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AGE OF TERRACE LEVELS AND PALAEOMEANDER SYSTEMS IN THE LIGHT OF OVERESTIMATED RADIOCARBON DATINGS (THE CASE STUDY OF THE DNIESTER RIVER VALLEY, WEST UKRAINE)

Abstract: In the Dniester valley within the Halyč-Bukačivci Basin, there are the Late Vistulian terrace, 6.5–5.5 m high (above the riverbed), large palaeomeander from the Late Vistulian decline (Younger Dryas) and two Holocene terraces 4–5 m and 3–4 m high. The results of conventional radiocarbon dating admittedly indicate a consistent and logical arrangement from the oldest dates (13.01–12.45 ka BP) for the Late Vistulian terrace and the large palaeomeander to more and more younger ones (8.6–7.89 ka BP) for the distinguished systems of the Holocene palaeomeanders; however, they are generally significantly older compared with findings from palynological analyses. The overestimation of the age of sediments is much greater for the Subboreal and Subatlantic generations of palaeomeanders than for the Late Vistulian large palaeomeander of the Dniester river. The error of radiocarbon dates may be caused by the admixture of older re-deposited organic material or, more likely in the case of the profiles concerned, by the reservoir effect (hard water effect) associated with the presence of old carbonates. Based on the presented analysis, there is a reasonable supposition that some of the existing radiocarbon dating of the Late Vistulian palaeomeander fills may be significantly overestimated.

Key words: old radiocarbon dates, palaeomeanders, palynological analysis, Dniester River

INTRODUCTION

In order to reconstruct the evolution stages of fluvial systems, it is important to discern the generations of palaeochannels, determine their morphometric characteristics and, if possible, provide precise dating measurements. The ages of fluvial forms and chronostratigraphy of Late Vistulian and Holocene alluvial fills are based on radiocarbon dating, the results of which are usually verified by pollen analysis (Starkel 1981; Kozarski et al. 1988; Starkel, Granoszewski 1995; Kasse et al. 2005; Kalicki 2006; Borisova et al. 2006;

Gębica et al. 2009; Wójcicki 2013; Kołaczek et al. 2017; Gerlach et al. 2019). By dating the base of palaeomeander fill sediments it is possible to determine the time of its cut-off, which in fact occurred slightly earlier than indicated by the radiocarbon date (Starkel 2002). The accuracy of the radiocarbon dating depends on the error of the method itself (conventional, AMS dating), type of sample (bulk sample in the case of conventional ^{14}C method and terrestrial macrofossils in the case of AMS method) and type of dated material (peat, calcerous gyttja, wood, organic mud or humic clay). Most often it is either of the two cases, i.e. under- or overestimation of the radiocarbon age of the palaeomeander fills. The reversal of dates in the base of palaeomeander fill is not a rare occurrence. The occurrence of younger dates in the bottom part of fill deposits and older ones above can be explained by the penetration of the roots of the plants that grow through the sediment and cause rejuvenation of the sediments (Kalinovyč 2013; Kołaczek et al. 2017). In the case of the ^{14}C datings of the palaeomeander fills which reveal too old ages in comparison to the palynological analysis, the difference in ages of deposits could reach several thousand years, evidenced by study of two palaeomeanders of the Warta river near Poznań (Okuniewska, Tobolski 1981). The age of one of the oldest, but not large palaeomeander in the Sandomierz Basin determined by means of conventional radiocarbon dating in the 1990s to the Plenivistulian decline (16–14 ka BP) (Klimek et al. 1997) seems to be much overestimated in the light of recent AMS dating and palynological analyses (Gębica et al. 2017; Kołaczek et al. 2017). The overestimation of the age of palaeomeanders fills may be due to contamination of the sample with older re-deposited organic material (see the case of the Tisza river palaeomeanders with the partly reworked organic material in the loamy sediments – Kasse et al. 2010) or from the presence of old carbonates (the so-called hard water effect) dissolved in water and originally coming from older layers that can be re-deposited to younger sediments, or in the form of an aqueous (ionic) solution assimilated by aquatic plants and re-deposited in the sediment (Walanus, Goslar 2009).

The overestimation of the age of the sediments is most probably the case in a series of radiocarbon dates that come from the profiles of terraces and fills of palaeomeanders in the Middle Dniester river valley in Ukraine (Fig. 1). This is an interesting case inasmuch as the phenomenon does not concern a single cut-off meanders but probably all the dated systems of palaeomeanders. The chronology based on the dating of palaeomeander fills is complemented by a sequence of Subatlantic alluvial series with subfossil tree trunks (Figs 2, 3) (Gębica et al. 2016).

The aim of this paper is: (i) dating the Late Vistulian and Holocene alluvial fills, (ii) attempt to verify radiocarbon age by palynological method and (iii)

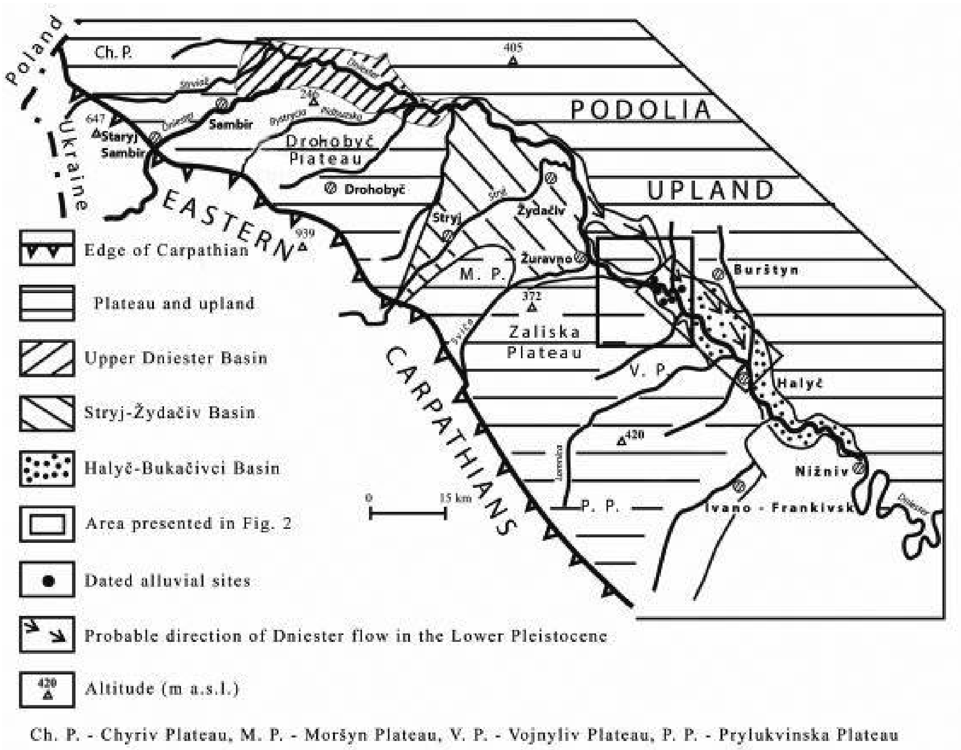


Fig. 1. Study area on the background of the geomorphological subdivision of the Eastern Fore-Carpathians Plateaus and Upland (Kravčuk 1998; Gębica, Jacyšyn 2013, modified)

explain the causes and source of overestimation of the age of the terraces and palaeomeander fills. Based on the presented material, there is a reasonable supposition that some of the existing results of radiocarbon dating of the Late Vistulian systems of palaeomeanders may be overestimated.

HISTORY OF THE RESEARCH

Joint Polish-Ukrainian geomorphological surveys in the Middle Dniester Valley in the area of the Halyč-Bukačivci Basin were conducted in collaboration with archaeologists and palaeobotanists. One of the aims was to explain the role of human settlement and economic activity in environmental changes in prehistoric periods in the area concerned through palynological studies of peat sediments and geomorphological surveys of the Dniester Valley bottom. The results of the joint research have been published in the 6th volume

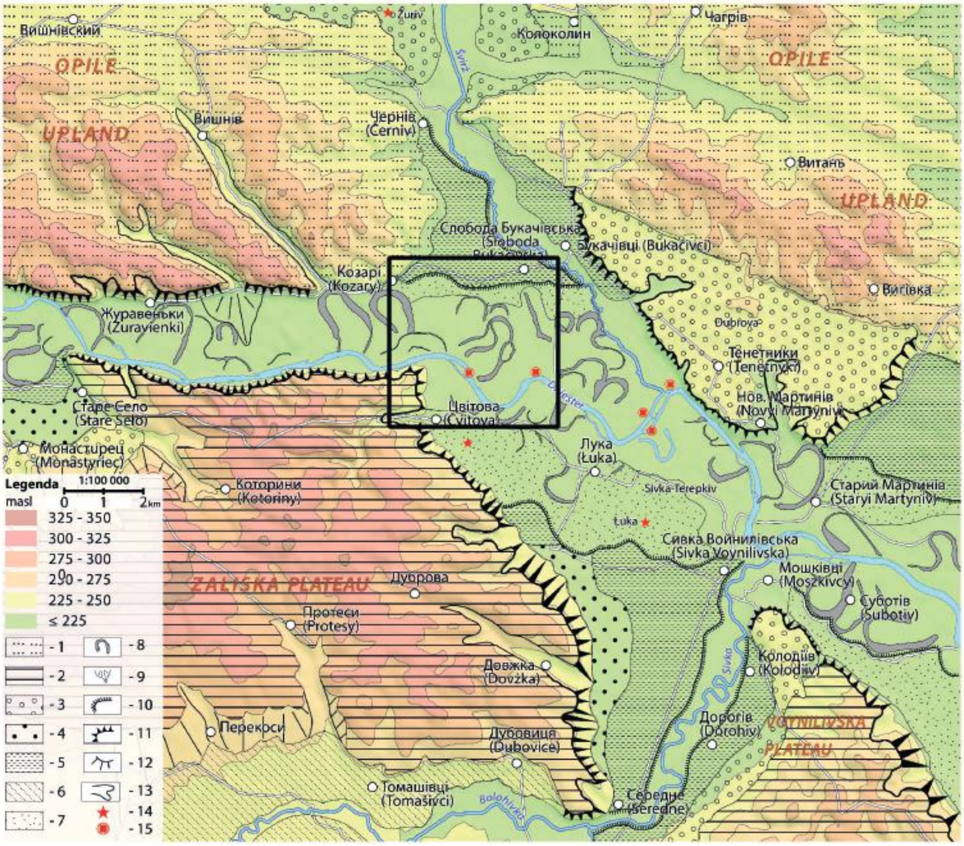


Fig. 2. Geomorphological map of Halyč-Bukačivci Basin with detailed study area (Gębica, Jacyšyn 2013, modified). 1 – Erosion-accumulation surface of the Opillje Upland, 2 – Lojeva planation surface (terrace VI of the Dniester), 3 – terrace V (Lower Pleistocene), 4 – terrace III (Middle Pleistocene), 5 – terrace II (Upper Pleistocene), 6 – terrace II-V (not divided), 7 – terrace I (Late Vistulian), 8 – floodplain with palaeomeanders (Holocene), 9 – alluvial fans, 10 – erosional edges up to 10 m high, 11 – erosional edges higher than 10 m, 12 – slopes and valley sides, 13 – denudational-erosional valleys, 14 – sites of sampled organic sediments for the palynological analysis, 15 – outcrops of alluvia bearing subfossil tree trunks dated by radiocarbon method; black square marked detailed study area presented in Figure 3

