Early Ordovician fauna of the Gap Creek Formation, Canning Basin, Western Australia

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The trilobite and brachiopod fauna of the Gap Creek Formation is revised. Recorded are the trilobites: *Geragnostus* aff. *splendens*, *Opipeuter angularis*, *O. ?inconnivus*, *Carolinites ?genacinaca*, *Canningella hardmani*, *Encrinurella ?reedi*, and several indeterminate forms. Brachiopods include *?Pseudomimella* sp., *?Oligorthis* sp., *Tritoechia* sp., *Spanodonta hoskingiae*, and *Tinopena shergoldi* gen. et sp. nov. Also recorded are the gastropods *Teiichispira* sp. and *Helicotoma* sp., and calcareous plates of uncertain affinities. Correlations based largely on the telephinid trilobites indicate this fauna is of late Bendigonian (Be3–Be4) age.

Introduction

The Canning Basin, situated between latitudes 17° and 24°S and longitudes 119° and 128°E (Fig. 1), is a large northwest–southeast-oriented Ordovician to Cretaceous pericratonic basin which covers an area of about 430 000 km^2 in northern Western Australia. It is bounded by the Early Proterozoic Halls Creek Province to the northeast, and by other Archaean and Proterozoic blocks and several Proterozoic to Palaeozoic basins to the east and south (Palfreyman 1984). The northeastern
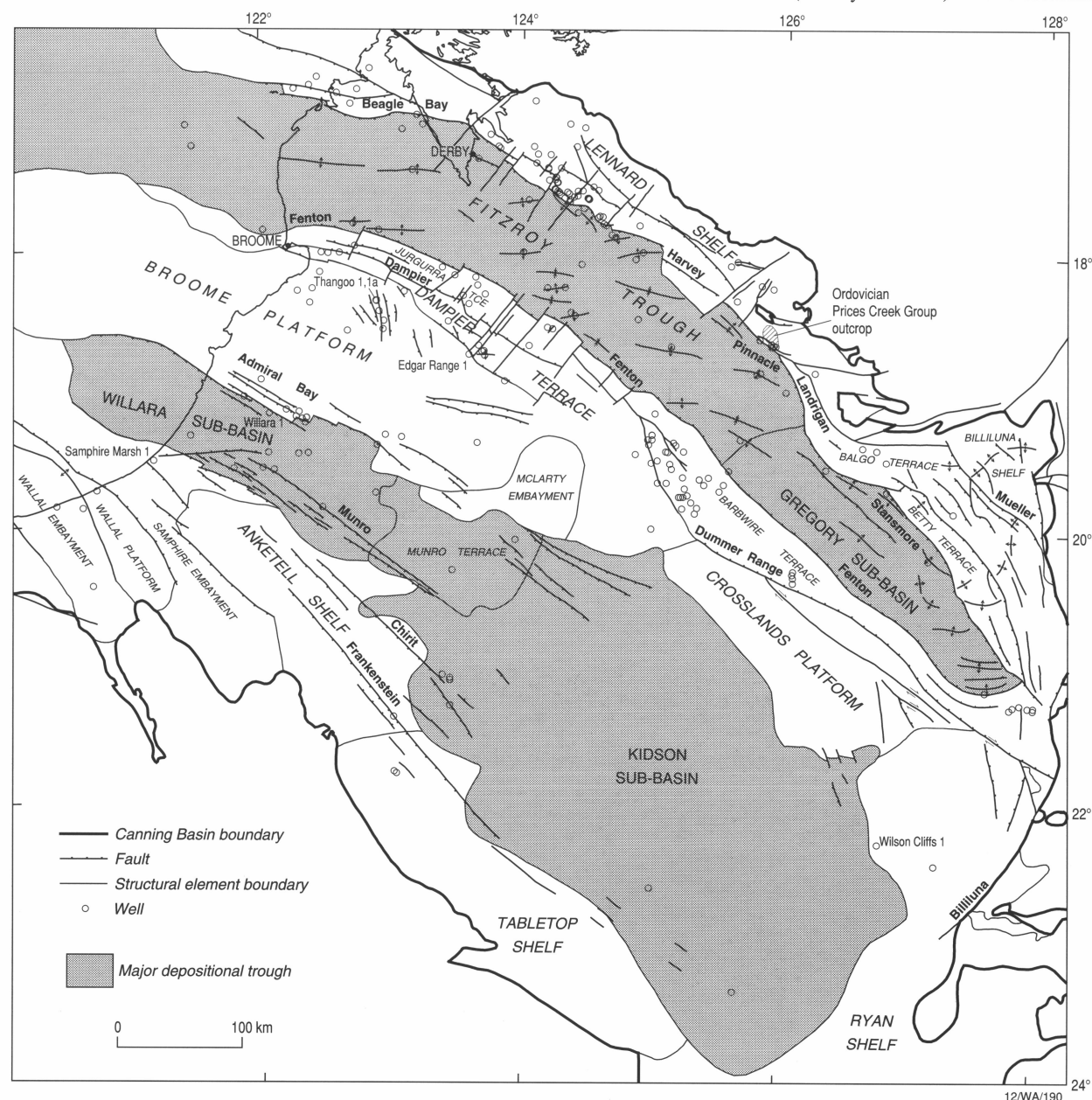

Figure 1. Major structural features of the Canning Basin. The Prices Creek Group outcrop is midway along the northeastern margin of the basin (modified from Kennard et al. 1994).

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marginal portion of the basin is referred to as the Lennard Shelf, and it is here where most of the outcropping Ordovician rocks occur. The outcrops containing the fauna described herein are restricted to an area of about 20 km² between Prices Creek and Gap Creek (Fig. 2), south of the Emanuel Range, and about 60 km southeast of the township of Fitzroy Crossing.

The Ordovician age of rocks in the Prices Creek area on the northern margin of the Canning Basin was first recognised from fossils found in 1949 by D.J. Guppy and A.W. Lindner during the mapping of rocks previously considered Devonian in age. The discovery was reported by Guppy & Öpik (1950) establishing the Prices Creek Group, which they divided into a lower 'Emanuel Limestone' (509 m thick) and an upper 'Gap Creek Dolomite'.

Exposures near Gap Creek, north of the Emanuel Formation type section (705 in Fig. 2), and apparently overlying the Emanuel Formation were named the Gap Creek Formation by Guppy & Öpik (1950). The type section, comprising 186 m of dolomite, calcareous sandstone, and lesser limestone, was detailed by Guppy et al. (1958).

In a study of the prioniodontacean conodonts from the Emanuel Formation, McTavish (1973) referred to three stratigraphic sections. The longest of these was the type section of the unit (Guppy et al. 1958), whose base is attached to the section in BMR Noonkanbah No.3 (termed BMR 3 Prices Creek by McTavish). The third section, RM10 of McTavish (corresponding to section 707 in Fig. 2), was asserted to represent the top of the Emanuel Formation. However, this part of the sequence represents the lower part of the Gap Creek Formation as defined by Guppy et al. (1958). The
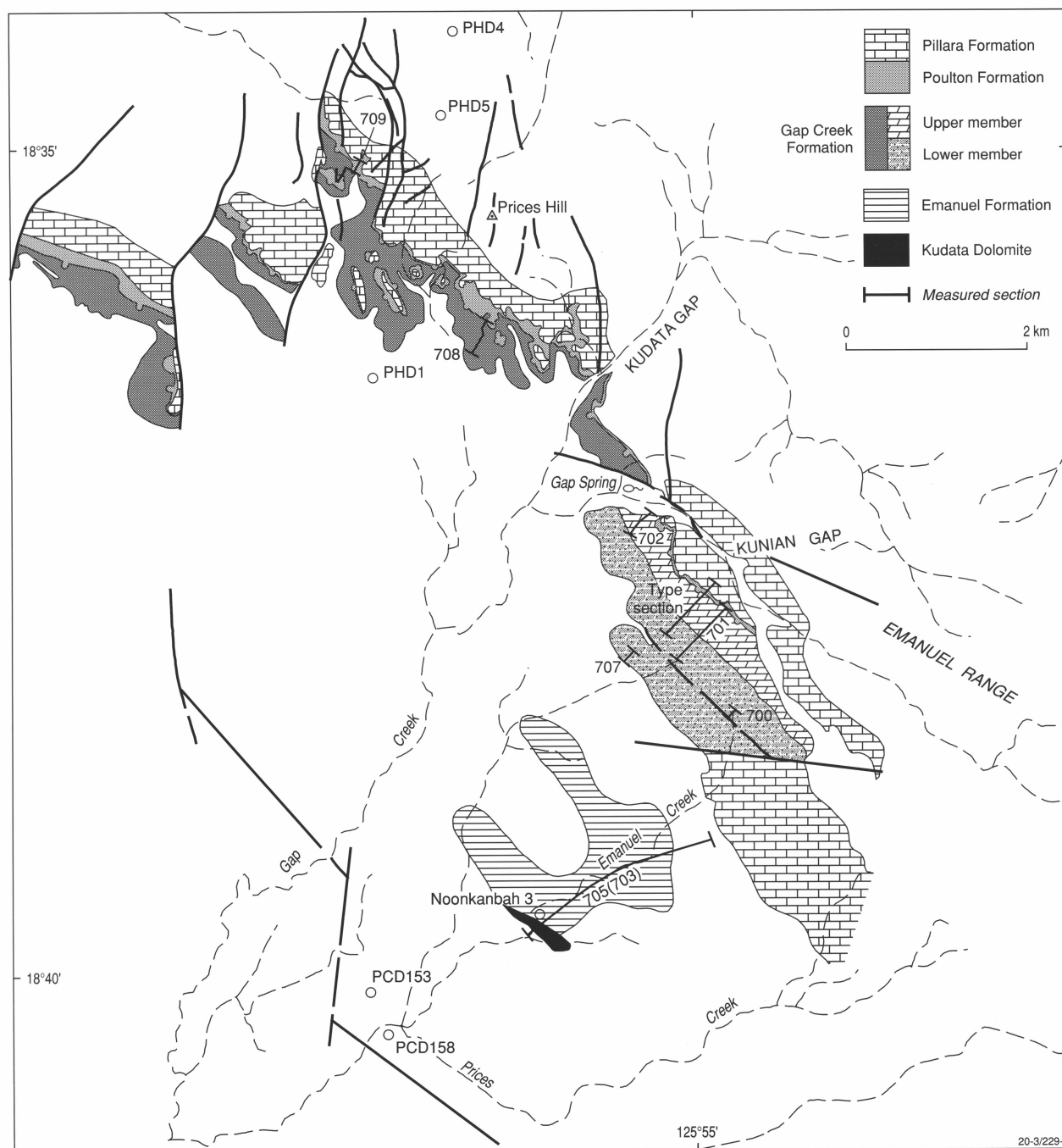

Figure 2. Geology of the Prices Creek outcrop area, showing location of measured sections. The type section of the Gap Creek Formation is near Kunian Gap and is labelled 'type section'. The other sections of the Gap Creek Formation discussed herein are 707 (southwest of the type section) and 708 (west of Kudata Gap). Localities with PHD and PCD prefixes are BHP–Utah coreholes.

recent lithological analysis by Nicoll et al. (1993) indicates that the boundary between the Emanuel and Gap Creek Formations lies well below the base of section RM10 of McTavish (1973). This is the concept of the Gap Creek Formation used herein; it includes McTavish's section RM10, which has been remeasured (as section WCB 707) and sampled for conodonts and macrofauna.

