Proc. Estonian Acad. Sci. Geol., 2006, **55**, 2, 175–184

Siliciclastic grain size composition of the Upper Ordovician rocks of the Blidene Formation in western Latvia

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Received 15 February 2006, in revised form 17 April 2006

IUGS UNESCO IGCP Project 503
ORDOVICIAN PALAEOGEOGRAPHY AND PALAEOCLIMATE

Abstract. New data on the siliciclastic grain size composition of the Upper Ordovician Blidene Formation in its stratotype region in western Latvia are presented. The formation represents a marly interval at the transition from Keila to Oandu stages, where the succession of deposits has been influenced by essential changes in the depositional regime in the Baltic palaeobasin. The Blidene Formation overlies the organodetrital limestones of the Adze Formation and is succeeded by the organic-rich black shales of the Mossen Formation. It is characterized by a high content (50–85%) of siliciclastic material, increasing upwards. The siliciclastic material consists mainly of clay fraction (<2 μm), decreasing amounts of fine, medium, and coarse silt, and sporadic sand grains (>63 μm), forming less than 5%. The data obtained on the Blidene Formation in western Latvia are compared with earlier data from southern Estonia. The increase in the siliciclastic component of the Ordovician carbonate sequence in Keila time is considered to be related with climatic and sea level changes, and with the changes in the sea bottom topography due to tectonic movements.

Key words: Blidene Formation, Keila Stage, Upper Ordovician, grain size composition, western Latvia.

INTRODUCTION

The Upper Ordovician Blidene Formation of the upper half of the Keila Stage is distributed in western Latvia, northern Lithuania, and southern Estonia (Männil 1963; Ulst et al. 1982; Paškevičius 1994; Ainsaar & Meidla 2001). It overlies the organodetrital limestones of the Adze Formation and underlies the black shales (Plunge Member) of the lower part of the Mossen Formation (Ulst et al. 1982).

The formation is characterized by a high content of siliciclastic material (insoluble residue) and a specific association of fossils (Männil et al. 1968).

The Blidene Formation was established by Männil (1963) in the Blidene-5, Sturi-8, Piltene-1, and Remte-3 drill cores in western Latvia, where it lies at a depth of about 1000 m (Fig. 1). The stratotype of the formation (beds by Männil 1963) was identified in the Blidene-5 core in the interval of 892.0–895.5 m (Birkis et al. 1976). However, this core was destroyed and the interval of 1061.0–1063.0 m in the Saldus-5RM drill core was proposed as the neostratotype (Brangulis et al. 1989). Initially (Männil 1966; Männil et al. 1968) the Blidene Formation was correlated with the Oandu Stage, but was later attributed to the Keila Stage (Ulst et al. 1982; Männil 1990; Nõlvak 1997; Ainsaar et al. 1999, 2004; Fig. 2). Männil et al. (1968) included in some sections (Priekule, Blidene-5) the uppermost part of grey-coloured marls, sometimes with thin dark-grey shaly interlayers, into a separate unit together with the overlying black shales. This subdivision was supported by some biostratigraphical data, mainly the first appearance of the trilobite genus *Flexicalymene*.

In southern Estonia, like in western Latvia, the Blidene Formation comprises a complex of marls overlain by the dark blackish shale-like marls of the Plunge Member of the Mossen Formation. In the Valga-10 core (Põldvere 2001), the Blidene Formation is up to 3.8 m thick, thinning in onshore direction (1.4 m in the Ruhnu-500 core; Põldvere 2003). The unit is presumably present also in the Karula core, where black shales overlie marls in a thickness of 3.7 m (Männil 1966, fig. 12).

In northern Lithuania the Blidene Formation is poorly known. It has been identified together with the underlying Adze Formation in some sections (Kriukai-146 and Stačiunai-8; Paškevičius 1994), but the boundary between them has not been determined.

