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LATE PLEISTOCENE EVOLUTION OF HYDROGRAPHICAL NETWORK RECORDED AT GEOSITES IN THE MIDDLE NEMAN AREA (WESTERN BELARUS)

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Abstract. Geosites in the Belarussian part of the Middle Neman area contain a rich information on sedimentary environments and development of hydrographical network within the drainage basin of Neman – one of the largest rivers of central Europe. A study of sediment successions of the best stratigraphically defined sites has revealed the general features of prevailing sedimentary environments existed in the Late Pleistocene. An occurrence of interglacial sediments of lake origin of the Muravian (Eemian) Interglacial together with the absence of synchronous fluvial records has led to the conclusion that no large water stream was developed within the present Neman valley in the Late Pleistocene Interglacial. A basin sedimentation prevailed there since the Muravian Interglacial (lake sedimentation) including the Poozerie (Weichselian) Glaciation (ice-dammed lake sedimentation) till the Late Glacial. The actual Neman watercourse was formed during the final phases of the last glaciation and the Late Glacial.

Key words: geosites, Middle Neman area, fluvial sediments, lake deposits, Late Pleistocene.

Abstrakt. Geostanowiska położone w białoruskiej części środkowego Niemna zawierają obszerną informację o środowiskach sedymentacyjnych oraz rozwoju sieci hydrograficznej w obrębie zlewni Niemna — jednej z wielkich rzek Europy centralnej. Badania sukcesji sedymentacyjnych w stanowiskach z jednoznaczną pozycją stratygraficzną ujawniły główne cechy środowisk sedymentacyjnych późnego plejstocenu. Rozprzestrzenienie osadów pochodzenia jeziornego z okresu interglacjału murawińskiego (emskiego) oraz brak równowiekowych osadów rzecznych dowodzi, że na miejscu współczesnej doliny Niemna w okresie ostatniego interglacjału plejstocenu nie istniała żadna duża arteria wodna. Sedymentacja zbiornikowa przeważała w rejonie środkowego Niemna od początku interglacjału murawińskiego (sedymentacja jeziorna), w okresie zlodowacenia pojezierskiego (sedymentacja zastoiskowa) do okresu późnego glacjału. Współczesny kierunek przepływu Niemna został ukształtowany w czasie końcowych faz ostatniego zlodowacenia i w późnym glacjale.

Słowa kluczowe: geostanowiska, obszar środkowego Niemna, osady rzeczne, osady jeziorne, późny plejstocen.

INTRODUCTION

The Middle Neman region appears to be the unique area as regards important geological sections of the Quaternary. Many profiles with Pleistocene interglacial sediments, as well as the most expressive glaciotectonical structures, had been located in this very area. An abundance of interglacial sections and their clear geological position makes the area very important for stratigraphical subdivision of Pleistocene not only for Belarus but also for neighbouring countries. A geological significance of the area is redoubled by the fact that besides buried interglacial profiles, there are many key sections of Middle and Upper Pleistocene interglacial sediments cropped out along the Neman river valley: Kolodezhny Rov (sediments of the Alexandrian/Holsteinian Interglacial), Bogatyrevichi, Poniemun, Rumlovka, Zhukevichi, Pyshki (Muravian/Eemian and Early Poozerian/Weichselian sediments) and others. These sites represent not only a geological significance but also a historical one as they were studied since the end of 19th century by such famous Polish, Russian and Belarusian scientists as Gedroits

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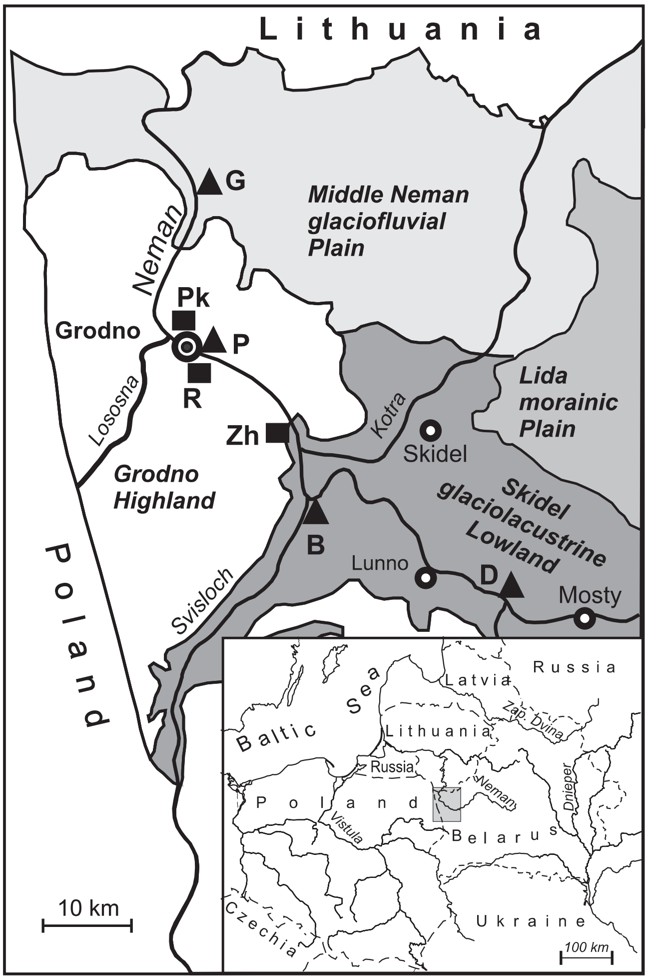

