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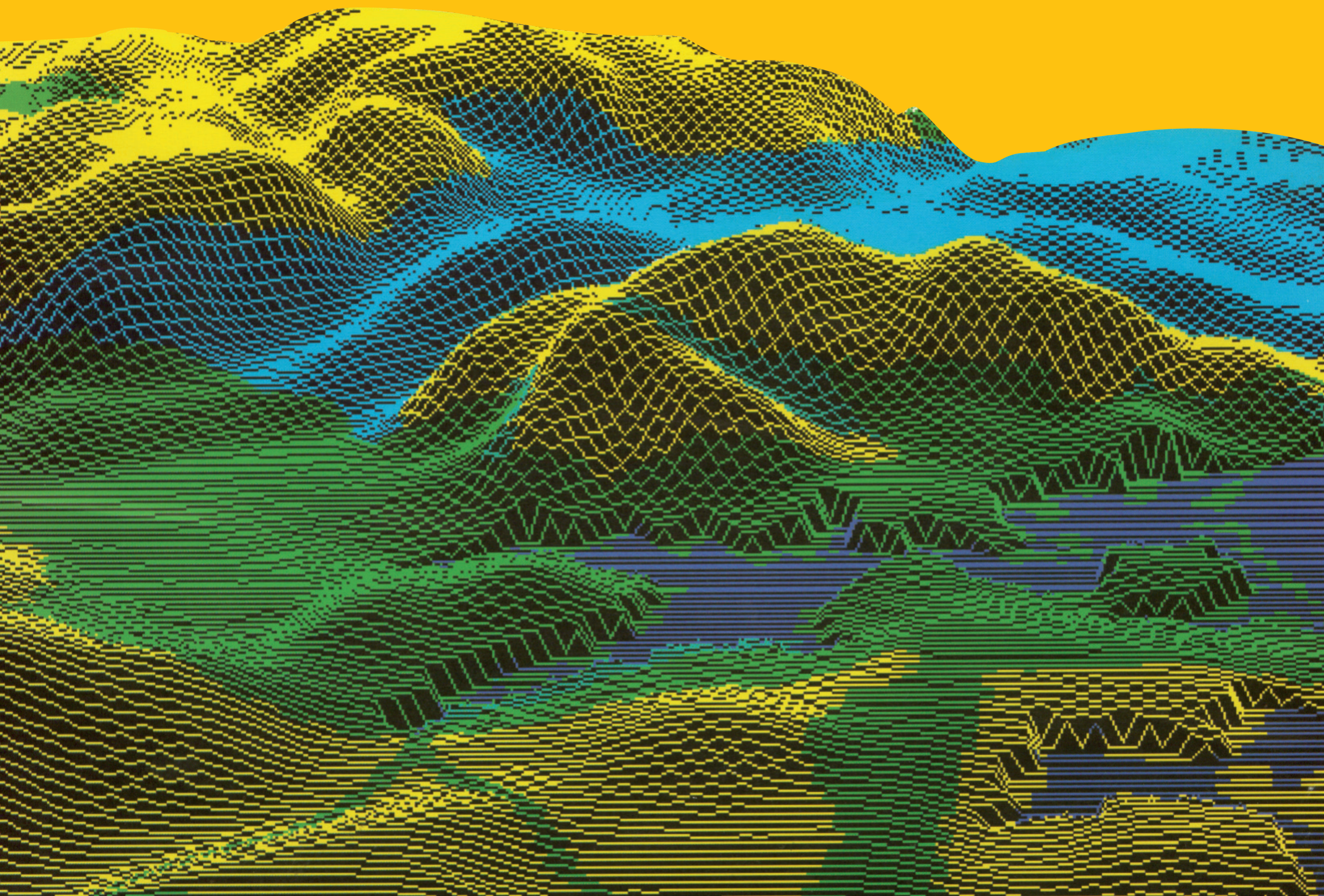

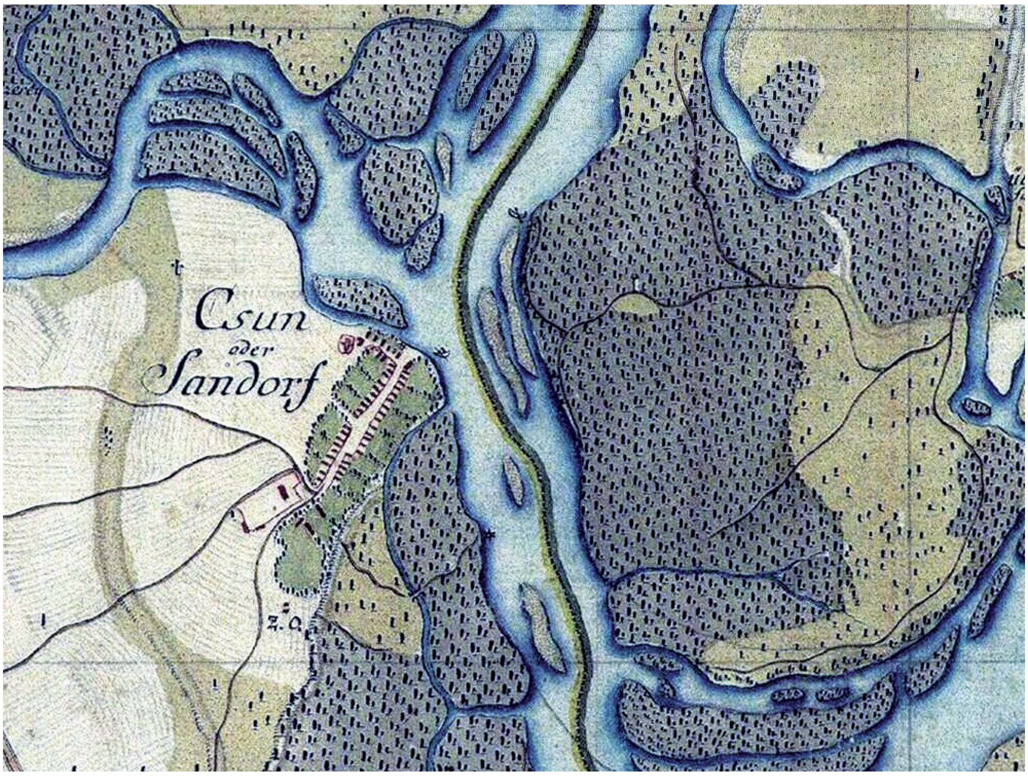

Fig. 2: Character of the Danube River next to the riverside village of Čunovo in 1783–4 depicted on the Ist Military Survey map. Mainchannel width reached from 500 to 600 m

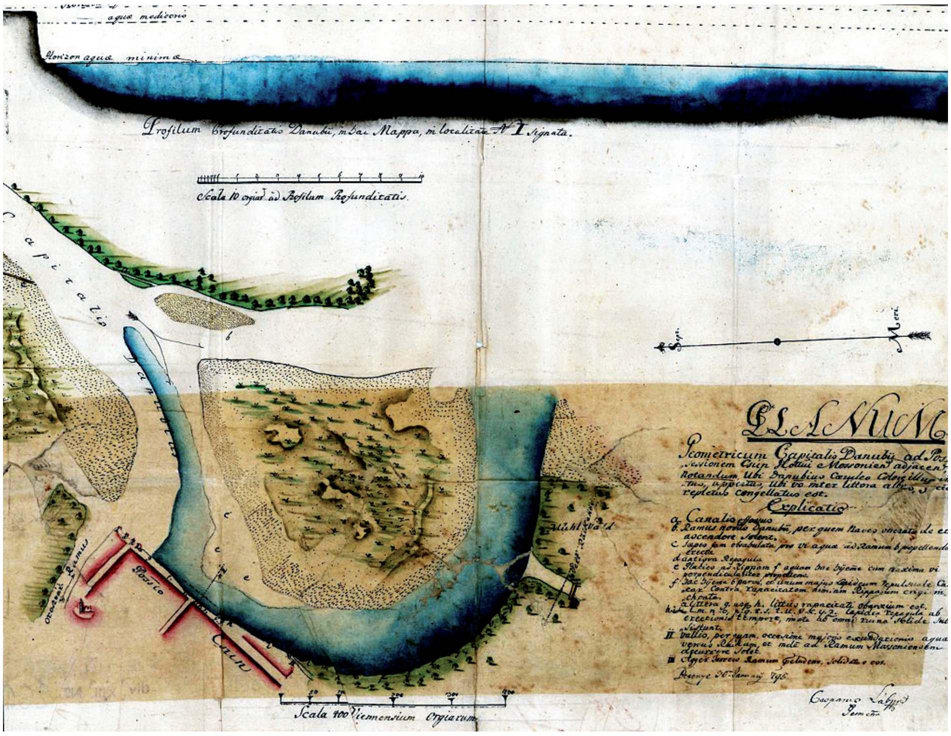

Fig. 6: The map from 30 January 1795 is an excellent example documenting unpredictable past hazards connected even with the „ordinary“ winters with ice on the river. Partial freezing of the Danube bend upstream Čunovo dramatically narrowed the flow-through profile to only 60 m, thus deflecting the stream in perpendicular toward the village. This resulted in local bank retreat up to 29 m during this single event, lasting perhaps only a few days. The attached cross-section of the bend in its deepest part helps us to understand the major erosion force at cut banks of the rapidly developing meanders: by the lowest flow (Horizon aquae minimae), the channel was still 5.31 m deep (2.8 Viennese ells), whereas by mean water stage (Horizont aquae mediocris) it reached even 10.05 m (5.3 ells)

Illustrations related to the papert by P. Pišút

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EDITORIAL

As a joint initiative of major world geo-scientific associations, the General Assembly of the United Nations declared the year 2008 as the International Year of Planet Earth in January 2006. Main objective of the initiative is to commemorate and highlight the significance of geo-scientific disciplines for global sustainable development, mitigation of natural hazards, rationalization of building and optimum exploitation of natural resources. Maximum emphasis is put on bringing into limelight the significance of geosciences for the society, enhancement of cooperation between geo-scientists and politicians, and geo-scientists and community (details see www.yearofplanetearth.org, www.rokplanetyzeme.cz). The Year of Planet Earth in the Czech Republic will be held under the auspices of the Ministry of Environment of the Czech Republic, and a number of institutions and organizations join the initiative, among other the Academy of Sciences of the Czech Republic; one of partners is also the Czech Geographic Society.

