserved specimens of *Cristallinium cambriense* have numerous (and not rare, as mentioned in the original diagnosis), small, spinose projections on the septa. In Czechoslovakia and Newfoundland, as in Belgium (Vanguestaine, 1978), the apparent variability of the species is related mainly to the state of preservation of the ornamentation.

As emphasized by Downie (1982, p. 279), *Cristallinium* resembles *Retisphaeridium* Staplin, Jansonius and Pocock, 1965 in possessing sutures coinciding with the sides of the polygonal fields, along which the specimens open preferentially. At Manuels River and at Random Island, the determination of *Cristallinium cambriense, Retisphaeridium howellii* Martin <u>in</u> Martin and Dean, 1983 (see Pl. 12, figs. 3, 4 of present paper) and *R. dichamerum* Staplin, Jansonius and Pocock, 1965 (see Pl. 12, figs. 7-9 of present paper) can only be established on well preserved specimens. The two last-named species differ from the first in having a smooth vesicle whose ribs diminish or disappear on the equatorial margin. *Retisphaeridium dichamerum* possesses a number, often greater than twenty-five, of raised polygonal fields, compared with about fifteen in *R. howellii.*

Occurrence. In eastern Newfoundland, the species ranges from the Middle Cambrian, where it is most common, into the Tremadoc. At Random Island and Manuels River it is commonly present in variable abundance in the Manuels River Formation, where it appears in the "*Paradoxides hicksi* Zone"; it is rare in the Elliott Cove Formation. It is very rare at Random Island in the Clarenville Formation (Martin <u>in</u> Martin and Dean, 1981), and at Bell Island in the Tremadoc portion of the Bell Island Group (Martin <u>in</u> Dean and Martin, 1978; see also Ranger et al., 1984 for a recent review of stratigraphy).

Cristallinium randomense Martin <u>in</u> Martin and Dean 1981 emend. Martin herein

Plate 13, figures 1-17

Cristallinium randomense sp. nov. Martin <u>in</u> Martin and Dean, 1981, p. 18, Pl. 3, figs. 2, 10, 12, 17, 20, 24, 26; Pl. 6, figs. 4, 6.
Cristallinium randomense Martin, 1982, Pl. 1, fig. 18.
Cristallinium sp. Volková, 1983, Pl. 2, figs. 3, 5.

Figured specimens. GSC 83140 (Pl. 13, fig. 1), GSC 83141 (Pl. 13, fig. 2), GSC 83142 (Pl. 13, fig. 3), GSC 83143 (Pl. 13, fig. 4), GSC 83144 (Pl. 13, fig. 5), GSC 83145 (Pl. 13, figs. 6, 10), GSC 83146 (Pl. 13, fig. 7), GSC 83147 (Pl. 13, fig. 8), GSC 83148 (Pl. 13, fig. 9), GSC 83149 (Pl. 13, fig. 11), GSC 83150 (Pl. 13, fig. 12), GSC 83151 (Pl. 13, fig. 13), GSC 83152 (Pl. 13, figs. 14, 17), GSC 83153 (Pl. 13, fig. 15), GSC 83154 (Pl. 13, fig. 16).

Emended diagnosis. Based on more than one thousand specimens, including about sixty examined with the SEM. Vesicle originally globular, slightly polygonal in outline with psilate, shagreenate, or weakly granulate, surface. Low, sometimes discontinuous septa delimit six to about ten pentagonal fields on each side of the vesicle. Most of the numerous processes are aligned along sides of fields. Rarely, single processes may develop directly from the vesicle surface. Secondary, and relatively rather broad, folds along the polygonal sides (for example, Pl. 13, figs. 9, 13, 15-17) may obscure the septa. The processes are formed by reduced, solid, relatively squat projections, more or less conical with a truncated top that is simple, bilobate or trilobate according to the number (one to three) of narrow, filamentous spines emerging from it; the basal projections often appear solid and opaque, but originally were probably hollow. The filamentous, sinuous spines are simple or branch at between one and two-thirds of their length; very often they are broken. Numerous, very fine, anastomosing threads are developed along the filamentous spines and link them together (for example, Pl. 13, figs. 6, 17). Excystment by rupture of the vesicle wall along the sides of the polygonal fields produces a "mouth-like" aperture (Pl. 13, figs. 1-4, 7). Clusters of two (Pl. 13, fig. 3) to four specimens occur rarely.

Dimensions. Based on one hundred specimens. Diameter of vesicle from 25 to 55 (average 36) µm; wall thickness about 0.3 µm; diameter of polygonal fields from 12 to 18 µm; height of septa from 0.5 to 3 µm; length and basal width of projection at base of processes from 1 to 2 µm and 0.5 to 2 µm, respectively; distance between bases of processes from 1 to 4 µm; maximum length of distal filaments 5 µm.

Discussion. Variability of the species is apparent rather than real and depends largely on the preservation. The shagreenate or weakly granulate ornamentation of the vesicle wall appears to be increased by corrosion and is more obvious in transmitted light than under the SEM; in particular, the very low, narrow, discontinuous ornamentation that may connect the granules, mentioned in the original diagnosis, seems to be produced by degradation of the membrane. The anastomosing threads along the filamentous spines are preserved locally, and are seen clearly only under the SEM. The holotype and most other specimens observed in transmitted light present a confused mass of superimposed filaments. On the basis of the grouping and ornamentation of the filamentous, anastomosed spines arranged along the septa, the species represents a transition between the genera *Cristallinium* and *Vulcanisphaera*.

Cristallinium neriscum (Jankauskas) Martin (in Martin and Dean, 1981) possesses, according to the original diagnosis (Jankauskas, 1976, p. 191, Pl. 25, figs. 11, 19), a polygonal network of low, distinct ridges, the summit of which is provided with a zigzag pattern of protuberances. This species, in which spinose distal projections are not mentioned, resembles corroded specimens of *C. randomense*. The latter is retained as a distinct taxon in the absence of a sufficiently detailed description of the former. *Cristallinium neriscum* has been considered successively (Jankauskas, 1976, 1980), on the basis of palynological criteria, as being characteristic of the Lower and of the Middle Cambrian in the northwest part of the east European platform.

Occurrence. Often present in variable abundance in the Elliott Cove Formation, where it enters in the Upper Cambrian, at Random Island and Manuels River. The species appears in strata without macrofossils between the *Olenus* Zone and the *Parabolina spinulosa* Zone, and ranges upward into the Clarenville Formation (GSC loc. 93000 in Martin and Dean, 1981), uppermost Cambrian or lower Tremadoc, where it is extremely rare.

Genus *Cymatiogalea* Deunff, 1961 emend.
Deunff, Gorká, and Rauscher, 1974

Type species. Cymatiogalea margaritata Deunff, 1961 by original designation.

Cymatiogalea aspergillum Martin sp. nov.

Plate 14, figures 1-7, 9

Holotype. GSC 83157 (Pl. 14, fig. 3).

Paratypes. GSC 83155 (Pl. 14, fig. 1), GSC 83156 (Pl. 14, figs. 2, 6), GSC 83158 (Pl. 14, fig. 4), GSC 83159 (Pl. 14, fig. 5), GSC 83160 (Pl. 14, fig. 7), GSC 83161 (Pl. 14, fig. 9).

Type locality. GSC loc. C-98011, Random Island. Elliott Cove Formation; strata containing *Orusia lenticularis*, indicative of the Upper Cambrian, *Parabolina spinulosa* Zone.

Derivation of name. Latin, *aspergillum* = sprinkler; by apposition.

Diagnosis. Based on one hundred specimens. Vesicle originally globular, circular to slightly polygonal in outline, with psilate to shagreenate surface; vesicle wall solid and apparently single-layered. Approximately twenty to thirty, more or less cylindrical processes, with smooth or finely spinose wall, are developed on each side of the vesicle. The processes are aligned along the sides of the quadrangular, pentagonal or hexagonal fields, and are interconnected proximally by low ridges; they support along the whole of their length a delicate, transparent membrane. The trunks of the processes are hollow and communicate with the vesicle cavity; the distal half to one-third of their length branches to form usually two, or sometimes three, branches that are unequally divided, up to the second or third order. Total length of processes is between a quarter and a half the diameter of the vesicle. Excystment by polygonal opening, the diameter of which is between one third and one half that of the vesicle. Processes fringe the opening and are not observed on the operculum.

Dimensions. Based on forty specimens. Diameter of vesicle from 20 to 30 (average 26) µm; diameter of polygonal fields from 11 to 15 µm; thickness of vesicle wall about 0.3 µm; length and basal width of processes from 6 to 11 µm and from 0.7 to 1.5 µm, respectively; distance between processes 3 to 5 µm.

Discussion. Most of the specimens are corroded; processes and ridges are usually black and the vesicle wall is irregularly brown. Ridges and transparent membrane are often locally preserved (for example, Pl. 14, fig. 6). The junction between the interior of the vesicle and that of the processes is visible only on homogeneously translucent specimens.

Four Tremadoc species bear some resemblance to *C. aspergillum*, but differ as follows: *C. membrana* Rasul, 1974 has processes thicker at the base and with forked tips; *C. cylindrata* Rasul, 1974 has processes with distally digitate tips; neither of these two species has ridges connecting the bases of the processes. *Cymatiogalea velifera* (Downie) Martin, 1969 has processes that bifurcate or trifurcate more distally. *Cymatiogalea multarea* (Deunff) Deunff et al., 1974 has much narrower processes without transparent membranes.

Occurrence. Variably abundant in the Elliott Cove Formation at Random Island and Manuels River. The species ranges from the *Parabolina spinulosa* Zone, where it is common in the lowest part of the zone, to the *Peltura* zones, and the *Acerocare* Zone (additional observations for GSC loc. 94432) in Martin and Dean, 1981).

Cymatiogalea virgulta Martin sp. nov.

Plate 14, figures 10, 13, 14, 17

Holotype. GSC 83166 (Pl. 14, fig. 17).

Paratypes. GSC 83163 (Pl. 14, fig. 10), GSC 83164 (Pl. 14, fig. 13), GSC 83165 (Pl. 14, fig. 14).

Type locality. GSC loc. C-98011, Random Island. Elliott Cove Formation, strata containing *Orusia lenticularis*, indicative of the Upper Cambrian, *Parabolina spinulosa* Zone.

Derivation of name. Latin, *virgulta* = small branches; by apposition.

Diagnosis. Based on fifty specimens. Vesicle originally globular, its outline circular to slightly polygonal, with psilate surface; vesicle wall solid and apparently single-layered. Linear arrangement of processes, between which delicate, translucent membranes are occasionally preserved. Faint, but usually distinct, suture ridges delimit quadrangular, pentagonal, or hexagonal fields. About thirty, more or less cylindrical, hollow, psilate processes occur on each vesicle side; within a single specimen their interior cavities may either be connected with that of the vesicle, or be occluded by an opacity developed proximally or extending along the whole trunk. Subdivision of processes occurs rarely at mid-length or close to the base of the trunk, and is generally located at, or very near, the tips. The subdivisions may consist either of short digitations arising from the same level, or of two to three branches that are multidigitate distally, with rare lateral subdivisions. Total length of processes between one-tenth and one-fifth the diameter of the vesicle. Excystment by polygonal opening fringed by processes; the smooth, slightly polygonal operculum has a diameter about one half that of the vesicle.

Dimensions. Based on thirty specimens. Diameter of vesicle 17 to 30 (average 24) μm; diameter of polygonal fields from 9 to 15 μm; wall thickness about 0.3 μm; length and basal width of processes from 3 to 6 μm and from 0.6 to 1 μm, respectively; distance between processes from 2 to 6 μm.

Discussion. Two comparable Tremadoc species are distinguished from *C. virgulta* as follows: *C. cylindrata* forma 1 Rasul, 1974 has a reticulate surface wall without ridges, and relatively shorter processes that are absent on the margin of the opening. *Cymatiogalea multarea* (Deunff) Deunff et al., 1974 has relatively longer processes and no transparent membrane. However, *C.* sp. cf. *C. cylindrata* in Deunff et al. (1974, Pl. 6, fig. 11), from the Tremadoc of the Sahara, has low ridges delimiting polygonal fields, and appears to have processes that subdivide in a similar way to those of *C. virgulta*.

Occurrence. Commonly present in the Elliott Cove Formation at Random Island and Manuels River. The species ranges from the lowest part of the *Parabolina spinulosa* Zone to the *Peltura* zones and is most abundant in the *Leptoplastus* Zone at Random Island.

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, p. 191).

Generic characters. Vesicle outline elliptical to slightly trapezoidal with two polygonal to rounded poles that have virtually the same basic shape, but differ in the number of processes carried by each; one pole has approximately, and at least, one third more processes than the other. Processes are hollow, elongate, communicate freely with the vesicle interior, and have usually simple, uncommonly divided, tips. Wall is thin, laevigate or ornamented with granules or spines. No definite excystment opening observed.

Remarks. Dasydiacrodium differs from *Actinotodissus* in having on each pole a different number of processes that may, exceptionally, be divided on one pole. *Schizodiacrodium* Burmann, 1968 has an equal number of processes, which are always divided, on each pole.

Dasydiacrodium obsonum Martin sp. nov.

Plate 10, figures 6, 7, 10, 11, 13-15

Holotype. GSC 83169 (Pl. 10, fig. 6).

Paratypes. GSC 83170 (Pl. 10, fig. 7), GSC 83171 (Pl. 10, fig. 10), GSC 83172 (Pl. 10, fig. 11), GSC 83173 (Pl. 10, fig. 13), GSC 83174 (Pl. 10, fig. 14), GSC 83175 (Pl. 10, fig. 15).

Type locality. GSC loc. C-98014, Random Island (= GSC loc. 87792 in Martin and Dean, 1981, p. 11). Elliott Cove Formation; Upper Cambrian, *Parabolina spinulosa* Zone.

Derivation of name. Latin, *obsonus* = different.

Diagnosis. Based on one hundred specimens. Vesicle outline elliptical to slightly trapezoidal, a little longer than wide, with two polygonal to rounded poles. One pole has three to nine (generally five or six) processes; the other pole has eight to fifteen, and usually more than ten. All the processes are conical, elongate, and of approximately the same length, between one half and the same as that of the vesicle. They are hollow, communicate freely with the interior of the vesicle, and most often are distally simple; rarely (5% of the specimens) one or two, exceptionally three, of the processes on one of the poles may be subdivided, and then they are usually simply bifurcated. The point at which branching of the processes begins ranges from the proximal third to the distal end of the trunk. Central area of vesicle without processes or longitudinal ridges. Wall of both vesicle and processes is apparently single-layered, covered with discrete spines that have a slightly bulbous base. No definite excystment mechanism was observed.

Dimensions. Based on thirty specimens. Length and width of vesicle from 21 to 38 (average 28) μm and 17 to 29 (average 21) μm, respectively; length and basal width of processes from 12 to 20 μm and from 1.5 to 3.5 μm, respectively; thickness of wall about 0.4 μm; length of spines 0.3 to 1.5 μm.

Discussion. Specimens from a single sample may show continuous variation in number and division of processes. A similar scarcity of divided processes has not been described for other species of *Dasydiacrodium*. Typically *D. obsonum* has twice as many processes on one pole as on the other; in the holotype, for example, the numbers are six and twelve. The limit between *D. obsonum* and *Actinotodissus achrasi* is arbitrary, and specimens with more than three supernumary processes on one of the poles are attributed to the former species. *Dasydiacrodium annosum* Rasul, 1979, from the Tremadoc of Shropshire, has an entirely smooth surface and the processes are always simple. *Dasydiacrodium palmatilobum* Timofeev, 1959, from the Upper Cambrian and Tremadoc of the U.S.S.R. has simple-tipped processes that are shorter on one of the poles, and shagreenate ornamentation.

From the general shape and the different number of processes on each pole (about 11 and 6, respectively), *Acanthodiacrodium uniforme* Burmann, 1968 determined by Yin (in Chen et al., 1985, Pl. 28, fig. 24, non fig. 1) from the Upper Cambrian of northeast China, could belong to *Dasydiacrodium obsonum*. However, the spinose ornamentation on the wall is not apparent. From personal observation, *D. obsonum* is present at the same, Dayangcha section, about 4 m below the level from which Yin figured his specimen.

Occurrence. Often present in the Elliott Cove Formation at Random Island, where it appears in the upper part of the *Parabolina spinulosa* Zone and ranges upward into the *Peltura* zones and the *Acerocare* Zone (additional observations for GSC loc. 94432 in Martin and Dean, 1981).

Genus *Impluviculus* Loeblich and Tappan, 1969 emend. Martin, 1977

Type species. Impluviculus miloni (Deunff) Loeblich and Tappan, 1969 by original designation.

Impluviculus sp. A

Plate 15, figures 4-6, 10, 11

Figured specimens. GSC 83181 (Pl. 15, fig. 4), GSC 83182 (Pl. 15, fig. 5), GSC 83183 (Pl. 15, fig. 6), GSC 83184 (Pl. 15, fig. 10), GSC 83185 (Pl. 15, fig. 11).

Description. Based on thirty specimens. Vesicle originally lenticular, polygonal to subcircular in outline. Vesicle wall psilate and apparently single-layered. Processes are psilate, hollow, and communicate with the vesicle interior; they are slightly conical, with narrow base and simple, tapered tip. Four to eight processes extend in the same plane as the vesicle; rarely, one to three supplementary processes are inserted more or less perpendicular to the plane of the vesicle. Length of processes is equal to, or slightly greater than, the vesicle diameter. An opening, originally circular but usually deformed, was observed rarely in the middle of the vesicle.

Dimensions. Based on fourteen specimens. Diameter of vesicle from 8 to 16 (average 13) µm; length and basal width of processes from 8 to 17 µm and from 1.5 to 2.5 µm, respectively; wall thickness about 0.3 µm; diameter of vesicle opening from 4 to 6 µm.

Discussion. The variability within a single sample of *Impluviculus* sp. A is both wide and continuous, and involves the form of the central body and the number of processes. Most of the specimens are badly preserved, and the taxon has been left in open nomenclature. It resembles two Upper Cambrian forms whose variability has not been described: ?*Impluviculus* sp. in Vanguestaine (1978, p. 270, Pl. 4, figs. 4, 5), from the Franco-Belgian Ardennes, and *Veryhachium* sp. in Volková (1983, Pl. 2, fig. 10) and in Volková and Goloub (1984, Pl. 1, fig. 10) from the northwest of the eastern European Platform. *Impluviculus* sp. A differs from three Tremadoc species as follows. Quadrangular specimens, each angle of which is prolonged to form a process, are distinguished from *I. miloni*, from the Moroccan Anti Atlas, by the sides, which are not incurved, and by the processes, which are narrower at the base. Polygonal specimens provided with only peripheral processes differ from *I. stellaris* Martin, 1977, from the Brabant Massif, Belgium, and *I. stellum* Rasul, 1979, from Shropshire, England, in having an entirely smooth surface.