of the Commission on the Prehistory of the Carpathians Polish Academy of Arts and Sciences (Harmata et al. 2013a). One of the profiles of peat deposits located in the Late Glacial palaeomeander of the Dniester in the southern part of the valley floor was dated by pollen analysis to the Younger Dryas (Harmata et al. 2013b). The age of this palaeomeander was later confirmed by means of radiocarbon dating (Kołaczek et al. 2017). The younger system of palaeomeanders is represented by the Dniester oxbow-lake from the Atlantic period (Harmata et al. 2013a). Several profiles with subfossil tree trunks

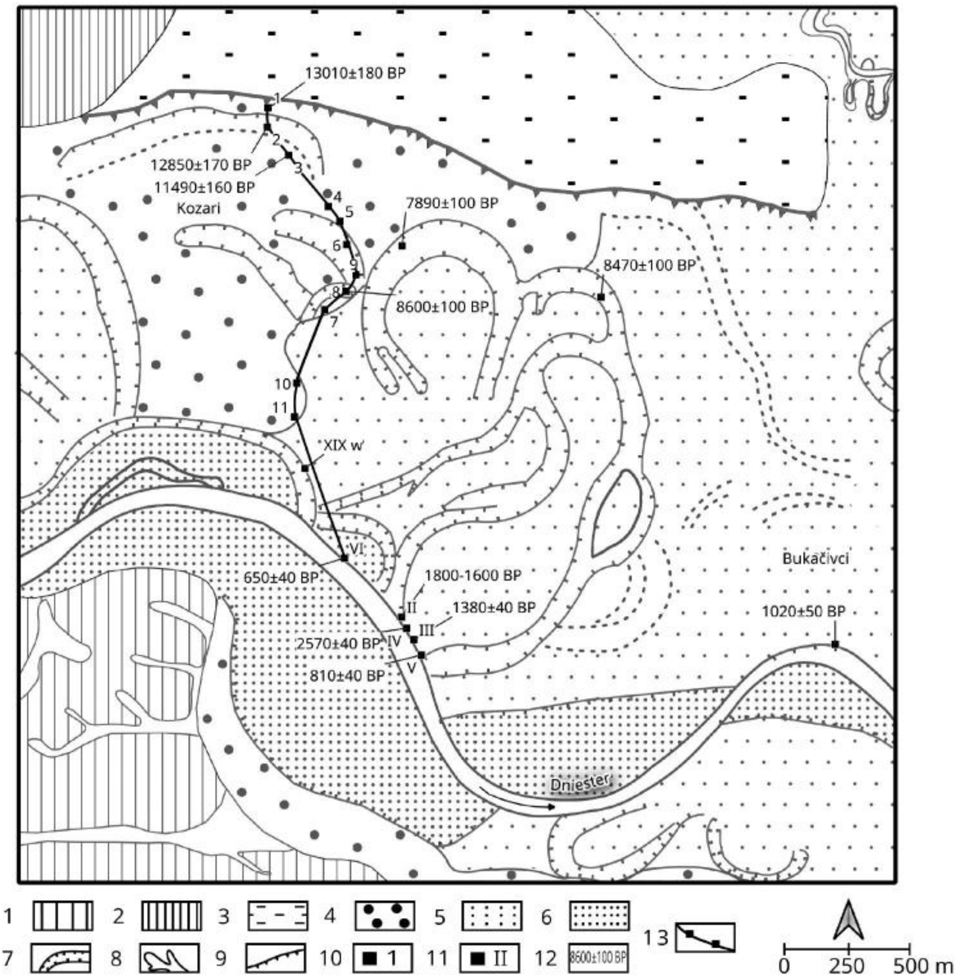


Fig. 3. Geomorphological map with the localization of bore–holes (profiles) and outcrops described in the text with results of radiocarbon datings. 1 – Zaliska Plateau, 2 – Opillje Upland, 3 – loess terrace II (10–15 m above the river channel), 4 – first (I) overflood terrace (5,5–6,5 m), 5 – floodplain (higher level, 4–5 m), 6 – floodplain (lower level (3–4 m), 7 – Late Vistulian and Holocene palaeomeanders 8 – denudational valleys, 9 – erosional edges, 10 – drillings, 11 – outcrops with subfossil tree trunks, 12 – ^{14}C datings (BP), 13 – line of the geological cross–section

from the Subatlantic period (Gębica et al. 2016) were dated in the outcrops located on the floodplain with a height of 4–5 m above the Dniester riverbed. In additions to the tree trunk stands, borings were made along the cross-sectional line covering a Late Vistulian terrace with a height of 5.5–6.5 m and 2–3 levels of the Holocene floodplains with heights of 4–5 m and 3–4 m above the Dniester riverbed with systems of palaeomeanders (Gębica, Jacyšyn

2013). M. Huhmann and H. Brückner (2002) distinguished two Late Pleistocene terraces and as many as seven levels of Holocene terraces in the Middle Dniester Valley. The ages of these terraces were determined on the basis of analysis of alluvial soil maturation stages as well as radiocarbon datings of single black oaks and subfossil wood fragments.

MATERIALS AND METHODS

The profiles of the outcrops with tree trunks were complemented by a 1.3 km long cross-section of the floodplain, drawn up based on 13 drillings. In the field, core descriptions were performed and samples were collected for analysis. For the benchmark profile for the Kozari 2 palaeomeander fill, grain-size analyses of 24 sediment samples were performed in the Laboratory of the Department of Geoenvironmental Research of the Institute of Geography and Spatial Organisation, Polish Academy of Sciences in Krakow. Furthermore, grain-size analyses on 70 samples from outcrops with subfossil trunks located in Kozari and Bukačivci were performed in the Laboratory of the Department of Geomorphology of the Jagiellonian University. In the initial stage, the samples were dried and organic remains visible to the naked eye were removed then, the samples were sieved through a 1 mm diameter sieve. For samples with a diameter smaller than 1 mm, the grain-size analysis was performed by laser diffraction using a Mastersizer 3000 particle size analyser. Gradistat 5.11 PL beta program was used to calculate the basic indicators of grain-size distribution (Folk, Ward 1957), i.e. mean diameter (Mz), sorting (δ_I), skewness (S_k) and kurtosis (K_G). The results of the analyses are presented in grain-size distribution diagrams. For the Kozari 2 profile, the contents of organic carbon and calcium carbonate were also analysed. The analysis of calcium carbonate content was carried out using the Scheibler method following preliminary macroscopic determination of carbonates in 34 samples using HCl 10%. The organic carbon content in 11 samples was determined by the dry combustion method.

The age interpretation of alluvial fills is based on a total of 18 radiocarbon dating measurements (Tab. 1) supported by pollen analysis of the sediments. Table 1 presents new, previously unpublished dating results for 10 samples from palaeomeander fills and age analysis of 8 wood samples from subfossil tree trunks (Gębica et al. 2016). The dating was performed using the conventional liquid scintillation counting (LSC) technique at the Laboratory of Absolute Dating in Skała near Kraków, Poland (Lab Code: MKL). The radiocarbon ages were calibrated using the INTCAL13 (Reimer et al., 2013).

Table 1.

Radiocarbon ages of samples from palaeomeanders and subfossil tree trunks in the Dniester river valley near Kozari (Halyč-Bukačivci Basin)

Profile name	Depth (m)	Type of material	Facies of deposits	Laboratory No	Radiocarbon age (years BP)	Calibrated age (years BP) 95.4%)
Kozari 1	2.65–2.67	organic clay	overbank	MKL-2264	13,010±180	16,177–15,133
Kozari 2	2.37–2.41 3.91–3.94 5.78–5.82 6.03–6.07	organic mud organic silt organic silt organic silt	palaeochannel fill	MKL-2265 MKL-2281 MKL-2280 MKL-2266	5,720±60 5,090±90 12,190±100 12,850±170	6,716–6,449 6,054–5,658 14,590–13,813 15,977–14,766
Kozari 3	4.73–4.78 5.04–5.07	organic detritus organic silt	point bar	MKL-2279 MKL-2267	11,450±110 11,490±160	13,527–13,136 13,681–13,108
Kozari 8	2.59–2.61	silt with organic detritus	palaeochannel fill	MKL-2282	8,600±100	9,963–9,475
Kozari 12	2.28–2.32	organic silt	palaeochannel fill	MKL-2268	7,890±100	9,059–8,564
Kozari 13	1.5–1.59	silt with organic detritus	palaeochannel fill	MKL-2269	8,470±100	9,930–9,296
Kozari II*	3.5 4-5	tree trunk	overbank channel	MKL-1681 MKl-1682	1,620±40 1,800±30	1,605–1,410 1,820–1,625
Kozari III*	3.5	tree trunk	point bar	MKL-2045	1,380±40	1,370–1,255
Kozari IV*	4.0	tree trunk	point bar	MKL-2044	2,570±40	2,755–2,500
Kozari V*	4.0	tree trunk	point bar	MKL-2046	810±40	790–675
Kozari Va*	3.0–3.2	tree trunk	overbank	MKL-2233	2,060±40	2,120–1,910
Kozari VI*	3.0	tree trunk	overbank	MKL-2234	650±40	675–550
Bukačivci	3.5–4.0	tree trunk	point bar	MKL-2235	1,020±40	1,040-800

*older ^{14}C dates published in P. Gębica et al. (2016)

Pollen analysis of 17 samples was performed at the Institute of Botany of the Jagiellonian University in Krakow. Sediment samples with a volume of 1 cm^3 were boiled in hydrofluoric acid (HF) and then modified Erdtman's acetolysis method (Berglund, Ralska-Jasiewiczowa 1986) was applied. For each sample, sporomorphs from vascular plants were determined and counted on an area of 400 mm^2 of microscopic preparations. The results of the determinations of sporomorphs and the quantity of the individual sporomorph taxa in 13 samples from drilling profiles are shown in Table 2.

