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The replacement Global Stratotype Section and Point (GSSP) of the Telychian Stage of the Llandovery Series, Silurian System, at El Pintado (Spain)

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The El Pintado 1 Silurian section in Seville Province, Spain, described by Loydell et al. (2015), has been ratified by the IUGS as the replacement GSSP for the base of the Telychian Stage, to replace the Cefn Cerig quarry section in the Llandovery area of Wales, which was found to be within a sedimentary mélange and therefore not a continuous section. No section other than El Pintado 1 has been found to be continuously fossiliferous across the Aeronian/Telychian boundary. In the absence of useful chitinozoan and conodont markers, the base of the Telychian is recognised biostratigraphically solely by major changes in graptolite assemblages and is at the base of the Spirograptus guerichi *graptolite Biozone, marked by the first appearances of the cosmopolitan graptolite species* Spirograptus guerichi *(the stratigraphically lowest* Spirograptus *to have an entirely helically spiralled rhabdosome with torsion of its proximal end),* Monograptus *sensu stricto and* Paradiversograptus runcinatus*, and by diversification within* Streptograptus*. Chemostratigraphically, the base of the Telychian is straddled by the "Rumba low" negative $\delta^{13}C$ excursions. The upper Aeronian and lower Telychian of the El Pintado 1 section have been thoroughly documented by Loydell et al. (2015), based on examination of tens of thousands of graptolites collected from more than 12 m of strata representing the* Stimulograptus halli *and* Spirograptus guerichi *graptolite biozones which form part of a largely continuous section through much of the Silurian. The upper Aeronian–lower Telychian part of the section represents apparently continuous sedimentation of graptolitic muds, silts and sands in an outer shelf location. Lithologically, the GSSP is within graptolitic mudstones, 0.6 m above the top of a nodule and 0.25 m below a conspicuously rusty weathering layer. At the GSSP (at 37°59'7.0"N 5°55'42.8"W), helically coiled* Spirograptus *makes its first appearance as does the first new Telychian* Streptograptus *species,* Streptograptus picarrai*. A negative $\delta^{13}C_{org}$ excursion, culminating 1.4–1.6 m above the GSSP, represents the Rumba low in the El Pintado 1 section.*

Introduction

The aim of this paper is to announce the formal ratification of the replacement Global Stratotype Section and Point (GSSP) of the Telychian Stage of the Llandovery Series (Silurian System). Full details of the section, its palaeontology and organic carbon isotope stratigraphy were published in Loydell et al. (2015), to which the reader is directed for more details.

The need for a new GSSP resulted from the recognition of the serious shortcomings of the former GSSP, ratified by the IUGS in 1985 (Bassett, 1985): the Cefn Cerig quarry section in the Llandovery area of Wales, UK. The most important was Davies et al. (2011, 2013) demonstrating that the GSSP lay within a sedimentary mélange and not within a continuous stratigraphical succession. As a result, in 2014 the International Subcommission on Silurian Stratigraphy (ISSS) of the International Commission on Stratigraphy (ICS) established a "Base of Telychian GSSP Restudy Working Group", led by Michael J. Melchin, which commenced a search for a replacement stratotype for the Cefn Cerig quarry section. At the business meetings of the International Subcommission on Silurian Stratigraphy at the STRATI conferences in Milan (2019) and Lille (2023), the only section put forward as a potential replacement GSSP for the base of the Telychian Stage was on the shore of the El Pintado reservoir in Seville Province, Spain. The absence of alternatives is not for want of looking, but in very large part due to the presence of graptolitically barren strata and/or unconformities within the vast majority of sections through the upper Aeronian and lower Telychian (summarized by Loydell et al., 2015, fig. 1 and pp. 744–747). As announced at the Milan 2019 Business Meeting of the

ISSS, the Chinese localities referred to in Loydell et al. (2015, p. 747), which had been considered as having potential in replacing the GSSP for the base of the Telychian Stage, ultimately did not provide a continuous graptolitic section.

Following the Lille ISSS meeting, a proposal to designate the El Pintado section as replacement GSSP for the Telychian Stage was prepared and circulated to the voting members of the ISSS. Of the 14 (out of 15) of these ISSS voting members who voted in November 2023 regarding forwarding the proposal to the ICS for formal approval of the replacement GSSP, 12 voted in favour, and two abstained. On 29th December 2023, the result of the ICS vote on the proposal was announced: 16 votes in favour, out of 17 cast, with one abstention. On 24th January 2024 the Secretary General of the International Union of Geosciences (IUGS), Prof. Stan Finney, wrote to the Secretary General of the ICS, Prof. Philip Gibbard, to inform him that the IUGS Executive Committee had voted unanimously to ratify the proposal.

Guiding Criteria

Regarding the base of the Telychian Stage, Melchin et al. (2020, p. 703) in GTS 2020 wrote: "A working group of the Subcommission on ISSS is currently restudying this boundary, focusing on the base of the *S. guerichi* Zone as the preferred level… in keeping with current usage." The "current usage" referred to resulted from the absence of graptolites from the original GSSP (Cefn Cerig quarry) when it was formally defined (Loydell, 1993a). Thus, some marker was required and the distinctive helically coiled spiral rhabdosome of the globally distributed *Spirograptus guerichi* Loydell, Štorch and Melchin, 1993 (Fig. 1) made it the logical choice, especially in the absence of viable alternatives (see below). A specimen of *S. guerichi* was subsequently discovered above the "golden spike" at the GSSP (Davies et al., 2013), but in the same study it was demonstrated that the strata at the GSSP are structurally disrupted and form part of a sedimentary mélange, prompting the calls for its replacement.

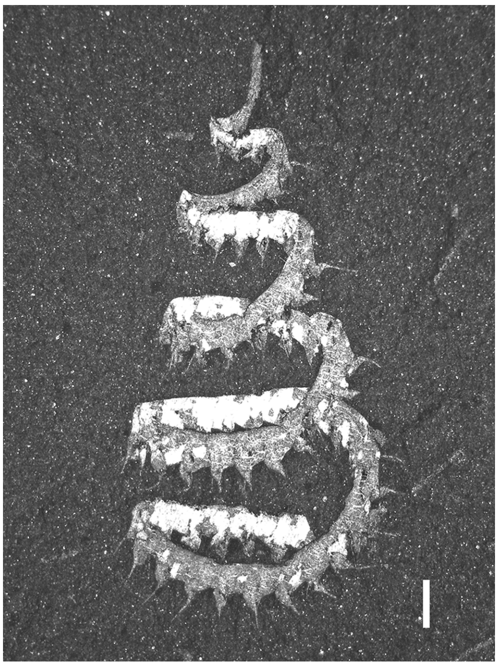

Figure 1. The distinctive lower Telychian graptolite* Spirograptus guerichi *Loydell, Štorch and Melchin, 1993; specimen from the El Pintado 1 section; MGM6550-O, S1.48, housed in the Museo Geominero of the Spanish Geological Survey (IGME-CSIC), Madrid. Scale bar represents 1 mm.

