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Age and main phases of accumulation of sediments in Nidzica valley bottom (Southern Poland)

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Polish loess areas belong to a belt that stretches from the French Atlantic coast to the Central European uplands, to the Urals. The loess covers consist of stratigraphically varied layers with a dominance of the Vistulian stratum. The object of this study is to understand ages and main phases of sediment accumulation in the Nidzica valley bottom. Paleogeographic interpretation of this sediments was adopted as the main method for the understanding of the Holocene development of the Nidzica valley. A detailed investigation was carried along a 19-km long mouth reach of the Nidzica valley, a left-hand side tributary of the Vistula valley, running through the Małopolska Upland.

Fieldwork and detailed laboratory data were analysed in order to characterise the sediments. A total of 30 boreholes were drilled, ranging along six valley bottom transects. Altogether, 385 samples of mineral and mineral-organic sediments were taken for laboratory analyses. The sediments were tested for granularity, calcium carbonate content and organic content. Four principal lithological series were identified based on the sediments found along the six valley transects: sandy-gravelly; fine-grained carbonate; mineral and organic; and mineral overbank deposits.

Based on the interpretation of the valley bottom sediments, the mouth reach of the Nidzica valley can be broken down into four main stages: late Vistulian; early Holocene and Mid-Holocene; late Atlantic and early Subboreal, and finally the Subatlantic period. Late Holocene sediment analysis suggests a diachronism of floodplain sediment build-up both during the Subboreal and the Subatlantic periods.

Key words: sediments, loess, sediment analysis, Nidzica valley

INTRODUCTION

Polish loess areas belong to a belt that stretches from the French Atlantic coast to the Central European uplands, to the Urals. The loess covers consist of stratigraphically varied layers with a dominance of the Vistulian stratum (Jersak, 1973). Since the termination of the eolian accumulation of loess in the upper Vistulian age, the loess cover has been subject to continuous degradation. Climate change and human activity played a crucial role in the change of the type and rates of morphogenetic processes and, consequently, in the supply of clastic material to the valley bottoms (e. g. Chotinski, Starkel, 1982; Kruk et al., 1996; Heine, Niller, 2003). In the past, research into valley evolution in the Polish loess areas focused mostly on short river valley reaches (Klatka, 1958; Kosmowska-Sufczyńska, 1983; Rutkowski, 1984; Harasimiuk et al., 2002), or on dry denudation valleys. The understanding of the larger valleys of the area, and especially of their mouth reaches, is still insufficient.

The object of this study is to understand ages and main phases of accumulation of the sediments in the Nidzica valley bottom. The paleogeographic interpretation of these sediments was adopted as the main method for the understanding of the Holocene development of the Nidzica valley.

STUDY AREA

A detailed investigation was carried along a 19-km long mouth reach of the Nidzica valley, a left-hand side tributary of the Vistula valley, running through the Małopolska Upland (Fig. 1). The river Nidzica (63 kilometres) drains a basin of 708 square kilometres. Quaternary sediments sit on Cretaceous limestones and marls in the northern part of the basin and on Miocene clay formations in the southern section. The Miocene formations are found at a depth of 6 to 15 metres in the centre of the valley reach studied. The mouth reach is located in the southern section of the basin which has experienced only one glaciation (San 2) and was outside the direct reach of the Scandinavian ice-sheet for the remaining part of the Pleistocene (Lindner, 1988). The loess formations which accumulated in the Małopolska Upland under periglacial climatic conditions (Dwucet, Śnieszko,

1995) vary in thickness and reach a maximum of 20 m deep, as found by drilling. The southern section of the drainage basin features an erosional-denudational land relief characterised by a very low resistance of the loess covers and a considerable anthropogenic transformation of the natural environment. Long-term archaeological studies suggest that this is one of the most anthropogenically transformed areas of the Polish loess uplands following the start of human settlement in the area during the Neolithic period at 6550 yr BP (Tunia, ed., 1997). This section of the Nidzica basin characteristically features broad and short ridges ranging between 210 to 263 m a. s. l. Denudational plains are commonly found on hill-tops and on the slopes whose gradients range from 7 to 35° and whose long profile is convex/concave. A dense network of denudational valleys (2.5 km/km^2) (Photo 1) is dominated by the bowl and flat-bottom types, while the slopes feature numerous anthropogenic forms, such as field roads and field terraces. Older terraces of Pleistocene origin are found at 4 to 18 m above the valley bottom on the valley sides, as well as on late-Vistulian remnant hummocks located in the valley bottom and rising up to 1.4–3.0 m high. The bulk of the valley bottom is occupied by the Holocene terrace which varies between 0.3 and 1.2 kilometres wide and contains the river Nidzica channel in the middle, trained along most of its length and with a dense network of drainage ditches on each side (Photo 2). The river has an average gradient of 0.17% and the average annual discharge of 2.63 m^3/s. Contemporary morphological processes include sheet-flow and linear erosion on the slopes and hill-tops and accumulation of deluvial and flood deposits causing build-up of the valley bottoms.

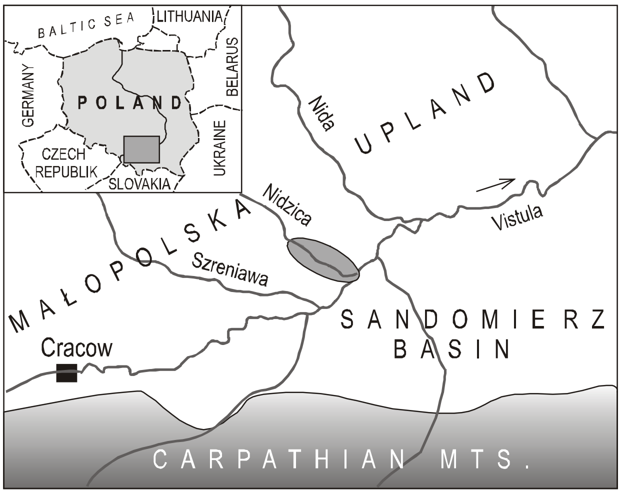

Fig. 1. Location of study area
1 pav. Tyrimų arealas

METHODS

Fieldwork and detailed laboratory data were analysed in order to characterise the sediments in the Nidzica valley bottom. A total of 30 boreholes were drilled, ranging between 2.8 and 7.7 metres deep, along six valley bottom transects (Fig. 2A). The transects were selected taking into account the specific features of valley width and relief. An Ejkelkamp Cobra 248 impact

Photo 1. Denudational valleys in the Nidzica river catchment (by J. Kościelniak)
1 nuotr. Denudacinis baseinėlis Nidzicos slėnyje

