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Sedimentary succession in Berezno in the Volhynia Polesie (Ukraine) as an example of depositional environment changes in the periglacial zone at the turn of the Vistulian and the Holocene

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This paper reports the results of investigations in the eastern part of the European sand belt. The lithological variability of alluvia as well as overlying aeolian sands and silts was determined in the Berezno site (Western Ukraine) located on the right-bank, higher terrace of the Slutcha River. Based on the described deposit succession, using the results of lithofacial, granulometric, morphoscopic, and TL analyses, the primary deposition environments were reconstructed. Periglacial structures were also characterized and interpreted. The dependence of the deposition conditions and rate on the transformation of Plenivistulian and Late Vistulian severe climate was shown. An attempt was also made to define the influence of local factors on fluvial, fluvio-aeolian, and aeolian deposition. Alimentation areas for aeolian deposits and dominant wind directions were also indicated.

Key words: periglacial zone, fluvio-aeolian and aeolian deposition Berezno site

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INTRODUCTION

In the periglacial zone, most typical are fluvial and aeolian processes. During the last glaciation, the periglacial area covered the entire East and Central European Lowland. The intensive pro- and extraglacial deposition left an extensive sediment deposition zone in this area, the so-called sand belt. Currently, these are mainly extensive sand and sand–silt aeolian covers and inland dune fields. Alluvial sands, outwash deposits or moraine plateaus prevail in their substratum (Nowaczyk, 1977; Kocurek, Nielson, 1986; Goździk, 1980a, 2000). They spread from the eastern part of the British Isles through Northern Belgium, the Netherlands, Northern Germany, the western part of Denmark, Poland, Belarus and the northern part of Ukraine, as well as through Lithuania, Latvia and Estonia, reaching as far as Russia (Koster, 1988; Böse, 1991; Kasse, 1997; Zeeberg, 1998; Fig. 1). Studies on sedimentary succession within this zone enabled a detailed description of the diversity of the periglacial depositional environment during the last glaciation, which in turn allowed constructing climatic models for this period of time (Isarin et al., 1997; Liedtke, 1993; Huijzer, Vanderberghe, 1998; Kasse, 2002; Kasse et al., 2003; van Huisstenden et al., 2003; van Huisstenden, Pollard, 2003). A vast majority of detailed data used in these reconstructions come from the Netherlands, Germany as well as from Eastern and Central Poland, i. e. from the western part of the belt. Although the researchers have been studying the eastern part of this belt for a long time (Tutkowskij, 1909; Lencewicz, 1922; Krygowski, 1947; Zeeberg, 1988; Zaleski, 2004; Zaleski, Zieliński, 2005; Zieliński et al., 2008), the results do not fully substantiate such inferences. In particular, attention should be drawn to two studies which contribute to the discussion on the overall atmospheric circulation during inland dune formation. The first study is Zeeberg's work (1998) which contains palaeogeographical conclusions based primarily on the studies of dune orientation in Central and Eastern Europe. Based on lithofacial analysis and TL dating of three sites in the Volhynia Polesie, the second study presents variations in wind direction and velocity in relation to circulation changes in the Late Vistulian (Zieliński et al., 2008).

In this context, it seems reasonable to examine the eastern part of the sandy belt, i. e. on the territory of Ukraine, which would facilitate characterizing sediments of various genetic origin (alluvial, aeolian) and age (Plenivistulian, Late Vistualian) deposited in periglacial climate conditions, and to compare the nature of deposition with analogous profiles from Western and Central Europe. The research on aeolian forms in the Volhynia Polesie resulted in documenting a site located in the aeolian cover in the vicinity of Berezno (Figs. 1, 2). Encouraged by the discovery of sediments of various origin, the authors decided to conduct a more detailed study. The aim of the research was to reconstruct depositional environments at the site and to specify the age and factors that determine the changeability of sediment accumulation. To this end, the authors applied the following methodology: 1) geomorphological mapping; 2) lithological description of sediments, i. e. texture evaluation, recording of depositional structures, measurements of scale and frequency of recorded lithofacies, measurement of structural directional elements and recording of periglacial structures; 3) laboratory analyses to define grain composition by the sieve method and to determine the shape and surface of quartz grains (Krumbein, 1941; Krygowski, 1964; Goździk, 1980b); 4) lithofacial analysis: the lithofacial features of deposits determined in the field studies as well as the outcome of laboratory analysis helped to identify the depositional environment according to Zieliński's (1997) classification for the fluvial environment and Lea's (1990) classification for the aeolian environment; 5) thermoluminescence dating using the multi aliquot regeneration method (Wintle, Prószyńska, 1983), in accordance with the sample treatment proposed by Fedorowicz (2006).

LITHOFACIAL ANALYSIS OF DEPOSITS

Morphological and geological situation. The study site is located in the Slutcha River valley, north-west of Berezno (Fig. 2). It covers the right-bank, eastern part of the valley. It is here that the undercut fragment of the Vistulian terrace gently bends its way into an outwash valley from the Oder (Dnieper) age, composed of fluvioglacial deposits. In the place where the two forms meet, there is an aeolian cover which covers most of the terrace. The surface of the cover is wavy and slightly inclined towards the valley axis on the ordinate of just above 168 m. Distinct culminations of the cover reach 176 m a. s. l. and are various types of inland dunes, usually with western orientation.

