GEOLOGICAL SURVEY OF CANADA
BULLETIN 409

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W.H. Fritz

1991

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Available in Canada through
authorized book store agents
and other book stores

or by mail from

Canada Communications Group – Publishing
Supply and Services Canada
Ottawa, Ontario K1A 0S9

and

Institute of Sedimentary and Petroleum Geology
Geological Survey of Canada
3303 - 33rd Street N.W.
Calgary, Alberta T2L 2A7

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M42-409E
ISBN 0-660-13836-0

Price subject to change without notice

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Manuscript submitted: 89.05.17
Approved for publication: 90.12.07

PREFACE

The paleontological and stratigraphic records of the Cambrian in North America lack balance. Transgressive deposits provide copious data, whereas data available from regressive deposits are meagre. This study takes advantage of this bias by focusing on a stratigraphic section in the Wernecke Mountains that represents peak transgression at the end of the Early Cambrian and thus peak availability of data. The section has a great thickness of upper *Bonnia – Olenellus* Zone strata containing numerous trilobite-bearing beds; a combination that makes it a key biostratigraphic reference section. Biostratigraphic information from this section can be used to collate data from widespread but relatively isolated and vertically limited sections elsewhere in North America.

The *Bonnia – Olenellus* Zone lies immediately below one of the larger, more significant unconformities in the Phanerozoic strata of North America. The magnitude of the weathering and erosion represented by this unconformity make it attractive to those interested in the stratiform ore deposits typically associated with such unconformities. In order to evaluate and characterize the gap represented by this unconformity at isolated and incomplete sections, and to assess the economic potential of strata associated with the unconformity at such sections, economic geologists must compare these sections with the rare, relatively complete, reference sections found elsewhere. The Wernecke Mountains section described in this report constitutes one of the best reference sections currently available for this purpose.

Elkanah A. Babcock
Assistant Deputy Minister
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PRÉFACE

Les données paléontologiques et stratigraphiques sur le Cambrien en Amérique du Nord sont en désiquilibre numérique. Les données sur les dépôts de transgression sont abondantes tandis que celles sur les dépôts de régression sont restreintes. La présente étude tire parti de cette situation en mettant l'accent sur un profil stratigraphique dans les monts Wernecke, qui représente une transgression maximale à la fin du Cambrien inférieur et qui constitue, de ce fait, une source importante de données. Ce profil comporte d'épaisses couches de la partie supérieure de la zone à *Bonnia – Olenellus* contenant de nombreux horizons renfermant des trilobites, ce qui contribue à en faire une coupe de référence biostratigraphique clé. Les renseignements biostratigraphiques recueillis dans ce profil peuvent servir à collationner les données provenant de profils largement dispersés en Amérique du Nord mais relativement isolés et verticalement limités.

La zone à *Bonnia – Olenellus* s'étend directement au-dessous de l'une des plus vastes et des plus importantes discordances observées dans les couches phanérozoïques de l'Amérique du Nord. L'importance de la météorisation et de l'érosion représentée par cette discordance en fait une zone intéressante pour ceux qui étudient les gisements stratiformes généralement associés à de telles discordances. Afin d'évaluer et de caractériser l'écart représenté par cette discordance dans certains profils isolés et incomplets et afin de déterminer le potentiel économique des couches associées à la discordance dans ces profils, les spécialistes en géologie économique doivent comparer ces profils avec les rares profils de référence relativement complets que l'on trouve ailleurs. Le profil des monts Wernecke décrit dans le présent rapport constitue l'un des meilleurs profils de référence actuellement utilisables à cette fin.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada

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Abstract

Trilobites from a 946 m thick measured section of the Illtyd Formation were collected from 25 horizons belonging to the upper half of the *Bonnia – Olenellus* Zone. The trilobites belong to 14 genera (2 new) and 38 species (15 new). *Proliostracus, Variopelta, Wanneria*, and a cone-shaped fossil, *Salterella*, provide a middle *Bonnia – Olenellus* Zone age for the lower part of the formation. *Antagmus, Bonnia* (with one pair of pygidial spines), *Syspacephalus* and *Zacanthopsis* provide evidence of what would conventionally be considered a young age within the zone well below the top of the formation. Evidence of even younger trilobites within this Lower Cambrian zone, and near the top of the formation, suggests continued Early Cambrian subsidence at the site of the Illtyd section at a time when bypassing and/or erosion began in various parts of North America and elsewhere. New genera are *Bonnima* and *Illtydaspis*. New species are *Antagmus ducketti, Bonnia carnata, B. decora, B. quadrata, Bonnima semidiscoidea, Illtydaspis aphylla, I. ornata, I. quartetensis, Olenellus bufrontis, O. parvofrontatus, O. sphaerulosus, Proliostracus ampliatus, Syspacephalus werneckensis, Variopelta brevicervicata,* and *Zacanthopsis expansa*.

Résumé

Les trilobites prélevés dans une coupe de 946 m d'épaisseur de la formation d'Illtyd étaient répartis dans 25 horizons de la moitié supérieure de la zone à *Bonnia – Olenellus*. Les trilobites appartiennent à 14 genres (2 nouveaux) et 38 espèces (15 nouvelles). *Proliostracus, Variopelta, Wanneria* et un fossile cônique, *Salterella*, permettent d'attribuer à la partie inférieure de la formation un âge intermédiaire pour la zone à *Bonnia – Olenellus* intermédiaire. *Antagmus, Bonnia* (avec une paire d'arêtes au pygidiums), *Syspacephalus* et *Zacanthopsis* permettent d'établir des datations considérées, par convention, récentes au sein de la zone, bien au-dessous du sommet de la formation. Des indices de la présence de trilobites encore plus récents dans cette zone du Cambrien inférieur et près du sommet de la formation, semblent indiquer une subsidence continue au Cambrien inférieur, au site de la coupe d'Illtyd à une époque où diverses parties de l'Amérique du Nord et d'autres régions ont commencé à subir un transport sédimentaire sans dépôt et (ou) une érosion. Les nouveaux genres sont *Bonnima* et *Illtydaspis*. Les nouvelles espèces sont *Antagmus ducketti, Bonnia carnata, B. decora, B. quadrata, Bonnima semidiscoidea, Illtydaspis aphylla, I. ornata, I. quartetensis, Olenellus bufrontis, O. parvofrontatus, O. sphaerulosus, Proliostracus ampliatus, Syspacephalus werneckensis, Variopelta brevicervicata* et *Zacanthopsis expansa*.

Summary

The trilobites described in this study are from a 946 m thick stratigraphic section in the Lower Cambrian Illtyd Formation. The formation unconformably overlies Precambrian strata and is overlain by the Middle Cambrian Slats Creek Formation. Clastics and interbedded limestone are dominant in the lower half of the formation, and thinly bedded to massive carbonate dominant in the upper half.

Large carbonate buildups within the studied section reflect the position at the edge of the Richardson Trough, which separated the Illtyd depositional site on the Yukon Block to the west from clastics coming from the Mackenzie Platform to the east. Studies of Illtyd Formation strata from the southeast margin of the Yukon Block, have shown that the Illtyd was probably once lithologically connected with the Lower Cambrian to Middle Ordovician Jones Ridge Formation, now locally preserved at the southwest margin of the Yukon Block. The Illtyd Formation also correlates with all or parts of the following formations at the localities given: Road River Formation, Richardson Trough and Selwyn Basin; Sekwi Formation, Mackenzie Mountains and Selwyn Basin; Gull Lake Formation, Selwyn Basin; Mount Clark and Mount Cap formations, Mackenzie Platform; Gog Group, Kechika Basin; Rosella Formation, Cassiar Mountains; Peyto, Mahto, and Eager formations, Canadian Rocky Mountains; Mural and Dome Creek formations, Cariboo Mountains; Brigham, Pioche, Prospect Mountain, Mule Springs, Harkless, Carrara, Letham, and Chambless formations, United States Great Basin; Buelna and Cerro Prieto formations, Mexico; Police Post Formation, Ellesmere Island; and Wulff River Formation, Greenland.

Trilobites belonging to 14 genera (2 new) and 38 species (15 new) are described. A medial *Bonnia – Olenellus* Zone age near the base of the Illtyd Formation is documented by the index fossil *Salterella* and by trilobites belonging to the genera *Proliostracus, Variopelta*, and *Wanneria*. Well below the top of the Illtyd Formation are genera commonly found near the top of the *Bonnia – Olenellus* Zone elsewhere. These are *Antagmus, Syspacephalus*, and *Zacanthopsis*. Trilobites near the top of the formation have characteristics suggesting a very young part of the zone. These are *Olenellus parvofrontatus, O. sphaerulosus, O. bufrontis, O. romensis*?, and *Bonnima semidiscoidea*. These forms suggest that the Illtyd section may contain some of the youngest Lower Cambrian strata known from within the middle carbonate belt in North America.

Sommaire

Les trilobites décrits dans la présente étude proviennent d'un profil stratigraphique de 946 m d'épaisseur dans le Cambrien inférieur de la formation d'Illtyd. La formation repose en discordance sur des couches précambriennes et est à son tour recouverte par la formation de Slats Creek du Cambrien moyen. Dans la partie inférieure de la formation, les roches dominantes sont les roches clastiques et le calcaire interstratifié et, dans la partie supérieure, ce sont les roches carbonatées de finement stratifiées à massives.

De vastes monticules carbonatés au sein du profil à l'étude correspondent à la position limite de la cuvette de Richardson qui séparait le site sédimentaire Illtyd sur le bloc du Yukon, à l'ouest, des roches clastiques provenant de la plate-forme de Mackenzie, à l'est. Les études des couches de la formation d'Illtyd, à la marge sud-est du bloc du Yukon révèlent que la formation d'Illtyd a probablement déjà été lithologiquement reliée aux couches équivalentes de la formation de Jones Ridge du Cambrien inférieur à l'Ordovicien moyen, qui subsistent par endroits à la marge sud-ouest du bloc du Yukon. La formation d'Illtyd peut également être corrélée à toutes les formations suivantes ou certaines d'entre elles, aux localités indiquées: la formation de Road River, cuvette de Richardson et bassin de Selwyn; la formation de Sekwi, monts Mackenzie et bassin de Selwyn; la formation de Gull Lake, bassin de Selwyn; les formations de Mount Clark et de Mount Cap, plate-forme de Mackenzie, le groupe de Gog, bassin de Kechika; la formation de Tosella,

monts Cassiar; les formations de Peyto, de Mahto et d'Eager, Rocheuses canadiennes; les formations de Mural et de Dome Creek, monts Cariboo; les formations de Brigham, de Pioche, de Prospect Mountain, de Mules Springs, de Harkless, de Carrara, de Letham et de Chambless, bassin Great (États-Unis); les formations de Buelna et de Cerro Prieto, Mexique; la formation de Police Post, île d'Ellesmere; et la formation de Wulff River, Groenland.

Les trilobites appartenant à 14 genres (2 nouveaux) et 38 espèces (15 nouvelles) sont décrits. Un âge intermédiaire pour la zone à *Bonnia – Olenellus* près de la base de la formation d'Illtyd est documenté par le fossile repère *Salterella* et par les trilobites des genres *Proliostracus, Variopelta* et *Wanneria*. Bien au-dessous du sommet de la formation d'Illtyd se trouvent des genres qu'ailleurs on observe généralement près du sommet de la zone à *Bonnia – Olenellus*. Ce sont *Antagmus, Syspacephalus* et *Zacanthopsis*. Les tribolites présents près du sommet de la formation possèdent des caractéristiques indiquant qu'il s'agit d'une partie très récente de la zone. Ce sont *Olenellus parvofrontatus, O. sphaerulosus, O. bufrontis, O. romensis*? et *Bonnima semidiscoidea*. Ces formes amènent à supposer que le profil d'Illtyd pourrait contenir des couches du Cambrien inférieur qui seraient parmi les plus récentes observées dans la zone carbonatée intermédiaire en Amérique du Nord.

INTRODUCTION

In 1973, the writer assisted in Operation Porcupine, a Geological Survey of Canada project implemented for the purpose of mapping the Yukon Territory north of 65 degrees latitude. As requested by D.K. Norris, head of the project, the writer obtained stratigraphic and paleontological data from Cambrian formations that had been, for the most part, mapped. Ten of the best stratigraphic sections were studied and briefly described (Fritz, 1974). One of these sections (op. cit., section 8; Figs. 1, 2; Pl. 1, figs. 1-3) contained the trilobites described in this paper. The fossils are from the Lower Cambrian Illtyd Formation, which occupies the lower half of the section. In this section the Illtyd Formation unconformably overlies Proterozoic strata, and is overlain by the Middle Cambrian Slats Creek Formation, upper Middle and lower Upper Cambrian Taiga Formation, and unnamed Late Cambrian to Devonian formations.

LOCATION AND ACCESS

Work done on the Illtyd section and part of the overlying formations was accomplished from a single camp (Pl. 1, fig. 2) supplied by helicopter from a base located 27 km to the northeast on Margaret Lake. The base camp was supplied by fixed wing aircraft from Mayo, Yukon Territory. Closer lakes, on which fixed-wing aircraft can land, are the Quartet Lakes, located 12 km east of the measure section (Fig. 1). Aircraft transport is presently the only feasible method of access to the section.

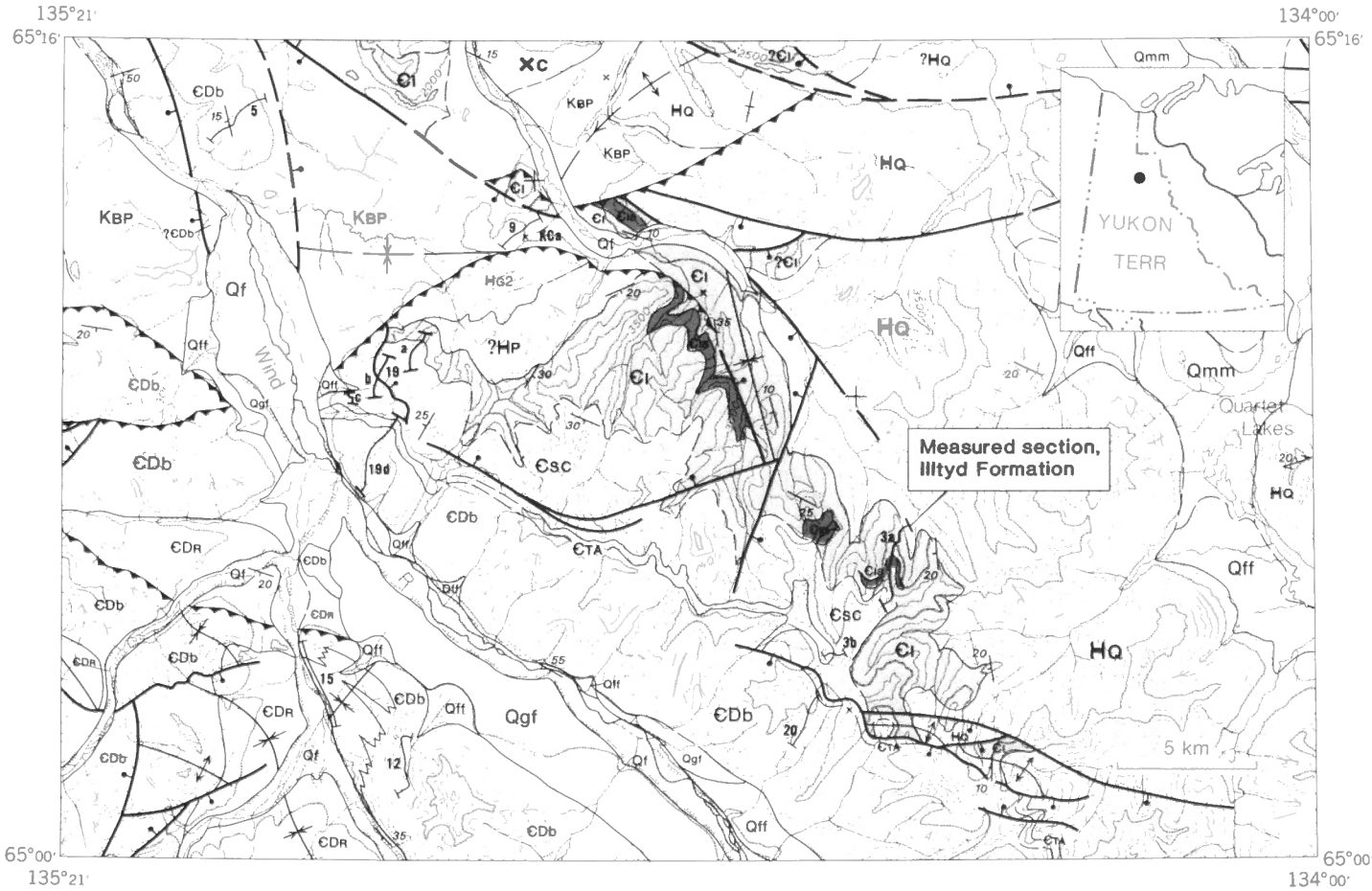


Figure 1. Locality map of Wernecke Mountains, Yukon Territory. Stratigraphic section is located at latitude 65°05'30"N, longitude 134°42'30"W. Details of section are given in Figure 2. Lightly shaded areas in locality map are underlain by Illtyd Formation, and darkly shaded areas by carbonate buildups within the formation. (Map from D.K. Norris, 1982.)

STRATIGRAPHIC SETTING

The upper Lower Cambrian Illtyd Formation unconformably overlies Proterozoic strata on the Yukon Platform (Fig. 2, inset map). The clean white carbonate, which characterizes the upper, resistant part of the formation, is attributed to a depositional setting isolated from Mackenzie Platform clastics by the intervening Richardson Trough (Fritz, in press, a). Large carbonate buildups within the Illtyd Formation at the measured section (Pl. 1, fig. 1) probably reflect deposition at the transition between the Yukon Platform and the adjacent trough. Southeast of the Yukon Platform, where clastics passed from the Mackenzie Platform into the Selwyn Basin without entrapment by an intervening trough, the depletion of clastics is less abrupt, and the occurrence of thick bedded white carbonate is restricted to minor, isolated buildups that are far less conspicuous. There, the typical upper Lower Cambrian strata (upper Sekwi Formation) are composed of thin, nodular bedded limestone (Fritz, 1979).

At the southwestern margin of the Yukon Platform are equivalent strata in one or more east-verging thrust sheets containing Lower Cambrian to Lower Ordovician white limestone in a thick, nearly continuous succession assigned to the Jones Ridge Formation (Fig. 2, inset map). These strata represent the outer margin of the platform and are bordered to the west in Alaska by slope deposits of the same age within the Funnel Creek, Adams Argillite, and Hillard Peak formations (Brabb, 1967; Palmer, 1968). Tracing the white Illtyd and equivalent strata along the remaining western and northern part of the Yukon Platform is impossible because of erosion, cover by younger strata, and complex faulting, which may include large-scale transverse displacement.

At the base of the Illtyd Formation in the measured section is a thin succession of fine grained quartzite believed to represent rapid transgression over the Yukon Platform, which had low relief throughout the earlier part of the Cambrian (Fritz, in press, a). Above the Illtyd Formation are clastics and minor carbonates of the Middle Cambrian Slats Creek Formation, which exhibit striking lateral changes in composition and thickness. Deposition of the Slats Creek is believed to have been strongly influenced by Middle Cambrian block faulting (op. cit.).

STRATIGRAPHY

At the measured section (Fig. 2; Pl. 1, figs. 1-3) the Illtyd Formation is composed of clastic rocks and interbedded limestone in the lower half, and carbonate in the upper half. The formation is 946 m thick and, for ease of description, can be divided into six local units. Although poorly exposed at the site of the section, the base of the formation is located immediately above maroon weathering Proterozoic quartzite. The level of the basal horizon can be closely confined in dry gullies (Pl. 1, fig. 3).

The lowest unit (Unit 1, 76 m) contains sandstone, which is light brown on weathered and fresh surfaces, and some beds that are maroon on both types of surface. The basal 23 m is poorly sorted, resistant, and contains clasts from 1/16 to 4 mm in diameter. The overlying 53 m comprise mainly very fine grained sandstone, which is recessive.

Unit 2 (70.5 m) contains limestone that is thin and wavy bedded with light brown or light orange-brown weathering surfaces. The limestone is finely crystalline or dense, and medium or dark grey on fresh surfaces. Some beds of this limestone are of medium thickness and some bioclastic beds are present in the basal 39 m.

The next unit (Unit 3, 236.5 m) contains light yellowish brown weathering shale, which is medium brown or dark grey on fresh surfaces. Within the basal 65.5 m are some red weathering interbeds. Abundant interbeds of limestone similar to the limestone in Unit 2 are present 65.5 to 185.5 m above the base. Medium brown to orange-brown weathering sandstones in thin and thick interbeds are present in the 185.5 to 236.5 m interval.

Unit 4 (129 m) is composed of light to medium brown weathering limy sandstone to sandy limestone. The uppermost 14.5 m of the unit contains limy grit with quartzite fragments that average 5 mm in diameter. Within the interval 44.5 to 83.5 m above the base is thin blue-grey weathering limestone.

The resistant, light grey carbonate buildups illustrated in Plate 1, figure 1, and on the locality map (Fig. 1), characterize the next unit (Unit 5, 245.5 m). At the site of the measured section, the unit is dominated by a 128.5 m limestone buildup altered to light grey dolostone in thick to massive beds. The large buildup, which occupies the interval 66.5 to 195.0 m above the base, is medium crystalline and medium light grey on fresh surfaces. A few areas within the buildup have not been dolomitized, and these are of dense limestone, which is medium light grey on weathered and fresh surfaces. At the base of Unit 5 are 26 m of thick bedded to massive limestone, which is light to medium grey on fresh and weathered surfaces. The limestone is dense and, except for faint peloids visible on fresh surfaces, is similar to the unaltered limestone in the buildup above. Between the basal subunit and the

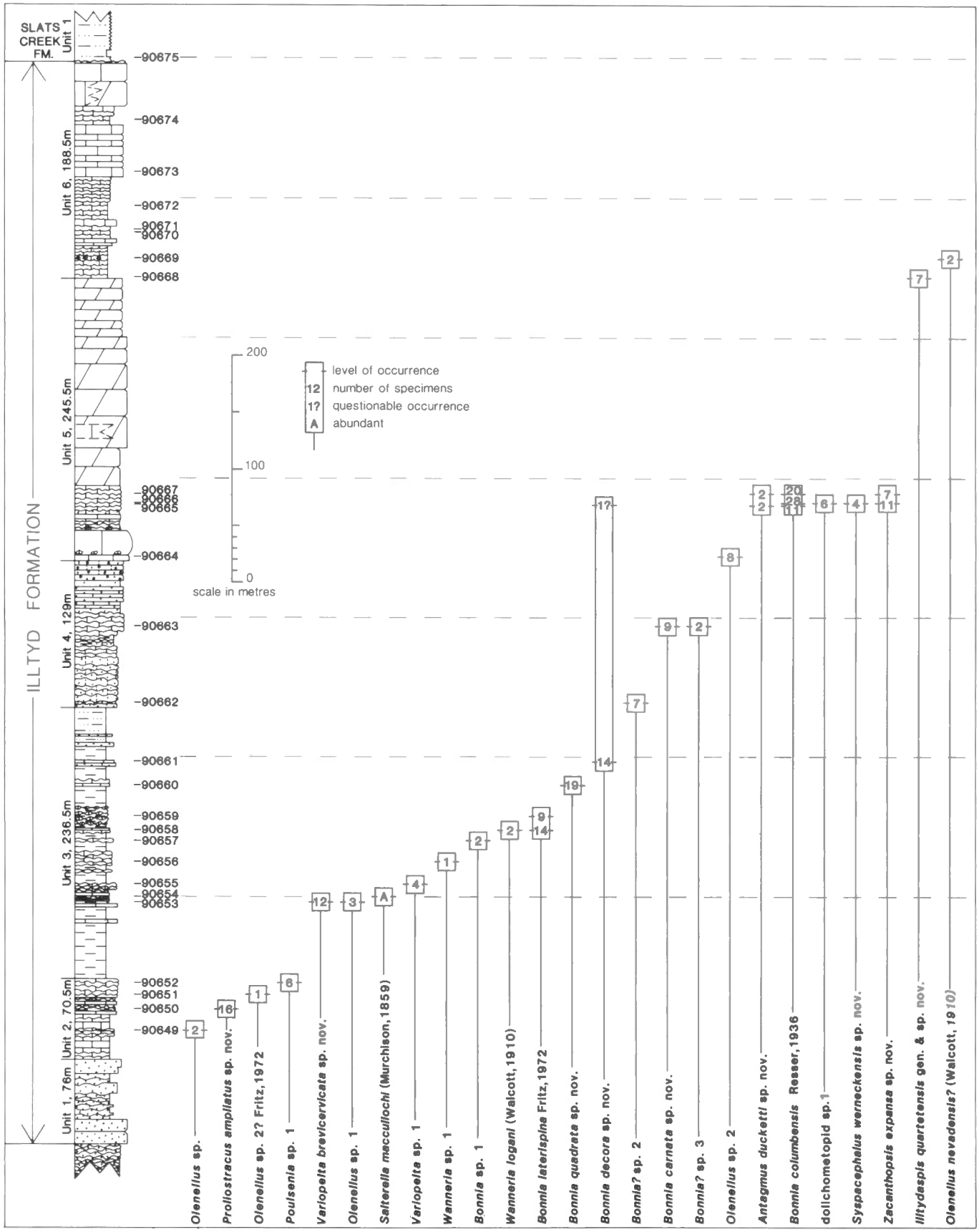
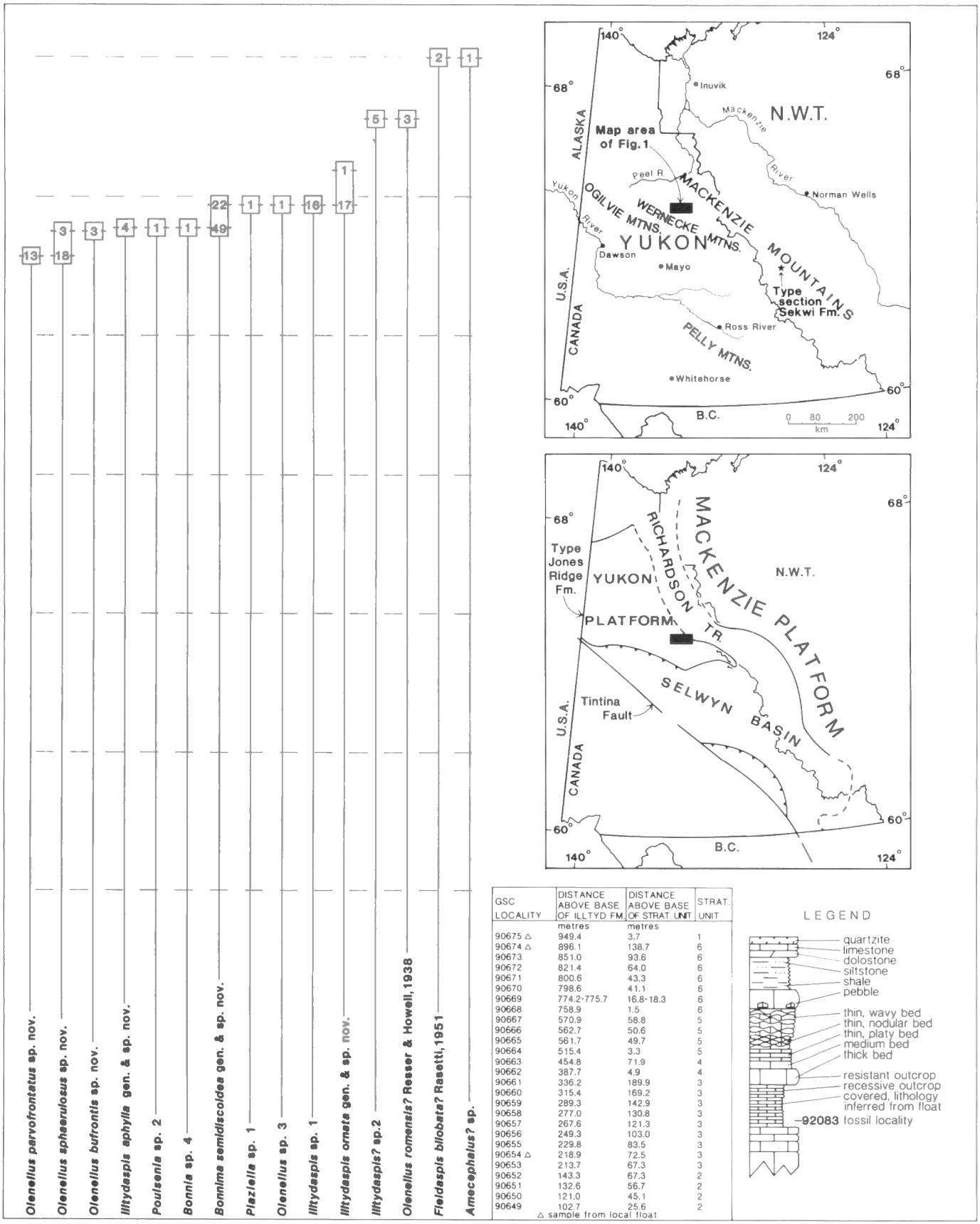


Figure 2. Stratigraphic section for Illtyd Formation, and trilobite range chart. Number of specimens given at each locality represents number of parts (cephala, cranidia, or pygidia) that can definitely be recognized as



GSC LOCALITY	DISTANCE ABOVE BASE OF ILLTYD FM.	DISTANCE ABOVE BASE OF STRAT. UNIT	STRAT. UNIT
	metres	metres	
90675 △	949.4	3.7	1
90674 △	896.1	138.7	6
90673	851.0	93.6	6
90672	821.4	64.0	6
90671	800.6	43.3	6
90670	798.6	41.1	6
90669	774.2-775.7	16.8-18.3	6
90668	758.9	1.5	6
90667	570.9	58.8	5
90666	562.7	50.6	5
90665	561.7	49.7	5
90664	515.4	3.3	5
90663	454.8	71.9	4
90662	387.7	4.9	4
90661	336.2	189.9	3
90660	315.4	169.2	3
90659	289.3	142.9	3
90658	277.0	130.8	3
90657	267.6	121.3	3
90656	249.3	103.0	3
90655	229.8	83.5	3
90654 △	218.9	72.5	3
90653	213.7	67.3	3
90652	143.3	67.3	2
90651	132.6	56.7	2
90650	121.0	45.1	2
90649	102.7	25.6	2

△ sample from local float

belonging to indicated taxon. Also shown is level of ***Salterella maccullochi*** *(Murchison). Views of section area shown in Plate 1 (figs. 1-3). Locality is shown in the two inset maps in this figure, and in Figure 1.*

large buildup (26 to 66.5 m) is limestone in thin to thick, wavy beds, some of which resemble the blue-grey weathering limestone in Unit 4 or the limestone in the 26 m subunit immediately below. Overlying the large buildup (195 to 245.5 m), and extending to the top of Unit 5, is uniformly medium and thick, well bedded dolostone, which weathers bright orange and is light brown on fresh surfaces. This colouration changes laterally in some areas, giving a light grey or cream weathering dolostone with light grey fresh surfaces. Three metres above the base of the subunit is a thin (5 cm) layer of ooids.

Unit 6 (188.5 m) contains mainly recessive, thin and medium bedded limestone in the lower part, and mainly medium and thick bedded, resistant limestone in the upper part. In the lower part (89.5 m) are intervals of medium grey weathering, wavy-bedded, medium dark grey fractured limestone alternating with intervals of medium light grey limestone with irregular parting surfaces. The latter limestone is medium light grey on weathered surfaces and is slightly darker on fresh surfaces. This limestone is fine to coarsely crystalline and granular (fine grained to grit sized limestone clasts). The upper part (99 m) of Unit 6 comprises light to medium light grey limestone similar to that in the basal 40.5 m in Unit 5. Within the lower 44.5 m of the upper part, the light grey, thin to medium beds contain both dense limestone and limestone composed of fine to grit sized limestone fragments. The top 38 m, and the top of the Illtyd Formation, are predominantly composed of thick bedded to massive light grey dense limestone, which locally grades into light grey or cream coloured dolostone. Between the two intervals of light grey limestone are 16.5 m of medium grey, thin bedded limestone which is in part finely crystalline and in part medium grained.

The contact between the light grey resistant limestone at the top of the Illtyd Formation and the overlying 148.5 m of medium grey and maroon weathering basal siltstone of the Slats Creek Formation can be easily recognized at a distance. At the outcrop, one metre of medium grey weathering, dark grey limestone in thin, wavy beds is visible at the top of the Illtyd Formation. This limestone can be assigned to the Illtyd, because of the similar lithotypes below.

BIOSTRATIGRAPHIC CONSIDERATIONS

The trilobites described in this paper belong to the upper half of the *Bonnia – Olenellus* Zone of Rasetti, 1951, which starts with the first occurrence of *Olenellus* and is the same as the *Olenellus* Zone of Lochman (1952) and Palmer (1979). It is generally agreed that the top of this zone is immediately above the highest occurrence of *Olenellus*. The base was indeterminate until Fritz (1972) erected the underlying *Nevadella* Zone, and demonstrated that the *Fallotaspis* Zone of North Africa (Hupé, 1952) lies below the *Nevadella* Zone in North America.