Occurrence. Rare in the Elliott Cove Formation at Random Island and Manuels River; ranges from the *Parabolina spinulosa* Zone to the *Peltura* zones.

Genus *Rugasphaera* Martin gen. nov.

Type species. Rugasphaera terranovana sp. nov., here designated.

Derivation of name. Latin, *ruga* = crease or wrinkle; *sphaera* = sphere. Gender feminine.

Diagnosis. Vesicle originally spheroidal; outline circular to slightly oval. Numerous, evenly distributed, discrete processes are hollow and communicate with the interior of the vesicle; their bases are variably fused, and the flared, homoeomorphic, closed distal ends bear thin, short projections. Wall of both vesicle and processes is thin, apparently single-layered, with projecting sculpture reduced or absent. Preferential folds of the vesicle wall toward the interior join some of the process bases and produce a variably developed, polygonal pattern that is more noticeable under the transmitted light microscope than under the scanning electron microscope.

Comparisons. Rugasphaera differs from the Lower Cambrian genus *Skiagia* Downie, 1982 in having processes that are variably fused basally and never plugged, and that are closed distally and never connected to each other. *Ammonidium* Lister, 1970, known from the Ordovician to the Devonian, has a thicker vesicle wall, with no preferential folding to form a polygonal pattern, and the proportionately narrower, usually more elongate processes are never fused basally.

Rugasphaera terranovana Martin sp. nov.

Plate 17, figures 1-11

Holotype. GSC 83198 (Pl. 17, fig. 8).

Paratypes. GSC 83194 (Pl. 17, figs. 1, 2), GSC 83195 (Pl. 17, figs. 3, 4), GSC 83196 (Pl. 17, figs. 5, 6), GSC 83197 (Pl. 17, fig. 7), GSC 83199 (Pl. 17, fig. 9), GSC 83200 (Pl. 17, fig. 10), GSC 83201 (Pl. 17, fig. 11).

Type locality. GSC loc. C-98041, west bank of Manuels River. Lower part of Manuels River Formation; middle Middle Cambrian, "*Paradoxides hicksi* Zone".

Derivation of name. Latin, *Terra Nova*, Newfoundland.

Diagnosis. Based on three hundred specimens. Vesicle originally spheroidal, its outline circular to slightly oval. Wall of vesicle psilate or weakly shagreenate, apparently single-layered, as thick as that of the processes and commonly folded toward the vesicle interior. The folds produce preferentially an irregular, polygonal network, arranged according to the bases of the processes and variably developed; the network is generally discontinuous, much more accentuated in transmitted light than under the scanning electron microscope, where it is observed only rarely and locally. Numerous (approximately one hundred) discrete, evenly distributed, squat processes with psilate walls are located on each side of the vesicle. Their conical trunks are variably turgescent; the hollow interiors communicate with the vesicle cavity. Proximal contacts of processes are variably curved; bases of two to four adjacent processes fuse locally to form a single trunk. Distal termini of processes are homoeomorphic, always flared, closed, bearing four to six spinose, simple projections. Length of processes from one twentieth to one seventh the vesicle diameter. Clusters of up to a maximum of three specimens occur rarely. No excystment structure observed.

Dimensions. Based on fifty specimens. Vesicle diameter from 25 to 49 (average 33) µm; wall thickness less than 0.4 µm; length and basal width of processes from 1.2 to 4 µm; length of distal spinose projections up to 2 µm; distance between bases of processes from 1 to 5 µm.

Discussion. Rugasphaera terranovana differs from *Ammonidium furtivum* Playford and Martin, 1984, from the Ordovician of Australia, mainly in possessing a vesicle wall that is folded to form an irregular, reticulate pattern, and more inflated, conical processes whose interiors always communicate with the vesicle cavity, and the contiguous bases of which may be locally fused. *Skiagia brevispinosa* Downie, 1982, from the Lower Cambrian of Greenland, Alberta and Norway, has processes that are proximally plugged and distally funnel shaped, without divisions.

Occurrence. Variably abundant in the lower part, but absent at the base, of the Manuels River Formation at Manuels River and Random Island (additional observations at GSC locs. C-97982 and C-97979 of Martin and Dean, 1984). Restricted to the lower part of the "*Paradoxides hicksi* Zone".

Genus *Stellichinatum* Turner, 1984

Type species. Stellichinatum celestum (Martin) Turner, 1984 by original designation.

Stellichinatum uncinatum (Downie) Martin, comb. nov.

Plate 17, figures 12-15

Hystrichosphaeridium longispinosum var. *uncinatum* nov. Downie, 1958, p. 337, Textfig. 2a.
Baltisphaeridium uncinatum Martin, 1966, p. 425, Textfig. 1.
Goniosphaeridium uncinatum (Martin) comb. nov. Kjellström, 1971, p. 27, fig. 18.

Figured specimens. GSC 83202 (Pl. 17, fig. 12), GSC 83203 (Pl. 17, fig. 13), GSC 83204 (Pl. 17, figs. 14, 15).

Dimensions. Based on fifty specimens. Diameter of vesicle from 22 to 45 (average 28) µm; maximum wall thickness 0.5 µm; length and basal width of processes from 11 to 32 (average 22) µm, and approximately 2 to 6 µm, respectively; spinose ornamentation of wall surface up to 2 µm long, but usually broken and about 0.5 µm.

Discussion. Based on two hundred specimens. The subpolygonal vesicle outline and hollow, proximally open, conical processes, plus the spinose ornamentation of processes and vesicle wall justify the new generic attribution. *Stellichinatum uncinatum* from eastern Newfoundland has processes that are mainly simple distally; rarely, on a single specimen, one of about ten to twenty processes has the proximal third divided into two. *Stellichinatum uncinatum* differs from *S. celestum*, of post-Tremadoc age, in having more numerous processes that are usually shorter than the vesicle diameter, and the proximal part of which is less widened. The outline of *S. uncinatum* may be slightly modified, depending on compression and orientation, and may become tetragonal (Pl. 17, fig. 12) or approximately pentagonal (Pl. 17, fig. 13). Certain specimens included here within the variability of *S. uncinatum* could be attributed, if seen individually, to *Tectitheca spinifera* Burmann, 1968, from the Llanvirn of East Germany. *Tectitheca* cf. *T. filigera* Burmann, 1968, *T.? multispinula* Yin in Chen et al., 1985 and *Baltisphaeridium* cf. *B. longispinosum* Eisenack, 1959 were figured from the Upper Cambrian of northeast China by Yin (in Chen et al., 1985, Pl. 27, figs. 22-25; Pl. 28, figs. 4, 17, 18, 20, 22, 23). They show an apparently continuous variation very close to, if not identical with, that accepted here for *Stellichinatum uncinatum*.

Occurrence. At Random Island, the species is often rare in the Elliott Cove Formation, where it appears in, though not at the base of, the *Parabolina spinulosa* Zone. Occurs sporadically in the Clarenville Formation, lower Tremadoc and perhaps, in part, uppermost Cambrian, at Random Island (Martin in Martin and Dean, 1981); it occurs commonly in the Bell Island Group and Wabana Group, Tremadoc to lower Arenig, at Bell Island (Martin in Dean and Martin, 1978; Ranger et al., 1984, for a recent review of stratigraphy).

Genus *Stelliferidium* Deunff, Gorká and Rauscher, 1974

Type species. Stelliferidium striatulum (Vavrdová) Deunff, Gorká and Rauscher, 1974 by original designation.

Stelliferidium pingiculum Martin sp. nov.

Plate 14, figures 11, 12, 15, 16, 18, 19

Holotype. GSC 83205 (Pl. 14, figs. 11, 12).

Paratypes. GSC 83206 (Pl. 14, fig. 15), GSC 83207 (Pl. 14, fig. 16), GSC 83208 (Pl. 14, figs. 18, 19).

Type locality. GSC loc. C-98062, west bank of Manuels River; Elliott Cove Formation, Upper Cambrian, *Olenus* Zone.

Derivation of name. Latin, *pingiculus* = plump.

Diagnosis. Based on ninety specimens. Vesicle originally globular, circular in outline; vesicle wall firm, apparently single-layered. Numerous, approximately 40 to 60, cylindrical or slightly conical processes are developed on each side of vesicle; they are divided distally into short, dichotomous branches, up to the third order, and the total length of the processes is between one fifth and one quarter of the vesicle diameter; SEM observation of broken processes shows that the interior is hollow, separated from the vesicle cavity by at least the wall of the latter. Vesicle wall is ornamented with striae, radiating outward from each of the processes, which are variably developed and appear to be emphasized by corrosion. Parallel striae are developed along the whole of each process trunk, though mainly on the proximal part. Wall of processes spinose. Excystment by polygonal, always compressed opening, fringed by processes. The pentagonal operculum has always been observed corroded, but apparently lacks processes; its diameter is between one third and one half that of the vesicle.

Dimensions. Based on thirty specimens. Diameter of vesicle from 19 to 36 (average 29) µm; wall thickness about 0.4 µm; length and basal width of processes from 4 to 8 µm and from 1.5 to 2 µm, respectively; distance between bases of processes from 3 to 5 µm; length of spines on processes from 0.5 to 1 µm.

Discussion. In transmitted light, all specimens are very black; they are therefore illustrated only by scanning electron microscope pictures. *Stelliferidium pingiculum* differs from *S. stelligerum* (Gorká) Deunff et al., 1974, from the Tremadoc of Poland, and *S. striatulum*, from the Arenig of Czechoslovakia, in having a network of striae less well developed on the central body. In addition the processes of *S. stelligerum* are smooth or finely "hairy", and less divided distally; those of *S. striatulum* are smooth, become narrower at the base, and their membrane is thinner than that of the central body. "*Priscogalea*? sp. A n. sp." of Vanguestaine (1974, p. 70, Pl. 1, fig. 13) from zone 4b of the Franco-Belgian Ardennes (Vanguestaine, 1978), comprising strata attributed on palynological grounds to the lowest Upper Cambrian by Vanguestaine and Van Looy (1983, p. 78), is comparable with *Stelliferidium pingiculum* in having radiating striae around the bases of the processes, but the processes themselves are smooth, more widely spaced and always incomplete distally.

Occurrence. Variably abundant in the Elliott Cove Formation at Manuels River and Random Island, in Upper Cambrian strata belonging to the *Olenus* Zone and to the lower part of the *Parabolina spinulosa* Zone.

Genus *Trunculumarium* Loeblich and Tappan, 1976

Type species. Trunculumarium revinium (Vanguestaine) Loeblich and Tappan, 1976 by original designation.

Trunculumarium revinium (Vanguestaine) Loeblich and Tappan, 1976

Plate 15, figures 7, 12-20

Ooidium revinium nov. sp. Vanguestaine, 1973, p. 30, Pl. 1, figs. 3-6, 10, 14.
Trunculumarium revinium (Vanguestaine, 1973) comb. nov. Loeblich and Tappan, 1976, p. 305.
Trunculumarium revinium (Vanguestaine) Loeblich and Tappan, 1976. Martin in Martin and Dean, 1981, p. 22, Pl. 2, figs. 5, 18; Pl. 5, figs. 4, 6.
?*Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan. Volková and Goloub, 1984, Pl. 2, fig. 1.

Figured specimens. GSC 83218 (Pl. 15, fig. 7), GSC 83219 (Pl. 15, fig. 12), GSC 83220 (Pl. 15, fig. 13), GSC 83221 (Pl. 15, figs. 14, 15), GSC 83222 (Pl. 15, fig. 16), GSC 83223 (Pl. 15, fig. 17), GSC 83224 (Pl. 15, fig. 18), GSC 83225 (Pl. 15, figs. 19, 20).

Dimensions. Based on fifty specimens. Length and width of vesicle from 25 to 43 (average 32) µm and from 23 to 34 (average 26) µm, respectively; wall thickness from about 0.3 to 0.5 µm; length and basal width of processes from 8 to 16 µm and from 1 to 3 µm, respectively; length and basal width of spinose granules on surface wall approximately from 0.5 to 1 µm and from 0.3 to 0.5 µm, respectively.

Discussion. Based on more than four hundred specimens. Vesicle outline originally oval, but may appear secondarily subcircular, depending on orientation and compression. About ten to thirty processes are located on one of the poles. The processes, which are straight or curved, generally have a simple tip, but one to three of them may be forked beyond the proximal third. The sometimes bulbous appearance of certain process tips is due to irregular compression and corrosion of the processes and their spines. The preservation of spinose granules over the whole surface is very variable, either between different specimens or within a single specimen. A specimen from the Upper Cambrian in the northwest of the eastern European platform determined by Volková and Goloub (1984) as *T. revinium* differs from that species in having shorter, broader based, conical processes, and the attribution seems questionable.

Occurrence. Present in the upper part of the Elliott Cove Formation at Random Island; appears, and is generally abundant, in the upper part of the *Parabolina spinulosa* Zone and ranges upward into the lower part of the *Peltura* zones, where it is much rarer.

Genus *Veryhachium* Deunff, 1954
ex Downie, 1959
emend. Downie and Sarjeant, 1963

Type species. Veryhachium trisulcum (Deunff) Deunff, 1959 by subsequent designation of Downie, 1959.

Veryhachium dumontii Vanguestaine, 1973

Plate 16, figures 2, 3, 4 (cf.), 6 (cf.), 7, 9 (cf.), 10-18

Veryhachium dumontii nov. sp. Vanguestaine, 1973, p. 28, Pl. 1, figs. 1, 2, 8.
Veryhachium dumontii Vanguestaine. Martin in Martin and Dean, 1981, p. 22, Pl. 1, figs. 7, 8.
Veryhachium dumontii Vanguestaine. Volková, 1983, p. 14, Pl. 2, fig. 11.

Figured specimens. GSC 83226 (Pl. 16, fig. 2), GSC 83227 (Pl. 16, fig. 3), GSC 83237 (Pl. 16, fig. 4), GSC 83238 (Pl. 16, fig. 6), GSC 83228 (Pl. 16, fig. 7), GSC 83239 (Pl. 16, fig. 9), GSC 83229 (Pl. 16, fig. 10), GSC 83230 (Pl. 16, fig. 11), GSC 83231 (Pl. 16, fig. 12), GSC 83232 (Pl. 16, figs. 13, 14), GSC 83233 (Pl. 16, fig. 15), GSC 83234 (Pl. 16, fig. 16), GSC 83235 (Pl. 16, fig. 17), GSC 83236 (Pl. 16, fig. 18).

Dimensions. Based on seventy specimens. Length and maximum width of vesicle from 24 to 49 (average 32) µm and from 14 to 35 (average 27) µm; wall thickness from 0.3 to 0.5 µm; maximum length of main and secondary processes

50 μ m and 25 μ m, respectively; length of spines on surface usually about 1 μ m, rarely up to 4 μ m.

Discussion. Based on more than five hundred specimens. In the most common examples, the outline of the central body is an isosceles triangle, the two longest sides of which are convex just below the apex and concave near the base. The length of the principal processes, each of which prolongs, and is in the same plane as, the angles of the central body, varies from 0.7 to 1.3 times that of the two equal sides of the triangle; the processes are often incomplete. One or two, rarely three, secondary processes are situated near the shortest side of the central body; their length is less than that of either of the equal sides. All the processes are hollow and their internal cavities communicate with that of the central body; they are generally simple, conical and tapered. In less than one per cent of specimens from strata of the *Parabolina spinulosa* Zone, one of the principal processes is divided into two or three either near its base (GSC locs. C-98011, C-98017), where it has so far only been observed incomplete (Pl. 16, figs. 4, 9), or at approximately mid-length (GSC locs. C-98013, C-98017; Pl. 16, fig. 6). These exceptions are determined here as *Veryhachium* cf. *V. dumontii* and are not included in the distribution tables (Figs. 7, 8, 10).

The state of preservation of the specimens may vary considerably within a single assemblage, with the colour ranging from light yellow to dark brown. The ornamentation of spines, slightly bulbous at the base, is sometimes variably preserved, even on a single specimen (Pl. 16, figs. 3, 4), and may be entirely corroded (Pl. 16, fig. 16). The outline of well preserved specimens that lack supplementary processes (Pl. 16, fig. 18) is similar to that of the Silurian taxon *Domasia limaciformis* (Stockmans and Willière) Cramer, 1970. The development of pyrite crystals may deform the central body considerably (Pl. 16, figs. 10, 12). Compression and distortion may produce a more or less equilaterally triangular outline (Pl. 16, fig. 17) resembling that of *Veryhachium trispinosum* (Eisenack) Deunff, 1959, a widespread Ordovician and Silurian species in the Northern Hemisphere. Deformation may also result in an asymmetric outline (Pl. 16, fig. 3), which resembles that of *Veryhachium primaevum* Deunff, 1966, from the Tremadoc of the Sahara. *Veryhachium dumontii* is distinguished from *Dasydiacrodium caudatum* Vanguestaine, 1973 (Pl. 16, figs. 5, 8 herein) mainly by the principal process that prolongs each of the three angles of the central body, and by the number of supplementary processes, not exceeding three, arranged along the shortest side.

Occurrence. Variably abundant in the Elliott Cove Formation at Random Island and Manuels River. The oldest specimens were found in strata lacking macrofossils at GSC loc. 92994 (in Martin and Dean, 1981), about 110 m below the level of first macrofossil evidence of the *Parabolina spinulosa* Zone at Random Island. *Veryhachium dumontii* is usually abundant in the same zone and ranges upward into the *Peltura* zones, where it is rarer. One specimen was observed in a sample (additional observations for GSC loc. 92999 in Martin and Dean, 1981) from the Clarenville Formation that contains *Parabolina* cf. *P. argentina*, and is probably of Tremadoc age.

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

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

Vulcanisphaera lanugo Martin sp. nov.

Plate 18, figures 7, 9-12, 14-17

Holotype. GSC 83252 (Pl. 18, fig. 12).

