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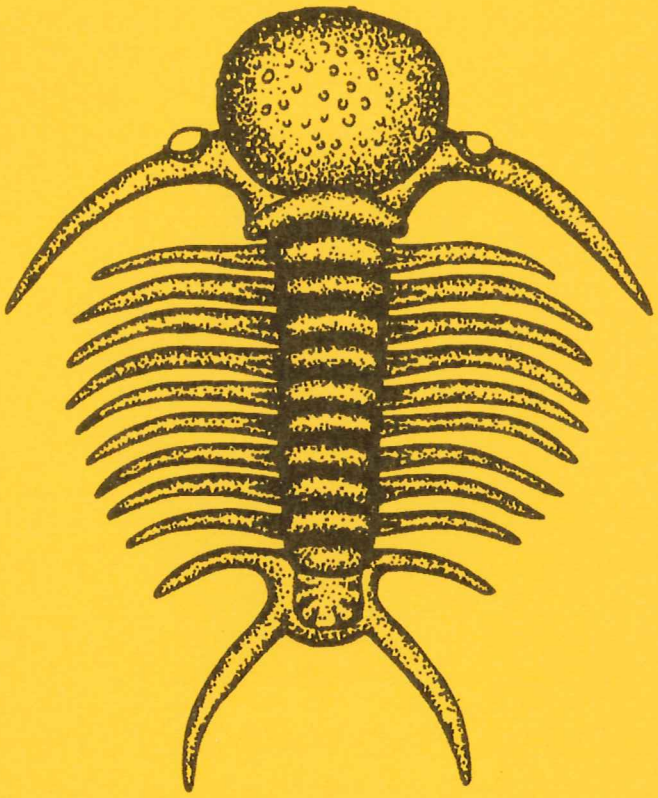

Silurian graptolites from Bohemia, Czech Rebublic

Christian Persson

Examensarbete, 20 p
Institutionen, Lunds Universitet

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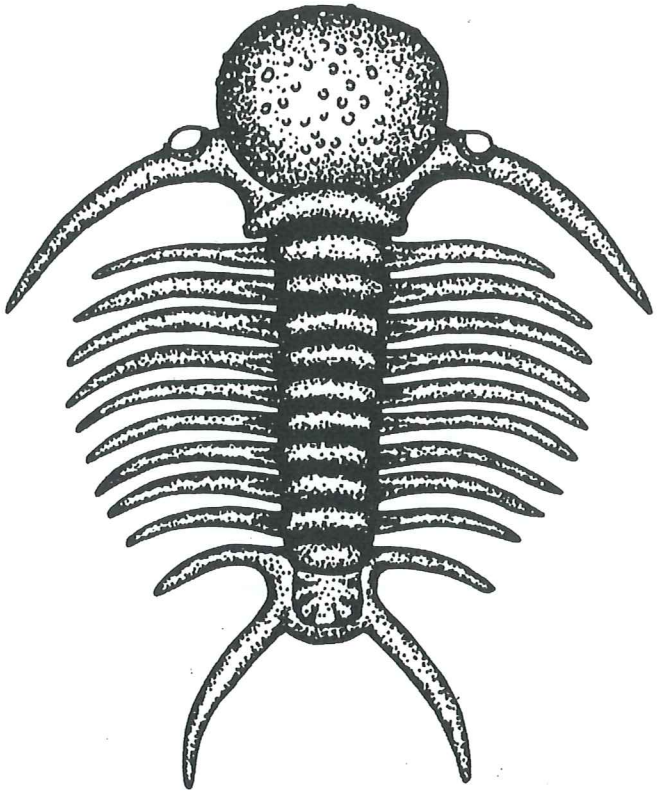

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CHRISTIAN PERSSON

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Abstract: The only relatively undisturbed Ordovician to Middle Devonian sequence in the Bohemian Massif is preserved in the central parts of the Prague Basin. This part stretches c. 35 km from Prague in the north towards Želkovice in the southwest. During Ordovician and Silurian times this area is thought to have been a part of the northern Gondwana margin. The lower Silurian shales were deposited in a tectonically controlled depression on a sediment-starved shelf with about 100-200 m water depth. Marine sedimentation in the Prague Basin started in the Tremadoc and continued to its culmination in mid-Devonian times during the Variscan Orogeny. The lower Silurian in the Prague Basin is composed of a continuous sequence of black shales, rich in fairly well preserved and highly diverse graptolite faunas. These faunas were the most cosmopolitan during graptolite evolution.

Graptolites mainly collected by J. C. Moberg in Bohemia in the summer of 1893 have been examined. The collections consist of more than 400 samples of shale and mudstone. 39 species (predominantly monograptids), ranging in age from lower Llandovery to lower Pridoli, have been identified. 16 of these are index graptolites in Bohemia, but since the material was not collected for stratigraphical purposes a proper correlation with other areas is difficult. No obvious trend of size variations between species from different faunas was discovered, though slight differences from coeval assemblages of Britain, Bornholm and Bohemia can be observed.

Keywords: Bohemian Massif, Prague Basin, Silurian, graptolites, monograptids, correlation.

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Bohemia in the Czech Republic is a classical area where a lot of studies have provided important palaeontographical data. In 1850, J. Barrande presented the classical paper *Graptolites de Bohême*, in which 21 different graptolites from Bohemia were described as well as their occurrence and stratigraphical distribution in the Prague Basin (Barrande 1850). Furthermore, he discussed the Silurian System with an attempt to correlate internationally. Since then, a lot of stratigraphical work has been carried out in the Prague Basin, continuously improving the zonal scheme of the so called Barrandian area (lower Palaeozoic). The first zonal scheme based on graptolites was introduced in 1919 by Perner and Kodym (information from Štorch 1994). About ten years later, from 1930-33, a more detailed zonal scheme was worked out by Bouček. According to Štorch (1994), these studies eventually resulted in a comprehensive biostratigraphic paper in 1953. New exposures and findings have since then led to minor improvements of the biostratigraphy (Štorch 1994).

The Silurian Prague Basin of Bohemia exhibits fairly well preserved and highly diverse graptolite faunas (Štorch 1994) within its variable facies development (Kříž 1992). Graptolites are mostly flattened but almost never tectonically distorted (Štorch 1994). Graptolite faunas with similarities to those in Bohemia can be found in e.g. Bornholm (Bjerreskov 1975), the British Isles (Rickards 1965, 1970, 1976), Alaska (Churkin & Carter 1996), Nevada (Berry & Murphy 1975), and in Poland (Urbanek & Teller 1997).

The examined graptolite faunas come from an old collection at the Department of Geology, Lund, and represent strata ranging from the *vesiculosus* Biozone in the Mid-Rhuddanian of the lower Llandovery up to the *ultimus* Biozone in the lower Pridoli.

Geological setting

The only relatively undisturbed Ordovician-Middle Devonian sequence in the Bohemian Massif is preserved in the central parts of the Prague Basin. This area (Fig. 1) extends c. 35 km from Prague in the north-east towards Želkovice in the south-west. During Ordovician and Silurian times this area is thought to have been a part of the northern margin of Gondwana (Štorch 1990). The lower Silurian shales were deposited in a tectonically controlled depression (Kříž 1990) on a sediment-starved shelf with about 100-200 m water depth (Štorch 1994).

The classical Barrandian area is renowned for its exceptionally fossiliferous sedimentary units. It consists of the Prague Basin and an area with Cambrian deposits; the Pribram-Jince Basin south of Želkovice (Štorch 1994). Marine sedimentation in the Prague Basin start-

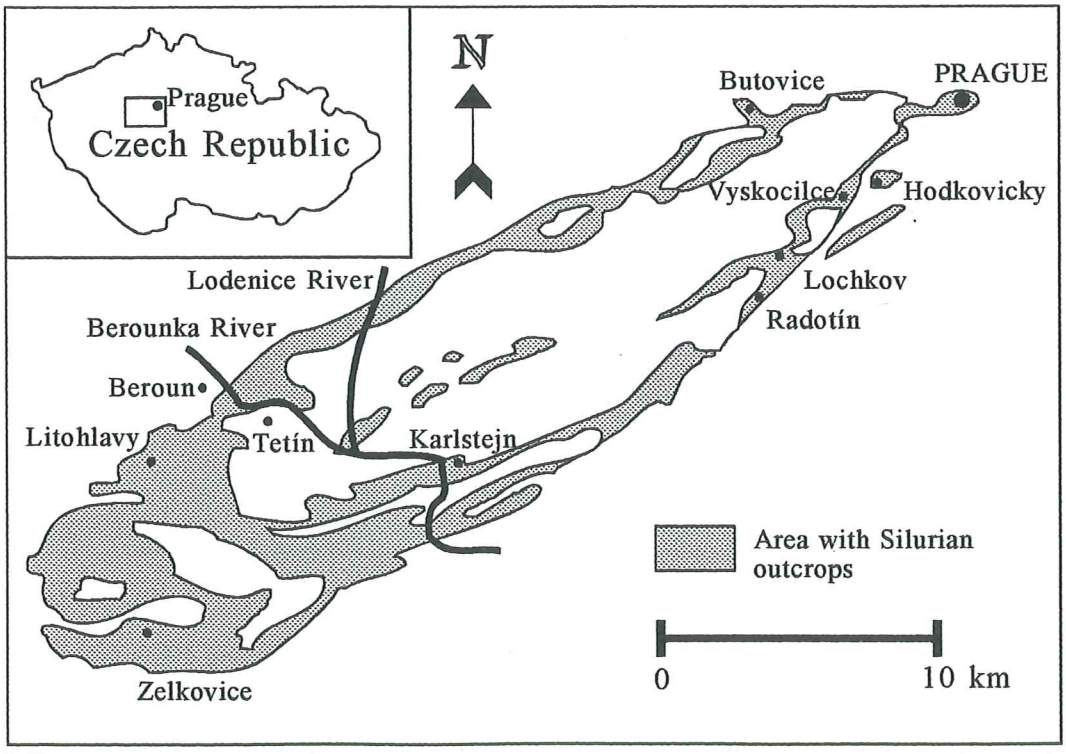
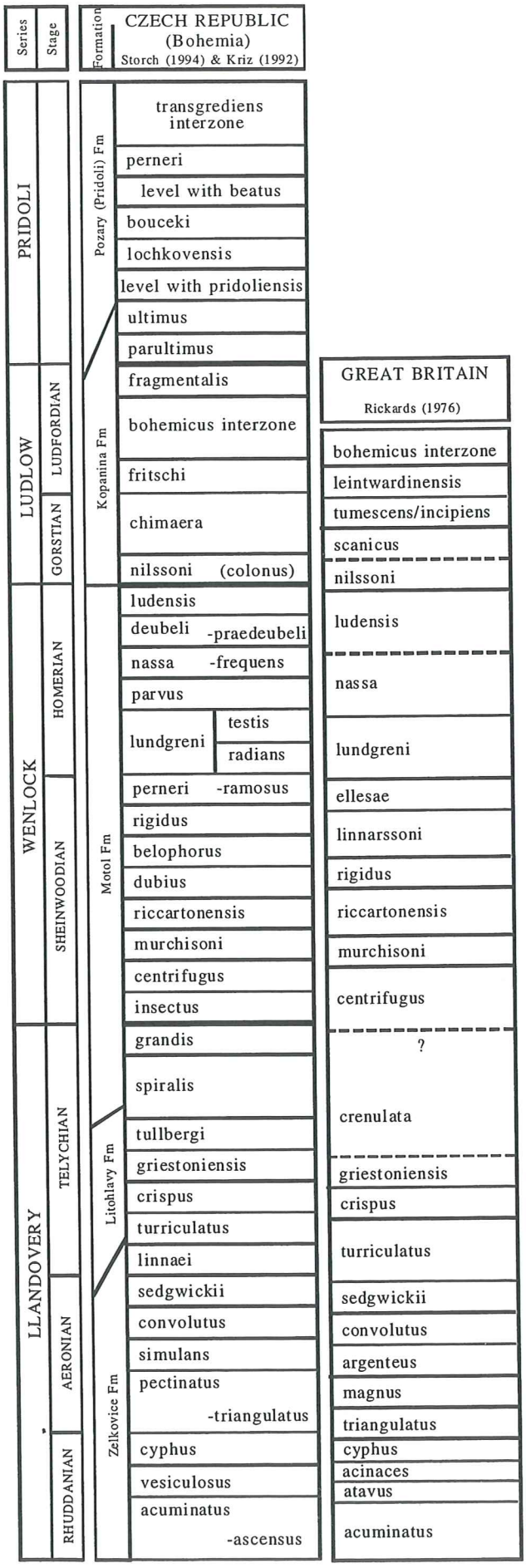


Fig. 1: Map of the Prague Basin in the Czech Republic.



ed in the beginning of the Silurian and continued to its culmination in mid-Devonian times and sedimentary rocks from the Ordovician, Silurian and Devonian were weakly folded during the Variscan Orogeny (Kříž 1990). Later these Palaeozoic sequences were again folded and faulted, which resulted in erosion of vast areas. Nowadays, the Silurian strata are confined to the area between Prague and Želkovice.