Photo 2. Channel of Nidzica river (by A. Michno)
2 nuotr. Nidzicos upės vaga

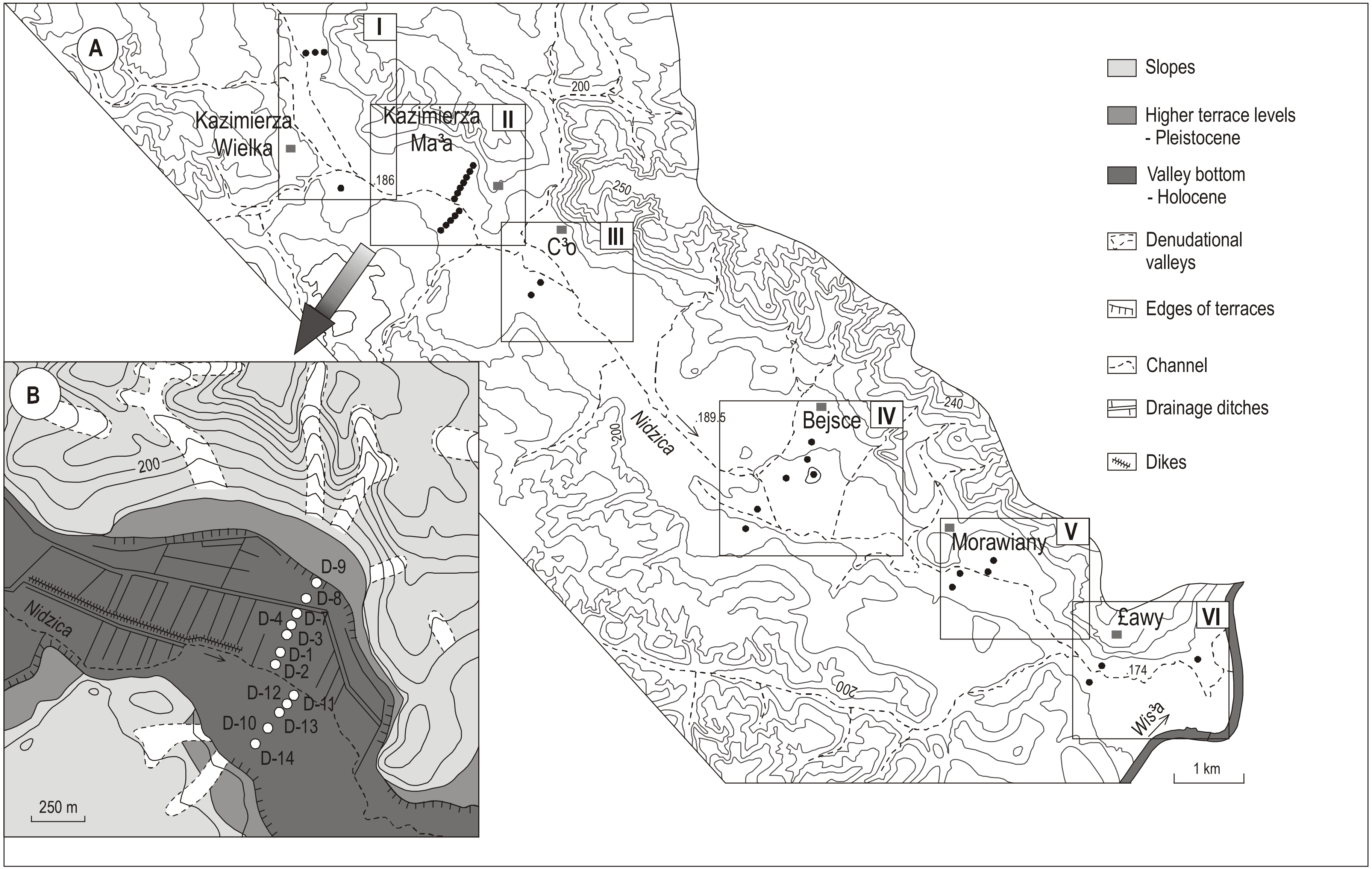

Fig. 2. Boreholes and study transects (*A*). Detailed location of boreholes on a geomorphological map: transec II – Kazimierza Mała (*B*)
2 pav. *A* – gręžinių vietos ir transektai. *B* – transektas II – Kazimierza Mała

Photo 3. Core probes of the diesel hammer drill (by H. Hajdukiewicz)
3 nuotr. Kalamojo grąžto antgaliai kernui imti

drilling machine was equipped with steel core samplers with diameters from 4 to 10 cm and length from 0.5 to 1.0 m (Photo 3). Altogether, 385 samples of mineral and mineral-organic sediments were taken for laboratory analyses, but the number of samples in each well differed depending on the textural and structural features of the sediment being sampled. The sediments were tested for granularity, calcium carbonate content and organic content. Granularities above 1 mm were determined by screening and those below 1 mm using the Fritsch Analysette 22 Comfort laser particle meter. This sediment analysis was used to identify four lithological series. The statistical parameters of the granularity distribution were calculated using the Siewca 2.0 software package (Folk, Ward, 1957). To determine the sediment age, 12 peat samples were taken. Carbon dating was performed at the Institute of Physics of the Silesian University of Technology in Gliwice, at the Radiocarbon Laboratory in Kiev, Ukraine, and at La Sapienza University in Rome.

RESULTS AND INTERPRETATION: TRANSECT II – KAZIMIERZA MAŁA

The deposits were characterised along six valley reaches describing the ranges of thickness, granularity and the content of carbonate and organic matter. Particular attention was paid to the incidence of fossil erosional forms, variations in sediment granularity within each drill sample and in valley bottom cross-sections, the influence of the width and relief of the valley bottom on the rates and patterns of aggradation, and the age of mineral and organic sediments and their links with Holocene climate change and with human settlement.

The fullest picture of the sedimentological diversity in the Nidzica valley bottom is provided by transects near Kazimierza Mała (transect II, Fig. 2B). Altogether, 12 boreholes were drilled along the Kazimierza Mała transect, ranging between 2.8 and 7.7 m deep. This paper presents a detailed lithological breakdown of the sediments of two boreholes: D-2 and D-4.

