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The lower Williamson Shale (Silurian) of New York: a biostratigraphical enigma

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Abstract – The lower Williamson Shale at Tryon Park, Rochester, New York State is unique in the co-occurrence of *Stimulograptus clintonensis* (Hall), previously recorded only from the middle Telychian, and *Pterospathodus amorphognathoides amorphognathoides* Walliser, previously recorded only from the upper Telychian (*Cyrtograptus lapworthi* Biozone and higher). These two co-occurring fossils are clearly providing contradictory ages for the lower Williamson Shale. The incorporation of chitinozoan data from both the Williamson and Willowvale shales does not support unequivocally either the graptolite- or conodont-derived biostratigraphy and thus the age of the lower Williamson Shale remains problematical.

Keywords: graptolites, chitinozoans, conodonts, Llandovery, Silurian.

1. Introduction

In August 1996 the first author visited the exposure of the Williamson Shale Formation at Palmer's Glen, Tryon Park, Rochester, New York State, during one of the field trips associated with the James Hall Symposium (Brett & Goodman, 1996). The lower part of the Williamson Shale at this locality yields common *Stimulograptus clintonensis* (Hall, 1852) (Fig. 1), a species with which the first author had become very familiar due to its abundance in the middle Telychian (*crispus* to lower *griestoniensis* biozones) of Wales (Loydell & Cave, 1993, 1996; Zalasiewicz, 1994). James Hall's and Ruedemann's (1908, 1947) type and figured material of *Stimulograptus clintonensis* were also examined (discussed in Loydell, 1992) in order to confirm the identifications of the Welsh material.

One of us (GLM) later processed for chitinozoans a sample of graptolitic lower Williamson Shale collected on this James Hall Symposium field trip; the expectation was that this would yield a typical middle Telychian, *Eisenackitina dolioliformis* Biozone assemblage. Surprisingly, however, the sample yielded the biozonal index species *Margachitina banwyensis* Mullins, 2000, previously recorded only from the upper Telychian upper *Cyrtograptus lapworthi* Biozone through to *Cyrtograptus centrifugus* Biozone (Mullins & Loydell, 2001). Clearly the two fossil groups were providing contradictory ages for the Williamson Shale at Tryon Park. A possible explanation appeared when Loydell & Nestor (2005) recorded anomalously early *Margachitina banwyensis* and *M. margaritana* in the *Oktavites spiralis* Biozone of Latvia. This was a species previously considered to have its lowest occurrence in the *Cyrtograptus insectus* Biozone (Mullins & Loydell, 2001, text-fig. 7). Loydell & Nestor (2005, p. 375) concluded 'that some unknown environmental factors controlled the distribution of *Margachitina* and that in the pre-*insectus* Biozone part of its stratigraphical range the genus was generally rare and highly limited in its distribution, either palaeogeographically or palaeoenvironmentally'. In Mullins' (2000) morphological lineage, *M. banwyensis* is intermediate between *Calpichitina densa* and *M. margaritana*. With the former known from the *crispus* Biozone and the latter now from the *spiralis* Biozone, a middle Telychian *sartorius* or early *griestoniensis* Zone age for the lower Williamson Shale looked reasonable and entirely in accord with the high eustatic sea-level recorded for this interval (Loydell, 1998, p. 457 and fig. 3).

The addition of conodont data, however, suggests a rather different, younger age for the lower Williamson Shale. The graptolites, chitinozoans and conodonts are described herein and the implications of this new conodont data are discussed. Figured specimens are housed in the type collection of the Orton Geological Museum at The Ohio State University (OSU) and in the New York State Museum, Albany (NYSM).

2. Locality and lithologies

Tryon Park is approximately 5 km west of central Rochester, in Monroe County, west-central New York

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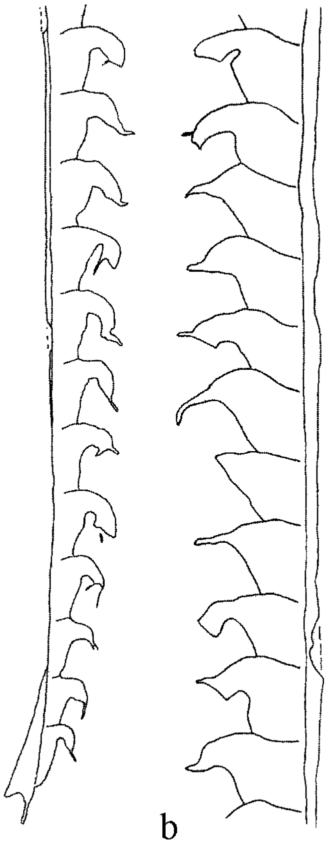

Figure 1. *Stimulograptus clintonensis* (Hall) from the lower Williamson Shale of Tryon Park. (a) OSU 52,490, proximal end. (b) OSU 52,520, distal fragment; × 10.

State. A detailed road log, with precise directions to the locality, was provided by Brett & Goodman (1996, p. 171). Exposures occur along the banks of an unnamed creek, informally referred to as Palmer's Glen, that flows into the west side of Irondequoit Bay, just east of Route I-590, about 1 km north of Browncroft Boulevard.

