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Geomorphological records of human activity reflected in fluvial sediments in the Carpathians and their foreland

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Abstract: Records of human activity in valleys of the Upper Vistula River catchment and the Upper Dniester River catchment in the area of the Eastern Carpathian Foreland are synchronic and date back to the Neolithic Period. They include alluvia and colluvia in small valleys, linked with local downpours, as well as changes in large valleys, where flooding is reflected in modifications to river channels and an acceleration in the deposition of overbank facies. Among these periods are phases determined climatically (5th–7th centuries AD) and those reflecting human activity (1st–3rd centuries AD), as well as phases recording the coincidence of both factors (middle Neolithic, 10th–11th centuries AD and the Little Ice Age). The most distinct changes leading to transformation in valley slopes and bottoms are linked with the coincidence of humid climatic phases and periods of increased human impact.

Key words: human impact, climate change, fluvial deposition, Eastern Carpathians, Holocene

Introduction

In the temperate climatic zone of the northern Carpathians foreland, the problem of the relationship between the influence of climate changes (changes in precipitation) and the impact of economic activity on soil erosion and fluvial deposition is a matter of great interest to geomorphologists, palaeobotanists and archaeologists (Wasylikowa *et al.* 1985, Starkel 1987, 2005a, Kalicki 1996a, Kruk *et al.* 1996, Berglund 2003, Dobrzańska, Kalicki 2004, Dotterweich 2008, Gębica *et al.* 2008, 2013, Twardy 2011, Klimek 2012, Starkel *et al.* 2012, Superson 2012). However, it is very difficult to distinguish the influence of climate changes from the anthropogenic factors (Kalicki 1996b, Starkel 2006). These agents often affect the development of valley relief synchronically.

The Roman Period and the Early Middle Ages are appropriate examples of the relationship between climate, man and river activity. During the Roman Period (1st–4th centuries AD) in particular, when beyond agriculture there occurred a deforestation of floodplains linked with the development of industry, river activity increased in southern Poland (Kalicki 1991, Dobrzańska, Kalicki 2004, Starkel 2005a, b). Observed in the Migration Period (5th–6th centuries AD) are a regression in agriculture, a reforestation and a simultaneous rise in precipitation (Büntgen *et al.* 2011) linked with a greater frequency of floods, recorded in channel sediments bearing subfossil oak trunks (Kalicki, Krąpiec 1996, Krąpiec 1996, Starkel 2001, Gębica, Krąpiec 2009, Starkel *et al.* 2009). In turn, the period of the Early Middle Ages (8th–10th centuries AD) is characterised by a descent of settlements to the bottoms of river valleys (e.g. settlements in the Greater Moravian Empire – Havlićek 1991). In the 10th–12th centuries AD an expansion of settlements and deforestation of alluvial plains is associated with an increase in the frequency of floods (Starkel 1981, 2006, Łanczont *et al.* 2006, Klimek 2012, Gębica *et al.* 2013). The Late Middle Ages and the Modern Period are marked by increased colonisation in the Upper Vistula River catchment (Maruszczak 1988), including the mountainous areas (Kukulak 2004).

The period of human impact encompassing the past 7,000 years on the territory of the Eastern Carpathians and their foreland will be the subject of a similar analysis conducted on the basis of research into the Holocene alluvia in valleys of the Upper Dniester River and its tributaries, the Strvjaž, Bystrycia Pidbuzska, Stryj and Velyky Lukavets (a tributary of the Bystrycia Solotvynska), performed at the turn of the 21st century (Alexandrowicz *et al.* 2005, Harmata *et al.* 2006, Gębica *et al.* 2008, Starkel *et al.* 2009, Gębica, Jacyszyn 2012, Gębica *et al.* 2013). Simultaneously in the middle section of the Dniester River valley geomorphological studies were being performed by German researchers (Huhmann, Brückner 2002).

These investigations make it possible to correlate records of Neoholocene flood phases with phases identified earlier in the Carpathian tributaries of the Upper Vistula River (in particular in fore-mountain sections of the Wisłoka, Wisłok and San rivers) involving accumulation of overbank sediments, linked with heightened human activity in the Eastern Carpathian Foreland. The paper is therefore an attempt to demonstrate the synchronicity of climate changes in the Eastern Carpathian Foreland with phases of human impact (deforestation and land cultivation) recorded in the Western Carpathian Foreland.

Research status, objective and methods

Increased human impact (deforestation, cultivation, pasture) generates accelerated soil erosion and accumulation of overbank facies, associated with a tendency towards the development of braided river channels. Such changes are registered in the uppermost sections of alluvial sedimentary sequences by a growth in the grain size of overbank sediments (Kalicki 2000, Kukulak 2004). The concentration of subfossil tree trunks in channel alluvia, in particular trunks with traces of processing (cutting) by man, indicates felling phases linked with deforestation of alluvial plains (Krąpiec, Kalicki 1996). Human activity is connected by palynologists with a fall in the pollen curve of elm and other deciduous trees and the appearance of synanthropic plants in pollen diagrams of samples dated by radiocarbon methods (Ralska-Jasiewiczowa 1980, Harmata, Kalinovyč 2006). Dendrochronological study and dating of subfossil trunks (Krąpiec, Kalicki 1996) enable the dating of alluvial fills and the correlation of phases of heightened river activity with stages of intensive human impact in valley systems of the Upper Vistula and Upper Dniester River catchments. This problem has been identified in detail in the Upper Vistula River catchment (Starkel 1981, Kalicki 1991, Starkel *et al.*, 1996, Gębica, Krąpiec 2009, Gębica 2011). In the Dniester, Strvjaž and Bystrycia Pidbuzska River valleys in the Eastern Carpathian Foreland such investigations have been performed since the 1990s as part of interdisciplinary scientific projects related to archaeological expeditions. More than 10 alluvial sequences and several peat bog sequences have been studied and dated by radiocarbon, palynological and archaeological methods (Harmata *et al.* 2006, Budek *et al.* 2001). An increase in river activity at the transition of the Atlantic and Subboreal Phases, as well as during the Roman Period and the Early Middle Ages was found (Starkel, Jacyszyn 2006).