In the Prague Basin, the Silurian consists of five formations (Fig. 2): the Želkovice Formation (L. and M. Llandovery), the Litohlavy Formation (U. Llandovery), the Motol Formation (uppermost Llandovery and Wenlock), the Kopanina Formation (Ludlow), and finally the Požáry Formation (Pridoli).

Black graptolitiferous shales dominate the lower Silurian. During the middle and upper Wenlock, volcanic highs were formed from submarine basalt outlets. These highs were surrounded by shallow water limestone facies. In Ludlow time the limestone facies extended over most of the basin, while black shale facies was limited to the deeper parts. The upper Ludlow and Pridoli are recognised mostly by biodetrital and bioclastic limestones (Štorch 1994).

The Silurian biostratigraphy in the Barrandian area is based on graptolites and defined by 36 range-biozones, and two proliferation zones in the late Silurian (the *bohemicus* interzone and the *transgrediens* interzone) and also two undefined levels (Fig. 2), roughly corresponding with the chronostratigraphic units. The lower Silurian graptolite faunas are the most cosmopolitan during graptolite evolution, but certain provincialism did exist. Faunas from northern Canada, Alaska, and Siberia differ from those in Gondwanan Europe, Baltoscandia and South America (Štorch 1994).

The Želkovice Formation consists at its base of black and clayey shales, belonging to the *ascensus-acuminatus* Biozone (Kříž 1990). These black shales are overlain by laminated black sandy-micaceous mudstone in the upper parts of the zone. The mudstones correspond with a hiatus in the northeastern part of the outcrop area. This was caused by a sudden rise of sea level, which restricted the supply of sedimentary material into the basin. Furthermore, the rise of sea level led to a change of currents in the Prague Basin. These currents contributed to reworking of sediments in the Prague Basin, locally resulting in hiata or condensation of the sequence (Štorch 1994). In the younger succeeding biozones, the *vesiculosus – triangulatus* Biozones, laminated mudstones are usually replaced by shales. In the middle of the *sedgwickii* Biozone in the upper part of the Želkovice Formation, a new depositional mode began to dominate, with the onset of black clayey shales with thin greenish intercalations (Kříž 1990). The mean thickness of the black shale sequence of the Želkovice Formation is about 15 m (Štorch 1994).

Fig. 2: Silurian biostratigraphy of the Prague Basin and a correlation with Great Britain.

The major part of the Telychian Stage is represented by the Litohlavy Formation, which in principal comprises black shales, rich in graptolites (Štorch 1994). The reduced facies diversity of the upper parts of the Želkovice Formation is characteristic for the whole of the Litohlavy Formation. This reduction reflects increasing depth of the basin due to continuous transgression and slow synsedimentary movements (Kříž 1990). The shales have numerous intercalations of greenish or yellowish claystones and mudstones, usually bioturbated (Štorch 1994). The bioturbation indicates a more favourable environment for benthic organisms than during the formation of the Želkovice sediments (Kříž 1990). The mudstone intercalations have been explained as formed in periods with better oxygenation of the bottom environment, although a volcanic explanation can not be excluded (Štorch 1994). The mean thickness of the Litohlavy Formation in the outcrop area is about 40 m, but in some places, it can be as thick as 75 m (Štorch 1994).

The succeeding formation, the Motol Fm, shows that there was a progressive environmental change in the basin. Varied litofacies and biofacies appear in the beginning of the late Telychian (Štorch 1994) due to a distinct shallowing of the basin (Kříž 1990). At the base of the Motol Formation, the first appearances of carbonate within the shale can be noted. The barren intercalations disappear here. A major increase of carbonate content occurs in the topmost Telychian and in the Sheinwoodian, and black calcareous shales occupy most of the basin (Kríz 1990). Strong volcanic activity was initiated at the beginning of the *belophorus* Biozone along the northwestern flank of the basin, where a large submarine elevation was created (Štorch 1994). This volcanic complex was fringed by various tuffitic-carbonate sediments with a rich and diverse shallow water fauna. Graptolite shales were limited to deeper parts of the Prague Basin. Elsewhere, volcanic input does not appear until the *lundgreni* Biozone. The shaly facies in the Motol Formation is usually between 50 and 70 m thick, and the volcanic-carbonate facies reaches about 350 m (Štorch 1994).

The lower boundary of the Kopanina Formation coincides with the base of the *nilssoni* Biozone. The facies development near the volcanic centres is diverse, though the deeper parts of the basin had monotonous sedimentation of calcareous shales with tuffaceous input (Kříž 1990). The formation displays a varying average thickness with a minimum of 32 m and a maximum of 150 m in the southern part of the basin (Kříž 1990).

The uppermost formation in the Prague Basin is the Požáry (Prídolí) Formation with a diachronous lower boundary. The Požáry Formation is distinguished by transition from the more facially diverse Kopanina Formation to a sequence of dark platy limestones with calcareous shale intercalations (Kříž 1990). These platy limestones were deposited in the deeper parts of the basin under low oxygen conditions during the Prídolí transgression. The upper part of the formation is characterised by the occurrence of bioclastic crinoid and cephalopod limestones, deposited during the subsequent regression (Kříž 1990).

Systematic palaeontology

Terminology.- The terms used to describe the morphology of the graptolites herein are in accordance with Bulman (1970). The length of the rhabdosome is exclusive of the virgella and virgula, and the width is generally the total dorso-ventral width of the rhabdosome, measured in the proximal part and at 10 mm from the aperture of the sicula. "Two thecae repeat distance", abbreviated 2TRD, is according to Howe (1983). Here 2TRD is generally measured between th2 and th3.

The classification follows Bulman (1970), though the systematic order on generic and specific level is written alphabetically. The material discussed herein was collected in Bohemia by J.C. Moberg in the summer of 1893.

Repository.- Specimens discussed and illustrated are deposited at the Department of Geology, Lund University, Sweden

Family Dendrograptidae Roemer *in* Frech, 1897

Genus *Rhabdinopora* Eichwald, 1855

Rhabdinopora sp.
Not figured

Material.- Fragments from approximately six specimens, poorly preserved in grey mudstone. The samples were collected at an unknown locality.

Remarks.- The rhabdosome belongs to the genus *Rhabdinopora*, but since the preservation of the material discussed herein is poor and no match with known species is found, the identification is set as *Rhabdinopora* sp.

The length of the dissepiments varies between 0.15-0.5 mm and they are set apart at 0.4-1.65 mm. Furthermore, the dissepiments of the present material have an average width of 0.05 mm, though occasionally thinner. The stipes of the probable mid-rhabdosome average a width of 0.2 mm and number 18-27 per 10 mm.

Family Diplograptidae Lapworth, 1873

Genus *Climacograptus* Hall, 1865

Climacograptus scalaris (Hisinger, 1837)
Fig. 4K-L

Material.- 8 specimens, which are all preserved as flattened carbon film in either black shale or grey mudstone. The specimens were collected in the area of Litohlavy and at unknown localities.

Remarks.- The preservation of the specimens are of varying quality and for this reason, not all of the different attributes have been measured on every single specimen. The 2TRD varies from 1.1 to 1.7 mm between $th2^1$ and $th3^1$. The deviation is not alarmingly great since the prox-

imal growth pattern of thecae can be somewhat irregular, but is still usually more regular than counting the number of thecae (Howe 1983). The number of thecae per 10 mm is 11-14 in contrast to Wærn's (1948) 10-12.5 measured on material from Kullatorp, Västergötland. Measurements on the species show a general width and length of 1.5 mm and 2 mm respectively (Elles & Wood 1901-1918), which is close enough to both the specimens measured here and to those of Wærn (1948). The specimens described by Wærn (1948) have a proximal rhabdosome width of 1.5 mm, while that of the present material shows a variation from 1.5 to 2.0 mm. As with the Kullatorp specimens, a virgella is usually present, though broken most of the time. The length of the virgella is 0.95-1.85 mm, compared to 1.3-3.1 mm in the specimens examined by Wærn (1948). The somewhat greater variation of the Bohemian material can be due to presence of different varieties of the species.

Occurrence.- According to Rickards (1976) *Climacograptus scalaris* is found from the base of the *argenteus* Biozone to the top of the *sedgwickii* Biozone in mid-Llandovery. In Bohemia, however, *Climacograptus scalaris* is only found within the *linnaei* Biozone of the lowermost Telychian Stage (Štorch 1994).

Genus *Petalograptus* Suess, 1851

Petalograptus altissimus Elles & Wood, 1908
Fig. 4H

Material.- One flattened specimen preserved in black shale at Litohlavy.

Remarks.- The rhabdosome is large and massive. It is 20-30 mm long, with a thecal number of ten per 10 mm (Elles & Wood 1901-1918). Bjerreskov (1975) described specimens of *P. altissimus* from Bornholm with a thecal density of 13-16 in the proximal 10 mm. Apart from the higher thecal count on Bjerreskov's material, the specimens are similar. The Bohemian material is similar to Bjerreskov's, though there are some size differences. The proximal width on the present material is 1.2 mm and the distal width is 3.0 mm, compared to 0.5 mm and 3.5-3.8 mm measured by Bjerreskov (1975).

Occurrence.- The species occurs in the middle part of the *turriculatus* Biozone at Øleå, Bornholm (Bjerreskov 1975), while it has a longer range in Britain, where it is found in the *sedgwickii* and *turriculatus* Biozones (Elles & Wood 1901-1918). In the Barrandian area, its stratigraphical range is from the upper *linnaei* Biozone to the top of the *griestoniensis* Biozone (Štorch 1994).

Family Retiolitidae Lapworth, 1873

Genus *Retiolites* Barrande, 1850

Retiolites geinitzianus (Barrande, 1850)
Fig. 5D

Material.- 7 flattened specimens in black shale collected at Radotín and 4 flattened specimens preserved in either black shale or black clayey shale from Litohlavy and its surroundings.

Remarks.- The rhabdosome is straight with a rounded proximal end. The width across th1[1] varies between 0.85-1.05 mm on the present material. It should be noted however, that this attribute has not been measured on all specimens since the proximal portion is missing in a few specimens. The distal width varies between 2.3 and 3.4 mm. This variation can be due to either widening of the rhabdosome during compaction or to the natural difference between two varieties: *R. geinitzianus geinitzianus* and the smaller *R. geinitzianus angustidens.* The virgula is 1.75-2.15 mm long.

Material from Bornholm examined by Bjerreskov (1975) shows that the variety *R. geinitzianus angustidens* never exceeds the width 3.0 mm in the distal portion, while *R. geinitzianus geinitzianus* can be as wide as 3.9 mm. The width across th1[1] is about the same in both types on the Bornholm material, only differing 0.05 mm with *R. geinitzianus geinitzianus* being the smaller one at 0.75 mm. Which of the two subspecies the present specimens belong to can not be determined.