Fig. 1. Location map with sites discussed (triangles) and mentioned (squares)

D — Dubna, B — Bogatyrevichi, Zh — Zhukevichi, P — Poniemun, R — Rumlovka, Pk — Pyshki, G — Gozha

(1895), Missuna (1909), Sobolev (1910), Szafer (1925), Jaroń (1933), Środoń (1950), Halicki (1951), Vozniachuk (1971; Vozniachuk *et al.*, 1975; Vozniachuk, Valchik, 1978)), 1975, 1978), Goretsky (1980) and others.

The Middle Neman region includes several geomorphological units: Grodno glacial Highland, Lida morainic Plain, Middle Neman glaciofluvial Plain and Skidel glaciolacustrine Lowland (Fig. 1). Stratigraphical sequence, glaciotectonical features and glaciation history of the Middle Neman area are well studied due to investigations of Goretsky (1980), Karabanov (1987), Matveyev (1990), Yakubovskaya (1976) and others. Despite these detailed studies, many important questions remain unanswered as regards an evolution of the Neman River during the Pleistocene, especially concerning its Late Pleistocene history. Prevailing opinions on the Neman evolution within the Belarussian part of the Neman drainage basin in the Late Pleistocene have been summarised in books of Goretsky (1980) and Vozniachuk, Valchik (1978), who assumed an inherited development of the Neman valley. These authors believed the Neman watercourse to be almost invariable during the whole Quaternary period.

However, borehole records obtained in the last decade have brought new materials which have engendered other views on the Middle Pleistocene evolution of the Neman River. According to these data, the Neman valley during the Alexandrian Interglacial was located quite far to the south in comparison with its present position (Pavlovskaya, 1998) and the main watercourse in the Middle Neman area was directed to the south-west (Marks, Pavlovskaya, 2003). Such a conclusion born a necessity to re-examine existing records of the Late Pleistocene development of hydrographical network in the area. Fortunately, there are numerous sites with synchronous deposits which are exposed within the Neman valley and available for study at present.

GEOSITES AS SEDIMENTARY ARCHIVES

Geosites in the Middle Neman area, informative for reconstruction of the Late Pleistocene environment and history of hydrographical network, are known for more than a hundred years mainly due to palaeobotanic researches who definitely determined stratigraphical position of organogenic sediments exposed in sections. However, a study of sediment succession as a whole, as well as facies characteristics have been less developed. In the last years such a study was done for some sites in order to reveal a sedimentological evidence for the hydrographical reconstruction of the area. These sites cropped out along the Neman valley at a distance of about 90 km from the mouth of the Ross River, Neman right tributary, and exposed downstream to the Belarussian–Lithuanian boundary (Fig. 1). An attempt to explain the sedimentary environment in this paper has been made on examples of the best stratigraphically recognised sections.

Poniemun site. The site represents lake interglacial deposits exposed in the Poniemun gully on the right bank of the Neman River. Several outcrops in the Poniemun gully have been studied since 1925 by Polish and Belarussian geologists and stratigraphers (Szafer, 1925; Środoń, 1950 — section *Poniemun-1*; Kryger *et al.*, 1971 — section *Poniemun-2*; Vozniachuk, 1971; Makhnach, 1971; Rylova, Khursevich, 1978 — section *Poniemun-3*). All authors determined Muravian (Riss–Würm, Eemian) age of deposits. This age has been confirmed by recent pollen data obtained by Yelovicheva who studied the section *Poniemun-4* (Pavlovskaya *et al.*, 2002).