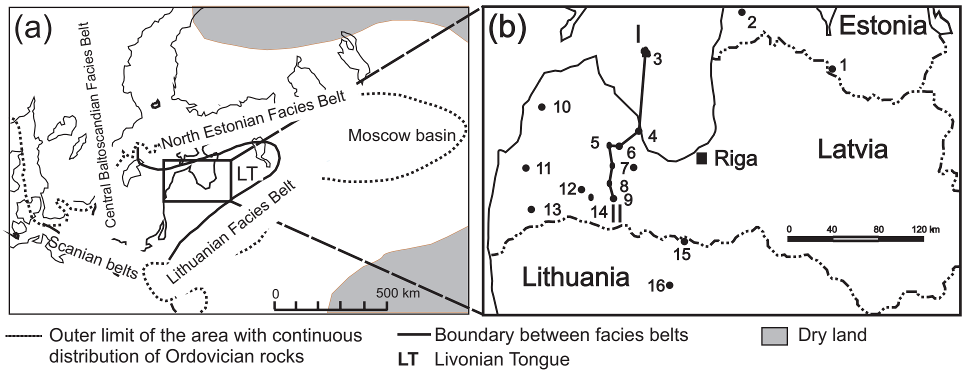

Fig. 1. (a) Baltic Ordovician confacies belts (after Jaanusson 1995, modified from Nõlvak 1997); (b) Location of the core sections mentioned in the text: 1, Valga-10; 2, Ristiküla-174; 3, Ruhnu-500; 4, Engure; 5, Kandava-26; 6, Kandava-25; 7, Remte-3; 8, Blidene-5; 9, Sturi-8; 10, Piltene-1; 11, Aizpute-41; 12, Saldus-5RM; 13, Priekule; 14, Skrunda-25; 15, Kriukai-146; 16, Stačiunai-8.

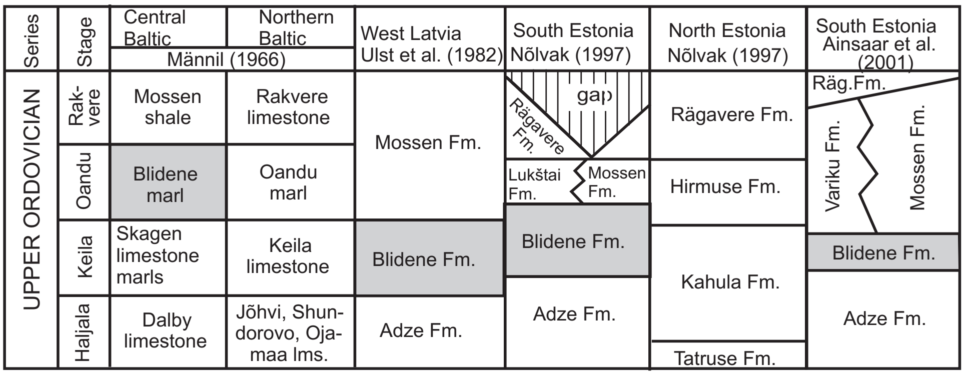

Fig. 2. Stratigraphical position of the Blidene Formation (shadowed area) described by different authors.

Up to now very little information has been published on the lithology and rock composition of the Blidene Formation. The only data are available from the Ruhnu-500 and Valga-10 cores in southern Estonia (Põldvere 2001, 2003; Ainsaar et al. 2004) and the Engure core in Latvia (Põlma 1972). In the last section the general chemical composition of the rocks and composition of the organodetrital material in the Blidene Formation were studied in three samples.

The present study provides new data on the lithological composition of the Blidene Formation obtained from the drill cores of the stratotype region. The Blidene Formation is treated here as an argillaceous unit between the variably argillaceous biodetrital limestones of the Adze Formation below and the black shales of the Plunge Member of the Mossen Formation above. The data from westernmost Latvia, representing the deeper part of the Baltic palaeobasin, contribute essentially to the characterization of the Blidene Formation in the East Baltic. Comparison of Latvian data with those from other parts of the Livonian Tongue (southern Estonia) enable us to understand the trends of changes in the siliciclastic grain size and the formation of siliciclastic-rich deposits in the basin and can be used as additional criteria in correlation of sections.