Table 2.

Results of palynological analysis. Absolute numbers of sporomorphs (Szczepanek unpblished, 2014)

Taxon \ Profile No/sample No	13/3	12/5	12/6	2/5	6/1	8/1	1/2	2/9	4/1	3/1	3/4	2/13	2/14
Pinus	3	9	1	32	2	8	1	2		5	8	9	4
Betula	1	1		20	33	14		5		2	2	9	8
Salix	1	3		2	3	4		1		1	1		
Populus				11				4					
Ulmus	8	1		6	2	2		2			2	16	7
Corylus	1	2	1	19	22	1		20	1		3	38	17
Tilia	1			2	1	1		1				3	3
Quercus	3	3		33	19	27		11		3		21	11
Alnus	3	10	1	22	13	26		23			4	71	22
Picea	3	3	1	4	7	4		6		2	1	9	2
Fraxinus					1	2		3				1	2
Carpinus	1	2		22	30	13		13					
Fagus	3		1	4	7	9							
Abies	2	3	1			4							
Sambucus											1		3
Poaceae	22	2		71	28	7		21			1	24	18
Polypodiaceae	7	7	1	48	5	1	1	10	4	2	3		2
Pteridium					1	1							
Plantagolanceol.	3	1		4	4	4							
Rumex						1							
Artemisia		2		6	8	8	1				1	8	1
Secale	1					2							
Triticum				1									

Taxon \ Profile No/sample No	13/3	12/5	12/6	2/5	6/1	8/1	1/2	2/9	4/1	3/1	3/4	2/13	2/14
Cannabis					2	190							
Typha	1			1									
Sparganium								1					
Menyanthes													1
Lemna	1												
Myriophyllum								1			1	4	
Rosaceae		3		8				3		2		2	
Filipendula					7								
Apiaceae	1	2		4	3	5						1	
Asteraceae				1	1	1		1					
Caryophyllaceae						1		1					
Urtica													1
Sphagnum	1			21	1								
Varia		2	1	4	5						2	4	4
Cyperaceae								1					

STUDY AREA

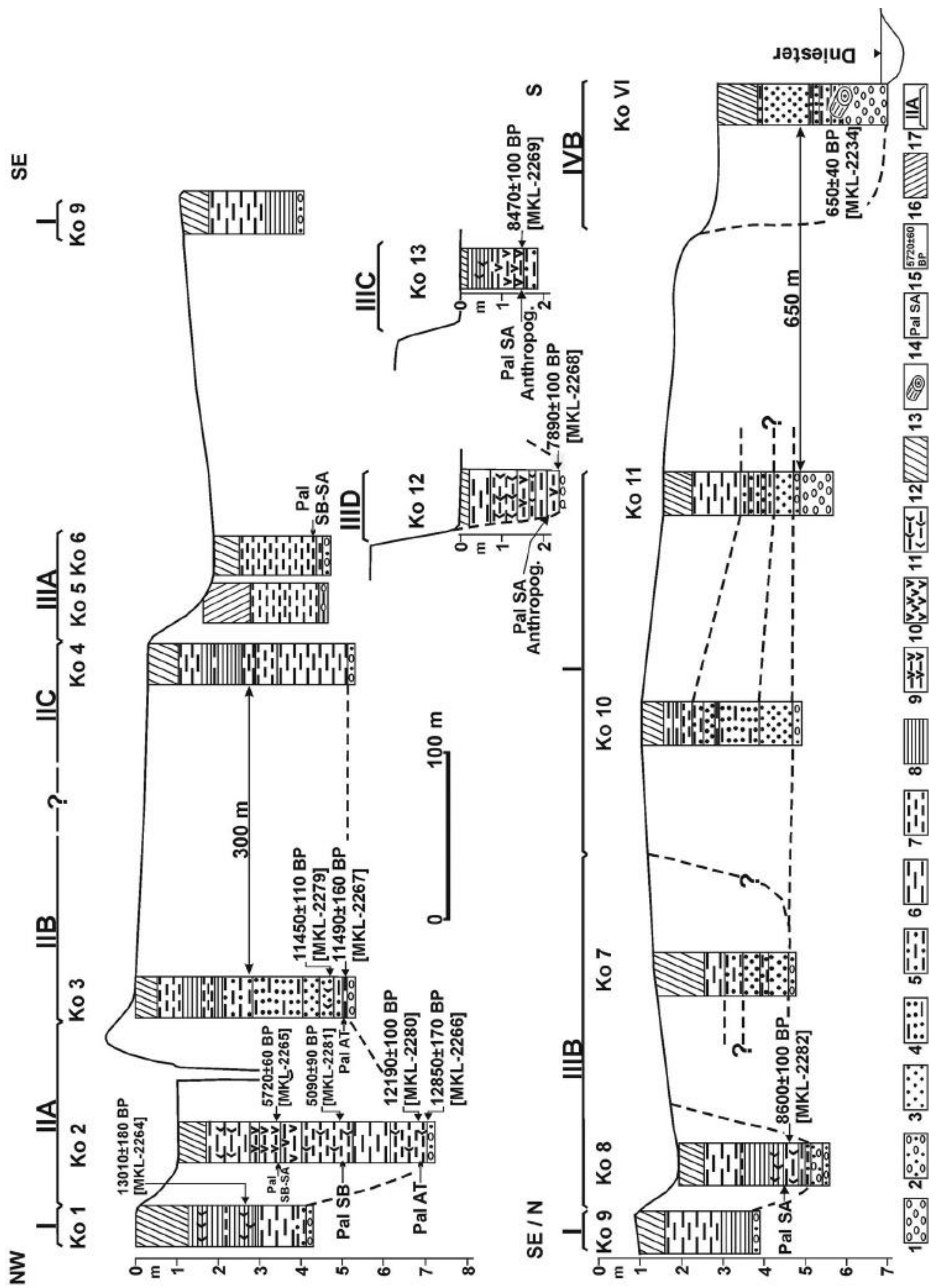
The Halyč-Bukačivci Basin is located on the border area between the high-elevated plateaus of the Eastern Fore-Carpathian Plateaus and the Podolia Upland (Fig. 1). The territory situated to the north of the Dniester river valley represents the Opillje Upland being the southern segment of the Podolia Upland. To the south, the bottom of the examined section of the Basin is separated by the edge of the Lojeva morphological surface (level), and to the north by the edge of the fifth terrace with a height of 30–40 m and the slope of the Opillje Upland. The main morphological element of the northern part of the valley is the Lower Pleistocene fifth Dniester terrace with a height of 25–35 m to 55 m above the Dniester riverbed (Fig. 2). The terrace strath a height of 20 m is built of Cretaceous sandstones and covered with alluvia thickness of 6–8 m and a loess at the top. The largest areas in the Basin are occupied by the Upper Pleistocene second terrace and the Late Vistulian first terrace and the system of Holocene floodplains (Huhmann, Brückner 2002; Gębica, Jacyšyn 2013) (Figs 2, 3). The second terrace is developed mainly in the northern part of the Basin between Kozari, Bukačivci and Černiv. The terrace plain is situated 10–15 m above the Dniester riverbed. The terrace strath is overlain by sandy-gravel alluvia covered with loess. The wood fragments in the alluvia of this terrace were dated to over 19 ka BP (Huhmann, Brückner 2002). The first terrace is developed both on the northern and the southern edges of the Dniester Valley (Figs 2, 3). It occurs mainly in marginal parts of the valley floor between Kozari and Bukačivci and between Novyj Martyniv and Niemczyn. Between Kozari and Bukačivci its area rises to a height of 230–231 m a.s.l., i.e. 5.5–6.5 m above the Dniester riverbed, and is 200–400 m wide. The surface of the terrace is dissected by systems of large-radius abandoned channels of the Dniester which are dated to the Younger Dryas (Huhmann, Brückner 2002). Beneath the first terrace there are 2–3 levels of Holocene floodplains, 4–5 m high and 3–4 m above the Dniester riverbed, dissected by palaeomeanders. On the southern edge of the Basin, the first terrace is developed between the villages of Čvitova, Luka and Sivka Voynilovskaya (Fig. 2). The terrace is dissected by large palaeomeander of the Dniester filled with peat dated to the Younger Dryas by the palynological method (Harmata et al. 2013b).

RESULTS

In the cross-section of the alluvial plain with a height of 6.5 m to 3-4 m above the Dniester riverbed a several Late Vistulian and Holocene alluvial fills and systems of palaeomeanders were distinguished (Figs 3, 4):

I. The first (I) (overflood) terrace with a height of 6.5–5.5 m above the Dniester riverbed. The succession of the sediments in the distal part of the terrace is represented by the Ko 1 profile. Below the soil, from 1.3 m to 2.97 m, there are steel overbank clays with organic matter. At the depth of 2.97–4.1 m, there are stratified silts and sandy silts of flood origin (flood rhythmites) without plant remnants with low carbonate content (below 1% $CaC0_3$) deposited on gravels with sand (channel facies deposits). The similar sequence of deposits was evidenced in the two other profiles of the terrace I (Ko 10 and Ko 11). In the inlier (erosional remnant) of the terrace I (Ko 9 profile), the flood rhythmite is absent, which proves that active channel occupied the central part of the alluvial plain.