Biostratigraphy

Öpik (*in* Guppy & Öpik 1950) recognised four faunal stages within the Emanuel Formation in its type area, and one stage in the Gap Creek Formation. Öpik's trilobite biostratigraphy is readily recognised, and was essentially used as the basis of a revised scheme devised by Legg (1973, 1978). This author (1973) recognised in the Emanuel Formation three trilobite assemblages based on *Kayseraspis, Ogygiocaris,* and *Encrinurella.* The *Encrinurella* zone occurs in the uppermost beds, which Legg included in the Emanuel Formation. However, these beds are here regarded as Gap Creek Formation, since they are much more dolomitic than and faunally unlike the underlying Emanuel Formation and more like that of the remainder of the Gap Creek Formation. From this part of the sequence, Legg (1976, 1978) recorded the trilobites *Opipeuter emanuelensis, Carolinites bulbosa, Canningella hardmani,*

Encrinurella reedi, Gogoella wadei, Bumastus sp., and *Geragnostus* sp., and the brachiopod *Spanodonta hoskingiae.*

The trilobite biostratigraphic scheme recognised in the Emanuel Formation has been revised by Laurie & Shergold (1996, in press). The trilobite and brachiopod fauna from the Gap Creek Formation, which Öpik referred to his stage V (characterised by the plectambonitacean brachiopod *Spanodonta),* is revised herein.

Although *Spanodonta hoskingiae* Prendergast is found throughout most of the unit (sections 707 and 708; Figs. 3 and 4), the lower part of the formation is characterised also by the presence of trilobites, and is here referred to as the *Encrinurella/Carolinites* assemblage zone. This assemblage contains the trilobites *Geragnostus* aff. *splendens* (Holub), *Opipeuter angularis* (Young), *Opipeuter ?inconnivus* Fortey, *Carolinites ?genacinaca* Ross, *Canningella hardmani* Legg, *Encrinurella ?reedi* Legg, and several indeterminate species of asaphids. Brachiopods include *?Oligorthis* sp., *Tritoechia* sp., *?Pseudomimella* sp., and *Spanodonta hoskingiae* Prendergast. The gastropods *Teiichispira* sp. and *Helicotoma* sp. are also present.

The upper part of the formation is mostly lacking in trilobites and is characterised by the plectambonitoidean brachiopods *Spanodonta hoskingiae* and *Tinopena shergoldi.* *T. shergoldi* is restricted to this assemblage, termed the
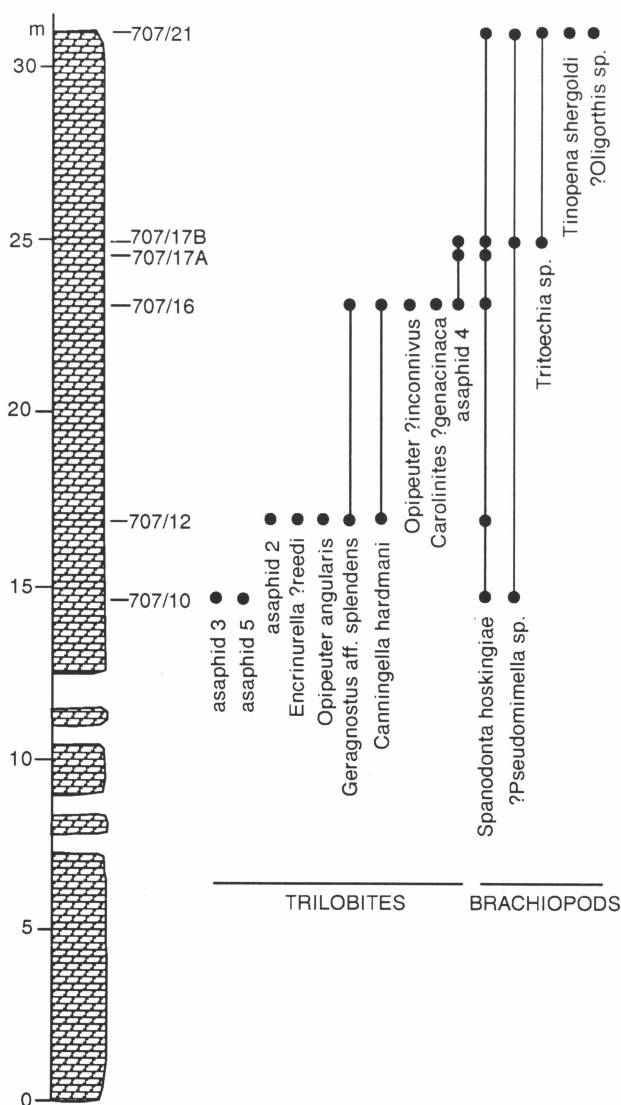

Figure 3. Graphic representations of section WCB 707 (SW of type section) of the Gap Creek Formation, and the stratigraphic ranges of selected trilobites and brachiopods.
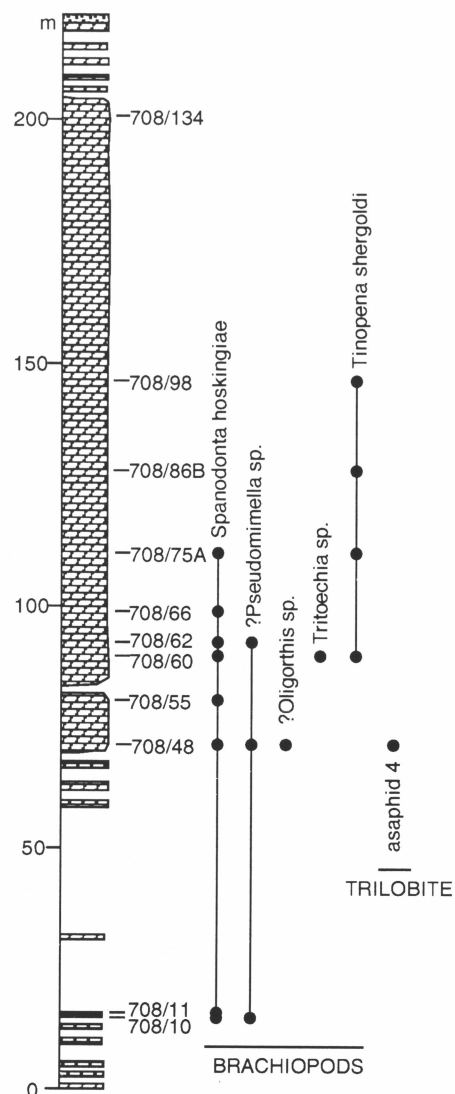
Figure 4. Graphic representations of section WCB 708 (W of Kudata Gap) of the Gap Creek Formation, and the stratigraphic ranges of selected trilobites and brachiopods.

Spanodonta/Tinopena assemblage, and its first appearance denotes the base of the assemblage zone. This assemblage also contains the brachiopods *?Oligorthis* sp., *Tritoechia* sp., and *?Pseudomimella* sp.

Correlations

Canning Basin

The Gap Creek Formation fauna was referred to as subfauna 3b by Legg (1978), who recorded it from cores in two petroleum exploration wells: core 13 in Willara No.1, and core 12 in Edgar Range No.1. However, in his taxonomic treatment of the faunas, he recorded neither of the characteristic pliomerids (*Encrinurella* and *Canningella*) from either of these cores. Legg's record of *Opipeuter emanuelensis* from his subfauna 3b is apparently in error, and so is his record of *Carolinites bulbosa* from subfauna 3a (Laurie & Shergold 1996, in press). Therefore there is some doubt as to the veracity of records of these species in the subsurface.

Amadeus Basin

The Gap Creek Formation probably correlates with the lower part of the Horn Valley Siltstone of the Amadeus Basin. The faunas of these two units show some similarities in that *Carolinites genacinaca,* tentatively recorded from the Gap Creek Formation, occurs throughout most of the Horn Valley Siltstone, whose lower part contains a species of *Encrinurella* (Laurie unpublished data).

One of the dominant asaphid genera from the Horn Valley Siltstone, *Lycophron,* has also been recorded as *?Aulacoparia* sp. by Legg (1976, p. 9) in his subfaunas 4 and 5 in the Canning Basin. Examination of Legg's specimens has shown that they are probably referable to the unnamed species of *Lycophron* characteristic of the upper part of the Horn Valley Siltstone, rather than to *L. howchini,* which characterises the lower part of the unit (Laurie unpublished data).

Georgina Basin

Correlation with the Georgina Basin is difficult because little is known of the faunal content of much of this part of the Ordovician sequence. The Gap Creek Formation probably correlates with the Coolibah Formation of the Georgina Basin insofar as the base of the overlying Nora Formation contains *Carolinites genacinaca* and a species of *Lycophron* similar to that from the upper Horn Valley Siltstone (Fortey & Shergold 1984; Laurie unpublished data), and is therefore probably younger than the Gap Creek Formation. Furthermore, like the Gap Creek Formation, the Coolibah Formation also contains the gastropod *Teiichispira* (Gilbert-Tomlinson 1973; Hill et al. 1969).

Northeastern Queensland

The fauna in the Rollston Range Formation in the Mount Windsor Subprovince near Charters Towers contains *Carolinites genacinaca* and *Opipeuter insignis* (Henderson 1983). The latter is most unlike *Opipeuter angularis.* Rather, having a very narrow glabella tongue, it more closely resembles both *O. inconnivus* Fortey and the unnamed species that succeeds *O. inconnivus* in the Spitsbergen sequences (Fortey 1974, 1980). As both *C. genacinaca* and *O. inconnivus* are tentatively recorded from the Gap Creek Formation, it is likely that the Rollston Range fauna is of similar age.

Northwestern New South Wales

Little detailed work has been done on the Gnalta Shelf and Mount Arrowsmith areas of northwestern New South Wales, where most of the information comes from the unpublished work of Warris (1967) updated by Shergold (1971) and Webby et al. (1981). On the Gnalta Shelf, the Rowena Formation contains *Carolinites* (probably *C. genacinaca*). In the Mount

Arrowsmith area, the Tabita Formation also contains *Carolinites genacinaca,* as well as specimens of *Lycophron,* possibly conspecific with that from the upper part of the Horn Valley Siltstone of the Amadeus Basin. This indicates that they are probably slightly younger than the Gap Creek Formation.

Tasmania

The basal Karmberg Limestone of the Florentine Valley in southern Tasmania contains an unnamed species of *Canningella* and possibly representatives of *Carolinites*; a species of *Teiichispira* occurs higher in the formation (Laurie 1991, p. 21). Thus the Karmberg Limestone may well be of similar age to the Gap Creek Formation.

In the Caroline Creek Sandstone of northern Tasmania, both *Carolinites tasmaniensis* (Etheridge) and a species of pliomerid tentatively assigned to *Protoencrinurella* by Jell & Stait (1985) are recorded. This unit may thus correlate with the lower part of the Gap Creek Formation and upper part of the underlying Emanuel Formation insofar as *C. tasmaniensis* predates *C. genacinaca,* and *Protoencrinurella* is found in the upper part of the Emanuel Formation.