GEOLOGICAL SETTING

In the East Baltic part of the Baltic palaeobasin the deposition of the Ordovician carbonate sediments and distribution of biofacies was divided between different facies belts (Männil 1966; Jaanusson 1995). The deposits of shallower environments (upper ramp; Nestor & Einasto 1997) belong to the North Estonian and Lithuanian facies belts and those of the deeper environments (lower ramp) to the Livonian Tongue of the Baltoscandian Facies Belt (Fig. 1). Essential changes in the evolution of the Baltic palaeobasin took place in the early Late Ordovician, in the transition between Keila and Oandu times (Põlma 1982; Nestor & Einasto 1997; Ainsaar et al. 2004). This stratigraphical interval can be roughly correlated with the boundary interval of the fifth and sixth global stages (Webby et al. 2004). At that time the main Ordovician transgression reached a stabilization stage in the Baltic palaeobasin, followed by predominantly regressive nature of sedimentation with transgressive phases (unification and differentiation stages by Nestor & Einasto 1997). The latter phases are characterized by increased accumulation of siliciclastic deposits at different stratigraphical levels (Hints et al. 1989). The facies and faunal changes at the Keila–Oandu transition showed the rearrangement of the whole ecosystem of the Baltic palaeobasin. The corresponding event is known as the Middle Caradocian Facies and Faunal Turnover (Ainsaar et al. 2004).

The accumulation of the Blidene Formation took place during the above-mentioned transitional period between two different sedimentation regimes (stages) in the Baltic basin, which by Põlma (1982) falls into late Keila time. This formation is the oldest unit in the Keila–Oandu transition, dominated by siliciclastic clay and silt (Fig. 2). According to Ainsaar et al. (2004), the Blidene Formation terminated the Haljala–Keila sedimentary sequence in the Livonian Tongue. Thus, the sedimentation of siliciclastic material dominated during the latest highstand (Blidene Formation) and following rapid sea level rise (Mossen Formation; Ainsaar et al. 2004).

MATERIAL AND METHODS

A total of 42 samples from four core sections of western Latvia were analysed: 5 from the Blidene-5 section, 14 from the Kandava-25 section, 12 from the Priekule section, and 11 from the Aizpute-41 section (Figs 1, 3, 4). The samples were collected in the 1960s–1970s, from the Blidene-5 drill core by V. Karpitski (Geological Survey of Latvia), from the other cores, excluding Aizpute-41, by researchers of the Institute of Geology at Tallinn University of Technology (IG TUT). The Aizpute-41 core, housed at the field station of the IG TUT, was sampled and described by the author of this paper. Twenty-seven samples represent the Blidene Formation, 14 the Adze Formation, and 1 sample comes from the Mossen Formation. The sample depths were calculated by the initial drilling intervals without later corrections by geophysical data. In addition, published (Männil 1963; Männil et al. 1968; Põlma 1972) and unpublished lithological data (core descriptions by L. Põlma) were used.

Grain size analysis was performed on 20–90 g rock samples. The carbonate component of the rock was dissolved in diluted hydrochloric acid. The insoluble