On the Strvjaž riverbank and in the Upper Dniester Basin archaeologists explored numerous sites representing the Neolithic Period, Bronze Age, Roman Period and the Early and Late Middle Ages. In the neighbouring uplands they discovered hundreds of Neolithic barrows, of which they excavated several (Machnik 2000, Harmata *et al.* 2006). Simultaneously in the Dniester River valley (downstream of the Upper Dniester Basin) German researchers were conducting their investigations (Huhmann, Brückner 2002). They distinguished seven Holocene terraces and ascribed the formation of the youngest terraces and alluvia to human activity during the Iron Age and the Early and Late Middle Ages, as well as the Little Ice Age. In the years 2008–12 (as a continuation of projects of the Scientific Research Committee) the area of study was expanded to include the valleys of the Lower Strvjaž, Dniester and Stryj in the Stryj-Żydačiv Basin (pol. *Kotlina Stryjsko-Żydaczowska*) and the Halyč-Bakačiv Basin (pol. *Kotlina Halicko-Bakaczowska*). Distinguished within the 4–6 m Holocene terraces were several alluvial fills dated to the Late Vistulian (Weichselian), Atlantic Phase, Subboreal Phase and the past 2,000 years. The channel and overbank alluvia, bearing numerous tree trunks, indicate an aggradation in the Roman Period and the Early Middle Ages (Starkel *et al.* 2009, Gębica, Jacyszyn 2012, Gębica *et al.* 2013). In recent years the valley of the Michidra River – the left tributary of the Siret River – and the Prut River valley in the Bukovyna Carpathian Foreland (pol. *Podkarpacie Bukowińskie*) have been included in the study area (Gębica *et al.* 2012).

The objective of the paper is the provision of an answers to a) the question of whether climatic changes and phases of human impact (deforestation and cultivation) are synchronic in the Eastern Carpathian Foreland and b) the question of whether the phases of human impact in this area are recorded as clearly as the contemporary phases in the Western Carpathian Foreland.

Study area

The Outer Carpathians on Polish territory are composed of several W-E stretched morphological zones linked with the tectonic overthrust of the Flysch Carpathians on the Carpathian Foredeep, and with the subsequent expansion of the Scandinavian ice-sheet of the San–1 Glaciation (Cromerian). The southern morphological zone consists of the mountain ranges of the Western Beskidy (pol. *Beskidy Zachodnie*), culminating as high as 1,725 m a.s.l., and the Eastern Beskidy (pol. *Beskidy Wschodnie*) – the Bieszczady Mts.– with their extension in the Ukrainian Carpathians. To the north, the Carpathian Foothills (pol. *Pogórze Karpackie*) are built predominantly of Flysch sandstones, forming ranges as high as 350–450 m a.s.l. with culminations as high as 600 m a.s.l. The Foothills fall toward the Fore-Carpathian Basins (pol. *Kotliny Podkarpackie*) in a hillslope (edge) 80–150 m high. The foreland of the Carpathians forms a plateau zone 1–20 km wide, called the Carpathian Foreland, which is composed of hills of 240–280 m a.s.l., divided by valleys and covered with loess. The eastern part of this loess plateau between the Wisłok and San River valleys is the Kańczuga Plateau (pol. *Wysoczyzna Kańczucka*). North of the Carpathian Foreland is the erosional depression of the Fore-Carpathian Trough, of a height of 200–215 m a.s.l. During the San–1 Glaciation this depression was used by proglacial waters flowing to the east, toward the Dniester River catchment. At present, it is used by lower, terraced sections of the valleys of the Wisłoka River and its trib-

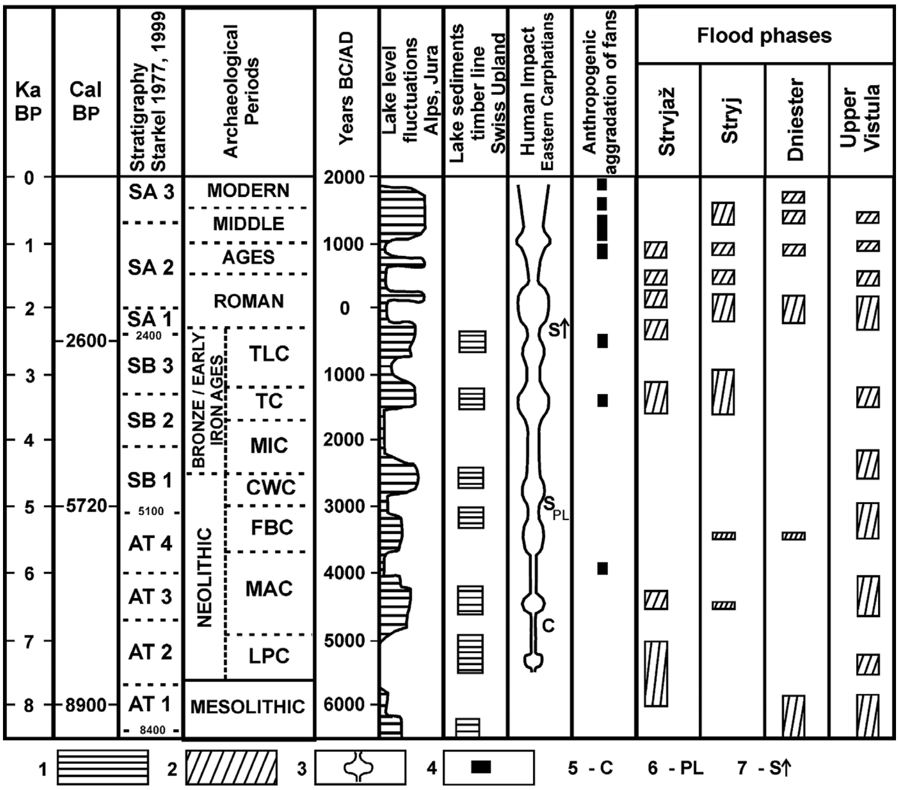

Fig. 1. Correlation model of lake level fluctuations, flood phases and human impact in the Carpathians and their foreland (completed on the basis of various materials: lake level fluctuations in Alps and Jura after Magny 1992, Lake sediments and changes of timberline in Swiss Upland after Haas *et al.* 1997)

1 – wet climatic phases recorded in high lake levels, 2 – flood phases, 3 – Human activity (intensity of deforestation and cultivation) shown by the height of column, after Harmata, Kalinovyč 2006, 4 – phases of anthropogenic deposition of colluvial fans in the Nałęczów Plateau (SE Poland) after Superson 2013, 5 – first appearance of cereals, 6 – first appearance of *Plantago lanceolata*, 7 – increase of *Secale* cultivation

Archaeological periods: LPC – Linear Pottery Culture, MAC – Malice Culture, FBC – Funnel Baker Culture, CWC – Corded Ware Culture, MIC – Mierzanowice Culture, TC – Trzciniec Culture, TLC – Tarnobrzeg Lusatian Culture

utary the Wielopolka River, as well as of the Wisłok and San.

