Sedimentology and vertebrate fossils of the Frasnian Ogre Formation, Gurova outcrops, eastern Latvia

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Received 27 July 2020, accepted 11 September 2020, available online 11 November 2020

Abstract. Combined sedimentological and palaeontological study of the siliciclastic sequence of the Ogre Formation in the easternmost area of its distribution in Latvia was aimed at the facies analysis of the deposits and at detailed observation of the taxonomical and taphonomical peculiarities of the fossil vertebrate assemblage. Two facies associations, tidally-influenced fluvial channels and lateral tidal bars, have been identified in exposures along the Gurova River. Sedimentological evidences suggest that the studied deposits were formed in the fluvial environment with strong tidal influence. The sedimentary concentrations of vertebrate remains, dominated by the antiarch *Bothriolepis maxima*, porolepiform *Holoptychius* cf. *nobilissimus* and psammosteid heterostracans, have been formed under the influence of fluvial and tidal processes in the shallow-water environment, deltaic or estuarine settings. The finding of the psammosteid *Obruchevia heckeri* has confirmed the distribution of this species outside the type area.

Key words: facies analysis, tidal processes, vertebrate assemblage, taphonomy.

INTRODUCTION

Devonian deposits are widely distributed in the Baltic countries and the northwestern part of Russia, cropping out in a relatively narrow belt in the northwestern part of the East European Platform, along the southern margin of the Baltic Shield. The western part of this belt is known as the Devonian Baltic Basin (Pontén & Plink-Björklund 2009) or the Baltic Devonian Basin (BDB; Lukševičs et al. 2011). This territory developed in Devonian time as a shallow epicontinental basin, often with restricted connection to an open ocean. This setting determined the peculiarities of the living habitats and burial environments of Devonian organisms. The mostly clastic sedimentation model typical for the Lower, Middle and lowermost Upper Devonian section in the BDB was replaced by the predominantly carbonate sedimentation and mixed model in the Frasnian (Kuršs 1975), starting with Pļaviņas time (Fig. 1). Salaspils and Daugava times were represented by carbonate, clay and gypsum sedimentation, replaced by prevailing clay in Katleši time and sand in Ogre time. In contrast to the dolomites of the Daugava Formation (Fm.) with abundant and diverse fauna of invertebrates including stromatoporates, rugose corals, molluscs, articulate brachiopods, echinoderms, etc., vertebrate and spore fossils dominate the deposits of the Katleši and Ogre formations corresponding, respectively, to the Katleši and Pamūšis regional stages in Latvia. The stratigraphically important ammonoids and conodonts are missing in these sandy-clayey deposits. It makes the precise correlation with stratotypical sections and sections from neighbouring areas of the East European Platform more difficult (Esin et al. 2000); only vertebrates and spores can be used in stratigraphic correlations. Therefore, detailed sedimentological studies and facies analysis are needed to determine changes in the sedimentary environment in time, which can be an important marker in stratigraphy.

The deposits of the Ogre Fm. are widely exposed in Latvia. The most representative sections of the Ogre Fm. in Latvia are in the Abava River Basin in Kurzeme and in the Daugava River and Ogre River basins in Vidzeme, Latvia. Detailed studies of the Devonian deposits in these areas were performed in the 1930s by E. Kraus and N. Delle. Previous studies by the authors of this article in western Latvia suggest that these deposits are important for understanding the changes in sedimentary environments of the Frasnian of the entire BDB. For example, indications of tidal influence have been recorded in the Langsēde locality (Lukševičs et al. 2011), and the maximum content of sand in the middle part of the Frasnian after the Amata Fm. has been demonstrated.

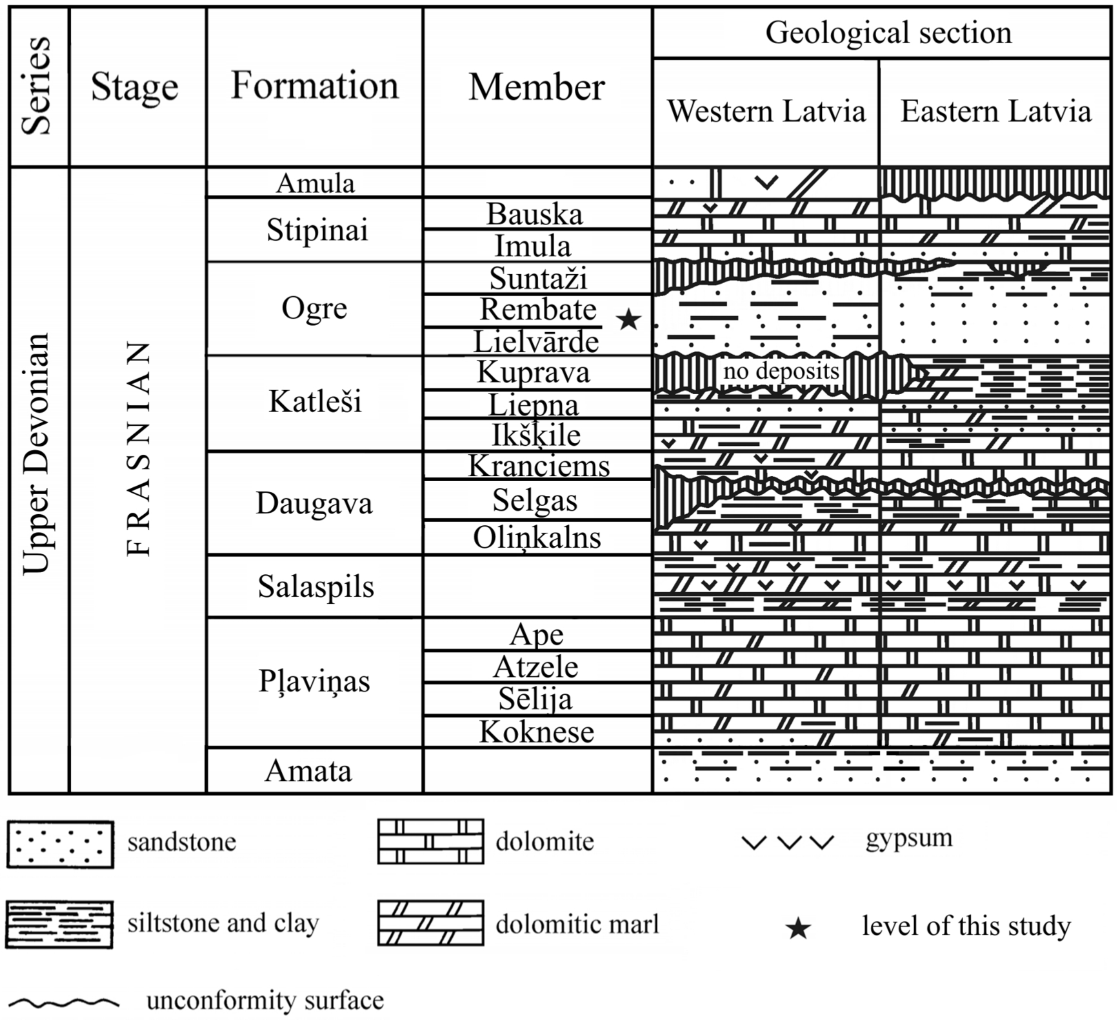

Fig. 1. Stratigraphy and schematic geological section of the Frasnian deposits in Latvia (modified from Lukševičs et al. 2011).

The deposits of the Ogre Fm. are rather well exposed in several outcrops in the eastern corner of their distribution area in Latvia, which enables the analysis of the sedimentary environment and its changes as well as the comparison with the sections in western Latvia. However, detailed sedimentological studies in this area were not performed until 2014. Vertebrate fossils from these deposits were never studied before. Recently the remains of the poorly known placoderm fish *Walterilepis* were revised, including material from the Gurova Ravine which constitutes part of the study presented here (Lukševičs in press). The main aim of this study is to provide the results of facies analysis, interpretation of sedimentary environments and palaeontological analysis of the Ogre Fm. deposits in the Gurova Ravine locality in eastern Latvia.