It is now clear that the *Bonnia – Olenellus* Zone is thick and represents a considerable amount of time. However, knowledge of fossil ranges within the zone is not adequate to permit subdivision. At a time when many believed that *Olenellus* ranged throughout the trilobite-bearing portion of the Lower Cambrian, Lochman (1952) proposed an Upper and a Lower *Olenellus* Zone, the Lower being characterized by *Olenellus* exclusive of ptychoparioids, and the Upper by the coexistence of both types of trilobites. As discussed below, there is some merit in Lochman's concept when applied to the *Bonnia – Olenellus* Zone as presently understood, but this concept has not been rigorously pursued by others.

Wheeler (1947, 1958, p. 21) also once believed that *Olenellus* ranged throughout the whole of the Early Cambrian and by emphasizing this genus implied, without clearly stating his case, that the evolution of *Olenellus* would aid in establishing biostratigraphic levels within its range. Since then there have been few attempts to plot the ranges of various species of *Olenellus* within the *Bonnia – Olenellus* Zone, and these species have not been used to define more than local subzonal units.

Having reviewed *Olenellus* in a large number of Lower Cambrian collections, the writer is of the impression that the genus is restricted to the *Bonnia – Olenellus* Zone and that it may eventually play an important, but not exclusive, role in subdividing the zone. In collections viewed so far, the intergenal spines of older *Olenellus* species are closer to the axis than those of younger species, but there are exceptions to this general trend. Those with a large spherical anterior lobe, such as in *Olenellus sphaerulosus* sp. nov. (Pl. 10, figs. 1-13), and species that combine large, strongly bowed eye lobes, low axes, and relatively small anterior glabellar lobes, such as *Olenellus parvofrontatus* sp. nov. (Pl. 11, figs. 1-11), seem to be restricted to the upper part of the *Bonnia – Olenellus* Zone.

The presence of the genus *Bonnia* may also contribute significantly in subdividing the zone. This genus has not been reported from the lower part of the zone. Species with pygidia bearing more than one pair of spines appear in the middle of the zone, and those with one pair of spines are common in the upper part.

Abundant, small, relatively smooth, ptychoparioid trilobites appear near the top of the zone. Rigorous attempts to organize these trilobites into recognizable genera (Lochman, 1947; Rasetti, 1951, 1955; Palmer, 1958; Shaw, 1962) have met with mixed results. In hindsight it now seems likely that these trilobites are nearly all restricted to a relatively high biostratigraphic interval within the Lower Cambrian, which may explain their limited number of distinguishing (evolutionary) features. Therefore, an abundance of small ptychoparioid trilobites, even though of questionable assignment, could be an indication of a high position within the *Bonnia–Olenellus* Zone.

It has been recently proposed (Fritz and Yochelson, 1988) that *Salterella*, a small cone-shaped fossil, be considered as a guide to the medial part of the *Bonnia–Olenellus* Zone. If this proposal proves workable, this genus can be used to define a biostratigraphic interval that should be useful in testing many reported trilobite ranges within the *Bonnia–Olenellus* Zone. In the Illtyd section *Salterella* is present near the base of the Illtyd Formation (Fig. 2). Photographs documenting this presence are shown in Plate 1 (Figs. 4-6).

LOWER-MIDDLE CAMBRIAN BOUNDARY AND TOP OF THE ILLTYD FORMATION

As mentioned above, the lithological contact between the top of the Lower Cambrian Illtyd Formation and the overlying Middle Cambrian Slats Creek Formation is relatively sharp. The highest Illtyd fossils are *Olenellus romensis* Resser and Howell and *Illtydaspis*? sp. 2 in local float 49.5 m below the contact, and the lowest Slats Creek fossils are *Amecephalus*? sp. and *Fieldaspis bilobata*? Rasetti in local float 3.7 m above. There is no evidence that strata are missing between the two formations because the lowest Slats Creek fossils indicate the lowest zone recorded in the Middle Cambrian, the *Plagiura–Poliella* Zone (Lochman-Balk and Wilson, 1958). However, a widespread unconformity between Lower and Middle Cambrian strata has been recorded at various locations in North America and elsewhere. Moreover, a Lower–Middle Cambrian unconformity cannot be ruled out even below the best known development of the *Plagiura–Poliella* Zone in British Columbia (Rasetti, 1951).

Biostratigraphic evidence of the presence or absence of a disconformity at the Lower–Middle Cambrian boundary in the Illtyd section is best approached by examining the degree of similarity between the Illtyd trilobites and those of the same age described from the type section of the Sekwi Formation (Fritz, 1972), located 310 km to the southeast. There, the upper part of the Sekwi Formation, from *Salterella* to a disconformity at the top of the Sekwi, contains only three species in common with the Illtyd section. These are *Bonnia columbensis* Resser, *Bonnia laterispina* Fritz, and *Wanneria logani* (Walcott). Within the same interval, and at the generic level, the trilobites in common are *Olenellus, Proliostracus, Variopelta, Poulsenia, Wanneria, Bonnia, Zacanthopsis, Antagmus,* and *Syspacephalus*. These genera, listed in order of first (lowest) occurrence in the Sekwi section, appear in approximately the same order in the Illtyd section—strong evidence that the enclosing strata at both sections are coeval.

The weaker than expected species agreement between the two sections cannot presently be explained. If the correlation between the Illtyd and upper part of the Sekwi Formation is correct, a semirestrictive barrier between the Selwyn Basin and the Richardson Trough might be an explanation. However, if free circulation could be proven, it might be argued that the difference in species is a response to a slightly different environment. The latter explanation, together with the limited work accomplished so far on trilobites of this age in the northern Cordillera, suggests that this region contains a high number of undescribed species.

A third explanation bears more directly upon the Lower–Middle Cambrian boundary problem. It is based on the assumption that the correlation between the two sections is basically correct, but that the fit is not as close as expected because Lower Cambrian strata are missing at the top of the *Bonnia–Olenellus* Zone in the Sekwi section. In this interpretation, erosion at the known disconformity at the top of the Sekwi (Fritz, 1972, p. 3) is considered to have removed the upper part of the *Bonnia–Olenellus* Zone, explaining the absence there of the new genera *Bonnima* and *Illtydaspis* (four species), described in this paper from the top of the zone in the Illtyd section. It might also explain why *Olenellus romensis*? Resser and Howell, known from Virginia and near the top of the Illtyd Formation, is missing at the top of the Sekwi Formation. If this is indeed the case, the Illtyd Formation may contain some of the youngest Lower Cambrian strata known in the *Bonnia–Olenellus* Zone within the Middle Carbonate Belt in the North American Cordillera. This would imply narrowing of the suspected biostratigraphic gap between the Lower and Middle Cambrian if the new Lower Cambrian biostratigraphy from the Illtyd section were added. The meagre Middle Cambrian fauna in the overlying Slats Creek Formation provides little new evidence of the Middle Cambrian narrowing or widening of the gap beyond that described by Rasetti (1951) in Alberta and British Columbia.

CORRELATION

North of the Yukon Block, in the British – Barn Basin (Fritz, in press, a), the Lower Cambrian trace fossil *Oldhamia* has been reported from unnamed strata in the Barn Mountains (Cecile, 1988) and in similar strata 80 km to the northwest (Lane and Cecile, 1989). This find, together with a report of the upper Lower Cambrian fossils in nearby Alaska (Dutro et al., 1972, p. 813), suggests Illtyd equivalent strata occur in the area. Strata of this age at the southwest margin of the Yukon Platform are probably present in an apparently barren interval within the Jones Ridge Formation (Palmer, 1968). Equivalent strata are present immediately to the west in the lower Hillard Formation and probably in at least part of the underlying Adams Argillite (op. cit.).

To the east of the Yukon Block, in the Richardson Trough, and to the south in the eastern Selwyn Basin, the Road River Group shares a diachronous boundary with the top of the Illtyd and Sekwi formations (Fritz, 1985). In these areas the oldest part of the lower Road River is equivalent to the Illtyd Formation. In what was a deeper part of Selwyn Basin, Illtyd equivalent strata are probably present in the upper part of the Gull Lake Formation (Gordey, in press). Farther east, over the western Mackenzie Platform, equivalent strata are present in the Mount Cap and Mount Clark formations (Aitken et al., 1973).

Along the eastern margin of Kechika Basin, equivalent strata are present in the upper Gog Group and in an unnamed dark brown siltstone unit (Fritz, in press, b). Farther south, in the Robson Trough, equivalent strata occur in the Mahto and Peyto formations of the Gog Group and in the Eager Formation.

West of the Rocky Mountain Trench-Tintina Trench lineament, strata equivalent to the Illtyd Formation have been eroded locally, and are overlain by Upper Cambrian strata in the Pelly Mountains (Read, 1980). In the Cassiar Mountains, the Illtyd Formation equivalent strata form Unit 6 of the Rosella Formation and an unknown overlying thickness within that formation (Fritz, 1978). At the north end of the Columbia Basin, in the Cariboo Mountains, strata of this age are found in the uppermost Mural Formation and the overlying basal dark shale of the Dome Creek Formation (Campbell et al., 1973). At the eastern edge of the Columbia Basin, in the Dogtooth Range, these strata form part of the Donald Formation (Evans, 1933).

In the U.S. Cordillera, strata equivalent to the Illtyd Formation occur in part of the Brigham Formation of Idaho and Utah (Oriel and Armstrong, 1971) and in the upper Prospect Mountain Quartzite and Pioche (lower part) formations of Utah and Nevada (Palmer, 1964b; Fritz, 1968; Robison and Hintze, 1972). In Nevada and southern California, strata of that age are present in the Harkless, Mule Spring, and lower Carrara formations and in the Latham and Chambless formations (Mount, 1974; Nelson, 1978; Palmer, 1979). Coeval strata in northern Mexico are the Buelna and Cerro Prieto formations (Lochman, 1952).

On Ellesmere Island, in the Police Post Formation at Bache Peninsula, two species, *Bonniopsis* sp. Cowie, 1968 and *Olenellus turmalis* (Cowie, 1968) closely resemble, but are not identical to, the upper Illtyd species *Bonnima semidiscoidea* gen. et sp. nov. and *Olenellus parvofrontatus* sp. nov., respectively (see discussion of *B. semidiscoidea* and *O. parvofrontatus* in the Systematic Paleontology section). The Police Post Formation, which is only 3 m thick at its type section (Christie, 1967, p. 29), is overlain by the Cape Kent Formation, which is not locally fossiliferous but has been correlated with the Middle and (?)Lower Cambrian Cape Kent in Northwest Greenland (Norford, 1968, p. 33). The similarity between the species mentioned suggests that the Police Post Formation be placed in the upper part of the *Bonnia–Olenellus* Zone.

The Police Post Formation has also been correlated with the Wulff River Formation or older strata of northwest Greenland (Poulsen, 1946; Cowie, 1961). This is inconsistent with the biostratigraphic data in the present paper and that from the Sekwi Formation to the south (Fritz, 1972). The Wulff River Formation contains *Salterella* and numerous species of *Wanneria*, and can therefore be correlated with the lower part of the Illtyd Formation, which can be assigned to the medial part of the *Bonnia-Olenellus* Zone.

Recent work by Russian scientists on Lower Cambrian fossils from the Sekwi Formation, Mackenzie Mountains (Voronova et al., 1987) has refined North American – Siberian correlations. Using correlations by these scientists, the Illtyd Formation at the type section can be correlated with at least part of the Russian Toyonian Stage.

ACKNOWLEDGMENTS

D.K. Norris provided the writer with field support, guidance to sections, and the loan of his field assistant, M.J. Duckett. F.J. Collier of the Smithsonian Institution arranged for study space and access to comparative fossil material in the United States Museum of Natural History. The fossils were cleaned and photographed by

H.M. McLaughlin, who also constructed the photographic plates and some of the figures used in this paper. The writer extends his grateful appreciation to each of the mentioned individuals for their contributions toward completion of this paper.

SYSTEMATIC PALEONTOLOGY

Introduction

Most of the terminology in the following descriptions is that given in "Part O" of the "Treatise on Invertebrate Paleontology" (Moore, 1959). This terminology is best suited for the description of trilobites flattened in shale, whereas those described in the present paper are relatively undistorted in a limestone matrix. Trilobites in shale may have their entire outlines preserved, and delicate, protruding parts may remain intact. The trilobites described in the present paper are from a shallow water depositional environment in which exoskeletons were typically disarticulated, parts abraded, and delicate projections either damaged or removed. To facilitate a better description of the material at hand, a few modifications and additions have been made to the nomenclature from the Treatise. The palpebral lobe (usually broken) is excluded from the palpebral area, and the area's width is measured from the axial furrow to the palpebral furrow. Lengths given for the cephalon, cranidium, and pygidium are sagittal lengths that exclude occipital and border spines. The term "crestline" is added to denote the uppermost surface on the cephalon or cranidium and pygidium, and the occipital ring is excluded from the glabella. An effort has been made to include frequent side and end views in order to illustrate the preservation of relief.

Figures 3 and 4 illustrate the terms most frequently applied to cranidia and cephala. Unless indicated otherwise, descriptions are of parts that have the outer surface of the test preserved. All of the trilobites figured in this publication are stored in the National Type Fossil Collection at the Geological Survey of Canada in Ottawa.

Family OLENELLIDAE Vogdes, 1893

Discussion. Ahlberg et al. (1986) summarized some of the changes made in the interpretation of the family Olenellidae. The writer is in general agreement with their classification but some changes, such as the removal of *Wanneria* from the Olenellidae and the formation of the family Wanneriidae, need documentation before they can be fully accepted. Ahlberg et al. (1986) and Repina (1979)

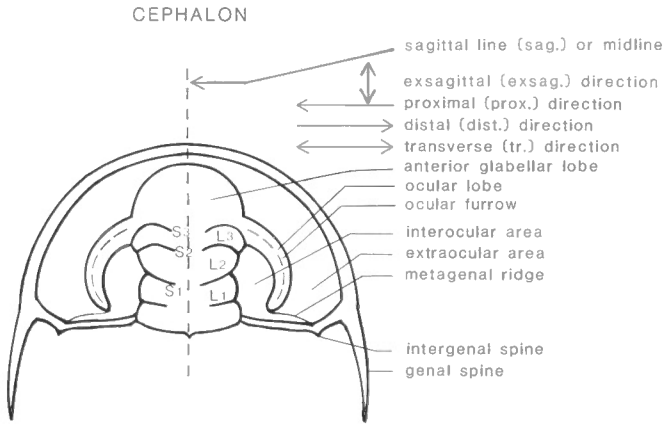


Figure 3. Illustration of some commonly used terms for olenellid cephalic parts. See Moore (1959) for additional terms.

have speculated on the distribution of genera within Olenellidae but problems of provenance, relative age, and incomplete material continue to plague these attempts. Data in the present paper add little to that already known.

Genus *Olenellus* Billings, 1861

Olenellus Billings, 1861, p. 11; Walcott, 1910, p. 311 (synonymy to date); Resser, 1928, p. 3; Bell, 1931, p. 1-22; Poulsen, 1932, p. 35; 1959, p. O192; Resser and Howell, 1938, p. 217; Lake, 1937, p. 236; Stormer, 1939, p. 242; Shimer and Shrock, 1944, p. 613; Kindle and Tasch, 1948, p. 135; Riccio, 1952, p. 29, 33; Hupé, 1953, p. 73; Shaw, 1955, p. 790; Raw, 1957, p. 149; Pokrovskaya, 1959, p. 157; Suvorova, 1960, p. 62; Fritz, 1972, p. 11; Robison and Hintze, 1972, p. 5; Bergström, 1973, p. 313; Palmer, 1979, p. 66; Repina, 1979, p. 22; Ahlberg, Bergström, and Johansson, 1986, p. 40.

Fremontia Raw, 1936, p. 243; Harrington, 1956, p. 57; Poulsen, 1959, p. O192.

Mesonacis Walcott, 1885, p. 328; 1910, p. 261 (synonymy to date); Resser, 1928, p. 5; Bell, 1931, p. 1-22; Kobayashi, 1935, p. 117.

Paedeumias Walcott, 1910, p. 304; Burling, 1916, p. 55-57; Raw, 1927, p. 137; 1936, p. 242; Raymond, 1928a, p. 169; Resser, 1928, p. 4; Bell, 1931, p. 1-22; Poulsen, 1932, p. 36; 1959, p. O192; Resser and Howell, 1938, p. 225; Shimer and Shrock, 1944, p. 615; Lermontova, 1951, p. 46; Riccio, 1952, p. 30; Best, 1952, p. 15; Palmer, 1957, p. 124, 126; Suvorova, 1960, p. 62; Öpik, 1961, p. 419; Cowie, 1968, p. 13.

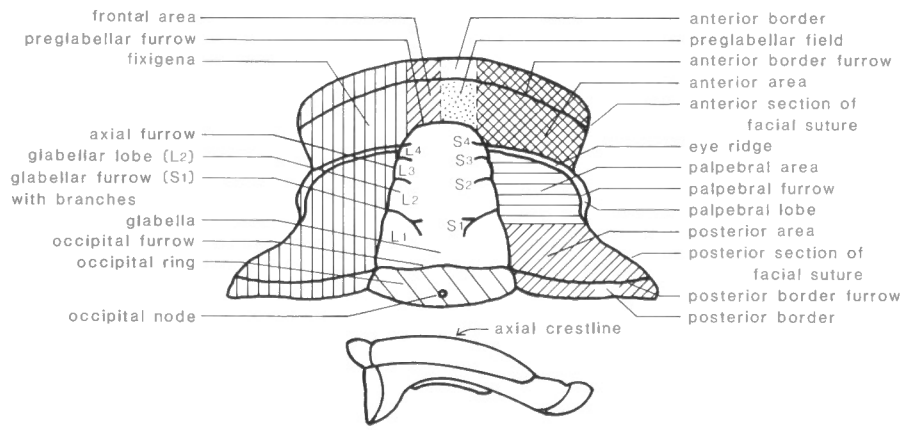


Figure 4. *Illustration of some commonly used terms for ptychoparioid cranidial parts. See Moore (1959) for additional terms.*

Type species. Olenellus thompsoni Hall, 1858.

Discussion. The generic description provided by Fritz (1972) is followed in this publication. Some of the generic characteristics, which seem to have evolved with time, are given above under "Biostratigraphic considerations".

Olenellus bufrontis sp. nov.

Plate 12, figures 6-8

Material. Three cephala 5 to 9 mm long (excluding spines), from GSC locality 90670. Holotype, GSC 91851, GSC locality 90670.

Etymology. Latin, *bu*, large; *frontis*, fore-part, referring to the large size of the anterior glabellar lobe relative to the remaining glabella.

Description. Cephalon strongly curved along front margin, relief high for genus. In side view, crestline nearly horizontal between occipital ring and anterior glabellar lobe, curved evenly forward and upward on lobe to posterior one-third point, curved evenly downward to two-thirds point, then broadly curved and steeply inclined to anterior border furrow. Anterior glabellar lobe circular in plan view, length on medium-small (6.5 mm) and medium (9 mm) cephala is equal to combined length of remaining glabella and occipital ring, width is nearly twice that of minimum width of glabella. Glabellar furrows deep distally, shallowing and broadening to join across axial midline. Posterior pair (S1) steeply inclined backward, second pair (S2) transverse, anterior pair (S3) inclined slightly backward. Occipital ring tilted forward, bearing raised spine? (broken) on posterior margin. Distal portions of occipital furrow deep and inclined slightly backward, medial portion wide and shallow. Interocular area slightly convex, tilted inward. Ocular lobes marked by well defined ocular furrow, broadly curved out and backward along anterior half, strongly curved along posterior half, terminating opposite anterior one-third point on lateral margin of occipital ring. Extraocular area convex (tr.), outer margin slopes steeply downward to border furrow. Anterior border furrow touches but is not offset by anterior glabellar lobe, width and depth of anterior and lateral border furrows uniformly narrow and deep on normal cephala, moderately wide and deep on exfoliated cephala. Anterior and lateral border rounded in cross-section, average slope is horizontal at front of cephalon, sloping outward at sides, width uniform and only slightly expanded near genal angle. Posterior border narrow proximally, expanding (exsag.) gradually in outward direction and inclined slightly backward. Inner edge of large intergenal spine is at seven-tenths point on border, remaining border beyond intergenal spine narrower than that immediately inward from spine, and directed sightly forward. Intergenal spine directed outward and backward; genal spine half as long(?) (broken) as cephalon at axial midline, inclined slightly outward. Ornamentation consists of granules covering cephalon, weak radial venation on extraocular area; on exfoliated cephalon venation on extraocular area is strong; single row of small nodes present in anterior and lateral border furrows.

Remarks. Cephalon of this species resembles that of *Olenellus* sp. 3, but the latter cephalon exhibits enough difference despite its small size to tentatively exclude it

from *O. bufrontis*. On *O.* sp 3 the glabella is lower throughout, the ocular lobes are proportionately larger, more uniformly curved, and they originate farther back on an anterior glabellar lobe that is less circular in plan view. The anterior and lateral border is flatter and inclined inward throughout.

Olenellus nevadensis? (Walcott, 1910)

Plate 12, figures 3-5

1884 *Olenellus gilberti* Walcott (part); p. 29, Pl. 9, fig. 16.

1886 *Olenellus gilberti* Walcott; Walcott (part), p. 170, Pl. 19, fig. 2g.

1890 *Olenellus gilberti* Walcott; Walcott (part), p. 636, Pl. 85, fig. 1e.

1910 *Callavia*? *nevadensis* Walcott, p. 285, Pl. 38, fig. 12.

1928 *Paedeumias nevadensis* (Walcott); Resser, p. 9, Pl. 3, figs. 3-7.

1952 *Paedeumias nevadensis* (Walcott); Riccio, p. 33, Pl. 9, figs. 5, 6.

1979 *Olenellus nevadensis* (Walcott); Palmer, p. 73, Pl. 4, figs. 10, 13, 17.

Material. Two incomplete cephala, each with a projected length of 12 mm, both from GSC locality 90669.

Discussion. Palmer (1979) has given a lengthy description of *Olenellus nevadensis*, much of which is applicable to the two Illtyd cephala. Palmer's material and the types for *O. nevadensis* differ from the Illtyd specimens as follows: 1) anterior margin of cephalon more strongly curved, 2) anterior and lateral border furrow better defined due to abrupt break in slope between border and extraocular area, 3) preglabellar field longer (sag.), 4) glabellar furrows deeper, 5) ocular lobes shorter and unmarked by faint central ridge, and 6) venation stronger on extraocular area. With only the small amount of Illtyd material available, it is not possible to assess these differences against those that might otherwise be attributed to preservation or interspecific variation. *Olenellus borealis* (Poulsen, 1946) from Ellesmere Island resembles *O. nevadensis*, but is represented only by a partial glabella with attached ocular lobes. The axis of *O. borealis* appears to be wider at the level of the posterior pair of glabellar lobes (L1), but more than the existing cephalic fragment representing *O. borealis* is needed for a valid comparison. *Olenellus groenlandicus* (Poulsen, 1958) from northwestern Greenland resembles *O. nevadensis*, but its posterior cephalic border extends obliquely back.

Olenellus parvofrontatus sp. nov.

Plate 11, figures 1-11; Plate 12, figures 1, 2

Material. Thirteen cephala and two partial thoraxes, from GSC locality 90669. Holotype, GSC 91842, GSC locality 90669.

Etymology. Latin, *frons*, forehead; *parvus*, small, referring to the small anterior glabellar lobe.

Description. Outline of cephalon is uniformly curved half-circle, length to width ratio of large cephala approximately 11:25. In front view cephalon low except for prominently raised ocular lobes. In side view crestline slopes gently forward from occipital ring to posterior third of anterior lobe, anterior two thirds of lobe curves moderately downward to preglabellar field that is two thirds as long (sag.) as anterior border. Anterior glabellar lobe short (sag.), broadly curved at front, turning strongly backward at anterolateral margin to give anterior third "squared" outline. Anterior glabellar furrow (S3) curved and inclined steeply backward; medial pair (S2) slightly inclined; both pairs slit-like, each faintly joined by broad, shallow depression across axial midline and similarly connected to lateral glabellar margin by faint depression. Posterior glabellar furrows (S1) and occipital furrow of equal, medium depth, posterior furrows exhibit slight curvature and are inclined backward slightly more steeply than distal segments of occipital furrow. Posterior margin of occipital ring nearly transverse, marked by small spine. Ocular lobes directed strongly outward, very wide, marked by shallow ocular furrow, terminating opposite anterior one third of occipital ring; imaginary, straight, transverse line resting across highest point on eye lobes would be elevated above highest point on glabella. Interocular area low, tilted inward; extraocular area broadly curved, inclined outward. Anterior and lateral borders of medium width, moderately curved in cross-section, tilted inward at front of cephalon, outward at sides, extending into narrow genal spines approximately two fifths as long as cephalon at axial midline. Posterior border directed outward and slightly backward along four fifths of length to short, blunt intergenal spine, then slightly forward over remaining length. Posterior border furrow shallow throughout. Cephalon including glabella, ocular lobes, and border covered with faint fingerprint pattern. Exfoliated

extraocular field displays weak radial venation. Very faint preglabellar ridge visible on some cephala.

Thorax bears anterior pleurae of medium size, second and third pairs largest, third pair macropleural with wide (exsag.) anterior border (especially at abrupt curvature near distal end), fourth and remaining pairs are progressively smaller. Axial rings each marked by small spine on posterior margin similar to that on occipital ring.

Remarks. Olenellus turmalis (Cowie), 1968, which bears a striking resemblance to the present material, is known from one partial cephalon preserved as an internal mould in limestone from the Police Post Formation, Ellesmere Island. That specimen resembles those in the Illtyd material, except for eye lobes that do not rise above the level of the glabella, ocular furrows that are much deeper, and slightly longer (sag.), broadly pointed and much higher anterior glabellar lobe. *Olenellus* sp. 1 Palmer, 1979 resembles the present material but has a longer anterior glabellar lobe, wider (tr.) extraocular field, and granular ornamentation. *Olenellus puertoblancoensis* (Lochman, 1952), and *Olenellus* sp. 5 Fritz, 1972 differ from the Illtyd material in having a longer anterior glabellar lobe with a strongly curved front margin, lower, narrower (tr.) ocular lobes, and a less inflated anterior pair (L3) of glabellar lobes. An unnamed species, which Palmer (1957, Pl. 19, figs. 16, 19) assigned to *Olenellus gilberti* Meek, 1874, resembles *Olenellus parvofrontatus*, but has a slightly longer cephalon, larger anterior glabellar lobe rounded in front, no preglabellar ridge, longer eye lobes, and intergenal spines located in a more distal position.

Olenellus romensis? Resser and Howell, 1938

Plate 17, figures 11-14

1938 *Olenellus romensis* Resser and Howell; p. 221, Pl. 7, figs. 4-6; Pl. 12, figs. 2, 3.

1938 *Olenellus romensis* Resser and Howell; Resser, p. 52, Pl. 5, fig. 12.

Material. Three cephala 5 to 7 mm long, three cheeks and two partial hypostomes, from GSC locality 90674.

Description. Cranidium broadly curved along front margin, estimated length to width ratio is 1:2. Axial crestline between occipital ring and two-sevenths point on anterior lobe averages almost horizontal, then curves steeply downward to front of lobe. In plan view, axial furrows gradually converge forward along occipital ring and first pair of glabellar lobes (L1), then diverge rapidly along second, triangular-shaped pair (L2), attaining maximum furrow separation at third pair (L3); maximum axial width of third pair same as maximum width of anterior lobe. Anterior lobe strongly curved in front, terminating just short of anterior border. Occipital and glabellar furrows deep, broadening and shallowing inward and crossing axial midline. Posterior glabellar furrows (S1) straight and inclined moderately backward; second pair (S2) broadly curved, average inclination is slightly backward; third pair (S3) inclined slightly less backward than posterior pair. Anterior and lateral borders broadly curved in cross-section, maintaining nearly uniform width, average inclination horizontal; adjacent furrow narrow, shallow, undergoing abrupt change in slope at contact between border furrow and border. Ocular lobe narrow (tr.), marked by shallow ocular furrow, extending backward to level that is just posterior to ends of occipital furrow. Interocular area convex, sloped inward. Posterior border inclined slightly backward, broadening gradually in distal direction to three-fifths point, then becoming narrow and inclined moderately forward along next fifth to small intergenal spine, continuing in that direction and maintaining uniform width for final one fifth to genal spine. Genal spine thin, maintaining course set by lateral border for considerable distance before curvature increases in a slightly inward direction, length (broken) at least five ninths that of cephalon at axial midline. Ornamentation consists of metagenal ridge that closely parallels posterior border before meeting border at an angle, and terminating as part of intergenal spine. Radial venation on extraocular areas visible on both external surface and internal moulds. Fine granules cover cephalon and increase to medium size near axial crestline. Small but strongly raised, elongate node present near posterior margin of occipital ring.

Remarks. The Illtyd specimens agree closely with type material of *O. romensis* from the Rome Formation, Virginia. The latter material is somewhat distorted in shale, but is abundant and exhibits various details, such as the metagenal ridge terminating at the intergenal spine (see Resser and Howell, 1938, Pl. 12, fig. 2). *Olenellus romensis* topotype material exhibits ocular lobes consistently slightly shorter than those on the questionably assigned Illtyd material. *Olenellus romensis* can be distinguished from *Olenellus gilberti* Meek, 1874 and *Olenellus clarki* (Resser, 1928) by its broadly curved anterior border, shorter anterior glabellar lobe, deeper glabellar furrows, and hourglass shaped glabella. The assignment of the present specimens is questionable due to the meagre amount of Illtyd material available.

Olenellus sphaerulosus sp. nov.

Plate 10, figures 1-13

Material. Eighteen cephala from GSC locality 90669, and three cephala from GSC locality 90670. Holotype, GSC 91835, GSC locality 90669.

Etymology. Latin, *sphaerula*, ball, referring to the sphere-like appearance of the anterior glabellar lobe.

Description. Cephalon approximately twice as wide as long, convex, in plan view outline is a half-circle. Anterior glabellar lobe nearly round in plan view; crestline on lobe attains greatest height opposite level of attachment for ocular lobes, then curves abruptly forward, dipping steeply to anterior border furrow. Anterior pair of glabellar furrows (S3) uniformly deep, curved back and joining across axial midline without appreciable shallowing. Medial pair (S2) shallow distally, inclined slightly backward, of moderate depth near midlength, and shallowing at connection across axial midline. Posterior pair (S1) and distal segments of occipital furrow angling backward, shallowing where joined across axial midline; posterior pair angled backward more strongly than distal segments of occipital furrow. Occipital ring and posterior two pairs of glabellar lobes (L1, L2) are approximately equal in length (exsag.), anterior lobes (L3) much shorter. Occipital ring rises near posterior margin to form small occipital spine (broken). Ocular lobes on small specimens terminate behind level of occipital furrow, lobes on large specimens terminate farther forward. Ocular furrow present on at least anterior part of lobe. Interocular area strongly swollen, maximum width equivalent to adjacent width of ocular lobe. Extraocular area convex on smaller specimens, steepest near border furrow. Anterior and anterolateral border furrow narrow, of medium depth, displaced slightly forward and downward in front of anterior glabellar lobe; on exfoliated cephala, outer edge of furrow marked by single row of granules. Lateral border furrow shallows near genal angle and there furrow granules are absent. Posterior border furrow on exfoliated cephala shallow and of medium width along proximal four sevenths, broader and deeper along distal three sevenths. Shallow but distinct groove in metagenal position closely approaches posterior border furrow at steep angle, then turns to remain near furrow until merging with furrow at approximately four-sevenths point on posterior border furrow. Distal segment of border furrow shallows and passes between intergenal and genal spines to terminate at outer edge of cephalon. Anterior and lateral border rounded in cross-section, of uniform width except for widening near genal angle. Intergenal spine short and blunt. Small cusp on posterior margin of cepahon occupies distance between intergenal and genal spines. Posterior border transverse on most large cephala, inclined slightly backward on medium and small cephala, terminating in intergenal spine. Genal spine longer than cephalon at axial midline, broadly curved, directed slightly outward at base and slightly inward near terminal end. Outer surface of cephalon covered with medium sized granules, extraocular area on normal and exfoliated specimens marked by closely spaced pattern of radial venation.

Remarks. Olenellus altifrons Fritz, 1972 and a similar species, *Olenellus euryparia* Palmer, 1979, resemble *Olenellus sphaerulosus* sp. nov. Both species differ in having a proportionally larger anterior glabellar lobe that rises forward at a more gradual rate from the anterior pair of glabellar furrows (S3), and therefore attains its greatest elevation in a more forward position. The anterior glabellar furrows are much shallower on *O. altifrons* and *O. euryparia*, the anterior glabellar lobes much longer, the glabella markedly more constricted (tr.) at the level of the posterior pair of glabellar furrows (S1), and the ocular lobes are shorter. *Holmia*? *argentus* (Walcott, 1910) from Esmeralda County, Nevada, has a proportionally even larger anterior glabellar lobe than *O. altifrons* and *O. euryparia*, and its *Holmia*-like features, such as narrower extraocular areas, thicker border and prominent, proximally located intergenal spines readily distinguish it from *O. sphaerulosus*. *Olenellus hermani* Kindle and Tasch, 1948 from Vermont is another species with a large anterior glabellar lobe. On that species the lobe is proportionally larger and bears a spine near its rear margin; the ocular lobes are narrower and shorter, and the glabella is more constricted at the medial (S2) and posterior (S1) glabellar furrows.