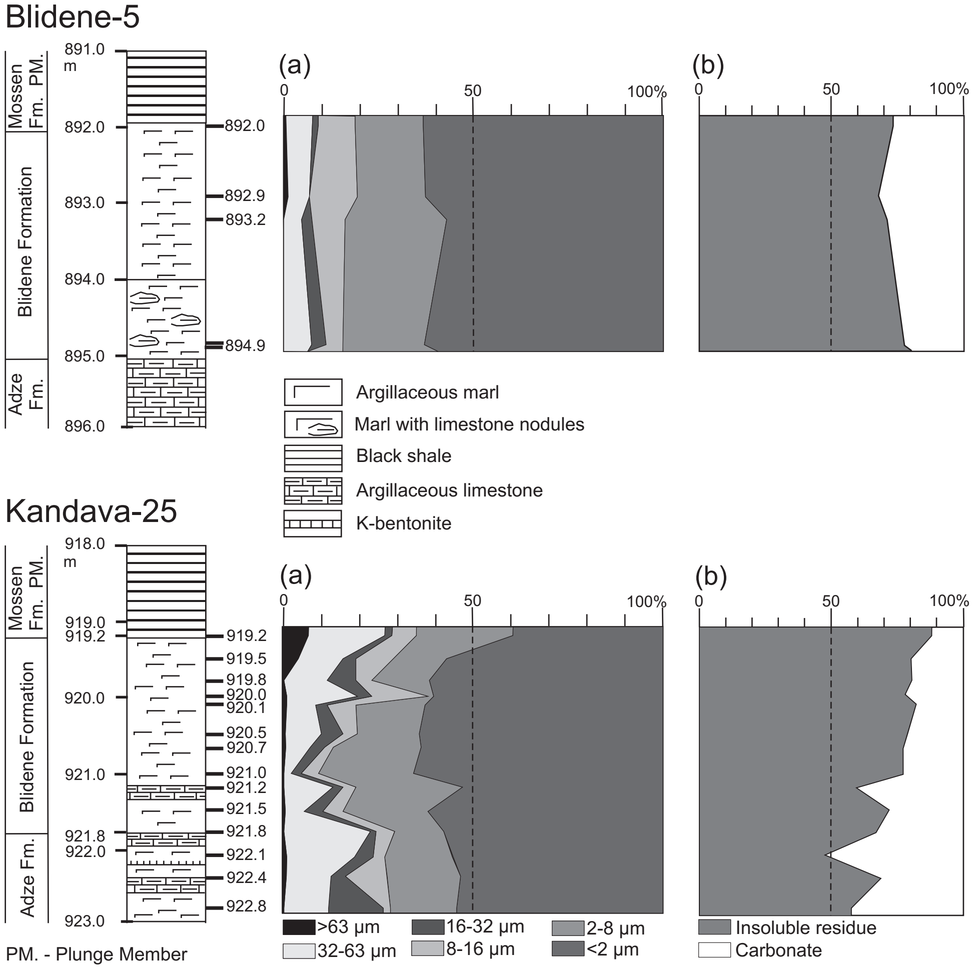

Fig. 3. Grain size composition of the insoluble residue (a) and content of the carbonate and siliciclastic component in the rock (b) of the Blidene-5 and Kandava-25 cores.

residue was fractionated by gravity sedimentation and sieving into the fractions of <2 μm (clay), 2–8 and 8–16 μm (both fine silt), 16–32 and 32–63 μm (medium and coarse silt), and >63 μm (sand) (Ainsaar & Meidla 2001).

Some samples of organic-rich shaly marls and black shales (Aizpute-41 core, depths 1045.95 and 1046.10 m; Priekule core, depth 1419.7 m) showed a high content (over 50%) of sand fraction (>63 μm). This value is presumably incorrect due to the occurrence of clay aggregates, which cannot be disintegrated by the method used in this study (Fig. 4).

