

GRAPTOLITE BIOSTRATIGRAPHY OF THE LOWER DEVONIAN (LOCHKOVIAN) OF THE MUHURR AREA (ALBANIA): A REVIEW WITH NEW DATA

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ABSTRACT

The graptolite biostratigraphy of the Lower Devonian tuffaceous shale sequence of the Muhurr area is here dated. Currently, Lochkovian and graptolite faunas represent the youngest of the graptolite assemblages in the Muhurr area. It is characterized by abundant moderate diversity or extremely abundant monospecific biozonal assemblages and includes a total number of 8 graptolite species of the *Uncinatograptus*, *Slovinograptus?*, *Neomonograptus* and *Linograptus* genera. Their stratigraphic distribution allows us to recognize three graptolite biozones: i) the *uniformis*, tentatively recognized for the first time, ii) *praehercynicus* and, iii) *hercynicus* biozone. It includes cosmopolitan species the Lochkovian graptolite biozones correlated with other European and worldwide graptolites schemas. The Silurian/Devonian boundary placed in continuous shale sedimentation at a drastic lithological change coincides with the first appearance of *Uncinatograptus uniformis*, whereas the boundary within biozones has not been defined due to tectonic disruption.

Keywords: Lower Devonian (Lochkovian), graptolite biostratigraphy, Muhurr, Albania

1. INTRODUCTION

The graptolite black shales are part of the Ordovician-Devonian marine sedimentary succession that makes up the Lower Paleozoic Variscan basement of the Korabi Zone and occur in the Muhurr Caja-Malësia e Korabit subunit (Aliaj and Kodra 2016). It covers a time interval from Lower Silurian (Llandovery) to Lower Devonian (Lochkovian stage) and represents the unique graptolitic shale outcrop within the Dinarides-Albanides-Hellenides Belt. The Silurian fossil faunas have been found and studied during stratigraphical and paleontological research on the Paleozoic deposits of the Korabi Zone and reported in the first unpublished studies, in 1985. This fossil

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fauna predominantly consists of abundant, diversified, mostly well-preserved graptolite assemblages. A level with abundant crinoids columnals *Scyphocrinites* and extremely rare bivalvia is also found. The first Silurian stratigraphical succession has been obtained and preliminary Silurian graptolite biozonal schemas have been dated based on the stratigraphical distributions of the graptolite species. The first Lower Devonian graptolites from Muhurr area (Figure 1) have been subsequently collected, recognized and reported in unpublished report, in 1988. The most complete description of the Silurian-Devonian sequence and fossil faunas' graptolites, tentaculites, Orthoceras and conodonts from the Muhurr Caja-Malësia e Korabit subunits has been made. For the graptolite shale sequence there are two lithostratigraphic units distinguished: i) the Silurian Muhurr Black shale formation and, ii) Lower Devonian Fushë-Muhurr tuffaceous shale formation. The first record of Lower Devonian (Lochkovian) graptolites from the Muhurr area was obtained from the measured stratigraphic sections of Hurdhë-Muhurri and Fushë-Muhurri and from Bulaci and Sharakane exposures that were sampled in detail (Figure 1). The more complete Fushë-Muhurr sections show continuous Lochkovian succession and detailed graptolite collections allow a biostratigraphic subdivision in graptolitic biozones. Lower Devonian graptolitic shale sequence consists of a continuous sequence of yellow tuffaceous shale (Fushë-Muhurr Fm) that forms uppermost part of the complete graptolite shale successions, only partially preserved due to all geological background of the Korabi Zone (Pashko 1989; 2004b). Data about the biostratigraphy of the Silurian-Lower Devonian graptolite shale sequence could be found in (Pashko 2005; 2006; 2016; Pashko *et al.*, 2014), and the documents related to the field Meeting of IGCP Project No 276, in Alger (Pashko 1990; 1992; Xhomo *et al.*, 1990; 1992).