The central and eastern parts of the Fore-Carpathian Basins are covered by extensive plateaus with elevations of 220–265 m a.s.l. formed of Miocene clays overlain with fluvial gravels and fluvioglacial sediments. The area of the Carpathians and the Fore-Carpathian Basins is drained by rivers of the Upper Vistula River catchment, belonging to the Baltic Sea basin. The river valleys are filled with alluvia of the Pleistocene and Holocene terraces. Studies of the Holocene terraces and alluvia in the Upper Vistula River catchment, in particular in fore-mountain sections of the Wisłoka, Wisłok and the San River valleys, have made it possible to distinguish several alluvial fills representing phases of heightened river activity (8,500–7,800 BP, 7,500–7,200 BP, 6,500–6,000 BP, 5,500–4,900 BP, 4,500–4,100 BP, 3,400–3,100 BP, 2,200–1,800 BP, 1,600–1,500 BP, 1,100–900 BP) (Starkel 1983, Kalicki 1991, Starkel *et al.* 1996, 2006, Gębica, Krąpiec 2009, Gębica 2011) (Fig. 1).

In valleys of small rivers and streams (the Uszwica, Wielopolka, Bystrzyca, Mleczka, Rada) floodplains are formed of various fine-grained alluvia and peats dated in lower sections to the Late Vistulian-Early Holocene (Starkel 1960). Pollen diagrams of alluvia and peat horizons dated to the Atlantic Phase and the Subboreal Phase record human activity related to the Neolithic Period, the Bronze Age and the Iron Age (Harmata in Starkel *et al.* 2002). Fine gravel inserts in silts, overlain by organic sediments dated at 4,300–4,100 BP (e.g. in the alluvial fan of Słocina Stream in the town of Rzeszów, Starkel *et al.* 2002) are evidences for local downpours synchronised with the flood phase in the Upper Vistula River valley. The 2–3 m thick upper part of the alluvial sequences is formed of silty overbank alluvia or – in the margins of peat bogs – proluvial fans, considered to be the products of soil erosion during the Middle Ages and the Modern Period (Starkel *et al.* 2002, Łanczont *et al.* 2006).

The area of the Upper Dniester River catchment being studied, situated on the territory of the Eastern Carpathian Foreland, is framed from the west by a distinct edge of the Eastern Beskidy Mts. standing 200–300 m above the surrounding plateaus, and from the east by the edge of the Podilian Upland (pol. *Podole*). In the Eastern Carpathians the zone of the Carpathian Foothills, so characteristic of the eastern part of the Western Carpathians, is absent. In the Eastern Carpathian Foreland the Dniester River and its Carpathian tributaries are separated with plateaus (uplands) reaching 420 m a.s.l. and formed of Miocene rocks covered with alluvia, glacial sediments and loess in the upper parts (Łanczont, Boguckij 2002). Following deforestation, the thick loess covers were primary sources of overbank sediments (silts) deposited in the floodplains. The Dniester River, at a length of 1,360 km, is one of the largest with sources in the Eastern Beskidy (Bieszczady Mts.), at an elevation of 913 m a.s.l. It crosses Ukraine and Moldova and flows into the Black Sea. In the section between the Carpathian outlet and the Dniester Canyon the Dniester River valley is characterised by an alternation of basins (the Upper Dniester Basin (pol. *Kotlina Górnego Dniestru*), the Stryj-Žydačiv Basin (pol. *Kotlina Stryjsko-Żydaczowska*), the Halyč-Bukačiv Basin (pol. *Kotlina Halicko-Bukaczowska*) and valley narrowings of the nature of gaps. In the basins of the Dniester river and its tributaries (the Strvjaž, Bystrycia Pidbuzska, Stryj, Śvica and Łomnyca) the system of Pleistocene and Holocene terraces is preserved. The Holocene terraces (floodplains) 4–6 m above the riverbeds form alluvial fills and systems of paleochannels recording the phases of increased flood accumulation, dated at 8,700–8,000 BP, 5,600–5,400 BP and 2,300–2,100 BP, the Roman Period (1^{st}–4^{th} century AD), Early Middle Ages (5^{th}–7^{th} and 10^{th}–12^{th} centuries AD), Little Ice Age and 19^{th}–20^{th} centuries AD (Starkel *et al.* 2009, Gębica, Jacyszyn 2012, Gębica *et al.* 2013) (Fig. 1).

Phases of colonisation and human impact

In order to present phases (stages) of colonisation and human impact on the natural environment, use has been made of numerous publications summarising results of archaeological studies in the Western Carpathians as well as results of archaeological-natural expeditions in the lower Dniester River catchment in the Eastern Carpathian Foreland (Harmata *et al.* 2006). The distribution of the most important archaeological sites attributed to the Neolithic Period, Bronze and Early Iron Ages, Roman Period and Middle Ages is presented on the maps (Figs. 2, 3). Recognised as important were excavated sites, including multi-culture sites, at which settlements, cemeteries, graves, barrows, hillforts etc. were found. The distribution of such sites is very irregular. A larger concentration is situated in the eastern part of Polish Carpathians and in the Fore-Carpathian Basins, with a far smaller number of such sites recognised in the area of the Eastern Carpathian Foreland in the Ukraine.

The earliest documented traces of man in the Eastern Carpathian Foreland in the Ukraine come from the Palaeolithic and Mesolithic Periods (Łanczont, Boguckij 2002). Between 7,500 and 7,000 BP (5,500–5,000 BC) the oldest agricultural societies of the Early Neolithic Period represented by the Linear Pottery Culture (LPC) colonised the loess-covered Carpathian Foreland occupied by oak-hornbeam forest. The people of this culture applied a fire-fallow economy and colonised the plateaus and loess terraces (the Pleszów site near Kraków, the Majnyč site in the Upper Dniester Basin near Sambir) (Figs. 1, 2), cultivating small fields abandoned following the impoverishment of the soil. Wood was also used for construction of houses and palisades and in this way the forests suffered devastation (Machnik 2000, Harmata *et al.* 2006). As shown by the studies of the Vistula River paleochannel at the Pleszów site, between 6,300 and 5,400 BP three phases of economic activity took place, during which the forest of terrace margins was destroyed, while in periods marked by a low water table fields were cultivated in the floodplain (Wasylikowa *et al.* 1985). Since around 6,000 BP (4,000 BC), during the colonisation of the Malice Culture (MC) (Fig. 1), agriculture based on cultivation of cereals predominated (the Kotoriny-Grodzisko site, located on the Zaleska Plateau (pol. *Wysoczyzna Zaleska*), ca 80 m above the Dniester riverbed).