GEOLOGICAL SETTING AND STRATIGRAPHY

The studied sections are situated in eastern Latvia, the northern part of the historical region of Latgale (Fig. 2). The deposits of the Ogre Fm. are exposed in several picturesque outcrops along the Gurova River, which belong to the Velikaya River Basin. The Gurova Ravine is in the vicinity of Aizgalīne village, Medņeva Parish, Viļaka Municipality. The sections are small, up to 4 m high and up to 8 m wide outcrops. They are located 8 km north of the outcrops of deposits of the Ogre Fm. at the Stiglova site and 15 km south of other small outcrops of the same formation at the Makšinava site. Other known closest outcrops of deposits of the Ogre Fm., the Kalnrēžas outcrop belt at the banks of the Ogre River, are situated more than 150 km westwards from the Gurova site. The

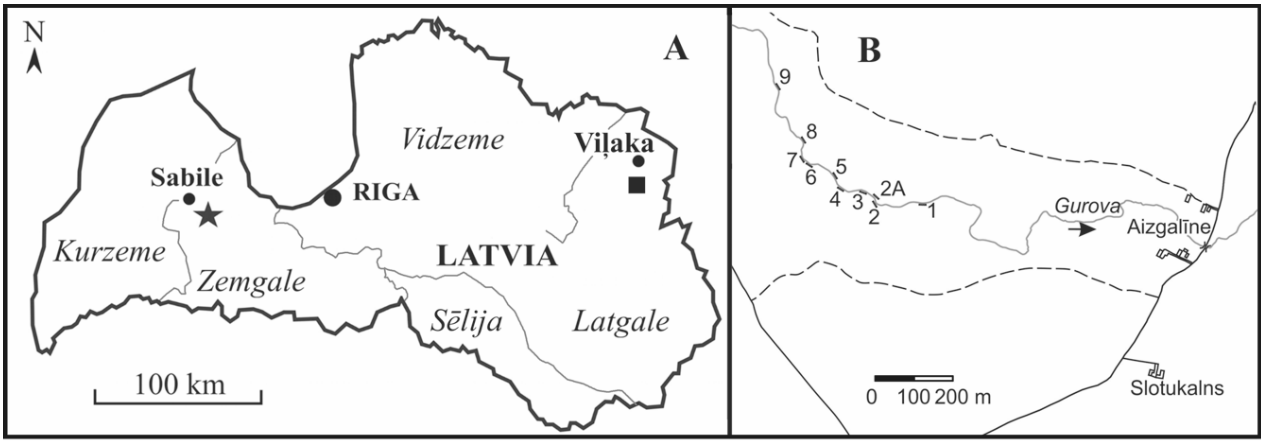

Fig. 2. A, location of the studied outcrops (black rectangle) and the Langsēde site (black star) relative to the area of Latvia; **B** (corresponds to the black rectangle in A), studied sections and their numbers in the vicinity of Aizgalīne.

investigated sections were correlated to the nearby drillings Nos 22279, 24779, 23236 and 25188 (Takcidi 1999). According to data of topographic maps, the lowermost part of the studied outcrops has an absolute elevation of 112 m. The correlation of the drillings suggests that the lower boundary of the Katleši Fm. near the studied objects has an absolute elevation of 74 m, thus the lower boundary of the studied sections is 38 m above the lower boundary of the Katleši Fm. The deposits of the Katleši and Ogre formations are mapped together in the study area due to similar lithologies. In accordance with the data of Sorokin (1978), the Katleši Fm. is 25 m thick in the vicinity of Liepna, 25 km north of the Gurova site. It may suggest that the studied objects correspond to the part of the Ogre Fm. 13–19.5 m above its lower boundary. According to descriptions of the members and their thicknesses given in Sorokin (1978), the deposits studied at the Gurova site correspond to the upper part of the Lielvārde Member or to the lower part of the Rembate Member of the Ogre Fm.

MATERIAL AND METHODS

In the summer of 2017 detailed logging of the Devonian succession was carried out for the outcrop No. 7 in the Gurova Ravine by E. Lukševičs; in the spring of 2019 logging was carried out for the outcrops Nos 1, 6, 8 and 9 by Ģ. Stinkulis, T. Reķe and Simona Mačute (Fig. 2B). A total of 68 cross-beds, current-ripple lamination and bedding surfaces were measured in order to determine the direction of palaeotransport and to study bedform morphology. Facies analysis was performed by T. Reķe and Ģ. Stinkulis. Vertebrate remains were gathered by the team of participants of the Summer school of the field palaeontology led by E. Lukševičs in August 2017. All collected specimens were prepared mechanically by T. Reķe and E. Lukševičs under the optical microscope ZEISS KL 1500 LCD using the steel needle and brush in the Mineralogical-Paleontological Laboratory (MinPal) of the University of Latvia. The main part of the obtained collection of vertebrates is kept in the MinPal, University of Latvia, Riga. The described and figured specimens of *Walterilepis speciosa* are kept in the Latvian Museum of Natural History, Riga, Latvia.

RESULTS

Facies

As a result of the sedimentological logging of the four studied sections (Nos 1, 6, 7 and 8) seven facies were distinguished:

- F 1: clay and fish conglomerate,
- F 2: trough cross-bedded sandstone without tidal features,
- F 3: trough cross-bedded sandstone with tidal features,
- F 4: sandstone with current ripple marks,
- F 5: sandstone with wave ripple marks,
- F 6: cross-bedded sandstone with climbing ripple marks on the cross-bed surfaces,
- F 7: clay to siltstone.

Data on their lithology, structures, geometry and interpretations are summarized in Table 1. Logged geological sections with data of facies, facies associations and current directions are demonstrated in Fig. 3.

Facies associations

Two facies associations were distinguished based on spatial relationships of the facies and common bedform architecture:

- FA 1: tidally-influenced fluvial channels,
- FA 2: tidal bars.

Table 1. Facies distinguished in the Ogre Formation, Gurova outcrops

Facies	Bed (cross-set) thickness, lithology, and fossils	Structures	Geometry, bounding surfaces	Interpretation
F 1: clay and fish conglomerate	Cross-sets 5–14 cm thick; clay clasts (up to 5 cm large) and fish bones in matrix of fine-grained sand. Vertebrate remains are often present	Rather parallel distribution of clasts, in some cases trough cross-stratification	Irregular erosional base, scour to 40 cm (section 1), in other cases no visible indications of erosion	Channel lag deposits (Pontén & Plink-Björklund 2007; Nichols 2009). Vertebrate bones transported and accumulated by rapid currents
F 2: trough cross-stratified sandstone	Sets 2–35 cm thick; fine- to medium-grained sandstone. Clay clasts and vertebrate fossils are present in some cross-sets	Trough cross-stratification	Scoured bases, lateral thinning of cross-sets	Accumulation of sand in migrating lingoid or lunate dunes in a fluvial channel (Allen 1968). Vertebrate fossils transported and accumulated by fluvial currents
F 3: trough cross-bedded sandstone with tidal features	Sets 2–34 cm thick, in half of the cases very fine- to fine-grained, but in other half of the cases fine- to medium-grained sandstone. Vertebrate fossils in some places are present	Trough cross-stratification with clay or mica drapes on the cross-beds. Tidal bundles are present	Scoured bases, lateral thinning of cross-sets	Accumulation of siliciclastic material in migrating lingoid or lunate dunes in a tide-influenced environment (Allen 1968; Pontén & Plink-Björklund 2007). Vertebrate fossils transported and accumulated by fluvial and/or tidal currents
F 4: sandstone with current ripples	Beds 5–30 cm thick, mainly very fine-grained, rarer fine-grained and medium-grained sandstone	Current ripple-lamination is present. In approximately 30% of the succession represented by this facies the ripples are climbing, in places under various angles	Sub-horizontal, non-erosive. Usually sharp, but in few cases gradual upward transition from cross-stratification. In several cases in section 1 well-preserved top parts of ripples, also climbing ripples	Accumulation of sand by water currents in a low-energy environment (Reineck & Singh 1980). Climbing ripples indicate high sediment load and/or water level rise. Changes in the ripple climbing angle point to rhythmic water level changes, likely due to tidal processes (Lanier & Tessier 1998). Good preservation of upper parts of bedforms indicates the rise of water level
F 5: sandstone with wave ripples	Bed 16 cm thick, coarse-grained siltstone to very fine-grained sandstone	Wave-ripple lamination	Sharp, non-erosive	Accumulation of silt- to sand-sized material in a rather low-energy environment under the influence of waves (Nichols 2009)

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Table 1. *Continued*

Facies	Bed (cross-set) thickness, lithology, and fossils	Structures	Geometry, bounding surfaces	Interpretation
F 6: cross-stratified sandstone with opposite-oriented ripple-marks on the cross-bed surfaces	Bed 25 cm thick, very fine-grained sandstone	Trough cross-stratification. Current ripples on the whole length of cross-beds are oriented opposite to the cross-beds	Rather sharp, non-erosive	Accumulation of siliciclastic material in migrating lingoid or lunate dunes (Allen 1968). Current ripples climbing in opposite direction to the flow indicate the existence of tidal currents (Van den Berg et al. 2007)
F 7: clay to siltstone	Beds 3–6 cm thick, clay to clayey siltstone	Homogeneous, deposits, sedimentary structures are not visible	Sharp, non-erosive	Accumulation in a thick low-energy environment

FA 1: tidally-influenced fluvial channels

The facies association is present in all studied sections. It is composed of 0.22–1.2 m thick units, which are represented by most of the facies distinguished in the studied sections: F 1, F 2, F 3, F 4 and F 7. The lower part of section 1 (hypsometrically the lowermost part of the studied sections) contains four cycles, 0.22–0.4 m thick, where F 3 changes upwards to F 4. The thickness of these fining-upwards cycles decreases upwards in the section.