The Williamson Shale at Tryon Park was described in detail by Lin & Brett (1988). Its sharp, unconformable base is overlain by a thin (20 mm; see Lin & Brett, 1988, fig. 4A) phosphatic conglomerate, the Second Creek Phosphate Bed of Brett *et al.* (1995; referred to as the 'Second Creek Bed' by Lin & Brett, 1988). Above this, the lower Williamson Shale is grey to black, fissile to platy shale (Lin & Brett, 1988, p. 242), interbedded in its lower part with thin beds of laminated, fine-grained calcareous sandstone (Lin & Brett, 1988, p. 250) and two bentonites (geochemical analyses of these appear in an unpublished 2001 University of Wales, Aberystwyth Ph.D. thesis by J. Thorogood entitled *The geochemistry of Silurian bentonites from the Welsh Basin: implications for magmatism and stratigraphy*). The upper part of the formation differs in being a greenish grey silty shale. A log (by MAK) of the section is given in Figure 2. This paper is concerned primarily with the lower part of the Williamson Shale.

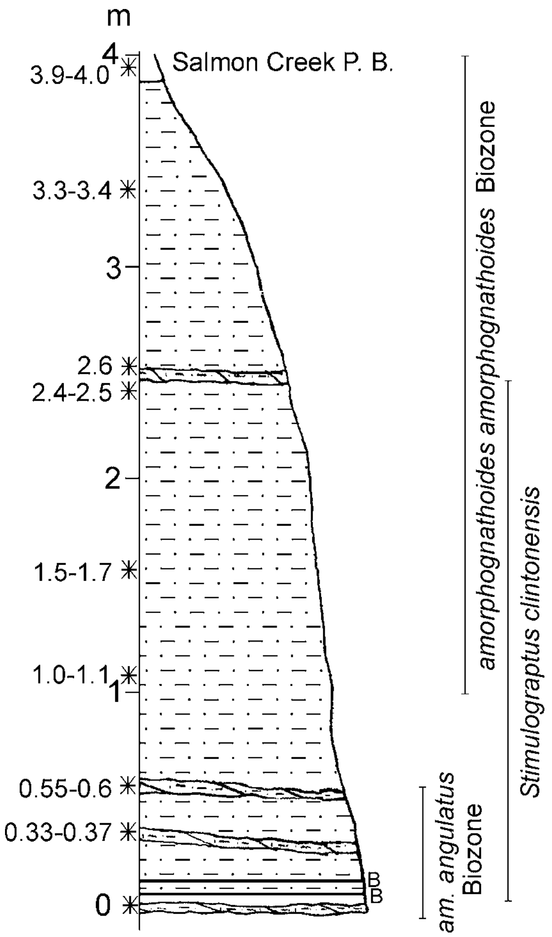

Figure 2. Weathering profile log of the section through the Williamson Shale at Tryon Park, Rochester, New York, showing extent of conodont biozones and range of *Stimulograptus clintonensis*. Stars mark horizons sampled for conodonts. The basal bed is the Second Creek Phosphate Bed. Calcareous sandstones occur at 0.33 m, 0.55 m and 2.6 m above the base of the formation. Abbreviations: *am.* – *amorphognathoides*; B – bentonite; P. B. – Phosphate Bed.

3. Graptolites, chitinozoans and conodonts from the Williamson Shale Formation

3.a. Graptolites

The Williamson Shale is the only Llandovery formation in New York to yield graptoloid graptolites. Graptolitic horizons at Tryon Park within the lower Williamson Shale (Lin & Brett, 1988, fig. 7), above the Second Creek Phosphate Bed, yield monospecific assemblages of superabundant *Stimulograptus clintonensis* (Hall) (Fig. 1); bedding surfaces are crowded with rhabdosomes, often showing alignment (see analysis in Eckert & Brett, 1989; Brett, 1999, fig. 44.5).

3.b. Chitinozoans

A graptolitic sample from the Williamson Shale was processed for chitinozoans using the standard HCl–HF–HCl technique. The sample yielded abundant chitinozoans (1733 specimens per gram of rock), poorly to moderately well preserved, in a low-diversity assemblage.

Figure 3. Chitinozoans from the lower Williamson Shale, Tryon Park. (a, e, f, h, i, k) *Conochitina iklaensis* Nestor; (a) OSU 52,498, stub WS-4, × 200; (e) OSU 52,496, stub WS-3, × 200; (f) OSU 52,499, stub WS-4, × 200; (h) OSU 52,493, stub WS-2, × 200; (i) OSU 52,503, stub WS-5, × 200; (k) OSU 52,505, stub WS-7, × 200. (b–d, g, j) *Conochitina praeproboscifera* Nestor; (b) OSU 52,508, stub WS-9, × 200; (c) OSU 52,504, stub WS-5, × 200; (d) larger specimen, OSU 52,500, stub WS-4, × 200; (g) close-up of the base of c showing the mucron, × 400; (j) OSU 52,509, stub WS-9, × 200. (d, q, r). *Bursachitina* sp.; (d) smaller specimen (attached), OSU 52,501, stub WS-4, × 200; (q) OSU 52,494, stub WS-2, × 400; (r) OSU 52,495, stub WS-2, × 400. (l) *Conochitina* sp.; OSU 52,492, stub WS-1, × 200. (m) *Calpichitina densa* (Eisenack); OSU 52,506, stub WS-7, × 250. (n, p) *Margachitina banwyensis* Mullins; (n) OSU 52,507, stub WS-8, × 250; (p) OSU 52,502, stub WS-4, × 250. (o) *Ancyrochitina ancyrea* (Eisenack); OSU 52,497, stub WS-3, × 300.