Well D-2 was 7 metres deep and 30 metres away from the contemporary Nidzica river channel. The drilling stopped short of the Miocene formations, and the lithological profile in the sample begins with a minimum of 2 m of sandy gravels. This layer reaches up to 5 m below the contemporary valley bottom. The formation contains medium and poorly sorted material (δ_1 0.1) transported mainly by saltation (Mz 0.5). The sediment contains ca. 24% of sand (Fig. 3), as well as Scandinavian porphyry and granite material. Above the sandy gravels there are fine-grained sediments which can be broken down into three groups. Directly on the top of the previous formation lie regular silts and clayey silts of a combined thickness of 2.10 m. This formation is characterised by the grey colour and a considerable content of calcium carbonate (up to 13.8% at the ceiling level). The sediment is of a suspension type (Mz from 4.6 to 4.9). The second group of sediments is 1.73 m thick and consists of mineral and organic material, namely black and dark-brown clay, with up to 10% of sand, i. e. is poorly sorted (δ_1 from 1.1 to 2.1). The mean size of the grains (Mz from 5.7 to 7.7) and skewness (Sk from –0.1 to +0.4) indicate a suspended matter transport mode and then re-deposition in the valley bottom. The clayey sediments contain a varied concentration of $CaCO_3$ (from 0.8% to 10.4%) and organic matter (from 1.4% to 18.2%). The organic matter is a 8–15 cm peat layer which is mostly decayed. The peat was dated to 1650 ± 150 yr BP (at 2.40 m), 1410 ± 70 yr BP (at 1.27 m), and 1060 ± 70 yr BP (at 1.18 m). The top layer of sediments sampled at well D-2 includes brown clayey silt, silty clay and, at the ceiling level, silt of a combined thickness of 1.17 m (mineral overbank deposits). The entire formation is poorly sorted and characterised by a low concentration of carbonates (ca. 4%) and organic matter (up to 0.4%). The formation also features an inverted granularity sequence with a much more clayey fraction and up to 12% of sand at the ceiling level.

Well D-4 was 6 m deep and nearly 200 m from the Nidzica channel. This profile mainly contains coarse-grained material (gravel and sand). The two are interspersed with fine grained sediments ranging from 2 to 17 cm in thickness (Fig. 4). The composition of the mean size of the coarse-grained material (Mz from 0.4 to 0.6) suggests that these are channel sediments transported by creeping. The sediments contain Scandinavian porphyry and granite, just as in D-2, and their ceiling is very shallow at 0.7 m below the valley bottom ground level.

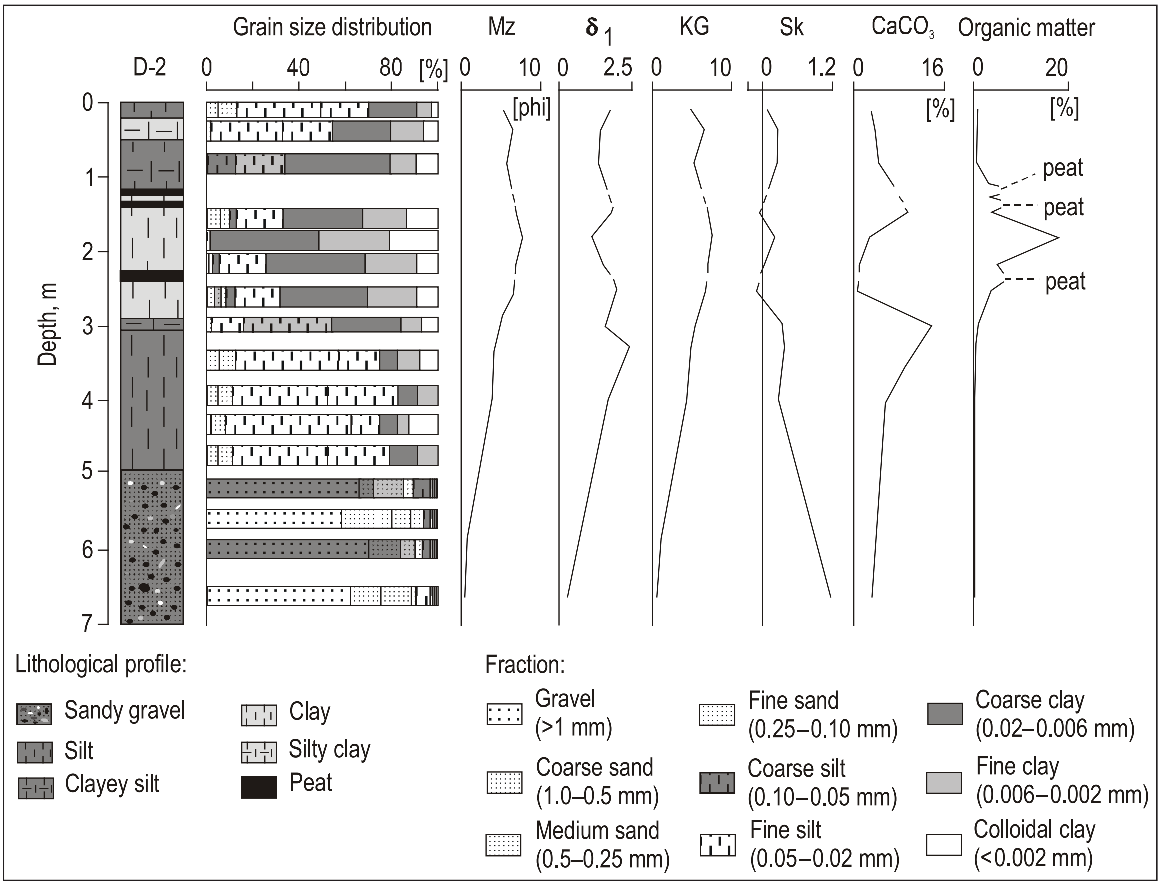

Fig. 3. Lithology of the sedimentary samples drilled from boreholes D-2
3 pav. D-2 gręžinio nuosėdų pavyzdžiai

