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PALAEO
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Late quaternary landscape evolution of the upper Dnister valley, western Ukraine

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Received 12 March 2003; accepted 5 February 2004

Abstract

The broad and flat valley of the upper Dnister in western Ukraine is characterized by a complex setting of ecotopes and a relatively natural state of floodplain dynamics. Excellent geo-archives – extended peat bogs and postglacial river terraces – document late Quaternary landscape evolution with special regard to changes in fluvial morphodynamics, vegetation and human impact. The terraces were studied by detailed geomorphological mapping as well as sedimentological and pedological analyses in connection with information from historical maps. Vegetation history was studied by palynological methods in combination with radiocarbon dating.

Two Late Pleistocene (NT1 and NT2) and seven Holocene (H1 – H7) river terraces are evident. The ecological transformation during the period of climatic warming at the end of the last glacial maximum (LGM) caused the most significant change in runoff and sediment load, as well as in the vegetation cover. The Dnister changed from a braided to a meandering river system. It was soon after the spreading of postglacial forests with an increasing dominance of broadleaved trees that the pollen diagrams reflected the first signs of anthropogene influence. Intensified agricultural land use since the Iron Age is mirrored in the increasing amount of herbaceous pollen as well as the rise of fluvial sediment redeposition. Modern hydraulic engineering on the Dnister has caused visible transformations. Because of these impacts, the stability of the upper Dnister ecosystem has decreased significantly and is now highly sensitive to environmental change.

Keywords: Floodplain evolution; Holocene; Radiocarbon dating; Palynology; Vegetation history; Ukraine; Dnister

1. Introduction

The Holocene evolution of river valleys is of great interest for multidisciplinary studies. Rivers are sensitive to climate and vegetation changes, as well as human-induced variations in the catchment area (Brown, 1997). Palaeoecological evidence can also provide useful information about the future reaction of river systems to global climate changes.

The Dnister, which drains into the Black Sea, is one of the largest rivers in the south of Eastern Europe with a total length of 1360 km. The Dnister basin is about 72,100 km^2 in size and covers a large

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doi:10.1016/j.palaeo.2004.02.014

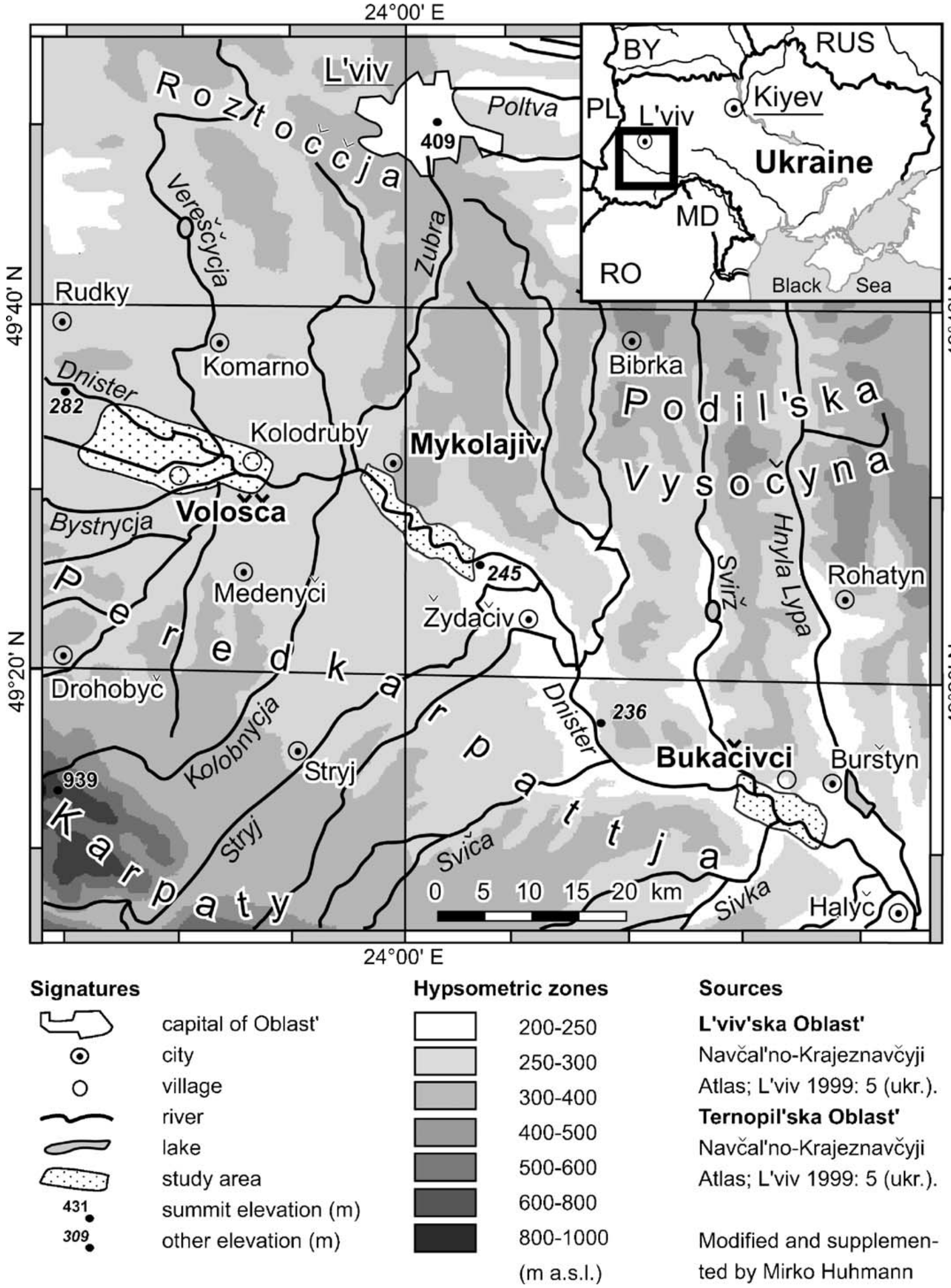

Fig. 1. Topographic map with indication of the study areas in the environs of Vološča, Mykolajiv and Bukačivci.

part of southwestern Ukraine and Moldova (Fig. 1). This area is located in the transitional belt from Central European to East European vegetation provinces. Situated between temperate and continental climates, the catchment area of the upper Dnister shows a sensitive reaction to shifts in climate and vegetation. They are well preserved in the geoarchives of the Dnister valley. The western Ukraine has a long record of the human impact on landscapes, though not as intense as in Central Europe (Pashkevich, 1997).

At present, studies of river valley development in eastern Europe are limited. Some research has been done in South Poland (e.g. Starkel, 1991a; Kozarski, 1991; Ralska-Jasiewiczowa and Latałowa, 1996), especially within the framework of IGCP-Project No. 158 (Baker, 1991). In the Russian Plain (Wohl and Georgiadi, 1994; Panin and Karevskaya, 2000) and in Byelorussia (Kalicki, 1995) several studies were carried out, concerning the synchronous shift of river channels due to climatic control. The influence of human impact on soil erosion and redistribution of sediments within small river catchments was investigated in that region by Golosov (1998) and Sidorchuk (1997). A few comparable studies exist for the lower and middle Dnister regions (Adamenko et al., 1996; Gerasimenko, 1997; Kremenetski, 1997). However, only general information about floodplain geomorphology (Kovaltchuk, 1997) or Pleistocene step terraces (Jermolenko, 1962; Cys, 1962) is available for the upper Dnister basin. Recently, Bogutskiy et al. (2002) investigated the glacial relief, Pleistocene terraces and loess cover.

Dobrowolski et al., (2002) published data on the formation of some peat bogs and the rate of their biogenic sedimentation for the Vohlynia Polesiye north of the Dnister basin. The reconstruction of the Holocene vegetation history of the region is based on a few dated pollen diagrams from peatlands (Artushenko et al., 1984; Kremenetski, 1995).

This paper presents the first detailed multiproxy study of the Late Quaternary evolution of the upper Dnister valley. It is based on sedimentology, pollen analysis and radiocarbon dating, supplemented by archaeological information and cartographic evidence of land use changes (cf. Huhmann and Brückner, 2002).

2. Natural setting of the study area

The Holocene evolution of the upper Dnister valley was studied at three sites: Vološča, Mykolajiv and Bukačivci (Fig. 1). They are situated in the Molasse trough of the Precarpathian foredeep (ukr. Peredkapattja) between the folded Carpathian mountain chain (ukr. Karpaty) in the southwest and the Paleozoic craton of the Podilia plate (ukr. Podilska Vysočyna) in the northeast. In the Precarpathian foredeep as well as on the Podilian plate, Miocene sediments are covered by Pleistocene loess (average thickness: 5–8 m, the maximum is reached on the Podilian plate with 20 m). Due to the widespread Pleistocene loess deposits, the region is mainly occupied by Lessivés and weakly developed Chernozems. The vegetation distribution reflects the transition between Middle European forests and East European forest-steppes.

The climatic regime of western Ukraine belongs to the temperate continental type, i.e. to a transition between Middle and East European climates. The increased continental climate regime expresses itself in an increased variability in the temperature and moisture regimes. Mean January temperature registers -4 °C; mean July temperature $+18$ °C. The quantity of precipitation varies from 500 to 700 mm/year on the Podilian plate up to 800–1200 mm/year in the Carpathian Mountains as an effect of the orographic barrier. Because of the distinct convective rainfall pattern, about 40% of the annual precipitation occurs during the vegetation period (Fig. 2; cf. Mucha, 2000).

