

New Data on the Devonian Plant and Miospores from the Lode Formation, Latvia

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The higher plant of Progymnospermopsida *Svalbardia banksii* Matten is described from taphocoenosis A of the Devonian Lode Formation in Lode clay pit. This locality is the second in the world besides the type locality from North America where this plant has been found. Miospores taken from the same deposits containing impressions of *S. banksii* demonstrate the Givetian age of the taphocoenosis A.

Key words: Frasnian • Givetian • Lode clay pit • miospores • progymnosperm.

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Introduction

Devonian period is characterized by rapid development of higher plants from the first primitive land plants to the first representatives of gymnosperms. Flora is represented by hundreds of plant genera and species in many parts of the world. Information about the Devonian plants from Latvia is scarce. In the early 80-ies of the last century mass graves of fishes, as well as plant remains were discovered at the base of the supposedly Upper Devonian deposits cropping out in the Liepa (Lode) clay pit in the north-eastern part of Latvia (Kuršs and Lyarskaya 1973). In 1971-1972 one of us (A.L. Jurina) had opportunity to collect fossil plants in the Lode quarry by the invitation of L.A. Lyarskaya. Plants are represented by imprints, preserved in clay. According to the method used in storing and transporting of fossil remains, the clay gypsum-plaster capsules with the rock and the fossils inside them were prepared. During transportation from Riga to Moscow samples were lost in the Moscow State University and seemed impossible to find. Fortunately, as a result of enhanced searching most of the capsules with the plant remains were found.

The purpose of this article is to describe these plants, discuss the status of the genus *Svalbardia* and evaluate the age of the deposits based on the described plants and miospores extracted from the clay, containing imprints of plants.

Stratigraphy

Typical deposits of the Lode Formation (Fm) are present in the Lode clay pit. This formation has been established for the north-eastern Latvia by V. Kuršs (1975) and corresponds to the upper part of the Gauja Regional Stage (RS). Many researchers (Kuršs and Lyarskaya 1973; Kuršs 1975; Kuršs *et al.* 1998; Upeniece 2001, 2011) placed this formation within the Upper Devonian (Frasnian). Now the most of scientists attribute this formation to the Late Givetian age and suggest drawing the Givetian-Frasnian boundary between the Amata and the Plaviņas RS (Lukševičs 2001; Stinkulis *et al.* 2011; and others). In Lode clay pit the Lode Fm contains mainly fish and plant remains, forming several taphocoenoses designated by capital Latin letters (Kuršs *et al.* 1998). Plant and miospore assemblages described in this paper have been collected in the taphocoenosis A (Kuršs and Lyarskaya 1973). Fishes *Asterolepis ornata* Eichw., *Laccognathus panderi* Gross, *Panderichthys rhombolepis* Gross in this taphocoenosis are found at three levels. Plants lie below the levels with fishes. Taphocoenosis A was situated probably in the upper part of the Lode Fm in accordance with verbal supposition of E. Lukševičs. His opinion is that the taphocoenosis A approximately is slightly older than the taphocoenosis F and situated below (Kuršs *et al.* 1998). Now this part of geological section with taphocoenosis A is deeply buried under the scree.

It was originally mentioned (Kuršs and Lyarskaya 1973; Kuršs *et al.* 1998) that flora in the taphocoenosis A is represented by *Rhacophyton* sp. and *Archaeopteris* sp. (preliminary determination of A.L. Jurina). Later it was considered that the collection is lost. A.L. Jurina (1988) has made specification in flora definition based on the field sketches as *Archaeopteris fissilis* Schmalh., which appeared incorrect as the preliminary determinations. A new study of collection material shows that there is the higher plant *Svalbardia banksii* Matten in the taphocoenosis A.

Systematic palaeontology

Class Progymnospermopsida Beck

Order Pityales

Family Svalbardiaceae Nemejc

Genus *Svalbardia* Høeg, 1942

Svalbardia banksii Matten, 1981

Figs 1-2

Svalbardia banksii: Matten, 1981, p. 1383, fig. 1-7.

Holotype. Southern Illinois University, Paleobotanical Collection, No 685; Sullivan County, New York State; Delaware River Flags, Oneonta Formation, lower Upper Devonian (Frasnian).

