

EARLY ORDOVICIAN GASTROPODS FROM THE CANNING BASIN, WESTERN AUSTRALIA

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ABSTRACT

Fossil gastropods collected from the Lower Ordovician Emanuel Formation and Gap Creek Formation, Canning Basin, Western Australia, comprise eight species in seven genera, including two new species. The most common gastropods of the Emanuel Formation are *Peelerophon oehlerti* (Bergeron), *Ecculiomphalus* cf. *abendanoni* (Frech), *Pararaphistoma* (*Pararaphistoma*) *qualteriatum* (Schlotheim), *Pararaphistoma* (*Climacoraphistoma*) *vaginati* (Koken and Perner) and *Seelya emanuelensis* sp. nov. This gastropod fauna shows strong resemblances to those of southeastern Asia including China and to those of South America and Western Europe, ranging in age from Tremadocian to early Arenigian. Two species of Lower Ordovician gastropod, *Teiichispira kobayashi* Yochelson and Jones and *Oriostoma?* *canningense* sp. nov., are described from the Gap Creek Formation.

INTRODUCTION

The material utilized in the present paper were mainly collected by B.F. Glenister, A.W. Lindner and W.S. Johnson, all then of the University of Western Australia from the Emanuel Formation and Gap Creek Formation of Emanuel Creek, Canning Basin in 1957, 1958 and 1987 respectively. It also includes part specimens procured by D. Merrilees of the Western Australian Museum and J. Pas from the Emanuel Formation and Gap Creek Formation in 1960 and 1991 respectively (Figure 1).

The Lower Ordovician strata are extensively developed in the Canning Basin, but nearly all occur in the subsurface. The outcrop of the type section is along the Emanuel Creek. The Lower Ordovician in the Canning Basin has been divided in ascending order into Emanuel Formation and Gap Creek Formation (Guppy *et al.* 1958; Playford *et al.* 1975; McTavish and Legg 1976; Legg 1976; Forman and Wales 1981).

The Emanuel Formation is chiefly composed of light grey, nodular limestone and green-grey calcareous shale with a basal bed of sandy dolomite and arkose, about 594m in thickness (Playford *et al.* 1975). The formation yields various groups of fossils, such as conodonts, graptolites, trilobites, brachiopods, gastropods and cephalopods. More than 130 specimens of gastropods belonging to six species in five genera, were mainly obtained from the limestone, including *Peelerophon oehlerti* (Bergeron), *Bucania* sp., *Ecculiomphalus* cf. *abendanoni* (Frech), *Pararaphistoma* (*Pararaphistoma*) *qualteriatum* (Schlotheim), *Pararaphistoma*

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Canning Basin Ordovician gastropods

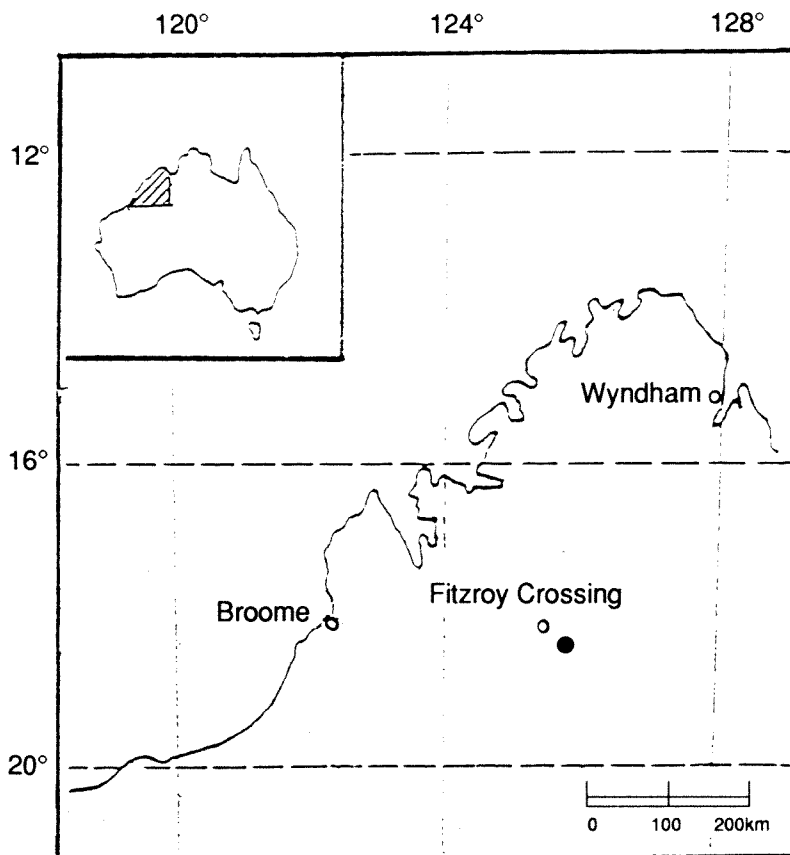


Figure 1 Map showing the locality of Early Ordovician gastropods in Canning Basin, Western Australia.

(*Climacorphistoma*) *vaginati* (Koken and Perner) and *Seelya emanuelensis* sp. nov. The characteristic elements of this assemblage are *Peelerophon oehlerti*, *Paraphistoma* (*Paraphistoma*) *qualeriatum*, *P. (Climacorphistoma) vaginati* and *Ecculiomphalus abandononi*. The *Peelerophon oehlerti* assemblage has been found widely distributed in South America, Western Europe, Southeast Asia and Australia, from the Tremadocian to early Arenigian.

The Gap Creek Formation is about 192m (Playford *et al.* 1975) thick and consists mainly of light-brown dolomite with interbedded dolomitic sandstone and shale, which conformably overlie the Emanuel Formation and is overlain with angular unconformity by the Upper Devonian Pillara Limestone. The common Lower Ordovician fossils of the Gap Creek Formation are the brachiopod *Spanodonta hoskingiae* Prendergast, the gastropod *Teiichispira kobayashi* Yochelson and Jones and *Oriostoma? canningense* sp. nov. The associated conodonts which have been referred to Zone OCE by McTavish and Legg (1976), indicating a late Arenigian age.