Olenellus sp. 2? Fritz, 1972

Plate 2, figure 9

1972 *Olenellus* sp. 2, Fritz, p. 17, Pl. 13, figs. 6-18.

Material. One incomplete cephalon 4.2 mm long, from GSC locality 90651.

Description. Cephalon approximately one and a half times as wide as long, front margin strongly curved for olenellid. Border of uniform width, flat, tilted inward at front of cephalon, horizontal at sides, slightly widened near genal angle. Proximal four sevenths of posterior border directed slightly downward and backward, offset at intergenal spine, remaining border inclined slightly

forward. Glabella front bullet-shaped, immediately preceded by low preglabellar ridge, which is distinct along posterior quarter, remainder barely visible. Ocular lobes uniformly curved at outer margin, extending backward almost to posterior border. Extraocular area marked by radial venation. Small granules present on extraocular field near genal angle, on border, and on genal spine.

Remarks. This specimen closely resembles *Olenellus* sp. 2 Fritz, 1972, but differs in having a proportionally narrower cephalon, a weaker preglabellar ridge, intergenal spines located in a more proximal position, no metagenal ridge, and genal spines that narrow less rapidly and continue the border curvature rather than diverging slightly outward. The close resemblance of the specimen to *O.* sp. 2 Fritz, 1972 merits its questionable placement in that species. *Olenellus nevadensis* (Walcott, 1910) resembles *O.* sp. 2? Fritz, but has shorter ocular lobes that terminate no farther back than opposite the posterior pair of glabellar furrows, intergenal spines located in a more distal position, a stronger preglabellar ridge, and posterior borders that angle forward immediately before meeting the genal spine. *Olenellus praenuntius* Cowie, 1968 is similar to *O.* sp. 2? Fritz, 1972, but has intergenal spines located closer to the axis, and a more rounded glabellar front, which terminates closer to the anterior border.

Olenellus sp. 1

Plate 2, figures 7, 8

Material. Three cephala 8.3 to 15.2 mm long, from GSC locality 90653.

Description. Cephalic length to width ratio slightly less than 3:5. Anterior and lateral border uniformly narrow, rounded in cross-section, raised abruptly above extraocular field; border extending into narrow genal spines directed slightly outward, length of spine unknown (broken). Posterior border of uniform, medium width (exsag.), directed outward and slightly backward along proximal half and slightly forward along distal half; at two-thirds point from axis small node indicates position of nearly obsolete intergenal spine. Glabella outline in plan view is slightly concave at sides, front uniformly rounded and extending to anterior border furrow without displacing furrow's course, maximum height of anterior glabellar lobe slightly exceeds maximum height elsewhere on axis. Posterior pair (S1) of glabellar furrows of medium width and depth, inclined moderately backward, slightly arcuate; second and third pairs (S2, S3) uniformly arcuate, average direction transverse, third pair joined across axial midline by transverse segment. Eye lobes swept strongly backward, terminating at level opposite middle of posterior glabellar lobe (L1). Interocular area shaped like acute triangle, area inclined backward; surface of extraocular area broadly curved (tr.). Distal ends of occipital furrow slightly deeper than posterior glabellar furrows and inclined slightly less steeply backward, medial four ninths of furrow shallow. Cephalon marked by irregular ridges on anterior glabellar lobe, radial venation on extraocular area of internal moulds; venation on upper surface of test restricted to short radial ridges starting at outer margin of extraocular area, crossing anterior and lateral border furrow, and attaching to inner edge of border. Occipital lobe bears very small spine(?) on posterior margin.

Remarks. Olenellus sp. 1 differs from *Olenellus truemani* Walcott, 1913 and *Olenellus romensis* Resser and Howell, 1938 in having a shorter anterior glabellar lobe and ocular lobes, and from *Olenellus fremonti* Walcott, 1910 in having a shorter anterior glabellar lobe and genal spines that are less advanced.

Olenellus sp. 2

Plate 6, figures 1-8

Material. Eight partial cephala, estimated lengths between 9 and 32 mm, from GSC locality 90664.

Description. Cephalon length slightly greater than one half of width, relief low. In plan view, outer margin exhibits strongest curvature at anterolateral position. Anterior glabellar lobe broadly curved along front margin, strongly curved at anterolateral position, then broadly curved and averaging nearly straight backward to ocular lobe. Anterior glabellar lobe touches anterior border furrow on large and medium sized cephala, terminating farther back on smaller cephala. Proximal segments of anterior two pairs of glabella furrows (S2, S3) narrow, of medium depth and inclined moderately backward, medial segments shallow and strongly curved, distal segments shallow, directed outward and then strongly backward; course of anterior glabellar furrows continuous with furrows separating anterior half of anterior lobes (L3) from ocular lobes. Posterior glabellar furrows (S1) and distal segments of occipital furrow deep and wide from distal end to near sagittal midline before shallowing abruptly; posterior furrows inclined slightly less steeply backward than distal segments of occipital furrow. Ocular lobes marked by ocular furrow, broadly curved, anterior segment swept strongly backward, posterior segment curving inward, average lobe direction straight backward, ocular lobe borders interocular area with slight change in relief; ratio of width of ocular lobe

to maximum width of interocular area is 3:4. Border gradually widens from axial midline to genal angle; in cross-section outer three fourths of upper surface is broadly curved to flat and tilted slightly outward, inner quarter inclined steeply inward, terminating abruptly against uniformly narrow border furrow. Genal spine thin and two thirds as long as cephalon at axial midline. Intergenal spine short, directed slightly outward, separated from slightly advanced genal spine by broad cusp at outer edge of border. Normal and peeled surfaces of extraocular areas marked by radiating and anastomosing venation. Border furrow on some large, peeled cephala crossed by small ridges (distal ends of venation), which terminate on inner part of adjacent border.

Remarks. Available material is too incomplete to be assigned to a described or new species. Furthermore, one specimen (Pl. 6, fig. 2) displays markedly stronger curvature (some tectonic deformation apparent) at the front of the glabella and front margin of the cephalon, which raises the possibility that the above description, based upon incomplete parts, may be a composite of two olenellid species. However, if the remaining parts do belong to one species, that species resembles *Olenellus paraoculus* Fritz, 1972 but has a wider interocular area. The glabella resembles that of *Olenellus cylindricus* Palmer, 1979 and *Olenellus fremonti* Resser, 1928, but those glabellae are on cephala bearing more advanced genal spines and long ocular lobes. *Olenellus truemani* Walcott, 1913 has the same general proportions, but intergenal spines located in a more proximal position. *Olenellus romensis* Resser and Howell, 1938 compares favourably with the present material, but has more convexity at the front margin of the anterior glabellar lobe.

Olenellus sp. 3

Plate 15, figure 19

Material. One small cephalon 4.2 mm long, from GSC locality 90672.

Description. Cephalic length to width ratio slightly less than 2:3. Axial crestline drops lower from front of occipital lobe, is horizontal from rear of glabella to halfway point on anterior lobe, then curves steeply downward to preglabellar field. In plan view lateral margins of occipital lobe, posterior lobes (L1), and third pair of lobes (L3) are nearly aligned, whereas second pair (L2) is narrower (tr.) and maximum width of anterior glabellar lobe is slightly wider; sides and front of anterior lobe outline a half-circle. First and second pairs of glabellar furrows (S1, S2) narrow, of medium depth, broadly curved, average direction inclined slightly backward; third pair (S3) slightly wider and shallower, inclined steeply backward, joined by shallow transverse medial segment. Anterior and lateral border broadly curved in cross-section, tilted moderately backward in front of cephalon, on average horizontal at sides. Preglabellar field slightly longer than border is wide, marked by low medial ridge. Interocular area flat, tilted slightly inward; extraocular area slightly wider than eye lobes, moderately curved, sloping moderately outward. Eye lobes large, evenly curved, raised to level above that of glabella, terminating short distance posterior to level of occipital furrow. Posterior border broadly curved in cross-section and inclined slightly backward, bearing intergenal spine located close to genal spine, border between spines directed steeply forward. Length of intergenal and genal spines unknown (broken). Occipital ring bears large medial node or small spine; shallow, transverse furrow passes behind node. Occipital furrow narrow, of medium depth distally, of medium width and shallow near axial midline. Ornamentation consists of radial venation on both internal mould and upper surface of cephalon.

Remarks. Although small, it is unlikely that the specimen designated as *Olenellus* sp. 3 belongs to any of the species of *Olenellus* described here from the Illtyd Formation. The specimen possesses the large, raised ocular lobes of *Olenellus parvofrontatus* sp. nov., but those on *O.* sp. 3 are shorter and are accompanied by a wider anterior and lateral border and a relatively longer and less quadrate anterior glabellar lobe.

Genus *Wanneria* Walcott, 1910

Wanneria Walcott, 1910, p. 296; Poulsen, 1932, p. 35; 1958, p. 16; 1959, p. O197; 1969, p. 15; Lake, 1937, p. 245; Resser and Howell, 1938, p. 227; Shimer and Shrock, 1944, p. 619; Hupé, 1953, p. 75; Suvorova, 1960, p. 62; Palmer, 1964a, p. 3; Fritz, 1972, p. 28; Repina, 1979, p. 22; Ahlberg, Bergström, and Johansson, 1986, p. 40.

Type species. Olenellus (*Holmia*) *walcottanus* Wanner, 1901.

Diagnosis. The generic diagnoses of Palmer (1964) and Fritz (1972) are followed in assigning this material.

Wanneria logani (Walcott, 1910)

Plate 3, figures 16, 17

Olenellus logani Walcott, 1910, p. 333, Pl. 41, figs. 5, 6.

Wanneria narthorsti Poulsen, 1932, p. 40, Pl. 12, figs. 1-13.

Wanneria logani (Walcott); Poulsen, 1958, p. 16; Fritz, 1972, p. 29, Pl. 14, figs. 1-14; Pl. 16, figs. 1-7.

Material. One partial cephalon 3.4 mm long and one partial cephalic mould 6.6 mm long, from GSC locality 90658.

Remarks. The small specimen closely resembles specimens in the growth series of *Wanneria logani* illustrated by Fritz (1972). It is intermediate in size between specimens illustrated there (op. cit., Pl. 14, figs. 4, 5), and therefore shows slight, but not unexpected differences. A latex cast of the larger specimen resembles that illustrated in Fritz (1972, Pl. 14, figs. 8, 9), except for a stronger curvature of the anterolateral border. Similarity of other details, including the ornamentation, suggests the curvature may be the result of differential compaction and is not grounds for excluding the specimen from the species.

Wanneria sp. 1

Plate 3, figure 2

Material. One partial cephalon 6.5 mm long, from GSC locality 90656.

Description. Cephalon twice as wide as long, broadly curved at front. Anterior and lateral borders uniformly curved in cross-section, average slope horizontal, width of anterior and anterolateral segments half as wide as border near genal angles. Anterior glabellar lobe broadly curved along front margin, distance to anterior border equal to half border's width (sag.). Occipital furrow deep, narrow at distal ends, directed inward and slightly backward, widening rapidly, then narrowing before becoming shallow almost to extinction along medial third. Posterior glabellar furrows (S1) deep distally, straight and angled backward, shallowing inward for seven eighths of length, remaining eighth shallow and transverse, joining opposite furrow across midline. Second pair (S2) narrow, of medium depth, uniformly curved, average direction transverse, shallowing to join across midline. Anterior pair (S3) shallow, uniformly curved, average direction is slightly forward, obscure near midline. Ocular lobes long, terminating opposite occipital furrows, small node located between end of lobes and furrows. Occipital ring raised above level of adjacent axis, probably bearing medial spine or node (broken). Posterior border directed outward, slightly backward, widening from proximal end to bulge at four-sevenths point, remaining three sevenths of border angled slightly forward to genal spine. Cephalic axis, genae, and posterior border marked by polygonal network of narrow ridges; grain located at centre of each polygon. Anterior and lateral border and genal spine marked by terrace lines.

Remarks. The axial region of *Wanneria* sp. 1 closely resembles that of *Wanneria parvifrons* Fritz, 1972, but *W.* sp. 1 differs in having a short preglabellar field (*W. parvifrons* has none), an extraocular area narrower and less convex, and a posterior border inclined slightly backward and then slightly forward as opposed to the transverse border on *W. parvifrons*. Both species display a network of polygonal ridges with a granule in each polygon; however on *W. parvifrons* the ornamentation has a finer texture with the exception of large granules on the interocular area and immediately posterior of that area.

Family DORYPYGIDAE Kobayashi, 1935

Genus *Bonnia* Walcott, 1916

Corynexochus (*Bonnia*) Walcott, 1916, p. 325.

Bonnia Walcott. Raymond, 1928b, p. 309; Resser, 1936, p. 6; 1937, p. 44; Lermontova, 1940, p. 142; 1951, p. 118; Lochman, 1947, p. 68; Rasetti, 1948, p. 14; 1966, p. 43; Hupé, 1955, p. 111; Pokrovskaya, 1959, p. 135; Poulsen, 1959, p. O217; Suvorova, 1960, p. 80; 1964, p. 143; Egorova et al., 1960, p. 194, 195; 1961, p. 225; Demokidov and Lazarenko, 1964, p. 207; Repina et al., 1964, p. 300; Palmer, 1964a, p. 5; 1968, p. 46; 1979, p. 81; Fritz, 1972, p. 31.

Type species. Bathyurus parvulus Billings, 1861.

Discussion. Numerous descriptions of *Bonnia* adequately characterize the genus, and the addition of the present material does not require another definition. However, fragmentary material at hand and elsewhere indicates that several similar genera may be described in the future, and a more rigorous generic description of *Bonnia* will be necessary. The incomplete material upon which *Bonniopsis* Poulsen, 1946 is based clearly justifies a separate genus from *Bonnia*, but more *Bonniopsis* parts are needed before the two genera can be compared fully. *Bonniopsis* and *Bonnima* gen. nov. share the semidetached anterior segment in the pygidium, resulting in two, rather than one, pairs of pygidial spines on the anterolateral margin. Some *Bonnia*-like species with more than one pair of pygidial spines, such as those assigned to *Bonnia laterispina* Fritz, 1972, seem to fit satisfactorily under *Bonnia*, whereas others which have more elongate

pygidial proportions may not. Species described here as *Bonnia*? sp. 2 and *Bonnia*? sp. 3 have additional spines and elongate pygidia. They also have internal moulds displaying pleural furrows continuous with a furrow extending onto the anterior axial ring. These furrows resemble the well defined transverse pleural furrows on the flatter pygidium of *Bonnima semidiscoidea* gen. et sp. nov. and *Bonnima laevigata* (Rasetti, 1948), which give a semidetached appearance to the anterior segment. Collections of *B.*? sp. 2 and *B.*? sp. 3 are presently too small to merit a decision of whether they belong to *Bonnia* or not. The differences between *Bonnima* and *Bonnia* are given under the diagnosis of the former genus.

Finally, if the description of *Bonnia* is broadened to include species such as *B.*? sp. 2 and *B.*? sp. 3, then deeper interpleural furrows and numerous spines would automatically be included in the revised description of *Bonnia* pygida. This would necessitate a review of *Kootenia diutina* Fritz, 1972 for inclusion within the genus and, with that consideration, the possibility of a downward extension of the range of *Bonnia* into the underlying *Nevadella* Zone.

Bonnia carnata sp. nov.

Figure 5, i, j; Plate 5, figures 7-17

Material. Seven cranidia 2.7 to 5.3 mm long, one internal pygidial mould 2.6 mm long and half a pygidium approximately 3.8 mm long, from GSC locality 90663. Holotype, GSC 91758, GSC locality 90663.

Etymology. Latin, *carnata*, fat, referring to the stout, rounded outline of the glabella.

Description. Cranidium convex, ratio of length to width across palpebral lobes is 5:7. Glabella length to width ratio 5:4; in side view crestline evenly curved; in plan view sides convex, average direction is parallel to midline. Posterior pair of glabellar furrows (S1) associated with small indentations at sides of glabella, of medium depth, bifurcating with very short, transverse anterior branch and strongly curved posterior branch inclined backward, second pair (S2) located opposite glabellar midpoint, shallow at glabellar sides, short, transverse; third pair (S3) obsolete; anterior pair (S4) shallow, nearly circular depressions near outer edge of glabella and opposite proximal ends of eye ridges. Palpebral area convex (tr.), width slightly more than three eighths of maximum width of glabella. Eye ridges wide (exsag.), widest and highest at midlength. Anterior border near distal ends broadly convex to flat, tilted slightly backward, rounding and narrowing inward, nearly half distal width (exsag.) in front of glabella where curvature along anterior margin increases. Anterior border furrow shallow near distal ends, markedly deepening in front of glabella. Palpebral lobes slightly less than one third of glabellar length, tilted inward; palpebral furrow of medium depth and width. Proximal half of posterior border horizontal and directed slightly backward, distal half twice as wide (exsag.), angled down and slightly forward; posterior border furrow wide and deep. Distal one fifth of occipital furrow narrow, deep and inclined backward, medial three fifths of medium depth and width. Occipital ring short (exsag.), inclined upward and backward, developing into spine with large base, length unknown (broken).

Internal mould of pygidium of medium height, length to width ratio 2:3. Axis composed of articulating half-ring (broken), five rings and terminal piece; anterior and second rings successively narrower (tr.), posterior three rings and terminal piece narrower still and comprising posterior half of axis; this half is parallel sided. In side view, anterior ring slopes upward and forward well above average height of axis. Furrows defining anterior ring uniformly deep and of medium width, furrow between second and third ring slightly shallower and narrower, furrow between third and fourth rings narrow and of medium depth, between fourth and fifth rings shallow and narrow, between fifth ring and terminal piece very shallow distally and obsolete at axial midline. Terminal piece short, height rapidly decreasing posteriorly, intersection with border steep but not abrupt. Pleural field marked by three pairs of ribs, anterior margin of anterior rib rises gradually from anterior border furrow and posterior margin drops steeply into succeeding furrow. Pleural furrows of medium width, moderately shallow proximally and grading to moderately deep at distal ends. Border furrow shallow. Border broadly curved to flat, tilted outward, bearing four pairs of spines; anterior two pairs short, thorn-like, posterior two pairs blunt spines or nodes. Surface of internal mould smooth; half specimen with outer surface preserved exhibits closely spaced granules of various sizes.

Remarks. One and a half pygidia assigned to *Bonnia* sp. 3 were also found at this locality; they are also granular. The pygidial assignment made in the above description is therefore speculative, and there is a need for a comparison with pygidia associated with *B. carnata* at other localities. The present assignment is based on the assumption that cranidia belonging to *B. carnata* should be accompanied by pygidia of average or greater width, whereas the long pygidium assigned to *B.*? sp. 3 should belong to a species with a longer cranidium. The similarity between pygidia of *B.*? sp. 3 and *B.*? sp. 2, and the latter's association with an exceptionally long cranidium, supports this assumption.

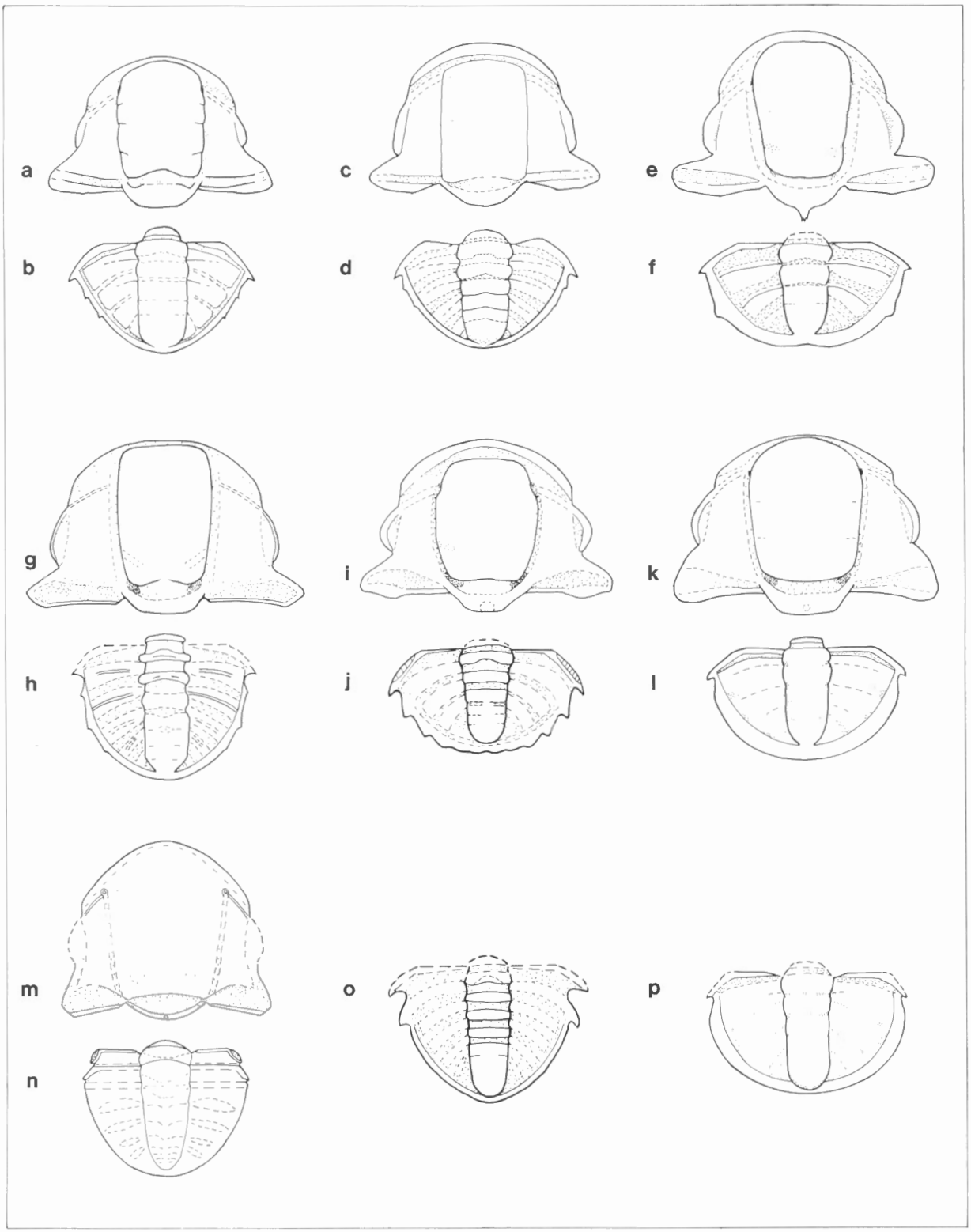


Figure 5. ***Bonnia*** *and related genera:* ***a, b, Bonnia laterispina*** *Fritz;* ***c, d, Bonnia quadrata*** *sp. nov.;* ***e, f, Bonnia decora*** *sp. nov.;* ***g, h, Bonnia****? sp. 2 (internal moulds illustrated):* ***i, j, Bonnia carnata*** *sp. nov.:* ***k, l, Bonnia columbensis*** *Resser;* ***m, n, Bonnima semidiscoidea*** *gen et sp. nov. (internal moulds illustrated, see Pl. 13-15 for external surface;* ***o, Bonnia****? sp. 3 (internal mould illustrated); and* ***p, Bonnia*** *sp. 4.*

Bonnia columbensis Resser, 1936

Figure 5, k, l; Plate 7, figures 1-12; Plate 8, figures 1-20; Plate 9, figures 1-15

1916 *Corynexochus senectus* Walcott, p. 319, Pl. 55, figs. 7, 7a-c [*non* Pl. 56, figs. 1, 1a-g].

1917 *Corynexochus senectus* Walcott; Walcott, p. 66, Pl. 9, figs. 2, 2a-c [*non* Pl. 9, figs. 1, 1a-d].

1936 *Bonnia columbensis* Resser, p. 9.

1947 *Bonnia columbensis* Resser; Lochman, p. 69.

1951 *Bonnia fieldendis* (Walcott); Rasetti, p. 82.

1968 *Bonnia copia* Fritz, p. 194, Pl. 36, figs. 17-24.

1972 *Bonnia columbensis* Resser; Fritz, p. 32, Pl. 18, figs. 1-13.

Material. Twenty-seven cranidia 1.8 to 11.7 mm long, thirty-two pygidia 1.1 to 11.2 mm long, one free cheek and six hypostomes, from GSC localities 90665-90667.

Description. Cranidium has medium relief, ratio of length to width across palpebral lobes is slightly greater than 4:5. Glabella broadly curved along crestline and in transverse direction, sides nearly straight and diverging forward to anterior pits, curved strongly at anterolateral position, broadly curved at front. Glabellar furrows nearly obsolete, posterior pair (S1) very shallow, wide, transverse, no additional pairs visible. Axial furrows of medium depth and width throughout; anterior pits oval in outline, of medium depth. Anterior border furrow shallow and narrow; border broadly convex in cross-section, average tilt (exsag.) is horizontal, half as wide in front of glabella as maximum width elsewhere. Eye ridge obsolete. Palpebral area convex, ratio of maximum width to minimum width of glabella is 9:16. Palpebral furrow of medium width and depth throughout; palpebral lobes slightly longer than one third of length of glabella, tilted inward. Posterior border furrow deep, broad (exsag.), increasing in breadth distally. Posterior border in plan view is nearly straight, narrow proximally and gradually attaining medium width (exsag.) distally; in rear view horizontal along proximal five ninths of border, inclined downward over remaining distance. Occipital furrow moderately deep and expanding inward along distal one seventh, medial five sevenths of medium width and depth. Occipital ring of uniform length (exsag.), half again as long as occipital furrow is broad, inclined forward, marked by medial node.

Librigena relatively small, lateral border as wide (tr.) as maximum width of remaining area between border and facial suture; segment of border opposite distal end of posterior border furrow narrows to one half of average border width; border has truncated posterior end located just anterior to level of adjacent posterior margin of cranidium.

Pygidium moderately low, length to width ratio of large pygidium (11.2 mm long) slightly greater than 7:10, ratio for medium to small pygidia 2:3. Axis low, sides nearly straight, diverging moderately forward, composed of articulating half-ring, four axial rings and terminal piece that nearly reaches posterior border. Ring furrows shallow, furrow between anterior and second ring shallow at sides, very shallow and broadening (exsag.) near axial midline, furrow between second and third rings very shallow and narrow throughout, furrows between third and fourth and between fourth and terminal piece very shallow at distal ends and obsolete near axial midline. Pleural field broadly convex, marked by three pairs of low ribs and two pairs of shallow pleural furrows. Border moderately curved in cross-section, tilted outward, wide; border furrow wide and shallow. Internal pygidial moulds display two anterior axial rings of medium width (exsag.) distally, narrowing proximally, and bowed forward near axial midline; medial portion of anterior ring consists of two ridges separated by furrow, furrow shallows toward axial midline where it is extinct. Furrows between anterior four rings widen (exsag.) appreciably near axial midline. Fifth axial ring is visible on internal moulds, posterior margin defined by shallow furrow, which becomes extinct near axial midline.

Hypostome has large anterior wings. Medial body is of moderate height, oval in plan view, anterior margin more pointed than posterior margin. Medial furrow shallow distally, very shallow to nearly extinct across axial midline. Maculae low and weakly defined. Lateral and posterior border furrow relatively deep and of medium width; adjacent border half as wide as border furrow. Small and medium sized cranidia and pygidia are smooth except for fingerprint pattern on anterior cranidial border and pygidial border. Large cranidia exhibit fingerprint pattern on glabella and to a lesser extent on fixigena; small granules present on latter area and on large pygidia. Internal moulds of large pygidia exhibit sparse punctae. Hypostome bears fingerprint pattern on anterior wings and on lateral and posterior border.

Remarks. The Illtyd specimens compare favorably to type material of *Bonnia columbensis* from British Columbia. This includes details on the hypostome, lack of punctae on the outer surface of the test, and lack of a steep slope at the outer margin of the pygidial pleural field. A

detailed comparison of *B. columbensis* with *Bonnia fieldensis* (Walcott) has been given by Fritz (1972, p. 32).

Bonnia decora sp. nov.

Figure 5, e, f; Plate 4, figures 16-23

Material. Seven cranidia and seven pygidia from GSC locality 90661 and one questionably assigned cranidium from GSC locality 90665. Cranidial lengths range between 3.5 to 5.1 mm, and pygidial lengths from approximately 1.9 to 5.2 mm. Holotype, GSC 91748, GSC locality 90661.

Etymology. Latin, *decorus*, beautiful, referring to the elaborate ornamentation compared with other species in this genus.

Description. Cranidium convex, ratio of length to width measured from outermost margin of palpebral lobes is 4:5. In plan view, glabella expands uniformly and gradually forward from occipital furrow to anterior pits, from pits converging moderately before curving strongly around anterolateral margins, then terminating at a broadly curved front. In side view, glabellar crestline uniformly curved, except for stronger curvature from four-fifths point to front of glabella. Two pairs of shallow glabellar furrows visible, posterior pair (S1) deepest, inclined moderately backward, bifurcating, anterior branch short and inclined slightly backward, other branch inclined steeply backward; second pair of glabellar furrows (S2) inclined slightly backward. Axial furrow wide and deep, shallowing slightly between anterior pair of glabellar furrows and narrow, slit-like anterior pits. Anterior border flat, horizontal, wide (exsag.) distally and narrowing in front of glabella; anterior border furrow of moderate width (exsag.) distally and also narrowing in front of glabella. Eye ridges wide, moderately raised but poorly defined at margins. Palpebral area convex, average slope is outward; palpebral furrow of medium depth, widening from ends toward midlength; palpebral lobes slightly longer than one third of length of cranidium, tilted inward. Distal one fifth of occipital furrow deep and angled backward, medial three fifths transverse and of medium width and depth. Occipital ring inclined upward to base of spine on posterior margin; spine one and one half times as long (sag.) as occipital ring, inclined upward and backward, curved to horizontal, terminating at blunt point. Posterior border furrow deep, directed slightly forward, expanding distally. Posterior border transverse along proximal half, bending slightly forward and downward over remaining half.

Pygidium of medium convexity, length to width ratio 1:2. Axis expands gradually forward, comprising articulating half-ring, three axial rings and terminal piece. Furrow between anterior and second ring of medium depth, widening near axial midline; furrow between second and third rings shallow and transverse, furrow between third ring and terminal piece shallow at distal ends, nearly obsolete near axial midline. Pleural field marked by two pairs of deep, wide pleural furrows, three "plump" pairs of pleural ribs; interpleural furrows on anterior two pairs of ribs closely parallel anterior margin of ribs. Anterior border furrow wide and deep; lateral and posterolateral border furrow of medium depth. Lateral border rounded in cross-section, widening (tr.) from anterior end to posterolateral position, then maintaining width until narrowing and bowing upward behind terminal piece. Border bears anterolateral pair of spines and incipient second pair expressed as broad swellings on lateral margin. Cranidium and pygidium decorated by large granules, those on cranidium irregular in outline, hollow, merging on anterior part of glabella to form fingerprint pattern.

Remarks. Rasetti (1948) illustrated ornamented species of *Bonnia* from the south shore of the St. Lawrence River, such as *Bonnia bicensis* Resser, 1936, *Bonnia brennus* (Walcott, 1916), *Bonnia sculpta* Rasetti, 1948, and *Bonnia senecta* (Billings, 1865). Of these, *B. sculpta* most closely resembles *B. decora*, especially in ornamentation and in having a short (exsag.) occipital ring with a similar spine. However, *B. sculpta* is readily distinguished from *B. decora* by its wider glabella with convex lateral margins, palpebral lobes centred farther forward and a pygidium proportionately longer, bearing shallower pleural furrows, and lacking an incipient second pair of spines on the lateral border.

Bonnia laterispina Fritz, 1972

Figure 5, a, b; Plate 3, figures 7-15

1972 *Bonnia laterispina* Fritz, 1972, p. 33, Pl. 15, figs. 1-7.

Material. Fifteen cranidia 1.6 to 5.6 mm long and eight pygidia 2.4 to 6.7 mm long, from GSC localities 90658 and 90659.

Remarks. This species was described in detail by Fritz (1972) and no new data has been obtained from the present collection. The species is characterized by 1) a glabella widest near the two-thirds mark from the rear, 2) strong curvature at the front of the glabella, 3) pygidium with two well defined axial rings followed by two rings

and an axial piece fused to a degree such that the latter three segments are barely differentiated, 4) axis nearly reaching posterior pygidial margin, 5) three pairs of pleural furrows deep at the outer edge of the pleural field, shallowing rapidly inward, 6) narrow pygidial border bearing three pairs of thin, short spines, and 7) large punctae on the cranidium and pygidium. Species that resemble *Bonnia laterispina* are discussed by Fritz (1972, p. 33).

Bonnia quadrata sp. nov.

Figure 5, c, d; Plate 4, figures 1-15

Material. Sixteen cranidia and three pygidia, from GSC locality 90660. Cranidia are 1.4 to approximately 3.8 mm long and pygidia are 2.3 to 3.2 mm long. Holotype, GSC 91744, GSC locality 90660.

Etymology. Latin, *quadrata*, square, referring to the pronounced rectangular outline of the glabella.