Around 5,500–5,000 BP (3,500–3,000 BC) on the high terraces of the Dniester River valley in the Halyč-Bukačiv Basin saw the settlement of tribes belonging to the Funnel Beaker Culture (FBC), which cultivated cereals and built barrows in the deforested areas (Figs. 1, 2). This generated soil erosion on slopes and silt deposition on the Dniester River floodplain (the Majnyč II site). Numerous remnants of this culture, particularly barrows and agricultural settlements (camps), were located on hills of the Strzyżów Foothills (pol. *Pogórze Strzyżowskie*), Dynów Foothills (pol. *Pogórze Dynowskie*) and Kańczuga Plateau (Gedl 2000) (Fig. 2). The people of this culture are known also as constructors of megalithic graves discovered recently in Skołoszów village on the Rada River on the Kańczuga Plateau (Rybicka 2011).

From 5,000 BP to 3,000 BP (3,000–1,000 BC), in the Late Neolithic Period and Early Bronze Age, the Corded Ware Culture (CWC) developed (Figs. 1, 2). The colonisation of this culture was followed by that of the Mierzanowice Culture (MC) and the Trzciniec Culture (TC) settled on the Zaleska Plateau near the Dniester River gap (the Kotoriny-Grodzisko III site), on the Drohobyč Plateau (the Bykiv site in the Bystrycia Pidbuzska River catchment) and on loess terraces of the Dniester River valley (the Kozary and the Majnyč sites) (Fig. 2). Numerous barrows built by nomadic pastoralists on previously deforested areas of the Dynów Foothills (a cluster of barrows at the Średnia site) (Machnik 2000) and the Kańczuga Plateau (e.g. a barrow at the Cieszacin Wielki site) (Łanczont *et al.* 2006), as well as inter-valley plateaus of the right-side catchment of the Upper Dniester River (Harmata *et al.* 2006), are characteristic elements of the Corded Ware Culture. These areas were used for agriculture dominated by meadows grazed by cattle. Developing from ca 4,000 BP (2,000 BC) was permanent settlement of the Trzciniec Culture type (Fig. 1). Subsequently, in the period 3,300–2,500 BP (1,300–500 BC), cultivating societies of the Tarnobrzeg Group of the Lusatian Culture expanded and densely colonised slopes and terraced valley floors of the Fore-Carpathian Trough (pol. *Rynna Przedkarpacka*) (Czopek 1996).

A common advance in colonisation took place during the Roman Period (2,100–1,700 BP, 1^{st}–4^{th} centuries AD), which is represented by archaeological sites located on the loess terraces of the Vistula valley (e.g. the Igołomia

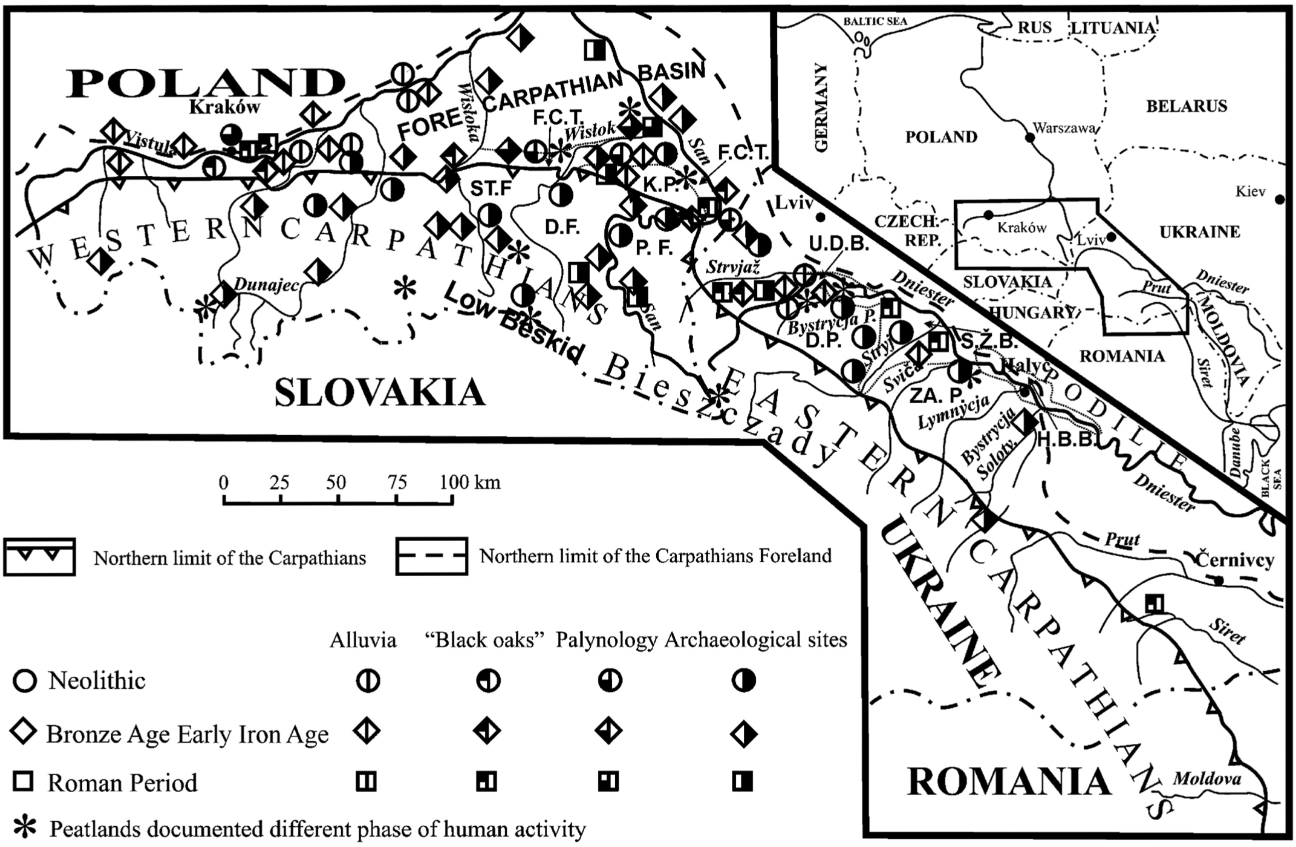

Fig. 2. Distribution of more important dated sites of alluvia and archaeological sites of the Neolithic Period, Bronze and Early Iron Ages and Roman Period in the Carpathians and their foreland. Selected sites of palynological sequences of pet-bogs dated by radiocarbon method are marked