The exposure *Poniemun-4* appears to be the most complete sedimentary sequence available at present for study at the Poniemun site. There are six lithosomes illustrating changes of sedimentary environment (Fig. 2).

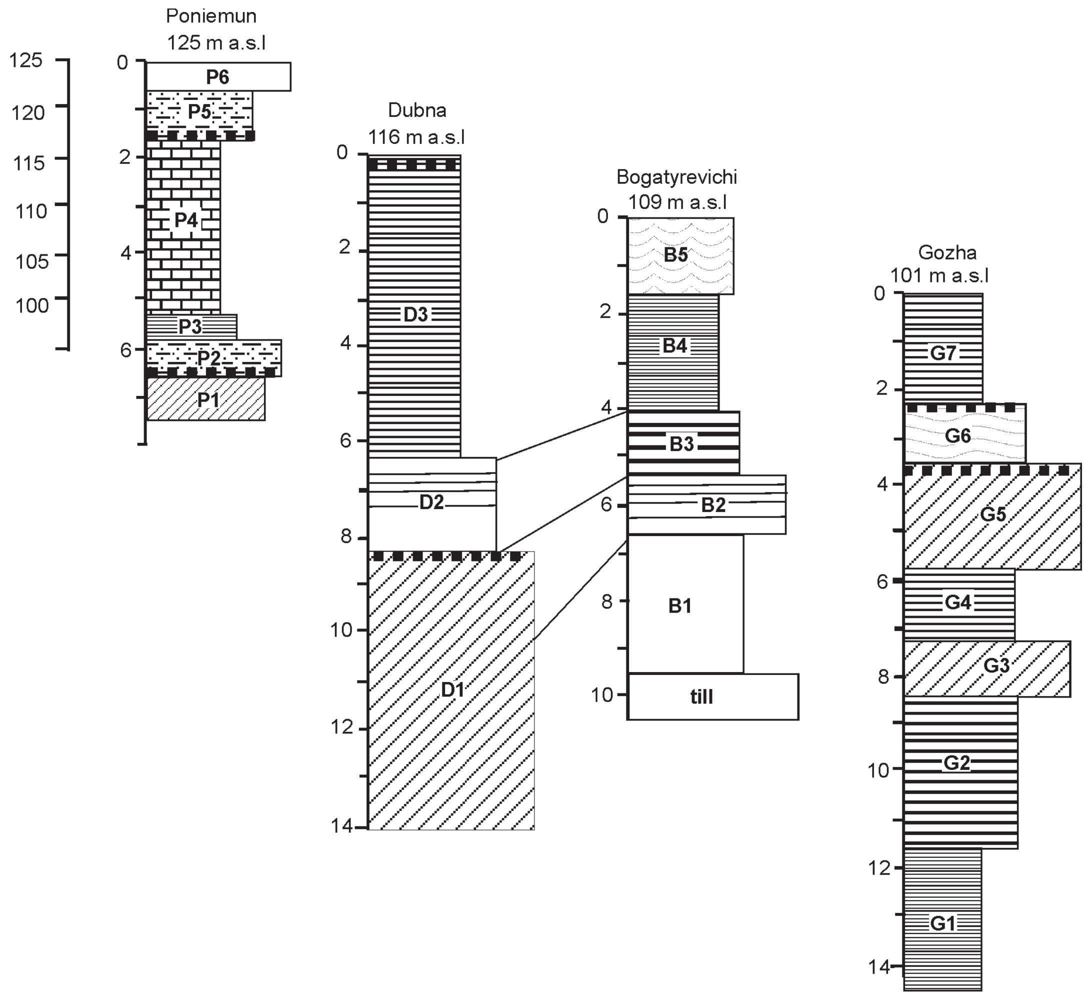

Fig. 2. Lithosome successions at studied sites

Erosional beds are shown by thick dotted lines, thin lines indicate correlative layers; for other explanations see the text

Lower lithosome (P1) consists of fine-grained cross-laminated sand. It changed upwards by poorly sorted vari-grained gravel sand (P2), with erosional gravel-pebble bed at the bottom. Lithosome P3 is represented by horizontally stratified silt, rich in organic matter. The most part of the section (P4) consists of carbonate sediments (chalk and limestone), faintly stratified due to thin (1–2 mm) laminae of yellow marl. These laminae divide the layer into rhythms, thickness of which varies upwards from 15–20 cm to 3–5 cm. According to mineralogical and X-ray fluorescent analyses carried out by Murashko (Pavlovskaya *et al.*, 2002), calcite is the main component of these deposits which contain 82.9% of CaO. The topmost lithosome of lake origin (P5) represents sand, vari-grained, coarser to the bottom, with erosional lower boundary marked by pebble layer. The lake sequence is overlain by poorly sorted sandy diamicton (P6) including gravel and admixture of clay particles.