Most of the chitinozoans recovered are long-ranging species. For example, *Calpichitina densa* (Eisenack) (Fig. 3m), which comprises 61.5 % of the assemblage, has a range of upper *turriculatus* Biozone to upper Sheinwoodian (Nestor, 1994; Loydell, Kaljo & Männik, 1998; Mullins & Loydell, 2001, 2002). *Conochitina praeproboscifera* Nestor (5.8 %; Fig. 3b–d, g, j) ranges from the upper Aeronian

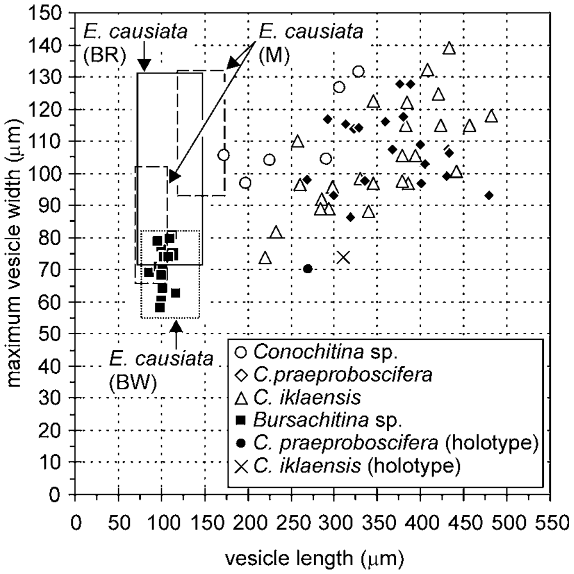

Figure 4. Size distribution of *Bursachitna* sp., *Conochitina* sp., *C. praeproboscifera* and *C. iklaensis* in the Williamson Shale. The size distribution of *E. causiata* in the Banwy River section (BR, Mullins & Loydell, 2001) and Builth Wells area (BW, Verniers, 1999), Wales, and the normal and large varieties from the Mehaigne area (M, Verniers, 1999), Belgium, are shown. The size of the holotypes, with the measurements taken from the illustrations, of *C. praeproboscifera* and *C. iklaensis* are also shown.

through to the lower Wenlock (Nestor, 1994; Mullins & Aldridge, 2004). *Conochitina iklaensis* Nestor (1.9 %; Fig. 3a, e, f, h, i, k) occurs in the Rhuddanian–Aeronian, Õhne Formation (Juuru Stage)–Rumba Formation (Adavere Stage) of the Baltic region (Nestor, 1994). However, identical morphotypes to those recovered herein have been illustrated from the basal Wenlock Series of the Global Boundary Stratotype Section and Point (GSSP) at Hughley Brook, England, by Mullins & Aldridge (2004, pl. 8, fig. 3, as *C. praeproboscifera*). It is thus likely that *C. iklaensis* is long-ranging and of little biostratigraphical value. *Ancyrochitina ancyrea* (Eisenack) (3.9 %; Fig. 3o) ranges from the Ordovician to the upper Silurian (Nestor, 1994).

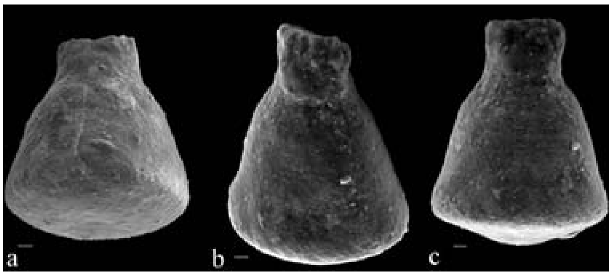

Figure 5. *Cyathachitina campanulaeformis* (Eisenack) from the 1.0–1.1 m level in the Williamson Shale (see Fig. 2), Tryon Park, Rochester, New York. (a) OSU 52,513. (b) OSU 52,514. (c) OSU 52,515. Scale bars represent 10 μm.

Some material has been left in open nomenclature. Specimens of *Bursachitina* sp. (15.4 %, Fig. 3d, q, r) have a cono-ovoid vesicle, with convex flanks, and are considerably smaller than *C. praeproboscifera*, but are comparable to small examples of *Eisenackitina causiata* Verniers, 1999 (Figs 3d, 4). However, *Bursachitina* sp. differ in lacking the characteristic granulate–verrucate ornament of *E. causiata*. The *Conochitina* sp. (1.9 %, Fig. 3l) have a smooth, broad base, which lacks a mucron, and straight flanks that taper towards the aperture. These specimens may be *C. iklaensis*, which also lacks a basal mucron, but are distinguished by their larger width and distinctly tapering, straight flanks (compare Fig. 3k and l; see also Fig. 4). The presence or absence of a basal mucron was used herein to distinguish *C. praeproboscifera* and *C. iklaensis*, respectively. However, compaction has perhaps led to incorrect identification in some instances, as the bases of several specimens are folded inwards, obscuring any mucron that may be present. Specimens of *Ancyrochitina* spp. (7.7 %) are also present. This material left in open nomenclature is clearly of no biostratigraphical significance.

