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MIOSPORE ASSEMBLAGE FROM THE LODE MEMBER (GAUJA FORMATION) IN ESTONIA AND THE MIDDLE–UPPER DEVONIAN BOUNDARY PROBLEM

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Abstract. A miospore assemblage, equivalent to that of the *Ancyrospora incisa–Geminospora micromanifesta* (IM) Subzone of the East European Platform, was identified in a sample from the old refractory clay quarry at Küllatova, SE Estonia. It permits us to correlate the Gauja Formation of the Baltic area with probable coeval stratigraphic units in the adjacent regions – Belarus and the Moscow Basin. The Middle–Upper Devonian boundary probably lies close to, but somewhat above, the top of the Gauja Formation.

Key words: miospores, biostratigraphy, Middle–Upper Devonian boundary, Estonia, Baltic area.

INTRODUCTION

The Devonian series of the Main Devonian Field, on the eastern side of the Baltic Sea (northwestern subregion of the East European, or Russian, Platform), includes subsurface Lower Devonian deposits as well as subsurface and outcrop Middle and Upper Devonian strata. It is a classical series for the Devonian of Europe, which has been particularly well studied for its fossil vertebrate fauna including over 250 different species. All higher groups of Devonian agnathan and gnathostome vertebrates of the Old Red Sandstone Continent are recorded in this series. Vertebrates form palaeocommunities which are dominated by agnathans in the Lower Devonian, by placoderms in the Middle Devonian, and by placoderms plus sarcopterygians in the Upper Devonian (Blieck et al., 1988; Janvier & Blieck, 1993).

The vertebrate biozonation of the East Baltic Devonian series is based upon both agnathans (thelodont microremains and heterostracan pteraspidomorph macroremains) and gnathostomes (acanthodian microremains and placoderm macroremains) (Karatajūtė-Talimaa, 1978; Lyarskaya, 1978, 1981; Sorokin, 1981; Lyarskaya & Lukševičs, 1992; Mark-Kurik, 1991, 1995, 1997, in press; Valiukevičius, 1994; Lukševičs, 1996; Lukševičs & Ivanov, 1996). However, the troublesome dating of that series in terms of the standard Devonian conodont biozonation (Mark-Kurik, 1996; Sorokin, 1996) remains largely unsolved. Tentative correlations have been worked out during several years by the IUGS Subcommission on Devonian Stratigraphy (SDS) and in connection with the IUGS-IGCP project 328 on Palaeozoic microvertebrates. Our paper represents one step towards the solution of the particular problem, viz., the identification of the Middle–Upper Devonian boundary.

STRATIGRAPHIC SETTING

Of the entire Devonian series in the Baltic area [Baltic States and neighbouring regions of the CIS (former USSR)], only a few horizons have yielded conodonts. This is certainly due to the unsuitable lithofacies, which are mainly composed of siliciclastics (see, e.g., Kleesment, 1995 for the interval studied here). Conodont biozones have been defined for regional equivalents of the lower Lochkovian (*woschmidti* Zone from the Brest depression of Belarus), the uppermost Eifelian (*kockelianus* Zone from the Kernavė Regional Substage), the lower Frasnian (*asymmetricus* Zone in the Pļaviņas Regional Stage), and the Famennian [from the *gigas* (?) to the lower *costatus* (?) zones] (Žeiba & Valiukevičius, 1972; Žeiba, 1994; Valiukevičius, 1994; review in Blieck et al., in press). According to the current standard conodont zonation (Clausen et al., 1993), the *asymmetricus* Zone corresponds to the interval ranging from the *falsiovalis* to lower *hassi* zones.

In order to solve the problem of conodont biozone correlation, miospore-based investigations have been carried out through nearly the whole series, with particular attention to the late Emsian–early Famennian interval (Vaitiekūnienė in Narbutas et al., 1993; Valiukevičius, 1994; Kõrts & Mark-Kurik, 1997). However, the comparison of East Baltic miospore data with palynozonal schemes of the Central Devonian Field (central subregion of the East European Platform) (Avkhimovitch et al., 1993) and the Ardenne–Rhenish type regions of western Europe (Streel et al., 1987) turned out problematic too (Blieck et al., in press).