These units are overlaid by two fining-upwards cycles of different composition. The lower cycle, 0.1–0.5 m thick, is composed of conglomerate (F 1) fining upwards into F 2. The deposits generally are coarse-grained, marking the bottom of an erosional channel. The upper cycle is of the same structure, but better preserved from erosion. It starts with the conglomerate (F 1), fining upwards into medium- to fine-grained trough cross-bedded sandstone without tidal features (F 2) and more fining upwards into very fine-grained sandstone with the current ripple marks (F 4).

In sections 6, 7 and 8 the trough cross-bedded sandstones of F 2 are dominant, but similar deposits with tidal features (F 3) are also present. There is one well-developed fining-upwards cycle in the upper part of sections 6 and 7. These cycles start with the conglomerate (F 1), which is followed by cross-bedded sandstone (F 2 and F 3) and current ripple-marked sandstone (F 4). The cycle ends with a 6 cm thick clay bed (F 7) in section 6.

Cyclic changes in the thickness of sandstone cross-beds are well developed in sections 1, 6 and 8. Sets of cross-beds, 8–15 cm thick, gradually change into 2–6 cm thick sets of cross-beds. The phenomenon is best represented in section 6, where the sets of thicker cross-beds reach a total thickness of 0.6–0.8 m, but the sets of thinner cross-beds are 0.3–0.4 m thick.

The units of the facies association are oriented parallel and almost horizontal. The exception is bottoms of two erosional channels at two levels (1.45 and 1.7 m) in section 1.

Vertebrate fossils often occur in the deposits of this facies association. They are present in F 1 (sections 1, 6 and 7), F 2 (sections 6, 7 and 8) and F 3 (sections 1 and 3).

Interpretation

Fining-upwards sedimentary cycles with erosional bases, the dominance of trough cross-bedded sandstones formed in lingoid or lunate subaqueous dunes and wide presence of current ripple marks are typical features of the fluvial channel infilling (Pontén & Plink-Björklund 2007; Nichols 2009; Miall 2014). Usually these sedimentary units in the studied sections are parallel and horizontally-lying, which indicates their development as sheet-like bodies in flat-bottom channels.

In some cases (interval 1.45–1.7 m, section 1) channels with irregular, erosional bottoms developed. The erosional surfaces were covered by fish and clay clast conglomerates. These channels were filled with sandy deposits fining upwards. Cross-bedded sandstones (F 3) in 40% of their total thickness in the geological sections have evident tidal structures such as mud and mica drapes, organized in tidal bundles (Nichols 2009). Other 60% of cross-bedded sandstones (F 2) do not exhibit obvious tidal signatures.

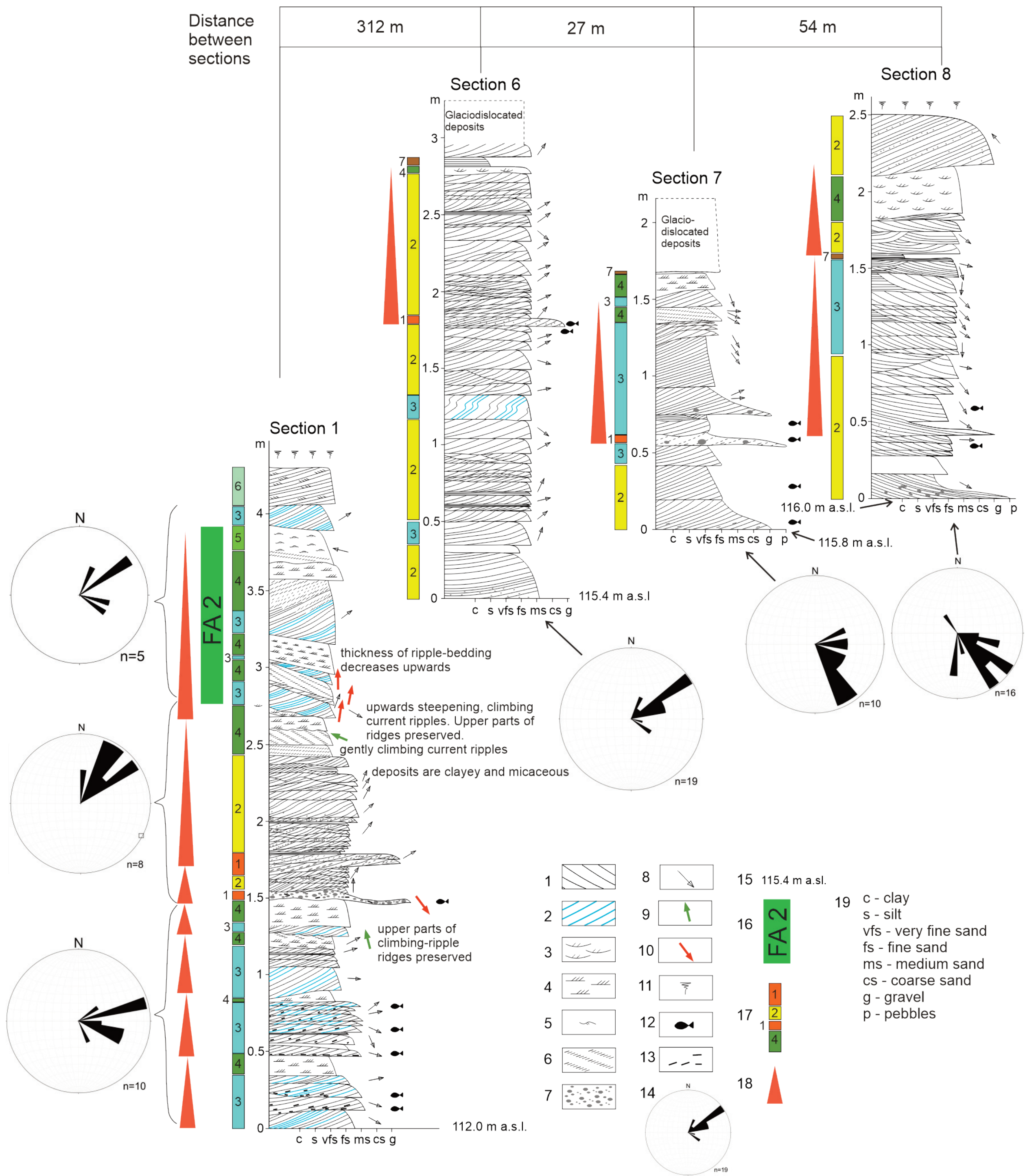

Fig. 3. Studied geological sections of the Frasnian Ogre Formation of the Gurova site. Legend: 1, cross-bedding and other structures; 2, mud and mica drapes (tidal features); 3, parallel current ripple-lamination; 4, trough current ripple-lamination; 5, wave ripple-lamination; 6, climbing ripple-lamination; 7, clay clasts; 8, current direction derived from cross-bedding; 9, current direction derived from ripple-lamination; 10, master bedding surface dip azimuth; 11, soil and debris cover; 12, intervals of vertebrate finds; 13, vertebrate fossils in deposits; 14, rose diagrams of current directions derived from cross-bedding and ripple-lamination direction (‘n’ is the number of measurements); 15, hypsometric position of lower boundaries of sections; 16, facies association 2 (all the rest of deposits correspond to facies association 1); 17, facies and their numbers; 18, fining-upwards cycles; 19, grain-size of siliciclastic deposits.

However, in section 6, where tidal structures were not documented, the cross-beds show regular cyclic changes in their thickness, described as an evidence of water-level changes under the influence of tides (Pontén & Plink-Björklund 2009; Longhitano et al. 2012). Thus, the presence of sandstones without tidal structures (F 2) does not obviously indicate the absence of tidal processes.

