Seven species of graptoloid graptolites are described from Hirnantian and lower Rhuddanian formations of the Austrian part of the Carnic and western Karavanke Alps. The Plöcken Formation, of latest Ordovician (Hirnantian) age, yields the biozonal index graptolite *Metabolograptus persculptus* in the Cellon Reference Section and, tentatively, the Feistritzgraben Section. A distinctive graptolite assemblage indicating an earliest Silurian (early Rhuddanian) age comes from the Waterfall Section near Zollnersee Hütte. Along with the presence of the biozonal index *Parakidograptus acuminatus* and accompanying taxa, common *Rickardisograptus bifurcatus* (Ye) and other easily recognizable lowermost Rhuddanian species which are dominant in this level throughout peri-Gondwanan Europe indicates the peculiar character of the *acuminatus* Biozone assemblage encountered in the Carnic Alps. • Key words: graptolite, biostratigraphy, palaeobiogeography, Hirnantian, Rhuddanian, Southern Alps, Austria.


Petr Štorch, Institute of Geology v.v.i., Academy of Sciences of the Czech Republic, 165 00 Praha 6, Czech Republic; storch@gli.cas.cz • Hans-Peter Schönlaub, Austrian Academy of Science, Center for Geosciences, Dr. Ignaz Seipel-Platz 2, 1010 Vienna (Austria); hp.schoenlaub@aon.at

The Carnic Alps of Southern Austria and Northern Italy (Fig. 1) represent one of the few places in the world where an almost continuous and biostratigraphically well-constrained sequence of Palaeozoic rocks is preserved. Nearly complete successions of Upper Ordovician to Permian marine sedimentary rocks, representing shallow shelf carbonates to deeper-water dark siliceous shales including flysch deposits in the Carboniferous, are exposed in a series of closely spaced thrust sheets. They form part of the Peri-Gondwanide terranes and arcs similar to Avalonia, Armorica-Iberia, Perunica and others which formed originally around the northern margin of Gondwana. The splitting of the latter supercontinent in the Early Ordovician resulted in a rapid northward drift of continental fragments which successively collided and accreted with Laurentia and Baltica, respectively, starting in the Devonian and ending in the Early to Late Carboniferous Variscan Orogeny. Consequently, the microplate named the Apulia Terrane, of which the Southern Alps were a part, has a long-term drifting history from a moderately cold climate of approximately 50° southern latitude in the Ordovician to the equatorial belt in the Permian (Schönlaub 1992).

With regard to Lower Palaeozoic correlation, the Carnic Alps is a key area along the northern margin of Gondwana. For example, the world-famous Cellon Section has been a reference for the Upper Ordovician to Lower Devonian conodont biozonation (e.g., Walliser 1964, Kleffner 1995), the occurrence of the late Ordovician Hirnantia fauna (Jäger et al. 1975), evaluation of Silurian global eustatic sea-level changes (Brett et al. 2009, Johnson 2010), correlation of Lower Palaeozoic K-bentonites (Histon et al. 2007) and isotope chemostratigraphy (Wenzel 1997).

For this paper, the previously scattered records of uppermost Ordovician (Hirnantian) and lowermost Silurian (lower Rhuddanian) graptolites encountered from several sections throughout the Austrian part of the Southern Alps (namely the Carnic and Karavanke Alps) have been revised and supplemented by new data in order to reach higher resolution in local and global biostratigraphical correlation and chronology of past environmental changes. The presence of an exotic graptolite of Chinese provenance and the peculiar composition of the lowermost Rhuddanian faunal assemblage of the Carnic Alps pose new questions that challenge present knowledge of graptolite distribution and palaeobiogeography.