Margachitina banwyensis Mullins (1.9 %, Fig. 3n, p) also occurs in this Williamson sample. As mentioned above, this taxon is biozonal index of the *banwyensis* chitinozoan Biozone.

Four additional chitinozoans were found within the 1.0–1.1 m conodont residue. All four are *Cyathachitina campanulaeformis* (Eisenack) (Fig. 5). This is a species stratigraphically restricted to strata below the upper Telychian (e.g. Nestor, 1994), although Grahn (1998) has recorded *Cyathochitina* sp. aff. *campanulaeformis* from strata stated to be of *Cyrtograptus lapworthi* Zone age from the Ljunghusen Drilling 1, Skåne, Sweden and from strata stated to be of not older than Wenlock age from Nederberga 1, Dalarna, Sweden.

3.c. Conodonts

The Second Creek Phosphate Bed, at the base of the Williamson Shale, has yielded a moderately diverse conodont assemblage (Fig. 6). From a biostratigraphical viewpoint, the most important species present is *Pterospathodus amorphognathoides angulatus* (Walliser), index subspecies of the eponymous conodont subzone of the *Pterospthodus celloni* Biozone.

The 1.0–1.1 m sample contains *Pterospathodus amorphognathoides amorphognathoides* Walliser (Fig. 7a–c) and *Oulodus petila* (Nicoll & Rexroad) (Fig. 7d). The former is index species of the well-known *P. am. amorphognathoides* Biozone and may be recognized, even in fragmentary material, by its distinct basal platform/platform ledges (Männik, 1998). Higher horizons in the Williamson Shale and the overlying Salmon Creek Phosphate Bed also yield *P. am. amorphognathoides* Biozone conodonts.

