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**UPPER SILURIAN (GORSTIAN, LUDFORDIAN, PŘÍDOLÍ) GRAPTOLITE BIOZONATION IN THE MUHURR AREA (ALBANIA)**Pandeli Pashko<sup>1</sup><sup>1</sup>Institute of Geological Research of Albania (Tirana)[pandipashko@gmail.com](mailto:pandipashko@gmail.com)**Abstract**

Three stratigraphical sections and several outcrops through the upper Silurian graptolite shales of the Muhurr area, Albania have been revised. Based on a new detailed re-examination and re-evaluation of graptolite collections and previously unpublished and published studies, a biozonal scheme with much new biostratigraphical data is established. The graptolite assemblages are dominated by *Monograptidae*: *Neodiversograptus*, *Saetograptus*, *Bohemograptus*, *Colonograptus*, *Pseudomonoclimacis* and *Lobograptus* which are associated with several *Retiolitidae*. A total of 37 graptolite species has been identified; selected important species are illustrated. The present study recognized and defined the following seven upper Silurian graptolite biozones: *nilssoni* and *scanicus-chimaera* in the Gorstian Stage, *leintwardinensis*, *tenuis* and *formosus* in the Ludfordian Stage and *parultimus-ultimus* and *perneri* in the Přídolí Series.

**Keywords:** Upper Silurian, Biostratigraphy, Graptolites, Muhurri, Albania.**Περίληψη**

Στην παρούσα εργασία αναθεωρούνται τρεις στρωματογραφικές τομές και αρκετές επιφανειακές εμφανίσεις γραπτολιθικών σχιστολίθων του Ανω Σιλουρίου από την περιοχή Muhurr της Αλβανίας. Βασίζόμενοι σε νέα λεπτομερή επανεξέταση και επανεκτίμηση τόσο αδημοσίετων όσο και παλαιότερα δημοσιευμένων συλλογών γραπτολίθων προτείνεται ένα βιοζωνικό σχήμα που εμπεριέχει νέα, επικαιροποιημένη βιοστρωματογραφική πληροφορία. Οι γραπτολιθικές συναθροίσεις κυριαρχούνται από αντιπροσώπους *Monograptidae*: *Neodiversograptus*, *Saetograptus*, *Bohemograptus*, *Colonograptus*, *Pseudomonoclimacis* και *Lobograptus* τα οποία συνδυάζονται με ορισμένα *Retiolitidae*. Συνολικά ταυτοποιούνται 37 είδη γραπτολίθων και απεικονίζονται επιλεγμένα ορισμένα σημαντικά είδη. Η μελέτη αναγνωρίζει και προτείνει τις ακόλουθες επτά βιοζώνες γραπτολίθων για το Ανω Σιλούριο: *nilssoni* και *scanicus-chimaera* κατά την Βαθίδα του Gorstian (Γκόρστιου), *leintwardinensis*, *tenuis* και

*formosus* κατά τη Βαθμίδα του Ludfordian (Λουτφόρδιου) και *parultimus-ultimus* και *perneri* κατά τη Σειρά του Přídolí.

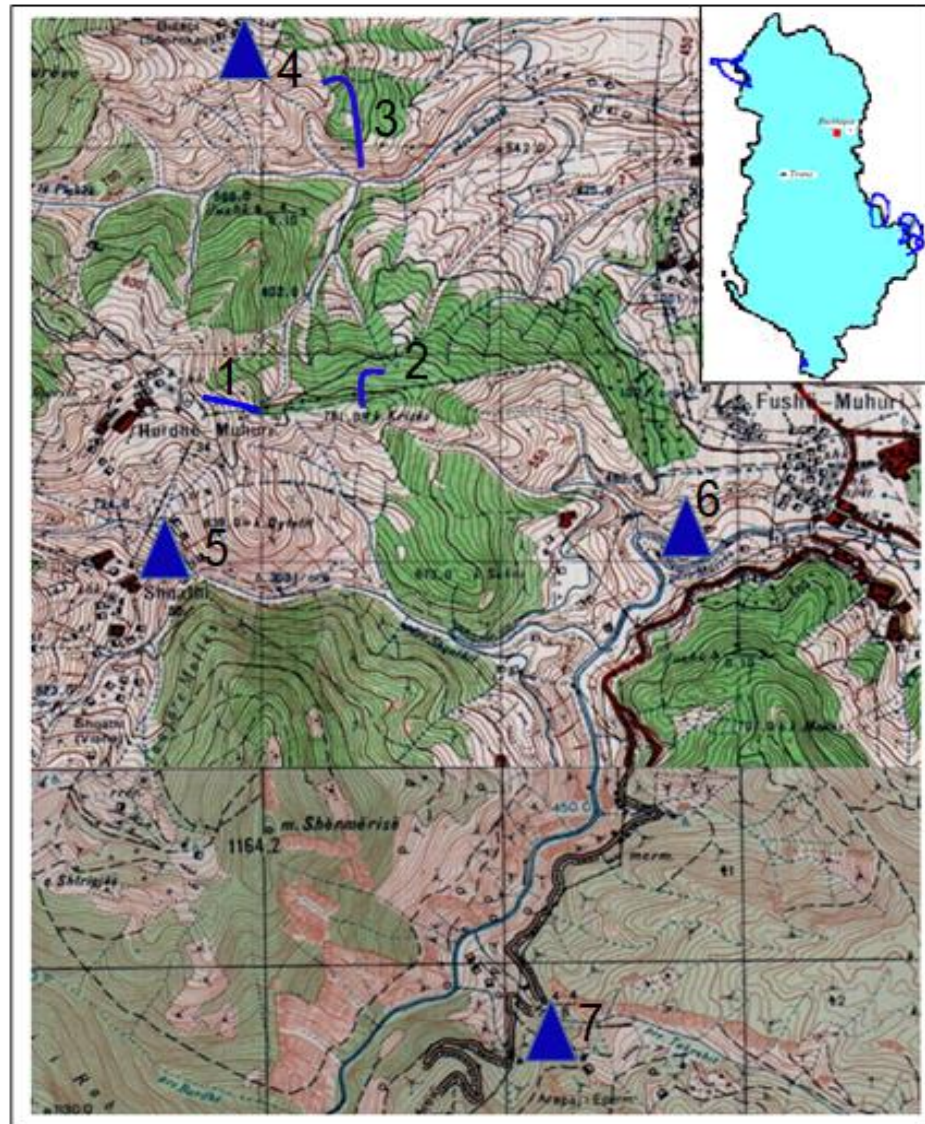
**Λέξεις κλειδιά:** Άνω Σιλλούριο, Βιοστρωματογραφία, Γραπτόλιθοι, Muhurr, Αλβανία

## 1. Introduction

The Muhurr area (Fig. 1) in the western part of the Muhurr-Caje and Malesia e Korabit Subzone (Korabi-Pelagonian Zone; see below for details) of Albania comprises a continuous Silurian-Lower Devonian graptolitic shale sequence which represents unique graptolitic outcrops within the Dinaric-Albanian-Hellenic Belt, and is remarkable because of the great abundance of graptolites. The Silurian-Lower Devonian biostratigraphy here is based exclusively on the graptolite faunas.