**Sections**

The Cellon Section (UTM coordinates 33T, E342386, N5163763, GPS coordinates N 46°36´ 32˝, E 12°56´ 30˝)
is located at an altitude between 1480 m and 1560 m on the eastern face of the Cellon mountain in the central Carnic Alps, SSW of the village of Kötschach-Mauthen, close to and accessible from the Austrian/Italian border (Fig. 1) at Plöcken Pass. The section ranging from the Upper Ordovician to the lower Carboniferous is exposed in a narrow avalanche gorge. Previous studies on different faunas and in particular on conodonts (see Schönlaub et al. 2011) make it an ideal place for the study of faunal changes across the Ordovician/Silurian boundary and through the Silurian. The bedded argillaceous Uggwa Limestone, 4.11 m thick (Bed Nos 1–4: after Walliser 1964), is overlain by 20 cm of greenish siltstone and 25 cm of marlstone (Bed 4A of Walliser l.c.). This is succeeded by 40 cm thickness of greenish siltstone. Schönlaub et al. (2011) assigned the whole package to the Uggwa Limestone Formation (Fig. 2). This sequence of strata is separated from the overlying Plöcken Formation by a disconformity. The latter formation begins with a 77 cm thick greyish siltstone that is intercalated with muddy-limestone lenses (Bed No. 5 of Walliser) with a *Hirnantia* brachiopod fauna, the trilobite *Mucronaspis* and rare specimens of the biozonal index graptolite *Metabolograptus perculptus* (Elles & Wood). Higher up, the Plöcken Formation continues with 5.40 m thick pyritiferous limestones and sandstones (Bed Nos 6–8).

The Oberbuchach I-Section (UTM coordinates 33T, E355221, N5165485, GPS coordinates N 46°37´38˝, E 013°06´32˝) is located at an altitude of 1120 m, south of the village of Gundersheim in the Gail Valley. The section is exposed in the roadcut on the western and southwestern side of small road running from the Gail Valley near Gundersheim to Gundersheim Alm (see also Jaeger & Schönlaub 1980, Schönlaub & Kreutzer 1994). Poorly bedded silty shales and muddy sandstones, 10–11 m thick, are assigned to the Plöcken Formation which terminates with pyrite-bearing sandstones exposed where the road bends. A shaly horizon 50 cm below the top of the Plöcken Formation yields uncommon rhabdosomes of *Normalograptus cf. transgrediens* (Waern). The pyrite-bearing sandstone is disconformably overlain by a 0.5 m to 1 m thick bed of quartzite which subsequently passes upwards through laminated dark-grey silty micaceous shale into black graptolitic shale. At the Oberbuchach-I Section we did not find the middle Rhuddanian *Cystograptus vesiculosus* (Nicholson, 1868) reported by Jaeger & Schönlaub (1977) and Schönlaub (1988) from the westward situated
Nöblinggraben Section but confirmed the presence of a rich assemblage of the lower Demirastrites triangulatus Biozone (lowermost Aeronian) in the black shale succession, ca 30 cm above the basal quartzite.

The Feistritzgraben Section (UTM coordinates 33N, E411235, N5153490, GPS coordinates N 46°31´40˝, E 013°50´36˝) is exposed at an altitude of some 930 m, southwest of the village of Finkenstein on Austrian map sheet No. 201 or UTM sheet No. 3118, respectively. Detailed descriptions are provided by Schönlaub (1971) and Jaeger et al. (1975). The section comprises some 3 m of shale (slate) which is overlain by the typical Upper Ordovician Uggwa Limestone reaching a thickness of 6.50 m. It contains a conodont assemblage of the Amorphognathus ordovicianus Biozone, widely represented in other coeval strata of the Carnic Alps. This limestone unit is succeeded by ca 10 m of black siltstones, calcareous sandstones and laminated arenaceous shales and slates which resemble the Pöcken Formation at the Cellon section. The critical interval immediately above the limestone unit comprises black graphic slates, sheared and affected by small scale folds, which are rich in deformed graptolite rhabdosomes. Rare brachiopods have been encountered [Eostropheodonta? hirnantensis (M'Coy)] in addition to a monospecific assemblage of Metabolograptus persculptus (Elles & Wood). Globular nodules of pyrite, up to 20 mm in diameter, are common in the slate. This distinct package of rocks is overlain by interbedded black platy limestones and slates which presumably are early Silurian in age although index fossils have not yet been found.