Occurrence.- In the Prague Basin *R. geinitzianus geinitzianus* has a much shorter range than *R. geinitzianus angustidens,* from which the former may have evolved (Bjerreskov 1975). *R. geinitzianus geinitzianus* occurs only in the *murchisoni* Biozone in the Sheinwoodian Stage of Lower Wenlock, while *R. geinitzianus angustidens* has a long range, from the base of *griestoniensis* Biozone to the lower *insectus* Biozone (Štorch 1994). This differs slightly from studies based on material from Scotland, Wales, Bohemia and Spain (Loydell et al. 1997). Globally, the stratigraphical range is greater, and *R. geinitzianus geinitzianus* has a range from the *?crispus* Biozone to the *murchisoni* Biozone and *R. geinitzianus angustidens* from the *crispus* Biozone to the *murchisoni* Biozone. On Bornholm, however, *R. geinitzianus geinitzianus* is only found within the *centrifugus* Biozone, and *R. geinitzianus angustidens* has a total range from the *?spiralis* Biozone to the *?centrifugus,* with a dominance in the *insectus* Biozone (Bjerreskov 1975). *R. geinitzianus angustidens* is the dominating *Retiolites* in graptolite assemblages of the upper Telychian (Loydell et al. 1997).

Genus *Spinograptus* Bouček & Münch, 1952

Spinograptus spinosus (Wood, 1900)
Fig. 5C

Material.- One flattened specimen preserved in black shale. Collected at an unknown locality in the Barrandian area.

Remarks.- The specimen is of poor quality and an only a few attributes have been measured. The maximum rhab-

dosome width (excluding apertural spines) is 2.15 mm and the length of the apertural spines are 1.2-1.5 mm. These measurements fit well with specimens from Nevada (Berry & Murphy 1975), which are described as having relatively short rhabdosomes which widen rapidly to a maximum width of 1.7-2.0 mm. The maximum width is then maintained throughout the remainder of the rhabdosome. Apertural spines are up to 1.7 mm long and are not connected to one another. The Nevada specimens are closely similar to British specimens of the species (Berry & Murphy 1975).

Occurrence.- In Britain *Spinograptus spinosus* is found in the lower Ludlow within the *nilssoni* Biozone (Elles & Wood 1901-1918) and this is also the case in Poland, where it has a relatively short range (Kozłowska-Dawidziuk 1997). In Central Nevada, however, *S. spinosus* is found in an interval between the last occurrence of *Testograptus testis* and the first occurrence of *Neodiversograptus nilssoni* and *Bohemograptus bohemicus* (Berry & Murphy 1975).

Genus *Stomatograptus* Tullberg, 1883

Stomatograptus grandis (Suess, 1851)?
Not figured

Material.- One flattened specimen with the proximal portion missing. Preserved in black shale and collected north of Tetín.

Remarks.- The specimen is incomplete and poorly preserved. However, the maximum rhabdosome width of the specimen is 3.1 mm, which is comparable to Bjerreskov's (1975) description at th10[1], where the width is 3 mm. Furthermore, the Bornholm material has a maximum width of 7 mm which is attained distally. The rhabdosome is straight and may reach a length of more than 60 mm. The width increases rapidly in the proximal portion from 1 mm across th1[1] to 6 mm between th10[1] and th30[1] (Bjerreskov 1975).

Occurrence.- In the Barrandian area, *Stomatograptus grandis* is the index fossil of the uppermost Llandovery. The *grandis* Biozone comprises the interval between the first occurrence of that species and the first occurrence of *Cyrtograptus insectus*, the following index graptolite (Štorch 1994). At Øleå on Bornholm, *Stomatograptus grandis* is found within the *lapworthi* and *centrifugus* Biozones (Bjerreskov 1975).

Family Monograptidae Lapworth, 1873

Genus *Bohemograptus* Přibyl, 1967

Bohemograptus bohemicus (Barrande, 1850)
Fig. 5A-B

Material.- 57 flattened specimens in grey laminated mudstone and one sample preserved in calcareous mudstone from Karlštejn.

Remarks.- The observed rhabdosomes have a distinct ventral curvature, straightening slightly distally. The rhabdosomes widen from 0.35-0.55 mm across th1 to 0.75-1.05 mm at 10 mm from the proximal end, which agrees relatively well with descriptions by Berry & Murphy (1975). The thecae in the present material are simple, tubular, with a slight overlap and widening from their base to the aperture. Berry & Murphy (1975) found that the ventral walls of the thecae are slightly curved. Specimens from Nevada (Berry & Murphy 1975) have a thecal count of 9-10 in the proximal 10 mm and British specimens examined by Elles & Wood (1901-1918) have 9-11 thecae per 10 mm. These thecal densities are slightly higher than in the present specimens, which have a thecal count of 7-10 thecae per 10 mm. The observed sicular have maximum widths of 0.35-0.45 mm which agrees well with observations made by Berry & Murphy (1975). Furthermore, the sicular apertures bear a virgella that is 0.6-0.95 mm long and also a short dorsal tongue. Berry & Murphy (1975) found specimens with virgellae as long as 1.5 mm and the dorsal tongue 0.2-0.4 mm. The present specimens agree well with illustrations of British specimens from Holland & Palmer (1974).

Occurrence.- *Bohemograptus bohemicus* is a common component of Ludlow graptolite faunas in the Prague Basin. The species gives name to an interzone in the upper Ludlow of the Barrandian area (Kříž 1992). In Britain *B. bohemicus* is common in the lower Ludlow, especially from the *scanicus* Biozone and up through the *tumescens/incipiens* Biozone, and reappearing again in the *bohemicus* Zone after having been absent in the *leintwardinensis* Biozone (Rickards 1976).

Genus *Campograptus* Obut, 1949

Campograptus communis (Lapworth, 1876)
Fig. 5E

Material.- Three flattened specimens preserved in black shale were collected at Litohlavy and by the Berounka River, and two specimens preserved in grey mudstone were collected by the Loděnice River.

Remarks.- The specimens of the present material are of varying quality, but resemble specimens of *Campograptus communis* as described from Bornholm by Bjerreskov (1975). The specimens are dorsally curved with the strongest curvature in the proximal part, where the dorso-ventral width is 0.4-0.5 mm across th1 and gradually widening to 0.8-0.85 mm at th8. The distal end is missing on the specimens but previously studied specimens show maximal dorso-ventral widths of 1.5 mm (Bjerreskov 1975) and 1.4 mm (Elles & Wood 1901-1918). The thecal count of 9 per 10 mm, in the present material, is slightly higher than that found by Elles & Wood (1901-1918), but the same as that found by Bjerreskov (1975).

Rickards (1970) found that the thecal count can be as high as 12 in 10 mm. The length of the sicula is 1.35-1.7 mm, which is longer than specimens studied by Elles & Wood (1901-1918) and Bjerreskov (1975). Measurements conducted by Elles & Wood (1901-1918) on British specimens showed a general length of 1.2 mm, while Bjerreskov's (1975) specimens never had a sicula exceeding 0.9 mm. The thecae are isolated and triangular with an apertural hook (Bjerreskov 1975).

Occurrence.- Campograptus communis has a vertical range from about the middle of the *pectinatus-triangulatus* Biozone to the middle of the *simulans* Biozone in the lower Aeronian Stage (Štorch 1994). This stratigraphical range corresponds to that in Bornholm, where the species has its first occurrence in the lower *gregarius* Biozone, with *triangulatus* and *pectinatus* as subzones. *Campograptus communis* disappears in the upper *gregarius* Biozone on Bornholm (Bjerreskov 1975). In Britain, the species has a range from the *triangulatus* Zone to the *argenteus* Zone (Rickards 1970).

Genus *Colonograptus* Přibyl, 1942

Colonograptus colonus (Barrande, 1850)
Not figured

Material.- Two flattened specimens, one preserved in black shale and collected at Vyskočilce and the other in grey mudstone from the area of Litohlavy.

Remarks.- The rhabdosome is straight, though gently curved ventrally in the proximal end, and the thecal density in the proximal portion is 10 per 10 mm. The proximal width is 0.7 mm and it widens to 1.25 mm at 10 mm from the aperture of the sicula. The virgula has a length of 2.2-2.3 mm. The observations on the present material agree with the description by Elles & Wood (1901-1918), although British specimens often show intraspecific variation (Elles & Wood 1901-1918).

Occurrence.- Colonograptus colonus is fairly abundant within the *nilssoni* Biozone in the lower Ludlow in Britain (Elles & Wood 1901-1918), where it should also appear in Bohemia.

Genus *Demirastrites* Eisel, 1912

Demirastrites cf. *convolutus* (Hisinger, 1837)
Fig. 5H-I

Material.- Nine flattened specimens preserved in black shale. The samples were collected at Litohlavy and its surroundings and at Radotín.

Remarks.- Due to preservation it has only been possible to make measurements on one specimen. But since the general appearance of the rhabdosome and the shape of the thecae on all the specimens resemble that of *Demirastrites convolutus*, it is most likely that all the specimens belong to the same species.

Bjerreskov (1975) described the species as more or less spirally coiled with the thecae on the convex side of the rhabdosome. Distally, the rhabdosome is less curved and occasionally with thecae on the concave side. The present specimen has a minimal dorso-ventral width of 0.6 mm and a maximum one of 1.25 mm. This is slightly less than in Bjerreskov's (1975) Bornholm material, which has a minimum width of 0.75 mm in the extreme proximal portion.

The thecae are isolated and rastritiform with hooks in the proximal portion. Distally, the thecae are also isolated but more slender and triangulate with the hooks retracted. The thecae number is 10 per 10 mm in the proximal portion; distally the count is 9 per 10 mm.

Occurrence.- Demirastrites convolutus is an index graptolite and defines the *convolutus* Biozone in the Aeronian Stage worldwide. In Bohemia, the species defines a taxon-range zone and has a vertical range from the base of the *convolutus* Biozone to the base of the next zone defined by *Stimulograptus sedgwickii* (Štorch 1994). In Britain, the species is also limited to the *convolutus* Biozone (Rickards 1976).

Demirastrites cf. *decipiens* (Törnquist, 1899)
Fig. 3B

Material.- Three flattened specimens preserved in black shale. The samples were collected in the area of Litohlavy.

Remarks.- The rhabdosome is coiled in an open spiral and usually a dorsal curvature. The thecae are isolated and slender in the proximal portion. Distally, the thecae become triangular with a conspicuous apertural hook (Elles & Wood 1901-1918). The thecal count on specimens from Bornholm described by Bjerreskov (1975) is 4 in 5 mm proximally and 8 per 10 mm distally, which is lower than that originally described by Törnquist (1899) and in the present material, both collections having 10 thecae per 10 mm. The distal rhabdosome width between thecae varies between 0.6-0.85 mm, while specimens examined by Bjerreskov (1975) showed a width of 0.65 mm across th1 and gradually widening to a maximum of 1.4 mm.

Occurrence.- In Bohemia, *Demirastrites decipiens* has its first occurrence in the lower *convolutus* Biozone, but does not become abundant until further up and then disappears in the middle of the zone (Štorch 1994). Also on Bornholm (Bjerreskov 1975), *D. decipiens* is limited to the *convolutus* Biozone, whereas in Britain it is found from the base of the *convolutus* Biozone to the middle of the *turriculatus* Biozone (Rickards 1976).

Demirastrites pectinatus (Richter, 1853)
Fig. 4D

Material.- Two flattened specimens preserved in black shale. The sample locality is unknown.

Remarks.- Bjerreskov (1975) described *Demirastrites pectinatus* as having a dorsally flexed rhabdosome with the proximal portion recurved and forming a hook. The distal part is more gently curved. The present material lacks the most proximal end and hence, no hook-like portion can be observed. The specimens collected in Bohemia measure 0.2-0.35 mm between thecae in the upper proximal part of the rhabdosome, widening to 0.5 mm distally in between thecae. Bjerreskov (1975) measured the dorso-ventral width across th1 to 0.5 mm and a maximum width of 1.8 mm in the distal end.

The thecae are triangular and isolated throughout the rhabdosome; the proximal thecae being more slender with a small apertural hook (Bjerreskov 1975). The state of preservation of the present specimens obscures thecal details.