It is worthy to mention that lake sediments of the Muravian Interglacial, like these at Poniemun, are cropping out in many sections in the Middle Neman area at similar altitude and geological position (the best known are sites Zhukevichi, Rumlovka and Pyshki — see Fig. 1). They are represented by lake marl and silt usually several metres thick.

Another type of basin sedimentation is represented by glaciolacustrine deposits which are quite typical for the area and can be observed at many sites. The thickest glaciolacustrine succession is registered at Dubna (Kalicki *et al.*, 2000).

Dubna site. The site is located on the right steep bank of the Neman River within the Skidel glaciolacustrine Lowland. Glaciolacustrine series of the Late Poozerian (Weichselian) Glaciation are underlain by fluvial deposits. The section represents separate lithosomes including several lithofacies and illustrating certain depositional environments (see Fig. 2).

The lower lithosome (D1) consists of vari-grained sand with alternating sub-layers of ripple cross-lamination, planar cross-lamination (15–20 cm thick) and horizontal gradational lamination (30–50 cm thick). Oblique laminae fall at an angle varying from 16 to 350° and orientation of 300–320°. Sediments are coarser to the bottom, streaks of gravel and pieces of re-deposited clay occur at the Neman water level. The lithosome represents fluvial sequence that was formed under conditions of various stream energy. Most of cross-laminated lithofacies are relatively thick and possess almost constant angle of laminae inclination that is characteristic for planar cross-stratification of channel facies. Ripple stratification has a subordinate significance. Alternating horizontally laminated sands with gradational sorting of grains can represent river-bed facies of low-energy stream. Horizontally stratified packs include lenses of flash laminated sand.

To the top of the section it is superseded by lithosome D2 — fine- and medium-grained sand, horizontally laminated in places. The stratification is similar to horizontally laminated packs of sand in lithosome D1 but the material is thinner and better sorted. Thin laminae of silt and streaks of clay occur at the top of the layer that suggests a stagnant hydrodynamic sedimentation regime.

Upper lithosome (D3) is represented by horizontally laminated thickness of clay, silt and sand laminae with deformations of convolution type in some laminae. Thickness of laminae varies from several to 217 mm. Rhythmites of the layer cannot be considered as classic varves as some rhythms have no clay laminae which are very different in thickness. According to structural and lithological differences, this series can be subdivided into 4 sub-units (Fig. 3). The sub-unit D3a is characterised by moderately thick laminae. It starts with rather thick sand laminae alternating with silt ones. Thickness of sand laminae decreases upwards. Thickness of clay and silt laminae changes rhythmically. The sub-unit ends with thick (11 cm) sand rhythm. The sub-unit D3b includes irregular and quite coarse sand laminae. Thickness of clay and silt laminae between sand rhythms decreases to the top of the sub-unit which ends with thick (21 cm) sand band. The sub-unit D3c consists of relatively thin sand and clay laminae, generally thicker upwards, which end abruptly at the top of the sub-unit. The sub-unit D3d is represented by irregular thickness of laminae, coarser and thicker sand laminae and rhythmically increasing silt ones. Clay rhythms are thinner upwards and disappear to the end of the sub-unit. The series ends with thick coarser sand rhythm.

Another example of glaciolacustrine succession is the ice-dam lake series at Bogatyrevichi.

Bogatyrevichi site. The site is located on the left bank of the Neman River near the Bogatyrevichi village, within the Skidel glaciolacustrine Lowland. The section consists of bog and lake deposits overlain by glaciolacustrine sediments and underlain by till (Fig. 2). The outcrop has been mentioned in the literature since the end of 19th century and became well known mainly due to palaeobotanic studies of Szafer (1925), Velichkevich (1982), Shalaboda (2001), Litviniuk and Yelovicheva (Litviniuk *et al*., 2002) and others. These authors defined that the lake and bog sediments beneath glaciolacustrine deposits were formed during the Muravian (Eemian) Interglacial.