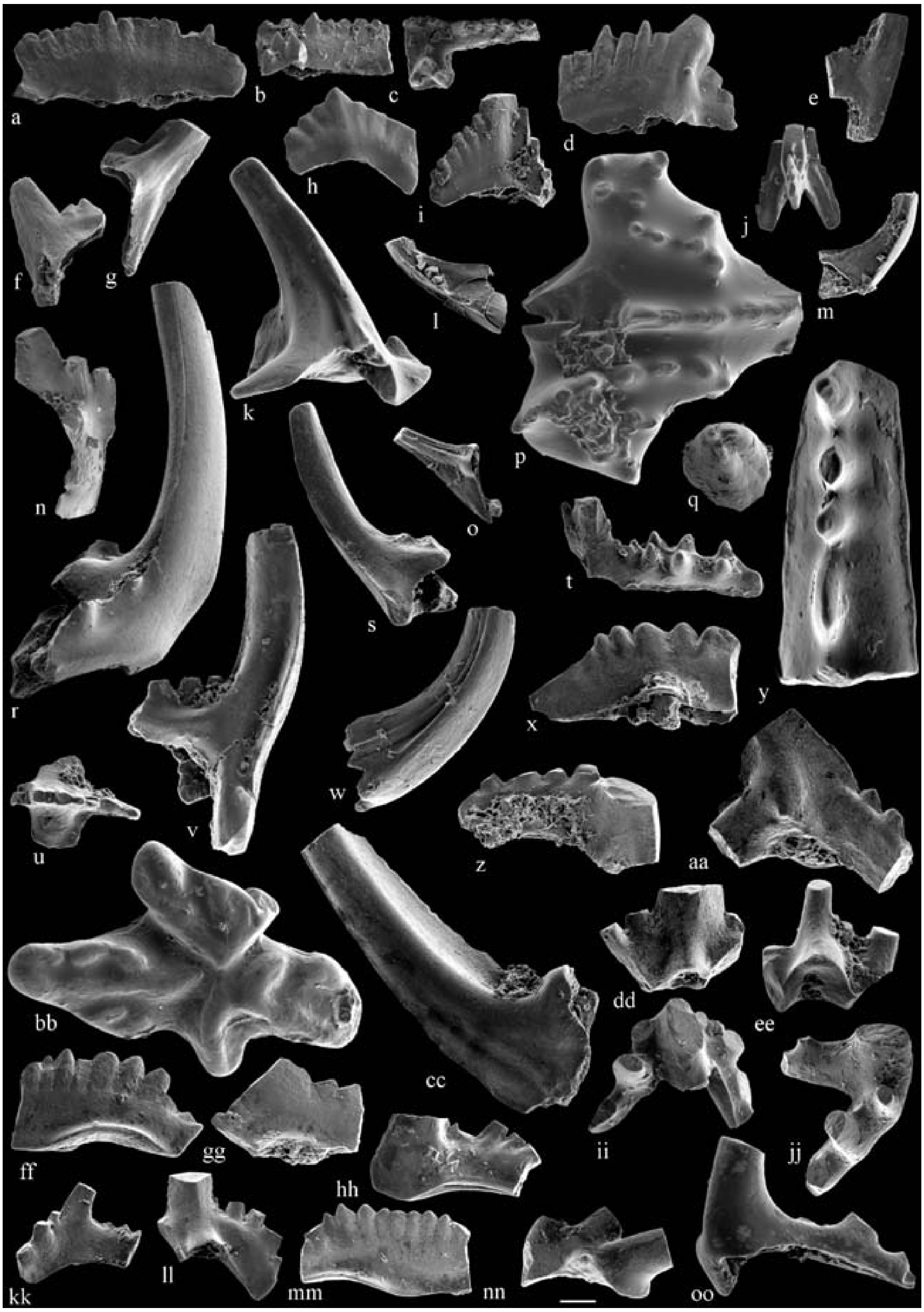

Figure 6. Conodonts from the Second Creek Phosphate Bed at the base of the Williamson Shale, Tryon Park. (a–j) *Pterospathodus amorphognathoides angulatus* (Walliser); (a) lateral view of Pa element, OSU 52,451; (b) lateral view of Pa element, OSU 52,452; (c) upper view of same Pa element; (d) lateral view of Pa element, OSU 52,453; (e) lateral view of Sc$_2$ element, OSU 52,454; (f) lateral view of Pc element, OSU 52,455; (g) lateral view of M$_1$ element, OSU 52,456; (h) lateral view of Pb$_2$ element, OSU 52,457; (i) lateral view of curved element, OSU 52,458; (j) posterior view of Sa element, OSU 52,459. (k, r, s, v, y, bb, cc) *Distomodus staurognathoides* (Walliser); (k) anterolateral view of Pb element, OSU 52,460; (r) anterolateral view of Sb element, OSU 52,461; (s) posterolateral view of Sb element, OSU 52,462; (v) lateral view of Sa element, OSU 52,463; (y) upper view of '*Johnognathus*' element, OSU 52,464; (bb) upper view of Pa element, OSU 52,465; (cc) lateral view of M element, OSU 52,466. (l, m) *Walliserodus* sp. 1, lateral view of Sd? element, OSU 52,467; (m) lateral view of Sb element, OSU 52,468. (n) *Aspelundia fluegeli*? (Walliser), lateral view of Pa element, OSU 52,469. (o) *Decoriconus fragilis* (Branson & Mehl), lateral view of Sc element, OSU 52,470. (p) *Aulacognathus* sp., upper view of Pa element, OSU 52,471. (q) *Pseudooneotodus tricornis* Drygant, upper view of three-tipped squat element, OSU 52,472. (t) *Icriodella* sp., lateral view of Pa element, OSU 52,473. (u) *Ozarkodina* sp., upper view of Pa element, OSU 52,474. (w) *Panderodus greenlandensis*

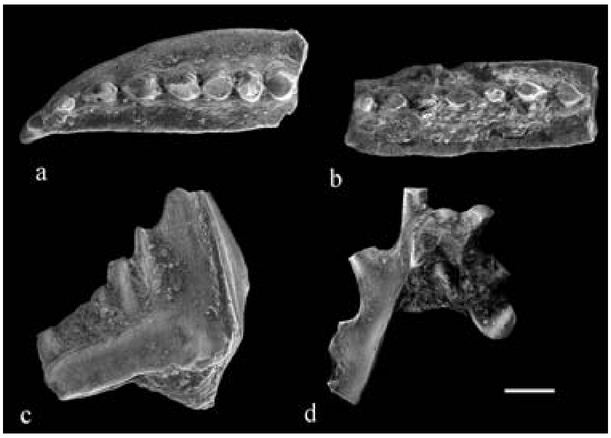

Figure 7. Conodonts from the 1.0–1.1 m level in the Tryon Park section, Williamson Shale. (a–c) *Pterospathodus amorphognathoides amorphognathoides* Walliser; (a) upper view of fragment of Pa element, OSU 52,516; (b) upper view of fragment of Pa element, OSU 52,517; (c) lateral view of Pb1 element, OSU 52,518. (d) *Oulodus petila* (Nicoll & Rexroad), lateral view of Pa element, OSU 52,519. Scale bar represents 100 μm.

4. Discussion

The chitinozoan occurrences recorded above for the Williamson Shale Formation are unusual, regardless of whether the age of the formation is middle or late Telychian. If the Williamson Shale is middle Telychian, then *Margachitina banwyensis* is occurring earlier than previously recorded, but this can be explained (see Introduction). If the Williamson Shale is late Telychian in age, then *C. campanulaeformis* is occurring well above its normal range, although Grahn (1998) has recorded *Cyathachitina* from the upper Telychian and Wenlock (see Section 3.b). Thus the chitinozoan occurrences, although unusual, do not present an insurmountable barrier to providing a date for the Williamson Shale.

The graptolite and conodont data are more problematical, however. Based on the known stratigraphical ranges of *Stimulograptus clintonensis* and *Pterospathodus amorphognathoides amorphognathoides* (Fig. 10), the Williamson Shale is either middle Telychian in age, in which case *P. am. amorphognathoides* is occurring significantly lower in the Silurian than previously recorded, or it is late Telychian in age, in which case *S. clintonensis* is occurring significantly higher in the Silurian than previously recorded. To indicate how unusual the co-occurrence of these two species is, the known stratigraphical ranges of the two taxa are reviewed below. The correlation with the graptolite biozonation of the *Pterospathodus amorphognathoides angulatus* Biozone, which occurs at the base of the Williamson Shale (Fig. 2), is also discussed.