The aim of the present study is to review the proposed correlations in the light of our miospore results from the Middle Devonian series with reference to the Middle and Upper Devonian miospore zones of Eastern Europe, which are reliably dated by conodonts (Avkhimovitch et al., 1993, fig. 4).

SAMPLING AND STUDY AREA

One of us (E. M.-K.) obtained several samples from the Devonian series of SE Estonia and adjacent areas – Latvia and Pskov District of Russia. Eleven samples in the collections of the Institute of Geology, Tallinn, and Geological Museum of the University of Tartu are from the Gauja, Amata, and Pļaviņas formations (Snetnaya Gora and Pskov beds). These units encompass the stratigraphical interval where the Middle–Upper Devonian boundary is classically placed in the Baltic area (Mark-Kurik, 1993, 1996; Lukševičs & Ivanov, 1996; Sorokin, 1996). Unfortunately, of all studied samples, only one contained miospores. It comes from the Lode Member of the Gauja Formation at Küllatova, SE of Tartu, near the Russian border (Fig. 1).

In an attempt at more accurate biostratigraphical results, a second sample was processed for palynomorphs. It is from the Abava Beds of the Givetian Burtnieki Formation, exposed at Joosu refractory clay quarry in SE Estonia. This locality has yielded a quite rich fish assemblage, including *Psammosteus*, *Actinolepis*, *Watsonosteus*, etc. (Mark-Kurik, 1997) and macroremains of the pteridophyte plant *Pseudosporochnus estonicus* (Kalamees, 1988). However, the Joosu sample contained only small, coalified, opaque organic fragments and very rare, light-yellow but corroded miospores. Most of these are morphologically simple and have no biochronostratigraphic significance. Besides, the co-occurrence of *Geminospora lemurata* and *Samarisporites* sp. cf. *S. triangulatus*, two Middle Devonian key-species ranging from the late early Givetian to the earliest Famennian, has no bearing on the location of the Givetian–Frasnian boundary. Hence, we will focus on the miospore content of the Küllatova sample only.

This sample is from a long abandoned refractory clay quarry, which before World War II was operated by the "Eesti Schamott" company. The rock succession at Küllatova is roughly equivalent to that of Lode clay quarry near Liepa village in Latvia. Lode quarry is famous for its rich fish assemblage, including numerous articulated specimens of *Asterolepis*, *Panderichthys*, and *Laccognathus* (see, e.g., Lyarskaya, 1981; Mark-Kurik et al., 1989).

Küllatova is mainly known for its fossil flora, which, according to Thomson (1940), contains miospores and plant remains attributed to "*Hostimella*" sp. (now *Hostinella*). From this locality as well as from Lode quarry were also identified *Archaeopteris* sp. and *A. fissilis* (Yurina, 1988). Both the Lode and Küllatova intervals correspond to the upper part of the Gauja Formation, i.e., to a section within the Lode Member (Kuršs, 1992; Kleesment, 1995; Kleesment & Mark-Kurik, 1997).