Lower Devonian sequence occurs only in the Muhurr area and yields abundant well-preserved, but moderately diverse graptolite assemblages. Seven Lower Devonian important graptolite species corresponding to Lochkovian stage have been identified. Three successive assemblages of lower *uniformis* tentatively recognized *praehercynicus* and upper *hercynicus* biozones were recognized in the Muhurr area, within 25 Silurian-Devonian biozones (Pashko 1989; 2004b). Higher, Devonian succession followed by shale-limestone intercalations with *Tentaculites*, *Cephalopods* and *Conodonts* shows continuous marine sedimentation from the Lochkovian to the Pragian-Eifelian and forms the base of the Korabi Shale-Limestone Formation of Devonian Age (Pashko 1989; Xhomo *et al.*, 1992; 2006). Currently, Lochkovian graptolite assemblage represents the youngest graptolite assemblage in the Muhurr area.

The present paper aims to review the synthesis of a new more detailed investigation and re-evaluation of the Muhurr Lochkovian graptolitic

biostratigraphy (subdivision and correlation) based on both previous unpublished and published works and current investigation. The Lower Devonian (Lochkovian) graptolites are here for the first time illustrated.

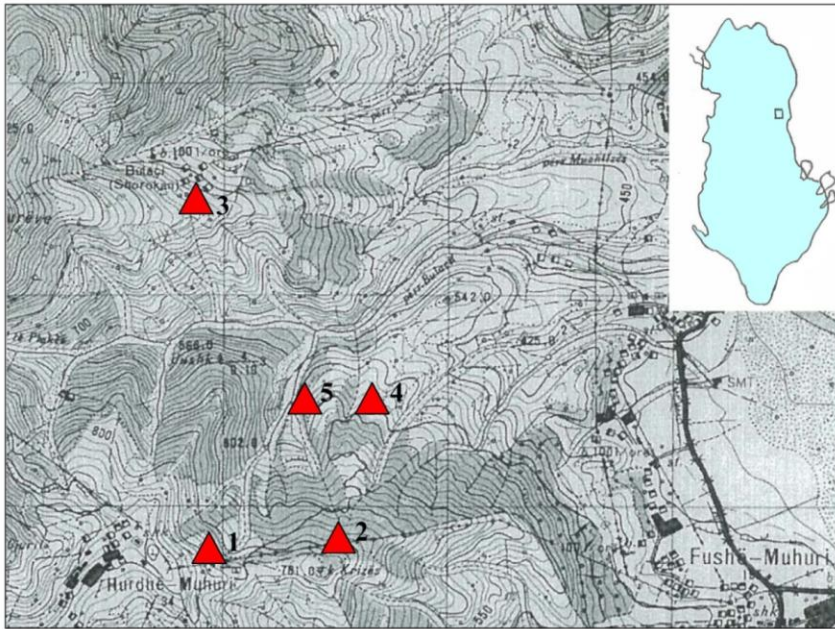


Fig.1: Muhurr area: the main sites of Lochkovian graptolites and tentaculites collection. Graptolite location: 1- Hurdhë-Muhurr section, 2- Fushë-Muhurr section, 3- Sharakane outcrop, 4-Bulaci outcrop, 5- Outcrop with Pragian Tentaculites.

2. Geological Setting

The Silurian-Lower Devonian graptolite shale succession of the Muhurr area is part of the Ordovician-Devonian marine sedimentary succession and represents the Lower Paleozoic Variscan basement of the Korabi structural Zone. The Korabi structural Zone with a general NW-SE direction was part of the Dinaric-Albanian-Hellenic Belt and its geotectonic picture has been discussed and different interpretations have been proposed. Recently it has been included within the inner Albanides as a continental microblock was subdivided in eastern Kollovozi and western Muhurr-Caja-Malësia e Korabit subzones (Aliaj and Kodra 2016). Its Lower Paleozoic basement during the Hercynian orogenesis, was affected by strong tectonic deformation, metamorphism and magmatic activity, subsequently eroded and

