2005

Silurian graptolites from the Barnby Hills Shale and the Hanover Formation, New South Wales

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Publication Details

Rickards, R. B., Farrell, J. R., Wright, A. J. & Morgan, E. J. (2005). Silurian graptolites from the Barnby Hills Shale and the Hanover Formation, New South Wales. Proceedings of the Linnean Society of New South Wales, 126 153-169.

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Abstract
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Keywords
GeoQuest

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Silurian graptolites from the Barnby Hills Shale and Hanover Formation, New South Wales

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Rickards, R.B., Farrell, J.R., Wright, A.J. and Arundell, E.J. (2005). Silurian graptolites from the Barnby Hills Shale and Hanover Formation, New South Wales. *Proceedings of the Linnean Society of New South Wales* **126**, 153-169.

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Manuscript received 9 September 2004, accepted for publication 10 January 2005.

KEY WORDS: Barnby Hill Shale, graptolites, Hanover Formation, Ludlow, Přídolí, Silurian.

INTRODUCTION

A diverse Late Silurian (late Ludlow: *inexspectatus* or *kozlowskii* Biozones) graptolite fauna was described by Rickards and Wright (1997a) from the Barnby Hills Shale at Neurea, NSW (Fig. 1). In this paper we document further biostratigraphic control for this region of NSW by describing additional Silurian graptolites from the Barnby Hills Shale from various localities, and documenting the first Silurian graptolites from the Hanover Formation in the vicinity of Cumnock in central western NSW (Fig. 1). These new collections provide definitive age controls for the latter formation, in particular.

GEOLOGICAL BACKGROUND

The fossils described here are from two largely Late Silurian formations located in the northern part of the Lachlan Fold Belt, New South Wales, in the region from east of Orange to south of Wellington (Fig. 1). The Barnby Hills Shale is part of the Early Silurian to earliest Devonian Mumbil Group, a carbonate - volcanic - fine-grained clastic sequence, which was deposited on the Mumbil Shelf. The Hanover Formation was deposited in the Cowra Trough, a marine basin to the west of the Mumbil Shelf, and forms part of the Early Silurian to earliest Devonian Cudal Group (Meakin and Morgan 1999).

Barnby Hills Shale

Strusz (1960) introduced the term Barnby Hills Shale Member for the upper unit of his 'Mumbil Formation', and Vandyke and Byrnes (1976) subsequently raised the unit to formation status; the Mumbil Group was established by Pickett (1982). Discussions of the formation were given by Morgan

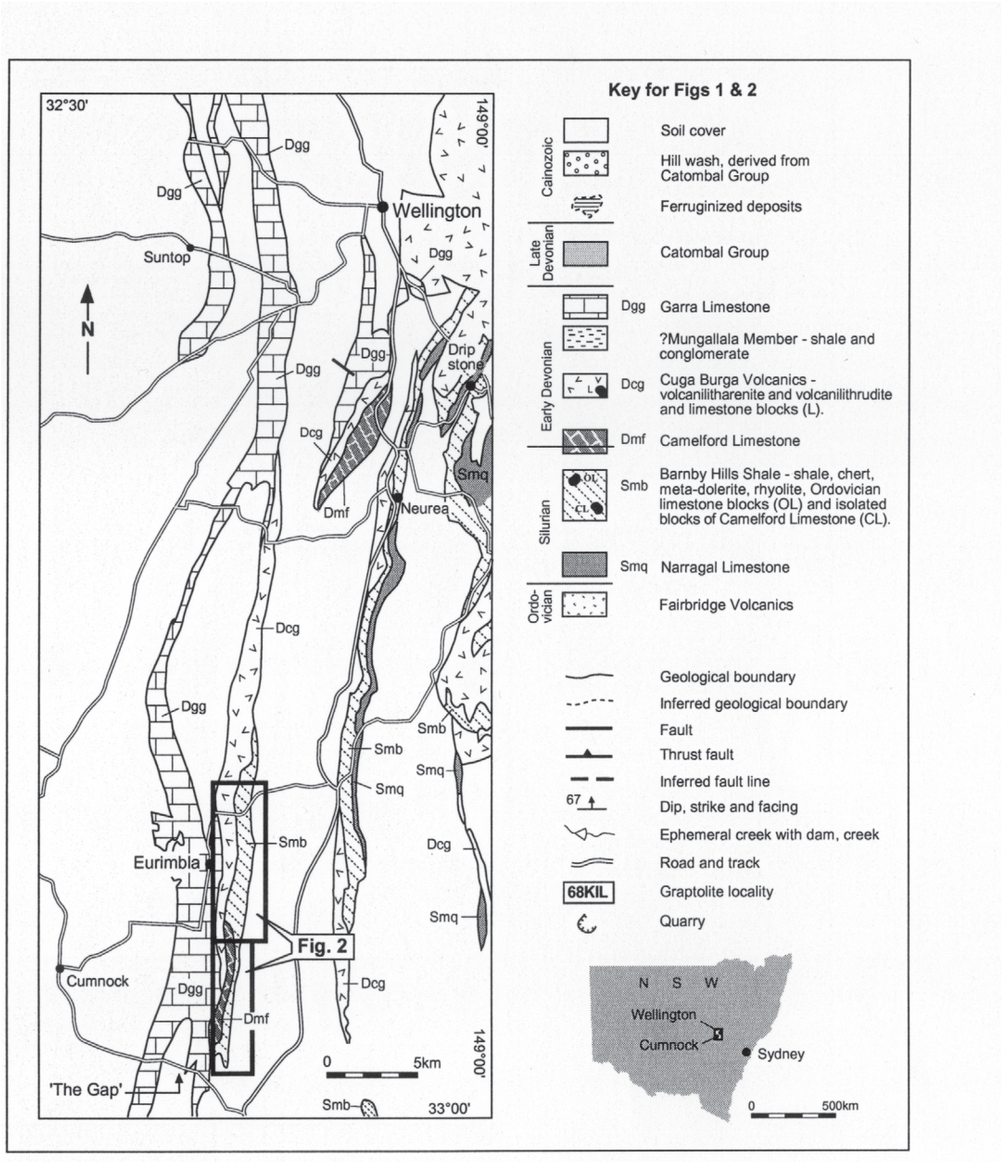

Figure 1. Simplified geology of the area between Wellington and Cumnock (NSW) (modified after Talent and Mawson 1999) showing major Silurian and Early Devonian carbonate units and associated shale sequences along the Mumbil Shelf, and showing location of Fig. 2.

(in Pogson and Wyborn 1994; in Meakin and Morgan 1999).

Talent and Mawson (1999) and Cockle (1999) advocated the relegation of this unit to a junior synonym of the Wallace Shale, a formation erected for strata in the Four Mile Creek area, SSE of Orange (Stevens and Packham 1953) but which also occurs in the Spring-Quarry Creek area (Packham and Stevens 1955) west of Orange. The Wallace Shale exhibits distinctive red, green and yellow banding, and is easily distinguished lithologically from the Barnby Hills Shale. The age of the Barnby Hills Shale is late Wenlock to late Ludlow, based on earlier data (Rickards and Wright 1997a) as well as data presented here. The only age-diagnostic fossils described from the Wallace Shale are the Přídolí graptolites described by Sherwin and Rickards (2002) and, probably, the Přídolí graptolite fauna from near Cadia described by Rickards et al. (2001); the deeply weathered graptolitic strata at the latter locality cannot be assigned with certainty to the Wallace Shale on the basis of their lithology. There is insufficient reason, we believe, to synonymise and

discard this very distinctive stratigraphic unit (see also Zhen et al. 2003).

The formation crops out mainly in four meridional fault slices (Morgan et al. 1999) and extends from the town of Molong in the south to north of Wellington in the north, a strike distance of almost 80 km. The bulk of the fauna described here from the Barnby Hills Shale is from the western belt that extends from 'The Gap' to north of Eurimbla (Figs 1-2). Farrell (1992; in Talent 1995) recognised its Late Silurian age in the western belt, and also identified a number of interbedded limestones of Silurian and Ordovician ages, which had been earlier noted by Byrnes (in Pickett 1982, fig. 19). Dating of graptolites from shales enclosing Ordovician limestone outcrops in the northern section by Sherwin (1994a, 1997) as Silurian proved that the limestone is allochthonous and that the shales correlate with the Barnby Hills Shale (Zhen et al. 2003).

The western belt is faulted at its base against the Late Devonian Catombal Group (Fig. 2). In the south, the formation is conformably overlain by the Siluro-Devonian Camelford Limestone but, to the north, it is faulted against the early Devonian Cuga Burga Volcanics. The Silurian limestone outcrops in the southern section are Přídolí and are thought to be remnants of the lower horizons of the Camelford Limestone 'grounded' along the Curra Creek Thrust (Farrell 2001). To the east, the Barnby Hills Shale forms part of a continuous Siluro-Devonian sequence.

In the vicinity of the original road cutting type section just east of the Mitchell Highway at Neurea (see Rickards and Wright 1997a, and Fig. 1 herein) the formation conformably overlies the Narragal Limestone. This road cutting, which yielded the material described by Rickards and Wright (1997a), has been, regrettably, over-collected and the now almost barren exposures have been also severely damaged by large-scale removal of rock for other, non-geological purposes. Morgan (in Meakin and Morgan 1999) nominated a new type section for the formation along a railway cutting at Dripstone (Fig. 1) where exposures are good and formation boundaries are exposed. Unfortunately graptolites are extremely rare in this section: on our first visit we found rare graptolites identified in the field as *Bohemograptus*, *Linograptus* and *Dictyonema*, but these specimens have been mislaid; no more material was collected on a second visit to the section. In this type section the formation is 290 m thick; in the Eurimbla area, the western belt appears to reach a thickness of over 700 m but the unit may be internally folded (Morgan in Meakin and Morgan 1999).