Occurrence.- In the Barrandian area *Demirastrites pectinatus* is one of the index fossils in the concurrent range zone, *triangulatus-pectinatus* Biozone. *Demirastrites pectinatus* has its first appearance in the lower quarter of the zone and continues up to a little above the first appearance of *Demirastrites simulans* (Štorch 1994). On Bornholm *D. pectinatus* first appears in the middle of the *gregarius* Biozone and continues throughout the *pectinatus* Subzone (Bjerreskov 1975).

Genus *Monoclimacis* Frech, 1897

Monoclimacis cf. *griestoniensis* (Nicol, 1850)
Fig. 4I

Material.- Two black clayey samples of shale; one with hundreds of flattened fragments of *Monoclimacis* cf. *griestoniensis*, and one with c. 20 fragmentary specimens collected at Litohlavy. Two flattened specimens preserved in black shale are from the area of Beroun.

Remarks.- The rhabdosomes of the present material are straight and slender with dorso-ventral widths of 0.1-0.2 mm and 0.45-1.05 mm. The thinner specimens probably represent proximal parts, since measurements made by Bjerreskov (1975) show widths of 0.2 mm proximally to 0.8-0.9 mm distally.

The specimens investigated herein are poorly preserved, but they agree with the description by Bjerreskov (1975). According to Bjerreskov (1975), thecae are slender with parallel-sided protheca and specimens in relief show prothecal folds, which are weakly developed on some of the present specimens. Well preserved specimens from Bjerreskov's Bornholm material show that the apertural portions of the thecae are retroverted, forming small, closely adpressed hooks with the apertures facing the proximal end. The thecal count in the proximal portion is 11 in 10 mm and distally the thecae number 10 in 10 mm (Bjerreskov 1975), which agrees with the material discussed herein.

Occurrence.- In the global standard *Monoclimacis griestoniensis* has given name to the mid-Telychian biozone *griestoniensis*. In Bohemia, *M. griestoniensis* has a vertical range from the base of the *griestoniensis* Biozone to the lowermost *spiralis* Biozone, where it is rare (Štorch 1994). On Bornholm the species is found from the base of the *griestoniensis* Biozone to the base of the following *spiralis* Biozone (Bjerreskov 1975).

Monoclimacis vomerinus (Nicholson, 1872)
Fig. 3A

Material.- 42 flattened specimens, usually preserved in black shale but occasionally in grey, laminated mudstone. The material was collected at Litohlavy and its surroundings and along the Berounka River, and at Hodkovičky, Vyskočilce, Radotín and unknown localities.

Remarks.- The rhabdosome is usually straight, but can occasionally be dorsally curved in the proximal end. The thecal density is 11-12 per 10 mm in the proximal portion. The rhabdosome is 0.3 mm wide just below th1, widening to 0.6-1.6 mm distally at 10 mm. It should be noted that only a few specimens have been measured, because several specimens lack the proximal and distal portions and are poorly preserved. Though there is not a perfect match in the measurements compared to Bjerreskov's (1975) material from Bornholm, there is no doubt in the identification, due to the typical thecal shape of *M. vomerinus*. According to Bulman (1970), a *Monoclimacis* theca has a straight supragenicular wall which is almost parallel to the axis of the rhabdosome, and slightly everted apertural margins. However, there is a great chance that the present material includes different morphotypes, since the measurements fit the descriptions of different varieties of Elles & Wood (1901-1918). Bjerreskov (1975) considered *Monoclimacis vomerinus* to belong to the genus *Monograptus*, but identified the thecal type as that of *Monoclimacis*.

Occurrence.- *Monoclimacis vomerinus* has a long vertical range in the Barrandian area. Its first occurrence is in the uppermost part of the *spiralis* Biozone and it does not disappear until the middle of the *riccartonensis* Biozone (Štorch 1994). On Bornholm its stratigraphical range differs a bit, since the first occurrence is at the base of the *spiralis* Biozone and it continues all the way up to the top of the *centrifugus* Biozone (Bjerreskov 1975).

Genus *Monograptus* Geinitz, 1852

Monograptus atavus Jones, 1909
Fig. 3I

Material.- Two flattened specimens preserved in grey mudstone from the area of Litohlavy.

Remarks.- The rhabdosomes are slender with a gentle dorsal curvature. The width is varying between 0.3-0.35 mm between thecae. The thecal shape is simple with a 2TRD of 3.4-3.5 mm distally. The Bornholm specimens

described by Bjerreskov (1975) are all as fragmentary as the present material, but she found that the rhabdosome width increases gradually from 0.25 mm at th1 to a maximum of 1 mm distally. The thecae are slender tubes with an overlap from one fourth proximally to less than a half distally (Bjerreskov 1975). Rickards (1970) described the species as being more robust than, e.g., *Monograptus sanderssoni* Lapworth, 1876. In the proximal portion the rhabdosome is dorsally flexed, whilst distally it can vary between ventral, dorsal and straight (Rickards 1970). The number of thecae in uncompressed state is 7-11 per 10 mm, but elongated specimens show a lower density of 5-7 in 10 mm (Rickards 1970).

Occurrence.- Monograptus atavus has a short vertical range in the Barrandian area, from the base of the *vesiculosus* Biozone to just before the middle of the zone in the lower Llandovery (Štorch 1994). On Bornholm, the species is found in the *revolutus* Biozone (corresponding to the *cyphus* Biozone in Bohemia) and then again after another break in the middle of the *triangulatus* Subzone (Bjerreskov 1975). In Britain *M. atavus* has a slightly longer range from the base of the *atavus* Biozone to the base of the *triangulatus* Biozone, though very rare in the latter (Rickards 1970).

Monograptus belophorus (Meneghini, 1857)
Fig. 3D

Material.- 3 flattened specimens preserved in black shale. The samples were collected at an unknown locality in Bohemia.

Remarks.- The rhabdosome has a strong proximal curvature and distinctive sicula of 1.65-1.8 mm length. The thecal density is 10 per 10 mm in the proximal portion. The rhabdosome widens from 0.65 mm at th1 to 1.25 mm at 10 mm distally. 2TRD between th2 and th3 is 1.7 mm and the thecae are hooked with apertural spines in the proximal part. The present material agrees well with the description of *Monograptus flexilis* by Elles & Wood (1901-1918) and by Rickards (1965). Complete specimens have a typical S-shaped curvature, where the rhabdosome is dorsally flexed in the proximal portion and ventrally flexed distally (Rickards 1965).

Although the species was already described in 1857 by Meneghini, Elles & Wood (1901-1918) described it as a new species, *Monograptus flexilis* (Elles, 1900). However, there is no doubt that *M. flexilis* is a junior synonym of *M. belophorus*, though distal portions can be difficult to identify correctly.

Occurrence.- Monograptus belophorus is an index fossil in the Lower Wenlock and according to Rickards (1976) one of the most common species in Europe. Its stratigraphical range in Bohemia is from the base of the *belophorus* Biozone to just above the base of the next biozone, the *rigidus* Biozone (Štorch 1994). In Britain, *M. belophorus* is found from the base of the *linnarssoni* Biozone to the base of the next biozone (Rickards 1976).

Monograptus crinitus Wood, 1900
Fig. 4G

Material.- About 150 flattened specimens, possibly fragments, lying in clusters on two sample surfaces. The samples, consisting of black clayey shale, were collected at unknown localities.

Remarks.- The rhabdosomes are very slender, approximately 0.1-0.15 mm, with hooked metathecae. According to Elles & Wood (1901-1918), the rhabdosomes are irregularly flexed and very slender, widening from a thread-like proximal portion to 0.4 mm. The thecal count is 5-7 in 10 mm, the thecae being of the same type as in *M. scanicus*, but even more slender (Elles & Wood 1901-1918).

It would not be surprising if most of the specimens are only fragmentary, since they are very slender and hence, should break easily during post-mortem transportation.

Occurrence.- Monograptus crinitus appears in the *nilssoni* Biozone of the lower Ludlow in Britain (Elles & Wood 1901-1918). The most probable stratigraphical horizon in the Barrandian may therefore be the *nilssoni* Biozone.

Monograptus crispus Lapworth, 1876
Fig. 4A

Material.- Four flattened, fragmentary specimens preserved in black and grey shale from the area of Litohlavy.

Remarks.- The rhabdosome is S-shaped, where the proximal end is dorsally curved. The mesial portion of the rhabdosome is straight and the distal portion is ventrally curved. The thecae are isolated and somewhat enrolled, and the thecal density is 9-10 per 10 mm. The width in the proximal part is less than 0.2 mm and widens to a maximum of 1 mm in the mesial part (Bjerreskov 1975). The present material has a thecal count of 8-11 per 10 mm and the width of the rhabdosome between thecae in the mesial and distal portions, varies between 0.3-0.45 mm. The thecal density agrees well with the measurements by Bjerreskov (1975). The slightly wider mesial and distal widths may be due to preservation.

Occurrence.- In Bohemia *Monograptus crispus* can be found in the mid-*turriculatus* Biozone and then very rarely up to the base of the *crispus* Biozone. Here the species becomes abundant and continues to be so to the lowermost *griestoniensis* Biozone (Štorch 1994). On Bornholm, however, *Monograptus crispus* is very rare and is only found from the base of the *crispus* Biozone and it disappears below the base of the *griestoniensis* Biozone (Bjerreskov 1975).

Monograptus cf. *denticulatus* Törnquist, 1899
Fig. 3G-H

Material.- Two flattened specimens preserved in black shale, collected in the area of Litohlavy.

Remarks.- The rhabdosome of *Monograptus denticulatus* has a dorsal curvature with a hook-like proximal portion and gently curved proximal portion (Bjerreskov 1975), similar to *Demirastrites pectinatus.* There is no obvious hook-like proximal portion on the present specimens, but more of a loosely coiled proximal portion. The present measured specimen widens from 0.3 mm proximally to 0.8 mm in the distal portion. Specimens of *Monograptus denticulatus* examined by Bjerreskov (1975) show a rhabdosome width of 0.5 mm across th1, gradually increasing to a maximum of 1.3 mm.

The present thecal shape is isolated triangular with a slightly hooked appearance, but due to the state of preservation, details are indistinct. Specimens from Bornholm (Bjerreskov 1975) show biform thecae, though all are isolated and hooked. The four proximal thecae are rastritiform and distally the thecae become more triangular. Furthermore, the Bornholm specimens have a thecal count of 11 in 10 mm proximally and 9 in 10 mm distally.

All of the above mentioned attributes, apart from the coiled proximal portion, imply that the present material belongs to *Monograptus denticulatus.*

Occurrence.- In the Barrandian area, *M. denticulatus* has a relatively long vertical range. It first appears in the upper *simulans* Biozone and continues up to the transition from the *sedgwickii* Biozone to the *linnaei* Biozone (Štorch 1994). On Bornholm *M. denticulatus* is found in the *convolutus* Biozone (Bjerreskov 1975) and in Britain the species ranges from the *argenteus* Biozone to the *convolutus* Biozone (Rickards 1970).

Monograptus flemengii (Salter, 1852)?
Not figured

Material.- One flattened specimen, poorly preserved in black shale. The sample was collected somewhere along the Berounka River.

Remarks.- The specimen is poorly preserved with proximal and distal ends missing, but its general features strongly resemble those of *Monograptus flemengii.* Laursen (1940) investigated material from Bornholm and described the species as having a straight rhabdosome with a conspicuous dorsal curvature proximally. Distally at c. 30 mm from the proximal end it reaches its maximum dorsal-ventral width of 2.5 mm. The thecal density is 9-14 per 10 mm. Furthermore, it can be distinguished from *Monograptus priodon* due to its wider rhabdosome, larger thecal overlap, and stronger curvature in the proximal portion (Laursen 1940). The apertural regions of the thecae are abruptly narrow, giving them a beak-like appearance (Elles & Wood 1901-1918).