Deposit description. In the northern part of the meander undercutting (Fig. 2) there is an excavation site where the sediment profile was identified (Fig. 3A). The sediment profile comprises three complexes. In the lower fluvial complex, the sand → silt cycles composed of fractional sequences, were identified (Fig. 3B, 4F, G, H). The sandy element of the sequence consists of sands with large and medium-scale trough cross-stratification. Towards the profile top, the trough scale clearly decreases. This element is crowned with fine-grained sands with ripple cross-lamination (Fig. 4G). Laterally, there are sands with tabular cross-stratification developing into sands with horizontal or small-angle stratification, which are crowned with sands with ripple lamination (Fig. 4H). The silty / silty-sandy element consists of silty sands with climbing ripple lamination, silts with flasher lamination developing into horizontal lamination (Fig. 4F). Subsequent cycles in this complex become less thick, while the scale of the lithofacies

Fig. 1. Situation of the study area against the background of sand belt extent in Central Europe according to Kasse, 1997 and Zeeberg, 1998
1 pav. Tyrimų teritorijos padėtis Vidurio Europos smėlingoje juostoje (pagal Kasse, 1997 ir Zeeberg, 1998)

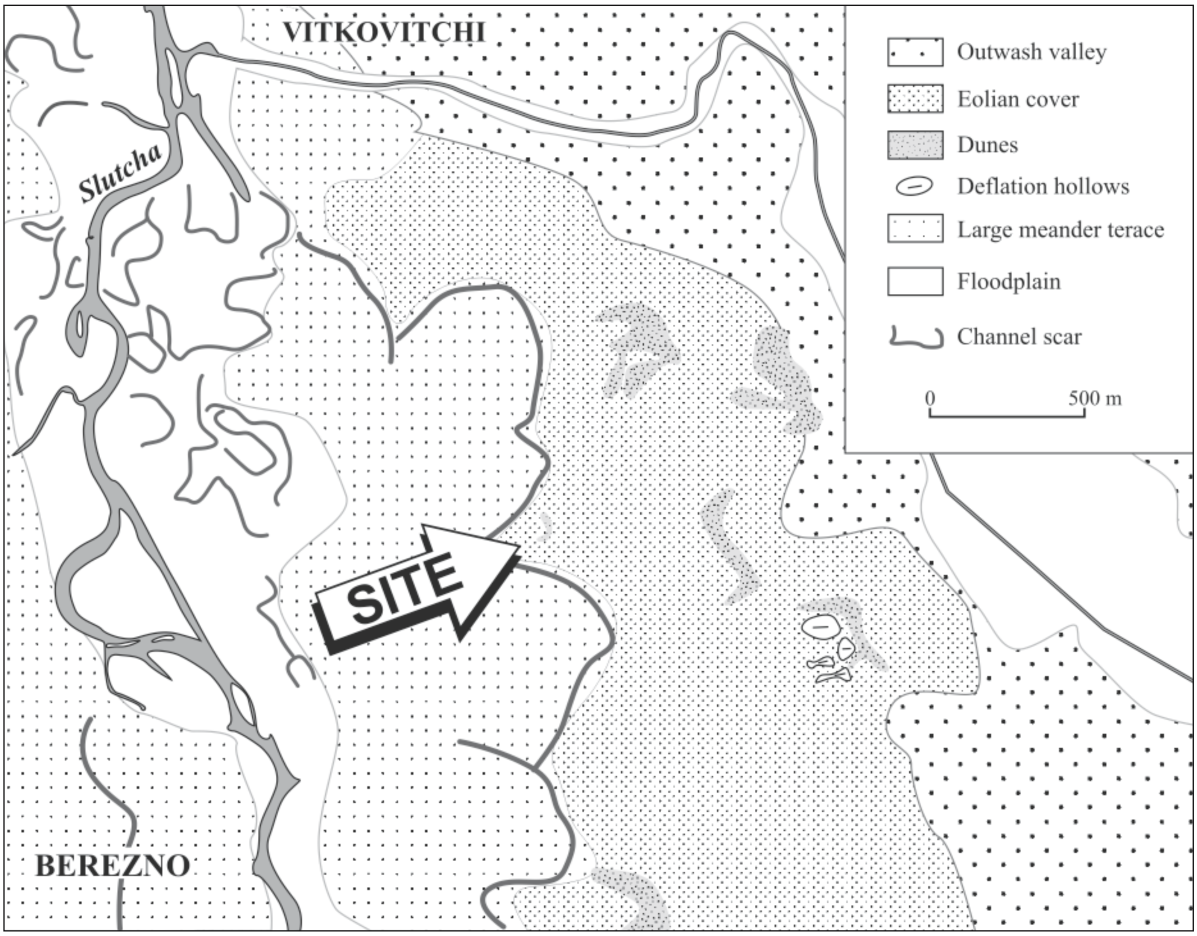

Fig. 2. Location of the research site in geomorphological sketch
2 pav. Geomorfologinė tyrimų vietos lokalizacija

of which they consist decreases. Structural directional elements show a relatively large discrepancy and the dominant NNE direction (Fig. 3A).

The middle – fluvio-aeolian – complex consists of two lithofacial associations (Fig. 3B, 4D, E): 1) sands with small and medium-scale trough cross-stratification, most often inserted into single large-scale troughs, sometimes are accompanied by sands or sands with fine gravels of small and medium-scale tabular cross-stratification, crowned with sands of horizontal stratification; 2) fine gravels, mostly aeolized, most often in the sandy matrix, which create discontinuous strata of small thickness (up to 5 cm), rhythmite of sands with horizontal stratification, low-angle cross-stratification or adhesion climbing ripple pseudo-cross-lamination occurring alternately with silts and sandy silts with streaky or horizontal lamination. Structural directional elements are largely dispersed; however, an increased frequency of three directions (E, N, SW) is observed (Fig. 2A).

The upper – aeolian – complex consists of (Fig. 3B, 4A, B, C): 1) in the floor, rhythmite of sands with horizontal stratification, climbing ripple cross-lamination, translatent stratification or tabular cross-stratification, and sandy silts with horizontal lamination or massive structure; 2) in the top, sands with climbing ripple cross-lamination, translatent stratification or small-scale tabular cross-stratification or massive structure, while culminations consist of sands with high-angle inclined stratification. Directional preferences include two dominant directions: SE and WSW (Fig. 2A).