Vertebrate fossils are distributed mostly in the lower parts of channel fills that accumulated in the most active hydrodynamic regime (F 1, F 2 and F 3). They are present both in deposits without obvious tidal features, including channel basal lags, and tidally-influenced deposits. The location and considerable fragmentation of fossils indicate their transportation and accumulation by high-energy fluvial and tidal currents.

FA 2: lateral tidal bars

The facies association is represented by one 1.2 m thick unit present in section 1 (Fig. 4). It is composed of obliquely lying beds of F 3 (cross-bedded sandstones with tidal features), F 4 (current ripple-marked sandstones) and F 5 (wave ripple-marked sandstones). Master bedding surfaces dip to the north (359–11°) at an angle of 12–23°. It shows the accretion of beds over the northerly-dipping inclined surfaces. The current directions derived from the cross-bed and ripple-mark measurements are mainly to the east (53–120°), but in one case to the north (21°). The cross-bedded sandstones are rich in tidal bundles, but the current ripple marks show a changing angle of climbing. These are indicators of tidal processes (Pontén & Plink-Björklund 2009).

A considerable part of this unit (interval 3.2–3.6 m) is one cross-bed, the bottom of which is dipping to the north, but the top is almost horizontal. Thus, its visible thickness in the outcrop wall changes from 70 to 30 cm. In its thinner portion the cross-bedding gradually changes in the lateral direction into the current ripple-lamination. In the upper part of this cross-bed and other beds in the upper part of the lateral tidal bar the tops of beds are preserved from erosion. No vertebrate fossils are found in FA 2.

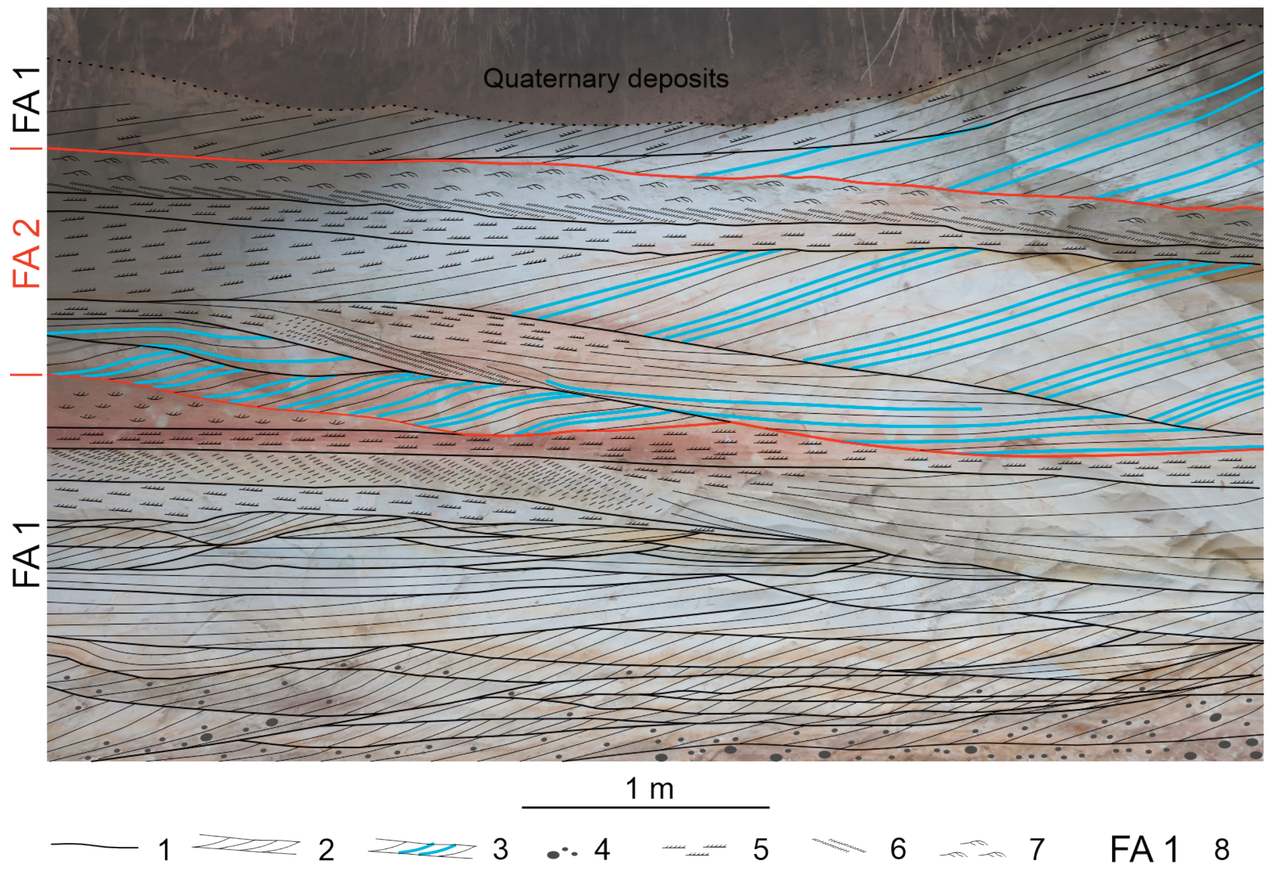

Fig. 4. Lateral tidal bar (facies association 2) bordered with deposits of facies association 1 in section 1 with dominant sedimentary structures and bedform morphology. Note the climbing cross-beds, convex-upwards surfaces of beds, as well as the changing sedimentary structures – cross-bedding to ripple-lamination – within the same beds. Legend: 1, main bedding surfaces; 2, cross-bedding; 3, cross-bedding with tidal bundles; 4, clay clasts; 5, current ripple-lamination; 6, climbing current ripple-lamination; 7, wave ripple-lamination; 8, facies associations and their numbers.

Interpretation

The bedding pattern of this sedimentary unit consisting of a set of obliquely lying beds points to its development as a united bedform. The above-mentioned data on dip azimuths of master bedding surfaces and cross-beds suggest that the currents mainly flowed perpendicular to the dip azimuth of the bar surface, indicating that it is a laterally-accreted bar unit developed in a channel margin (Allen 1983; Pontén & Plink-Björklund 2009) or a channelwards-dipping margin of a larger tidal bar. Abundant tidal features show a strong role of tidal currents in the development of the bar. This facies association lacks the features of compound dunes described by Dalrymple & Choi (2007), such as, for example, the forward accretion and not lateral accretion, upwards-coarsening sand grain-size, upward increase in the energy levels. The preservation of bedforms from erosion could reflect the temporary accommodation space created by tides, but it can also be related to general water level rise trends. The lack of vertebrate remains indicates that the bar was not a favourable location for their accumulation and burial.

Sedimentary environment

Analysis of sedimentary environments for the studied deposits of the Ogre Fm. has limits due to the small size and fragmented distribution of the outcrops, as well as due to problems with their correlation. Most possibly the oldest deposits are present in section 1, the base of which is 3.4–4 m lower than the lower parts of the rest of the sections (Fig. 3). There the succession starts with the development of four stacked small channels (interval 0.0–1.5 m). Cross-beds of medium-grained sandstones there are rich in fish fossils. Channel infill cycles become thinner upwards from 0.45 to 0.22 m, suggesting a decrease in the accommodation space.

The next interval (1.5–2.7 m) contains two channel infills with a thickness of 0.25 m (lower) and 1.0 m (upper). Several cross-beds with convex tops representing complete preservation of subaqueous dunes are present in the upper channel infill. The increase in the thickness of channel infills and good preservation of bedforms point to the increase in the accommodation space.

The following interval (2.7–3.9 m) is represented by the lateral tidal bar (facies association 2) with master bedding surfaces dipping to the north and currents flowing along it to the east. Smooth, non-eroded upper parts of beds suggest further increase in the accommodation space. The uppermost part of section 1 is represented by two rather thick (from 0.2 m to more than 0.3 m) cross-beds with good indications of tidal processes.

Good preservation of upper parts of bedforms is typical for section 1 (interval 1.3–3.7 m). The increase in the accommodation space is created either by the tidal processes or it is related to general transgressive trends.

The rest of the studied outcrops (sections 6, 7 and 8) are situated 300 m to the west-northwest from section 1 (Figs 2 and 3). The base of these sections corresponds to the upper part of section 1 (lateral bar) by the hypsometric position, but their correlation is problematic due to a large distance. Judging from quite considerable changes in sedimentary structures and bedform geometry, we suggest that sections 6, 7 and 8 already from their base correspond to the more upper part of the Ogre Fm. than section 1.