We also describe and illustrate poorly-preserved graptolites from this formation near Lewis Ponds; this locality, 15 km northeast of Orange, was described as the Mullions Reserve by Meakin in Pogson and Wyborn (1994). This material was first reported by Sherwin (1993) as "*Monograptus bohemicus* subsp., with siculae of *hercynicus* type", and the occurrence was further documented by Meakin (in Pogson and Wyborn 1994). All the abundant graptolites (Fig. 5D-E) belong to a monospecific assemblage of *Bohemograptus paracornutus* Rickards and Wright, 1999b, are tectonically deformed, and occur in black cleaved pyritic slates; this is the southernmost known fossiliferous development of the formation.

Hanover Formation

The term Hanover Formation was introduced by Maggs (1963) and first published by Offenberg et al. (1971). Bradley (in Pickett 1982, fig. 14) included the formation in the Cudal Group. Morgan (in Meakin and Morgan 1999) found that the unit was much more widespread than shown by previous workers and provided a thorough discussion of the formation. The Hanover Formation crops out in a number of complex meridional fold and fault repetitions from Cumnock to Geurie (Morgan et al. 1999). The fossils described here were found in the easternmost block of Hanover Formation, in a rail cutting east of Cumnock (Fig. 1). Previous workers considered the rocks in the cutting to be part of a Devonian package (the 'Carinya Shale' of Maggs [1963] and Offenberg et al. [1971]), but Morgan (in Meakin and Morgan 1999) determined a Silurian age and correlated the rocks with the Hanover Formation.

The Hanover Formation has few diagnostic features and closely resembles the Barnby Hills Shale in lithology, as well as a number of other shale-siltstone dominated facies in the area. The formation conformably overlies the Wenlock Canowindra Volcanics and is overlain either by the Early Devonian Cuga Burga Volcanics or their lateral equivalent, the Berkley Formation. In the study area the formation is faulted at its base against the Cudal Fault, and is internally complexly folded and faulted. No one section has yielded both top and base of the Hanover Formation, so its total thickness is not known; Bradley (in Pickett 1982) estimated a thickness of 300 m.

Lithological Description

The Barnby Hills Shale and the Hanover Formation consist dominantly of poorly-outcropping siltstone and shale, with subordinate interbedded fine- to coarse-grained volcaniclastic sandstone, radiolarian chert, marly siltstone and detrital calcareous horizons

Figure 2. Simplified geological map showing graptolite localities in the area between The Gap and Larras Lee.

(Morgan in Meakin and Morgan 1999; Morgan in Meakin and Morgan 1999). The formations are characterised by poorly- to well-bedded and finely-laminated buff siltstone and shale, and vary from brown to grey to green to red. Beds are in the order of 1 mm to 2 cm in thickness. Laminations exhibit slump, scour, grading, flame and other sedimentary structures, and bioturbation is common (Morgan in

Meakin and Morgan 1999; Morgan et al. in Meakin and Morgan 1999).

Numerous detrital limestone beds are present within both formations, including allochthonous limestone blocks up to 180 m long. The beds are commonly highly fossiliferous and are of varying ages. In the Hanover Formation, a massive to well-bedded fossiliferous detrital limestone bed is present 100 m across strike to the west of the graptolite locality, for which Percival (1998) determined a probable late Llandovery age. In the Barnby Hills Shale, large allochthonous limestone blocks containing Late Ordovician fossils (Zhen et al. 2003, Webby 1969) lie adjacent to one of the graptolite localities (68 KIL on Figure 2A). In contrast, a large limestone block at the southern end of the western belt of the Barnby Hills Shale contains Late Silurian fossils (Farrell 2001).

PALAEONTOLOGY AND AGE

Barnby Hills Shale

Graptolites from the Barnby Hills Shale were first recorded by Strusz (1960) as *Monograptus bohemicus*. Sherwin (1993, 1994b) identified the common species in the fauna as an undetermined subspecies of *Bohemograptus bohemicus*, indicating a middle to late Ludlow age; a late Ludlow age was suggested by Sherwin (1997). Sherwin (1994a, 1997) identified *Saetograptus colonus* from shale in the KIL study area in the western belt, indicating an early Ludlow age (basal *nilssoni* Biozone to part way through the *scanicus* Biozone). No graptolites were described or illustrated until Rickards and Wright (1997a) described the substantial late Ludlow (*inexspectatus* or *kozlowskii* Biozones) fauna of dendroids and graptoloids including the age-diagnostic *Bohemograptus bohemicus tenuis* (Bouček 1936) from the belt at Neurea (Fig.1). The Barnby Hills Shale is locally conformably overlain by the Přídolí to Lochkovian Camelford Limestone (Farrell 1992, 2003).

Meakin (in Pogson and Wyborn 1994, p. 105) drew attention to the occurrence of this formation at South Mullion Reserve, ENE of Orange. The occurrence at this locality (W859) of poorly preserved *Bohemograptus paracornutus* (Figs 5D-E) indicates the *cornutus* Biozone.

The graptolite faunas described here from this formation are thus from four localities (Figs 1-2):

68 KIL (Fig. 2): 'Kildara' property; *ludensis* Biozone, late Wenlock, Barnby Hills Shale; *Monograptus ludensis* (Murchison, 1839) and indeterminate retiolitids.

Blind Gully (WEEM 13b: see Fig. 2): *praecornutus* Biozone, late Ludlow, Barnby Hills Shale; *Bohemograptus praecornutus* Urbanek, 1970; *Linograptus posthumus* Richter, 1875; *Dendrograptus* sp. nov.; *Acanthograptus aculeatus aculeatus* (Počta, 1894); *Thallograptus acanthicus vandenbergi* Rickards and Wright, 1997a; and *Dictyonema* sp.

W 825: Dripstone railway cutting, type section of Barnby Hills Shale, late Ludlow; *Bohemograptus*, *Dictyonema* and *Linograptus* (not described or figured); this collection has been mislaid.

W 859: roadside quarry at South Mullion Reserve, lower Lewis Ponds Road (Bathurst 1:250 000 sheet, grid reference 705420E, 6320760N). Poorly-preserved and highly-deformed graptolites occur in cleaved, pyritic black slate. The only species identified is the late Ludlow *Bohemograptus paracornutus* Rickards and Wright, 1999b.

Hanover Formation

The Hanover Formation has yielded graptolites including *Saetograptus chimaera* and brachiopods (Sherwin 1997), and plant fragments (Morgan *in* Meakin and Morgan 1999). Maggs (1963) identified *Monograptus colonus*, *M. salweyi*, *M. bohemicus* and *?Spinograptus spinosus* from a locality 3 km roughly along strike north of the graptolite locality described here; his identifications suggest the *nilssoni* or *scanicus* Biozone, early Ludlow. Sherwin (1996) identified the graptolites *Agastograptus* spp., ?*Paraplectograptus* sp. and *Monograptus ludensis*, indicating a latest Wenlock age (*ludensis* Biozone). The Hanover Formation thus probably extends from late Wenlock throughout the Ludlow and possibly to the end of the Přídolí, considering that the formation appears to be conformably overlain by the early Devonian (Lochkovian) Cuga Burga Volcanics and Berkley Formation (Morgan et al. in Meakin and Morgan 1999). Graptolite data reported here indicate an age range of *spineus* Biozone (late Ludlow) to *parultimus* Biozone (Přídolí).

The fauna described here from this formation is from one locality:

WEEM 409 (a, c): *spineus* (late Ludlow) and *parultimus* (early Přídolí) Biozones, Cumnock railway cutting, Hanover Formation; *Dictyonema elegans* Bulman, 1928; *Dictyonema paululum hanoverense* subsp. nov.; *Pristiograptus shearsbyi* Rickards and Wright, 1999b; *Monograptus spineus* (Tsegelnuk, 1976); *Neocolonograptus*

parultimus (Jaeger, 1975). Three collections have been made from different levels in this cutting, as follows: WEEM 409 has *Neocolonograptus parultimus* and *Dictyonema elegans* and *D. paululum*; WEEM 409a has ?*Neocolonograptus parultimus*, *Linograptus posthumus*, *P. shearsbyi* and *N? mitchelli*; and WEEM 409c has *Monograptus spineus* and *P. shearsbyi*.