4.a. *Stimulograptus clintonensis*

In Wales, *S. clintonensis* is very common in the middle part of the Telychian (*crispus*, *sartorius* and lower *griestoniensis* biozones). For example, in both Buttington Brick Pit and the Banwy River section, it comprises more than 90 % of the graptolites present in some middle Telychian horizons (Loydell & Cave, 1993, p. 97, 1996, p. 49). In both of these shelf sections, strata between the lower *griestoniensis* and *spiralis* biozones are non-graptolitic, so it could be argued that *S. clintonensis* was still present in the area, but simply not preserved. However, in more basinal sequences in Wales, which preserve a more complete sequence of graptolite biozones, *S. clintonensis* is again not known above the lower *griestoniensis* Biozone (Zalasiewicz, 1994).

In the Girvan area of Scotland, *S. clintonensis* occurs in the Protovirgularia Grits Formation (graptolitic horizons straddle the *sartorius*/*griestoniensis* Biozone boundary; Floyd & Williams, 2003, fig. 2), but not at higher levels. The first author has identified for the British Geological Survey extensive collections of graptolites from the Gala Group of the Southern Uplands. *Stimulograptus clintonensis* occurs at 45 localities, all within the uppermost *turriculatus* to middle *griestoniensis* Biozone interval; no specimens occur in the nine collections made from higher in the Telychian.

In the Baltic region, *S. clintonensis* has been recorded from the *crispus*, *sartorius* and lower *griestoniensis* biozones, but not from higher in the Telychian (Loydell, Kaljo & Männik, 1998; Loydell, Männik & Nestor, 2003). Examination of thousands of graptolites in the Czech Geological Survey collections in Prague has revealed that *S. clintonensis* occurs here also in the middle Telychian, but not in the *crenulata* Biozone or higher (note that the collections do not indicate whether material is from low or high within the *griestoniensis* Biozone).

To summarize, the first author has examined tens of thousands of Telychian graptolites from localities in Europe (representing the palaeocontinents Baltica,

Armstrong, lateral view of sym. p element, OSU 52,475. (x, z, aa, dd) *Ozarkodina hadra* (Nicoll & Rexroad); (x) lateral view of Pa element, OSU 52,476; (z) lateral view of Sc element, OSU 52,477; (aa) lateral view of Pb element, OSU 52,478; (dd) posterior view of Sa element, OSU 52,479. (ee, ii, jj, nn, oo) *Oulodus*? *petilus* (Nicoll & Rexroad); (ee) posterior view of Sa/Sb element, OSU 52,480; (ii) upper view of Sb element, OSU 52,481; (jj) lateral view of Sc element, OSU 52,482; (nn) lateral view of Sb element, OSU 52,483; (oo) lateral view of M element, OSU 52,484. (ff–hh, kk–mm) *Ozarkodina polinclinata estonica* s.l. Mannik; (ff) lateral view of Pa element, OSU 52,485; (gg) lateral view of Pb element, OSU 52,486; (hh) lateral view of M element, OSU 52,487; (kk) lateral view of Sc element, OSU 52,488; (ll) posterior view of Sa element, OSU 52,489; (mm) outer lateral view of a Pa element. Scale bar represents 100 μm.

Avalonia, the periphery of Gondwana and Laurentia). He has never seen *S. clintonensis* from a level higher than the middle *griestoniensis* Biozone; neither has it been recorded by any other author from higher than this level in any section world-wide.

4.b. *Pterospathodus amorphognathoides angulatus and P. am. amorphognathoides*

A detailed biozonation for the lower Telychian to lower Sheinwoodian based on the genus *Pterospathodus* has been erected by Männik (1998). The succession of biozones is firmly established. Only in one study, on the Aizpute-41 core, Latvia (Loydell, Männik & Nestor, 2003), however, has it been possible to tie the first appearance of *P. amorphognathoides angulatus*, the conodont occurring at the base of the Williamson Shale, to the graptolite biozonation. In the Aizpute-41 core *P. am. angulatus* occurs from the middle part of the *crenulata* Biozone to the lower part of the *spiralis* Biozone. Loydell, Männik & Nestor (2003, p. 207) noted that *P. am. angulatus* occurred in the Aizpute-41 core only in 'low numbers'. Thus the absence of *P. am. angulatus* at lower levels may simply reflect the fact that the core was only 70 mm in diameter and thus less common elements of the conodont assemblage were unlikely to be encountered in the samples from it. This of course would require *P. amorphognathoides angulatus* to co-occur with *P. eopennatus*, index species of the preceding conodont biozone. Although such co-occurrences are not common, Männik (1998, text-fig. 3) does show the upper part of the ranges of morphs 2 and 3 of *P. eopennatus* overlapping with the lower part of that of *P. am. angulatus*.