Within the Carpathian Mountains, the course of the upper Dnister has an average gradient of 8.7‰ and a mean discharge of 5 m^3/s (at the village of Strilky; cf. Kovaltchuk, 2000). Reaching the Precarpathian foredeep, the average gradient of the river is reduced to 0.7‰ and most of the sediment load is accumulated at a short distance downstream in several gravel bars near the city of Sambir. Downstream, the channel pattern changes into a meandering river. The first major tributaries (e.g. Bystrycia, Stryj) increase the mean discharge of the Dnister to 124 m^3/s in the vicinity of the city of Žydačiv (Fig. 1). When entering the Podilian Plate, the Dnister formed a deeply incised ‘canyon’ with huge alternating valley meanders formed during the neotectonical uplift of the craton.

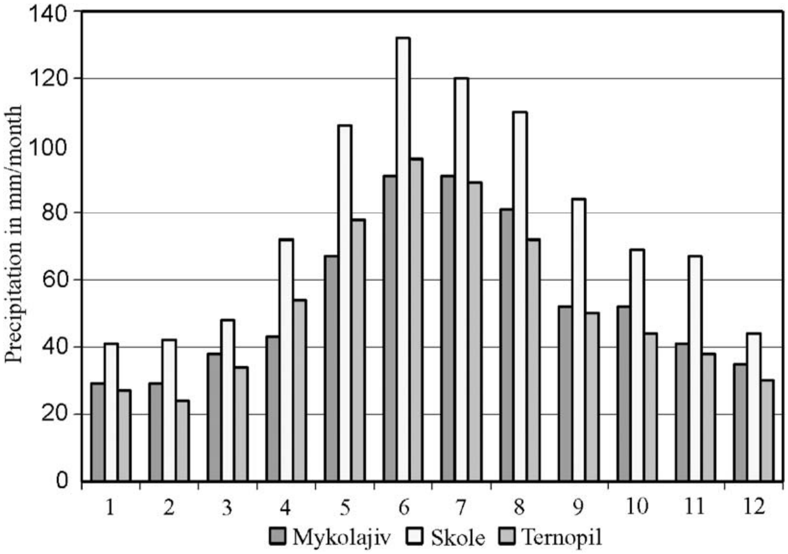

Fig. 2. Typical seasonality of mean precipitation 1961 – 1991 at the gauging stations Mikolajiv (Precarpathian foredeep), Skole (Carpathian mountains) and Ternopil (Podilian Plate). Source: Mucha (2000).

There the river grows up to 200 m in width and the mean discharge increases to 219 m^3/s. Generally the annual discharge distribution is characterised by a pluvio-nival hydrologic regime with three peaks, i.e. snowmelt in spring, precipitation maximum in summer and thawing period in winter (Fig. 3).

The study areas reveal details of the postglacial geomorphologic evolution and its controlling factors.

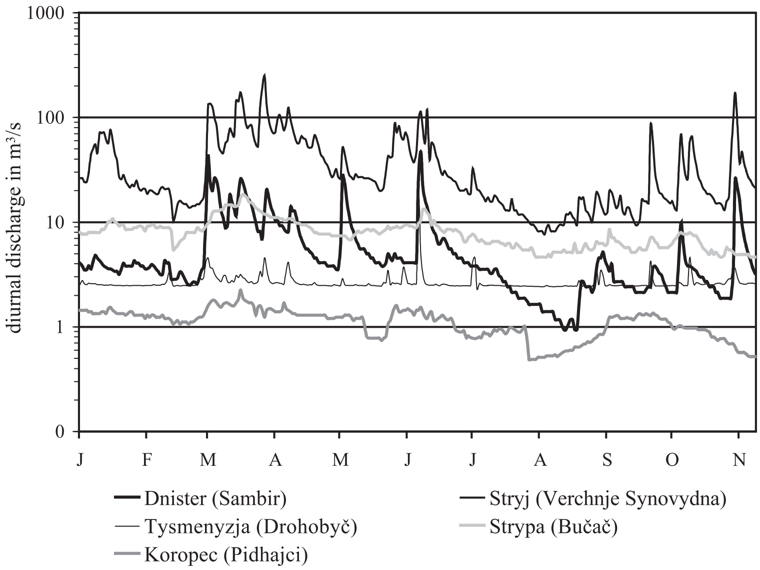

Fig. 3. Discharge of 1994 for the Dnister and an assortment of tributaries in m^3/s (Stryj and Tysmenyzja from the Carpathian mountains, Strypa and Koropec from the Podilian Plate). Source: UNESCO/BMBF-Project ''Transformation Processes in the Dnister Region'', Subproject ''Hydrology''. Prof. I. Kovaltchuk, Department of Geography, University of Lviv, Ukraine.

Alterations both of vegetation cover and fluvial morphodynamics left visible traces in the landscape. It is noteworthy that the human impact is of minor importance. Therefore, the valley floor of the upper Dnister still shows typical elements of a natural floodplain and relatively undisturbed fluvial dynamics. Due to the generally low river gradient and the broad valley bottom, the area has well developed geo-archives, such as extended peat bogs (especially at Vološča and Bukačivci).

3. Methods

3.1. Geomorphological and pedological methods

In a detailed geomorphologic study, nine late Pleistocene and Holocene Dnister terraces were mapped (cf. Fig. 4). Altitudinal differences and morphological unconformities between meander generations were the principal criteria for their differentiation (sensu Schirmer, 1983). Pedological and

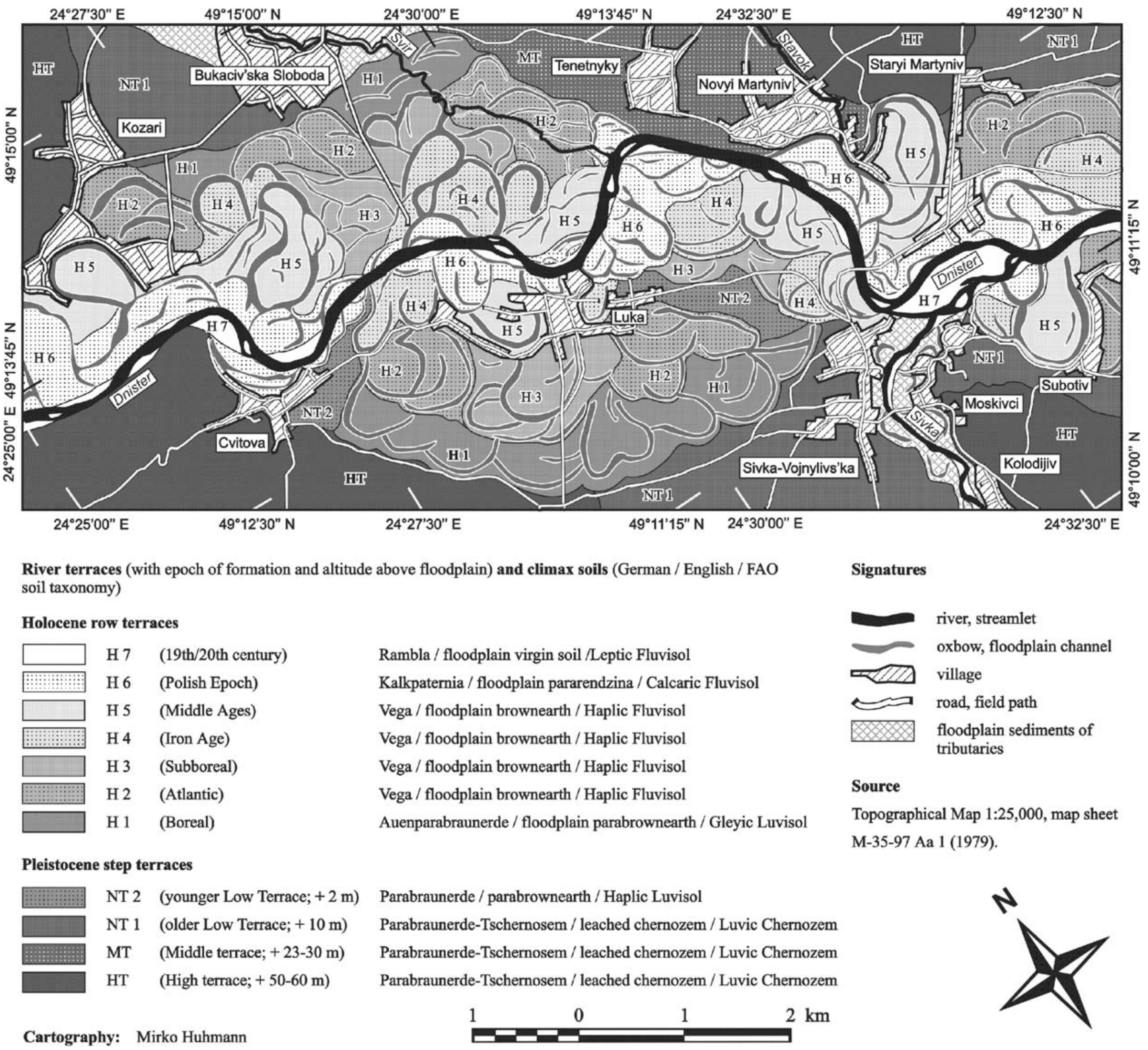

Fig. 4. Late Pleistocene and Holocene river terraces with floodplain morphology and soil formations in the study area of Bukačivci. Soil Taxonomy according to AG Boden (1994) and WRB (ISSS-ISRIC-FAO, 1998).