DEPOSITIONAL ENVIRONMENTS

The Barnby Hills Shale and Hanover Formation were deposited in a quiet, deepwater environment, reflecting the progressive subsidence of the Cowra Trough and Mumbil Shelf during the Middle to Late Silurian (Byrnes 1976; Morgan, Colquhoun and Meakin in Meakin and Morgan 1999), which allowed widespread distribution of fine-grained sediments. The time of initiation of subsidence varied, beginning in the Cowra Trough in the Wenlock, and on the western margin of the Mumbil Shelf in the early Ludlow. Ordovician basement rocks were still locally exposed, shedding large limestone blocks downslope into deeper water (Morgan, Colquhoun and Meakin in Meakin and Morgan 1999**;** Zhen et al. 2003; Zhen and Percival 2004). By middle or late Ludlow the Mumbil Shelf was totally submerged. Fine-grained sedimentation continued in the Cowra Trough and on the margins of the Mumbil Shelf into the earliest Devonian. Parts of the Shelf underwent shallowing during the late Ludlow or early Přídolí, permitting local deposition of the Camelford Limestone. Conditions changed substantially in the early Devonian, with the onset of dominantly mafic to intermediate volcanism in the Cowra Trough and on the Mumbil Shelf (Cuga Burga Volcanics and Berkley Formation), thus terminating quiet mud sedimentation (Morgan, Colquhoun and Meakin in Meakin and Morgan 1999).

The late Ludlow *praecornutus* Biozone, and the slightly younger *cornutus* Biozone characterised by *B. paracornutus* and *B. b. tenuis*, are now known to range widely within central N.S.W. Both characteristic taxa have been recorded from the Yass area by Rickards and Wright (1999b); we have also seen *B. paracornutus* in collections made by G.H. Packham just south of Neurea, and probably the same species collected by him from the Manildra area (Savage 1968). *Bohemograptus b. tenuis* was described from Neurea by Rickards and Wright (1997b).

In both the Yass (Rickards and Wright 1999b) and Neurea (Rickards and Wright 1997a) areas, Ludlow graptolitic beds are succeeded sharply by shallow water strata (the Rainbow Hill Marl at Yass and the Camelford Limestone near Wellington), providing evidence for a sea-level highstand followed by a latest Ludlow shallowing. Various authors have drawn attention to the regression at the end of the Ludlow (Talent 1989, Johnson et al. 1991, Johnson and McKerrow 1991, Kaljo et al. 1995) and Pickett (1982) noted the widespread deposition in NSW during the period dominated by bohemograptid graptolites; the NSW setting appears to conform to the global sea-level pattern at this time.

SYSTEMATIC DESCRIPTIONS

Material described here is deposited in the Australian Museum, Sydney (AM F).

Class Graptolithina Bronn, 1849
Order Dendroidea Nicholson, 1872

Genus *Dendrograptus* J. Hall, 1858

Type species.

Graptolithus hallianus Prout, 1851; subsequently designated by J. Hall (1862).

Dendrograptus typhlos sp. nov.

Fig. 3A-B

?1995 *Dendrograptus* sp.; Rickards et al., p. 18, fig. 12B.
?1997a *Dendrograptus* sp.; Rickards and Wright, p. 214, fig. 6A.
?1999b *Dendrograptus* sp.; Rickards and Wright, p. 191, fig. 3A.

Type Material

Holotype AM F114618; paratypes AM F114620-1; all well-preserved though not showing the autothecae too well; all from Blind Gully, locality WEEM 13B; *praecornutus* Biozone, late Ludlow, Barnby Hills Shale.

Etymology

The species name is the Greek word for blind, after the Blind Gully locality.

Diagnosis

Dendrograptus branching every 1-3 mm, more or less regularly, at angles from 40-90°; younger parts of colony have a lateral stipe width of 0.2-0.4 mm

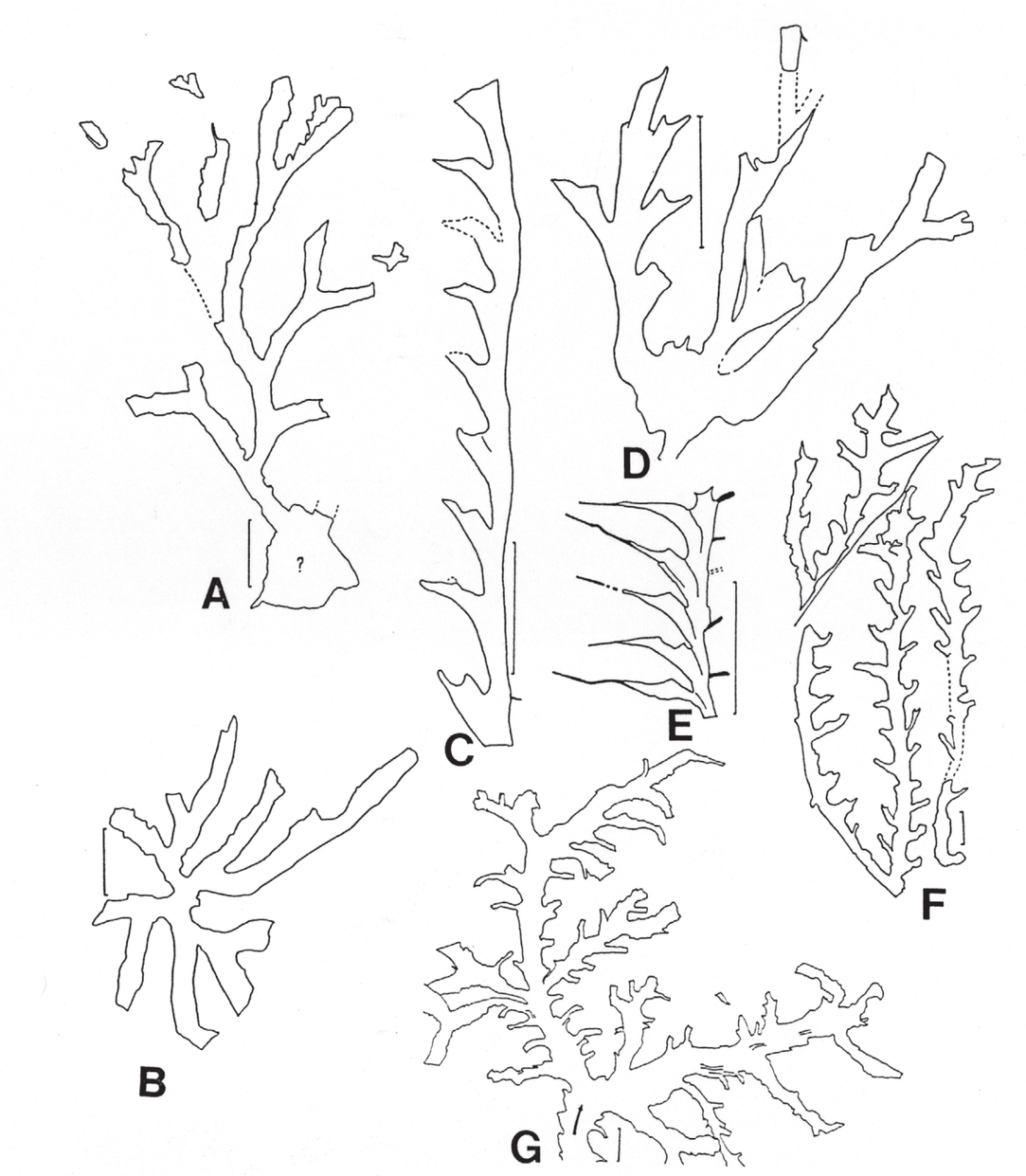

Figure 3A-G. A-B, *Dendrograptus typhlos* sp. nov.; respectively AM F114618 (holotype) and 114620; question mark indicates possible holdfast in holotype. Blind Gully, *praecornutus* Biozone, Ludlow. C-D, *Dictyonema elegans* Bulman, 1928; respectively AM F 92382 and 92381, locality WEEM 409, *parultimus* Biozone, Přídolí; E, *Dictyonema paululum hanoverense* subsp. nov., AM F92380 (holotype), WEEM 409, *parultimus* Biozone, Přídolí. F, *Acanthograptus aculeatus aculeatus* (Pocta, 1894), AM F114616, Blind Gully, *praecornutus* Biozone, Ludlow. G, *Thallograptus acanthicus vandenbergi* Rickards and Wright, 1997a, AM F14619, Blind Gully, *praecornutus* Biozone, Ludlow. Scale bars 1 mm.

but, nearer the proximal end, lateral widths of 0.3-0.5 mm occur. Possible compound stipes proximally but no indication of them distally. Autothecae difficult to see, possibly spaced at ca 30 per 10 mm. Largest specimen 25 mm × 20 mm.

Remarks

Perusal of the studies of Rickards et al. (1995) and Rickards and Wright (1997a, 1999b) demonstrates that identification of *Dendrograptus* specimens is not easy. In Australian rocks the genus seems to be relatively rare, occurring sporadically throughout the Silurian and the earliest Devonian (Rickards and Wright 2001). The specimen figured by Rickards et al. (1995, fig. 12B) as *Dendrograptus* sp. has similar dimensions to *D. typhlos* and may be an earlier occurrence of it: the Quarry Creek specimen is from the *lundgreni/ testis* Biozone of the Wenlock. *Dendrograptus* sp. (of Rickards and Wright 1997a, fig. 6A) from the Ludlow Barnby Hills Shale at Neurea has similar dimensions but may have a lower autothecal spacing (15-20 in 10 mm). *Dendrograptus* sp. (of Rickards and Wright 1999b, fig. 3A) from the *praecornutus* Biozone of the Yass district also has an apparently lower thecal spacing (20 in 10 mm), although is otherwise similar and occurs only a little lower stratigraphically than the Blind Gully specimens.

Genus *Dictyonems* J. Hall, 1851

Type species

Gorgonia retiformis J. Hall, 1843; subsequently designated by Miller (1889).