Intercontinental

Correlations outside Australia are largely accomplished through the cosmopolitan telephinids *Opipeuter* and *Carolinites*. These

NW AUSTRALIA			W UNITED STATES	
1	2	3	4	5
BE 4 BE 3 to	7	Spanodonta/ Tinopena	Oepikodus communis	J — *P. nasuta* — *T. typica* — Reutterodus andinus
				I — *P. libexensis* —
	6	Encrinurella/ Carolinites		H — Oepikodus communis
LA3 to BE 2	5	Priceaspis guppyi	E D	Protopliomerella contracta — G2 — D. deltatus/O. costatus
	4	Priceaspis oepiki- Priceaspis rochei	C	
	3	E. (Emanuelaspis) teicherti	B	
	2	E. (Emanuelaspis) nicolli		Hintzeia celsaora — G1
	1	Kayseraspis cf. brackebuschi	A	*R. super-* *ciliosa* — F
	0	"Dikelocephalinids"	Drepan- oistodus/ Paltodus	Tessella- cauda — E — ?	M. dianae ?

Figure 5. Correlation of the northern Canning Basin Early Ordovician biostratigraphic scheme with that from western North America. Column 1 is a tentative correlation with the Victorian graptolite standard. Column 2 is an amalgamation of the trilobite zonation of Laurie & Shergold (1996) and the trilobite–brachiopod zonation of this paper. Column 3 is the current state of conodont biostratigraphic analysis (R.S. Nicoll, Australian Geological Survey Organisation, personal communication 1996). Column 4 is the trilobite zonation from Nevada and Utah (Ross 1951; Hintze 1952, 1973; Ross et al. 1982). Column 5 is the conodont zonation of Ross et al. (1993). The hatched area represents the 100–200-metre-thick covered interval spanning the boundary of the Emanuel and Gap Creek Formations (from Shergold et al. 1995).

genera facilitate the correlation of the Gap Creek faunas with the trilobite zonations established by Ross (1951) and Hintze (1952, 1973) in Utah and Nevada. Laurie & Shergold (1996) have shown that the underlying Emanuel Formation probably correlates with zones F, G1, and G2 (Fig. 5). The presence of *Opipeuter angularis* in locality 707/12 (Fig. 3) of the Gap Creek Formation indicates a correlation with zone H of the Fillmore Formation, where this species has been recorded from a single cranidium as *Remopleuridiella angularis* by Young (1973). Additionally, the presence of *Carolinites genacinaca* in locality 707/16 of the Gap Creek Formation suggests a correlation with zones I or J of the Utah and Nevada scheme.

The presence of *O. angularis* in the lower part of the Gap Creek Formation allows a correlation with the lowermost Olenidsletta Member (V1a) of the Valhallfonna Formation in Spitsbergen (Fortey 1974, 1980). According to Cooper & Fortey (1982), the graptolite fauna at this level correlates with the late Bendigonian Be3, a correlation in accordance with the Be1–Be2 age assigned to the underlying Emanuel Formation by Laurie & Shergold (1996). The subsequent appearance of *Carolinites genacinaca* and *Opipeuter ?inconnivus* indicates a correlation of the upper parts of the Gap Creek Formation with perhaps the V1b or later assemblages in the middle Olenidsletta Member in Spitsbergen (Fortey 1980). Cooper & Fortey consider the graptolites in the V1b assemblage to indicate a correlation with Bendigonian Be3 to Chewtonian Ch1.

Although no telephinid trilobites have been described from the lower Setul Limestone of Pulau Langgun, off the west coast of Malaysia, the similarities of its fauna to the Gap Creek fauna are worthy of note, and suggest a close correlation. The Setul Limestone is the only other place from which the brachiopod genus *Spanodonta* has been recorded, as the species *S. floweri* (Cooper; see Laurie & Burrett 1992). In addition, the gastropods *Teiichispira* (Yochelson & Jones 1968) and *Helicotoma* (Kobayashi 1959) have also been recorded from the same locality within the lower Setul Limestone.

Systematic palaeontology

Phylum Arthropoda Siebold & Stannius, 1845

?Class Trilobita Walch, 1771

Order Agnostida Salter, 1864

Superfamily Agnostoidea M'Coy, 1849

Family Metagnostidae Jaekel, 1909

Genus *Geragnostus* Howell, 1935

Type species. *Geragnostus sidenbladhi* (Linnarsson, 1869).

Geragnostus aff. *splendens* (Holub, 1912)

Figures 6.1–6.3

Material. Three cephala from locality 707/16, one of which is illustrated (CPC 33223); one cephalon found in float (CPC 33224); and one pygidium from locality 707/12 (CPC 33225)

Comments. These specimens belong to the peculiar Early Ordovician group of agnostid species, currently assigned to *Geragnostus*, which have a short, generally unfurrowed glabella and a long, broad pygidial axis with a clearly defined, rounded, slightly bulbous posterior axial lobe. This morphological group may well represent one species, and several names are available, of which *G. splendens* (Holub) appears to have priority.

Geragnostus splendens (Holub) comes from the Arenig Klabava Formation of central Bohemia (Pek 1977). Specimens similar to it (*G.* cf. *splendens*) have been recorded from the *M. planilimbata* zone of the Hunnebergian to the *M. estonica* zone of the late Billingenian (Ahlberg 1992) of southern Sweden.

Class Trilobita Walch, 1771

Order Proetida Fortey & Owens, 1975

Superfamily Bathyuroidea Walcott, 1886

Family Telephinidae Marek, 1952

Comments. Fortey (1974) considered the genus *Opipeuter* to be related to the Remopleurididae, although he believed it to be sufficiently distinct to require the introduction of the new family Opipeuteridae. Laurie & Shergold (1996) have demonstrated that *Opipeuter* belongs to the Telephinidae and this systematic position is adopted herein.

Genus *Opipeuter* Fortey, 1974

Type species. *Opipeuter inconnivus* Fortey, 1974.

Opipeuter angularis (Young, 1973)

Figures 6.6, 6.10

1973 *Remopleuridiella angularis* n. sp.; Young, p. 112, pl. 1, figs. 21, 22, 26; not figs. 25, 27.

1980 *Opipeuter angularis* (Young); Fortey, p. 48, pl. 6, figs. 9, 13.

Material. One cranidium (CPC 33228) and one librigena (CPC 33229), both from locality 707/12; other fragmentary material, possibly conspecific, from locality 707/10.

Comments. Although represented by only a few poorly preserved specimens, they show features which are consistent with assignment to *O. angularis* (Young) rather than *O. inconnivus* Fortey. Compared with the latter, the Gap Creek specimens have a glabella which, in lateral profile, is of greater convexity relative to length, and has a broader, shorter tongue and a more forwardly placed anterolateral glabellar angle with consequent longer (exsag.) posterior portion of the fixigena.

The librigena has more in common with that illustrated by Fortey (1974, pl. 13, fig. 10) for *O. inconnivus* than any other assigned to the genus, apart from those referred to *O. emanuelensis translator* by Shergold (in Laurie & Shergold 1996). It has a small genal spine, and between the eye and the border furrow, at about the midlength level of the eye, there is a moderately short (exsag.), narrow (tr.) genal field. On the other hand, anterolaterally, the border of the librigena abruptly begins to narrow towards the front, such that in front of the eye it is extremely narrow (exsag.). At the same position, the border also abruptly bends ventrally through about 60°. This is unlike the librigenal border in all subspecies of *O. emanuelensis*, in which the border does not alter direction to anywhere near the same extent. It is unclear whether this feature is present in either *O. angularis* or *O. inconnivus*.

Opipeuter ?inconnivus Fortey, 1974

Figures 6.7–6.9

?1974 *Opipeuter inconnivus* sp. nov.; Fortey, p. 112, pl. 13, figs. 2–4, 9, 11, 12; pl. 14, figs. 1–3, 5, 8–10, 11–13.

?1980 *Opipeuter inconnivus* Fortey; Fortey, p. 47, pl. 6, figs. 12, 14, 15.

Material. Two cranidia, one of which is illustrated (CPC 33230); and two librigenae, both of which are illustrated (CPC 33231, CPC 33232). All from locality 707/16.

Comments. One very poorly preserved cranidium from locality 707/16 is probably pathological because it is asymmetrical, but it seems to have a glabellar tongue that is narrower than that of *O. angularis* from 707/12. A narrow glabellar tongue is characteristic of the type and subsequent species of *Opipeuter*; therefore this specimen is tentatively assigned to the type species, *O. inconnivus*.
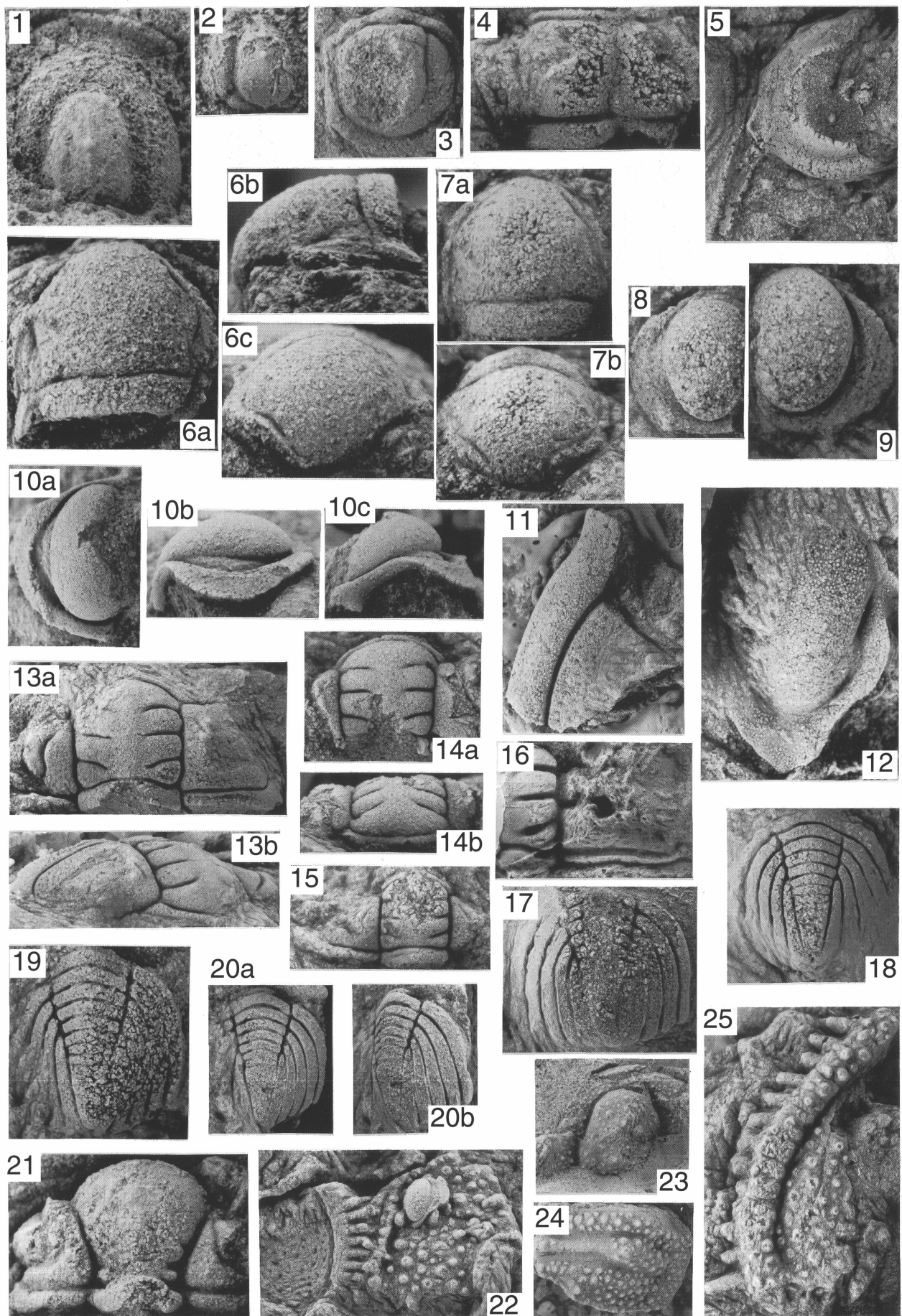
Genus *Carolinites* Kobayashi, 1940

[= *Keidelia* Harrington & Leanza, 1957;
= *Dimastocephalus* Stubblefield, 1950]

Type species. *Ptychoparia? tasmaniensis* Etheridge, 1919 = *Carolinites bulbosus* Kobayashi, 1940 = *Carolinites genacinaca nevadensis* Hintze, 1953.