Description. The larger axis is about 12 mm wide at its base and up to 5 mm wide in upper part and is 51 cm long. This main axis (or the axis of first order?) bears spirally arranged up to 5 cm long and from 5 to 7 mm wide subordinate axes. The angle between the main and subsidiary axes is 30°-35°. All the axes are

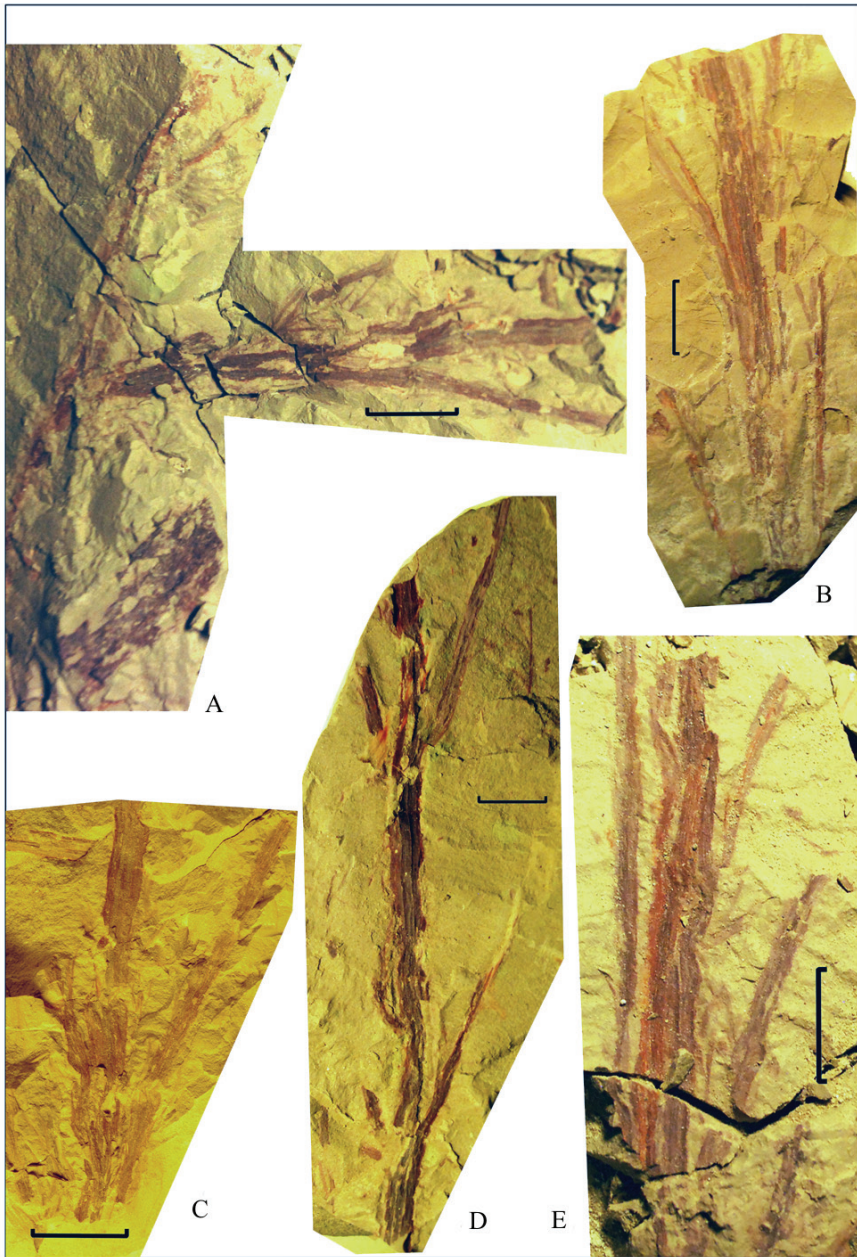


Figure 1. *Svalbardia banksii* Matten, 1981, from Liepa (Lode) clay pit; Devonian, Lode Fm, taphocoenosis A. A, general view of the imprint of the main (first order?) and lateral axes, MSU, No 330/11. B, attachment of leaf to the axis, MSU, No 330/2. C, irregularly striated axes, MSU, No 330/10. D, axis of first order with three lateral axes (the “ribs” reflected of vascular strands), MSU, No 330/1. E, irregularly striated axes, MSU, No 330/15. Scale bars 1 cm.