The first record on the Silurian (Ludlow) graptolite fauna of the Muhurri area (Nasi et al., 1973) reported many poorly preserved *Monograptus* sp., cf. *Pristiograptus* and Retiolitidae. The stratigraphical and palaeontological investigation of the Silurian-Devonian succession was initiated in 1983, with study of the Korabi and Albanian Alps structural Zones. The first comprehensive stratigraphical studies were by Xhomo and others in the mid 1980s but these were not published. The presence of Silurian graptolites and Devonian graptolites and tentaculites was established. Several graptolite assemblages indicating most of the Silurian and Lower Devonian regional stages were discovered and the first biostratigraphical succession was identified. More detailed biostratigraphical studies of the graptolites were initiated in 1985, focusing on the Silurian-Lower Devonian sequence of the Muhurri-Caja Unit but were not published. New outcrops with abundant, important graptolite faunas were discovered and collected in much more detail. Precise new stratigraphical ranges of graptolite species, established. From the total Silurian-Lower Devonian 115 graptolite species were listed, including 29 upper Silurian species, and important selected taxa illustrated. Based on additional records a preliminary graptolite biozonal scheme for the Silurian-Lower Devonian was established and within a total of 25 biozones, the upper Silurian *nilssoni*, *scanicus*, *leintwardinensis primus*, *formosus* and *perneri* graptolite biozones were recognized (Pashko, 1989). Subsequently, some reviews of the

biostratigraphy and graptolites of the Silurian-Lower Devonian sequence were published (Pashko, 1987, 1988, 1990, 1992; Xhomo et al. 1992, 2006). Later, a detailed description of the latest Homerician *ludensis* and early Gorstian *nilssoni* biozones succession, with 14 species of monograptids and retiolitids from the Muhurri area, was produced by Maletz et al., (1998).



**Fig. 1:** Map of the Muhurr area showing the principal localities (sections and outcrops) from which upper Silurian graptolites have been collected: 1- Hurdhe Muhurri; 2- Fushe Muhurri and 3- Bulaci 1 sections and 4--Sharakane; 5- Shqathi; 6- water mill of Perroi Fures and 7- Arabi Eperm outcrops.

The present paper is based on a new more detailed investigation of the Gorstian-Přídolí graptolite faunas and critical re-evaluation of the biostratigraphical data obtained from previous unpublished studies and published works by the author accompanied by a synthesis of these new data. This gives a more complete graptolite biostratigraphical scheme. A diverse upper Silurian graptolite fauna including 37 species is recognized from the graptolite shales of the Muhurri area. The poor preservation of some specimens permits only identification as cf. or sp. cf. The studied graptolite faunas have been deposited in the palaeontological collection of Institute of Geological Research of Albania (Tirana), partially now deposited as a personal collection.

## 2. Geological Setting

The Korabi-Pelagonian Structural Zone is part of Dinaric-Albanian-Hellenic Alpine Belt affected by strong tectonic activity and represents a nappe system running with a general NW-SE direction. It is subdivided into two principal geological units, the Muhurri-Caja and Malesia e Korabit and Kollovozi subzones (Aliaj and Kodra, 2016), which are displaced by major thrust faults. The Silurian-Lower Devonian sequence is represented by euxinic basinal facies predominantly consisting of graptolite shales which are widespread throughout the western part of the Muhurri Caja-Malesia e Korabit Subzone. There is insufficient exposure and outcrop conditions for studies to be undertaken. The marine sedimentary sequence of the Muhurri-Caja area starts with Ordovician silty-schists and quartzite intercalations without graptolites, followed by graptolitic shale of Silurian-Lower Devonian (Lochkovian) age and continues up to Pragian-Eifelian shale-limestone intercalations with tentaculites (Pashko, 2004) and conodonts (Meco, 1987, 2010). During the Hercynian orogeny, this Lower Palaeozoic basement was tectonized and metamorphosed, subsequently eroded and unconformably covered by Permian-Lower Triassic sandstones and conglomerates (Verrucano Fm). The graptolitic shale sequence extends from the Muhurri area, where it is best developed and represented by a complete Llandovery-Lower Devonian sequence, to Buzemadhe where only the lower part of the sequence (LlandoverySeries) is preserved (Pashko 1987, 1990, 1992). Due to lithological differences, the graptolitic shale sequence was divided into two formations: the Muhurr Black Shale Formation (Silurian) represented