DISCUSSION

The species *Peelerophon oehlerti* (Bergeron) is a characteristic form in the Emanuel Formation. The geographical and stratigraphical distribution as well as ecology of *Peelerophon oehlerti* have been discussed in detail by Jell *et al.* (1984). This species proves to be a common form in Argentina, southwestern France, western Australia, Tasmania and southern Thailand from the Tremadocian to early Arenigian. Subsequently, this species has been reported from the Ordovician of Bolivia (Babin and Branisa 1987) and southeast China

Table 1 Geographic and stratigraphic distribution of the Lower Ordovician gastropods in the Canning Basin of Western Australia.

Species	Formations						
	Western Australia Emanuel	Gap Creek	Queensland Coolibah	Tasmania Florentine Valley	Malaysia Setul	Thailand Thung Song	N.China Liangchiashan
<i>Peelerophon oehlerti</i> (Bergeron)	X			X		X	
<i>Bucania</i> sp.	X						
<i>Teiichispira kobayashi</i> Yochelson and Jones		X	X		X		
<i>Ecculiomphalus</i> cf. <i>abendanoni</i> (Frech)	X						
<i>Pararaphistoma</i> (<i>Pararaphistoma</i>) <i>qualteriatum</i> (Schlotheim)	X						X
<i>Pararaphistoma</i> (<i>Climacoraphistoma</i>) <i>vaginati</i> (Koken and Perner)	X						
<i>Oriostoma?</i> <i>canningense</i> sp. nov.		X					
<i>Seelya emanuelensis</i> sp. nov.	X						

Species	Formations						
	S. China		SW France		Baltic region	Argentina Cardonal	Bolivia
	Yinchupu	Dawan	St Chinian	La Maurerie			
<i>Peelerophon oehlerti</i> (Bergeron)	X		X	X		X	X
<i>Bucania</i> sp.							
<i>Teiichispira kobayashi</i> Yochelson and Jones							
<i>Ecculiomphalus</i> cf. <i>abendanoni</i> (Frech)		X					
<i>Pararaphistoma</i> (<i>Pararaphistoma</i>) <i>qualteriatum</i> (Schlotheim)					X		
<i>Pararaphistoma</i> (<i>Climacoraphistoma</i>) <i>vaginati</i> (Koken and Perner)					X		
<i>Oriostoma?</i> <i>canningense</i> sp. nov.							
<i>Seelya emanuelensis</i> sp. nov.							

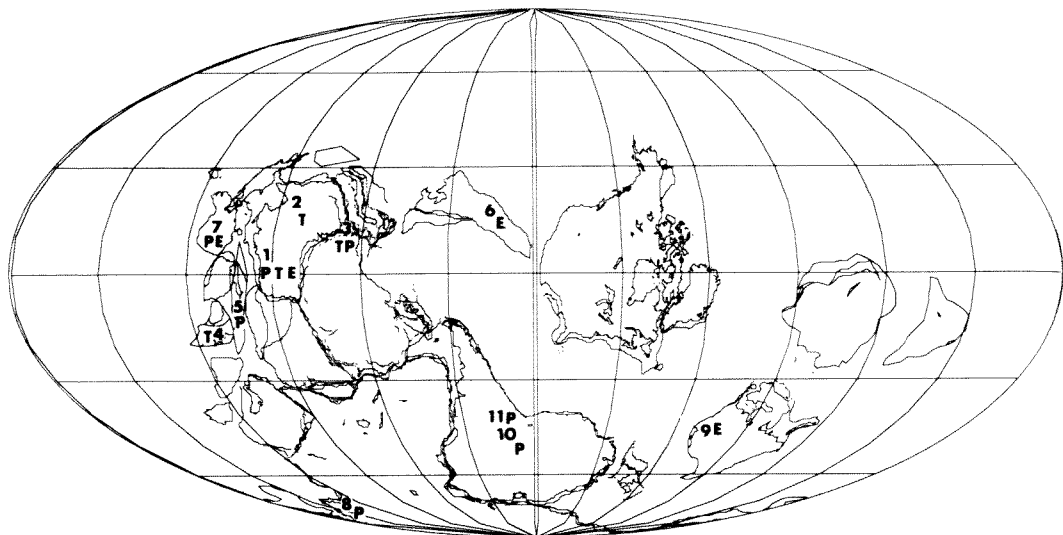


Figure 2 Paleogeographic distribution of Early Ordovician gastropod *Peelerophon* (P), *Teiichispira* (T), and *Bucania*, *Eccuimophalus*, *Pararaphistoma* and *Seelya* (E). Continent reconstruction after Li *et al.* in Long (1993). (1) W. Australia, (2) Queensland, (3) Tasmania, (4) Malaysia, (5) Thailand, (6) N. China, (7) S. China, (8) SW France, (9) Baltic Region, (10) Argentina and (11) Bolivia.

(Yu 1989). In Bolivia, this species has been found from the Middle Ordovician (upper Llanvirnian) and in association with *Ribeiria*, *Ekaterodonta* and Endoceratoidea (Babin and Branisa 1987). In China, *Peelerophon oehlerti* has been recorded from the Lower Ordovician Liuxia Formation of Yuhang County, Zhejiang Province (Yu 1989). Five specimens of this species occur in the dark-grey nodular limestone, in association with the trilobites *Asaphopsis*, *Symphysurus*, *Geragnostus* and *Shumadia* and nautiloids *Ellesmeroceras* and *Proendoceas*. *Asaphopsis* is widely distributed in the Lower Ordovician in Himalaya, southwestern France, Argentina and Tasmania. *Geragnostus* and *Shumadia* are also reported from the Emanuel Formation.

Eccuimophalus abandononi (Frech) was first described from the Lower Ordovician Dawan Formation of Hubei, China (Frech 1911). Nine specimens of this species were procured at Emanuel Creek.