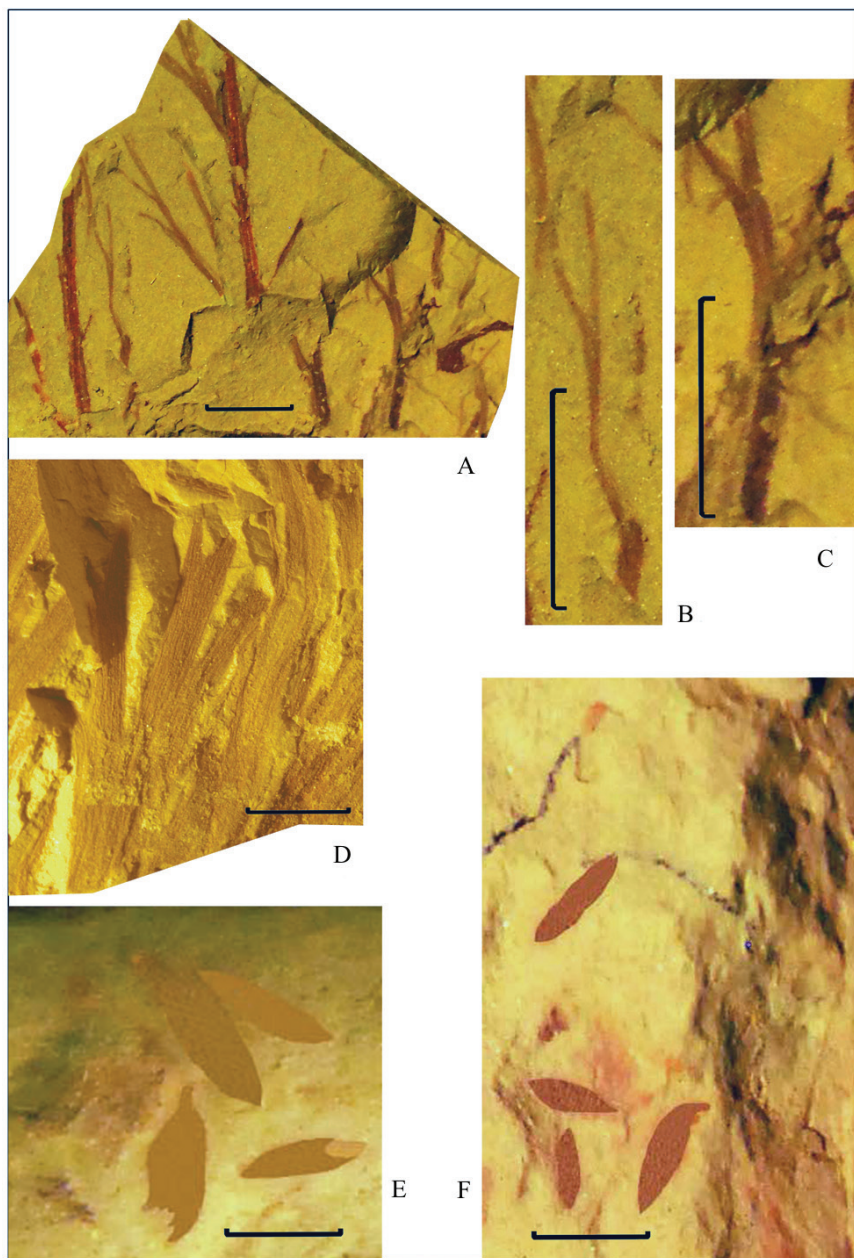


Figure 2. *Svalbardia banksii* Matten, 1981, from Liepa (Lode) clay pit; Devonian, Lode Fm, taphocoenosis A. A, isolated leaves, MSU, No 330/3. Scale bar 1 cm. B-C, the same specimen as in A, leaf dichotomized two times. Scale bar 3 cm. D, dichotomized striated leaves, MSU, No 330/8. Scale bar 3.5 cm. E, uncoordinated sporangia, MSU, No 330/7. Scale bar 2 mm. F, uncoordinated sporangia, MSU, No 330/6. Scale bar 2 mm.

somewhat irregularly striated, perhaps reflecting remains of vascular strands passing towards the leaves. The subordinate axes bear what are interpreted as leaves. Leaves unwebbed dichotomizing from 2 to 4 (in the main 3) times are deeply divided into identically long (from 7 mm to 1-2 mm) and wide (0.5-0.6 mm) four, sometimes eight, lobes. The angle between lobes is 8°-10°. The leaves are cuneiform (overall outline is fan-shaped), about 3 cm long and up to 4 mm at the base. In the matrix the leaves are found in the main separately from axes.