unconformably covered by the Permian-Lower Triassic sandstones and conglomerates of Verrucano Series. The continuous Silurian-Lower Devonian graptolite shale sequence occurs throughout the western part of Muhurr-Caja-Malësia e Korabit subzone and extends from Muhurr area where it is represented by the most complete Llandovery-Lower Devonian sequence to Buzëmadhe and Nimcearea, where only the lower Silurian sequence is preserved. In general, graptolitic shale sequence is of great scientific interest due to its characteristics. The continuous Silurian-Lower Devonian graptolite shale overlay Ordovician silty-schists and quartzite intercalations without graptolites, and more upwards, up to Pragian-Eifelian shale-limestone intercalations with tentaculites (Pashko 2004) and conodonts (Meco 1987; 2010). The Silurian-Lower Devonian graptolite shale succession represents euxinic basinal facies. The complete Muhurr graptolitic shale sequence was subdivided into two formations: i) Muhurr black shale formation (Silurian age) represented mostly by black shale with thin bedded lydites, particularly in Lowermost Silurian (Llandovery) to almost totally black-dark shale and varied intrusive beds, and ii) Fushë-Muhurr tuffaceous shale formation (Lower Devonian age), that consists of mostly yellow, argillaceous-tuffaceous shale with Lochkovian graptolites. Due to the strong tectonic activity occurred in Korabi Zone throughout its geological history and disruption of the shale sequence, the Silurian-Lower Devonian and Llandoveryan graptolitic fauna in particular, mostly derived from the discontinuous sections and outcrops. However, the Silurian and Lower Devonian sequences in general are well-dated based exclusively on important graptolitic assemblages.

3. MATERIALS AND METHODS

The Figure 1 depicts the abundant important graptolite faunas collected from all the fossil levels of detailed Hurdhë-Muhurr and Fushë-Muhurr stratigraphic sections and Bulaci and Sharakane outcrops. A continuous detailed sampling for paleontological investigation has been carried out. The fossil graptolites that were collected from individual layers involve also the rhabdosome remains of the both parts of the rock slabs which are of low contrast against the surrounding rock, particularly the *Uncinatograptus hercynicus* specimens. Graptolitic rhabdosomes were concentrated on distinct relatively thin bedding planes with mass occurrence and particularly in Upper Lochkovian *hercynicus* biozone are extremely abundant, ranged more 100 specimens, and occur in one 5-7-centimeter-thick beds only. The Lochkovian graptolite species are represented mostly by the small to medium-sized, straight to moderately curved rhabdosomes, particularly with 10-15, but the longest specimens bear to 29 (*U. uniformis*) or 31 (*U. hercynicus*) thecae. The

graptolitic rhabdosomes were studied and illustrated using binocular microscope with a drawing mirror. The drawings in black ink were used. These graptolite faunas have been deposited in the paleontological collection of Geological Research Institute, partially now as a personal collection.

4. Biostratigraphy and Correlation

The Lower Devonian (Lochkovian) graptolites have been recognized from tuffaceous shales of the best exposed Hurdhë-Muhurr (Figure 2) and Fushë-Muhurr (Kodra e Krizës) (Figure 3) measured sections and two isolated outcrops. The stratigraphical sections occurred along the rural road, from Fushë-Muhurr to Hurdhë-Muhurr village (Locality 1 in the Figure 1), whereas the two outcrops located in the riverside of Bulac River (Locality 4 in the Figure 1) and Sharakane area (Locality 3 in the Figure 1). Stratigraphical ranges and relative abundance of abundant well-preserved and moderately diverse Lochkovian graptolite from the Muhurr area are depicted in the Figure 2 and 3. Lochkovian graptolite assemblage consists of 8 species of the *Uncinatograptus*, *Slovinograptus?* (sensu Chen *et al.*, 2015), *Neomonograptus* and *Linograptus* genres which are illustrated as drawings in three paleontological tables (Figure 4-6). Three biozones which have been recognized by presence of their index graptolite species are depicted in Figure 7.