The Waterfall Section near Zollnersee Hütte (UTM coordinates 33N, E352340, N5163175, GPS coordinates N 46°36´23˝, E 013°04´19˝) is located at an altitude of 1680 m to 1700 m. The exposure is at the base of a 25 m high waterfall below the alpine road from Rösser Hütte to Ochsenalm (Fig. 1). The massive Bischofalm Quartzite crops out at the top of the overturned sequence. The quartzite is succeeded by a succession of layered black cherts.
with subordinate interbeds of cherty shales; both are rich in pyrite. A lenticular bed of massive pyrite is developed ca 130 cm stratigraphically above (actually below in the exposure) the quartzite. Several thin pyrite beds and nodules are scattered throughout the whole thickness of the black cherty succession. Poorly preserved normalograptid rhabdosomes occur in cherts 40–70 cm stratigraphically above (actually below in the exposure) the top of the quartzite. The first determinable graptolites, including Parakido-graptus acuminatus (Nicholson), came from a cherty shale 92 cm above the quartzite and then, still better preserved, at 100–102 cm (Fig. 2). The graptolites described in this paper came from these two levels. Poorly preserved normalograptids occur also 160 cm stratigraphically above the quartzite. Some bedding planes are covered also by sponge spicules. The further succession is interrupted by a fault ca 180 cm above the quartzite and continues with massive black cherts that did not yield any graptolites.

**Stratigraphy and correlation**

Uppermost Ordovician graptolites were first reported in the Southern Alps by Jaeger et al. (1975) from the Feistritz-graben Gorge (see also Schönlaub 1988), from the lowermost Plöcken Fm. just above the Uggwa Limestone. Abundant graptolite rhabdosomes, confined to a black slate rich in globular pyrite and affected by tectonic strain, were tentatively assigned to Glyptograptus persculptus (Salter) (=Metabolograptus persculptus (Elles & Wood) of present usage). Poorly preserved specimens of the upper Hirnian biozonal index graptolite Metabolograptus persculptus, however, can be easily confused with its likely ancestor Metabolograptus ojsuensis (Koren’ & Mikhaylova), which is common in the lower Hirnian Metabolograptus extraordinarius Biozone. Hence, the late Hirnian age of this graptolite occurrence must be considered with some reservation.

Uncommon, but better preserved specimens, assignable with confidence to Metabolograptus persculptus, co-occur with the Hirnantia fauna in greyish siltstones of the lowermost Plöcken Fm. in the Cellon Section. This association is assignable to the upper Hirnian Metabolograptus persculptus Biozone.

In the Oberbuchach-I Section, a thin silty-shaly intercalation high in the Plöcken Formation yielded several poorly to moderately well preserved rhabdosomes of Normalograptus cf. transgrediens (Waern). Normalograptus transgrediens (Waern) is known from the upper persculptus Biozone (Davies 1929), the post-persculptus pre-ascensus interval (Koren’ et al. 2003), tentatively from the acuminatus Biozone (Davies 1929, Waern 1948, Howe 1982), and also from the vesiculosus Biozone (Loydell 2007). The biostratigraphical significance of this monospecific normalograptid assemblage is rather limited although the same species, referred to Normalograptus cf. transgrediens, is common in the definite acuminatus Biozone in the Waterfall Section near Zollnersee Hütte. Similar monospecific normalograptid occurrences are known from shaly interbeds within the post-glacial, late Hirnian through to Llandovery Los-Puertos Quartzite (Gutiérrez-Marcos & Štorch 1998) and Criadero Quartzite (Štorch et al. 1998) in Spain. In the Oberbuchach-I Section the Plöcken Formation is topped by an apparent unconformity and succeeded by the so-called ‘basal quartzite’ which grades into the typically finely laminated graptolitic shale with abundant graptolites of the lowermost Aeronian Demirastrites triangulatus Biozone through at least 20 cm of silty-micaceous black shale without determinable graptolites. In the neighbouring Nöblinggraben Section (Jaeger & Schönlaub 1977, Schönlaub et al. 2011) the highest quartzite bed in the sequence is overlain by a silty black shale in which H. Jaeger found the middle Rhuddanian biozonal index graptolite Cystograptus vesiculosus and also abundant graptolites of the triangulatus Biozone (Jaeger & Schönlaub 1977, Schönlaub 1985).

At the Waterfall Section near Zollnersee Hütte a graptolite assemblage of early Rhuddanian (earliest Silurian) age is identified from an apparently overturned succession of black lydites and siliceous shales, ca 1 m below the massive Bischofalm Quartzite. Graptolites were first recorded by H. Jaeger (unpublished record noted by Schönlaub 1988). The assemblage includes Parakido-graptus acuminatus (Nicholson), Normalograptus aijeri (Legrand), Normalograptus cf. transgrediens (Waern), Glyptograptus aff. tamariscus (Nicholson), Rickardsograptus lautus (Štorch & Feist) and Rickardsograptus? bifurcus (Ye) and can be assigned with confidence to the Parakido-graptus acuminatus Biozone. The assemblage, however, is rather peculiar since several abundant and morphologically distinct taxa typical of lower Rhuddanian assemblages in other Peri-Gondwanan sections are missing (e.g. Neodiplograptus lanceolatus Štorch & Serpagli, 1993 and Normalograptus trifilis (Manck, 1923), see Štorch (1996)) whereas R.? bifurcus, previously known only from China, is new to Europe.