Fig. 4. Geological transect across the late Vistulian and Holocene palaeochannel systems of Dniester river in the northern part of the Halyč-Bukačivci Basin (Kozari site). 1 – gravel, 2 – sand with gravel, 3 – sand, 4 – silty sand, 5 – sandy silt, 6 – silt (mud), 7 – clayey silt, 8 – clay, 9 – organic mud, 10 – peat, 11– organic detritus, 12 – Holocene soil, 13 – subfossil tree trunk, 14 – palynological indications: AT – Atlantic, SB – Subboreal, SA – Subatlantic, Anthropog. – Anthropogenic indications, 15 – ^{14}C datings (BP), 16 – mound earth, 17 – numbering of alluvial fills and systems of palaeomeanders accordance with description in the text



NW
SE
I Ko 1
IIA Ko 2
Ko 3
IIB
?
IIC Ko 4
IIIA Ko 5 Ko 6
I Ko 9
13010±180 BP [MKL-2264]
Pal SB-SA
5720±60 BP [MKL-2265]
5090±90 BP [MKL-2281]
Pal SB
Pal AT
12190±100 BP [MKL-2280]
12850±170 BP [MKL-2266]
11450±110 BP [MKL-2279]
11490±160 BP [MKL-2267]
300 m
0 100 m
Pal SB-SA
IIID Ko 12
IIIC Ko 13
Pal SA Anthropog.
7890±100 BP [MKL-2268]
8470±100 BP [MKL-2269]
S
SE / N
I Ko 9
Ko 8
IIIB
Ko 7
Ko 10
Ko 11
IVB
Ko VI
Pal SA
8600±100 BP [MKL-2282]
650 m
650±40 BP [MKL-2234]
Dniester
m
1 2 3 4 5 6 7 8 9 10 11 12 13 14 Pal SA 15 5720±60 BP 16 17 IIA

IIA. The large palaeomeander dissected the first terrace is very poorly marked in the field; its width on the section w = 60–70 m; in the western part the channel is much wider, w = 100–130 m, radius of curvature R = 260 m. The palaeomeander fill (Ko 2 profile) with a thickness of 6.07 m is built in the top of clayey silt and organic silts with fragments of plants. In the bottom part there are clayey silt with organic matter resting on sands with admixture of gravels (Figs 4, 5). The grain-size of the sediments throughout the profile is very similar, which is proved by mean diameter Mz = 6.5–7.5 Ø) (clayey silts), poor sorting (σ_I = 1.4–2.1) and positive graphic skeweness (Sk = 0.1–0.5). Fine grained silts (0.02–0.002 mm) prevail, constituting 48–72% of the material. In the lowermost section of palaeomeander fill, below the organic-mineral layer, these fraction exceeds 60%. A small percentage of sand (0.05––0.25 mm) is recorded at a depths of 3–4 m and 1.6–1.7 m (Fig. 5), which indicates that flood water reached the oxbow-lake during extreme floods in the Neoholocene. The content of calcium carbonate ($CaC0_3$) down to a depth of 4.74 m is less than 1%; from a depth of 4.74 m to 6.07 m it increases from 2% to 12%. The organic matter content ranges from 3.5% to 7%, with a maximum of 16.3%. Mentioned above features of deposits suggest that suspended material were deposited in stagnant water, especially at the beginning (older) phase of existence of the oxbow-lake, where silts derived from loess erosion were delivered.

IIB. The point bar zone of the large palaeomeander (Ko 3 profile) is made up of clays and overbank silts in the top; from 2.85 to 4.98 m fine carbonate sands and silts with fragments of wood at a depth of 5.04–5.07 m overlying the gravels with sands of the channel lag deposits (Fig. 4). The fining upward sequence of channel sands and silty sands overlain by flood silts in the top is interpreted as point bar deposits.

IIC. The alluvial plain sediments (at the level of the first terrace), at a distance of 27 m from the edge of the large palaeomeander, are represented by the Ko 4 profile. Overbank clayey silts and clays with a thickness of 2.5 m are underlain by ash-grey silts resting on gravels with sands at a depth of 4.75 m.

III. Alluvial fills with systems of Holocene palaeomeanders and remnants of terrace I (Figs 3, 4).

IIIA. The cut-off meander has a clearly marked outer edge, 1.5 m high; bottom width w = 50–60 m and radius of curvature R = 200 m. The palaeochannel fill deposits (Ko 5 and Ko 6 profiles) is made up of overbank silty loams with a thickness of up to 2.9 m resting on gravels of channel facies with diameters of 1–4 cm.

IIIB. The palaeomeander undercut an erosional inlier (remnant of terrace I) where a farm is located. Its small size, i.e. a narrow bottom w = 25–30 m and

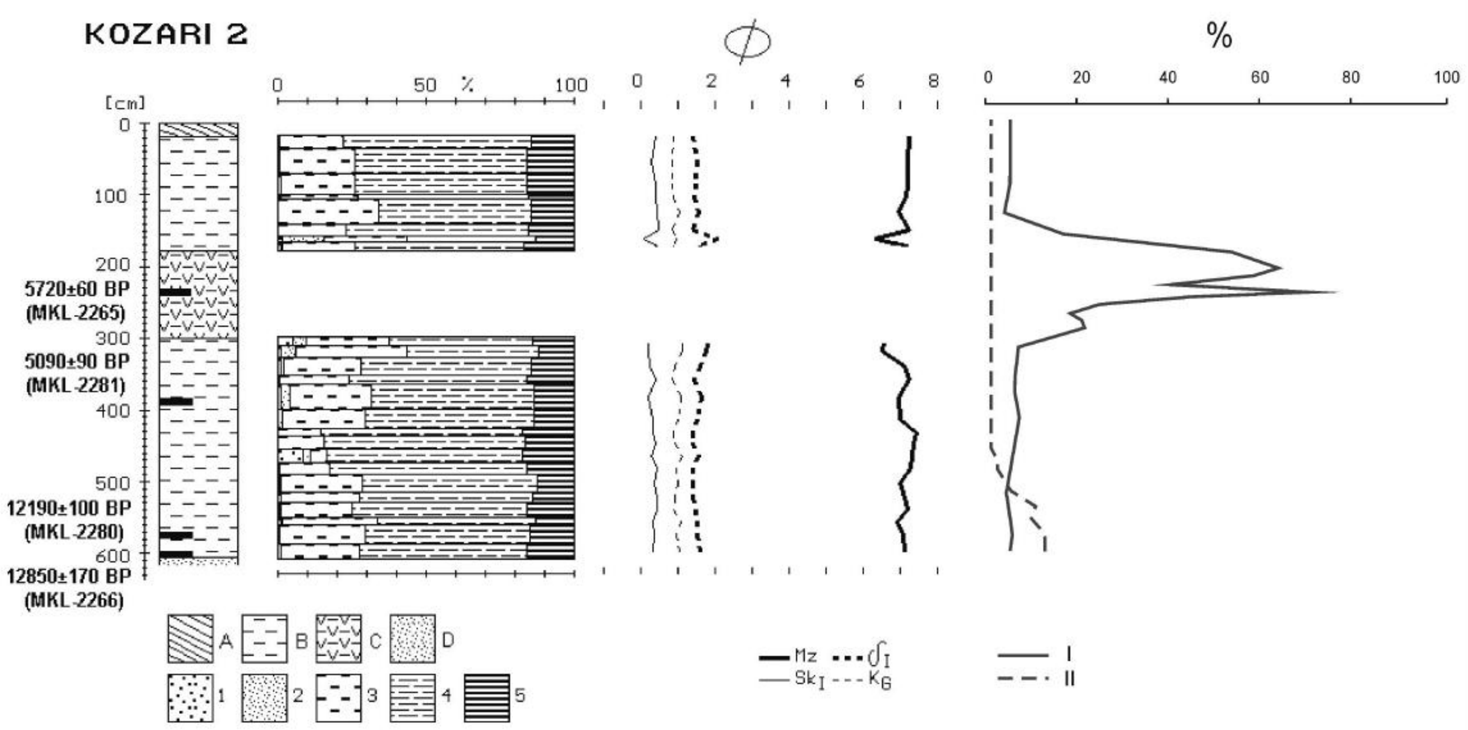


Fig. 5. Palaeomeander fills in the Kozari 2 profile with lithological diagram, grain size composition, grain size indices, carbon and $CaC0_3$ content. Lithological log: A – humus layer of Holocene soil, B – silt (mud), C - organic mud, D – sand; Grain size composition: 1 – coarse sand, 2 – fine sand, 3 – coarse silt, 4 – fine silt, 5 – clay; grain size indices: Mz – mean grain size, δ_I – standard deviation (sorting index), s_k – skeweness, K_G – kurtosis; I – carbon content, II – $CaC0_3$ content

a small radius of curvature R = 80 m allow it to be classified as a generation of small palaeomeanders. The filling of this palaeomeander (Ko 8 profile) is built up in the top of clayey silts and steel clay with organic matter at a depth of 2.52–2.71 m. In the bottom, the silts are deposited directly on the channel sands and gravels with diameters of 0.5 to 3 cm. On the outer (convex) bank of this palaeomeander (Ko 7 profile) there is a fining upward sequence of sands, silty sands and silts with a thickness of 3.25 m interpreted as point bar deposits.

IIIC. Due to its small size (w = 40–50 m, R = 150 m), the cut-off meander is similar to the palaeomeander described in IIIB and belongs probably to the generation of small palaeomeanders. The channel fill sediments (Ko 13 profile) is made up of clays with a thickness of 0.74 m overlying organic silts (from a depth of 0.74 to 1.54 m) and sandy silts (from 1.54 to 1.83 m). In the silts there are organic remains and fragments of aquatic vegetation (Figs 3, 4).

IIID. The large palaeochannel younger generation (Ko 12) undercut the systems of palaeomeanders IIIA and IIIB. It has a clear erosion scarp on the side of the concave bank, with a height of approx. 2 m; waterlogged bottom with a width of w = 60 m and radius of curvature R = 300 m (Figs 3, 4). The parameters specified allow this cut-off meander to be classified among palaeomeanders of the younger generation. The oxbow-lake sediments (Ko 12 profile) is represented by clayey silts and silts with organic remains with a thickness of 2.34 m resting on channel sands and gravels.