Dictyonema elegans Bulman, 1928
Fig. 3C-D

1928 *Dictyonema elegans* sp. nov; Bulman, p. 52, text-fig. 26; pl. 6, figs 22-3**.**
1997a *Dictyonema elegans* Bulman; Rickards and Wright, p. 214, figs 5C, 8D.
A fuller synonymy was given by Rickards and Wright (1999b).

Material

Several fragmentary specimens (AM F 92381-2, AM F114613 a-b, AM F114614) from locality WEEM 409, *parultimus* Biozone, Hanover Formation, near Cumnock.

Description

Dorsoventral width (excluding ventral apertural processes) 0.4-0.5 mm. Ventral apertural processes robust and relatively short: however, their distal extremities may be broken. Autothecal spacing 20 in 10 mm. One specimen (Figure 3D) may be close to the holdfast position, or may enclose the holdfast between 3 or 4 diverging stipes; the latter are seen partly in profile and partly in dorsoventral view. No obvious signs of bithecae.

Remarks

Rickards and Wright (1999b) gave a summary of the variation seen in Australian records of the species, which is now known to range through the Ludlow and Přídolí (the type British material being Wenlock). The present specimens agree with previous records (Rickards and Wright 1997a) from the Barnby Hills Shale in having an autothecal spacing of only 20 in 10 mm, which may be contrasted with the types and with Quarry Creek specimens from the Wenlock and Ludlow respectively, which have 25 in 10 mm, and with the Yass Ludlow and Přídolí specimens, which have 30 in 10 mm. Thus, whilst it is certain that these are all very similar forms, it cannot be argued that the range of variation is as yet constrained in any stratigraphic sense. Even so, *D. elegans* has great potential in this regard.

Dictyonema paululum Bulman, 1928

1928 *Dictyonema paululum,* n. sp.; Bulman, p. 58, pl. 5, figs 9-11; ?pl. 4, fig. 13.

Dictyonema paululum hanoverense subsp. nov.
Fig. 3E

Material

Holotype, a single fragment of well-preserved stipe in profile view, AM F 92380, locality WEEM 409, *parultimus* Biozone, Přídolí; Hanover Formation.

Diagnosis

A subspecies of *Dictyonema paululum* characterised by dorsoventral width of 0.50 mm, crowding of autothecae (28-30 in 10 mm) and dissepiments.

Description

Five autothecae seen on the specimen, spaced at ca 28-30 in 10 mm. Autothecal apertures slightly isolated and, whilst there is no dorsal apertural spine, there is a long ventral spine approaching 0.5 mm in length. Fine dissepiments seen at dorsal edge of stipe; spacing rather close at 20-30 per cm, possibly one to each autotheca. One possible bithecal tube visible on free ventral wall of penultimate theca. No indications

of internal structure save traces of some autothecal overlap.

Remarks

This specimen differs from Bulman's late Llandovery originals in that the dorsoventral width is greater (0.50 mm compared with 0.15-0.25 mm), as is the crowding of autothecae (28-30 in 10 mm compared with 19-20 in 10 mm in Bulman's originals) and dissepiments. In overall appearance they are very similar, however, and especially resemble Bulman's (1928, pl. 5, fig. 11) specimen. *Dictyonema elegans* Bulman, 1928 (see also Rickards and Wright 1997a) is another similar form, although all the biocharacters have different measurements; clearly they belong to the same dictyonemid group typified by slightly isolated autothecal apertures, ventral spines, no dorsal process, and external bithecae. *Dictyonema paulului australis* Rickards and Jell, 2002, from the *griestoniensis* Biozone of the Graveyard Creek Subprovince of Queensland, has very similar dimensions overall but differs in having a low dissepimental spacing (12-14 in 10 mm) and a higher stipe spacing (20+).

Dictyonema paulului hanoverense subsp. nov. is not associated with dendroids other than *D. elegans,* but the Blind Gully locality has yielded several rhabdosomal fragments we refer to *Dictyonema* spp. indet.; further material is needed for a more satisfactory identification.

Genus *Acanthograptus* Spencer, 1878

Type species

Acanthograptus granti Spencer, 1878; by original designation.

Acanthograptus aculeatus aculeatus (Počta, 1894)
Fig. 3F

1894 *Inocaulis aculeatus* n. sp.; Počta, p. 199, pl. 7, figs 22-25.
1894 *Inocaulis demetosa* n. sp.; Počta, p. 200, pl. 7, figs 7, 8a.
?1909 *Inocaulis diffusus* (Spencer); Gurley *in* Bassler, p. 53, fig. 68.
1957 *Acanthograptus aculeatus* (Počta); Boucek, p. 88, pl. 15, figs 1-9, text-figs 37 a-g.
1995 *Acanthograptus aculeatus* (Počta); Rickards et al., p. 24, figs 11F, 15C-F.

Material

One well-preserved rhabdosome, AM F114616a, b, from Blind Gully locality WEEM 13B, Barnby Hills Shale, *praecornutus* Biozone.

Description

Acanthograptus with a lateral stipe width of 1.5 mm, parallel-sided; 10-12 twigs per 10 mm of stipe, on each side; twigs alternating on opposite sides (in dorsal or ventral view); stipe diversions infrequent and irregular; twigs may have two autothecae in each termination; broad bases to twigs suggest presence of bithecal openings there; stipe may be compound; central part of stipe ca 0.4 mm in diameter.

Remarks

Previous records of *A. a. aculeatus* range from the late Wenlock to early Ludlow, but the Blind Gully specimens are late Ludlow (*praecornutus* Biozone). Thus the species seems to have a long range with little morphological change. However, Rickards and Wright (1997a) described a more slender subspecies, *A. a. neureaensis*, from the *inexspectatus* or *kozlowskii* biozonal level in the Barnby Hills Shale at Neurea.

Genus *Thallograptus* Ruedemann, 1925

Type species

Dendrograptus? succulentus Ruedemann, 1904; by original designation.

Thallograptus acanthicus Bouček, 1957

Thallograptus acanthicus vandenbergi Rickards and Wright, 1997a
Fig. 3G

1997a *Thallograptus acanthicus vandenbergi* subsp. nov.; Rickards and Wright, pp. 219-20, fig. 6I.

Material

Four specimens AM F114619, 114622-4, and one possible specimen AM F114617a-b, all from Blind Gully locality WEEM 13B, *praecornutus* Biozone, late Ludlow, Barnby Hills Shale.

Description

Thallograptus reaching 20 mm x 15 mm, with robust, spiky stipes which branch and diverge more or less at right angles; stipes compound, with bundles of long, narrow tubes; main stipe width 1.5 mm proximally, down to 0.5 mm most distally; progressive dichotomies become narrower, and all stipe termination is by single, conspicuous autothecal tubes.

Remarks

No bithecae have been detected and the autothecal spacing cannot be given until more autothecal openings can be seen on the ventral stipe surface. This subspecies resembles *Acanthograptus a. aculeatus* but the latter is more slender and has a very regular association of twigs opening alternately on one side of the stipe and the other. *Thallograptus a. vandenbergi* is a smaller and more slender subspecies than the type subspecies. The species is very rare, with one specimen only recorded from Bohemia (the holotype of Bouček's 1957 nominate subspecies) and five definite Australian specimens.

Order Graptoloidea Lapworth, 1875

Genus *Pristiograptus* Jaekel, 1889

Type species

Pristiograptus frequens Jaekel, 1889, by original designation.

Pristiograptus shearsbyi Rickards and Wright, 1999b
Figs 4D-E

1999b *Pristiograptus shearsbyi* n. sp.; Rickards and Wright, p. 194, figs 3J-P, 11A-B, 13B-E.

Material

AM F 92371, 92376, 114574-81 from localities WEEM 409 and 409c, respectively the *parultimus* and *spineus* biozones, Hanover Formation.

Description

Straight, thin *Pristiograptus* with dorsoventral width proximally 0.5 mm, distally 0.8-1.2 mm; sicula 1.2-2.1 mm long, reaching midway between apertures of th1 and th2 in case of shorter siculae, and up to the level of th2 aperture in rhabdosomes with long siculae; ∑ = 1.2-1.4 mm; thecal overlap ca ½; thecal inclination 20-30°; proximal thecal spacing 11 in 10 mm; distal thecal spacing 10 in 10 mm; sicula with short, dorsal tongue.

Remarks

This material is very close to the Yass material; the species ranges from the *praecornutus* Biozone into the Přídolí. Some Hanover specimens have a slightly greater dorsoventral width (up to 1.2 mm compared with 0.85 mm) and some have a longer sicula (up to 2.1 mm compared with 1.65 mm).

Genus *Monograptus* Geinitz, 1852

Type species

Lomatoceras priodon Bronn, 1835; subsequently designated by Bassler (1915).

Monograptus spineus (Tsegelnuk, 1976)
Fig. 4A

1976 *Acanthograptus spineus* sp. n.; Tsegelnuk, p. 113, pl. 34, figs 6-9.
1983 *Bugograptus spineus* (Tsegelnuk); Tsegelnuk, p. 145, fig. 34.
1988 *Monograptus spineus* (Tsegelnuk); Koren' et al., p. 17, fig. 8.
1995 *Monograptus* (*Uncinatograptus*) *spineus* (Tsegelnuk); Urbanek, p. 3, figs 1D, 2, 7C-E.
1997 *Monograptus* (*Uncinatograptus*) *spineus* (Tsegelnuk); Urbanek, pp. 149-154, pl. 11, figs 3-6; pl 12; pl. 13, figs 13, 35-41.
1997 *Monograptus spineus* (Tsegelnuk); Koren' and Sujarkova, p. 80, pl. 6, figs 1-2, text-figs 14A-I.

