Graptolite and conodont biostratigraphy of the upper Telychian–lower Sheinwoodian (Llandovery–Wenlock) strata, Jabalón River section, Corral de Calatrava, central Spain

D. K. LOYDELL*, G. N. SARMIENTO†, P. STORCH‡ & J. C. GUTIÉRREZ-MARCO‡
*School of Earth and Environmental Sciences, University of Portsmouth, Burnaby Road, Portsmouth, PO1 3QL, UK
†Departamento de Paleontología e Instituto de Geología Económica CSIC-UCM, José Antonio Novais 2, 28040 Madrid, Spain
‡Institute of Geology, Academy of Sciences of the Czech Republic, Rozvojová 135, Praha 6, 16500, Czech Republic

Abstract – A graptolite biostratigraphy is erected for the upper Telychian (upper crenulata Biozone) to lower Sheinwoodian (riccartonensis or dubius Biozone) strata of the Jabalón River section, Spain. Two unconformities are recognized in the section: one between the lapworthi and murchisoni biozones; the other between the murchisoni and riccartonensis biozones. These unconformities coincide with intervals of lowered eustatic sea-level. Graptolite assemblages include both cosmopolitan taxa and some which have been recorded previously from Morocco and/or other Spanish sections. At some stratigraphical levels Pristiograptus or Euroclimacis species are abundant; Monoclimacis, Streptograptus and Mediograptus species are generally uncommon. Conodonts were examined from the upper spiralis through to lower murchisoni Biozone; the occurrences of Pterospathodus amorphogonathoides are consistent with the species’ known range elsewhere. Four new graptolite species are described: Euroclimacis jabalonenensis, E. hamata, Monoclimacis flexa and Stimulograptus pradoi.

Keywords: graptolites, Conodonta, Silurian, biostratigraphy, Central Iberian Zone, Spain.

1. Introduction

Recent interest in the Llandovery/Wenlock boundary has prompted detailed examination of sections considered to be stratigraphically complete through this interval. As no unconformities had been recognized in the Jabalón River section near Corral de Calatrava by Storch et al. (1998), this peri-Gondwanan section was selected for detailed study through its upper Telychian–lower Sheinwoodian part. This paper describes the results of this study, focusing upon the graptolite and conodont biostratigraphy of the section.

2. Locality details and previous work

The section lies about 4 km NE of the small town of Corral de Calatrava, Ciudad Real Province, central Spain, above the southern bank of the Jabalón River (Fig. 1b). Tectonostratigraphically, the section lies within the Central Iberian Zone of the Iberian Massif (see Robardet & Gutiérrez-Marco, 2002, fig. 5.1, locality 22). Black, graptolitic Telychian–Homerian strata of the Guadarranquejo Formation overlie the pale quartzose sandstones of the Criadero Quartzite. Exposure is excellent (individual beds can be followed for several tens of metres), although the section is cut by numerous small faults with curving traces.

The first record of Silurian graptolites from the Corral de Calatrava area was from the Puente Morena exposures in the Jabalón river valley, ∼6 km NE of the town (Prado, Verneuil & Barrande 1855, p. 1015) (Fig. 1a), later confirmed by Cortázár (1880, p. 23), Machens (E. Machens, unpub. Dissertation, Univ. Münster, 1954, p. 78), Gutiérrez-Marco (in Portero Garcia et al. 1988, p. 25) and A. Kappes (unpub. Diplomarbeit, Univ. Würzburg, 1991, locality G2).

A log of the Upper Ordovician–Llandovery strata was provided by García Palacios, Gutiérrez-Marco & Herranz Araújo (1996, fig. 1) from a section located 3.5 km north of Corral de Calatrava, on the northern bank of the Jabalón River, 700 m upstream from its confluence with the Guadiana River (Fig. 1c).