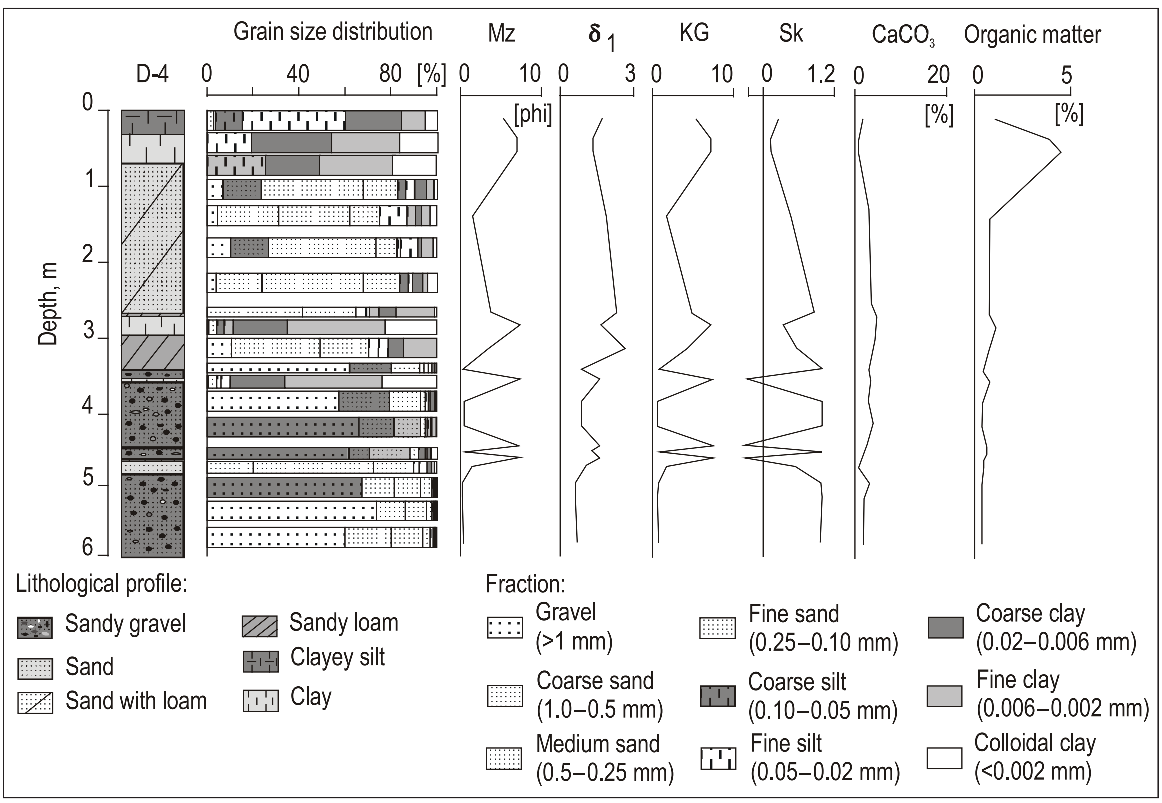

Fig. 4. Lithology of the sedimentary samples drilled from boreholes D-4
4 pav. D-4 gręžinio nuosėdų pavyzdžiai

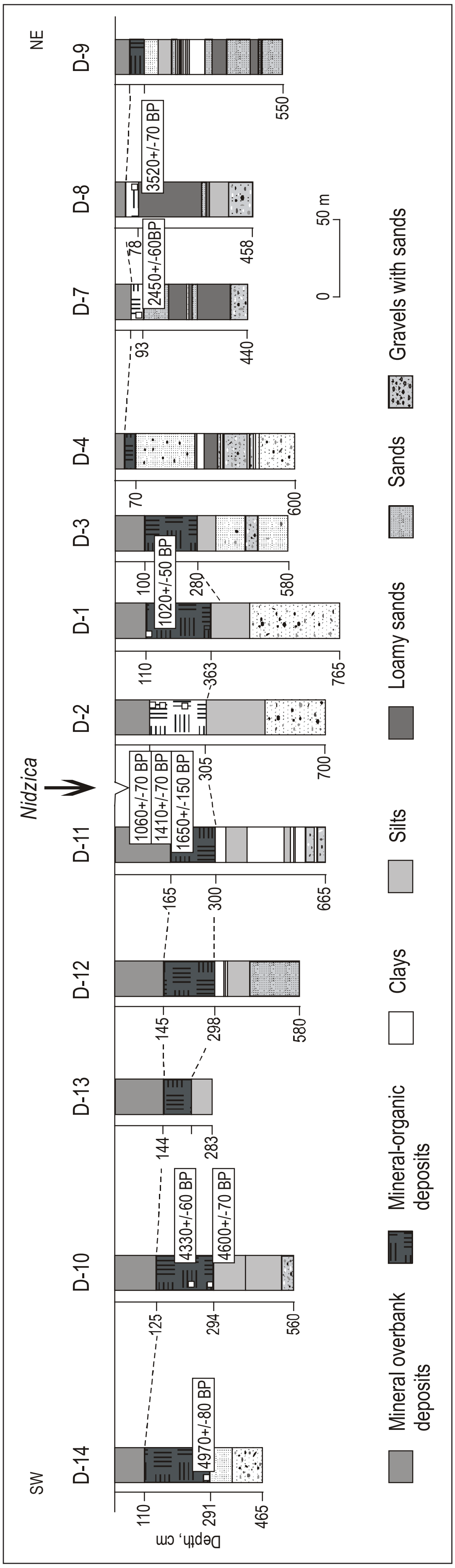

Fig. 5. A simplified transcet of the Nidzica valley bottom near Kazimierza Mała; transect II
5 pav. Nidzicos slėnio prie Kazimierza Mała schematizuotas II transekto vaizdas

The top layer of the D-4 sample contains fine-grained formations that can be divided into two groups. The lower of the two is a 38-centimetre thick layer of black clay with up to 5% of organic matter. On top of it lies a 32-centimetre layer of brown clayey silt.

A detailed analysis of sediments in the Nidzica valley bottom near Kazimierza Mała revealed coarse-grained sediments (including gravel, sandy-gravel and sand) with ceilings at various depths ranging from 0.7 m (profile D-4) to 5.2 m (profile D-10). These formations are found to be buried the deepest near the contemporary Nidzica channel and on the right-hand side of the floodplain (Fig. 5). Their most shallow occurrence was found along the D-4, D-7, D-8 and D-9 profiles where the granularity variation was also the greatest as the coarse-grained sediments were interspersed with sandy or even silty-clayey layers. The latter three drilling profiles were located within a fossil erosional remnant buried entirely in younger sediments. The fine-grained formations found in the valley featured various thicknesses and concentrations of carbonates and organic matter. Grey-coloured fine-grained formations with significant carbonate concentrations (up to 38.4%) are commonly found directly on top of the coarse-grained sediments. Typically, these are silt layers with a thickness ranging from 0.3 m (profile D-3) to 3.0 m (profile D-11), the only exception being drilling profiles in the fossil erosional remnant (D-4 to D-9) where these sediments are not clearly visible in the lithological profile. In all the profiles sampled near Kazimierza Mała there is a distinct occurrence of mineral-organic sediments ranging from 0.3 to 2.5 m in thickness. The organic component consists of well-degraded peat (5–18 cm thick) at various depths (from 0.7 m to 2.9 m). Carbon dating suggests a different timing of peat accumulation in various parts of the valley – from 4970 ± 80 yr BP (profile D-14) to 1020 ± 50 yr BP (profile D-1). On the top of the mineral-organic sediments lie brown-coloured fine-grained sediments, primarily silts (mineral overbank deposits), typically structureless, building a valley cover from 0.3 to 1.65 m thick.

Fine-grained sediments of various colours and carbonate and organic concentrations lie on top of older fossil fluvial landforms (erosional remnants and terraces). This suggests a strong impact of valley bottom relief on aggradation rates and patterns. The nature and sequence of sediments found in the samples suggests a lateral contact of sediments developed at different times and in different sedimentation environments (channel and overbank faciae, and organic sediments).

INTERPRETATION OF THE MAIN LITHOLOGICAL SERIES

Four principal lithological series were identified based on the sediments found along the six Nidzica valley transects: sandy-gravelly, fine-grained carbonate, mineral and organic, and mineral overbank deposits.