sedimentological analyses of terrace deposits provided additional information to ensure the placement of the mapped units in stratigraphic order. The stages of pedogenesis in relation to the ages of the terraces as well as sedimentological and age dependent parameters–soil texture, decalcification depth, phosphate and organic contents as indicators of paleosols, relation of pedogenic iron and manganese to their

Table 1
Radiocarbon dates from peat of percussion coring FA 21 near the village of Vološča (upper part) and from wood samples of percussion corings in the environs of Mikolajiv and Bukačivci (lower part)

Sample	Depth (cm)	Organic substance (%)	Laboratory code	$\delta^{13}C$ (‰ PDB)	Conventional ^{14}C age (years BP $\pm 1\sigma$)	Calibrated (1σ) age range[a] rounded (cal. BP)	Remarks
Vološča profile							
FA 21/2	15–21	58	LZ-1587	– 27.5	960 ± 55	930–800	disturbed by land use
FA 21/7	70–74	60	LZ-1589	– 27.7	350 ± 50	480–310	
FA 21/11	114–119	55	LZ-1590	– 27.9	520 ± 60	620–510	
FA 21/16	161–165	95	LZ-1591	– 28.4	2150 ± 55	2300–2060	[b]
FA 21/21	217–224	56	LZ-1588	– 27.7	2700 ± 55	2850–2750	
FA 21/25	261–265	90	LZ-1583	– 27.2	3500 ± 60	3840–3690	[b] and much carbonate
FA 21/28	284–290	76	LZ-1656	– 27.2	4180 ± 65	4830–4570	some carbonate
FA 21/31	316–321	66	LZ-1584	– 27.5	1510 ± 55	1510–1330	[b]
FA 21/33	331–338	67	LZ-1657	– 27.0	1850 ± 60	1870–1710	[b]
FA 21/37	375–381	58	LZ-1585	– 27.1	5930 ± 65	6850–6670	
FA 21/38	386–390	8	Beta-113230	– 25.0	6520 ± 80	7550–7330	clay zone
FA 21/41	417–422	66	LZ-1586	– 27.1	7330 ± 65	8180–8030	
FA 21/45	459–466	11	LZ-1592	– 27.5	6230 ± 65	7250–7010	some carbonate
Surrounding area of Vološča							
FA 12/9	170–190	57	Beta 113227	– 25.0	2510 ± 80	2765–2345	
FA 17/9	180–200	69	Beta 113228	– 25.0	4190 ± 70	4860–4525	
FA 20/A	358	wood	Beta 113229	– 25.0	440 ± 50	535–430	
FA 22/6	460–470	58	Hd-22425	– 28.7	9928 ± 37	11,340–10,235	some carbonate
FA 22/12	550	wood	Hd-22396	– 25.7	10,552 ± 43	12,835–12,365	
FA 24/4	240–250	61	Hd-22418	– 29.2	3378 ± 22	3685–3590	
FA 24/10	560–580	39	Hd-22426	– 28.7	11,478 ± 35	13,780–13,330	
FA 26/9	350–360	66	Hd-22419	– 29.1	7235 ± 25	8110–7980	
FA 26/16	760	wood	Hd-22176	– 27.6	10,842 ± 95	12,990–12,670	
Mikolajiv and Bukačivci							
CO 10/11	1065	wood remains	Beta 113224	– 22.4	>40,000	–	AMS
CO 13/9	560	wood remains	Hd 18737	– 27.8	>40,000	–	
Co 13/8	490	wood remains	Beta 113225	– 28.5	>20,000	–	AMS
HC 6/15	580	wood remains	UtC 10239	– 28.5	>19,000	–	
HC 11/11	470	wood remains	UtC 10240	– 26.7	5514 ± 43	6380–6280	
CO 15/7	470–490	wood remains	Hd 18736	– 26.1	5185 ± 310	6290–5600	
A 2	540	wood remains	Beta 113222	– 25.0	3720 ± 60	4150–3930	fossil oak
CO 8/7	358	wood remains	Beta 113223	– 27.9	3460 ± 50	3700–3590	AMS
HCX 2/9	335	wood remains	Hd 20990	– 25.9	3294 ± 27	3555–3475	fossil elm
CO 12/6	382	wood remains	Hd 18646	– 24.3	3180 ± 120	3550–3270	
HC 2/7	495	wood remains	UtC 10238	– 27.4	1705 ± 32	1690–1550	

Laboratories: LZ = UFZ Leipzig, Hd = Acad. Sc. Heidelberg, Beta = Beta Inc. Miami, UtC = Univ. Utrecht.
AMS: Accelerator-Mass-Spectrometer.

[a] According to INTCAL Radiocarbon Calibration Program (Stuiver et al., 1998).

[b] High content of roots/rootlets, removed by hand under binocular.

respective total amounts (Fig. 6)–served as additional criteria for age classification (cf. Schröder, 1983). That was then calibrated to local sites where ages had been determined by radiocarbon dating (Table 1) or from historical sources (cf. Tolochko, 1998).

3.2. Radiocarbon dating

All ^{14}C ages (Table 1) are quoted in conventional ^{14}C years, i.e. corrected for isotopic fractionation by normalizing $\delta^{13}C$ values to -25‰ and referred to the ANU sucrose as a reference standard. Quoted errors ($\pm 1\sigma$) only account for uncertainties in counting statistics. Conventional ^{14}C ages were calibrated using the INTCAL 98 calibration program (Stuiver et al., 1998).

Most of the peat samples were interspersed with modern rootlets. After their removal under a binocular microscope, the usual acid–alkaline–acid pretreatment was not applied in favour of the sole HCl pretreatment (0.5 M HCl, 60 °C) in order to avoid the relative enrichment of root material. After washing and drying, the organic matter was converted into benzene. The ^{14}C activities were measured with a Packard Tri-Carb 2560 TR/XL liquid scintillation spectrometer.

The Wood samples were processed by different laboratories (Table 1) using the acid–alkaline–acid procedure. After chemical preparation, the activities of the samples were measured by liquid scintillation counting and/or gas proportional counters. AMS results were derived from reduction of sample carbon to graphite in an accelerator-mass-spectrometer.

3.3. Pollen and botanical analyses

Standard methods were used for the preparation of samples for pollen analysis and pollen counting (Stockmarr, 1972; Faegri and Iversen, 1989). Botanical composition of the peat was studied according to standard Russian methodology (Bazin et al., 1992). Plant remains were identified using an atlas of plant remains in peat (Kats et al., 1977).

For pollen analysis, a minimum of 300 grains per sample was counted in order to ensure a statistically significant sample size (Maher, 1972). The pollen reference collection of the Institute of Geography, Russian Academy of Sciences, Moscow, was used for pollen identifications with reference to Andrew (1984), Erdtman (1992) and Reille (1999). The pollen taxonomy and nomenclature follows guidelines specified by Moore et al. (1991) and Berglund and Ralska-Jasiewiczowa (1986). Zonation of the pollen diagram was established using the CONISS procedure of the TILIA program (Grimm, 1987, 1990).

4. Geo-scientific characteristics of the fluvial terraces in the environs of Mykolajiv and Bukačivci

Seven Holocene (H1–H7) and two Late Pleistocene river terraces (NT1 and NT2) were mapped in the valley floor of the upper Dnister (Fig. 4) by detecting their characteristics as shown in Table 2 (Huhmann and Brückner, 2002; cf. Figs. 4 and 5). Local factors like the higher volumes and velocities of discharge and higher sediment loads downstream from the mouths of bigger tributaries such as Stryj and Sviča affect the specification of the terraces. However, in the areas of Mykolajiv and Bukačivci (in contrast to the area of Vološča; Fig. 7), these local factors did not overprint the principal geologic characteristics (Huhmann and Brückner, 1999, 2000).

Both areas are flanked by Pleistocene step terraces at 50–60, 25–30 and 5–10 m above base level (valley floor). Holocene terraces, on the other hand, are represented by row terraces with their surfaces at approximately similar altitudes. The same is true for the basal elevations of respective row terraces. This results in more or less the same thickness of deposition across the whole sequence. It is only the younger Holocene terraces that are also characterized by a laterally accreted fill terrace inset.