Material

A single, well-preserved proximal end, AM F 92370, from locality WEEM 409c, Hanover Formation, *spineus* Biozone, Ludlow.

Description

The well-preserved proximal end has 3.5 thecae, the sicula, virgella, virgula and sicula thickening bands all clearly preserved. Thecal overlap low; thecal hooks well-developed, with a pair of lateral spines and a central retroflexed portion showing fuselli on th1. Upper sicular band coincides with base of th2, but it may or may not represent pro-metasicular boundary. Second band halfway along sicula, which is 1.4 mm long, its apex reaching midway between th1 and th2. Thecal spacing 12.5 in 10 mm and dorsoventral width 1.1-1.2 mm. ∑ = 0.9 mm.

Remarks

This specimen is the first record of the species outside Podolia, Poland, and Russia. Urbanek (1997) considered the species indicative of the late Ludfordian (Ludlow) *spineus* Biozone. It overlaps with the lower (Ludlow) part of the range of the more common species *M. formosus* Bouček, 1931, previously recorded from Yass, N.S.W. by Packham (1968) and Rickards and Wright (1999b).

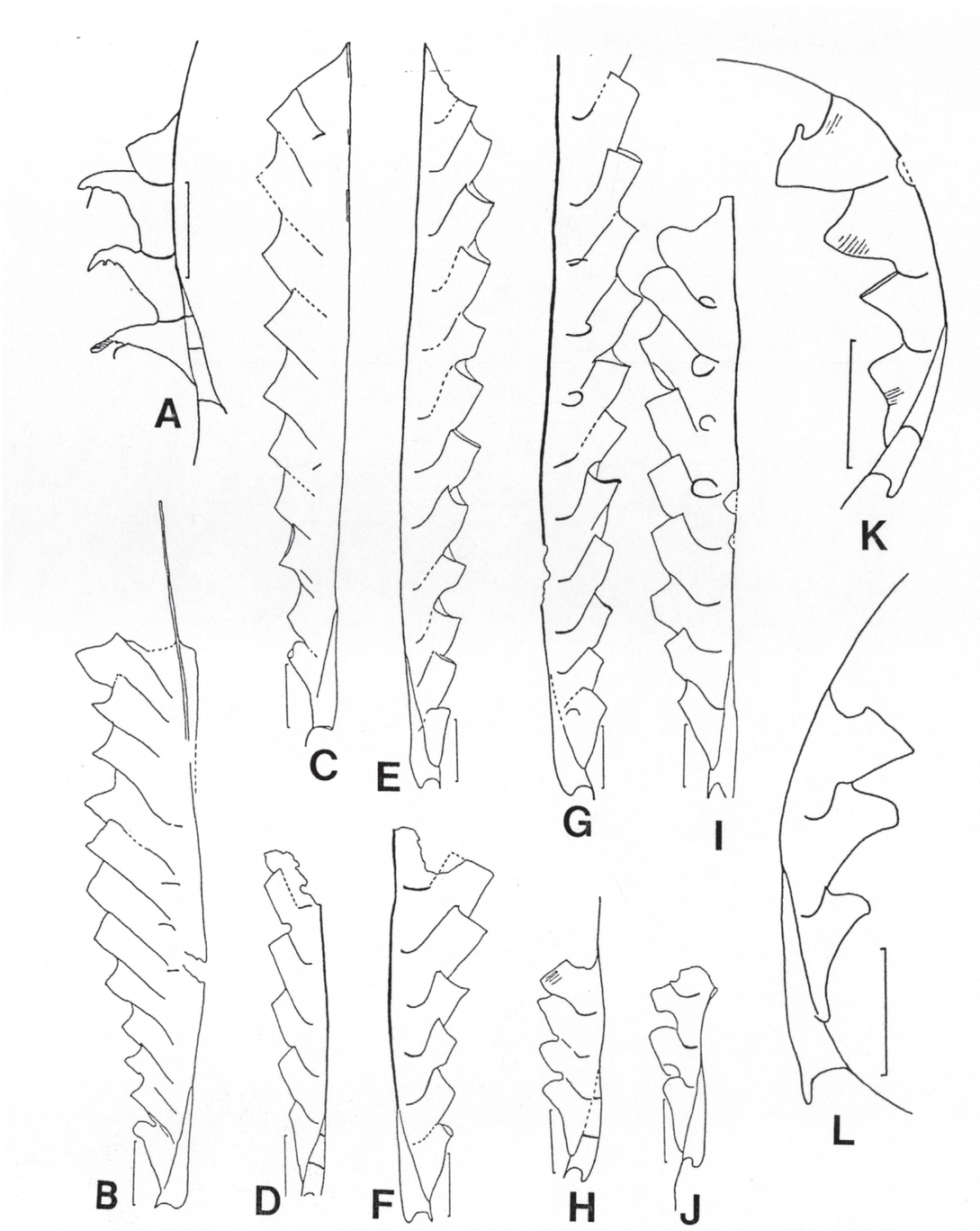

Figure 4A-L. A, *Monograptus spineus* (Tsegelnuk, 1976), AM F92370, WEEM 409c, *spineus* Biozone, Ludlow. B-C, *Monograptus ludensis* (Murchison, 1839), AM F114572-3, 68 KIL, *ludensis* Biozone, Wenlock. D-E, *Pristiograptus shearsbyi* Rickards and Wright, 1999b, AM F92376 and 923371, WEEM 409c, *spineus* Biozone, Ludlow. F-J, *Neocolonograptus parultimus* (Jaeger, 1975), respectively AM F92379, 92377, 92378, 92374 and 92375, WEEM 409, *parultimus* Biozone, Přídolí. K-L, *Bohemograptus praecornutus* Urbanek, 1970, AM F102918 from Blind Gully; and MMF 33611, WEEM 409a, both *praecornutus* Biozone, Ludlow. Scale bars 1 mm.

Monograptus ludensis (Murchison, 1839)
Fig. 4B-C

1839 *Graptolithus ludensis* n. sp.; Murchison, p. 694, pl. 26, fig. 2 (*non* fig. 1).
1996 *Colonograptus ludensis* (Murchison); Lenz et al., p. 1396, figs 3P, D, 4M-R.
1997b *Monograptus ludensis* (Murchison); Rickards and Wright, pp. 236-7, figs 2D-H, 4A-E, 5J.
For further references see Rickards et al. (1995) and Rickards and Wright (1997b).

Material

Well-preserved specimens: AM F114572-3, 114582-600, from locality KIL 68, *ludensis* Biozone, Barnby Hills Shale.

Description

Robust pristiograptid-like rhabdosomes up to 30 mm long and 2 mm broad, but with aperture of th1 clearly rounded; proximal end and sicula often slightly curved ventrally; proximal dorsoventral width 0.8-1.0 mm; proximal thecal spacing 14-10 in 10 mm; sicula 1.8-2.2 mm reaching to level of aperture of th2; thecal overlap ca ½ - ¾; thecal inclination 45-50°.

Remarks

These forms are very close to many previous descriptions and would correspond with the sort of *M. ludensis* that has been sometimes called *M. praedeubeli* Barca and Jaeger, 1990; this matter was discussed by Rickards and Wright (1997b).

Genus *Neocolonograptus* Urbanek, 1997

Type species

Monograptus lochkovensis Přibyl, 1940; by original designation (Urbanek 1997, p. 128).

Neocolonograptus parultimus (Jaeger, 1975)
Fig. 4F-J

1899 *Monograptus ultimus* n. sp.; Perner, p. 13, pl. 10, figs 4, 5 (*non* fig. 14 a, b =*Neocolonograptus ultimus*).
1975 *Monograptus parultimus* n. sp. Jaeger, p. 119, pl. 2, figs 4, 8; text-fig. 4.
1997 *Neocolonograptus parultimus* (Jaeger); Urbanek, pp. 166-7, pl. 21, figs 1-7; fig. 48.
1999b *Monograptus parultimus* Jaeger, 1975; Rickards and Wright, p. 165, figs 3Q-S, U.

More detailed synonymies are given by Urbanek (1997), Koren' and Sujarkova (1997) and Rickards and Wright (1999b).

Material

Well-preserved specimens from localities WEEM 409 and 409a: AM F 92374-5, 92377-9, 114601-11, *parultimus* Biozone, Hanover Formation.

Description

Neocolonograptus rhabdosomes up to 12 mm long with distal dorsoventral width up to 1.6 mm, proximally 0.6-0.8 mm and proximal end often with slight ventral curvature; sicula 1.6-2.0 mm long, with occasionally-preserved thickening bands, apex below level of aperture of th2; dorsal tongue conspicuous; virgella short; slight rounding on first theca or some higher thecae; thecal overlap ca ½; thecal spacing 10.5-13 in 10 mm; $\sum$ = 1.3-1.4, 1.6 in one specimen.

Remarks

This material is close to that described from Yass by Rickards and Wright (1999b), which in turn was shown to be close to Jaeger's types from Kosov Quarry; however, the Barnby Hills Shale specimens have a $\sum$ value closer to that of the material from south Tien Shan described by Koren' and Sujarkova (1997). There is also a suggestion in our present collection that the apertural undulations of the proximal thecae are slightly less than in the specimens from Yass. It is possible that they are slightly earlier, perhaps near the base of the *parultimus* Biozone.