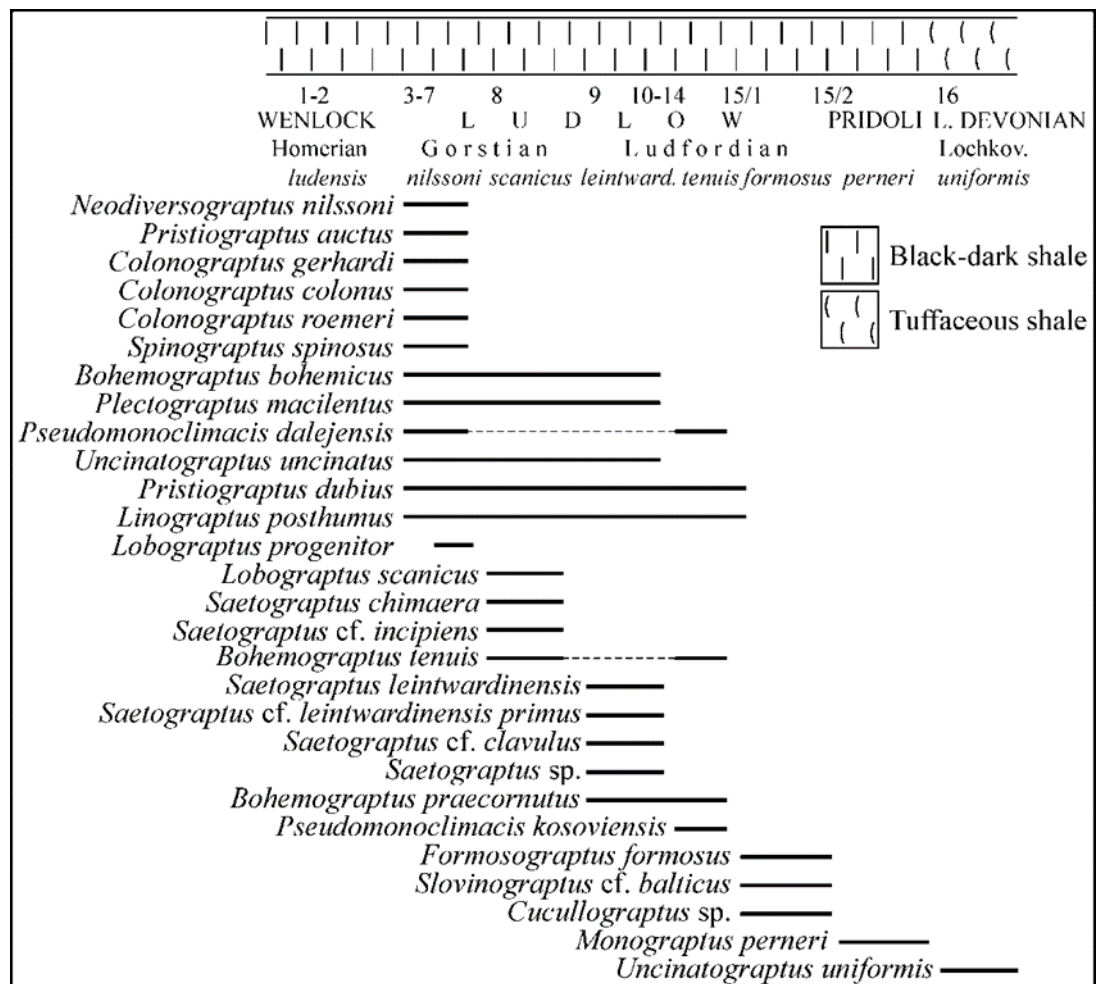


mostly in the lower part of sequence (Llandovery) by black shale with thin-bedded lydites and various intrusive beds becoming almost totally black-dark shale in its upper part; and the Fushe Muhurri tuffaceous shale (Lower Devonian), that consists of mostly yellow, argillaceous-tuffaceous shale with Lochkovian graptolites (Pashko, 1989). The studied upper Silurian graptolite shale sequence forms the upper part of the Muhurri Black Shale Fm. and occurs only in Muhurri area of the Unit. This mainly dark-grey clayey and sandy shale overlain by yellow tuffaceous shale occurs within a continuously exposed Silurian-Lower Devonian succession and yields different graptolite assemblages: abundant and diverse, relatively well-preserved Silurian assemblages; and well preserved, but moderately diverse Lower Devonian assemblages. Many shale intervals are rich in graptolites, some others in generally thick intervals, were poor. The Silurian/Devonian boundary coincides with a drastic change in the lithology of the sequence from Silurian black-dark to Devonian dominant yellow tuffaceous shale and is defined biostratigraphically at the base of the *Uncinagraptus uniformis* Biozone. The three measured sections and upper Silurian localities, water-mill of Perroi Fures, Shqathi, and Arrab Eperm and the Lochkovian Sharakane outcrop have been useful for graptolite biostratigraphy.

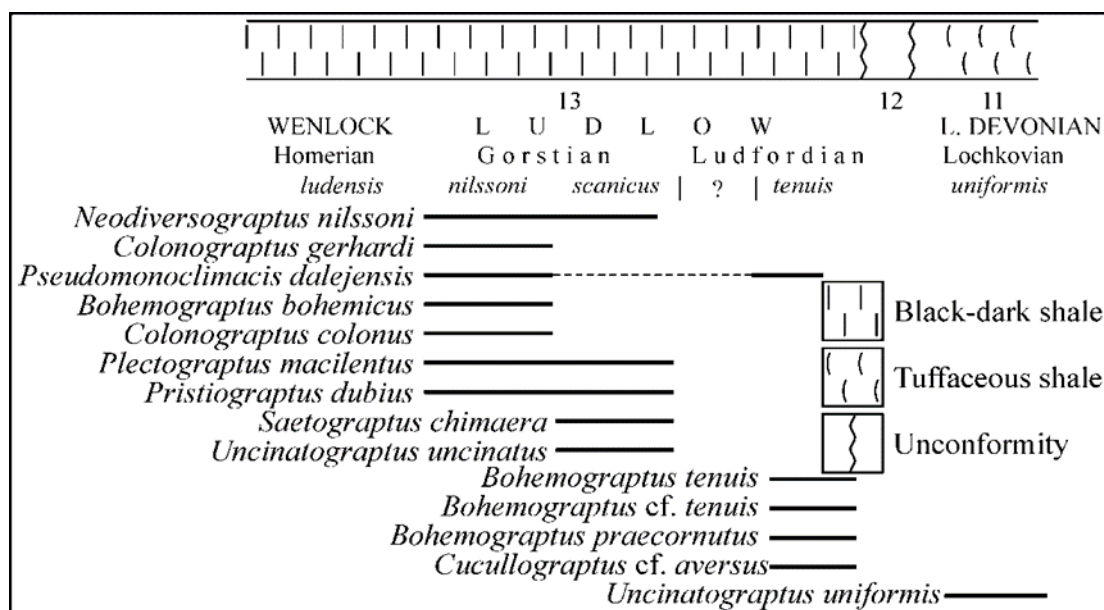
The best and most complete sequence for upper Silurian graptolite biostratigraphy is located to the rightwards of the rural road, east of the Hurdhe-Muhurri village, and is exposed near cemetery (Section 1 in Figure 1). It shows a continuous graptolite shale sequence from the uppermost Wenlock *ludensis* Biozone to the Lower Devonian *uniformis* Biozone (interval 16 of sections). Detailed examination of the section allowed recognition of the six upper Silurian graptolite biozones, which in ascending order are *nilssoni* (intervals 3-7), *scanicus-chimaera* (interval 8) the Gorstian, *leintwardinensis* (interval 9), *tenuis* (intervals 10-14), and *formosus* (interval 15/1) of the Ludfordian and *perneri* (interval 15/2) of the Přídolí (Figure 2). The Fushe Muhurri section (Section 2 in Figure 1) is located in K. Krizes, along the rural road from Fushe Muhurri to Hurdhe Muhurri and shows a shale sequence ranging from the uppermost Wenlock (Silurian) to the Lower Devonian. The upper Silurian sequence is represented by small, 4-5 m thick exposure (interval 13) showing transitional beds of the uppermost Wenlock to those of predominantly Ludlow age. The

uppermost Ludfordian biozones are not present in section. There is structural disruption between the Ludfordian *tenuis* Biozone and the basal Lower Devonian (Lochkovian) *Uncinagraptus uniformis* Biozone (Pashko, 2019). The rich, diverse and well-preserved graptolite faunas of this upper Silurian sequences allow recognition of the uppermost Homerician *ludensis* to the Ludfordian *tenuis* biozones (Figure 3)

In the third, rather tectonized Bulaci 1 section (Section 3 in Figure 1) exposed on the left riverside of Bulaci, under Sharakane village. The lower part of the stratigraphical sequence (intervals 1-17) is excluded because of the difficulty of being fully reconstructed, due to tectonic disruption.