The older *Late Pleistocene terrace NT1* shows a remarkable difference in altitude of 5–10 m above the present floodplain. Coarse grain-size deposits close to the surface are covered by a loess layer (Fig. 5), which distinguishes this from the younger terraces. In the area of Bukačivci the climax soil of this terrace is a Luvic Chernozem (Fig. 4). Further to the west, the maximum stage of pedogenesis on NT1 changes to an Albic Luvisol (e.g. in the study area around Mikolajiv and Vološča), due to the transition from the forest-

Table 2
Geomorphological, sedimentological and pedological characteristics of the Dnister terraces in the environs of Mikolajiv and Bukačivci

	NT1	NT2	H1	H2	H3	H4	H5	H6	H7
Epoch	Last Glacial (Waldai)	Younger Dryas	Boreal	Late Atlantic	Subboreal	Iron Age	Medieval Period ("Kyivan Rus")	Little Ice Age ("Polish Epoch")	Modern Times
Present elevation above floodplain	+ 5–10 m	± 0 m[a], + 2 m[b]	± 0 m[a], ± 1 m[b]	± 0 m[a], ± 0.5 m[b]	± 0 m[a], ± 0.2 m[b]	± 0 m	± 0 m	± 0 m	± 0 m
Floodplain morphology and meander radii	erosional surface with steep front range	traces of oldest meander with widest radius	first distinct paleomeander	mosaic terrace pattern, medium meander radius	mosaic terrace pattern, decreasing meander radius	first oxbows lakes remain up to date, mosaic terrace pattern	well preserved oxbows and floodplain channels	accompanying the recent river on both banks (seam terrace pattern)	only on present inner banks, technical impact (e.g. flood protection measures)
Channel pattern	braided	anastomosing/ meandering	meandering	meandering	meandering	meandering	meandering with tendency to anastomosing	meandering with tendency to anastomosing	canalization (causing incision) or anastomosing
Top soil cover	Albic Luvisol[a] *pale earth*/Luvic Chernozemb[b] *leached Chernozem*	Gleyic Luvisol[a] *floodplain parabrownearth*/ Haplic Luvisolb[b] *parabrownearth*	Gleyic Luvisol/ *floodplain parabrownearth*	Haplic Fluvisol/ *deeply decalcified floodplain brownearth*	Haplic Fluvisol/*decalcified floodplain brownearth*	Haplic Fluvisol/*moderately developed floodplain brownearth*	Calcaric Fluvisol/*floodplain pararendzina*	Calcaric Fluvisol/*floodplain pararendzina*	Leptic Fluvisol/ *floodplain virgin soil*
Type of aggradation	vertical	vertical	lateral	lateral	lateral	lateral	lateral	lateral	lateral
Stratigraphical and sedimentary characteristics	covered by loess	no loess, still coarse sediment cover, ascending terrace base level	strong gradation	silty loam as alluvial deposits with two paleosols	decreasing surface extension, preserved on both river banks[a]	thicker cover of silty loam as alluvial deposits (around 1.5 m) than older terraces	coarser sediments and ascending terrace base level due to human impact	last sediments that were accumulated under natural floodplain dynamics	ascending base level, without cover of silty loam alluvial deposits
Terrace texture	step terrace	row terrace	row terrace/inset fill structure	row terrace	row terrace	row terrace	row terrace/inset fill structure	row terrace	row terrace/ incision
Medium terrace thickness	>20 m	9–11 m	9–11 m	9–11 m	8–10 m	8–10 m	6–7 m	6–7 m	3–4 m
Ages in cal. years BP (Table 1)	>20,000/ >19,000	13,780–13,330, 12,835–12,365, 11,340–10,235	8110–7980	6380–6280, 6290–5600	4150–3930, 3700–3590, 3550–3270	2765–2345	1690–1550	535–430	–
Assumed period of terrace formation in cal. years BP[c]	25,000–18,000	13,000–11,300	9500–8350	6500–6000	4400–2800	2300–1800	1500–1000	16th–19th centuries AD	19th–20th centuries AD

[a] Only at the site of Mikolajiv.
[b] Only at the site of Bukačivci.
[c] Main phases of increased fluvial morphodynamics according to different authors (quotations in the text).

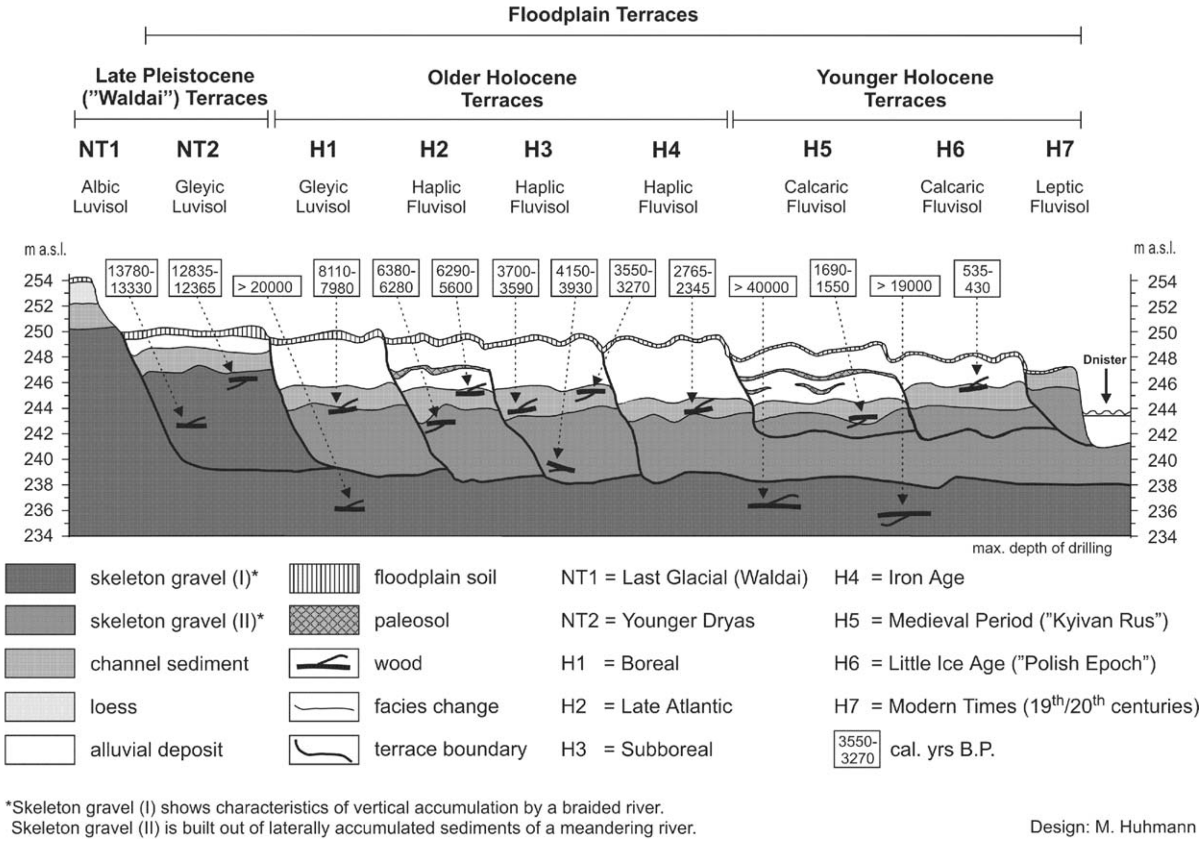

Fig. 5. Schematic sequence of the Late Quaternary terraces of the Dnister valley near Mikolajiv, showing facies, texture, radiocarbon dates and climax soils (Huhmann and Brückner, 2002; Fig. 3, modified).

steppe to Middle European forests. Wood from the NT1 gravel gave only a minimum age of >20,000 cal. years BP (Table 1; Fig. 5).

The younger *Late Pleistocene terrace NT2* is incised about 15 m into the older Pleistocene terrace NT1. Obviously the Dnister could not fill the valley up to the level of the previous terrace anymore. The base level of NT2 is higher than the respective levels of the older NT1. The sedimentary profiles still show coarse grain-size deposits of a frequently changing channel system (Fig. 5); however, it is for the first time that paleomeanders with a wide radius occur. In Mikolajiv the paleomeanders are preserved geomorphologically as flat floodplain channels, whereas in Bukačivci with only isolated occurrences of NT2, paleomeanders are preserved sedimentologically in an outcrop of an undercut slope. NT2 is topped at higher positions by a Haplic Luvisol (Bukačivci) and at floodplain level by a Gleyic Luvisol (Mikolajiv).

The *oldest Holocene terrace H1* shows a strong gradation upwards due to the lateral accumulation of sediments at inner bank lamellae of meander slopes (Fig. 6, column 6). The total thickness of H1 is only slightly reduced as compared to the previous NT2, while alluvial deposits (silty loam) are considerably thicker. The system of Pleistocene step terraces finally changed to Holocene row terraces (Fig. 5). H1 is the youngest terrace with a Gleyic Luvisol as climax soil, reflecting the location of H1 in the marginal parts of the recent floodplain. The numerous paleochannels of the meandering Dnister during the H1 time still have spacious radii, an average of 500 m, obviously due to high runoff.