The two other fossil groups used extensively in Silurian biostratigraphy are the conodonts and chitinozoans. There are no last or first appearances of common or widespread conodont or chitinozoan taxa close to the base of the Telychian, which lies approximately in the middle of the *Distomodus staurognathoides* conodont Biozone and in the lower part of the *Eisenackitina dolioliformis* chitinozoan Biozone (Melchin et al., 2020, fig. 21.2; Fig. 2). Thus, graptolites provide the key biostratigraphical marker taxa for the base of the Telychian.

There are other important changes in graptolite faunas recorded in the fossil record at or close to the base of the Telychian, as follows.

Paradiversograptus runcinatus (Lapworth, 1876) (Fig. 3c, f) has been recorded only from the *Spirograptus guerichi* Biozone, first appearing very low within the biozone (Bjerreskov, 1975; Loydell, 1993b). The single Aeronian record referred to by Melchin et al. (2020, p. 703) had been reassigned to *Par. rectus* (Manck, 1923) by Loydell (1993b).

Following the late Aeronian *sedgwickii* Event graptolite extinctions (Štorch and Frýda, 2012), diversification occurred within various graptolite genera. For *Rastrites* and *Parapetalolithus* this diversification commenced in the latest Aeronian (represented in the rock record by the *Stimulograptus halli* Biozone), but for *Streptograptus* it was the beginning of the Telychian that witnessed the rapid increase in diversity (Loydell and Maletz, 2004; Loydell et al., 2015; Fig. 4).

The earliest representative of *Monograptus sensu stricto*, a genus characterized by its rhabdosome bearing hooked, overlapping thecae, is *Monograptus bjerreskovae* Loydell, 1993b (Fig. 3d, e). This appears at or very close to the base of the Telychian (Loydell, 1993b; Loydell and Maletz, 2004).

"*Monograptus*" *gemmatus* (Barrande, 1850) (Fig. 3a), a species of uncertain generic affinities, appears close to the base of the Telychian, having its First Appearance Datum (FAD) in uppermost Aeronian strata in the El Pintado 1 section (Loydell et al., 2015, fig. 9; Figs 4, 5) and possibly also in Sweden (Loydell and Maletz, 2004, fig. 1).

Many other graptolite species appear within the *Spirograptus guerichi* Biozone, but not necessarily at its base (see e.g. Loydell, 1993b; Loydell et al., 2015, figs 9, 10, which show more than 50 species having their FADs in the *Spirograptus guerichi* Biozone). A range chart for the upper Aeronian–lower Telychian of El Pintado section 1 is provided in Figure 5. The upper part of section 1 overlaps stratigraphically with and can be correlated with El Pintado section 5 (Loydell et al., 2015; Fig. 4).

Chemostratigraphically, the base of the Telychian is straddled by negative $\delta^{13}C$ excursions, collectively referred to as the "Rumba low", named after the Rumba Formation in Estonia (Kaljo and Martma, 2000). This excursion was initially considered to lie entirely within the antepenultimate Aeronian *Stimulograptus sedgwickii* graptolite Biozone (Kaljo and Martma, 2000), but the Rumba Formation has a very poor graptolite record and subsequently at least the upper part of the "Rumba low" negative excursion has been dated in graptolitic sections to a higher stratigraphical level, in the lower *Spirograptus guerichi* Biozone of the lower Telychian (Hammarlund et al., 2019; Fig. 6). As

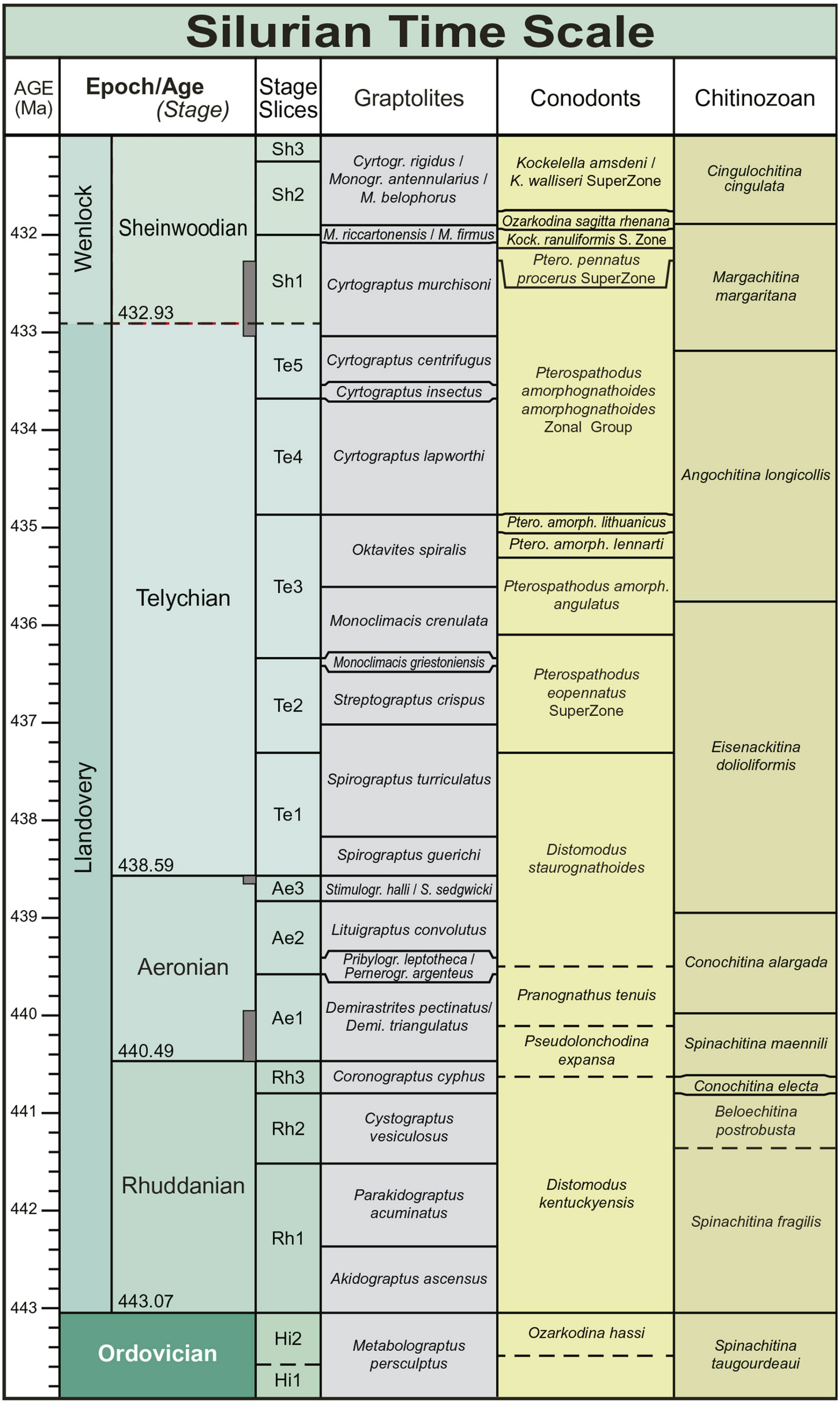

Figure 2. GTS2020 biozonations for the upper Hirnantian–Sheinwoodian. Note the level of the base of the Telychian Stage in relation to graptolite, conodont and chitinozoan biozones. Note that the **Stimulograptus sedgwickii** *and* **St. halli** *graptolite biozones are separate entities, the* **St. halli** *graptolite Biozone being the highest of the Aeronian (Figure from Melchin et al., 2020).*