Periglacial structures. Two generations of periglacial structures have been identified in the sediment profile studied. In the top part of the lower (fluvial) complex, there are wedge structures 0.2–0.6 m long and several up to 20 cm wide (Fig. 4E). They are filled with silt and sandy silt, and the widest of them are additionally filled with sandy material along their axes. In this layer, there are also involutions, drop structures; oftentimes the primary deposit structure is obliterated. The second generation of structures is found in the bottom part of the middle sediment complex. These are mainly syngenetic wedge structures. The longest of them are over 1 m long and several cm wide; they cut through the top part of the lower complex. The structures correspond to the fine-gravel stratum. This material fills the upper parts of the largest structures. In addition, there are small reverse faults and flexure deflections with the throw reaching up to 10 cm (Fig. 4B, E).

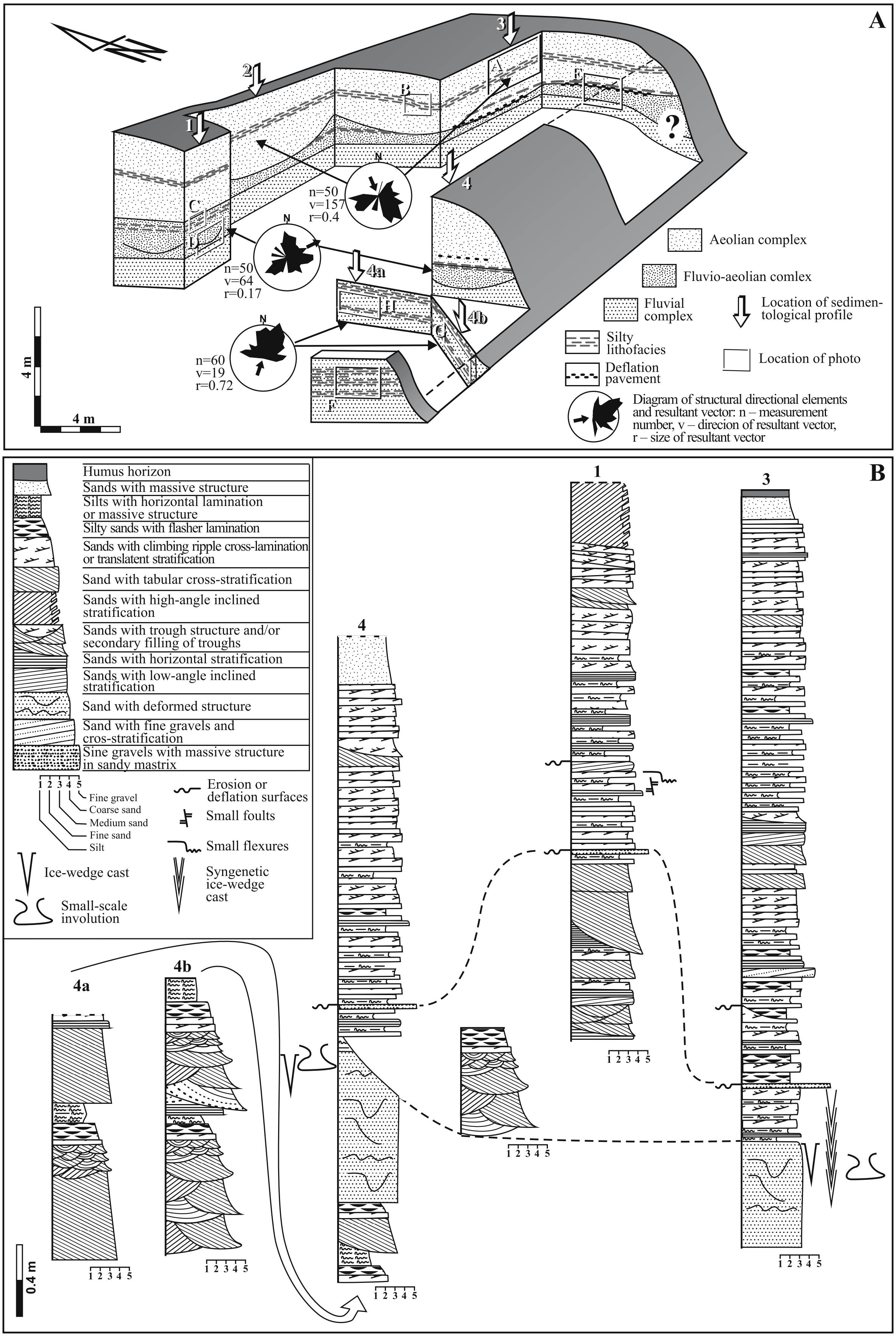

Fig. 3. Depositional succession in Berezno: *A* – arrangement of the lithofacies complexes in the exposure, *B* – detailed picture of lithofacial differentiation

3 pav. Nuogulų seka Berezno vietovėje: *A* – litofacinių kompleksų išsidėstymas ekspozicijoje, *B* – detalūs litofacinio pasiskirstymo paveiksliukai