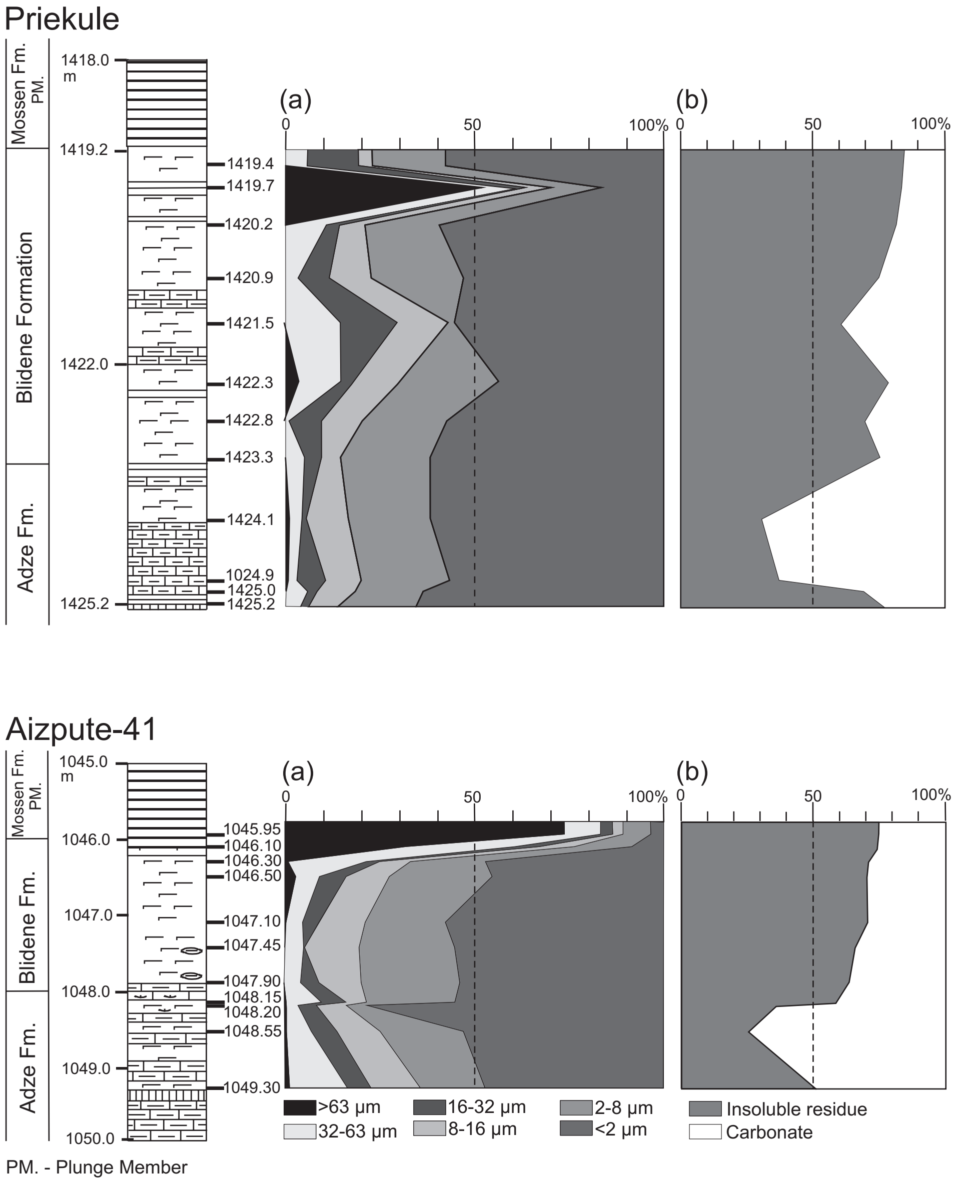

Fig. 4. Grain size composition of the insoluble residue (a) and content of the carbonate and siliciclastic component in the rock (b) of the Priekule and Aizpute-41 cores.

RESULTS AND DISCUSSION

In the stratotype area in western Latvia, the Blidene Formation comprises greenish-grey argillaceous marls with thin interlayers or nodules of organodetrital limestone in the lower part (Ulst et al. 1982). The measured thickness of the Blidene Formation varies from 0.5 m in the Engure-4 to 3.5 m in the Skrunda-25 cores (Ulst et al. 1982), reaching about 4 m in the Sturi-8 core (Fig. 5). The boundaries of the formation may be distinct or transitional. The organodetrital limestones in the lowermost part of the Blidene Formation are replaced upwards by argillaceous marlstone or by marlstone with thin interbeds or nodules of limestone. In the Priekule, Aizpute-41, and Kandava-25 cores the underlying Adze Formation contains 30–60% or more insoluble material (Figs 3, 4), which is similar to the content of siliciclastic material in the upper part of the Adze Formation in the Valga-10 core in southern Estonia (Ainsaar & Meidla 2001; Põldvere 2001). Considering the trends of changes in the siliciclastic component in the three cores mentioned above, the depth 1423.3 m in the Priekule core is proposed here as the lower boundary of the Blidene Formation. In Männil et al. (1968) this boundary was drawn on the level of a thin K-bentonite at a depth of 1425.2 m. However, rocks with a relatively high content of carbonates (above 50%) are present above that level, similar to the uppermost Adze Formation in other sections. Besides, the lower boundary of the Blidene Formation lies commonly somewhat higher than the uppermost K-bentonite bed occurring in the Adze Formation (Männil 1966, 1976). In the Engure (Põlma 1972), Kandava-25, and Aizpute-41 cores the uppermost bentonite lies respectively 0.4, 1.4, and 0.75 m below the boundary between the Adze and Blidene formations (Fig. 4).