Occurrence.- In Bohemia, *Monograptus flemengii* has long stratigraphical range. It first appears in the uppermost part of the *belophorus* Biozone and continues up to the base of the *parvus* Biozone. *Monograptus flemengii* also has a long vertical range in Britain, where it is found from the mid-Sheinwoodian (the *rigidus* Biozone) to within the *lundgreni* Biozone in the mid-Homerian (Elles & Wood 1901-1918). At Øleå, Bornholm, *M. flemengii* is restricted to the *murchisoni* Biozone (Laursen 1940).

Monograptus gemmatus Barrande, 1850
Fig. 3N

Material.- 10 specimens preserved in black shale. All samples were collected at Tetín.

Remarks.- All the present specimens are fragmentary with a dorso-ventral width of 0.1-0.15 mm between thecae, which agrees with British specimens described by Rickards (1970). Furthermore, the present material has a thecal density of 6-7 per 10 mm, which is the same as Rickards' (1970) specimens from the *turriculatus* Biozone though older specimens in Britain have a higher thecal count of 10 in 10 mm. The rhabdosome width across thecae on Rickards' (1970) material never exceeds 0.26 mm whereas material examined by Štorch (1998*a*) has an average dorso-ventral width of 0.4 mm. The rhabdosome of a complete specimen is weakly coiled, probably into a conical spiral, with proximal thecae on the convex side and distal thecae usually on the ventral side of the curvature (Štorch 1998*a*). The thecal shape of *Monograptus gemmatus* is a thread-like protheca with a loosely hooked metatheca in the proximal portion, whilst distally the thecae become low and triangular with metathecal hooks (Štorch 1998*a*). Metathecal hooks are not visible on the present material due to its state of preservation.

Occurrence.- *M. gemmatus* is found throughout the *palmeus* Subzone of the lower *linnaei* Biozone in Bohemia (Štorch 1994). In Great Britain, however, *M. gemmatus* has a longer stratigraphical range, from the base of the *sedgwickii* Biozone to the base of the *crispus* Biozone (Rickards 1976).

Monograptus kolihai Bouček, 1931
Fig. 4B

Material.- One flattened specimen preserved in laminated mudstone. The sample is from the area of Litohlavy.

Remarks.- The rhabdosome is dorsally flexed and slender, having a width of 0.3 mm distally. According to Bouček & Přibyl (1951) the rhabdosome attains its maximum width a few millimetres from the sicula, a width then maintained along the entire rhabdosome. The thecae are bent semicircularly to a lobate shape and the distal 2TRD is 2.1 mm on the present material and the rhabdosome is ended in a 0.95 mm long virgula. Specimens described by Bouček & Přibyl (1951) are relatively short (15-30 mm), 0.4-0.6 mm wide, and the thecal density is 6-7 in 10 mm.

Occurrence.- Monograptus kolihai is endemic to the Silurian of Bohemia in the Czech Republic and Thüringen in Germany (Bouček & Přibyl 1951). In Bohemia the species range is from the uppermost *grandis* Biozone to the middle *murchisoni* Biozone, where it becomes less abundant (Štorch 1994).

Monograptus lobiferus (M'Coy, 1850)?
Not figured

Material.- Four flattened specimens preserved in black shale. The samples were collected at Litohlavy and at unknown localities.

Remarks.- The quality of the specimens is poor; the proximal portions are missing and this makes identification difficult. The thecal number is 11 per 10 mm and the width is generally about 0.6 mm between thecae. It was only possible to measure one specimen. The rhabdosome is straight with lobate thecae. According to Bjerreskov (1975) the proximal portion is always dorsally curved. Specimens examined by Bjerreskov (1975) show a widening from 0.5 mm across th1 to a maximum of 2 mm in the distal end. The thecal density in the proximal portion is 10 per 10 mm and 7.5 in the extreme distal part of the rhabdosome. Elles & Wood (1901-1918) describe *Monograptus lobiferus* as having a slender rhabdosome, widening fairly quickly from 0.2 mm to 2 mm and having a thecal count of 7-10 per 10 mm. However, since my material is poor, and measurements were carried out in only one specimen there is not a perfect match of measurements between the present material and that of previous studies, although there is a general resemblance, especially regarding the thecal shape.

Occurrence.- In Bohemia, *Monograptus lobiferus* ranges from the uppermost part of the *simulans* Biozone to the end of the *convolutus* Biozone (Štorch 1994). On Bornholm, however, it is only found within the *convolutus* Biozone (Bjerreskov 1975).

Monograptus planus (Barrande, 1850)
Fig. 4C

Material.- One flattened specimen with the proximal portion and the most distal parts missing. It is preserved in black shale, collected in the area of Litohlavy.

Remarks.- The present specimen is dorsally curved with the greatest curvature in the middle part. The thecae are triangulate with a tendency to be hooked; a description that fits with the specimens from Bornholm (Bjerreskov 1975). The thecal density of the present material is 10 per 10 mm and 11 further distally. The rhabdosome width is 0.4 mm. All these measurements agree with those by Bjerreskov (1975). British specimens described by Elles & Wood (1901-1918) have a higher thecal count.

Occurrence.- In the Barrandian, *Monograptus planus* has a stratigraphical range from the base of the *linnaei* Biozone in the lower Telychian to the lower part of the *turriculatus* Zone (Štorch 1994). On Bornholm *M. planus* is restricted to the *turriculatus* Biozone (Bjerreskov 1975). In Britain the species has a much greater vertical range than in both the Barrandium and Bornholm. *Monograptus planus* occurs from the lower *turriculatus* Biozone to the base of the *crenulata* Biozone in Great Britain (Rickards 1976).

Monograptus priodon (Bronn, 1835)
Fig. 3J-K

Material.- 32 flattened specimens preserved in black shale and one specimen in grey laminated mudstone, from an unknown locality. The rest of the material was collected at Prague, Radotín, in the area of Litohlavy, and at unknown localities.

Remarks.- Monograptus priodon has a long straight or slightly curved rhabdosome with hooked thecae. The sicula is 0.2-0.6 mm wide and across th1 it varies between 0.55-0.7 mm. The distal width at 10 mm is 1.45-2.4 mm. 2TRD between th2 and th3 is 1.1-1.7 mm and the width of the sicula is 0.2-0.4 mm. The number of thecae in the first 10 mm is 11-14. In the description by Elles & Wood (1901-1918), the initial width is 0.75 mm and reaches a maximum of 3 mm distally. The thecal number varies between 8-13 per 10 mm. This description is close to the present material and to that of Bjerreskov (1975), where the width of the rhabdosome initially, across th1, is 0.6-0.75 mm, reaching a maximum of 2.5-3.0 mm. Bjerreskov (1975) also noted that early specimens in the *turriculatus* Biozone tend to be wider in the proximal portion than stratigraphically younger ones.

Occurrence.- Monograptus priodon has a long range in the Barrandian area, where its first occurrence is in the middle of the *griestoniensis* Biozone and it does not disappear until the base of the *riccartonensis* Biozone in Wenlock (Štorch 1994). On Bornholm *M. spiralis* has an earlier first occurrence, where it is found already in the uppermost *turriculatus* Biozone and continues up through the entire *centrifugus* Biozone, where the Silurian shale facies ends. Previous studies in Britain (Elles & Wood 1901-1918) also show a long range for *M. spiralis*, from the *?turriculatus* Biozone to the top of the *linnarssoni* Biozone (comparable to the *rigidus* Zone in Bohemia).

Monograptus scanicus Tullberg, 1883
Fig. 3M

Material.- One flattened specimen preserved in black clayey shale from an unknown locality.

Remarks.- The proximal and distal parts of the ventrally flexed rhabdosome are missing. The thecal number is 7 per 10 mm on the present material, which is slightly lower than its British counterparts (Elles & Wood 1901-1918), which have a thecal count of 8-9 in 10 mm. The different

thecal densities are due to the circumstance that Elles & Wood counted thecae in the proximal portion, while in the present investigation the number of thecae was counted in the mesial and distal portion of the rhabdosome. The general rhabdosome width is 0.35 mm across thecae, which are simple with a hooked metatheca. Specimens described by Elles & Wood (1901-1918) widen from a thread-like initial portion to a maximum width of 1 mm.

Occurrence.- In Britain, *Monograptus scanicus* has a stratigraphical distribution from the middle of the *nilssoni* Biozone to the top of the *scanicus* Biozone (Rickards 1976), the latter being contemporary with the *chimaera* Biozone of Bohemia.

Monograptus sedgwickii (Portlock, 1843)
Fig. 4J

Material.- One flattened specimen preserved in black clayey shale from an unknown locality.

Remarks.- The rhabdosome is straight or gently curved. Thecae are hooked and an apertural spine can be seen on some thecae. Since the specimen is incomplete, proximal and distal measurements are not possible. The general appearance of the specimen suits the description by Churkin & Carter (1996).

Occurrence.- *Monograptus sedgwickii* is a global index fossil. In Bohemia the vertical range of the species is within the *sedgwickii* Biozone (Štorch 1994). In Britain, *M. sedgwickii* is found from the uppermost part of the *convolutus* Biozone to the top of the *sedgwickii* Biozone (Elles & Wood 1901-1918). In North America, it ranges from the top of the *convolutus* Biozone to the base of the *turriculatus* Zone (Churkin & Carter 1996).

Monograptus spiralis (Geinitz, 1842)
Fig. 3L

Material.- 7 flattened specimens all preserved in black shale. The material was collected at Hodkovičky, Radotín and Tetín.

Remarks.- The rhabdosome is coiled in a spiral with isolated triangular and hooked thecae. The rhabdosome widens proximally from 0.6-0.7 mm to 3 mm distally (Bjerreskov 1975). The rhabdosome width on the present material varies between 0.7-2.0 mm. This variation is probably due to the preservation of the graptolites. The thecal number is 9-10 per 10 mm which fits with the descriptions by Bjerreskov (1975) and Elles & Wood (1901-1918). The thecal number is lower in the distal portion (Bjerreskov 1975). The common canal occupies a great portion of the rhabdosome and according to Bjerreskov (1975) it grows from ¼ proximally to ½ of the rhabdosome distally. Furthermore, the Bornholm material (Bjerreskov 1975) shows that most specimens reach a length of 10 cm, but can be as long as 50 cm, which is twice as much as described by Přibyl in 1944 (from Bjerreskov 1975).

Occurrence.- *Monograptus spiralis* is an index fossil in the Telychian Stage in the Barrandian area as well as on Bornholm. In the Czech Republic, the *spiralis* Biozone is an abundance zone, which represents the interval where the index fossil is particularly abundant. The first occurrence of *M. spiralis* is in the upper *tullbergi* Biozone and the last occurrence in the lowermost part of the *grandis* Biozone (Štorch 1994). This correlates relatively well with Bornholm, but *M. spiralis* is found much lower in Britain, that is in the *crispus*- and *griestoniensis* Biozones (Rickards 1970).

Genus *Neocolonograptus* Urbanek, 1997

Neocolonograptus ultimus (Perner, 1899)
Fig. 5L

Material.- 15 specimens preserved either as moulds or in relief in calcareous mudstone collected in the area of Litohlavy. Also, several hundred specimens preserved as moulds or in relief in calcareous mudstone from Lochkov Quarry. The latter samples were collected during the Department excursion to Czechoslovakia in the summer of 1967.

Remarks.- Proximal and distal ends are usually missing on the present specimens but otherwise these are relatively well preserved. The specimens with intact proximal portions display a distinct virgella of c. 0.3 mm and a conspicuous dorsal process. The rhabdosome is straight with a dorso-ventral width of 0.45-0.5 mm across th1 and it gradually widens to 0.85-1.25 mm at 10 mm from the proximal end. Urbanek (1997) described rhabdosomes from Poland as 0.5 mm immediately beyond th1 and 0.75 mm at th5. The thecae are of pristiograptid general shape but provided with elaborated apertures forming either paired lobes or conspicuous elevations on the apertural border (Urbanek 1997). This feature can not be observed on the present material since the thecal apertures probably have become blunt during compaction and diagenesis.