The trough cross-bedded sandstones with minor current ripple-marked sandstones dominant in sections 6, 7 and 8 were formed in high- to low-energy water current environments. The parallel, horizontal orientation of sedimentary units indicates that they formed as sheet-like bodies in flat-bottom channels. They are very thin to thin channel-fill bodies organized in the multistorey pattern, according to the classification of Gibling (2006). Tidal structures such as mud drapes and tidal bundles (Nichols 2009) are present only in part of the geological succession of sections 6, 7 and 8, however, the cyclic, gradual changes in cross-bed thickness are also indicative of tide-induced water level fluctuations. The good preservation of upper parts of bedforms documented in section 1 is not typical for sections 6, 7 and 8.

The water depth of the studied deposits was approximately evaluated using the formulas of Leclair & Bridge (2001). The water depth is derived from the thickness of the cross-beds, thus the data well correspond to the outcrop logging information.

The deposits exposed in section 1 started to form as several channel infillings (interval 0.0–1.5 m). The water depth during this time changed from 0.3 to 4 m. The next two channels with erosional bases and basal conglomerate lags were filled with shallow water (0.3–2 m). Trends of water depth fluctuation are observed, possibly related to tidal processes. The lateral tidal bar (facies association 2) probably developed in 0.3–4 m deep water. Deepening likely happened after that and the last cross-bed measured in the section may have formed in 3–5 m deep water.

The cross-bedded sandy deposits exposed in sections 6 and 7 probably formed in 0.3–9 m deep water, but the sandstones cropping out in section 8 correspond to the 0.3–5 m depth interval. Water depth evaluations clearly show several water-level fluctuation episodes for the 3 m thick sandstones present in section 6 (from bottom to top): relatively deep (1.5–9 m), shallowing (0.3–1.7 m), deepening (1.4–4 m), shallowing (0.3–1.4 m), deepening (1.2–3.5 m) and shallowing (0.3–2.6 m). The water-depth fluctuations most possibly were related to tidal processes.

The current directions derived from the measurements of the dip azimuths of cross-beds and current ripples show large variability. The channel infills present in the interval 0.0–1.5 m in section 1 were formed under the influence of easterly flowing currents (Fig. 3). After the erosion, when the two next channel infills formed (interval 1.5–2.7 m), the currents changed to the north-northeast. During the development of a lateral tidal bar (interval 2.7–3.9 m) the currents flowed in two main directions – to the northeast and southeast. The slope of the bar dips to the north. Thus none of the measurements is perpendicular to this direction, however, the average azimuth of current flow coincides with the perpendicular orientation (to the east). This supports the interpretation of the lateral bar.

We could expect some current direction changes from section 1 to section 6 located at 300 m distance, but the latter shows almost the same directions mainly to the northeast. However, abrupt changes in the current directions occur from section 6 to close-lying (27 m distance) section 7, where currents were directed to the south-southeast with some flowing to the east. Almost the same directions were derived from measurements in section 8: to the southeast, with minor flows to the south and east (Fig. 3).

Rather similar current directions in sections 1 and 6 and their change for approximately 90° in sections 7 and 8 could point to the meandering of a channel or correspondence of sections 7 and 8 to another channel than that in section 6. In any case such changing current directions from site to site indicate various orientation of channels.

Fossil assemblage

The palaeontological material collected from the outcrops of the Ogre Fm. in the Gurova Ravine is highly fragmented and usually eroded, particularly skeletal elements of such large-sized fishes as *Obruchevia*, *Bothriolepis maxima* and *Holoptychius*. However, small and sometimes thin plates of the head shield of small antiarchs and small tesserae of heterostracans, usually less than 1 cm in diameter, are relatively well preserved. Despite the poor degree of preservation, almost 700 collected fossils were identified and their taxonomic attribution to a species or to a genus was determined. In total, fossil remains of 10 vertebrate taxa representing heterostracans, antiarchs, placoderms, acanthodians and sarcopterygians were found in outcrops Nos 1, 3, 6, 7 and 8 (Table 2).

In comparison with the vertebrate assemblage characteristic of the Pamūšis Regional Stage of the Main Devonian Field, the faunal diversity of the Gurova Ravine site is slightly lower, but strongly resembles that of the Langsēde site (see Table 2), except the presence of the heterostracan *Obruchevia heckeri* at the Gurova site. Previously this taxon has been mentioned erroneously as being found from the Katleši and Pamūšis regional stages in Latvia (Lyarskaya & Lukševičs 1992). It has been first described from the time-equivalent deposits cropping out along the Lovat´ River in the

Table 2. List of vertebrate taxa identified in the Gurova Ravine, at the Langsēde site (Lukševičs et al. 2011) and in the Pamūšis Regional Stage of the Main Devonian Field (MDF; after Esin et al. 2000)

Group	Genus/species	Gurova Ravine	Langsēde site	MDF
Heterostracomorpha	*Traquairosteus*? *falcatus* (Gross)	+	+	+
	Psammosteus tenuis Obruchev	–	–	+
	Psammosteus sp.	+	+	–
	Obruchevia heckeri (Obruchev)	+	–	+
Placodermi	*Bothriolepis maxima* Gross	+	+	+
	Bothriolepis evaldi Lyarskaya	+	+	+
	Grossilepis spinosa (Gross)	–	+	+
	Walterilepis speciosa (Gross)	+	+	+
Acanthodii	*Devononchus laevis* Gross	+	+	+
	Acanthodii gen. et sp. indet.	–	+	–
Sarcopterygii	*Holoptychius* cf. *nobilissimus* Agassiz	+	+	+
	Platycephalichthys bischoffi Vorobyeva	+	+	+
	‘*Dipterus*’ cf. *marginalis* Agassiz	–	–	+
	Dipteriformes gen. et sp. indet.	+	+	–
	Obruchevichthys gracilis Vorobyeva	–	–	+
	Webererpeton sondalensis Clément & Lebedev	–	–	+

Novgorod Region of northwestern Russia (Elliott et al. 2004).

Similarly to the Langsēde site, three placoderm species, *Bothriolepis maxima*, *B. evaldi* and *Walterilepis speciosa*, occur at the Gurova Ravine site, while from western Latvia (Kurzeme) *Grossilepis spinosa* has been reported (Lukševičs 2001). Outside the studied area, *B. maxima* is widely distributed in various formations of Latvia, Lithuania and northwestern Russia (Lukševičs 2001), *B. evaldi* is known from two localities in Kurzeme and one locality in Vidzeme, *G. spinosa* is known only from the locality of the Ogre Fm. outcropping in Velna ala (Devil's Cave) in Kurzeme not far from the Langsēde site (Lukševičs 2001) and *W. speciosa* has been described from the Ogre Fm. cropping out along the Daugava River locality in Vidzeme (Gross 1933). *Asterolepis*? *amulensis* Lyarskaya mentioned by various authors (Lyarskaya 1981; Esin et al. 2000; Lukševičs et al. 2011), as well as Antiarchi gen. et sp. by Gross (1942), were recently synonymized with *Walterilepis speciosa* (Lukševičs in press). Antiarch remains, particularly those of *B. maxima*, scales of *Holoptychius* and fragments of psammosteids strongly dominate the assemblage by the number of identified skeletal elements (Table 3). The proportion of heterostracan remains is much larger and the number of antiarch fragments is lower in the assemblage from the Gurova Ravine in comparison with these from the Langsēde site (Lukševičs et al. 2011). Macroscopic (fin spines) and microscopic (scales) remains of acanthodians, scales of *Platycephalichthys* and plates of *Bothriolepis evaldi* are comparatively rare. The remains belonging to the same taxa are also rare in the assemblage from the Langsēde locality (Lukševičs et al. 2011).

DISCUSSION

During the Devonian period approximately half of the territory of the Euramerican Continent was covered by epeiric basins (Scotese 2014). The BDB (Pontén & Plink-Björklund 2009; Lukševičs et al. 2011), including the sites of this study, was a part of a shallow epeiric basin in the eastern part of Euramerica. The sedimentation style in the BDB was influenced by its proximity to the eastern margin of a wide terrestrial area occupying the middle part of the continent, including present areas of Fennoscandia, and location in a high latitude, close to the palaeoequator (De Vleeschouwer et al. 2014; Scotese 2014).

