1-1-2005

Llandovery (Early Silurian) graptolites from the Quidong Basin, NSW

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Abstract
Late Llandovery (Early Silurian) graptolites from several localities in the Merriangaah Siltstone, Quidong Basin, southern NSW, are described as Monograptus priodon (Bronn, 1835), Oktavites falx (Suess, 1851) and Oktavites bodentoeriensis Loydell, 2003. This is the first use of the generic name Oktavites in Australia. The firm age for this fauna to the spiralis graptolite Biozone and new age data from the Quidong Limestone place a maximum age for the unconformity between the Siltstone and the overlying Quidong Limestone, constraining the Quidongan Orogeny between the latest part of the Llandovery and the late or latest Wenlock.

Keywords
GeoQuest

Disciplines
Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details
Rickards, R. B., Parkes, R. A. & Wright, A. J. (2005). Llandovery (Early Silurian) graptolites from the Quidong Basin, NSW. Linnean Society of New South Wales, 126 143-152.

Llandovery (Early Silurian) Graptolites from the Quidong Basin, NSW

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Rickards, R.B., Parkes, R.A. and Wright, A.J. (2004). Llandovery (Early Silurian) graptolites from the Quidong Basin, NSW. *Proceedings of the Linnean Society of New South Wales* **126**, 143-152.

Late Llandovery (Early Silurian) graptolites from several localities in the Merriangaah Siltstone, Quidong Basin, southern NSW, are described as *Monograptus priodon* (Bronn, 1835), *Oktavites falx* (Suess, 1851) and *Oktavites bodentoeriensis* Loydell, 2003. This is the first use of the generic name *Oktavites* in Australia. The firm age for this fauna to the *spiralis* graptolite Biozone and new age data from the Quidong Limestone place a maximum age for the unconformity between the Siltstone and the overlying Quidong Limestone, constraining the Quidongan Orogeny between the latest part of the Llandovery and the late or latest Wenlock.

Manuscript received 6 September 2004, accepted for publication 12 January 2005.

KEY WORDS: Early Silurian, graptolites, Llandovery, Merriangaah Siltstone, Quidong.

INTRODUCTION

Graptolites were first reported from the Quidong Basin in southeastern NSW by Crook et al. (1973, p. 116), who listed "*Retiolites geinitzianus angustidens*, *Monograptus* cf. *auduncus* and *Monograptus* of the *priodon* group" from the Merriangaah Siltstone, and inferred an age of "late Llandoverian to early Wenlockian" (middle of the Early Silurian). This material was found at Quidong by M. Tuckson (see Sherwin 1972) and the identifications cited by Crook et al. (1973) were by G.H. Packham. The Quidong Basin, 20 km N of Delegate (Fig. 1), is a farming region, although sulphides (copper–lead–zinc) in the carbonates of the area were mined in the 1860s, and the locality continues to be targeted as a mineral prospect (McQueen 1989).

Here we describe graptolites collected by us in May 2004 from three localities in the Quidong Basin (Fig. 2). Re-collection of the fauna was necessitated by the almost complete disappearance of the original collection; three poorly preserved, indeterminate specimens exist in the Mining Museum collections, presumably representing salvage from the collections of the University of Sydney.

This graptolite fauna is important because Crook et al. (1973) recognised the Quidongan Orogeny to account for what they considered an unconformity between the Merriangaah Siltstone and the overlying Quidong Limestone (Fig. 2). Scheibner (1972) originally introduced the term without definition. Crook et al. (1973, p.116) inferred that the Quidong Limestone was Ludlow in age, based on comparison of brachiopods in the mudstone conformably overlying the Quidong Limestone (the Delegate River Mudstone) to those in the "Ludlovian Silverdale Formation at Yass". This age was consistent with the late Wenlock-early Ludlow age assigned to the limestone by Hill (1943, p. 58) based on the similarity of the Quidong rugose coral fauna to the rugose fauna at Yass from the Bowspring and Hume limestones of the Silverdale Formation. Packham (1969, p. 121) also concluded the Quidong Limestone was "Wenlockian to early Ludlovian", comparing its diverse fauna of brachiopods, trilobites and corals with faunas from Hattons Corner, Yass. On this basis the orogeny was placed by Crook et al. (1973) within the Wenlock. Our studies of the Quidong Basin graptolites allow refinement of the age of this graptolite fauna; along with new data on the age of the Quidong Limestone, the