The Silurian section described herein is located half-way between those described above (Fig. 1b); it was briefly mentioned by Kappes (unpub. Diplomarbeit, Univ. Würzburg, 1991) and described in some detail as the Jabalón river section by Storch et al. (1998, fig. 3), who provided a complete log through the Telychian–Homerian strata. Storch (1998) described several Telychian graptolites from Spain, including four from the Jabalón River section from the lower part of the stratigraphical interval discussed herein: Euroclimacis iberica Storch, ‘Monograptus’ curvus Manck, Oktavites falk (Suess) and Stimulograptus splendens Storch. The section was visited by the Subcommission on Silurian Stratigraphy in June, 1998 (for which Storch et al. 1998 was the field...
Figure 1. Silurian graptolite localities in the Corral de Calatrava area: (a) Puente Morena outcrops (Prado, Verneuil & Barrande, 1855 et seq.); (b) Jabalón River section, southern bank, described herein (A. Kappes, unpub. Diplomarbeit, Univ. Würzburg, 1991; Storch et al. 1998 et seq.); (c) Jabalón River, northern bank (García Palacios, Gutiérrez-Marco & Herranz Araújo, 1996); (d) Guadiana River section (unpublished locality with poorly preserved graptolites). The geology has been modified from the maps of Portero García et al. (1988) and Kappes (unpub. Diplomarbeit, Univ. Würzburg, 1991). Inset map of the Iberian Peninsula shows location of the studied area within the Iberian Massif (stippled) and its Central Iberian Zone (dense stippling).

guide). García Palacios & Rabano (1996) described a Telychian trilobite from the CO-12 horizon (Fig. 2) and Sarmiento & García Palacios (1996) recorded conodont–graptolite co-occurrences in the Telychian–lower Sheinwoodian part of the section.

3. Methods

The graptolites and conodonts forming the basis of this paper were collected in June 1999. The section was measured from marker levels painted onto the section by Storch et al. (1998; shown on Fig. 2 as CO12, etc.); shelly horizons (e.g. Fig. 3b, c) and thin micaceous siltstones also provided useful marker beds. Sample thickness was 0.2 m; finer sampling was undertaken around the Llandovery/Wenlock boundary, measuring up from CO15. Levels CO15 and CO16/17 are on opposite sides of a small fault (with a lateral displacement of ≈ 0.4 m); correlation across the fault was achieved using the shell bed at CO15 + 1.2 m and CO16/17−0.3 m (Fig. 3c). Graptolites are extremely abundant; shelly fossils, including bivalves, eurypterids, phyllocarids, cornulitids, brachiopods, trilobites, orthocones and crinoid columnals, also occur in varying abundances.

The number of graptolites examined from each sample ranged from hundreds to many thousands; thus those species represented by one to three specimens in a collection were indeed ‘rare’ in our collections. All of the graptolites are preserved flattened, many with a white clay mineral coating the graptolite periderm (Fig. 3a).

Some of the conodonts were collected in the field, by visual hand lens scanning of slabs; many others were found subsequently during microscopic examination of the graptolite assemblages. All are preserved as external moulds and were studied by examination of latex casts. The interval covered by the conodont collections is less than that for the graptolites, from 1.2 m below CO15 (within the upper spiralis Biozone) to CO16/17 (within the lower murchisoni Biozone).

All figured specimens are housed in the Museo Geominero of the Spanish Geological Survey (IGME), Madrid (numbers prefixed MGM).

4. Graptolite biostratigraphy

Figure 2 is a range chart showing the stratigraphical ranges of all identified graptolites from the section. Most of the species encountered (including all those
of biostratigraphical significance) are illustrated in Figures 4–6.

The studied section commenced in the upper part of the *crenulata* (= *tullbergi*) Biozone. The lowest samples yielded low diversity graptolite assemblages (only three species present, despite the lithology being a black shale) with abundant *Stimulograptus splendens* S.torch (Fig. 4c), ‘*Monograptus’ curvus* Manck (Fig. 4a) ± *M. priodon* Bronn (Fig. 4v). A single specimen of *Stimulograptus novaki* Bouček (Fig. 4s) was also encountered. ‘*M.’ curvus’ has long been recognized as occurring in the upper *crenulata* Biozone (Bouček, 1953). Its range extends into the *spiralis* Biozone in Germany (Schauer, 1971) and in the Jabalón
River section. Storch (1998, p. 126) noted that *St. splendens* is both widespread and common in the upper *tullbergi* and lower *spiralis* biozones of the Iberian peninsula. With the exception of the cosmopolitan and stratigraphically very long-ranging *M. priodon*, none of the species identified has been found to come from outside of peri-Gondwanan Europe. Whether this reflects a restricted original distribution is uncertain, as the *crenulata/spiralis* Biozone transition is represented by non-graptolitic strata in many sections outside of peri-Gondwanan Europe; for example, in the Aizpute-41