Intending to contribute to the above initiative, the Editorial Board of Moravian Geographical Reports decided to publish papers from the field of environmental geography focused onto the concerned complex issue dealing with mutual relations and impacts of human activities onto landscape and environment where the significance of the interdisciplinary geo-scientific knowledge shows most. Some contributions to the topic were already published in MGR No. 2-2008.

The papers were particularly focused on the impact of the extraction of minerals onto relief and on some specific problems connected with the deep mining of bituminous coal and its impact onto landscape and environment in the Ostrava-Karviná Coal District. Some papers dealt with selected natural processes such as floods and landslides, their geo-ecological effects and hazards in the susceptible mountain region of Moravia and Silesia.

The current MGR number presents articles that contribute to the knowledge of natural processes in the landscape and their environmental impacts. Basis for our selection were papers presented at the international conference "State of Geomorphological Studies in 2008" held in Šlapanice (Brno) in June 2008 – more details see ***Z. Máčka*** (p. 45-47). The below listed papers we chose with respect to the discussed geo-scientific and environmental policy.

J. Demek: The role of geomorphology in the landscape-ecological research. The contribution shows the role of geomorphology as a geo-scientific discipline in the landscape-ecological research, pointing out the significance of both morphology and processes, and anthropogenic impact in landscape evolution.

M. Stankoviansky et al.: Geomorphic response of dry valley basin to large-scale land use changes in the second half of the 20th century and problems with its reconstruction. The authors demonstrate that large-scale land use changes in the flysh relief of the Myjavská pahorkatina (Hilly Land) in the 1950s resulted in a considerable increase of mud floods and landscape disturbance. Accumulations deposited by mud floods are at the present time analyzed geomorphologically and assessed in respect of a possible reconstruction of geo-ecological conditions at the times of mud flood occurrence.

J.B. Szmańda et al.: Sedimentological record of flood events from years 2002 and 2007 in the Danube River overbank deposits in Bratislava. The paper is focused on the analysis of flood sediments, which point to a high variability of sedimentation processes during floods.

P. Pišút: Endangerment of the village Čunovo by lateral erosion of the Danube River in the 18th century. The case of Čunovo, which was partly destructed by lateral erosion of the Danube River during the last onrush of the Little Ice Age, is presented on the basis of the assessment of map groundworks.

Regarding its focus, the periodical Moravian Geographical Reports will publish articles and scientific communications from the field of geo-scientific knowledge, which fruitfully shows in the environmental issue not only during the International Year of Planet Earth but also in other coming years.

Karel Kirchner

THE ROLE OF GEOMORPHOLOGY IN THE LANDSCAPE-ECOLOGICAL RESEARCH

Jaromír DEMEK

Abstract

This paper was presented as an opening address at the international conference of the Czech Geomorphologic Society "State of Geomorphological Studies in 2008" in the town of Šlapanice in 2008. The paper deals with the evaluation of the role of geomorphology in the landscape research. It is shown in the paper that geomorphology plays an important role in the landscape-ecological studies.

Shrnutí

Úloha geomorfologie v krajinně-ekologickém výzkumu

Článek je shrnutím referátu předneseného na zahájení konference České geomorfologické společnosti "Stav geomorfologických výzkumů v roce 2008" ve Šlapanicích 2008 a zabývá se hodnocením úlohy geomorfologie při výzkumu krajiny. V práci je ukázáno, že geomorfologie hraje významnou úlohu při krajinářských výzkumech.

Key words: *Geomorphology, landscape, landscape-ecological studies, relief as palimpsest, anthropogenic geomorphology, Czech Republic*

1. Introduction

Geomorphology is the study of landforms and processes that shape them. Landforms represent an important part of the system of landscape, which is the main focus of geography as a science. The author uses the term landscape to describe the sum total of the "appearance" of an area (Witherick, Ross, Small, 2001, p.149). Landscape is a dynamic complex thing with many interactions. Abiotic, biotic and anthropogenic elements interact, forming a heterogeneous mosaic in the landscape. Thus, natural landscape refers to the combined effect of landforms, climate, waters, soils and biota. Cultural landscape includes all modifications made in the natural landscape by the Human activity. The complex of landforms in a certain area is called landscape relief.

Components of landscape systems are studied by scientists from different disciplines. The term "landscape ecology" was devised by geographer Carl Troll (1939) to marry geography (the landscape) with ecology (Huggett, 1995, p. 14). Relief as the most conspicuous and stable among landscape components forms the background in trying to give an integrated picture of landscapes. Integrating the concepts of geomorphology with landscape ecology has, however, come slowly (Butler, 2001, p. 237).

2. The role of relief in the landscape

Due to its properties, namely its vertical and horizontal dissection, the relief influences other parts of the landscape system and also Man's activities in the landscape. Vertical dissection of the relief causes vertical gradient in the landscape according to altitude. The result is the division of ecosystems into distinct vertical layers with specific relief conditions. The spatial landscape zonation primarily corresponds to the altitude, but vertical dissection also causes vertical zonation of climate, vertical soil zonality, high-altitude geomorphic processes and other landscape phenomena. Mountain landscapes in Czechia are in many ways quite different from their lowland counterparts.

The horizontal relief dissection primarily influences the aspect, slope gradient, slope curvature and slope length, which controls firstly the type and intensity of geomorphic processes, but secondarily also the climate just above the ground (mesoclimatic conditions) and, of course, also the microspatial differentiation of soils and biota. In the Northern Hemisphere, south facing slopes tend to be warmer, and hence more prone to drought than north facing slopes. Horizontal relief dissection is also the source of the origin of some landscape phenomena, especially the valley phenomenon. Large mountain ranges cast a rain shadow in their lee that is sufficient enough to alter ecosystems.

Complexes of landforms classified according to morphographic and morphometric criteria compose morphographic types of the relief. Fig. 1 shows morphographic relief types of the Czech Republic, whose spatial distribution primarily reflects the vertical zonation.

The lowermost vertical layer represents floodplains. During the catastrophic floods in 1997 and 2002, nearly the whole floodplains of the Labe, Morava and Ohře R. were flooded.

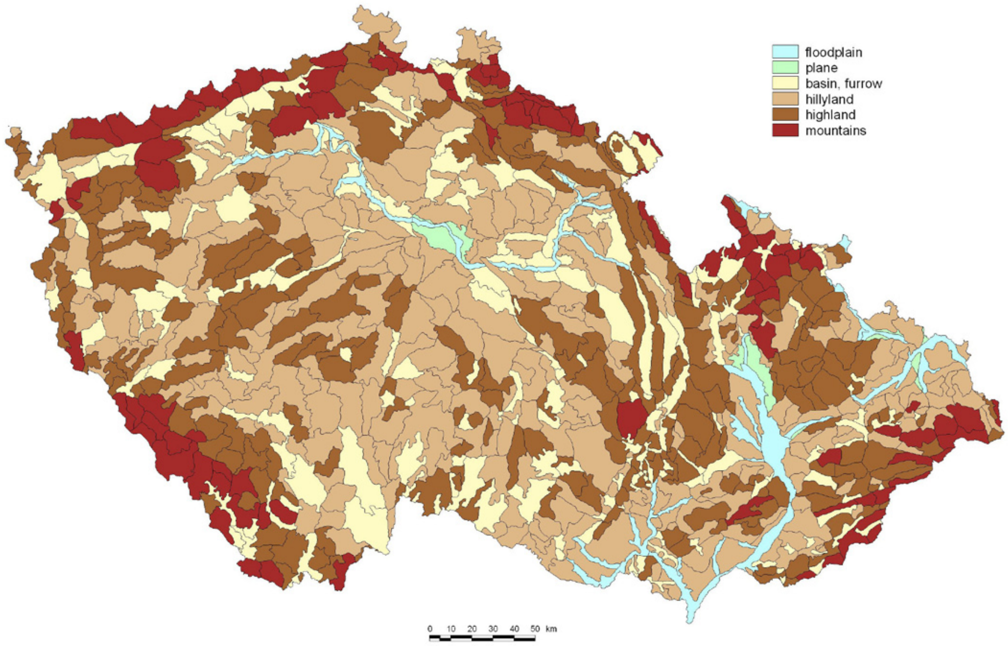

Fig. 1: Morphographic Types of Relief in the Czech Republic (Demek, Slavík, 2005)

The tops of some mountains – Krkonoše, Králický Sněžník and Jeseníky Mts. - reach above the natural upper timberline (Figs. 2 and 3 – see cover p. 4). The upper timberline represents a steep ecotone in which a noticeable change of dominant life form occurs. The boundary between the subalpine vegetation and the low-growing alpine vegetation tells much about elevation influences on biota (despite the fact that in the Hrubý Jeseník Mts. the upper timberline was lowered by pasture).

