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**Wenlock-Ludlow boundary interval revisited: New insights
from the off-shore facies of the Prague Synform, Czech
Republic**

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1 **Wenlock-Ludlow boundary interval revisited: New insights from the off-shore facies of**
2 **the Prague Synform, Czech Republic**

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Abstract: Wenlock-Ludlow boundary beds exposed near Nesvačily in the Prague Synform are documented in terms of their lithology, faunal content, high-resolution record of 19 graptolite species, graptolite biostratigraphy and conodont record. This is the first time in Bohemia and peri-Gondwanan Europe that a continuous graptolite-bearing section through upper *ludensis*–middle *nilssoni* biozones is described in detail in order to refine high-resolution biostratigraphy and correlation of the Wenlock-Ludlow boundary. Organic-rich shale, relatively rare non-graptolite fauna and absence of bioturbation indicate a stable deep-water off-shore setting with sporadic, low level bottom oxygenation. The uninterrupted succession revealed a series of origination events of principal graptolite taxa employed in determination of the Wenlock-Ludlow boundary strata world-wide. *Bohemograptus* represented by *B. praecox* appeared as early as in the uppermost Wenlock *ludensis* Biozone. *B. praecox* is later accompanied and replaced by *B. bohemicus*, associated with *Uncinagraptus uncinatus*. The lowest *Neodiversograptus nilssoni* marked the base of the Ludlow *nilssoni* Biozone. Speciation within *Bohemograptus* continued in the middle *nilssoni* Biozone when the robust *B. butovicensis* evolved from *B. bohemicus*. *Colonograptus colonus* shows its lowest occurrence in the middle part of the *nilssoni* Biozone together with the latest *C. gerhardi*. The monograptids are associated with abundant and diverse plectograptids that are at present mostly known from Baltica. *B. praecox* sp. nov. and *B. butovicensis* (Bouček, 1937) are described in the systematic part. The conodont *Kockelella ortus absidata*, found in the lower-middle part of the *nilssoni* Biozone, is consistent with a stratigraphic interval within *Oz. bohemica* and *K. crassa* conodont biozones. Silurian, graptolite, stratigraphy, Wenlock-Ludlow boundary, *Bohemograptus*.

Key words: Silurian, graptolite, Stratigraphy, Wenlock-Ludlow boundary, *Bohemograptus*

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53 **Introduction**

54

55 Silurian series and stages belong among the first chronostratigraphic units defined by
56 Global Boundary Stratotype Section and Point (Holland and Bassett 1989). The GSSP of the
57 Ludlow Series (and Gorstian Stage) has been placed at the base of Lower Elton Formation at
58 Pitch Coppice in Shropshire, England. The only biostratigraphically important fossils
59 recovered from the boundary interval are two fragmentary and poorly preserved graptolite
60 rhabdosomes tentatively assigned to *Saetograptus varians* (Wood) and *Neodiversograptus*
61 *nilssoni* (Lapworth), (White 1981). Despite such limited evidence it has been generally
62 accepted that the “golden spike” at the base of the Lower Elton Formation lies at or close to
63 the base of *Neodiversograptus nilssoni* graptolite Biozone (Holland and Bassett 1989).
64 Graptolite data have been of particular importance since Aldridge et al. (2000) stated that “no
65 widely correlatable changes in microfaunas occur at the boundary” in this GSSP. It must be
66 noted that *S. varians* is confined to the stratigraphically higher *Lobograptus progenitor*
67 Biozone where it co-occurs with the uppermost populations of *N. nilssoni* according to our
68 unpublished records from the Všeradice and Bykoš sections. Despite these uncertainties, the
69 *nilssoni* Biozone is taken as the formal basal biostratigraphic unit of the Ludlow Series and its
70 Gorstian Stage.

71 Kříž et al. (1993) described in detail all accessible sections across the Wenlock-Ludlow
72 boundary in the Prague Synform. Most of these sections preserved the boundary interval in
73 the volcanic-carbonate facies, which yielded a limited and discontinuous graptolite record.
74 Shale-dominated Wenlock-Ludlow boundary strata in the Všeradice section (Kříž et al. 1993),
75 with its relatively good graptolite record described by Kozłowska et al. (2001), are weathered,
76 condensed and interrupted by prominent intervals of pyroclastic deposition.