Paratypes. GSC 83249 (Pl. 18, fig. 7), GSC 83250 (Pl. 18, fig. 9), GSC 83251 (Pl. 18, figs. 10, 11), GSC 83253 (Pl. 18, fig. 14), GSC 83254 (Pl. 18, fig. 15), GSC 83255 (Pl. 18, fig. 16), GSC 83256 (Pl. 18, fig. 17).

Type locality. GSC loc. C-98042, west bank of Manuels River. Lower part of the Manuels River Formation; middle Middle Cambrian, "*Paradoxides hicksi* Zone".

Derivation of name. Latin, *lanugo* = down, by apposition.

Diagnosis. Based on three hundred specimens. Vesicle originally globular, slightly polygonal in outline, with psilate to slightly shagreenate surface. Vesicle wall apparently single-layered. Very low, solid protuberances, linked by reduced, sometimes discontinuous, narrow ridges, delimit about ten to twenty pentagonal or hexagonal fields on each side of the vesicle. Sinuous, fragile, anastomosing filament-like processes that become thinner distally are grouped into tufts of two or three on each protuberance. Single processes rarely develop directly from the vesicle wall inside the polygonal fields and on the ridges. The vesicle wall breaks easily along the sutures coincident with the sides of the polygonal fields; no regular opening is observed. Clusters of three to six specimens commonly occur. In any given cluster, the size of the specimens may be almost uniform or may vary up to double.

Dimensions. Based on seventy specimens. Diameter of vesicle from 14 to 35 (average 27) μ m; wall thickness from about 0.2 to 0.4 μ m; diameter of polygonal fields from 5 to 11 μ m; height of ridges from 0.3 to 1 μ m; length and basal width of protuberances about 1 μ m maximum; distance between protuberances from 1 to 6 μ m; length of sinuous filaments 12 μ m maximum, usually 4 to 8 μ m.

Discussion. Vulcanisphaera lanugo differs from *V. turbata* Martin in Martin and Dean, 1981, in having a smaller size, a thinner vesicle wall, and ornamentation that is much less well developed and more fragile. *Vulcanisphaera hermosa* Fombella, 1977, from the Middle Cambrian of northern Spain, has more strongly developed proximal protuberances and no obvious polygonal fields. The silhouettes of corroded specimens of *V. lanugo*, in which the ornamentation is abraded and the ridges altered, resemble those of *Retisphaeridium dichamerum* (Pl. 12, figs. 7-9), *R. howellii* (Pl. 12, figs. 3, 4) and *Cristallinium cambriense* (Pl. 12, figs. 1, 2). Only specimens that are sufficiently complete have been determined; consequently the counts of *Vulcanisphaera lanugo* are largely underestimated.

Occurrence. Variably abundant in the lower part, but absent at the base, of the Manuels River Formation at Manuels River and Random Island (additional observations at GSC locs. C-97978 and C-97979 in Martin and Dean, 1981). Restricted to the middle part of the "*Paradoxides hicksi* Zone".

Vulcanisphaera turbata Martin in Martin and Dean, 1981

Plate 18, figures 3, 5, 6, 8, 13

?*Vulcanisphaera* aff. *V. africana* Deunff. Jankauskas, 1980, fig. 9 in Plate.

Vulcanisphaera turbata sp. nov. Martin in Martin and Dean, 1981, p. 23, Pl. 1, figs. 2-4; Textfig. 6.
Vulcanisphaera turbata Martin in Martin and Dean, 1981. Martin, 1982, p. 32, Pl. 1, fig. 19.
Vulcanisphaera turbata Martin. Vavrdová, 1982, Pl. 2, fig. 2.
Vulcanisphaera turbata Martin, 1981. Albani et al., 1985, Pl. 1, fig. 19.

Figured specimens. GSC 83243 (Pl. 18, fig. 3), GSC 83244 (Pl. 18, fig. 5), GSC 83245 (Pl. 18, fig. 6), GSC 83246 (Pl. 18, fig. 8), GSC 83247 (Pl. 18, fig. 13).

Dimensions. Based on fifty specimens. Diameter of vesicle from 28 to 55 (average 37) μm; wall thickness from about 0.5 to 0.7 μm; diameter of polygonal fields from 8 to 18 (average 12) μm; height and basal width of protuberances from 1 to 2 μm and from 1 to 3 μm, respectively; length of processes from 6 to 20 μm; diameter of granules on vesicle wall 0.5 μm maximum.

Discussion. Based on more than four hundred specimens. The granulate ornamentation of the vesicle wall, observed in transmitted light and mentioned in the original diagnosis, is very variably developed and appears to be increased by corrosion; it has never been observed on the approximately forty specimens examined under the SEM. Typical examples of *V. turbata* differ from those of *V. africana* Deunff, 1961 (Pl. 18, figs. 1, 4 herein) in having less numerous tufts (about 15-25 compared with about 25-40 on each side of the vesicle) of filament-like processes that are generally one third shorter and tend to be stouter proximally. In addition, the vesicle tabulation in *V. turbata* is more obvious and is increased externally by ridges that arise from the inflexion of the polygonal fields toward the centre of the vesicle; the polygonal fields are also visible on the inner surface of the vesicle (Pl. 18, fig. 3). In *V. africana*, the polygonal fields are rather obscure, and are indicated mainly by rupture lines along their sides; a discrete polygonal pattern of the latter is visible also on the holotype figured by Deunff (1961, Pl. 18, fig. 1). Specimens of intermediate type (Pl. 18, fig. 2) are determined here as "transition *V. turbata* → *V. africana*". *Vulcanisphaera* aff. *V. africana* in Jankauskas (1980), from the Upper Cambrian in the northwest of the east European platform, appears to be very close to, if not identical with, *V. turbata*.

Occurrence. Commonly present in variable abundance in the Elliott Cove Formation at Random Island and Manuels River. The species ranges from the uppermost Middle Cambrian (?*Lejopyge laevigata* Zone) to the Upper Cambrian (*Leptoplastus* Zone). Transitions *V. turbata* → *V. africana* appear first in strata dated as *Olenus* Zone; rare specimens of *V. africana* appear in the lower part of the *Parabolina spinulosa* Zone (additional observations for GSC loc. 92996 in Martin and Dean, 1981).

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LOCATION OF SAMPLES

W.T. Dean and F. Martin

In the following list of GSC locality numbers, those without a prefix refer to the locality catalogue at the Geological Survey of Canada, Ottawa; those with the prefix C- refer to the locality catalogue at the G.S.C.'s Institute of Sedimentary and Petroleum Geology, Calgary. All the cited material is in G.S.C.'s type fossil collection, Ottawa. The stratigraphic sections at Manuels River and on the northwest coast of Random Island are treated separately, and localities are listed in ascending order within each formation; the estimated stratigraphic position of certain localities outside the principal measured sections is also noted. Previously published localities at Manuels River (Martin and Dean, 1983) and at Random Island (Martin and Dean, 1981, 1984) are omitted, except for cases where they are relevant to the location of more recent samples.

The fossil content of each sample is denoted by the following symbols:

A - acritarchs;
B - barren or with undeterminable acritarchs;
C - *Cyclotron* (bradoriid arthropod);
O - *Orusia lenticularis* (brachiopod);
T - trilobites.

SECTION AT MANUELS RIVER

In each case, the stratigraphic position is given with reference to the base or top of the appropriate formation. For the Chamberlains Brook Formation and Manuels River Formation, the bed numbers used by Howell (1925) are listed, though in some cases it was not possible to identify his thinnest units satisfactorily. For the Elliott Cove Formation, measured or estimated distances above the formational base are given.

Chamberlains Brook Formation (Figure 3)

***Ptychagnostus gibbus* Zone**

GSC loc. C-98035. Shale 3.67 m below top of formation, in Bed 25 of Howell. B.

GSC loc. C-98036. Shale 2.7 m below top of formation, in Bed 29 of Howell. A.

GSC loc. C-98037. Shale 1.75 m below top of formation, in Bed 31 of Howell. B.

GSC loc. 101552. Shale 1 m below top of formation, in Bed 32 of Howell. T.

GSC loc. C-98038. Shale 25 cm below top of formation, in Bed 35 of Howell. B.

Manuels River Formation (Figure 3)

All samples are from the west bank of Manuels River, except for C-98070 and C-98071, which are from the east bank.

***Tomagnostus fissus* and *Ptychagnostus atavus* Zone**

GSC loc. C-98039. Shale 25 cm above base of formation, in Bed 37 of Howell. B.

GSC loc. C-98040. Shale 1.47 m above base of formation, in Bed 40 of Howell. B.

GSC loc. C-98041. Shale 2.3 m above base of formation, near top of Bed 43 of Howell. A.

GSC loc. C-98042. Shale 3.25 m above base of formation; low in Bed 51 of Howell. A.

GSC loc. C-98043. Shale 4.3 m above base of formation, in Bed 55 of Howell. A.

GSC loc. C-98044. Shale 5.25 m above base of formation, in Bed 58 of Howell. A.

GSC loc. C-98045. Shale 6.3 m above base of formation, in Bed 69 of Howell. A.

GSC loc. C-98070. Shale 6.7 m (est.) above base of formation, in Bed 73 of Howell. B, T.

GSC loc. C-98046. Shale 7.3 m above base of formation, in Bed 76 of Howell. A.

GSC loc. C-98071. Shale 7.5 m (est.) above base of formation, in Bed 77 of Howell. A, T.

GSC loc. C-98047. Shale 7.8 m above base of formation, in Bed 80 of Howell. A.

GSC loc. C-98048. Shale 8.3 m above base of formation, in Bed 82 of Howell. A.

GSC loc. C-98049. Shale 9.37 m above base of formation, near base of Bed 86 of Howell. A.

GSC loc. C-98050. Shale 10.2 m above base of formation, in Bed 88 of Howell. A.

Trilobite zone uncertain.

Up to this point in the succession, localities have been assigned to the *Tomagnostus fissus* and *Ptychagnostus atavus* Zone on the basis of their occurring within the recorded vertical range (not yet verified) of *Paradoxides* (*Hydrocephalus*) *hicksii*. The following locality may belong to the *Hypagnostus parvifrons* Zone, but no agnostid evidence is available. GSC loc. C-98051. Shale 12.3 m above base of formation, in Bed 96 of Howell. A.

Ptychagnostus punctuosus Zone

Only the last of the following four localities yielded the zonal agnostid and the others are assigned to the zone on the basis of their occurrence well within the recorded vertical range (Howell, 1925, not yet verified) of *Paradoxides* (*Paradoxides*) *davidis*.

GSC loc. C-98052. Shale 16.25 m above base of formation, in Bed 108 of Howell. B.

GSC loc. C-98053. Shale 17.5 m above base of formation, in Bed 113 of Howell. B.

GSC loc. C-98054. Shale 18.1 m above base of formation, in Bed 115 of Howell. A.

GSC loc. 101553. Lenticular limestone, 11 cm thick, 1.6 m (est.) below top of formation. T.

Elliott Cove Formation (Figure 4)

?*Lejopyge laevigata* Zone

GSC loc. C-98055. Shale 1.25 m above base of formation, cliff in west bank. A.

GSC loc. C-98059. Shale in east bank at approximately same stratigraphic level as loc. C-98055. A.

GSC loc. 101554. Shale 4.6 m above base of formation, west bank. T.

GSC loc. C-98056. Shale 4.8 m above base of formation, west bank. A.

Agnostus pisiformis Zone

GSC loc. 101555. Shale 5.75 m above base of formation, cliff in west bank. T.

GSC loc. C-98057. Shale 9.5 m (est.) above base of formation, cliff in west bank. A.

GSC loc. C-98058. Shale 11.8 m (est.) above base of formation, cliff in west bank. A.

Olenus Zone

GSC loc. C-98063. Shale 20 m (est.) above base of formation, large cliff exposure in west bank. B, T.

GSC loc. C-98062. Shale 23 m (est.) above base of formation, large cliff exposure in west bank. A, T.

GSC loc. C-98061. Shale 25.7 m (est.) above base of formation, upper part of large cliff exposure in west bank. B, C, T.

GSC loc. C-98060. Shale 29 m (est.) above base of formation, upper part of large cliff exposure in west bank. B, T.

GSC loc. C-98069. Shale 45.5 m (est.) above base of formation, low cliff in east bank. B, C, T.

Parabolina spinulosa Zone

GSC loc. C-98067. Shale 106 m (est.) above base of formation. This and the four following localities are part of a sequence of alternating siltstones and shales that forms a low cliff in the west bank. A.

GSC loc. C-98066. Shale 107 m (est.) above base of formation. A.

GSC loc. C-98065. Shale 108 m (est.) above base of formation. A.

GSC loc. C-98064. Shale 109 m (est.) above base of formation. A.

GSC loc. C-98068. Shale 112.5 m (est.) above base of formation. A, O, T.

SECTION ON NORTHWEST COAST OF RANDOM ISLAND

In each case the stratigraphic position of the locality is given with reference either to the base of the formation or to an easily recognized rock unit. Geographic locations are given with reference to the promontories shown in Figure 5, which indicates also the basal conglomerate of the Elliott Cove Formation.

Chamberlains Brook Formation

All localities providing acritarch data are given in Martin and Dean, 1984.

Manuels River Formation

Previous palynological samples and some of those yielding macrofossils are noted in Martin and Dean, 1981, 1984. No evidence of the *Ptychagnostus gibbus* Zone is known from Random Island.

***Tomagnostus fissus* and *Ptychagnostus atavus* Zone**
(= "*Paradoxides hicksi* Zone" approx.)

GSC loc. 89107. Persistent bed, 12-20 cm thick, of grey, silty limestone, 14.7 m below top of formation. T.

GSC loc. 89106. Impersistent bed, 15 cm thick, of grey, silty limestone, 14 m below top of formation. T.

Hypagnostus parvifrons Zone

No trilobite evidence from Random Island.

***Ptychagnostus punctuosus* Zone**
(= "*Paradoxides davidis* Zone")

GSC loc. 89131. Bedding plane in dark grey shale, 12.3 m below top of formation. T.

GSC loc. 89105. Bed, 12 cm thick, of dark grey siltstone, 4.6 m below top of formation. T.

GSC loc. 89104. Thin (2 cm) silty bed in highly jointed, dark grey shale, 3.3 m below top of formation. T.

Elliott Cove Formation (Figures 5, 6)

Previous palynological samples, including material from the ?*Lejopyge laevigata* Zone, are noted in Martin and Dean, 1981, 1984.

***Agnostus pisiformis* Zone**

GSC loc. 89108. This and the succeeding seven localities are all in shale exposed in the lower part of the cliff, northwest of the basal conglomerate shown in Figure 5. Exposure is intermittent due to fallen cliff material and stream deposits; thicknesses are estimated.

GSC loc. 89108. Shale 22.7 m (est.) above base of formation. T.

GSC loc. 89132. Shale 32.8 m (est.) above base of formation. T.

GSC loc. 89110. Shale 34.8 m (est.) above base of formation. T.

GSC loc. 89109. Shale 38.2 m (est.) above base of formation. T.

GSC loc. 89113. Shale 42.6 m (est.) above base of formation. T.

GSC loc. 89111. Shale 58.8 m (est.) above base of formation. T.

GSC loc. 89112. Shale 69.3 m (est.) above base of formation. T.

GSC loc. 89133. Shale 71.7 m (est.) above base of formation. T.

The following samples are located, respectively, 0.9 m below and 1.1 m above GSC loc. 92939, in Martin and Dean, 1981:

GSC loc. C-98027. Shale 36.1 m (est.) above base of formation. A.

GSC loc. C-98026. Shale 38.1 m (est.) above base of formation. A.

***Olenus* Zone**

GSC loc. 89136. This and the succeeding twelve localities all form part of a predominantly shale unit exposed in the cliff immediately south of Promontory II; the location was noted (under GSC locs. 92990-92992) in Martin and Dean (1981, p. 10). The units, almost 31 m (est.) thick, comprise two sets of dark, pyritous shale, occasionally with thin siltstone beds; the lower set, 16 m (est.), is separated from the upper, 14.5 m (est.), by three, brown-weathering siltstone beds totalling 35 cm.

GSC loc. 89136. Shale 11.7 m (est.) above base of unit. T.

GSC loc. 89114. Shale 12.1 m (est.) above base of unit. T.

GSC loc. 89134. Shale 13.0 m (est.) above base of unit. T.

GSC loc. 89135. Same level as 89134, 3 m southeast along strike. T.

GSC loc. 89115. Shale 14.6 m (est.) above base of unit. T.

GSC loc. 89116. Shale 16.6 m (est.) above base of unit. T.

GSC loc. 89117. Shale 17.0 m (est.) above base of unit. T.

GSC loc. 89118. Shale 21.1 m (est.) above base of unit. T.

GSC loc. 89119. Shale 21.4 m (est.) above base of unit. T.

GSC loc. 89120. Shale 22.5 m (est.) above base of unit. T.

GSC loc. 89121. Shale 23.9 m (est.) above base of unit. T.

GSC loc. 89122. Shale 28.3 m (est.) above base of unit. T.

GSC loc. 89123. Shale 29.2 m (est.) above base of unit. T.

The two following samples from the same 31 m shale unit are also located, respectively, 3.25 m and 4.6 m above GSC loc. 92992, in Martin and Dean, 1981:

GSC loc. C-98024. Shale 17.7 m (est.) above base of unit. A.

GSC loc. C-98025. Shale 21 m (est.) above base of unit. A.

***Parabolina spinulosa* Zone**

The following samples are located with reference to the base of a 16 m (est.) unit of grey shale with uncommon, thin siltstone beds and occasional concretions that crops out at, and just south of, Promontory VII, and overlies a 35 cm bed of flaggy siltstone with shale partings. In Figure 6, the 16 m bed forms the lowest part of a 103 m unit of grey shale with siltstone beds and concretions. The zonal position of the localities results from their occurrence within the stratigraphic range of *Orusia lenticularis*.

GSC loc. 95175 of Martin and Dean (1981, p. 11). Shale 5.4 m below base of 16 m unit.

GSC loc. C-98011. Shale 2.3 m below base of 16 m unit. A, O.

GSC loc. C-98010. Shale 1.3 m below base of 16 m unit. A, O.

GSC loc. C-98012. Shale 0.5 m above base of 16 m unit. A.

GSC loc. C-98013. Shale 11.2 m above base of 16 m unit. A.

(The two last localities are, respectively, 2.2 m below and 8.5 m above GSC loc. 95176, in Martin and Dean, 1981).