Figure 4. Graptolites from the Jabalón River section. (a) ‘Monograptus’ *curvus* Manck; MGM-137-S; CO12 + 0.4–0.6 m, upper *crenulata* Biozone. (b) *Oktavites fals* (Suess); MGM-138-S; CO15–0.4–0.6 m, upper *spiralis* Biozone. (c) *Stimulograptus splendens* Štorch; MGM-139-S; CO12 + 0.4–0.6 m, upper *crenulata* Biozone. (d) *Stimulograptus vesiculosus* (Perner); MGM-140-S; CO12 + 1.8–2.0 m, middle *spiralis* Biozone. (e, h, i, o, y) *Oktavites spiralis* (Geinitz); (e) MGM-141-S; specimen with protracted proximal region; CO15–1.0–1.2 m, upper *spiralis* Biozone; (h) MGM-144-S; specimen from immediately below shell bed marking Llandovery/Wenlock boundary; CO15 + 1.19 m, *lapworthi* Biozone; (i) MGM-145-S; specimen with shorter proximal region; CO15 to −0.2 m, *lapworthi* Biozone; (o) MGM-151-S; CO12 + 1.0–1.2 m, lower *spiralis* Biozone; (y) MGM-161-S; CO15–1.0–1.2 m, upper *spiralis* Biozone. (f) *Streptograptus wimani* (Bouček); MGM-142-S; CO15 + 0.4–0.6 m, *lapworthi* Biozone. (g) *Stimulograptus* sp.; MGM-143-S; CO15 + 0.6–0.8 m, *lapworthi* Biozone. (j) *Diversograptus ramosus* Manck; MGM-146-S; CO15–1.0–1.2 m, upper *spiralis* Biozone. (k) *Streptograptus speciosus* (Tullberg); MGM-147-S; CO12 + 0.4–0.6 m, upper *crenulata* Biozone. (l) *Diversograptus* *pergracilis* (Bouček); MGM-148-S; CO12 + 0.4–0.6 m, upper *crenulata* Biozone. (m) *Monoclimacis vomerina* (Nicholson); MGM-149-S; CO15–1.0–1.2 m, upper *spiralis* Biozone. (n) *Monoclimacis subgeniiti* Fu; MGM-150-S; CO12 + 0.6–0.8 m, upper *crenulata* Biozone. (p) *Oktavites sp.*; MGM-152-S; CO12 + 0.6–0.8 m, upper *crenulata* Biozone. (q) *Pseudoretioletites?* sp.; MGM-153-S; CO12 + 1.4–1.6 m, lower *spiralis* Biozone. (r) *Pristograptus largus* (Perner); MGM-154-S; CO15 to −0.2 m, lower *lapworthi* Biozone. (s) *Stimulograptus novaki* (Bouček); MGM-155-S; CO12 + 0.2–0.4 m, upper *crenulata* Biozone. (t) *Monograptus parapriodon* Bouček; MGM-156-S; CO12 + 0.6–0.8 m, upper *crenulata* Biozone. (u) *Barrandeograptus* sp.; MGM-157-S; CO16/17 −0.2–0.3 m, *murchisoni* Biozone. (v) *Monograptus priodon* (Bronn); MGM-158-S; CO12 + 0.4–0.6 m, upper *crenulata* Biozone. (w) *Pristograptus praeclitus* (Bouček); MGM-159-S; CO15 + 1.0–1.2 m, *lapworthi* Biozone. (x) *Monoclimacis vikensis* Bassett & Rickards?; MGM-160-S; CO16/17 to + 0.2 m, *murchisoni* Biozone. (y) *Streptograptus nodifer* (Törnquist); MGM-162-S; CO12 + 1.8–2.0 m, middle *spiralis* Biozone. (aa) *Euroclimacis adunca* (Bouček); MGM-163-S; CO15 + 1.2–1.4 m, *murchisoni* Biozone.