We have seen no evidence of sporangia being preserved in organic connection with axes. There are four impressions of uncoordinated sporangia of poor preservation disposed in the matrix nearby the described axes. The sporangia are cylindrical, 1.5-2 mm long and 0.5-0.7 mm thick. These sporangia possibly belong to *Svalbardia banksii*.

Locality. Liepa (Lode) clay pit is located in the Liepa municipality, north-east of Riga, 15 km to the south from Valmiera, at the left bank of the river Gauja.

Horizon. Gauja RS, Lode Formation, taphocoenosis A, Devonian.

Material. The described plant remains occur in the clay. When clay dries up, the imprints break up to numerous fragments which are difficult to combine. About 30 fragments of impressions (parts and counterparts) with axes of different orders and leaves are preserved. This complicates the description and photography of specimens. Studied material belongs to the collection No 330, Department of Palaeontology, Faculty of Geology, Moscow State University, Moscow, Russia.

Miospores

Miospores are taken from the same clay containing *Svalbardia banksii* and have been studied by M.G. Raskatova. Miospores were studied with light microscope POLAM-312 and photographed by NIKON camera in the Laboratory of Historical Geology and Palaeontology, Faculty of Geology, Voronezh State University (VSU), Voronezh, Russia. Collection of preparations No L2011 is housed in VSU.

Composition of the assemblage from taphocoenosis A is reduced. Miospores have satisfactory and seldom good preservation. In total there are about 20 species of miospores in the assemblage including *Leiotriletes perpustillus* Naum., *L. laevis* Naum., *L. simplex* Naum., *Calamospora minutissima* (Naum.) Lub., *Punctatisporites solidus* (Naum.) Byvsch., *Lophotriletes minutissimus* Naum., *Retusotriletes radiousus* Rask., *R. simplex* Naum., *Dictyotriletes* sp., *Apiculatisporis uncatius* (Naum.) Oshurk., *A. eximius* (Naum.) Oshurk., *Iugisporis impolitus* (Naum.) Oshurk., *Geminospora rugosa* (Naum.) Obukh., *G. notata* (Naum.) Obukh., *G. micromanifesta* (Naum.) Arkh., *G. micromanifesta* (Naum.) Arkh. var. *crispus* Tschibr., *G. cf. nalivkinii* (Naum.) Obukh., *Ancyrospora incisa* (Naum.) M.Rask. et Obukh., *A. fidus* (Naum.) Obukh., *A. furcula* Owens, *Chelinospora concinna* Allen, *C. cf. timanica* (Naum.) Loboz. et Streel, *Stenozonotriletes simplex* Naum., *Biharisporites* sp., *Hystricosporites* sp. Miospore assemblage is characterized by the dominance of genus *Geminospora*: *G. micromanifesta* – 8.5%, *G. rugosa* – 7.5 %, *G. nalivkinii* – 5.5%, *G. notata* – 4.5% and also contains large miospores (<300 µm) with processes: *Ancyrospora incisa* – 3%, *A. fidus* – 3.5%, *A. furcula* – 1.2%, *Hystricosporites* sp., some of them with lost