In the horizontal dissection of the landscape, rivers and their valleys play a great role. Some organocomplexes developed on water divides and flat planation surfaces and others in valleys, especially in deep incised river valleys. A so-called valley phenomenon developed in the deep incised valleys of the Vltava and Berounka R. in Central Bohemia, in the canyon of the Labe R. in the Děčínská vrchovina Highland or in the deep meandering valley of the Dyje R. in the SE part of the Bohemian-Moravian Upland. On a stretch of some tens of meters, there is a large difference of ecological conditions between the flat planation surface just above the upper rim of the steep valley side, where the surface air temperature is higher than 50 °C, and the cold bottoms of deep valleys, where the temperature inversion occurs. The river valleys are also important migration corridors. Especially under the impact of global warming, submontane species use river valleys to migrate into the mountains.

3. Structurally controlled phenomena

Other landscape phenomena with some edaphic specialties are bounded to some bedrock-controlled reliefs such as karst or sandstone landforms. A typical feature of these landscapes is virtual absence of surface drainage and development of special karst and pseudokarst landforms.

4. Landscape forming geomorphic processes

Geomorphic processes studied by geomorphology belong among the main landscape forming processes. Two basic groups of processes form landscapes: The first group includes slow processes and the second group includes rapid up to catastrophic processes. Geomorphologists study both the slow and the rapid endogenic and exogenic geomorphic processes acting in the landscapes. Evaluation of slow geomorphic processes needs long-term observations and measurements of processes on monitoring plots (Mackovčin et al., 2007). For instance - The Silva Tarouca Research Institute for Landscape and Ornamental Gardening (VÚKOZ) in Průhonice carries out a long-term measurement of slow geomorphic processes on 7 monitoring plots in the Czech Republic (Fig. 4).

Identification and quantification of rapid geomorphic processes is relatively simple because, in a short time period they cause damages in the landscape and endanger Man's activities in the landscape (Demek, Kalvoda, Kirchner, Vilímek, 2006). Rapid geomorphic processes cause landscape disturbances. A working definition of disturbance reads as follows: any event that disrupts landscape and its ecosystem. Landscapes in Czechia may be physically disrupted by floods, landslides, rockslides, mud flows, snow avalanches, gullying, strong winds (which uproot trees), etc. The effects of these geomorphic disturbances in the landscape can be dramatic.

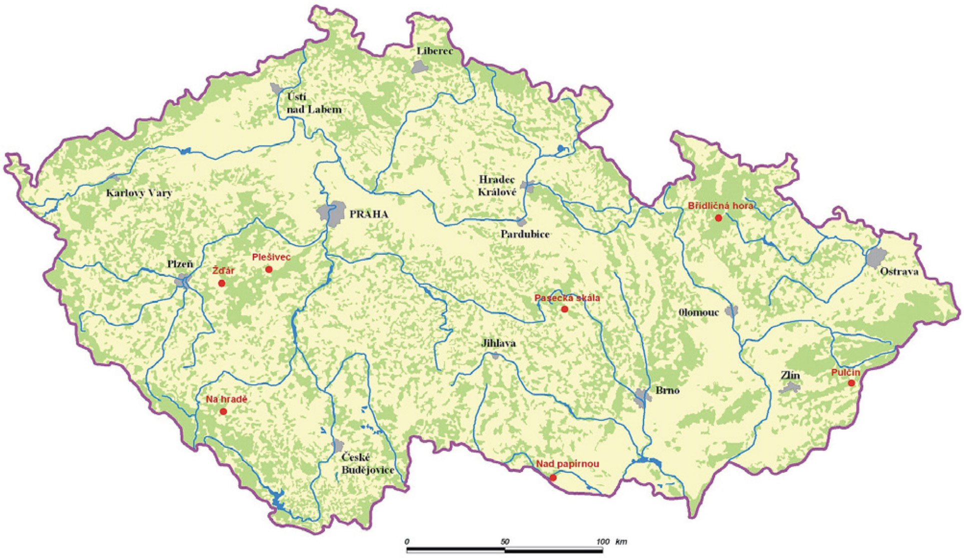

Fig. 4: Monitoring plots (red points) of slow geomorphic processes carried out by The Silva Tarouca Research Institute for Landscape and Ornamental Gardening (VÚKOZ) in the Czech Republic

5. Relief as palimpsest

Palimpsest is a surface bearing superimposed inscriptions of differing age. Also, the relief shows evidence of landscape environment changes over a long time. From the relief, which keeps superimposed features it is possible to reconstruct past phases of development of the landscape as well as various environments in which the landscape developed. Analysis of environmental changes during the Quaternary period is especially important for understanding the present day landscape.

Case study: Brno – Dobrovského Street tunnel – environmental changes during the Quaternary

During excavation works for a new tunnel in Brno – Dobrovského Street, Pleistocene ice wedge casts in loess were exposed in Žabovřeská ulice Street. These studies were carried out by Dr. Mackovčin (VÚKOZ), Dr. Kirchner (Academy of Sciences of the Czech Republic), Ass.Prof. Dr. Nehyba (Masaryk University), and by the author. The construction site is situated in the northern part of the City of Brno at an elevation of 240 meters a.s.l. In one stratigraphic profile, several superimposed paleosoils were found and with them connected nets of ice wedge casts originating in different phases of the Pleistocene. The nets of ice wedge casts were exposed in vertical and horizontal cross sections (Figs. 5 and 6).

Authors interpreted the described nets of wedge-shaped structures as casts or pseudomorphs of Pleistocene ice wedges. Such ice-wedge casts are among a few acceptable criteria for the former permafrost (Washburn, 1979, p. 113). Studied profiles on the walls of the Dobrovského tunnel are evidence that the permafrost repeatedly developed and degraded in the Pleistocene also at lower altitudes of the Czech Republic. Ice wedges require certain temperature conditions for growth and preservation. The mean annual temperature (MAAT) during the aggradation of permafrost and origin of the ice wedges net was approx. -6 to -8 °C. Upon climatic warming and thawing of permafrost, the site of an ice wedge is filled with the collapsed material that becomes a cast of the wedge. An example of recent local permafrost degradation and formation of ice wedge cast in loess loams of Siberia is in Fig. 7.

The lower part of the exposure in Fig. 8 is still frozen (permafrost) with pure veins of underground ice. In the upper part, due to local permafrost degradation, the ice wedge melted and the space left after ground ice was filled by black loam. Ice wedges grow preferentially in fine-grained material (as is the case of exposures in Brno – Dobrovského Street tunnel – Figs. 5 and 6); they are best preserved in sands and gravels (as in Fig. 8).

The identification and use of cryogenic features in environmental reconstructions in landscape-ecological studies is still a largely underdeveloped potential.

6. Anthropogenic landforms in the cultural landscape

The present-day landscape of the Czech Republic is a landscape that has resulted from many generations of human occupancy. Many features of contemporary landscapes were fashioned by the ancient societies who induced more or less permanent changes. Therefore, the present-day landscapes can be interpreted as palimpsests by geographers. Natural landscape elements provide the habitat, but a deciding factor in the cultural landscape is the Human society. Many anthropogenic landforms have originated and are still developing due to Man's activities

Fig. 5: The net of Pleistocene ice wedge casts. Vertical cross section of the middle buried soil and connected ice wedge casts. Excavation of the road tunnel in Brno – Žabovřeská ulice Street (Photo J. Demek)

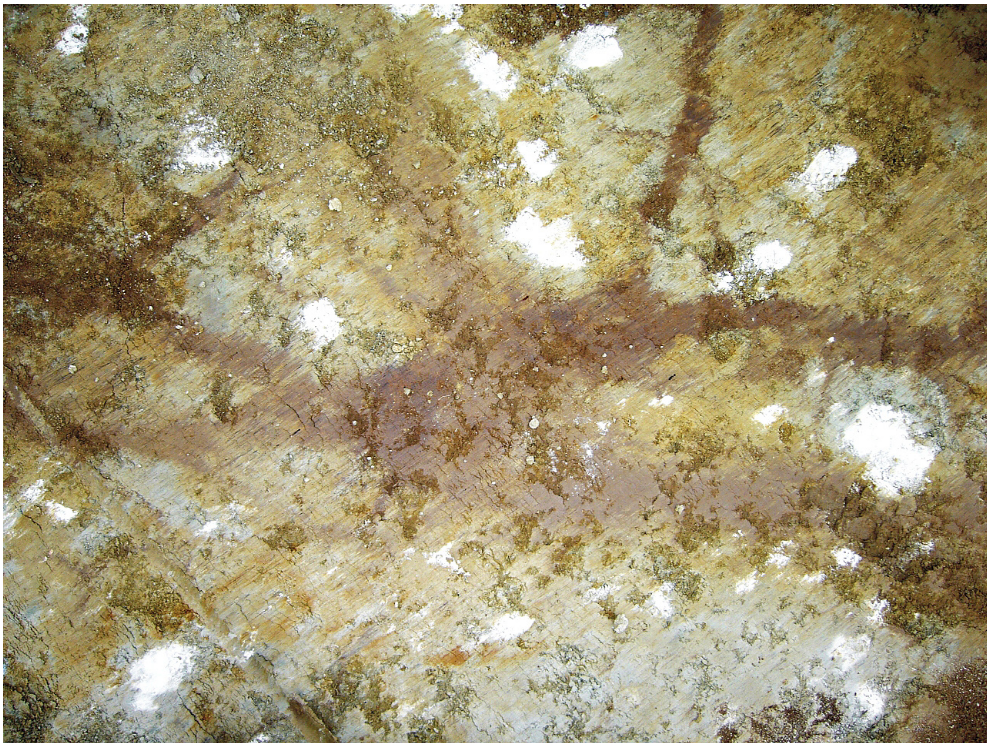

Fig. 6: Horizontal section of the net of Pleistocene ice wedge casts connected with the lowest buried soil. Excavation of the road tunnel in Brno – Žabovřeská ulice Street (Photo J. Demek)

in the landscape. The importance of anthropogenic geomorphology is therefore increasing. With respect to the evaluation of the impact of Human society on the landscape and on the origin of anthropogenic landforms in the last 250 years, the digitalized historical and modern topographic maps are interpreted in GIS milieu in VÚKOZ.