Of special interest is the occurrence of *Pararaphistoma* (*Climacoraphistoma*) *vaginati* (Koken and Perner) in the Emanuel Formation. This species was originally described from the Lower Ordovician of the Baltic Region (Koken and Perner 1925; Vostokova 1955) and subsequently from the Lower Ordovician La Maurerie Formation of the Montagne Noire, southwestern France (Yochelson 1982). *Pararaphistoma* (*Pararaphistoma*) *qualteriatum* (Schlothheim) is also a common form from the Lower Ordovician in the Baltic Region (Lindström 1884; Koken 1897; Koken and Perner 1925; Vostokova 1955), south Xinjiang and Hebei of China (Yu 1961), Norway (Yochelson 1962).

The gastropods of the Gap Creek Formation in the Canning Basin include *Teiichispira kobayashi* Yochelson and Jones and *Oriostoma? canningense* sp. nov. The macluritacean genus *Teiichispira* was erected by Yochelson and Jones from the Lower Ordovician Setul Formation of Langkawi Island, Malaysia in 1968, with *Teiichispira kobayashi* as its type

species. This genus has been found in the Lower Ordovician of Alabama and Utah, U.S.A.; western Newfoundland of Canada (Yochelson and Jones 1968; Yochelson 1992) and Australia (Gilbert-Tomlinson in Hill *et al.* 1969; Gilbert-Tomlinson 1973; Laurie 1991) (Table 1).

Oriostoma is one of the common fossils in the Silurian and Lower Devonian, but currently, two Ordovician species have been reported from North America, these are *Oriostoma? cf. angulatum* (Wahlenberg) from the Upper Ordovician of Alaska (Rohr and Blodgett 1985) and *Oriostoma bromidensis* Rohr and Johns (1990) from the Middle Ordovician Bromide Formation of Oklahoma.

To summarize what has been mentioned above of the gastropod genera described in this paper, *Peelerophon* is only distributed around the periphery of the Early Ordovician Gondwana Supercontinent (Jell *et al.* 1984), *Teiichispria* is restricted to the tropical zones (Yochelson 1979), while *Bucania*, *Ecculiomphalus*, *Pararaphistoma* and *Seelya* may be a group of cosmopolitan genera, widespread in Europe, North America and Asia (Figure 2).

Peelerophon, *Ecculiomphalus*, *Pararaphistoma* and *Seelya* are the common gastropods in the Emanuel Formation. Among them, *Peelerophon* has coarsely lamellose growth lines and Yochelson (1982) speculated that these prominently ornamented gastropods may be shallow water dwellers. The openly coiled euomphalariacean *Ecculiomphalus* is the predominant member of this gastropod assemblage, but most specimens are poorly preserved and about 70% of the individual shells are broken, suggesting a turbulent intertidal or subtidal taphonomic environment. The turbiniform murchisoniacean *Seelya* is the largest form in the Emanuel Formation, attaining a maximum height of 37.70 mm, and well developed slit and selenizone; the morphological characters are comparable with those modern epifaunal gastropods which live on hard substrates (Peel 1977). This thick-shelled form is generally considered to have lived as benthonic creeping form within subtidal or intertidal zone. As a whole, the gastropod assemblage of the Emanuel Formation indicates a subtidal or intertidal environments. It is interesting that sedimentological evidence appears to tend to the same conclusion (McTavish and Legg 1976, p. 460).

The Ordovician gastropod opercula have been widely recorded (Salter 1859; Billings 1865; Ulrich 1911; Yochelson 1957, 1966, 1975, 1979, 1986 1992; Yochelson and Jones 1968; Yochelson and Wise 1972; Rohr and Blodgett 1985; Rohr and Johns 1990), and some of them prove to be good environmental indicators. As Yochelson (1979) noted, provided with a heavy calcareous operculum, *Ceratopea* might have been an inhabitant of shallow, subtropical to tropical water. Recently, four opercula of *Teiichispria* have been obtained from the Gap Creek Formation. The operculum is heavy and elongate, and may add weight to the animal and allow it to live in more agitated water (Yochelson 1992). According to McTavish and Legg (1976), the Gap Creek Formation was formed under a predominantly intertidal or supratidal environment, as indicated by the development of desiccation cracks, algal laminae, intraclastic beds, small scale crossbedding, fossil trails, erosional truncation, scour-and-fill, abundant vertical burrows and some horizontal burrows.

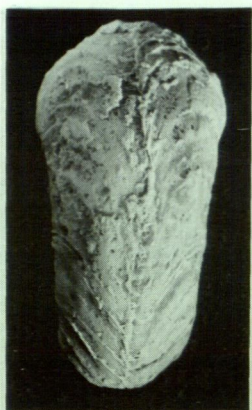
SYSTEMATIC PALAEOLOGY

Class Gastropoda Cuvier, 1797

Subclass Prosobranchia Milne Edwards, 1848

Order Archaeogastropoda Thiele, 1925

Canning Basin Ordovician gastropods



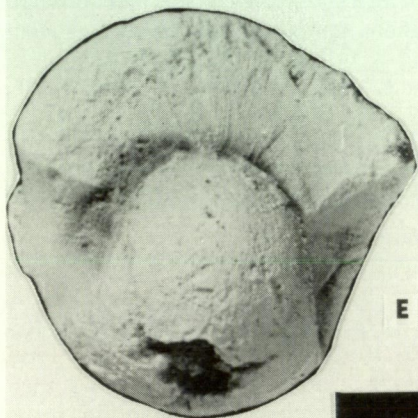
A



B



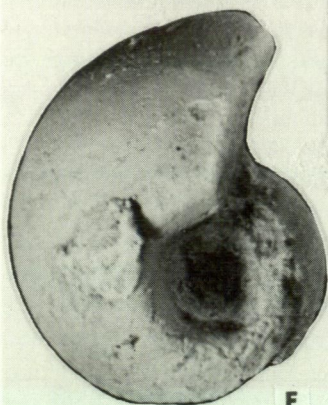
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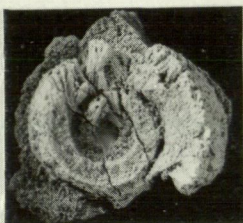
E