As the *crenulata/spiralis* Biozone boundary is approached, diversity increases and the highest diversity in the section (14 species, three of which are new) is recorded at the base of the *spiralis* Biozone. With the exception of *Streptograptus speciosus* (Tullberg) (Fig. 4k), *Streptograptus* is rare in the *spiralis* Biozone. Some species (e.g. *Mcl. flexa* sp. nov. (Fig. 5c, d, n–p), *Stimulograptus vesiculosus* (Perner) (Fig. 4d) and *Oktavites excentricus* (Bjerreskov) (Figs 3a, 6a))
Figure 4. For legend see facing page.
Figure 5. New graptolite species from the Jabalón River section. (a, b) *Stimulograptus pradoi* sp. nov.; lower *spiralis* Biozone; (a) MGM-164-S; CO12 + 0.8–1.0 m; (b) holotype, MGM-165-S; CO12 + 1.0–1.2 m. (c, d–p) *Monoclimacis flexa* sp. nov.; CO12 + 0.8–1.0 m; (c) MGM-166-S; (d) MGM-167-S; (e) holotype, MGM-177-S; (f) MGM-178-S; (g) MGM-179-S; (h) MGM-180-S; CO12 + 0.6–0.8 m, upper *crenulata* Biozone; (i) MGM-173-S; (j) MGM-174-S; (k) MGM-175-S; (l) MGM-176-S; (m) MGM-177-S; (n) holotype, MGM-177-S; (o) MGM-178-S; (p) MGM-179-S; (e–i, q) *Euroclimacis hamata* sp. nov. (e) holotype, MGM-168-S; CO15 + 0.8–1.0 m, *lapworthi* Biozone; (f) MGM-169-S; CO16/17 to −0.2 m, *murchisoni* Biozone; (g) MGM-170-S; CO16/17 to −0.2–0.4 m, *lapworthi* Biozone or *murchisoni* Biozone; (h) MGM-171-S; CO16/17 to −0.2–0.4 m, *lapworthi* Biozone or *murchisoni* Biozone; (i) MGM-172-S; CO15–0.6–0.8 m, upper *spiralis* Biozone; (q) MGM-181-S; CO16/17 to −0.2–0.4 m, *lapworthi* Biozone or *murchisoni* Biozone. (j–m) *Euroclimacis jabalonensis* sp. nov., CO15–0.6–0.8 m, upper *crenulata* Biozone. (j) holotype, MGM-173-S; (k) MGM-174-S; (l) MGM-175-S; (m) MGM-176-S.

are abundant, but occur in one sample only. *Streptograptus nodifer* (Törnquist) (Fig. 4z), and *S. anguinus* (Bouček) (Fig. 6k) occur within the middle part of the *spiralis* Biozone, which is consistent with previous records of these species (e.g. Loydell & Cave, 1993). *Stimulograptus vesiculosus* (Perner) has previously been taken to indicate the upper part of the *spiralis* Biozone (e.g. Loydell & Cave, 1996; Loydell, Männik & Nestor, 2003), but in sections with several metres of strata overlying the *S. vesiculosus*-bearing horizon that were either non-graptolitic or yielded non-diagnostic assemblages. The most abundant species of the upper *spiralis* Biozone in the Jabalón River section is *Euroclimacis iberica* Storch (Fig. 6e), a species recorded only from Spain (Storch, 1998). Some stratigraphical variation is seen within *Oktavites spiralis* (Geinitz) (Fig. 4e, h, i, o, y): those specimens from the top 0.8 m of the *spiralis* Biozone (e.g. Fig. 4e) have a longer proximal portion than specimens from lower in the biozone and from the *lapworthi* Biozone (e.g. Fig. 4i). Bjerreskov (1975, p. 72) noted the absence of *O. spiralis* from the middle of the *spiralis* Biozone on Bornholm, where it was replaced by *O. excentricus*. A similar stratigraphical relationship is exhibited by the Jabalón River section.