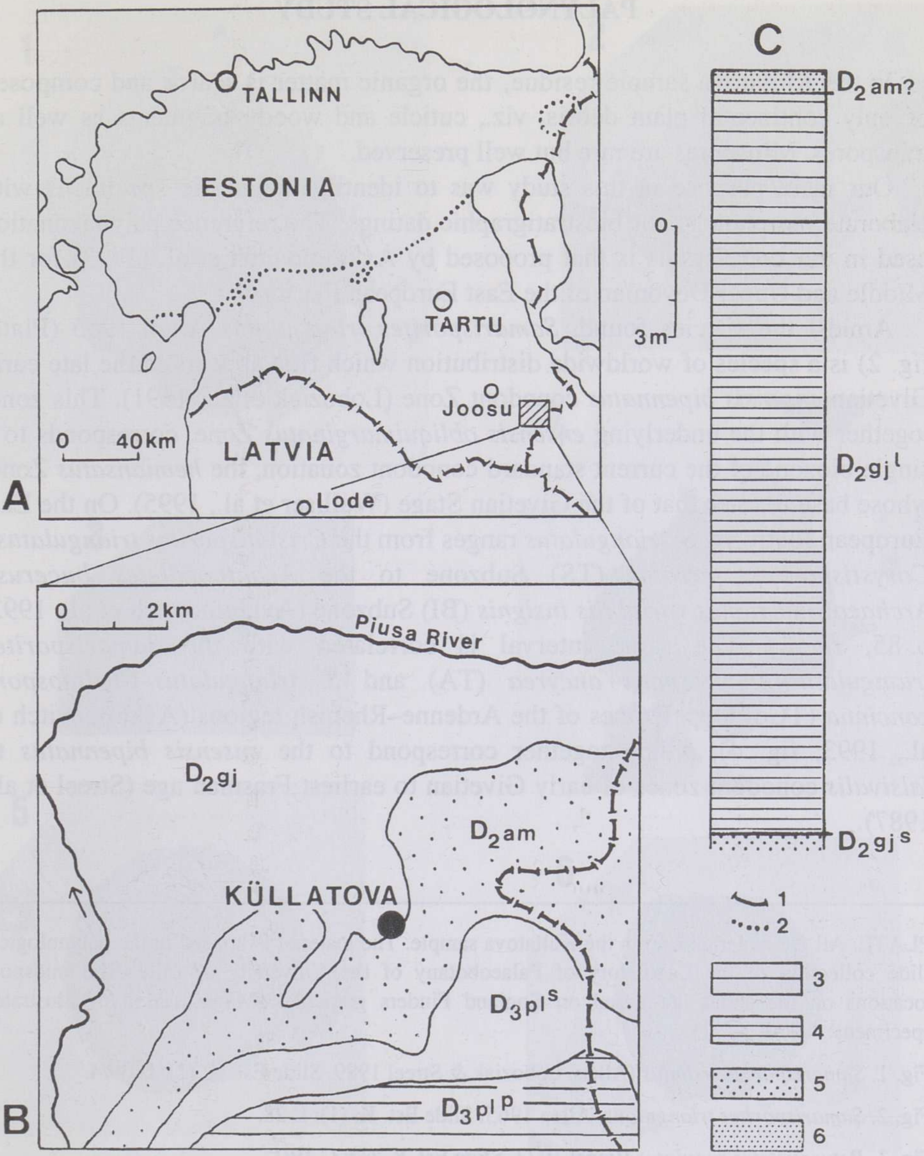


Fig. 1. Geographical and geological context of fossiliferous localities of the Gauja and surrounding formations in South Estonia and North Latvia. (A) Location map. (B) Bedrock sketch-map of the middle course region of the Piusa River (modified after Kajak, 1997). (C) Stratigraphical column of the Küllatova section (modified after Steinmann & Sarv, 1951): 1, frontier; 2, northern limit of the distribution area of the Devonian rocks; 3, light-grey clay; 4, dark-grey clay; 5, light-brown sandstone; 6, greenish-grey sandstone. Stratigraphical indices: D_2gj, Gauja Formation; D_2gj^s, Sietiņi Member of the Gauja Formation; D_2gj^l, Lode Member of the Gauja Formation; D_2am, Amata Formation; D_3pl^s, Snetnaya Gora Beds of the Pļaviņas Formation; D_3pl^p, Pskov Beds of the Pļaviņas Formation.

PALYNOLOGICAL STUDY

In the Küllatova sample residue, the organic matter is scarce and composed of only continental plant debris, viz., cuticle and woody fragments as well as miospores. Miospores are rare but well preserved.

Our main purpose in this study was to identify diagnostic specimens with elaborate morphology for biostratigraphic datings. The reference palynozonation used in our correlations is that proposed by Avkhimovitch et al. (1993) for the Middle and Upper Devonian of the East European Platform.