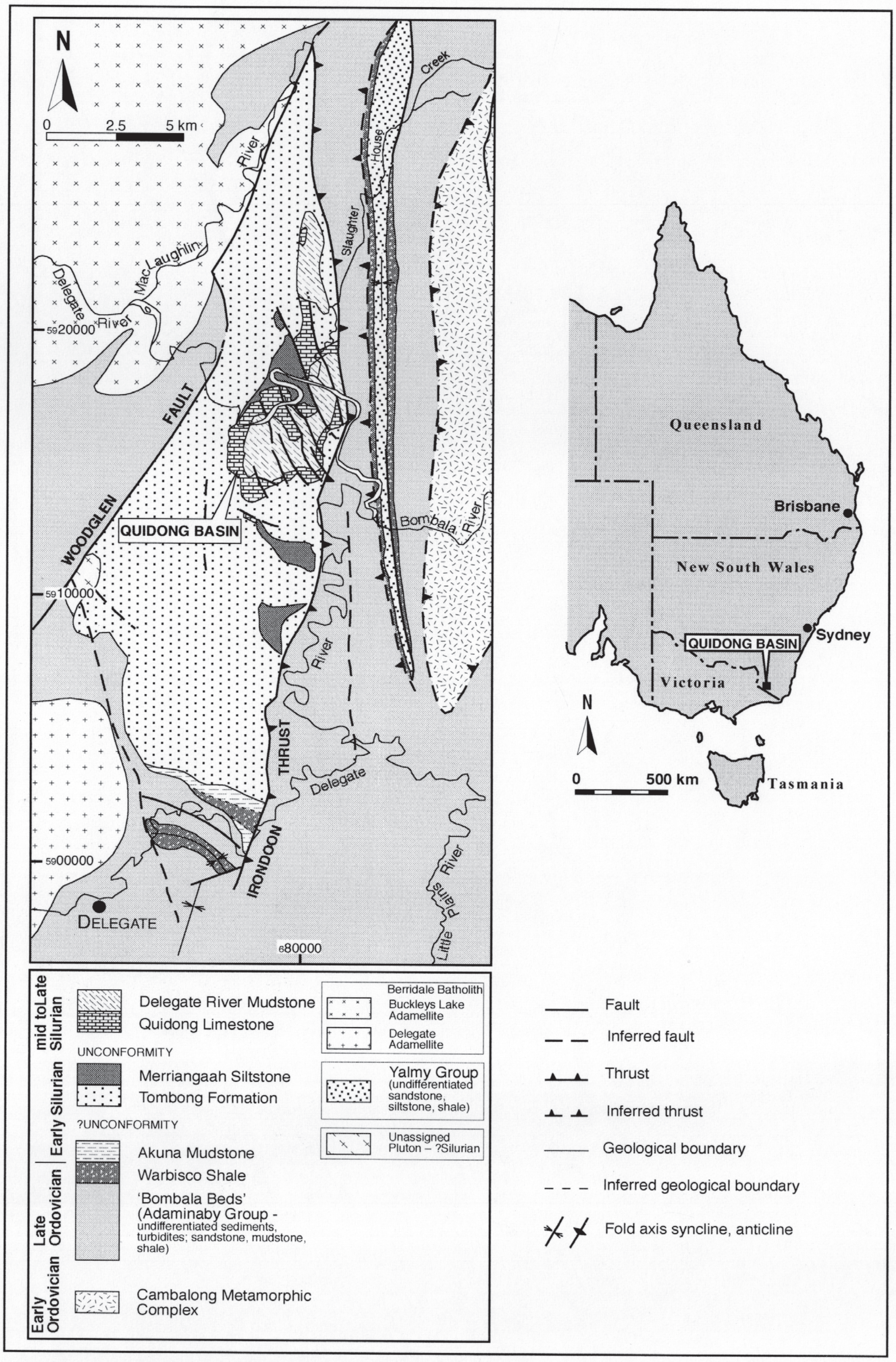

Figure 1. Location and geological setting of the Quidong Basin in the Tombong Block in southeastern New South Wales (modified after Lewis and Glen 1995, and McQueen 1989).