Occurrence.- In the Barrandian area *Neocolonograptus ultimus* defines a rather thin (c. 4 m) but distinct zone (Urbanek & Teller 1997). In Britain, *N.* cf. *ultimus* is found within the *leintwardinensis* Biozone (Elles & Wood 1901-1918).

Genus *Neodiversograptus* Urbanek, 1963

Neodiversograptus nilssoni (Barrande, 1850)
Fig. 4F

Material.- One flattened specimen in black shale from the area of Litohlavy.

Remarks.- The present specimen is incomplete with no

proximal or distal end. The rhabdosome is slender and ventrally curved and has a dorso-ventral width of 0.1-1.15 mm, which is the same as in specimens from Nevada examined by Berry & Murphy (1975). The thecae are simple, slender tubes and Berry & Murphy (1975) described them as becoming slightly wider and free from overlap in the medial and distal parts. Proximally, the thecae are 5 to 6 times as long as wide and distally 3 to 3.5 times as long as wide (Berry & Murphy 1975). Elles & Wood (1901-1918) found the thecae to have a slight tendency to sigmoidal curvature. Specimens from Nevada (Berry & Murphy 1975), usually have a thecal count of 8-8.5 per 10 mm, which agrees with the present specimen. Complete rhabdosomes are S-shaped with the proximal portion dorsally curved (Berry & Murphy 1975).

Occurrence.- Both in Britain (Rickards 1976) and Bohemia (Kříž 1992) *Neodiversograptus nilssoni* has a relatively short range, restricted to the *Neodiversograptus nilssoni* Biozone. In Nevada, *N. nilssoni* is found within the *colonus* Biozone and the *chimaera* Biozone (Berry & Murphy 1975).

Genus *Pristiograptus* Jaekel, 1889

Pristiograptus sp.
Fig. 5J-K

Material.- 4 flattened specimens preserved in black shale from different localities in the Barrandian area, e.g. Tetín, Beroun area and along the Berounka.

Remarks.- Due to the state of preservation of the present specimens, a closer identification is not possible.

Pristiograptus is characterised by simple, tubular or cylindrical thecae with a straight or only slightly curved ventral wall and simple, unadorned apertural margins (Berry & Murphy 1975).

The observed specimens are straight with relatively slender rhabdosomes. The dorso-ventral width across th1 varies between 0.5-0.75 mm and widens gradually to 1.45-1.5 mm at 10 mm from the proximal end. The thecal density is 10 per 10 mm. These observations and the general appearance agree with the description of *Pristiograptus vulgaris* (Wood, 1900), which is found in the *lundgreni* Biozone in Britain (Elles & Wood 1901-1918).

Genus *Rastrites* Barrande, 1850

Rastrites spp.
Not figured

Material.- Numerous flattened fragments in black or grey shale from the area of Litohlavy and localities along the Berounka.

Remarks.- The present material consists of fragmentary rhabdosomes, which makes identification difficult. The rhabdosomes are dorsally curved with straight, isolated and tubular thecae with hooked and retroflexed apertures. This agrees well with the diagnosis of the genus by Bulman (1970). The present material probably represents two or more species; one having a thecal interspacing of 0.6-0.9 mm with 1.95-2.45 mm long thecae and the other ranging 0.3-0.5 mm interthecae, and with a thecal length of 1.65-2.25 mm. The former species resembles *Rastrites longispinus* in appearance but with slightly shorter thecae.

Genus *Saetograptus* Přibyl, 1942

Saetograptus chimaera (Barrande, 1850)
Fig. 3E

Material.- Eight flattened specimens preserved in grey mudstone. The material was collected at an unknown locality in Bohemia.

Remarks.- The rhabdosomes are short and robust with a slight ventral curvature in the proximal portion. They widen rapidly from 0.6-0.8 mm across th1 to 2.0-2.2 mm at 10 mm from that position. *Saetograptus chimaera* is somewhat like *Colonograptus colonus* but shorter and wider (Elles & Wood 1901-1918). The thecae are simple with a spined apertural margin, which is a typical character of *S. chimaera* (Berry & Murphy 1975). The thecal density is 12-15 per 10 mm in the proximal part, comparable to specimens from Nevada (Berry & Murphy 1975), though slightly higher than British ones measured by Elles & Wood (1901-1918). The proximal width of the rhabdosome, just below th1, is 0.35-0.55 mm and distally at 10 mm from the sicular aperture the width is 1.3-1.55 mm. The distal width of the present specimens is slightly smaller than in the Nevada specimens (Berry & Murphy 1975) and they could be of a different, more slender, variety. Two complete specimens measured 1.0 and 1.1 cm, with virgulae measuring 2.85 and 1.1 mm respectively.

Occurrence.- *Saetograptus chimaera* is the index fossil of the *chimaera* Biozone in the lower Ludlow of Bohemia (Kříž 1992). In Nevada it has a relatively long vertical range in the lower Ludlow (Berry & Murphy 1975). Its stratigraphical range in Britain is the *nilssoni* and *scanicus* Biozones (Elles & Wood 1901-1918), the latter being comparable to the *chimaera* Biozone of the Barrandian area.

Saetograptus roemeri (Barrande, 1850)
Fig. 3F

Material.- 7 flattened specimens preserved in black clayey shale or grey mudstone. The material was collected in the area of Prague, at Karlštejn and several unknown localities.

Remarks.- The specimens are generally poorly preserved, which makes identification difficult. The rhabdosome has a slight dorsal curvature in the proximal end but is otherwise straight. The thecal shape is simple with a count

of 14-16 per 10 mm. The proximal width is generally 0.6-0.65 mm, though one specimen showed a width of 0.35 mm. The rhabdosome widens rapidly and at 10 mm it is 1.5-2.5 mm. The present material fits the description by Elles & Wood (1901-1918). The species closely resembles *Colonograptus colonus*, though its mature thecae are longer than those of *C. colonus* (Elles & Wood 1901-1918).

Occurrence.- Saetograptus roemeri is found in the *nilssoni* and *scanicus* Biozones in Britain (Elles & Wood 1901-1918), which are equivalent to the *nilssoni* and *chimaera* Biozones in the lower Ludlow of the Barrandian area (Kříž 1992).

Genus *Spirograptus* Gürich, 1908

Spirograptus turriculatus (Barrande, 1850)
Fig. 4M-N

Material.- 26 flattened specimens preserved in black shale from various localities around the Prague Basin; Litohlavy, Prague, Hodkovičky, the Berounka, and unknown localities.

Remarks.- In the present material the rhabdosome is characteristically coiled into a conical spiral with up to 5 whorls. Bjerreskov (1975) counted up to 8 whorls on some specimens from Bornholm, which is the same as in specimens from Alaska (Churkin & Carter 1996). The rhabdosome width on the first whorl varies between 0.45-0.55 mm and distally the rhabdosome widens to 1.35-1.55 mm on measurable specimens in my material. These measurements correspond well to the Bornholm specimens examined by Bjerreskov (1975). Churkin & Carter (1996), however, found that the rhabdosome width can be as wide as 3 mm.

The thecae on the present specimens are usually poorly preserved, but occasionally it can be seen that they are isolated, triangular, with apertural hooks. The thecal number is 7 per 5 mm in the distal portion.

Occurrence.- The species has a worldwide distribution and defines the *turriculatus* Biozone in the lower Telychian. In Bohemia the zone begins with the first appearance of *Spirograptus turriculatus* and continues up to the level where *Monograptus crispus*, the index graptolite of the next zone, becomes numerous. *Spirograptus turriculatus*, however, continues to exist until the middle of the *crispus* Biozone (Štorch 1994).

Genus *Streptograptus* Yin, 1937

Streptograptus plumosus (Baily, 1871)?
Not figured

Material.- One flattened specimen preserved in black shale at Litohlavy.

Remarks.- According to Loydell (1990), *Streptograptus plumosus* was earlier known as *Monograptus nodifer* and *Monograptus exiguus primulus.* It has a rhabdosome shaped like a hook (Bjerreskov 1975), which is ventrally curved in the mesial portion but straight or gently curved in the proximal and distal ends (Loydell 1990). The thecae are lobate with a density of 5 thecae per 5 mm on the present material. Distally the rhabdosome width is 0.75 mm, which is a bit wider than in descriptions by Baily (1871). *Streptograptus plumosus* collected by Baily (1871) show a maximum width of 0.7 mm (Loydell 1990). Bjerreskov (1975) found the thecal count, in her Bornholm material, to be 6 per 5 mm proximally and 11-12 per 10 mm distally, which is a slightly higher density than on the present material.

The present specimen is poorly preserved, but if the identification is correct, it could mean an earlier first occurrence of *Monograptus priodon* in the Barrandian area, since the two species occur on the same slab.

Occurrence.- Streptograptus plumosus is found in the *turriculatus* and *crispus* Biozones in Britain (Loydell 1990), on Bornholm (Bjerreskov 1975), and in Bohemia (Štorch 1994).

Genus *Testograptus* Přibyl, 1967

Testograptus testis (Barrande, 1850)
Fig. 4E

Material.- Two flattened specimens preserved in black shale. The samples were collected at Litohlavy.

Remarks.- The rhabdosome is ventrally curved and has a width of 1.5-1.75 mm mesially, which corresponds to 5 mm from th1 according to Berry & Murphy (1975). Specimens from Nevada are robust and widen from 0.8-1.3 mm across th1 to a maximum of approximately 3.5 mm at 30-40 mm from th1 (Berry & Murphy 1975). The present specimens have thecae with a conspicuous spinose appearance. Specimens examined by Urbanek & Teller (1974) also show the characteristic ventral curvature, described as basically planispiral. The first theca terminates in a distinct hook with a pair of strong lateral apertural spines (Urbanek & Teller 1974). Successively, the thecae show progressive loss of the hooked character, being slightly inclined or straight with the apertural spines growing longer, up to 1.8-2.0 mm (Urbanek & Teller 1974). The thecal density is 13-15 in 10 mm proximally, whilst distally the count is 7.5-9 in 10 mm (Berry & Murphy 1975). This is about the same as in specimens described by Elles & Wood (1901-1918). These British specimens have a thecal density of 10-15 per 10 mm (Elles & Wood 1901-1918).

Occurrence.- Testograptus testis has given name to the subzone in the upper half of the *lundgreni* Biozone, to which the species is limited both in Britain (Elles & Wood 1901-1918) and Bohemia (Štorch 1994). *Testograptus testis* has a short vertical range and its first appearance