Amidst the species found, *Samarisporites triangulatus* Allen 1965 (Plate, fig. 2) is a species of worldwide distribution which first appears in the late early Givetian *ensensis bipennatus* conodont Zone (Loboziak et al., 1991). This zone, together with the underlying *ensensis obliquimarginatus* Zone, corresponds to a single biozone of the current standard conodont zonation, the *hemiansatus* Zone, whose base defines that of the Givetian Stage (Walliser et al., 1995). On the East European Platform, *S. triangulatus* ranges from the *Cristatisporites triangulatus–Corystisporites serratus* (TS) Subzone to the *Acanthotriletes bucerus–Archaeozonotriletes variabilis insignis* (BI) Subzone (Avkhimovitch et al., 1993, p. 85, fig. 3). The same interval is correlated with the *Samarisporites triangulatus–Ancyrospora ancyrea* (TA) and *S. triangulatus–Chelinospora concinna* (TCo) Oppel zones of the Ardenne–Rhenish regions (Avkhimovitch et al., 1993, fig. 4), which together correspond to the *ensensis bipennatus* to *falsivalis* conodont zones of early Givetian to earliest Frasnian age (Streel et al., 1987).

PLATE. All the material is from the Küllatova sample. The material is housed in the palynological slide collection of the Laboratory of Palaeobotany of the University of Lille. The miospore locations on the slides are based on England Finders graticules. Magnification of illustrated specimens: × 500.

Fig. 1. *Samarisporites eximius* (Allen) Loboziak & Streel 1989. Slide Est. K. (1): D 39/4.

Fig. 2. *Samarisporites triangulatus* Allen 1965. Slide Est. K. (1): L 28.

Fig. 3. *Retusotriletes rugulatus* Riegel 1973. Slide Est. K. (1): G 19/1.

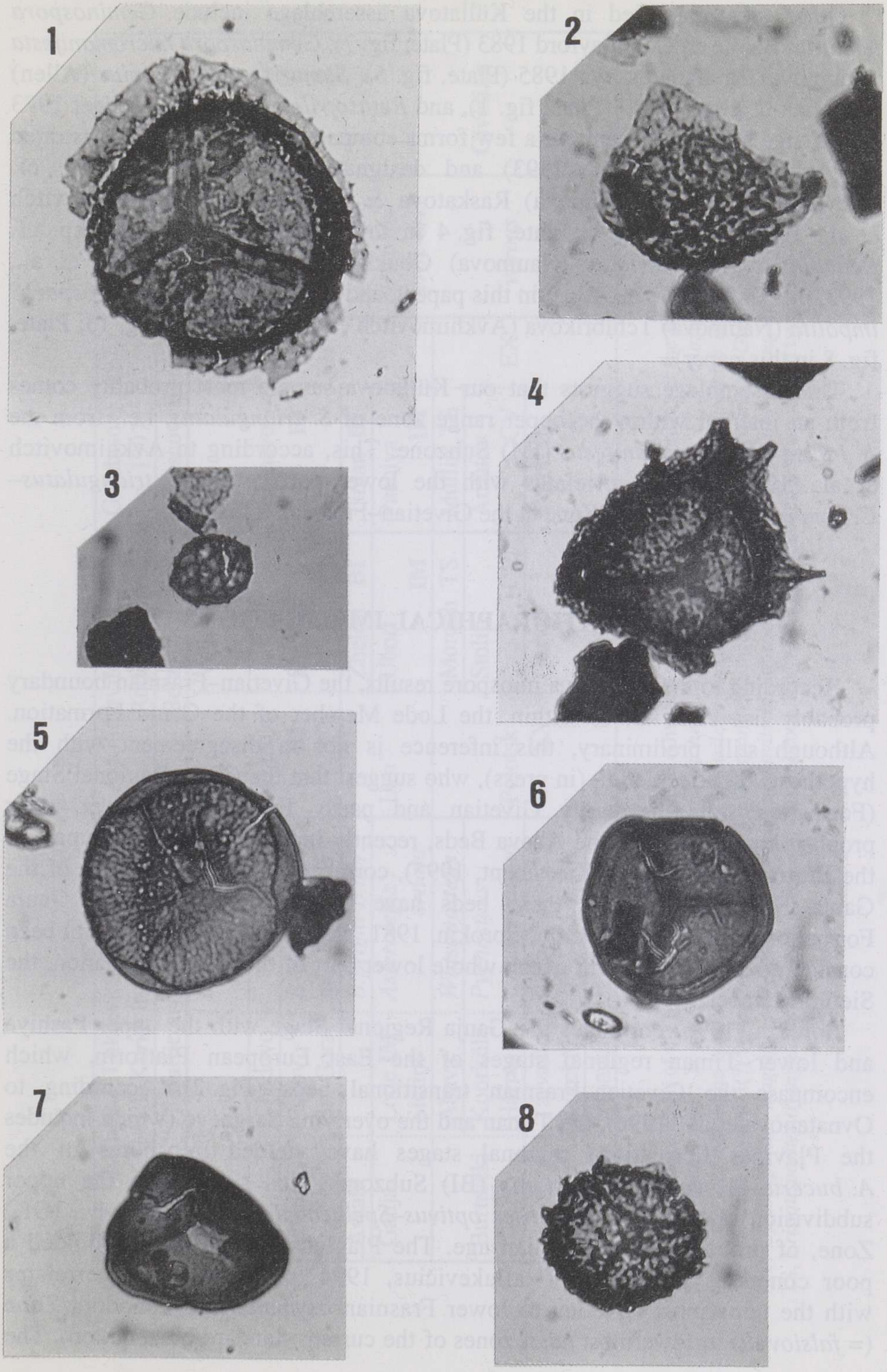
Fig. 4. *Ancyrospora* sp. cf. *Ancyrospora incisa* (Naumova) Raskatova & Obukhovskaya in Avkhimovitch et al., 1993. Slide Est. K. (2): L 41.