The lower (but not lowermost) part of the *lapworthi* Biozone yielded abundant *Streptograptus wimani* (Bouček) (Fig. 4f), a species recorded from a similar stratigraphical level in Wales (Loydell & Cave, 1996) and Bohemia (Storch, 1994a, fig. 3). *Cyrtograptus lapworthi* Tullberg (Fig. 6h) is rare in the lowermost part of the *lapworthi* Biozone, but increases in abundance at higher levels within the biozone. The presence of *O. spiralis* (Fig. 4b) immediately below the shell bed marking the Llandovery/Wenlock boundary (Fig. 3c) indicates that the Llandovery part of the Jabalón River section terminates below the top of the *lapworthi* Biozone. The long-ranging *Euroclimacis*
Figure 6. Graptolites from the Jabalón River section. (a) Oktavites excentricus (Bjerreskov); MGM-181-S; CO12 + 2.4–2.65 m, middle spiralis Biozone. (b) Cyrtograptus sp.; MGM-182-S; CO16/17 to −0.2 m, murchisoni Biozone. (c) Pristiograptus latissimus (Bouček); MGM-183-S; CO16/17 + 2.4–2.6 m, riccartonensis Biozone or dubius Biozone. (d) Monograptus riccartonensis Lapworth; MGM-184-S; CO16/17 + 2.0–2.2 m, riccartonensis Biozone. (e) Euroclimacis iberica Storch; MGM-185-S; CO15 + 0.8–1.0 m, upper spiralis Biozone. (f) Mediograptus inconspicuus (Bouček); MGM-186-S; CO16/17 + 1.4–1.6 m, murchisoni Biozone. (g, i) Cyrtograptus sp. nov.; CO16/17 – 0.3–0.4 m, lapworthi Biozone. (g) MGM-187-S; (i) MGM-189-S; (h) Cyrtograptus lapworthi Tullberg; MGM-188-S; CO15 + 0.8–1.0 m, lapworthi Biozone. (j) Pristiograptus lapworthi (Suess); MGM-190-S; CO16/17 + 2.2–2.4 m, riccartonensis Biozone. (k) Streptograptus anguinus (Bouček); MGM-191-S; CO12 + 2.2–2.4 m, middle spiralis Biozone. (l) Monoclimacis basilica (Lapworth); MGM-192-S; CO16/17 + 1.4–1.6 m, murchisoni Biozone. (m) Mediograptus cautleyensis (Rickards); MGM-193-S; CO16/17 + 1.0–1.2 m, murchisoni Biozone. (n) Stomatograptus sp.; MGM-194-S; CO16/17 + 1.0–1.2 m, murchisoni Biozone.

hamata sp. nov. (Fig. 5e–i, q) is abundant in the higher lapworthi Biozone samples and is joined in the last sample below the Llandovery/Wenlock boundary shell bed by Cyrtograptus? sp. nov. (Fig. 6g, i). Both species have been recorded previously only from Morocco (Lüning et al. 2000), the former as E. sp. nov. from the lapworthi Biozone, the latter as C. sp. nov., from the centrifugus Biozone. Pristiograptus praedubius (Bouček) (Fig. 4w) increases dramatically in abundance through the lapworthi Biozone.

The upper lapworthi, insectus and centrifugus biozones are not present in the section; there is an unconformity between the middle lapworthi Biozone and the murchisoni Biozone, marked by a thin shell bed (Fig. 3c).

The murchisoni Biozone contains only rare specimens of Cyrtograptus, but it can be identified by the presence of Euroclimacis adunca (Bouček) (Fig. 4a), a species characteristic of this biozone (Storch, 1994b, fig. 3; Loydell & Cave, 1996). Assemblages throughout the biozone are dominated by Pristiograptus praedubius and Monograptus priodon. The abundance of P. praedubius in both the upper Telychian and lower Sheinwoodian strata is unique to the Jabalón River section; in other sections through strata of this age Pristiograptus is uncommon. Euroclimacis
hamata sp. nov. is common in the lower part of the murchisoni Biozone. Mediangraptus and Monoclimacis species are rare throughout the biozone. Retiolitidae is sporadically abundant. Overall graptolite diversity declines (to two species) towards the top of the biozone and the highest sample is characterized by a mass occurrence of E. adunca. Monograptus firmus Bouček has not been recorded from the section, and this, combined with the abrupt appearance of Monograptus riccartonensis Lapworth (Fig. 6d) immediately above the E. adunca mass occurrence level, is taken to indicate the presence of a second unconformity in the section. This unconformity is marked also by a lithological change: a muddy limestone of variable thickness (up to 0.3 m) with a sharp erosive base overlies the E. adunca-bearing black shales.