D



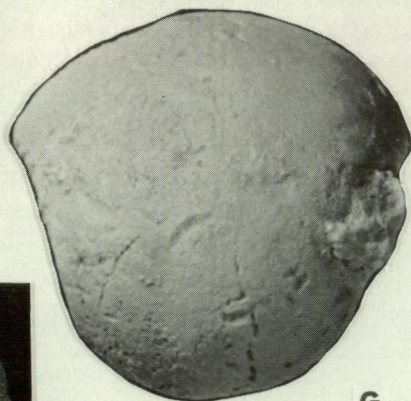
F



H



I



G

Suborder Bellerophontina Ulrich and Scofield, 1897

Superfamily Bellerophontacea M'Coy, 1851

Family Bellerophontidae M'Coy, 1851

Genus *Peelerophon* Yochelson, 1982

Peelerophon oehlerti (Bergeron, 1889)

(Figures 3 A-D)

Bellerophon oehlerti Bergeron, 1889: 343, pl. 4, figs 10-11; Throal, 1935: 149, pl. 12, figs 4a, 4b, 5.

Oxynodiscus keideli Kobayashi, 1935: 63, pl. 11, figs 19, 20.

Oxydiscus keideli Kobayashi: Harrington, 1937: pl. 7, fig. 6.

Bucania mudanensis Kobayashi, 1937: 424, pl. 1, fig. 30.

Bucania cyrtoglypha Harrington, 1938: 136, pl. 3, figs 8, 10, 11, 13, 15, 16.

Peelerophon oehlerti (Bergeron): Yochelson, 1982: 57, pl. 14, figs 1-3, 10-14; Jell, Burret, Stait and Yochelson, 1984: 169, fig. 1; Babin and Branisa, 1987: 121, pl. 1, figs 4-6; Yu, 1989: 679, fig. 1.

Material

This species is represented by four specimens. WAM 92.285 was collected by A.W. Lindner of the University of Western Australia from the Emanuel Formation at the Emanuel Creek of West Kimberley in 1958. WAM 92.286, 92.287 and 92.288 were collected by B.F. Glenister of the University of Western Australia in 1957 from the same locality and horizon.

Diagnosis

Shell uniformly coiled. Whorls three to four in number with elongate elliptical sections. The dorsum gently flattened and bearing a relatively wide and concave selenizone. Umbilicus wide. Surface ornamented with lamellose growth lines.

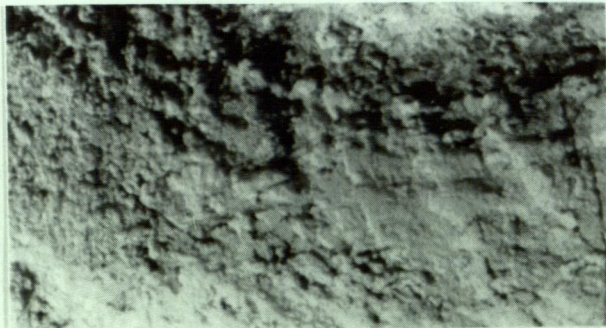
Description

Shell of medium size, consisting of three to four whorls with elongate elliptical sections. The whorls increase regularly in size, the last whorl embracing the penultimate whorl just above periphery. The umbilicus is wide and shallow and the umbilical suture is rather impressed. The umbilical wall steeply inclined with a subangular umbilical edge, from where the surface ascends first with greatest convexity and then slopes toward the dorsum. The dorsum gently flattened, near the median selenizone, very gently concave. Selenizone rather wide and concave with distinct lunulae, and bounded by two spiral lirae. The surface of the shell is ornamented with lamellose growth lines and with fine growth lines intercalated between the lamellae. Aperture is not well-preserved, but the general form can be observed, which is subelliptical in shape.

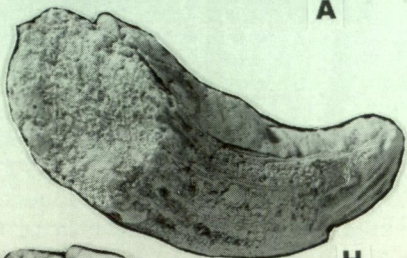
◀ **Figure 3** A-D, *Peelerophon oehlerti* (Bergeron). A-C, WAM 92.286, Emanuel Formation, Emanuel Creek, West Kimberley, dorsal, lateral and apertural views, x 4. D, WAM 92.285, lateral, x 4. E-G, *Bucania* sp. WAM 92.289, Emanuel Formation, Emanuel Creek, West Kimberley, apertural, lateral and dorsal views, x6. H-I, *Oriostoma? canningense* sp. nov. WAM 92.312, paratype, Gap Creek Formation, Emanuel Creek, West Kimberley, apical and apertural views, x 1.5.



A



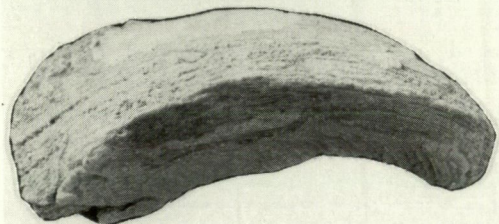
B



H



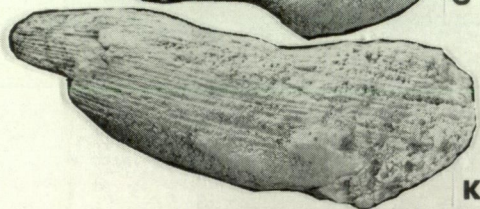
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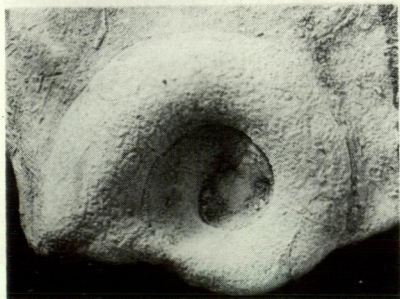
G



K



D



F



C



E

Dimensions (in mm)

	LENGTH	WIDTH	THICKNESS
WAM 92.285	13.04		10.06
WAM 92.286	11.30	6.46	10.44
WAM 92.287	10.49		8.86
WAM 92.288	11.06	5.00 approx.	10.58

Remarks

These specimens figured agree in general features with those described by the previous authors, except that the growth lines are finer.