Coring profile HC 6 (Fig. 6) exemplifies the stratigraphic sequence of H1 with a complete fluvial

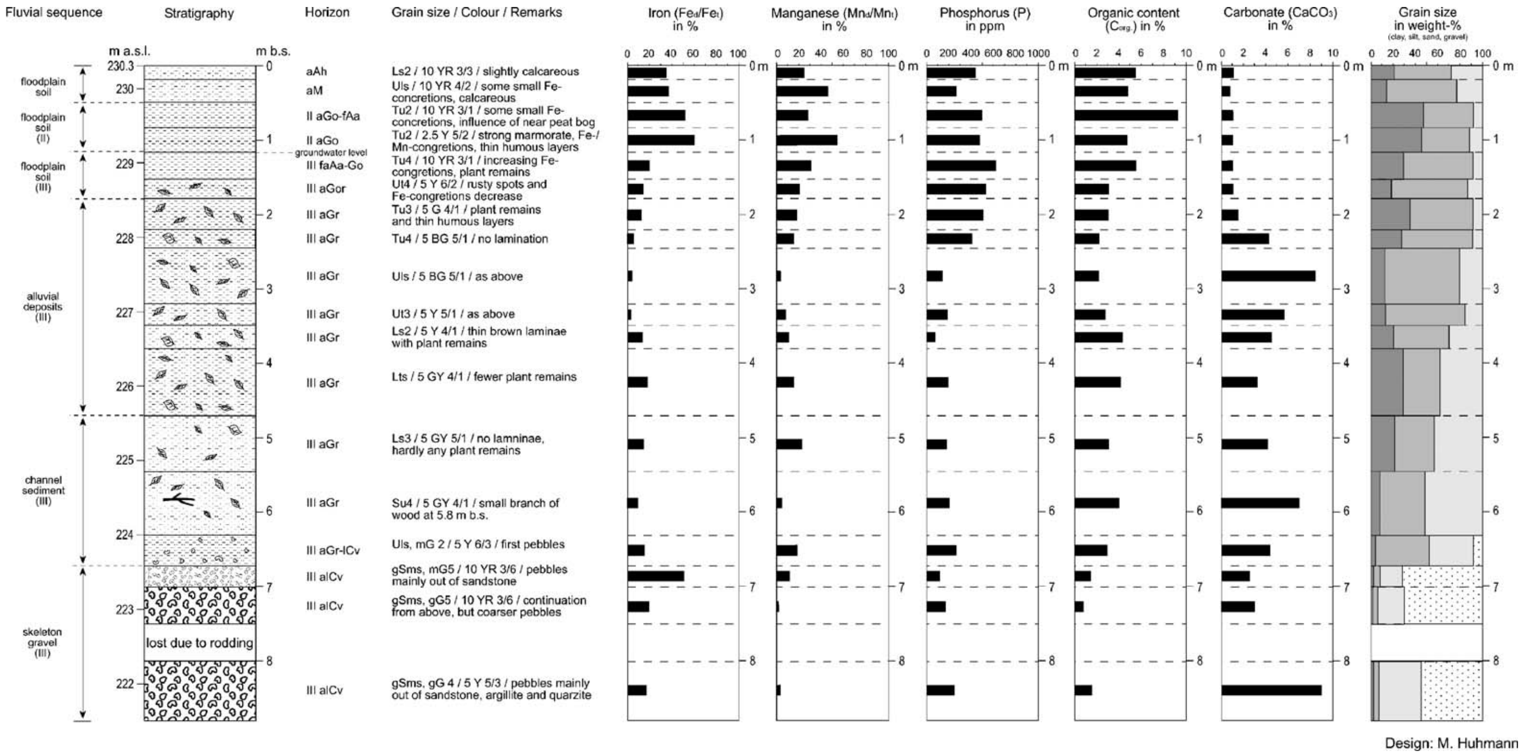

Fig. 6. Coring profile of the early Holocene terrace H1 near Luka (village close to Bukačivci); profile no. HC 6.

series from coarse skeleton gravel at the base, to sandy channel sediments, silty-loamy alluvial deposits with plant remains and paleosols. Due to its location in the outskirts of the floodplain in front of the rising slope of the NT1-terrace (Figs. 4 and 5) the continuous pedogenesis is interrupted by two fossil A-horizons. The decalcification depth of 2.2 m below surface (Fig. 6; column 5) points to a long period of pedogenesis. The fossil soils are characterized by a high content of organic matter and phosphorus (Fig. 6; columns 3 and 4). The increase of iron, e.g. at 6.7 m b.s. (below surface) helps to confirm the differentiation of this facies within the given fluvial series (Fig. 6; column 1).

The following *terraces H2 and H3* with a pronounced mosaic terrace pattern evidently display the morphological unconformities of different meander generations. On the other hand, both terraces are quite similar to each other. In both cases the thickness of the sedimentary inset is currently about 10 m. However, in the environs of Mykolajiv, the original surface of the H2 terrace is about 3 m below the one of H3. It is normally topped by silty loam covering a paleosol (Fig. 5). The following phase, with an increased number of high floods and greater morphodynamic action, forming the H3 terrace, was strong enough to fill up the areas of H2 and cover the latter with younger deposits. The topsoil is a decalcified Haplic Fluvisol on both terraces. In the area of Bukačivci, no distinct differences in the surface levels of H2 and H3 are documented, but decreasing decalcification depths of the Haplic Fluvisol enable the separation of these terraces. Both terraces are, however, too young to carry Lessivés as climax soils like the older H1. Wood from H2 yielded ages of 6380–6280 and 6290–5600 cal. years BP. Wood from H3 is 4150–3890, 3700–3590 and 3550–3270 cal. years BP old (Fig. 5; Table 1).

The development of *terraces H4 and H5* is connected with the next significant break in the evolution of the Dnister valley. Especially in the environs of Mykolajiv, the thickness of the alluvial deposits is increased for an average of 1 m as compared to the older Holocene terraces (Fig. 5). In the environs of Bukačivci, a thicker stratum of silty loam is first developed on H5. In both areas of research, the H5 terrace is also characterized by a rise in the terrace base level and by coarser sediments in the uppermost part of the profiles. Thus, H5–and this is also the case for the younger terraces–is incorporated into the bodies of the older terraces (Fig. 5). As a climax soil, H5 carries a Calcaric Fluvisol. Wood from H4 is dated to the Iron Age (2765–2345 cal. years BP). Wood from H5 to the time of the early Medieval Period (1690–1550 cal. years BP; Table 1). This course of the Dnister is the first that is still documented on the historic map from 1780 (see Huhmann and Brückner, 2002; Fig 5).

Terrace H6 is developed on both riverbanks of the Dnister over long distances as the directly accompanying terrace. The mosaic terrace pattern is replaced by a more or less drawn-out seam terrace pattern. The radii of paleomeanders are reduced to an average length of 300 m (Fig. 4). The Dnister seems to restrict itself to a narrower part of the floodplain, which is also shown by historical maps (Huhmann and Brückner, 2002; Fig. 5). The relatively fresh geomorphology of H6 is still strongly influenced by recent floods. Therefore, on young channel sediments of H6 with little amount of carbonate up to the surface, the climax soil is Calcaric Fluvisol.

The youngest, recently accumulated *H7 terrace* is represented by the fresh and active inner banks along the Dnister River. In sheltered positions, initial virgin soils (Leptic Fluvisol) are found, but normally the surfaces are just sandy areas without any vegetation cover. In many sections, the recent Dnister river is incised by 7 m. That is about 1 m deeper than the base level of the previous terraces H6 and H5.

5. Geomorphological and sedimentological evidence from a geologic cross-section near Vološča

Landscape evolution of the Dnister valley in the vicinity of the village of Vološča was reconstructed using the catena method (Fig. 7) and palynological data (Fig. 8). Thirteen radiocarbon dates were performed on peat and peaty sediments of the Vološča profile FA 21 (see Table 1).

The transect through the Dnister valley of Vološča based on percussion corings shows in principle the same stratigraphical sequence in all profiles. The base was made out of organic clay, overlain by Late Pleistocene sedimentary units, which are mainly built up out of gravely sand (Fig. 7). The marsh peat with

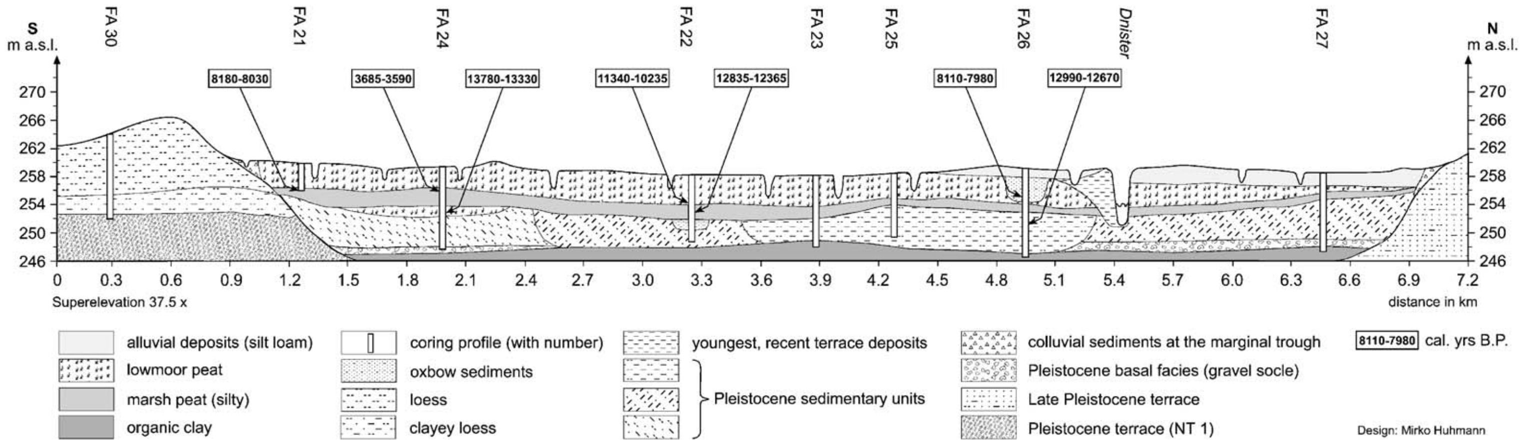

Fig. 7. Geologic cross-section through the Dnister valley in the study area of Vološča.