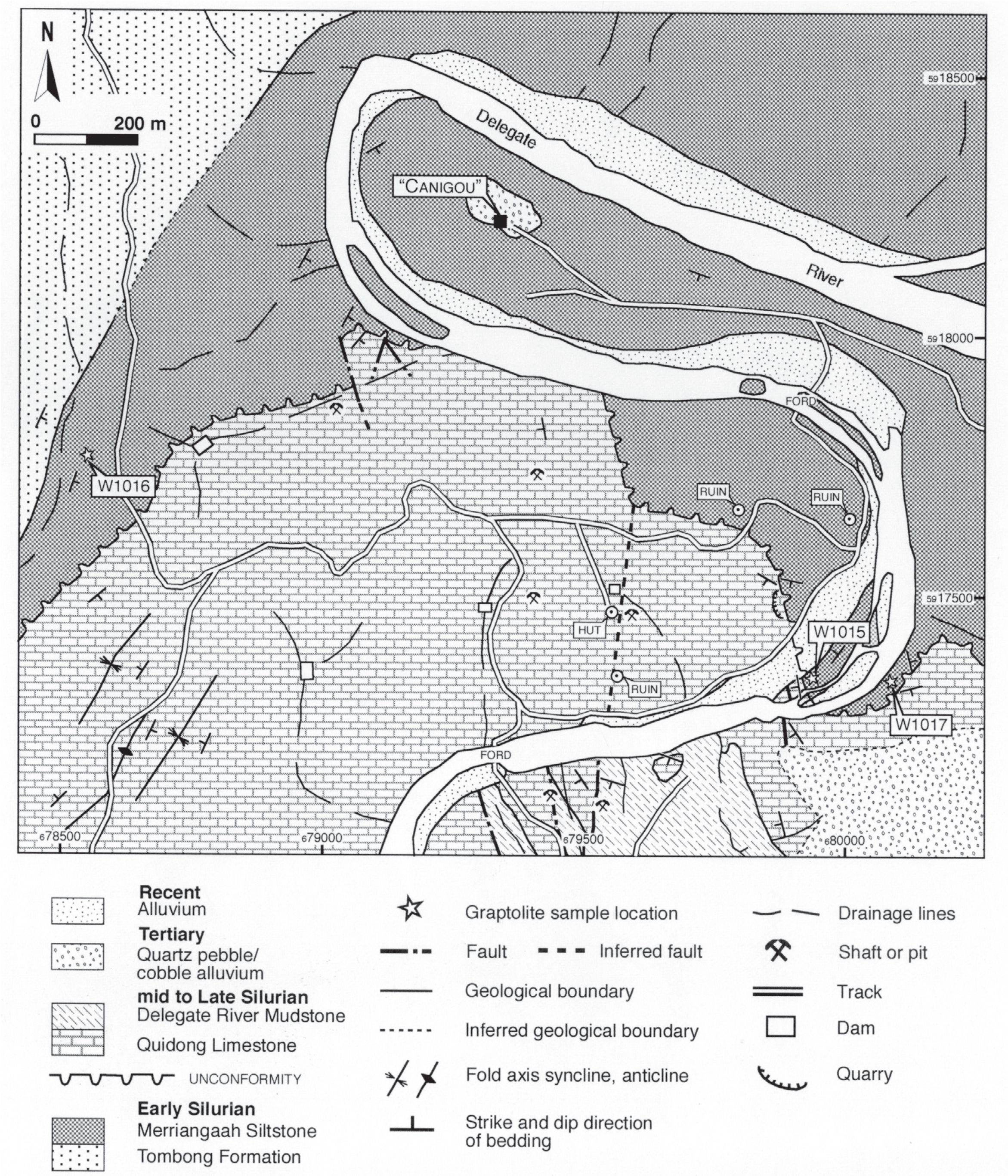

Figure 2. Geology of part of the northern area of the Quidong Basin. Sites sampled for graptolites indicated by W1015, W1016 and W1017.

age of the hiatus can be more closely constrained.

It is not our purpose here to discuss critically the whole matter of Early and Middle Silurian diastrophism in NSW. Crook et al. (1973) discussed the relationship of the tectonic history of the Quidong Basin area in relation to that of the Canberra and Orange districts. As two of us (RBR, AJW) are engaged in studies with Gordon Packham of the graptolite-rich sequences at the Spring-Quarry Creek area, at Four Mile Creek and the Angullong district near Orange, it is premature to comment on the nature of breaks in the sequence that have been recognised there by

Packham (1969) and Jenkins (1978, 1986). Further, the nature of the Merriangaah Siltstone – Quidong Limestone contact is a topic being investigated by RAP, and is only briefly discussed here.