IV. Alluvial fills with subfossil trunks of 4–5 m and 3–4 m terraces in Kozari and Bukačivci.

IVA. Terrace (floodplain) with a height of 4–5 m above present channel level with subfossil trunks exposed in the undercut of the present meander bend (Fig. 3). The subfossil black oak with a diameter of approx. 1 m are located in the western part of the outcrop at the level of the channel, between the sands of channel facies and overbank deposits (Fig. 6). The remaining trunks are buried in point bar deposits or overbank deposits. The point bar deposits are fine sands and sandy silts. Mz ranges from 4.1 to 5.8 Ø. Sorting is poor (σ_I = 1.4–1.8) and skewness is positive (Sk = 0.1–0.5). The point bar deposits are covered with fine grained silts and clayey silts (Mz = 6.1–6.5 Ø, σ_I = 1.3–1.6 and Sk = 0.01–0.07) deposited in flood basins (Ko III profile) (Figs. 6, 7). During a floods closer to the active channel the sedimentation in the flood basins was interrupted by the supply of coarser sandy-silty deposits (Mz ranges from 4.9 to 5.4 Ø). Sorting is poor (σ_I = 1.5–1.7 Ø) and skewness (Sk = 0.1–0.2) (Figs 8, 9). On the flood basin deposits, fine sands and silt of natural levees with a thickness of approx. 1.5 m were deposited (Ko III profile). In Ko V profile there are 4.3 m thick rhythmically stratified cross-beded sandy silts and silts with sands deposited during floods (Fig. 8). The grain size indices

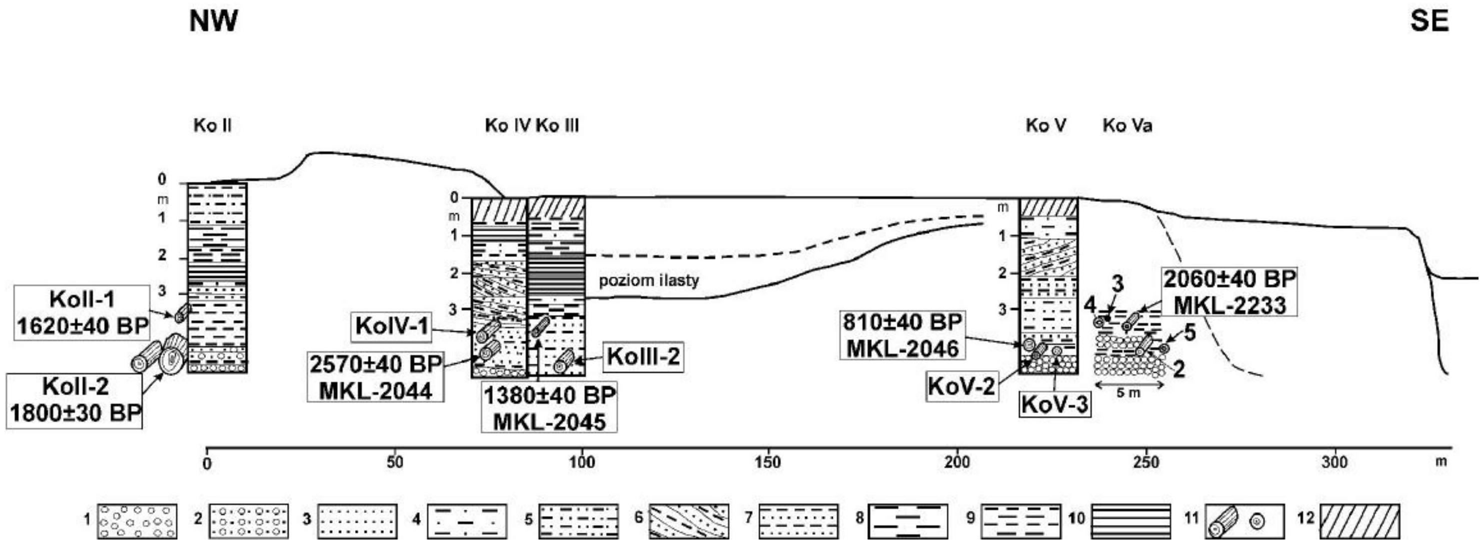


Fig. 6. Floodplain 4–5 m high with alluvial fills bearing subfossil trunks with radiocarbon ages at the Kozari site (Gębica et al. 2016). 1 –gravel, 2 – sand with gravel, 3 – sand, 4 – silty sand, 5 – sandy silt, 6 – cross–stratified silt and sand, 7 – horizontally stratified silt and sand, 8 – silt, 9 – clayey silt, 10 – clay, 11–subfossil trunks, 12 – Holocene soil

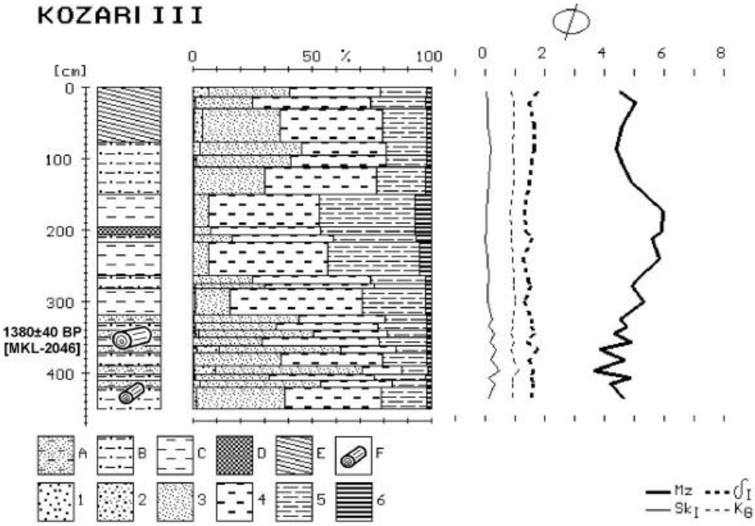


Fig. 7. Point bar and flood basin deposits at Kozari III profile with trunk dated to 1.38±0.04 ka BP. Lithological diagram, grain size composition and grain size indices. Lithological log: A – silty sand, B – sandy silt, C – silt, D – fossil soil (?), E – Holocene soil, F – subfossil trunk; Grain size composition: 1 – coarse sand, 2 – medium sand, 3 – fine sand, 4 – coarse silt, 5 – fine silt, 6 – clay; grain size indices: Mz – mean grain size, δ_I – standard deviation (sorting index), s_k – skeweness, K_G – kurtosis

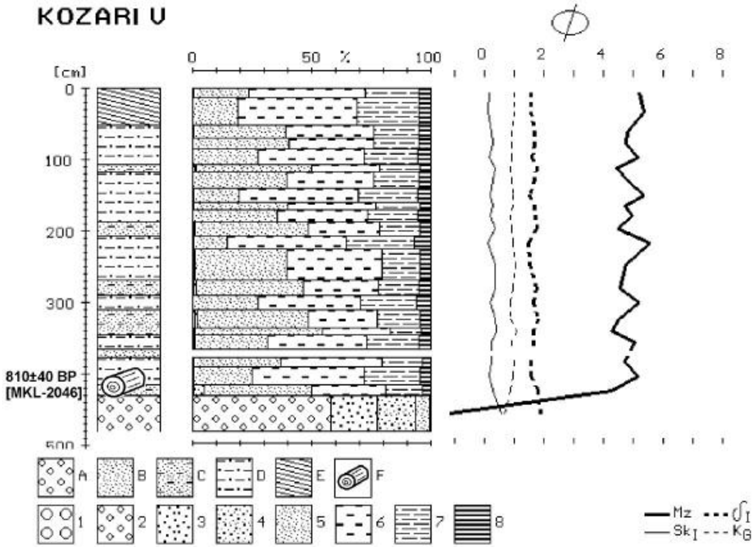


Fig. 8. Medieval trunk (0.8±0.04 ka BP) buried in point bar deposits in Kozari V profile. Lithological diagram, grain size composition and grain size indices. Lithological log: A – gravel, B – sand, C – silty sand, D – sandy silt, E – Holocene soil, F – subfossil trunk; Grain size composition: 1 – medium gravel, 2 –fine gravel, 3 – coarse sand, 4 – medium sand, 5 – fine sand, 6 – coarse silt, 7 – fine silt, 8 – clay; grain size indices: Mz – mean grain size, δ_I – standard deviation (sorting index), s_k – skeweness, K_G – kurtosis

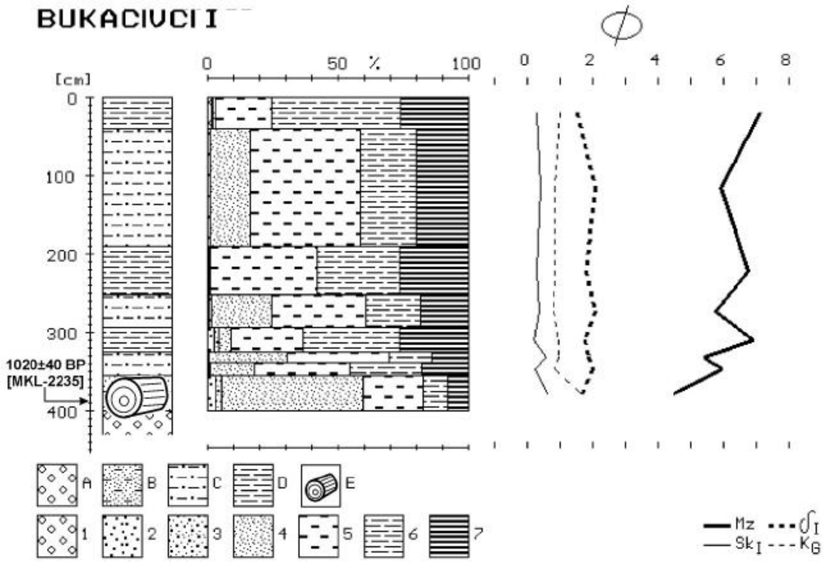


Fig. 9. Medieval trunk (1.02±0.04 ka BP) buried in channel sands in the Bukačivci profile. Lithological diagram, grain size composition and grain size indices. Lithological log: A – gravel, B – silty sand, C – sandy silt, D – silt (mud), E – subfossil trunk; Grain size composition: 1 – fine gravel, 2 – coarse sand, 3 – medium sand, 4 – fine sand, 5 – coarse silt, 6 – fine silt, 7 – clay; grain size indices: Mz – mean grain size, δ I – standard deviation (sorting index), sk – skeweness, KG – kurtosis