Fig. 5. *Dictyotriletes* sp. cf. *Reticulatisporites perlotus* (Naumova) Obukhovskaya in Avkhimovitch et al., 1993. Slide Est. K. (5): X 42/4.

Fig. 6. *Geminospora micromanifesta* (Naumova) Arkhangelskaya 1985. Slide Est. K. (1): R 23.

Fig. 7. *Geminospora lemurata* Balme emend. Playford 1983. Slide Est. K. (3): G 34/4.

Fig. 8. *Perotrilites* sp. cf. *Rugospora*? *impolita* (Naumova) Tchibrikova in Avkhimovitch et al., 1993. Slide Est. K. (4): T 47/1.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Other taxa identified in the Küllatova assemblage include *Geminospora lemurata* Balme emend. Playford 1983 (Plate, fig. 7), *Geminospora micromanifesta* (Naumova) Arkhangelskaya 1985 (Plate, fig. 6), *Samarisporites eximius* (Allen) Loboziak & Streel 1989 (Plate, fig. 1), and *Retusotriletes rugulatus* Riegel 1973 (Plate, fig. 3). Also present are a few forms comparable to miospores illustrated by Avkhimovitch et al. (1993) and designated as *Ancyrospora* sp. cf. *Ancyrospora incisa* (Naumova) Raskatova & Obukhovskaya (Avkhimovitch et al., 1993, pl. 10, fig. 1; Plate, fig. 4 in this paper), *Dictyotriletes* sp. cf. *Reticulatisporites perlotus* (Naumova) Obukhovskaya (Avkhimovitch et al., 1993, pl. 10, fig. 9; Plate, fig. 5 in this paper), and *Perotrilites* sp. cf. *Rugospora*? *impolita* (Naumova) Tchibrikova (Avkhimovitch et al., 1993, pl. 9, fig. 13; Plate, fig. 8 in this paper).

This assemblage suggests that our Küllatova sample most probably comes from an interval within the upper range zone of *S. triangulatus*, i.e., from the *A. incisa–G. micromanifesta* (IM) Subzone. This, according to Avkhimovitch et al. (1993, fig. 4), correlates with the lower part of the *S. triangulatus–C. concinna* (TCo) Oppel Zone at the Givetian–Frasnian transition.