Case study: Changes of the courses and lengths of water courses in floodplains

Floodplains are very dynamic geosystems. A quantitative and computer supported analysis of historic and modern topographic maps on scales 1:28 800, 1: 25 000 and 1:10 000 of the Svitavsko-svratecké nivy (Svitava-Svratka

Fig. 7: An example of the local degradation of recent permafrost with a net of ice wedges and origin of the net of pseudomorphs of ice wedges (ice wedge casts) in Siberia (Central Yakutiya near the town of Tommot - Photo J. Demek)

R. Floodplain) and Dolnojihlavské nivy (Lower Jihlava R. Floodplain) has shown large landscape changes caused by Man in the period 1765–2005. Disturbances in the floodplains caused by Human activities started during the 16th century (e.g. construction of large fishponds near the town of Pohořelice). But there was a dynamic equilibrium existing between geomorphic and ecologic processes in the floodplains dynamic equilibrium up to the middle of the 19th century (and in some areas up to 20th century). Topographic maps of the 2nd Austrian Military Mapping from the period 1838–1841 show meandering and anastomosing rivers in the floodplains. Beds of the tributary streams of rivers Svratka and Jihlava were of the deferred junction type (Yazoo contact). The tributary streams were prevented from joining the two rivers because of levees which flanked the latter until they have flowed in parallel for a considerable distance (e.g. tributaries of the Svratka R.: Ivanovický potok Creek, Litava R., Křepický potok Creek, Šatava Creek and others). However, in 1848 training of the Svratka R. started. A new deep river bed was excavated from the city of Brno in the north to the village Vojkovice in the south. (Fig. 9). The river training caused the fragmentation of floodplains. The natural geomorphic processes in floodplains have been very limited since that time. The reduction of floods ended the relation between the water courses and the floodplain surface. The ecotone function between the valley slopes and the stream was also lost. The accumulation of fluvial sediments on the floodplain surface, the erosion of flood water and cascade transporting sediments downstream was limited. Human stress on the floodplains has been very high in the last 150 years. Human activities caused not only changes in land-use (felling of floodplain forests, ploughing of floodplain meadows, various constructions on floodplains, etc.) but also changes of river courses, shortening of river beds and changes of river sinuosity (Tabs. 1 and 2). A river's sinuosity is the river's tendency to move back and forth across the floodplain in an S-shaped pattern, over time.

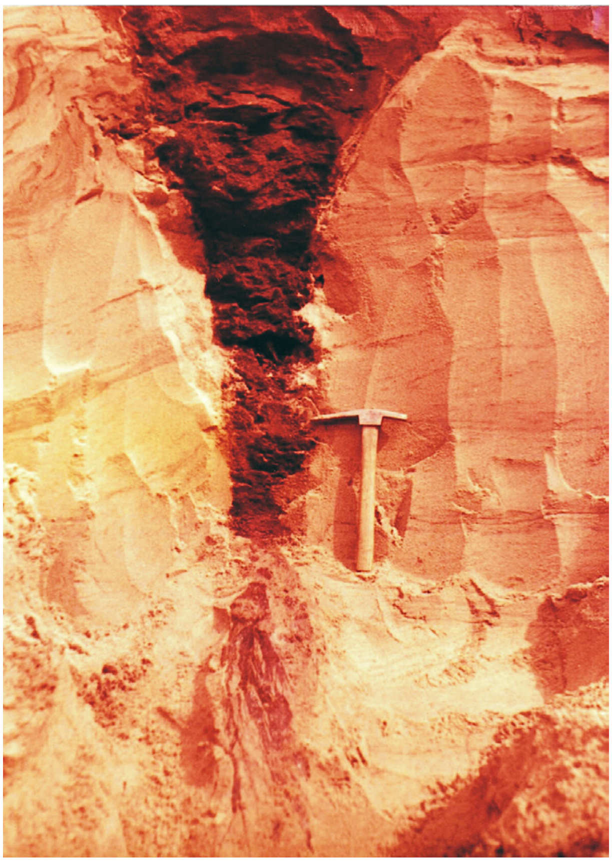

Fig. 8: Origin of the pseudomorph of recent ice wedge in fluvial terrace sands in Siberia. The side erosion of the Lena R. exposed the permafrost in the terrace scarp near the town of Yakutsk to sunshine, causing the accelerated melting of underground ice and formation of ice wedge cast (Photo J. Demek)

The sinuosity index is calculated as a length of the stream divided by the length of the valley (see Tab. 2).

The length of the Svratka R. bed was shortened from 52.50 km in 1836 to 36.75 km in 2007 (Tab. 1) and the sinuosity index decreased from 1.76 in 1836 to 1.23 in 2007 (Tab. 2). Geomorphic research substantially contributed to the knowledge of Human impact on floodplain landscapes and to the explanation of changes in landscape-ecological processes. The importance of such research is growing due to the application of computer supported methods e.g. GIS studies.

River	1836	1876	1944	1954	1991	2007
Svratka	52.50	44.62	40.25	40.21	35.33	36.75
Jihlava	26.32	25.20	25,36	25.55	24.52	24.97

Tab. 1: Changes of riverbed lengths in kilometers in time (Demek, Mackovčin, Borovec, Chrudina, 2008)

River	1836	1876	1944	1954	1991	2007
Svratka	1.76	1.50	1.35	1.35	1.22	1.23
Jihlava	1.47	1.40	1.41	1.42	1.36	1.39

Tab. 2: Changes of the sinuosity index in time (Demek, Mackovčin, Borovec, Chrudina, 2008)

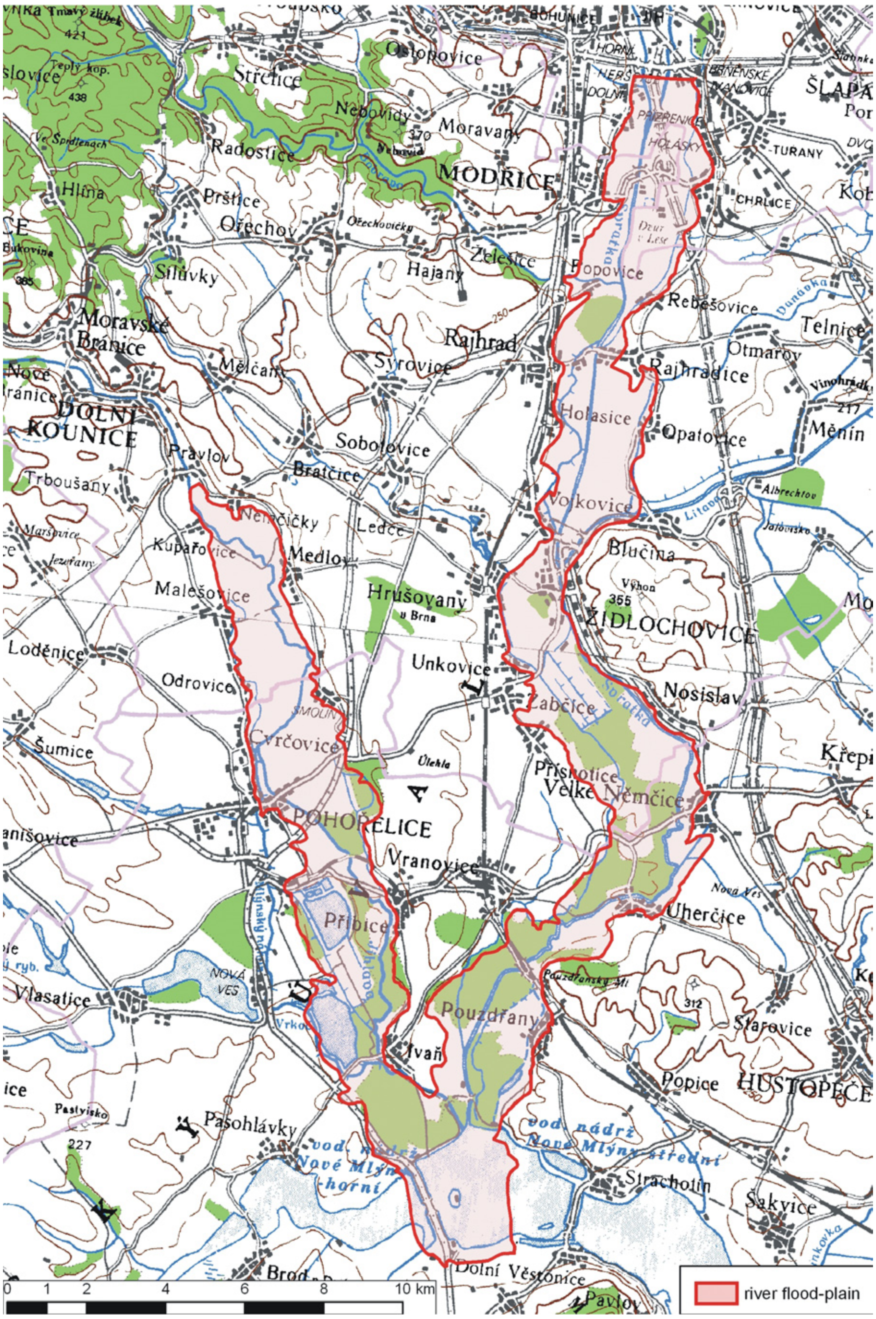

Fig. 9: The Svitava-Svratka R. Floodplain (Svitavsko-svratecká niva) and the Lower Svitava R. Floodplain (Dolnojihlavská niva). Compiled by Marek Havlíček