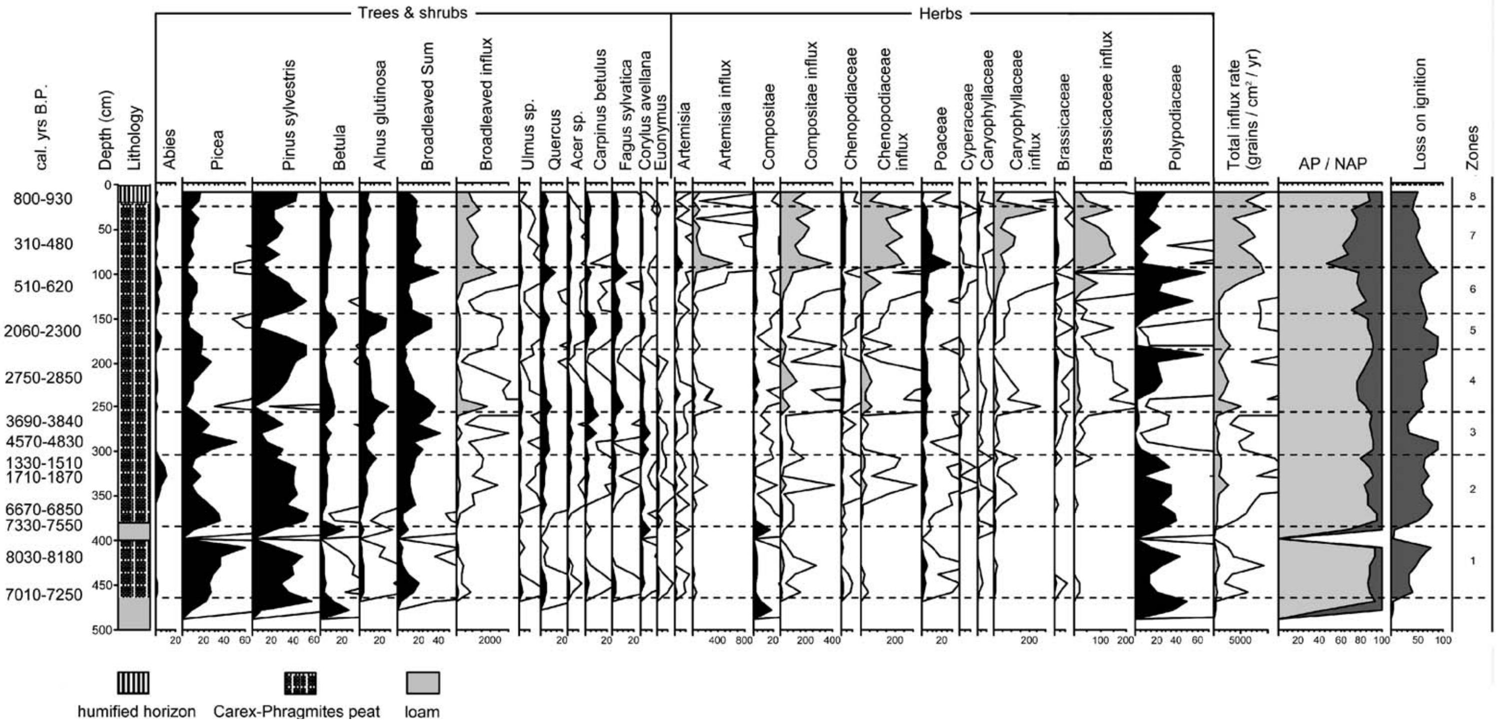

Fig. 8. Vološča pollen diagram. Pollen percentage and pollen influx diagram for main taxa plotted against depth. The sediment core was taken with a percussion core from a peat bog (profile FA 21, see also Fig. 7).

organic rich silty sediments occurs in the whole valley at the level of 254 m a.s.l. This layer is dated to 13,500–8100 cal. years BP (Table 1; Fig. 7). The basin peat described in Section 6 (see below), started to grow in the deepest part of the valley ca. 11,340–10,235 cal. years BP (Table 1) and at its southern margin ca. 8180–8030 cal. years BP (Fig. 7). Close to the recent course of the Dnister, the basin peat was dissected by alluvial deposits, whereas the widespread floodplain in the south shows peat almost undisturbed up to the surface.

It seems that peat accumulation in coring profile FA 21 (Fig. 8) was interrupted by an aggradation of silty sediments between about 7500 and 6700 cal. years BP, after which a mire environment was re-established. Another input of minerogenic material occurred at a depth of 260 cm, proved by a decrease in LOI.

In the environs of Kolodruby downstream of the basin peat area (Fig. 1), the sedimentary filling of the Dnister valley mainly consists of sandy channel sediments without a measurable organic content, overlain by alluvial deposits of minor thickness (< 1 m). In contrast to the profiles found in the areas of Mikolajiv und Bukačivci (cf. Section 4), coring profile FA 29 has no pronounced grading upward; it shows three unconformities with a refining of grain-size but lacking other distinctive parameters (e.g. colour, content of iron) common in the other corings (Fig. 6).

6. Palynological investigation of a peat bog in Vološča

In profile FA 21, the time span 300–8200 cal. years BP is established by the radiocarbon dates. In general the ages provide good chronological control. The dates LZ-1587, LZ-1584, LZ-1657 and LZ-1592 were excluded from consideration as erroneous. The organic content varies widely, the minimum value occurs at the base where the transition into the marsh peat is reached (Fig. 7). In a few samples, a significant amount of calcium carbonate was found. The rather uniform ^{13}C isotope values point to terrestrial plant material. Linear interpolation was used to estimate ages of undated horizons within the Vološča sequence.

The following schematic lithology is based on loss on ignition (LOI), organic content and botanical data (see also lithology section in Fig. 8):

Depth below surface (cm)	Stratigraphie
0–24	Humified horizon
24–380	*Carex–Phragmites* peat
380–400	Loam
400–465	*Carex–Phragmites* peat
465–500	Loam

Peat of the Vološča sequence mainly consists of *Carex lasiocarpa* Ehrh. and *Phragmites australis* with admixture of other sedges (*Carex caespitosa*, *Carex vesicaria*, *Carex appropinquata*, *Carex elata*, *Carex diandra*), Bryales, hypnum mosses (*Drepanocladus* sp., *Drepanocladus sendtneri*, *Comptothecium nitens*, *Meesia* sp.) with occurrence of *Equisetum* sp., *Calamagrostis* sp., *Menyanthes trifoliata* (Fig. 8). Thus the peat structure reflects a mire environment.

In most samples, the amount of pollen and spores was sufficient for percentage calculations. The loam layers, however, contained insufficient pollen for analysis. The sequence from the surface to a depth of 465 cm was subdivided into 8 pollen assemblage zones (PAZs; Fig. 8).

PAZ 1 from 465 to 400 cm (8200–7500 cal. years BP) corresponds to the lower part of the peat sequence between two loam layers. Pollen and spore spectra are dominated by arboreal pollen (up to 93%). *Picea* (up to 60%) and *Pinus* (up to 57%) largely dominate the arboreal pollen spectrum. Pollen percentage and influx of other trees are low. The gap between 7500–6700 cal. years BP corresponds to the loam layer accumulation (400–380 cm b.s.).

PAZ 2 covers the profile from 380 to 303 cm (6700–5100 cal. years BP). In the lower part, the structure of the pollen complexes is similar to that in PAZ 1. The pollen percentage of *Picea* decreases, but the pollen influx of *Picea* remains the same as in zone 1. *Pinus* pollen percentages also slightly decrease but the *Pinus* pollen influx increases. In the upper part a pollen percentage peak of *Abies* (up to 11%) occurs. Pollen percentage and influx values for all deciduous trees (*Betula*, *Alnus* and others) increase, including the continuous appearance of *Ulmus*, *Tilia*, *Quercus*, *Carpinus betulus* and *Fagus sylvatica*. Total pollen influx increases as compared with PAZ 1.

The general structure of PAZ 3 (303–255 cm; 5100–3500 cal. years BP) is the same as in PAZ 2, but the pollen influx rate is lower. Arboreal pollen ranges up to 92.5%. The percentage of Polypodiaceae spores drops dramatically while pollen of *Abies* disappears. A peak of *Picea* pollen (up to 52%) is recorded. *Pinus* pollen percentages and influx of decrease while the percentage values for *Alnus*, *Quercus* (up to 8.3%), *Carpinus* (up to 12%) and *Corylus* pollen (up to 10.6%) increase.

PAZ 4 (255–185 cm; 3500–2500 cal. years BP): In the lower half, the percentage of arboreal pollen decreases to 75.5%. *Picea* pollen percentages are low and slightly increase to the top of the zone. In the lower part of the zone, there is a minimum in the pollen percentage and influx of *Pinus* (up to 1.8%); however, *Pinus* pollen percentage increases upwards to 52.8% upwards. A minimum in *Pinus* pollen corresponds to the maximum in the pollen percentage and influx of broadleaved trees. *Betula* pollen percentages increase up to 13.7%, *Alnus* up to 27.5%, *Quercus* up to 10.6% and *Fagus* up to 10.5%. The total pollen influx rate also increases as compared to the underlying pollen zone. In the upper part of zone 4, the percentage and influx curves for almost all deciduous trees have minimal values. In the upper part of zone 4, Polypodiaceae spores reach a maximum of 65.6%.