F.C.T. – Fore-Carpathian Trough, K.P. – Kańczuga Plateau, ST.F. – Strzyżów Foothills, D.F. – Dynów Foothills, P.F. – Przemyśl Foothills, D.P. – Drohobyč Plateau, ZA.P. – Zaleska Plateau, U.D.B. – Upper Dniester Basin, S.Ž.B. – Stryj-Žydačiv Basin, H.B.B. – Halyč Bukačiv Basin

site, east of Kraków) and valley terraces in the Dniester and Strvjaž rivers (the Majnyč site, the Čapli site) (Fig. 2) recording industrial activity (kilns for pottery production) as well as agriculture. Development of metallurgy and the expansion of fields cultivated by people of the Przeworsk Culture required deforestation of oak forests on floodplains (Dobrzańska, Kalicki 2004). In the younger part of the Roman Period and the early phase of the Migration Period (3rd–5th centuries AD) the greatest increase in colonisation took place in the eastern part of the Polish Carpathians and their foreland (Czopek in Starkel *et al.* 2002, Parczewski *et al.* 2013). At that time it reached the Upper San River valley in the Bieszczady Mts., as confirmed by pollen diagrams (Szczepanek in Parczewski *et al.* 2013). The Migration Period (5th–7th centuries AD) is characterised by a regression of settlement in both the Western Carpathians and the Eastern Carpathians. There is no archaeological evidence of this period in the Upper Dniester valley (Harmata *et al.* 2006) (Fig. 2).

The beginning of Slav colonisation is dated to the 5th/6th–7th centuries AD. During the Tribal Period of the Early Middle Ages (8th–10th centuries) an intensive growth in population occurred. The populated territory included the loess terrains of the Carpathian Foreland, Fore-Carpathian Trough, mountain foothills (up to ca 350 m a.s.l.), inter-mountain basins and narrow sections of the valley bottoms of the San, Wisłok and Wisłoka rivers in the Carpathians (Parczewski *et al.* 2012) (Fig. 3). Beyond the large permanent settlements, e.g. at Żyraków on the Wisłoka River, Bachórz on the San River and Grodzisko Dolne on the Wisłok River, as well as the Majnyč and Tenetniki sites in the Dniester River valley, there are numerous hillforts from this period known in the San River valley (Hoczew, Wybrzeże, Trepcza), Dniester River valley (Halyč and Kotoriny) and Stryj River valley (the Zudeč hillfort in Żydačiv), among others (Fig. 3). This indicates a dense population of river valleys, deforestation and cultivation. From the 10th to the 14th century AD the areas of the San and Wisłoka River catchments were subject to the rule of the Kiev monarchy, followed by that of the Halyč principality.

In pollen diagrams sampled in mountain areas (the Low Beskid. and the Bieszczady Mts.) (Fig. 2) traces of the human economy are missing between the Migration Period and the Late Middle Ages (mid–13th century). After ca 550 BP (15th–16th centuries AD) a distinct fall in tree pollen visible in the sequence of the peat bog at the Tarnawa Wyżna site (Ralska-Jasiewiczowa 1980) can be correlated with the colonisation of the Bieszczady Mts. under the Wallachian statutes (Fastnacht 1962). This is confirmed by radiocarbon dating of alluvia in the Upper San River valley (Starkel 2001, Kukulak 2004).

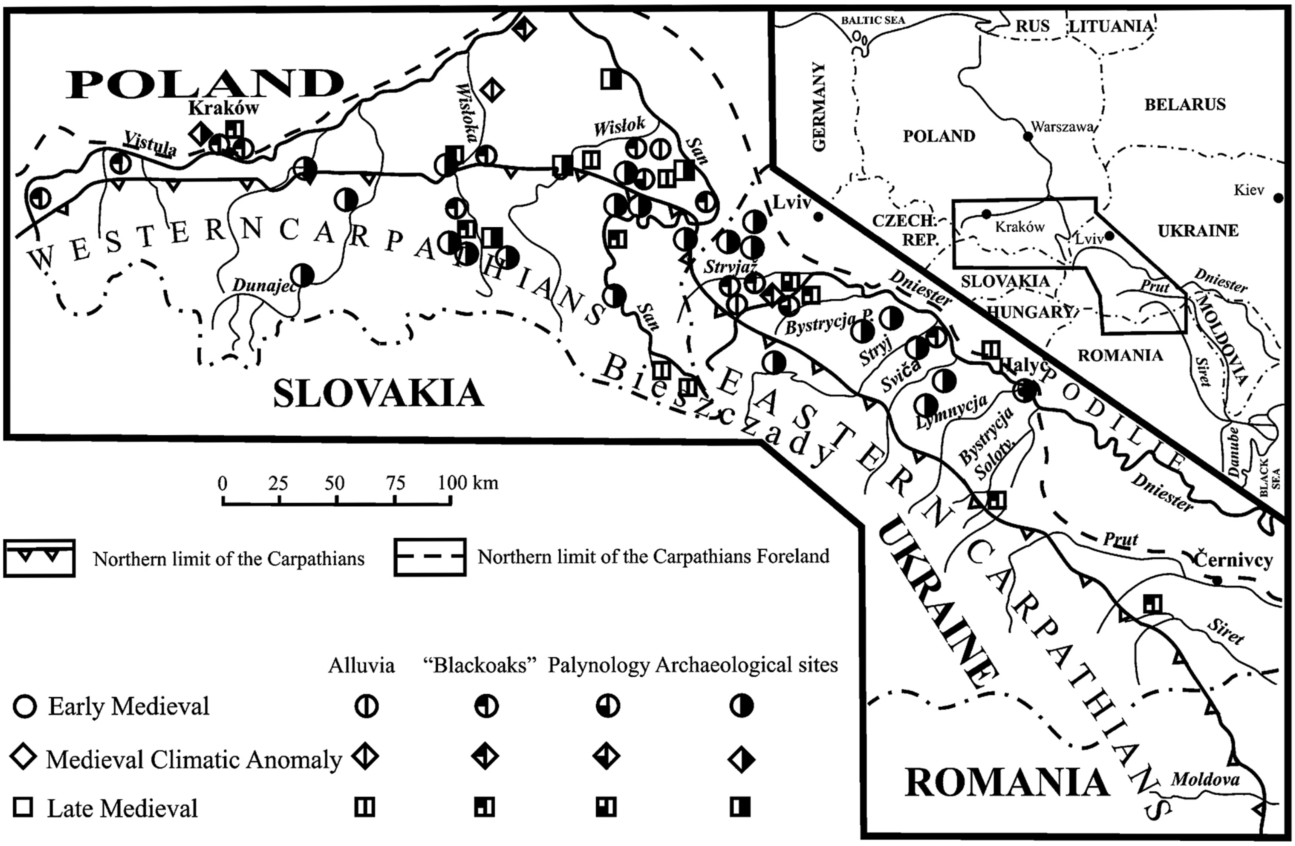

Fig. 3. Distribution of more important dated sites of alluvia and archaeological sites of the Early and Late Middle Ages in the Carpathians and their foreland