The Wenlock-Ludlow boundary strata exposed by a trench near Nesvačily in the southwestern part of the Silurian outcrop of the Prague Synform (Fig. 1), yielded a robust and continuous graptolite record comprising 19 species (Fig. 2). The boundary strata, assigned to the upper *ludensis* and lower-middle *nilssoni* graptolite biozones, are documented in this paper in terms of their lithology, faunal content, and graptolite and conodont record. This is the first record of a continuous graptolite-rich section through the Wenlock-Ludlow boundary in Central Bohemia and peri-Gondwanan Europe, providing the possibility of refining current high-resolution biostratigraphic dating and correlation of the Wenlock-Ludlow boundary interval.

The data obtained improved our insight in the earliest Ludlow graptolite radiation and succession of origination events close to the Wenlock-Ludlow boundary. The systematic part deals with new material, which sheds more light on the early evolution of *Bohemograptus*, perhaps one of the most iconic Ludlow graptolites. The oldest known record of *Bohemograptus* from the uppermost Wenlock *ludensis* Biozone – *B. praecox* sp. nov. and the new morphotype represented by the so far enigmatic *B. butovicensis* from the middle *nilssoni* Biozone are described.

Stratigraphy of the Nesvačily section

The section exposed a 700 cm-thick shale-dominated succession of the most offshore facies of that time preserved in the Prague Synform. The lowermost 200 cm-thick part of the section consists of dark-grey, distinctly laminated, calcareous shales of the Motol Formation. Common graptolites are associated with fragments of non-vascular plants, fecal pellets, sponge spicules and sporadic pelagic cephalopods. Higher up, the section continues with a 500 cm thick light-grey, finely laminated, calcareous shales of the Kopanina Formation

interbedded with several 5–20 cm-thick yellow-grey pyroclastic intervals. A 20 cm-thick bed of muddy skeletal limestone is developed 445 cm above the base of the section (Fig. 2, sample 545-565). The graptolite-rich shales yielded other fossils including pelagic cephalopods, ostracods, non-vascular plants, rare epibyssate cardiolid bivalves, epiplanktic anthozoan *Kolihaia*, a.o. The abundance of non-graptolite fossils increases upwards in the Kopanina Formation. Taken together, the section studied corresponds to a deep-water off-shore setting with low and occasional bottom oxygenation. In contrast to coeval sections in the Prague Synform, the Wenlock-Ludlow boundary interval is only slightly influenced by volcanism in the Nesvačily section. The pyroclastic deposits are intensely recrystallized by calcite and represent a distal facies of pyroclastic surges and fallouts. Limited portions of volcanoclastic rocks and the relatively thick shale succession of the interval studied indicate a high local subsidence rate that archived an exceptionally high-resolution record of graptolites across the Wenlock-Ludlow boundary.

The lowermost 220 cm thick part of the Nesvačily section, which is late Homerian (Wenlock) in age, is assigned to the upper part of *Colonograptus ludensis* Biozone, although dominated by its closely related species *C. gerhardi* (Kühne). The succeeding Ludlow strata (480 cm) are assigned to the earliest Gorstian *Neodiversograptus nilssoni* Biozone, defined by the lowest occurrence of its name-giving taxon. The rather robust record of 19 graptolite species sheds more light on little-known details of the graptolite succession during the post-*lundgreni* radiation culminating in the Wenlock-Ludlow boundary interval. Several graptolite genera typical of Ludlow graptolite faunas (*Bohemograptus*, *Neodiversograptus*, *Uncinograptus* and advanced *Colonograptus* ancestral to *Saetograptus*) originated in this stratigraphic interval and our data show a succession of these origination events (Fig. 2). The earliest, gracile *Bohemograptus praecox* sp. nov. appears in the upper *ludensis* Biozone, well before the first *N. nilssoni* (Lapworth). *Uncinograptus uncinatus* (Tullberg) made its lowest