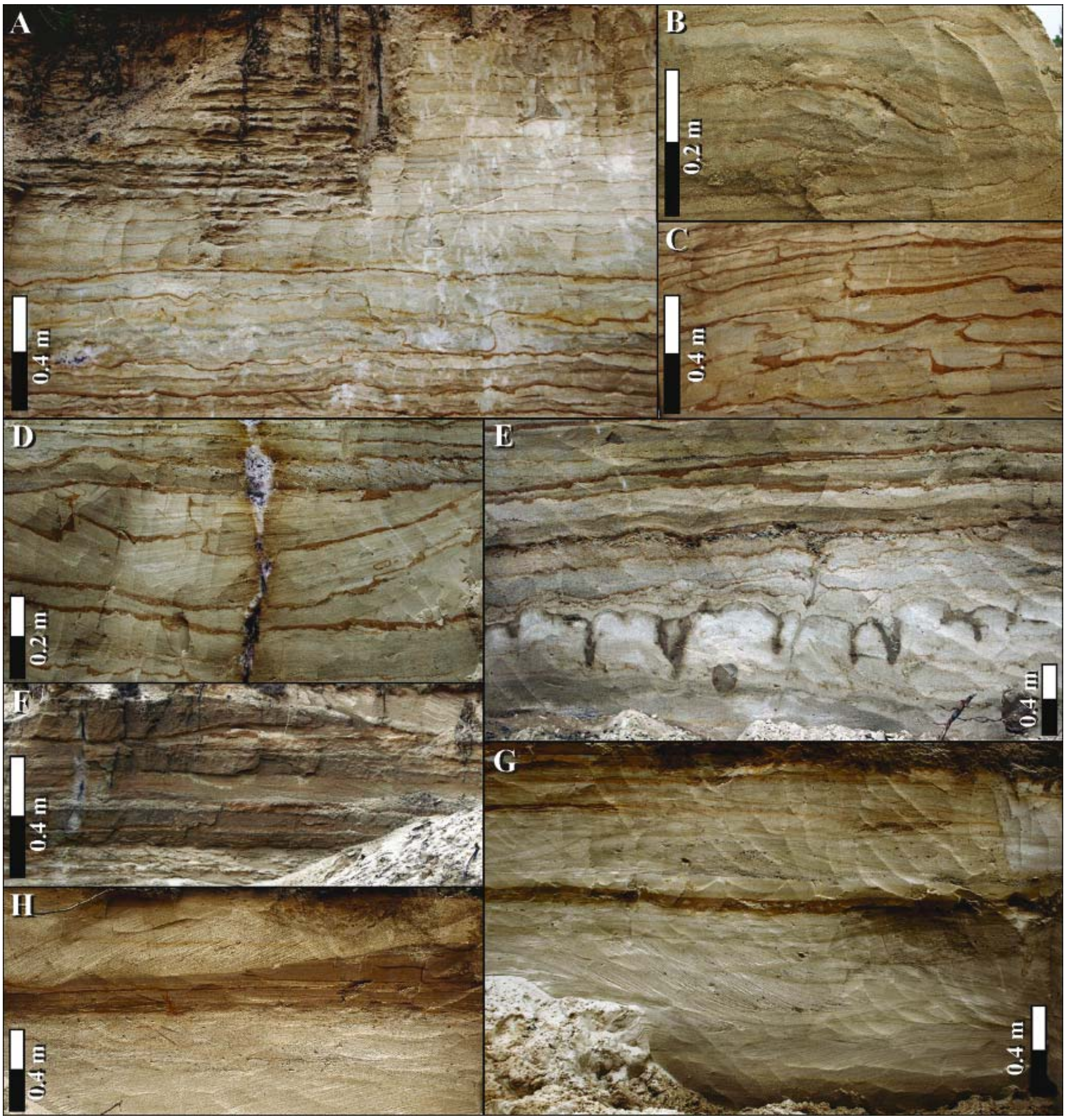

Fig. 4. Lithological features of depositional succession: *A* – upper (aeolian) complex; *B* – flexures in upper complex; *C* – small faults in the bottom of aeolian complex; *D* – episodic braided channel in middle complex; *E* – periglacial structures in the top of lower (fluvial) and middle complex; *F* – silty lithofacies in lower complex; *G, H* – braided river, with two typical sub-environments: deep channel (*G*) and transversal bar (*H*). Localization of photo in Fig. 3A

4 pav. Nuogulų sekų litologiniai bruožai: *A* – viršutinis (eolinis) kompleksas; *B* – įlinkiai (fleksūros) viršutiniame komplekse; *C* – smulkūs nešvarumai apatiniame eoliniame komplekse; *D* – atsitiktinių juostelių kanalai viduriniame komplekse; *E* – periglacialinės struktūros žemutinio ir vidurinio komplekso viršutinėje dalyje; *F* – dumblo frakcijos žemutiniame komplekse; *G, H* – juostinės upės kaip dvi tipiškos subaplinkos: gilūs kanaliukai (*G*) ir skersinės juostelės (*H*). Nuotraukų išdėstymą žr. 3A pav.

Interpretation. Lithological features of the lower complex, in particular their lateral diversity, suggest that these deposits formed: a) in the deep-channel zone – trough structures, and b) as a result of prograding sand bar – tabular structures (Miall, 1978; Rust, 1978; Van Huissteden, Vanderberghe, 1988; Kozarski et al., 1988; Zieliński, 1997). The fact that trough lithofacies decreases upwards as regards its scale and transforms into silty lithofacies points to a decrease in the flow size and energy and, as a consequence, to flow withering. The sequence of sands with tabular cross-stratification and horizontal stratification indicates that the flow depth decreases and the flow regime is transformed from the lower to the upper one. The documentation of three such cycles may indicate an intensive deposit aggradation in the river channel, while there are records of frequent channel avulsions. The decreasing thickness of successive cycles may mean that the size of the river flow was reduced or that secondary channels developed in this place. These features clearly indicate the existence of sand-bed braided river flowing in the northern direction. Furthermore, the sediment sequences document a decreasing flood and a gradual flow withering (compare Zieliński, 1997).

Wedge structures found in the top confirm the existence of long-term permafrost which most probably appeared on deposited alluvial sediments when the flow had withered. These are, most probably, ice wedge casts. Both casts and small-scale involutions allow to specify the average annual temperature as –2 – –5 °C (Rotnicki, 1970; Kozarski, 1995; Huijzer, Vandenberghe, 1998; Kasse et al., 1998; Mol, 1997; Mol et al., 2000; Kasse et al., 2003; Van Huissteden et al., 2003).