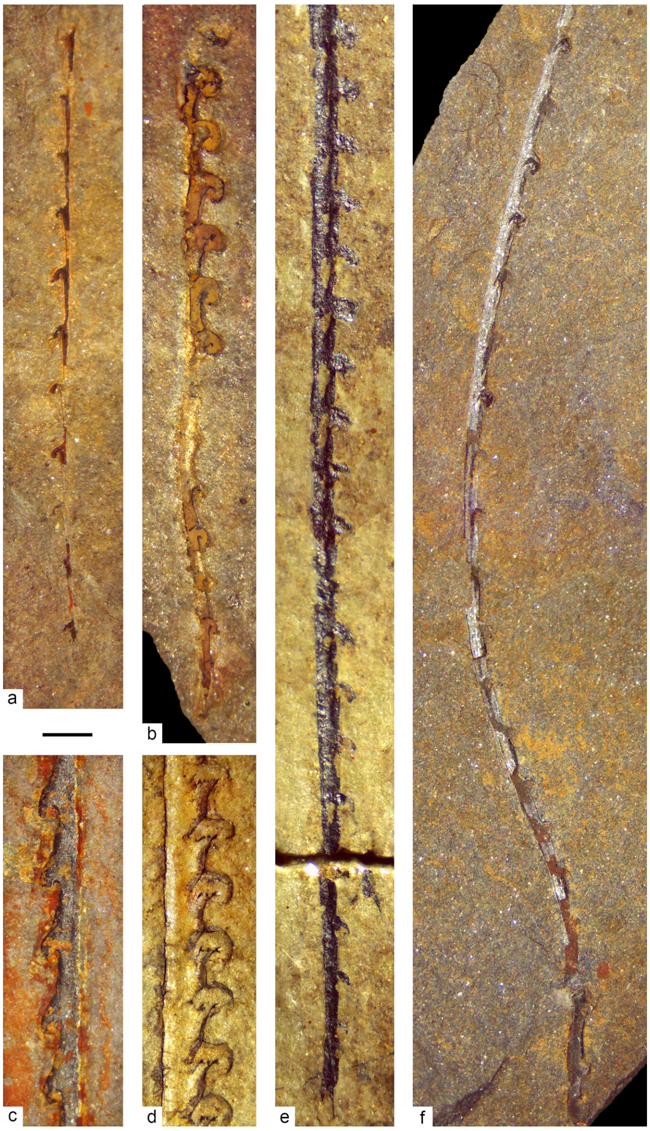

Figure 3. Graptolites that have their FAD at or very close to the base of the Telychian Stage. a) **"Monograptus gemmatus"** *(Barrande, 1850), typical proximal rhabdosome fragment, BGS DKL4018; b)* **Streptograptus picarrai** *Loydell, Frýda and Gutiérrez-Marco, 2015, proximal end, BGS 8E 848; c, f)* **Paradiversograptus runcinatus** *(Lapworth, 1876): c) distal rhabdosome fragment, BGS 7E 9325; f) bipolar proximal end, BGS 13E 9377; d, e)* **Monograptus bjerreskovae** *Loydell 1993b: d) distal rhabdosome fragment, BGS M4556a; e) proximal end, BGS ER6049. Scale bar represents 1 mm. All specimens are from the Southern Uplands of Scotland and are housed in the British Geological Survey. Specimens of these species from El Pintado are illustrated in Loydell et al. (2015).*

discussed by Walasek et al. (2018), evidence for a late Aeronian age for the lower part of the "Rumba low" comes from the Ikla core, Estonia, from which Kaljo and Vingisaar (1969) recorded *Pseudoclimacograptus* [now *Metaclimacograptus*] *hughesi* from 316.6 m, the same depth as the lowest $\delta^{13}C_{org}$ value of −30.02‰ and above the lowest $\delta^{13}C_{carb}$ value of −0.95‰ which is at a depth 320.0 m. There are no records worldwide of *Me. hughesi* (Nicholson, 1869) from the Telychian.

The "Rumba low" negative excursion is included in the Silurian carbon isotope record compilations of Cramer et al. (2011; Fig. 7) and Sullivan et al. (2018) at the base of the Telychian.

Setting of the El Pintado Section

The El Pintado reservoir lies in the northern part of Seville Province, Spain, approximately 13 km WNW of the town of Cazalla de la Sierra (Fig. 8). There are numerous exposures of Lower Palaeozoic strata around the eastern end of the reservoir, within the Valle syncline. The most important Silurian sections are on the northern shore of the reservoir and along gulleys leading into it. The replacement GSSP is at 37°59'7.0"N 5°55'42.8"W, within section 1 of Loydell et al. (2015; Fig. 8), which is continuously graptolitic through the upper Aeronian and lower Telychian.

The El Pintado sections, including the GSSP, lie within the Sierra Morena [ex "Sierra Norte"] de Sevilla UNESCO Global Geopark, Spain (Gutiérrez-Marco et al., 2021, 2024a). Access to the GSSP is via a dirt road, in good condition, that starts at km 10.380 along the provincial road SE-179 from Cazalla de la Sierra to El Real de la Jara. From this point the dirt road runs across 5.6 km of private land, passage across which needs to be authorized by the owners of the "Cortijo del Valle" livestock farm, until reaching a point located on the northern shore of the reservoir about 730 m WSW of the farm. The GSSP is easy to recognize because it lies c. 50 m SSE of five rectangular concrete towers (Fig. 9) that once served as tensioners to transport material to the dam under construction. Due to section 1 being located on the shore of El Pintado reservoir, the land where the GSSP is placed is under the ownership of the Guadalquivir River Hydrographic Confederation, part of the Spanish Ministry for Ecological Transition and Demographic Challenge. However, as the section is located in the Sierra Morena de Sevilla UNESCO Global Geopark, as well as in the homonymous Natural Park of the regional government of Andalusia, all scientific activities in the territory are coordinated by these administrators, which guarantees the protection and management of the area for future scientific studies. All scientists interested in obtaining permission to work on the section must do so through the Geopark & Natural Park unified authorities, who will facilitate contact with the owner of the access road and inform the owner of the land, while arranging and providing the corresponding authorization.

The amount of exposure available depends upon the water level within the El Pintado reservoir. The photos below (Figs. 9–12) were taken after a dry spell in 2009, with water levels unusually low, but even after exceptionally heavy rainfall (such as in 1998), exposures are available for study.