Sandy-gravely sediments

The coarse-grained series of sediments in the Nidzica valley bottom mainly consists of poorly consolidated gravels and sands (Photo 4). These sediments contain rounded pebbles of carbonate rocks, mainly marls, with a diameter up to 4 centimetres, as well as quartzite and sandstone. The overall thickness

Photo 4. Sandy-gravely sediments (by A. Michno)
4 nuotr. Smėlio ir žvirgždo nuogulos

of these formations, as found by sample drilling, varies from 0.4 m to 3.5 m. The low mean grain size (Mz up to 0.6) suggests that these are bedload material transported by creep and saltation. The sandy-gravelly sediments also contain Scandinavian material, mainly porphyry and granite. The ceiling of the coarse-grained sediments studied ranged greatly from 0.4 to 5.2 m below ground and were found to occur at its shallowest point on the left-hand side of the Nidzica channel and at its deepest point in the central section of the floodplain.

Fine-grained carbonate sediments
Fine-grained carbonate formations with $CaCO_3$ concentrations from 6.2 to 38.4% are commonly found on top of the coarse-grained sediments. Carbonate sediments are typified by their structureless section and varied thickness ranging from ca. 0.3 to 3.0 m (Photo 5). They are poorly sorted (δ_1 from 1.6 to 2.0) and mostly consist of silt or silty clay, while the mode of their transportation is principally as suspended matter (Mz from 5.1 to 7.55). They are the oldest group of overbank sediments in the Nidzica valley, and their considerable carbonate concentrations are explained by secondary enrichment with carbonate compounds leached away from the covers of the drainage basin in warm and humid climatic conditions.

Mineral-organic sediments
The mineral-organic sediments are characterised by their limited granularity differences across the vertical profile. They typically take the form of black and dark-brown clay or silty clay with a structure invisible to the naked eye. The sediments consist of mineral quartz grains, amorphous organic matter and pelitic $CaCO_3$. The proportions of these different components vary considerably between drillings, but the clastic content always exceeds 50%. The mean grain sizes suggest that these are mainly sediments transported in a suspended form (Mz from 5.2 to 8.1). However, the thin sand or gravel layers a few centimetres thick found interspersed with these mineral-organic sediments suggest a periodic supply of coarser material onto the floodplain. The negative values of skewness (Sk) calculated for certain samples suggest re-deposition and washing away of deposits on the floodplain. The thickness of the mineral organic sediments varies along the valley bottom from dozens of centimetres to more than 2 m, and they are mostly found more than one metre below the contemporary valley bottom surface. This pattern only changes around fossil erosional forms where the formation tends to be much thinner and comes quite close to the surface. The sediment is also missing altogether in erosional remnants raised above the valley bottom. Peat deposits,
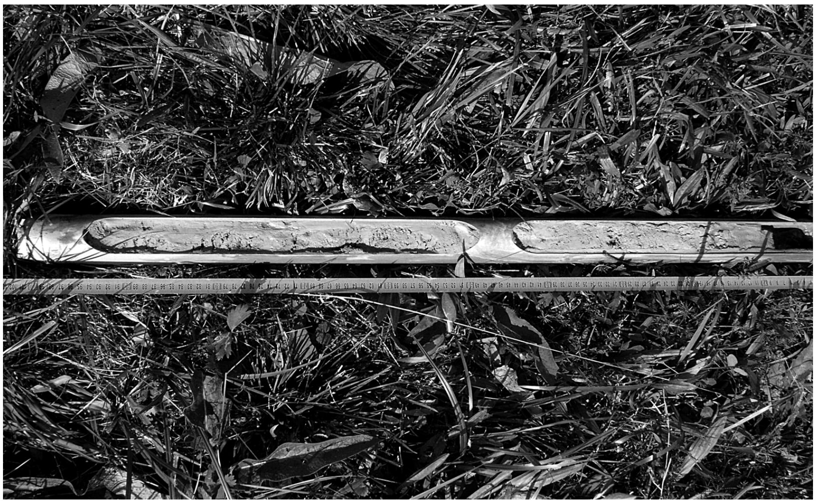
Photo 5. Fine-grained carbonate sediments (by A. Michno)
5 nuotr. Susmulkintos karbonatingos nuogulos

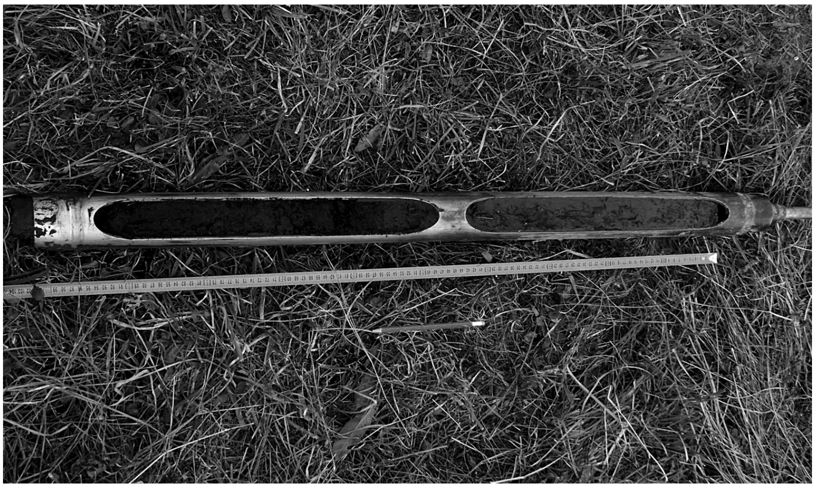

Photo 6. Mineral-organic sediments (by A. Michno)
6 nuotr. Mišrios mineralinės-organinės nuogulos

Table. **Results of peat radiocarbon dating**
Lentelė. **Radiokarboninio datavimo rezultatai**

Borehole profile	Sample depth (m)	Dates ^{14}C yr BP	Laboratory, No.
D-1	1.12	1020 ± 50	Rome – 1334
D-2	1.18	1060 ± 70	Kiev, Ki – 9795
D-2	1.27	1410 ± 70	Gliwice, Gd – 12257
D-2	2.40	1650 ± 150	Gliwice, Gd – 16053
D-7	0.82	2450 ± 60	Rome – 1332
D-8	0.70	3520 ± 70	Kiev, Ki – 10061
D-10	2.93	4600 ± 70	Rome – 1333
D-10	2.40	4330 ± 60	Rome – 1335
D-14	2.90	4970 ± 80	Kiev, Ki – 10062
C-2	1.07	1950 ± 70	Kiev, Ki – 9796
B-3	1.12	3150 ± 60	Kiev, Ki – 9797
M-4	1.06	510 ± 80	Kiev, Ki – 9798

ranging from 3 to 20 cm in thickness, are found within the mineral-organic formations (Photo 6). The peat has decayed considerably and occurs in the form of patches that laterally transit into clastic deposits. Peat deposits vary in depth (0.7–2.9 m) and age between profiles (Table). The earliest accumulation of peat was carbon dated to ca. 4970 ± 80 yr BP (near Kazimierza Mała, Transect II). Elsewhere, the oldest peat deposits were dated at 3150 ± 60 yr BP (near Bejsce, Transect IV), while the youngest deposit is only 510 ± 80 yr BP old (near Morawiany, Transect V), but it lies at 106 cm below the ground under mineral overbank deposits. This range of different ages and locations of peat suggests a considerable diversity in the valley bottom relief, as well as the rates and patterns of aggradation. The floodplain, which to this day has a very gradual slope, may have provided the right conditions for peat bog development in some places, while flood deposits or multiple re-deposited proluvia accumulated elsewhere.