PAZ 5 (185–145 cm; 2500–1400 cal. years BP): The percentage of arboreal pollen increases to magnitudes that are similar to those of PAZ 3. Percentage and influx values for *Pinus* and *Picea* decline in the upper part of zone 5. Percentages of all deciduous trees have peaks in the upper part of PAZ 5 while percentage and influx of Polypodiaceae spores reach their minimum. Pollen influx for all the main herb taxa is relatively low.

PAZ 6 (145–92 cm; 1400–450 cal. years BP): The percentage of arboreal pollen is slightly lower than in PAZ 5. Percentage and influx values for *Picea* and *Pinus* pollen have intermittent peaks in the middle of zone 6. Influx values for *Betula*, *Alnus*, *Ulmus*, *Quercus* and *C. betulus* have their minima in the lower part of zone 6 while percentage and influx values for all major herb taxa increase in zone 6. Percentage and influx values for Polypodiaceae spores increase, too. Percentage and influx values for broadleaved trees have their maximum in the upper part of PAZ 6.

PAZ 7 (72–24 cm; 450–100 cal. years BP): The percentage of arboreal pollen decreases and has a minimum of 46.2% at the 87 cm level. Pollen percentages of *Pinus* decrease. Pollen percentages of all major herb taxa have high values. Influx rates of all taxa increase but the most spectacular increase is recorded for herb taxa, such as *Artemisia*, Chenopodiaceae and Caryophyllaceae.

PAZ 8 (24–0 cm; 100–0 cal. years BP): Pollen percentages of arboreal pollen increase compared with PAZ 7 because of an increase in the percentage and concentration of *Pinus* and, to a lesser extent, *Picea*. Pollen percentage and influx values of all other tree taxa are at the same level as in the previous zone, or even slightly lower. Influx curves of all major herb taxa also demonstrate a slight decline as compared with previous pollen zones. High percentages of unidentified herbs in the top of the column are connected with recent changes caused by human impact, related to artificial drainage (Fig. 7).

7. Late Pleistocene and Holocene river evolution and vegetation history of the upper Dnister valley

The *Pleistocene low terrace NT1* with its altitude at 5–10 m above the recent floodplain shows a massive deposition by the braided river of the LGM between 25,000 and 18,000 years BP (Fig. 5; Table 2). Accumulation and extension of NT1 (Fig. 4) document the mobilisation of an enormous amount of sediment during the last (= "Waldai") glaciation. The sediment input was high due to low vegetation cover. The spreading of the vegetation brought aeolian erosion to a close in the source areas. According to Rousseau et al. (2001) loess sedimentation in Central Ukraine is estimated to have finished around 15,000 years BP Thus, of all Pleistocene Dnister terraces, NT1 is the youngest with a loess cover. In the former periglacial region of the upper Dnister, water which had been stored in snow and ground ice contributed to the surface runoff during the Bölling warm phase. This led to very strong river erosion with a lowering of the valley floor by about 10–15 m. The prominent terrace edge of NT1 documents the powerful incision caused by increased runoff. Since the Dnister has never again reached the same extent as at NT1, the first break in the fluvial regime must have occurred during the final phase of LGM.

This remarkable change probably took place during the Younger Dryas around 12,000 cal. years BP, when the *low terrace NT2* was accumulated by a river system other than a braided one. Due to the geomorphological and sedimentological structure (Table 2) it was at least in part an anastomosing river that formed the finiglacial valley floor (Fig. 4). NT2 shows the transformation of the Dnister from the braided glacial to the meandering postglacial river regime. The geological, geomorphological and pedological setting plus the ^{14}C dating makes the formation of this terrace during the Younger Dryas the most plausible explanation.

As a result of the spreading vegetation cover, surface runoff was then reduced and became less variable, and sediment load decreased (cf. Kozarski, 1991). River flow concentrated in several channels and formed the basis for the evolution of the modern landscape. The braided river system was replaced by local lateral redeposition on the inner and outer banks of a meandering river. Vast areas of the floodplain were only exposed to extended sedimentation during high floods. Thus, the accumulation of alluvial deposits started and these formed the basis for the development of the typical Holocene floodplain soils and for the modern flora and fauna.

Starting with the Holocene warming, climatic fluctuations triggered phases of increased morphological river activity, which are documented by the construction of the older Holocene terraces H1–H4 (Table 2). Fluvial morphodynamics led to temporarily increased discharges and large floods. They did, however, not reach the magnitudes of those during the Late Glacial epoch due to the stabilizing influence of the spreading vegetation cover. The Holocene Dnister was not strong enough to erode all of the preceding late Pleistocene terrace deposits; its morphodynamic activity rather resulted in a series of laterally accreted fill terraces inset into the valley floor (Fig. 5).

The occurrence of paleomeanders on the *first Holocene terrace H1* is a consequence of the relatively low discharges of the Dnister during that time. The gradual stabilisation of the environment promoted the evolution of floodplain soils. During the Boreal, coniferous forests dominated by *Picea* and *Pinus* with some admixture of broadleaved trees formed the regional vegetation (Fig. 8). Several other investigations (a) along Central European rivers (e.g. Starkel, 1991a; Schirmer, 1995) and (b) on other climatic indicators such as mires, alpine glaciers and lake levels (e.g. Bibus and Wesler, 1995; Ralska-Jasiewiczowa and Latałowa, 1996) point to a climatic deterioration for the time of the late Preboreal/early Boreal period between 9500 and 8350 cal. years BP. It is reasonable to attribute the development of H1 to this time span (Table 2).

Near Vološča, peat has formed in the valley bottom of the Dnister since the Early Atlantic period (Fig. 8). The coring section shows that it was triggered by a natural dam, accumulated by Dnister tributaries. Several tributaries discharge into the extremely flat valley of the main river in a spatially concentrated area close to the village of Kolodruby (Fig. 1). Due to their steeper slopes as compared with the gentle gradient of the main river (cf. Section 2), they accumulated significantly greater amounts of coarser sediments that finally formed the extended flat basin. Most likely, a low dam built up out of natural levees allowed peat bog formation (Fig. 7).

The following *terraces H2 and H3* represent somewhat more stable morphodynamic conditions of the Dnister regime between the first postglacial phase of strong climatic change and the first definite signs of human impact.

The period of 6700–3600 cal. years BP involves the dominance of broadleaved forests with the continuous presence of *C. betulus* and *F. sylvatica* in the regional forests. The area covered with *Alnus glutinosa* on mires was large. *Euonymus*, an indicator of warmer and more humid climate, is almost permanently recorded in the pollen spectra during this period (Fig. 8). Two phases of increased precipitation and high flood events during this time span are geomorphologically documented by the H2 and H3 terraces. Wood from H2 at Mykolajiv and Bukačivci dates to 6300–6280 and 6290–5600 cal. years BP, respectively. Thus, a good correlation exists with the bipartite late Atlantic phase of increased river activity (according to Starkel, 1997; Wohl and Georgiadi, 1994). In the prairie-forest ecotone of southeastern Minnesota, Baker et al. (2002) found a period of large floods around 6700–5500 cal. years BP; they attribute it to increased runoff in a drier climate. For the lower Dnister, Adamenko et al. (1996) connect the warmest and most humid period of the Holocene with a shift of deciduous forests and forest-steppe to the south and east of the Moldavian territory.

For H3, comparable terraces in Central Europe are attributed to the period of increased river activity, starting ca. 4400 cal. years BP (Bibus and Wesler, 1995; Kalicki, 1995) and having a peak around 2800 cal. years BP (Starkel, 1991b). Wood from H3 in Mykolajiv is 4150–3930, 3700–3590 and 3550–3270 cal. years BP old, respectively, which corresponds well with the Subboreal period. Locally the climatic change is noticeable around Vološča with the reduction of broadleaved forest areas and the spreading of pine forests after 3600 cal. years BP.

The peat bog of Vološča shows a continuous vertical growth without any further disturbance by fluvial activity. This may be attributed to a concentration of the Dnister on smaller parts of the central floodplain. Identical tendencies are recorded in the two other study sites, where the radii of paleomeanders and the dimension of the terraces likewise diminish (Fig. 4). The afforestation of valley floor and riverbanks by lowland forests increased the stability of the ecosystem.

H3 is the last naturally accumulated terrace with only minor signs of anthropogene influence on the stability of the landscape. The people of that time did not yet have the density of settlements or land use practices to cause significant ecosystem changes; however, they did cause the first local impacts (cf. also Schirmer, 1995). The Tripolian culture (around 6500–4000 cal. years BP) represents the first regional civilization in western Ukraine (Videjko, 2002). It is during the deposition of the Bronze Age H3 terrace that the first settlements of the valley floor occurred and produced the first human impact on the Dnister valley (Tolochko, 1998).

In Mykolajiv and Bukačivci the increased thickness of alluvial deposits on *terrace H4* (3–4 m) marks a major change. Since H4 time, the Dnister has transported a larger amount of suspended load, originating from extended erosion of top soils, which forms a thick stratum of silty loam (Fig. 5).

The pollen spectra of Vološča show an increase in percentage and influx of herbs such as Compositae, Chenopodiaceae and Brassicaceae (Fig. 8), which indicates that around 2400 cal. years BP, areas of open spaces had increased. This is the first definite sign of the anthropogenic disturbance of the natural ecosystem.