GEOLOGICAL SETTING

The Quidong Basin is a structural entity of approximately 25 sq. km representing the preserved remnants of a sedimentary basin comprising Mid to Late Silurian sediments that unconformably overlie a 500 m–thick Early Silurian quartzose turbidite pile. Collectively, these Silurian sediments occupy a fault-bounded, triangular area defined as the Tombong Block (Lewis and Glen 1995) that sits within Ordovician turbiditic sandstones and shales ('Bombala Beds' – Adaminaby Group) (Fig. 1). The Tombong Block forms part of the southernmost section of the Hill End–Cooma Zone, a meridional structural zone situated in the east of the Lachlan Fold Belt (Lewis and Glen 1995).

The Early Silurian component of the Tombong Block comprises two units: the lower Tombong Formation and the higher Merriangaah Siltstone. The Tombong Formation occupies the bulk of the Tombong Block and consists of approximately 400 m of quartz-rich sandstones and siltstones and interbedded shales. The presence of chert and slate pebbles in the Tombong Formation indicates that it was possibly derived from the Adaminaby Group (Lewis et al. 1994). Beds in the unit are generally 30 cm to 50 cm thick, but range up to 1 m in thickness, and have lateral continuity equivalent to outcrop exposure. No fossils have been recovered from the Tombong Formation.

The relationship between the Tombong Formation and the overlying Merriangaah Siltstone is conformable. The transitional boundary linking these formations is well-exposed on the northwest margin of the Quidong Basin (Fig. 2). Where the Merriangaah Siltstone is absent on the western and southern margins of the Basin (Fig. 1), the contact between the Tombong Formation and the overlying Quidong Limestone is disconformable.

In the north of the Quidong Basin (Fig. 2) are extensive exposures of the Merriangaah Siltstone, which is estimated to be at least 80 m thick (Lewis et al. 1994, p. 35), and is composed of laminated beds of fine to very fine quartz sand intercalated with coarse quartz siltstone. The graptolite specimens in this study were recovered from beds composed of sand-sized grains. Bed thicknesses are mostly between 5 cm and 15 cm; cross-laminations and ripple marks are common. The trace fossils *Paleodictyon* isp. and ?*Gordia* isp. were described from the unit (Webby 1969). Our material was collected at three localities (Fig. 2), as follows:

W1015: the riverside location illustrated by Crook et al. (1973, plate 2, fig. B), approximately 3-4 m below the unconformity. This locality has yielded a monospecific graptolite fauna of *M. priodon*;

W1016: most westerly locality sampled, about 10 m below unconformity. This locality has yielded *Oktavites bodentoeriensis*; and

W1017: 1-2 m below the unconformity first recognised by Herbert (1965) and Woodhill (1965). The fauna from here is *Oktavites falx* and *M. priodon*.

The mid to Late Silurian fill of the Quidong Basin consists of the highly fossiliferous Quidong Limestone and the conformably overlying, erosionally-truncated Delegate River Mudstone. Conodonts recovered from the Quidong Limestone by one of us (RAP) indicate that the unit ranges from the late or latest Wenlock. The unconformity separating the Quidong Limestone from the underlying Merriangaah Siltstone is angular.

During Honours studies at the University of Sydney, Woodhill (1965) and Herbert (1965) described the unconformity based on lithologic relationships and the angular contact between the Merriangaah Siltstone and the Quidong Limestone. The deformation indicated because of the angularity of the unconformity has been attributed to "inferred periods of compression" (Gray 1997, p. 149) that were a feature of the stabilization of the Lachlan Fold Belt between the end of the Ordovician and the Middle Devonian (Collins and Vernon 1992). However, cleavage trends within the Merriangaah Siltstone and the overlying mid to Late Silurian sediments are similar (RAP, unpublished studies), suggesting that, if the cleavage resulted from horizontal shortening, such deformation was subsequent to the termination of the second round of basin fill and was therefore not responsible for the angularity. An alternative hypothesis indicating that extensional rifting produced the angular unconformity has been suggested by Pickett (1982, p. 10) and Glen (1992, p. 373), the angular discordance being a manifestation of block rotation on listric normal faults that formed part of a new, or renewed, round of basin extension.