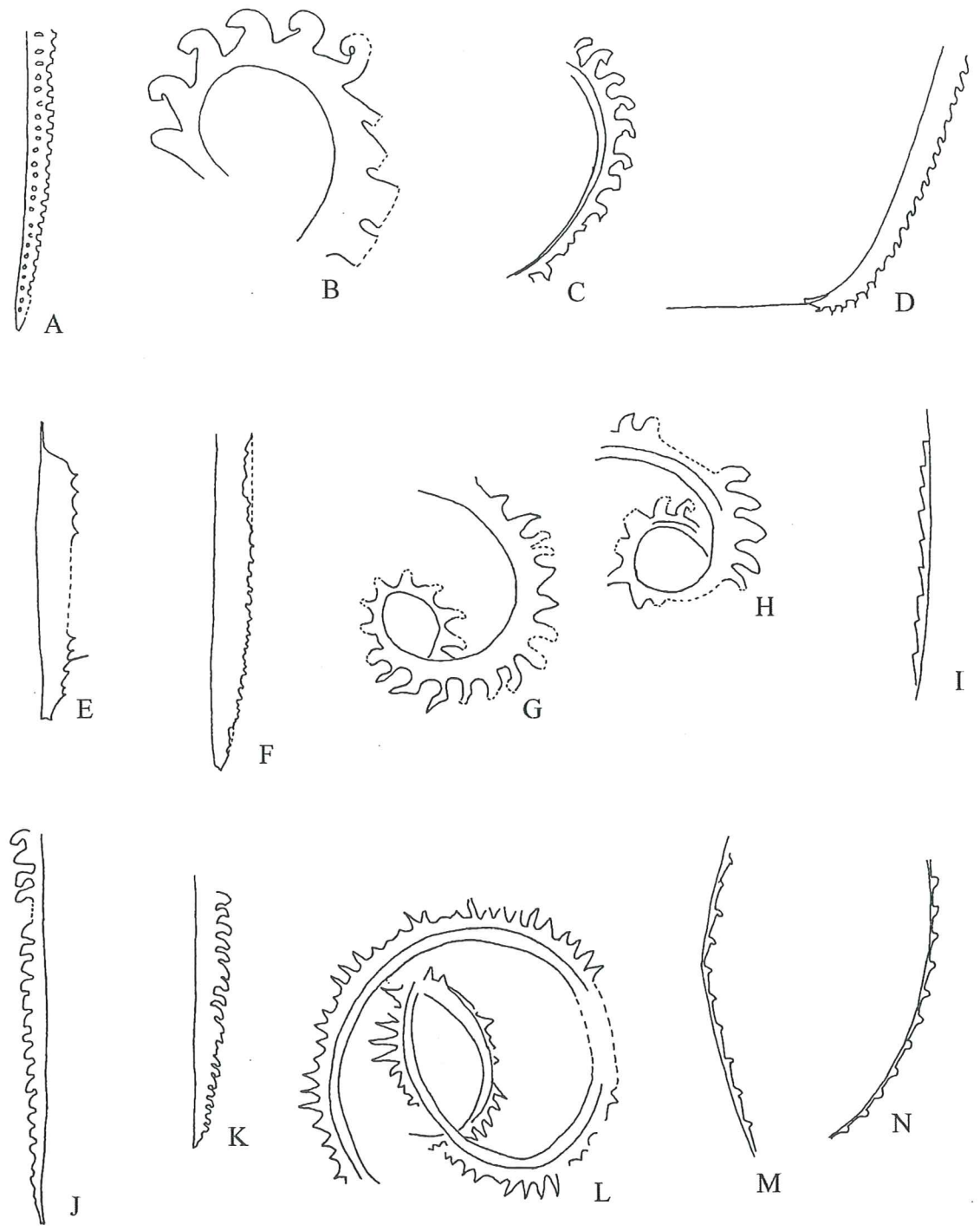


Fig. 3 **A**: *Monoclimacis vomerinus*, x2.3; **B**: *Demirastrites*cf. *decipiens*, x5.3; **C**: *Torquigraptus tullbergi*, x5.3; **D**: *Monograptus belophorus*, x2.3; **E**: *Saetograptus chimaera*, x3.9; **F**: *Saetograptus roemeri*, x2.8; **G-H**: *Monograptus* cf. *denticulatus*, x5.0 and x3.5 respectively ; **I**: *Monograptus atavus*, x2.3; **J-K**: *Monograptus priodon*, x2.5 and x2.3 respectively; **L**: *Monograptus spiralis*, x2.3; **M**: *Monograptus scanicus*, x3.5; **N**: *Monograptus gemmatus*, x2.8

is at the base of the *testis* Zone and it disappears before the base of the following biozone.

Genus *Torquigraptus* Loydell, 1993

Torquigraptus tullbergi (Bouček, 1931)
Fig. 3C

Material.- One flattened specimen preserved in black shale. The sample was collected at Hodkovičky.

Remarks.- The rhabdosome of the present specimen is dorsally flexed with the strongest curvature distally. The width across the thecal aperture in the proximal portion of the specimen is 1.3 mm. The thecal shape is triangular with a hooked metatheca.

Specimens examined by Štorch (1998*a*) displayed a dorso-ventral width of 1.1 mm across th10 and then gradually increasing in width. At th2 the rhabdosome width is 0.2-0.25 mm. Štorch (1998*a*) further observed that thecal shape changes from being low-triangular with a

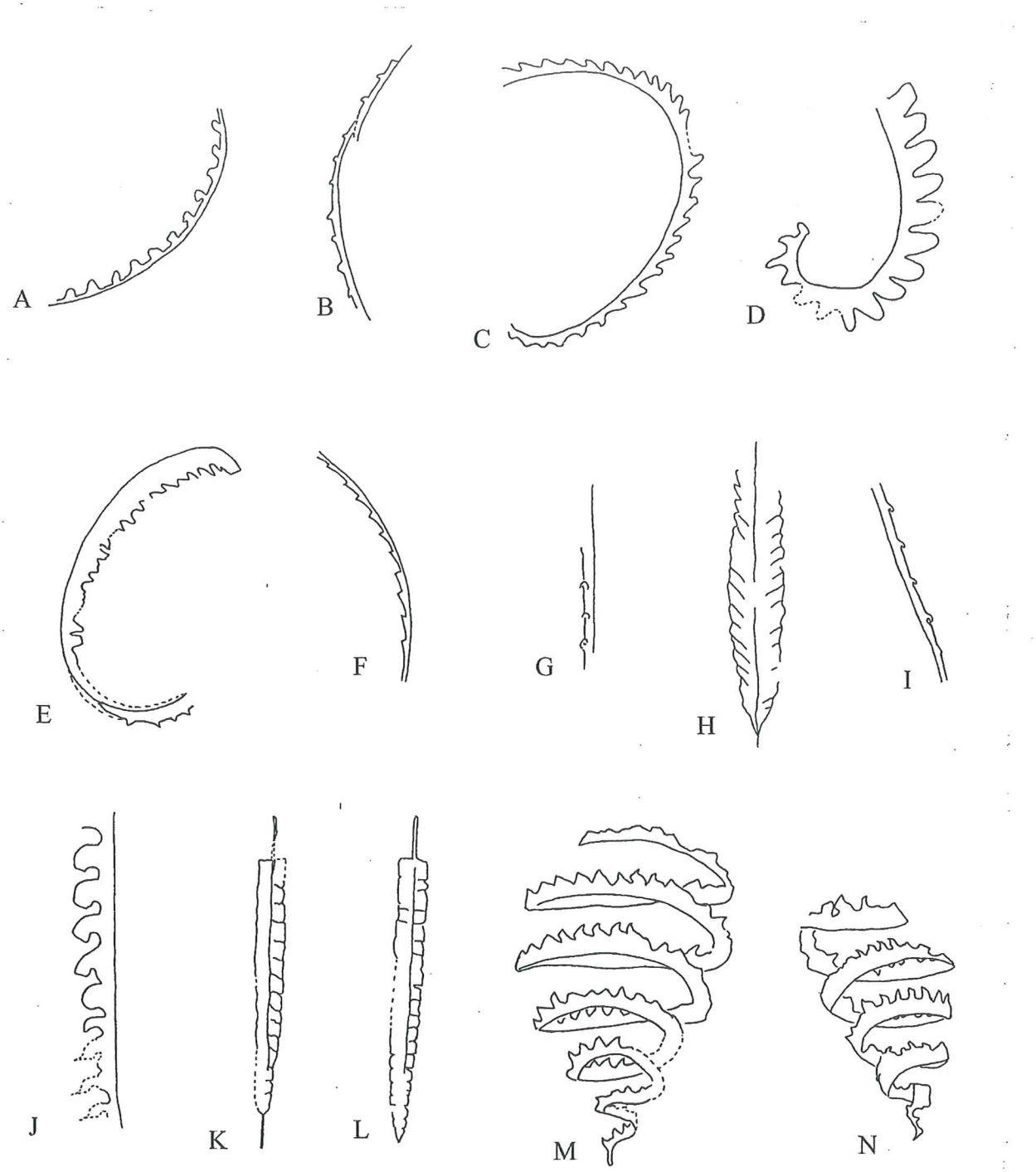


Fig. 4 **A**: *Monograptus crispus*, x6.0; **B**: *Monograptus kolihai*, x4.2; **C**: *Monograptus planus*, x2.3; **D**: *Demirastrites pectinatus*, x5.3; **E**: *Testograptus testis*, x2.3; **F**: *Neodiversograptus nilssoni*, x4.2; **G**: *Monograptus crinitus*, x5.6; **H**: *Petalograptus altissimus*, x2.3; **I**: *Monoclimacis* cf. *griestoniensis*, x3.9; **J**: *Monograptus sedgwickii*, x5.3; **K-L**: *Climacograptus scalaris*, x2.8 and x2.3 respectively; **M-N**: *Spirograptus turriculatus*, x4.6

hooked metatheca proximally to triangular, typically torquigraptid, mesially and distally. The rhabdosome of a complete specimen is loosely coiled two times into a low-conical spiral, where the most distal portion of the rhabdosome is almost straight (Štorch 1998*a*).

Occurrence.- The species has given name to the *tullbergi* Biozone in Bohemia, which corresponds to the *crenulata* Biozone in Britain (Štorch 1994). The stratigraphical range of *T. tullbergi* in Bohemia is from the base of the zone to the base of the following *spiralis* Biozone in the Telychian Stage. On Bornholm, however, where the *tullbergi* zone is not documented, the species ranges from the base of the *griestoniensis* Biozone to the base of the following *spiralis* Biozone (Bjerreskov 1975). *Torquigraptus tullbergi* thus has a longer range on Bornholm if the *griestoniensis* Biozone there is corresponding to both the *griestoniensis* Biozone and the *tullbergi* Biozone in Bohemia (cf. the occurrence of *Monoclimacis griestoniensis*). On Bornholm the two species have the same vertical range; in Bohemia, however, *M. griestoniensis* first occurs at the base of the *griestoniensis* Biozone but does not disappear until the lowermost *spiralis* Zone.