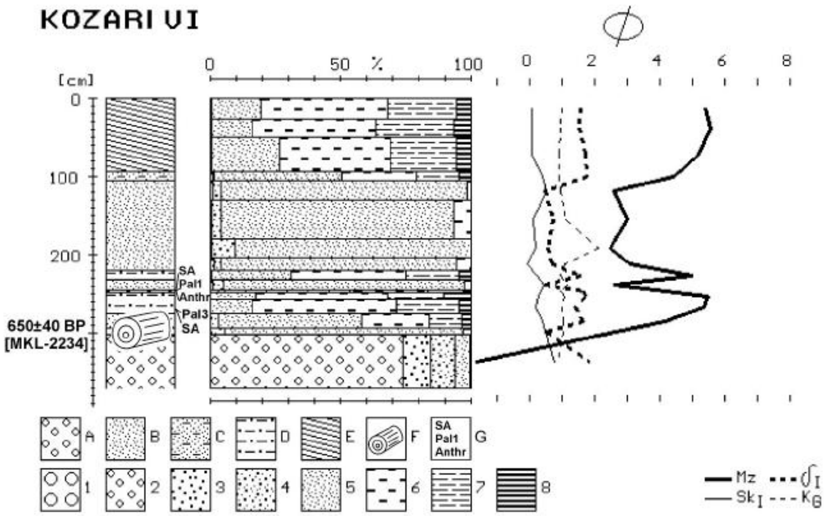


Fig. 10. Alluvial fill of the terrace 3–4 m with subfossil trunk dated at 0.65±0.04 ka BP in Kozari VI profile. Lithological diagram, grain size composition and grain size indices. Lithological log: A – gravel, B – sand, C – silty sand, D – sandy silt, E – Holocene soil, F – subfossil trunk; G – SA – Subatlanic, Pal1 – palynological analysis sample No, Anthr – anthropogenic indicator. Grain size composition: 1 – medium gravel, 2 – fine gravel, 3 – coarse sand, 4 – medium sand, 5 – fine sand, 6 – coarse silt, 7 – fine silt, 8– clay; grain size indices: Mz – mean grain size, δ_I – standard deviation (sorting index), s_k – skeweness, K_G – kurtosis

as mean diameter (Mz = 4.3 to 5.6 Ø), sorting (σ_I = 1.53–1.85) and skewness (Sk = 0.1–0.4) is very similar to the point bar deposits in Ko III profile.

IV. B. Terrace (lower floodplain) with a height of 3–4 m above the Dniester riverbed represent alluvia with elm tree trunk buried in the overbank deposits (Ko VI profile) (Fig. 10). These fine grained horizontally stratified sandy silts and silts contain pollen grains from cultivated plants. Mz varies from 4.1 to 5.3 Ø. Sorting is poor (σ_I = 1.4–1.7) and skewness is positive (Sk = 0.2–0.4). The overbank silts are overlain by fine grained channel sands, with a thickness of 1.3 m represented the point bar deposits. In the top of sequence the sandy alluvial Holocene soil has been developed.

RADIOCARBON DATING

I. First terrace. Overbank organic clay from the depth of 2.65–2.68 m was dated to 13.01±0.18 ka BP (16–15 ka cal BP) (MKL-226) (Fig. 4, Tab. 1), i.e. the decline of the Plenivistulian.

IIA. Four samples were dated in the large-radius palaeomeander fill (Ko 2 profile). A sample of organic silt from the base of the palaeomeander fill at the depth of 6.03–6.07 was dated to 12.85±0.17 ka BP (15.97––14.76 ka cal BP) (MKL-2266) and from the depth of 5.78–5.82 m was dated to 12.19±0.1 ka BP (14.59–13.81 ka cal BP) (MKL-2280) (Figs 4, 5). Both samples represent the Late Vistulian. The deposits from the top part were dated at the depth of 3.91–3.94 m to 5.09±0.09 ka BP (6.05–5.65 ka cal BP) (MKL-2281) and from the depth of 2.37–2.41 m to 5.72±0.06 ka BP (6.71–6.44 ka cal BP) (MKL-2265), i.e. the end of the Atlantic period or the beginning of the Subboreal.

IIB. Two samples were dated in the Ko 3 profile located in the point bar zone of a large-radius palaeomeander. A sample of silt with wood fragments at the depth of 5.04–5.07 m was dated to 11.49±0.16 ka BP (13.68–13.1 ka cal BP) (MKL-2267), and sample located at the depth of 4.73–4.78 m, was dated to 11.45±0.11 ka BP (13.52–13.13 ka cal BP) (MKL-2279), thus both have the same age and represent the decline of the Late Vistulian (Fig. 4).

III. Alluvial fills with systems of Holocene palaeomeanders

IIIB. Cut-off meander (Ko 8 profile) representing an older generation of palaeochannels filled with overbank silts. A sample of silt with numerous plant fragments from the depth of 2.59–2.61 m was dated to 8.6±0.1 ka BP (9.96–9.47 ka cal BP) (MKL-2282).

IIIC. Cut-off meander (Ko 13 profile) of the younger generation filled with silt sediments with plant fragments from the depth of 1.56–1.59 m was dated to 8.47±0.1 ka BP (9.73–9.29 ka cal BP) (MKL-2269), i.e. a very similar age to that of the abandoned channel in the Ko 8 profile.

IIID. Palaeomeander, much larger (R = 300 m, w = 60 m) than cut-off meander younger generation, waterlogged and filled with organic silts (Ko 12 profile) dated at the depth of 2.28–2.32 m to 7.89±0.1 ka BP (9.06–8.56 ka cal BP) (MKL-2268), i.e. the Atlantic period.

IV. Alluvial fills and systems of palaeomeanders from the Roman period to Medieaval time was determined based on dating measurements of 8 subfossil trunks in 6 profiles (Figs 3, 6, Tab. 1).

IVA. In the 4–5- metre terrace, a black oak trunk with a diameter of 1 m, located at the level of the riverbed in the western part of the outcrop (Ko II profile) was dated to 1.8±0.03 ka BP (1.82–1.625 ka cal BP) (MKL-1682) (Figs 3, 6, Tab. 1), i.e. the Roman period. In Ko II profile another trunk, located higher in overbank sediments was dated to 1.62±0.04 ka BP (1.6–1.41 ka cal BP) (MKL-1681). In the Ko III outcrop, at the depth of 3.5 m, a trunk was dated to 1.38±0.04 ka BP(1.37–1.25 ka cal BP) (MKL-2045) (Fig. 7) and in the Ko V profile at the depth of 4 m, was dated to 0,81±0,04 ka BP (0.79–0.675 ka cal BP) (MKL-2046) (Fig. 8), i.e. the Medieaval time. A much older, probably redeposited trunk in the Ko IV profile was dated to 2.570±40 ka BP (MKL-2044). In the Bukačivci profile (Fig. 9) an oak trunk at the depth of 3.6–4 m was dated to 1.020±0,04 ka BP (1.04–0.8 ka cal BP) (MKL-2235).

IVB. In the 3–4-metre terrace in Kozari, an elm tree trunk lying in overbank silts under sands, at the depth of 3 m, was dated to 0.65±0.04 ka BP (0.675–0.550 ka cal BP) (MKL-2234) (Ko VI profile, Figs 3, 10).

PALYNOLOGICAL ANALYSES

The results of pollen analyses of 13 samples from borings log are presented in Table 2. Well-preserved pollen grains and fern spores were found in the samples, with the exception of sample no. 2 in the Ko 1 profile (depth of 2.65–2.7 m), sample no. 1 in the Ko 4 profile (depth of 4.26–4.28 m) and sample no. 2 in the Ko 3 profile (depth of 4.73–4.76 m), in which very low occurrence of pollen grains cannot provide a basis for conclusions about the age of the deposits. In samples no. 2 in the Ko 1 profile, no. 1 in the Ko 4 profile, no. 13 in the Ko 2 profile (depth of 5.78–5.82 m) and no. 14 in the Ko 2 profile (depth of 6.06–6.07 m), traces of fires were most probably found in the form of very small fragments of organic tissues, black in colour after burning.

Taking into account the results of the palynological analysis of 13 samples (Tab. 2), three local palynological chronozone characterising the vegetation and the age of the sediments can be distinguished.

The oldest palynological chronozone comprises samples no. 13 and 14 in the Ko 2 profile (IIA) and no. 4 in the Ko 3 profile (IIB). This group is dominated by pollen grains from trees characteristic of the Holocene climatic optimum, such as hazel (*Corylus*), alder (*Alnus*), oak (Quercus) and elm (*Ulmus*), i.e. older than about 4,500 BP, although the Subboreal period cannot be ruled out.

The second, younger chronozone includes sample no. 2 in the Ko 1 profile (terrace I), samples no. 5 and 9 in the Ko 2 profile (IIA), sample no. 1 in the Ko 6 profile (IIIA) and sample no. 1 in the Ko 8 profile (IIIB). These samples were characterised by high quantities of pollen grains of such taxa as common hornbeam (*Carpinus Betulus*), common beech (*Fagus sylvatica*), alder (*Alnus*) and spruce (*Picea abies*). There is a more common occurrence of anthropogenic indicators (*Plantago lanceolata*, *Secale*, *Triticum* and *Artemisia*). A very high proportion of cannabis (hemp) pollen grains (*Cannabis sativa*) in sample no. 1 (depth of 2.46–2.48 m) in an abandoned channel fill (Ko 8 profile) may indicate that hemp was soaked by humans at this site (as part of a technological process). This plant was found in the area of Poland in the form of pollen grains not earlier than 2,5 ka BP (Szczepanek 2001). The most intensive period of hemp cultivation took place between 800–1400 AD (Schroeder 2019). Based on the above data, the samples listed above in the Ko 1, Ko 2, Ko 6 and Ko 8 profiles can be related to the Subboreal (ca. 4.5 ka BP to ca. 2.5 ka BP) or the Subatlantic period (from ca. 2,5 ka BP).