Description. Glabella low, parallel sided, broadly curved across the front, length to width ratio slightly greater than 4:3. Glabellar furrows very shallow, transverse, no associated indentations at glabellar sides, posterior two pairs (S1, S2) best defined and of approximately equal depth, second pair centred at glabellar midlength, anterior two pairs barely visible or extinct. Eye ridges low and of medium width. Palpebral area broadly curved, tilted moderately outward, width at base equals nine to ten twenty-fourths of glabellar width. Palpebral lobes have same outward slope as palpebral area, separated from area by shallow palpebral furrow, centred opposite three-sevenths mark on glabella midline. Anterior border broadly curved, tilted slightly backward; anterior border furrow of medium depth and slightly narrower (exsag.) than border, broad curvature of border and furrow not offset in front of glabella. Posterior border furrow directed slightly forward and widening slightly in distal direction. Posterior border directed transversely along proximal half and widening (exsag.) distally, remaining half tilted slightly downward and forward. Distal one fourth of occipital furrow deep and narrow; medial half broad and shallow. Occipital ring at approximately same height as occipital furrow on crestline, no node or occipital spine present.

Pygidium subtriangular in plan view, convex in cross-section, length to width ratio slightly less than 3:4. Axis high, tapering uniformly backward to level of terminal piece, composed of articulating half-ring, five axial rings and terminal piece. Furrow behind articulating half-ring and behind anterior ring of medium depth and width, latter furrow widening along medial half due to forward bowing of anterior margin; successive four furrows progressively shallower, narrower, and bowed slightly forward near axial midline. Proximal half of pleural field nearly horizontal, distal half curved strongly downward, becoming steep near border furrow; field marked by three pairs of relatively deep pleural furrows and four pairs of pleural bands. Anterior three pairs of pleural bands show faint interpleural furrow, which nearly parallels band margins. Lateral and posterior border broadly curved in cross-section, tilted steeply outward, bowed upward where fused with posterior ridge, marked by (?)three pairs of short border spines. Cranidium almost free of ornamentation; fine, sparse punctae visible on glabellae of best preserved cranidia, anterior part of cranidium and anterior border exhibit fingerprint pattern. Fingerprint pattern also visible on pygidial pleural bands and border.

Remarks. Cranidia of this species resemble those of *Bonnia tensa* Resser, 1938, a species based by Resser on a single cranidium from the Shady Formation, Virginia. Later, Rasetti (1948) assigned cranidia and pygidia from the south shore of the St. Lawrence River to the species. Cranidia of *B. quadrata* differ from those described by Resser and Rasetti in having a glabella that does not expand forward and a deeper, wider anterior border furrow. Pygidia associated with cranidia in Rasetti's material differ from those of *B. quadrata* in having less relief, a less subtriangular outline, and in exhibiting fewer and shallower furrows on the pygidial axis.

Bonnia sp. 1

Plate 3, figures 3-6

Material. One partial cranidium approximately 5.8 mm long and one partial pygidium 4.3 mm long, from GSC locality 90657.

Description. Glabella very high, crestline uniformly curved, sides nearly parallel (slightly convex) along posterior five sevenths, then curving inward; front broadly curved. Posterior pair of glabellar furrows very wide (exsag.), shallow, short (trans.); next two pairs (S2, S3) visible only as faint, narrow, transverse, smooth areas on an otherwise prominently ornamented glabella. Axial furrow very wide, shallow. Posterior border furrow wide and deep, expanding distally. Posterior border of medium width, relatively flat and tilted forward, directed out and slightly backward to (?)five-ninths point, then abruptly directed downward and slightly forward for remaining length.

Pygidium moderately high, length approximately equals width. Axis nearly parallel sided, comprising articulating half-ring (broken), three distinct rings and rather long terminal piece. Furrows between rings deep, of medium width distally and expanding slowly toward axial midline. Pleural field slopes moderately outward along proximal half and steeply outward along distal half, marked by wide anterior border furrow and three pairs of prominent but progressively narrower and shallower pleural furrows. Three pairs of short, narrow interpleural furrows originate at outer edge of axis and rapidly become obsolete. Pygidial border of medium width and tilted outward from imaginary intersection of projected anterior interpleural furrow and border to point where border merges with short, steeply inclined postaxial ridge; adjacent border furrow shallow and narrow. One pair of border spines probably present at anterolateral position and one pair opposite posterior edge of anterior pleural band (both pairs broken). Cranidial ornamentation of prominent, irregular, discontinuous ridges on glabella, medium and small granules in axial furrow and posterior border furrow, and large to small granules on fixigena. Pygidium has large to small granules over surface, except in furrows where granules are medium to small.

Discussion. *Bonnia tatondukensis* Palmer, 1968 has a similar high glabella marked by a weaker ornamentation that is more fingerprint-like and concentric. The adjacent axial furrows on *B. tatondukensis* are narrower, and the rear margin of the posterior border lacks an abrupt turn. Pygidia of *B. tatondukensis* are much wider, pleural furrows shallower and narrower (exsag.), and the outer pygidial surface is nearly smooth. *Bonnia caperata* Palmer, 1964a has a high, ornamented glabella more quadrate in plan view, the fingerprint pattern is relatively light and the adjacent axial furrow is much deeper than that on *B.* sp. 1. As with *B. tatondukensis*, the associated pygidium is wider, has shallower pleural furrows and is smoother.

Bonnia? sp. 2

Figure 5, g, h; Plate 5, figures 1-6

Material. Three cranidia 1.4 to approximately 6.4 mm long and four pygidia approximately 5.1 to 6.4 mm long, from GSC locality 90662.

Description (*internal moulds only*). Cranidial length to width across palpebral lobes gives ratio of slightly less than 4:5. Glabella rather low for genus, sides raised abruptly from axial furrow, expanding gradually and uniformly forward to slit-like anterior pits, converging slightly forward from pits to strongly curved anterolateral margin, front truncated. Only posterior pair of glabellar furrows visible on material at hand, associated with slight indentation at sides of glabella, branching with one limb transverse and second inclined steeply backward to reach posterior margin of glabella. Palpebral area broadly convex, average slope slightly outward. Eye ridges wide (exsag.), low. Palpebral furrow broad (tr.), of medium depth, centred opposite posterior one-third mark; palpebral lobes not preserved. Anterior border flat, nearly horizontal, adjacent border furrow shallow; combined border and border furrow width (exsag.) near distal ends two and a half times that of combined width in front of glabella. Proximal two thirds of posterior border horizontal and inclined slightly backward, distal one third angling forward and downward; posterior border furrow broad and deep. Distal one fifth of occipital furrow deep and inclined backward, medial three fifths broad (exsag.), of medium depth except for anterior margin where medial one fifth merges without change in relief into glabella. Occipital ring short (exsag.) and bearing medial node.

Pygidium has length to width ratio of 8:9. Axis comprising articulating half-ring, six axial rings and short terminal piece. Anterior two rings narrow (exsag.), each bearing transverse groove between raised ridges. Posterior four rings rise vertically from axial furrow, broadly curved (tr.) on upper surface, each longer (exsag.) than either of anterior two rings, compacted with axial piece to form near-continuous posterior nine thirteenths of axis as opposed to more widely spaced anterior two rings and articulating half-ring. Furrows immediately in front of and behind anterior ring deep and wide; latter furrow widest, shallowing and widening medially; posterior four axial furrows shallow distally, widening and very shallow on outer part of upper surface of axis, effaced at axial midline. Proximal half of pleural field broadly curved and on average horizontal, distal half curves moderately down to shallow border furrow. Pleural field marked by five pairs of ribs, anterior three pairs bear interpleural furrow expressed as low, narrow ridge paralleling anterior margin of rib and angling away from posterior margin. Pygidial border narrow (tr.) for genus, bearing short anterolateral and second pair of spines and two small pairs of nodes in third and fourth spine positions; border nearly or completely absent between anterolateral and second pair of spines, bowed slightly upward behind axis. No ornamentation visible on internal cranidial or pygidial moulds; external surface of single associated pygidium is punctate.

Remarks. A cranidium with a long, rectangular glabella and palpebral lobes centred far back, plus an exceptionally long pygidium differentiates this species from others within the genus.

Bonnia? sp. 3

Figure 5, o; Plate 5, figures 18, 19

Material. One pygidium and one pygidial internal mould 3.0 and 7.2 mm long, respectively, from GSC locality 90663.

Description. Pygidial internal mould subtriangular, length to width ratio approximately 5:6. Axis nearly parallel sided along posterior half, expanding slightly along anterior half, composed of articulating half-ring, five rings and long terminal piece. Anterior two axial rings well delineated by axial furrows of uniform, medium width and depth; third, fourth and fifth rings bordered posteriorly by progressively and uniformly shallower furrows. Terminal piece has high, well rounded posterior end, which drops steeply to border. Pleural field marked by five pairs of ribs rising abruptly above slightly narrower, deep pleural furrows; each rib bears broad (exsag.), shallow interpleural furrow. Pygidial border narrow throughout, except nearly obsolete between anterolateral and second pair of pygidial spines. External surface of small (3 mm) pygidium marked by irregular, poorly sized, closely spaced granules, anterior three axial rings bear medial nodes; internal mould smooth to slightly rough, nodes not visible on axial rings.

Remarks. See remarks under *Bonnia carnata* sp. nov.

Bonnia sp. 4

Figure 5, p; Plate 14, figures 17, 18

Material. One external pygidial mould approximately 6.2 mm long, from GSC locality 90671.

Description. Pygidial relief medium, length to width ratio approximately 2:3. Axis comprising articulating half-ring (broken), three axial rings and terminal piece, which intersects posterior border; axis parallel sided along posterior half, slightly wider at anterior and second axial rings. Axial rings approximately equal in length (exsag.), except for slightly shorter anterior ring. Pleural field marked by three pairs of ribs separated by pleural furrows of shallow (proximally) to medium (distally) depth. Anterior rib exhibits very shallow interpleural furrow. Anterior border furrow of medium depth, lateral furrows slightly shallower and becoming extinct behind axis. Lateral and posterior border curved in cross-section, average slope is slightly outward, lateral border maintains uniform width, posterior border slightly narrower. Border probably bears one pair of anterolateral spines (not preserved). Surface has rough texture (poorly preserved).

Remarks. This pygidium resembles those of *Bonnia columbensis* Resser, 1936 and *Bonnia fieldensis* (Walcott, 1916), but more material is needed for speciation.

Genus *Bonnima* gen. nov.

Type species. Bonnima semidiscoidea gen. et sp. nov.

Etymology. First part of name, *Bonn*, used to show resemblance to *Bonnia*, a genus based on a species from Bonn Bay, Newfoundland. Latter part (Latin, *imus*, lowest, last) reflects both an exoskeleton of low relief and occurrence in the uppermost, or "last" part of the Lower Cambrian.

Diagnosis. Genus resembles *Bonnia* in size and general outline of cranidium and pygidium, but has much less local and general relief and barely visible furrows. Occipital ring much narrower (exsag.) than in *Bonnia*. Internal pygidial moulds exhibit "semidetached" anterior pleural segment that is less obvious on upper surface of test where segment is outlined at posterior margin by deep, unusually narrow interpleural furrow. Pygidial border furrow absent on upper surface of pygidium and absent or very shallow on internal moulds.

Discussion. Bonnia laevigata Rasetti, 1948 from isolated boulders along the St. Lawrence River is assigned to this genus, as it exhibits both exceptionally low relief and a semidetached anterior segment on the pygidium. Pygidia with semidetached segments assigned by Cowie (1968) to *Bonniopsis* sp. resemble those of *Bonnima*, but have more relief. Cowie's specimens, from the Police Post Formation, southeastern Ellesmere Island, are from strata believed to be approximately coeval with those containing *Bonnima*. *Bonniopsis* pygidia are associated with cranidia that have more relief and differ from those of *Bonnima* in having a strongly pointed front margin.

Bonnima semidiscoidea gen. et sp. nov.

Figure 5, m, n; Plate 13, figures 8-19; Plate 14, figures 1-16; Plate 15, figures 1-18

Material. Thirty-three cranidia 1.1 to 6.9 mm long and thirty-eight pygidia 2.2 to 7.2 mm long, from GSC localities 90671 and 90672. Holotype, GSC 91877, GSC locality 90671.

Etymology. Latin, *semi*, half; *discus*, plate, disc, referring to the shape of the pygidium, which resembles half a disc.

Description. Cranidium moderately low, smooth, almost totally lacking in local relief, length slightly less than width measured across palpebral lobes. Axial furrows very shallow to extinct, diverging forward to shallow anterior pits containing node. Glabellar furrows, anterior border furrow and anterior border nearly or completely obsolete; position of anterior border marked by band of terrace lines. Width of palpebral area four ninths of width of glabella at base, sloping outward at same angle as adjacent glabella. Palpebral lobes defined by slight decrease in outward slope of fixigena. Posterior border furrow and occipital furrow very shallow, occipital lobe approximately as long (sag.) as occipital furrow is broad; occipital lobe bears very small node near posterior margin. Posterior section of facial suture inclined steeply backward between palpebral lobe and anterior margin of posterior border furrow.

Internal cranidial moulds exhibit two shallow, broad pairs of glabellar furrows (S1, S2); furrows are short and do not extend to axial furrow. Axial furrow of medium depth and width throughout. Anterior pits located at inner margin of axial furrow, mainly displacing glabella, round, bearing medial node. Anterior border and border furrow undifferentiated in front of glabella, weakly differentiated on fixigena. Eye ridges uniformly low and narrow (exsag.). Palpebral furrow very wide, of medium depth; depression extending posteriorly from palpebral furrow as low, broad area along outer margin of posterior area on fixigena and merging with posterior border furrow. In plan view, posterior border uniformly narrow and low, curving broadly outward and slightly backward, in end view broadly curving outward and downward. Posterior border furrow of medium depth, anterior margin bowed strongly forward with most advanced point at midlength. Occipital ring uniformly low and narrow (exsag.) along medial seven ninths, distal one ninth slightly narrower; at one-ninth point short, narrow furrows enter ring from posterior margin, furrows inclined forward and inward at high angle, terminating half way across (exsag.) occipital ring; ring marked by small medial node. Occipital furrow of medium depth, uniformly wide except for contraction near distal ends.

Hypostome of medium height, anterior margin strongly curved. Medial body has length to width ratio of approximately 3:2. Medial furrow of medium width and depth distally, shallowing to extinction before reaching axial midline. Maculae low but clearly expressed. Posterior and lateral border furrows approximately equal in width. Anterior border poorly defined, narrower (sag.) than anterior border furrow. Terrace lines present on posterior margin of anterior wings; fingerprint pattern grading into anastomosing pattern visible on medial body.

Pygidium low, smooth, lacking local relief, length to width ratio 7:8; in front or rear views broad curvature of upper surface not offset by axis. Axial furrows very shallow, diverging forward; axis comprises articulating half-ring, eight or nine axial rings and short terminal piece terminating well ahead of pygidial margin. Anterior axial ring narrow (exsag.), bisected by thin, moderately deep interpleural furrow bowed slightly forward on ring and straight and transverse across pleural region, intersecting pygidial margin at slight indentation between two pairs of short pleural spines. Articulating half-ring short (sag.), width (tr.) approximately five sevenths of maximum width of axis. Anterior border low, narrow, width (exsag.) approximately one third that of shallow anterior border furrow. Pleural region nearly smooth, faint outline of several pairs of pleural ribs visible, region broadly curved, gently inclined, curvature steep near outer margin of pygidium; pygidial border absent; terrace lines present at expected border position.

Internal pygidial mould exhibits shallow but nevertheless slightly deeper furrows and therefore provides better definition of pygidial components. Anterior two axial rings narrow (exsag.). Furrows behind articulating half-ring and first and second axial rings very broad (sag.), remaining six to seven furrows progressively narrower. Pleural field marked by six pleural ribs, wide (exsag.) anterior border furrow, equally wide anterior pleural furrow, and four to five additional pleural furrows that are markedly narrower.

Discussion. Bonnima semidiscoidea resembles *Bonnima laevigata* (Rasetti, 1948) in its generally smooth cranidium and pygidium, and deep, narrow furrow between the anterior and second pygidial pleural segments, which faintly crosses the axis, thus giving the anterior segment a "semidetached" appearance. On *B. laevigata* this furrow is less obvious (see Rasetti, 1948, Pl. 5, figs. 13, 14), and has not previously been described. Cranidia of *B. laevigata* exhibit more relief than those of *B. semidiscoidea* and the various furrows, although shallow, are relatively deeper. The occipital ring of *B. laevigata* is much longer (sag.) than in *B. semidiscoidea*, this being particularly evident when comparing internal moulds. Pygidia of *B. laevigata* have six rather than the eight or nine axial rings of *B. semidiscoidea*. In rear view, the axis of *B. laevigata* rises gradually but much higher above the adjacent pleural region than that of *B. semidiscoidea*, and the pleural region slants gradually to the outer margin rather than extending nearly horizontally and curving more rapidly at the outer portion before reaching the perimeter. Exfoliated pygidia of *B. laevigata* exhibit a shallow but clearly defined lateral border furrow, whereas those of *B. semidiscoidea* do not.

Family ZACANTHOIDIDAE Swinnerton, 1915

Genus *Zacanthopsis* Resser, 1938

Zacanthopsis Resser, 1938, p. 106; Hupé, 1953, p. 105; Rasetti, 1959, p. O230; Palmer, 1964a, p. 9.

Type species. Olenoides levis Walcott, 1886, p. 187.

Discussion. The generic description by Palmer (1964a) is followed in placing the new species below in *Zacanthopsis*.

Zacanthopsis expansa sp. nov.

Plate 6, figures 13-18; Plate 9, figures 19-23

Material. Eleven cranidia from GSC locality 90666, and five cranidia plus two pygidia from GSC locality 90667. Cranidial lengths range from 1.9 to 6.4 mm; pygidial lengths are 1.3 and 3.2 mm. Holotype, GSC 91776, GSC locality 90666.

Etymology. Latin, *expando*, spread out, referring to the unusual expansion along the length of the eye ridge.

Description. Cranidium subrectangular, relief high. Glabellar length to average width ratio is 5:2; outline in cross-section is a half-ellipse; in side view uniformly curved along crestline. In plan view glabellar sides nearly parallel to slightly converging from rear to narrowest point at second (S2) pair of glabellar furrows, then widening to immediately ahead of and behind fourth (S4) pair; front margin broadly curved. Glabellar furrows shallow, posterior pair wide distally, rapidly narrowing inward, bifurcating into short transverse branch and steeply inclined branch, which joins across axial midline on small cranidia and is obsolete there on larger cranidia. Second pair (S2) has same distal width (exsag.) as posterior pair, short, inclined backward. Third and fourth pairs (S3, S4) shallower than posterior and second pairs, wide and inclined forward. Axial furrow shallow, inner and outer margins grading into fixigena and glabella. Preglabellar field approximately as wide (exsag.) as eye ridges, contact with border is abrupt. Eye ridges raised, expanding distally, rapidly expanding and rising just before merging with palpebral lobes; lobes rounded in cross-section, nearly half as long as glabella. Palpebral furrows narrow, of medium depth. Palpebral area broadly curved to nearly flat, tilted inward, maximum width approximately equals minimum width of glabella. Occipital furrow transverse, of uniform width and depth. Occipital ring bears spine that starts as raised area just posterior of occipital furrow, gradually elevating to posterior margin of occipital ring where distinct spine with round cross-section departs from ring, rises gradually, and rapidly narrows to a point. Anterior sections of facial suture moderately divergent forward to anterior margin of broad glabellar furrow, then curving inward. Anterior border tilted steeply backward, approximately equal to border furrow in width (exsag.). Proximal half of posterior border nearly round in cross-section, directed transversely, equal to posterior border furrow in width (exsag.); distal half tilted slightly downward and forward, wider (exsag.) than proximal half, terminating at approximately same distance from axial midline as outermost edge of palpebral lobe.

Pygidial length slightly less than half of width. Axis high, composed of articulating half-ring, three axial rings and a short terminal piece. On peeled axis, furrows in front of and behind anterior axial ring are approximately equal in width and depth, next posterior furrow narrow at distal ends, widening greatly near axial midline; last furrow narrow, shallow, and bowed back. Pleural region broadly convex, sloping outward, crossed by (?)three pairs of pleural furrows and extending into (?)four spines and additional pair of very small spines posterior to axis. Cranidial surface covered with medium and small granules. Venation consisting of large ridges originates at side of glabella and extends short distance onto palpebral area before dividing into smaller anastomosing branches. Pleural area of pygidium granular and also marked with sparse, large granules.

Remarks. Zacanthopsis expansa differs from *Zacanthopsis levis* (Walcott, 1886) and *Zacanthopsis virginica* Resser, 1938 in possessing stronger eye ridges with progressive distal enlargement, a wider palpebral area, and an occipital spine that rises posteriorly and has a distinct base rather than being a gradual extension of the occipital ring. *Zacanthopsis virginica* has a wider (sag.) preglabellar area, shorter (sag.) anterior border, deeper palpebral furrows and less arcuate palpebral lobes. *Zacanthopsis stribuccus* Fritz, 1972 also exhibits these differences, plus a glabella with greater forward expansion and exceptionally wide (tr.) palpebral furrows.

Genus *Fieldaspis* Rasetti, 1951

Fieldaspis Rasetti, 1951, p. 159; 1959, p. O227; Palmer, 1979, p. 92.

Type species. Fieldaspis furcata Rasetti, 1951, p. 159.

Discussion. Rasetti's (1951) description of *Fieldaspis* is followed in this paper.

Fieldaspis bilobata? Rasetti, 1951

Plate 17, figures 16, 17

1951 *Fieldaspis bilobata* Rasetti, p. 161, 162, Pl. 16, figs. 1-9.

1957 *Fieldaspis bilobata* Rasetti; Rasetti, p. 956, Pl. 121, figs. 12, 13.

Material. One partial cranidium 12.3 mm long and one pygidium 9.4 mm long, both internal moulds from GSC locality 90675. Locality in local float 3.7 m above base of Slats Creek Formation.

Discussion. Rasetti provided an adequate description of this species, and no new data have been obtained from the fragments from strata overlying the Illtyd Formation. The anterolateral corners of the present glabella are less angular than in Rasetti's paratypes (1951, Pl. 16, figs. 1, 2); the palpebral furrows are not as deeply incised; the identification is therefore questionable.

Family DOLICHOMETOPIDAE Walcott, 1916

Dolichometopid sp. 1

Plate 7, figures 13-18

Material. Five cranidia 2.6 to 5.9 mm long and one questionably assigned pygidium, from GSC locality 90666.

Description. Cranidium has very long, narrow glabella and short (exsag.) posterior area of fixigena. Glabella nearly parallel sided along posterior half, expanding gradually forward along anterior half, front broadly curved. In side view axial crestline nearly horizontal along posterior five sevenths, remainder broadly and uniformly curved downward. Three pairs of glabellar furrows visible, posterior pair (S1) of medium depth, inclined steeply backward, rapidly widening inward; second and third pairs shallow, inclined slightly backward (S2) and transverse (S3), second pair located at glabellar midlength. Axial furrow shallow and narrow, slightly deeper and wider near posterior glabellar furrow. Anterior pits contain small granule near outer edge, inner edge of pits forms cusp-like displacement into sides of glabella. Frontal area very narrow (exsag.). Anterior area of fixigena expands (tr.) slightly forward. Eye ridges wide with low relief. Palpebral area broadly curved (tr.), average slope slightly outward, width three eights of glabella at base. Palpebral lobes narrow, tilted moderately inward, broadly curved, average direction slightly outward and backward, length nine twentieths of glabella, two-thirds point from rear of lobe is located opposite midpoint on glabella. Posterior border very narrow (exsag.) proximally, expanding distally; adjacent furrow of uniform medium width and depth. Posterior margin of occipital ring angles backward along distal quarter, medial half transverse. Occipital furrow of medium depth, wide distally and narrowing inward along distal quarter, medial half of uniform width and bowed gently forward.

Pygidial fragment tentatively assigned to this family consists of partial axis and minor part of pleural field. Axis nearly half-cylindrical in plan view and transverse section, expanding slightly forward. Parts of four axial rings present, each shorter (exsag.) than preceding ring; furrows in front and behind posterior ring shallow and narrow, anterior two furrows expand near axial midline. Interpleural and pleural furrows shallow, pleural furrows of medium width, interpleural furrows narrow, extending only short distance from narrow axial furrow, both types of furrows swept strongly backward. Ornamentation on pygidial and cranidial axes consists of dispersed, medium size punctae. Occipital ring marked by small medial node.

Remarks. Dolichometopid cranidia are common in the upper Lower Cambrian, but related pygidia of this size are rare. The Illtyd cranidia bear a close resemblance to those placed in the lower Middle Cambrian genus *Poliella*. The pygidial fragment clearly does not belong to that genus. Its large size relative to the associated cranidia, and its cylindrical axis, resemble the Lower and Middle Cambrian genus *Ogygopsis*. However, the pleural furrows on the pygidium are inclined backward at a far steeper angle than those on *Ogygopsis*, and the pleural and interplerual furrows are far less parallel.

Family ALOKISTOCARIIDAE Resser, 1939

Genus *Amecephalus* Walcott, 1924

Amecephalus Walcott, 1924, p. 53; Walcott, 1925, p. 65; Rasetti, 1951, p. 202; Kobayashi, 1962, p. 51; Poulsen, 1964, p. 41; Fritz, 1968, p. 227.

Type species. Ptychoparia piochensis Walcott, 1886.

Discussion. The description by Fritz (1968) is used here in placing the Illtyd material in the genus *Amecephalus*. The classification of this genus has undergone a turbulent history; its use has been suppressed by some writers (Resser, 1935; Palmer, 1954, 1979; Howell, 1959; Robison, 1971) in favour of *Alokistocare*, and has been

reestablished by others (Rasetti, 1951; Stoyanow, 1952, Kobayashi, 1962; Poulsen, 1958, 1964; Fritz, 1968).

Amecephalus? sp. 1

Plate 17, figure 15

Material. One partial cranidium and partial thorax totalling 28 mm in length, from GSC locality 90675. Locality is 3.7 m above base of Slats Creek Formation.

Discussion. The size, glabellar outline, shallow glabellar furrows, thorax with uniform transverse thoracic segments, and uniformly wide pleural furrows indicate the specimen probably belongs to *Amecephalus*.

Family PTYCHOPARIIDAE Matthew, 1887

Genus *Antagmus* Resser, 1936

Antagmus Resser, 1936, p. 3; Shimer and Shrock, 1944, p. 605; Lochman, 1947, p. 62; Hupé, 1953, p. 126; Rasetti, 1955, p. 9; 1959, p. O235; Shaw, 1962, p. 335.

"*Antagmus*" Palmer, 1968, p. 74.

Type species. Antagmus typicalis Resser, 1936 (=*Ptychoparia teucer* Walcott, 1886, p. 197, Pl. 26, fig. 3).

Discussion. Rasetti's diagnosis of the genus is used in assigning the species below.

Antagmus ducketti sp. nov.

Plate 9, figures 16-18

Material. Four cranidia 1.8 to 4.6 mm long, from GSC localities 90665 and 90667. Holotype, GSC 91825, GSC locality 90667.

Etymology. The species is named after M.J. Duckett, the field assistant who ably helped collect the trilobites described herein.

Description. Cranidium of medium relief, length to width ratio slightly greater than 7:11. Glabellar sides nearly straight to slightly concave, converging to broadly curved front. Three pairs of glabellar furrows, posterior pair (S1) of medium depth, bifurcating into shallow branches, anterior branch angled forward and posterior branch angled backward. Second pair (S2) shallow and inclined moderately backward. Third pair (S3) very shallow and inclined slightly forward. Axial furrow wide and deep to level of eye ridge, remaining furrow and continuation into preglabellar furrow of medium depth and width. Anterior border has rounded upper surface (exsag.), average slope is horizontal; in plan view anterior margin broadly curved, posterior margin recurved near axial midline. Border furrow of medium depth and width behind medial recurvature of border, narrower and deeper distally. Palpebral area inclined outward, ratio of palpebral width to maximum width of glabella is 4:7. Palpebral lobes centred opposite glabellar midpoint, half as long as glabella, strongly elevated and tilted inward. Posterior border furrow of medium width throughout, deep except near distal end. Posterior border widening uniformly (exsag.) distally, inclined slightly backward; in rear view proximal half tilted slightly downward and distal half moderately downward. Occipital ring narrow near ends, moderately wide (sag.) near axial midline, where height equals that of posterior margin of glabella. Ornamentation consists of conspicuous medium sized granules, large medial node on occipital ring, and small pair of protuberances located short distance anterior to forward pair (S3) of glabellar furrows.

Discussion. This species differs from others in the genus by having longer palpebral lobes. Most other species have a longer (exsag.) anterior border, a shorter (exsag.) anterior area and a proportionately wider glabella. *Antagmus tennesseensis* Resser, 1938 bears some resemblance to *A. ducketti*, but the former species is based upon small, internal moulds difficult to compare with the present material.

Genus *Illtydaspis* gen. nov.

Type species. Illtydaspis quartetensis gen. et sp. nov.

Etymology. The generic name indicates a skeletal part (Greek, *aspis*, shield) from the Illtyd Formation.

Diagnosis. Ptychopariid with low, semirectangular glabella, front very low and merging with short (sag.) preglabellar field without appreciable break in slope. Anterior border exhibits no (or only slight) backward recurvature of posterior margin. Palpebral area approximately half as wide as glabella at base. Palpebral lobes nearly half as long as glabella and centred posterior to level of glabellar midpoint.

Discussion. This genus resembles *Luxella* in the quadrate glabella with little or no recurvature along the posterior margin of the anterior border, and long palpebral lobes centred posterior to the level of the glabellar midpoint.

Illtydaspis has a much shorter preglabellar field and anterior segments of the facial suture directed nearly straight forward rather than diverging forward. *Illtydaspis* differs from *Eoptychoparia* in having a glabella with a lower, truncated front terminating closer to the anterior border, shallower glabellar furrows, and a wider palpebral area. *Illtydaspis* also resembles *Bythicheilus*, known from the Middle Cambrian of Idaho. However, exfoliated cranidia of *Bythicheilus* have a uniformly deep anterior border furrow preceded by a narrow, raised, wire-like anterior border (Resser, 1939, Pl. 6, figs. 1, 8, 10). Genera with larger cranidia, large, flat anterior borders, and less cranidial relief, which otherwise resemble *Illtydaspis*, are *Kochaspis, Kochiella*, and *Inglefieldia*. *Piaziella tuberculata* Rasetti, 1951 from the Middle Cambrian Mount Whyte Formation should be included in the genus *Illtydaspis*. A species from the Lower Cambrian of Mexico referred by Lochman (1952) to "genus and species undetermined 1" (op. cit., p. 108, Pl. 21, figs. 13, 14) may also belong to *Illtydaspis*.

Illtydaspis aphylla gen. et sp. nov.

Plate 13, figures 1-6

Material. Four cranidia 2.1 to 3.0 mm long, from GSC locality 90671. Holotype, GSC 91853, GSC locality 90671.

Etymology. Greek, *aphylla*, even, smooth, simple, referring to the cranidium, which lacks ornamentation and is low with shallow furrows.

Description. Cranidium relatively low, length to width ratio slightly less than 3:4. Glabellar crestline broadly and uniformly curved to terminate at low front; in plan view sides slightly convex, converging to broadly curved front. Two very shallow pairs of glabellar furrows, posterior pair (S1) inclined moderately backward, second pair (S2) inclined slightly backward; three pairs of furrows visible on internal moulds, posterior pair shallow and inclined moderately backward; second pair of medium depth, curved slightly backward, of medium width (exsag.) and narrow at both ends; anterior pair (S3) of medium width and inclined slightly backward. Axial furrow of medium depth, narrow; preglabellar furrow shallow. Anterior border broadly curved along anterior margin, especially along medial five sevenths; in front view, margin rises slightly toward centre; in plan view, posterior margin broadly curved with minute medial recurvature. Anterior border furrow narrow and shallow throughout. Preglabellar field approximately one third as long (sag.) as anterior border (sag.). Eye ridges low, barely visible, of medium width (exsag.). Palpebral lobes two thirds as long as glabella, centred behind glabellar midpoint, tilted slightly inward; palpebral furrow very shallow. Palpebral area flat, tilted moderately outward, width (tr.) slightly less than five ninths of width of glabella at base. Occipital ring relatively long, presence or absence of node unknown (poor preservation); occipital furrow narrow, bowed forward, of medium depth distally and shallowing toward axial midline. Posterior border straight, expanding (exsag.) gradually distally; adjacent border furrow of medium depth and narrow. Test very thick, upper cranidial surface smooth, internal cranidial mould exhibits sparse punctae.

Remarks. Two cranidia from Vermont that Resser (1937) described as *Antagmus*? *simplex* resemble this species, especially one specimen (Pl. 8, fig. 54), which is an internal mould. Resser's specimens also resemble the internal mould of *Illtydaspis*? sp. 2 shown in Plate 16, figure 18, but Resser's specimens both exhibit shorter palpebral lobes. *Illtydaspis aphylla* differs from (?)*I.* sp. 2 in the longer (sag.) anterior border, glabella with a more transverse front margin, longer palpebral lobes and smooth outer cranidial surface.

Illtydaspis ornata gen. et sp. nov.

Plate 17, figures 1-10

Material. Eighteen cranidia 1.2 to 6.1 mm long, from GSC localities 90672 and 90673. Holotype, GSC 91911, GSC locality 90672.

Etymology. Latin, *ornata*, bedecked, handsome, reflecting the high degree of ornamentation on the cranidium.