6. Conclusion

Landforms play an important role in the landscape. Vertical and horizontal dissection of the relief has a deciding impact on other natural landscape components as well as on Human activities in the landscape. Study of landforms and land-forming processes is therefore an important part in the evaluation of the present state of landscapes and prediction of their future development. The role of geomorphology in the landscape-ecological studies is also growing due to the growing importance of computer supported quantitative studies of landscapes (e.g. by GIS), which enables interdependence in landscape systems to be usefully viewed and analyzed.

Acknowledgement

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GEOMORPHIC RESPONSE OF DRY VALLEY BASIN TO LARGE-SCALE LAND USE CHANGES IN THE SECOND HALF OF THE 20TH CENTURY AND PROBLEMS WITH ITS RECONSTRUCTION

Miloš STANKOVIANSKY, Štefan KOCO, Jozef PECHO, Marián JENČO, Jozef JUHÁS

Abstract

Recent research revealed that large-scale land use changes in the Luskovica dry valley basin (the municipality of Krajné, Myjava Hilly Land, Slovakia) in the 1950s resulted in a significant increase of the number and geomorphic effectiveness of muddy floods. Based on the analysis of valley bottom filling, nine sediment layers were identified corresponding to nine muddy flood events in the period 1961–1995. The fact predestined this zero order agricultural catchment for an attempt to establish a sediment budget for it within a time scale of several decades. Current studies try to model water erosion, to estimate the volume of post-collectivization accumulation body laid by muddy floods, to date these events and to reconstruct meteorological, land cover and agrotechnical conditions of their formation.

Shrnutí

Geomorfologická odezva bazénu suché doliny na velkoplošné změny využití krajiny ve druhé polovině 20. století a problémy s její rekonstrukcí

Nedávné výzkumy potvrdily, že velkoplošné změny využívání krajiny v bazénu suché doliny při osadě Luskovica (obec Krajné v Myjavské pahorkatině, Slovensko) v padesátých letech 20. stol. měly za následek výrazný nárůst počtu a geomorfologické efektivity bahenních povodní. Na základě analýzy výplně dna doliny bylo identifikováno 9 vrstev nánosů odpovídajících 9 bahenním povodním, které se tu vyskytly v letech 1961–1995. Tato skutečnost předurčila toto zemědělsky využívané povodí nultého řádu k pokusu vyhodnotit zde bilanci eroze a akumulace a export sedimentů v časové škále několika dekád. Současný výzkum se snaží modelovat vodní erozi, hodnotit objem pokolektivizačního akumulačního tělesa uloženého bahenními povodněmi, datovat tyto události a rekonstruovat meteorologickou situaci, krajinnou pokrývku a agrotechnické podmínky v době výskytu povodní.

***Key words**: geomorphic response, land use changes, water erosion, dry valley basin, Myjava Hilly Land, Slovakia*

1. Introduction

In many parts of Europe, rates of water erosion have been on the increase since the middle of the 20th century (Boardman and Poesen, 2006). The reasons for this vary throughout Europe, but several factors are relevant, as for example the extensive removal of hedgerows and other types of field boundaries, implementation of land consolidation programmes leading to larger and longer parcels or increase in crop monocultures leaving the soil unprotected during a part of the year. The consequence of these changes has been a significant increase in geomorphic effectiveness and both on- and off-site environmental impacts of runoff and erosion. This statement is fully valid also for the territory of former Czechoslovakia, where large-scale land use changes associated with collectivization in agriculture took place after the political and social changes in 1948 that resulted in a profound acceleration of water erosion (e.g. Bulíček et al., 1977; Stehlík, 1981; Juráň, 1990; Jambor, 1997; Juráni, 2000).

These conclusions were corroborated also by the detailed investigation in the Myjava Hilly Land. The research was conducted within the framework of trilateral Israeli-Slovak-Czech project „Response of fluvial systems to large-scale land use changes (1992–1998)“, led by prof. A. P. Schick, Hebrew University, Jerusalem, the Slovak part of which was solved in the area of the Jablonka Catchment (163 km^2) (cf. Stankoviansky et al., 2000). The project was to compare the susceptibility of pre- and post-collectivization landscape to water erosion, the course, rate and behaviour of actual water erosion processes in the two mentioned periods and to assess total geomorphic effect of these processes during the entire post-collectivization period. Acceleration of water erosion processes was expressed by a marked increase of geomorphic effectiveness of extreme events provoked either by heavy rains or by sudden snowmelts. Result of this acceleration was a distinct total post-collectivization geomorphic effect of these processes, representing a sum of partial effects of the unknown number of anonymous consecutive extreme events (Stankoviansky, 2003, 2005).

The most dynamic relief elements in agricultural hilly lands are dry valleys concentrating the runoff (a similar attribute of dells was corroborated by Hrádek, 1989). Heads and sides of dry valleys are used as arable land, their bottoms are usually covered by grass, bush, hamlets with orchards, locally also by forest. The more intense erosion on fields, the more mud is deposited in sedimentary traps in places of weakening the driving force of ephemeral flow. The concentration of runoff and sediment in dry valley bottoms increases the effect of muddy floods, representing water flowing from agricultural fields and carrying large quantities of soil as suspended sediment or bedload (Boardman et al., 2006). Thus, the dry valleys and dells are landscape elements with a high potential of this significant environmental issue and natural hazard (Stankoviansky, 2002). As muddy floods are direct consequences of extreme erosion, the post-collectivization acceleration of water erosion processes resulted in their increased number and effectiveness. The research in the Myjava Hilly Land suggested that the most harmful manifestations of muddy floods, associated mostly with heavy rains in spring months, occurred in dry valley basins with monocultures of maize and potatoes (Stankoviansky, 2003).

The objective of this contribution is to present results from the study of geomorphic response to large-scale land use changes associated with collectivization on the example of the dry valley basin at the hamlet of Luskovica, village of Krajné in the Myjava Hilly Land in western Slovakia (Fig. 1). An enormous increase of water erosion processes due to these changes was observed already within the framework of the above mentioned research in the 1990s, based on a discovery of the post-collectivization accumulation body in its bottom (Stankoviansky, 1997). Probing works at that time identified layers corresponding with a series of muddy floods that occurred there in the post-collectivization period as an accompanying phenomenon of extreme precipitation and erosion events (Stankoviansky et al., 1999; Lehotský, 2001). The identified repeated occurrence of muddy floods in the single small agricultural basin predestined it for an attempt to establish a sediment budget on a time scale of some decades. The occasion for the new stage of research on this site in the indicated direction arose with the participation in the COST Action 634 „On- and off-site environmental impacts of runoff and erosion (2004–2008)“, that has laid stress exactly upon muddy floods. Thus, a perspective goal of this new research stage is to calculate soil loss in the course of individual, relevant, precisely dated extreme rainfall events, total soil loss during all investigated events, total sediment deposition and consequently total sediment export. Within the last period, we focused especially on the modelling of water erosion, estimation of the volume of post-collectivization accumulation body laid by muddy floods, attempt to date these events and on the reconstruction of meteorological, land use and agrotechnical conditions of their occurrence. The contribution brings an overview of results gained during the pioneer and current stages of research but it also refers to problems connected with the research.