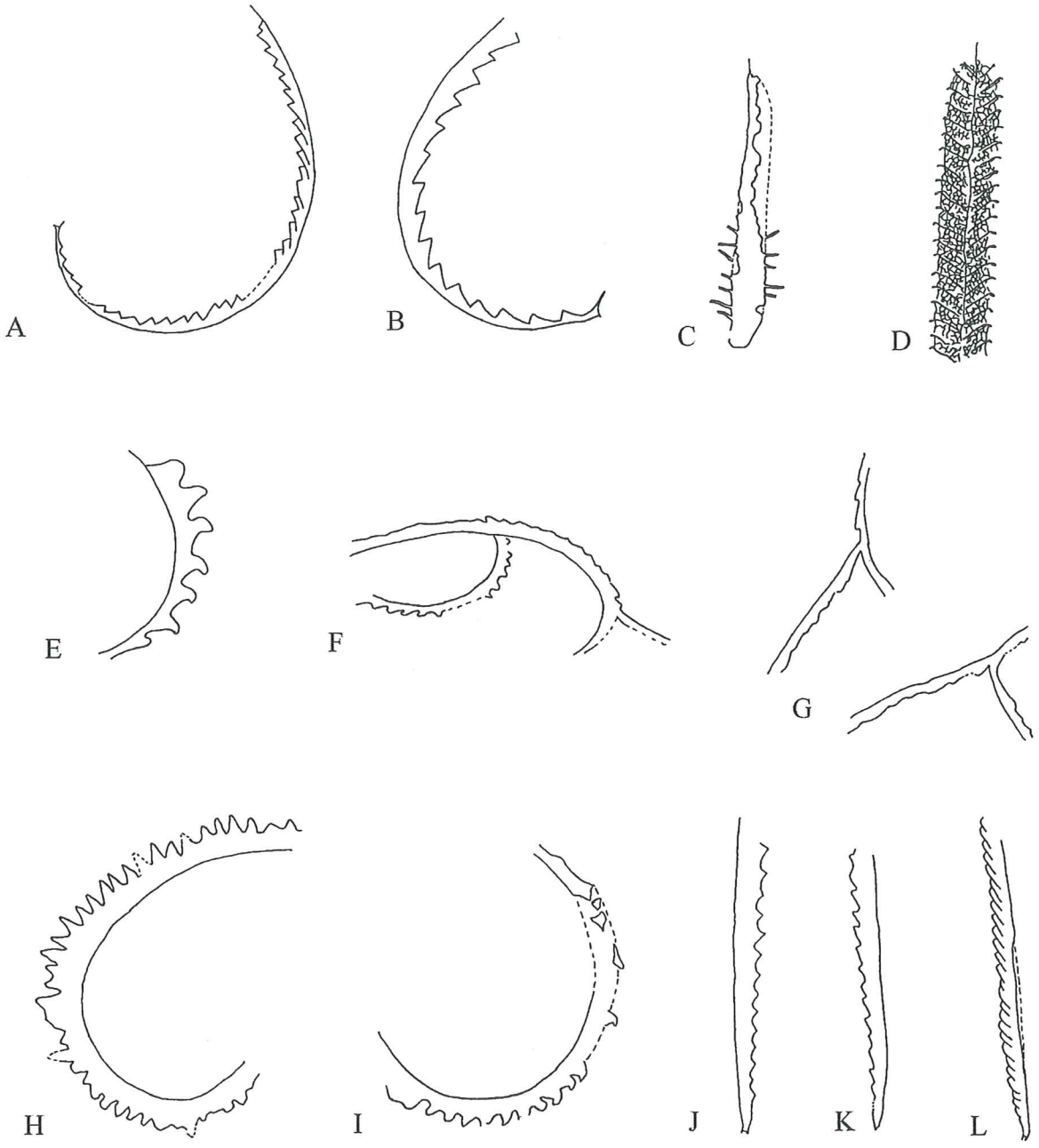


Fig. 5 **A-B**: *Bohemograptus bohemicus*, x2.3 and x4.6 respectively; **C**: *Spinograptus spinosus*, x2.3; **D**: *Retiolites geinitzianus*, x2.3; **E**: *Campograptus communis*, x5.6; **F-G**: *Cyrtograptus* cf. *lundgreni*, x2.3; **H-I**: *Demirastrites* cf. *convolutus*, x2.3; **J-K**: *Pristiograptus* sp., x3.5 and x2.3 respectively; **L**: *Neocolonograptus ultimus*, x2.3

Family Cyrtograptidae Bouček, 1933

Genus *Cyrtograptus* Carruthers, 1867

Cyrtograptus cf. *lundgreni* Tullberg, 1883
Fig. 5F-G

Material.- Fragmentary material on two samples. The specimens are flattened and preserved in calcareous mudstone from the area of Litohlavy.

Remarks.- The general dorso-ventral width of the rhabdosomes is 1.1 mm, which is corresponding to 15 mm from th1 (Berry & Murphy 1975). The main stipe is characteristically curved and widens from extreme slenderness to a maximum of 1.4-1.5 mm (Berry & Murphy 1975).

Cladia are present in one sample (Fig. 5G); as a rule there is only one thecal cladium but in some cases two or three may be present (Teller 1976). The cladium usually originates from where the stipe is most strongly curved, at about th16 to th20 (Berry & Murphy 1975) and cladia observed by Berry & Murphy (1975) are up to 20 mm long.

The thecae of *Cyrtograptus lundgreni* are sub-triangular with a hooked metatheca (Elles & Wood 1901-1918) and this is most distinct on the main stipe before the cladium (Berry & Murphy 1975). The thecal count var-

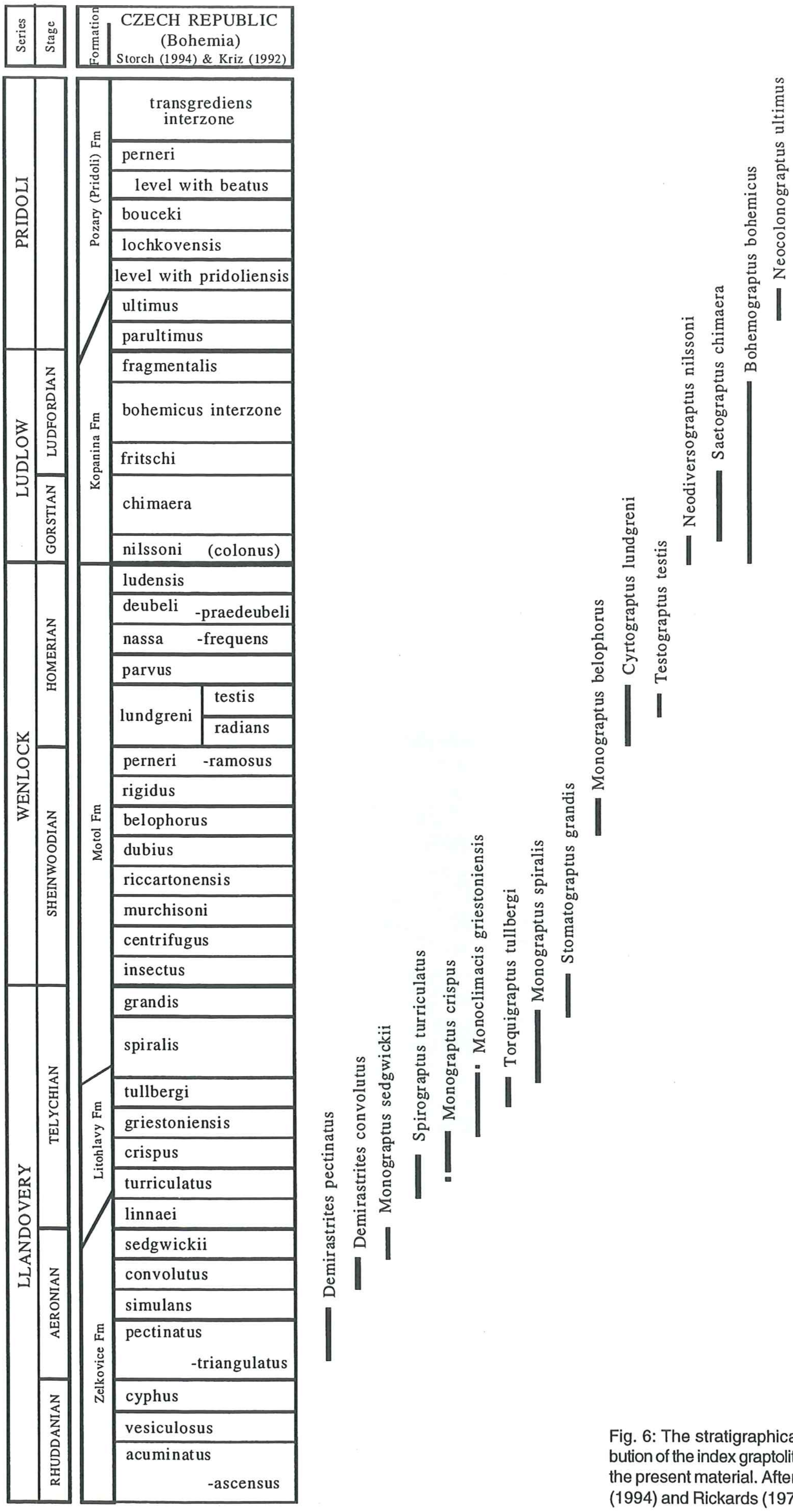


Fig. 6: The stratigraphical distribution of the index graptolites from the present material. After Štorch (1994) and Rickards (1976).

ies between 6-7 in the most proximal portion up to 8-9 distally on the main stipe (Berry & Murphy 1975). Elles & Wood (1901-1918) observed a thecal density of 10 per 10 mm while the thecal count on the cladia was 8 per 10 mm.

Occurrence.- Cyrtograptus lundgreni is an index fossil and has given name to the *lundgreni* Biozone in the Homerian Stage throughout the world. In the Barrandian area *C. lundgreni* has a vertical range from the base of the *lundgreni* Biozone to the base of the following *parvus* Biozone where *Pristiograptus parvus* first appears (Štorch 1994).

Discussion

Index species from the present material represent Silurian series from the lower Llandovery to the lower Pridoli, but since it was not collected for stratigraphical purposes a proper correlation with other areas is difficult. Several of the index graptolites have a longer range than the zone they define. A total of 16 index species were identified (Fig. 6) and based on Štorch's (1994) and Rickards' (1976) stratigraphical work, only five of these species definitely belong to their respective biozone, since they are taxon-range zones and representing the total vertical range of the graptolite species in the Prague Basin. Thus, *Demirastrites convolutus, Neodiversograptus nilssoni, Monograptus sedgwickii, Torquigraptus tullbergi, Neocolonograptus ultimus,* and *Cyrtograptus lundgreni* only appear in their respective biozone.

According to Štorch (1994), *Demirastrites pectinatus* has a vertical range from the lower *pectinatus-triangulatus* Biozone up to the lowermost *simulans* Biozone. The first appearance of *Spirograptus turriculatus* is at the base of the *turriculatus* Biozone and it disappears in the middle of the *crispus* Biozone, while *Monograptus crispus* has a stratigraphical range from the upper *turriculatus* Biozone to the lower part of the following *griestoniensis* Biozone. *Monoclimacis griestoniensis* has a long range from the base of the *griestoniensis* Biozone to the lower part of the *spiralis* Biozone. *Monograptus spiralis* defines the biozone above the *tullbergi* Biozone and is found all the way from the upper part of the latter zone to the lower part of the *grandis* Biozone. The first appearance of *Stomatograptus grandis* is at the base of the *grandis* Biozone, which is the uppermost biozone in the Telychian Stage, and it continues up to the middle of the *insectus* Biozone. *Monograptus belophorus* in the Sheinwoodian Stage has a vertical range from the base of the *belophorus* Biozone to the lowermost part of the next zone. *Testograptus testis* defines the subzone in the upper half of the *lundgreni* Biozone. *Testograptus testis* first appears at the base of the *testis* Subzone and disappears just before the top of it in Bohemia. In the Gorstian Stage to the lower Ludfordian Stage, *Saetograptus chimaera* is found from the upper *nilssoni* Biozone to the base of *fritschi* Biozone. *Bohemograptus bohemicus* has a long stratigraphical range from the *nilssoni* Biozone to the base of the *fragmentalis* Biozone. *Bohemograptus bohemicus* gives its name to a proliferation zone and is hence not a properly defined biozone (Rickards 1976).

According to Kříž (1992), the biostratigraphical correlation between Great Britain and Bohemia is good, but the lower boundaries of the Homerian and the Ludfordian cannot be correlated directly. This is due to a slightly different concept in graptolite zonation, and at these levels graptolites are also rare in the Prague Basin.

The biozonation of Bornholm (Bjerreskov 1975) matches that of Bohemia relatively well, though the Silurian is only represented up to the *centrifugus* Biozone in the lower Wenlock on Bornholm. There are slight differences, *Monograptus cyphus* having a short range on Bornholm and the *cyphus* Biozone of Bohemia, being represented by *Monograptus revolutus* instead (Bjerreskov 1975). *Demirastrites pectinatus* and *Demirastrites triangulatus* define subzones in the *gregarius* Biozone on Bornholm. On Bornholm, *Monograptus gregarius* has a vertical range from the base of the *gregarius* Biozone up to the base of the *convolutus* Biozone. The transition from the Llandovery to the Wenlock occurs within the *lapworthi* Biozone, which corresponds to the *grandis* Biozone and the *insectus* Biozone of Bohemia.

Slight differences in coeval assemblages from Britain, Bornholm and Bohemia can be explained by different depths and local environmental conditions of peri-Gondwanan Europe during the Silurian (Štorch 1998*b*).

When comparing rhabdosome widths and thecal densities of the Bohemian graptolites discussed herein, with material from Bornholm (Bjerreskov 1975) and the United States (Berry & Murphy 1975; Churkin & Carter 1996), no large differences can be observed.

Some species occur in much higher numbers than others do. This fact can have several explanations. Firstly, they may simply be the dominating species, occurring in great numbers in certain environments. This is probably the case for e.g. *Bohemograptus bohemicus*, since it clearly dominates samples in which it is preserved. Secondly, there is the human factor. Some species are larger and have a more conspicuous appearance than others. Such species, like *Spirograptus turriculatus*, might therefore attract attention more than others. Thirdly, there may be a sorting effect during post mortem transportation, which could be the explanation for e.g. clusters of *Monograptus crinitus.*

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