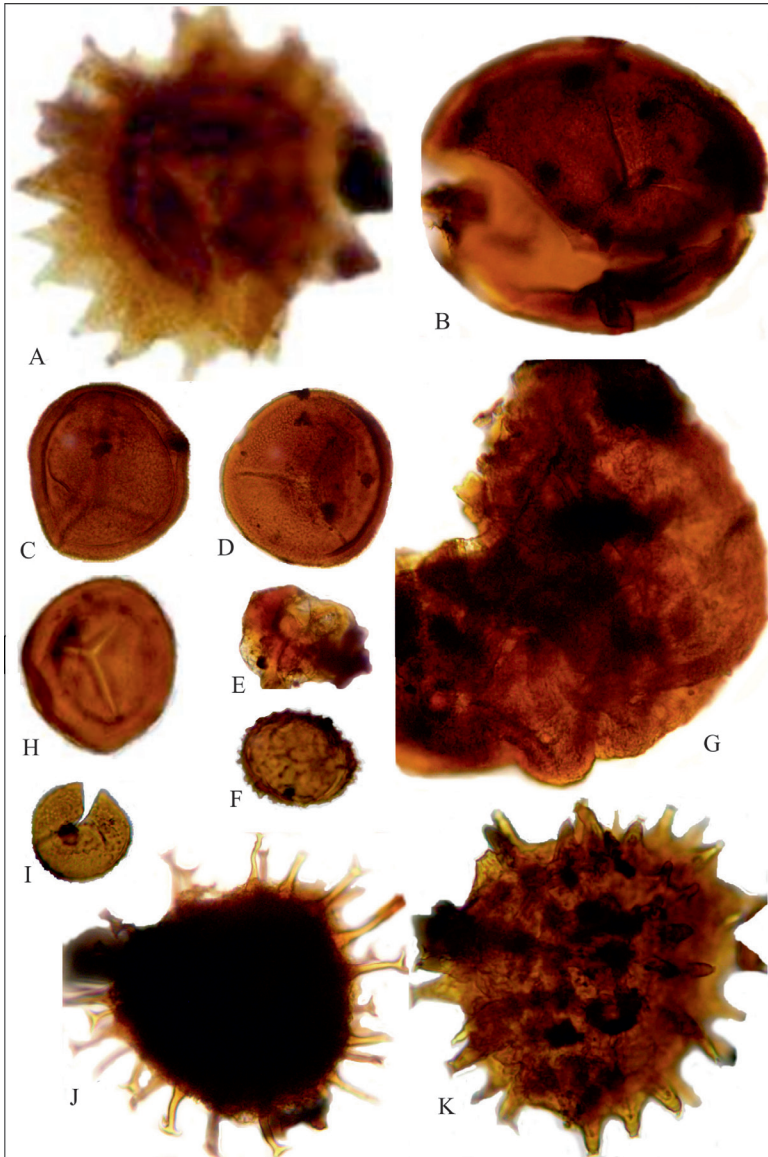


Figure 3. A-C, E-F, H-K: Miospore assemblage belonging to the *Ancyrospora incise* - *Geminospora micromanifesta* (IM) subzone. A, *Ancyrospora incisa* (Naum.) M.Rask. et Obukh.; B, *Biharisporites* sp.; C, *Geminospora micromanifesta* (Naum.) Arkh. var. *crispus* Tschibr.; E, *Chelinospora* cf. *timanica* (Naum.) Loboz. et Streele; F, *Chelinospora concinna* Allen; H, *Retusotriletes radius* Rask.; I, *Apiculatisporis eximius* (Naum.) Oshurk.; J, *Hystricosporites* sp.; K, *Ancyrospora fidus* (Naum.) Obukh., VSU, No L2011/4d; magnification x 500. D, microspore from dispersed microsporangium *Geminospora* cf. *nalivkinii* (Naum.) Obukh., VSU, L2011/5ms, x 500. G, fragment of dispersed microsporangium with microspores, VSU, L2011/5sp, x 450. All specimens from the Liepa (Lode) clay pit; Devonian, Lode Fm, taphocoenosis A.

processes and dark in colour. Other large miospores (<200 µm) from this assemblage belong to *Biharisporites* sp. – 3.5%, some of them were destroyed. Miospores with conate ornamentation: *Apiculatisporis uncatius*, *A. eximius*, *Iugisporis impolitus* and with reticulate patina: *Chelinospora concinna*, *C. cf. timanica* are present in equal amounts (2-3%). Species of *Leiotriletes* (10-15 µm) with a smooth exine partially covered with sporangial tissue have also been found in preparation. From the same clay we have taken one destroyed sporangium in which microspores are preserved, most likely, connected in tetrads. These microspores are very similar to the dispersed taxon *Geminospora cf. nalivkinii*.

Discussion

I. Genus *Svalbardia* was introduced by Høeg (1942) with one species of *S. polymorpha* based on a large amount of factual material. According to Høeg *Svalbardia* is a plant with spirally arranged branches and forked unwebbed leaves. Høeg (1942) recognized also the striking resemblance between his new genus and *Archaeopteris fissilis* (Schmalhausen 1894). The last is species with unwebbed pinnules. The separation between *Svalbardia* and *Archaeopteris* (especially *A. fissilis*) had gradually been eroded. There is considerable discussion in the literature concerning status of *Svalbardia* as a valid genus. Most of researchers (Høeg 1942; Petrosjan and Radczenko 1960; Stockmans 1968; Chaloner 1972; Matten 1981; Schweitzer 2006, as well as one of the authors of this paper, Jurina) accept *Svalbardia* as valid genus while minority (Beck 1971) can't agree with this opinion. Beck proposes to include it into the genus *Archaeopteris*, considering it a synonym of the latter. Gensel and Andrews (1984) incline toward the latter opinion but left themselves the possibility to solve this problem in the future when more information will come.