The following samples are located within a 38 m (est.) unit of soft-weathering, dark grey shale with occasional concretions and thin siltstone beds that begins on the northwest side of Promontory VII (Fig. 6) and succeeds the 16 m unit noted above.

GSC loc. 87794. Shale 0.3 m (est.) above base of unit. T.

GSC loc. 87796. Shale 4.4 m (est.) above base of unit. T.

GSC loc. 87795. Shale 5.4 m (est.) above base of unit. T.

GSC loc. C-98020. Shale 5.8 m (est.) above base of unit. A.

GSC loc. C-98019. Shale 6.8 m (est.) above base of unit. A.

GSC loc. 92997. Shale 7 m (est.) above base of unit. A.

GSC loc. C-98108. Shale 7.4 m (est.) above base of unit. A.

GSC loc. C-98017. Shale 7.8 m (est.) above base of unit. A.

GSC loc. C-98016. Shale 8.2 m (est.) above base of unit. A.

GSC loc. C-98015. Shale 8.5 m (est.) above base of unit. A.

GSC loc. 87792. Shale 8.8 m (est.) above base of unit; this level was re-sampled for microfossils as C-98014. A, T.

GSC loc. 87791. Shale 12.3 m (est.) above base of unit; this figure is approximate as the locality is separated from the underlying one by a small fault of unknown displacement. T.

Leptoplastus Zone

The following four localities are in an unfaulted sequence within the same 38 m shale unit, but are separated from loc. 87791 by a small fault of unknown displacement; apparent distances above the base of the unit are therefore only approximate.

GSC loc. C-98022. Shale 23.5 m (est.) above base of unit. A.

GSC loc. 87789. Shale 24.3 m (est.) above base of unit. T.

GSC loc. 87790. Shale 25.1 m (est.) above base of unit. T.

GSC loc. C-98021. Shale 25.5 m (est.) above base of unit. A.

Peltura zones

GSC loc. 87787 (T) is apparently 4.6 m above loc. C-98021, but is separated from the latter by a small fault of undetermined displacement; level is shown as 29.7 m (est.) above base of the 38 m unit (Fig. 9). This locality was resampled for microfossils as C-98023. A.

GSC loc. 87786. Shale 6.35 m above loc. 87787. T.

All the remaining localities are in an apparently unfaulted sequence of grey shale, folded in part, with a few thin beds of siltstone exposed in the cliff south of Promontory VIII. The unit is at least 25 m thick, underlain by folded grey shale with concretions in places, and siltstone beds totalling approximately 12 m. Continuity of exposure is hindered by fallen cliff material.

GSC loc. 87800. Shale 9 m (est.) above base of 25 m unit. T.

GSC loc. 89138. Shale 9.6 m (est.) above base of unit. T.

GSC loc. 87799. Shale 14.7 m (est.) above base of unit. T.

GSC loc. 89139. Shale 15 m (est.) above base of unit. T.

GSC loc. 89140. Shale 18.8 m (est.) above base of unit. T.

GSC loc. 89141. Shale 19.5 m (est.) above base of unit. T.

GSC loc. 89142. Shale 19.7 m (est.) above base of unit. T.

Acerocare Zone

GSC loc. 89143. Shale 23 m (est.) above base of 25 m unit. T.

Microfossil loc. 94432, previously listed in the *Peltura* zones (Martin and Dean, 1981, p. 9), is located 15 cm above loc. 89143 and so is re-assigned to the *Acerocare* Zone, though no trilobites were found there.

PLATES 1-18

All figured specimens are in the type fossil collection of the Geological Survey of Canada, Ottawa, and their numbers have the prefix GSC. Locality numbers with prefix GSC loc. refer to the locality catalogue at Ottawa; those with prefix GSC loc. C- are in the locality catalogue of the Institute of Sedimentary and Petroleum Geology, Calgary. All specimens are from eastern Newfoundland, except where stated, as in the case of three trilobite species from New Brunswick.

PLATE 1

Figures 1-4, 6, 7, 11, 15. *Paradoxides* (*Eccaparadoxides*) *eteminicus* Matthew, 1883. All from GSC loc. 101552.

1. GSC 83263, x 1.

2, 3. GSC 83264, x 2.5.

4. GSC 83265, x 2.

6. GSC 83264, x 2.

7. GSC 83266, x 2.5.

11. GSC 83267, x 4.

15. GSC 83268, x 3.

Figures 5, 12. *Paradoxides* (*Eccaparadoxides*) *eteminicus* Matthew, 1883. Fossil Brook Formation, Seely Street, Saint John, New Brunswick.

5. GSC 83269, x 3.

12. Pygidium with associated small meraspid cranidium of *Hartella matthewi*. GSC 83270, x 3.

Figures 8, 9. *Eodiscus punctatus* (Salter, 1864) *scanicus* Linnarsson, 1883). GSC loc. 89107.

8. GSC 83271, x 7.

9. GSC 83272, x 8.

Figure 10. ?*Badulesia tenera* (Hartt in Dawson, 1968). Fossil Brook Formation, Seely Street, Saint John, New Brunswick. GSC 83273, x 3.

Figure 13. *Clarella venusta* (Billings, 1874). GSC 83274, GSC loc. 89106, x 5.

Figure 14. *Parasolenopleura*? *applanata* (Salter in Salter and Hicks, 1869). GSC 83275, GSC loc. 89107, x 6.

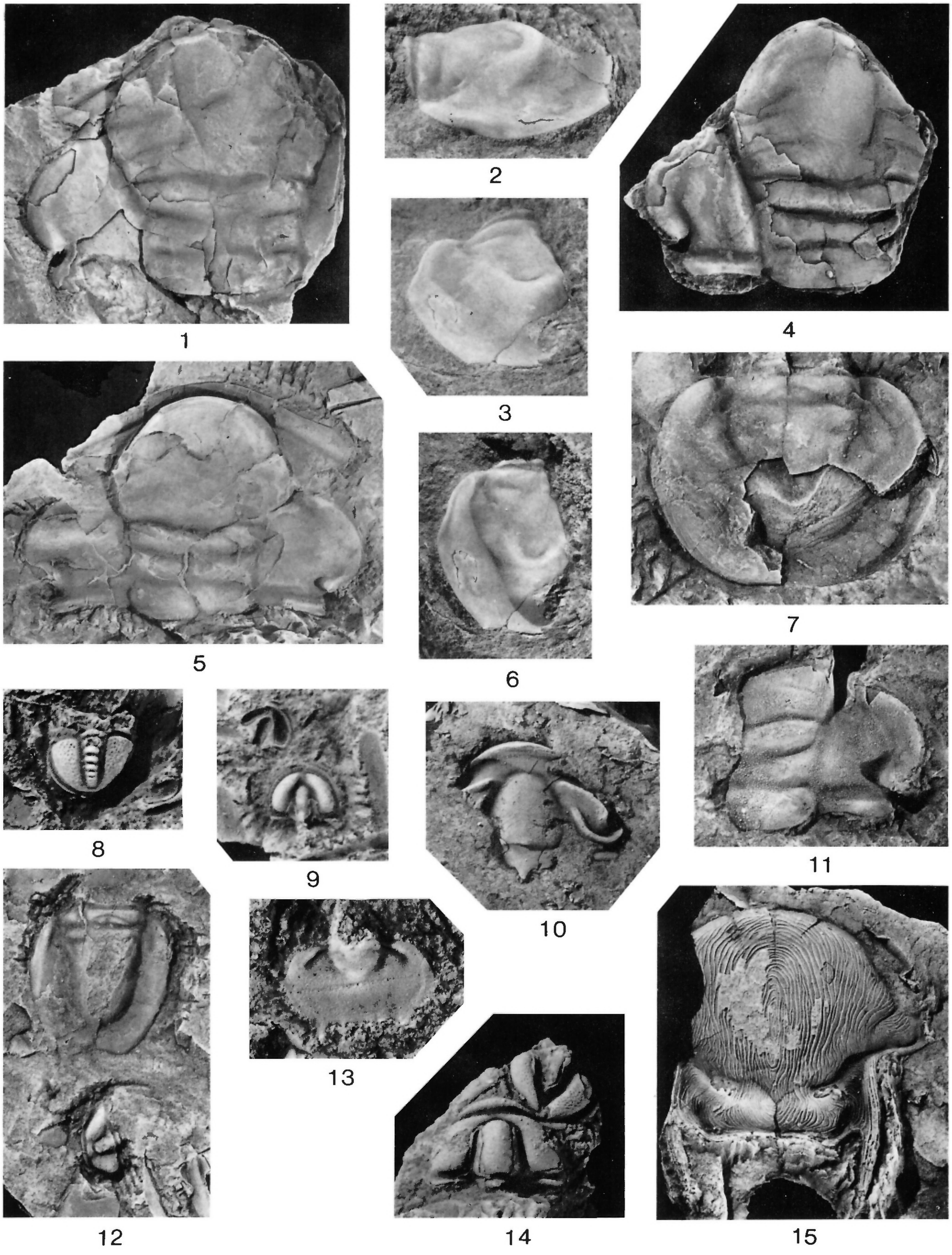
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PLATE 2

Figures 1, 2, 4-6, 8, 10. *Hartella terranovica* (Resser, 1937). GSC loc. 101552.

1, 10. GSC 83276, x 5.

2. GSC 83277, x 6.

4, 6. GSC 83277, x 3.

5, 8. GSC 83276, x 6.

Figure 3. *Hartella matthewi* (Hartt in Dawson, 1868). Fossil Brook Formation, Seely Street, Saint John, New Brunswick. GSC 83278, x 4.

Figures 7, 12. *Bailiella* cf. *B. tenuicincta* (Linnarsson, 1879). GSC loc. C-98070.

7. GSC 83279, x 2.5.

12. GSC 83279, x 3.

Figures 9, 11. *Badulesia* aff. *B. tenera* (Hartt in Dawson, 1868). GSC 83280, GSC loc. 101552, x 4.

Figure 13. *Bailiella manuelensis* Hutchinson, 1962. GSC 83281, GSC loc. 101552, x 2.

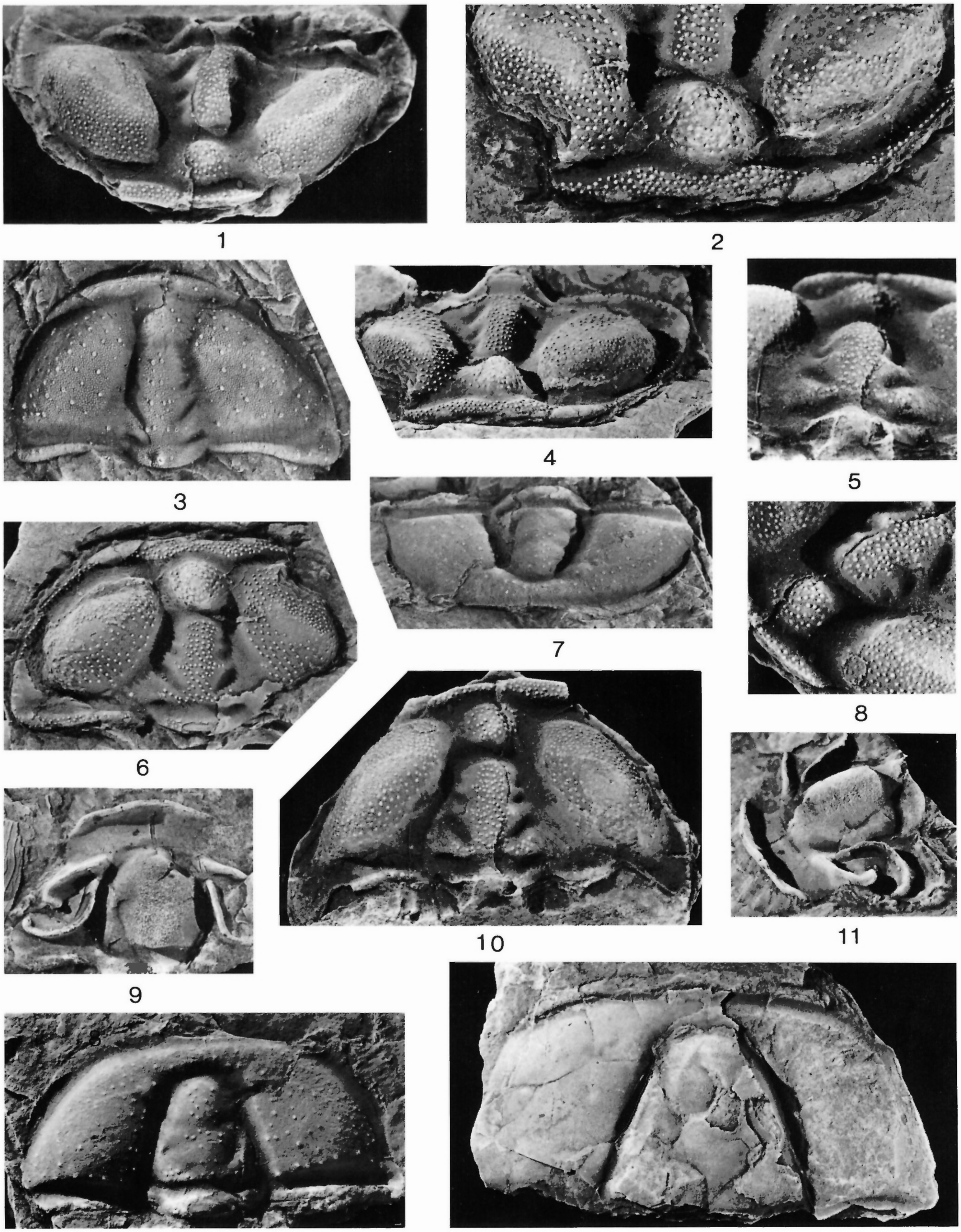
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PLATE 3

Figure 1. *Peronopsis* sp. GSC 83282, GSC loc. C-98070, x 7.

Figure 2. *Tomagnostus perrugatus* (Grönwall, 1902). GSC 83283, GSC loc. C-98070, x 7.

Figures 3, 6, 8, 14, 15. *Parasolenopleura*? *applanata* (Salter in Salter and Hicks, 1869).

3, 6. GSC 83284, GSC loc. C-98071, x 3.5.

8, 14. GSC 83285, GSC loc. C-98071, x 3.5.

15. GSC 83286, GSC loc. C-98070, x 4.

Figures 4, 7. *Paradoxides* (*Hydrocephalus*) *hicksii* Salter, 1866.

4. GSC 83287, GSC loc. C-98070, x 2.

7. GSC 83288, GSC loc. C-98071, x 3.

Figure 5. *Ptychagnostus* sp. GSC 83289, GSC loc. C-98071, x 3.

Figures 9-13. *Agraulos longicephalus* (Hicks, 1872).

9, 11. GSC 83290, GSC loc. C-98070, x 4.

10, 13. GSC 83291, GSC loc. C-98071, x 3.5.

12. GSC 83292, GSC loc. C-98071, x 3.

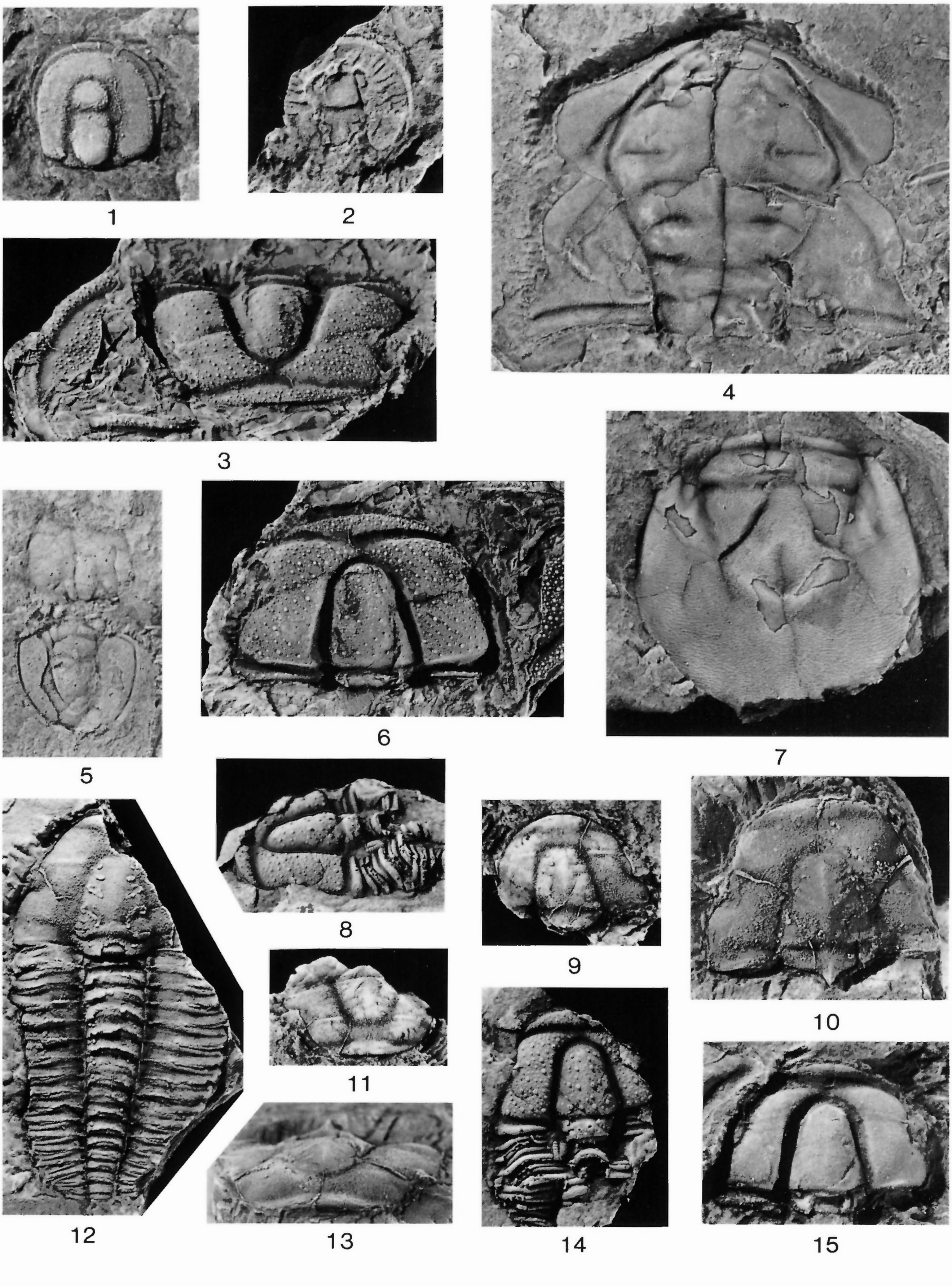
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PLATE 4

All specimens are from GSC loc. 101553

Figures 1, 2. *Ptychagnostus ciceroides* (Matthew, 1896).