Thus a co-occurrence of *P. am. angulatus* with *Stimulograptus clintonensis*, although not previously reported, is something that existing data suggest is possible. What existing biostratigraphical data do not suggest as possible, however, is the co-occurrence of *P. am. amorphognathoides* with *S. clintonensis*. *P. am. amorphognathoides* is a very widespread taxon (Männik, 1998, p. 1035) with a restricted stratigraphical range from the base of the *amorphognathoides* Biozone to the top of the *Pseudooneotodus bicornis* Biozone (Jeppsson, 1997; Männik, 1998). The base of the *amorphognathoides* Biozone has been shown to correlate with a level above a horizon yielding an *Oktavites spiralis* Biozone graptolite assemblage in the Carnic Alps of Austria by Jaeger & Schönlaub (1970; see Loydell, 2003 for description of the graptolites). In the Ohesaare core, Estonia (Loydell, Kaljo & Männik, 1998), Ruhnu core, Estonia (Kaljo *in* Põldvere, 2003; Männik *in* Põldvere, 2003; Loydell & Nestor, 2006) and Aizpute-41 core, Latvia (Loydell, Männik & Nestor, 2003), the base of the *amorphognathoides* Biozone correlates with a level at or close to the base of the *Cyrtograptus lapworthi* Biozone. At Waukesha, Wisconsin, the lower Brandon Bridge Formation yields *Oktavites spiralis* (Geinitz), whilst conodonts in the upper part of the formation indicate the *amorphognathoides* Biozone (Kluessendorf & Mikulic, 1996, p. 182). The base of the *amorphognathoides* Biozone is thus consistently being seen to lie high in the Telychian, with all data consistent with it coinciding with the base of the *Cyrtograptus lapworthi* Biozone.

5. The Willowvale Formation: a possible solution?

The Williamson Shale is generally considered to be the lateral equivalent of the Willowvale Formation in central New York State (e.g. Lin & Brett, 1988, fig. 1; Eckert & Brett, 1989, fig. 1; Brett, Goodman & LoDuca, 1990, fig. 7; Brett et al. 1995, fig. 9; Brett, 1999, fig. 44.1). *Pterospathodus am. amorphognathoides* occurs both in the Willowvale Shale and in the underlying Westmoreland Hematite.

Palynological processing of a sample from the lower part of the Willowvale Shale from Mallory Creek, immediately south of Elm Street, Chadwicks, Oneida County in central New York, yielded a generally well-preserved, low-diversity chitinozoan assemblage including *Ancyrochitina gutnica* Laufeld (Fig. 8a) and *Conochitina proboscifera* Eisenack (Fig. 8b). Both taxa appear first in the *Oktavites spiralis* graptolite Biozone (Dufka, Kříž & Štorch, 1995; Mullins & Loydell, 2001, text-fig. 7; Loydell, Männik & Nestor, 2003; Loydell & Nestor, 2005, fig. 3) or at higher levels

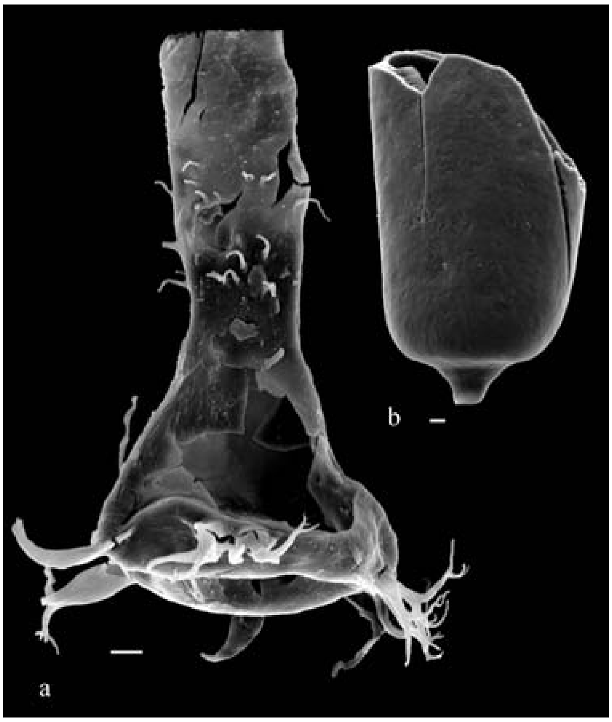

Figure 8. Chitinozoans from the lower Willowvale Formation at Chadwicks, Oneida County, New York State. (a) *Ancyrochitina gutnica* Laufeld, OSU 52,511. (b) *Conochitina proboscifera* Eisenack, OSU 52,512. Scale bars represent 10 µm.

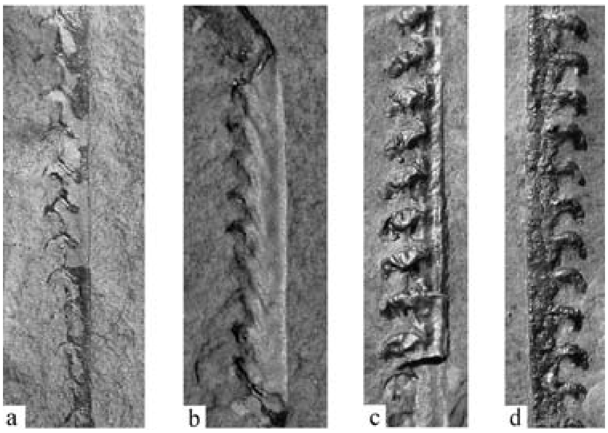

Figure 9. (a, b) *Monograptus priodon* (Bronn) from the lower Willowvale Formation at Chadwicks, Oneida County, New York; note thecal overlap. (a) NYSM 17458; (b) NYSM 17459. (c, d) *Stimulograptus clintonensis* (Hall) from Bed D, Buttington Brick Pit, Wales (see Loydell & Cave, 1993); note lack of thecal overlap. (c) OSU 52,491; (d) OSU 52510. All × 5.