Remarks. Jell & Stait (1985, pp. 40–41) redescribed the originally designated type species of the genus, *Carolinites*

bulbosus, and concluded that it was a junior subjective synonym of *Ptychoparia*? *tasmaniensis* Etheridge. They also concluded that *Carolinites genacinaca nevadensis* Hintze was similarly synonymous. Therefore, under Article 61d of the International Code of Zoological Nomenclature (Ride et al. 1985), the species *C. tasmaniensis* is the genotype and if one wishes *C. genacinaca* to be conspecific but of a separate subspecies then it should be referred to as *C. tasmaniensis genacinaca*. In his extensive revision of species of *Carolinites,* Fortey (1975, p. 103) discusses only some of the diagnostic features, and does not illustrate intermediate specimens, despite stating that the gradation between the two 'sub-species appears to be perfect'. Therefore, my preference is for *C. genacinaca* to be retained as a separate species.

Carolinites ?genacinaca Ross, 1951
Figures 6.4–6.5

?1951 *Carolinites genacinaca* n. sp.; Ross, p. 84, pl. 18, figs. 25, 26, 28–36.

?1975 *Carolinites genacinaca genacinaca* Ross; Fortey, p. 112, pl. 37, figs. 1–15, pl. 38, figs. 1–3.

Material. One poorly preserved cranidium (CPC 33226) and one librigena (CPC 33227), both from locality 707/16.

Comments. Although very poorly preserved, these specimens clearly belong to *Carolinites*. This is because the glabella is stout, quadrate, expands slightly forward, and is flanked posteriorly by small bacculae; the anterior cranidial border is narrow (sag.) and immediately in front of the glabella. The fixigenae are difficult to discern anteriorly, but the posterior part of the right fixigena is preserved and indicates that these specimens belong to either *C. genacinaca* or *C. tasmaniensis*. Despite the poor preservation, the presence of an advanced genal spine and the lack of a subocular ridge indicate that an assignment to the former species is more likely.

Superfamily incertae sedis
?Family Hystricuridae Hupé, 1953
Indeterminate ?hystricurid 1
Figures 6.22-6.25

Material. One partial cranidium from float (CPC 33246); three librigenae from locality 707/12 (CPC 33244, CPC 33245, CPC 33248); one librigena from locality 707/16; one partial pygidium from locality 707/12 (CPC 33247); and one partial pygidium from float.

Comments. This species is known only from the few fragmentary specimens listed above, most of which are illustrated. The entire dorsal carapace appears to be spinose. The glabella appears to taper forwards, the fixigenae are wide, the preglabellar field narrow (sag.), about the same width as the anterior border. The librigena is wide (tr.), and has low convexity and a well-developed roll-like border which has a

row of more-or-less radial spines extending outwards. The size of the eye socle indicates that the eye was fairly large. The fragment of the pygidium exhibits well developed pleural furrows and a narrow convex border. This species shows some resemblance to representatives of the spinose hystricurid *Amblycranium* Ross.

Indeterminate ?hystricurid 2
Figures 7.2–7.3

Material. Two librigenae, one each from locality 707/12 and 707/16 (CPC 33250 and CPC 33251 respectively).

Comments. This species is represented by only two librigenae. In these, the eye is large and reniform, similar in many respects to that of the Telephinidae. The librigenal field is small, and convex; the border moderately wide; and the genal spine long and posterolaterally directed.

Order Phacopida Salter, 1864
Suborder Cheirurina Harrington & Leanza, 1957
Family Pliomeridae Raymond, 1913
Genus *Canningella* Legg, 1976

Type species. *Canningella hardmani* Legg, 1976.

Revised diagnosis. Glabella nearly parallel-sided, evenly curved anteriorly, with S3 furrows arising immediately behind anterolateral angles of glabella. Pygidium has 7 or 8 axial rings and an elongate lanceolate terminal piece; pleurae have 5 ribs, the last pair of which run parallel to the axial furrow and posteriorly nearly envelop the terminal piece.

Comments. Legg (1976, p. 22) stated in his diagnosis of this genus that it had 10–11 pygidial axial rings in addition to the terminal piece. However, the specimens illustrated by him do not show that many rings. It seems that in his estimation of the number of axial rings, Legg included several of the incomplete transverse furrows in the terminal piece. Furthermore, he also stated that the 3p glabellar furrow (S3 herein) arose from the anterolateral glabellar angle. The furrow certainly is very close to that angle, but instead intersects the axial furrow a short distance behind it.

Canningella hardmani Legg, 1976
Figures 6.11–6.20

1976 *Canningella hardmani* sp. nov.; Legg, p. 23, pl. 7, figs. 1–10.

Material. Five cranidia from float, four of which are illustrated (CPC 33235, CPC 33236, CPC 33237, CPC 33238); one partial cranidium from locality 707/10; one cranidium from locality 707/16; two hypostomes from locality 707/16, one of which is illustrated (CPC 33234); one librigena from float (CPC 33233) and one from locality 707/16; one pygidium from float, two from locality 707/12, one of which is illustrated (CPC 33239), and five from locality 707/16, three of which are illustrated (CPC 33240, CPC 33241, CPC 33242).

Figure 6 (facing page). 1–3, *Geragnostus* **aff.** *splendens* **(Holub, 1912): 1,** partial cephalon, x12, CPC 33223, from loc.707/16; **2,** posterior part of cephalon, x15, CPC 33224, from float; **3,** damaged pygidium, x8, CPC 33225, from loc.707/12.
4–5, *Carolinites genacinaca* **Ross, 1951: 4,** damaged cranidium, x8, CPC 33226, from loc. 707/16; **5,** left librigena, x6, CPC 33227, from loc.707/16. **6, 10,** *Opipeuter angularis* **(Young, 1973): 6a–c,** cranidium, dorsal, lateral, and anterior views respectively, x10, CPC 33228, from loc.707/12; **10a–c,** left librigena, dorsal, lateral, and anterior views respectively, x9, CPC 33229, from loc.707/12. **7–9,** *Opipeuter* **?***inconnivus* **Fortey, 1974: 7a–b,** ?pathological cranidium, dorsal and anterior views respectively, x11, CPC 33230, from loc.707/16; **8,** left librigena, x13, CPC 33231, from loc.707/16; **9,** right librigena, x12, CPC 33232, loc.707/16. **11–20,** *Canningella hardmani* **Legg, 1976: 11,** partial left librigena, x6, CPC 33233, float; **12,** partial hypostome, x8, CPC 33234, from loc.707/16; **13a–b,** partial cranidium, dorsal and anterolateral oblique views respectively, x4, CPC 33235, float; **14a–b,** partial cranidium, dorsal and anterior view respectively, x8, CPC 33236, float; **15,** small cranidium, x8, CPC 33237, float; **16,** partial large cranidium, latex cast of internal mould, x3, CPC 33238, float; **17,** poorly preserved pygidium, x4, CPC 33239, from loc.707/12; **18,** pygidium, x4, CPC 33240, from loc.707/16; **19,** pygidium, x8, CPC 33241, from loc.707/16; **20a–b,** pygidium, dorsal and posterolateral oblique views respectively, x3, CPC 33242, from loc.707/12. **21,** *Encrinurella* **?***reedi* **Legg, 1976:** poorly preserved cranidium, x9, CPC 33243, from loc.707/12. **22–25,** indeterminate ?hystricurid 1: **22,** two partial librigenae, specimen on the left in ventral view showing marginal spines, CPC 33244, specimen on the right in dorsal view showing spinose dorsal surface, CPC 33245, with associated *Opipeuter* librigena, x4, from loc.707/12; **23,** latex cast of partial cranidium, showing anterior border, anterior part of glabella and portions of fixigenae, x4, CPC 33246, float; **24,** anterolateral fragment of pygidium, x4, CPC 33247, from loc.707/12; **25,** fragmentary librigena showing marginal spines, x4, CPC 33248, from loc.707/12.