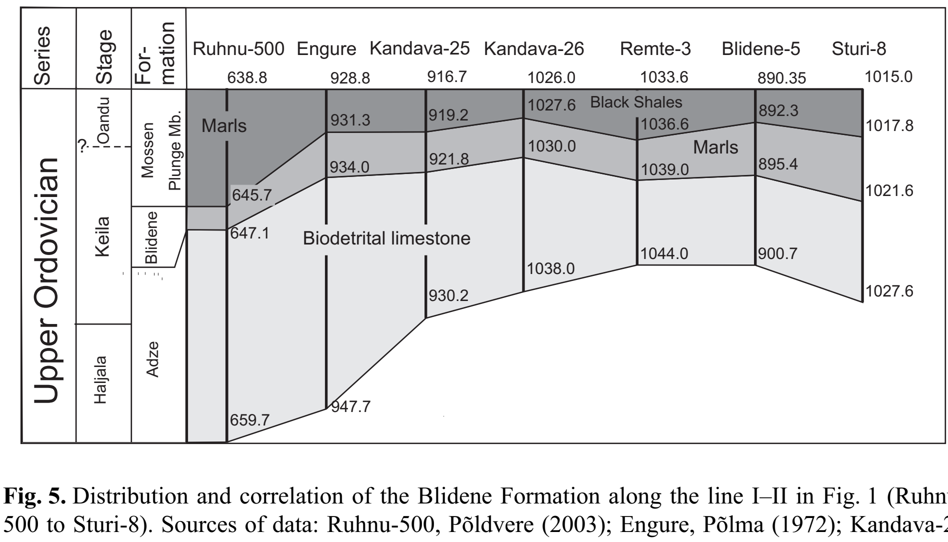

Fig. 5. Distribution and correlation of the Blidene Formation along the line I–II in Fig. 1 (Ruhnu-500 to Sturi-8). Sources of data: Ruhnu-500, Põldvere (2003); Engure, Põlma (1972); Kandava-25 and Kandava-26, unpublished data by L. Põlma and R. Männil; Remte-3, Blidene-5, and Sturi-8, Männil (1963). Depths are in metres.

The rocks of the Blidene Formation of the stratotype Blidene-5 core contain 70–80% siliciclastic material (Fig. 3), similar to those of the neostratotype Saldus-5RM section (Brangulis et al. 1989). The proportion of the siliciclastic component in other studied sections increases upwards from 70% in the lower part of the formation up to 85% just below the overlying black shales of the Mossen Formation (Figs 3, 4). It consists mainly (50–60%) of clay fraction (<2 μm). The fine silt fraction (2–16 μm) accounts for 15–20% of the insoluble residue, whereas the 2–8 μm fraction forms the main part of it (5–15%). The medium (16–32 μm) and coarse silt (32–63 μm) fractions, which together make up 5–15% of the insoluble residue, account for 1–7% and 2–9%, respectively. Some increase in coarse fractions is observed upwards in the Kandava-25 and Aizpute-41 cores and in the middle part of the Blidene Formation in the Priekule core (Figs 3, 4). The content of sand grains (>63 μm) is sporadically less than 5% (Figs 3, 4). The increase in the grain size upsection indicates a possible sea level lowering and/or increased input of siliciclastic material or changes in other environmental conditions affecting the distribution of deposits. The grain size increase is more distinct in southern Estonia, where the marls of the Kahula Formation contemporaneous with the Blidene Formation are overlain by the siltstones of the Variku Formation (Ainsaar & Meidla 2001).