Anthropogenic phases of accelerated soil erosion and river accumulation

The Neolithic Period and Bronze Age

Those sites recording the oldest evidence of human impact on the environment are situated in the Vistula river valley downstream of Kraków and are dated to the Early Neolithic (6,500–6,200 BP) (Wasylikowa *et al.* 1985, Gębica 1995) and Younger Neolithic Period (Kruk *et al.* 1996). The occurrence of indicators usually associated with agriculture found in the alluvia of the Wisłok River paleochannel dated at 5,200 BP coincide closely with the colonisation of this area by people of the Funnel Beaker Culture (Gębica *et al.* 2008). In the Upper Dniester basin the peat dated at 5,400 BP, bearing pollen of synanthropic plants was covered by channel sediments and silts 5.5 m thick at the end of the Atlantic Phase (Harmata, Kalinovyc 2006, Starkel, Jacyszyn 2006). Intensive aggradation of the overbank sediments in the Late Neolithic is evidenced by coarse-grained flood inserts with organic material, indicating heavy rains dated at 4,400–4,000 BP in small valleys of the Carpathian marginal zone and paleosol/peat accumulation in depressions (Starkel *et al.* 2002, Budek *et al.* 2012) (Figs. 1, 4). A younger phase of fluvial accumulation covering organic sediments falls in the period 3,300–3,100 BP (Kalicki, 1996, Starkel *et al.* 1996). Deposited at that time in the San and Strvjaž river valleys, were channel alluvia bearing subfossil trunks (Gębica, Krąpiec 2009, Starkel *et al.* 2009) (Fig. 5A).

The Roman Period

The Roman Period in southern Poland (1st–4rd centuries AD) was a time of heightened human activity and flood accumulation, as proved by subfossil stumps and tree trunks processed by man in the channel alluvia of the Vistula (Kalicki, Krąpiec 1991) and San River valleys (Gębica, Krąpiec 2009), as well as proluvial fans deposited in the outlets of small valleys in the Carpathian margin (Starkel *et al.* 2002). At the Grodzisko Dolne site, overbank sands bearing rye pollen, deposited at 1,780 BP on the organic sediments of the Wisłok paleochannel, represent the time at which people of the Przeworsk Culture were active (Gębica *et al.* 2008). In the Strvjaž River valley, at the Čapli site, the aggradation of the floodplain by alluvial loams ended prior to the 3rd–4th centuries AD, since this time is represented by a cultural horizon on the terrace plain (Starkel *et al.* 2009) (Fig. 5A). Alluvia bearing trunks dated at 2,100–1,700 BP have been found at several sites also downstream of the Upper Dniester Basin (Gębica, Jacyszyn 2012). Observed during the Migration Period (5th–7th centuries AD) are a regression in settlement, a reforestation and a simultaneous rise in the number of floods linked with a wetter climatic phase (Fig.

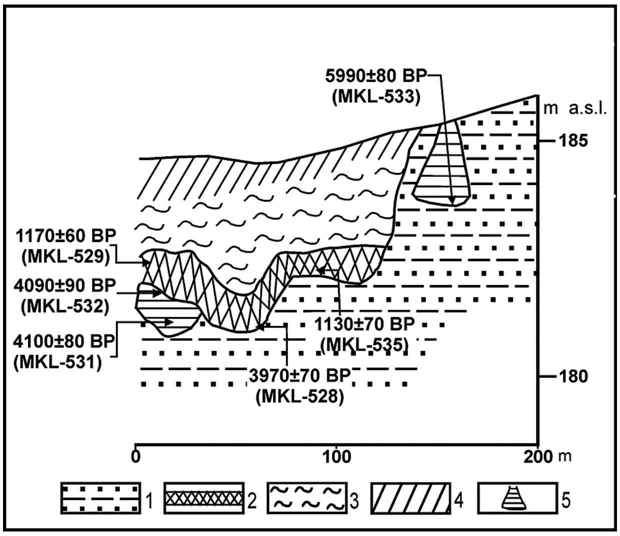

Fig. 4. Medieval slope sediments and paleosol covering Neolithic and Bronze Age pits at the foot of a hillslope of the Kańczuga Plateau (the example of the Rozborz archaeological site near Przeworsk)

1 – alluvial sediments; 2 – paleosol; 3 – slope (colluvial) sediments; 4 – Holocene soil; 5 – Neolithic and Bronze Age pits

1) (Starkel 2005b). This phase is recorded in a concentration of subfossil trunks in channel alluvia of the Vistula (Kalicki, Krąpiec 1991), Wisłoka (Starkel, Krąpiec 1995) and San River valleys (Gębica, Krąpiec 2009). This period is also represented by alluvial fill in the 5–6 m terrace of the Strvjaz and Stryj river valleys in the Ukrainian Carpathian foreland (Fig. 5A, C) (Starkel *et al.* 2009, Gębica, Jacyszyn 2012).

The Early Middle Ages

The 8th–10th centuries are characterised by a descent of colonisation to the valley floors, earliest of all in the Morava River valley (Havlićek 1991). Correlation of sequences of fluvial, slope and peat bog sediments in the Carpathian river valleys indicates that during the 10th–12th centuries the catchment area of the Upper Vistula River was colonised to a significant degree. In the Wisłoka River valley lateral migration of meandering channels began about 965±75 BP (940–1,240 cal AD) (Starkel ed. 1981). Similar dates – 925±30 BP (1,030–1,180 cal AD) and 1,080±30 BP (890–1,020 cal AD) – were obtained from subfossil trunks found in sediments of the Wisłok River valley (Gębica 2011). Deposition of colluvia 1–1.5 m thick at the foot of Kańczuga Plateau slopes caused fossilisation of paleosol dated at 1,230–1,010 BP overlying Neolithic pits (Fig. 4) (Budek *et al.* 2012). Alluviation of small river valleys in the Mleczka River catchment on the Kańczuga Plateau is also a result of deforestation and soil erosion (Łanczont *et al.* 2006).