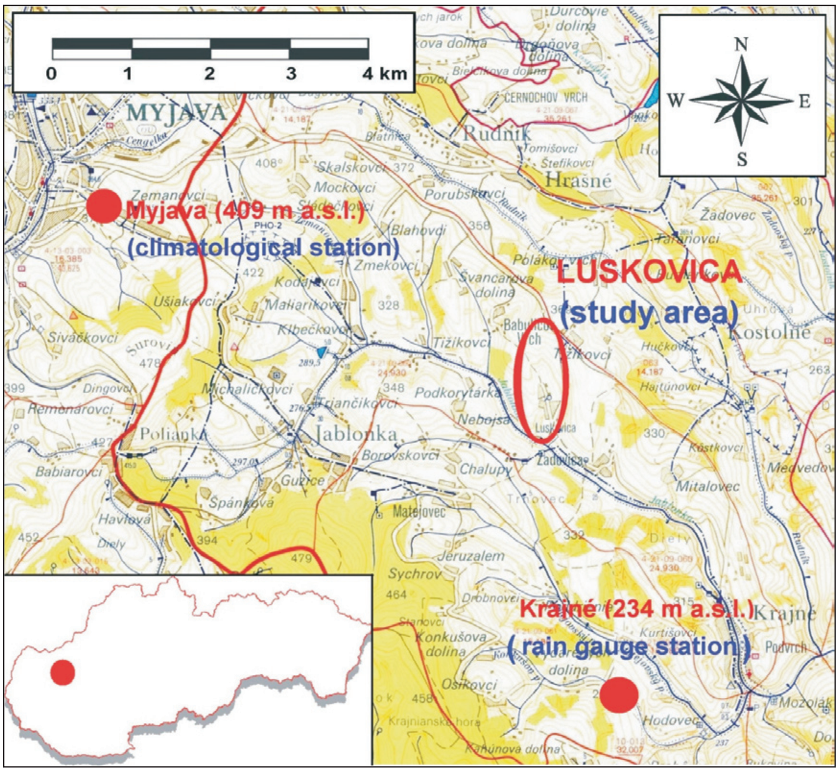

Fig. 1: Location map of broader surroundings of the Luskovica study area

2. Study area

2.1 Natural conditions

The Myjava Hilly Land (384 km^2) is situated in western Slovakia near the border with the Czech Republic. This geomorphic unit represents a depression between somewhat uplifted massifs of the White and Little Carpathians. Character of the Myjava Hilly Land is mostly planary with the relief ranging from 30 to 130 m. Characteristic and very frequent landforms are dry valleys formed in the Pleistocene, usually of a dell-like, rarely continuous cross-profile. There are accumulation bodies in their bottoms, the foundation part of which is of Pleistocene age. After the area settlement and consequent transformation of the original woodland into farmland, younger sediments were deposited on the original Pleistocene fill of valley bottoms what resulted in their gradual rising. These geometric landform changes are result of water erosion and tillage processes (Stankoviansky, 2003). The upper part of the valley bottom fill that was laid since the origin of the agricultural land until now represents correlated sediments to anthropically accelerated erosion (cf. Bork et al., 1998). Valley bottom floors are mostly cut by gullies.

The dry valley basin under study is situated in the western part of the Krajné cadastral area. It is deepened into the left side of the Jablonka River valley (Fig. 1). The basin area is 52.9 ha, its longitudinal axis being 1,430 m in length, its maximum width reaching 510 m and depth roughly 30 – 60 m. The basin is built of a complex of Eggenburgian sandstones and conglomerates. Prevailing soil types are Albic Stagnic Luvisol and Haplic Planosol. Paradoxically, the valley bottom is broadening upslope, being broadest (45 m) in its kettle-like head (Fig. 2). Two dells enter the kettle, which are source areas of the prevailing amount of the valley bottom fill.

Fig. 2: The Luskovica dry valley head state in the 1990s (Photo M. Stankoviansky)

2.2. History of land use changes

Beginnings of settlement in the area of the today's hamlet of Luskovica go back to the 17th century (Horváth, 1979). Until that time, the area under study was covered by natural oak-hornbeam forests. In the pre-collectivization period, the dry valley basin, except the hamlet itself, situated in its SE part, was covered by narrow fields of varied lengths, ploughed almost exclusively along the contours. Contour fields were terraced while their steps reached to a height of 1.5, locally even 2 m. Thus, the slopes had a step-like character. Crops most spread on the sloping fields were wheat and barley but also rye, oats, potatoes, maize, fodder beet and alfalfa. On the valley bottom, there were small fields ploughed perpendicularly to the longitudinal valley axis, usually with cabbage, vegetables, poppy and flax.

In 1959, one of three collective farms in the cadastral area of Krajné was built up in the NE part of the study area, named according to the nearby hamlet of Babulicov vrch Hill lying in the cadastral area of the neighbouring village of Kostolné. Still in the same year, the farm realized a so-called economical-technical adjustment of parcels also in the area of the hamlet of Luskovica. Merging original small private fields and ploughing smaller and medium steps between them resulted in the creation of two large blocks of cooperative fields in the upper part of the valley, namely the higher Vršky (6 ha) and the lower Korytárka (24.9 ha – Fig. 3). The two blocks of fields are in fact much larger, the mentioned areas represent only those parts of them that lie in the concerned dry valley. The third and at the same time the smallest cooperative field, situated to the south of the hamlet and called Pod Luskovicu, is negligible from the viewpoint of soil erosion and therefore we did not take it into account. The last profound interventions into the landscape, namely the removal of remaining, highest-situated field steps and ploughing of meadow in the valley bottom, set up by collective farmers, date back to recultivations in 1978. Thus, the step-like slopes with terraced fields and their variegated use were transformed gradually into large cooperative fields with the smooth surface appropriate for the employment of more efficient machinery and for the introduction of monocultures. Since the early 1970s, the four year crop rotation cycle was used on the cooperative fields, namely: potatoes, winter wheat, maize, winter wheat and so on, functional until the early 1990s. After the political and social changes in 1989, some smaller portions in marginal parts of parcels Korytárka and Vršky, as well as the whole parcel Pod Luskovicu were given back to private hands. The overwhelming majority of both main parcels belong to the current farm of Krajné that is a successor of the former collective farm. The part of the parcel Korytárka, lying in the study valley, is grassed now.

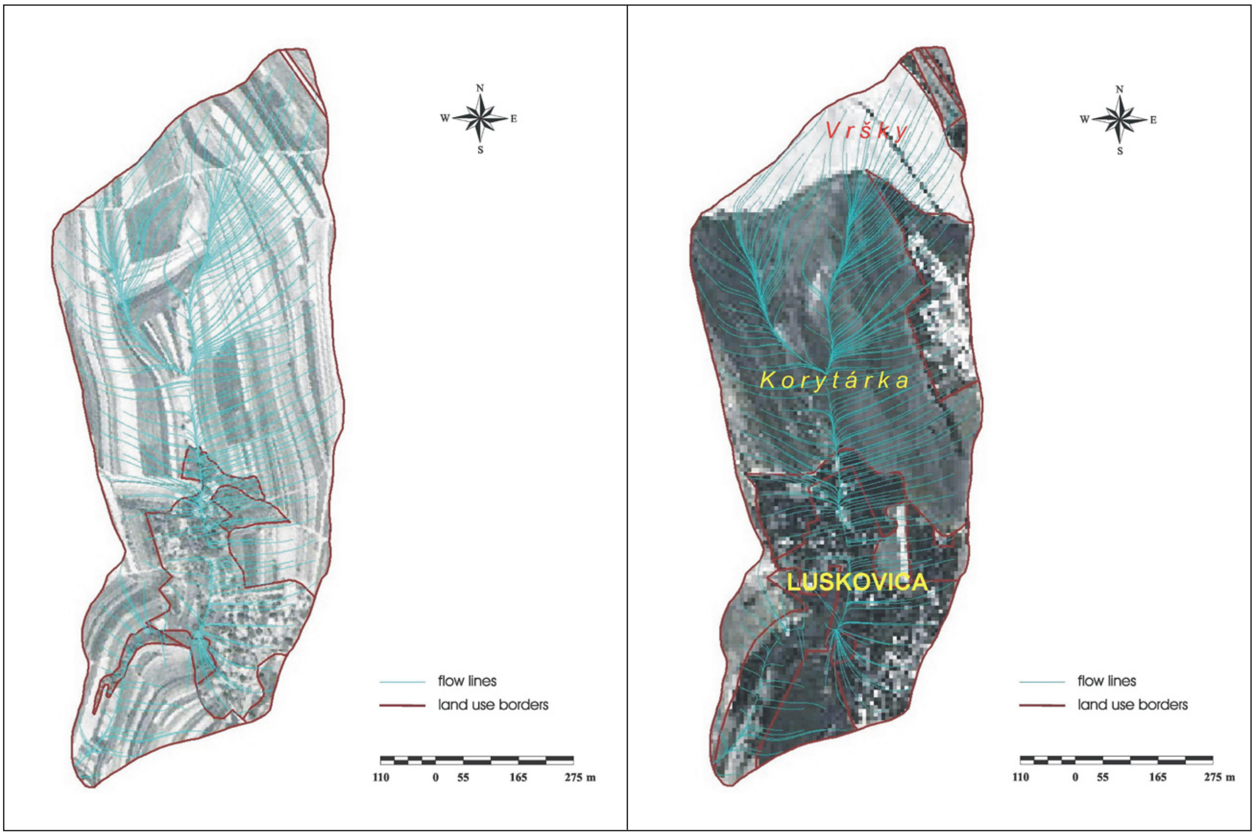

Fig. 3: Land use according to aerial photographs from 1955 (left) and 1990 with indicated flow lines constructed downhill (right)

3. Material and methods

One of key methods of the pioneer survey in the 1990s was the detailed field geomorphic research focused on searching for post-collectivization accumulation bodies and estimation of their thickness using buried objects, such as telephone poles, trees, etc. Methodological apparatus of the current research stage consists of modelling water erosion, field investigation coupled with probing works, analysis of aerial photographs, topographic and cadastral maps, meteorological data and collecting of relevant data from local institutions and individuals.