BIOSTRATIGRAPHICAL IMPLICATIONS

According to the Küllatova miospore results, the Givetian–Frasnian boundary probably lies close to, or within, the Lode Member of the Gauja Formation. Although still preliminary, this inference is not in disagreement with the hypothesis of Blieck et al. (in press), who suggest that the Gauja Regional Stage (Formation) may be partly Givetian and partly Frasnian. However, their proposition implies that the Abava Beds, recently included in the upper part of the Burtnieki Formation (Kleesment, 1995), correspond to the lower part of the Gauja Formation. Earlier, these beds have been included into the Gauja Formation as its basal part only (Sorokin, 1981, pp. 369, 372), and have not been considered as an equivalent of the whole lower part of the Gauja Formation, the Sietiņi Member.

Sorokin (1996) correlates the Gauja Regional Stage with the upper Pashiya and lower Timan regional stages of the East European Platform, which encompass the Givetian–Frasnian transitional beds (Fig. 2). According to Ovnatanova et al. (1996), the Timan and the overlying Sargaevo (which includes the Pļaviņas Formation) regional stages have yielded miospores of the *A. bucerus–A. variabilis insignis* (BI) Subzone. This subzone is the upper subdivision of the *Contagisporites optivus–Spelaeotriletes krestovnikovii* (OK) Zone, of probable early Frasnian age. The Pļaviņas Formation has yielded a poor conodont assemblage (Valiukevičius, 1994, p. 124), which correlates with the uppermost Givetian to lower Frasnian *asymmetricus* conodont Zone (= *falsiovalis* to lowermost *hassi* zones of the current standard biozonation). The

Ivanov & Lukševičs, 1996; Mark-Kurik, in press			Avkhimovitch et al., 1993; Golubtsov, 1997; Rodionova & Umnova, 1997				**Standard conodont zones**	
Baltic area			**Belarus**		**Moscow Basin**			
Dubniki		*B. trautscholdi* (in part)	Sargaevo **BI**	Vedrich	Sargaevo **BI**	**OK**	*transitans*	**Frasnian**
Pļaviņas	Chudovo			Sar'yan				
	Pskov Sn. Gora	*B. cellulosa* inc. ***R. secans***						
Amata		*B.prima-B.obr.*	Lan'	Zhelon' **BI**	Timan **BI**		*falsiovalis*	– – – – – –
Gauja	Lode **IM** Sietiņi	*Asterolepis ornata*		Ubort **IM**	Pashiya **IM**		*disparilis* *herm.-cris.*	
Burtnieki	Abava	***Watsonosteus***	Polotsk EX	Moroch TS	Mullin TS	EX	*varcus*	**Givetian**
	Koorküla Härma	*Pycnosteus tuberculatus*		Stolin CV	Ardatov CV			
Aruküla	Tarvastu Kureküla	*Pycnosteus pauli*		Goryn MT*	Vorob'ev MT			
	Viljandi	*P. palaeformis*						

Fig. 2. Correlation chart of the Middle and Upper Devonian (Givetian and lower part of the Frasnian) of the Baltic area, Belarus, and the Moscow Basin. *B*, *Bothriolepis*; *B. obr.*, *Bothriolepis obrutschewi*; *herm.–cris.*, *hermanni–cristatus*; *P.*, *Pycnosteus*; *R.*, *Rhinodipterus*; Sn. Gora, Snetnaya Gora. Miospore zones and subzones: **BI**, *Acanthotriletes bucerus–Archaeozonotriletes variabilis insignis* Subzone; CV, *Vallatisporites celeber–Cristatisporites*(?) *violabilis* Subzone; EX, *Geminospora extensa* Zone; **IM**, *Ancyrospora incisa–Geminospora micromanifesta* Subzone; MT, *Cymbosporites magnificus–Hymenozonotriletes tichonovitschi* Subzone; **OK**, *Contagisporites optivus–Spelaeotriletes krestovnikovii* Zone; TS, *Cristatisporites triangulatus–Corystisporites serratus* Subzone. The zones mentioned in text are in bold type.

Pļaviņas Formation, as well as the underlying Amata Formation and the upper part of the Gauja Formation, are also dated to early Frasnian on the basis of brachiopods (P. Sartenaer, pers. comm. to A. Blieck., Tallinn, 1996).