Kuršs (1992) suggested that the epeiric sea and delta slope environments prevailed in the BDB from the beginning of the Early Devonian to Late Devonian Amata time. The authors of later sedimentological studies focused mainly on siliciclastic deposits (Pontén & Plink-Björklund 2007, 2009; Tänavsuu-Milkeviciene & Plink-Björklund 2009; Tovmasjana 2013). They suggested the development of tidally-dominated and tidally-influenced deltas and estuaries for the Middle Devonian to the earliest Late Devonian. Shallow sea with carbonate sedimentation developed during the maximum Middle Devonian transgression in Narva time (Kuršs 1992; Tänavsuu-Milkeviciene et al. 2009).

From Pļaviņas time (Early Frasnian) to the end of the Famennian, the sedimentation regime changed from predominantly siliciclastic to carbonate, alternating with sand, clay and mixed-composition deposition, with minor gypsum in some episodes. The carbonate deposits accumulated in the shallow-marine environment (Sorokin 1981; Brangulis et al. 1998). Siliciclastic deposits of the Ogre Fm. (Frasnian), Tērvete Fm. and Ketleri Fm.

Table 3. Number and percentage (%) of skeletal elements from the Gurova Ravine

Taxon	No. of skeletal elements	%
Bothriolepis maxima	236	34.4
Holoptychius cf. *nobilissimus*	173	25.2
Traquairosteus? *falcatus* and *Psammosteus* sp.	101	14.7
Antiarchi gen. et sp. indet.	45	6.6
Obruchevia heckeri	39	5.7
Devononchus laevis	36	5.2
Walterilepis speciosa	22	3.2
Platycephalichthys bischoffi	15	2.2
Bothriolepis evaldi	8	1.2
Sarcopterygii gen. et sp. indet.	6	0.9
Dipteriformes gen. et sp. indet.	5	0.7
Total	686	100.0

(Famennian) are interpreted as deltaic or estuarine, with tidal influence on sedimentation (Lukševičs & Zupiņš 2004; Lukševičs et al. 2011; Vasiļkova et al. 2012).

Previous studies have provided numerous data on current directions in different times and places for the Baltic palaeobasin in the Middle and Upper Devonian. The dominant direction for almost all stratigraphic units is to the south, also southeast and southwest, which coincides with the main clastic supply direction from northerly placed provenances (Kuršs 1975, 1992; Pontén & Plink-Björklund 2007; Tovmasjana 2013). During Pärnu time (early Eifelian) tidal processes caused frequent development of northerly oriented current systems (Tovmasjana 2013). During Amata time (earliest Frasnian) the current flow was directed to the north when estuarine tidal bars formed, alternating between the northern and southern directions in tidal channels, and to the east and southeast in fluvial channels and tide-influenced fluvial channels (Pontén & Plink-Björklund 2009). Current directions were to the south-southeast during Famennian Tērvete time in the Klūnas locality (Vasiļkova et al. 2012), but to the south-southwest during Ketleri time at the Pavāri site (Lukševičs & Zupiņš 2004).

The interpretation of sedimentary environments for the post-Amata Fm. Frasnian to Famennian siliciclastic deposits has remained, however, somewhat uncertain. The reason is poor exposure in rather small and isolated outcrops, as well as insufficient drillcore availability.

In previous descriptions (Sorokin 1978; Sorokins 1997), the sedimentary environment of deposits of the Ogre Fm. was interpreted as a shallow-water zone of subaqueous parts of deltas and lagoons with brackish water. More recently the sandy deposits of the Ogre Fm. in the Langsēde Cliffs, western Latvia, were interpreted as formed in flowing water, but the clayey and silty particles settled during slack-water episodes. The dominant current direction during Ogre time at the Langsēde site was to the south-southwest. Quite abundant structures indicating the influence of tidal processes were found in the deposits exposed in the Langsēde Cliffs (Lukševičs et al. 2011). The Gurova site studied here is situated 300 km to the east of the Langsēde Cliffs. At the Gurova site we recorded two main current directions, to the northeast and to the southeast, characteristic of Ogre time (Fig. 5). The first direction is almost opposite to that in the Langsēde Cliffs, but the second is close to perpendicular.

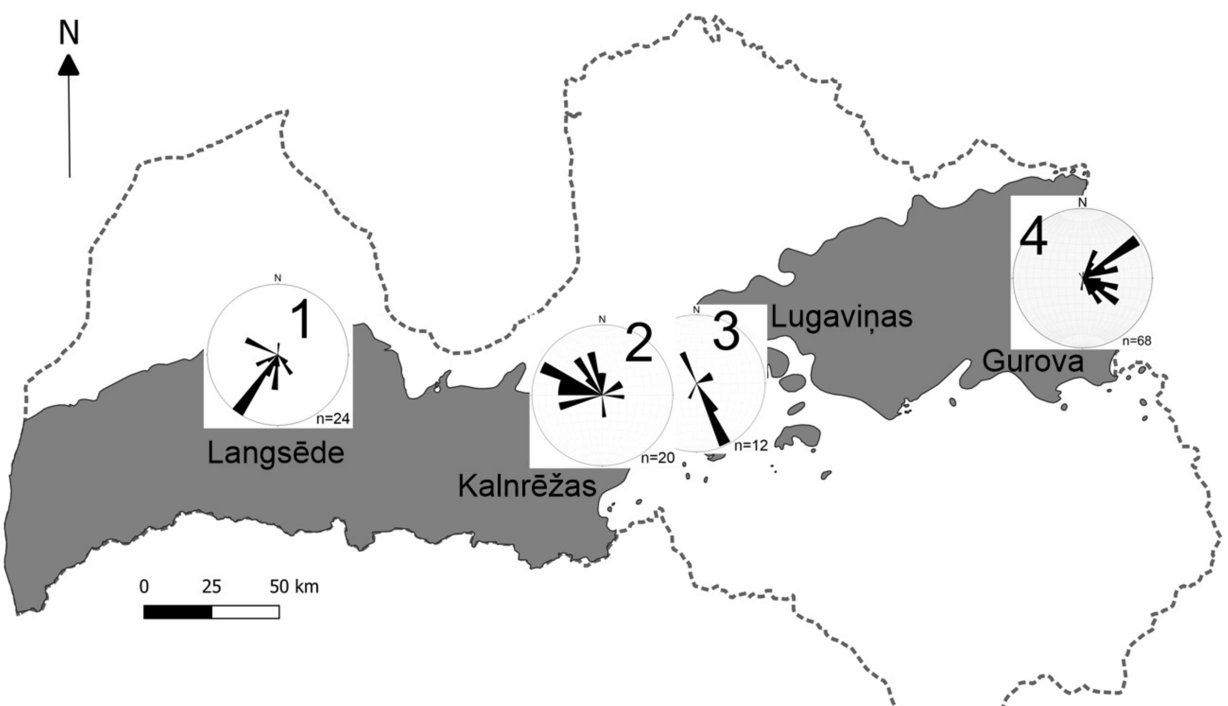

Fig. 5. Map of Latvia with the distribution area of the Ogre and Katleši formations (in grey colour; according to the bedrock mapping of Latvia at a scale of 1:200 000 (1998–2004); State Geological Survey of Latvia) and rose diagrams of current directions derived from measurements of cross-bedding and ripple-lamination: 1, data from the Langsēde site (Lukševičs et al. 2011); 2, data from the Kalnrēžas site (unpublished materials of A. Vasiļjevs); 3, data from the Lugaviņas site (unpublished materials of A. Vasiļjevs); 4, data from the Gurova Ravine (this study). Distribution areas of the Ogre and Katleši formations are not divided because these formations were mapped as unified in eastern Latvia.

Unpublished data of Artis Vasiļjevs suggest strong tidal influence, even opposite current directions, for the Kalnrēžas and Lugaviņas sites situated approximately in the middle between the above-mentioned sites. The measurements of the cross-bedding show that currents flowed in various directions in the locality of Kalnrēžas and Lugaviņas, mainly to the west-northwest, north-northeast and south-southeast (Fig. 5).

The large diversity of current directions at different sites likely shows a complex nature of the sedimentary system of Ogre time. According to Lukševičs et al. (2011) and results of this study, the sedimentation took place in channels and, as shown by the data obtained herein for section 1, in bars.

The current directions during Ogre time (Fig. 5) and abundant evidences of tidal processes found in this study and in the previous research of the Ogre Fm. (Lukševičs et al. 2011) are rather similar to the features described by Pontén & Plink-Björklund (2009) in the lowermost Frasnian Amata Fm. The latter formation is better exposed in a wider territory and has been interpreted as being formed in tide-dominated estuaries (Pontén & Plink-Björklund 2009).