Description. Cranidium of medium height, length to width ratio 2:3. Glabellar sides nearly straight, converging forward to truncated front, axial crestline broadly and uniformly curved along posterior four fifths, then more strongly curved downward. Glabellar furrows very shallow on outer surface and internal mould; posterior two pairs (S1, S2) originate near axial furrow as short, shallow indentations, rapidly shallowing and widening inward, posterior pair bifurcating with branches inclined slightly and steeply backward, second pair has average inclination slightly backward; anterior pair (S3) shallow and transverse, not extending outward to axial furrow. Axial furrow narrow and of medium depth to level of eye ridges, remaining furrow and preglabellar furrow narrow and shallow. Anterior border in plan view is uniformly curved along posterior margin; border widens (exsag.)

from distal ends inward with stronger curvature along medial one third of anterior margin; anterior margin in front view rises uniformly from distal ends to midpoint, forming low peak. Anterior border furrow of medium depth and width, shallowing near axial midline. Preglabellar field at axial midline nearly as long as anterior border. Eye ridges wide (exsag.) and low. Palpebral lobe length nine twentieths that of glabella, low at anterior ends and rising progressively to considerable elevation at posterior ends, centred opposite glabellar midpoint, tilted moderately inward; contact with palpebral area marked by sharp break in slope, which constitutes otherwise inconspicuous position of palpebral furrow. Palpebral area half as wide (tr.) as glabella at base, broadly curved, average slop horizontal. Posterior border directed slightly backward, in rear view uniformly curved outward and downward; adjacent furrow of medium depth and width, gradually widening outward. Occipital ring of medium length (sag.) and marked by low medial node. Occipital furrow narrow, of medium depth distally, shallowing and bowed forward near axial midline. Anterior segments of facial suture straight and slightly divergent from palpebral lobe to anterior border furrow; posterior segments strongly divergent. Cranidium punctate and marked by sparse, medium sized granules. Anterior border covered by smaller, closely spaced granules; anterior area of fixigena marked by venation.

Discussion. Small specimens (Pl. 17, figs. 1, 2, 7-9) of this species differ notably from larger ones in having a more rectangular glabella, which terminates closer to the anterior border furrow. These smaller specimens resemble *Onchocephalus buelnaensis* Lochman, 1952, but have longer palpebral lobes, which are centred farther back. *Antagmus tennesseensis* Resser, 1938 is also similar, but has a wider and longer posterior area. Large specimens exhibit resemblance to those Shaw (1955, Pl. 74, figs. 11, 12) figured as *Ptychoparella teucer* (Billings, 1861). The latter cranidia, however, are too poorly preserved for a full comparison.

Illtydaspis quartetensis gen. et sp. nov.

Plate 8, figures 21-28

Material. Seven cranidia 2.4 to 3.8 mm long, from GSC locality 90668. Holotype, GSC 91810, GSC locality 90668.

Etymology. The species is named after Quartet Lakes, located 12 km east of the Illtyd section.

Description. Cranidium of medium height, length to width ratio 2:3. Axial crestline broadly curved along glabella to low front; glabellar sides straight to slightly convex, converging moderately forward to truncated anterior margin. Three pairs of very shallow glabellar furrows, posterior pair (S1) inclined moderately backward, second pair (S2) slightly backward, third pair (S3) transverse. Axial furrow shallow and narrow; preglabellar furrow very shallow and narrow. Anterior border broadly and evenly curved along posterior margin, more strongly curved along anterior margin; in front view latter margin is broadly curved. Anterior border in cross-section is moderately curved, average slope is horizontal. Preglabellar field on larger cranidia two thirds as long (sag.) as anterior border; almost no change in relief from anterior edge of glabella to preglabellar field; medial area immediately in front of glabella exhibits broad, shallow depression. Eye ridges of medium width, low. Palpebral area on larger cranidia slightly over half as wide (tr.) as glabella at base, flat and nearly horizontal. Palpebral lobes nine twentieths as long as glabella, tilted strongly inward, centred posterior to level of glabellar midpoint. Posterior border expanding slightly and uniformly outward, curved strongly downward; adjacent furrow uniformly deep and narrow. Occipital ring relatively short; medial node, if present (poor preservation), is small. Occipital furrow of medium depth and narrow along distal quarter, narrow, shallow and broadly bowed forward along medial half. Cranidial ornamentation consists of medium sized punctae on glabella and occipital ring, medium large to small granules on palpebral area and posterior area of fixigena, and medium to small granules elsewhere.

Internal cranidial moulds differ considerably from normal cranidia due to thick test. Glabella on mould small, cone shaped, sides steep, front truncated. Axial furrows shallow and wide. Posterior border furrow wide and deep, posterior border narrow (exsag.). Occipital furrow of medium depth and width throughout. Mould surface covered with large punctae.

Discussion. Illtydaspis quartetensis differs from *Illtydaspis aphylla* in the relatively narrower cranidium, longer (sag.) frontal area, shorter palpebral lobes, and ornamentation on the outer surface consisting of both punctae and granules, whereas the outer surface of *I. aphylla* is smooth. *Illtydaspis quartetensis* differs from *Illtydaspis*? sp. 2 in having a longer (sag.) anterior border, shallower axial furrows, shallower glabellar furrows, a more truncated glabellar front and a slight medial depression on the posterior part of the preglabellar field.

Illtydaspis sp. 1

Plate 16, figures 1-11

Material. Sixteen immature cranidia 1.3 to 2.2 mm long, from GSC locality 90672.

Description. Small cranidium of medium relief, length to width ratio 3:4. Glabella relatively large, lateral margins slightly convex, converging slightly forward to truncated front that touches anterior border furrow. Glabella crestline straight and inclined moderately forward along posterior two thirds, curving and slightly steeper along anterior one third to front with low relief. Three pairs of glabellar furrows, short, of medium depth; posterior two pairs expand inward, inclined moderately (S1) and slightly (S2) backward, anterior pair (S3) inclined slightly forward. Axial furrow narrow, of medium depth to level of eye ridges, remaining portion and anterior glabellar furrow narrow and shallow. Anterior border well rounded in cross-section (exsag.), average slope is forward, in front view border bowed uniformly upward. Anterior border furrow narrow and of medium depth. Palpebral area sloped outward, width half that of glabella at base. Palpebral lobes half as long as glabella, centred short distance behind glabellar midpoint, inclined moderately inward. Palpebral furrow shallow and narrow throughout. Posterior border expanding (exsag.) outward and curving downward uniformly. Posterior border furrow of medium depth and width. Occipital ring relatively long (sag.), sloped forward at approximately same angle as adjacent glabella. Occipital furrow of medium depth and width distally, shallowing and becoming nearly obsolete along medial half. Cranidium nearly smooth, some cranidia exhibit sparse, low granules, especially smaller cranidia. Low medial node visible on some occipital rings and absent on others.

Discussion. The small size of cranidia assigned to *Illtydaspis* sp. 1 suggests they are immature, and it would therefore be imprudent to define a formal species on the basis of this material. These cranidia occur at GSC locality 90672 with cranidia of *Illtydaspis ornata* sp. nov., which are mainly larger. However, one very small cranidium of *I. ornata* is present, presenting an opportunity to compare specimens of nearly equal size. When the specimen of *I.* sp. 1 shown in Plate 16, figure 1 is compared with the small specimen of *I. ornata* shown in Plate 17, figure 1, it can be seen that the cranidium of *I.* sp. 1 has a relatively longer (tr.), more broadly curved anterior border, a glabella that tapers forward less rapidly and has a lower and more truncated front, shallower glabellar furrows, an occipital furrow transverse rather than bowed forward and almost no (rather than heavy) granular ornamentation.

Illtydaspis? sp. 2

Plate 16, figures 16-21

Material. Five cranidia approximately 2.7 to 6.9 mm long, from GSC locality 90674.

Description. Internal cranidial mould has relatively high relief, length to width ratio is 2:3. Glabellar crestline evenly curved from back to front, sides straight, converging to broadly rounded front. Three pairs of shallow glabellar furrows present, posterior pair (S1) bifurcates with branches inclined slightly forward and moderately backward; second pair (S2) broadens inward, average direction is transverse; third pair (S3) expands inward and inclined slightly forward. Fourth pair of furrows (S4) faintly visible on upper surface of test only, very shallow, narrow and inclined strongly forward. Axial furrow of medium width and depth; preglabellar furrow narrow and shallow. Anterior border short (exsag.), strongly curved in cross-section, average slope is forward; posterior margin of border locally recurved to lengthen (sag.) border near axial midline. In front view, anterior border rises uniformly along distal third, curving uniformly along medial third. Anterior border furrow moderately wide and deep, narrowing and shallowing near axial midline. Eye ridges of medium height and width throughout. Palpebral lobes (broken) estimated to be slightly longer than one third glabellar length. Palpebral furrow broad (tr.) and of medium depth. Palpebral area convex (tr.), average slope outward, width six tenths maximum width of glabella. Posterior border narrow along proximal three fifths, remaining border widens (exsag.) and then rapidly narrows near distal end. Posterior border furrow wide and deep. Occipital ring of medium length and inclined forward; occipital furrow of medium depth and narrow at distal ends, expanding slightly toward middle. Anterior segment of facial suture broadly and uniformly curved, average direction parallel to sagittal midline. Ornamentation on internal cranidial mould consists of irregular grains on palpebral and posterior area of fixigena; venation on anterior area of fixigena; punctae on posterior border and axial furrow; upper surface of cranidium covered by closely spaced, medium sized granules.

Discussion. The more convex cranidium with a higher glabella, especially in front, narrower palpebral area and longer (exsag.) preglabellar field suggests this species lies between *Illtydaspis* and *Eoptychoparia*, and the generic assignment is therefore questionable (see also remarks under *Illtydaspis aphylla*).

Genus *Piaziella* Lochman, 1947

Piaziella Lochman, 1947, p. 69; Hupé, 1955, p. 126; Rasetti, 1955, p. 6; p. O237; Fritz, 1972, p. 42.

Type species. Ptychoparia pia Walcott, 1917, p. 93.

Discussion. Lochman's description of *Piaziella* is used in assigning the material described below.

Piaziella sp. 1

Plate 16, figures 12-15

Material. One cranidium approximately 6.1 mm long, from GSC locality 90672.

Discussion. Piaziella sp. 1 differs from *Piaziella pia* (Walcott, 1917) in the shallower axial and preglabellar furrows, narrower (tr.) palpebral and posterior areas, longer and wider palpebral lobes, and punctate rather than granular test. The anterior sections of the facial sutures are directed nearly straight ahead on *Piaziella* sp. 1, whereas in *Piaziella pia* they diverge forward. The difference in furrow depth of the two species can best be seen in comparing the specimen of *P. pia* of similar size and preservation illustrated by Fritz (1972, Pl. 19, fig. 12) with the present specimen of *P.* sp. 1.

Genus *Poulsenia* Resser, 1936

Poulsenia Resser, 1936, p. 26; Hupé, 1955, p. 127; Rasetti, 1955, p. 5; 1959, p. O237; Balashova, Ivshin, and Chernysheva, 1960, p. 106; Shaw, 1962, p. 343; Fritz, 1972, p. 41.

Type species. Solenopleura groenwalli Poulsen, 1927, p. 265.

Discussion. The material below is assigned to *Poulsenia* in accordance with Rasetti's 1959 description of the genus.

Poulsenia sp. 1

Plate 2, figure 10

Material. Six partial cranidia 1.6 to 7.2 mm long, from GSC locality 90652.

Description. Internal mould of cranidium has high relief, length to width ratio 4:7. Glabella slightly longer than width at base, sides nearly straight and converging to truncated front. Three pairs of shallow glabellar furrows visible; posterior pair (S1) narrow near glabellar sides, rapidly becoming very broad, branching with one branch inclined forward and other backward, inclination of furrow in general moderately backward; second pair (S2) narrow at glabellar edge, rapidly widening inward, two short branches developed, one inclined forward and the other backward, inclination of furrow as a whole slightly backward; third pair (S3) of medium width, short, inclined forward. Axial furrow deep, wide, and straight. Anterior border furrow has posterior margin gradational with adjacent fixigena, medial segment immediately precedes glabella; front margin steeply inclined against anterior border. Anterior border of nearly uniform width (exsag.) except for tapering near ends and slight, gradual lengthening (sag.) near middle; greatest elevation and curvature along posterior margin, remainder relatively flat and tilted steeply forward; in front view border is bowed strongly upward. Eye ridge low, of medium width. Palpebral lobes centred opposite glabellar midpoint, length slightly greater than three tenths glabellar length, tilted steeply inward. Palpebral furrow of medium depth, gradually expanding from ends to moderate width at midlength. Palpebral area one fifth as wide (tr.) as glabella at base, tilted strongly outward. Occipital furrow wide and deep; occipital ring well below level of adjacent glabella, tilted forward, presence or absence of spine or node unknown. Posterior border furrow deep and wide (exsag.); posterior border narrow (exsag.). Anterior section of facial suture directed forward from palpebral lobe and then curving inward. Surface of internal cranidial mould punctate.

Discussion. Internal cranidial moulds of *Poulsenia* sp. 1 differ from those of *Poulsenia* sp. 1 Fritz, 1972 in having a much narrower (tr.) palpebral area and a wider (exsag.) occipital furrow.

Poulsenia sp. 2

Plate 13, figure 7

Material. One external cranidial mould 2.7 mm long, from GSC locality 90671.

Description. Small cranidium has medium relief. Glabella relatively large, nearly rectangular, sides straight and converging gradually to broadly curved front. Four pairs of shallow glabellar furrows present, posterior pair (S1) bifurcating, branches transverse and inclined moderately backward; second pair (S2) bifurcating, branches inclined slightly forward and slightly backward; third pair (S3) inclined slightly forward; fourth pair (S4) short, inclined strongly forward. Axial furrow of medium depth,

narrow; preglabellar furrow shallow and narrow, passing close to, but not intersecting anterior border furrow. Anterior border flat, tilted slightly forward; anterior border furrow shallow and narrow. Eye ridges of medium width (exsag.) and very low. Palpebral lobes two fifths as long as glabella, centred just posterior to level of glabellar midpoint, tilted inward; palpebral furrow narrow and shallow. Palpebral area convex (tr.), width at posterior margin of area two fifths maximum width of glabella, average slope is horizontal. Posterior border expanding uniformly from proximal end to two-thirds mark (remainder broken); posterior border furrow narrow and of medium depth over same distance. Occipital ring expanding inward along distal quarter, medial half of uniform length (exsag.), tilted slightly forward, marked by low medial node. Occipital furrow narrow, distal quarter of medium depth, medial half shallow. Cranidium ornamented by very sparse, medium sized granules.

Discussion. Poulsenia sp. 2 resembles *Poulsenia* sp. 1 (herein) in its narrow (tr.) palpebral area, but differs in having less cranidial relief, a less convex (exsag.) anterior border, a shallower anterior border furrow and less forward convergence of the axial furrows.

Genus *Proliostracus* Poulsen, 1932

Proliostracus Poulsen, 1932, p. 48; Lochman, 1947, p. 68; Hupé, 1955, p. 126; Rasetti, 1955, p. 5; 1959, p. O237; Shaw, 1959, p. 474-487; 1962, p. 338; Fritz, 1972, p. 43.

Type species. Proliostracus strenuelliformis Poulsen, 1932, p. 49.

Discussion. The diagnosis given by Fritz (1972) is used in this paper.

Proliostracus ampliatus sp. nov.

Plate 2, figures 1-6

Material. Sixteen cranidia 1.6 to 4.5 mm long, from GSC locality 90650. Holotype, GSC 91716, GSC locality 90650.

Etymology. Latin, *ampliatus*, enlarge, expand, widen, referring to width of cranidium.

Description. Internal cranidial mould has medium relief, length to width ratio of medium (2.9 mm) specimens 6:10, of large specimens (4.3 mm) 8:10. Glabella cone-shaped, truncated in front, marked by three prominent (S1, S2, S3) and one faint (S4) pair of glabellar furrows. Posterior three pairs narrow and shallow near axial furrow, expanding proximally and attaining medium depth, anterior margin of two posterior pairs directed slightly backward, posterior pair bifurcates with posterior branches curving and terminating close to back margin of glabella; average direction of third pair is slightly forward; anterior pair very shallow and short. Axial furrow wide and deep, maximum width one third of maximum glabellar width; preglabellar furrow half as wide and of medium depth. Anterior border furrow of medium depth and width distally, shallowing to extinction where displaced by low, wide preglabellar ridge. Anterior border rises abruptly above adjacent border furrow, slightly convex in cross-section, average tilt is forward, width (sag.) three-quarters that of preglabellar field. Eye ridges uniformly narrow (exsag.), low to moderately raised, sharply defined. Palpebral area approximately as wide as axial furrow; palpebral furrow wide and shallow; palpebral lobes unknown (not preserved). In plan view, posterior border nearly straight, angled slightly backward, uniformly narrow; posterior border furrow wide and deep, expanding slightly distally. Occipital ring of medium length (sag.), well below height of glabella, lacking spine or (?)node (poor preservation); occipital furrow wide, of medium depth, front margin bowed forward. Ornamentation on internal mould consists of fine ridges on frontal area and adjacent fixigena, ridges extend longitudinally (exsag.) across anterior border furrow and onto border; medium and large cranidia exhibit well developed punctae.

Discussion. Cranidia of this species differ from those of *Proliostracus strenuelliformis* Poulsen, 1932 and *Proliostracus rosenkrantzi* Poulsen, 1932 in being wider, having deeper axial and glabellar furrows and a relatively small glabella. These differences readily separate this species from *Proliostracus annosus* Fritz, 1972.

Genus *Syspacephalus* Resser, 1936

Syspacephalus Resser, 1936, p. 28; Lochman, 1947, p. 64; Rasetti, 1951, p. 241; 1959, p. O237; Hupé, 1955, p. 126; Shaw, 1962, p. 337; Palmer, 1979, p. 115.

Type species. Agraulos charops Walcott, 1917.

Discussion. The generic descriptions by Lochman (1947) and Rasetti (1951) were used in assigning the species below to *Syspacephalus*.

Syspacephalus werneckensis sp. nov.

Plate 6, figures 9-12

Material. Four cranidia 1.3 to 3.7 mm long, from GSC locality 90666. Holotype, GSC 91772, GSC locality 90666.

Etymology. Species is named after the mountains in which it was discovered.

Description. Cranidium of medium height, length to width ratio of medium sized cranidium (3 mm) is slightly less than 2:3. Glabellar sides straight, converging forward, front moderately curved. Glabellar crestline slopes slightly forward along posterior two thirds, more steeply forward along anterior third. Three shallow pairs of glabellar furrows present, posterior pair (S1) bifurcates with branches inclined moderately and strongly backward; second pair (S2) bifurcates, branches transverse and inclined moderately backward; anterior pair (S3) short and transverse. Anterior border approximately as wide (exsag.) as preglabellar field, flat, sloped forward; in front view border rises uniformly from distal ends to low medial peak. Anterior border furrow of medium depth and width distally, shallowing to near extinction medially. Crestline from rear of glabellar to cranidial front slopes uniformly forward with only slight dip near border furrow position. Palpebral area half as wide as glabella at base, broadly curved (tr.), average dip is outward. Palpebral lobes centred opposite three-fifths point on glabellar midline, length slightly less than half that of glabella, poorly defined by very shallow palpebral furrow. Eye ridges of medium width (exsag.), very low and barely visible. Anterior segments of facial suture converging moderately forward from palpebral lobe to anterior border furrow. Posterior border nearly transverse and horizontal along proximal two thirds; distal third inclined downward and moderately forward, narrowing at expense of widening posterior border furrow. Occipital furrow of medium depth, narrow distally, broadening and shallowing along distal quarter, medial half of furrow very shallow. Occipital ring narrow along distal fifth, medial three fifths of medium length (exsag.), marked by medial node. Cranidium ornamented with fine punctae, internal moulds marked by medium punctae.

Discussion. Syspacephalus werneckensis differs from *Syspacephalus vapidus* Fritz, 1972 in the glabella, which tapers forward rapidly and is higher and more strongly curved (tr.) in cross-section near the axial midline. The preglabellar field, anterior border furrow, and occipital ring are longer (exsag.) and the axial furrows deeper and straighter rather than slightly convex. The posterior border exhibits an abrupt steepening of slope and the distal third is inclined more steeply downward as opposed to the broadly curved posterior border of *S. vapidus*.

Genus *Variopelta* Fritz, 1972

Variopelta Fritz, 1972, p. 47.

Type species. Variopelta laevis Fritz, 1972.

Discussion. No additional data were obtained from the present material to alter or add to the generic description by Fritz (1972).

Variopelta brevicervicata sp. nov.

Plate 2, figures 11-16

Material. Twelve cranidia 1.9 to 3.7 mm long, from GSC locality 90653. Holotype, GSC 91723, GSC locality 90653.

Etymology. Variopelta with a short (for genus) occipital or neck ring (Latin, *brevi*, short; *cervix*, neck).

Description. Cranidium relatively smooth, length to width ratio slightly greater than 3:4. Glabellar sides broadly convex, converging forward to broadly curved front margin; in side view highest point near posterior end; forward curvature uniform to low glabellar front. Crestline dips only slightly at occipital furrow and curves backward broadly and gently downward along occipital ring. Three pairs of shallow glabellar furrows present, all expanding inward; posterior pair (S1) barely visible, second pair (S2) inclined slightly backward and third pair (S3) slightly forward. Axial and preglabellar furrows narrow and of medium depth. Frontal area and adjacent fixigena nearly smooth, broadly curved in cross-section (exsag.), average slope is moderately forward. Palpebral area slopes slightly inward, maximum width half maximum width of glabella. Eye ridge low, poorly defined; palpebral furrows narrow, shallow; palpebral lobe narrow, length three sevenths that of glabella, centred well ahead of glabellar midpoint. Posterior section of facial suture inclined steeply backward from palpebral lobe to posterior border furrow. Posterior border furrow shallow and narrow proximally, of medium depth and width medially, shallow distally. Posterior border directed transversely, widening uniformly with distance from axis. Occipital furrow very shallow, narrow near distal ends, medial portion of

medium width. Occipital ring long (sag.), strongly and uniformly curved along posterior margin, marked by low medial node.

Internal cranidial moulds exhibit greater relief, especially in depth and width of furrows. Glabellar furrows as previously described, but posterior pair (S1) better defined, exhibiting bifurcation with short, transverse anterior branch and strongly inclined posterior branch; additional pair (S4) of short, shallow furrows visible. Axial furrow wide and deep; preglabellar furrow narrower and of medial depth. Anterior border furrow faintly visible, delineating anterior border half as long (sag.) as preglabellar field. Ocular ridges very narrow and sharply defined. Posterior border furrow wide and deep. Ornamentation lacking on outer surface of test; internal moulds exhibit punctae.

Discussion. *Variopelta brevicervicata* differs from *Variopelta laevis* Fritz, 1972 in having a shorter occipital ring with a rounded rather than a pointed posterior margin, deeper cranidial furrows, and an anterior border, which is clearly defined on internal cranidial moulds. *Variopelta brevicervicata* differs from *Variopelta* sp. 1 in having a higher, relatively larger glabella, shallower axial furrows, a deeper preglabellar furrow and a shorter frontal area with less forward slope.

Variopelta sp. 1

Plate 3, figure 1

Material. Four cranidia 2.6 to 4.0 mm long, from GSC locality 90655.

Description. Cranidium generally smooth, fixigena low, cranidial axis attains medium height. Glabellar sides slightly convex, converging forward, front truncated; in side view glabellar crestline curves evenly forward from back to low glabellar front; toward rear, crestline offset slightly downward at occipital furrow, then curving moderately backward over occipital ring. Three pairs of faintly defined glabellar furrows, each pair expanding toward axial midline, posterior two pairs (S1, S2) inclined backward, anterior pair (S3) inclined forward. Axial furrows of medium width and depth; preglabellar furrow shallow and narrow. Frontal area and adjacent fixigena slope uniformly and gradually forward. Anterior border furrow obsolete. Eye ridges uniformly faint and narrow, slightly better defined on small (<2.7 mm) cranidia. Palpebral lobes narrow (tr.), tilted inward, half as long as glabella, and centred short distance ahead of glabellar midpoint; palpebral furrow shallow and narrow. Posterior border furrow very narrow and shallow proximally, narrow but deeper distally; posterior border directed slightly backward, expanding distally (length unknown, broken). Occipital furrow of medium width, shallow throughout. Occipital ring long (sag.), tapering backward to blunt point. Cranidial surface marked by fine punctae; faint terrace lines on anterior margin of one cranidium, not visible on other specimens.

Discussion. Cranidia of this species differ from those of *Variopelta laevis* Fritz, 1972 in having a thinner test, less curvature on the frontal area (sag.), and a much shallower preglabellar furrow.

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PLATES 1 to 17

PLATE 1

Figures 1-3. Photographs of stratigraphic section measured through Illtyd Formation.

1. View from helicopter looking southwest at Illtyd section. Lower part of section was measured in gully at "a". Base and top of large carbonate buildup are at "b" and "c". Arrow at "d" marks middle of unit 6, just below GSC locality 90673 (see Fig. 2 for localities). Arrow at "e" marks top of Illtyd Formation and probably marks Lower – Middle Cambrian boundary as well.

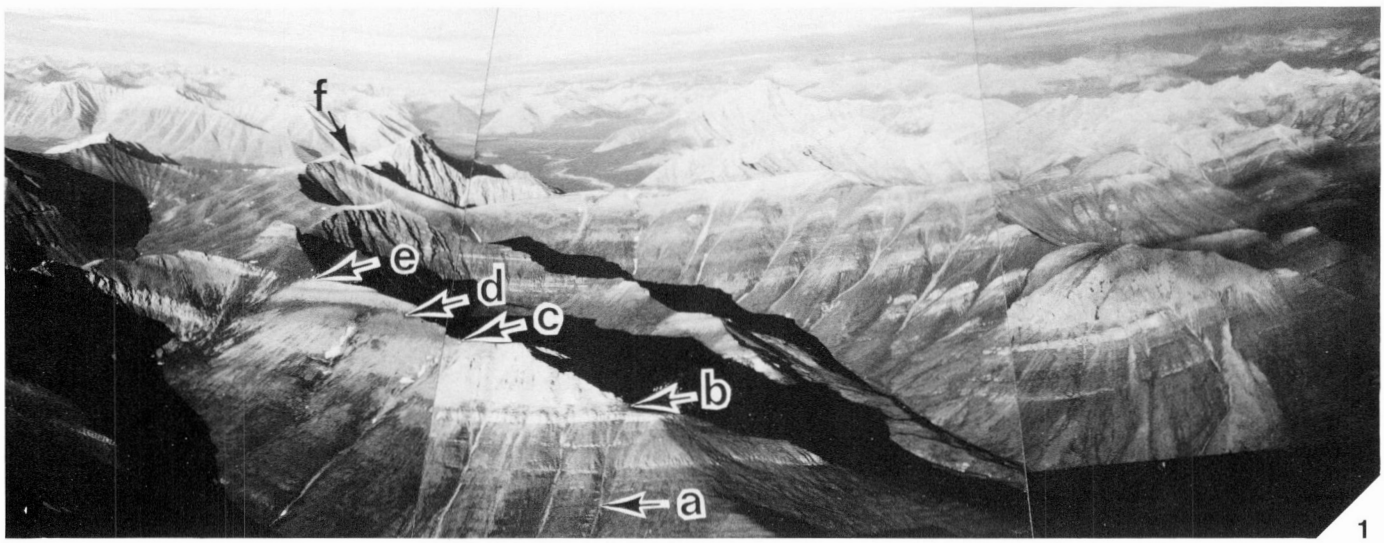
2. View looking southwest at upper part of Illtyd section from top of large carbonate buildup. GSC locality 90668 and campsite (note tent) is at "a", base of resistant outcrop at 789 m level is at "b", top of Illtyd Formation in section is at "c" and on nearby slope at "d".

3. View looking west at base of section. Arrow at "a" marks the approximate level of unconformity between Precambrian quartzite and base of Illtyd Formation. Arrow at "b" marks base of large carbonate buildup.

Figures 4-6. *Salterella maccullochi* (Murchison) in thin sections from GSC locality 90654.

4. Large specimens at lower right and lower left are in transverse section; recrystallized outer wall is light grey; inner laminar cone is dark grey. Note concentric rings in inner laminar cone reflecting alternating composition of laminae. Black central dot in specimen at lower left is central tube. GSC 91711, x 29.7.

5, 6. Large specimens in centre of each figure are in near-axial section. Light grey, broadly curved fragments are trilobite tests. GSC 91712 and GSC 91713, x 14.6.



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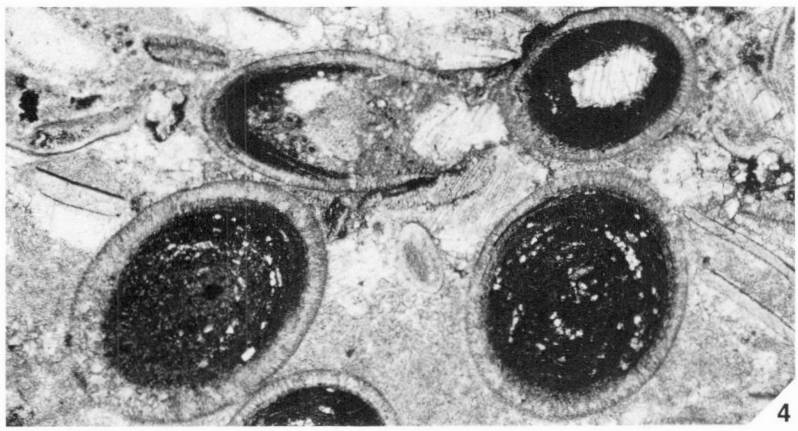

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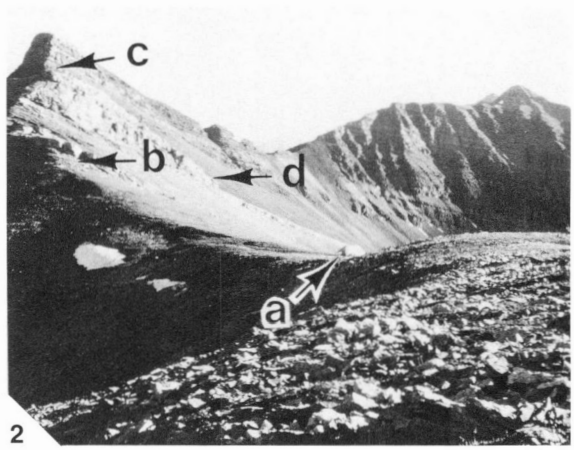

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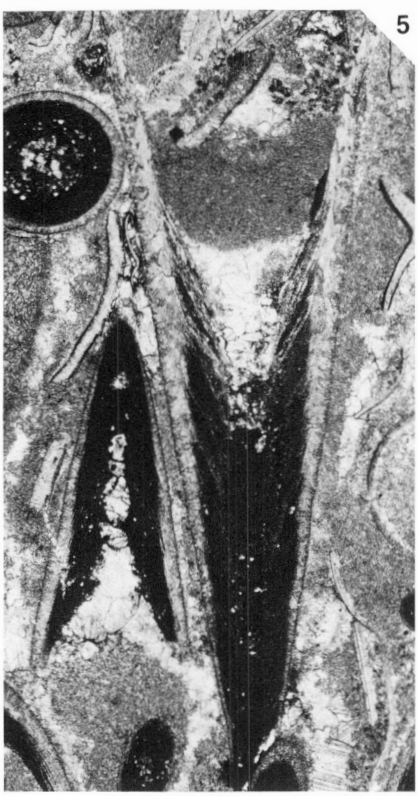

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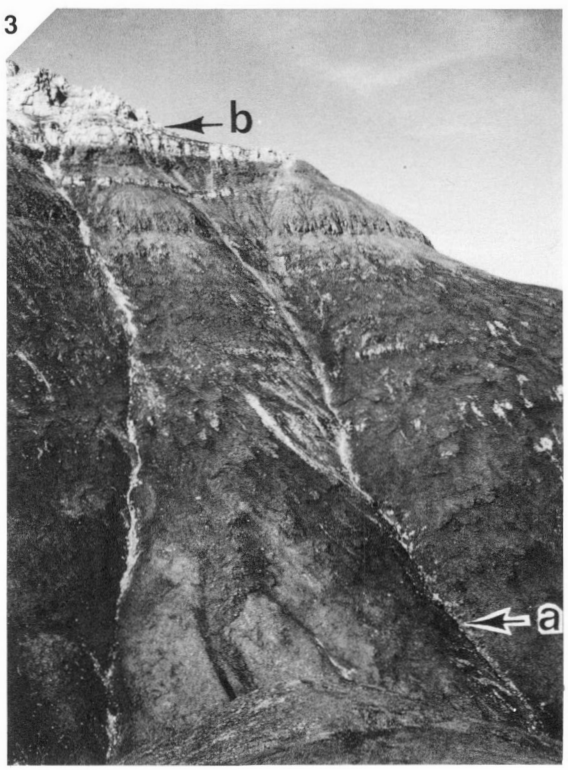

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PLATE 2

Figures 1-6. *Proliostracus ampliatus* sp. nov., GSC loc. 90650.

1. Cranidium, GSC 91714, x 12.0.
2. Cranidium, GSC 91715, x 12.0.
3. Holotype, internal cranidial mould, GSC 91716, x 9.2.
4. Internal cranidial mould, GSC 91717, x 10.0.