Biostratigraphy of the El Pintado Section

The potential stratigraphical importance of the El Pintado area was demonstrated by Jaeger and Robardet (1979). In particular, their section 1 (which is the same section 1 as in Loydell et al., 2015), named "SW. de la ferme du Valle", was shown as continuous from the Ordovician through to the upper Silurian and for much of its thickness to be lithologically monotonous "black shales". Graptolites were recorded by Jaeger and Robardet (1979) from numerous horizons, ranging

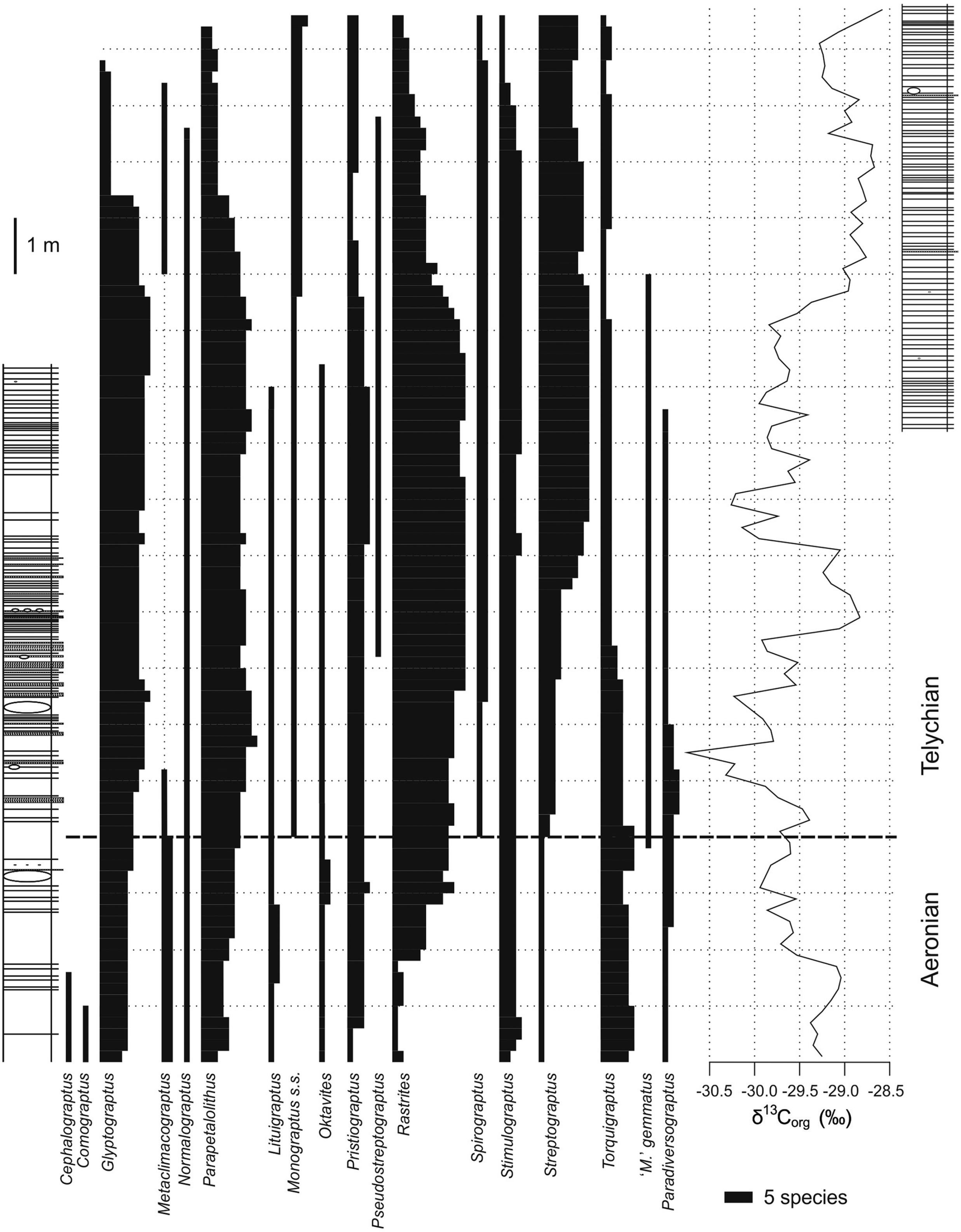

Figure 4. Changes in graptoloid graptolite species diversity (number of species indicated by the bar width) through the upper Aeronian and lower Telychian as exemplified by the El Pintado 1 (left) and 5 (right) sections, Spain (from Loydell et al., 2015). See Figure 8 for location of sections.

from the Rhuddanian to close to the Ludlow/Přídolí boundary. The Silurian in this section has a stratigraphical thickness exceeding 100 m. Additional records from El Pintado were provided by Robardet et al. (1998), in a field guide for the 1998 Field Meeting of the ISSS, in which Section 1 of Jaeger and Robardet (1979) was referred to as "Stop 1". Faunal lists were provided by Robardet et al. (1998) for