Genus *Bohemograptus* Přibyl, 1967

Type species

Graptolithus bohemicus Barrande, 1850; by original designation.

Bohemograptus praecornutus Urbanek, 1970
Fig. 4K-L

1970 *Bohemograptus praecornutus* n. sp.; Urbanek, pp. 301-10, text-fig. 16, pl. 20C, pls 23, 24
1999b *Bohemograptus praecornutus* Urbanek; Rickards and Wright, pp. 200-202, figs 5C-L, 13K
A full synonymy is given in Rickards and Wright (1999b)

Material

Two specimens, AM F102918, and MMF 33611 from Blind Gully locality WEEM 13B near Cumnock; and a less well-preserved specimen, AM F114612 from the same locality; *praecornutus* Biozone;

Barnby Hills Shale.

Description

Robust *Bohemograptus* with tight ventral curvature. Dorsoventral width at th1 0.6-0.7 mm, distal dorsoventral width not seen; proximal thecal spacing 14 in 10 mm (distal thecal spacing not seen); thecal overlap ca 1/2; thecal inclination 40-50°; ∑ 1.0-1.4 mm. Conspicuous sicula with pronounced dorsal tongue, 1.4-1.8 mm long, reaching to a little above aperture of th1.

Remarks

These specimens differ from the Yass material only in having a slightly longer sicula in one specimen: all the other measurements agree closely. They are, therefore, very close indeed to Urbanek's (1970) originals from Poland. As in the Yass district the presence of *B. praecornutus* can be taken as an indicator of the *praecornutus* Biozone**.**

Bohemograptus paracornutus Rickards and Wright, 1999b
Fig. 5D-E

1999b *Bohemograptus paracornutus* n. sp., Rickards and Wright, p. 202, figs 5M-Q, 6A-N, 7, 9A-B, 10A-E.

Material

AM F 114767-8 and at least 50 other specimens from the Mullions Reserve locality, all highly deformed tectonically, and in a monotypic assemblage.

Remarks

The highly deformed nature of the specimens precludes a useful description. There is, however, no doubt about the nature of the strikingly flared sicula, which is identical to that of the type material from Yass, nor in the nature of the thecae with their slightly raised lateral apertural rim and gently concave free ventral wall. Some specimens (e.g. Fig. 5E) are abnormal in thecal spacing and nature of the sicula, but this may be caused by tectonic deformation.

Genus *Enigmagraptus* Rickards and Wright, 2004

Type species

Neocucullograptus? *yassensis* Rickards and Wright, 1999; by original designation.

Species recognised

Enigmagraptus yassensis (Rickards and Wright, 1999b); *E.* sp. cf. *yassensis* (Rickards and Wright, 1999b); *E. mitchelli* (Rickards and Wright, 1999b); *E. pennyae* Rickards and Wright, 2004.

Diagnosis

One of the tiniest known graptolites, with a dorsoventral width up to 0.25 mm; widely spaced thecae; axially elongate protheca usually developed from thread-like origin; tiny metatheca up to half rhabdosome width, consisting of hood derived from dorsal metathecal wall, and variously enrolled ventrally to enclose simple ventral thecal margin; small sicula with virgella and dorsal apertural process in type species (corrected after Rickards and Wright 2004).

Remarks

Since the description of the Yass material of *E. yassensis* and *E. mitchelli* by Rickards and Wright (1999b), *E. yassensis* has also been found at Cumnock and *E.* sp. cf. *yassensis* has been found at the 'borrow pit locality (W910)' near Cadia mine (Rickards et al. 2001). *Enigmagraptus mitchelli* was, until now, known only from the type locality at Yass. *Enigmagraptus pennyae* was described by Rickards and Wright (2004) from the same locality (W910) as *E.* sp. cf. *yassensis*. All these localities are Přídolí; W910 is probably late Přídolí, whereas the other occurrences are best assigned to the *parultimus* Biozone, early Přídolí.

Enigmagraptus mitchelli **(**Rickards and Wright, 1999b)
Fig. 5A-C

1999b *Neocucullograptus? mitchelli* n. sp.; Rickards and Wright, p. 200, figs 4S, T.

Material

Three specimens, AM F 92372-3 and 114571, all from locality WEEM 409a; *parultimus* Biozone; Hanover Formation.

Description

There is one proximal end with a partially preserved sicula and 2 ½ thecae, with virgella and virgula also preserved. Sicula may be ca 0.5 mm long, although apex is missing; it reaches only part way along th1. Thecal spacing of this proximal part, and a fragment possibly also close to proximal end (Fig. 5A), ca 7.5-8 in 10 mm but there is some soft sediment deformation along specimen shown in Fig. 5C so thecal spacing of 7 in 10 mm might be more likely in undeformed material. A more distal fragment

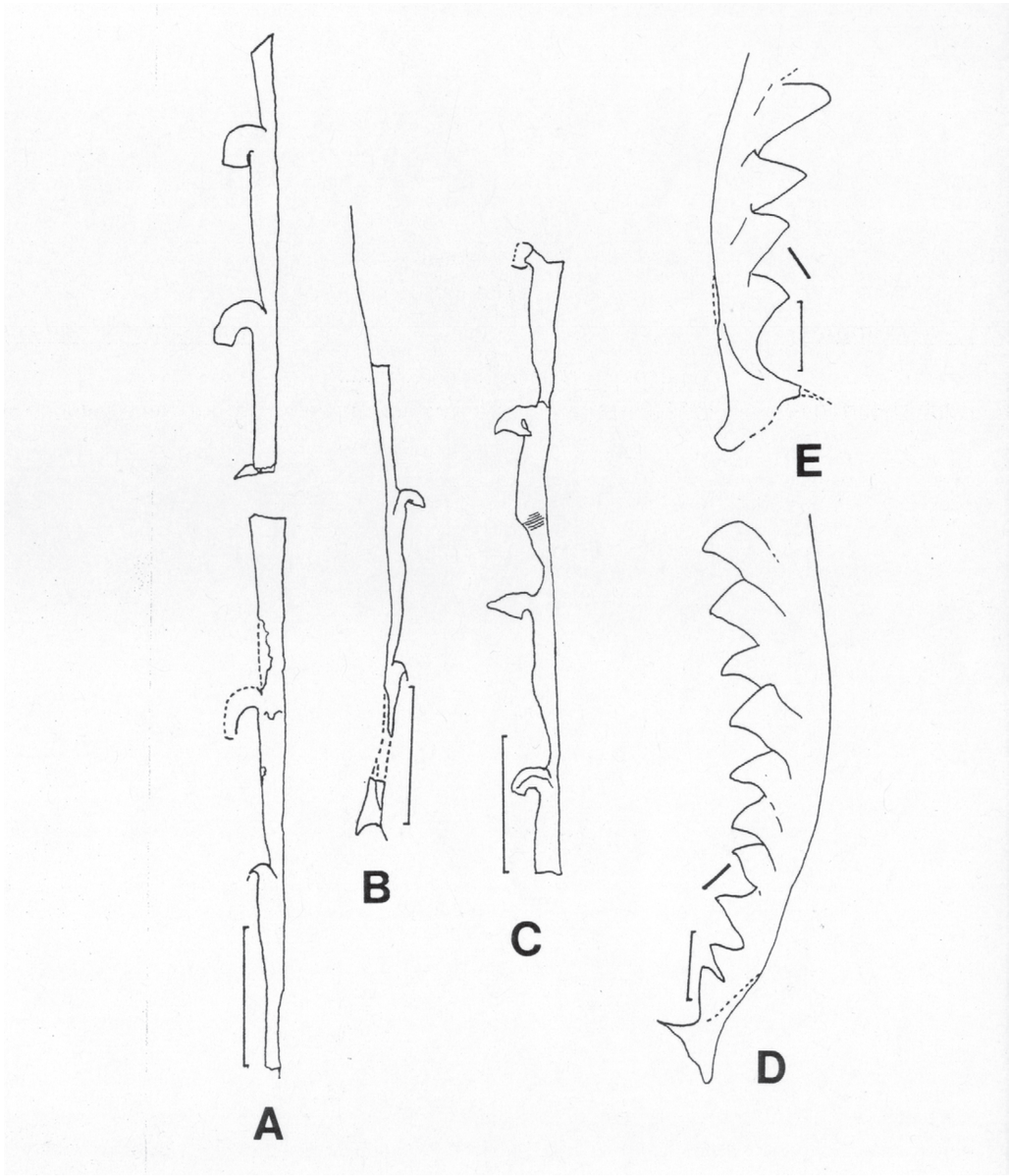

Figure 5A-E. A-C, *Enigmagraptus mitchelli* (Rickards and Wright, 1999b), respectively AM F92373, 92372 and 114571, WEEM 409a, ?*parultimus* Biozone, Přídolí; D-E, *Bohemograptus paracornutus* Rickards and Wright, 1999, AM F114768 and 114767 respectively; approximately *cornutus* Biozone, late Ludlow, W859, Mullions Reserve. AM F114767 appears to have abnormal dimensions: heavy bar = tectonic stretching direction. Scale bars 1 mm.