Significantly, the late Llandovery start of the hiatus in sedimentation represented by the unconformity in the Quidong Basin is approximately coeval with the metamorphism of turbidites forming the Cooma Complex, based on an age for the metamorphism

(433±3 Ma) derived from detrital zircon and monazite by Williams (2001). The Cooma Complex is one of five fault-bound metamorphic complexes in the Eastern Metamorphic Belt (EMB) located in the southeastern part of the Lachlan Fold Belt (Johnson, 1999, fig. 2); the Cambalong Complex, 6 km to the east of the Quidong Basin (Fig. 1), is another in this narrow (<50 km wide), generally meridionally-trending Belt. If the complexes comprising the EMB are similar in age and the metamorphism, at least in part, is due to compressional deformation (Johnson, 1999, p. 440), then the Quidong Basin and Cambalong Complex represent juxtaposed coeval elements with contrasting structural styles separated by a thrust boundary (Fig. 1).

SYSTEMATIC PALAEONTOLOGY

Figured material is lodged in the Australian Museum (AMF). Three specimens from Quidong are held by the Geological Survey of NSW (MMF 18915-7) and are now lodged in the repository at Londonderry, NSW.

Class Graptolithina Bronn 1849
Order Graptoloidea Lapworth, 1875
Family Monograptidae Lapworth, 1873
Genus *Monograptus* Geinitz, 1852

Type species

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

Monograptus priodon (Bronn, 1835)
Figures 3A-B

1835 *Lomatoceras priodon* Bronn, p. 56, pl. 1, fig. 13.
1842 *Gr. Priodon*; Geinitz, pp. 699-700, pl. 10, figs 16A-B.
1850 Grapt. *priodon*. Bronn; Barrande, pp. 38-40, pl. 1, figs 3-9, 14, (*non* 1-2, 10, 11-13).
1993 *Monograptus priodon* (Bronn, 1835); Loydell, pp. 107-112, pl. 5, figs 2, 12; text-fig. 20, figs 4-5, 11, 26.
1993 *Monograptus priodon* (Bronn, 1835); Štorch & Serpagli, pp. 42-43, pl. 9, figs ?3, 4-5, text-fig. 123A, ?H.

Loydell (1993) synonymised well over one hundred records of *M. priodon*; of these, however, *M. rickardsi* Hutt, 1975 seems to us specifically distinct from *M. priodon*. Loydell demonstrated the very widespread record of *M. priodon* in late Llandovery and Wenlock strata.

Material

Numerous adult rhabdosomes were collected from localities W1015 and W1017. Specimens from W1017 are associated with *Oktavites falx,* are preserved in low relief with minimal pyritisation and are current-aligned. Specimens from locality W1015 are rather weathered, pyritised adult specimens in full relief and are also current-aligned. At locality W1015 no associated species was found.

Description

Monograptus rhabdosome, at least 15 cm long, with a distal dorsoventral width of 2.8-3.0 mm in three-dimensional specimens; proximal observed dorsoventral width of rhabdosome 1.0 mm and observed thecal spacing 11-14 in 10 mm; distal thecal spacing 8-11 in 10 mm; thecal overlap ca ½; thecal hooks strongly retroverted with lateral processes (but not spines); sicula not seen.

Remarks

This material is on slabs covered with current-oriented specimens, but no proximal ends have been found, although some specimens probably end within 10 mm of the sicula. Specimens from W1017 are extremely well-preserved, agree with many other descriptions of the species and are typical of those found in the late Llandovery.

Genus *Oktavites* Levina, 1928

Type species

Graptolithus spiralis Geinitz, 1842, subsequently designated by Obut (1964), from the Llandovery of Germany.

Remarks

Oktavites was not recognised in the 1970 edition of the graptolite Treatise, being considered a junior synonym of *Monograptus* (Bulman 1970, p. V132) for reasons given by Bulman and Rickards (*in* Bulman 1970, p. V132). However, the thecal structure of *Oktavites spiralis* has long been quite well-known; Loydell (1993) effectively redefined *Oktavites* in modern terminology and, at the same time, drew a contrast with species of *Spirograptus,* including the type species *S. turriculatus* (Barrande, 1850). Thus *Oktavites* has broadly triangular thecae with the thecal apertures laterally expanded, whereas *Spirograptus* has 1 or 2 apertural spines, sometimes apertural symmetry, but usually little lateral expansion. The