1. GSC 83293, x 7.5.

2. GSC 83294, x 8.

Figures 3, 8. *Peronopsis scutalis* (Hicks, 1872) *exarata* (Grönwall, 1902).

3. GSC 83295, x 8.

8. GSC 83304, x 6.

Figures 4, 11-17. *Paradoxides* (*Paradoxides*) *davidis davidis* Salter, 1863.

4. GSC 83296, x 4.

11. GSC 83297, x 1.

12, 17. GSC 83297, x 2.5.

13-15. GSC 83298, x 1.2.

16. GSC 83299, x 1.5.

Figures 5, 6, 10. *Ptychagnostus punctuosus* (Angelin, 1851).

5. GSC 83300, x 8.

6. GSC 83301, x 8.

10. GSC 83302, x 5.

Figures 7, 9. *Solenopleuropsis variolaris* (Salter, 1864). GSC 83303, x 3.

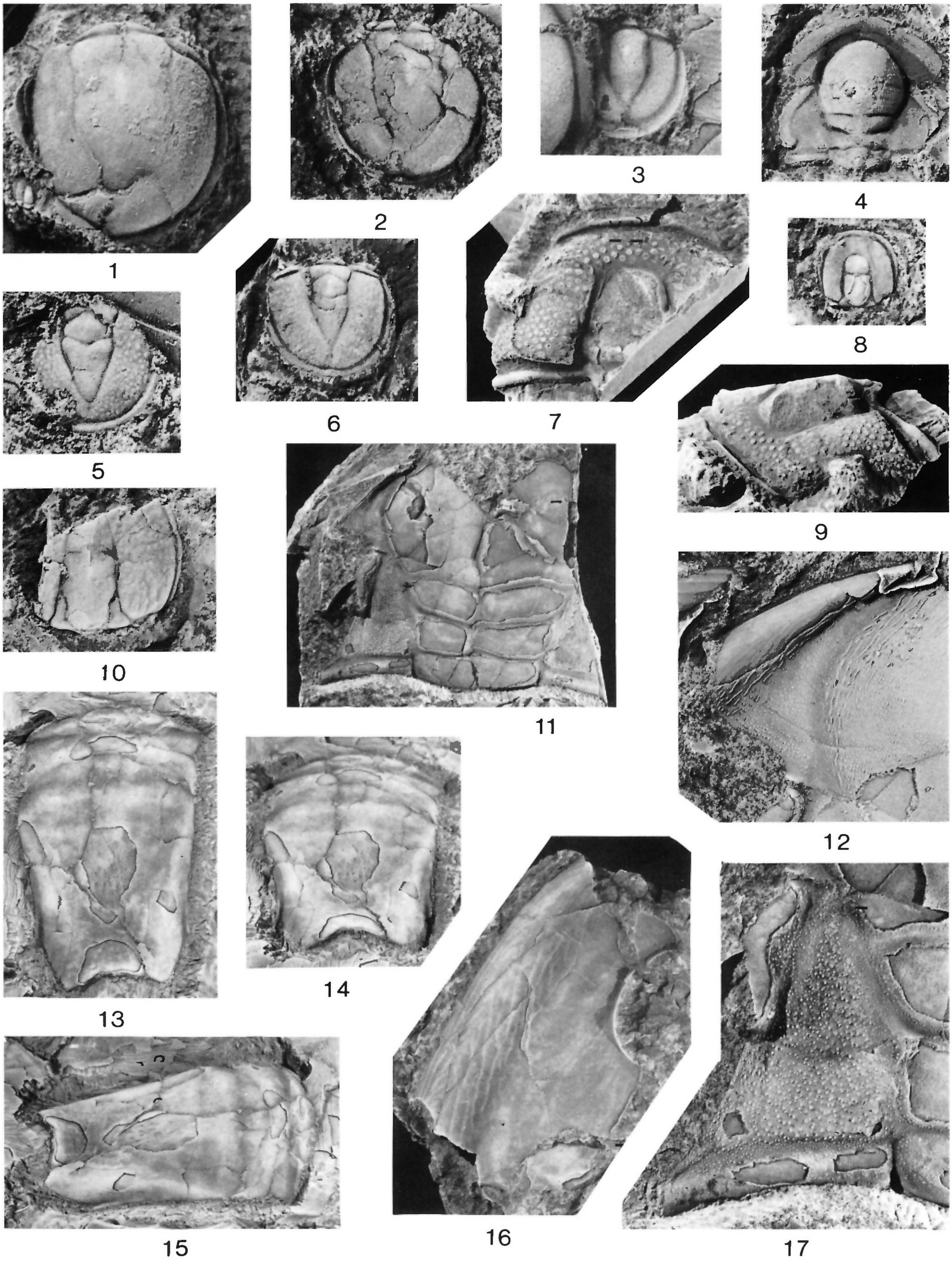

PLATE 5

Figures 1-4, 7, 9. *Agnostus pisiformis pisiformis* (Wahlenberg, 1821).

1. GSC 32662, GSC loc. 89109, x 10.
2. GSC 32683, GSC loc. 89132, x 12.
3. GSC 32685, GSC loc. 89133, x 10.
4. GSC 32661, GSC loc. 89108, x 8.
7. GSC 32684, GSC loc. 89132, x 10.
9. GSC 83305, GSC loc. 101555, x 7.

Figures 5, 6, 10-12. *Grandagnostus falanensis* (Westergård, 1947).

5. GSC 32694, GSC loc. 89136, x 8.
6. GSC 32687, GSC loc. 89134, x 12.
10. GSC 83306, GSC loc. 101554, x 6.
11. GSC 32690, GSC loc. 89134, x 8.
12. GSC 83307, GSC loc. 101555, x 8.

Figures 8, 14-16. *Homagnostus obesus* (Belt, 1867).

8. GSC 32679, GSC loc. 89121, x 10.
14. GSC 32668, GSC loc. 89116, x 10.
15. GSC 32670, GSC loc. 89117, x 10.
16. GSC 32681, GSC loc. 89121, x 10.

Figure 13. *Olenus truncatus* (Brünnich, 1781). GSC 32615, GSC loc. 89114, x 4.

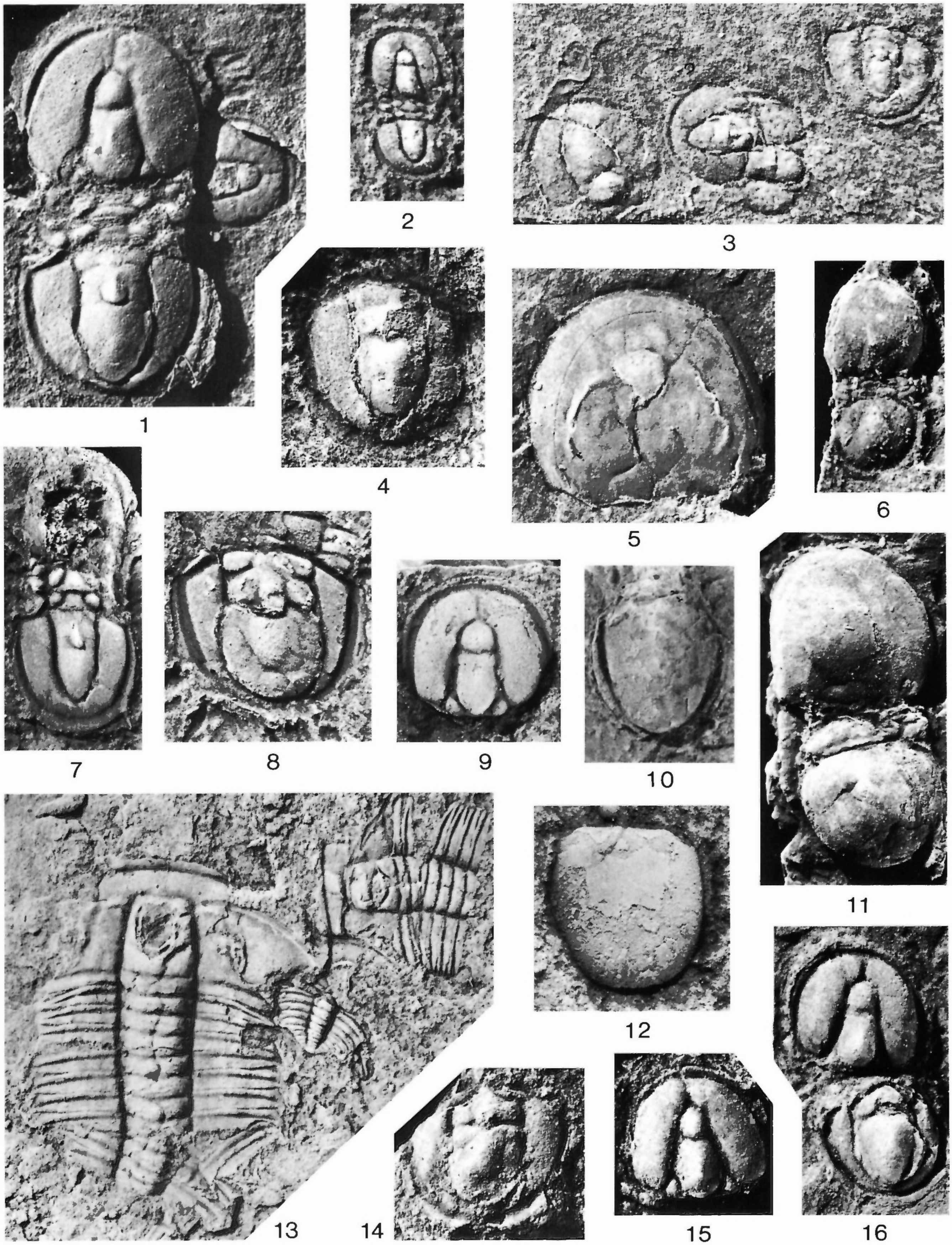
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PLATE 6

Figures 1-4, 7, 13. *Olenus truncatus* (Brunnich, 1781).

1. GSC 32693, GSC loc. 89136, x 8.

2. GSC 32664, GSC loc. 89114, x 8.

3. GSC 32616, GSC loc. 89114, x 3.

4. GSC 32692, GSC loc. 89136, x 8.

7. GSC 32617, GSC loc. 89114, x 3.

13. GSC 32618, GSC loc. 89114, x 6.

Figures 5, 14. *Olenus* cf. *O. transversus* Westergård, 1922.

5. GSC 32621, GSC loc. 89134, x 5.

14. GSC 32682, GSC loc. 89121, x 6.

Figures 6, 8, 9, 12, 16(?), 17. *Olenus wahlenbergi* Westergård, 1922.

6. GSC 32671, GSC loc. 89117, x 10.

8. GSC 32666, GSC loc. 89115, x 12.

9. GSC 32667, GSC loc. 89115, x 12.

12. GSC 32619, GSC loc. 89121, x 4.

16(?) GSC 32620, GSC loc. 89123, x 5.

17. GSC 32672, GSC loc. 89117, x 5.

Figures 10, 11. *Cyclotron* sp. GSC loc. 89134.

10. GSC 32680, x 10.

11. GSC 32689, x 12.

Figures 15, 18. *Olenus* sp.

15. GSC 83308, GSC loc. C-98061, x 4.

18. GSC 83309, GSC loc. C-98060, x 3.


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PLATE 7

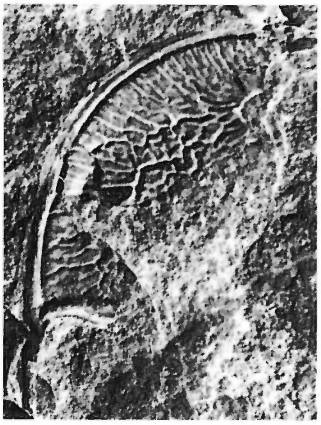
Figures 1, 2, 4, 7-13. *Parabolina spinulosa* (Wahlenberg, 1821).

1. GSC 32640, GSC loc. 87791, x 6.
2. GSC 32604, GSC loc. 87792, x 5.
4. GSC 32642, GSC loc. 87792, x 8.
7. GSC 32605, GSC loc. 87792, x 4.
8. GSC 32606, GSC loc. 87792, x 4.
9. GSC 32638, GSC loc. 87791, x 8.
10. GSC 32637, GSC loc. 87791, x 10.
11. GSC 32644, GSC loc. 87792, x 7.
12. GSC 32602, GSC loc. 87791, x 4.
13. GSC 32612, GSC loc. 87794, x 2.5.

Figure 3. *Pseudagnostus* sp. External mould of cephalon with valve of *Orusia lenticularis*. GSC 32643, GSC loc. 87792, x 10.

Figures 5, 6. *Protopeltura aciculata* (Angelin, 1854) *pusilla* Westergård, 1922. GSC loc. 87794.

5. GSC 32646, x 10.
6. GSC 32645, x 8.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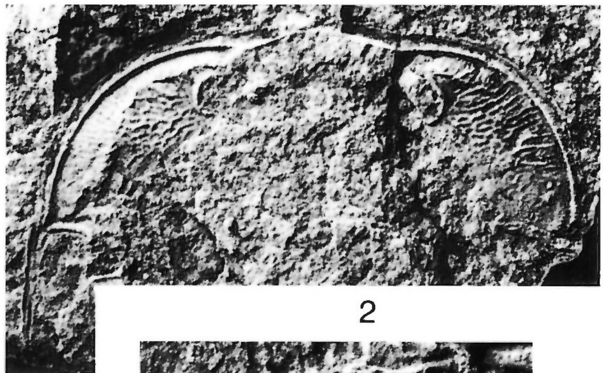
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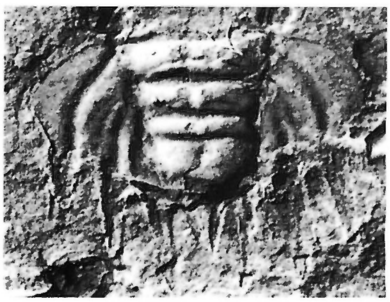
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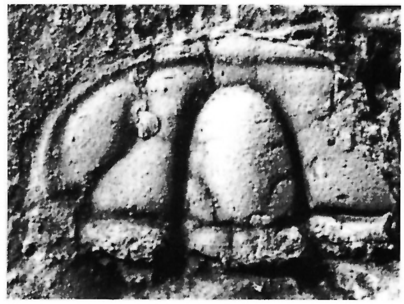
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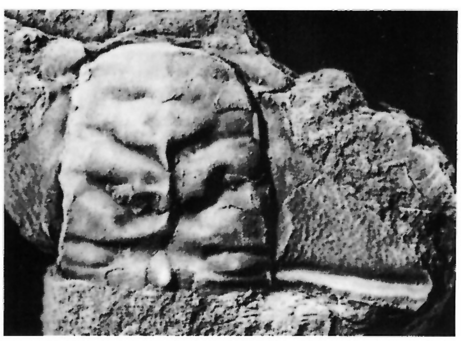
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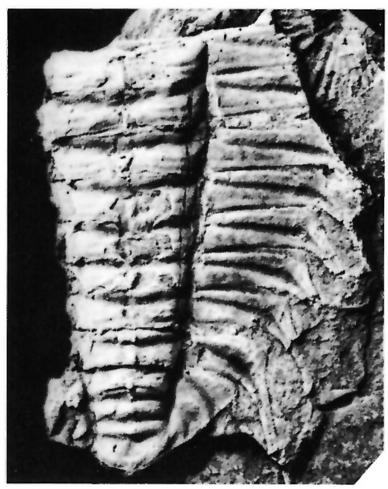
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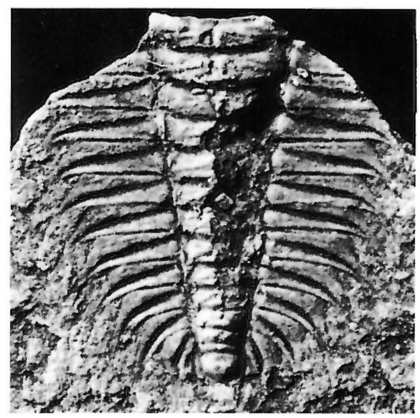
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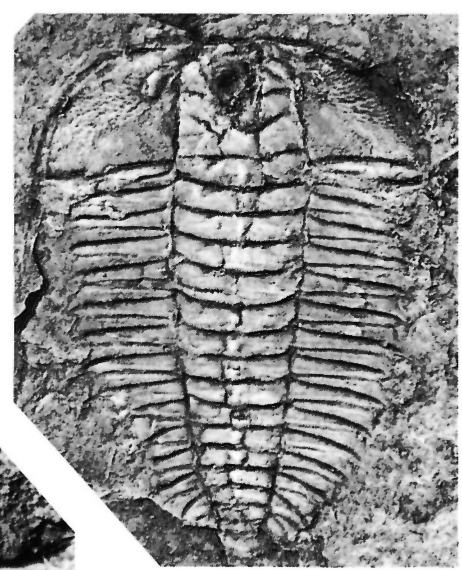
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PLATE 8

Figures 1-3, 6. *Parabolina spinulosa* (Wahlenberg, 1821). GSC loc. 87795.

1. GSC 32647, x 7.
2. GSC 32608, x 4.
3. GSC 32649, x 10.
6. GSC 32611, x 3.

Figure 4. *Parabolina* sp. GSC 32652, GSC loc. 87796, x 6.

Figures 5, 7, 10, 15(?) *Ctenopyge* (*Eoctenopyge*) *flagellifera* (Angelin, 1854). GSC loc. 87787.

5. GSC 32626, x 10.

7. GSC 32624, x 10.

10. GSC 32628, x 7.

15(?) GSC 32629, x 7.

Figure 8. *Pseudagnostus* sp. GSC 32651, GSC loc. 87796, x 8.

Figures 9, 11, 12. *Protopeltura* sp. GSC loc. C-98068.

9. GSC 83310, x 6.

11, 12. GSC 83311, x 4.

Figures 13, 14. *Leptoplastus* sp.