Lithofacial features of the middle complex prove that two distinct depositional environments interfingered. The lower, erosive borderline of sand sets with trough cross-stratification indicates the existence of episodic deep channels which were relatively quickly filled with alluvia. The channel was filled as a result of winding megaripple migration – medium-scale trough structures; as the flow depth was becoming smaller, the scale of bottom forms was decreasing. In addition, there is an evidence of channel shallowing as a result of transverse bar progradation (tabular structures) and flow passage in the upper regime (horizontal stratification). Features of the second lithofacial association, i. e. rhythmite of sands with horizontal stratification, low-angle cross-stratification or adhesion climbing ripple pseudo-cross-lamination occurring alternately with silts and sandy silts with streaky or horizontal lamination are typical of deposition in an aeolian environment. Sandy lithofacies with cross-stratification

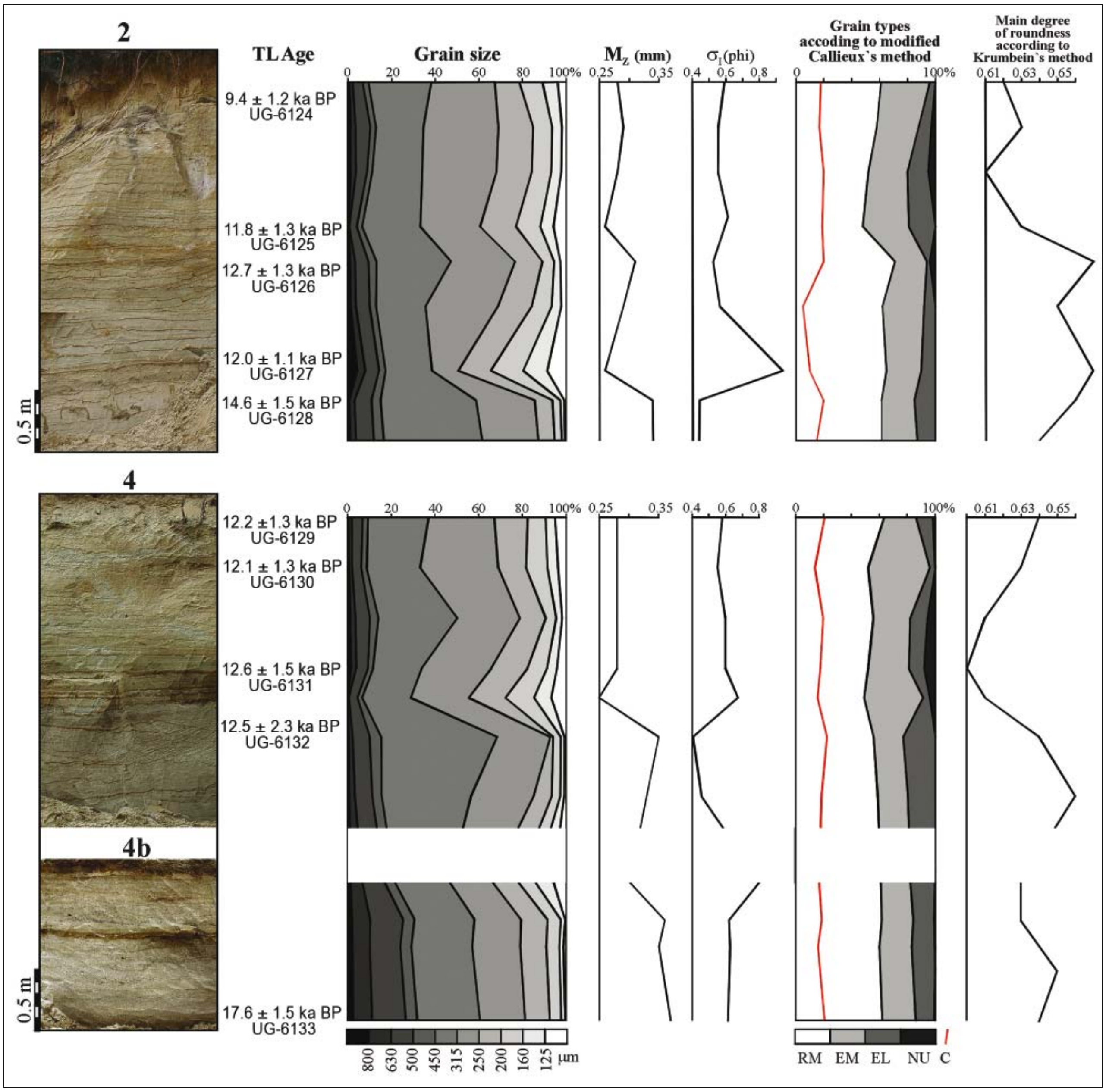

Fig. 5. Textural features and TL dates of deposits. Localization of sections in Fig. 3A

5 pav. Tekstūriniai bruožai ir nuogulų TL datavimo rezultatai Berezno vietovėje were deposited as a result of saltation transport (Sharp, 1963; Hunter, 1977; Lea, 1990), while those of horizontal structure were deposited from a near-ground suspension (Hunter, 1977; Borówka, 1990, 2001; Zieliński, Issmer, 2008). Silty lithofacies were deposited as a result of transport in suspension or modified saltation (Tsoar, Pye, 1987; Lea, 1990). The existence of adhesion climbing ripple pseudo-cross-lamination suggests deposition on a moist surface (Hunter, 1973; Kocurek, Fiedler 1982; Schwan, 1986; Borówka, 1990, 2001), while the wavy surface of sandy silty rhythms bears resemblance to fluvio-aeolian deposits distinguished by Kase (1997, 2002), Kase et al. (2003) or wet aeolian deposits distinguished by Bohncke et al. (1995), Mol (1997). Also, it is possible that the rhythms developed as a result of flood wave descending outside the channel zone. The fine-gravel layer with clear signs of aeolization is indicative of some changes in the functioning of the aeolian system which becomes dominated by deflation (Koster, 1988; Seppälä, 2004). The above-mentioned genetic interpretation of deposits clearly indicates an intensive aeolian deposition in the braided river area, and river flows are much lower than the ones recorded in the lower complex. The flow size decrease and the flood wave descent were accompanied by an intensive aeolian accumulation. Aeolian processes occurred also on the moist surface outside the channel, which made accumulation more intensive. When the surface became dry, deflation processes were activated, which is evidenced by the level of the aeolian pavement. Aeolian accumulation took place in severe periglacial conditions confirmed by synsedimental wedges which suggest that an average annual temperature was below −1 °C (Kozarski, 1995; Huijzer, Vandenberghe, 1998; Kasse et al., 1998; Mol, 1997; Mol et al., 2000; Kasse et al., 2003; Van Huissteden et al., 2003). Small reverse faults may also imply the existence of ground ice. However, such structures may also indicate that the accumulation took place on snow (Schwan, 1986; Dijkmans, Mücher, 1989; Dijkmans, 1990). Structural directional elements show a diverse deposition orientation. Still, lithofacies deposited in the fluvial environment suggest mainly the flow in the northern direction, and directional preferences of the aeolian environment suggest a slight predominance of western and north-eastern winds.