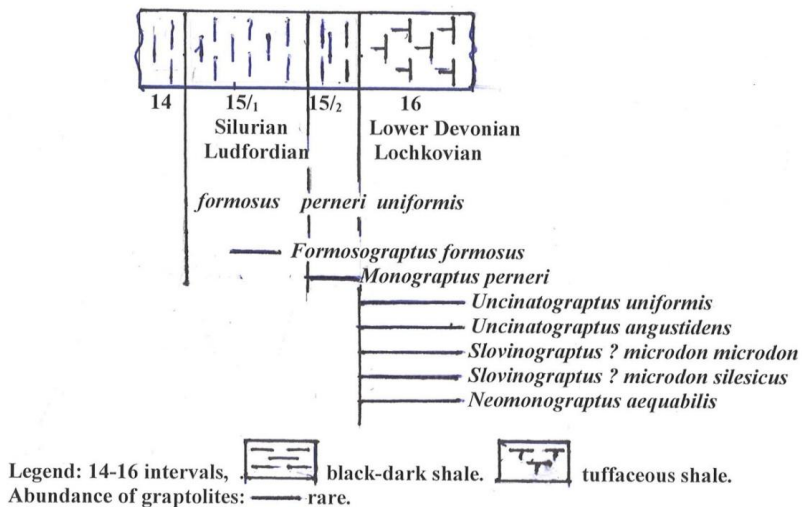


Fig. 2: Biostratigraphical ranges of the Lower Devonian (Lochkovian) graptolite species from Hurdhë-Muhurr section.

The biostratigraphical subdivision and correlation of the Lower Devonian Lochkovian stage is well known in many regions of the world, almost in the Peri-Gondwanan, Europe: (Bohemia, Germany) and Baltic area (East European Platform). Like in the stratotype section (Klonk section, the Czech Republic), the Lochkovian stage in Muhurr area is defined by the first appearance of the biozonal index taxa *Uncinatograptus uniformis*. In the evolution of the Silurian-Devonian graptolite faunas, the Lochkovian assemblage shows a greater increase in abundance and in diversity of graptolite than the preceding uppermost Gorstian Biozones. Detailed re-examination of the graptolites of the measured Hurdhë-Muhurr and Fushë-Muhurr sections and Bulac and Sharakane outcrops allowed us to recognize three successive Lochkovian graptolitic assemblages: the early *uniformis*, the middle tentatively recognized *praehercynicus* and the later *hercynicus* graptolite biozones, although its boundary has not been defined due to tectonic disruption. The Silurian/Devonian boundary coincides with the drastic change in the lithological compositions of sequence from Silurian black-dark (Hurdhë-Muhurr Fm) to Devonian dominant yellow tuffaceous shale (Fushë-Muhurr Fm) and is correlated with the base of the *uniformis* biozone.

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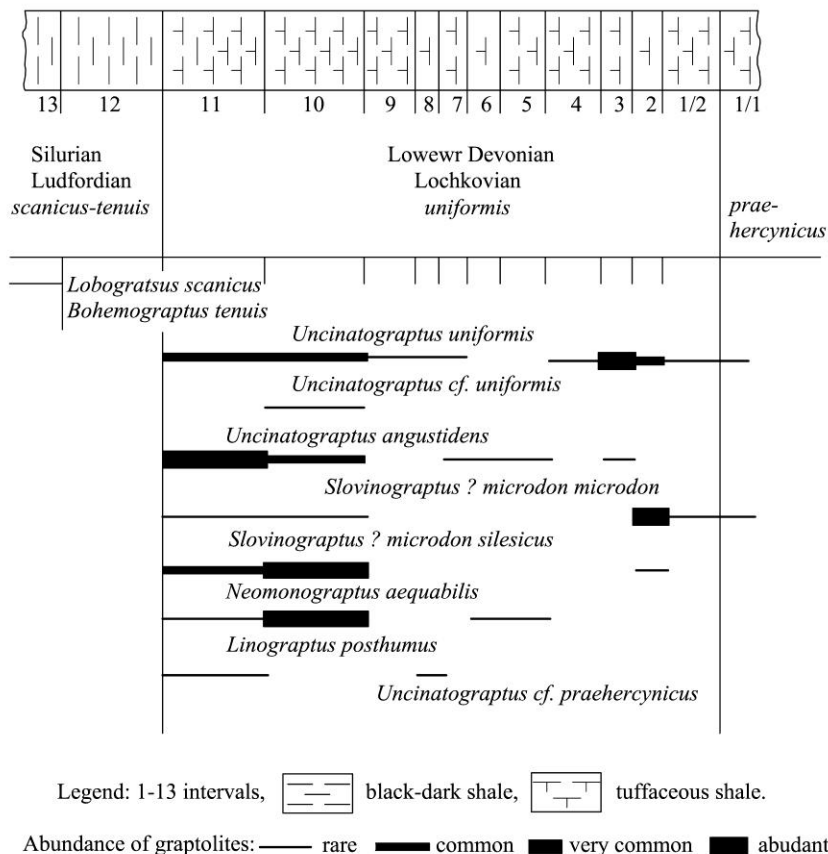


Fig.3. Biostratigraphical ranges of the Lower Devonian (Lochkovian) graptolite species from Fushë- Muhurri section.