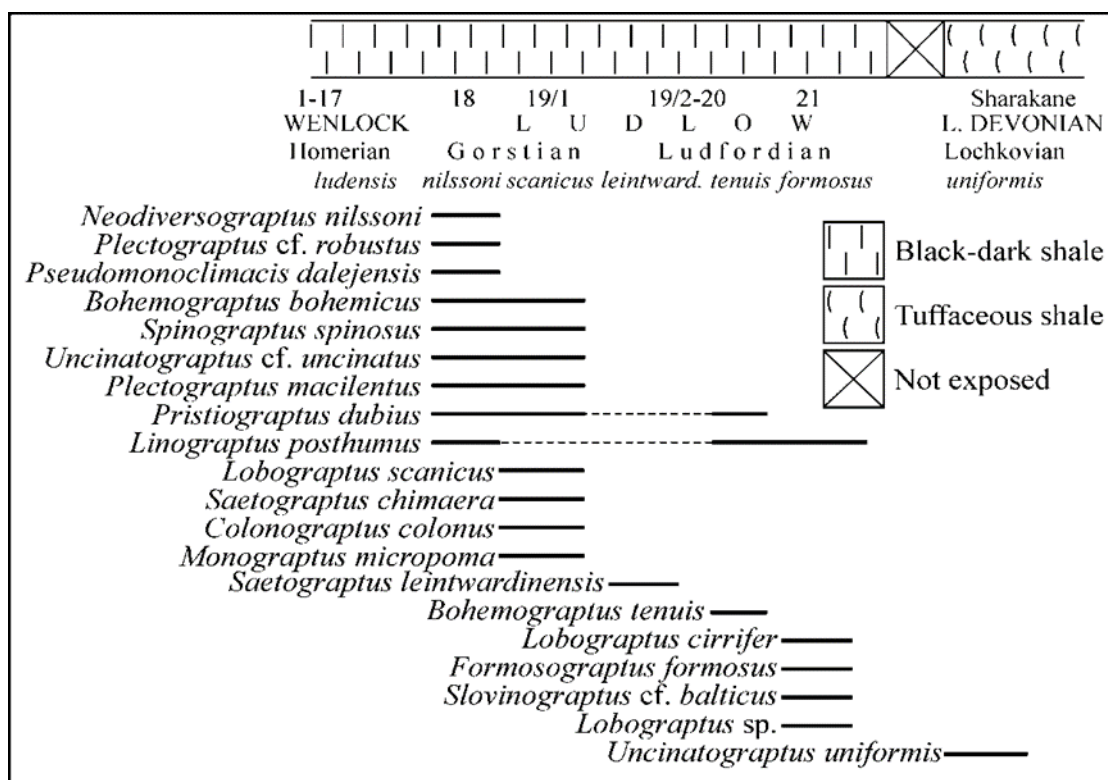


**Fig. 2:** Range chart showing the stratigraphical range of Ludlow and Pridoli (upper Silurian) graptolites identified from the Hurdhe Muhurri section (lithological column not in scale).



**Fig. 3:** Range chart showing the stratigraphical ranges of Ludlow (Gostian and Ludfordian) graptolites identified from the Fushe Muhurri section (lithological column not in scale).

Only the upper part of the sequence (intervals 18-21), represented by dark-grey and yellow-grey shale with rare big lamprophyre beds (to 12-13 m, interval 19), ranging from the uppermost Wenlock (intervals 1-17) to the Ludfordian, was examined in detail; the *nilssoni* (interval 18 of 10,0 m thick) and *scanicus-chimaera* (interval 19/1 of 9,0 m thick, samples 124-125) biozones of the Gorstian and *leintwardinensis* (interval 19/2 of 1,5 m thick, sample 126), *tenuis* (interval 20 of 28,0 m thick, sample 127b/1) and *formosus* (interval 21 of up to 5,0 m thick, sample 127b/2) biozones of the Ludfordian are identified. Upwards, after almost 20 m thick not exposed sequence, the yellow tuffaceous shale sequence yielded graptolites of the Lochkovian (Lower Devonian) *uniformis* biozone (Figure 4). The small Arabi Eperm, Nr. 139 outcrop is located along the small locally road from Selishte to Arabi Eperm (outcrop 7 in Figure 1), close to the forest remarkable for the great abundance of its well-preserved graptolites. The Ludlow-Pridoli graptolite assemblages include rare *C. colonus* and *S. cf. chimaera*, common *Uncinograptus uncinatus* (Tullberg) and *S. spinosus*, rare *B. tenuis* and *M. cf. perneri*, abundant *L. posthumus*, *Neocolonograptus cf. parultimus* (Jaeger) and *Neocl. ultimus* (Barrande).



**Fig. 4:** Range chart showing the stratigraphical range of Ludlow (Gorstian and Ludfordian) graptolites identified from the Bulaci 1 section (lithological column not in scale).

### 3. Preservation and Occurrence of Graptolites

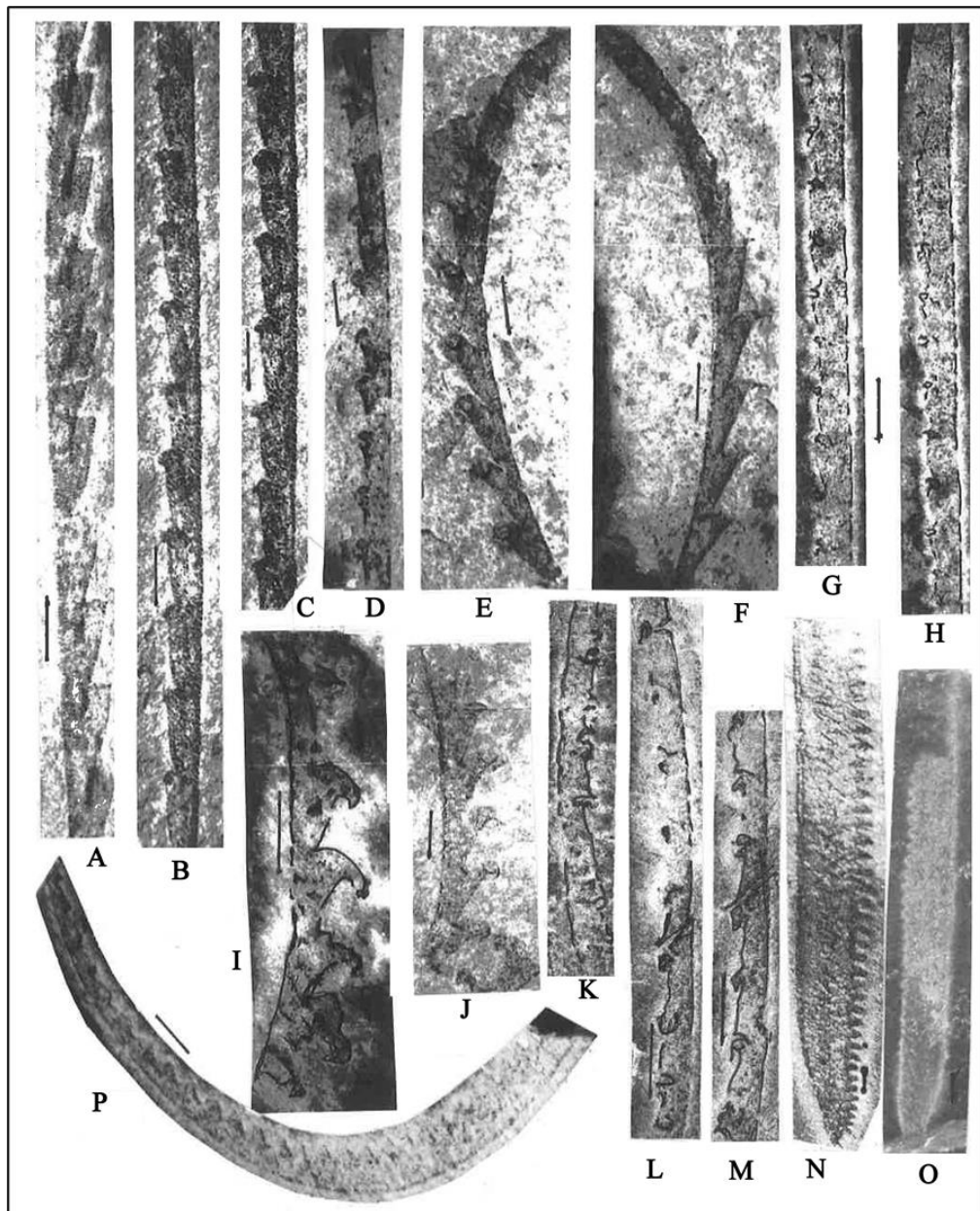
Graptolites have been collected from all fossiliferous levels of the sections studied, and from several outcrops throughout the Muhurri area. The fossil assemblage consists only of graptolites with variable, from moderate to poor preservations and low species diversity and occurs mostly in silty or soft clayey dark shale. As a result of the highly developed tectonic disruptions and small-scale folding of the shale the graptolite rhabdosomes are deformed, crushed, flattened, and also fragmented by the parallel and transversal cleavages. Graptolite rhabdosomes were commonly concentrated on distinct bedding planes and their abundance is varied: many intervals of the sequence, relatively thin (1-2 m), with mass occurrences particularly in lower parts of successions, are separated by moderately poor or barren mostly thick layers, particularly in the upper part of the sequence. The graptolite rhabdosomes were studied using a binocular microscope; some specimen preparation was necessary. Important selected species were photographed or drawn. They are illustrated in Figures 5,



6, 7 and 8. Wenlock/Ludlow boundary has been recognized in the transitional beds between the uppermost Homerician *ludensis* and the lower Gorstian *nilssoni* biozones and is defined at the first appearance of *Neodiverograptus nilssoni* (Barrande). In the lowermost part (basal 1-2 intervals) of the Hurdhe-Muhurri section the Wenlock graptolite assemblage includes the biozonal index *Colonograptus ludensis* (Murchison) (formerly referred to *Pristiograptus vulgaris* Wood (Pashko 1988, 1989), and includes rare *Colonograptus gerhardi* (Kühne) and common specimens of the long-ranging *Pristiograptus dubius* (Suess).