occurrence considerably higher, but still preceded the first *Colonograptus colonus* (Barrande) and *Bohemograptus butovicensis* (Bouček), both of which made their debut as high as the middle *nilssoni* Biozone. The long-time enigmatic *B. butovicensis* – a robust, polonograptid-like *Bohemograptus* – is limited to a narrow interval in the middle part of the biozone. The partly bleached calcareous shale of the Nesvačily section has also preserved diverse plectograptines, for the most part previously unknown from the Prague Synform [*Neogothograptus eximinassa* Maletz, *Ng. balticus* (Eisenack), *Ng. ornatus* Maletz, *Plectograptus robustus* (Obut and Zaslavskaya), *Pl. macilentus* (Törnquist), *Spinograptus spinosus* (Wood), *Sp. clathrospinosus* (Eisenack), and *Valentinagraptus* aff. *simplex* Piras] (Figs. 3, 4).

A conodont fauna has been recorded in a single limestone bed in the lower-middle part of the *nilssoni* Biozone (Fig. 2, sample 545-565). The recovered conodonts contain *Kockelella ortus absidata* Barrick and Klapper, which represents an index taxon of the latest Homerian conodont Biozone in the global scale (Calner and Jeppsson 2003). The taxon, however, has a longer stratigraphic range (Homerian–Gorstian) as has been proved from the Prague Synform where it defines a Subzone within the late Homerian *Ozarkodina bohémica* Interval Zone (Slavík 2014). Because the taxon crosses the Wenlock-Ludlow boundary, it indicates an age between *Oz. bohémica* and *K. crassa* conodont biozones; the latter corresponding to the *N. nilssoni* graptolite Biozone. Associated conodont elements are mostly fragmentary and belong to a spathognathodontid apparatus. Simple cone elements are represented by *Panderodus unicostatus* (Branson and Mehl) and *Dapsilodus obliquicostatus* (Branson and Mehl).

Systematic palaeontology

The specimens studied are from P. Štorch's collection housed in the Czech Geological Survey, Prague (prefix PŠ) except for the types of *Bohemograptus butovicensis* (Bouček), which are housed in the National Museum, Prague (prefix L). Abbreviations: 2TRD – two thecae repeat distance, DVW – dorso-ventral width of the rhabdosome, th – theca.

Bohemograptus butovicensis (Bouček, 1936)

Figures 4N, Q, W; 5A, C

1936 *Monograptus butovicensis* n. sp., Bouček, pp 4–5, pl. 1, figs 6, 7.

1983 *Polonograptus butovicensis* (Bouček), Příbyl, pl. 2, fig. 1; pl. 3, fig. 1.

Holotype: By original designation, specimen L 17753 figured by Bouček (1936, pl. 1, fig. 6) and refigured by Příbyl (1983, pl. 3, fig. 1), from the *N. nilssoni* Biozone at Praha-Butovice, Bohemia.

Material: More than twenty flattened specimens including immature and incomplete rhabdosomes along with ten complete mature rhabdosomes, holotype L 17753 and paratype L 19968.

Diagnosis: Robust, regularly ventrally curved rhabdosome forming almost complete whorl when mature. Proximal part of *B. bohemicus* type; sicula ventrally curved, with rutellum. Thecal length and overlap rapidly increase in the mesial part. Distal part more than 2 mm wide, composed by *ca* 4 mm long, relatively slender ventrally curved thecae overlapping for at least three-quarters of their length.