The Silurian/Devonian boundary coincides with the drastic change in the lithological compositions of sequence from Silurian black-dark (Hurdhë-Muhurr Fm) to Devonian dominant yellow tuffaceous shale (Fushë-Muhurr Fm) and is correlated with the base of the *uniformis* biozone.

The best section through the Silurian and Lower Devonians sequences includes only the lowermost part of the Lochkovian shale and is exposed in the east of Hurdhë-Muhurr (Figure 2, locality 1 in the Figure 1), where the Silurian/Devonian boundary has also been documented based on graptolite faunas. In this continuous shale sedimentation cross the Silurian/Devonian boundary the Pridoli (Silurian) dark shale (interval 15/2) with index biozonal taxon *Monograptus perneri* Boucek followed by the Lochkovian (Lower Devonian) tuffaceous shale (interval 16) and at the base of this shale

sequence, the first appearance of *Uncinagraptus uniformis* accompanied by abundant *U. angustidens*, *Slovinograptus? microdon microdon* and *Neomonograptus aequabilis*, marks the base of the *uniformis* Biozone and defined the Lochkovian stage, also.

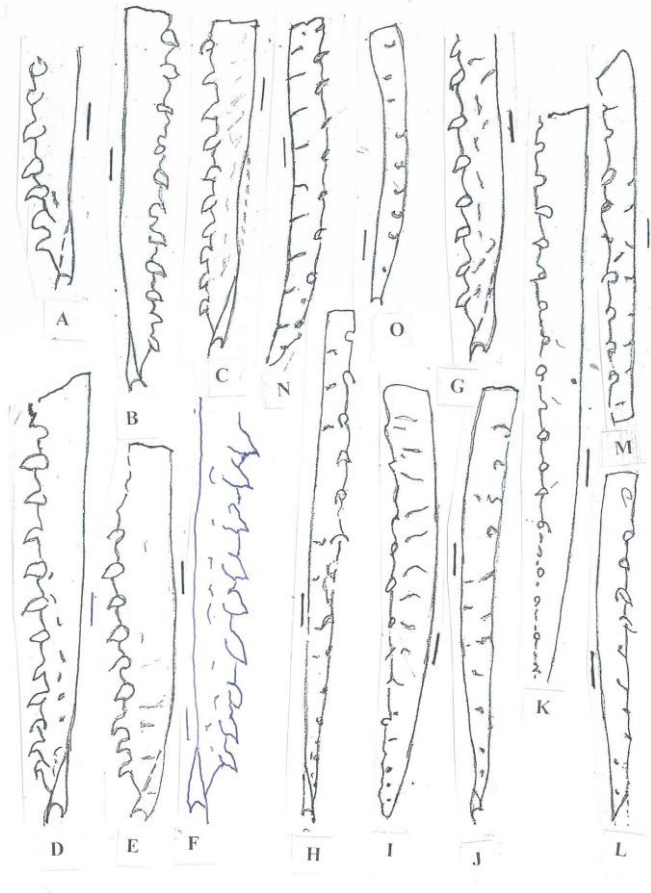


Fig.4: A-C. *Uncinagraptus uniformis* (Pribyl, 1940), A, 6668, int. 1; B, 6658, int. 1, C- nr 6661, int. 1. Fushë Muhurr, *uniformis* biozone; D-G, *Uncinagraptus angustidens* (Pribyl, 1940), D, 6650, int. 1, E, 5468, int. 10; F, 5357, int. 3, 5518, int. 11, Fushë-Muhurr *uniformis* Biozone; H-L, *Slovinograptus? microdon microdon* (Richter, 1875), Fushë-Muhurr *uniformis* Biozone, H, 5530 int. 11, I, 6595, int. 10, J, 5329, int. 2, K, 6661, int. 1, L, 5432, int. 7, Fushë-Muhurr *uniformis* Biozone; M-O, *Slovinograptus? microdon silesicus* (Jaeger, 1959), M, 5370/1, int. 3, N, 5532, int. 2, O, 5432/1 ? int. 7, Fushë-Muhurr, *uniformis* Biozone. All scale bars represent 1 mm.