The lithofacial features of the upper complex show diverse conditions of accumulation in the aeolian environment. Sandy facies were deposited as a result of ripple migration – sands with climbing ripple cross-lamination or translatent stratification (Bagnold, 1954; Sharp, 1963; Hunter, 1977), megaripple migration – sands with tabular cross-stratification (Borówka, 1990, 2001; Pye, Tsoar, 1990; Goździk, 1998), and as a result of material transport in the near-ground suspension – sands with horizontal stratification (Hunter, 1977; Zieliński, Issmer, 2008). Alternately, there were conditions with a lower wind velocity, favouring the deposition of silty and sandy-silty lithofacies transported in suspension or intermittent saltation (Pye, Tsoar, 1987; Lea, 1990; Goździk, 1998). Top lithofacies, i. e. sands with high-angle cross-stratification, were deposited on the leeward slopes of dunes (McKee, 1966; Nowaczyk, 1976; Hunter, 1977; Borówka, 1990, 2001), and sands with a massive structure are the effect of obliterating the primary structure as a result of pedogenic (Wojtanowicz, 1970) or periglacial (Stankowski, 1963; Urbaniak, 1969) processes. Directional preferences in this complex show the predominance of ENE and NW winds.

TEXTURAL FEATURES

Granulometric and morphoscopic analysis was conducted in two most representative profiles (Fig. 5). Medium- and fine-grained sands are the main constituents with the maximum (25.1–52.9%) in 0.315–0.45 and 0.25–0.315 mm fractions and average diameter 0.26 to 0.37 mm. The coarsest grains are found in channel sediments while the finest in strictly aeolian sediments. They are well and medium sorted (0.44–0.94φ). The best sorting was observed in channel sediments, while the worst one was recorded in channels with withering flow and in sandy-silty covers deposited as a result of fluvial-aeolian or aeolian processes. The deposits contain well-rounded grains ($\overline{K}$ = 0.6–0.67). Round matt grains are predominant (RM = 48–71%); however, polished rounded grains (EL = 2–23%) and cracked grains (C = 14–23%) have a large share. The largest share of RM grains is found in lower and upper complex sediments and the largest percentage of EL grains in the middle complex. The small percentage of unabraded grains (NU up to 8%), occurring almost exclusively in upper complex sediments, deserves attention. However, the occurrence of these grains in the sample is accompanied by the increasing percentage of cracked grains (C up to 20%).

The high level of aeolization, i. e. the content of RM and EM grains both in fluvial and aeolian sediments, confirms the periglacial origin of the sediments. This indicator is particularly explicit in periglacial braided rivers in the Polish Lowland, with almost 100% of grains showing signs of aeolization (Goździk, 1980a, 1995). A comparison of this sediment indicator from Berezno with the analogous one from the Polish Lowland allows a conclusion that the content of aeolized grains is slightly smaller to the advantage of polished grains. The content of EL grains increases towards the profile top and in episodic channel sediments (middle complex) up to 23%, and RM grains reach 56%, possibly because the site was located in the close vicinity of steppe and forest steppe areas (Büdel, 1948; Gerasimov, Velichko, 1982). A slightly thicker layer of vegetation may have slightly impeded the intensity of aeolian processes and the supply of material to the river valleys. This hypothesis is supported by the increase of EL grain share in younger alluvia. Another reason may be the a close vicinity of sediments which form the outwash valley and contain a large percentage of EL, NU and C grains. Thus, these sediments may have contributed to the fluvial deposition.

The high degree of similarity between textural features of sediments from all the three complexes supports the conclusion that braided river alluvia were the main alimentation area for aeolian sediments (compare Krygowski, 1947; Wojtanowicz, 1970; Nowaczyk, 1976, 1986; Goździk, 1980a, 1991, 2000). Also, the vast area of outwash valley slightly contributed to the supply process, as suggested by the increased percentage of NU and C grains in aeolian sediments. Preservation of these grains suggests that aeolian transport took place at a small distance. The fact that the closest outwash valley is located east and northeast from the site indicates that the wind from the eastern sector contributed significantly to the grain deposition.