Description: The ventral curvature of the robust rhabdosome, slightly accentuated in the proximal part, forms an almost complete circle in mature, about 100 mm-long specimens. The rhabdosome widens from 0.45–0.6 mm at theca 1, through 0.5–0.7 mm at th 3, 0.6–0.85 mm at th 5 to 0.9–1.2 mm at th 10. The dorso-ventral width (DVW) further increases through 1.35–1.9 mm at th 20 to distal maxima of 1.7–2.2 mm (2.5 mm recorded in one >120 mm long rhabdosome). The sicula is 1.3–1.7 mm, long, ventrally curved, 0.28–0.35 mm wide at the aperture, which is furnished with a tiny virgella and more or less prominent rutellum. The sicular apex attains a level either slightly below or slightly above the first thecal aperture. Th1 is 1.05–1.15 mm long, having a concave ventral wall and an even, slightly everted aperture. The following thecae are simple, ventrally curved tubes with perpendicular or slightly everted apertures, overlapping for max. half of their length at th 5, half to two-thirds at th 10, and more than two-thirds at th 20. Distal thecae 4.0–4.3 mm long, and overlap for about three-quarters of their length. Two-thecae repeat distance (2 TRD) increases from 1.45–1.9 mm at th 2, through 1.8–2.0 mm at th 10 to 1.9–2.3 mm in distal thecae of mature specimens.

Discussion: The species “*Monograptus*” *butovicensis* was established upon two distal parts of mature rhabdosomes preserved in relief in a muddy limestone. Both types originated from a highly fossiliferous, 100 cm-thick bed of shale with abundant limestone nodules exposed at Barrande’s classic locality Butovice in Praha-Jinonice. Associated graptolites included abundant *Colonograptus colonus* (Barrande), *C. roemeri* (Barrande), *Uncinograptus uncinatus* (Tullberg), and rare fragments referred to *Neodiversograptus nilssoni* (Lapworth). The generic assignment of “*M.*” *butovicensis* remained doubtful until this study due to the absence of the proximal part of the rhabdosome. Despite incomplete preservation, “*M.*” *butovicensis* was used as the type species of *Polonograptus* Tsegelnyuk, 1976 before Urbanek and Teller (1997) suggested that *Polonograptus podoliensis* Tsegelnyuk should be designated

as a type species of the genus instead of “*M.*” *butovicensis* (see Riva et al. 2001). Urbanek and Teller (1997) proposed that “*M.*” *butovicensis* might be a „preservational species“ representing deformed distal fragments of *C. roemerii*, which, however, never exhibits such overlapping and ventrally curved thecae.

The present specimens of “*M.*” *butovicensis* from the Nesvačily section provided undoubted evidence of its *Bohemograptus* affiliation. The ventrally curved sicula with rutellum, and straight, rather short proximal thecae overlapping for up to half of their length match well those of the type species *Bohemograptus bohemicus* (Barrande). Distal of about th 10, the thecal length and overlap regularly increase, finally resulting in the very robust, ventrally curved distal part of the rhabdosome composed of *ca* 4 mm long, relatively slender, ventrally curved thecae overlapping for at least three-quarters of their length. *Bohemograptus butovicensis* likely represents an early, morphologically distinct offshoot from the long-ranging *B. bohemicus* lineage.

Extremely robust bohemograptid rhabdosomes recorded in a narrow time slice in about the middle part of the early Gorstian *nilssoni* Biozone represent the earliest occurrence of a specific morphotype combining a robust, ventrally curved rhabdosome and long, strongly overlapping, ventrally curved thecae. Analogous morphology developed in the thin-walled egregiograptids with an extremely long th 1, confined to the upper Gorstian and lower Ludfordian (Koren' and Sujarkova 2004, Štorch et al. 2014), and finally in the lower and middle Ludfordian polonograptids – the third and stratigraphically youngest group distinguished by a short th 1 and much elongated subsequent thecae of a rapidly widening rhabdosome (Koren' and Sujarkova 2004, Manda et al. 2012). Polonograptids vanished during the late Ludfordian *kozłowskii* Extinction Event along with all other ventrally curved monograptids. Independent acquisition of a ventrally curved rhabdosome and long overlapping, ventrally curved thecae in three lineages of Ludlow graptolites can be ascribed to

adaptive convergence.

Bohemograptus praecox sp. nov.

Figures 4L, O–P; 5B, D–E

Holotype: Specimen PŠ 3773 figured on Fig. 5B from the upper *ludensis* Biozone (Sample - 160-180) at the Nesvačily section, Bohemia.