Strong evidences of tidal processes in several exposures found in almost all over the elongated distribution area of the Ogre Fm. across the territory of Latvia demonstrates a considerable role of tides in the movement and accumulation of clastic sediments. However, the data obtained so far can only be related to isolated exposures that are difficult to attribute to the whole thickness of the Ogre Fm. The abundance of deposits with features indicating tidal dominance is not enough to conclude on the tidal dominance of a larger environment (Dalrymple & Choi 2007). Therefore, the question about tidally-influenced or tidally-dominated sedimentation during Ogre time in the territory of Latvia remains open. Overall trends of progradation, aggradation or retrogradation of the sedimentary system need to be evaluated in further studies.

The high sand proportion in the deposits of the Ogre Fm. most probably was caused by an increase in siliciclastic material supply from Fennoscandia. The direction of clastic supply is indicated mainly by the facies zonation of deposits (Sorokins 1997), but current directions in the case of the Ogre Fm. (Fig. 5) are too variable for such a conclusion. This study also shows that the main material transportation ways were to the northeast and southeast, and were related to the complexity of the sedimentary system and/or tidal dominance.

The climate gradually became warmer during the Frasnian. The tropical temperatures increased from 20–25 ^{o}C to 30–35 ^{o}C from the beginning to the end of the age (Joachimski et al. 2009; Brugger et al. 2019). Thus, the changes in the composition of deposits in the BDB are not related to general warming and cooling trends, but rather to variations in the humidity of climate, some local climate differences or tectonic processes in the provenances. The influence of changes in the humidity and aridity of climate is supported by the Late Devonian climate modelling, indicating a high variability of climate in the central to eastern part of Euramerica (De Vleeschouwer et al. 2014).

Abundant, but isolated and usually fragmentary remains of various vertebrates collected from outcrops Nos 1, 3, 6, 7 and 8, which are exposed in the Gurova Ravine, suggest that the oryctocoenosis is a sedimentary concentration and corresponds to an allochthonous assemblage. Vertebrate fossils are found in FA 1, both in the cross-bedded sandstones with tidal bundles (F 3) and similar sandstones without tidal evidences (F 2). They are present also in the most coarse-grained basal lag deposits (F 1). However, no vertebrate remains were found in deposits with ripple-lamination, and no fishes were found in the lateral bar deposits (FA 2). The abundance of fish remains seems not to be depth-dependent. Their fragmentation and relation to the lower parts of channel infills formed in the highest-energy environment suggests that the fossils are not located in their initial burial places but were transported and rede-posited by water currents.

The Ogre Fm. vertebrate assemblage corresponds to the *Psammosteus falcatus* (now the zonal taxon is known as *Traquairosteus*? *falcatus*; Glinskiy 2018) and *Bothriolepis maxima* biozones, which correlate with the Late *rhenana* Standard Conodont Biozone (Esin et al. 2000); conchostracans and lingulid brachiopods, although rarely, have also been found in this formation (Sorokin 1981). The vertebrate assemblages from the Gurova Ravine and from the Langsēde site are almost identical, except that *Obruchevia heckeri* has been found at the Gurova Ravine and the distribution of this species in the Ogre Fm. in Latvia has been confirmed. Almost all components of the vertebrate assemblage have been reported from various environments, from freshwater basins to the open marine environment, and thus cannot be used as indicators of the living environment. However, the antiarch *Walterilepis* may be an exception since it could possibly be treated as an indicator of marine influence. It is important to note that most of the Frasnian pterichthyodids closely related to *Walterilepis* have been found in typical marine facies (e.g., Denison 1978; Lukševičs in press).

During Ogre time vertebrates most probably lived in the same deltaic or estuarine environment. Still, post-mortem transportation of fish carcasses from the open sea by storm or tidal currents cannot be excluded either.

CONCLUSIONS

The Devonian siliciclastic deposits exposed in the Gurova Ravine correspond to the upper part of the Lielvārde Member or to the lower part of the Rembate Member.

These deposits formed in tidally-influenced fluvial channels and lateral tidal bars. The comparison of the results of this study with those of previous studies (Lukševičs et al. 2011) points to a strong role of tidal currents in the transportation and accumulation of siliciclastic material, as well as to a complex nature of the sedimentary system of Ogre time with highly variable directions of palaeocurrents.

The vertebrate assemblage of the Ogre Fm. from the Gurova Ravine is almost identical to the one from the Langsēde site. The results of this study confirm the distribution of *Obruchevia heckeri* in the Ogre Fm. in Latvia. The vertebrate oryctocoenosis of the Gurova site is a sedimentary concentration and corresponds to an allochthonous assemblage. The abundance of vertebrate remains in deposits seems not to depend on the influence of water depth and tide intensity. Fossils do not occur in places of their initial burial but were transported and redeposited by high-energy water currents. Vertebrates most probably lived in the same fluvial environment with strong tidal influence. Post-mortem transportation of vertebrate carcasses from the open sea by storm or tidal currents is not excluded.

Acknowledgements. The authors would like to thank the referees Leho Ainsaar and Oive Tinn for constructive reviews that improved the manuscript. Thanks are due to Kalle Kirsimäe for his helpful comments and improvements. Many thanks to all participants of the Summer school in the field palaeontology in 2017, students and graduates from the University of Latvia Valters Alksnītis, Dārta Ansaberga, Laura Bērtiņa, Mikus Daugavvanags, Sandra Dombrovska, Simona Mačute, Evita Maderniece, Līva Matisone, Jekaterina Matuko, Kristīne Molnare, Edgars Novickis, Līga Paparde, Amanda Stūrmane, as well as Dr. geol. Sandijs Mešķis. Jana Būdniece, S. Mačute, K. Molnare and S. Mešķis participated in the field work in April 2019. The study was partly supported by grant No. lzp-2018/2-0231 'Influence of tidal regime and climate on the Middle-Late Devonian biota in the epeiric Baltic palaeobasin' financed by the Latvian Council of Science. The publication costs of this article were covered by the Estonian Academy of Sciences and the Estonian Environmental Investment Centre (project KIK17233).

REFERENCES

Allen, J. R. L. 1968. The nature and origin of bed-form hierarchies. *Sedimentology*, **10**, 161–182.

Allen, J. R. L. 1983. Studies in fluviatile sedimentation: bars, bar complexes and sandstone sheets (low-sinuosity braided streams) in the Brownstones (L. Devonian), Welsh Borders. *Sedimentary Geology*, **33**, 237–293.

Brangulis, A. J., Kuršs, V., Misāns, J. & Stinkulis, Ģ. 1998. *Latvijas ģeoloģija* [*Geology of Latvia*] (Misāns, J., ed.). State Geological Survey, Riga, 70 pp. [in Latvian].

Brugger, J., Hofmann, M., Petri, S. & Feulner, G. 2019. On the sensitivity of the Devonian climate to continental configuration, vegetation cover, orbital configuration, CO_2 concentration, and insolation. *Paleoceanography and Paleoclimatology*, **34**, 1375–1398.

Dalrymple, R. W. & Choi, K. 2007. Morphologic and facies trends through the fluvial–marine transition in tide-dominated depositional systems: a schematic framework for environmental and sequence-stratigraphic interpretation. *Earth-Science Reviews*, **81**, 135–174.

Denison, R. H. 1978. Placodermi. In *Handbook of Paleoichthyology*, *Part 2* (Schultze, H.-P., ed.), pp. 1–128. Gustav Fischer Verlag, Stuttgart and New York.

De Vleeschouwer, D., Crucifix, M., Bounceur, N. & Claeys, P. 2014. The impact of astronomical forcing on the Late Devonian greenhouse climate. *Global Planet Change*, **120**, 65–80.

Elliott, D. K., Mark-Kurik, E. & Daeschler, E. 2004. A revision of *Obruchevia* (Psammosteida: Heterostraci) and a description of a new obrucheviid from the Late Devonian of the Canadian Arctic. *Acta Universitatis Latviensis*, **679**, 22–45.

Esin, D., Ginter, M., Ivanov, A., Lebedev, O., Luksevics, E., Avkhimovich, V., Golubtsov, V. & Petukhova, L. 2000. Vertebrate correlation of the Upper Devonian and Lower Carboniferous on the East European Platform. *Courier Forschungsinstitut Senckenberg*, **223**, 341–359.

Gibling, M. R. 2006. Width and thickness of fluvial channel bodies and valley fills in the geological record: a literature compilation and classification. *Journal of Sedimentary Research*, **76**, 731–770.