**Systematic palaeontology**

All specimens are flattened and more or less deformed by a tectonic strain which is almost negligible at Cellon but strongly affects rhabdosomes from the Feistritz-graben Section. The pyrite-rich black chert and siliceous shale from the Waterfall Section near Zollnersee Hütte may undergo complete decomposition into small sub-millimetre cubes, when kept in wet conditions or photographed in water. This is how we lost rich material collected during a previous field
campaign in 2001. Therefore the new material, collected in 2010, was photographed only in alcohol. Specimens prefixed GBA are housed in the Dept of Palaeontology and Collections of the Geologische Bundesanstalt, Vienna. Graptolite genera are used as in the recent phylogenetic analysis by Melchin et al. (2011).

Genus Normalograptus Legrand, 1987, emend. Melchin et al., 2011

Normalograptus aijeri (Legrand, 1977)
Figures 3A, B, ?D, ?O, 4E, F

1977 Climacograptus (Climacograptus) normalis aijeri nov. subsp.; Legrand, p. 171, text-figs 9A–D, 10A–B.

Material and stratigraphical range. – 4 flattened rhabdosomes from the acuminatus Biozone at the Waterfall Section near Zollnersee Hütte.

Discussion. – Medium-sized normalograptid, gently widening from 0.8–0.85 mm at the first thecal pair through 1.2–1.3 mm at the fifth thecal pair to the maximum of 1.5–1.6 mm attained at ca th10. The median septum of the present specimens is complete, although proximal details are not recognizable due to poor preservation. The rhabdosome is furnished with a thread-like virgella and distally projecting nema. Strongly geniculated thecae exhibit parallel-sided supragenicular walls and thecal apertures opening into prominent semicircular excavations. 2TRD increases from 1.55–1.6 mm at th5 to 1.6–1.8 mm distally.

Discussion. – Several normalograptid rhabdosomes found in the acuminatus Biozone of the Waterfall Section agree well with N. aijeri (Legrand) in rhabdosome outline, width and thecal spacing (2TRD). The present specimens are considerably narrower than rhabdosomes of Normalograptus normalis (Lapworth, 1877) or N. medius (Törnquist, 1897), less tapering than N. transgrediens (Waern, 1948), and have thecae more densely spaced than those in N. premedius (Waern, 1948). N. angustus (Perner, 1895) and N. mirnyensis (Obut & Sobolevskaya in Obut et al., 1967) are narrower; the former can be recognized also by its greater thecal spacing.

Normalograptus cf. transgrediens (Waern, 1948)
Figures 3C, 4L, M, 5E

cf. 1929 Climacograptus scalaris-C. medius transient; Davies, pp. 8, 22; figs 28, 31.

Genus Metabolograptus Obut & Sennikov, 1985, emend. Melchin et al., 2011

Metabolograptus persculptus (Elles & Wood, 1907)
Figure 5C, D, ?A, B

1865 Diplograptus persculptus (Salter); Salter, p. 25 (see Strachan 1971).
1907 Diplograptus (Glyptograptus) persculptus Salter; Elles & Wood, p. 257, pl. 31, fig. 7a–c; text-fig. 176a, b.
2005 Normalograptus persculptus (Elles & Wood, 1907). – Chen et al., pp. 266–268, text-figs 5B, 9A, F, L (see for further references on N. persculptus).

Material and stratigraphical range. – 9 flattened rhabdosomes from the acuminatus Biozone at the Waterfall Section near Zollnersee Hütte.