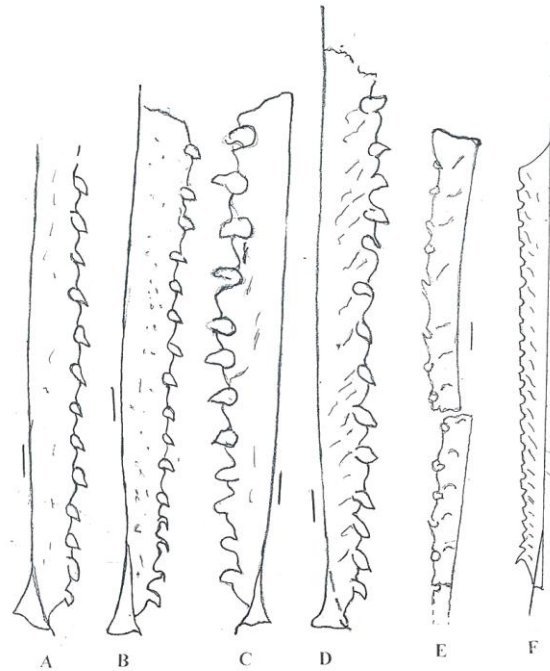


Fig. 5: A-D, *Uncinatograptus hercynicus* (Perner 1899), A, 6440, B, 6436, C, 6461, D, 6463 Muhurr, sample 179, *hercynicus* Biozone; E, *Slovinograptus? microdonsilesicus* (Jaeger, 1959), Fushe Muhurr *uniformis* Biozone, 5333, int. 2, Fushë-Muhurr *uniformis* Biozone; F, *Neomonograptus aequabilis* (Pribyl, 1941); 3755, Sharakane, *uniformis* Biozone. All scale bars represent 1 mm.

The most complete sequence of the *uniformis* biozone could be met in the Kodra e Krizës, along rural road from Fushë-Muhurr to Hurdhë-Muhurr (locality 2, Figure 1) and shows a continuously exposed succession range in age, from Ludlow to the Lower Devonian *uniformis* and a tentative *subhercynicus* biozones. The Lower Devonian part of the section includes relatively abundant graptolite assemblage: *U. uniformis* (Perner), *U. cf. uniformis* (Perner), *U. angustidens* (Perner), *Slovinograptus? microdon microdon* (Richter), *S.? microdon silesicus* (Jaeger), *Neomonograptus aequabilis* (Pribyl), *Linograptus posthumus* (Richter). Detailed re-examination of the Lochkovian graptolite assemblage of the uppermost part of the Fushë-Muhurr section allowed us to recognize the probably tentative species identification of *Uncinatograptus cf. praehercynicus* (Jaeger) based on the two specimens (nr 6655-6656), with poor preservation and are recorded for the first time in Muhurr. In this section, the Silurian/Devonian boundary has not been reconstructed because Silurian dark shale sequence (interval 13) with a mixture of Upper Silurian zonal species ranging from the

Gorstian *scanicus-chimaera* to the Ludfordian *tenuis* biozones is interrupted by a 16 m thick (interval 12) dark shale sequence without graptolites. Further to the north, on the left side of Bulac tuffaceous shale exposed in Sharakane (locality 4 in Figure 1), rests conformably on the latest Silurian dark shale (*formosus* Biozone) and includes rare *Uncinatograptus uniformis* (6787-6789) corresponds in age with the *uniformis* Biozone.