The placoderm *Watsonosteus*, which characterizes the Abava Beds, is also known in the Blacourt and basal Beaulieu formations of Le Griset and Le Banc Noir quarries of Boulonnais, northern France (Lelièvre et al., 1988). These units range from the *varcus* to the lowermost *asymmetricus* conodont zones of Givetian age (Brice, 1988). A second fossil fish, the dipnoan *Rhinodipterus secans*, has been identified from both the Baltic and Ardenne (Namur Synclinorium, Belgium) areas. In the Baltic area the fish occurs in the Snetnaya Gora and Pskov beds of the Pļaviņas Formation (Ivanov, 1990), of early Frasnian age. In Belgium it is known from the Mazy Member, in the upper part of the Bois de Bordeaux Formation, dated to late Givetian (Bultynck et al., 1991). So, the occurrence of *Watsonosteus* suggests a more limited age (late Givetian for the Abava Beds) than *R. secans* (late Givetian–early Frasnian).

CONCLUSIONS

For the time being, the miospore assemblage identified from the Lode Member of the Gauja Formation in the Baltic area is only of limited stratigraphical significance. This is because, on the one hand, the precise location of our single productive sample in the Küllatova section is not known, and on the other hand, we are still unable to determine which part of the Lode Member (more completely seen in Lode quarry) the interval exposed at Küllatova corresponds to.

The miospore assemblage in the Küllatova sample is similar to that of the *A. incisa–G. micromanifesta* (IM) Subzone. This allows us to correlate the Gauja Formation with equivalent stratigraphic units of the East European Platform, such as the Ubort' Beds of the Lan' Regional Stage of Belarus and the Pashiya Regional Stage of the Moscow Basin (Fig. 2). Those units roughly correspond to the *hermanni–cristatus* and *disparilis* conodont zones (Rodionova & Umnova, 1997).

To sum up, our correlations suggest that the Gauja Formation is most likely of Middle Devonian age, and that the Middle–Upper Devonian boundary probably lies close to, but somewhat above, the upper limit of that formation.

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LODE KIHISTIKU (GAUJA KIHISTU) MIOSPOORIDE KOOSLUS EESTIS NING KESK- JA ÜLEMDEVONI PIIRI PROBLEEM

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Proovist, mis pärineb endisest Küllatova rasksulava savi leiukohast Kagu-Eestis, on kindlaks tehtud miospooride kooslus, mis vastab oma koosseisu poolest Ida-Euroopa platvormi *Ancyrospora incisa–Geminospora micromanifesta* (IM) alamtsooni omale. Nimetatud kooslus annab võimaluse korreleerida Gauja kihistut ligikaudu sama vanusega stratigraafiliste üksustega Baltikumi naaberaladelt. Valgevenes on selleks üksuseks Lani lademe Ubordi kihid, Moskva basseinis aga Pašija lade. Saadud korrelatsiooni alusel võib Gauja kihistut pidada keskdevoni vanuseks. Kesk- ja ülemdevoni piir paikneb nähtavasti nimetatud kihistu ülemise piiri lähedal, kuid siiski sellest mõnevõrra kõrgemal.

КОМПЛЕКС МИОСПОР ЛОДЕСКОЙ ПАЧКИ (ГАУЙСКАЯ СВИТА) В ЭСТОНИИ И ПРОБЛЕМА СРЕДНЕ- И ВЕРХНЕДЕВОНСКОЙ ГРАНИЦЫ

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и Анне-Мари КАНДИЛЕР

В образце тугоплавких глин из старого карьера Кюллатова (Юго-Восточная Эстония) установлен комплекс миоспор, который по своему составу аналогичен ассоциации подзоны *Ancyrospora incisa–Geminospora micromanifesta* (IM) Восточно-Европейской платформы. Этот комплекс миоспор позволяет скоррелировать гауйскую свиту с примерно одновозрастными стратиграфическими подразделениями смежных регионов Прибалтики. В Беларуси гауйской свите соответствуют убортские слои ланского горизонта, а в Московском бассейне – пашийский горизонт. Согласно этой корреляции, гауйская свита имеет, вероятно, среднедевонский возраст. Граница между средним и верхним девоном проходит вблизи верхов этой свиты или, возможно, несколько выше ее.