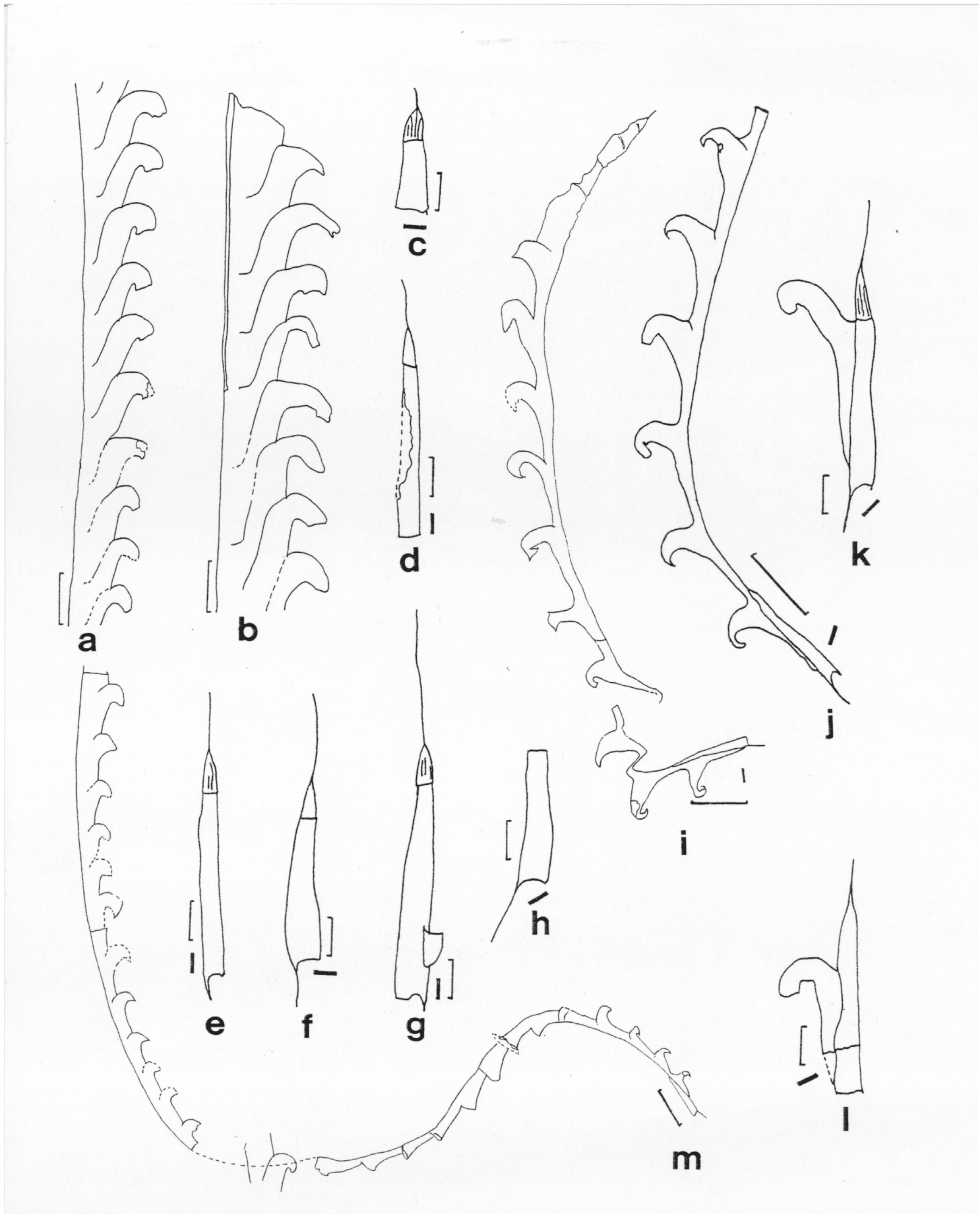

Figure 3. (a-b) *Monograptus priodon* (Bronn), respectively AM F 123128, 123129 from locality W1017, preserved in moderate relief, specimen a being quite close to the proximal end, specimen b of mesial thecae; scale bar 1 mm. (c-l) *Oktavites bodentoeriensis* Loydell, respectively AM F123120, 123114, 123116, 123119, 123121, 123118, 123115, 123113, 123124 and 123117, all from locality W1016; scale bars of c-h, k-l are 0.10 mm; scale bars of i-j are 1 mm. (m) *Oktavites falx* (Suess), AM F123125, from locality W1017; heavy bar indicates a lineation on the bedding plane that may be soft sediment deformation rather than tectonic deformation; scale bar of m is 1 mm.

generic name *Oktavites* has not been previously used for Australian graptolites, although *O. spiralis* was recorded from the Melbourne Trough, Victoria as *Monograptus spiralis* (see Rickards and Sandford 1998). Neither *Oktavites falx* nor *O. bodentoeriensis* (see below) has previously been recorded from Australia.