(Fig. 5A) shows 7 in 10 mm. Maximum dorsoventral width, including hook, of most distal fragment is 0.4 mm, but proximal end is only 0.2 mm at th1. Late metathecal part has a dorsoventral width of 0.15 mm on th2 and 0.2 mm on most distal thecae seen. Thecal overlap low and thecal angle (of free ventral wall) only a few degrees at most.

Remarks

These rare specimens are similar to those described from the same stratigraphic level (*parultimus* Biozone) from Yass by Rickards and Wright (1999b).

They differ in being more slender and in having a higher thecal spacing (7 in 10 mm compared with 4.5 in 10 mm). However, it is possible that these represent the proximal ends of the same species: certainly the profile of the hook is very similar as are most other features such as overlap and inclination. Only four specimens are known (including one from Yass) and the nature of the thecal hook is far from certain.

Acknowledgments

Support for a visit to Australia by RBR was supported by The Royal Society; Emmanuel College, Cambridge; the Department of Earth Sciences, Cambridge; and the University of Cambridge. Field work by AJW was supported by the University of Wollongong. EJM publishes with the permission of the Deputy Director-General of the NSW Department of Primary Industry and Mineral Resources. We are grateful to two anonymous reviewers who greatly improved an initial draft of the manuscript.

REFERENCES

Adrian, J. (1971). Stratigraphic units in the Molong district, New South Wales. *Records of the Geological Survey of New South Wales* **13**, 179-198.

Barca, S. and Jaeger, H. (1990). New geological and biostratigraphical data on the Silurian in SE Sardinia. Close affinity with Thuringia. *Bollettino della Società Geologica Italiana* **108**, 565-580.

Barrande, J. (1850). *Graptolites de Bohême*. *Extrait du Systême Silurien du Centre de la Bohême*. Prague, published by the author, 74 pp.

Bassler, R.S. (1909). Dendroid graptolites of the Niagaran dolomites at Hamilton Ontario. *Bulletin of the United States National Museum* **65**, 76 pp.

Bassler, R. (1915). Bibliographic index of American Ordovician and Silurian fossils. *Bulletin of the United States National Museum* **92**, 718 pp.

Bouček, B. (1931). Předběžná zpráva o některých nových druzích graptolitů z českého gotlandienu (část II). Věstník Státního Geologickeho Ústavu Československé Republicky, series 7, 3, 293-313.

Bouček, B. (1936). Graptolitová fauna céskeho spodnilo ludlowii. Rozpravy II. *Tridy Ceské Akademie* **46**, 1-26.

Bouček, B. (1957). The dendroid graptolites of the Silurian of Bohemia. *Rozpravy Ústředního Ústavu Geologickeho* **23**, 294 pp.

Bronn, H.G. (1835). *Lethaea geognostica.* 1. Schweitzerbart'sche, Stuttgart. 768 pp.

Bronn, H.G. (1849). *Index Palaeontologicus B, Enumerator Palaeontologicus*. Schweizerbart'sche, Stuttgart. 980 pp.

Bulman, O.M.B. (1928). *Odontocaulis* Lapworth, a synonym of *Callograptus* Hall. *Geological Magazine* **65**, 337-343.

Byrnes, J.G. (1976). Silurian environments of the northern Molong Rise. *Bulletin of the Australian Society of Exploration Geophysicists* **7**, 18-21.

Cockle, P. (1999). Conodont data in relation to time, space and environmental relationships in the Silurian (late Llandovery-Ludlow) succession at Boree Creek (New South Wales, Australia). *Abhandlungen der Geologischen Bundesanstalt* **54**, 107-133.

Farrell, J.R. (1992). The Garra Formation (Early Devonian: Late Lochkovian) between Cumnock and Larras Lee, New South Wales, Australia: stratigraphic and structural setting, faunas and community sequence. *Palaeontographica* **222A**, 1-41.

Farrell, J.R. (2001). *Conodont faunas (Late Ordovician, Silurian and Early Devonian) from the Larras Lee and Wellington districts, central western New South Wales*. Unpublished PhD thesis, Department of Earth and Planetary Sciences, Macquarie University, Sydney.

Farrell, J.R. (2003). Late Pridoli, Lochkovian and early Pragian conodonts from the Gap area between Larras Lee and Eurimbla, central western NSW, Australia. *Courier Forschungsinstitut Senckenberg* **245**, 107-181.

Geinitz, H.B. (1852). *Die Versteinerungen der Grauweckenformation in Sachsen und den Angrenzenden Länder - Abtheilungen*. Leipzig, Verlag Wilhelm Engelmann, 95 pp.

Gurley, R.R. (1909) (see Bassler, 1909).

Hall, J., 1843. Geological Report of the 4th District of New York. *Geology of New York*, **115-116.**

Hall, J. (1851). New genera of fossil corals. *American Journal of Science* **11**, 398-401.

Hall, J. (1858). Descriptions of Canadian Graptolites. *Geological Survey of Canada Report for 1857*, 111-145.

Hall, J. (1862). New species of fossils from the investigations of the Survey. *Wisconsin Geological Survey Report for 1861*, 18 pp.

Jaeger, H. (1975). Die Graptolithen führung in Silur/Devon des Celon-Profils (Karnische Alpen). *Carinthia II*, **165/185**, 111-126.

Jaekel, O. (1889). Ueber das Alter des sogen Graptolithengesteins. *Zeitschrift der Deutschen Geologischen Gesellschaft* **41**, 653-716.

Johnson, M.E., Kaljo, D. and Rong, J.-Y. (1991). Silurian eustasy. *Special Papers in Palaeontology* **44**, 145-163.

Johnson, M.E. and McKerrow, W.S. (1991). Sea level and faunal changes during the latest Llandovery and earliest Ludlow (Silurian). *Historical Biology* **5**, 153-169.

Kaljo, D., Boucot, A.J., Corfield, R.M., Le Herisse, A., Koren', T.N., Kriz, J., Mannik, P., Marss, T., Nestor, V., Shaver, R.H., Siveter, Derek J. and Viira,

V. (1995). Silurian bio-events, 177-224. In *Global Events and Event Biostratigraphy in the Phanerozoic*, O.H. Walliser, ed., Springer, Berlin.

Koren', T.N., Lytochkin, V.N. and Rinenburg, R.E. (1998). The Upper Silurian-Lower Devonian biostratigraphy based on graptolites in central part of the Alai Range, 15-18. In *Graptolites in the Earth History, Vilnjus 1988*, (*Abstracts for the 5th Symposium on Investigation of Graptolites in the USSR*).

Koren', T.N. and Rinenburg, R.E. (1988). The *ludgreni* event in the Wenlock pelagic facies of South Tien Shan, 11-14. In *Graptolites in the Earth History, Vilnjus* 1988, (*Abstracts for the 5th Symposium on Investigation of Graptolites in the USSR*).

Koren', T.N. and Sujarkova, A.A. (1997). Late Ludlow and Přídolí monograptids from the Turkestan-Alai Mountains, South Tien-Shan. *Palaeontographica* **247A**, 59-90.

Lapworth, C. (1875). *In* Hopkinson, J. and Lapworth, C., Descriptions of graptolites of the Arenig and Llandeilo rocks of St. Davids. *Quarterly Journal of the Geological Society of London* **31**, 631-672.

Lenz, A.C., Chen, X. and Ni, Y.-N. (1996). Wenlock-Ludlow and Přídolí? graptolites from Yulin, Guangxi, China. *Canadian Journal of Earth Sciences* **33**, 1390-1401.

Maggs, D.F. (1963). *The stratigraphy of the Yeoval-Cumnock-Manildra region*. MSc thesis, University of New South Wales, Sydney (unpublished).

Meakin, N.S. and Morgan, E.J. (1999). *Dubbo 1:250 000 Geological Sheet SI/55-4: Explanatory Notes*. Geological Survey of New South Wales, Sydney, 504 pp.

Miller, S.A. (1889). *North American geology and palaeontology*, Western Methodist Book Concern, Cincinnati, Ohio, 664 pp.

Morgan, E.J. (ed.) 1997. *Geology and Metallogenesis of the Fifield-Peak Hill-Wellington-Gulgong-Mudgee region of New South Wales*. *Narromine and Dubbo 1:250,000 Geological Sheets. Field Conference Guide. 6-11 April 1997. New South Wales Geological Survey Report* **GS 1997/080**, 213 pp.

Morgan, E.J., Cameron, R.G., Colquhoun, G.P., Meakin, N.S., Raymond, O.L., Scott, M.M., Watkins, J.J., Barron, L.M., Henderson, G.A.M., Krynen, J.P., Pogson, D.J., Warren, A.Y.E., Wyborn, D., Yoo, E.K., Glen, R.A. and Jagodzinski, E.A. (1999). *Dubbo 1:250 000 Geological Sheet SI/55-04* (second edition). Geological Survey of New South Wales, Sydney/Australian Geological Survey Organisation, Canberra.

Murchison, R.I. (1839). *The Silurian System, founded on Researches in the Counties of Salop, Hereford, Radnor, Montgomery, Caermarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester and Stafford: with descriptions of the Coal-Fields and Overlying Formations*. John Murray, London, 768 pp.

Nicholson, H.A. (1872). *Monograph of the British Graptolites*. Blackwood and Sons, Edinburgh, London, 133 pp.

Offenberg, A.C., Rose, D.M. and Packham, G.H. (1971). *Dubbo 1:250 000 Geological Sheet SI 55-4* (1st edition). Geological Survey of New South Wales, Sydney.