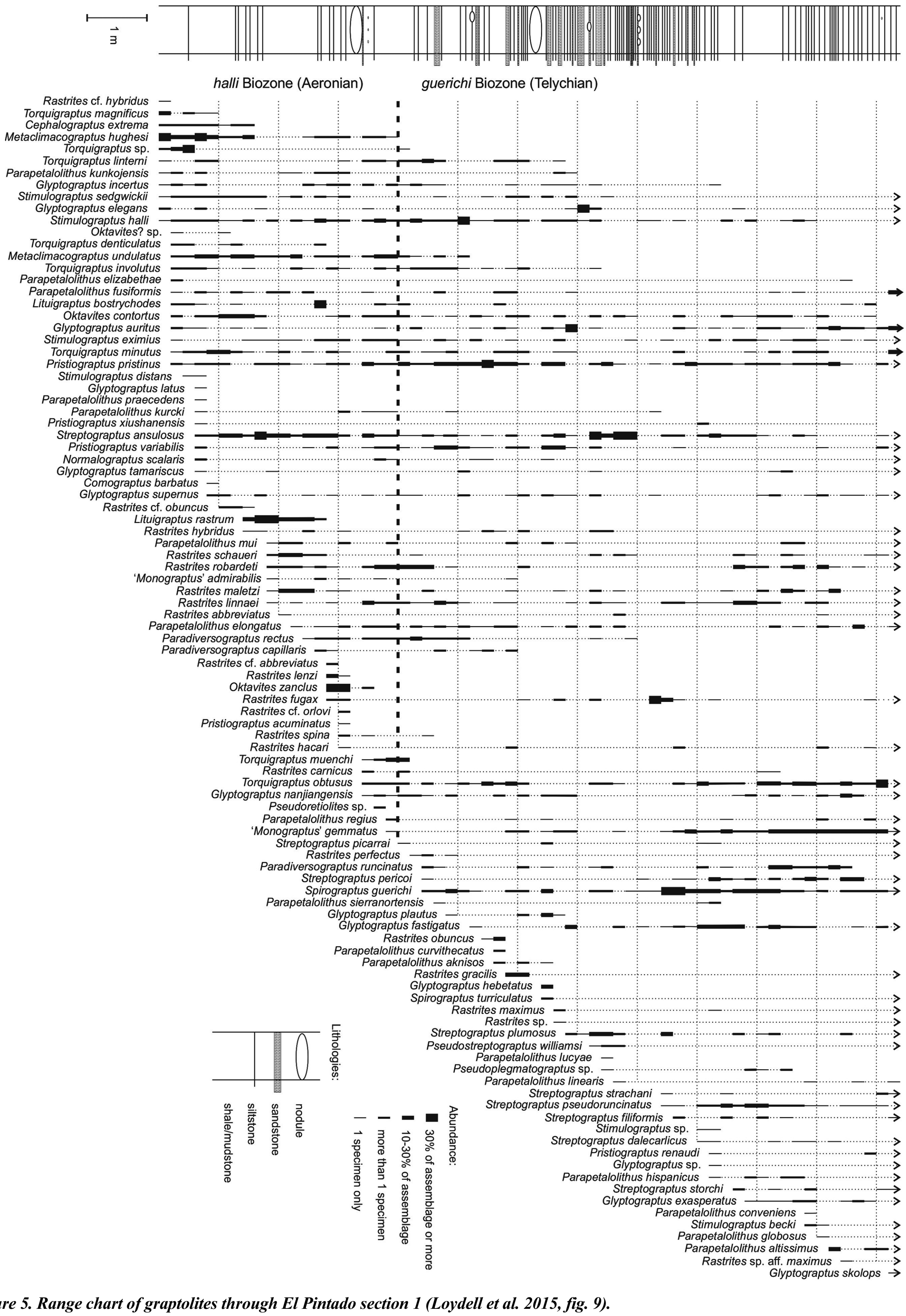

Figure 5. Range chart of graptolites through El Pintado section 1 (Loydell et al. 2015, fig. 9).

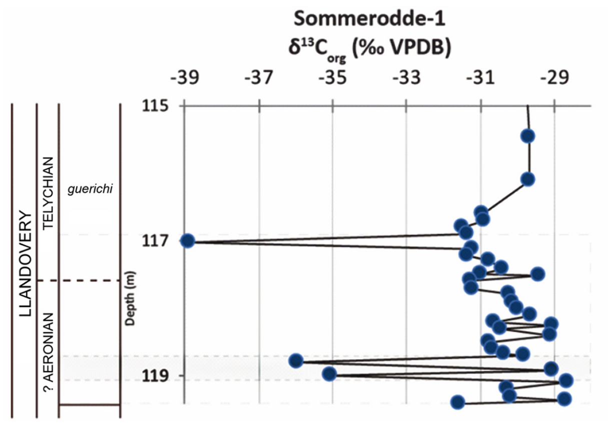

Figure 6. The "Rumba low" negative excursion in the Sommerodde-1 core, Bornholm, where the lowest value lies within the lower* Spirograptus guerichi *Biozone (graptolite biostratigraphy from Loydell et al., 2017), with other low values in the underlying unfossiliferous strata that may be of late Aeronian age. Figure modified from Hammarlund et al. (2019).

more than 20 numbered beds within the Llandovery Series, numbers (no longer visible) having been painted on the exposures in readiness for the visit of the Field Meeting participants. These faunal lists indicated the high graptolite diversity and potential for high resolution biostratigraphy. Further fieldwork on the El Pintado sections was carried out in 1999 and 2009 by David Loydell, Petr Štorch and Juan Carlos Gutiérrez-Marco, with Štorch focusing on the Rhuddanian and Aeronian and Loydell on the uppermost Aeronian and Telychian. The latter work is published (Loydell et al., 2015). Work on the stratigraphically underlying Llandovery strata is at an advanced stage. Gutiérrez-Marco et al. (2024b) have recently published on the Hirnantian–Rhuddanian strata of El Pintado Section 1.

Loydell et al. (2015) discussed the sedimentology and graptolite preservation at El Pintado as follows (references to figures, etc. within that paper have been removed): "The strata studied lie within a lithostratigraphical unit referred to in the literature as the "Lower graptolitic shales" (e.g. Robardet and Gutiérrez-Marco, 2004). A wider range of lithologies is represented within the sections, however: although dark-grey to black mudstones and shales are common, they are interbedded with innumerable thin micaceous siltstones and occasional fine sandstones. These have sharp bases, variable thickness and are in many cases laterally discontinuous: they are interpreted as distal tempestites. The lithologies are typical of an outer shelf setting, with intervals of fine-grained deposition punctuated by storms introducing coarser grained sediment. The absence of shelly benthos within the tempestites suggests that the sediments may have been derived from locations in which bottom water anoxia prevailed. The only trace fossils recorded from the El Pintado sections were some possible *Chondrites* mottling (in the middle and upper [*Spirograptus*] *guerichi* Biozone). This, combined with the absence of demonstrably benthic fossils, indicates that the El Pintado depositional environment was anoxic (or very nearly so) throughout the late Aeronian and early Telychian. Sandstones occurred predominantly within the lower *guerichi* Biozone of section 1. The micaceous siltstones were too numerous to log individually – they were least common in the [*Stimulograptus*] *halli* Biozone and middle *guerichi* Biozone of section 1. Nodules or nodular layers were recorded at a number of stratigraphical levels and suggest brief periods of non-deposition to enable their growth (Raiswell, 1987). They proved to be useful marker beds, the 0.2 m thick nodular layer 3.2 m above the base of the studied part of section 1 enabling confident correlation of collections made in 1999 and 2009. Graptolites were present in all lithologies with the exception of the nodules. They were generally not evenly distributed through the beds, but were more abundant on certain shale laminae and especially within some of the siltstone/sandstone tempestites presumably as a result of hydrodynamic sorting.

Jaeger and Robardet (1979) placed bars on their illustrations of El Pintado graptolites "to denote the direction of stretching (lineation)" with crosses placed on photographs where there was a "more or less pronounced all-round enlargement of the graptolites due to a second factor of deformation that runs parallel to the bedding". Tectonic deformation of graptolites was recorded in our samples only adjacent to a zone of quartz veining in the highest sample from section 1. A few specimens show minor displacement (measured in mm) along microfaults, but overall, features such as rhabdosome width and thecal spacing are identical to those in undeformed material from other localities.