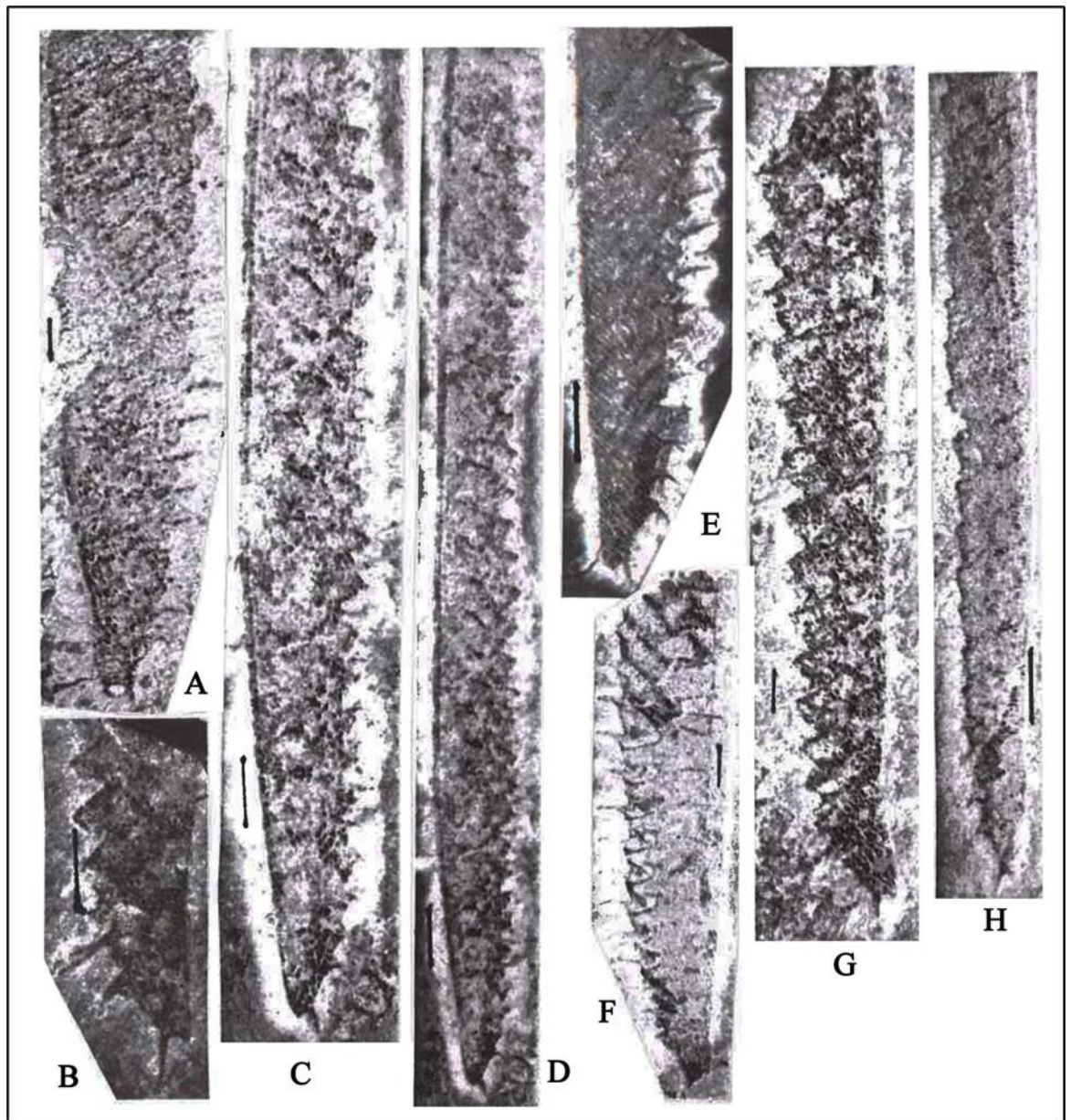
Detailed re-examination of the particularly rich graptolite assemblage of interval 13 of the Fushe Muhurri section allows recognition of a “mixture” of index species from several predominantly Ludlow graptolite biozones. Among them, the Homerician *ludensis*, the Gorstian *nilssoni*, *scanicus-chimaera* and *tenuis* index species have been recognized. The Wenlock graptolite assemblage includes rare specimens, usually poorly preserved of *Neogothograptus* cf. *examinassa* Maletz, *Spinograptus* cf. *munchi* (Eisenack), *Sp.* cf. *clathrospinosus* (Eisenack) and *Testograptus* cf. *testis* from the middle-upper part of the tectonized Bulaci 1 section (Pashko 2016) followed by relatively rich Ludlow graptolite assemblages, ranging from the basal Gorstian *nilssoni* to the uppermost Ludfordian *formosus* biozones.

The Gorstian assemblage show a much greater graptolite diversity than the underlying Homerician (Wenlock). Appearing species are dominated by monograptids: *Neodiversograptus*, *Saetograptus*, *Lobograptus*, *Pseudomonoclimacis*, *Bohemograptus* and *Colonograptus*, accompanied by long-ranging taxa such as *Pristiograptus dubius* (Suess), *Linograptus posthumus* (Reinhart Richter), *Uncinatograptus uncinatus* (Tullberg) and several plectograptinids, *Plectograptus* and *Spinograptus*.