The mineral-organic and peat sediments are not found in samples taken near Ławy (Transect VI, Fig. 2A). Downstream from this point the river enters the Vistula valley whose channel cut into the Małopolska Upland during the Pleistocene (Starkel, 2001). In samples taken along this reach, one only finds the carbonate-free sands and gravels of accumulation derived from the Vistula below floodplain sediments (overbank deposits). The steeper valley gradient along this reach and a deeper incision of the Nidzica channel (due to the proximity to the base of erosion) were not conducive to a long-lasting water and sediment retention or to the development of marshes in the floodplain. This would suggest that following several stages of downcutting that occurred late in the Vistulian period and early in the Holocene, the Nidzica reach downstream from Ławy developed under a strong influence of fluvial processes in the Vistula valley (the impact of a lowering of the erosion base and alluvial accumulation from the Vistula). Upstream from Ławy, on the other hand, sedimentation was strongly influenced by of the basin relief, including the numerous denudational planation levels, flat and broad bottoms of side valleys.

Mineral overbank deposits

Fine-grained formations of mineral overbank deposits are found on top of the mineral-organic sediments. Typically taking the form of clayey silt or silty clay, these sediments line the entire width of the valley bottom with a layer ranging from 0.3 m to 1.65 m. The finding of the thickest layers in samples close to the current Nidzica channel suggests a higher aggradation rate in the proximal floodplain than in the distal floodplain. The formation is the thinnest in profiles taken from fossil erosional forms and disappears altogether from the sequence on erosional remnants rising above the contemporary accumulational valley bottom (Transect IV, Bejsce). The beginning of the proximal mineral accumulation in the Nidzica valley varies from reach to reach. It started earliest near Kazimierza Mała (Transect II), i. e. ca. 1000 yr BP, while near Morawiany (Transect V) it only began ca 510 yr BP. The rates of deposition were slow, but also varied: from 20 cm per 100 years near Morawiany (where ca. 1 m was deposited over 500 years), to 10 cm per 100 years near Kazimierza Mała (Transect II) and to 5 cm per 100 years near Cło (Transect III). The mean grain sizes (Mz from 4.6 to 8.6) suggest suspended transport. There is a strong correlation between the falling mean grain size and the falling degree of their sorting, suggesting a deposition environment favouring sorting and re-deposition of sediments over the floodplain

Photo 7. Mineral overbank sediments (by A. Michno)
7 nuotr. Mineralinės salpos nuogulos

(Michno, 2004). The mineral overbank deposit sediments are not uniform in their origin and include both floodplain accumulation sediments and proluvia supplied directly from the valley sides. Overall, this lithological series is poorly or very poorly sorted (δ_1 from 1.2 to 2.5). It contains up to 10.2% $CaCO_3$, with its highest concentration at the bottom of the series. The reverse pattern is true of the organic matter concentration, i. e. from 0.2% at the bottom to 4% at the top of the series. The mineral overbank deposits began to accumulate in a wet valley bottom environment (with gleyic properties), but the floodplain buildup rate gradually surpassed that of the groundwater table. Mineral overbank deposits are typified by their structureless build or weak lamination in the top sections (Photo 7). The massive structure of the sediment is secondary in origin and comes from soil processes and bioturbation. The mineral overbank deposits have an inverted granularity sequence with much more of a coarse fraction in the top of the series.

THE EVOLUTION OF THE NIDZICA VALLEY DURING THE HOLOCENE IN THE LIGHT VALLEY BOTTOM DEPOSITS

Based on the interpretation of the valley bottom sediments, the mouth reach of the Nidzica valley can be broken down into four main stages: late-Vistulian, early Holocene and Mid-Holocene, late-Atlantic and early Subboreal, and finally the Subatlantic period (Fig. 6). During the late Vistulian stage, the valley experienced several stages of downcutting that produced the fossil erosional forms seen today. The deepest drilled samples reached into the early Holocene Nidzica valley bottom, but even these samples revealed, at their bottom, coarse-grained Pleistocene sediments suggesting that the erosion had failed to cut through into Miocene formations. Erosion activity in the Nidzica valley is clearly linked to late-glacial erosion phases known from the Vistula valley (Kalicki, 1991).

The least is known about the development of this Nidzica valley reach during the Lower Holocene and Middle Holocene (Preboreal, Boreal and Atlantic periods). Indeed, no paleochannels or organic sediments were found dating to these periods. The enrichment of the fine-grained sediments topping the Pleistocene gravels and sands with carbonates suggests an intensive leaching process in the covers of the drainage basin, occurring under warm and humid climatic conditions. The lack of dating makes it impossible to determine the stratigraphy of these formations. No Lower Holocene floodplains survive in the Nidzica valley, in contrast to the situation in the Vistula valley, since all the older accumulation plains of floodplain sediments are buried beneath younger sediments. This fact indicates a continued trend to aggradation in the Nidzica valley bottom, which is further confirmed by a fluctuation in the types and rates of fluvial processes occurring in the large transit Vistula valley (with its frequent channel avulsion) and its small tributary valley. The variation comes from the nature of the local environment (including the valley size, basin relief, valley gradient and hydrological regimen), which determines the different timing and type of the response of fluvial processes to changes in the natural environment.