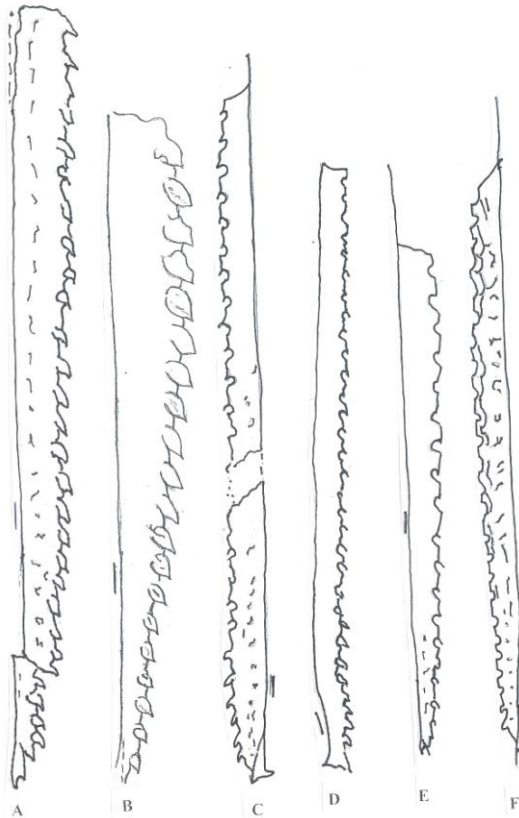


Fig.6: A-*Uncinatograptus angustidens* (Pribyl, 1940), 5513, int. 11, Fushë-Muhurr, *uniformis* Biozone; B-*Uncinatograptus* cf. *uniformis* (Pribyl, 1940), 6636, int. 10, Fushë-Muhurr, *uniformis* Biozone; C-*Uncinatograptus hercynicus* (Perner, 1899), 6450, sample 179, *hercynicus* Biozone; D-*Uncinatograptus hercynicus* (Perner 1899), 6437, sample 179, *hercynicus* Biozone; E-F, *Neomonograptus aequabilis* (Pribyl, 1941), *uniformis* Biozone, E-6594, Fushë-Muhurr, int. 10, F- 3745 Sharakane, *uniformis* Biozone.

All scale bars represent 1 mm.

The late Lochkovian *hercynicus* biozone has been documented on the downward riverside of Bulac (locality 3 in the Figure 1). This Bulac outcrop represents a shale sequence which show a graptolite succession ranges in age from the mix upper Silurian assemblage with *Spinograptus spinosus* (Wood), *Colonograptus cf. ultimus* (Perner), *Monograptus cf. transgrediens* (Perner) (sample 177) to the Lower Devonian (Lochkovian) *Uncinatograptus uniformis* (Perner) biozone (sample 178), following upwards of abundant monospecific assemblage of *Uncinatograptus hercynicus* (Perner) biozone (sample 179). In the evolution of the Lower Devonian graptolite faunas the assemblage of the *hercynicus* biozone shows greater increases in abundance and representation of a monospecific assemblage of the biozonal *hercynicus* taxon.

The latest Devonian sequence of Muhurr area is represented by the Pragian-Eifelian dark shale-limestone intercalations (locality 5 Figure 1) with *Tentaculites* (Pashko 2004). In general, exempt of the Silurian/Lower Devonian boundary in the Hurdhë-Muhurr section the boundaries within Lochkovian biozones, also within Lochkovian and Pragian stages has not been reconstructed due to the unclearly exposed transitional layers.

The graptolite assemblage of the Lochkovian sequence from Muhurr area composed of species with high value for correlations, shows a remarkable similarity in species and faunal succession to the other well-known Lochkovian graptolite assemblages from European areas: Bohemia (Chlupac 1988), Germany (Jaeger 1979), Poland (Porebska 1984), Southwestern Europe (Catalonian Coastal Ranges) and Sardinia (Lenz *et al.*, 1996), Lochkovian graptolite biozonation of the Muhurr also reminds to Lochkovian global standard biozonation (Loydell 2012).