SEDIMENT AGE

Simultaneously with laboratory analyses, TL dating was conducted in both profiles for 10 sediment samples (Table, Fig. 5). In the lower fluvial complex, dates ranging from 17.2 ± 1.8 to 14.6 ± 1.5 ka BP were obtained; therefore, it may be assumed that braided river sediments developed in the Upper Plenivistulian (Liedtke, 1993; Bohncke, 1995; Kase, 1997; Mol, 1997). The middle fluvio-aeolian complex was dated in the range from 12.5 ± 2.3 to 12.0 ± 1.1 ka BP. The first of the two dates is much less certain than the remaining ones in the profile, i. e. its uncertainty rate is 18%. This situation is due to a large scatter of results of the absorbed ED dose measurements. This discrepancy may be explained by a short exposure of some grains to solar radiation or by the fact that the grains originated from two different sites. Considering that sediments in this complex were accumulated in the aeolian or fluvial environment, the latter explanation seems to be more plausible. The age of the upper aeolian complex was determined within the range from 12.7 ± 1.3 to 9.4 ± 1.2 ka BP. Sandy and silty bottom lithofacies are characterised by the date 12.7 ± 1.3 ka BP, while the top sandy lithofacies are younger than 12.2 ± 1.3 ka BP. The youngest date (9.4 ± 1.2 ka BP) represents near-surface sediments – a massive cover and its culminations. The dates show that the middle and upper complexes were deposited in the Late Vistulian and the Preboreal (Nowaczyk, 1986, 2000; Kozarski, Nowaczyk, 1991 a, b; Kase, 1997; a. o.). Accumulation of fluvio-aeolian sediments started most probably prior to the Older Dryas, which is suggested by the dates older than 12.000 years. Their occurrence over the sediments of the first complex, whose top part is dated to 14.6 ± 1.5 ka BP, may suggest that these sediments date back to the Older Dryas and their deposition still continued in the Bölling. It is in this period that the accumulation of strictly aeolian sediments began, which is indicated by the data obtained for the upper complex bottom, i. e. 12.7 ± 1.3 ka BP. The main period of their accumulation dates back probably to the Older Dryas, which is evidenced by three dates in the range of 12.2 ± 1.3–11.8 ± 1.3 ka BP covering most of the upper complex. Aeolian deposition was completed with the dune formation. However, the beginning of dune formation is not precisely identified, while the end is marked by the date 9.4 ± 1.2 ka BP, i. e. the Preboreal.

DEPOSITIONAL ENVIRONMENT EVOLUTION IN THE CONTEXT OF CLIMATIC CHANGES

The discussed documentation, together with its interpretation, indicate that the depositional succession in Berezno took place in the interval of the Upper Plenivistulian – Preboreal. Typical of this period are dynamic climate changes from the Vistulian pessimum, with the average annual temperature –5 to –8 °C and in July up to 5 °C, until the beginning of the Holocene warming in the Preboreal, with the average annual temperature of about 7 °C and in June 14–15 °C. Changes in thermal conditions were accompanied by a changing humidity. In this period, probably in the Alleröd, the permafrost was subjected to the degradation process (Maarleweld, 1964; Nowaczyk, 1986, 2000; Liedtke, 1993; Kozarski, Nowaczyk, 1991 a, b; Kozarski, 1995; Kase 1997; Huizer, Vanderberghe, 1998; Van Huissteden et al., 2003).

The peak time for the development of the braided river which was formed in two sub-environments typical of this river – deep channel and transversal bar – was the Upper Plenivistulian. The main supply from the melting snow cover in spring and permafrost active layer in summer caused significant flow variations (Bohncke et al., 1995; Mol, 1997; Mol

Table. **Results of TL dating of aeolian and fluvial deposits in Berezno site**
Lentelė. **Berezno vietovės eolinių ir fliuvialinių nuosėdų TL datos**

Sample	Depth (m)	Lab. No	Dr (Gy/ka)	ED (Gy)	TL age (ka BP)
Berezno-II/6	0.6	UG-6124	1.79 ± 0.06	16.8 ± 1.6	9.4 ± 1.2
Berezno-II/7	2.2	UG-6125	1.83 ± 0.06	21.6 ± 2.1	11.8 ± 1.3
Berezno-II/8	2.5	UG-6126	1.73 ± 0.06	21.9 ± 2.2	12.7 ± 1.3
Berezno-II/9	3.4	UG-6127	1.80 ± 0.07	21.6 ± 2.2	12.0 ± 1.1
Berezno-II/10	3.8	UG-6128	1.71 ± 0.06	25.0 ± 2.6	14.6 ± 1.5
Berezno-V/1	0.7	UG-6129	1.73 ± 0.06	21.1 ± 2.2	12.2 ± 1.3
Berezno-V/2	1.1	UG-6130	1.66 ± 0.07	20.1 ± 2.2	12.1 ± 1.3
Berezno-V/3	2.1	UG-6131	1.77 ± 0.06	22.3 ± 2.4	12.6 ± 1.5
Berezno-V/4	2.9	UG-6132	1.83 ± 0.06	22.9 ± 4.2	12.5 ± 2.3
Berezno-V/5	5.5	UG-6133	1.96 ± 0.08	29.7 ± 3.0	17.2 ± 1.8

et al., 2001; Vanderberghe, 2001). The severity of climate in this period is documented by the structures remaining after ice wedges and small-scale involutions which evidence the existence of permafrost. With all probability, the permafrost was aggregated following the flow withering. Another feature of severe climate is a large content of aeolized grains in alluvia. Periglacial conditions provided the background for an intensive aeolian process development. Sand was transported at a distance of tens or even hundreds of kilometres (Goździk, 1991, 2000). River valleys provided a natural trap for the material transported in such a way. It seems, however, compared to the conditions in Poland, that conditions in the profile under scrutiny were slightly milder, as suggested by a small percentage of polished rounded grains typical of rivers in a milder climate. This fact may be confirmed by the increasing content of EL grains in younger deposits (Fig. 5).

According to most researchers, climatic conditions in the Oldest Dryas seem to be very similar to the ones in the Plenivistulian (Rotnicki, 1970; Nowaczyk, Kozarski, 1991 a, b; Kozarski, 1995; Nowaczyk, 1986, 2000). Frost structures in Berezno clearly evidence severe climate, with the average annual temperature below −1 °C. Therefore, compared with the earlier period, the conditions improved insignificantly, which may be proved by the maximum content of EL grains in the sediments. This period was marked by the flow in episodic braided channels, accompanied by an intensive aeolian deposition. However, one should bear in mind that the dates obtained for these deposits show a continuation of the deposition in the Bölling; therefore, an improvement of conditions demonstrated by the increased content of EL grains is likely to reflect this period. Still another reason may be the fact that aeolian transport is supplied by deposits which form outwash valleys occurring in the close vicinity. The increased participation of the aeolian component in deposits from this period provides additional evidence.