Description. Cranidium much wider than long, of moderate convexity. Glabella with finely granular ornament, parallel-sided or expanding slightly forward. Occipital furrow deep, evenly bent forward. S1 furrows curving backwards toward occipital furrow, extending about two-thirds distance from axial furrow to glabellar midline. S2 furrows nearly straight, transverse, or directed slightly backwards. S3 furrows curved, arising from the axial furrow a very short distance behind the anterolateral glabellar angle, convex anteriorly with both extremities about level with one another. Anterior margin of
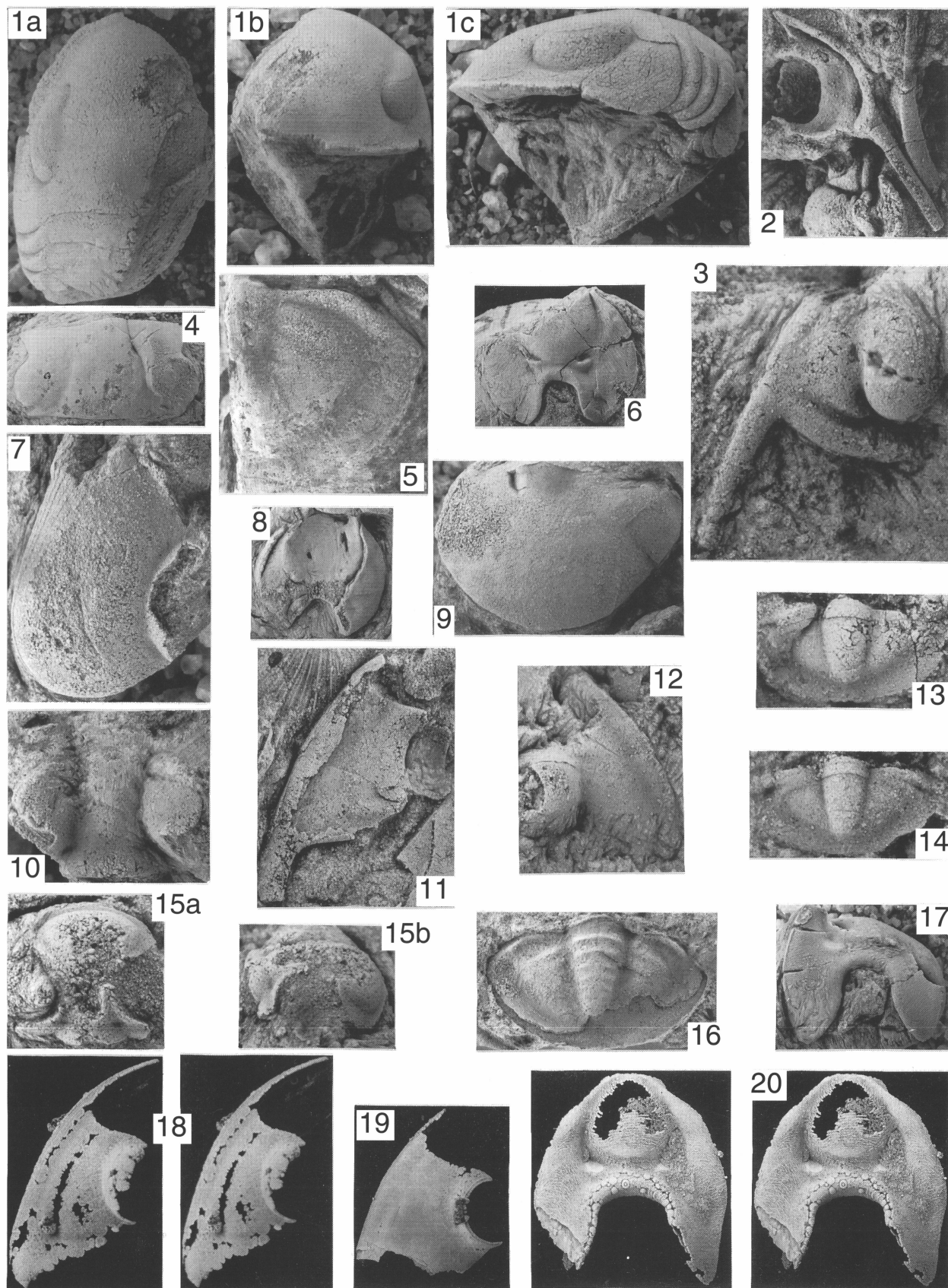
glabella broadly and evenly curved, separated from narrow border by a narrow, well-defined preglabellar axial furrow. Anterior limb of fixigena narrow (tr.). Palpebral lobe large, wide, long, evenly curved, separated from remainder of fixigena by a well-developed palpebral furrow. Posterior limb of fixigena very broad (tr.), with well-developed border widening laterally, anteriorly defined by deep narrow border furrow.

Librigena represented only by fragmentary specimens, most of which are poorly preserved. The illustrated specimen shows that the border has a finely granular ornament, similar to that of the glabella, while that of the librigenal field has superimposed on this a more coarsely pitted ornament.

Hypostome represented by usually poorly preserved fragmentary specimens. Illustrated specimen exhibits a finely granular ornament over entire surface. Middle body clearly defined by deep border furrow, elongate ovate, with oblique middle furrow very weakly developed. Border incompletely preserved, of moderate width, widening slightly posteriorly; posterior extremity probably pointed.

Pygidium subcircular to subquadrate. Axis consisting of 7 or 8 axial rings and an elongate lanceolate terminal piece, clearly separated from pleural lobes by deep narrow axial furrow. Pleural lobes consisting of 5 pleural ribs; only the anterior two are adjacent to their respective axial rings; the more posterior ribs are more offset; the posteriormost (fifth) arises level with the sixth axial ring, and extends alongside the remainder of the axis, widening posteriorly, and curving at the posterior extremity to nearly envelop the terminal piece of the axis.

Genus *Encrinurella* Reed, 1915

Type species. *Pliomera insangensis* Reed, 1906.

Encrinurella ?reedi Legg, 1976

Figure 6.21

?1976 *Encrinurella reedi* sp. nov.; Legg, p. 22, pl. 7, figs. 11–13, 15, 16, 18, 19.

Comments. Only one cranidium (CPC 33243) has been recovered (from locality 707/12) in the present collections. It is too poorly preserved to make any detailed comparison with the specimens described by Legg (1976, p. 22), but has a glabella that expands more strongly forward and has a more broadly curved anterior margin than the single enrolled specimen illustrated by Legg (1976, pl. 7 fig. 16). The assignment is therefore very tentative.

Order Asaphida Salter, 1864

Superfamily Asaphoidea Burmeister, 1843

?Family Asaphidae Burmeister, 1843

Indeterminate asaphid 1

Figure 7.1

Comments. This specimen is represented by a single incomplete enrolled individual (CPC 33249) found as float. It has been laterally compressed and is weathered, such that the right side of the cephalon and thorax are missing and the pygidium is also missing. The axial furrows are effaced; the eyes are large; the preglabellar area is short (sag., exsag.); the librigena is narrow (tr.) and steeply inclined; and the genal angle is broadly rounded. This species is similar in many respects to *Fitzroyaspis irritans* Fortey & Shergold (1984) from the Nora Formation of the Georgina Basin and to a similar species from the Horn Valley Siltstone of the Amadeus Basin (Laurie unpublished data). However, the present species lacks the well-defined cephalic border of these other two species.

Indeterminate asaphid 2

Figures 7.4–7.5, 7.7–7.8

Material. One partial cranidium (CPC 33252); a partial librigena (CPC 33254); a partial pygidium (CPC 33253) doubtfully associated; and a hypostome (CPC 33255). All from locality 707/12.

Comments. Several asaphid fragments were obtained from locality 707/12 and are here tentatively grouped together for no other reason than their co-occurrence. The partial cranidium and librigena probably come from the same species insofar as they have a characteristic extremely rearwardly located eye, and the cranidium has a very short (tr.) prong-like posterior limb of the fixigena. The occipital furrow is effaced, and the axial furrow seems to fade out anteriorly. The associated pygidium is unlike that expected for such an effaced cephalon, and may not belong to the same species.

Indeterminate asaphid 3

Figures 7.6, 7.9

Comments. This species is represented by a partial hypostome (CPC 33256) and a damaged and weathered pygidium (CPC 33257), both of which come from locality 707/10. These specimens may be conspecific with indeterminate asaphid 1, because they are also very similar to *Fitzroyaspis irritans* Fortey & Shergold (1984) and a similar species from the Amadeus Basin (Laurie unpublished data). The hypostome is very similar to that from the Amadeus form, from which it differs in having slightly longer posterior prolongations of the margin. The pygidium differs from that of the Amadeus Basin form in lacking a border, a feature which is always present if only weakly developed in the Amadeus form.

Indeterminate asaphid 4

Figures 7.10–7.15, 7.17–7.20

Material. Three cranidia from float, two of which are illustrated (CPC 33258, CPC 33263), one from locality 707/16 and one partly silicified from locality 707/17B; one hypostome (CPC 33264) from float and one silicified (CPC 33267) from locality 707/17A; three librigenae, two of which are illustrated (CPC 33259, CPC 33260), from locality 707/16 and two silicified librigenae from localities 707/17A (CPC 33266) and 707/17B (CPC 33265); two pygidia from locality 707/16 (CPC 33261, CPC 33262).

Comments. This is perhaps the best understood of the Gap Creek asaphids insofar as it is represented by the most specimens, some of which are partly silicified. The species is represented by several cranidia, many librigenae, two

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Figure 7 (facing page). 1a–c, indeterminate asaphid 1: enrolled specimen with deeply weathered posterior thorax and pygidium; dorsal, anterior, and lateral views respectively, x4, CPC 33249, float. 2–3, indeterminate ?hystricurid 2: 2, ventral surface of librigena, x4, CPC 33250, from loc. 707/12; 3, dorsal surface of librigena, x7, CPC 33251, from loc. 707/16; 4–5, 7–8, indeterminate asaphid 2, all from loc. 707/12: 4, posterior part of cranidium, x1, CPC 33252; 5, fragmentary pygidium, x4, CPC 33253; 7, partial librigena, x4, CPC 33254; 8, hypostome, x1.5, CPC 33255. 6, 9, indeterminate asaphid 3, both from loc. 707/10: 6, partial hypostome, x1, CPC 33256; 9, damaged and weathered pygidium, x3, CPC 33257. 10–15, 17–20, indeterminate asaphid 4: 10, posterior part of cranidium, x6, CPC 33258, from float; 11, ventral surface of librigena, x4, CPC 33259, from loc. 707/16; 12, partial librigena, x4, CPC 33260, from loc. 707/16; 13, small (meraspid?) pygidium with thoracic segment attached, x8, CPC 33261, from loc. 707/16; 14, small (meraspid?) pygidium with thoracic segment attached, x9, CPC 33262, from loc. 707/16; 15a–b, small weathered cranidium in dorsal and oblique lateral views respectively, x6, CPC 33263, from float; 17, partial hypostome, x2, CPC 33264, from float; 18, stereo pair of partly silicified librigena, x4, CPC 33265, from locality 707/17B; 19, silicified fragment of librigena, x2, CPC 33266, from loc. 707/17A; 20, stereo pair of silicified hypostome, x2, CPC 33267, from loc. 707/17A. 16, indeterminate ?asaphid 5: internal mould of pygidium, x2, CPC 33268, from loc. 707/10.
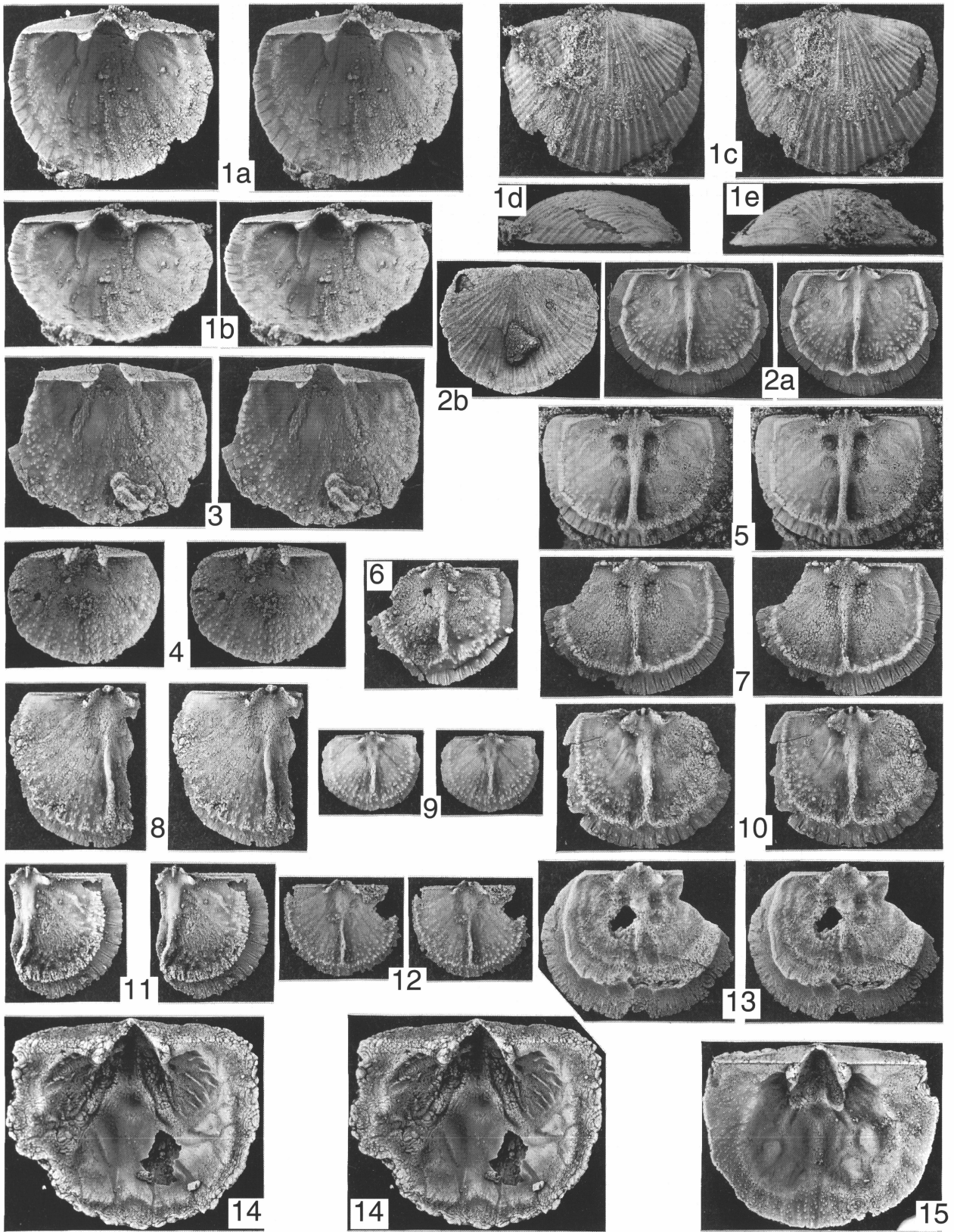
Figure 8. 1–13, *Tinopena shergoldi* gen. et sp. nov., all x4, all stereo pairs except figs. 1d, 1e, 2b, and 6, all from loc. 707/21: 1a–e, well-preserved paratype ventral valve, interior, interior oblique, exterior, lateral, and posterior views respectively, CPC 33269; 2a–b, well-preserved paratype dorsal valve, interior and exterior view respectively, CPC 33270; 3, paratype ventral interior, CPC 33271; 4, paratype small ventral interior, CPC 33272; 5, holotype dorsal interior, CPC 33273; 6, paratype dorsal interior, CPC 33274; 7, paratype dorsal interior, CPC 33275; 8, paratype partial dorsal interior, CPC 33276; 9, paratype small dorsal interior, CPC 33277; 10, paratype dorsal interior, CPC 33278; 11, paratype partial dorsal interior, CPC 33279; 12, paratype small dorsal interior, CPC 33280; 13, paratype (gerontic?) dorsal interior with median ridge broken off, CPC 33281. 14–15, *Spanodonta hoskingiae* Prendergast, 1935, both x3, both from loc. 707/21: 14, stereo pair of ventral interior showing mantle canal systems, CPC 33282; 15, ventral interior showing mantle canal systems, CPC 33283.