5. Biozones

Detailed examination of the vertical distribution of the Lochkovian graptolite assemblages in the Muhurr area sequence allowed author to recognize three Lochkovian biozones: i) the earlier *uniformis*, ii) tentative recognized *praehercynicus* and, iii) the latest *hercynicus* graptolite biozones which are based on the lowest occurrence of its Lochkovian biotaxons: the earlier *uniformis*, tentative recognized *praehercynicus* and the latest *hercynicus* graptolite biozones, which are based on the lowest occurrence of its biozonal index taxa. Based on the cosmopolitan character of the graptolites, the Lochkovian graptolites zones are elsewhere known (Figure 7).

5a. *Uncinatograptus uniformis* biozone is the lowest Lochkovian biozone. It is characterized by moderate diversity and changed density of the well-preserved graptolite species. The graptolite assemblage are: *Uncinatograptus*

uniformis (Pribyl), *U. angustidens* (Pribyl), *Slovinograptus? microdon microdon* (Reinhard Richter), *S.? microdon silesicus* (Jaeger), *Neomonograptus aequabilis* (Pribyl) and *Linograptus posthumus* (Reinhard Richter).

The lower boundary of biozone has been defined by the first occurrence of index taxa *Uncinatograptus uniformis* within continuous shale sedimentation, in the upper part of the Hurdhë-Muhurr section. Here, the base of the biozone (interval 11 of 15 m thick) is defined by the lowest relatively rare appearance of the *U. uniformis* species that correspond to the particularly highest occurrence of the *Uncinatograptus angustidens*, accompanied by abundant *Slovinograptus? microdon silesicus*, *Linograptus posthumus* and rare *S.? microdon microdon*, *Neomonograptus aequabilis*. Slightly higher, in the interval 10 to 12 m thick, except relatively rare *U. angustidens*, rare *S.? microdon microdon* and *L. posthumus*, the biozonal taxa *U. uniformis* and other biozonal species appears in great number of specimens. Upwards, in the medium part of the biozones, from 9 to 4 intervals of 32 m thick, the poor zonal graptolite assemblage although inclusion of all zonal species, appears in small number of specimens. In the uppermost part (interval 3-1/2) of the biozone *U. uniformis* and *S.? microdon microdon* have increased particularly very rapidly in abundance, and present also extremely rare occurrence of *U. angustidens*, *S.? microdon silesicus* and *Linograptus posthumus*.

Stage	This study	Peri-Gondwanan Europe	Baltica (East European Platform)
PRAGIAN	Tentaculites Conodonts	?	<i>falcarius</i>
LOCHKOVIAN	<i>Uncinatograptus hercynicus</i>	<i>Uncinatograptus hercynicus</i>	<i>Uncinatograptus hercynicus</i>
	<i>Uncinatograptus ?praehercynicus</i>	<i>Uncinatograptus praehercynicus</i>	?
	<i>Uncinatograptus uniformis</i>	<i>Uncinatograptus uniformis</i>	<i>Uncinatograptus uniformis</i>
PRIDOLIAN	<i>perneri</i>	<i>transgrediens perneri</i>	<i>transgrediens perneri</i>

Fig. 7: Biozonal subdivision of the Lower Devonian (Lochkovian) sequence in the Muhurr area (Albania) and correlation with the European graptolite schemas, in addition to (Loydell, 2012).

5b. *Uncinatograptus praehercynicus* biozone. The identification of this biozone till now has in the Muhurr area remains a tentative as it is based only on the two specimens of not well-preserved index species recognized as

Uncinagraptus cf. praehercynicus (Jaeger). Rhabdosomes are not well preserved and are found in the uppermost part of the Fushë-Muhurr section (interval 1/1) accompanied by rare *U. uniformis* and *S.? microdon microdon*.

5c. *Uncinagraptus hercynicus* biozone. Is the latest Lochkovian biozone, defined and characterized by the abrupt occurrence of large numbers in specimens of monospecific assemblage of the biozonal taxa. In the evolution of the Lochkovian graptolite faunas, the assemblage of the *hercynicus* biozone shows a much greater increase in abundance of specimens than the preceding biozones. This broadly defined biozone is a most recognized throughout the European area particularly in Bohemia Basin, Germany, Sardinia, Barcelona regions, and “is easily recognized globally based solely on the biozonal species *Uncinagraptus hercynicus*” (Lenz 2013).

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