Starting from the Older Dryas, the deposition of the aeolian layer took place in much milder conditions, with the average annual temperature of −1 °C and temperature in July reaching 10–12 °C in the Older Dryas and about 12 °C in the Younger Dryas (Nowaczyk, 1986, 2000; Nowaczyk, Kozarski, 1991 a, b; Kozarski, 1995; Huijzer, Vandenberghe, 1998; Kasse et al., 1998; Mol, 1997; Mol et al., 2000; Kasse et al., 2003; Van Huissteden et al., 2003). This is confirmed in sediments from Berezno by traces related to ground ice melting – reverse faults. However, they may also evidence the accumulation on snow (Schwan, 1986; Dijkmans, Mücher, 1989; Dijkmans, 1990; Lea, 1990). The intensification of aeolian processes is probably connected with a decrease in the groundwater level, which is supported by the definite predominance of accumulation on the dry surface (cf. Bohncke et al., 1995; Kase, 1997, 2002; Mol, 1997; Kase et al., 2003). At that time, aerodynamic conditions varied. Dusty material, transported in the suspension, was deposited by the weak wind, while the sandy material was deposited by the medium-velocity wind as a result of ripple migration, or by the high-velocity wind from the near-ground suspension (Pye, Tsoar, 1990; Borówka, 1991, 2000; Zieliński, Issmer, 2008). The wind direction also varied; however, ENE and NW directions were slightly predominant. The latter direction is confirmed by the orientation of dune forms deposited in the Younger Dryas and Preboreal. This orientation corresponds with the reconstruction of the overall atmospheric circulation in Europe (Isarin et al., 1997; Zeeberg, 1998).

CONCLUSIONS

1. Sediments in Berezno were accumulated in three depositional environments, in the periglacial climate conditions: a) in the fluvial environment connected with the functioning of a braided river; b) in the fluvio-aeolian environment, i. e. as a result of an intensive accumulation of aeolian sediments on the moist bottom of the river valley (outside the river channel zone), interrupted by the episodic channel flow; the flow was relatively short-term, while the channel deposition was to a large extent supplemented by aeolian accumulation; c) in the aeolian environment, which resulted in the formation of a thick aeolian cover in the first stage and dunes in the second stage.

2. Climatic changes caused changes in the depositional environments. The fluvial environment predominated in the Upper Plevistulian. Coming from this period, a commonly acknowledged high indicator of alluvium aeolization clearly indicates a high intensity of aeolian processes with a low depositional efficiency. The aeolian depositional efficiency increased in the Oldest Dryas which exerted a significant influence on the functioning of river channels, fluvio-aeolian deposition becoming evident in this period of time. Improvement of climatic conditions, degradation of the permafrost and transformation of braided channels into meandering channels activated a large amount of sandy material which contributed to the predominance of aeolian deposition.

3. The main alimentation areas of aeolian accumulation were braided river alluvia. Outwash valley deposits were of secondary importance.

4. The sedimentological analyses clearly show a significant influence of eastern wind on the process of aeolian cover formation. The direction from the western sector, in particular the NW wind which is most evident in the dune formation, should be considered general.

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NUOGULŲ SEKA BEREZNO VIETOVĖJE (VOLUINĖS POLESĖJE, UKRAINA) – SEDIMENTACINĖS APLINKOS POKYČIŲ PERIGLACIALINĖJE ZONOJE PAVYZDYS VISTULIANO IR HOLOCENO POKYČIŲ KONTEKSTE

Santrauka

Tyrimų objektas yra Europos smėlingosios juostos rytinė dalis – Berezno (Rytų Ukraina) vietovė Slucios upės dešiniajame krante esančioje aukštesniojoje terasoje, apimanti litologiniu požiūriu kaičias aliuvines nuogulas, jas dengiantį smėlį ir eolines dulkes. Naudojant litofacinę, granuliometrinę ir morfoskopinę analizę, taip pat TL datavimą aprašomos nuosėdinės storymės pagrindu buvo rekonstruotos ankstesnės sedimentacinės aplinkos, apibūdintos ir interpretuotos periglacialinės struktūros. Atskleistas salygų kaitos ir nuogulų sedimentacijos intensyvumo ryšys su drėgno klimato transformacijomis, taip pat bandyta išsiaiškinti vietinių veiksnių įtaką fliuvialinei, fliuvialinei-eoliniai bei eolinei sedimentogenezei. Nustatyta teritorijų priklausomybė eolinėms nuoguloms ir vyraujančiai vėjų krypčiai.

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ПОСЛЕДОВАТЕЛЬНОСТЬ ОТЛОЖЕНИЙ В БЕРЕЗНО (ВОЛЫНСКОЕ ПОЛЕСЬЕ, УКРАИНА) КАК ПРИМЕР ИЗМЕНЕНИЯ СЕДИМЕНТАЦИОННОЙ СРЕДЫ В ПЕРИГЛЯЦИАЛЬНОЙ ЗОНЕ В КОНТЕКСТЕ ВИСТУЛИАНСКИХ И ГОЛОЦЕНОВЫХ ИЗМЕНЕНИЙ

Резюме

Объект исследований – восточная часть европейского песчаного пояса с учетом позиции Березно (Восточная Украина), расположенной на правобережной высшей террасе реки Слуця. Представлена литологическая изменчивость аллювия, а также прикрывающих песков и эоловой пыли. На основе описанного осадочного наследования, путем литофациального, гранулометрического и морфоскопического анализа, а также TL датирования реконструированы первичные депозиционные среды. Представлены характеристики и интерпретация перигляциальных структур. На этой основе показана взаимозависимость перемен условий и темпа депозиции отложений и трансформации сурового климата плены и позднего вистулиана. Также предпринята попытка определить влияние местных факторов на флювиальную, флювиально-эоловую и эоловую депозицию, также показаны территории алиментации для эоловых отложений и доминирующие направления ветра.