Although the upper part of the section studied continues to be graptolitic, shelly fossils dominate at this level (e.g. Fig. 3b). Diversity remains very low, with M. riccartonensis co-occurring with Pristiograptus dubius (Suess) (Fig. 6j). The highest sample contains only Pristiograptus. All three of these samples are assigned to the riccartonensis Biozone, although it is possible that the highest sample should be placed in the dubius Biozone, recognized at a similar level in, for example, Bohemia (Storch, 1994a, fig. 4) and Estonia (Loydell, Kaljo & Männik, 1998, p. 777).

5. Conodonts from the Jabalón River section

Of the 145 conodont elements recognized in the 17 samples to yield them, 86 were identifiable at least to generic level. Only one sample yielded no conodonts at all; this was immediately below the shell bed marking the Llandovery/Wenlock boundary. As this horizon was represented by the largest sample examined for graptolites, the absence of conodonts may reflect taphonomic loss at this level. The highest number of conodont elements recognized from any one sample was 31, from the lower part of the lapworthi graptolite Biozone. The occurrence of conodonts in the Jabalón River section is shown in Figure 7.

The size of conodont elements is very variable, even on a single slab; of two ramiform elements from the uppermost spiralis graptolite Biozone, one is ten times larger than the other. This suggests that hydrodynamic sorting of conodont elements was minimal or absent, although some post-mortem dissociation of apparatus must have taken place, perhaps during decay or as a result of scavenging. Morphologically, ramiform elements are the most abundant in all but one sample (CO15 + 0.8–1.0 m), in which only coniform elements were found. Otherwise coniform elements occur only sporadically and in low numbers.

Ozarkodina is the most common genus in the collections, having been confidently identified in eight samples. Distomodus elements occur in seven samples and Aspelundia in six. Other genera are either questionably identified or occur in small numbers in one or only a few samples. Unfortunately, from a biostratigraphical viewpoint, only two specimens could be assigned confidently to Pterospathodus: an Sb element from the lower lapworthi Biozone and a Pa element from the lower murchisoni graptolite Biozone (Fig. 8k), both of Pt. amorphognathoides Walliser. By comparison with the Aizpute-41 core (Loydell, Männik & Nestor, 2003), these two occurrences lie towards the lower and upper ends of the stratigraphical range of Pt. amorphognathoides (marking the boundaries of the Pt. amorphognathoides Zonal Group of Jeppsson.

Figure 7. Distribution of conodonts through the upper spiralis–lower murchisoni graptolite biozones of the Jabalón River section.
Figure 8. For legend see facing page.
6. Discussion

Figure 9 summarizes the upper Telychian–lower Shinwoodian stratigraphy of the Jabalón River section and compares it with the eustatic sea-level curve of Loydell (1998). The rock record is dominated by black graptolitic shales deposited during intervals of rising or high sea-level (late \textit{crenulata} through to middle \textit{lapworthi} zones; \textit{murchisoni} Zone), with muddy limestones and shell beds representing deposition during the \textit{riccartonensis} Zone. The two unconformities in the section correspond with intervals of lowered sea-level, commencing in the late \textit{lapworthi} Zone in the late Telychian and late \textit{murchisoni} Zone in the early Shinwoodian.

7. Systematic palaeontology (DKL, PŠ, JCG-M)

The following abbreviations are used below: DVW – dorso-ventral width; 2TRD – two thecae repeat distance (Howe, 1983).

Table 1. Measurements (in mm) of proximal DVW and 2TRD in \textit{Euroclimacis jabalonensis} sp. nov.

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\textit{Euroclimacis jabalonensis} sp. nov.

\textit{Figure 5j–m}

Name. After the Jabalón River.

Material. About 50 specimens, including 9 proximal ends, from the uppermost \textit{crenulata} Biozone and lower and middle \textit{spiralis} Biozone. The species is most abundant in the lower part of its stratigraphical range.

Holotype. Specimen MGM-173-S (Fig. 5j), from sample CO12 + 0.6–0.8 m, upper \textit{crenulata} Biozone.