hypostomes, and two small pygidia. The glabella is very strongly constricted at about the level of the eyes, but expands strongly forward such that its widest point is near its anterior extremity. Its anterior margin is evenly and broadly rounded and steeply inclined towards the narrow cephalic border. The posterior limbs of the fixigenae are short (exsag.). The eyes are large, and the librigenal field convex and laterally bounded by a flattened border. The genal angle is produced into a large spine.

The hypostome is typically asaphine. It has a short (sag.) ovate middle body, at the posterolateral extremities of which are located two transverse ridge-like maculae. The posterior border notch is deep (sag.) and wide (tr.), and the prolongations occupy nearly half the total length of the hypostome. The pygidia available are quite small and have a wide unsegmented axis, a convex, smooth pleural field, and a wide flattened border.

This species has a combination of characters which makes it difficult to interpret. It has a cranidium with the constricted, anteriorly expanded glabella and narrow (tr.) anterior fixigenae similar to *Asaphus* and closely related genera. Similarly, the hypostome is unusual in being similar in dimensions to that of *Lycophron*, but different in character, insofar as it possesses a small but clearly defined middle body.

Indeterminate ?asaphid 5

Figure 7.16

Comments. This specimen, from locality 707/10, is represented by a single pygidium (CPC 33268) which may belong to an asaphid species.

Phylum Brachiopoda Duméril, 1806

Class Calciata Popov, Bassett, Holmer & Laurie, 1993

Order Orthida Schuchert & Cooper, 1932

Suborder Orthidina Schuchert & Cooper, 1932

Family Plectorthidae Schuchert & LeVene, 1929

Genus *Pseudomimella* Xu & Liu, 1984

Type species. *Mimella formosa* Wang, 1955.

?Pseudomimella sp.

Figures 10.3–10.5, 11.2

Material. One complete, unsilicified, weathered specimen (CPC 33290) found in float; and two silicified partial dorsal valves (CPC 33287, CPC 33289) and a partly silicified fragmentary ventral valve (CPC 33288) all from locality 707/17B.

Comments. Xu & Liu (1984) distinguished *Pseudomimella* from *Mimella* by its smaller ventral muscle field and the considerable difference in the arrangement of both ventral and dorsal mantle canal systems. Although the Gap Creek specimens exhibit little of their mantle canal systems, the single associated fragmentary ventral valve seems to have a rather small ovate muscle field, unlike that characteristic of species assigned to *Mimella* Cooper. For this reason the Gap Creek specimens are tentatively assigned to *Pseudomimella* Xu & Liu.

Genus *Oligorthis* Ulrich & Cooper, 1936

Type species. *Oligorthis arbucklensis* Ulrich & Cooper, 1936.

?Oligorthis sp.

Figure 10.6

Material. One nearly complete dorsal valve (CPC 33291) and several fragmentary specimens, all from locality 707/21.

Comments. This species is represented by several, mostly fragmentary dorsal valves, one of which is illustrated. It is a small brachiopod with a multicostellate ornament, a well-developed sulcus in the dorsal valve, well-developed brachiophore bases which converge onto a low broad median ridge, well-developed small fulcral plates, and a short broad quadripartite adductor field whose anterior scars are separated from the posterior ones by narrow oblique ridges. The cardinal

process is developed as a very low blade.

Genus *Tritoechia* Ulrich & Cooper, 1936

Type species. *Deltatreta typica* Schuchert & Cooper, 1932.

Tritoechia sp.

Figures 10.1–10.2

Material. One nearly complete ventral valve (CPC 33285) from locality 707/17B; and several nearly complete small dorsal valves, one of which is illustrated (CPC 33286), and several fragmentary small ventral valves from locality 707/21.

Comments. This species is represented by only one large, nearly complete silicified ventral valve, several small dorsal valves, and many fragmentary specimens. It is similar in general proportions to the type species, but possesses a weak ventral sulcus and lacks the hollow costellae of the latter.

Family Taffiidae Schuchert & Cooper, 1931

Comments. Cocks & Rong (1989) included several subfamilies within the Taffiidae, but their scheme is not followed here for reasons outlined by Laurie (1991, pp. 52 and 62). This family therefore includes the genera *Taffia* Ulrich, *Aporthophyla* Ulrich & Cooper, *Aporthophylina* Liu, *Spanodonta* Prendergast [=*Archambona* Cooper], and the new genus *Tinopena*, which is described below.

Genus *Spanodonta* Prendergast 1935

[=*Archambona* Cooper, 1988]

Type species. *Spanodonta hoskingiae* Prendergast 1935.

Comments. The reasons for assigning *Spanodonta* to the Taffiidae and for including *Archambona* in its synonymy are explained by Laurie (1987) and Laurie & Burrett (1992).

Spanodonta hoskingiae Prendergast 1935

Figures 8.14–8.15, 9, 11.3

1935 *Spanodonta hoskingiae* Prendergast, p. 13, pl. 3, figs. 1–3.

1987 *Spanodonta hoskingae* (sic) Prendergast; Laurie, p. 44, figs. 2–4.

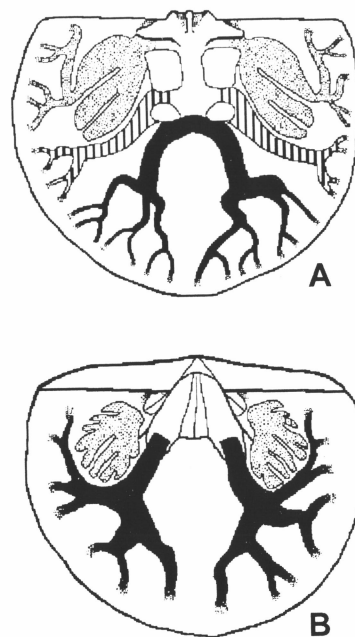1989 *Spanodonta hoskingiae* Prendergast; Cocks & Rong, p. 98, figs. 36–40.

Figure 9. Interpretation of mantle canal systems of dorsal (A) and ventral (B) valves of *Spanodonta hoskingiae* Prendergast, 1935. In both valves the vascula media are black, the vascula genitalia stippled, and in the dorsal valve the vascula myaria are ornamented with parallel lines.

1992 *Spanodonta hoskingiae* Prendergast; Laurie &
Burrett, pp. 16–17 (no description).

Material. Several unsilicified complete specimens, one of
which is illustrated (CPC 33284), all from float; many
unsilicified specimens from localities 707/10, 707/12, and
707/16; several hundred silicified specimens from localities
707/17A, 707/17B and 707/21, of which two (CPC 33282,
CPC 33283) from this last locality are illustrated.

Comments. Details are much as described by Laurie (1987),
but some specimens which are better preserved than most
allow further details of the mantle canal systems to be discerned.
One specimen, although somewhat damaged, shows the ventral
mantle canal system in detail. A reconstruction of the saccate
ventral mantle canal system based on this and one other
specimen is shown in Figure 9. The reconstruction of the
lemniscate dorsal mantle canal system is included in Figure 9
for the sake of completeness, and was obtained almost entirely
from specimens illustrated by Laurie (1987).

Genus *Tinopena* gen. nov.

Etymology. Random selection of letters; the accent is on
the o: feminine.

Type species. *Tinopena shergoldi* sp. nov.

Diagnosis. Concavoconvex, subcircular to transversely
ovate, parvicostellate. Ventral interarea orthocline to apsacline;
delthyrium with apical pseudodeltidium. Dorsal interarea
catacline. Chilidium completely covering notothyrium.

Ventral muscle field subcordate, diductor scars extending
beyond but not enclosing triangular adductor field. Teeth with
narrow shelf-like fossettes, dental plates receding. Sub-
peripheral rim present.

Cardinal process bladelike to knob-shaped. Socket ridges
short. Subperipheral rim well developed, usually undercut.
Posterior dorsal adductor scars ovate, larger than subcircular
anterior pair. Median ridge narrow, extending to sub-
peripheral rim.

Comments. Despite the lack of knowledge of details of
the musculature and mantle canal systems in *Taffia*, this genus
is assigned to the Taffiidae because the morphology of its
ventral and dorsal musculature, dorsal cardinalia, and mantle
canal system is consistent with a close relationship to other
genera, such as *Aporthophyla* and *Spanodonta*, commonly
assigned to that family.