5, 6. Internal cranidial mould, side and plan views, GSC 91718, x 10.0.

Figures 7, 8. *Olenellus* sp. 1, GSC loc. 90653.

7. Internal cepahlic mould, GSC 91719, x 3.5.
8. Latex cast of outer surface of cephalon, GSC 91720, x 6.2.

Figure 9. *Olenellus* sp. 2(?) Fritz, 1972, cephalon, GSC 91721, x 6.0, GSC loc. 90651.

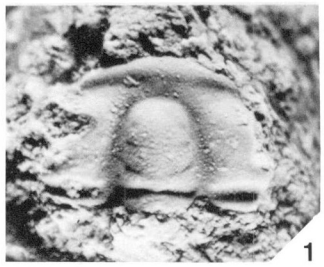
Figure 10. *Poulsenia* sp. 1, latex cast of internal cranidial surface, GSC 91722, x 6.5, GSC loc. 90652.

Figures 11-16. *Variopelta brevicervicata* sp. nov., GSC loc. 90653.

11, 12. Internal cranidial mould, plan and side views, holotype GSC 91723, x 13.0.

13. Cranidium, GSC 91724, x 13.0.
14. Partially exfoliated cranidium, GSC 91725, x 13.0.

15, 16. Cranidium, plan and side views, GSC 91726, x 13.0.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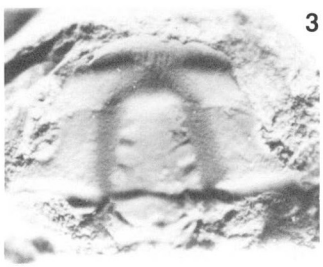
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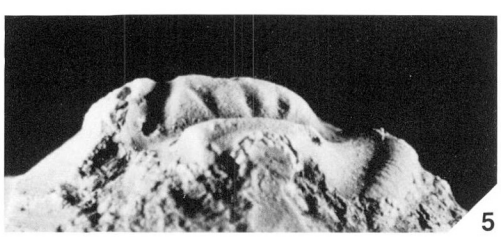
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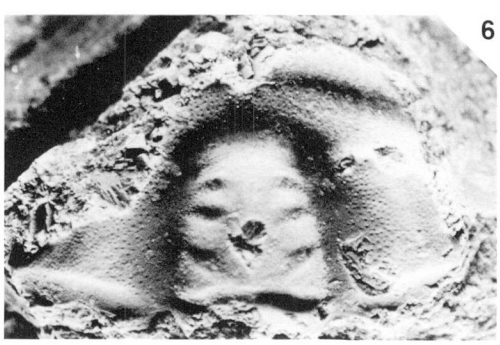
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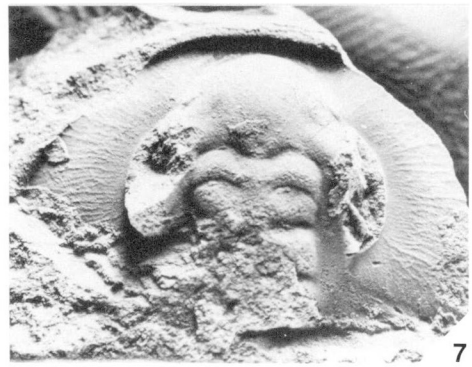
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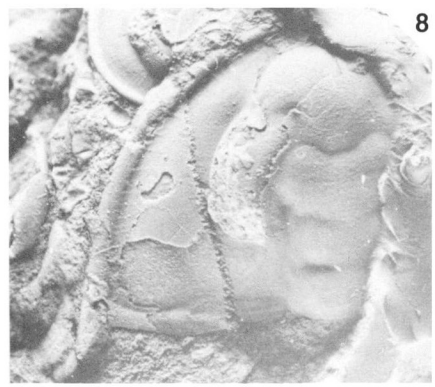
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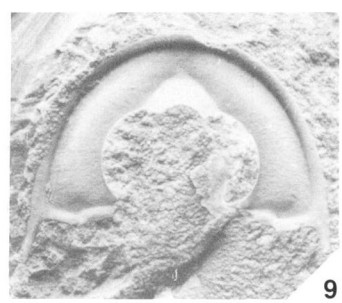
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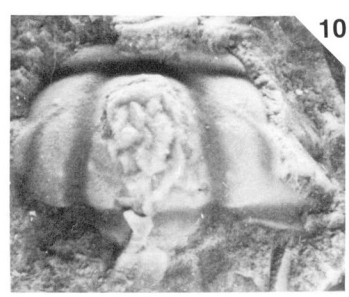
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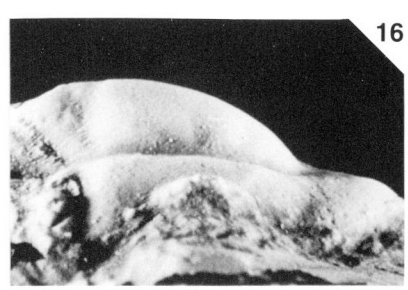
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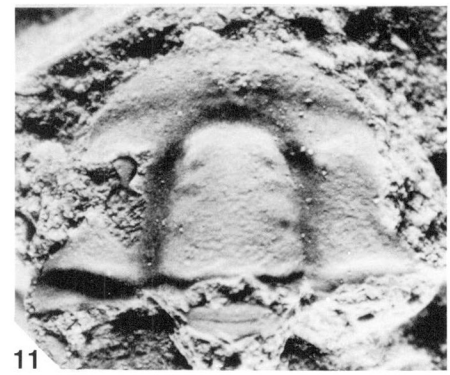
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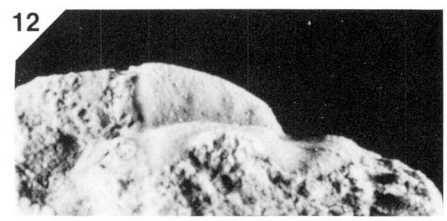
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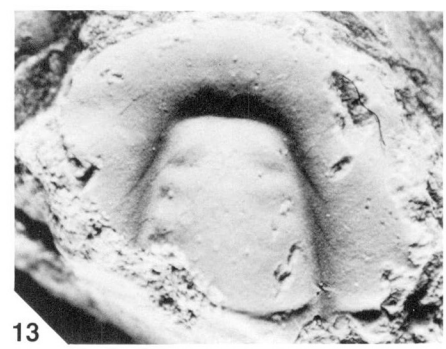
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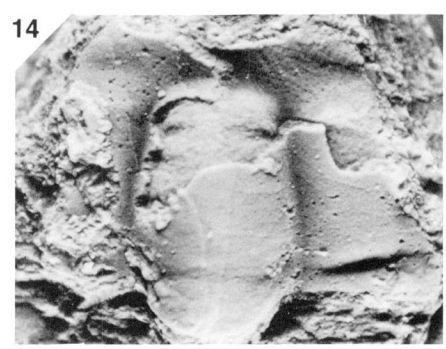
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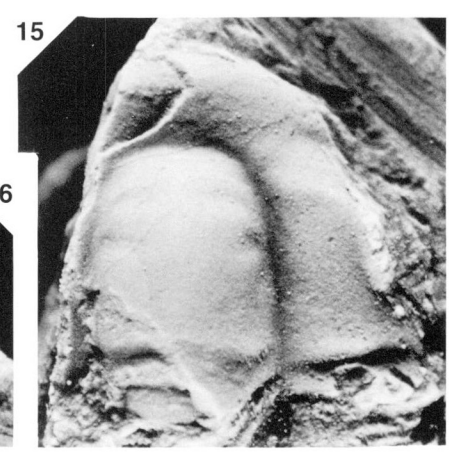
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PLATE 3

Figure 1. *Variopelta* sp. 1, cranidium, GSC 91727, x 9.7, GSC loc. 90655.

Figure 2. *Wanneria* sp. 1, cephalon, GSC 91728, x 5.9, GSC loc. 90656.

Figures 3-6. *Bonnia* sp. 1, GSC loc. 90657.

3, 4. Cranidium, side and plan views, GSC 91729, x 8.0.

5, 6. Pygidium, plan and side views, GSC 91730, x 10.0.

Figures 7-15. *Bonnia laterispina* Fritz, 1972, GSC loc. 90658.

7. Cranidium, GSC 91731, 13.7.

8. Cranidium, GSC 91732, x 9.8.

9. Cranidium, GSC 91733, x 6.7.

10-12. Cranidium, front, side, and plan views, GSC 91734, x 5.8.

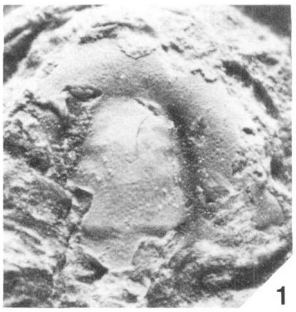
13, 14. Pygidium, plan and side views, GSC 91735, x 10.8.

15. Pygidium, GSC 91736, x 8.3.

Figures 16, 17. *Wanneria logani* (Walcott, 1910), GSC loc. 90658.

16. Cephalon, GSC 91737, x 10.0.

17. Latex cast of external cephalic surface, GSC 91738, x 7.3.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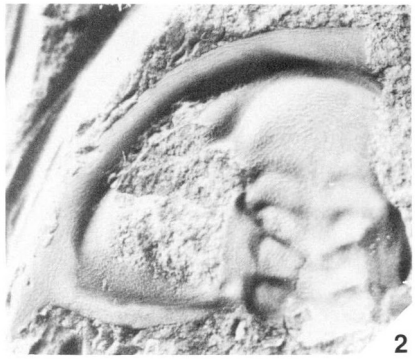
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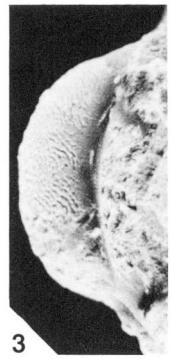
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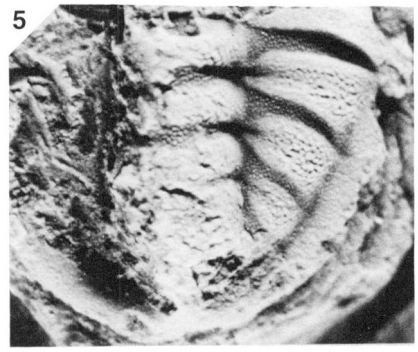
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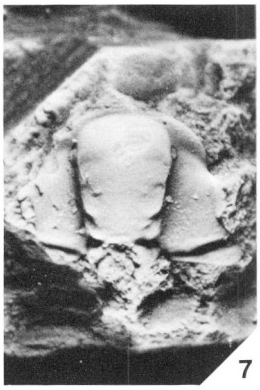
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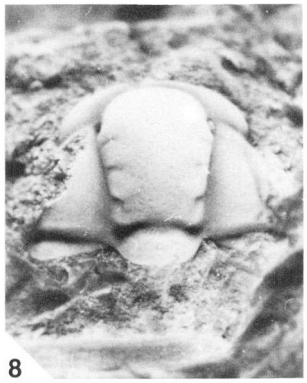
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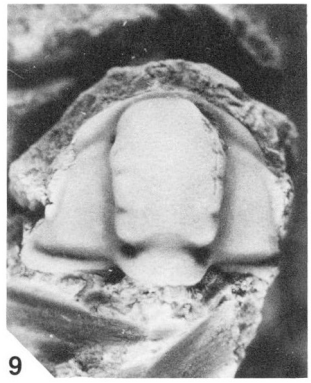
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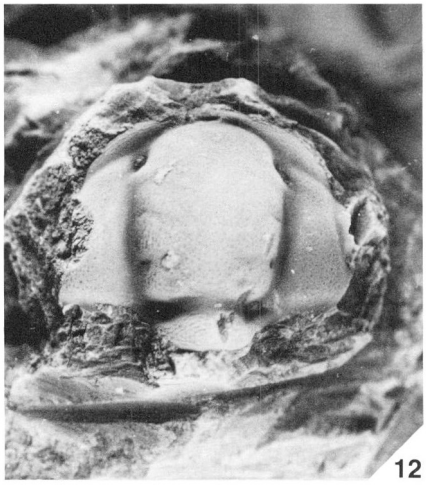
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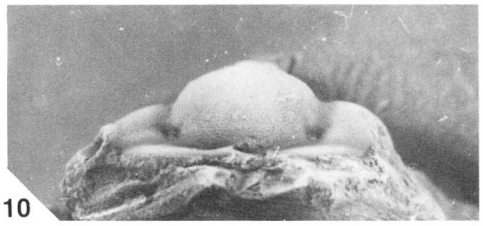
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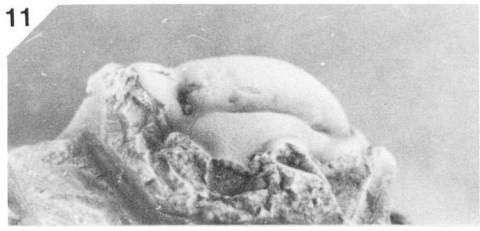
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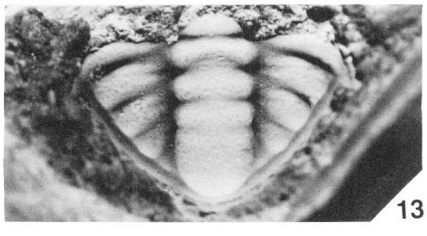
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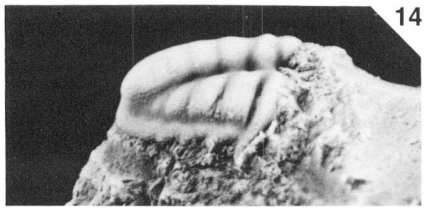
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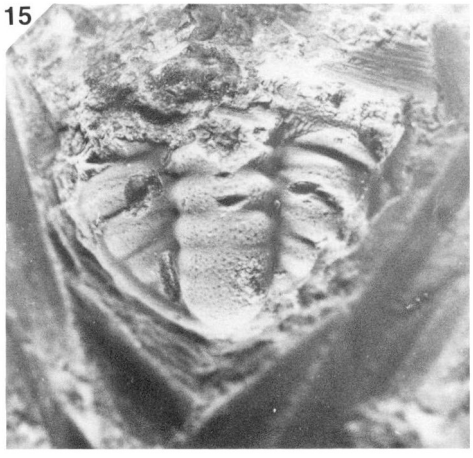
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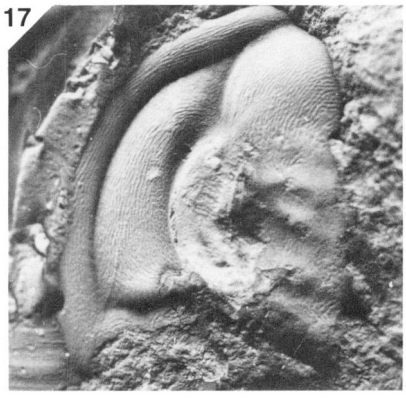
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PLATE 4

Figures 1-15. *Bonnia quadrata* sp. nov., GSC loc. 90660.

1. Cranidium, GSC 91739, x 13.2.
2. Cranidium, GSC 91740, x 11.5.
3. Cranidium, GSC 91741, x 11.5.
4. Cranidium, GSC 91742, x 11.5.
5. Cranidium, GSC 91743, x 11.5.

6-8. Holotype, cranidium, plan, front, and side views, GSC 91744, x 11.5.

9-11. Pygidium, plan, rear, and side views, GSC 91745, x 13.0.

12-14. Pygidium, plan, rear, and side views, GSC 91746, x 13.0.

15. Pygidium, GSC 91747, x 11.5.

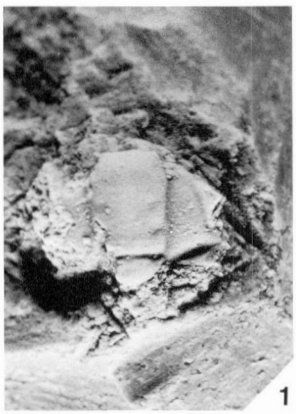
Figures 16-23. *Bonnia decora* sp. nov., GSC loc. 90661.

16-18. Holotype, cranidium, plan, front, and side views, GSC 91748, x 8.3.

19. Pygidium, GSC 91749, x 8.3.

20. Latex cast of external pygidial surface, GSC 91750, x 8.3.

21-23. Pygidium, plan, rear, and side views, GSC 91751, x 8.3.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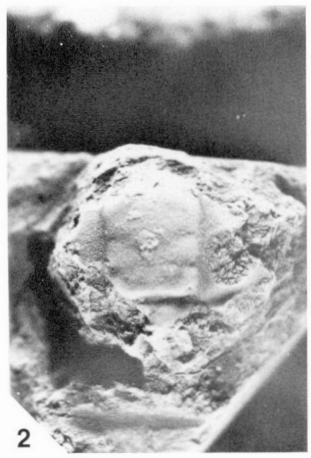
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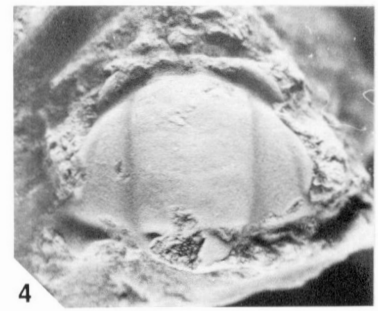
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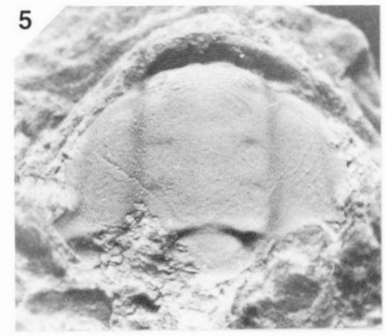
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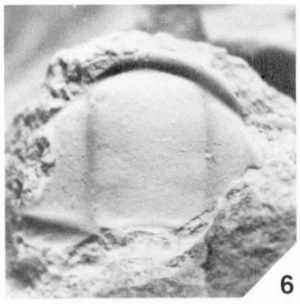
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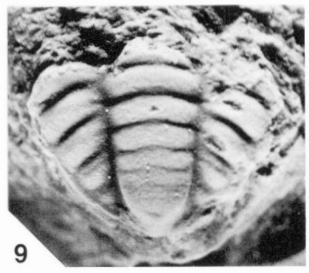
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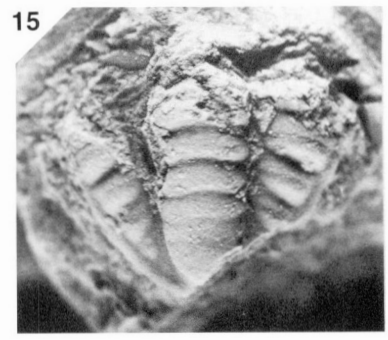
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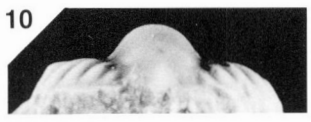
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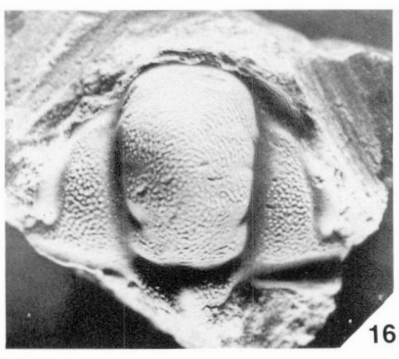
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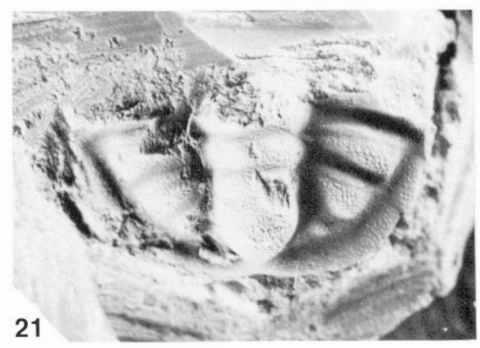
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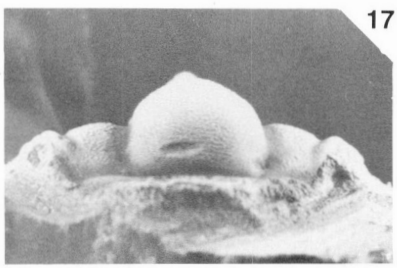
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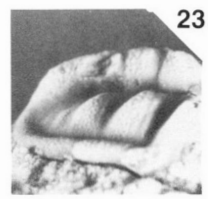
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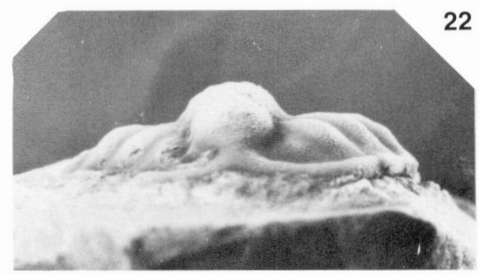
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PLATE 5

Figures 1-6. *Bonnia*? sp. 2, GSC loc. 90662.

1, 2. Internal cranidial mould, plan and side views, GSC 91752, x 6.0.

3. Latex cast of external pygidial surface, GSC 91753, x 7.0.

4-6. Internal pygidial mould, plan, rear, and side views, GSC 91754, x 7.0.

Figures 7-17. *Bonnia carnata* sp. nov., GSC loc. 90663.

7. Cranidium, GSC 91755, x 8.6.

8. Cranidium, GSC 91756, x 8.6.

9. Cranidium, GSC 91757, x 8.2.

10. Holotype, partially exfoliated cranidium, GSC 91758, x 8.0.

11-13. Cranidium, plan, front, and side views, GSC 91759, x 8.0.

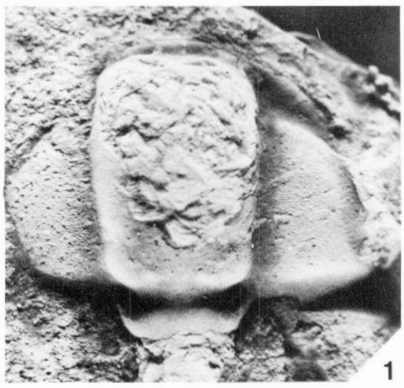
14-16. Internal pygidial mould, plan, rear, and side views, GSC 91760, x 10.0.

17. Pygidium, GSC 91761, x 9.0.

Figures 18, 19. *Bonnia*? sp. 3, GSC loc. 90663.

18. Pygidium, GSC 91762, x 8.5.

19. Internal pygidial mould, GSC 91763, x 4.7.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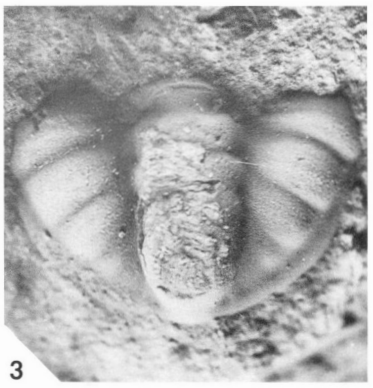
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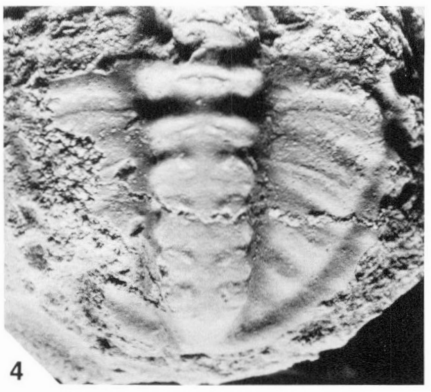
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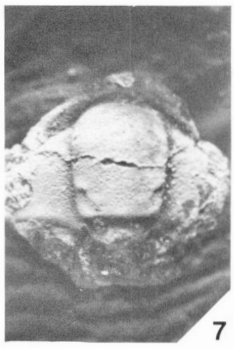
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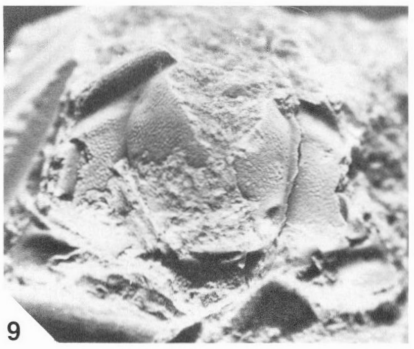
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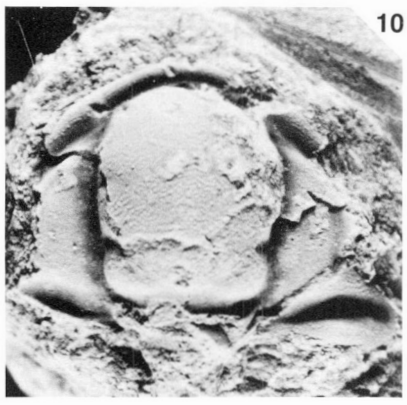
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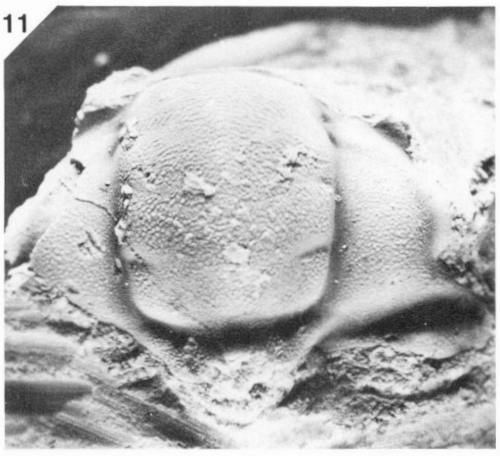
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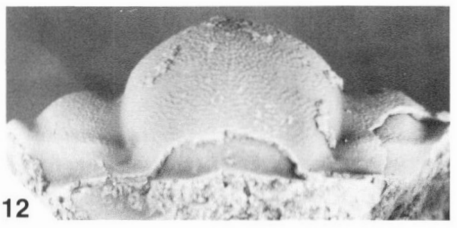
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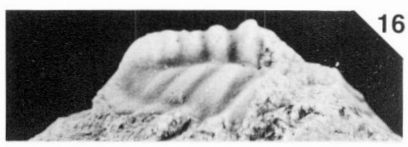
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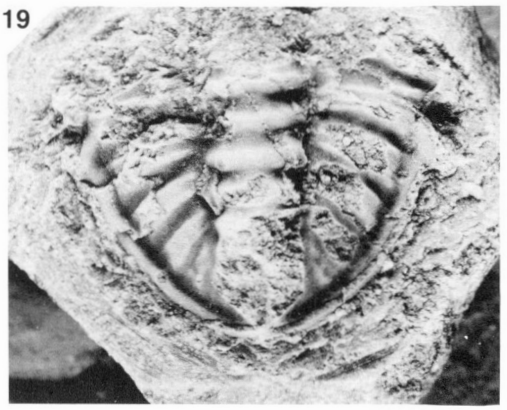
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PLATE 6

Figures 1-8. *Olenellus* sp. 2, GSC loc. 90664.

1. Partially exfoliated cephalic fragment, GSC 91764, x 2.8.
2. Cephalic fragment, GSC 91765, x 2.1.
3. Cephalic fragment, GSC 91766, x 2.3.
4. Partial glabella, GSC 91767, x 2.3.
5. Internal mould of partial glabella, GSC 91768, x 2.3.
6. Partially exfoliated cephalic fragment, GSC 91769, x 2.3.
7. Partially exfoliated cephalic fragment, GSC 91770, x 2.3.
8. Internal mould of cephalic fragment, GSC 91771, x 2.3.

Figures 9-12. *Syspacephalus werneckensis* sp. nov., GSC loc. 90666.

9-10. Holotype cranidium, plan and side views, GSC 91772, x 4.1.

11. Cranidium, GSC 91773, x 4.1.
12. Partially exfoliated cranidium, GSC 91774, x 4.1.

Figures 13-18. *Zacanthopsis expansa* sp. nov., GSC loc. 90666.

13. Cranidium, GSC 91775, x 10.7.
14. Holotype, cranidium, GSC 91776, x 11.3.
15. Cranidium, GSC 91777, x 12.8.

16-18. Cranidium, plan, front, and side views, GSC 91778, x 7.1.

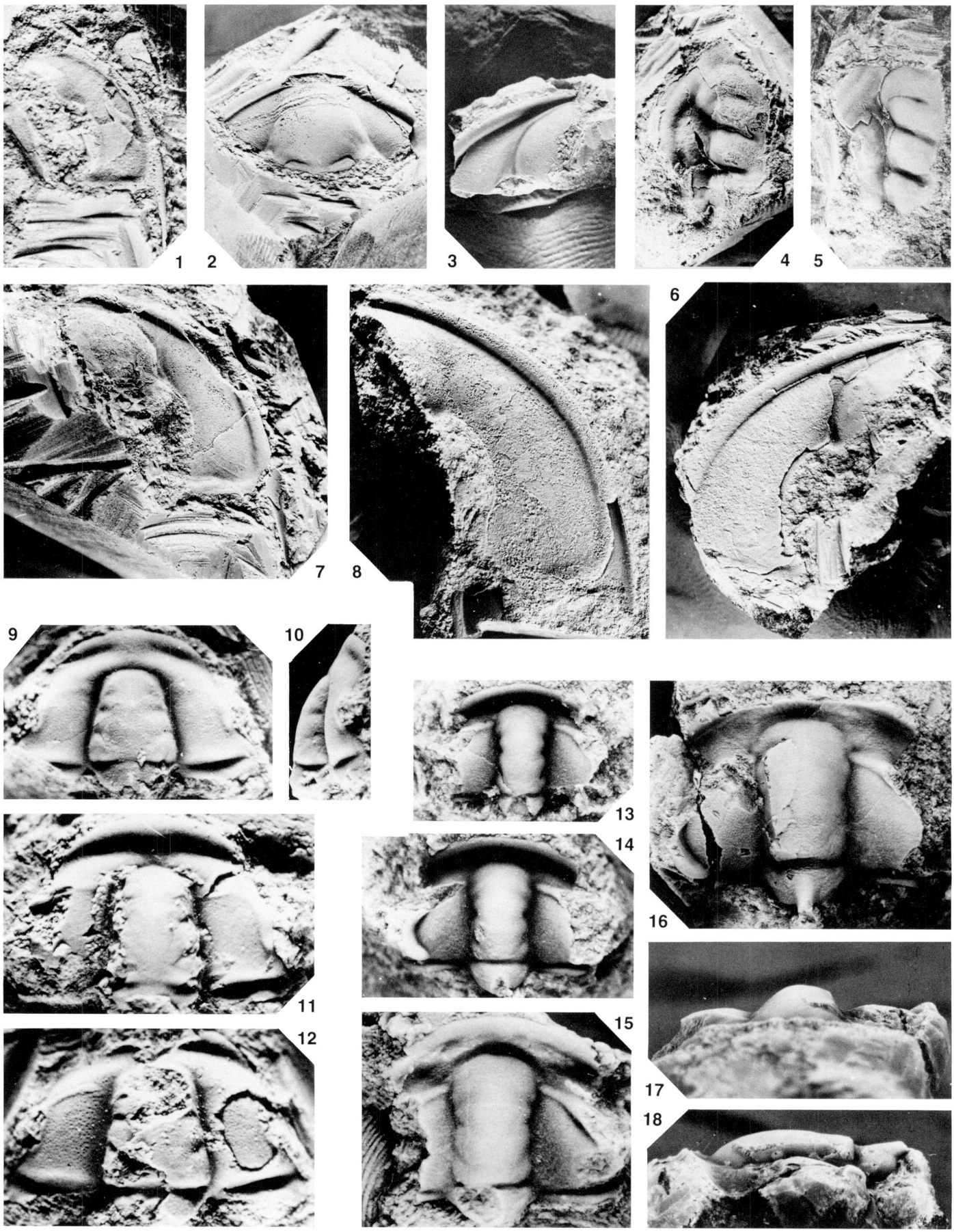
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PLATE 7

Figures 1-12. *Bonnia columbensis* Resser, 1936, GSC loc. 90665.

1. Cranidium, GSC 91779, x 8.7.
2. Cranidium, GSC 91780, x 8.7.
3. Cranidium, GSC 91781, x 4.8.
4-6. Cranidium, plan, front, and side views, GSC 91782, x 9.2.
7-8. Pygidium, plan and rear views, GSC 91783, x 8.2.
9-11. Cranidium, plan, front, and side views, GSC 91784, x 7.3.
12. Latex mould of internal pygidial surface, GSC 91785, x 5.9.

Figures 13-18. Dolichometopid sp. 1, GSC loc. 90666.

13. Cranidium, GSC 91786, x 21.9.
14. Cranidium, GSC 91787, x 11.3.
15. Cranidium, GSC 91788, x 11.3.
16, 17. Cranidium, plan and side views, GSC 91789, x 6.8.
18. Partial pygidium, GSC 91790, x 6.8.