13. GSC 32634, GSC loc. 87790, x 7.

14. GSC 32632, GSC loc. 87789, x 11.

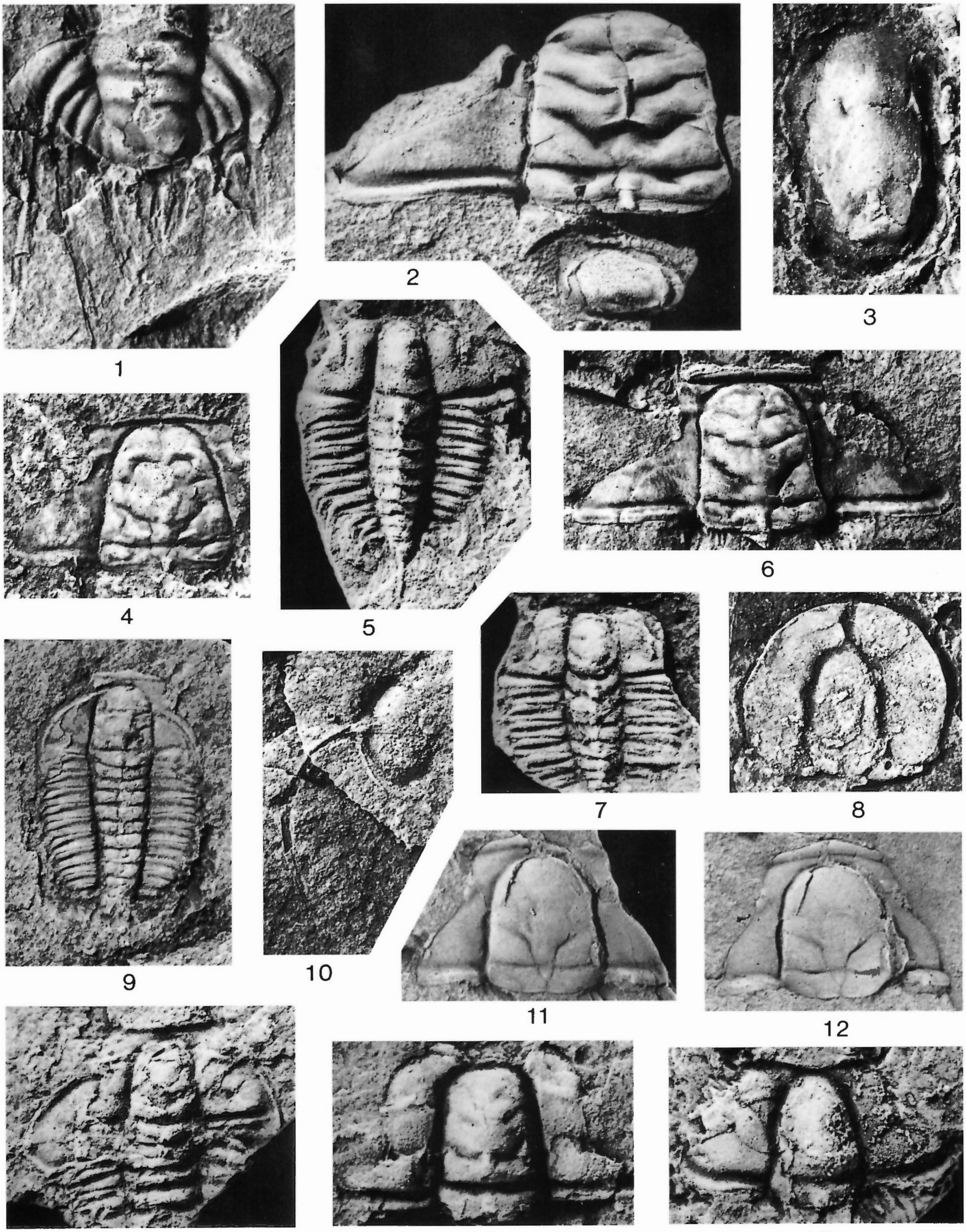
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PLATE 9

Figures 1(?), 5, 7(?), 11(?) *Ctenopyge (Mesoctenopyge) similis* Henningsmoen, 1957.

1(?) GSC 32623, GSC loc. 87786, x 8.

5. GSC 32658, GSC loc. 87800, x 6.

7(?) GSC 32656, GSC loc. 87800, x 10.

11(?) GSC 83312, GSC loc. 87800, x 6.

Figures 2-4, 6(?), 8(?), 10, 13(?) *Ctenopyge (Mesoctenopyge) tumida* Westergård, 1922.

2. GSC 32700, GSC loc. 89139, x 12.

3. GSC 32655, GSC loc. 87799, x 6.

4. GSC 32698, GSC loc. 89138, x 10.

6(?) GSC 32697, GSC loc. 89138, x 8.

8(?) GSC 32654, GSC loc. 87799, x 10.

10. GSC 32701, GSC loc. 89139, x 10.

13(?) GSC 32699, GSC loc. 89138, x 10.

Figure 9. *Ctenopyge* (s.l.) sp. undet. GSC 32702, GSC loc. 89140, x 12.

Figures 12, 14, 16-18. *Peltura scarabaeoides scarabaeoides* (Wahlenberg, 1821). GSC loc. 89793.

12. GSC 38972, x 6.

14. GSC 38973, x 6.

16. GSC 38975, x 8.

17. GSC 38974, x 6.

18. GSC 38979, x 5.

Figure 15. *Westergaardia lata* (Matthew, 1891). GSC 32703, GSC loc. 89143, x 10.

Figure 19. *Ctenopyge (Ctenopyge) linnarssoni* Westergård, 1922. GSC 38971, GSC loc. 89793, x 6.

Figure 20. *Sphaerophthalmus majusculus* Linnarsson, 1880. GSC 38978, GSC loc. 89793, x 7.

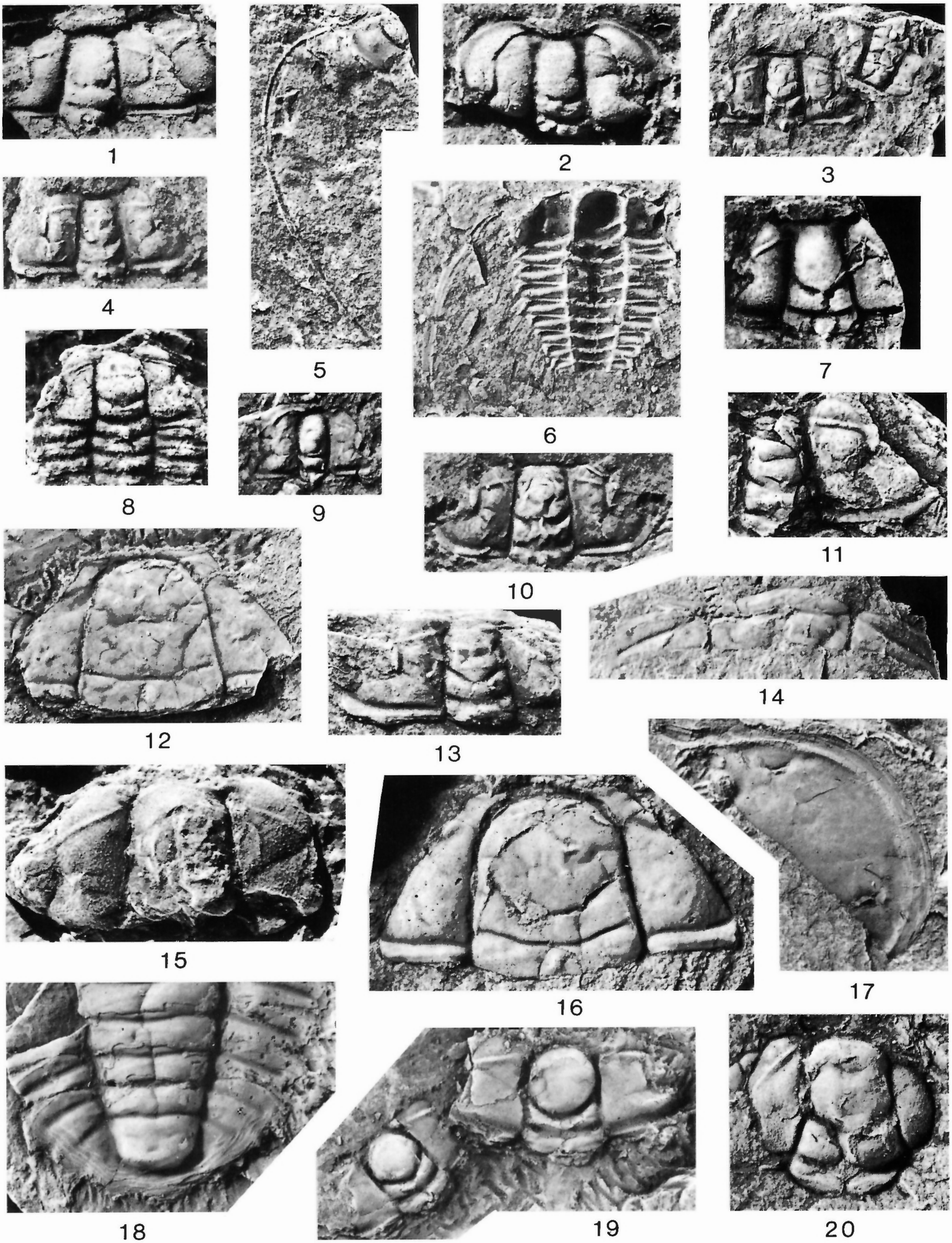
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PLATE 10

Magnification x 1000, except where otherwise stated

Figures 1-5. *Actinotodissus achrasi* (Martin, 1973) Martin comb. nov.*

1. GSC 83124, GSC loc. C-98014, enlargement, x 5000, of two processes in lower left part of figure 2.
2. GSC 83124, GSC loc. C. 98014.
3. GSC 83125, GSC loc. C-98014.
4. GSC 83126, GSC loc. C-98015.
5. GSC 83127, GSC loc. C-98021.

Figures 6, 7, 10, 11, 13-15. *Dasydiacrodium obsonum* Martin sp. nov.*

6. Holotype, GSC 83169, GSC loc. C-98014.
7. GSC 83170, GSC loc. C-98015.
10. GSC 83171, GSC loc. C-98012.
11. GSC 83172, GSC loc. C-98019.
13. GSC 83173, GSC loc. C-98010.
14. GSC 83174, GSC loc. C-98019.
15. GSC 83175, GSC loc. C-98015, x 2000.

Figures 8, 9, 12. *Leiofusa stoumonensis* Vanguestaine, 1973.

8. GSC 83186, GSC loc. C-98010, x 500.
9. GSC 83187, GSC loc. C-98010, x 500.
12. GSC 83188, GSC loc. C-98011, x 750.

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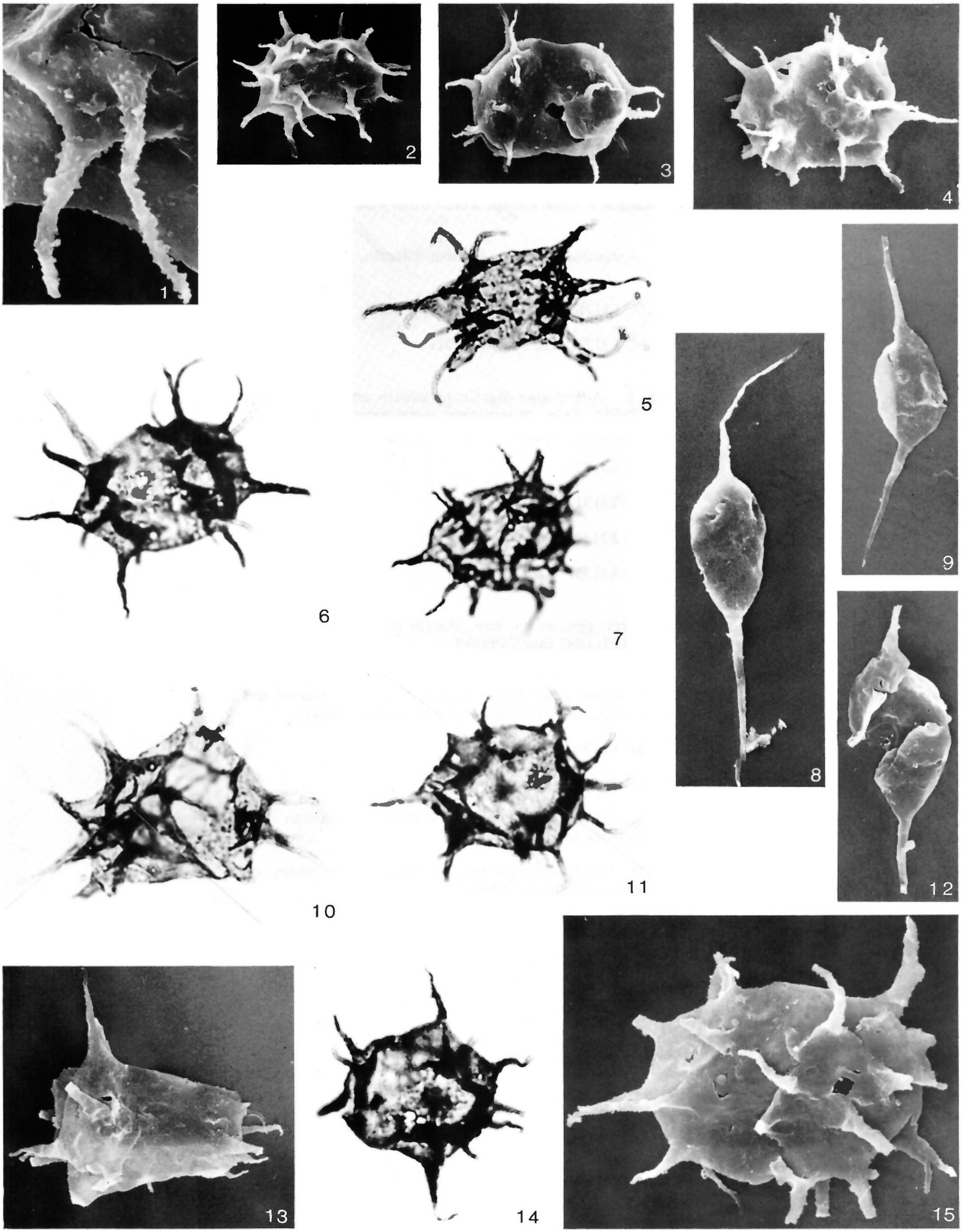
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PLATE 11

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Figures 1, 2. *Actinotodissus* cf. *A. ubui* (Martin, 1969) Martin, comb. nov.*

1. GSC 83128, GSC loc. C-98022, x 2000.

2. GSC 83129, GSC loc. C-98021.

Figures 3, 5, 6, 8. *Adara alea* Martin in Martin and Dean, 1981. GSC loc. C-98049. Thin, transparent membrane preserved in left part of figure 5 and upper left part of figure 6.

3. GSC 83130.

5. GSC 83131.

6. GSC 83132.

8. GSC 83133.

Figure 4. Acritarch gen. et sp. nov. Martin in Martin and Dean, 1984. GSC 83123, GSC loc. C-98049.

Figures 7, 9-13. *Arbusculidium rommelaerei* Martin in Martin and Dean, 1981.* GSC loc. 94432 in Martin and Dean, 1981.

7. GSC 83134.

9. GSC 83135.

10. GSC 83136, enlargement, x 5000, of median left processes of figure 12.

11. GSC 83135, enlargement, x 5000, of processes on upper right side of figure 9.

12. GSC 83136, x 2000.

13. GSC 83137, x 2000.

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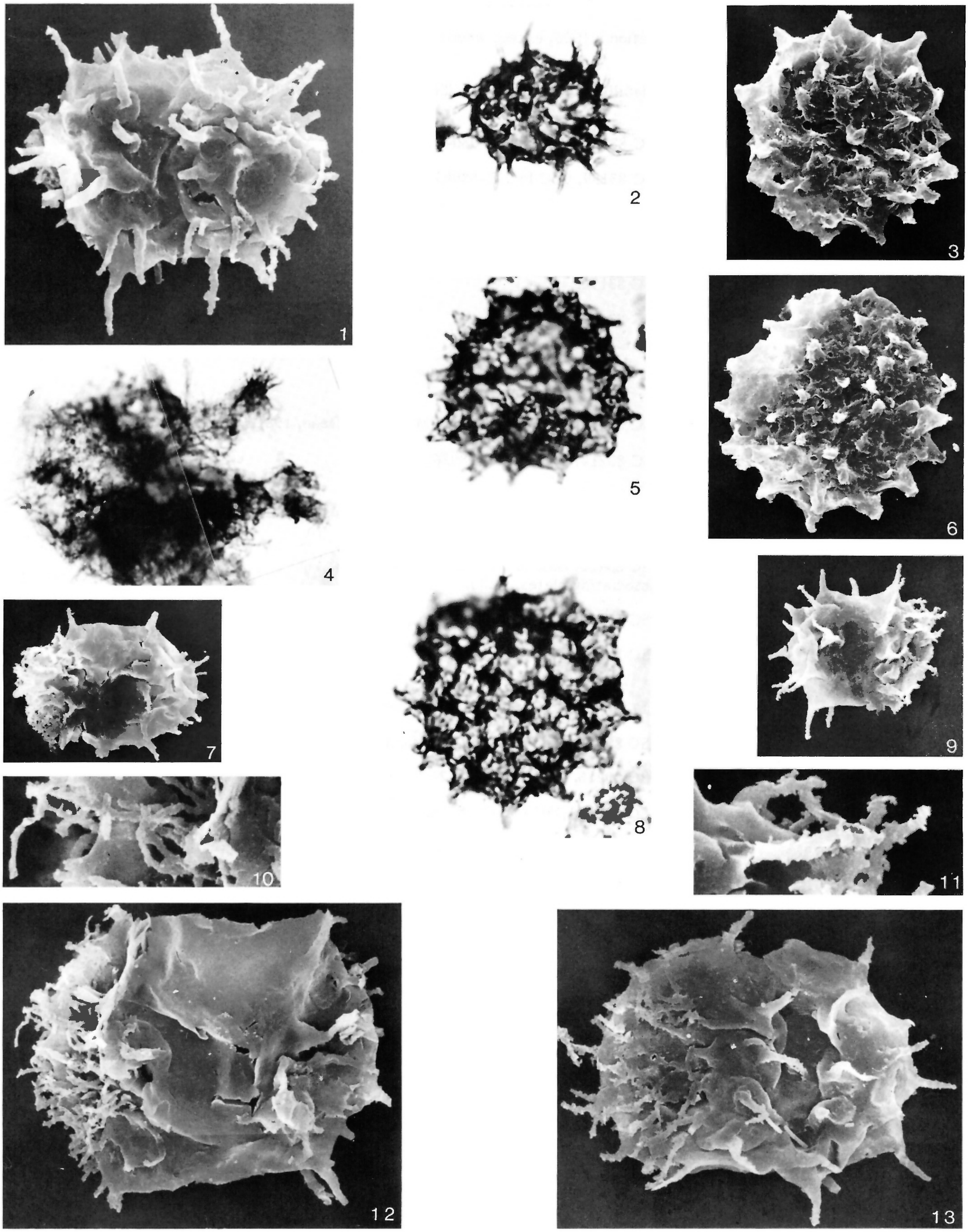
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PLATE 12

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Figures 1, 2. *Cristallinium cambriense* (Slavíková) Vanguestaine, 1978.*

1. GSC 83138, GSC loc. C-98041.

2. GSC 83139, GSC loc. C-98049.

Figures 3, 4. *Retisphaeridium howellii* Martin in Martin and Dean, 1983. GSC loc. C-98041.