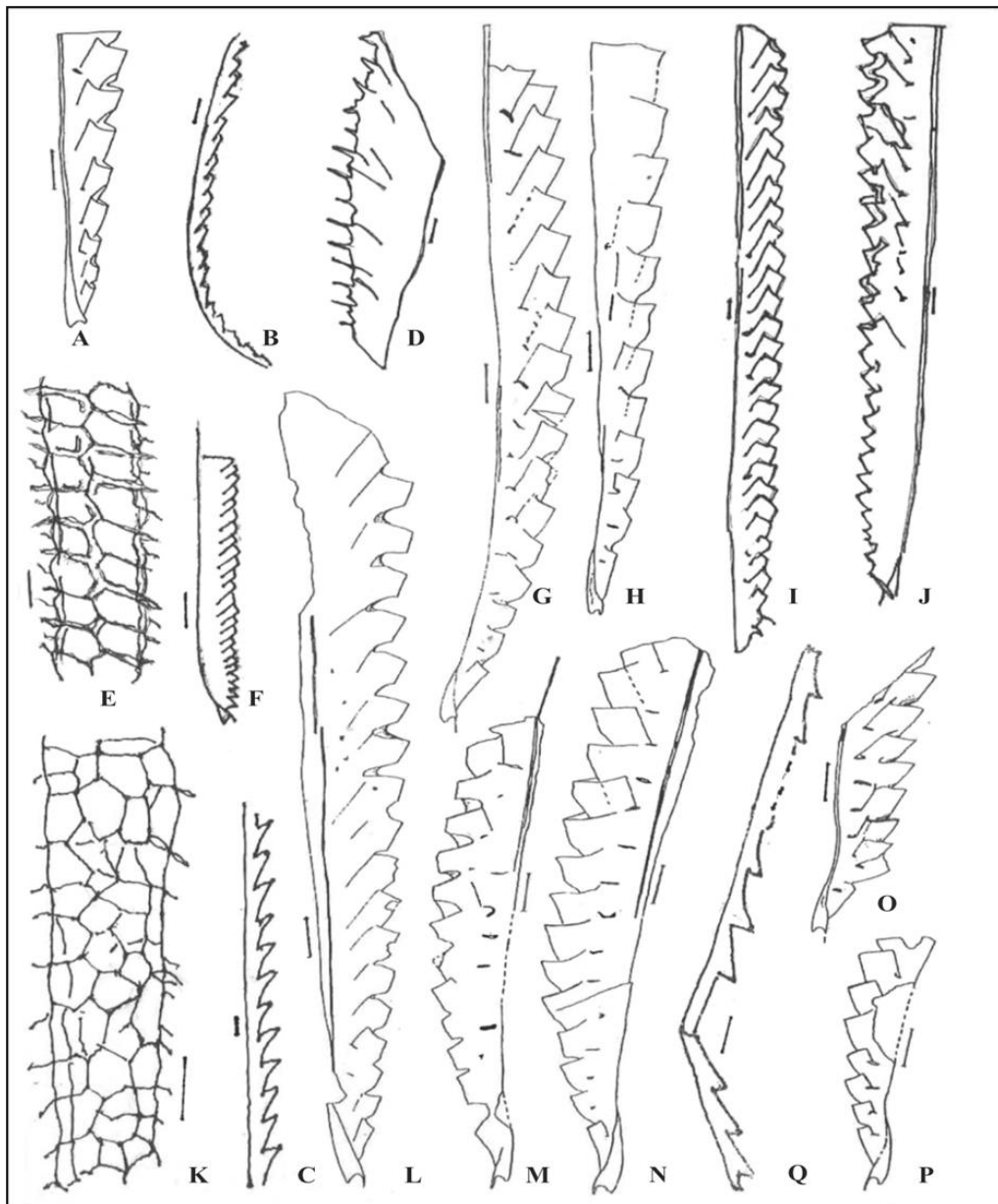


**Fig. 5:** A, *Lobograptus progenitor* Urbanek, 1966; A, nr. 4329, Hurdhe Muhurri, *nilssoni* Biozone; B-D, *Lobograptus scanicus* (Tullberg, 1883); B-C, nr 4412, 4412<sup>+</sup>, Hurdhe Muhurri, D, nr 4802, Bulaci, *scanicus-chimaera* Biozone; E, *Lobograptus cirrifer* Urbanek, 1996; nr 4803, Bulaci, *scanicus-chimaera* Biozone; F, *Lobograptus* sp., nr 4810; Bulaci, *formosus* Biozone; G, H, *Slovinograptus* cf. *balticus* (Teller, 1966); nr 4520, 4520<sup>+</sup>; Hurdhe Muhurri, *formosus* Biozone; I, J, *Formosograptus formosus* (Bouček, 1931); nr 4809, Bulaci, *formosus* Biozone; nr 3870, Sharakane, *formosus* Biozone; K, *Slovinograptus* sp. cf. *balticus* (Teller, 1966); nr 4708, Bulaci, *formosus* Biozone; L, M, *Cucullograptus* cf. *aversus* (Eisenack, 1942); nr. 6520, 6520<sup>+</sup>, Fushe Muhurri, *tenuis* Biozone. N, O, *Colonograptus gerhardi* (Kühne, 1955), N, nr 1524; O, nr 674, Hurdhe Muhurri, *nilssoni* Biozone; P, *Bohemograptus bohemicus* (Barrande, 1850); nr 694, Hurdhe Muhurri, *nilssoni* Biozone..All scale bars represent 1 mm.





**Fig. 6:** A, F, G, *Saetograptus leintwardinensis* (Lapworth, 1880); A, nr. 4489, F, nr. 4464, G, nr. 4439, Hurdhe Muhurri, *leintwardinensis* Biozone; B, *Saetograptus* cf. *clavulus* (Perner, 1899); nr. 4443, Hurdhe Muhurri, *leintwardinensis* Biozone; C-E, *Saetograptus chimaera* (Barrande, 1850); C, nr. 4361, D, 4361<sup>+</sup>, E, nr. 4369, Hurdhe Muhurri, *scanicus-chimaera* Biozone; H, *Saetograptus* sp. cf. *incipiens* (Wood, 1900), nr. 4427, Hurdhe Muhurri, *scanicus-chimaera* Biozone. All scale bars represent 1 mm.



**Fig. 7:** A, *Pristiograptus dubius* (Suess, 1851), nr 4438, Hurdhe Muhurr, *nilssoni* Biozone; B, *Neodiversograptus nilssoni* (Barrande, 1850); nr. 4229, Hurdhe Muhurri, *nilssoni* Biozone; C, nr. 1419, Hurdhe Muhurri, *nilssoni* Biozone; F, *Colonograptus colonus* (Barrande, 1850); nr. 1524, Hurdhe Muhurri, *nilssoni* Biozone; D, *Saetograptus* sp., nr. 4483, Hurdhe Muhurr, *leintwardinensis* Biozone; E, *Plectograptus macilentus* (Törnquist, 1887), nr. 752, Hurdhe Muhurri, *nilssoni* Biozone; G, H, M-P, *Pseudomonoclimacis dalejensis* (Bouček, 1936); G, nr. 6511, Fushe Muhurri, *tenuis* Biozone; H, nr. 4539, Hurdhe Muhurri, *tenuis* Biozone; M, nr. 6507, N, nr. 6515, O, nr. 6568, P, nr. 6513, Fushe Muhurri, *tenuis* Biozone; I, *Saetograptus* cf. *leintwardinensis primus* (Bouček, 1936), nr. 4464 Hurdhe Muhurri, *leintwardinensis* Biozone; J, *Colonograptus gerhardi* (Küchne, 1955), nr. 6520 Fushe Muhurri, *nilssoni* Biozone; K, *Plectograptus* cf. *robustus* (Obut and Zaslavskaya, 1983); nr. 875, Bulaci, *nilssoni* Biozone; L, *Pseudomonoclimacis* cf. *kosoviensis* (Bouček, 1936), nr. 4438, Hurdhe Muhurri, *leintwardinensis* Biozone; Q,

*Linograptus posthumus* (Reinhart Richter, 1875), nr. 4313, Hurdhe Muhurri, *nilssoni* Biozone.. All scale bars represent 1 mm.