The interglacial sediments, about 3 m thick, compose of peat overlain by faintly and horizontally laminated lake silt with intercalations of fine-grained sand at the top of the interglacial series (layer B1). It is superseded by vari-grained sand with gravel and pebble gradually changed by horizontally laminated and massive well-sorted sand at the top (lithosome B2). Horizontally stratified rhythmical thickness of alternating sand and silt, and laminae occurs above layer B2. It consists of three layers which differ in thickness and composition of laminae. In lithosome B3 clay laminae occur occasionally, mainly at the bottom. The layer is formed by silt and sand laminae. Lithosome B4 represents horizontally stratified rhythmical thickness of alternating silt, clay and sand laminae (Fig. 4a). Silt and clay laminae prevail in rhythms, sand ones occur at the top of the layer. In this layer, a regular change of lamina thickness occurs upwards: clay laminae are thicker at the bottom and disappear at the top of the layer (Fig. 4b), in contrary, sand laminae are absent at the bottom and attain maximum thickness at the top. Topmost rhythmites (lithosome B5) are formed by alternating laminae of clay, silt and sand, strongly disturbed due to post-sedimentary processes.

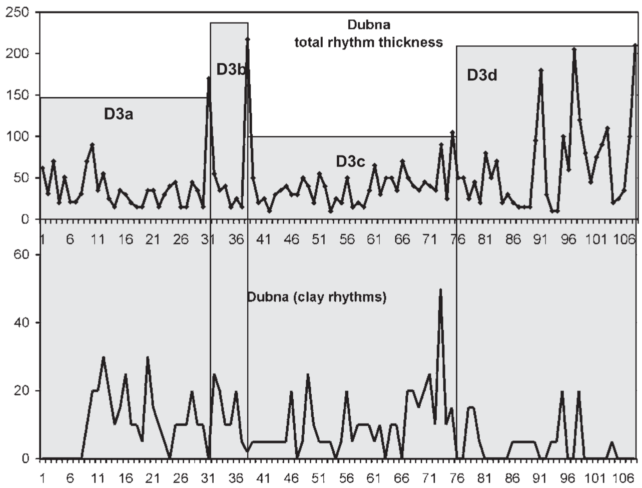

Fig. 3. Rhythmograms of different rhythms of lithosome D3 at Dubna

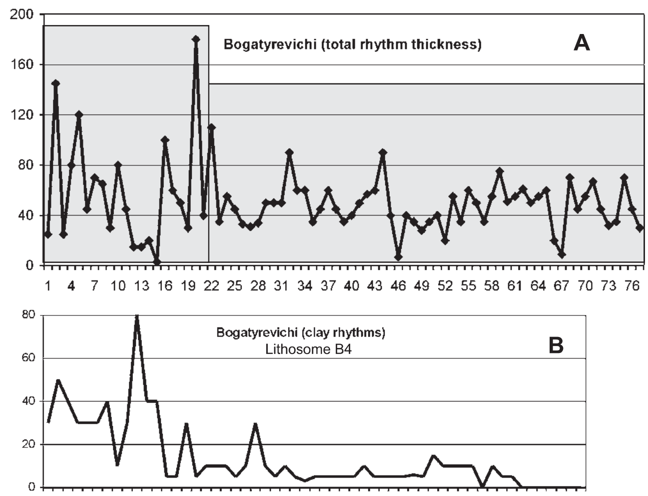

Fig. 4. Rhythmograms of different rhythms of lithosomes B3 and B4 at Bogatyrevichi

Convolute deformations prevail. Layer is underlain by thin sand streak (2–5 mm) with gravel.

Deposits at Poniemun, Dubna and Bogatyrevichi sites illustrate a basin (lake/ice-dam lake) sedimentary environment in the Muravian Interglacial and Poozerian (Weichselian) Glaciation. River sediments, cropped out within the valley, are younger and correspond to the Late Poozerian time. The impressive example of this kind of deposits is the well-known section at Gozha.

Gozha site. The Gozha outcrop is the key site for understanding the Late Poozerian geological history and evolution of Neman in the Grodno area. First it was studied in detail by Vozniachuk (1971) who considered sediments of the site as alluvial sequence of the Poozerian pleniglacial terrace of the Neman River. According to radiocarbon dating, the chronostratigraphy of the whole sequence is constrained between the maximum advance of the last ice sheet and the beginning of the Late Glacial. Organic matter from the lowermost layer (G1 — see Fig. 2) was dated with ^{14}C method (Arslanov *et al*., 1972; Vozniachuk *et al*., 1975; Zimenkov, Kuznetsov, 1985; Zimenkov, 1989). The results suggest that silts of the layer were formed just before and during the maximum advance of the last ice sheet. This has been confirmed by palaeobotanic studies of Velichkevich (1982), Valchik and Yelovicheva (Vozniachuk, Valchik, 1978) who have revealed in pollen spectra and flora remnants species of "cold" periglacial flora. The upper age limit of the sequence was determined by dating of oxbow lake sediments accumulated in Allerød, 11,080 year BP (Vozniachuk, Valchik, 1978; Zimenkov, 1989).