3. GSC 83192.

4. GSC 83193.

Figures 5, 6. *Timofeevia pentagonalis* (Vanguestaine) Vanguestaine, 1978.

5. GSC 83213, GSC loc. 92989 in Martin and Dean, 1981.

6. GSC 83214, GSC loc. C-98026.

Figures 7-9. *Retisphaeridium dichamerum* Staplin, Jansonius and Pocock, 1965.

7. GSC 83189, GSC loc. C-98041, fragment of dissociating plates, x 500.

8. GSC 83190, GSC loc. C-98041.

9. GSC 83191, GSC loc. C-98049.

Figures 10, 11, 14. *Timofeevia phosphoritica* Vanguestaine, 1978.

10. GSC 83215, GSC loc. 92989 in Martin and Dean, 1981.

11. GSC 83216, GSC loc. C-98026.

14. GSC 83217, GSC loc. C-98026.

Figures 12, 15, 16. *Timofeevia lancarae* (Cramer and Diez de Cramer) Vanguestaine, 1978.

12. GSC 83209, GSC loc. C-98026.

15. GSC 83210, GSC loc. 92989 in Martin and Dean, 1981, secondary, probably organic, material on part of the vesicle.

16. GSC 83211, GSC loc. 92989 in Martin and Dean, 1981.

Figure 13. *Timofeevia microretis* Martin in Martin and Dean, 1981. GSC 83212, GSC loc. 92990 in Martin and Dean, 1981.

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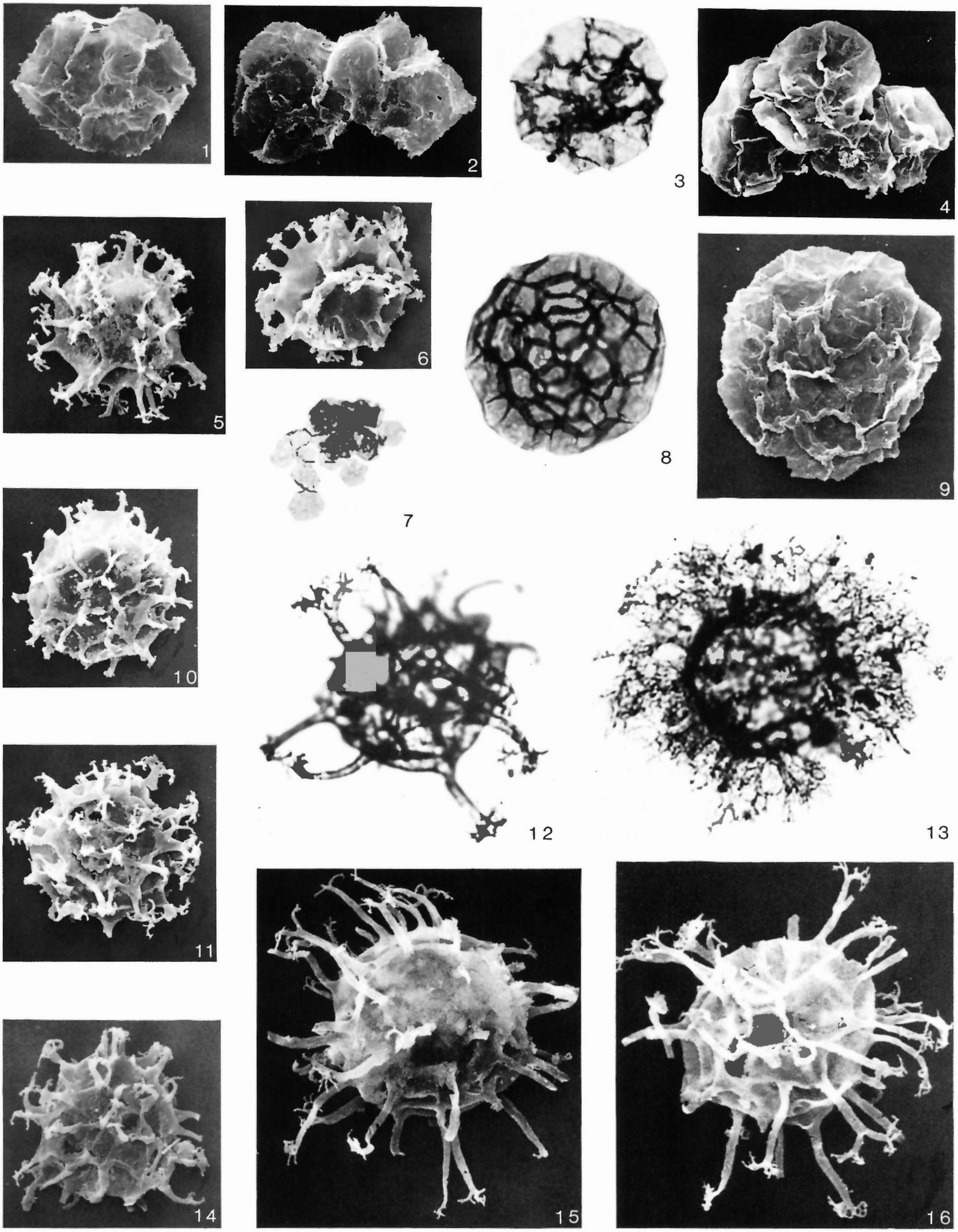
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PLATE 13

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Figures 1-17. *Cristallinium randomense* Martin in Martin and Dean, 1981, emend.*

1. GSC 83140, GSC loc. C-98013.
2. GSC 83141, GSC loc. C-98067.
3. GSC 83142, GSC loc. C-98013.
4. GSC 83143, GSC loc. C-98012.
5. GSC 83144, GSC loc. C-98012.
6. GSC 83145, GSC loc. C-98010, enlargement, x 5000, of processes at top of figure 10.
7. GSC 83146, GSC loc. C-98011.
8. GSC 83147, GSC loc. C-98011.
9. GSC 83148, GSC loc. C-98010.
10. GSC 83145, GSC loc. C-98010.
11. GSC 83149, GSC loc. C-98011.
12. GSC 83150, GSC loc. C-98010.
13. GSC 83151, GSC loc. C-98010, x 750.
14. GSC 83152, GSC loc. C-98011.
15. GSC 83153, GSC loc. C-98011.
16. GSC 83154, GSC loc. C-98010.
17. GSC 83152, GSC loc. C-98011, enlargement, x 2000, of processes at top of figure 14.

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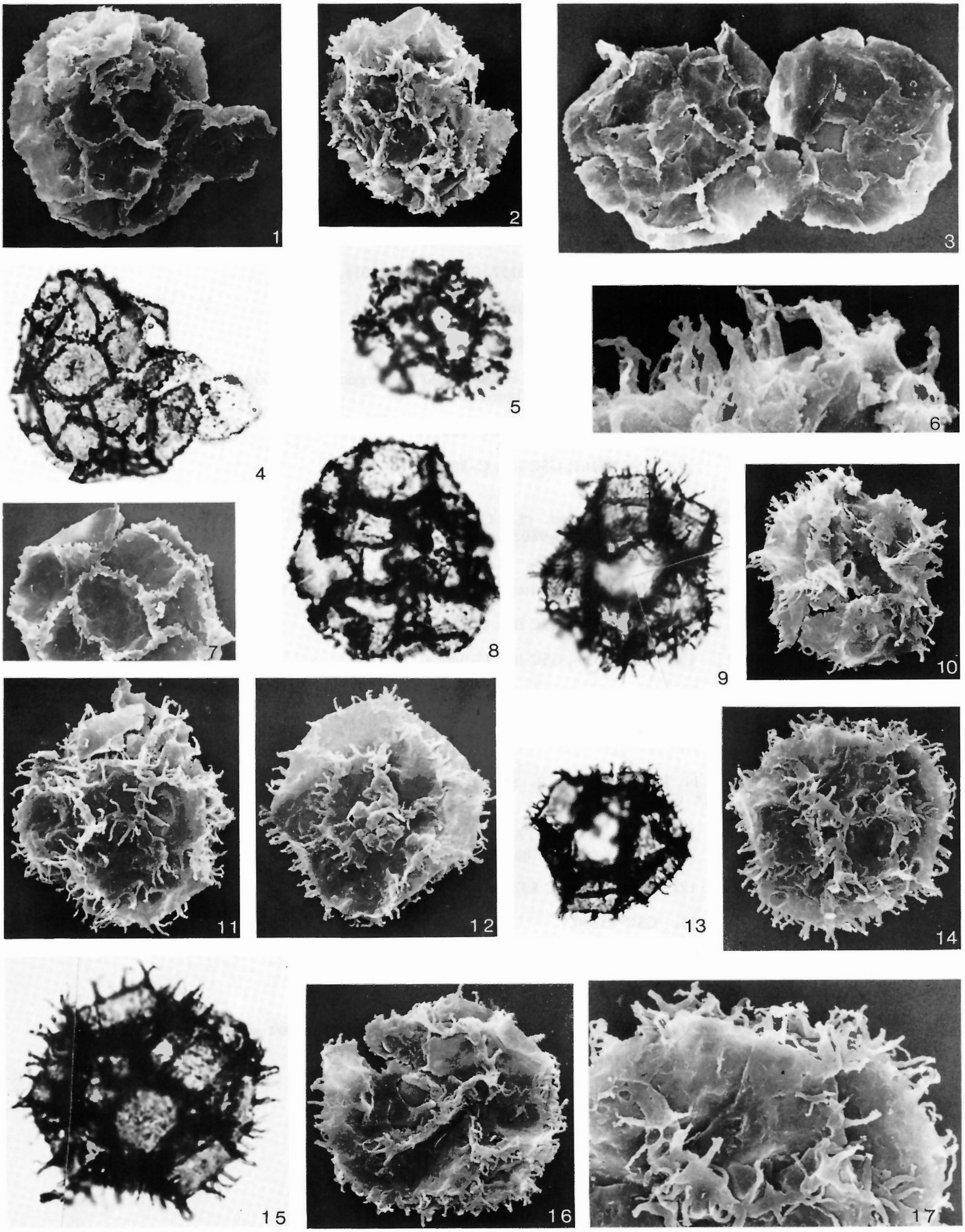
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PLATE 14

Magnification x 1000, except where otherwise stated

Figures 1-7, 9. *Cymatiogalea aspergillum* Martin sp. nov.*

1. GSC 83155, GSC loc. C-98010.
2. GSC 83156, GSC loc. C-98067.
3. Holotype, GSC 83157, GSC loc. C-98011.
4. GSC 83158, GSC loc. C-98011.
5. GSC 83159, GSC loc. C-98014.
6. GSC 83156, GSC loc. C-98067, enlargement, x 5000, of lower part of figure 2.
7. GSC 83160, GSC loc. C-98011.
9. GSC 83161, GSC loc. C-98013.

Figure 8. *Cymatiogalea* cf. *C. cylindrata* Rasul, 1974. GSC 83162, GSC loc. C-98021.

Figures 10, 13, 14, 17. *Cymatiogalea virgulta* Martin sp. nov.*

10. GSC 83163, GSC loc. C-98011.
13. GSC 83164, GSC loc. C-98011.
14. GSC 83165, GSC loc. C-98013.
17. Holotype, GSC 83166, GSC loc. C-98011.

Figures 11, 12, 15, 16, 18, 19. *Stelliferidium pingiculum* Martin sp. nov.* GSC loc. C-98062.

11. Holotype, GSC 83205, enlargement, x 5000, of central part of figure 12.
12. Holotype, GSC 83205.
15. GSC 83206.
16. GSC 83207.
18. GSC 83208.
19. GSC 83208, enlargement, x 5000, of central part of figure 18.

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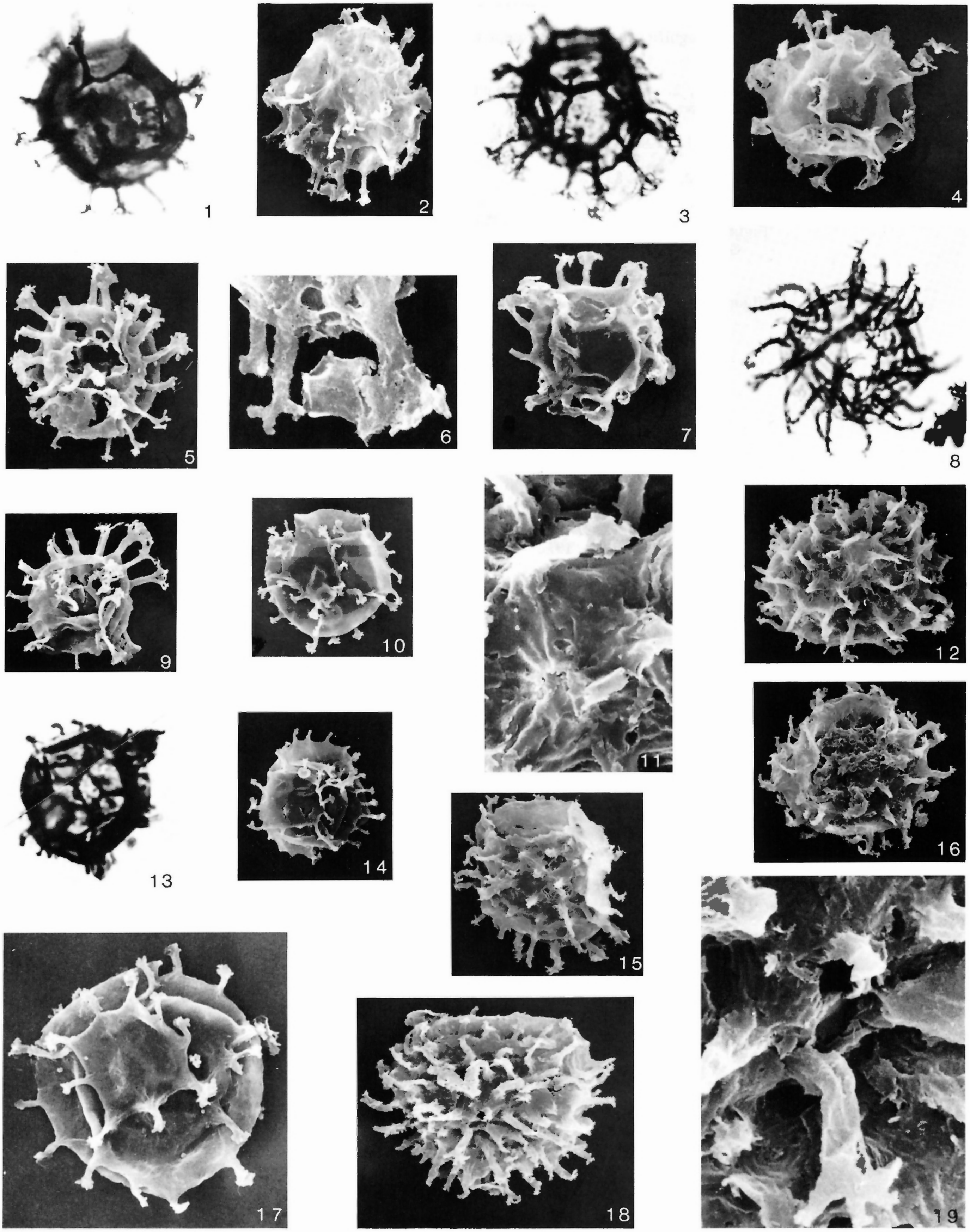
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PLATE 15

Magnification x 1000, except where otherwise stated

Figures 1, 2. *Eliasum jennessii* Martin in Martin and Dean, 1984. GSC loc. C-98036, x 750.

1. GSC 83177.

2. GSC 83178.

Figure 3. *Eliasum* cf. *E. asturicum* Fombella, 1977. GSC 83176, GSC loc. C-98050, x 750.

Figures 4-6, 10, 11. *Impluviculus* sp. A* GSC loc. C-98011.

4. GSC 83181.

5. GSC 83182.

6. GSC 83183, x 2000.

10. GSC 83184.

11. GSC 83185.

Figures 7, 12-20. *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976*

7. GSC 83218, GSC loc. C-98014.

12. GSC 83219, GSC loc. C-98014.

13. GSC 83220, GSC loc. C-98014.

14. GSC 83221, GSC loc. C-98017.

15. GSC 83221, GSC loc. C-98017, enlargement, x 5000, of upper right part of figure 14.

16. GSC 83222, GSC loc. C-98017.

17. GSC 83223, GSC loc. C-98015.

18. GSC 83224, GSC loc. C-98917.

19. GSC 83225, GSC loc. C-98014.

20. GSC 83225, GSC loc. C-98014, enlargement, x 5000, of lower right part of figure 19.

Figures 8, 9. *Eliasum llaniscum* Fombella, 1977. GSC loc. C-98049, x 750.