Carluccio *et al.* (1966) examined similarities and differences of *Svalbardia* from *Archaeopteris* and proposed the following conception: genus *Archaeopteris* possessing varying degrees of webbed pinnules; a species of *Svalbardia* are with unwebbed pinnules. The authors of this paper accept the proposal of Matten (1981) and use the genus *Svalbardia* in this sense as the form-genus. In conclusion according to Carluccio *et al.* (1966), Matten (1981) and our opinion *Archaeopteris fissilis* should be placed in genus *Svalbardia*. Chaloner (1972) also noted the difference between the two genera: species of *Archaeopteris* have laminate leaves, but species of *Svalbardia* have leaves dissected into narrow lobes. However, the reproductive structures of the two genera are of basically rather similar organization.

II. Seven species have been mentioned in literature belonging to the genus *Svalbardia*: the type species *S. polymorpha* Høeg, 1942 (Givetian or Frasnian, Spitsbergen); *S. osmanica* Petrosjan et Radczenko, 1960 (Frasnian, Russia); *S. boyi* Kräusel et Weyland, 1960 (Givetian, Germany); *S. fissilis* (Schmalhausen) Carluccio *et al.*, 1966 (Upper Devonian, Ukraine, Canada); *S. avelinesiana* Stockmans, 1968 (Givetian, Belgium); *S. scotica* Chaloner, 1972 (Givetian, Scotland); *S. banksii* Matten, 1981 (Frasnian, New York, USA). Lode in Latvia is now the second locality of *S. banksii* in the world. Today the third and fifth of seven species just cited are not belonging to the genus *Svalbardia*. *S. boyi* is considered to be a species of

Archaeopteris (Carluccio *et al.* 1966). We agree with the opinion of Beck (1971) that *Svalbardia avelinesiana* might be assigned to several different genera including *Archaeopteris*, *Pseudosporochnus* and others. It is necessary to study the original material. According to our concept of the genus *Svalbardia* and following Carluccio *et al.* (1966) and Matten (1981) we include the species *Archaeopteris fissilis* into the genus *Svalbardia*. The species of *Svalbardia* are characterized by variability in leaf form, between several deeply divided lobes of various length and width with filiform segments. The filiform segments of leaves are typical only to *S. polymorpha*. *S. banksii* is characterized by long and narrow leaf segments which are divided dichotomously more than twice into four or eight lobes. *S. banksii* more closely resembles *S. osmanica* from the Frasnian of Russia but differs from it by lack of decurrent petioles.

III. C.B. Beck (1960) proposed the class of higher plants Progymnospermopsida. It is characterized by free spore-bearing plants with a pteridophyte standard of reproduction and foliage combined with gymnospermous anatomy. Beck demonstrated that certain fossils of fern-like foliage (genus *Archaeopteris*) were borne on petrified stems of gymnospermous anatomy (genus *Callixylon*). Later several orders have been allocated into this class. *Archaeopteris* is placed in the Pityales of this class. The researchers previously described *Svalbardia* noted the similarity with genus *Archaeopteris*. We accept the views of Carluccio *et al.* (1966) and Chaloner (1972) that similarity between these two genera should be acknowledged grouping in the same order Pityales. Gensel and Andrews (1984) and Taylor *et al.* (2009) include tentatively genus *Svalbardia* in the order Archaeopteridales because all distinctive features of the progymnosperms are not present.

IV. Devonian miospores of Latvia for the first time have been studied by Ozoliņa (1963). She distinguished miospore assemblages on the basis of study of large material from the boreholes and outcrops in Latvia. Gauja Fm and Amata Fm were characterized by a uniform assemblage V. Ozoliņa compared the V assemblage to the XVI assemblage of the Central Devonian Field (CDF). She didn't propose zones and subzones. We compared miospore assemblage from the Lode Fm with the miospore assemblage V of Ozoliņa. Miospore assemblage V is characterized by a larger number of genera and species (about 30) in comparison with the assemblage from taphocoenosis A because the former corresponds to a wider stratigraphical interval and studied in a wide area (Plaviņas, Ālanda, Līvāni, Katlakalns, Ķemeri). The common forms for the assemblage from the taphocoenosis A and assemblage V are species of genera: *Geminospora*, *Apiculatisporis*, *Lugisporis* and *Retusotriletes*. Difference between them consists in the absence of *Ancyrospora incisa* in the assemblage V.