At present, the most complete section available for study is located in the southern part of the Gozha outcrop (Fig. 5). The section starts from the bottom with horizontally laminated clayey silt (laminae are 3–25 mm thick) containing decayed organic material scattered mainly on stratification surfaces (G1 — see Fig. 2). Sediments of this lithosome lying horizontally are traced along the river bank for a distance of almost 2 km. They are observed also in the Gozhka valley where they form steps at the bottom and occur at least for 300 m across the Neman river bed. The lake sediments are separated by erosional surface from the layers lying above.

The G1 lithosome is superseded by silty sand (G2) which includes lenses of poorly sorted gravel sand with clay admixture at the lower boundary. It is passing upwards to silt with laminae of fine-grained sand (0.5–4 cm thick). Frequency and thickness of sand laminae increase to the bottom. The next G3 lithosome is represented by fine-grained, planar cross-laminated sand and gravel cross-laminated sand with separate pebbles. It is changed upwards by fine-grained horizontally laminated sand (G4), with clayey silt laminae to 10 cm thick. Further changes of sedimentary environment are illustrated by

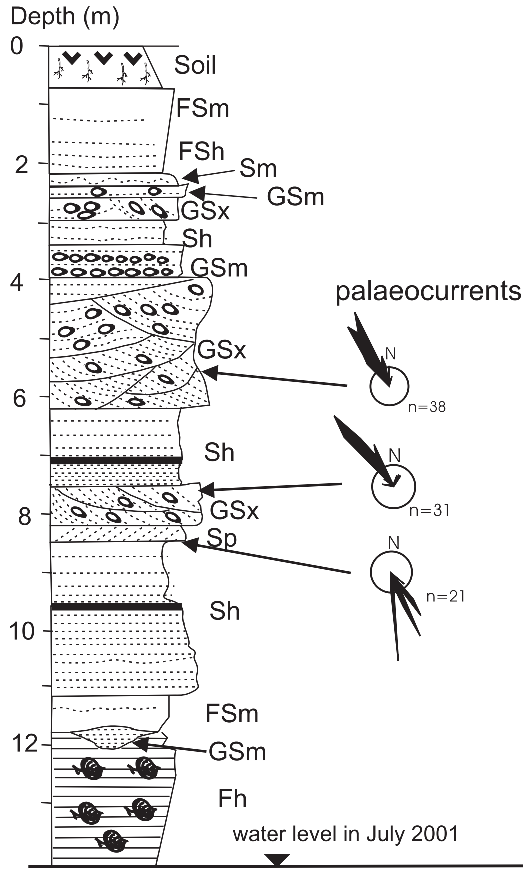

Fig. 5. Lithofacies and palaeocurrents at Gozha (compiled by Pavlovskaya and Davydik — Pavlovskaya *et al*., 2002, modified)

Symbols (after Mialle, 1978, modified by Zieliński, 1998): G — gravel, S — sand, F — silt; m — massive structure, h — horizontal stratification and lamination, x — cross-lamination of all types, p — planar cross-stratification

G5 lithosome which is composed of cross-laminated gravel sand with pebble and poorly sorted massive gravel sand and pebble. The above lying G6 lithosome consists of fine-grained, horizontally laminated sand overlain by cross-laminated and massive gravel sand with pebble. The section ends with G7 lithosome represented by fine-grained massive sand passing into fine-grained horizontally laminated sand with silt laminae up to 7 cm thick. According to palaeocurrent measurements (see Fig. 5), general direction of flow was changed from South (this direction was recorded in the lower fluvial series) to NNW which was similar to the present Neman watercourse.

INTERPRETATION OF SEDIMENT RECORDS

Sediment successions at Poniemun, Dubna, Bogatyrevichi and Gozha reflect a complicate development of sedimentary environment in the Middle Neman area during the Late Pleistocene.

The almost whole sequence of the Poniemun section was formed in lacustrine environment, illustrating all phases of basin infilling, from the very beginning of sedimentation under conditions of high water discharge (P1–3) within overflowing lake system, to deposition in a closed lake hollow during warm interval (P4). However, the topmost part of the lake series (P5) with erosional bed reflects a possible drainage of the lake hollow which changed into more open sedimentary environment. This change occurred probably before the maximum advance of the last ice sheet. In terms of sedimentology, the section represents a full lake sedimentary succession formed during a single cycle characteristic for interglacial lake: “cold” episode of the end of glaciation — “warm” episode of interglacial — “cold” episode of the next glaciation. This agrees with pollen records, according to which the sediments were accumulated during the end of the last Middle Pleistocene Glaciation, Muravian Interglacial and at the beginning of the last glaciation (according to pollen analysis of Yelovicheva — Pavlovskaya *et al*., 2002).