All of the graptolites (and chitinozoans) are surrounded by clay minerals, the organic material of the graptolite periderm presumably having acted as a template for clay mineral growth (Underwood, 1992; Page et al., 2008). This clay mineral coat is generally thickest in the coarser lithologies and around graptolites preserved in relief regardless of lithology (although these are most common in the siltstones and sandstones); it grew preferentially parallel to bedding. It commonly obscures fine details, for example in many cases preventing identification of the position of the sicular apex. Very occasionally, the clay minerals enhanced the detail visible on the graptolites, but this was the case in only a very few specimens. Diagenetically flattened graptolites characterize the shales and mudstones, with partial to full relief specimens occurring predominantly in the siltstones and sandstones within which flattened specimens are also often present. It is very likely that the three dimensionally preserved specimens were originally pyrite internal moulds."

Graptolite diversity is very high within the El Pintado section 1: Loydell et al. (2015) recorded nearly 100 species from the 12.4 m of *Stimulograptus halli* and *Spirograptus guerichi* biozones that were sampled from Section 1. The base of the Telychian in El Pintado section 1 coincides with:

1. The FAD of helically spiralled *Spirograptus* with a proximal end exhibiting torsion (Loydell et al., 2015, p. 759); and

2. The FAD of *Streptograptus picarrai* Loydell, Frýda and Gutiérrez-Marco, 2015 (Fig. 3b), marking the commencement of increased *Streptograptus* diversity within the section (Figs 4, 5).

The FAD of *Paradiversograptus runcinatus* in the section is 0.4–0.6 m above the base of the Telychian (Fig. 5). The FAD of "*Monograptus*" *gemmatus* (Barrande, 1850) is within the 0.2 m of strata below the base of the Telychian (Figs 4, 5).

All of the graptolites (both figured and unfigured) collected for the Loydell et al. (2015) publication are housed in the Museo Geominero of the Spanish Geological Survey (IGME-CSIC), Madrid.

No identifiable macrofossils other than graptolites were encountered in the upper Aeronian–lower Telychian of El Pintado section 1.

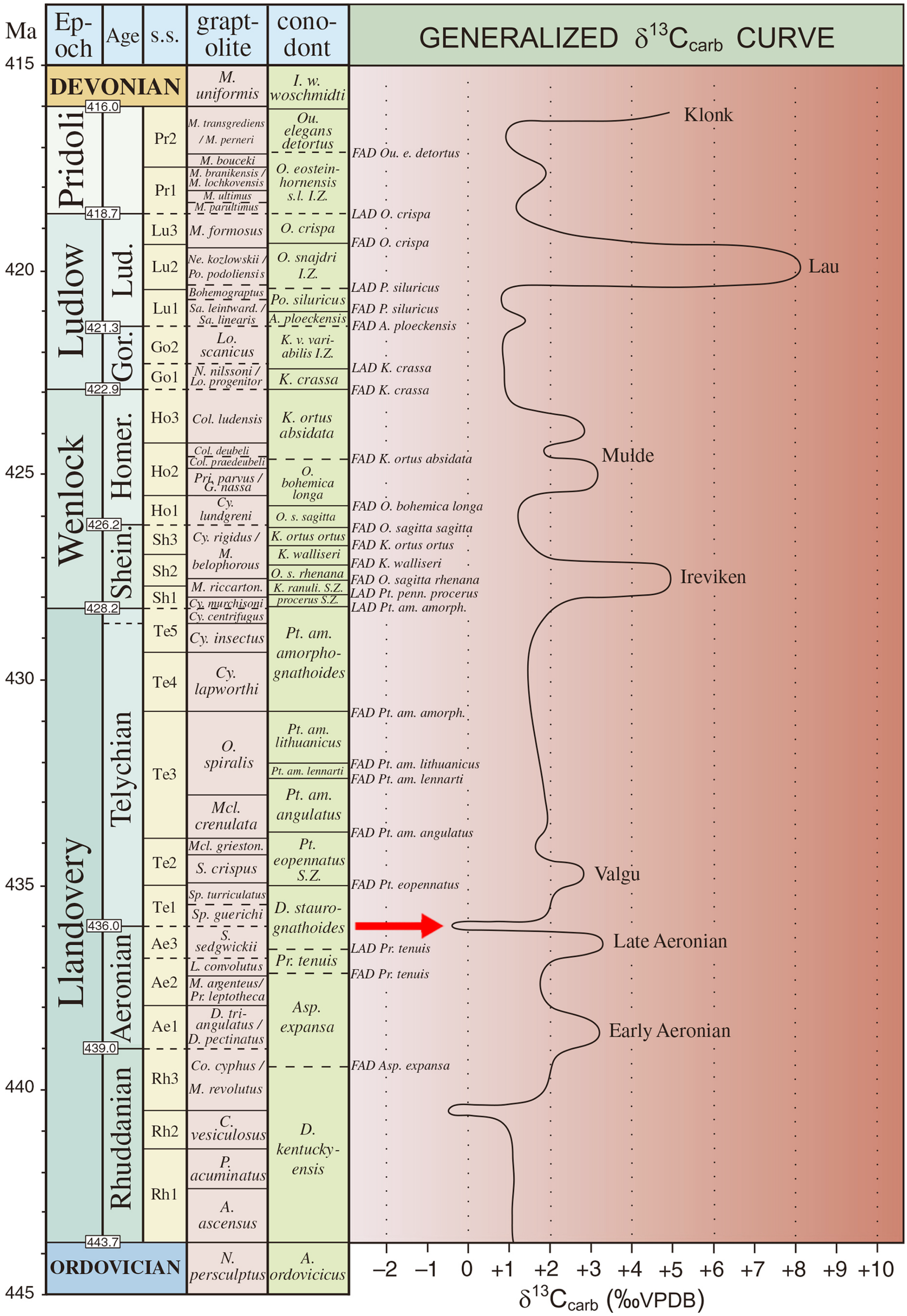

Figure 7. The "Rumba Low" (red arrow) in the generalized $\delta^{13}C_{carb}$ curve of Cramer et al. (2011).