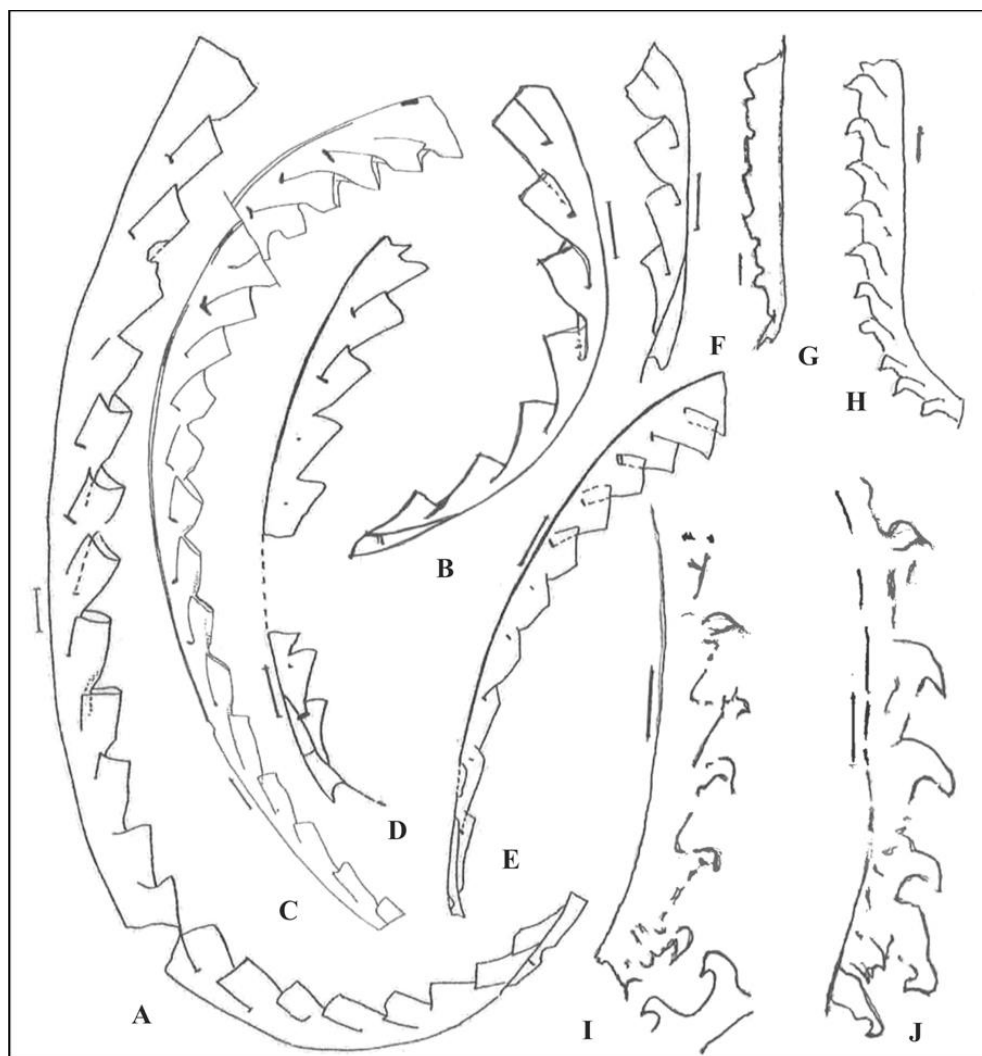
But more considerable abrupt increases in graptolite abundance and diversity, particularly in *Saetograptus* species occurs in the *scanicus-chimaera* and *leintwardinensis* biozones (intervals 8 and 9 of the Hurdhe Muhurr section), which represents also an extinction intervals. Their rich graptolite assemblage includes various *Saetograptus* taxa and many other monograptids representing the important taxa for the biostratigraphy of the Gorstian/Ludfordian boundary. Upwards in the section, the *tenuis* Biozone is characterized by a high species diversity but low abundance graptolite assemblage. Subsequently, in the overlying thick upper Silurian sequence the higher biozones are much impoverished, are characterized of sporadic graptolite species occurrences and the boundaries between biozones are poorly defined due to the presence of the several barren intervals. The non-recognition of some upper Silurian biozones cannot be attributed to collecting and outcrops failure, therefore discovering their presence needs additional studies. A Lower Devonian graptolite assemblage indicate the Lochkovian *uniformis* Biozone, characterized by a high density and low diversity of large and well preserved *Uncinatograptus uniformis* (Příbyl), *Monograptus microdon* Reinhard Richter, *Neomonograptus aequabilis* (Příbyl), etc., and the *hercynicus* Biozone characterized by abundant monospecific assemblage of the biozonal index (Pashko, 2019).

#### 4. Graptolite Biozones, Biostratigraphy and Correlations

Examination of the stratigraphical distribution of the upper Silurian graptolite assemblages has enabled recognition of the following assemblage biozones named after index taxa: Gorstian *nilssoni* and *scanicus-chimaera*, Ludfordian *leintwardinensis*, *tenuis* and *formosus* and Přídolí *parultimus-ultimus* and *perneri* biozones. The transition between the Wenlock/Ludlow series has been observed in the lowermost part of the Hurdhe Muhurri (intervals 1-2) and Fushe Muhurri (interval 13 with a mixed assemblage) sections and is defined between the Homeric *Colonograptus ludensis* and Gorstian *Neodiversograptus nilssoni* biozones. The upper Silurian/Devonian boundary in the Hurdhe Muhurri section is between the Ludfordian *perneri* and Lochkovian *Uncinatograptus uniformis*



Biozones. The Muhurri upper Silurian graptolite faunas show similarity in species and faunal succession to other graptolite assemblages of European areas (especially Bohemia) and its graptolite biozonation can be correlated with the well-established European graptolite biozonation particularly from Peri-Gondwanan Europe (Loydell, 2012) and the former Graptolite Standard Biozonation for the Silurian (Koren' et al., 1995) (Figure 9).



**Fig. 8:** A-B, *Bohemograptus tenuis* (Bouček, 1936); A, nr. 4363, Hurdhe Muhurri, *scanicus-chimaera* Biozone; nr. 6508, Fushe Muhurri, *tenuis* Biozone; C-F, *Bohemograptus praecornutus* Urbanek, 1970, C, nr. 4486, E, nr. 4492, F, nr. 4482, Hurdhe Muhurri, *leintwardinensis* Biozone; D, nr. 6512, Fushe Muhurri, *leintwardinensis* Biozone; G, *Neocolonograptus ultimus* (Perner, 1899), nr. 5137, Arab Eperm, *parultimus-ultimus* Biozone, H, *Monograptus perneri* (Bouček, 1931, nr. 4542, Hurdhe Muhurri, *perneri* Biozone; I-J, *Formosograptus formosus* (Bouček, 1931), I, nr. 3870, Sharakane, nr 4809, Bulaci, *formosus* Biozone. All scale bars represent 1 mm.

**4. 1. The Gorstian Stage** is the most widely and easily recognized throughout the Muhurri area and represented by follows biozones.