The deforestation proceeding in the 10th–12th centuries is shown by pollen diagrams of overbank sediments of the Wisłoka River dated at 1,040±95 BP (Starkel ed. 1981),

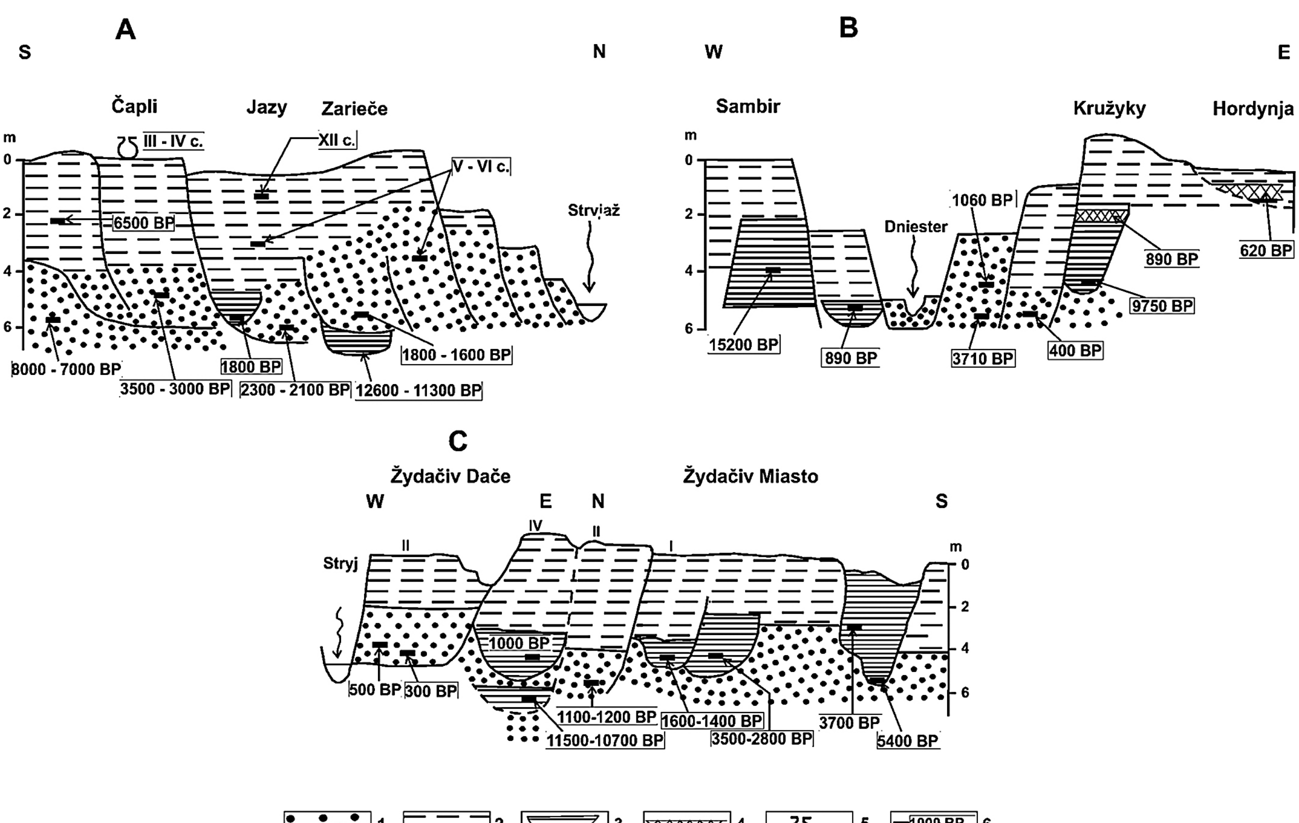

Fig. 5. Models of the structure and age of alluvial fills in the Strvjaž, Stryj and Dniester River valleys, illustrating phases of increased accumulation of alluvia in the Eastern Carpathian foreland.

1 – channel alluvia; 2 – overbank alluvia; 3 – palaeochannel fills; 4 – peat; 5– archaeological sites; 6 – radiocarbon datings (conventional)

as well as pollen diagrams of peat bogs and organic sediments overlain by overbank sediments in the Upper Dniester Basin (Harmata, Kalinovyč 2006). Records of the Early Medieval floods are reflected in the Dniester River valley, in its Carpathian outlet, by the insert of a 2–4 m gravel terrace (Gębica *et al.* 2013) (Fig. 5B).

In the Upper Vistula River valley downstream of Kraków, tree felling, overbank deposition and displacements of river channels indicate frequent floods in the period 900–1150 AD (Starkel ed. 1981, Kalicki, Krąpiec 1992, Kalicki 1996, Krąpiec 1996). Beginning at that time in the foothills of the Beskid Śląski Mts. was an aggradation of the Upper Vistula alluvial fan (Niedziałkowska *et al.* 1985). Simultaneous aggradation is also observed in the Lower Strvjaž and Lower Stryj River valleys in the Eastern Bieszczady Mts. foreland (Starkel *et al.* 2009, Gębica, Jacyszyn 2012, Gębica *et al.* 2013). The dating of an oak trunk at 990±40 BP (Gębica, Jacyszyn 2012) at the bottom of a 6 m thick series of overbank sediments in the Stryj River alluvial fan (Fig. 5C) indicates the beginning of a flood accumulation occurring at precisely the time at which the Zudeč hillfort at the Żydačiv site functioned (Korczyński 2007). It coincides with the short phase of cooling and growing humidity in the first half of the 11th century (Steinhilber *et al.* 2009).

The covering of peat bogs by overbank sediments, dated at 620±110 BP (1160–1490 cal AD) and 650±75 BP (1,220–1,430 cal AD), in the Upper and Middle Dniester valley (Gębica *et al.* 2013) (Fig. 5B) indicates an increase in the frequency and violence of flooding in the 14th–15th centuries, which may have been connected with deforestation and a rise in precipitation (Dotterweich 2008, Büntgen 2011). It is correlated with dendrochronologically dated sequences of tree trunks fallen or cut during the floods in the 14th century in Starunia, in the Velyky Lukavets River valley in the Ukrainian Carpathians (Alexandrowicz *et al.* 2005). The flood phase in the 14th–15th centuries is also confirmed by subfossil trunks dated at 650±40 BP and 660±45 BP (1270–1400 cal AD) deposited in the alluvia of the Michydra and Moldova rivers (tributaries of the Siret River) in the Bukovyna Carpathian Foreland (Gębica *et al.* 2012, 2013, Chiriloaei *et al.* 2011). Similarly, single subfossil trunks from the 14th–15th centuries have been found in the Vistula (Kalicki, Krąpiec 1991), Wisłoka (Krąpiec 1996) and San River valleys (Gębica *et al.* 2013).