Material: 26 complete flattened specimens and a dozen incomplete rhabdosomes.

Etymology: *praecox*, Latin, meaning premature.

Diagnosis: Slender, gently ventrally curved *Bohemograptus* with straight, 0.4–0.55 mm wide proximal part comprising 3–4 thecae; straight sicula with slightly expanded aperture and dorsal wall extending outwards from the straight dorsal outline of the proximal part.

Description: The ventrally arcuate rhabdosome, at least 100 m long, possesses a straight proximal part comprising 3–4 thecae. Rhabdosome widens gradually from 0.4–0.5 mm at th 1, 0.42–0.55 mm at th 3, 0.5–0.65 mm at th 5, 0.6–0.85 mm at th 10, and 0.75–1.0 mm at th 20, to distal maximum of 0.8–1.2 mm. The straight sicula, 1.25–1.7 mm long, is 0.3–0.4 mm wide across the slightly expanded aperture and furnished with a short virgella and moderately developed rutellum. The sicular apex attains about level of the aperture of the 0.95–1.3 mm long th 1. The thecae are straight tubes, overlapping for one-third their length in the proximal part of the rhabdosome and for half their length distally. Even thecal apertures are perpendicular to the thecal axis or slightly everted. The 2TRD varies between 1.8 and 2.1 mm

in 90 % of specimens, lower values are common in proximal thecae whereas high values are typical in distal thecae. Extreme 2TRD values of 1.6–2.6 mm have been observed rarely in both proximal and distal thecae.

Remarks: *B. praecox* sp. nov. resembles the Ludfordian *Bohemograptus garratti* Rickards et al. in having a gracile, arcuate rhabdosome but differs in the more open rhabdosome curvature, straighter proximal part, and shorter sicula with expanded aperture and dorsal wall that protruded outwards from an otherwise straight proximal dorsal outline. The proximal thecae of *B. praecox* are less inclined and, in general, less widely spaced with 2TRD about 2 mm as opposed to 2.5 mm, which is a common value in *B. garratti*. Other bohemograptids can be differentiated by their more robust, generally less openly curved, and fish-hook shaped rhabdosomes with slightly ventrally curved sicula and more strongly overlapping thecae. Juvenile rhabdosomes of *B. praecox*, composed of sicula and initial thecae, can be distinguished from juvenile *Neodiversograptus nilssoni* (Lapworth) by the absence of a dorsal spine on the sicular aperture and by the sicular apex attaining the level of th 1 aperture.

Bohemograptus has been considered a typical indicator of Ludlow strata. Rickards and Wright (1999) assumed, quite reasonably, that the ancestor of the Gorstian *B. bohemicus* „must occur in the lowest levels of the *nilssoni* Biozone or high in the underlying *ludensis* Biozone“. This is exactly the range of *B. praecox* sp. nov. The similar morphology of juvenile *B. praecox* and *N. nilssoni* suggests speciation from a common ancestor in the course of the *ludensis* Biozone.

Conclusions

Organic-rich, subsequently bleached shales, uncommon non-graptolite fossils (see Fig. 2) and absence of bioturbation in the Nesvačily section indicate a stable, deep-water, off-shore

setting with low and occasional oxygenation of a soft bottom, i.e. an environment, in which graptolites flourished. The graptolite record is enhanced locally by the high sedimentation rates and limited input of pyroclastic material. Continuous sedimentation revealed a succession of origination events of principal graptolite taxa employed in determination of the Wenlock-Ludlow boundary strata world-wide. *Bohemograptus* appeared as early as in the uppermost Wenlock upper *ludensis* Biozone (FAD of *Bohemograptus praecox* sp. nov.). It is succeeded by the FAD of *Neodiversograptus nilssoni* indicating the base of the Ludlow *nilssoni* Biozone. *B. praecox* is later accompanied and subsequently replaced by *B. bohemicus* associated with *Uncinagraptus uncinatus*. Speciation within the *Bohemograptus* plexus continued in the middle *nilssoni* Biozone when the robust, short-ranging *B. butovicensis* evolved from *B. bohemicus*. *Colonograptus colonus* made its lowest occurrence in the middle part of the *nilssoni* Biozone together with the LAD of *C. gerhardi*. The monograptid fauna is also accompanied by abundant and diverse plectograptids, which broadly correspond with species recorded, so far, only from erratic boulders of Baltic origin (Maletz 2008, 2010) and from boreholes in Poland (Kozłowska-Dawidziuk 1995). The conodont *Kockelella ortus absidata* found in a single limestone sample in the lower-middle part of the *nilssoni* Biozone is consistent with a stratigraphic interval between the *Oz. bohémica* and *K. crassa* conodont biozones. The present data from Nesvačily has shown that the base of the *nilssoni* graptolite Biozone is a very suitable high-resolution correlation base for the Ludlow Series despite the rather problematic value of the current GSSP.