The third youngest pollen chronozone comprises samples no. 3 in the Ko 13 profile (IIIC) and samples no. 5 and 6 in the Ko 12 profile (IIID), i.e. in abandoned channel fills of the younger generation. The occurrence of pollen grains characterises intensive anthropopressure in modern times although the indicators in the form of pollen grains of cultivated plants and weeds are very sparse here (Tab. 2). This may be the result of growing mainly wheat, which is a self-pollinating plant and its pollen grains are rarely found in a fossil state.

In the Kozari II profile (4–5-metre terrace), in the overbank silts at a depth of 3,38–3,45 m (Fig. 6) well preserved pollen grains of hornbeam (*Carpinus*), beech (*Fagus*), fir (*Abies*) and alder (*Alnus*), as well as pollen grains of oak (*Quercus*), elm (*Ulmus*), lime (*Tilia*), and ash (*Acer*) were recorded. The occurrence of such tree species in pollen spectrum indicated that deposition took place during the Subatlantic Phase. The radiocarbon dating of subfossil oak trunk buried in silts, ranging 1.62±0.04 ka BP, defines the age of sedimentation at the Roman period or the Early Middle Ages.

In the Kozari VI profile that represents alluvia of the 3–4 m high terrace (Fig. 10), in the three samples taken from silts under channel alluvia at a depth of 2.45–2.78 m pollen spectrum is very similar to Ko II profile (hornbeam, beech, fir, alder) and, additionally pollen grains of rye (*Secale cereale*) were recorded, while lime, elm and ash are absent here. Lesser concentrations of alder, hornbeam and oak pollen were evidenced here. It probably records the degeneration of mixed forest communities in the Middle Ages (13–14th centuries) owing more intensive, comparing to the Roman period, human activity confirmed by numerous archaeological sites in the Kozari and Tenetnyky villages (Machnik et al. 2013). Apart from the presence of rye pollen (*Secale* sp.) and ruderals, such as: ribwort plantain (*Plantago lanceolata)*, mugwort (*Artemisia*), and goosefoot family (*Chenopodiaceae*), there are not plant indicators of vast open area.

DISCUSSION

CHRONOSTRATIGRAPHY OF ALLUVIAL FILLS AND THE SOURCE OF THE ERROR OF RADIOCARBON DATES

In analysed all profiles the age of sediments determined by ^{14}C dating is significantly overestimated in relation to the age determinations obtained based on pollen analysis. The age of the overbank deposits of the first terrace with a height of 5.5–6.5 m above the Dniester riverbed equal to 13.01±0.18 ka BP (16–15 ka cal BP)(MKL-2264) corresponds to the Plenivistulian decline or the beginning of Late Vistulian (Fig. 11). The dating of the bottom of a large palaeomeander fill to 12.85±0.17 ka BP (15.97–14.76 ka BP) (MKL-2266) indicates that the meander cut-off took place at the end of the Plenivistulian or in the Oldest Dryas (Fig. 11). The dating result for the second sample, 12.19±0.1 ka BP (14.59–13.81 ka cal BP) indicates that the sediments were accumulated in the Bölling Interstadial. On the other hand, based on the pollen analysis, both bottom samples of the palaeochannel fill represent the Holocene climatic optimum and therefore they were included in the Atlantic period (Tab. 2).

Similarly, the result of dating of sediments from point bars of the large palaeomeander, 11.49±0.16 ka BP (13.68–13.1 ka cal BP) (MKL-2267) and 11.45±0.11 ka BP (13.52-13.13 ka cal BP) (MKL-2279), was recognized as Atlantic after age verification by the pollen analysis method (Fig. 11).

If we hand not had any age determinations by the pollen analysis method, we would have recognised the large palaeomeander to be from the Plenivistulian decline. Fortunately, it was possible to localise at the southern edge of the valley (near Luka village) large palaeomeander (R = 600 m, w = 200 m) filled with peat, from which a 3.45 m thick sediment core was collected for palynological analyses (Fig. 2). Pollen analysis of the peat from the bottom of the abandoned channel at the depth of 2.95 –3.40 m showed the presence of pollen grains of swiss pine (*Pinus cembra*), birch (*Betula*), willow (*Salix)*, larch (*Larix*), juniper (*Juniperus*) and mugwort (*Artemisia),* which are characteristic of the Younger Dryas (Harmata et al., 2013b). Radiocarbon dating of the palaeomeander fill was performed using the AMS method. The age of macroscopic plant remains at the depth of 3.35–3.36 m equals to 10.89±0.09 ka BP (Poz-61495) and 3.15–3.16 m 10.68±0.08 ka BP (Poz-61598) (Kołaczek

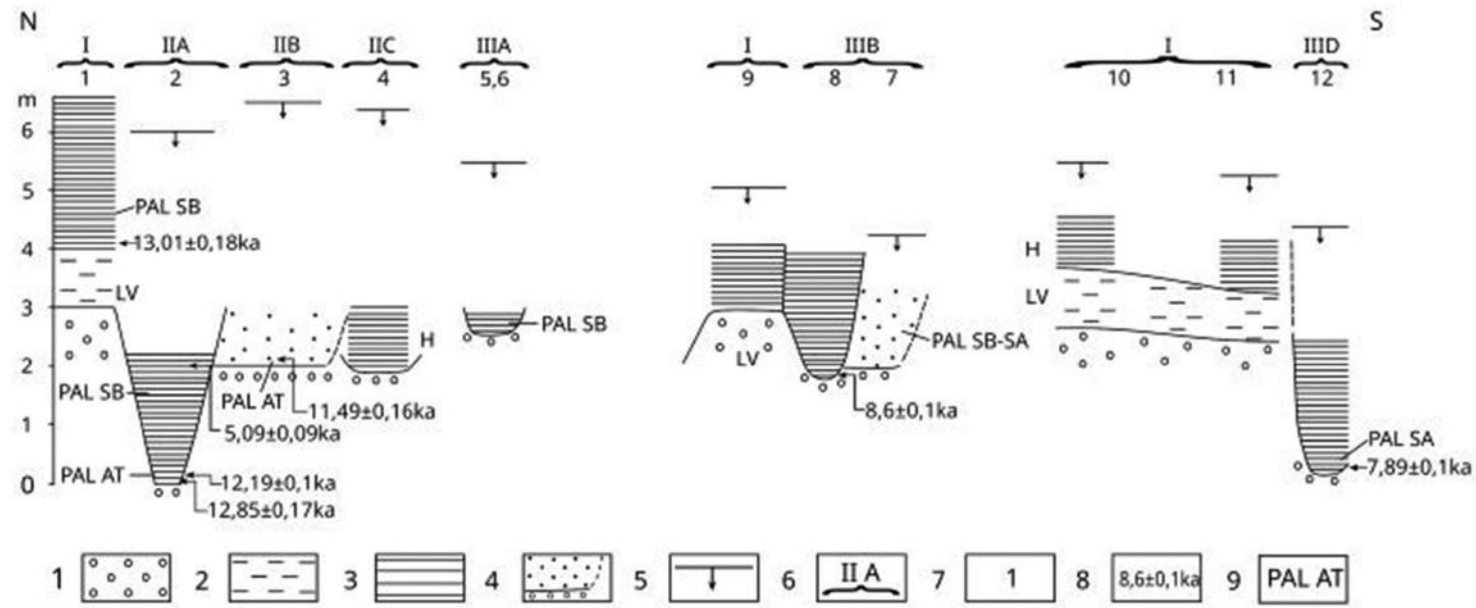


Fig. 11. The location of the radiocarbon dated deposits of Late Vistulian terrace (I) and the large palaeomeander (IIA, IIB) in relation to the palaeomeander systems from the Subboreal and Subatlantic phases. 1 – channel facies, 2 – overbank facies (flood rhythmites) of the Late Vistulian, 3 – overbank (silty–clay) facies of the Holocene, 4 – point bar deposits, 5– the height of the terrace surface (in metres above present riverbed), 6 – Number of the alluvial series and palaeomeander systems (described in the text), 7 – Number of the drilling profile, 8– ^{14}C dates, conventional age (ka BP), 9 – palynological indications: AT – Atlantic, SB – Subboreal, SA– Subatlantic; the remaining age determination: LV – Late Vistulian, H – Holocene

et al. 2017) indicates the Younger Dryas. The samples that were higher in the profile showed older age (11.28–11.14 ka BP) corresponding to the Alleröd Interstadial. The sample collected at the depth of 2.85-2.86 m was dated to 10.18±0.08 ka BP (Poz-61495) corresponding to the Preboreal Phase (Kołaczek et al. 2017). Of the same age is the large Late Vistulian palaeomeander in the valley of the Bystrycia Pidbuzska (tributary of the Dniester river) (Kalinovyč et al. 2006) and the very large palaeomeander of the Wisłoka (tributary of the Vistula river) near Dębica (Starkel, Granoszewski 1995). The example of the Luka profile shows that dating of individual plant remains by the AMS method clearly reduces the probability of dating contaminated material; however, we are not entirely sure of a good correlation between the radiocarbon date and the sediment level dated.

Similarly, in the case of dating Holocene alluvial fills and palaeomeander systems, the radiocarbon dates do not correspond to the age determination based on palynological analyses.