Stratigraphic range (Australia)

Emanuel Formation. Tremadocian - lower Arenigian.

Genus *Bucania* Hall, 1847***Bucania* sp.**

(Figures 3 E-G)

Material

Only a small, imperfectly preserved specimen of this species was gathered (WAM 92.289). Collected by B.F. Glenister in 1957 from the Emanuel Formation at Emanuel Creek, West Kimberley.

Description

Shell of small size, compressed-subglobose, nearly as high as wide, consisting of a few whorls with semi-circular cross-section. The last whorl increases rapidly in size, embracing about one-half of the preceding one. The dorsal side is broadly rounded, the selenizone is narrow and very obscure. Umbilicus is rather wide and deep, about one-half of the diameter of the shell. Umbilical wall high and steeply inclined, with a subangular umbilical edge and exposing the inner whorls. The aperture is slightly expanded, more or less reniform, wider than high; inner lip thin, outer and lateral lips not well-preserved. The ornamentation of the shell is very poorly preserved.

◀ **Figure 4** A-B, *Oriostoma? canningense*, sp. nov. WAM 92.311, holotype, Gap Creek Formation, Emanuel Creek, West Kimberley. A, apical view, x 1.5. B, enlargement of sculpture on the inner side of whorl, x 10. C, *Ecculiomphalus* cf. *abandanoni* (Frech), WAM 92.299, Emanuel Formation, Emanuel Creek, West Kimberley, apical view, x1. D-F, *Pararaphistoma* (*Pararaphistoma*) *qualteriatum* (Schlotheim). D-E, WAM 92.319, Emanuel Formation, Emanuel Creek, West Kimberley, lateral and apical views, x 1.5. F, WAM 92.320, basal view, x 1.5. G-K, *Teiichispira kobayashi* Yochelson and Jones. G, WAM 92.291, Gap Creek Formation, Emanuel Creek, West Kimberley, basal view, x2. H-K, WAM 92.294, oblique attachment surface, basal surface, upper surface and convex outer surface, x 2.

Dimensions (in mm)

	LENGTH	WIDTH	THICKNESS
WAM 92.289	8.57	8.96	7.48

Remarks

A definite specific name cannot at present be given to this specimen. The wide aperture and large umbilicus, suggest that it resembles some species of *Bucania*, particularly *B. sulcatina* (Emmons) from the Middle Ordovician of New York, U.S.A. but it can be distinguished by its wider aperture and more angulate umbilical edge. In some respects, this species is similar to *Bucania sublata* Ulrich and Scofield (1897, p. 888. pl. LXVI, figs 16-19), differing in the proportion between the length and width of the shell and in the cross-section, which is more or less reniform. It is also allied to *Bucania gravada* Reed (1920, p. 31, pl. VI, figs 9, 9a) from the Lower Ordovician of England, but differs from the latter in the wider dorsal surface and smaller umbilicus.

Stratigraphic range

Emanuel Formation. Tremadocian - lower Arenigian.

Suborder Macluritina Cox and Knight, 1960**Superfamily Macluritacea Fischer, 1885****Family Macluritidae Fischer, 1885****Genus *Teiichispira* Yochelson and Jones, 1968*****Teiichispira kobayashi* Yochelson and Jones, 1968**

(Figures 4 G-K)

Teiichispira kobayashi Yochelson and Jones, 1968: 138, p. 1, figs 2-8; Kobayashi, 1984: 195; Yochelson, 1992: 1340.

Teiichispira cornucopiae Gilbert-Tomlinson, in Hill, Playford and Woods, 1969: pl. O I, figs 12, 13; Gilbert-Tomlinson, 1973: 79, pls 29-32, pl. 33, figs 1-4, 6-9, pl. 34, text-figs 2, 5, 6; Yochelson, 1992: 1340.

Material

The species is represented by four incomplete shells and four opercula (WAM 92.290, 92.291, 92.292, 92.293, 92.294, 92.295, 92.296 and 92.297). Collected by W.S. Johnson in 1987 from the Gap Creek Formation at Emanuel Creek, West Kimberley.

Diagnosis

Shell discoidal, hyperstrophic, apical cavity deep and narrow; outer whorl moderately high; operculum slightly twisted and curved, upper edge sharply angulated, consisting of many elongate tubes, each tube with a polygonal cross-section.

Description

Shell of medium size, hyperstrophic, discoidal, with broadly rounded base and deep apical cavity. It consists of about three to four rapidly increasing whorls. Apical cavity wall steep

and separated by moderately shallow sutures. Outer whorl surface gently convex and gradually sloping to the basal edge. Basal edge roundly angulated. Outer part of basal whorl surface slightly rounded and then sloping to the suture. Suture well impressed. The ornamentation of the shell is very poorly preserved.

Operculum elongated, slightly twisted and curved, consisting of many elongate tubes, each tube with a polygonal cross-section. Upper edge sharply angulated. Outer surface broadly rounded and slightly curved. Juncture of outer surface and basal surface well rounded. Basal surface gently rounded. Inner surface curving upward and outward to near the midline. Attachment surface poorly preserved.

Remarks

In the round basal surface of the whorls, in the strongly curved and weakly twisted operculum, in the sharply angulated upper edge and in the roughly teardrop cross-section, this form is very closely related to *Teiichispira kobayashi* Yochelson and Jones from the Lower Ordovician Setul Formation of Malaysia, but differs from the latter in the broader size.

From the outline of the shell, the regularly increasing whorls, the arched basal surface and the general characters of the operculum, *Teiichispira cornucopiae* Gilbert-Tomlinson is possibly conspecific with the present species.

Stratigraphic range (Australia)

Gap Creek Formation. upper Arenigian.