In most respects, *Tinopena* is very similar to *Spanodonta*,
with which it occurs. However, it differs in being only slightly
more than half the dimensions of the latter, and in having a
thinner shell and a consequently shorter trail in the dorsal
valve. *Spanodonta* also lacks the well-defined narrow dorsal
median ridge so characteristic of *Tinopena*.

Aporthophyla is similar to *Tinopena* in the arrangement of
the mantle canal systems and musculature, general shell shape,
and valve thickness, but is larger and lacks the dorsal median
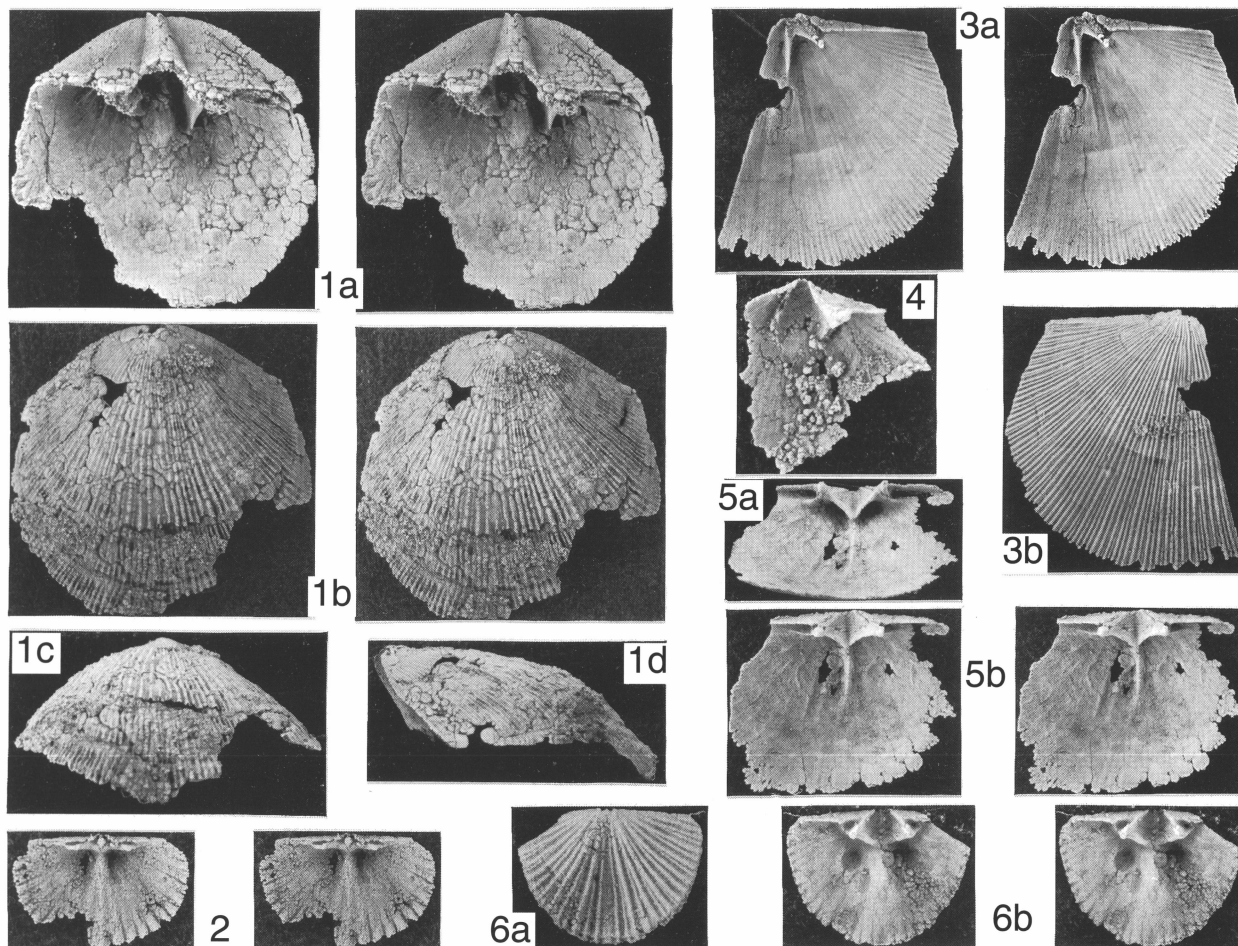ridge.

Figure 10. 1–2, *Tritoechia* sp.: 1a–d, ventral valve, stereo pair of interior, stereo pair of exterior, anterior, and lateral views respectively, x3, CPC 33285, from loc. 707/17B; 2, stereo pair of small dorsal valve, x6, CPC 33286, from loc. 707/21. 3–5, ?*Pseudomimella* sp., all from loc. 707/17B: 3a–b, partial dorsal valve, stereo pair of interior and exterior views respectively, x3, CPC 33287; 4, interior of fragmentary ventral valve, x6, CPC 33288; 5a–b, partial dorsal valve, oblique interior view and stereo pair of interior in normal view respectively, x3, CPC 33289. 6a–b, ?*Oligorthis* sp.: dorsal valve, exterior and stereo pair of interior respectively, x6, CPC 33291, from loc. 707/21.

Aporthophylina Liu is also reported to possess a dorsal median ridge, but from Liu's (1976, pl. 2, fig. 12) illustration it appears to be a much broader structure than the narrow blade-like dorsal median ridge in *Tinopena*. *Aporthophylina* also has subparallel ventral vascula media, unlike those of *Tinopena*, which are strongly divergent anteriorly.

Tinopena shergoldi sp. nov.

Figures 8.1–8.13

Etymology. After Dr J.H. Shergold, for his work on the Canning Basin Ordovician

Material. About 50 silicified specimens, all from locality 707/21, of which thirteen are illustrated (CPC 33269–33281)

Description. Concavoconvex, transversely ovate, ventral valve 83% as long as wide; dorsal valve 79% as long as wide. Maximum width at or behind midlength of valve; hinge width about 81% maximum width. Ornament parvicostellate; costellae on dorsal valve fine and poorly defined, on ventral valve they are broader and more clearly defined, with about 10 per 5 mm at the anterior margin. Ventral interarea planar, orthocline to apsacline, about 11% as high as wide. Delthyrium with broad, convex, apical pseudodeltidium. Dorsal interarea planar, low, catacline. Chilidium broad, convex, completely covering notothyrium.

Ventral muscle field subcordate, extending about one-third of the distance to the anterior valve margin; narrow diductor scars extend beyond but do not enclose the broad triangular adductor field. Vascula media diverge anteriorly from each other at about 40°. Remainder of vascular system obscure.

Teeth moderately large, and have narrow shelf-like fossettes, dental plates receding, and low ridge-like extensions laterally bounding muscle field. Subperipheral rim present laterally, fading out anteriorly.

Cardinal process well developed, posteriorly directed, ranging from bladelike to knob-shaped, posteriorly ankylosed to chilidium. Socket ridges short, diverging anteriorly from one another at about right-angles, anteriorly bounding triangular rearward-opening sockets. Subperipheral rim well developed, usually undercut; in some specimens forming a low wall around visceral disc. Visceral disc large, planar. Dorsal adductor field commonly well defined, occupying 25% of valve width, and extending anteriorly about 43% of valve length. Posterior dorsal adductor scars longitudinally ovate, larger than anterior pair. Anterior scars subcircular, separated from posterior pair by low rounded transverse ridges. Median ridge broad posteriorly, narrowing towards anterior, extending to subperipheral rim as narrow blade, reaching maximum height anterior to dorsal adductor field. Dorsal mantle canal system with vascula media diverging anteriorly from the median ridge at about 20°; vascula myaria diverging anteriorly at about 50° from midline of valve. Remainder of vascular system obscure.

Comments. This species is uncommon at the type locality, and its juveniles can be distinguished from those of *Spanodonta hoskingiae* only by the presence of the characteristic dorsal median ridge.

Order Pentamerida Schuchert & Cooper, 1931
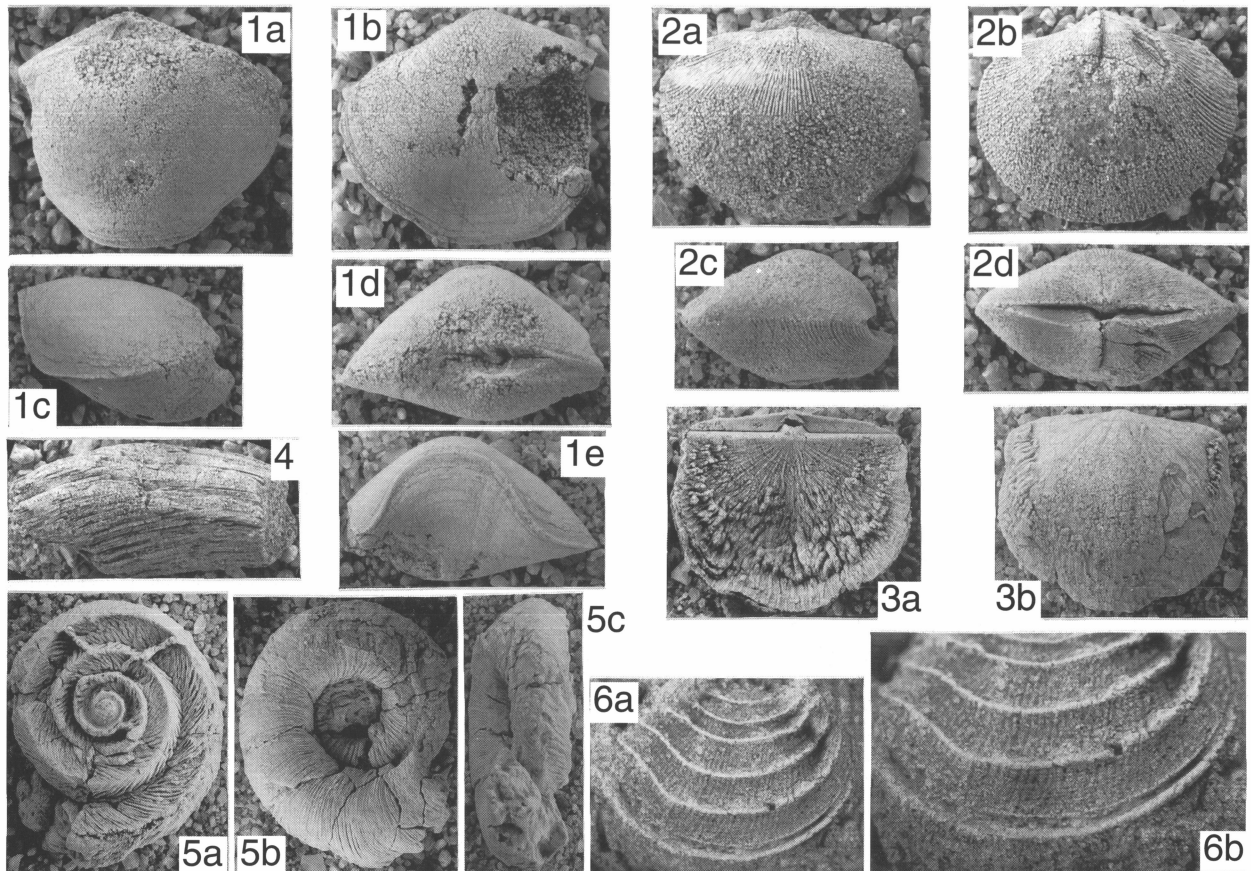### Suborder Syntrophiidina Ulrich & Cooper, 1936

Figure 11. 1a–e, indeterminate syntrophiidine: complete but weathered unsilicified articulated specimen in dorsal, ventral, lateral, posterior, and anterior views respectively, x2, CPC 33292, from float. 2a–d, ?*Pseudomimella* sp.: complete but weathered unsilicified articulated specimen in dorsal, ventral, lateral, and posterior views respectively, x2, CPC 33290, from float. 3a–b, *Spanodonta hoskingiae* Prendergast, 1935: complete unsilicified articulated specimen in dorsal and ventral views respectively, x2, CPC 33284, from float. 4, *Teiichispira* sp.: fragment of unsilicified operculum, x1.5, CPC 33293, from float. 5a–c, *Helicotoma* sp.: complete unsilicified shell, in apical, umbilical, and apertural views, x1, CPC 33294, from loc. 707/10. 6a–b, problematicum, nearly complete plate: 6a, entire specimen, x8; 6b, detail of distal portion showing ornament, x12, CPC 33295, from loc. 707/16.