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Figure captions

Fig. 1. Location map of the Ordovician-Devonian Prague Synform within the Czech Republic; location of the Nesvačily area in the south-western part of the Silurian outcrop area and location of the Nesvačily section on a topographic map. GPS coordinates of the section: 49°53'13.18" N, 14°06'55.07" E.

Fig. 2. Lithology, graptolite record and non-graptolite body fossils across the Wenlock-Ludlow boundary interval in Nesvačily; including sample intervals referred to in the text.

Fig. 3. Minute plectograptid graptolites from the Nesvačily section. (A) *Neogothograptus ornatus* Maletz, PŠ 3805. (B) *Neogothograptus eximinassa* Maletz, PŠ 3721. (C) *Spinograptus clathrospinosus* (Eisenack), broad apertural spines with reticulo-fusellar structures, PŠ 3652. (D) *Neogothograptus balticus* (Eisenack), PŠ 3699. (A, D) *nilssoni* Biozone, (B, C) *ludensis* Biozone. Scale bar equals 1 mm.

Fig. 4. Graptolites from the Nesvačily section. (A) *Spinograptus spinosus* (Wood), PŠ 3695. (B) *Neogothograptus eximinassa* Maletz, PŠ 3724. (C) *Neogothograptus balticus* (Eisenack),

377 PŠ 3688. (D) *Spinograptus munchi* (Eisenack), PŠ 3656. (E) *Neogothograptus ornatus*
 378 Maletz, PŠ 3811. (F, K) *Neodiversograptus nilssoni* (Lapworth); (F) PŠ 3804, slender bipolar
 379 form; (K) PŠ 3833b, unipolar early form, see also juvenile rhabdosome with long antivirgellar
 380 spine. (G) *Plectograptus robustus* Obut and Zaslavskaya, PŠ 3799. (H) *Bohemograptus*
 381 *bohemicus* (Barrande), PŠ 3662. (I) *Spinograptus clathrospinosus* (Eisenack), PŠ 3823. (J)
 382 *Plectograptus macilentus* (Törnquist), PŠ 3822. (L, O–P) *Bohemograptus praecox* sp. nov.;
 383 (L) PŠ 3801, (O) PŠ 3760, (P) PŠ 3746. (M) *Valentinagraptus* aff. *simplex* Piras, PŠ 3832b.
 384 (N, Q, W) *Bohemograptus butovicensis* (Bouček); (N) PŠ 3827, (Q) PŠ 3691, (W) PŠ 3825.
 385 (R) *Colonograptus gerhardi* (Jaeger), PŠ 3718. (S) *Uncinagraptus uncinatus* (Tullberg), PŠ
 386 3745. (T) *Colonograptus colonus* (Barrande), PŠ 3828. (U) *Colonograptus ludensis*
 387 (Murchison), PŠ 3726. (V) *Pristiograptus frequens* Jaekel: PŠ 3738. (A, C, E–Q, S–T, V–W)
 388 *nilssoni* Biozone, (B, D, R, U) *ludensis* Biozone. Scale bar equals 1 mm.
 389
 390 **Fig. 5.** (A, C) *Bohemograptus butovicensis* (Bouček); (A) –PŠ 3691, immature specimen; (C)
 391 PŠ 3820b, large rhabdosome without sicula, mesial part broken out. (B, D–E) *Bohemograptus*
 392 *praecox* sp. nov.; (B) PŠ 3773, holotype; (D) PŠ 3779, (E) PŠ 3712. (B, D–E) *ludensis*
 393 Biozone, (A, C) *nilssoni* Biozone. Scale bars equal 1 mm.