**4.1a. *Neodiversograptus nilssoni* Biozone.** The widespread distribution of this biozone suggests that it is present throughout the entire Muhurri area. It has been recognized by the appearance of the abundant biozonal index taxon *N. nilssoni*. In the Hurdhe Muhurri section together with abundant *N. nilssoni*, the following graptolite species are recorded: rare *Lobograptus progenitor* Urbanek in the uppermost part (interval 7), rare *Pristiograptus auctus* Rickards, *Colonograptus gerhardi* (Kühne) in the lower part of biozone, common *Colonograptus roemeri* (Barrande), common *P. macilentus* (Törnquist) and *Spinograptus spinosus* (Wood), and many specimens of the long-ranging *Prs. dubius*, *L. posthumus* (Reinhart Richter). The graptolite assemblage of the Fushe Muhurr section (interval 13) includes several index species from predominantly Ludlow graptolite biozones. The common *N. nilssoni*, *C. gerhardi*, *C. colonus*, *Pl. macilentus* and relatively frequent Gorstian species *Pseudomonoclimacis dalejensis*, *Bohemograptus bohemicus* Bouček, *Prs. dubius*, *U. uncinatus* and *L. posthumus* are identified. In the Bulaci 1 section the biozonal taxa are accompanied by *C. colonus*, *Prs. dubius*, *P. macilentus*, *Sp. spinosus* and rare *Plectograptus cf. robustus* (Obut and Zaslavskaya) (interval 5 nr. 879, Fig. 8 K and int. 18, nr. 1850).

**4.1b. *Lobograptus scanicus*-*Saetograptus chimaera* Biozone.** This biozone has been recognized at a number of localities in the Muhurri area and is characterized by an increase in graptolite diversity and abundance. It is recognizable by the first occurrence of the biozonal index species in interval 8 of the Hurdhe Muhurri sections. Apart from the biozonal taxon, the biozone is characterized by rich graptolite assemblages dominated by monograptids. In the Hurdhe Muhurri section, alongside the common biozonal indices *Lobograptus scanicus* (Tullberg) and *Saetograptus chimaera* (Barrande), the graptolite assemblage includes rare *Saetograptus sp. cf. incipiens* (Wood), *Colonograptus roemeri* (Barrande) and frequent *N. nilssoni*, *B. bohemicus*, *Pl. macilentus*, *U. uncinatus*, and the long-ranging *Prs. dubius* and *L. posthumus*. In the Fushe Muhurri section have been identified the biozonal index taxon *S. chimaera*, many *B. praecornutus*, rare *Bohemograptus tenuis* (Bouček) and some *C.*

*colonus*, *P. macilentus*, *Prs. dubius*, and *U. uncinatus*. In the Bulaci 1 section the biozonal assemblage comprises rare *N. nilssoni*, *Heisograptus micropoma* (Jaekel), *C. colonus*, *Pl. macilentus*, *U. uncinatus* and *Prs. dubius*.

Age Mya		Graptolite Biozones		
Epocs	Stages	Muhurr	Peri-Gondwanan Europe. (Loydell, 2012)	Graptolite Standard for the Silurian (Koren' et al., 1995)
P R I D O L I	423	<i>perneri</i>	<i>transgrediens</i> <i>perneri</i> <i>boučeki</i> ? <i>lochkovensis</i>	<i>boučeki-transgrediens</i> <i>branikensis-lochkovensis</i>
		<i>parultimus-ultimus</i>	<i>parultimus/ultimus</i>	<i>parultimus-ultimus</i>
L U D F O W	Ludfordian	<i>formosus</i>	<i>fragmentalis</i> <i>latilobus/balticus</i> <i>kozlowskii</i> <i>inexpectatus</i>	<i>formosus</i> <i>bohemicus tenuis-kozlowskii</i>
	425.6	<i>tenuis</i> <i>leintwardinensis</i>	<i>tenuis</i> <i>linearis</i>	<i>leintwardinensis</i>
	Gorstian 427.4	<i>scanicus-chimaera</i> <i>nilssoni</i>	<i>scanicus/chimaera</i> <i>progenitor</i> <i>nilssoni</i>	<i>scanicus</i> <i>nilssoni</i>

**Fig. 9:** Biozones of the studied upper Silurian sequence of the Muhurr (Albania) area and correlation with biozonal schemes of Peri-Gondwanan Europe (Loydell, 2012) and the former Graptolite standard zonation for the Silurian (Koren' et al., 1995).

**4.2. Ludfordian stage.** A marked faunal change at the base of the Ludfordian succession shows an important event in late Silurian graptolite evolution associated with the *leintwardinensis* Biozone. In the succeeding *tenuis* and *formosus* biozones the poor graptolite assemblage consists of the biozonal index taxa accompanied by some mostly long ranging species.

**4.2a. *Saetograptus leintwardinensis* Biozone.** This thin biozone has been recognized in interval 9 of the Hurdhe-Muhurr sections. The graptolite

assemblage of this biozone is characterized by an increase in graptolite diversity and abundance and is much more diverse than that of the lower biozones. The most common elements of the rich graptolite assemblage are numerous well-preserved specimens of various species of *Bohemograptus* and particularly *Saetograptus* which are important taxa for biostratigraphy. Within the graptolite assemblage of this biozone are the biozonal index *Saetograptus leintwardinensis* (Hopkinson, in Lapworth 1880), the rare *S. cf. leintwardinensis primus* Bouček (nr 4464), *S. clavulus* Perner, *Saetograptus* sp. cf. *incipiens* (Wood), *Saetograptus* sp., *Bohemograptus praecornutus* (Bouček), *B. bohemicus*, *Pl. macilentus*, and the long-ranging taxa *Prs. dubius*, *U. uncinatus* and *L. posthumus*, whereas in the Bulaci 1 section only the *S. cf. leintwardinensis primus* (Bouček) (nr 4776, 4778) is found.

**4.2b. *Bohemograptus tenuis* Biozone.** This is identified in a relatively thick shale interval in the Hurdhe Muhurri section and recognized by the occurrence of a poorly preserved graptolite association containing the biozonal index taxon *Bohemograptus tenuis* (Bouček) accompanied by a relatively rich graptolite assemblage consisting of the rare *Pseudomonoclimacis kosoviensis* (Bouček), some *Pm. dalejensis*, rare *Cucullograptus* sp. and the long-ranging taxa *Prs. dubius*, *U. uncinatus* and *L. posthumus*, whereas in the Bulaci 1 section the biozonal taxon is accompanied by *Lobograptus cirrifer* Urbanek. The graptolite assemblage of the Fushe Muhurri section includes the index taxon together with rare *Cucullograptus cf. aversus* Eisenack and frequent *Pm. dalejensis*.

**4.2c. *Formosograptus formosus* Biozone.** This is characterized by a low diversity assemblage and has been identified by the presence of the biozonal index species *Formosograptus formosus* (Bouček). In uppermost part of the Hurdhe Muhurri (Fig. 1, loc. 4) the biozonal index occurs with *Slovinograptus cf. balticus* (Teller) and *Pr. dubius* whereas in the Bulaci 1 sections, it occurs with *Slovinograptus* sp. cf. *balticus*, *Lobograptus* sp. (nr 4810) and the long-ranging species *Prs. dubius* and *L. posthumus*.

**4.3. The Přídolí Series.** Is composed of dark shale and is recognized in the Arab Eperm outcrops by the presence of biozonal index taxa within a rich mixed upper

Silurian graptolite assemblage, and in the upper parts, the 15/2 interval, of the Hurdhe Muhurri section.

**4.3a.** *Neocolonograptus parultimus-ultimus* Biozone. This biozone is not present in a stratigraphical section and has been tentatively identified only in the Arab Eperm outcrop (Figure 1, locality 7) based on the identification of abundant *Neocolonograptus* cf. *parultimus* (Jaeger) and *N. ultimus* (Barrande).

**4.3b.** *Monograptus perneri* Biozone. This biozone is defined by the occurrence of the biozonal index taxon *Monograptus perneri* Bouček within a large barren interval in the upper part of the Hurdhe Muhurri section (interval 15/2) and in the mixed graptolite assemblage of the Arab Eperm outcrops.

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