Glinskiy, V. 2018. Phylogenetic relationships of psammosteid heterostracans (Pteraspidiformes), Devonian jawless vertebrates. *Biological Communications*, **62**, 219–243.

Gross, W. 1933. Die Fisches des baltischen Devons. *Palaeontographica*, **A 79**, 1–74.

Gross, W. 1942. Die Fischfaunen des baltischen Devons. *Korrespondenzblatt des Naturforscher Vereins zu Riga*, **64**, 373–436.

Joachimski, M., Breisig, S., Buggisch, W., Talent, J., Mawson, R., Gereke, M., Morrow, J., Day, J. & Weddige, K. 2009. Devonian climate and reef evolution: Insights from oxygen isotopes in apatite. *Earth and Planetary Science Letters*, **284**, 599–609.

Kuršs, V. 1975. *Litologiya i poleznye iskopaemye terrigennogo devona Glavnogo polya* [*Lithology and Mineral Resources of the Terrigenous Devonian of the Main Field*]. Zinātne, Rīga, 216 pp. [in Russian].

Kuršs, V. 1992. *Devonskoe terrigennoe osadkonakoplenie na Glavnom devonskom pole* [*Devonian Terrigenous Deposition on the Main Devonian Field*]. Zinātne, Rīga, 208 pp. [in Russian].

Lanier, W. P. & Tessier, B. 1998. Climbing-ripple bedding in the fluvio-estuarine transition: a common feature associated with tidal dynamics (modern and ancient analogues). In *Tidalites: Processes and Products* (Alexander, C. R., Davies, R. A. & Henry, V. J., eds), *SEPM Special Publication*, **61**, 109–118.

Leclair, S. F. & Bridge, J. S. 2001. Quantitative interpretation of sedimentary structures formed by river dunes. *Journal of Sedimentary Research*, **71**, 713–716.

Longhitano, S. G., Mellere, D., Steel, R. J. & Ainsworth, R. B. 2012. Tidal depositional systems in the rock record: A review and new insights. *Sedimentary Geology*, **279**, 2–22.

Lukševičs, E. 2001. Bothriolepid antiarchs (Vertebrata, Placodermi) from the Devonian of the north-western part of the East European Platform. *Geodiversitas*, **23**, 489–609.

Lukševičs, E. (in press). Revision of asterolepidoid antiarch remains from the Ogre Formation (Upper Devonian) of Latvia. *Estonian Journal of Earth Sciences* [accepted].

Lukševičs, E. & Zupiņš, I. 2004. Sedimentology, fauna, and taphonomy of the Pavāri site, Late Devonian of Latvia. *Acta Universitatis Latviensis*, **679**, 99–119.

Lukševičs, E., Ahlberg, P. E., Stinkulis, Ģ., Vasiļkova, J. & Zupiņš, I. 2011. Frasnian vertebrate taphonomy and sedimentology of macrofossil concentrations from the Langsēde Cliff, Latvia. *Lethaia*, **45**, 356–370.

Lyarskaya, L. 1981. *Baltic Devonian Placodermi. Asterolepididae.* Zinatne, Riga, 152 pp. [in Russian, with English summary].

Lyarskaya, L. & Lukševičs, E. 1992. Sostav i rasprostranenie beschelyustnykh i ryb v silurijskikh i devonskikh otlozheniyakh Latvii [Composition and distribution of agnathan and vertebrate assemblages in the Silurian and Devonian deposits of Latvia]. In *Paleontologiya i stratigrafiya fanerozoya Latvii i Baltijskogo morya* [*Palaeontology and Stratigraphy of the Phanerozoic of Latvia and the Baltic Sea*] (Sorokin, V. S., ed.), pp. 46–62. Zinātne, Riga [in Russian].

Miall, A. D. 2014. *Fluvial Depositional Systems*. Springer, 316 pp.

Nichols, G. 2009. *Sedimentology and Stratigraphy*. Wiley-Blackwell, 419 pp.

Pontén, A. & Plink-Björklund, P. 2007. Depositional environments in an extensive tide-influenced delta plain, Middle Devonian Gauja Formation, Devonian Baltic Basin. *Sedimentology*, **54**, 969–1006.

Pontén, A. & Plink-Björklund, P. 2009. Regressive to transgressive transits reflected in tidal bars, Middle Devonian Baltic Basin. *Sedimentary Geology*, **218**, 48–60.

Reineck, H. E. & Singh, I. B. 1980. *Depositional Sedimentary Environments.* Springer-Verlag, New York, 549 pp.

Scotese, C. R. 2014. Atlas of Devonian Paleogeographic Maps, PALEOMAP Atlas for ArcGIS, Volume 4, The Late Paleozoic, Maps 65–72 (Mollweide Projection). Evanston, IL: PALEOMAP Project.

Sorokin, V. S. 1978. Verkhnefranskij pod´yarus Glavnogo devonskogo pol´ya [Upper Frasnian Substage of the Main Devonian Field]. In *Stratigrafiya fanerozoya Pribaltiki* [*Stratigraphy of the Phanerozoic of the Peribaltics*] (Sorokin, V. S., ed.), pp. 44–111. Zinatne, Riga [in Russian].

Sorokin, V. S. 1981. Ogrskaya svita [Ogre Formation]. In *Devon i karbon Pribaltiki* [*Devonian and Carboniferous of the Peribaltics*] (Sorokin, V. S., ed.), pp. 275–281. Zinatne, Riga [in Russian].

Sorokins, V. 1997. Ogres svīta [Ogre Formation]. In *Latvijas Daba*, IV (Kavacs, G., ed.), pp. 52–53. Preses Nams, Rīga [in Latvian].

Takcidi, E. 1999. Data base: “Drillings”. State Geological Survey of Latvia, Riga. Data summarised within the ESF project “Establishment of interdisciplinary scientist group and modelling system for groundwater research”, contract No. 2009/0212/1DP/1.1.1.2.0/09/APIA/VIAA/060.

Tänavsuu-Milkeviciene, K. & Plink-Björklund, P. 2009. Recognizing tide-dominated versus tide-influenced deltas: Middle Devonian strata of the Baltic Basin. *Journal of Sedimentary Research*, **79**, 887–905.

Tänavsuu-Milkeviciene, K., Plink-Björklund, P., Kirsimäe, K. & Ainsaar, L. 2009. Coeval versus reciprocal mixed carbonate–siliciclastic deposition, Middle Devonian Baltic Basin, Eastern Europe: implications from the regional tectonic development. *Sedimentology*, **56**, 1250–1274.

Tovmasjana, K. 2013. *Depositional Environment of the Tidally-Dominated Transgressive Succession: Rēzekne and Pärnu Regional Stages, Baltic Devonian Basin.* Summary of doctoral thesis. University of Latvia, Riga, 88 pp.

Van den Berg, J. H., Boersma, J. R. & Van Gelder, A. 2007. Diagnostic sedimentary structures of the fluvial-tidal transition zone – evidence from deposits of the Rhine and Meuse. *Netherlands Journal of Geosciences – Geologie en Mijnbouw*, **86**, 287–306.

Vasiļkova, J., Lukševičs, E., Stinkulis, Ģ. & Zupiņš, I. 2012. Taphonomy of the vertebrate bone beds from the Klūnas fossil site, Upper Devonian Tērvete Formation of Latvia. *Estonian Journal of Earth Sciences*, **61**, 105–119.

Ülem-Devoni Ogre kihistu sedimentoloogia ja selgroogsete kivistised Ida-Läti Gurova paljandites

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Ogre kihistu purdkivimite sedimentoloogilise ja paleontoloogilise uuringu eesmärgiks oli fatsiaalne analüüs ning fossiilikoosluste taksonoomiliste ja tafonoomiliste eripärade selgitamine kihistu leviku idapiiril. Gurova jõe paljandites tuvastati sedimentoloogiliste tunnuste põhjal kaks settefaatsiest: tõusu-mõõna mõjutustega fluviaalsed kanalid ja loodetega seotud barrid. Selgroogsete kivististe kuhjetes domineerisid rüükala *Bothriolepis maxima*, lihasuimne *Holoptychius* cf. *nobilissimus* ja lõuatud psammosteiidid. Kuhjed moodustusid madalveelises deltas või estuaaris fluviaalsete ja tõusu-mõõna protsesside tulemusena. Psammosteiidi *Obruchevia heckeri* leid Gurova paljanditest kinnitas selle liigi levikut väljaspool tüüpala.