Superfamily Euomphalacea de Koninck, 1881

Family Euomphalidae de Koninck, 1881

Genus *Ecculiomphalus* Portlock, 1843

Ecculiomphalus cf. *abendanoni* (Frech, 1911)

(Figures 4C, 5 G-H)

Raphistoma (*Eccyliopterus*) *abendanoni* Frech, 1911: 12, pl. III, figs 1 a-d.

Eccyliopterus abendanoni (Frech): Yabe and Hayasaka, 1920: 47, pl. 19, figs 7a-b.

Ecculiomphalus abendanoni (Frech): Yu, Wang and Li, 1963: 72, pl. 17, figs 1-4.

Material

Of this species there are nine internal moulds in the collection (WAM 92.298, 92.299, 92.300, 92.301, 92.302, 92.303, 92.304, 92.305 and 92.306). Collected by J. Pas in 1991 from the Lower Ordovician Emanuel Formation at Emanuel Creek, West Kimberley.

Diagnosis

Shell discoidal and openly coiled. Whorls four in number, increasing slowly in early whorls, rapidly in last one. Whorl profile subtriangular with sharp crest at upper-outer edge. Basal side widely rounded.

Description

Shell of medium size, discoidal and openly coiled. Whorls three to four in number, early

whorls increasing slowly and regularly, while last one abruptly increasing in size and with a sharp angulation at upper-outer edge. The inside of the last whorl below upper angulation is slightly curved inward and inclined downward; the outer whorl surface gently convex. The basal whorl surface widely rounded, curved to join the outer whorl surface at a rounded angulation. The surface markings are not well preserved, but the faint lines of growth can be observed on the inside of the last whorl. The aperture is more or less subtriangular in shape, the outer lip is not well preserved.

Dimensions (in mm)

	WIDTH	HEIGHT
WAM 92.298	16.26	2.60 approx.
WAM 92.299	21.20	4.50
WAM 92.300	20.41	3.60 approx.
WAM 92.301	24.00	4.20
WAM 92.302	19.00	
WAM 92.303	26.84	5.60 approx.
WAM 92.304	37.40	8.32
WAM 92.305	39.71	
WAM 92.306	13.00	

Remarks

In apical view, the Australian specimens appear to be closely related to *Ecculiomphalus abendanoni* (Frech) from the Lower Ordovician Dawan Formation of Hubei, China, except that the Australian shell is smaller in size.

Ecculiomphalus, one of the openly coiled gastropods, is known to occur from the Lower Ordovician to the Silurian in North America, Europe and China. In China, eleven Ordovician species and varieties have been attributed to this genus. After making a comparison with the generic diagnosis of *Ecculiomphalus*, the species *Ecculiomphalus abendanoni* (Frech), *E. tangshanensis* (Grabau), *E. magniumbilicatus* (Endo) and *E. robustus* (Koken) may be included in this genus. The other species, such as *Ecculiomphalus sinensis* (Frech) from the Lower Ordovician Dawan Formation of Jiangsu, Hubei and Guizhou and the Lower Ordovician Quilitagh Formation of southern Xinjiang; *E. kushanensis* (Grabau), *E. solitarius* (Endo) and *E. louderbacki* (Endo) from the Lower Ordovician Machiakou Formation of North China; *E. kepintaghensis* Yu and *E. kepintaghensis* var. *similis* Yu from the Lower Ordovician Saergan Formation from southern Xinjiang and *E. dainelli* (Gortani) from the Middle Ordovician of Karakorum Mountains are characterized as having tightly coiled or advolute whorls. They are very different from *Ecculiomphalus*. For this reason, they are better placed in the genus *Lesueurilla* Koken than in *Ecculiomphalus*.

Stratigraphic range (Australia)

Emanuel Formation. Tremadocian to lower Arenigian.

Suborder Pleurotomariina Cox and Knight, 1960
 Superfamily Pleurotomariacea Swainson, 1840
 Family Raphistomatidae Koken, 1896
 Genus *Pararaphistoma* Vostokova, 1955
 Subgenus *Pararaphistoma* Vostokova, 1955

Pararaphistoma (Pararaphistoma) qualteriatum (Schlotheim, 1820)
 (Figures 4 D-F)

Helicites qualteriatum Schlotheim, 1820: 103.

Pleurotomaria qualteriata Schlotheim: Lindström, 1884: 108, pl. 13, figs 15, 16.

Raphistoma qualteriatum Schlotheim: Koken, 1897: 163, fig. 19; Koken and Perner, 1925: 75-76, pl. 5, figs 1-3, 11-12.

Pararaphistoma (Pararaphistoma) qualteriatum (Schlotheim): Vostokova, 1955: 85, pl. 1, fig. 1; Yochelson, 1962: 243, pl. 1, figs 1-4.

Pararaphistoma cf. qualteriatum (Schlotheim): Yu, 1961: 369, pl. III, figs 8-11; Yu, Wang and Li, 1963: 66, pl. 14, figs 12-15.

Material

This species is represented by three internal moulds. WAM 92.319 and 92.320, collected by B.F. Glenister in 1957 from the Emanuel Formation at the Emanuel Creek, West Kimberley. WAM 92.318 was collected by D. Merrilees in 1960 from the same locality and horizon.

Diagnosis

Lenticular, spire depressed-conical, early whorls increasing slowly, last one rapidly and embracing below the periphery. Upper whorl surface broadly flattened; periphery sharp; basal surface convex. Umbilicus deep and wide.

Description

Shell of medium size, lenticular, spire depressed-conical. Whorls four in number, early whorls increasing slowly and regularly, the last one enlarging rapidly and embracing the penultimate whorl below the periphery. Upper whorl surface of inner whorl is almost flat, the last one is slightly rounded, gently sloping from the suture to periphery. Periphery sharp. Suture rather deep. Lower side is convex and sloping to the umbilicus. Umbilicus deep and wide, more than one-half of the diameter of the shell. The aperture is more or less subtriangular in shape, the outer lip is rather thick but not very well-preserved. The ornamentation of the shell is very poorly preserved.