The rhythmical sequences at Dubna and Bogatyrevichi reflect also a basin sedimentary environment but different conditions of sedimentation. They were accumulated within a large ice-dammed basin — the Skidel extraglacial lake, which was formed during the maximum advance of the last Pleistocene (Poozerian, Weichselian) glaciation and initial phases of its recession. According to Vozniachuk and Valchik (1978), the Skidel lake had a maximum water level at 130 m a.s.l. There were 4 phases of drainage during which the level dropped to 125, 123, 118 and 115 m a.s.l. The lake was drained before the Braslav (Pomeranian) phase of the Poozerian ice sheet retreat.

However, traces of fluvial activity were studied at Dubna (lithosome D1). Vozniachuk and Valchik (1978) considered this layer as sediments of pleniglacial terrace. Lithofacies arrangement of the layer D1 suggests that sands of the layer were deposited by stream with unstable hydrodynamic regime. In general, change of lithofacies upward this lithosome indicates decrease in stream energy. Presence of horizontally laminated well-sorted sands allows to suppose that the stream was dammed periodically. Most likely, this fluvial sequence was formed in a braided river with prevalence of aggradation processes in periglacial conditions. That might have been caused by change of threshold just before the maximum advance of the last ice sheet. The most complete history of development of the Skidel ice-dammed lake during the maximum advance and retreat of the last ice sheet is recorded in the rhythm sequence at Dubna. Horizontally laminated sands of layer D2 are supposed to correspond to initial phases of accumulation in a relatively shallow lake with a high water discharge close to the main source of deposition (subaquatic delta of periglacial river). Thick sand laminae suggest a large amount of transported clastic material due to prevalence of open woodless landscapes. Thinner material and appearance of clay laminae upwards this lithosome may indicate gradual rise of lake level. Differentiation in composition and thickness of rhythmites of layer D3 demonstrates unstable conditions of sedimentation that are characteristic for a distal part of extraglacial ice--dammed lake. This part was situated near the delta of periglacial river, water of which filled the basin. Rhythmites of sub-units D3a, D3b and D3c illustrate a high water level and climate cooling during sedimentation. The sub-unit D3d was formed probably in a more shallow lake with a high water discharge due to climate warming.

According to lithofacies, there were traces of at least 5 drainage episodes. The first drainage is marked by thick sand laminae at the top of sub-unit D3a and can represent a drop of the Skidel lake level from 128 to 130 m. The lake was drained through the Pripilia–Nurka valley to Narev (Vozniachuk, Valchik, 1987).

The second drainage episode occurred some time later at the end of deposition of the sub-unit D3b. The drainage band is represented by thick coarser sand lamina, accompanied by thin silt and clay rhythms. This episode could reflect a drop of the lake level from 128 to 125 m during recession of the Poozerian ice sheet from its maximum limit to Porechye end moraines, formed during the Frankfurt phase of the last glaciation (Vozniachuk, Valchik, 1987). Later on the lake was dammed once again and water level became relatively stable or slightly rising that is illustrated by rhythmites of the sub-unit D3c. The third drainage episode might be connected with a level drop from 125 to 123 m due to progressive recession of the ice sheet. Water flew probably off by the Volkushanka–Bebrza valley to Vistula.

Lithofacies of sub-unit D3d reflect a high water discharge and climate amelioration, as rhythmite thickness is varying, sand and silt laminae prevail and generally become coarser to the top of the sub-unit. There are features illustrating an unstable lake regime with two drainage episodes marked by sand laminae. Those episodes might be related to level drops from 123 to 118 m and from 118 to 115 m. Water runoff was probably directed to the Balberishkes–Simnas basin in Lithuania (Micas, 1974; Mikaila, 1974; Vozniachuk, Valchik, 1978). Only separate residual lakes remained in the area of the Skidel basin after the last drainage.