Mineral-organic and peat accumulation began in the Nidzica valley towards the end of the Atlantic period. This represented a clear-cut shift as a result of climatic change and anthropogenic changes in the environment. Indeed, the end of the Atlantic period coincides with a marked increase of temperature and humidity. This precipitated changes in vegetation communities and an increased frequency of flooding in large river valleys (Starkel, 1983; Ralska-Jasiewiczowa, 1991; Starkel, Ralska-Jasiewiczowa, 1991). In smaller and more gradual valleys, the greater humidity raised water tables in the floodplains and caused them to turn into marshes. During the Atlantic period, the loess uplands of today's Poland experienced the development of stable settlement and the spread of agriculture (Neolithic settlement). Crop farming was concentrated on hilltops and upper slope sections contributing to an increased rate of mechanical denudation of the slopes, primarily through linear erosion and sheet flow. These slope processes were linked to deluvial and floodplain accumulation in the valleys (Śnieszko, Grygierczyk, 1991; Śnieszko, 1996). Research into older and contemporary deluvial covers on the Polish loess uplands points to selective slope denudation and to significant modifications of the physico-chemical parameters of sediments deposited at the foot of the slopes and in the valley bottoms (Śnieszko, 1995;

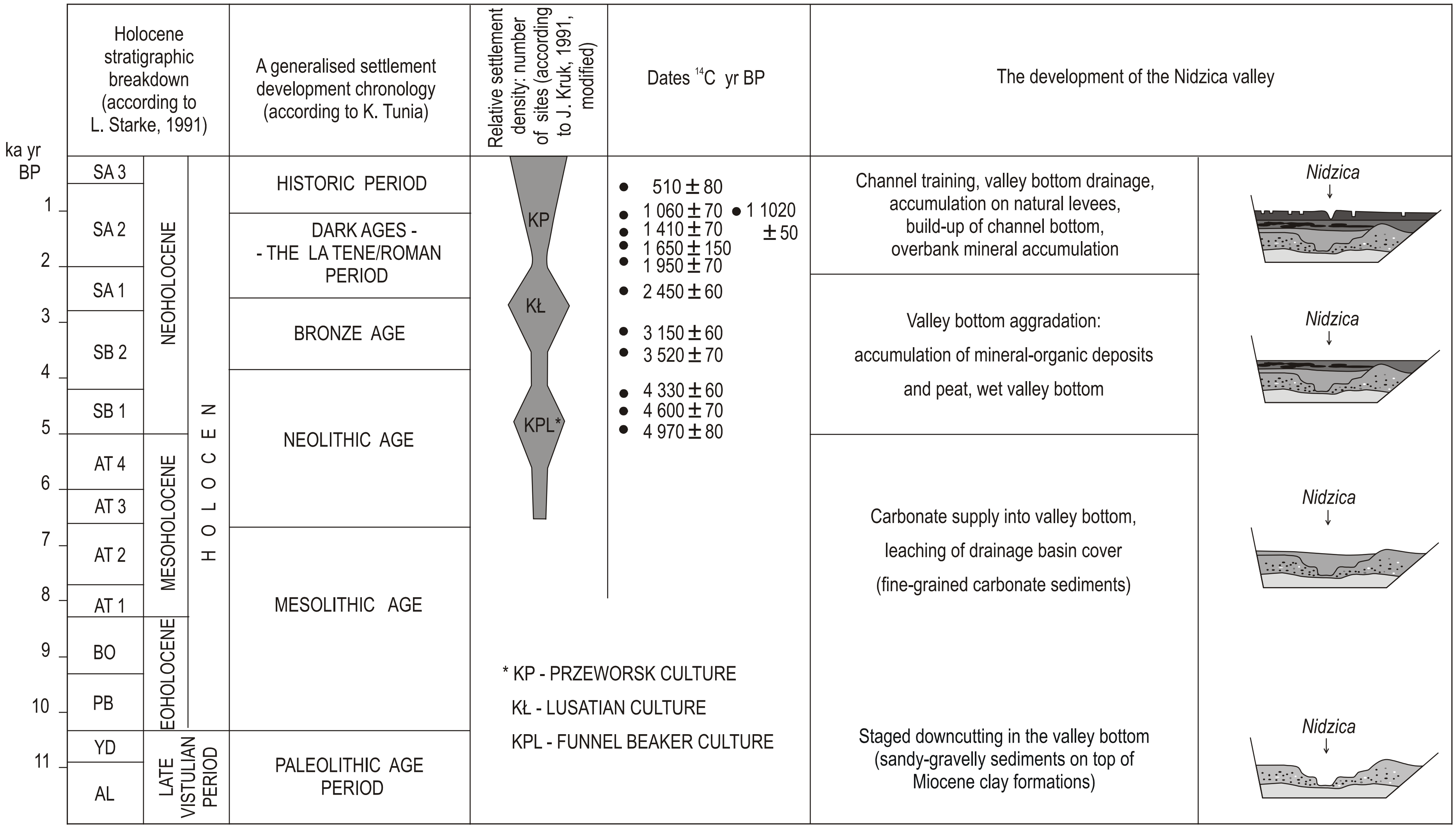

Fig. 6. Major stages in the development of the Nidzica valley – a schematic chart
6 pav. Svarbiausi Nidzicos slėnio raidos etapai

Dwucet, Śnieszko, 1997). The past and present land relief in the southern section of the drainage basin caused a staged pattern of sediment transport in the basin. This type of strong influence of the basin relief on the thickness and age of accumulated sediments has also been found in loess areas elsewhere in Europe (e. g. Rommens et al., 2006). The gradual slopes of the Nidzica basin, together with the existence of denudational plains and field terraces, restrict the direct supply of sediments into the valley bottoms. Material denuded on the slopes is retained on flat parts of the slopes and in the bottoms of denudational valleys. The broad accumulational valley bottoms, in turn, restrict direct supply of the material into the river channel. Indeed, due to the relatively gradual bottoms of the side valleys, the sediments are generally accumulated within them, and only during major hydro-meteorological events they do travel over longer distances. In the end, a large portion of the sediments denuded from the slopes remains within the side valleys, and the smaller quantities that make it through to the main valley do so after a considerable delay, especially in the mouth reach.

Accumulation of the mineral-organic formations continued in certain sections of the Nidzica valley until the Subatlantic period when the youngest anthropogenic sedimentation of the mineral overbank deposits began. Around Cło (Transect III) this accumulation began during the La Tène and Roman periods, while around Morawiany the shift from mineral-organic to mineral occurred only in the 16th c. A similar acceleration of mechanical denudation on the slopes and accumulation of mineral sediments in the valley bottoms occurred during the La Tène and Roman periods, in the Dark Ages, and later this was also identified in other areas in southern Poland and elsewhere in Europe (e. g. Śnieszko, 1985; 1991; 1995; Chiverrell et al., 2004; Dotterweich 2005; Macaire et al., 2006; Vanwalleghem et al., 2006). These two processes were caused by a distinct expansion of settlement, field area, development of field roads and a gradual stabilisation of the socio-economic systems (Tunia ed., 1997). This mineral accumulation was only curbed in the 19th c. by river training and the building of embankments (Michno, 2004).

Late Holocene sediment analysis suggests a diachronism of floodplain sediment build-up both during the Subboreal and the Subatlantic periods. Studies of the Nidzica valley north of Kazimierza Wielka reveal that the shift from mineral-organic into mineral overbank deposits accumulation began as early as ca. 3460 yr BP (Śnieszko, 1987; 1995). In the study reach, this stage was reached much later, e. g. ca. 1000 yr BP at Kazimierza Mała (Transect II), and only in ca. 500 yr BP near Morawiany (Transect V). The diachronism of the floodplain sedimentation was also reported in other valleys of Małopolska Upland, including the valleys of the Rudawa (Pazdur, Rutkowski, 1987), the Prądnik (Alexandrowicz, 1988) and the Racławka (Rutkowski, 1991). Elsewhere in Europe, the same phenomenon was found in the English Perry valley (Brown, 1990) and the Lower Saxonian valleys of Germany (Hagedorn, Rother, 1992). These patterns fit with the river continuum model known from the literature, whereby the record of an event or a series of events may vary at different points of the river. The record of climate change or human activity is also clearly dependent on the location of the profile of the floodplain analysed.