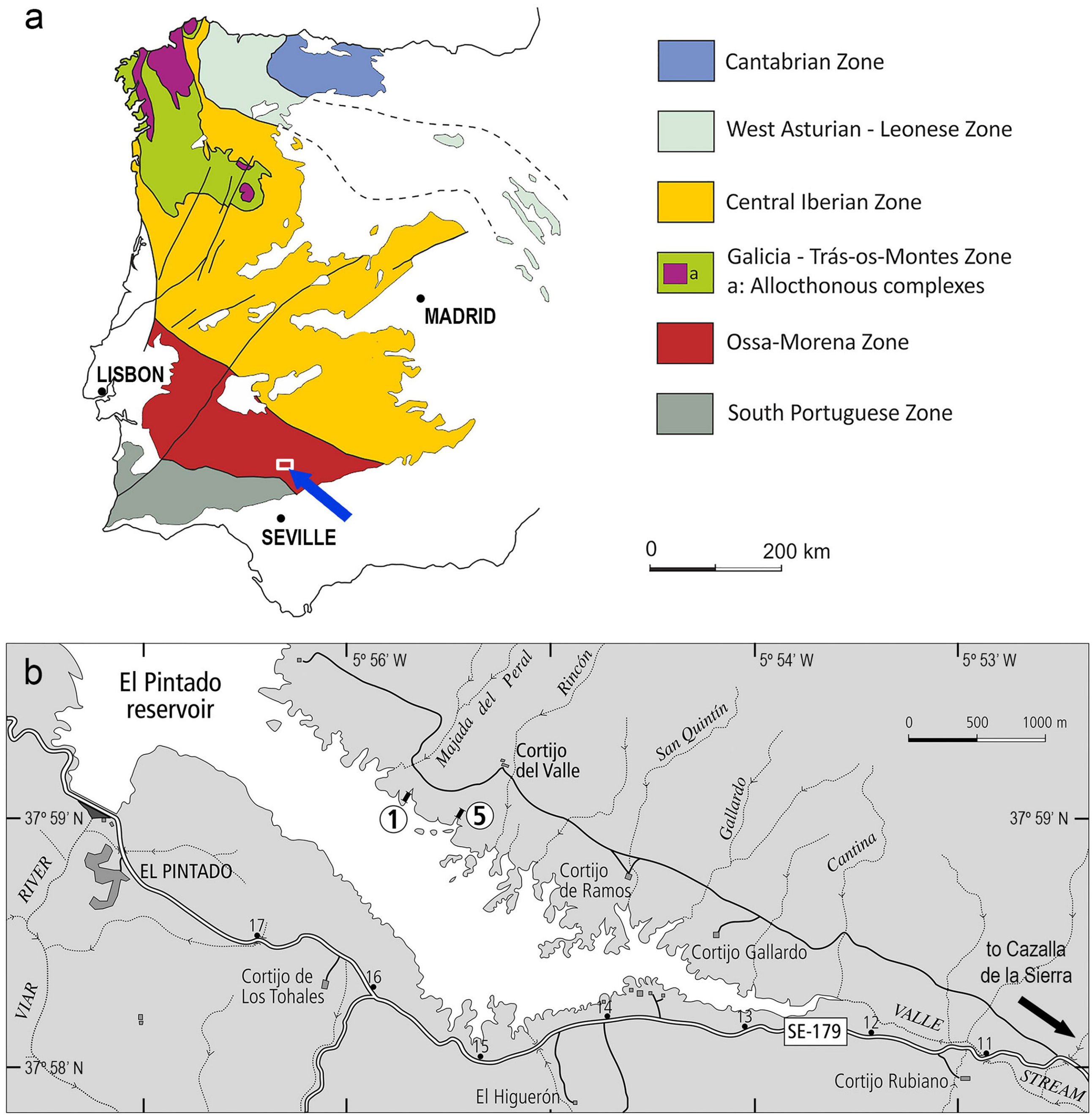

Figure 8. Location of the El Pintado Reservoir within the Ossa-Morena Zone of the Iberian Massif (white square, above) and of the replacement GSSP section (section ① on lower map, from Loydell et al., 2015) for the base of the Telychian Stage.

Chitinozoans were, however, observed on several slabs and were particularly conspicuous where concentrated within laminae (Loydell et al., 2015, fig. 8C, D). Initial palynological processing of samples from the section by Dr Anthony Butcher (University of Portsmouth) yielded no identifiable palynomorphs. Dr Jakub Vodička (Charles University, Prague), however, was more successful in extracting some three dimensional, poorly to moderately well preserved chitinozoans from samples from the section. The chitinozoan biostratigraphy of the section remains to be studied but, as noted above, no significant differences have been noted from other sections worldwide between upper Aeronian and lower Telychian chitinozoan assemblages, with the *Eisenackitina dolioliformis* chitinozoan Biozone spanning from the upper part of the Aeronian *Lituigraptus convolutus* graptolite Biozone through the lower and middle Telychian up to a level within the *Monoclimacis crenulata* graptolite Biozone (Fig. 2).

Precise Location of the GSSP

Within a somewhat monotonous sedimentary sequence of largely dark grey to black graptolitic mudstones (Fig. 9), it is useful to have lithological markers to help locate the GSSP.

The photos below (Figs. 10–12) show the level of the GSSP, with arrows indicating the GSSP itself and the most useful lithological markers.

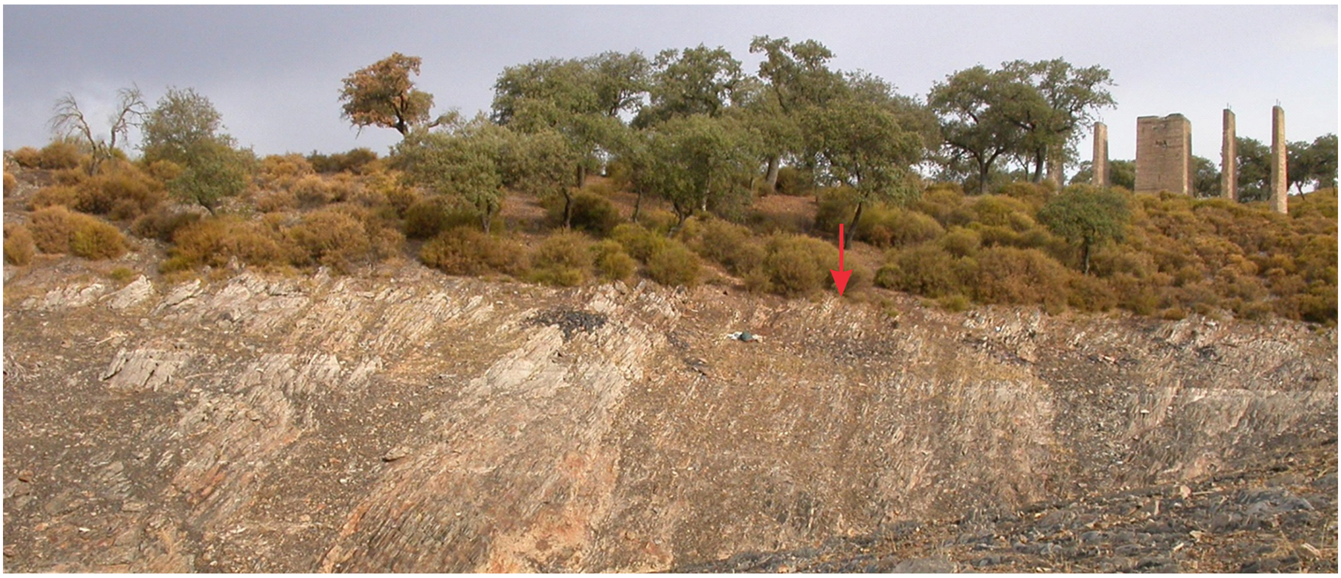

Figure 9. Overview of the Aeronian to lower Telychian of El Pintado section 1, replacement GSSP section for the base of the Telychian Stage. Strata young to the left (SW). Red arrow marks the base of the Telychian Stage (see Figs 10 and 11 for close-up views).

Figure 10. Upper Aeronian and lower Telychian strata of El Pintado section 1, replacement GSSP for the base of the Telychian Stage. Area in red rectangle is enlarged in Fig. 11.