Oktavites falx (Suess, 1851)
Figure 3m

1851 *Graptolithus falx* n. sp.; Suess, p. 119, figs 10a-b.
1945 *Spirograptus falx* (Suess, 1851); Přibyl, pp. 11-32, pl. 5, figs 1-6.
?1990 *Oktavites falx* (Suess); Ge, pp. 152-153, pl. 64, figs 3, 6, 9.
1993 *Oktavites? falx* (Suess, 1851); Loydell and Cave, figs 8k-n.
?1994 *Monograptus* aff. *falx* (Suess, 1851); Zalasiewicz and Tunnicliffe, text-fig. 8A-B.
1998 *Oktavites? falx* (Suess, 1851); Štorch, pp. 124-5, text-fig. 3, figs 11-13.
2003 *Oktavites falx* (Suess, 1851); Loydell, pp. 59-60, text-fig. 1, figs 11-12.

Lectotype

The specimen figured by Suess (1851, pl. 9, fig. 10a) from the *spiralis* zone of the Litohlavy Formation, Praha-Malá Chuchle, Bohemia, was designated by Přibyl (1945).

Material

Two specimens from locality W1017, AM F123125a-b and AM F123126a-b; the former is on a bedding plane with many well-preserved specimens of *M. priodon.* Specimens are more or less flattened except for the proximal end, which is in low relief and well preserved.

Description

Oktavites with low-angled triangular thecae, reaching 13-9 in 10 mm; proximal dorsoventral width 0.4-0.5 mm, distally about 1 mm; thecal apertures with small lateral expansion and suggestions in places of tiny spines; dorsal wall strongly recurved; thecal height at th1 (hence dorsoventral width at same point) 0.4-0.5 mm; distal thecae inclined at a lower angle and less triangular than proximal ones (20º down to 10º); thecal overlap slight; rhabdosome with some spiral coiling beginning around th7; sicula 1.2 mm long, apex to just above level of hook of th1; origin of th1 halfway from sicular aperture; sicular aperture simple; virgella short, slim spine.

Remarks

The proximal thecae of *O. falx* are similar to those of *O. bodentoeriensis* from Quidong but are essentially smaller, much more closely spaced (13-12 in 10 mm compared with 7½ -8 in 10 mm) and with a lower metathecal height. Štorch's (1998) specimens from Spain are very close to the Quidong specimens, perhaps beginning their spiral coiling a little later (ca th10-15, rather than ca th7), but otherwise having the same dimensions and measurement. The stratigraphically earlier forms illustrated by Loydell (2003) have stronger rhabdosomal coiling but have exactly the same proximal end as the Quidong specimens.

Oktavites bodentoeriensis Loydell, 2003
Figs 3C-L

2003 *Oktavites bodentoeriensis* sp. nov.; Loydell, p. 60, text-fig. 1, figs 14-17; text-fig. 3.

Holotype

Specimen figured by Loydell (2003, text-fig. 1, fig 15) from the lower *spiralis* Biozone of the Rauchkofel Bodentöri section, Carnic Alps, Austria.

Material

Two adult specimens, AM F123113 and 123115, and eight early growth stages, AM F123114, 123116-121, 123124 all from locality 1016. Two further, poorly-preserved possible early growth stages from the same locality, AMF 123122-3.

Diagnosis

Oktavites with some rhabdosomal coiling beginning ca th12; prosicula 0.16-0.28 mm long; sicula 1.2-1.5 mm long; virgella short and fine. Proximal dorsoventral width of rhabdosome 0.6-0.8; distal dorsoventral width 0.75-0.85 mm. Proximal thecal spacing 7 in 10 mm; distal thecal spacing 7.5-8 in 10 mm; thecal overlap very low (diagnosis modified after Loydell on the basis of our new material).

Description

Of the two adult rhabdosomes AM F23113 (Fig. 3J) shows no twisting of the stipe after th7, whereas AM F123115 (Fig. 3I) begins to twist at around th10-11, so an open spiral coiling of rhabdosome can be predicted.

Prosicula well seen on several specimens, occuring as isolated specimens on bedding planes. Several longitudinal spiral strengthening threads visible (Fig. 3C) and these may coalesce to form nema, a fine thread up to 0.7 mm long and commonly seen on early growth stages. There seems to be a slight constriction at the origin of the metasicula (Figs 3d, g, k). When complete, the sicula is 1.2-1.5 mm long and its apex is invariably above the level of the hook of th1.