Dimensions (in mm)

	HEIGHT	WIDTH
WAM 92.318	13.41	32.71
WAM 92.319	11.32	22.50
WAM 92.320		27.60

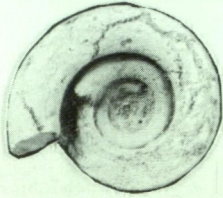
Canning Basin Ordovician gastropods



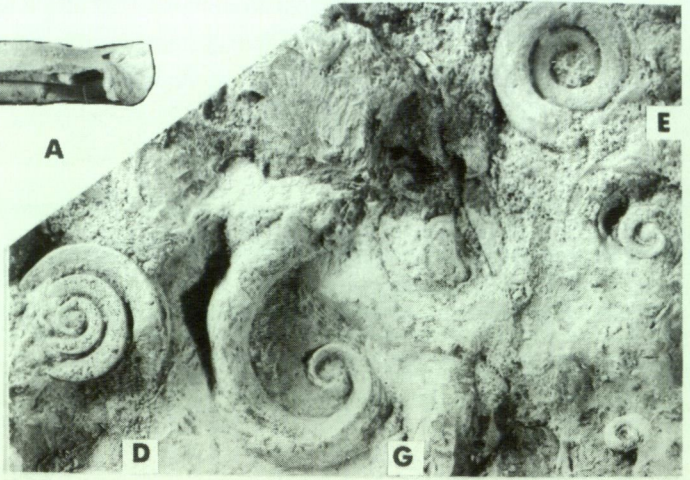
B



A



C



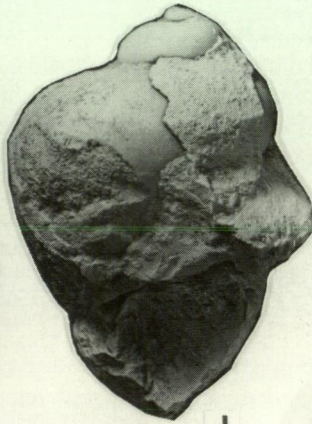
D

E

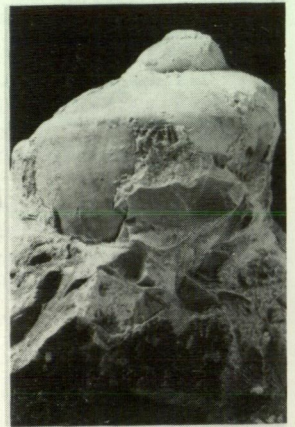
G



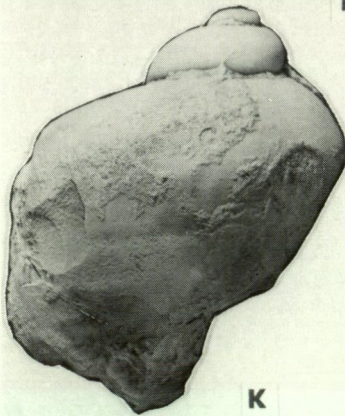
L



J



I



K



F



H

Remarks

This form closely resembles *Pararaphistoma* (*Pararaphistoma*) *qualteriatum* (Schlotheim) from the Lower Ordovician of Western Europe and South Xinjiang, China in the general shape of the shell, particularly in the flattened upper whorl surface, except that this material is smaller.

Stratigraphic range (Australia)

Emanuel Formation. Tremadocian to lower Arenigian.

Subgenus *Pararaphistoma* (*Climacoraphistoma*) Vostokova, 1955

Pararaphistoma (*Climacoraphistoma*) *vaginati* (Koken and Perner, 1925)

(Figures 5 A-F)

Raphistoma vaginati Koken and Perner, 1925: 85, pl. 12, fig. 7.

Pararaphistoma (*Climacoraphistoma*) *vaginati* (Koken and Perner): Vostokova, 1955: 87, pl. 1, fig. 6; Yochelson, 1982: 58, pl. 13, figs 5-7, 10.

Material

This species is represented by five specimens (WAM 92.313, 92.314, 92.315, 92.316 and 92.317). Collected by D. Merrilees in 1960 from the Emanuel Formation at Emanuel Creek, West Kimberley.

Diagnosis

Discoidal, whorls increasing regularly and embracing at the periphery. Upper surface of all the whorls rising to the same height and with a rounded rim at the upper-outer edge. Outer surface nearly vertical. Basal surface rounded. Umbilicus wide and concave.

Description

Shell of medium size, discoidal, consisting of four whorls. Whorls increase slowly and regularly, and embracing at the periphery. The upper whorl surface of all whorls rising to the same height. Suture moderately deep. The upper side gently inclined and sloping inward towards the suture and with a rounded rim at the upper-outer edge. Outer whorl surface broadly flattened, nearly vertical. Basal surface broadly rounded. The umbilicus wide and concave, being two-thirds the diameter of the shell. Umbilical wall flattened. The inner side of the whorls in the umbilicus is flattened and separated by the deep umbilical sutures. The ornamentation of the shell is very poorly preserved.

◀ **Figure 5** A-F, *Pararaphistoma* (*Climacoraphistoma*) *vaginati* (Koken and Perner). A-C, WAM 92.313, Emanuel Formation, Emanuel Creek, West Kimberley, apertural, apical and basal views, x 2. D, WAM 92.317, apical view, x 2. E, WAM 92.316, Basal view, x 2. F, WAM 92.315, basal view, x 2. G-H, *Ecculiomphalus* cf. *abendanoni* (Frech). G, WAM 92.298, Emanuel Formation, Emanuel Creek, West Kimberley, apical view, x 2. H, WAM 92.301, apical view, x 1. I-L, *Seelya emanuelensis* sp. nov. I, WAM 92.307, holotype, Emanuel Formation, Emanuel Creek, West Kimberley, dorsal view, x 1.5. J-K, WAM 92.309, paratype, apertural and dorsal views, x 1.5. L, WAM 92.310, paratype, dorsal view, x 1.5.