The Late Middle Ages and Little Ice Age

In the 15th–16th centuries agriculture spread to upland and mountainous areas. The deforested areas were exposed to soil erosion, in particular in terrains formed of silt covers. The colonisation of the Upper San River catchment in the Bieszczady Mts. at the turn of the 16th century was directly reflected in soil erosion and accumulation of flood sediments both in small valleys (460±50 BP, Starkel 2001) and the San River valley (Starkel 2001, Kukulak 2004). In the valley of Čudyn Stream (a tributary of the Little Siret River) in the Bukovyna Carpathian Foreland, dendrochronologically dated a fir trunk with traces of processing was felled in 1503 (Krąpiec unpubl.). The scale of flow oscillations and the rate of overbank deposition are shown in lower accumulation terraces formed in recent centuries e.g. in the outlet of the Wisłoka River in the Carpathian margin (Klimek 1974), as well as in the Dniester River valley at the Krużyki site, where at the bottom of a 5 m terrace an oak trunk processed by man has been found, dated at 400±35 BP (1,440–1,620 cal AD) (Gębica *et al.* 2013) (Fig. 5B). At the same time the fill in the 5 m terrace at the Stryj-Žydačiv site was proceeding (Gębica, Jacyszyn 2012) (Fig. 5C). Growth in economic activity coincided with the beginning of the Little Ice Age, when throughout Europe a rise in the frequency of flooding (Brazdil *et al.* 1999, Starkel 2001) and a transformation of river channel systems from meandering to braided were both observed (Szumański 1977). Mention should also be made of the lateral migration of river channels in alluvial fans in valley outlets from the Carpathians in recent centuries (Fig. 6), as well as the deepening of these channels as a result of artificial regulation in the 19th and 20th centuries, the extraction of gravel from riverbeds after 1945 and/or the closure of water-mills (Klimek 1974, Starkel 1981, Huhmann, Brückner 2002, Gębica, Jacyszyn 2012). On the other hand, the construction of flood dams has generated a rise in overbank deposition between dams (Czajka 2000), while flood waters, constricted excessively between them, have frequently broken through and flooded densely populated valley bottoms.

Conclusions

The research performed allows the following conclusions to be formulated:

1) The intensive colonisation of the loess plateaus and foothills, initiated by the oldest cultivation cultures (the Linear Pottery Culture, from 6,000 BC) lasted throughout the Neolithic Period up to the beginning of the Bronze Age (the beginning of the second mil-

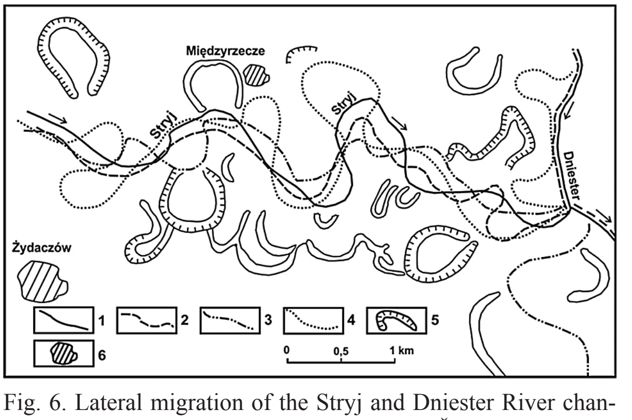

Fig. 6. Lateral migration of the Stryj and Dniester River channels in the past 150 years near the town of Žydačiv

1 – river channel ca 1870; 2 – river channel ca 1914; 3 – river channel ca 1945; 4 – river channel in 2012; 5 – channels cut off before 1878; 6 – towns and more important villages

lennium BC). On the terraced bottoms and slopes of river valleys the largest number of archaeological sites represent the Late Bronze Age and Early Iron Age (the Tarnobrzeg Type of the Lusatian Culture) and the Roman Period (the Przeworsk Culture, 2nd–5th centuries AD), as well as the Early Middle Ages (Czopek 1996, Machnik 2000, Harmata *et al.* 2006).

2) Analysis of materials demonstrated that despite a far lower number of dated archaeological sites in the Eastern Carpathian Foreland, phases of colonisation and human impact in the Upper Vistula River catchment and in the Upper Dniester River catchment were contemporary.

3) The study evidenced synchronicity of flood phases in valleys of the Upper Dniester, Stryj and Strvjaž rivers with previously distinguished phases of increased river activity in the Upper Vistula River catchment (Kalicki 1996, Starkel *et al.* 1996, Gębica 2011) (Fig. 1). However, not all of the flood phases distinguished in the Upper Vistula River basin are similarly represented in the Upper Dniester River valley, e.g. the period 4,400–3,800 BP was humid (Figs. 1, 4), yet a distinct flood phase in the Dniester River valley was not observed. During the Pre-Roman Period (la Tene Period) the humid phase (2,500–2,200 BP) is marked by an aggradation of gravels bearing subfossil trunks only in the Strvjaž River valley (Figs. 1, 5A), whereas a common aggradation is most characteristic of the Upper Dniester River valley in the Carpathian foreland in the 1st–3rd centuries AD (2,100–1,700 BP), a situation similar to that of the Upper Vistula River valley, where an expansion of agriculture and iron metallurgy took place (Fig. 1).

4) An increasing number of sites in river valleys indicates a sequential occurrence of increased flood deposition linked exclusively with human impact (e.g. the Roman Period), phases determined by a rise in climate humidity in the periods of economic recession (5th–6th centuries AD) and phases in which both factors coincide (e.g. the middle Neolithic Period, the 10th–11th centuries AD and the Little Ice Age) (Starkel 2005, Starkel *et al.* 2006, Gębica, Jacyszyn 2012, Gębica *et al.* 2013).

5) The scale of anthropogenic changes in morphology in the period analysed is differentiated, but not significant. The denudation of loess terrain in the Carpathian Foreland should be estimated at 0.5–1 m, while deposition of silts in the bottoms of small valleys does not exceed 3 m, and the thickness of colluvial cover at the foot of loess hillslopes often amounts to 1–2 m.

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