The siliciclastic grain size composition of the rocks of the Blidene Formation in western Latvian sections is rather similar to that in the Valga-10 and Ruhnu-500 cores of southern Estonia. In both areas, representing the westernmost and easternmost parts of the Livonian Tongue, the content of carbonates in the rocks of the Blidene Formation decreases from about 40% to less than 10% upwards in the section. The Blidene Formation in the Valga-10 core (Ainsaar et al. 2004) shows a higher content of medium and coarse silt than in western Latvia, which can be due to its closer location to the input areas. The exceptional increase in fine and medium silt established in the middle of the Blidene Formation in the Priekule core is close to the interval where new trilobites appear by Männil et al. (1968). The positive carbon isotope excursion reported in the Blidene Formation in two sections, Jurmala-R1 in Latvia and Valga-10 in Estonia, has been used for the correlation of sections of different facies zones (Ainsaar & Meidla 2001; Ainsaar et al. 2004). Future lithological, biostratigraphical, and isotopic studies should supposedly clear up the details of sedimentation and enable more exact correlation of the Blidene Formation.

The grain size composition of rocks of the Blidene Formation differs essentially from that of the Variku Formation by a low (up to 25%) content of medium and coarse silt (16–63 μm). The content and distribution of different grain size fractions in the Blidene Formation are similar to those of the marls in the uppermost part of the Kahula Formation (Ristiküla-174 section; Ainsaar & Meidla 2001; Fig. 2) in southernmost Estonia. The Blidene Formation, which has been deposited in the deeper part of the basin, is characterized by a lower content of silt fractions.

CONCLUSIONS

The Blidene Formation in its stratotype region in westernmost Latvia is represented by siliclastic-rich marls. The content of siliciclastic material increases upwards and shows a persistently high proportion (50–60%) of clay fraction similar to that in southern Estonia. The short-term increase in coarse fractions established in the middle of the Blidene Formation deserves attention in future studies of that formation.

The Blidene Formation differs essentially from the Variku Formation by the finer grain size composition and is similar to the uppermost argillaceous part of the Kahula Formation. The differences in the siliciclastic grain size composition of the Blidene Formation in the Latvian and Estonian sections can be explained by different location of sections in relation to the facies belts of the palaeobasin. New data on the Blidene Formation contribute to the understanding of the changes in sedimentation in the Baltic palaeobasin in the transition between the Keila and Oandu stages, which is characterized by the Mid-Caradoc Facies and Faunal Turnover.

ACKNOWLEDGEMENTS

I would like to thank L. Hints and A. Kleesment for their support and help in the study and preparation of the manuscript and the reviewers L. Ainsaar and P. Männik. The paper is a contribution to IGCP Project 503. This research was supported by the Estonian Science Foundation (grants Nos 5922 and 6127).

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Ülem-Ordoviitsiumi Blidene kihistu kivimite silikaat-purdkomponendi lõimisest Lääne-Lätis

Jaanika Lääts

Neljast Lääne-Läti puursüdamikust (Blidene-5, Kandava-25, Priekule ja Aizpute-41) pärit 42 Ülem-Ordoviitsiumi kivimiproovi analüüside põhjal on iseloomustatud Baltoskandia fatsiaalse vööndi Liivi Keele piires leviva Keila lademe Blidene kihistu ja tema lamamiks oleva Adze kihistu lõimist. Blidene kihistu 27 proovis on valdavaks (50–60%) savi fraktsioon (<2 μm), seejuures moodustab karbonaatne komponent 15–35%, suurenedes Adze kihistu suunas. Kõrge savikomponendi sisalduse poolest on Blidene kihistu lõimis sarnane Valga-10 puuraugus esineva Blidene kihistuga, mis kuulub Keila lademe ülemisse ossa. Kõrge savisisalduse poolest sarnaneb Blidene kihistu veel Lõuna-Eestis paikneva Kahula kihistuga (Ristiküla-174). Lõuna-Eestis paiknev Variku kihistu (Ristiküla-174) erineb uuritud kihistust aga kõrge kesk- ja jämedateralise aleuriidi (16–63 μm) sisalduse (35–75%) poolest. Priekule puursüdamikus varem täheldatud fauna koosseisu muutus Blidene kihistus ja selle jagunemine kahe stratigraafilise üksuse vahel ei kajastu lõimise koosseisus, mis on suhteliselt püsiv kogu kihistu piires.