Chemostratigraphy of the El Pintado Section

A negative shift in $\delta^{13}C_{org}$ values commences from 0.2–0.4 m above the base of the Telychian (where $\delta^{13}C_{org}$ = 29.4‰), culminating 1.4–1.6 m above the base of the Telychian (where $\delta^{13}C_{org}$ = 30.7‰, the lowest value recorded from the upper Aeronian and lower Telychian of the section; Fig. 13). This is considered to be the local expression of the "Rumba low" negative $\delta^{13}C$ excursion.

Geochemical work on the El Pintado sections has been limited thus far to the $\delta^{13}C_{org}$ and TOC analyses by Jiří Frýda presented in Loydell et al. (2015). There is therefore plenty of potential for additional studies.

Conclusions

El Pintado section 1 of Loydell et al. (2015) has been ratified by the IUGS as replacement GSSP for the base of the Telychian Stage. The section is continuous through the upper Aeronian–lower Telychian, is graptolitic throughout and has been intensively studied, both for its graptolite biostratigraphy and $\delta^{13}C_{org}$ chemostratigraphy. The base of the Telychian is marked in the section by the FAD of helically spiral *Spirograptus* showing torsion of the proximal end and the onset of diversification of *Streptograptus* (the FAD of *S. picarrai*). *Paradiversograptus runcinatus* appears 0.4–0.6 m above the base of the Telychian and the "Rumba low" negative $\delta^{13}C_{org}$ excursion culminates

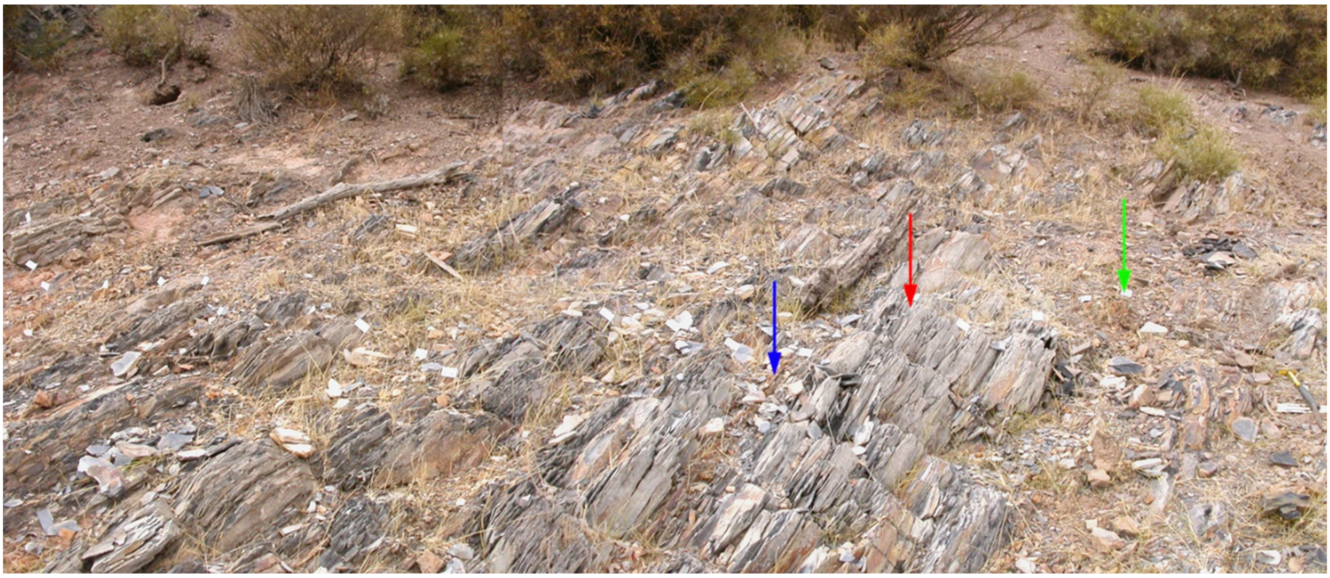

Figure 11. The uppermost Aeronian and lowermost Telychian of El Pintado section 1, replacement GSSP for the base of the Telychian Stage. Red arrow = base of Telychian; green arrow = nodule, top of which is 0.6 m below base of Telychian; blue arrow = rusty weathering layer 0.25 m above base of Telychian.

Figure 12. Nodule (arrowed, left), top of which is 0.6 m below base of Telychian; and rusty weathering layer (arrowed, right) 0.25 m above base of Telychian. Numbered "flags" are at intervals of 0.2 m.

1.4–1.6 m above the base of the Telychian.

It is hoped that establishing the GSSP for the base of the Telychian in El Pintado section 1 will provide long-term stability in Silurian stratigraphy. Due to the apparent absence of continuous graptolitic sections across the Aeronian/Teychian boundary in any other part of the world, as concluded by the activities of the ISSS-Base of Telychian GSSP Restudy Working Group, initiated in 2014, no Standard Auxiliary Boundary Stratotype (SABS) has been proposed alongside the redefined GSSP.

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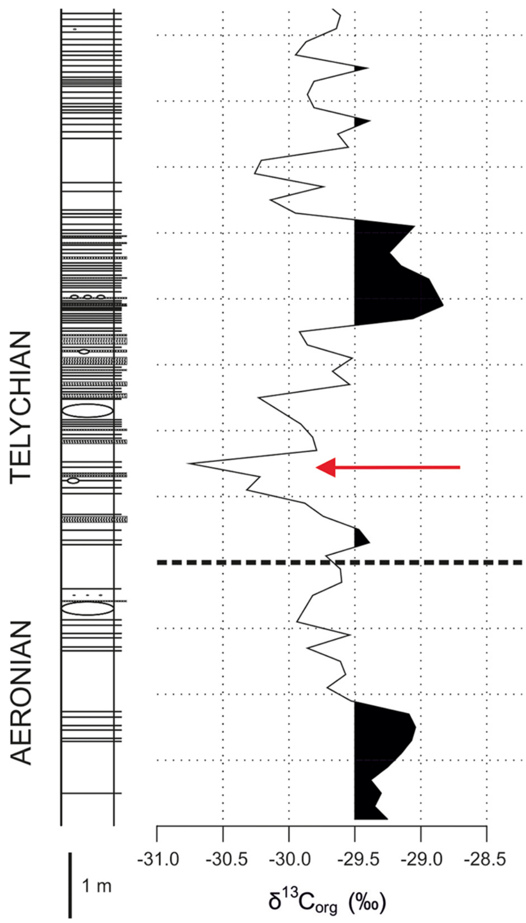

Figure 13. The $\delta^{13}C_{org}$ record through the upper Aeronian and lower Telychian of El Pintado section 1. The dashed line marks the base of the Telychian. Lowest value of "Rumba low" negative $\delta^{13}C_{org}$ excursion is arrowed. (Part of figure 13 of Loydell et al., 2015, slightly modified).

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