A fragment of a narrow palaeochannel very poorly marked in the field (Ko 8 profile, Figs 3, 4, 11) was dated to 8.6±0.1 ka BP (9.96–9.47 ka cal BP) (MKL-2282), i.e. the Boreal period. According to the palynological analysis, the sediments of this palaeomeander represent the Subboreal period, or more likely due to the occurrence of cannabis (hemp) pollen grains, the Subatlantic period (Fig. 11, Tab. 2). A slightly larger palaeomeander, with clearly marked erosion scarps (Ko 13 profile, Figs 3, 4) was dated to 8.47±0.1 ka BP (9.73–9.29 ka cal BP) (MKL-2269), which is very similar to the previously dated palaeomeander. The results of the pollen analysis indicate the Subatlantic age of these palaeomeander, confirmed by the occurrence of anthropogenic indicators (Fig. 4, Tab. 2). The age of the palaeomeander of a relatively large size (R = 300 m , w = 60 m), with deep-incised channel (IIID, Ko 12 profile) (Fig. 11) was determined at 7.89±0.1 ka BP (9.06–8.56 ka cal BP) (MKL-2268), which corresponds to the beginning of the Atlantic period. On the other hand, the pollen spectrum is characteristic of the vegetation of the Subatlantic period. Furthermore, human activity indicators were found in the deposits.

Two samples dated in the top of large palaeomeander fill (IIA, Fig. 11) have slightly inverted ages. The sample at the depth of 3.91–3.94 was dated to 5.09±0.09 ka BP (6.05–5.65 ka cal BP) (MKL-2281) while the sample at the depth of 2.37–2.41 m was dated to 5.72±0.06 ka BP (6.71–6.44 ka cal BP) (MKL-2265). The pollen spectrum of the analysed samples may be related to the Subboreal period (Fig. 4, Tabs 1, 2). In this case, despite the reversed dates, the radiocarbon age of the sediment is generally consistent with the pollen analysis results.

Although radiocarbon dates indicate a logical time sequence of the distinguished generations of palaeochannels, based on the pollen analysis, it is known that the overestimation of their age is at least in the range of several thousand years. In the case of the ^{14}C datings of the palaeomeander fills which reveal too old ages in comparison to the palynological analysis, the difference in ages of deposits could reach several thousand years, evidenced by study of two palaeomeanders of the Warta river near Poznań (Okuniewska, Tobolski 1981). Both palaeomeanders of Warta river – large and small ones – were dated by radiocarbon method to the Plenivistulian (datings from the bottom section of the sequence range 23–24 ka BP), while palynological analyses indicate, that accumulation in the larger palaeomeander started in the Younger Dryas, while in the small palaeomeander – in the Boreal Phase (Okuniewska, Tobolski 1981). The mentioned above authors of these datings exclude the possibility of surface redeposition of the older Tertiary or Quaternary sediments, because pollen spectra contain occasional presence of older spores, in similar quantity which are noticed in many other postglacial depositional basins.

These thesis is confirmed by the results of our study. Independently of the time (age) of the accumulation beginning in the oxbow-lake, old carbon was transported by the groundwater to the depositional basins both in the Late Vistulian and in the Holocene. Only the non-carbonate deposits at a top of the Late Glacial palaeomeander fills were not contaminated with old carbon and, thus, their radiocarbon datings are in accordance with the age obtained by palynological method, although a little inversion of age was observed.

The significant overestimation of the ^{14}C age of the sediments can probably be accounted for by the reservoir effect (hard water effect). The value of reservoir effect (i.e. reservoir age) in the depositional basins, such as lakes or oxbow-lakes could range from 0 to 2000 years (www.adamwalnus.pl/datowanie/p7.html). The source of reservoir effect, responsible for overestimation of deposits is the presence of old re-deposited calcium carbonate dissolved in groundwater supplied to the oxbow-lake. Organisms which received carbon from the carbonate dissolved in water, contain considerably lower concentration of ^{14}C, than terrestrial plants which adopt carbon directly from atmosphere, and consequently, the "radiocarbon ages" of these organisms after dead are much larger than their real ages (Walanus, Goslar 2009). The content of calcium carbonate at the bottom of large palaeomeander fill at the Kozary site at a depth of 5.14–6.07 m was between 9 and 12% (Fig. 5).

THE ACCUMULATION AND EROSION PHASES IN THE HALYČ-BUKAČIVCI BASIN

Despite the discordance of the obtained datings, it is possible to reconstruct the sequence of the accumulation and erosion phases in the Halyč-Bukačivci

Basin on the basis of presented material and results of datings from other sites in the Upper Dniester basin.

The youngest, covered with loess, Pleistocene terrace II (10–15 m above riverbed) formed in the Plenivistulian. The fragment of wood in the channel alluvia of this terrace was dated at >19 ka BP, determining in this way the minimum age of this terrace (Huhmann, Brückner 2002). The dissection of the terrace II occurred after the Last Glacial Maximum (LGM). In the Late Vistulian the accumulation of the terrace I reached the height of 3–4 m above the present riverbed (Fig. 11). Alluvial plain of a width over 1 km was formed by the braided river, which deposited rhythmically stratified deposits in the distal part of plain during floods (Fig. 11). In the decline of the Late Vistulian the development of mosaic pine-birch woodland and spread of tundra and steppe communities (Harmata et al. 2013b) confined the bed load supply to the river channel and caused the concentration of water flow. Consequently, the transformation of the channel pattern from braided to meandering occurred.

Such meandering channel was dated to the Younger Dryas in the southern part of the Halyč-Bukačivci Basin (Harmata et al., 2013a, Kołaczek et al. 2017). Similar in age are palynologically dated organic deposits of the oxbow-lake in the Svirž river valley (the tributary of Dniester river dissecting the Opillje Upland) (Kalinovyč 2013). Lateral migration of the large meander caused erosion of the terrace I. This erosion occured simultaneously with accumulation of point-bars, which were covered in the Holocene by flood deposits that reached the level of the terrace I (Fig. 11). The stabilization of the channel occurred in the early Holocene, however, dated alluvial deposits from this period are lacking. The onset of filling of the large palaeomeander fell into the climatic optimum (Atlantic Phase) (Fig. 11, IIA).

However, the palaeomeander in the southern part of the Halyč-Bukačivci Basin is dated to 6.44 ± 0.035 ka BP (5.48–5.34 cal BC) (Poz-51171) i.e. was formed in the decline of the Atlantic Phase (Harmata et al. 2013c). During the Subboreal Phase, due to the deterioration of the climate (Starkel 2014) and the increase in the bed load derived from reworking of the alluvia of the terrace I, aggradation took place and shallow anastomosing channel was formed. One branch of this channel cuts the erosion inlier (comp. Fig. 3), whereas the second branch from the northern side of erosion inlier caused the formation of the erosional scar separating the Late Vistulian alluvial fills (IIA and IIB) from the floodplain (IIIA) (Fig. 11). Possibillity of the existence of such anastomosing channel pattern on the floodplain of the Dniester river was referred by M. Huhmann and H. Brückner (2002).

The deposits filling the large paleomeander dated to 5.09±0.09 ka BP, as well as the overbank deposits overlying the terrace I are assigned to the Subboreal Phase. The paleomeander from the transition of the Subboreal and Subatlantic phases was probably deeper and narrower, comparing to the former one (Figs 3, 11, IIIB). During the Subatlantic Phase the incision of channel proceeded, meandering channel were larger and deeper than during the Subboreal Phase. The basis of the palaeomeander fills from this period (Fig. 11, IIID) reached the level of the present riverbed.

The series of radiocarbon dating measurements of subfossil trunks presented below reflects very well the chronology of the fluvial events of the last 2,000 years.

The position of the trunks in the profiles and the distribution of radiocarbon dates indicate three phases of increased activity of the Dniester river. The aggradation phase in the Roman period (1.8–1.6 ka BP) was followed by a phase of lateral erosion and alluvial accumulation during mediaeval floods (1.38–0.81 ka BP). At that time, the channel of the Dniester river moved to the south-east, which is evidenced by the trunks that were fallen down during recurrent floods and deposited in point bars. In the 13th and 14th centuries (the beginning of the Little Ice Age), the 4–5-metre terrace was dissected, and the channel alluvia of the lower 3–4-metre terrace were deposited. This was related to the cooling of the climate and an increase in human activity, which is marked by the presence of pollen grains from cultivated plants in overbank sediments. Overbank clayey silts and clay were deposited in the flood basins far from the active channel. The increase in the river activity in the last 100–150 years is associated with lateral migration of the channel and accumulation of sandy-silty natural levees.

CONCLUSIONS

In the middle Dniester valley (Halyč-Bukačivci Basin) the Late Vistulian terrace 5.5–6.5 m high and alluvial fill series from the decline of the Late Vistulian (Younger Dryas) and Holocene occurred. Alluvial fill series and palaeomeander systems formed two terrace levels (floodplains) 4–5 m and 3–4 m above river channel. M Huhmann and H. Brückner (2002) based on radiocarbon dating of wood fragments and differences in degree of development of the Holocene alluvial soils, distinguished two terraces formed in the Vistulian and seven Holocene terrace levels.

The results of radiocarbon dating on the cross-sectional area in Kozary village admittedly indicate a consistent and logical arrangement from the oldest dates (13.01–11.45 ka BP) to more and more younger ones (8.6–7.89 ka BP) for the distinguished systems of terraces and palaeomeanders; however, they are generally significantly older compared with findings from palynological analyses. The overestimation of the age of sediments is much greater for Holocene (Subboreal and Subatlantic) generations of palaeomeanders than for the Late Vistulian terrace and large palaeomeander of the Dniester river.

The overestimation of the age of the sediments may be caused by the admixture of older re-deposited organic material or, more likely in the case of the profiles discussed above, by the reservoir effect (hard water effect) associated with the presence of old carbonates. These carbonates could have been leached from loess covers; then, in the dissolved form (solution) they seeped into abandoned channels with groundwater and there they were deposited with aquatic vegetation.

The confirmation that the source of the error is old carbon derived from dissolution of carbonate rocks, is that in the large palaeomeander overestimation of age is connected only with carbonate silts at the bottom of the depositional sequence of the oxbow-lake. However the deposits at the top of palaeochannel fills do not contain calcium carbonate and their radiocarbon age is in accordance with results of the palynological analysis.

Therefore, AMS dating of macroscopic plant remains may reduce the probability of dating contaminated material. Based on the presented analysis, there is a reasonable supposition that some of the existing radiocarbon dating of the Late Vistulian palaeomeander fills may be significantly overestimated.

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