CONCLUSIONS

1. The Holocene bottom of the Nidzica valley consists of floodplain mineral and organic sediments built on late-Vistulian erosional levels. This suggests that the Nidzica valley bottom was aggrading during the Holocene. The deep incision of the Nidzica channel during the late Vistulian period, caused by down-cutting in the Vistula channel and a resulting lowered erosion base, restricted the channel's lateral migration. Only a short valley reach, located downstream of Ławy, developed under a strong influence of the Vistula's fluvial processes.

2. The shape of the valley bottom sediments indicates a material impact of the floodplain width on its aggradation rate and pattern. Differences in the development of the different sections of the floodplain are accentuated by the differences in the thickness of the main lithological formations and the side-by-side occurrence of sediments of different ages and sedimentation environments.

3. The land relief of the southern section of the Nidzica basin has long caused sediments to build up where the slope flattens and in side valleys. For this reason, many of the sediments are retained within tributary valleys, while a smaller proportion reaches the main valley bottom, and even this with a delay, especially in the mouth reach.

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PAGRINDINĖS NUOGULŲ SEDIMENTACIJOS FAZĖS IR JŲ AMŽIUS NIDZICOS SLĖNYJE (PIETŲ LENKIJA)

Santrauka

Lenkijos liosų nuogulos – tai plačios juostos, besitęsiančios nuo Atlanto vandenyno Prancūzijos pakrantėje per Vidurio Europos aukštumas iki Uralo kalnų, segmentas. Liosų dangą sudaro gana įvairūs stratigrafiniai sluoksniai, kuriuose vyrauja Vyslos laikmečio nuogulos. Nuo tada, kai

baigėsi vėlyvosios Vyslos laikmečio liosų dangos akumuliacija, jų storymę nuolat veikė degradacijos procesai, vienas iš jų – fliuvialinė paviršiaus transformacija. Pristatomo tyrimo tikslas – nustatyti ir įvertinti pagrindines nuogulų sedimentacijos fazes ir jų amžių Nidzicos slėnyje, kuris yra Pietų Lenkijos liosų aukštumose. Paleogeografinė nuogulų kilmės ir amžiaus interpretacija padėjo įvertinti Nidzicos slėnio raidos ypatumus holoceno metu.

Remiantis lauko tyrimų ir laboratorinių analizių duomenimis, buvo įvertintos Nidzicos upės slėnyje susikaupusios nuogulos. Tyrimų metu tolygiai išgręžta 30 gręžinių šešiuose išilginiuose slėnio transektuose – nuo 2,8 iki 7,7 metrų gylio. Išilginiai slėnio transektai išskirti atlikus specialius slėnio plotį bei jo reljefo struktūrą apibūdinančius matavimus ir skaičiavimus. Išilginiame Nidzicos slėnio profilyje išskirti keturi litologiniai nuogulų kompleksai: smėlio-žvirgždo, išrūšiuotų karbonatinių uolienų apvalainukų, mišrių mineralinių ir organinių nuogulų, mineralinių uolienų sąnašynų.

Slėnio nuogulų analizė leidžia daryti prielaidą, kad Nidzicos slėnio formavimas apėmė keturias stadijas: vėlyvosios Vyslos, ankstyvojo ir vidurinio holoceno, vėlyvojo atlančio ir ankstyvojo subborealio bei subatlančio. Vėlyvosios Vyslos stadijos metu vyko keli slėnio gilinimo etapai, per kuriuos susidarė dabar matomos senosios erozinės reljefo formos. Giliausiai Nidzicos slėnis buvo įsigraužęs ankstyvajame holocene. Atodangose matomos to laikotarpio gerai apgludintos nuogulos rodo, kad vaga graužėsi į mioceno darinius. Paskutinis gilinamosios erozijos suaktyvėjimas glaudžiai siejasi su vėlyvojo ledynmečio erozijos faze, ryškiai pasireiškusia Vyslos slėnyje.

Vėlyvojo holoceno nuogulų analizė rodo, kad slėnio salpos formavosi subborelyje ir subatlantyje. Šiauriau Kazimierza Wielka miesto atlikus tyrimus upės slėnyje paaiškėjo, kad mineralinės-organinės medžiagos akumuliacija salpoje prasidėjo anksčiau nei 3460 metais prieš mūsų erą. Ties Kazimierza Mala tokios medžiagos akumuliacija prasidėjo vėliau – maždaug 1000 metais prieš mūsų erą, o ties Morowiany – tik 500 metais prieš mūsų erą. Salpų formavimasis dviem etapais būdingas ir kitų Mažosios Lenkijos aukštumos upių slėniams (Rudawa, Prądnik, Raclawka). Panašūs reiškiniai Europoje užfiksuoti English Perry slėnyje Škotijoje bei Žemutinės Saksonijos upių slėniuose Vokietijoje. Tokie slėnių raidos modeliai leidžia susieti išilginių salpų profilių padėtį su vykusia klimato kaita bei žmonių veikla.

Holocenines Nidzicos slėnio dugno nuogulas sudaro aliuvinės bei organogeninės, kurios siejamos su vėlyvosios Vyslos erozijos baze. Tai liudija, kad Nidzicos slėnio dugnas kilo visą holoceną. Giliausiai Nidzicos slėnis buvo įsirėžęs vėlyvosios Vyslos laikotarpiu. Tą lėmė pačios Vyslos upės įsirėžimas ir erozijos bazės pažemėjimas, sustabdęs šoninę vagos eroziją. Trumpų upių, tokių kaip Lawa, slėnių raidai didelį poveikį turėjo Vyslos slėnyje vykstantys fliuvialiniai procesai.

Slėnio nuogulų tekstūrose matyti slėnio pločio pokyčiai, agradacinių procesų intensyvumas ir slėnio struktūros. Atskirų slėnio atkarpų raidą atspindi pagrindinių litologinių darinių storymės kaita, įvairiaamžių nuogulų slūgsojimo pobūdis bei sedimentacinės aplinkos pokyčiai.

Pietinėje Nidzicos baseino dalyje ilgą laiką kaupėsi nuogulos, labai sulėkštinusios vidinius slėnio šlaitus. Be to, Nidzicos slėnio nuogulos yra glaudžiai susijusios su intakais, kurių nešmenys formavo slapos nuogulas, – tai labai aiškiai matyti intakų žiočių aplinkoje.