Miospores have been examined in details from the Lode Member (Gauja Fm) in the locality Kūllatova (Estonia). Following assemblage of miospores has been established there and was compared to the IM Subzone (Mark-Kurik *et al.* 1999): *Geminospora micromanifesta* (Naum.) Arkh., *G. lemurata* Balme, emend. Playford, *Retusotriletes regulatus* Riegel, *Cristatisporites triangulatus* (Allen) McGreg. et Camf., *Samarisporites eximius* (Allen) Loboz. et Streel, *Ancyrospora* sp. cf. *A. incisa* (Naum.) M.Rask. et Obukh., *Dictyotriletes* sp. cf. *Reticulatisporites perlotus* (Naum.) Obukh., *Perotriletes* sp. cf. *Rugospora? impolita* (Naum.) Tchibr.

Systematic composition of the miospore assemblage from Küllatova is close to the assemblage from taphocoenosis A. Species in common are: *Geminospora micromanifesta*, *G. lemurata*, *Ancyrospora incisa*. Difference consists in the absence of *Cristatisporites triangulatus*, *Samarisporites eximius*, *Reticulatisporites perlotus*, *Rugospore? impolita* in the assemblage from taphocoenosis A. Miospore assemblage described from the Lode Fm by us is richer in systematic composition (20 species compared with 8), miospores demonstrate a better preservation in the whole, and the index of Subzone has better preservation. Distinctive feature of the assemblage from taphocoenosis A is the presence of megaspores *Biharisporites* differing it from the assemblage V (Ozoliņa 1963) and from the Küllatova assemblage.

According to our research the general structure of miospore assemblage from the taphocoenosis A corresponds to the *Ancyrospora incisa* - *Geminospora micromanifesta* (IM) Subzone, which previously was located at the base of the Frasnian stage (Avkhimovitch *et al.* 1993). At the present time Stratigraphical Committee of Russia offers to trace the boundary of the Givetian and Frasnian stages at the base of the Upper Timan Substage of the East European Platform (Sobolev and Evdokimova 2008). According to this decision IM Subzone is moved to the Givetian stage and characterizes its upper part. We have made a conclusion that the age of the taphocoenosis A in the Liepa clay pit, according to miospores, is Late Givetian.

V. *Svalbardia banksii* was established in the taphocoenosis A. Holotype of *Svalbardia banksii* has been found from the Upper Devonian (Frasnian) of New York State (Delaware River Flags, Oneonta Fm). From the same locality of Oneonta Fm other plants have been also described. The palaeobotanists consider their age as Frasnian. The age of the host rocks of the Lode Fm by the presence of only one plant *Svalbardia banksii* could be defined as the Frasnian. Miospores are characteristic for the upper part of the Givetian (subzone IM). Therefore it is possible that in Latvia representatives of *Svalbardia banksii* appeared earlier than the type area, in Late Givetian. This doesn't contradict the stratigraphical interval of genus *Svalbardia* from Givetian to Frasnian, which may be sporadically found even in the Famennian (Ukraine, Donbass). We can't discuss the age of all the Lode Fm because we have material (imprints of higher plants and miospores) only from the taphocoenosis A.

VI. Presence of the higher plants and algae in the Liepa (Lode) clay pit in the Lode Fm was mentioned by I. Upeniece (2001, 2011). She provided photos of some plant remains, which were defined by N.M. Petrosjan (Russia, St. Petersburg), without the descriptions. Identification of genera and species causes some doubt. Short comments: on the photo of *Archaeopteris fissilis* Schmalh. (correct name of this plant in modern representations should be *Svalbardia fissilis* (Schmalh.) (Carluccio *et al.*, 1966) attributes of this specimen are not shown (Upeniece 2001, pl. 4, fig. 1). *S. polymorpha* Høeg (ibid., pl. 4, figs 2, 3, 5) most likely concerns *S. banksii*. The fragment of plant *Platyphyllum* sp., which belongs to the higher plants instead of algae (ibid., pl. 4, fig. 4), doesn't reflect the features of this genus. For the final conclusion about regular structure of the plants determined by N.M. Petrosjan from the Lode Fm of Latvia, it is necessary to work with originals of plants and redefine them.

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