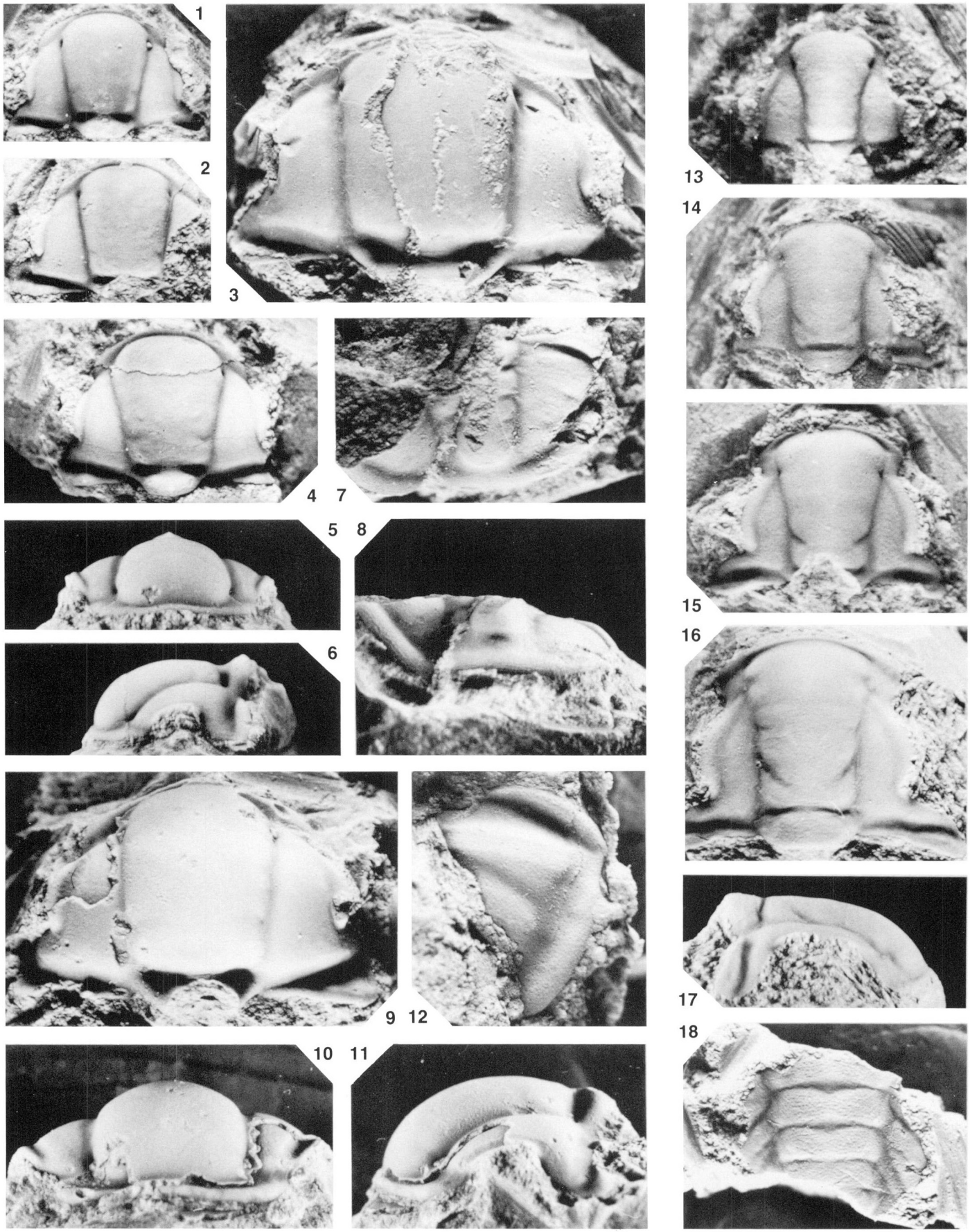
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PLATE 8

Figures 1-20. *Bonnia columbensis* Resser, 1936, GSC loc. 90666.

1. Cranidium, GSC 91791, x 12.0.
2. Cranidium, GSC 91792, x 11.1.
3-5. Cranidium, plan, front, and side views, GSC 91793, x 10.0.
6. Cranidium, GSC 91794, x 10.8.
7. Pygidium with thoracic segments attached, GSC 91795, x 12.5.
8. Pygidium with thoracic segment attached, GSC 91796, x 11.0.
9. Pygidium, GSC 91797, x 8.4.
10. Pygidium, GSC 91798, x 6.7.
11. Latex cast of outer pygidial surface, GSC 91799, x 8.8.
12. Pygidium, GSC 91800, x 9.4.
13. Pygidium, GSC 91801, x 8.1.
14. Pygidium, GSC 91802, x 7.6.
15-17. Pygidium, plan, side, and rear views, GSC 91803, x 5.9.
18. Hypostome, GSC 91804, x 9.2.
19. Nearly exfoliated pygidium, GSC 91805, x 5.7.
20. Pygidium, GSC 91806, x 5.7.

Figures 21-28. *Illtydaspis quartetensis* gen. et sp. nov., GSC loc. 90668.

21. Cranidium, GSC 91807, x 10.4.
22. Cranidium, GSC 91808, x 10.4.
23. Cranidium, GSC 91809, x 9.5.
24-26. Holotype, cranidium, plan, front, and side views, GSC 91810, x 9.5.
27. Partially exfoliated cranidium, GSC 91811, x 10.4.
28. Internal cranidial mould, GSC 91812, x 9.5.

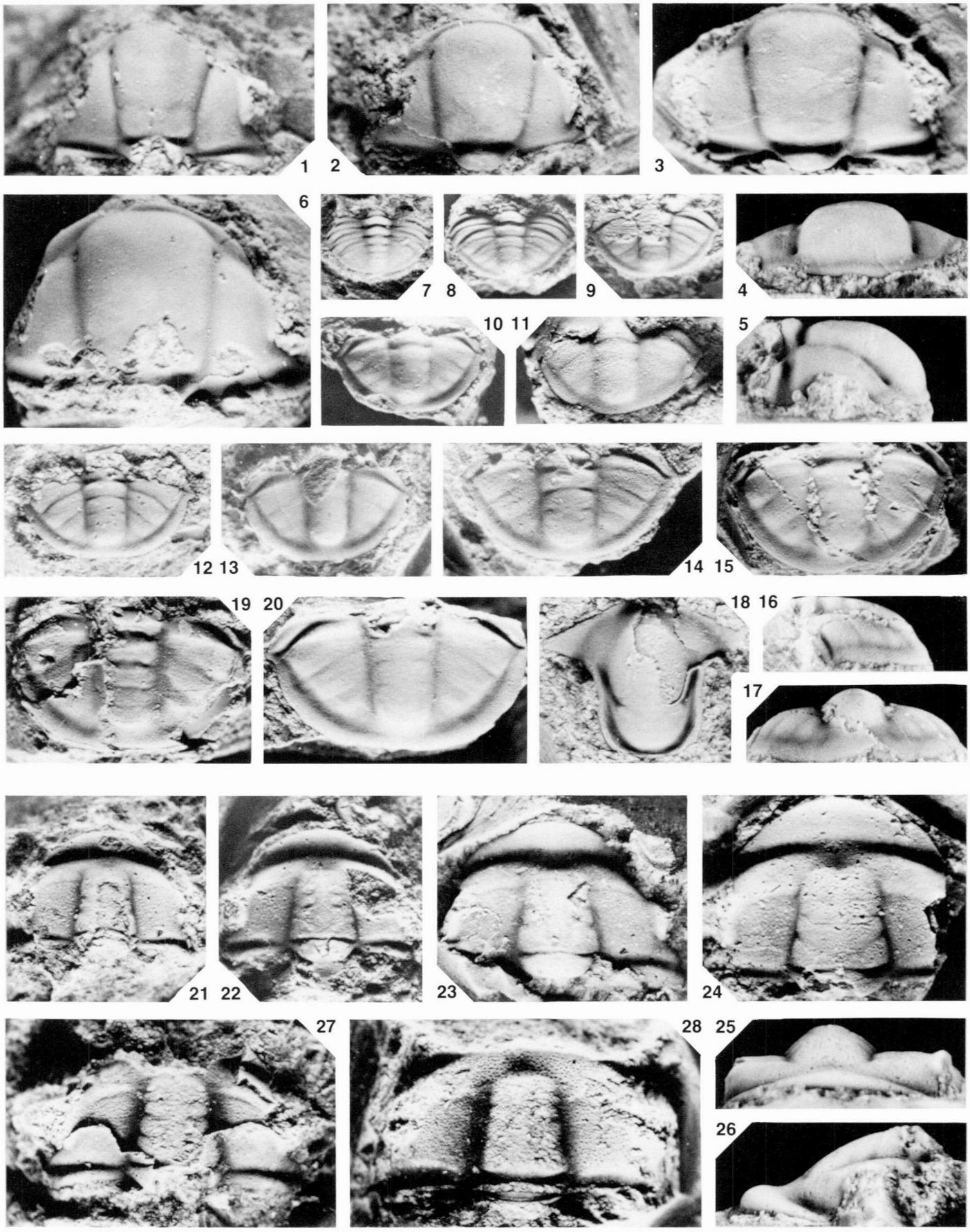
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PLATE 9

Figures 1-15. *Bonnia columbensis* Resser, 1936, GSC loc. 90667.

1. Cranidium, GSC 91813, x 9.4.
2. Cranidium, GSC 91814, x 8.2.
3. Cranidium, GSC 91815, x 8.2.
4. Cranidium, GSC 91816, x 7.7.
5. Cranidium with abnormal indentation developed on glabella, GSC 91817, x 5.8.
6. Cranidium, GSC 91818, x 3.8.

7, 8. Cranidium, plan and side views, GSC 91819, x 3.4.

9. Pygidium, GSC 91820, x 9.5.
10. Pygidium, GSC 91821, x 9.5.
11. Pygidium, GSC 91970, x 6.2.

12-14. Internal pygidial mould, plan, rear, and side views, GSC 91822, x 3.8.

15. Pygidium, GSC 91823, x 3.8.

Figures 16-18. *Antagmus ducketti* sp. nov., GSC loc. 90667.

16, 18. Holotype, cranidium, side and plan views, GSC 91825, x 9.5.

17. Cranidium, GSC 91824, x 10.1.

Figures 19-23. *Zacanthopsis expansa* sp. nov., GSC loc. 90667.

19. Cranidium, GSC 91826, x 10.0.
20. Latex cast of external cranidial mould, GSC 91828, x 10.0.

21, 22. Cranidium, plan and side views, GSC 91827, x 6.6.

23. Partially exfoliated pygidium, GSC 91829, x 9.1.

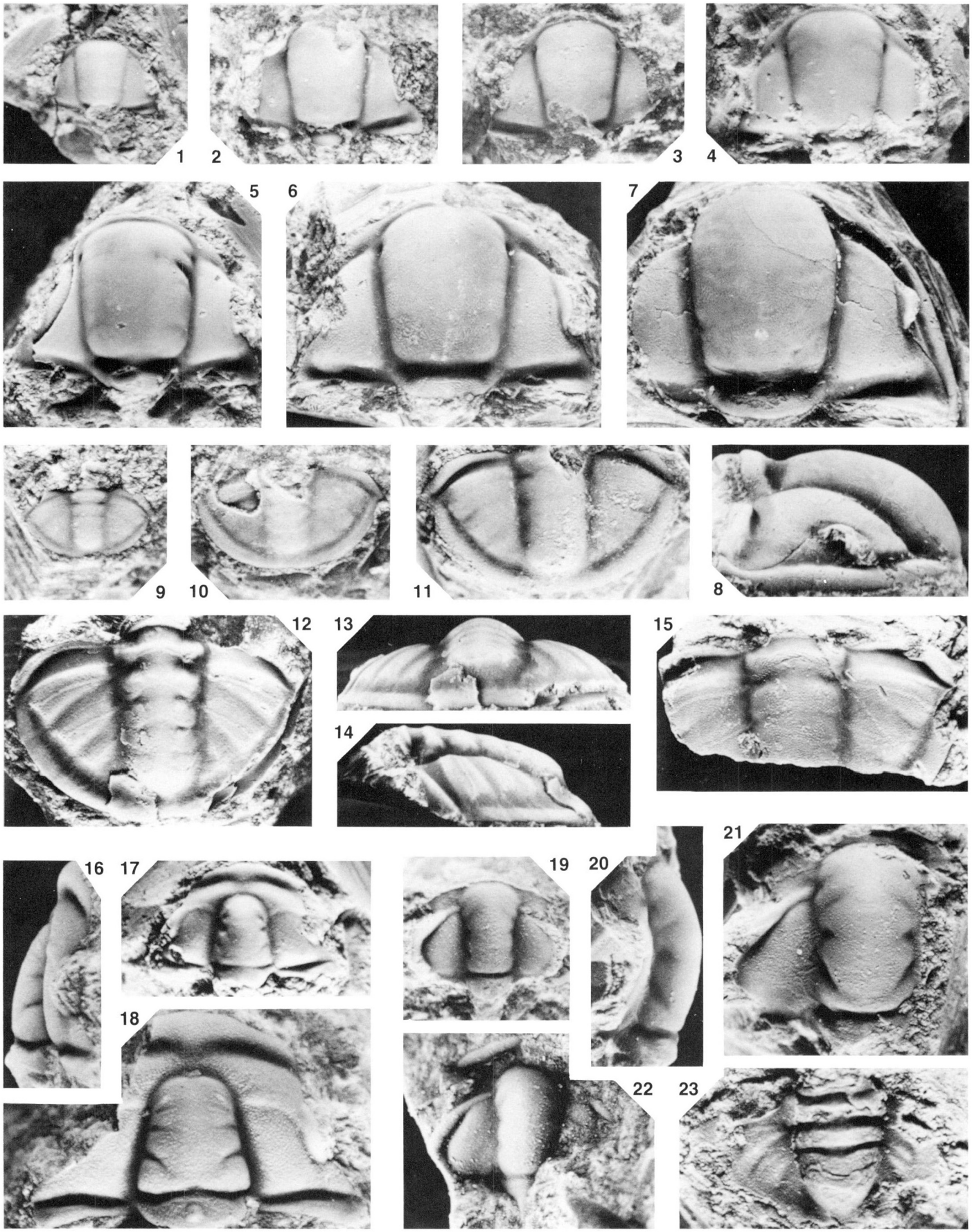
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PLATE 10

Figures 1-13. *Olenellus sphaerulosus* sp. nov., GSC loc. 90669.

1. Latex cast of partially exfoliated cephalic mould, GSC 91830, x 2.9.

2, 3. Partially exfoliated cephalon, plan and side views, GSC 91831, x 2.9.

4. Internal cephalic mould, GSC 91832, x 2.4.

5. Latex cast of partially exfoliated cephalic mould, GSC 91833, x 2.4.

6. Cephalic mould, mainly exfoliated, GSC 91834, x 2.7.

7-9. Latex cast of holotype, partially exfoliated cephalic mould, plan, front, and side views, GSC 91835, x 2.7.

10. Internal cephalic mould, GSC 91836, x 2.4.

11. Internal cephalic mould, GSC 91837, x 2.4.

12. Internal cephalic mould, GSC 91838, x 2.4.

13. Internal cephalic mould, GSC 91839, x 2.4.

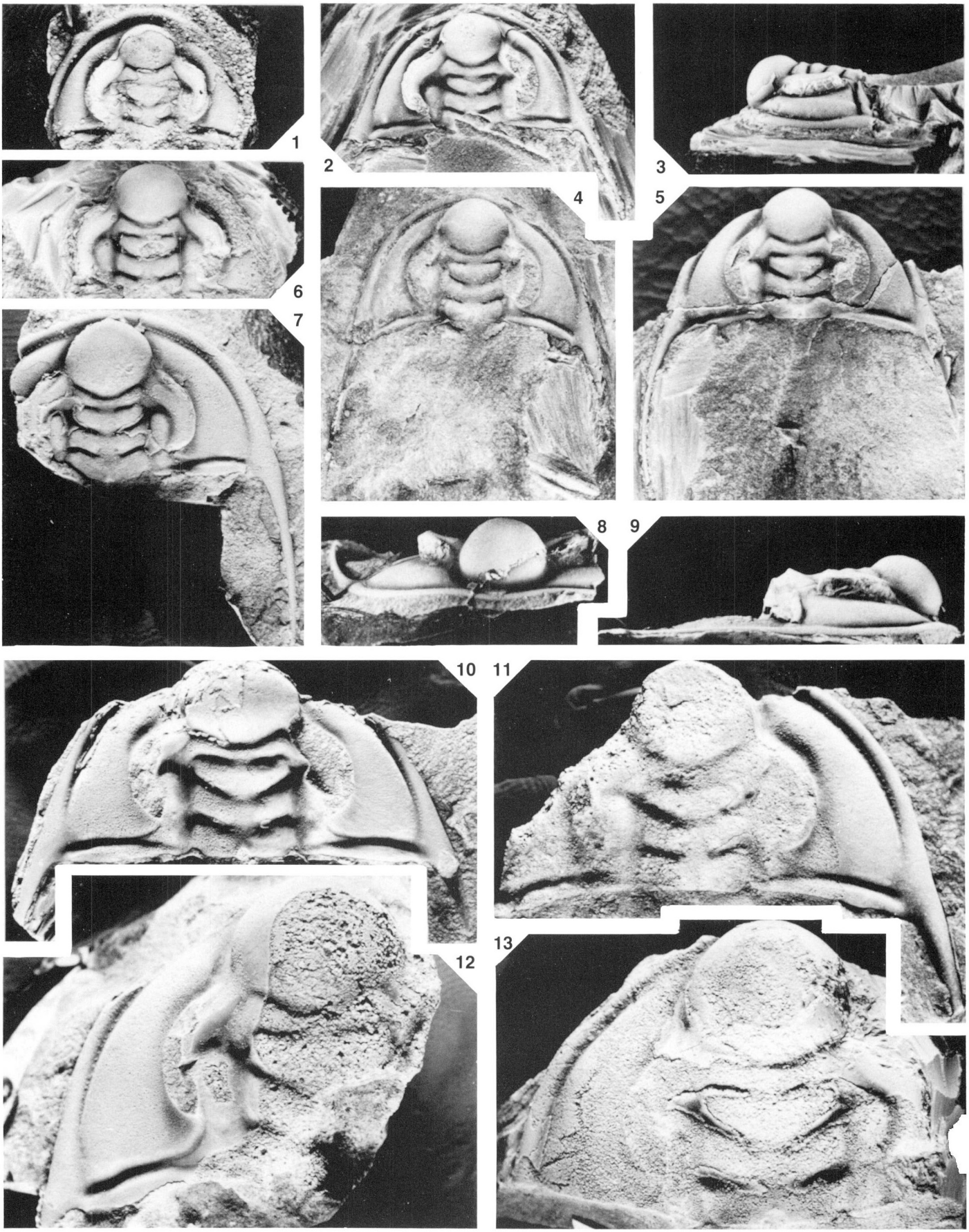
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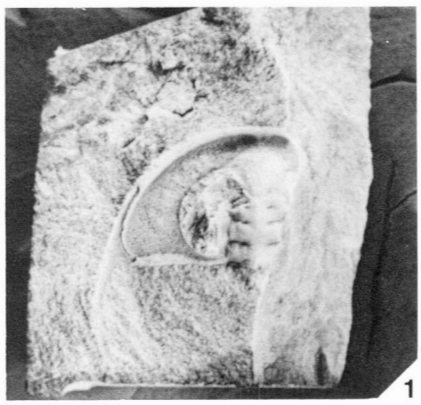
PLATE 11

Figures 1-11. *Olenellus parvofrontatus* sp. nov., GSC loc. 90669.

1. Internal cephalic mould, GSC 91840, x 2.1.
2. Latex cast of external cephalic mould, GSC 91841, x 2.1.
3-6. Latex cast of holotype, external cephalic mould, plan, side, front, and oblique views, GSC 91842, x 2.1.
7. Partially exfoliated cephalon, GSC 91843, x 2.1.
8. Latex cast of external cephalic mould, GSC 91844, x 2.1.
9, 10. Latex cast of external cephalic mould, GSC 91845, x 2.1, enlargement x 7.1.
11. Mostly exfoliated internal cephalic mould, GSC 91846, x 2.8.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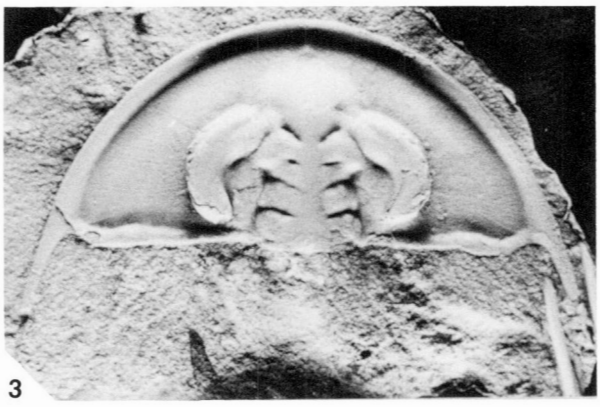
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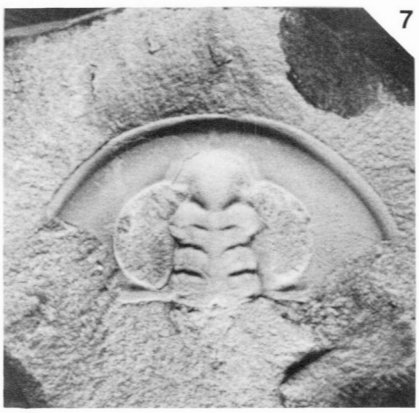
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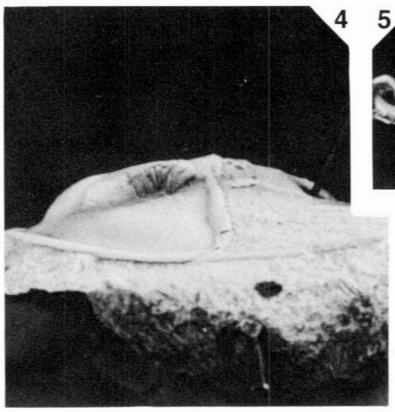
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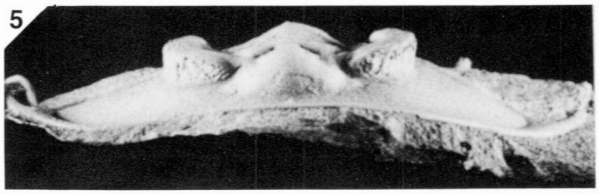
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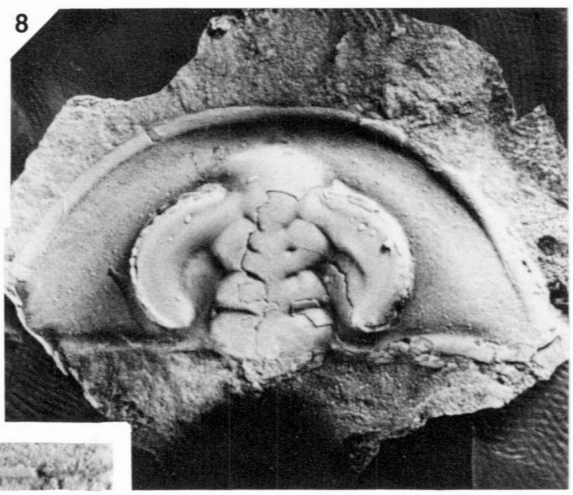
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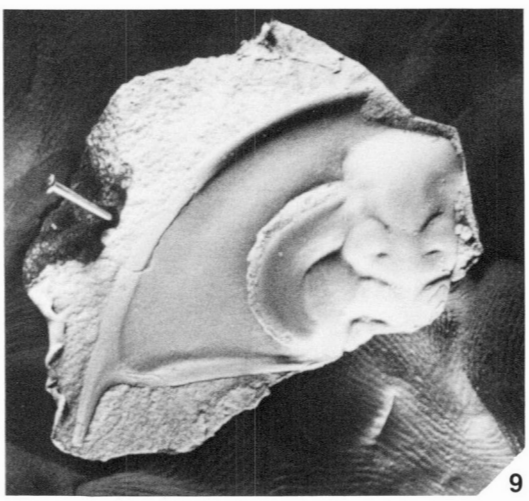
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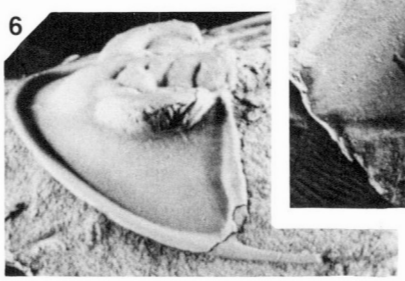
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PLATE 12

Figures 1, 2. *Olenellus parvofrontatus* sp. nov., GSC loc. 90669.

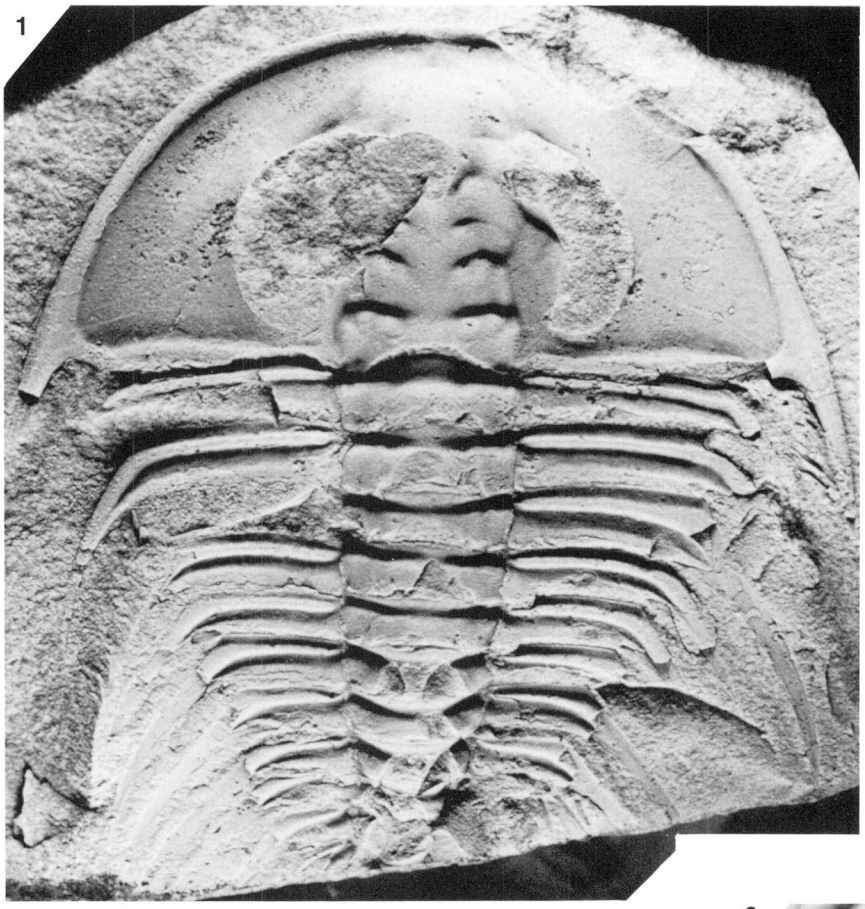
1. Internal mould of cephalon and partial thorax, GSC 91847, x 2.0.
2. Latex cast of internal mould of cephalon and partial thorax, GSC 91848, x 2.0.

Figures 3-5. *Olenellus nevadensis*? (Walcott, 1910), GSC loc. 90669.

3, 4. Internal cephalic mould, plan and side views, GSC 91849, x 3.7.
5. Internal mould of cephalic axis and eye lobes, GSC 91850, x 4.2.

Figures 6-8. *Olenellus bufrontis* sp. nov., GSC loc. 90670.

6, 7. Holotype, internal cephalic mould, plan and side views, GSC 91851, x 6.9.
8. Internal cephalic mould, GSC 91852, x 7.3.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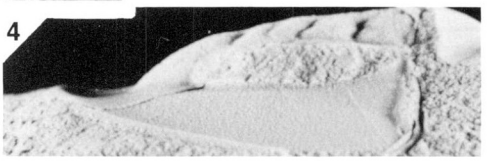
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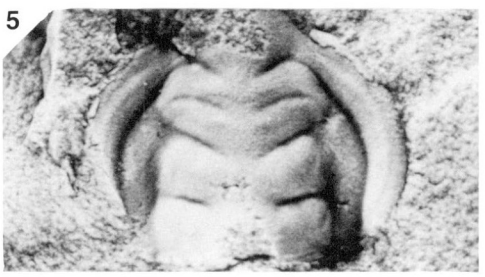
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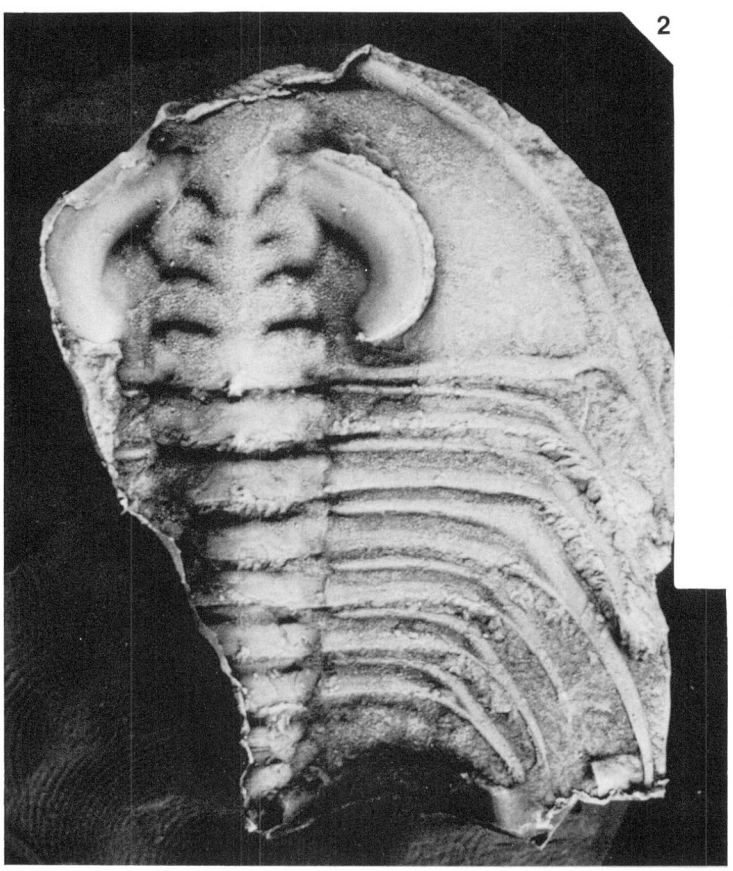
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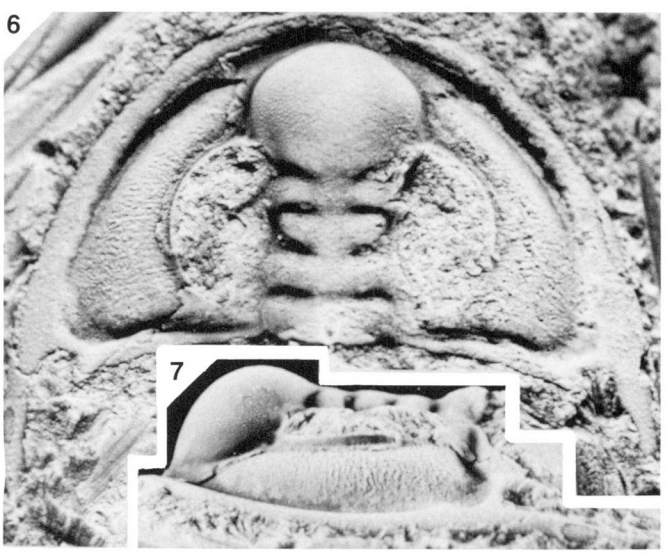
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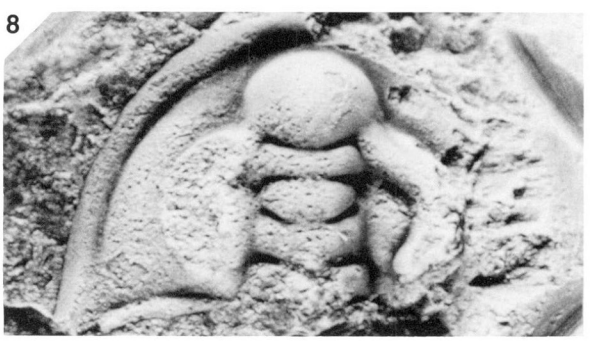
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PLATE 13

Figures 1-6. *Illtydaspis aphylla* gen. et sp. nov., GSC loc. 90671.

1-3. Holotype, cranidium, plan, front, and side views, GSC 91853, x 14.0.

4. Cranidium, GSC 91854, x 12.5.

5. Cranidium, GSC 91855, x 14.6.

6. Partially exfoliated cranidium, GSC 91856, x 14.6.

Figure 7. *Poulsenia* sp. 2, latex mould of external cranidial surface, GSC 91857, x 16.8, GSC loc. 90671.

Figures 8-19. *Bonnima semidiscoidea* gen. et sp. nov., GSC loc. 90671.

8. Cranidium, GSC 91858, x 16.4.

9. Cranidium, GSC 91859, x 16.4.

10. Internal mould of cranidium, GSC 91860, x 6.6.

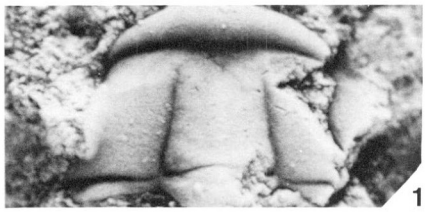
11. Internal mould of cranidium, GSC 91861, x 6.6.