Moreover, a climatic deterioration with increased frequency of high floods is reported in Middle Europe for the period 2300–1800 cal. years BP (Starkel, 1991a; Kalicki, 1995). This fits quite well with the chronostratigraphic position of the upper Dnister terrace H4 (Table 2) and minimum values of broadleaved trees around 2400 cal. years BP in the pollen record of the peat bog of Vološča (Fig. 8). By 1400 cal. years BP, an extension of the areas with *F. sylvatica* and *C. betulus* is apparent which probably represents reforestation of some areas that had been cleared for agriculture.

In the early Subatlantic period, the impact of agriculture on the environment increased distinctly (Heine, 2001). The manufacturing of iron for ploughshares and scythes as well as the invention of new agricultural techniques during the Iron Age led to intensified land use (Tolochko, 2000). The agricultural impact on fluvial runoff in the form of higher sediment loads and a more irregular runoff hydrograph led to a second remarkable change in the evolution of the Dnister valley (cf. Klimek and Starkel, 1974).

Thus the change in sediment texture is not only an expression of climatic changes but also of human impact. The consequences of increased surface runoff and soil erosion due to extended deforestation and more intensified agriculture on the valley slopes led to notable changes in the flow regime of the river. As a result of the increased sediment load, the Dnister turned into a somewhat shallower and a more anastomosing river (cf. Mycielska-Dowgiałło, 1977).

The development of the *H5 terrace* also reveals the transition to a more anastomosing river. This distinct change in the hydrodynamics of the upper Dnister is due to human impact. As for Bukačivci, the deepest thickness of silt loam alluvium is restricted to this terrace. After 1400 cal. years BP the natural evolution of the regional vegetation has been complicated by anthropogenic factors, which caused a decline in the forested area (see also the pollen spectra; Fig. 8). In the central parts of the floodplain near Vološča, peat growth is interrupted by fluvial deposits (Fig. 7). In Bukačivci the sedimentary complex of H5 is dated to the time of the Migration time and very early Medieval Period (wood in the lower part of H5 of Bukačivci: 1690–1550 cal. years BP; Table 1). This may correspond to the terrace formation in Central Europe around 1500–1100 cal. years BP (cf. Bibus and Wesler, 1995). The first formation of a political state–the "Kyivan Rus" (500–988 AD)–led to a stricter organisation of the agricultural system and to governmental support for the expansion of arable land. Inventions like the so-called "Three-Field System" led to a massive release of manpower. The foundation of towns, new trade and new types of handicrafts began. The installation of water mills was the first direct impact on the course of the Dnister. Thus, human factors started to play an increasing role in the fluvial morphodynamics (cf. Igl et al., 2000).

H5 is the first sedimentary unit of the younger Holocene terraces that can be characterized by decreasing thickness on the one hand and a smaller surface extension in comparison to the total extension of the Dnister valley on the other. The development of the Dnister towards a shallower anastomosing river was a direct consequence of the accelerated destabilization of the riverbanks. Deforestation and human land use of the valley floor enhanced this erosion at the undercut banks.

The significantly shortened periods of terrace building–the three youngest terraces (H5–H7) were built within the last 1400 years, while all the older Holocene terraces (H1–H4) are related to phases of an average of over 600 years each–supports this assumption. It is also expressed by the reduced aerial extensions of terraces H5–H7 as compared to earlier terraces (Fig. 4). As a consequence of the growing sensitivity of the environment, even smaller climatic and hydrodynamic fluctuations led to stronger geomorphological modifications of the river valley.

Increased landscape sensitivity as a reaction to the clearance of natural vegetation cover for agricultural purposes has also been demonstrated for the upper Mississippi Valley (Knox, 2001). There the high-resolution floodplain stratigraphy showed increased peak discharges from high-frequency floods by about 200–400%, with erosion and deposition of large volumes of sediments and quick responses of the fluvial system to changes in land cover and agricultural techniques.

The *H6 terrace* is developed on both riverbanks of the Dnister over long distances as the directly accompanying terrace, interrupting the preceding formation of mosaic terrace pattern. Its morphology is strongly influenced by recent floods (Fig. 4). The H6 dates from the so-called "Polish Epoch" (15th–17th centuries AD; cf. Polonska-Vasylenko, 1988). It can be correlated with the climatic deterioration of the "Little Ice Age", AD 1550–1850 (Glaser, 2001). Starkel (2001) pointed out the numerous flood records of this period, which coincide with humid decades visible in various other phenomena like glaciers (Lang, 1994) and landslides (Gil et al., 1974). The lower Dnister basin was afflicted by frequent cold winter months but also by a few strong droughts (Adamenko et al., 1996). Like H5, H6 is an inset erosion and deposition within older Holocene terraces, indicating the tendency of the Dnister to become shallower and wider. The numerous shifts in the river course during the evolution of this terrace are evident from historic maps, too. The H6 morphology represents the last natural course of the Dnister before construction work (e.g. canalisation, embankment, etc.) was carried out.

During the last 400 years or so, the recorded increase in the pollen influx rate cannot be explained in terms of changes in the natural vegetation cover (Fig. 8). However, the loss on ignition values decreased and the sedimentation rate increased. Therefore, we conclude that during the last four centuries, no major changes in the structure of the regional vegetation cover occurred. The upper Dnister basin experienced an increase in arable land with a consequently higher rate of soil erosion, which completed the change from the forested valley to the meadow-covered floodplain.

Normally, the surface of the *H7 terrace* is just sandy areas without vegetation. Due to the small area occupied by H7, its evolution is not comparable to a phase of climatic deterioration but to the low amount of permanent redeposition within the meandering system. The structural and engineering modifications strongly affected runoff dynamics and were a catalyst for the third change of the fluvial regime. Flood in a narrow riverbed causes erosion. In some parts of its course, the present Dnister shows a distinct incision (Fig. 5). The inset structures of the Holocene terraces have been terminated by the modern H7 terrace.

8. Conclusion

In the study areas of the upper Dnister valley, two Late Glacial and seven Holocene terraces were classified and interpreted with regard to the history of the Dnister floodplain evolution. Several remarkable changes occurred in the hydrodynamic regime, which profoundly affected the surrounding landscape as well. The first occurred in the Late Glacial period. It is documented by the change from a braided to a meandering river system which prepared the stage for the modern landscape evolution. The second break is connected with the first definite traces of human impact on the sedimentary architecture of the younger Holocene terraces at the study sites of Mykolajiv and Bukačivci; it is also visible in the pollen diagram of the peat bog of Vološča.

Since the Neolithic revolution, anthropogenic influences have increased continuously. However, it is only since the Iron Age that the human factor has played an important role that is comparable to the climatic impact on the fluvial dynamics. Human activity is the most important agent in the modern environment. Human modifications through land use and engineering measures are much more significant now than climate. Direct human-induced changes of the fluvial regime and land use modifications of the vegetation cover are mostly responsible for the transformation that marks the third break in the landscape evolution.

The general scheme of the regional vegetation changes corresponds well with earlier studies (Artushenko et al., 1984; Chernavskaya and Fogel, 1991). The decline in the broadleaved forest area around 3500 cal. years BP is attributed to a climatic cooling reconstructed for the Carpathian region (Chernavskaya and Fogel, 1991). The increase in the forested area and the corresponding decrease in percentage, concentration and influx of herb taxa indicate still minor human disturbance of the natural ecosystem around 2400–1400 cal. years BP, which is cum grano salis comparable to environmental changes in Eastern Poland (Szczepanek, 1992; Harmata, 1995). Recent (last 400 years) human-induced vegetation changes are also paralleled by evidence from southeastern Poland (upper Vistula basin) (Szczepanek, 1992; Harmata, 1995). In general, the late Holocene fluvial activity of the Dnister is quite similar to that of other rivers in Europe (Starkel, 1983; Bibus and Wesler, 1995; Kalicki, 1995; Adamenko et al., 1996). The increasing sensitivity of landscapes due to enhanced human impact leads to strong modifications that lie beyond the range attributed to natural processes (cf. Knox, 2001).

It has been demonstrated that the floodplain of the Dnister valley is a good geo-archive of valuable information about the geomorphological evolution and the vegetational history of the landscape. The research results showed that the sensitivity of the Dnister ecosystem to any kind of changes increased following the introduction of anthropogenic influences represented by land use and engineering measures. The knowledge about process-response relations for the Dnister system can be useful for anticipating the potential consequences of the ongoing agricultural transformation in the Ukraine.

Acknowledgements

The investigations were carried out under the umbrella of the German–Ukrainian research project "Transformation Processes in the Dnister region", funded by the German Ministry of Education, Research, Science and Technology (BMBF, Project No. 00339699) and coordinated by UNESCO (Paris). Additional support was given by the German Academic Exchange Service (DAAD), which is gratefully acknowledged. Dr. L.V. Golubeva cared for pollen preparation, Dr. O.N. Uspenskaya for peat botanical analyses. Prof. Dr. J.C. Knox and Prof. Dr. F. Oldfield made helpful comments on the manuscript. We want to express our gratitude to the Ukrainian colleagues from Lviv State University for stimulating scientific discussions and for their generous hospitality. Thanks are also due to Martha E. Barth, Chania (Greece) for polishing our English.

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