Indeterminate syntrophiidine

Figure 11.1

Material. One unsilicified complete but weathered specimen (CPC 33292) found in float.

Comments. Only one reasonably well preserved unsilicified specimen is available; no silicified specimens have been found. This specimen is a typical Early Ordovician syntrophiidine: it is smooth and slightly transverse, and has a strongly plicate anterior commissure.

Phylum Mollusca

Class Gastropoda Cuvier, 1797

Order Archaeogastropoda Thiele, 1925

Suborder Macluritina Cox & Knight, 1960

Superfamily Macluritoidea Fischer, 1885

Family Macluritidae Fischer, 1885

Genus *Teiichispira* Yochelson & Jones, 1968

Type species. *Teiichispira kobayashi* Yochelson & Jones, 1968.

Teiichispira sp.

Figure 11.4

1973 *Teiichispira* sp. indet.; Gilbert-Tomlinson, p. 85, pl. 33, figs. 5, 10.

1993 *Teiichispira kobayashi* Yochelson & Jones; Yu, p. 446, figs. 4g–k.

Material. Several unsilicified specimens were obtained from float, one of which is illustrated (CPC 33293); many unsilicified specimens were found at localities 707/10, 707/12, and 707/16; many fragmentary specimens were also found silicified at localities 707/17A, 707/17B, and 707/21.

Comments. The opercula of this large macluritid gastropod are very common in the Gap Creek Formation. However, no detailed examination was attempted. The species is left under open nomenclature despite the opinion of Yu (1993) that it belongs to the type species. This is because, in his discussion of the specimens, he noted that they are different in size and possibly in shape (the phrasing is ambiguous) to the type species, but are possibly conspecific with *T. cornucopiae* Gilbert-Tomlinson (1973).

Family Helicotomidae Wenz, 1938

Genus *Helicotoma* Salter, 1859

Type species. *Helicotoma planulata* Salter, 1859.

Helicotoma sp.

Figure 11.5

Material. Two well-preserved specimens, one from float and one from locality 707/10. Only the latter is illustrated (CPC 33294).

Comments. Compared with the Pulau Langgun species of *Helicotoma* (Kobayashi 1959), this specimen has a lower rate of increase in whorl diameter.

Phylum Problematicum

Figure 11.6

Material. Several dozen specimens, all from locality 707/16, only one of which is illustrated (CPC 33295).

Comments. These ridged plates were at first thought to be fragmentary bivalves or gastropods, but they occur in both dextral and sinistral versions, are uniform in shape, essentially planar and the distance between the concentric ridges is quite variable. It is considered most likely that they are either conchostracan valves or machaeridian plates.

Acknowledgments

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Appendix 1: Index of figured specimens

CPC number	Classification	Illustration	Horizon
Geragnostus aff. *splendens* (Holub, 1912)			
33223	Figured specimen	Fig. 5.1	707/16
33224	ditto	Fig. 5.2	707/float
33225	ditto	Fig. 5.3	707/12
Carolinites ?genacinaca Ross, 1951			
33226	ditto	Fig. 5.4	707/16
33227	ditto	Fig. 5.5	707/16
Opipeuter angularis (Young, 1973)			
33228	ditto	Fig. 5.6a–c	707/12
33229	ditto	Fig. 5.10a–c	707/12
Opipeuter ?inconnivus Fortey, 1974			
33230	ditto	Fig. 5.7a–b	707/16
33231	ditto	Fig. 5.8	707/16
33232	ditto	Fig. 5.9	707/16
Canningella hardmani Legg, 1976			
33233	ditto	Fig. 5.11	707/float
33234	ditto	Fig. 5.12	707/16
33235	ditto	Fig. 5.13a–b	707/float
33236	ditto	Fig. 5.14a–b	707/float
33237	ditto	Fig. 5.15	707/float
33238	ditto	Fig. 5.16	707/float

33239	ditto	Fig. 5.17	707/12
33240	ditto	Fig. 5.18	707/16
33241	ditto	Fig. 5.19	707/16
33242	ditto	Fig. 5.20a–b	707/16

Encrinurella ?reedi Legg, 1976

| 33243 | ditto | Fig. 5.21 | 707/12 |

Indeterminate ?hystricurid 1

33244	ditto	Fig. 5.22 left	707/12
33245	ditto	Fig. 5.22 right	707/12
33246	ditto	Fig. 5.23	707/float
33247	ditto	Fig. 5.24	707/12
33248	ditto	Fig. 5.25	707/12

Indeterminate asaphid 1

| 33249 | ditto | Fig. 6.1a–c | 707/float |

Indeterminate ?hystricurid 2

| 33250 | ditto | Fig. 6.2 | 707/12 |
| 33251 | ditto | Fig. 6.3 | 707/16 |

Indeterminate asaphid 2

33252	ditto	Fig. 6.4	707/12
33253	ditto	Fig. 6.5	707/12
33254	ditto	Fig. 6.7	707/12
33255	ditto	Fig. 6.8	707/12

Indeterminate asaphid 3

| 33256 | ditto | Fig. 6.6 | 707/10 |
| 33257 | ditto | Fig. 6.9 | 707/10 |

Indeterminate asaphid 4

33258	ditto	Fig. 6.10	707/float
33259	ditto	Fig. 6.11	707/16
33260	ditto	Fig. 6.12	707/16
33261	ditto	Fig. 6.13	707/16
33262	ditto	Fig. 6.14	707/16
33263	ditto	Fig. 6.15a–b	707/float
33264	ditto	Fig. 6.17	707/float
33265	ditto	Fig. 6.18	707/17B
33266	ditto	Fig. 6.19	707/17A
33267	ditto	Fig. 6.20	707/17A

Indeterminate ?asaphid 5

| 33268 | ditto | Fig. 6.16 | 707/10 |

Tinopena shergoldi gen. et sp. nov.

33269	paratype	Fig. 7.1a–e	707/21
33270	paratype	Fig. 7.2a–b	707/21
33271	paratype	Fig. 7.3	707/21
33272	paratype	Fig. 7.4	707/21
33273	holotype	Fig. 7.5	707/21
33274	paratype	Fig. 7.6	707/21
33275	paratype	Fig. 7.7	707/21
33276	paratype	Fig. 7.8	707/21
33277	paratype	Fig. 7.9	707/21
33278	paratype	Fig. 7.10	707/21
33279	paratype	Fig. 7.11	707/21
33280	paratype	Fig. 7.12	707/21
33281	paratype	Fig. 7.13	707/21

Spanodonta hoskingiae Prendergast, 1935

33282	figured specimen	Fig. 7.14	707/21
33283	ditto	Fig. 7.15	707/21
33284	figured specimen	Fig. 10.3a–b	707/float

Tritoechia sp.

| 33285 | figured specimen | Fig. 9.1a–d | 707/17B |
| 33286 | figured specimen | Fig. 9.2 | 707/21 |

?Pseudomimella sp.

33287	figured specimen	Fig. 9.3a–b	707/17B
33288	figured specimen	Fig. 9.4	707/17B
33289	figured specimen	Fig. 10.2a–d	707/float

?Oligorthis sp.

| 33291 | figured specimen | Fig. 9.6 a–b | 707/21 |

Indeterminate syntrophiidine

| 33292 | figured specimen | Fig. 10.1a–e | 707/float |

Teiichispira sp.

| 33293 | figured specimen | Fig. 10.4 | 707/float |

Helicotoma sp.

| 33294 | figured specimen | Fig. 10.5a–c | 707/10 |

Problematicum

| 33295 | figured specimen | Fig. 10.6a–b | 707/16 |

Appendix 2: Collections from the Gap Creek Formation

Section 707

707/10: indeterminate asaphid 3, indeterminate ?asaphid 5, *Spanodonta hoskingiae*, *?Pseudomimella* sp., *Helicotoma* sp., *Teiichispira* sp.

707/12: *Geragnostus* aff. *splendens*, *Opipeuter angularis*, *Canningella hardmani*, *Encrinurella ?reedi*, indeterminate asaphid 2, indeterminate ?hystricurid 1, indeterminate ?hystricurid 2, *Spanodonta hoskingiae*, *Teiichispira* sp.

707/16: *Geragnostus* aff. *splendens*, *Carolinites ?genacinaca*, *Opipeuter ?inconnivus*, *Canningella hardmani*, indeterminate asaphid 4, indeterminate ?hystricurid 1, *Spanodonta hoskingiae*, problematicum, *Teiichispira* sp., indeterminate gastropods

707/17A: indeterminate asaphid 4, *Spanodonta hoskingiae*, *Teiichispira* sp.

707/17B: indeterminate asaphid 4, *Spanodonta hoskingiae*, *Tritoechia* sp., *?Pseudomimella* sp. *Teiichispira* sp.

707/21: *Spanodonta hoskingiae*, *Tinopena shergoldi*, *Tritoechia* sp., *?Pseudomimella* sp., *?Oligorthis* sp., *Teiichispira* sp.

Section 708

708/10: indeterminate trilobite fragments, *Spanodonta hoskingiae*, *?Pseudomimella* sp., indeterminate gastropods

708/11: *Spanodonta hoskingiae*

708/48: indeterminate asaphid 4, *Spanodonta hoskingiae*, *?Pseudomimella* sp., *?Oligorthis* sp.

708/55: *Spanodonta hoskingiae*

708/60: *Spanodonta hoskingiae*, *Tinopena shergoldi*, *Tritoechia* sp., indeterminate plectambonitoidean, indeterminate trilobite

708/62: *Spanodonta hoskingiae*, *?Pseudomimella* sp., indeterminate trilobite

708/66: *Spanodonta hoskingiae*

708/75A: *Spanodonta hoskingiae*, *Tinopena shergoldi*

708/86B: *Tinopena shergoldi*.

708/98: *Tinopena shergoldi*, indeterminate gastropods

708/134: indeterminate gastropods