Dimensions (in mm)

	WIDTH	HEIGHT
WAM 92.313	14.51	4.36
WAM 92.314	10.90	3.10
WAM 92.315	10.32	
WAM 92.316	10.50	2.35
WAM 92.317	10.86	3.10

Remarks

These specimens differ from *Lesueurilla* Koken, 1898, which has a hyperstrophic shell and a rounded base. In the upper surface of all whorls rising to the same height, the nearly vertical outer side and the deep and wide umbilicus, the Australian specimens appear to be closely related to *Pararaphistoma* (*Climacoraphistoma*) *vaginati* (Koken and Perner) from the Lower Ordovician of the Baltic Region and southwestern France, except that the shell lacks ornamentation.

Stratigraphic range (Australia)

Emanuel Formation. Tremadocian to lower Arenigian.

Suborder Trochina Cox and Knight, 1960

Superfamily Oriostomatacea Wenz, 1938

Family Oriostomatidae Wenz, 1938

Genus *Oriostoma* Munier-Chalmas, 1876

***Oriostoma? canningense* sp. nov.**

(Figures 3 H-I, 4 A-B)

Material

This species is represented by two specimens (Holotype WAM 92.311 and paratype 92.312). Collected by D. Merrilees in 1960 from the Gap Creek Formation at the Emanuel Creek, West Kimberley.

Diagnosis

Discoidal, depressed-spined, phaneromphalous, whorls subcircular. Whorl surface with two spiral carinae, basal carina not well marked. Suture impressed. Covered with cancellate sculpture.

Description

Shell of medium size, discoidal, phanerompholus, composed of four to five whorls, subcircular in cross-section. The early whorls slightly depressed and increasing regularly, while the last one rapidly increasing in size. The upper whorl surface is marked by two spiral carinae, one close to the suture, the other at the whorl crest. Interspace between them is slightly concave. The inner surface is steep with about ten spiral threads and inclined to the

suture. Suture is rather impressed. The outer surface is gently convex with several spiral threads and gradually sloping to the base. The basal carina is not well marked. The growth lines are steeply prosocline, crossed by spiral threads to form cancellate sculpture, especially on the inner surface (Figure 4B). The aperture is not well-preserved, but the general form can be observed, which is subcircular in shape.

Dimension (in mm)

	HEIGHT	WIDTH
WAM 92.311 (Holotype)	9.50 approx.	30.20
WAM 92.312 (Paratype)	8.71	17.67

Remarks

In apical view, this species is somewhat similar to *Oriostoma?* cf. *angulatum* (Wahlenberg) (Rohr and Blodgett 1985, p. 672, figs 2.11-2.12) from the Upper Ordovician of Alaska. This species is distinguished from the American species in the more depressed early whorls, the fewer of carinae and presence of spiral threads. In some respects, the new species also resembles *Oriostoma bromidensis* Rohr and Johns (1990, p. 733, figs 2.1-2.6) from the Middle Ordovician Bromide Formation of Oklahoma, but differs from the latter in the more depressed spire, the cancellate sculpture and in the absence of crenulate growth lines.

Etymology

The specific name is derived from that of the Canning Basin in Western Australia.

Stratigraphic range

Gap Creek Formation. upper Arenigian.

Suborder Murchisoniina Cox and Knight, 1960
Superfamily Murchisoniacea Koken, 1896
Family Plethospiridae Wenz, 1938
Subfamily Plethospirinae Wenz, 1938
Genus *Seelya* Ulrich in Ulrich and Scofield, 1897

***Seelya emanuelensis* sp. nov.**
 (Figures 5 I-L)

Material

This form is represented by four specimens. Holotype WAM 92.307 and Paratype 92.308 was collected by B. F. Glenister in 1957 from the Emanuel Formation at the Emanuel Creek, West Kimberley. Paratype, WAM 92.309, 92.310 was collected by D. Merrilees in 1960 from the same locality and horizon.

Diagnosis

Turbiniiform, selenizone convex, located on periphery, bounded by two lines. Last whorl

ventricose, upper whorl surface broadly rounded, slightly concave near the selenizone, lower whorl surface convexly rounded and gradually sloping to the base. Surface covered with growth lines and low spiral cords. Differs from *S. ventricosa* Ulrich in Ulrich and Scofield in its more convex peripheral selenizone and the shorter penultimate whorl.

Description

Shell of medium size, moderately high-spired, nucleus and early whorls are usually damaged with only the three last whorls retained. First two whorls increasing slowly and regularly, the last one increasing very rapidly and becoming ventricose especially near the aperture, and embracing the penultimate whorl below the periphery. Suture slightly impressed. Adapical whorl surface broadly rounded, gently inclined near the suture then sloping to the peripheral selenizone, but slightly concave near the selenizone. Selenizone convex, bounded by two obscure lines and located on the periphery; below the peripheral selenizone the whorl surface is slightly concave, then gradually sloping to the base. The surface of the shell is ornamented with growth lines and spiral cords. The growth lines are strong and prosocline above the selenizone and opisthocline below it. The spiral cords are not very clear but can be seen on the last whorl which is strong and low (this feature is shown in Figure 51). The aperture is not well-preserved, the outer lip is broken, the inner lip slightly curved.

Dimensions (in mm)

	WIDTH	HEIGHT
WAM 92.307 (Holotype)	24.68	26.00 approx.
WAM 92.308 (Paratype)	25.10	
WAM 92.309 (Paratype)	31.00	37.70
WAM 92.310 (Paratype)	31.20	

Remarks

In the general form of the shell, in the convex selenizone and in the ornamentation, this species is similar to the type species of the genus, *Seelya ventricosa* Ulrich (Ulrich and Scofield, 1897, p. 1009, fig. 7 C-D; Knight, 1941 p. 313 pl. 25 fig. 5; Knight et al. (in Moore, 1960, p. 1295, figs 192-8) from the Lower Ordovician of Vermont, but differs in the more convex peripheral selenizone, the more flattened adapical whorl surface and the shorter penultimate whorl.

Etymology

Specific name after the Emanuel Creek where the species is found.

Stratigraphic range (Australia)

Emanuel Formation. Tremadocian - lower Arenigian.

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