Diagnosis. \textit{Euroclimacis} with straight or almost straight rhabdosome, increasing in DVW slowly from 0.45–0.6 mm at \textit{th1} to a distal maximum of 0.85 mm. All thecae are hooded.

Description. The rhabdosome is straight or shows very slight dorsal flexure. The sicula is 1.4–1.75 mm long, with an apertural width of 0.3–0.35 mm. It apex reaches between one-quarter and two-thirds up \textit{th2}. The virgella is short and inconspicuous. Thecae have small apertural excavations; all have hoods. Ventral prothecal walls are inclined to the rhabdosome axis proximally; distally they are nearly parallel to it. Measurements of proximal DVW and 2TRD are given in Table 1; distal maxima are 0.85 mm and 2.2 mm respectively.

Remarks. \textit{Euroclimacis jabalonensis} differs from other \textit{Euroclimacis} species in its lack of conspicuous dorsal rhabdosome curvature and in its low and slowly increasing DVW. Poorly preserved fragments can be confused with \textit{Monograptus parapriodon}, particularly when the aperture is obscured by the hood.

\textit{Euroclimacis hamata} sp. nov.

\textit{Figure 5e–i, q}

2000 \textit{Euroclimacis} sp. nov.; Lüning et al., pl. 1, fig. M.

Name. From the Latin, referring to the prominent metathecal hooks.

Material. Several hundred specimens, from the upper \textit{spiralis} Biozone, upper \textit{lapworthi} Biozone and lower to middle \textit{murchisoni} Biozone.

Holotype. Specimen MGM-168-S (Fig. 5e), from 0.8–1.0 m above CO15, \textit{lapworthi} Biozone.

Diagnosis. \textit{Euroclimacis} with dorsal rhabdosome curvature proximally; rhabdosome is straight distally. Metathecae have prominent hoods throughout the rhabdosome. Maximum DVW is 1.4 mm.

Description. The rhabdosome exhibits gentle dorsal curvature proximally and becomes straight distally. The sicula is 1.2–1.45 mm long, its apex usually reaching halfway up \textit{th2}, but ranging from just above the top of \textit{th1} to just below the top of \textit{th2}. The virgella is short and inconspicuous. Thecae throughout bear prominent hoods;
1.15 mm. This affects only hoods in all specimens, in its less pronounced and more strongly dorsally curved proximally. DVW increases from 0.4–0.45 mm at th1 to a distal maximum of 1.15 mm.

**Description.** The rhabdosome is dorsally curved. The amount of curvature proximally is variable (Fig. 5o with Fig. 5p), and decreases distally so that distal fragments are almost straight. Thecae are of typical monoclimacid form, although the free ventral wall gently inclined rather than parallel to the rhabdosome axis. The sicula is 1.3–1.6 mm long, with an apertural width of 0.25–0.35 mm. Its apex usually reaches to the aperture of th1, but occasionally reaches a higher level, to the top of or just above the top of th1. The virgella is short and inconspicuous. The prothecal wall of th1 is at between half-way up and the top of th2. The Sicula is 1.6–1.85 mm long, its apex reaching curved. The sicula is 1.6–1.85 mm long, its apex reaching between half-way up and the top of th2. The virgella is short and inconspicuous. The prothecal wall of th1 is at a high angle to the sicula and the DVW at th1 is greater than in other proximal thecae. The metatheca exhibits a pronounced hook, so that the aperture appears to face the ventral prothecal wall. From th2 onwards thecae are of typical stimulograptid form, lacking overlap, with hooked metathecae and prothecae at a low angle to the rhabdosome axis. Measurements of DVW and 2TRD are given in Table 3. Distal maxima are 1.15 mm and narrower proximally (DVW at th1 of E. adunca is 0.5–0.7 mm).

**Stimulograptus pradoi sp. nov.**

**Figure 5a, b**

**Name.** After mining engineer Casiano de Prado y Vallo (1797–1866), the first author to identify Silurian graptolites in Spain and who discovered the Silurian strata at Corral de Calatrava.