Description. – Rhabdosome up to 45 mm long, septate, widening from 0.9–1.1 mm at the level of the first thecal pair to a distal maximum of 2.3–2.5 mm (2.1–2.7 mm when affected by tectonic strain). DVW varies from 2.0 mm to 2.4 mm at the tenth thecal pair. Proximal astogeny of pattern H, corresponds with other species of Rickardsograptus. Thl1 grows down before it turns up 0.2 mm below the sicular aperture. The upward growing part of th1 is ca 0.8 mm long. Virgella 1.7–9.5 mm long; robust nema projecting well beyond thecate part of the rhabdosome. Proximal thecae glyptograptid with blunt geniculum. Thelcal geniculation weakens through the most rapidly widening mesial part of the rhabdosome; substantially overlapping distal thecae exhibit smooth, weakly expressed genicula. Thecal tube terminates with perpendicular or slightly introverted aperture. 2TRD is 1.3–1.6 mm at the level of the second thecal pair, 1.45–2.1 mm at the fifth thecal pair; distal 2TRD varies from 1.7 mm to 2.4 mm depending on orientation of the rhabdosome relative to the strain.

Discussion. – The maximum width is attained at the 12th–14th thecal pair – more gradually than in most other species referred to Rickardsograptus [e.g. R. icherskyi (Obut & Sobolevskaya in Obut et al., 1967); R. thuringicus (Kirste, 1919) and R. macroterminatus (Churkin & Carter, 1970)] but more abruptly than in Rickardsograptus elongatus (Churkin & Carter, 1970) which also exhibits a particularly gradual change from more geniculated proximal to less geniculated distal thecae. The virgella is slender in all of the present specimens of R. lautus but its length (when complete) varies from 1.0 mm to 9.5 mm, which is greater variation than observed in topotypic material from Montagne Noire, France.

Genus Rickardsograptus Melchin et al., 2011

Rickardsograptus lautus (Stöch & Feist, 2008) Figures 3P–R, 4H, 1

1974 Diplograptus aff. elongatus Churkin & Carter, 1970. – Hutt, pp. 31, 32, pl. 5, figs 1, 2; text-fig. 9, fig. 12; text-fig. 10, fig. 3.
1983 Diplograptus elongatus Churkin & Carter, 1970. – Stöch, p. 168, pl. 3, fig. 6; pl. 4, fig. 5; text-figs 3C, D.
2008 Neodiplograptus lautus new species; Stöch & Feist, p. 948, text-fig. 6, figs 3, 6, 8, 9; text-fig. 10, figs 12, 13.

Material and stratigraphical range. – 9 flattened rhabdosomes from the acuminatus Biozone at the Waterfall Section near Zollnersee Hütte.

Description. – Rhabdosome up to 45 mm long, septate, widening from 0.9–1.1 mm at the level of the first thecal pair to a distal maximum of 2.3–2.5 mm (2.1–2.7 mm when affected by tectonic strain). DVW varies from 2.0 mm to 2.4 mm at the tenth thecal pair. Proximal astogeny of pattern H, corresponds with other species of Rickardsograptus. Thl1 grows down before it turns up 0.2 mm below the sicular aperture. The upward growing part of th1 is ca 0.8 mm long. Virgella 1.7–9.5 mm long; robust nema projecting well beyond thecate part of the rhabdosome. Proximal thecae glyptograptid with blunt geniculum. Thelcal geniculation weakens through the most rapidly widening mesial part of the rhabdosome; substantially overlapping distal thecae exhibit smooth, weakly expressed genicula. Thecal tube terminates with perpendicular or slightly introverted aperture. 2TRD is 1.3–1.6 mm at the level of the second thecal pair, 1.45–2.1 mm at the fifth thecal pair; distal 2TRD varies from 1.7 mm to 2.4 mm depending on orientation of the rhabdosome relative to the strain.

Discussion. – The maximum width is attained at the 12th–14th thecal pair – more gradually than in most other species referred to Rickardsograptus [e.g. R. icherskyi (Obut & Sobolevskaya in Obut et al., 1967); R. thuringicus (Kirste, 1919) and R. macroterminatus (Churkin & Carter, 1970)] but more abruptly than in Rickardsograptus elongatus (Churkin & Carter, 1970) which also exhibits a particularly gradual change from more geniculated proximal to less geniculated distal thecae. The virgella is slender in all of the present specimens of R. lautus but its length (when complete) varies from 1.0 mm to 9.5 mm, which is greater variation than observed in topotypic material from Montagne Noire, France.
Rickardsograptus? bifurcus (Ye, 1978)
Figures 3L–N, 4B–D, K
1978 Glyptograptus bifurcus; Ye. p. 455, pl. 174, fig. 7.
1990 Glyptograptus bifurcus Ye. – Fang et al., p. 54, pl. 5, fig. 5; pl. 10, fig. 6.
2002 Glyptograptus bifurcus Ye. – Mu et al., p. 158, pl. 158, fig. 4.