Origin of th1 very low on metasicula, perhaps 0.1-0.15 mm above sicular aperture, which has a diameter of up to 0.12 mm. Th1 completed before protheca of th2 begins (Figs 3e, k). Protheca of th2 very slim (0.1 mm), and expands only slightly as metatheca is approached. A marked change occurs in angle of free ventral wall with onset of metatheca (a change from 5º to 20-40º) and metatheca is quite high (giving the full dorsoventral width). Thecal hook occupies about 1/3 of metathecal height. Overall thecal profile axially elongate-triangular, with prominent hook showing no sign of torsion; there is some indication of apertural expansion and there are tiny thecal spines (Fig 31, th5 and th6 of visible thecae). Central part of metathecal hook strongly retroverted, facing dorsal side of rhabdosome.

Remarks

The nature of the thecal hook confirms Loydell's (2003) attribution of this species to *Oktavites* rather than *Spirograptus* (which has less transverse expansion of the thecal aperture) or *Torquigraptus* (which shows thecal torsion of the metathecal axis). The Quidong specimens are very close to Loydell's originals from the Carnic Alps and differ only in having slightly more widely-spaced thecae (7.5-8 in 10 mm compared with 8-10 in 10 mm). The Quidong specimens give a fuller idea of the early development, which is not well known in species of *Oktavites* other than the type species *O. spiralis*. *Oktavites bodentoeriensis* differs from *O. falx* in the same part of the rhabdosome, in having a more robust proximal end and different thecal spacing.

BIOZONAL AGE OF THE QUIDONG BASIN GRAPTOLITES

The age indicated for the assemblage is probably early *spiralis* Biozone (in old terminology early to mid *crenulata* Biozone: Llandovery, Early Silurian). *Monograptus priodon* has a long time range, possibly appearing (Loydell 1993) in the upper part of the *turriculatus* Biozone (earliest Telychian=late Llandovery), but certainly is common from the *griestoniensis* Biozone (Telychian) to the early middle Wenlock. However, both *O. falx* and *O. bodentoeriensis* are restricted to the Llandovery; the former appears in the early *spiralis* Biozone (more coiled forms) and ranges into the upper *spiralis* Biozone (almost uncoiled specimens), whereas the latter was recorded from the early *spiralis* Biozone of the Carnic Alps by Loydell (2003). This seems the most likely level in the *spiralis* Biozone for the Quidong material.

Crook et al. (1973) listed the following graptolites from Quidong: *Retiolites geinitzianus angustidens* Elles and Wood, *Monograptus aduncus* Bouček and *Monograptus* ex gr. *priodon* (Bronn), stating that they were identified by G.H. Packham. It was suggested that the last of these named forms was similar to *M. parapriodon* Bouček because of the narrow rhabdosome and high thecal spacing; if so, it is different from the specimens of *M. priodon* described here but has broadly the same age implication, as *Monograptus parapriodon* occurs in the *crenulata* Biozone. *Retiolites g. angustidens* ranges from the *crispus* Biozone to the early Wenlock. *Monograptus aduncus* is now referred to *Monoclimacis* and is from the early Wenlock rather the late Llandovery; however, we would need to re-examine this material given the improvements in recent years of our understanding of *Monoclimacis.* We have been unable to locate these specimens but the ages indicated are not in dispute with our more precise age of early *spiralis* Biozone, except for the identification of *Monoclimacis aduncus.* With the help of Dr Ian Percival and Dr Lawrence Sherwin we were able to examine three specimens (MMF 18915-7) in the collections of the Geological Survey of NSW (now held in the NSW State Palaeontological Reference Collections at the Geological Survey of NSW Geoscience Centre, Londonderry); as no retiolitids were present, part of the original collection is missing.

We have also been unable to check the Pickett (1982) record of *M. sedgwickii* Portlock but, as we remark in the following description of *M. priodon,* there is a preservational view of *M. priodon* that can appear superficially like *M. sedgwickii*; however*,* even under these circumstances the two have a quite different thecal overlap.

ACKNOWLEDGEMENTS

We are grateful to property owners James and Marlene Adams of 'Canigou' and Buddy Stevenson of 'Quidong' for allowing us access to their properties for specimen collection at localities in the Quidong Basin. Mandy Lyne kindly assisted with collecting. Dr Ian Percival and Dr Lawrence Sherwin helped us to locate early collections of Quidong graptolites. RBR acknowledges financial support from the Royal Society. We thanks two anonymous reviewers for their helpful comments, including the point about the Sardine Graben.

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