Rhythmites at Bogatyrevichi also represent sediments of the Skidel extraglacial lake but they illustrate an environment of the central, deeper part of the basin. Sands of layer B2 were formed at high water and sediment supply but reflect rather stagnant hydrodynamic regime probably due to the rise of the threshold. These sands are supposed to correspond to the fluvial sequence D1 at Dubna. Layer B3 is interpreted as sediments of initial phases of basin sedimentation where water discharge and amount of clastic material were relatively high. This pack can be correlated with sand layer D2 at Dubna. Layer B4 might have been formed during the high level phase of the Skidel lake but it reflects two drainage episodes connected with subsequent drops of glacial lake levels due to an ice margin retreat. Layer B5 formed in a shallow basin at final phases of a lake existence and was deformed probably just after runoff of the lake. Deposition of sand with gravel at the bottom of the layer is interpreted as sedimentary break and could be related to a late drainage episode.

In contrast to the Late Poozerian sequences at Dubna and Bogatyrevichi, the sedimentary succession at Gozha starts with lithosome illustrating stagnant hydrodynamic regime (G1). Above-lying layer (G2) represents sediments accumulated under condition of gradually increasing water and sediment discharge, however, without significant current. Material is coarser and laminae are thicker toward the top of this layer that demonstrates an initial development of a current, the latter resulted in deposition of overlying fluvial series (G3). Planar cross--laminated sand changes into cross-laminated series of high-energy stream that ends quite abruptly. It is replaced by relatively thick horizontally laminated lithosome (G4) representing stagnant again hydrodynamic regime. It is worthy to mention that the thickness of laminae and grain size of material is thinner at the bottom of the layer, just above the GSx-lithofacies that could reflect a sudden change of stream energy. The lithosome G4 is superseded by thick fluvial coarse series (G5) with different types of cross-stratification characterising a high-energy stream. This rhythm ends with poorly sorted pebble-gravel-sand bed which might be related to supercritical flow phase. The next rhythm (lithosome G6) represents fluvial sediments of a middle-energy stream, cut by erosion. The upper series (G7) illustrate a stagnant hydrodynamic regime of a shallow basin.

Thus, the Gozha section appears to reflect 4 phases of damming (horizontally laminated lithosomes) and 5 phases of outflow (separating coarse cross-laminated series and erosional beds). Silts of the lowermost lithosome were probably formed in front of advancing ice sheet that dammed the stream from the north that was confirmed by radiocarbon data. An interchange of river erosion and accumulation phases is recorded in above-lying series, that suggests periodical damming connected with a development of chain of ice-dammed lakes during the last ice sheet recession in western Belarus and southern Lithuania: Skidel, Balberishkes–Simnas and Jura–Sheshupe lakes (Micas, 1974; Mikaila, 1974).

CONCLUDING REMARKS

Sedimentary archives of geosites in the Middle Neman area contain a rich environmental information which can be interpreted in different ways. However, their analysis from sedimentological point of view has led to some evident general conclusions.

Muravian sediments of lacustrine origin are widespread in the present Neman valley. So far, there is no signs recorded both in exposed and buried sections which could be interpreted as fluvial sediments of a large river valley like Neman. Numerous profiles with Muravian (Eemian) deposits represent accumulations of isolated sedimentary basins existed throughout Muravian Interglacial. Further to the north, in Lithuania, the geological situation is much the same: an abundance of sections of Eemian lake sediments within the present Neman valley with complete sediment and pollen successions. The best known is the Jonionys site that represents continuous sedimentation from the Eemian Interglacial up to the beginning of the Middle Weichselian (Satkunas, 1999). This evidence suggests that no significant river valley could occur in the Eemian Interglacial within the present Neman valley, at least in its longitudinal part downstream Bogatyrevichi.

A basin sedimentation, although on other scale and dimension of basins, continued during the last glaciation. It was connected with the development of the Skidel extraglacial ice-dammed lake, deposits of which formed the present surface of the Skidel Lowland.

According to the available sedimentary records, traces of fluvial activity in the present Neman valley correspond to the Late Poozerie time. The oldest fluvial sediments have been registered at Dubna, the most southern site of the area. These sediments were formed during the maximum extent of the last ice sheet, as well as initial phases of the Skidel lake infilling. Further to the north, within longitudinal part of the present Neman valley, river sediments are even younger. As recorded at Gozha, the large lake existed before and during the maximum advance of the last ice sheet. Forming of the river beds and development of the stream were connected with phases of the Skidel lake drainage and level drops in the Middle–Lower Neman ice-dammed lake system during the retreat of the ice sheet margin. The initial phases of evolution of the present Neman river channel downstream Grodno represent recurrent “fluvial” and “lake” episodes due to periodical damming or even change of the direction of stream. The Neman present course within the area was formed during the end of the last glaciation and the Late Glacial.

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