Material and stratigraphical range. – 12 flattened, mostly complete rhabdosomes from the acuminatus Biozone at the Waterfall Section near Zollnersee Hütte.

Description. – Robust septate rhabdosome widens from 0.95–1.2 mm at the first thecal pair, through 1.45–1.8 mm at the third thecal pair, 1.7–2.0 mm at fifth thecal pair and 2.3–2.55 mm at the tenth thecal pair, to the maximum of 2.9–3.5 mm attained distally in the most mature specimens. Proximal end is of pattern H with thl1 growing down the sicular aperture. The upward growing part of thl1 is 0.95 mm long; thl1 is 0.8–0.9 mm long. The metathecae of the first thecal pair are markedly inclined to the rhabdosome axis. Also subsequent proximal thecae, although geniculate, exhibit suprageneric walls inclined to the rhabdosome axis at an angle of ca 30°. Thecal geniculation becomes still less recognizable in distal thecae. 2TRD varies, for the most part due to tectonic strain. It is 1.3–1.6 mm at th2, 1.55–1.7 mm at th5, 1.7–2.0 mm at th10 and 1.7–2.0 mm in the most distal thecae. The prominent virgella bifurcates 3.1–5.95 mm from the sicular aperture; the two branches attain a further 15–20 mm in length in mature rhabdosomes. These two branches, which are in the most mature rhabdosomes, diverge from a thickened, broadly triangular junction and form a convex V-shaped arc.

Discussion. – Several species of biserial graptolites furnished with a virgella bifurcating into two prominent branches have been described from China (“Glyptograptus” zhui Yang, 1964; “Diplograptus” bifurcus Mu et. al. in NIGP, 1974; “Orthograptus” lonchoformis Chen & Lin, 1978; “Orthograptus” lonchoformis gijiangensis Ye in Jin et al., 1982; “Orthograptus” furcatus Ye in Jin et al., 1982; “Glyptograptus” bifurcus Ye, 1978; “Climacograptus” bicaudatus Chen & Lin, 1978; “Climacograptus” bicau-datus praelongus Li in NIGMR, 1983; “Climacograptus” bifurcatus Jiao in NIGMR, 1983), all of them from the interval corresponding to the ascensus and acuminatus biozones. Flattened and, in part, slightly deformed rhabdosomes exhibit climacograptid (those in scalariform view), glyptograptid or almost orthograptid thecae. It is beyond the scope of this paper to resolve the whole synonymy of these taxa. Rhabdosomes found at the Waterfall Section have been assigned to R.? bifurcus because they have 1) a relatively broad proximal end of slightly subtriangular appearance and metathecae of the first thecal pair inclined to the rhabdosome axis, 2) smoothly geniculated proximal thecae and gradual loss of geniculation distally and 3) a prominent virgella which bifurcates 3.1–5.95 mm from the sicular aperture to form a large, convex V-shaped fork. Simply flattened Chinese specimens, without strain effects, widen from 1.0 mm at the first thecal pair to 2.3 mm distally, with thecae overlapping for about half their length (2/5–3/5) and numbering 12 in 10 mm of rhabdosome length. Ye (1978) assigned his new species to Glyptograptus which differs, according to current knowledge (summarized by Melchin et al. 2011), from Rickardsograptus in having proximal astogeny of Pattern I and the nema embedded in or tightly attached to the obverse wall of the rhabdosome. We have assigned this species tentatively to Rickardsograptus, which comprises septate neodiplograptids with particularly robust nemata and bifurcate thecae, strongly geniculated in the proximal part and almost orthograptid in the distal part – such as Rickardsograptus tcherskyi (Obut & Sobolevskaya), R. sinuatus (Nicholson, 1869), R. elongatus (Churkin & Carter), R. thuringiacus (Kirste), R. lautz (Storch & Feist) and R.? parajanus (Storch, 1983). The mesial widening of the rhabdosome is accompanied by retreat of theca geniculation. Rickardsograptus? bifurcus is assigned to this group with reservation due to its relatively weakly bifurcate thecae and only slightly geniculated proximal thecae. R? bifurcus Ye differs from the most similar species – “Diplograptus” bifurcus Mu et. al. – in its more densely spaced thecae (10–12 in 10 mm compared to 8–9 in 10 mm) and more robust proximal end. “Glyptograptus” zhui Yang, “Orthograptus” lonchoformis Chen & Lin, “Orthograptus” lonchoformis gijiangensis Ye, “Climacograptus” bicaudatus Chen & Lin, “Clima-cograptus” bicau-datus lanceolatus Li in NIGMR, 1983, “Climacograptus” bicaudatus praelongus Li, “Climacograptus” bifurcat