(e.g. Loydell, Kaljo & Männik, 1998, p. 778). Thus, should *Stimulograptus clintonensis* occur in the Willowvale Shale, this would indicate that it did survive higher in the Telychian in New York State than has been recorded elsewhere in the world. Examination of Gillette's (1947) faunal lists suggests that *S. clintonensis* does indeed occur in the Willowvale Formation. It is interesting, however, to note that nowhere in Gillette's work is *Monograptus priodon* (Bronn) recorded. There is a long history of identification of specimens of *M. priodon* as *S. clintonensis* in New York, extending back to James Hall's original descriptions (see Loydell, 1992 for summary). Most recently, Brett (1999, pp. 596–7) referred incorrectly to '*Monograptus clintonensis* (= *priodon*)'. Given that *M. priodon* is a very long-ranging species, from the lower Telychian *turriculatus* Biozone well into the Wenlock, whereas previous records of *S. clintonensis* are exclusively from the middle Telychian, the correct identification of these monograptoideans with hooked thecae is of considerable stratigraphical importance. The whereabouts of Gillette's collections is not known (if indeed they survive), however, collections of graptolites from the Willowvale Formation have been made by one of us (DKM) and material, collected by C. A. Hartnagel in 1910 from the same locality ('Creek bed below the 3 corners, $^1\!/_2$ mile east of Chadwicks, Oneida Co. Horizon 7' below the "Red flux" bed') is present also in the collections of the New York State Museum at Albany. The monograptids present (more than 100 specimens) are without exception *M. priodon*, not *S. clintonensis*. They may be distinguished by the much greater amount of thecal overlap in *M. priodon* (see Fig. 9).

So, the Willowvale Shale material does not solve the problem that the lower Williamson Shale conodont and graptolite co-occurrence has thrown up. Indeed, the difference in the chitinozoan assemblage between the two formations and the apparent absence of *S. clintonensis* from the Willowvale Formation suggest that the Willowvale Shale and graptolitic lower Williamson Shale may not be lateral equivalents, although it is possible, of course, that these differences in fossil assemblages simply reflect different depositional environments.

6. Conclusions

The age of the Williamson Shale remains uncertain. Either of the ages provided by the graptolites and conodonts would in isolation be accepted based on the large amount of supporting biostratigraphical data from other sections. It would seem highly unlikely that *Stimulograptus clintonensis*, a very common and widespread graptolite, would have become so restricted in its geographical range in the late Telychian, especially as the area that is now New York State was in close proximity to Baltica and Avalonia where this graptolite occurs abundantly but no higher than the *griestoniensis* Biozone (see Section 4.a). Equally, it seems very difficult to imagine that one of the best known and most widespread conodont taxa, *Pterospatho-*

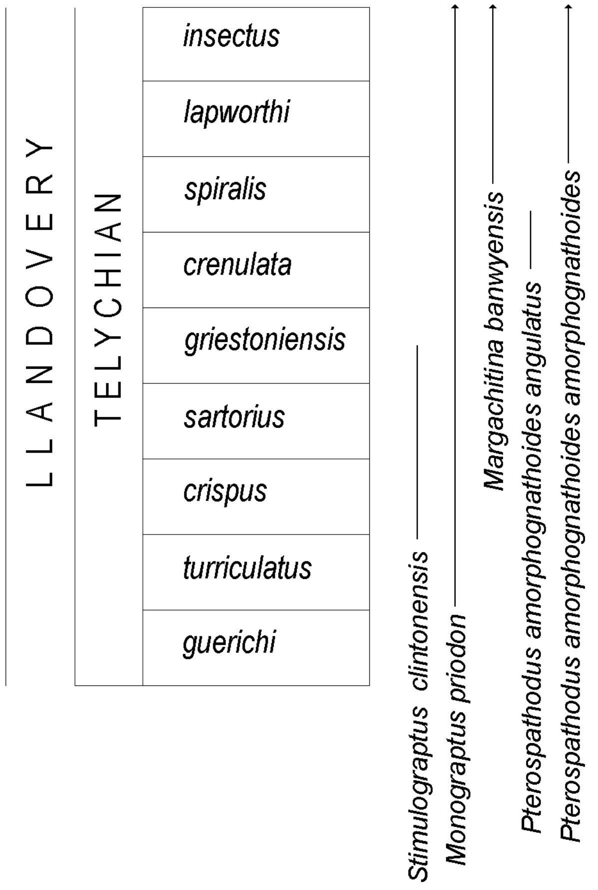

Figure 10. The known stratigraphical ranges (with reference to graptolite biozones) of the key graptolite, chitinozoan and conodont taxa recorded from the Williamson Shale Formation.

dus amorphognathoides amorphognathoides, occurs significantly earlier in New York than elsewhere. However, the fact is that the two species do occur together in the lower Williamson Shale, and the ages that they indicate contradict each other (Fig. 10). This emphasizes that there is still much to be learnt about the Silurian stratigraphy of New York and indeed about Silurian biostratigraphy in general. A solution to the biostratigraphical enigma that the lower Williamson Shale presents will presumably arise when one or other of the taxa concerned is found elsewhere at an apparently anomalously low or high stratigraphical level.

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