Packham, G.H. (1968). *Monograptus* cf. *ultimus* Perner and *Monograptus formosus* Boucek from the Hume Series of the Yass district, New South Wales. *Proceedings of the Linnea Society of New South Wales* **93**, 217-221.

Packham, G.H. and Stevens, N.C. (1955). The Palaeozoic strata of Spring and Quarry Creeks, west of Orange, New South Wales. *Journal and Proceedings of the Royal Society of New South Wales* **88**, 55-60.

Percival, I.G. (1998). The age of the Sourges Shale and adjacent formations. *Geological Survey of New South Wales, Palaeontological Report* **98/01**, **GS1998/225** (unpublished).

Perner, J. (1899). *Études sur les Graptolites de Bohême*. Part I, 14 pp.; Part II, 31 pp.; Part IIIa, 25 pp.; Part IIIb, 24 pp., Charles Bellman, Prague.

Pickett, J.W. (ed.) (1982). The Silurian System in New South Wales. *Bulletin of the Geological Survey of New South Wales* **29**, 264 pp.

Počta, P. (1894). Bryozoaires, Hydrozoaires et partie des Anthozoaires, in J. Barrande, *Systême Silurien du Centre de la Bohême*, **8**, part 1, Rivnac, Prague, 220 pp.

Pogson, D.J. and Watkins, J.J. (1998). *Bathurst 1:250 000 Geological Sheet SI/55-8: Explanatory Notes*. Geological Survey of New South Wales, Sydney, 430 pp.

Pogson, D.J. and Wyborn, D. (1994). *Excursion guide*. *Bathurst 1:250 000 Geological Sheet. 9-14 October 1994.* N.S.W. Department of Mineral Resources, Sydney and Australian Geological Survey Organisation, Canberra, 137 pp.

Přibyl, A. (1940). Die Graptolithenfauna des mittleren Ludlows von Böhmen (oberes eβ). *Věstník Státního Geologickho Ústavu Československé Republicky* **16**, 63-73.

Přibyl, A. (1967). O rodu *Bohemograptus* gen. nov. (Graptoloidea) z ceského a ciziho ludlowu. *Časopis Národního Musea* **136**, 133-136.

Prout, A.H. (1851). Description of a new graptolite found in the Lower Silurian rocks near the falls of St. Croix River. *American Journal of Science* **11**, 187-191.

Richter, R. (1875). Aus dem Thüringischen Schiefergebirge. V. *Zeitschrift der Deutschen Geologischen Gesellschaft* **27**, 261-273.

Rickards, R.B., Packham, G.H., Wright, A.J. and Williamson, P.L. (1995). Wenlock and Ludlow graptolite faunas and biostratigraphy of the Quarry Creek district, N.S.W. *Memoir of the Australasian Association of Palaeontologists* **17**, 68 pp.

Rickards, R.B, Percival, I.G., Simpson, A.J. and Wright, A.J., 2001. Silurian biostratigraphy of the Cadia area, South of Orange, New South Wales. *Proceedings of the Linnean Society of New South Wales* **123**, 173-191.

Rickards, R.B. and Wright, A.J. (1997a). Graptolites of the Barnby Hills Shale (Silurian, Ludlow), New South Wales, Australia. *Proceedings of the Yorkshire Geological Society* **51**, 209-227.

Rickards, R.B. and Wright, A.J. (1997b). Graptolite zonation in the late Wenlock (Early Silurian), with a new graptolite-brachiopod fauna from New South Wales. *Records of the Australian Museum* **49**, 229-248.

Rickards, R.B. and Wright, A.J. (1999a). Evolution of the Ludlow (Silurian) graptolite genus *Bohemograptus* Přibyl 1967. *Proceedings of the Yorkshire Geological Society* **52**, 313-320.

Rickards, R.B. and Wright, A.J. (1999b). Systematics, biostratigraphy and evolution of the late Ludlow and Přídolí (Late Silurian) graptolites of the Yass district, New South Wales, Australia. *Records of the Australian Museum* **51**, 187-212.

Rickards, R.B. and Wright, A.J. (2001). Early Devonian graptolites from Limekilns, New South Wales. *Records of the Western Australian Museum, Supplement* **58**, 123-131.

Rickards, R.B. and Wright, A.J. (2004). *Enigmagraptus* n. gen., a new graptoloid (Pridoli, Silurian, New South Wales, Australia). *Paläontologische Zeitschrift* **78**, 189-194.

Ruedemann, R. (1904). Graptolites of New York. Part 1, Graptolites of the lower beds. *Memoirs of the New York State Museum* **7**, 457-803.

Ruedemann, R. (1925). Some Silurian (Ontarian) faunas of New York. *Bulletin of the New York State Museum* **265**, 134 pp.

Savage, N.M. (1968). The geology of the Manildra district. *Journal and Proceedings of the Royal Society of New South Wales* **101**, 159-169.

Sherwin, L. (1993). Late Silurian graptolites from Mullions Reserve. *Geological Survey of New South Wales, Palaeontological Report* **93/06**, **GS1993/140** (unpublished).

Sherwin, L. (1994a). Late Silurian graptolites from the Cumnock district. *Geological Survey of New South Wales, Palaeontological Report* **94/03**, **GS1994/094** (unpublished).

Sherwin, L. (1994b). Fossils from the Molong 1:100 000 sheet No 2. *Geological Survey of New South Wales, Palaeontological Report* **94/09, GS1994/144** (unpublished).

Sherwin, L. (1996). Fossils from the Geurie district. *Geological Survey of New South Wales, Palaeontological Report* **96/05, GS1996/524** (unpublished).

Sherwin, L. (1997). Fossils from the Cumnock 1:50 000 sheet. *Geological Survey of New South Wales, Palaeontological Report* **97/03, GS1997/406** (unpublished).

Sherwin, L. and Rickards, R.B. (2002). Late Silurian (Přídolí) graptolites from the Wallace Shale, New South Wales. *Alcheringa* **26**, 87-101.

Spencer, J.W. (1878). Graptolites of the Niagara Formation. *Canadian Naturalist* **8**, 457-463.

Stevens, N.C. and Packham, G.H. (1953). Graptolite zones and associated stratigraphy at Four Mile Creek, southwest of Orange, New South Wales. *Journal and Proceedings of the Royal Society of New South Wales* **86**, 94-99.

Strusz, D.L. (1960). The geology of the parish of Mumbil, near Wellington, New South Wales. *Journal and Proceedings of the Royal Society of New South Wales* **93**, 127-136.

Talent, J.A. (1989). Transgression-regression pattern for the Silurian and Devonian of Australia, 201-219. In *Pathways in Geology: Essays in honour of Edwin Sherbon Hills*, R.W. Le Maitre (ed.), Blackwell, Melbourne.

Talent, J.A. (1995). *Ordovician-Devonian of southeastern Australia. First Australasian Conodont Symposium/ Boucot Symposium, Guidebook for the Pre-Symposium Field Excursion*. Macquarie University Centre for Ecostratigraphy and Palaeobiology, Sydney, 43 pp.

Talent, J.A. and Mawson, R. (1999). North-eastern Molong Arch and adjacent Hill End Trough (Eastern Australia): mid-Palaeozoic conodont data and implications. *Abhandlungen der Geologischen Bundesanstalt* **54**, 49-105.

Tsegelnuk, P.D. (1976). Late Silurian and early Devonian monograptids from the south-western margin of the East European Platform (in Russian). Pp. 91-133 in (P.L. Shulga, ed.), *Palaeontology and Stratigraphy of the Upper Precambrian and Lower Paleozoic of the SW part of the East European Platform*, 91-133. Naukova Dumka, Kiev.

Tsegelnuk, P.D. (1983). *The Silurian of Podolia*; *the guide of the excursion*. Naukova Dumka, Kiev, 222 pp.

Urbanek, A. (1970). Neocucullograptinae n. subfam. (Graptolithina) - their evolutionary and stratigraphic bearing. *Acta Palaeontologica Polonica* **15**, 164-388.

Urbanek, A. (1995). Phyletic evolution of the latest Ludlow spinose monograptids. *Acta Palaeontologica Polonica* **40**, 1-17.

Urbanek, A. (1997). Late Ludfordian and early Přídolí monograptids from the Polish lowland. *Palaeontologia Polonica* **56**, 87-231.

Urbanek, A. (1998). Oligophyly and evolutionary parallelism: a case study of Silurian graptolites. *Acta Palaeontologica Polonica* **43**, 549-572.

Vandyke, A. and Byrnes, J.G. (1976). Palaeozoic succession beneath the Narragal Limestone, Oakdale Anticline, near Mumbil. *Records of the New South Wales Geological Survey* **17**, 123-134.

Webby, B.D. (1969). Ordovician stromatoporoids from New South Wales. *Palaeontology* **12**, 637-662.

Zhen, Y.-Y. and Percival, I.G. (2004). Middle Ordovician (Darriwilian) conodonts from allochthonous limestones in the Oakdale Formation of central New South Wales. *Alcheringa* **28**, 77-111.

Zhen, Y.-Y., Percival, I.G. and Farrell, J.R. (2003). Late Ordovician allochthonous limestones in Late Silurian Barnby Hills Shale, central western New South Wales. *Proceedings of the Linnean Society of New South Wales* **124**, 29-51.