**Material.** Seven specimens, from the lowest 0.4 m of the spiralis Biozone.

**Holotype.** Specimen MGM-165-S (Fig. 5b) from sample CO12 + 1.0–1.2 m, lower spiralis Biozone.

**Diagnosis.** Dorsally curved Stimulograptus with very prominent th1.

**Description.** Only proximal ends with up to 7 thecae are present in the collections. The rhabdosome is gently dorsally curved. The sicula is 1.6–1.85 mm long, its apex reaching between half-way up and the top of th2. The virgella is short and inconspicuous. The prothecal wall of th1 is at a high angle to the sicula and the DVW at th1 is greater than in other proximal thecae. The metatheca exhibits a pronounced hook, so that the aperture appears to face the ventral prothecal wall. From th2 onwards thecae are of typical stimulograptid form, lacking overlap, with hooked metathecae and prothecae at a low angle to the rhabdosome axis. Measurements of DVW and 2TRD are given in Table 4.

**Remarks.** Stimulograptus pradoi differs from St. splendens Storch, 1998 primarily in its more prominent th1. It also has slightly closer thecal spacing proximally (in St. splendens 2TRD is 1.7–1.9 mm at th2). Fragments lacking the proximal end would be very difficult to distinguish.

### Table 2. Measurements (in mm) of proximal DVW and 2TRD in Euroclimacis hamata sp. nov.

<table>
<thead>
<tr>
<th>th1</th>
<th>th2</th>
<th>th3</th>
<th>th5</th>
<th>th10</th>
<th>th15</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVW</td>
<td>0.45–0.7</td>
<td>0.5–0.7</td>
<td>0.55–0.8</td>
<td>0.6–0.85</td>
<td>0.8–1.05</td>
</tr>
<tr>
<td>2TRD</td>
<td>1.3–1.8</td>
<td>1.3–1.8</td>
<td>1.35–2.0</td>
<td>1.55–2.05</td>
<td>1.4–1.7</td>
</tr>
</tbody>
</table>

### Table 3. Measurements (in mm) of proximal DVW and 2TRD in Monoclimacis flexa sp. nov.

<table>
<thead>
<tr>
<th>th1</th>
<th>th2</th>
<th>th3</th>
<th>th5</th>
<th>th10</th>
<th>th15</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVW</td>
<td>0.4–0.45</td>
<td>0.45–0.55</td>
<td>0.5–0.6</td>
<td>0.6–0.75</td>
<td>0.75–1.0</td>
</tr>
<tr>
<td>2TRD</td>
<td>1.3–1.7</td>
<td>1.3–1.7</td>
<td>1.4–1.7</td>
<td>1.5–1.85</td>
<td>1.6–1.85</td>
</tr>
</tbody>
</table>

### Table 4. Measurements (in mm) of proximal DVW and 2TRD in Stimulograptus pradoi sp. nov.

<table>
<thead>
<tr>
<th>th1</th>
<th>th2</th>
<th>th3</th>
<th>th5</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVW</td>
<td>0.75–0.9</td>
<td>0.65–0.8</td>
<td>0.65–0.8</td>
</tr>
<tr>
<td>2TRD</td>
<td>1.3–1.55</td>
<td>1.5–1.7</td>
<td>1.4–1.85</td>
</tr>
</tbody>
</table>

8. **Conclusions.**

The Jabalón River section is not as complete stratigraphically as previously thought. Two significant unconformities occur, such that the upper lapworthi, insectus, centrifugus and firmus biozones are not
represented in the section. Graptolites are extremely abundant; 45 species are recognized from upper Telychian–lower Sheinwoodian strata. Assemblages comprise a mixture of cosmopolitan species and those with a more restricted distribution (e.g. *Euroclimacis ibérica*, *E. hamata*, *Stimulograptus splendens*) recorded previously only from peri-Gondwanan Europe or Morocco. The composition of graptolite assemblages at some levels differs from that previously recorded from equivalent stratigraphical levels elsewhere, particularly in the high relative abundance of *Pristiodontus praedubius* and of *Euroclimacis*. The occurrences of the conodont *Pteraspis* amorphognathoides* (indicating the amorphognathoides Zonal Group) are within its recorded stratigraphical range (within the graptolite biozonation) elsewhere. The stratigraphical record of the Jabalón River section is consistent with the eustatic sea-level curve for the early Silurian of Loydell (1998).

Acknowledgements. Wendy Johnson and Zuzana Štorchova assisted in sample collection. GNS thanks Peep Männik for comments on conodont identifications.

References