The modelling of water erosion processes in the dry valley basin under study for pre- and post-collectivization periods is based on the two selected models, namely USPED (Unit stream power-based erosion/deposition model; Mitášová et al., 1996a, 1996b) and USLE (Universal soil loss equation; Wischmeier and Smith, 1978). The USPED allowed to identify the spatial distribution of erosion and deposition for two time horizons (1955, 1990). According to this model, the potential for erosion/deposition is defined as follows:

$$ED = K_t\left[\left(grad\ h\right)s\sin\beta - h\left(k_p + k_t\right)\right]$$

where K_t is transportability coefficient dependant on soil and land cover, h is water depth estimated from the upslope area [m], s is unit vector in the steepest slope direction, β is slope [°], k_p is profile curvature (terrain curvature in the direction of the steepest slope) and k_t is tangential curvature (curvature in the direction tangential to a contour line projected to the normal plane). However, soil and land cover parameters similar to those used in USLE were not developed for the USPED model. Therefore, we used the USLE factors to include the relative impact of soil and land cover on sediment transport capacity T [$kgm^{-1}s^{-1}$] defined as:

$$T = RKCPA^m(\sin\beta)^n$$

where R is the rainfall erosivity factor [$MJ.ha^{-1}.mm.h^{-1}$], K is the soil erodibility factor [$t.ha.h.MJ^{-1}.ha^{-1}.mm^{-1}$], C is the land cover factor and P is the prevention practices factor, m and n are constants for overland flow usually set to m=1.6, n=1.3 (Foster, 1990). Then the net erosion/deposition is estimated as:

$$ED = d\left(\frac{T\cos\alpha}{d_x}\right) + d\left(\frac{T\sin\alpha}{d_y}\right)$$

where α is an aspect of the terrain surface [°]. Index ED is positive for areas with the potential for deposition where sediment transport capacity decreases and negative for areas with the potential for erosion where sediment transport capacity increases.

Results from the USPED model were used to model average soil loss (erosion rate) by using the USLE model (Wischmeier and Smith, 1978). The problem is that the USLE model does not allow for modelling any deposition processes (Hofierka and Šúri, 1995; Mitášová et. al., 1996a); therefore, we excluded the areas that were defined by the USPED model as areas highly liable to deposition. The USLE model is defined as:

$$A = R.K.L.S.C.P$$

where A is average soil loss [$t.ha^{-1}.year^{-1}$], R is the rainfall erosivity factor [$MJ.ha^{-1}.mm.h^{-1}.year^{-1}$], K is the soil erodibility factor [$t.ha.h.MJ^{-1}.ha^{-1}.mm^{-1}$], LS is the topographic (length-slope) factor, C is the land cover factor, and P is the prevention practices factor. We specified the C factor from land use maps for the both time horizons (the maps were created from aerial photographs). Factor values are specified by Šúri et al. (2002). The two above models were implemented in GRASS GIS using a shell script (cf. Neteler and Mitášová, 2002).

Soil loss was modelled also for hypothetical extreme rainfall events, using actual daily precipitation totals and intensity values as well as particular crops. Specifically for that case, the R factor was derived (according to Malíšek, 1990) as:

$$R = \left[\sum_{j=1}^{n}\left(2.06 + 0.873\log i\right)\Delta h\right]I_{\max 30}$$

where R is the rainfall erosivity factor [$MJ.ha^{-1}.mm.h^{-1}$], i is intensity of rainfall division [$mm.h^{-1}$], Δh is rainfall amount in the time period with homogeneous rainfall intensity and I_{max30} is the maximum intensity of 30-min lasting rainfall [$mm.h^{-1}$].

For the purpose of the assessment of land use pattern and landform evolution within the last six decades there were analysed the already mentioned aerial photographs of 1955 and 1990, topographic maps on a scale of 1: 10 000 from various time horizons and cadastral maps from the pre-collectivization period. In connection with looking for data on crops grown both on small private plots before collectivization and on large blocks of cooperative fields after it, we contacted agronomists of both former and currently existing farm. In order to estimate the volume of the post-collectivization accumulation body deposited by muddy floods, additional probing works were carried out within the framework of renewed field investigation.

Our search for extreme rainfall events, likely followed by muddy floods in the post-collectivization period, was based on criteria defined by Starkel (2000–2003) who considers local extreme rainfall to be an event when the amount of total daily precipitation reaches at least 20 mm and the rainfall intensity exceeds 1–3 $mm.min^{-1}$. As there is no meteorolological station directly in the investigated valley, it was necessary to use for our purposes data sets from the climatological station in Myjava and from the rain gauge station in Krajné, lying 6.5 and 4 km, respectively, from Luskovica (Fig. 1). Rainfall strip charts from ombrographic records measured at the Myjava climatological station were used to calculate rainfall intensities for the respective temporal range. With regard to the well-known changes of rainfall intensity depending on time, we focused mainly on its maximum values recorded throughout the particular rainfall event. Rainfall intensity for any instant of time is defined as a tangens of the angle that the tangent of a curve line, recorded on the ombrographic stripe, contains with x-axis. Besides the maximum value of rainfall intensity, information on the duration of particular value of given rainfall intensity is very important, too. Understandably, it concerns mostly longer-lasting events with a minimum variability of massive rainfall (e.g. torrential rainstorm lasting at least 30–45 minutes). Based on a comparison of data sets from the two meteorological stations we chose some particular rainfall events with a purely meteorological potential to result in muddy flood formation in the investigated area. Subsequently, rainfall events that had no chance to result in the generation of muddy flood in connection with land cover and agrotechnical conditions were excluded from data processing.

In order to qualify the dates of muddy floods and to reconstruct the land cover and agrotechnical conditions at the time of their formation we tried to acquire relevant data from local institutions and individuals. We went through the chronicle of Krajné but we did not learn anything important. We also turned for help in writing also to members of the local municipal authority but without a success, unfortunately. We visited the local farm with the aim to look into field cards but the farm archives were in such a miserable condition that we were not let in it at all. We contacted representatives of the former collective farm as well as local people, especially in the hamlet of Luskovica, affected by muddy floods. Records on muddy floods were searched also at the Slovak Water Supply Company, Branch Piešťany, Works of the Middle Váh River II, and at insurance companies.

4. Results and discussion

Topographic conditions and agricultural use predestined the dry valley under study to be attacked often or even regularly by intense erosion-accumulation processes during extreme events. As early as the pre-collectivization period, a considerable amount of material was delivered from slopes by water erosion processes, most of which was deposited in its bottom on the older, Pleistocene fill as an accumulation body of variable thickness and a lesser part was carried away into the Jablonka valley. The substantial part of deposited sediment is situated in the upper part of the valley bottom, between its kettle-like head and the hamlet of Luskovica. However, the intensity of water erosion processes considerably weakened in this period, which was influenced by the step-like character of slopes (terraced fields) and by the mosaic character of land use.

The enormous increase of erosion-acumulation processes due to large-scale land use changes connected with the collectivization was suggested already by results from the above mentioned pioneer research in the 1990s. The current investigation is focused on the modelling of water erosion, on the assessment of the volume of post-collectivization accumulation body deposited by muddy floods, and it tries to date these muddy floods and to reconstruct meteorological, land cover and agrotechnical conditions of their formation. Conducting this research, we met with numerous obstacles that are likewise mentioned in this chapter.

4.1 Water erosion modelling

Main objective of water erosion modelling was to precisely formulate findings from the interviews with local farmers, living witnesses of the pre-collectivization period. According to them, the marked acceleration of water erosion processes resulted mainly from large-scale land use changes associated with the collectivization. The modelling allowed us to compare the potential water erosion in the pre-collectivization (1955) and post-collectivization periods (1990). We used the USPED and USLE models.

The two models show a considerably higher potential for soil erosion in 1990. The USPED model shows an increased erosion index on slopes whereas changes of erosion/accumulation index values on the valley bottom and divide ridges are minimal. The more profound differences between these two periods are expressed by results of the USLE model, which show that the average soil loss in 1990 was almost twice as high as in 1955, especially on the lowest and steepest slope sections near the valley bottom. The modelling confirms that the increase of erosion potential in the post-collectivization period was mainly due to a change in the use of arable land over the hamlet of Luskovica, where many small plots were consolidated into two large cooperative fields. Especially the field of Korytárka played an important role as a source of sediments transported by muddy floods (Figs. 4 and 5).

Thus, the comparison of both models indicates unambiguously an increase of potential erosion after collectivization (Tab. 1). Of course, a doubled erosion potential value in 1990 in comparison with 1955, based on averages of protective influence of commonly used crops in both temporal horizons and furthermore on average values of extreme precipitations, cannot by a wide margin reflect the increase of real erosion at all. This is why we decided to model water erosion for the post-collectivization period also for hypothetical events with daily total amounts and intensities corresponding to actually measured extreme precipitations. In the model, we chose potatoes as a core crop for the Korytárka field because most of muddy flood events happened when just this crop was planted there. Thus for example, the calculated average soil loss value under 45 mm of total daily precipitation amount and 5 $mm.min^{-1}$ of intensity was six times higher than its average values from the pre-collectivization period.