Jiao and “Orthograptus” furcatus Ye can be readily differentiated from R? bifurcus Ye by the early bifurcation of their virgellae (ca 1 mm below the sicular aperture) and the straight branches of the V-shaped fork. The extent of true thecal geniculation is hard to reconstruct in many Chinese specimens due to the different modes of their flattening and orientation of thecal profiles to the bedding plane. This is why the original generic assignments have been retained in quotation marks.

Genus **Glyptograptus** Lapworth, 1873, emend. Melchin et al., 2011

**Glyptograptus aff. tamariscus** (Nicholson, 1868)

Figure 3J, K

**Material and stratigraphical range.** – 2 flattened rhabdosomes from the acuminatus Biozone at the Waterfall Section near Zollnersee Hütte.

**Description.** – The rhabdosome of this early member of the aseptate glyptograptids attains a length of 16 mm. It widens from 0.85 mm at the first thecal pair, through 1.2–1.25 mm at the fifth thecal pair to a distal maximum 1.6 mm. The nema appears to be attached to the rhabdosome wall. The asymmetrical proximal end comprises a 1.1 mm long th1¹ and 0.95 mm long th1², which is slightly delayed in origin, leaving a 0.3 mm long part of the ventral side of the sicula exposed. Smoothly geniculate thecae with supragenicular walls markedly inclined to the rhabdosome axis correspond with those of other members of the tamariscus group. 2TRD increases from 1.5 mm at th2 to 2.1 mm in the most distal thecae.

**Remarks.** – Thecal overlap is greater than that in Glyptograptus dufkai Štorch, 1992 from the ascensus Biozone of Bohemia. The limited material available to date, however, does not allow definitive assignment of this form to one of the several closely morphologically similar species of the tamariscus group.

Genus **Parakidograptus** Li & Ge, 1981

**Parakidograptus acuminatus** (Nicholson, 1867)

Figures 3E–I, 4A, G, J

**Material and stratigraphical range.** – 25 flattened, mostly complete rhabdosomes from the acuminatus Biozone at the Waterfall Section near Zollnersee Hütte.

**Discussion.** – Typical wedge-shaped, slightly curved, septate biserial rhabdosomes of Parakidograptus acuminatus are fairly common in the Waterfall Section. The protracted proximal end is furnished with a short virgella which splits into more than two branches 0.2–0.3 mm below the sicular aperture. Maximum distal width of the rhabdosome attains 1.8–1.9 mm; distal 2TRD is 1.8–2.1 mm. A robust nema projects up to 15 mm beyond the thecate part. Thecae are straight, with apertures normal to the rhabdosome axis, which results in the typical acuminate profile of the thecae. Protraction of the proximal end, when quantified by the distance between sicular aperture and th1¹ aperture (1.8–2.2 mm), corresponds with that reported from stratigraphically younger populations of P. acuminatus (see Loydell 2007 for instance). However, insufficient preservation and tectonic strain prevent meaningful measurement and stratigraphical interpretation of these figures in a great majority of the present specimens.

**Acknowledgements**

Field work, carried out in 2010, was supported by ÖAW in the frame of a collaboration agreement with the Academy of Sciences...
of the Czech Republic. Grant IAA301110908 received by Petr Štorch from the Grant Agency of the AS CR contributed to the cost of manuscript preparation. Our thanks are due to Stéphan Manda and Filip Štorch for technical preparation of Fig. 2 and to Filip Storch for Fig. 1. Kathleen Histon kindly loaned her manuscript log through the Nöblinggraben Section for comparison with Oberbuchach-I Section. David K. Loydell and Michael J. Melchin are thanked for helpful comments on the manuscript.

References