12. Partially exfoliated cranidium, GSC 91862, x 6.6.

13-15. Cranidium, plan, front, and side views, GSC 91863, x 6.6.

16. Internal mould of cranidium, GSC 91864, x 6.6.

17-19. Internal mould of cranidium, plan, front, and side views, GSC 91865, x 6.6.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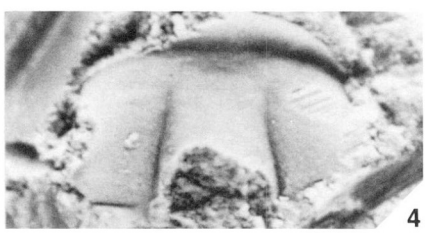
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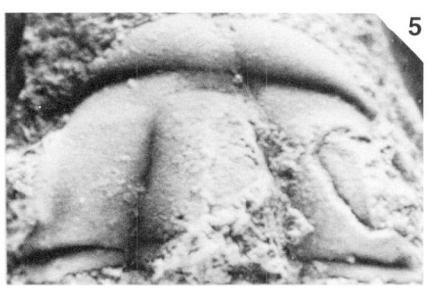
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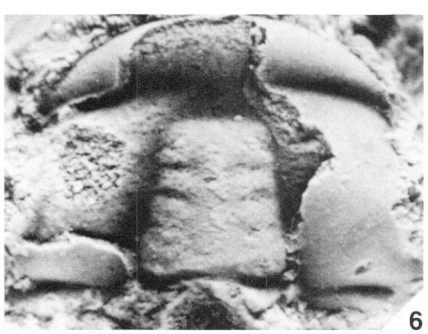
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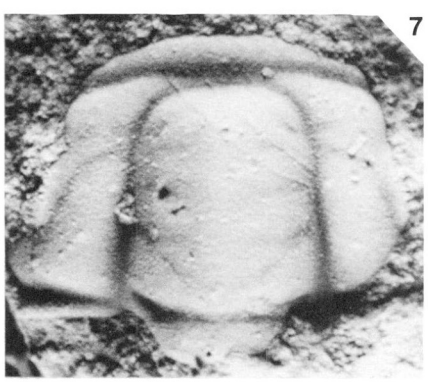
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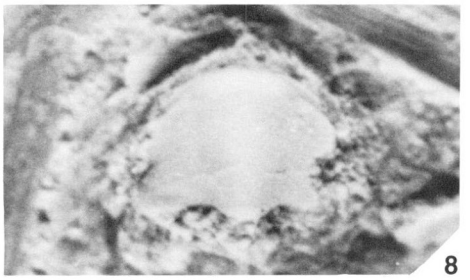
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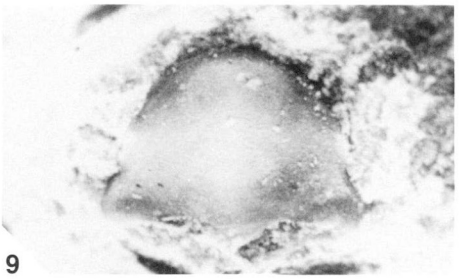
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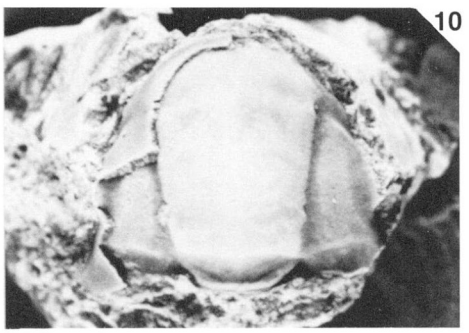
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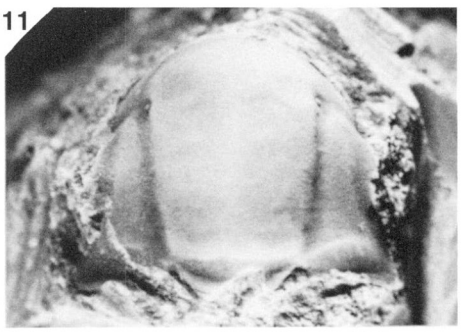
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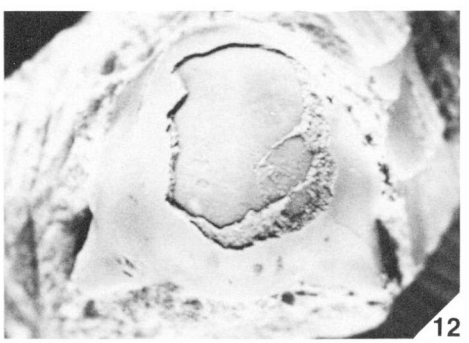
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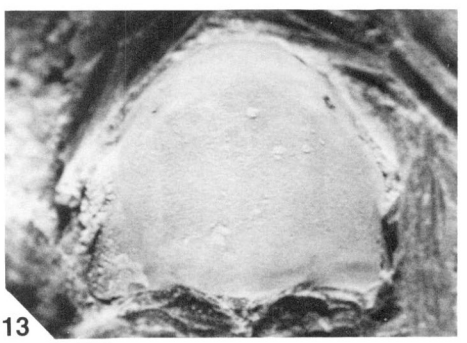
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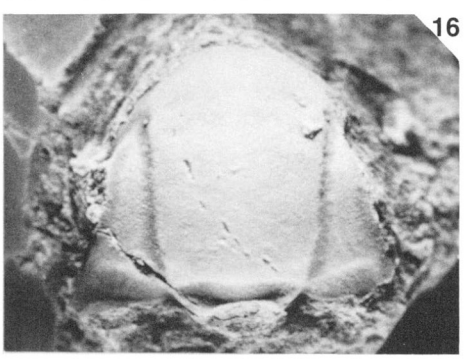
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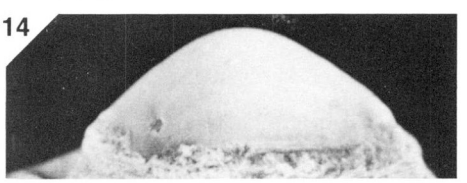
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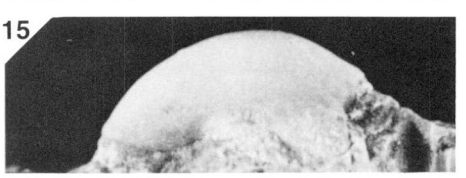
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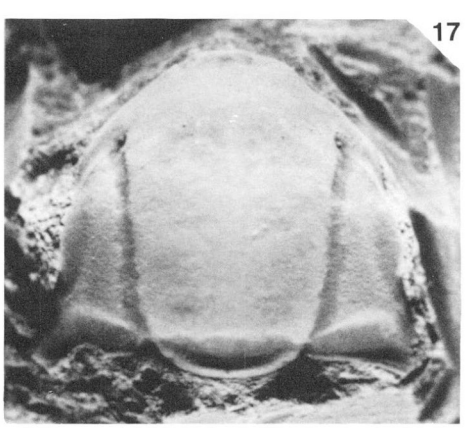
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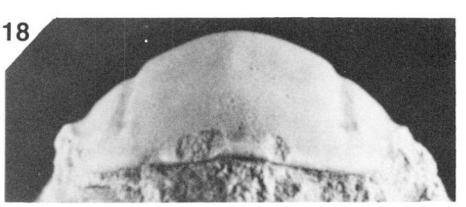
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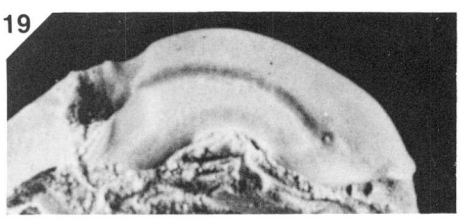
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PLATE 14

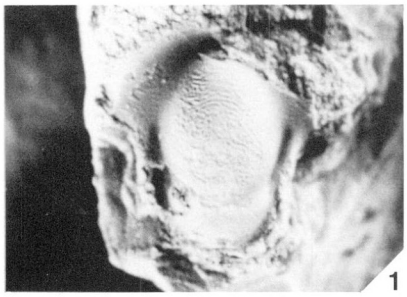
Figures 1-16. *Bonnima semidiscoidea* gen. et sp. nov., GSC loc. 90671.

1. Hypostome, GSC 91866, x 9.8.
2. Hypostome, GSC 91867, x 9.8.
3. Internal pygidial mould, GSC 91868, x 7.2.
4. Partially exfoliated pygidium, GSC 91869, x 6.6.
5. Pygidium, GSC 91870, x 8.3.
6. Partially exfoliated pygidium, GSC 91871, x 7.2.
7. Pygidium, GSC 91872, x 6.6.
8. Pygidium, GSC 92972, x 5.7.
9. Internal mould of pygidium, GSC 91873, x 7.7.
10. Internal mould of pygidium, GSC 91874, x 6.0.
11. Internal mould of pygidium, GSC 91875, x 7.2.
12. Internal mould of pygidium, GSC 91876, x 6.0.

13-15. Holotype, pygidium, plan, rear, and side views, GSC 91877, x 6.0.

16. Internal mould of pygidium, GSC 92973, x 5.7.

Figures 17, 18. *Bonnia* sp. 4, latex cast of external mould of pygidium, rear and plan views, GSC 91878, x 5.7, GSC loc. 90671.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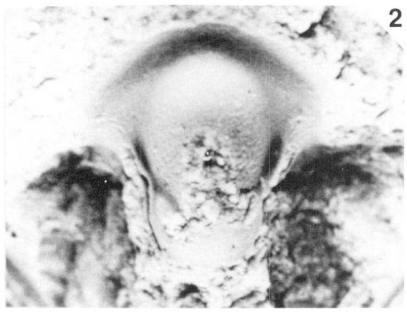
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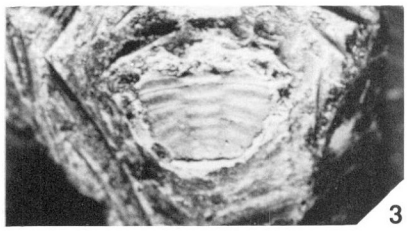
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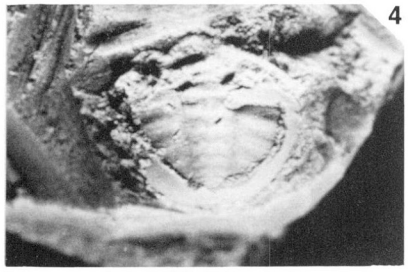
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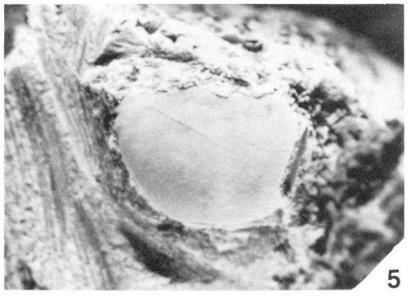
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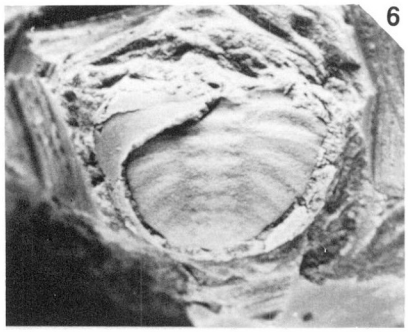
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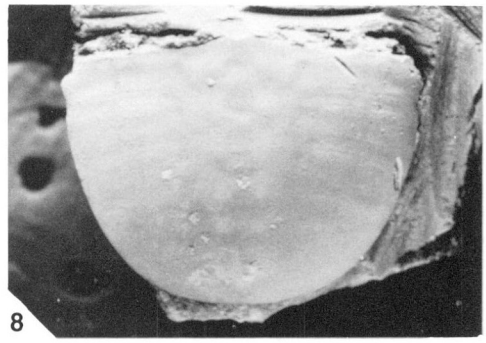
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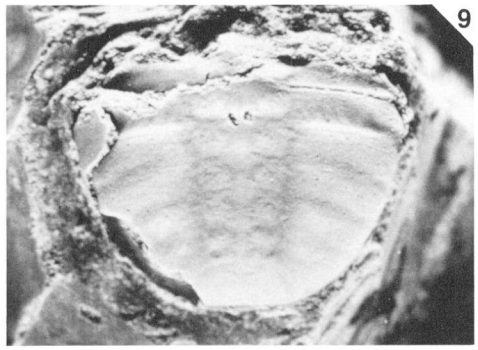
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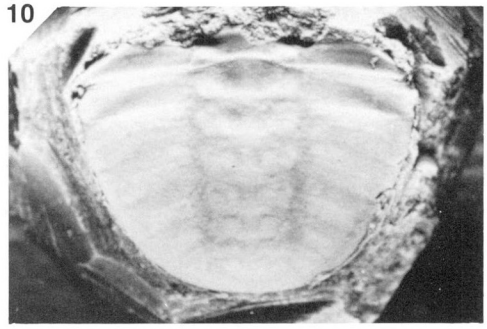
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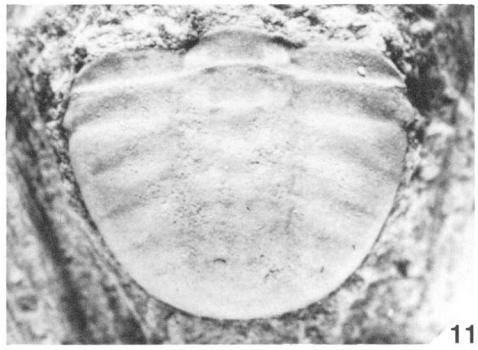
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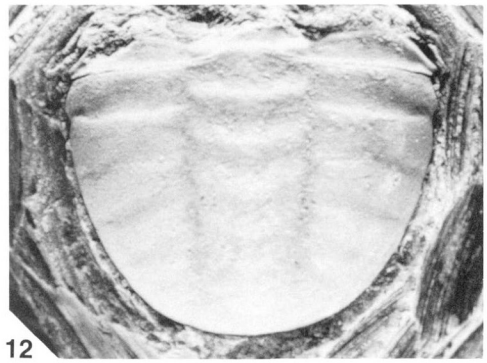
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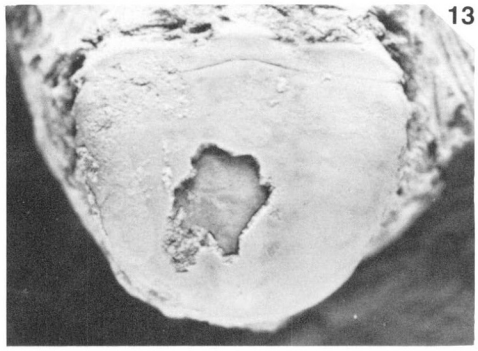
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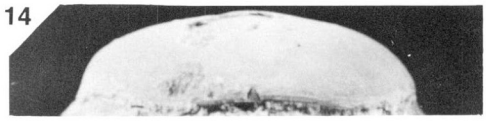
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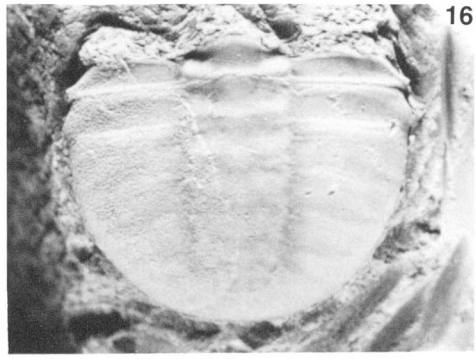
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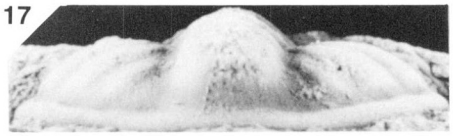
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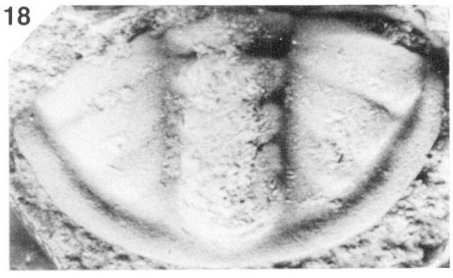
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PLATE 15

Figures 1-18. *Bonnima semidiscoidea* gen. et sp. nov., GSC loc. 90672.

1. Cranidium, GSC 91879, x 11.6.
2. Cranidium, GSC 91880, x 11.6.
3. Cranidium, GSC 91881, x 11.6.
4-6. Cranidium, plan, front, and side views, GSC 91882, x 11.6.
7. Internal mould of cranidium, GSC 91883, x 11.6.
8. Cranidium, GSC 91884, x 11.6.
9. Internal mould of pygidium, GSC 91885, x 9.3.
10. Partially exfoliated pygidium, GSC 91886, x 9.3.
11. Partially exfoliated pygidium, GSC 91887, x 9.3.
12. Partially exfoliated pygidium, GSC 91888, x 9.3.
13. Partially exfoliated pygidium, GSC 91889, x 9.3.
14. Pygidium, GSC 91890, x 9.3.
15-17. Pygidium, plan, rear, and side views, GSC 91891, x 9.3.
18. Internal mould of pygidium, GSC 91892, x 9.3.

Figure 19. *Olenellus* sp. 3. Partially exfoliated cephalon, GSC 91893, x 9.3, GSC loc. 90672.

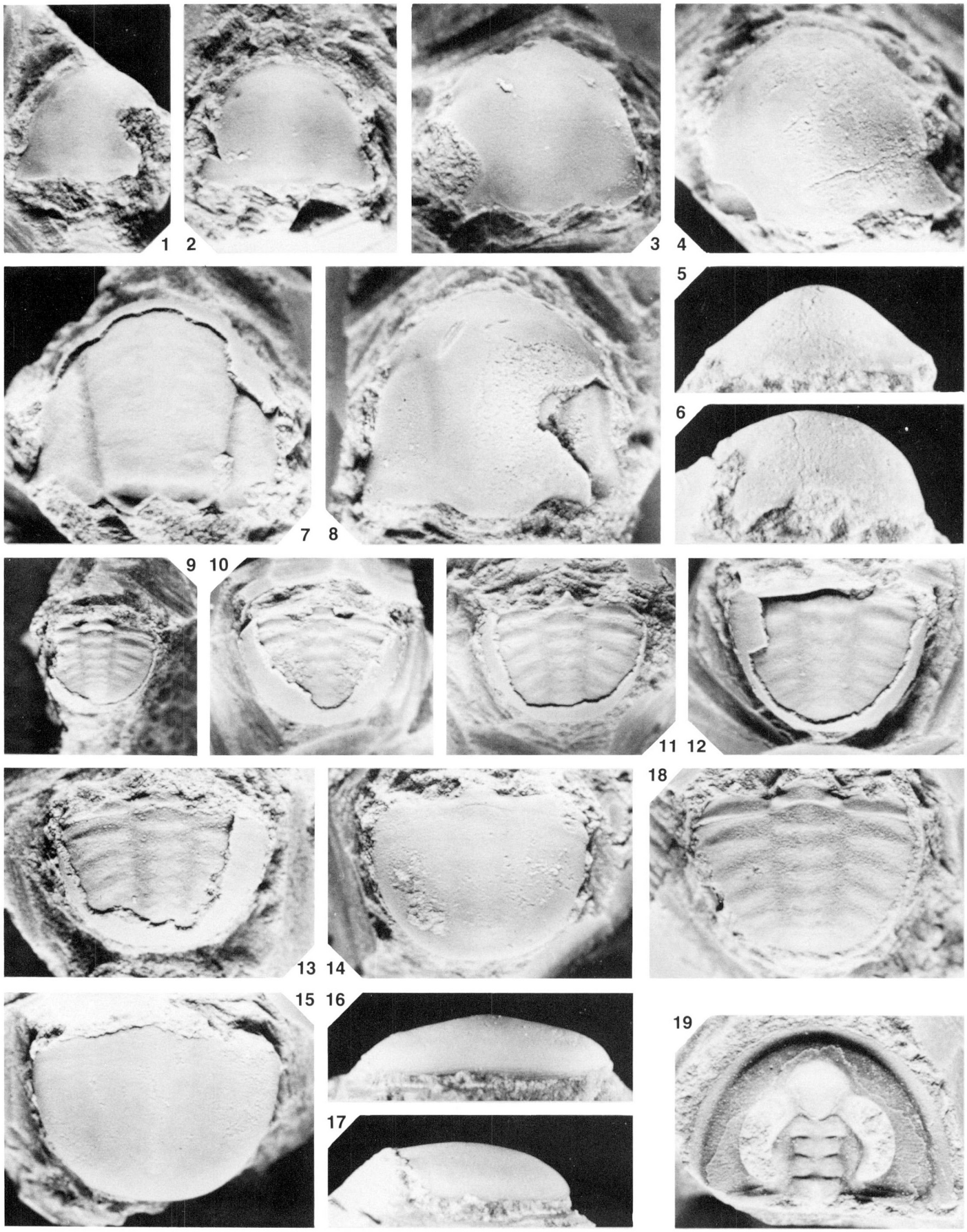
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PLATE 16

Figures 1-11. *Illtydaspis* sp. 1, GSC loc. 90672.

1. Cranidium, GSC 91894, x 21.0.
2. Cranidium, GSC 91895, x 21.0.
3. Cranidium, GSC 91896, x 21.0.
4. Cranidium, GSC 91897, x 21.0.
5. Cranidium, GSC 91898, x 21.0.
6. Cranidium, GSC 91899, x 21.0.
7. Cranidium, GSC 91900, x 23.4.
8. Cranidium, GSC 91901, x 23.4.

9-11. Cranidium, plan, front, and side views, GSC 91902, x 23.4.

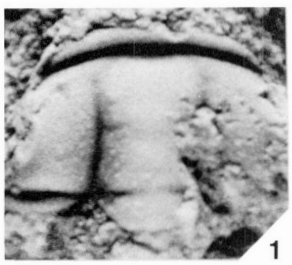
Figures 12-15. *Piaziella* sp. 1, cranidium, GSC 91903; plan view, x 6.7, enlarged plan view, x 12.9, front and side views x 6.7, GSC loc. 90672.

Figures 16-21. *Illtydaspis*? sp. 2, GSC loc. 90674.

16, 17. Cranidium, GSC 91904, x 7.0, enlargement x 13.0.

18. Internal mould of cranidium, GSC 91905, x 7.0.

19-21. Internal mould of cranidium, plan, front, and side views, GSC 91906, x 7.9.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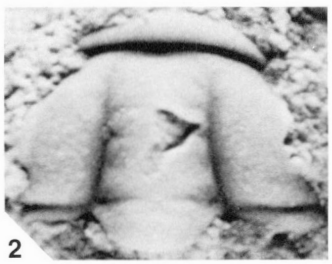
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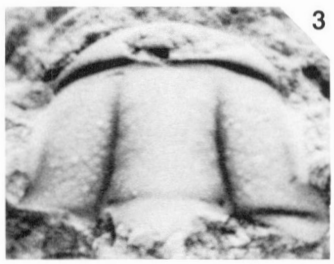
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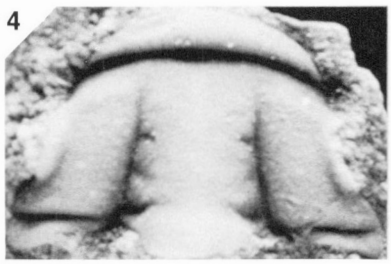
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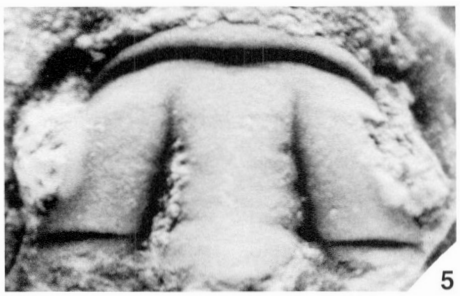
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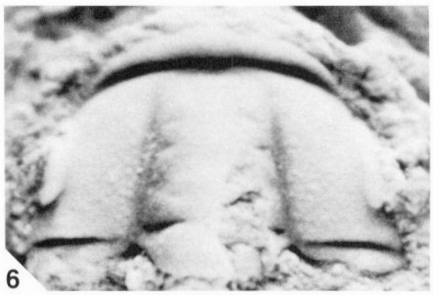
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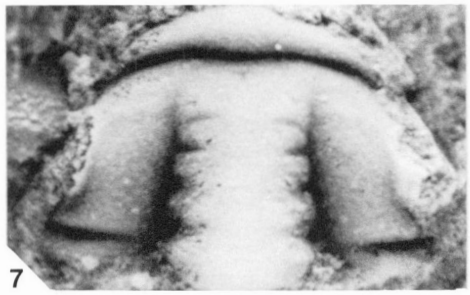
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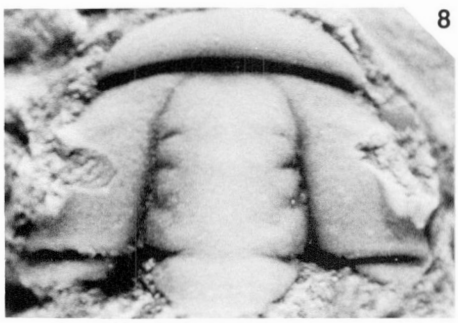
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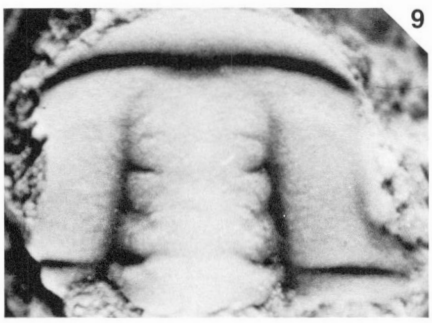
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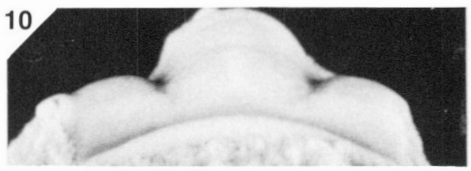
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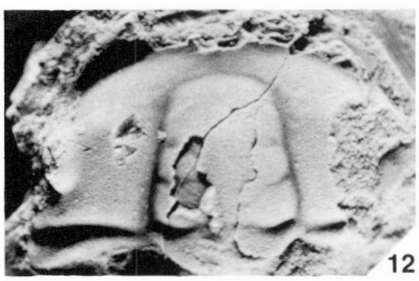
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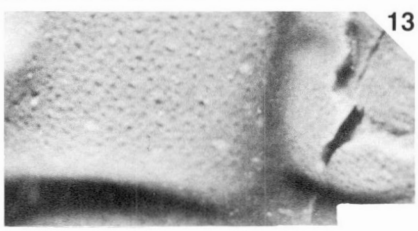
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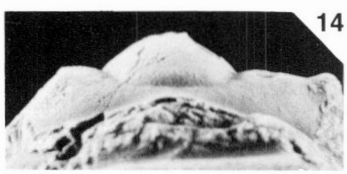
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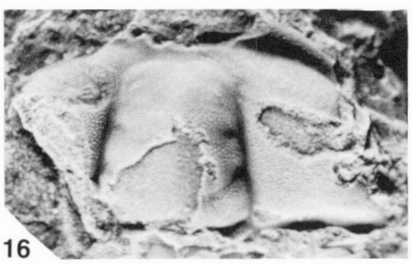
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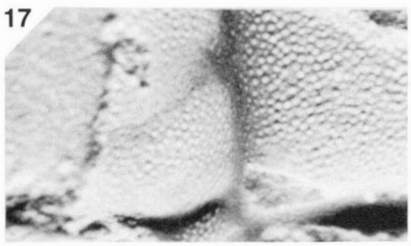
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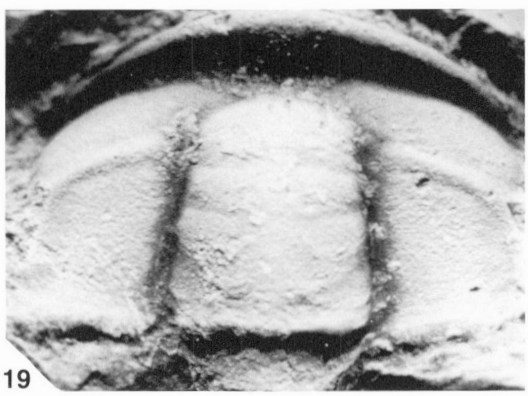
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PLATE 17

Figures 1-10. *Illtydaspis ornata* gen. et sp. nov., GSC loc. 90672.

1. Cranidium, GSC 91907, x 24.0.
2. Cranidium, GSC 91908, x 15.6.
3. Internal cranidial mould, GSC 91909, x 12.2.

4-6. Cranidium, plan, side, and front views, GSC 91910, x 10.2.

7-9. Holotype, cranidium, plan, front, and side views, GSC 91911, x 13.8.

10. Latex cast of external cranidial mould, GSC 91912, x 9.1.

Figures 11-14. *Olenellus romensis*? Resser and Howell, 1938, GSC loc. 90674.

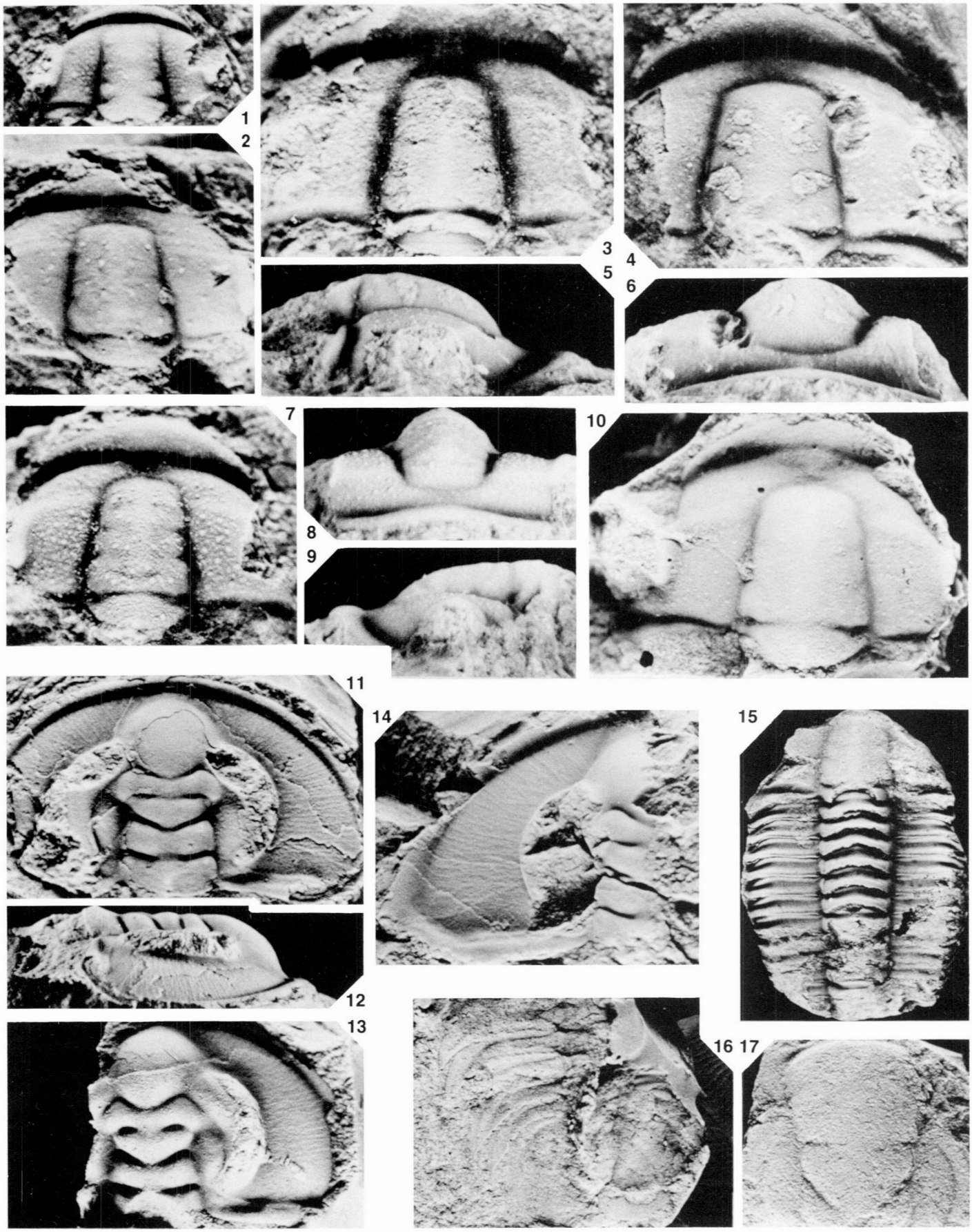
11, 12. Partially exfoliated cephalon, plan and side views, GSC 91913, x 7.2.

13. Latex cast of external cranidial mould, GSC 91914, x 7.2.
14. Partially exfoliated cephalon, GSC 91915, x 7.5.

Figure 15. *Amecephalus*? sp. Internal mould of partial cranidium and thorax, GSC 91916, x 2.0, GSC loc. 90675.

Figures 16, 17. *Fieldaspis bilobata*? Rasetti, 1951, GSC loc. 90675.

16. Latex cast of external pygidial mould and partial thorax, GSC 91917, x 2.6.
17. Internal cranidial mould, GSC 91918, x 3.2.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