8. GSC 83179.

9. GSC 83180.

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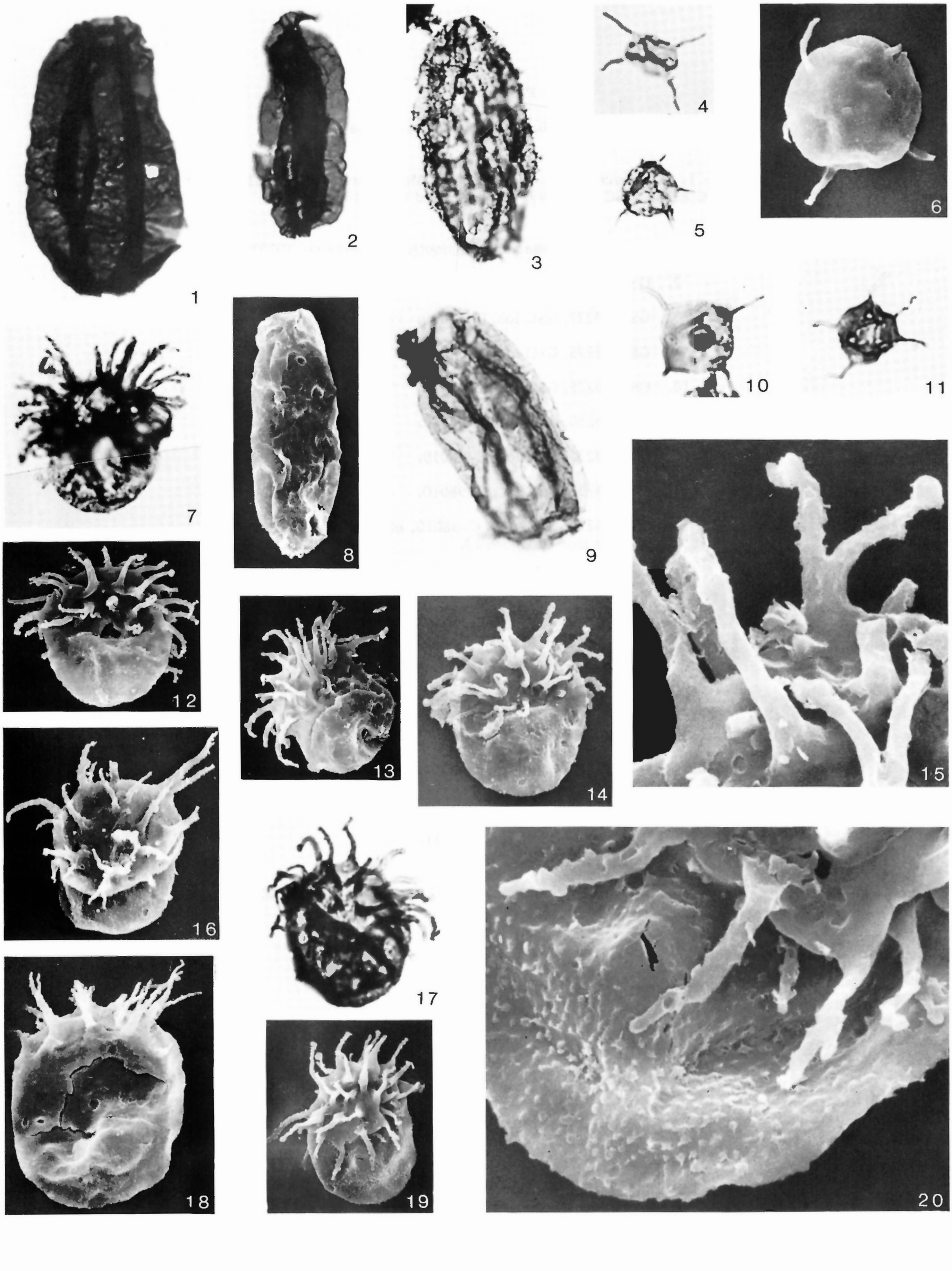
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PLATE 16

Magnification x 1000, except where otherwise stated

Figure 1. *Veryhachium* sp. A Martin in Martin and Dean, 1981. GSC 83240, GSC loc. 94432 in Martin and Dean, 1981, x 500.

Figures 2, 3, 7, 10-18. *Veryhachium dumontii* Vanguestaine, 1973*

2. GSC 83226, GSC loc. C-98010.
3. GSC 83227, GSC loc. C-98010.
7. GSC 83228, GSC loc. C-98011.
10. GSC 83229, GSC loc. C-98010.
11. GSC 83230, GSC loc. C-98012.
12. GSC 83231, GSC loc. C-98010.
13. GSC 83232, GSC loc. C-98010.
14. GSC 83232, GSC loc. C-98010, enlargement, x 5000, of right side of figure 13.
15. GSD 83233, GSC loc. C-98010.
16. GSC 83234, GSC loc. C-98017.
17. GSC 83235, GSC loc. C-98010.
18. GSC 83236, GSC loc. C-98011.

Figures 4, 6, 9. *Veryhachium* cf. *V. dumontii* Vanguestaine, 1973*

4. GSC 83237, GSC loc. C-98017.
6. GSC 83238, GSC loc. C-98017, x 500.
9. GSC 83239, GSC loc. C-98011.

Figures 5, 8. *Dasydiacrodium caudatum* Vanguestaine, 1973* GSC loc. C-98011.

5. GSC 83167.
8. GSC 83168.

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*Described in text

PLATE 16

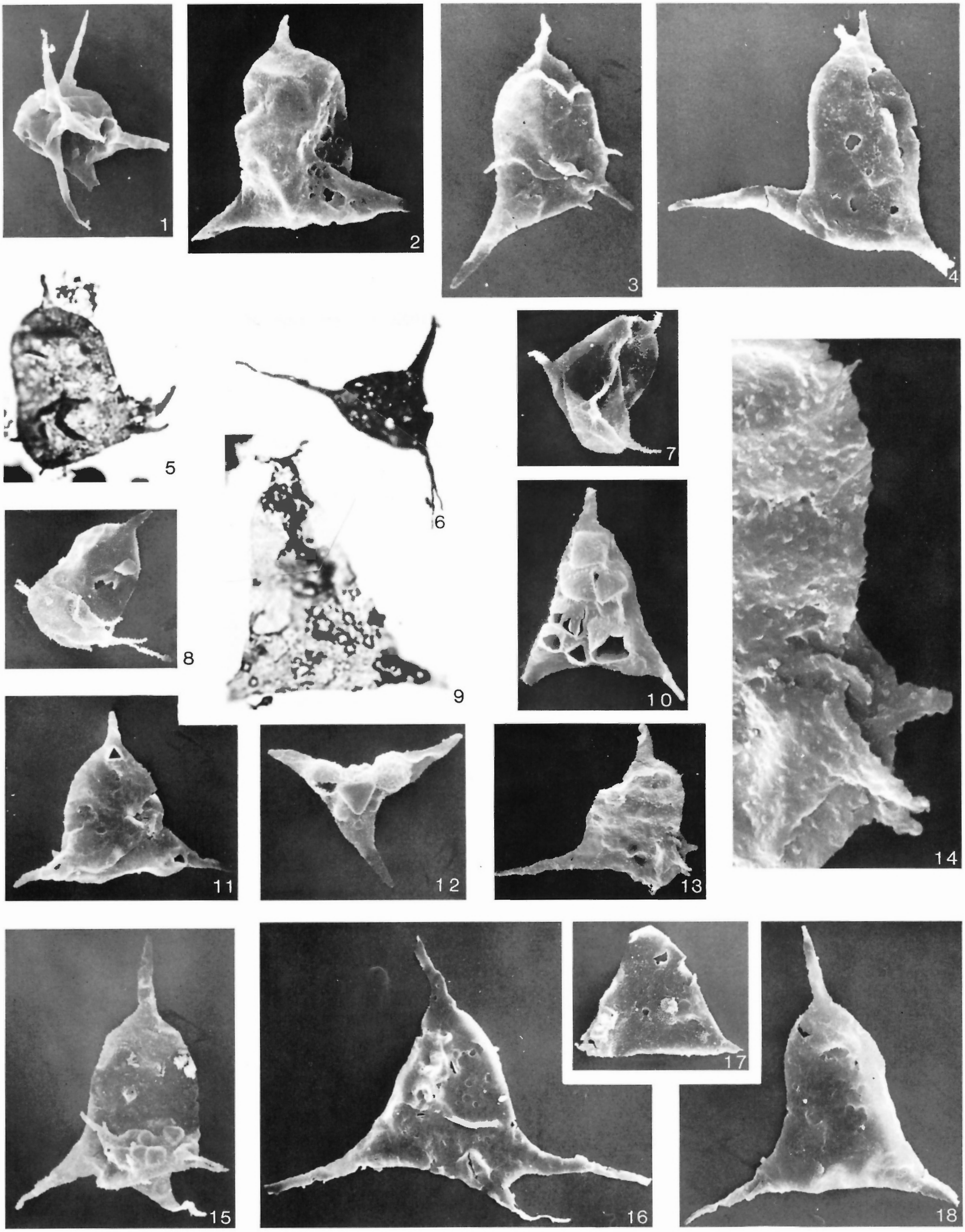

PLATE 17

Magnification x 1000, except where otherwise stated

Figures 1-11. *Rugasphaera terranovana* Martin gen. et sp. nov.*
GSC loc. C-98041.

1. GSC 83194, enlargement, x 5000, of left side of figure 2.
2. GSC 83194.
3. GSC 83195.
4. GSC 83195, enlargement, x 5000, of upper left side of figure 3.
5. GSC 83196, enlargement, x 10 000, of lower central part of figure 6.
6. GSC 83196.
7. GSC 83197.
8. Holotype, GSC 83198.
9. GSC 83199.
10. GSC 83200, x 1500.
11. GSC 83201, x 5000.

Figures 12-15. *Stellichinatum uncinatum* (Downie, 1958) Martin comb. nov.*

12. GSC 83202, GSC loc. C-98010.
13. GSC 83203, GSC loc. C-98013.
14. GSC 83204, GSC loc. C-98013.
15. GSC 83204, GSC loc. C-98013, enlargement, x 5000, of upper part of figure 14.

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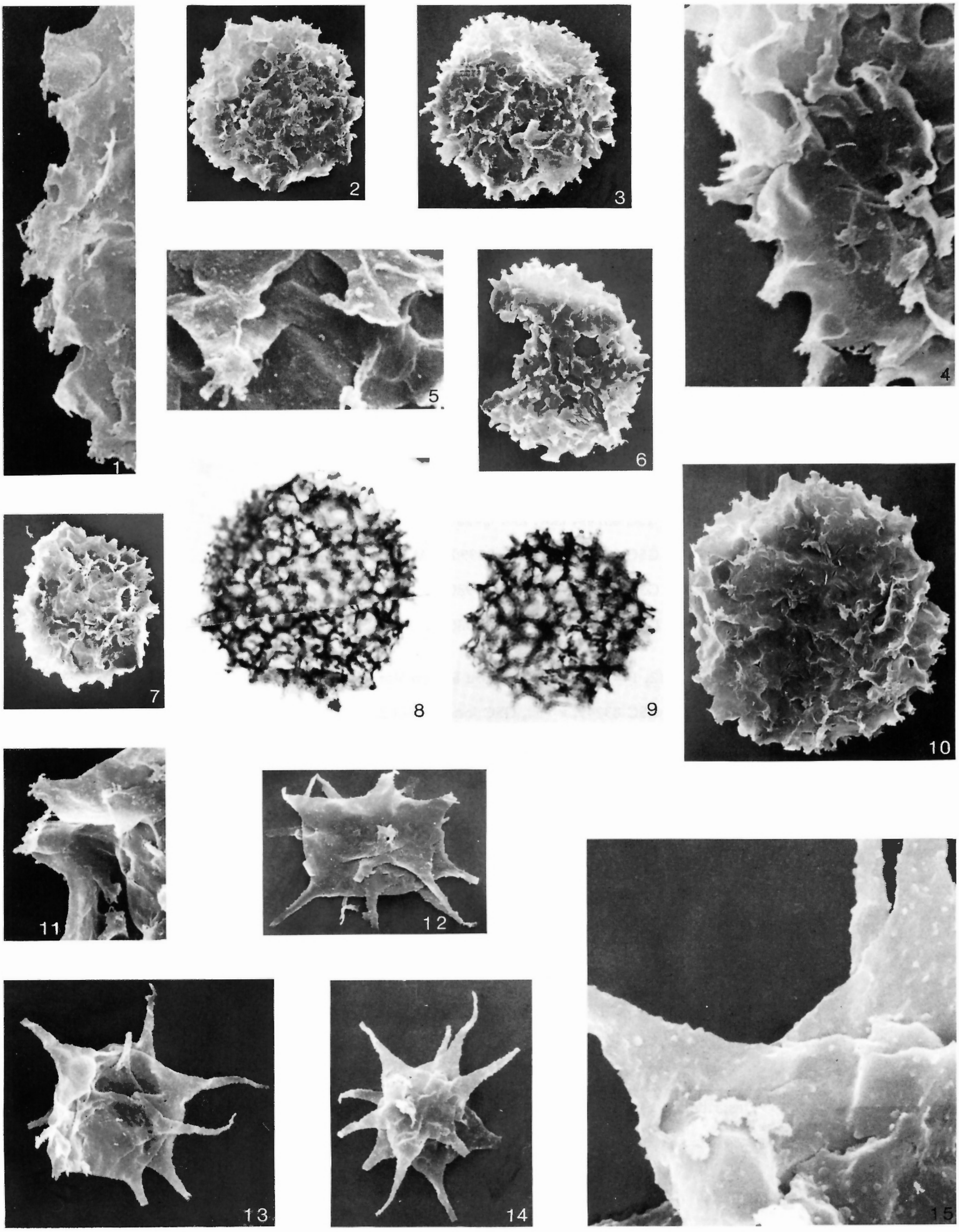
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PLATE 18

Magnification x 1000, except where otherwise stated

Figures 1, 4. *Vulcanisphaera africana* Deunff, 1961. GSC loc. C-98011.

1. GSC 83241.

4. GSC 83242.

Figure 2. Transition *Vulcanisphaera turbata* → *V. africana** GSC 83248, GSC loc. C-98010.

Figures 3, 5, 6, 8, 13. *Vulcanisphaera turbata* Martin in Martin and Dean, 1981*

3. GSC 83243, GSC loc. C-98013.

5. GSC 83244, GSC loc. C-98011.

6. GSC 83245, GSC loc. 92990 in Martin and Dean, 1981.

8. GSC 83246, GSC loc. C-98011.

13. GSC 83247, GSC loc. C-98010.

Figures 7, 9-12, 14-17. *Vulcanisphaera lanugo* Martin sp. nov.*

7. GSC 83249, x 750, GSC loc. C-98042.

9. GSC 83250, GSC loc. C-98042.

10. GSC 83251, enlargement, x 2000, of left side of figure 11.

11. GSC 83251, GSC loc. C-98042.

12. Holotype, GSC 83252, GSC loc. C-98042.

14. GSC 83253, GSC loc. C-98042.

15. GSC 83254, GSC loc. C-98042.

16. GSC 83255, GSC loc. C-98042.

17. GSC 83256, GSC loc. C-98041.

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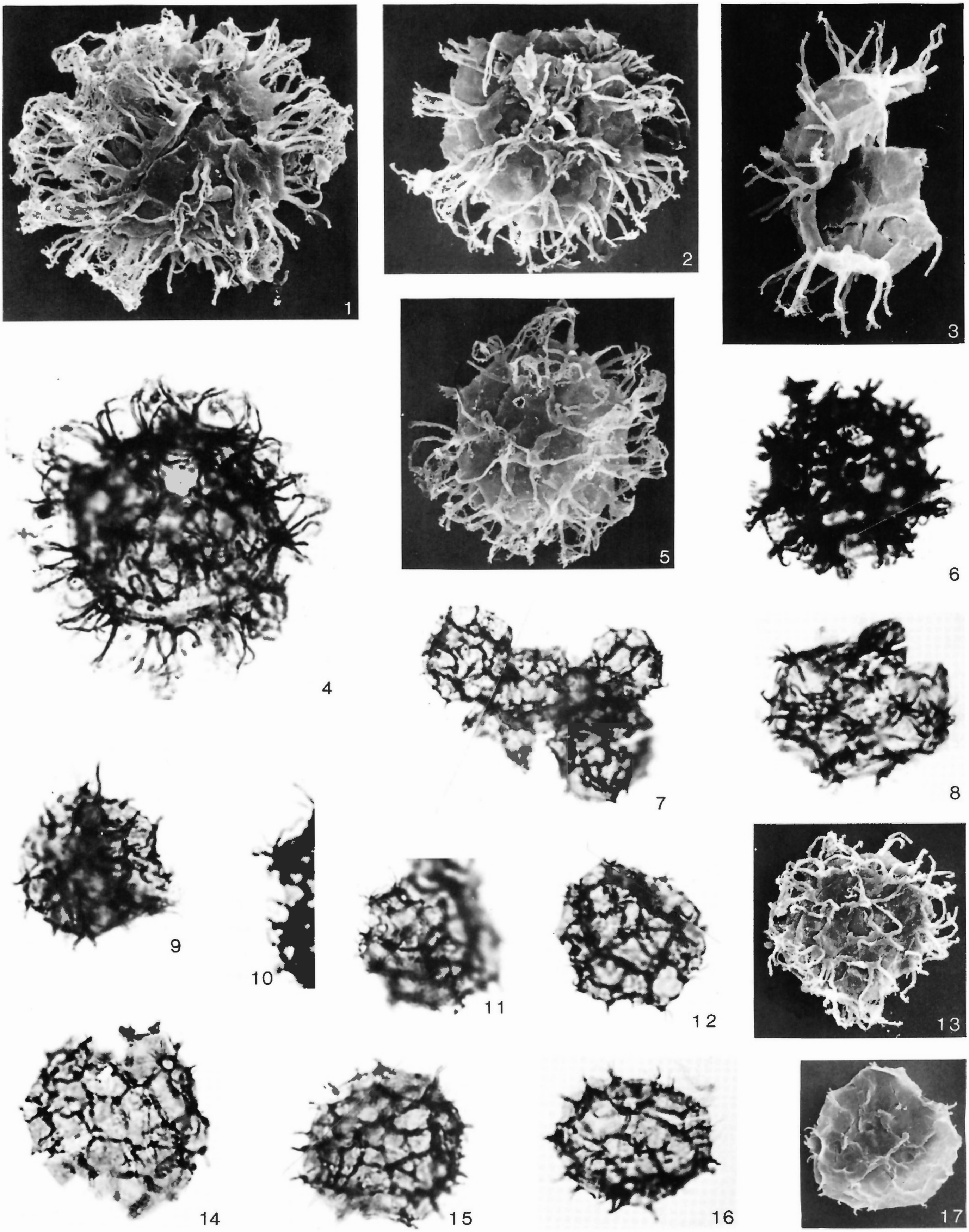
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