Fig. 1. Location map of the Ordovician-Devonian Prague Synform within the Czech Republic; location of the Nesvačily area in the south-western part of the Silurian outcrop area and location of the Nesvačily section on a topographic map. GPS coordinates of the section: 49°53'13.18" N, 14°06'55.07" E.
139x227mm (300 x 300 DPI)

Fig. 2. Lithology, graptolite record and non-graptolite body fossils across the Wenlock-Ludlow boundary interval in Nesvačily; including sample intervals referred to in the text.

234x301mm (300 x 300 DPI)

Fig. 3. Minute plectograptid graptolites from the Nesvačily section. (A) *Neogothograptus ornatus* Maletz, PŠ 3805. (B) *Neogothograptus eximinassa* Maletz, PŠ 3721. (C) *Spinograptus clathrospinosus* (Eisenack), broad apertural spines with reticulo-fusellar structures, PŠ 3652. (D) *Neogothograptus balticus* (Eisenack), PŠ 3699. (A, D) nilssoni Biozone, (B, C) ludensis Biozone. Scale bar equals 1 mm. 119x167mm (300 x 300 DPI)

Fig. 4. Graptolites from the Nesvačily section. (A) *Spinograptus spinosus* (Wood), PŠ 3695. (B) *Neogothograptus eximinassa* Maletz, PŠ 3724. (C) *Neogothograptus balticus* (Eisenack), PŠ 3688. (D) *Spinograptus munchi* (Eisenack), PŠ 3656. (E) *Neogothograptus ornatus* Maletz, PŠ 3811. (F, K) *Neodiversograptus nilssoni* (Lapworth); (F) PŠ 3804, slender bipolar form; (K) PŠ 3833b, unipolar early form, see also juvenile rhabdosome with long antivirgellar spine. (G) *Plectograptus robustus* Obut and Zaslavskaya, PŠ 3799. (H) *Bohemograptus bohemicus* (Barrande), PŠ 3662. (I) *Spinograptus clathrospinosus* (Eisenack), PŠ 3823. (J) *Plectograptus macilentus* (Törnquist), PŠ 3822. (L, O–P) *Bohemograptus praecox* sp. nov.; (L) PŠ 3801, (O) PŠ 3760, (P) PŠ 3746. (M) *Valentinagraptus* aff. *simplex* Piras, PŠ 3832b. (N, Q, W) *Bohemograptus butovicensis* (Bouček); (N) PŠ 3827, (Q) PŠ 3691, (W) PŠ 3825. (R) *Colonograptus gerhardi* (Jaeger), PŠ 3718. (S) *Uncinagraptus uncinatus* (Tullberg), PŠ 3745. (T) *Colonograptus colonus* (Barrande), PŠ 3828. (U) *Colonograptus ludensis* (Murchison), PŠ 3726. (V) *Pristiograptus frequens* Jaekel: PŠ 3738. (A, C, E–Q, S–T, V–W) *nilssoni* Biozone, (B, D, R, U) *ludensis* Biozone. Scale bar equals 1 mm.

229x290mm (300 x 300 DPI)

Draft

Fig. 5. (A, C) *Bohemograptus butovicensis* (Bouček); (A) –PŠ 3691, immature specimen; (C) PŠ 3820b, large rhabdosome without sicula, mesial part broken out. (B, D–E) *Bohemograptus praecox* sp. nov.; (B) PŠ 3773, holotype; (D) PŠ 3779, (E) PŠ 3712. (B, D–E) *ludensis* Biozone, (A, C) *nilssoni* Biozone. Scale bars equal 1 mm.
170x160mm (300 x 300 DPI)