	1955	1990
for the whole basin (52.9 ha)	36.7	68.7
for the whole area of arable land within the basin (43.7 ha)	38.2	71.3
for the parcel of Korytárka (24.9 ha)	38.7	73.3
for the parcel of Vršky (6 ha)	28.4	53.9

Tab. 1: Average values of potential water erosion for 1955 and 1990 in $t.ha^{-1}.year^{-1}$ (calculated by using the USLE model)

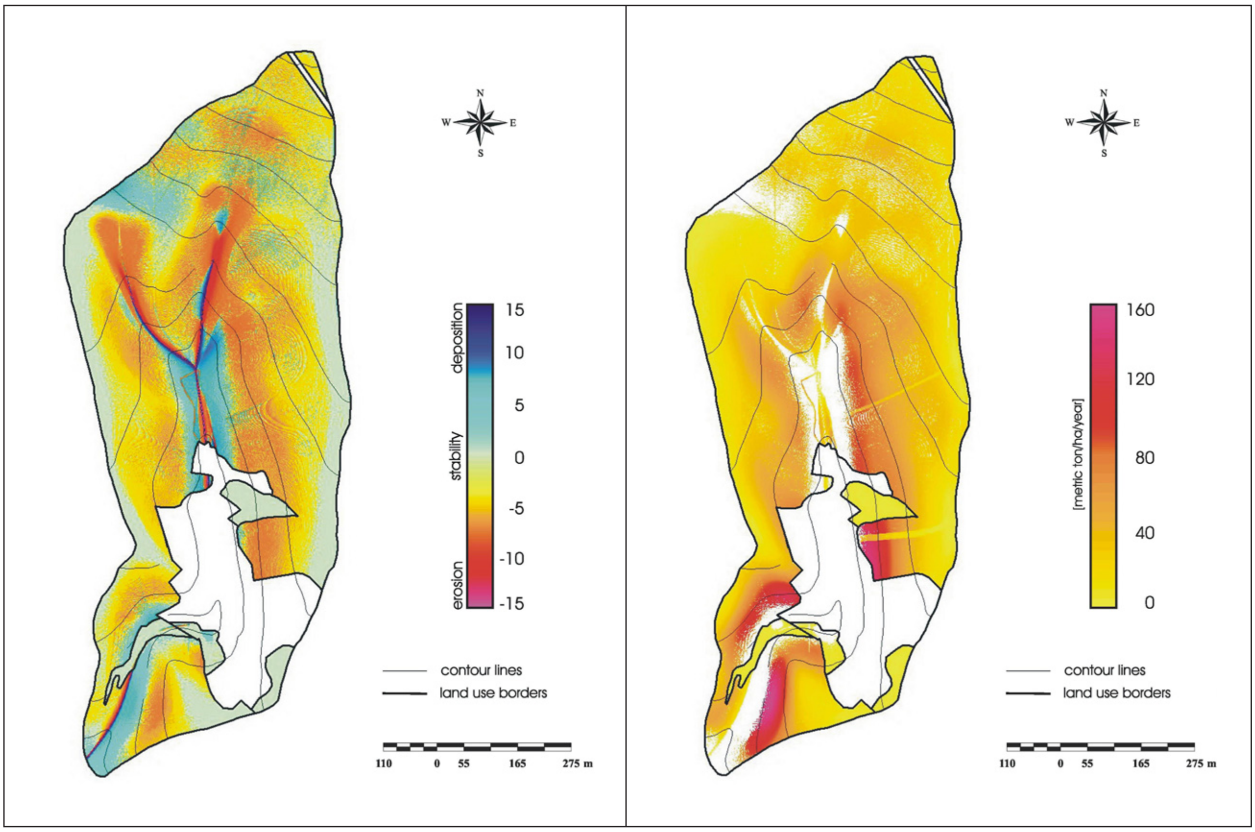

Fig. 4: Potential water erosion according to models USPED (left) and USLE for 1955 (right)

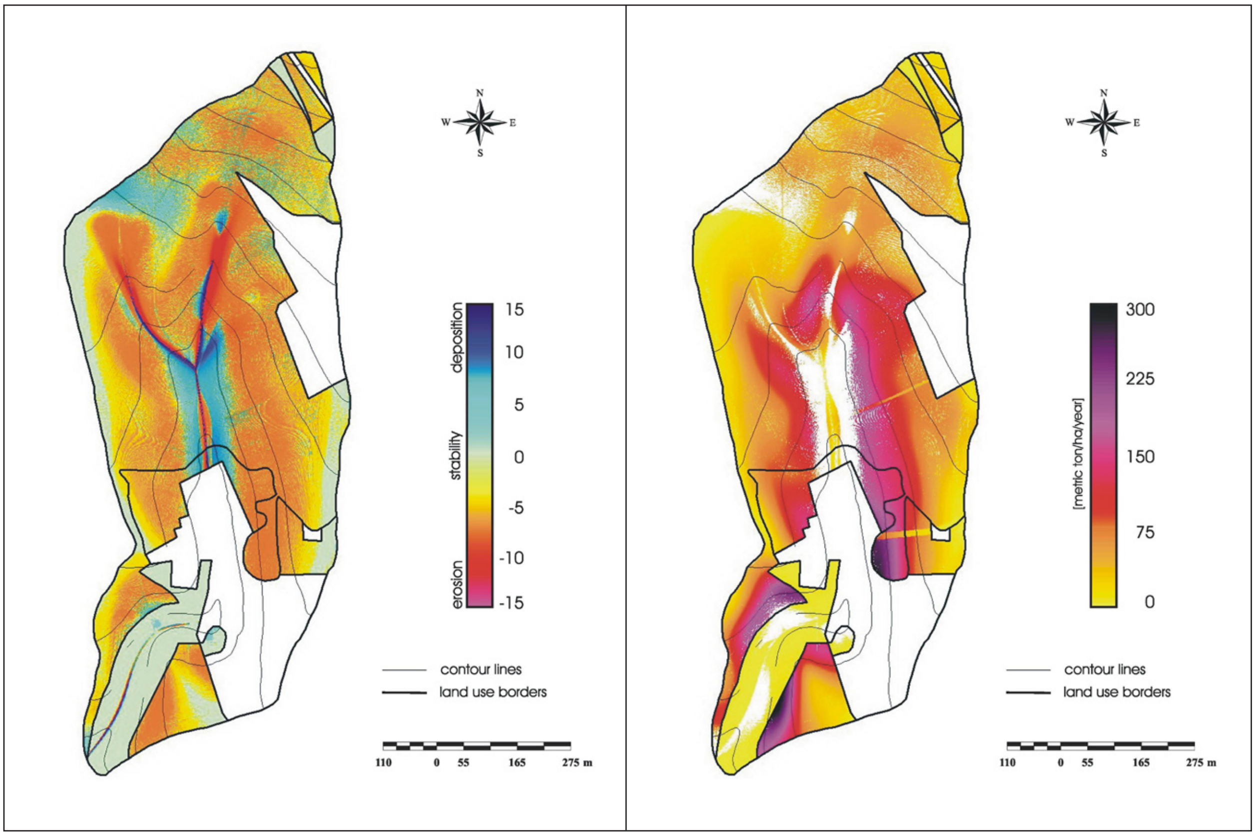

Fig. 5: Potential water erosion according to models USPED (left) and USLE for 1990 (right)

4.2 Assessment of geomorphic effect of accumulation due to muddy floods

Large-scale land use changes associated with collectivization created, especially in the upper part of the valley, conditions exceptionally favourable for effective action of water erosion processes in the course of extreme events, much better than it was in the pre-collectivization period. At the time when the main plots were not protected or only poorly protected by the vegetation cover, the surface runoff provoking both areal (sheet wash, rill and inter-rill erosion) and linear (concentrated flow) erosion in the kettle-like valley head and on valley sides, resulted in muddy flood formation. Thus, new sediment layers were deposited on the older (pre-collectivization) valley bottom fill. The sediment was laid along the whole length of the valley bottom below the joint of two dells in its head, but especially at places with the best conditions for accumulation. This selective accumulation is documented by three flat steps of the accumulation body on the valley bottom, disturbing the regular course of its longitudinal profile.

The first step from above was created under a marked fault in the slope at the foot of the broad kettle-like valley head in the middle of the field of Korytárka. It represents joint colluvial cones below the mouths of two convergent dells, entering into the valley kettle. The second step developed at a contact between the lower margin of the Korytárka field and the orchard at Luskovica due to flow slacking on a buffer zone represented by grass in the orchard. Pronounced features of these steps suggest a superimposition of both pre- and post-collectivization sediments there. In the case of the lower step, this assumption was proved still during the pioneer investigation. A pit excavated 7 m below the contact of the cooperative field and the orchard revealed a 70 cm thick post-collectivization layer, corroborated on the basis of the measured depth of buried original plum tree roots (Stankoviansky et al., 1999).

Lower situated deposits, laid under the influence of artificial barriers in the built-up part of the hamlet of Luskovica, are obviously mostly post-collectivizational. Interviews with local residents confirmed the hypothesis. According to them, the original, pre-collectivization valley bottom between the field of Korytárka and the built-up part of Luskovica hamlet had a rounded, dell-like cross-profile, while at present it is flat and markedly raised. The result of repeated accumulation is a layer of the youngest deposit, thickening downwards. It is indicated by another probe (excavated also in the pioneer phase of investigation) located directly in the built-up part of the hamlet about 170 m below the probe at the plum tree. Preliminary results of an interpretation of just this probe became a stimulus of the current research stage. The pit was excavated in the third of mentioned flat steps of the main accumulation body. This step originated due to a barrier represented by a low dike of the local road crossing obliquely the valley bottom. At this place, the valley bottom has a trough-like cross-profile, suggesting a former deeper cut. The thick layer of the young accumulation at this site was indicated originally by a partially buried wooden telephone pole fixed to a concrete pillar (Fig. 6 – by the way, the original telephone pole was substituted by a new, concrete pole in the meantime). The first estimate of the thickness of this deposit, made on the basis of ascertained dimensions of the concrete pillar, its burial by sediments (it sticked out less then 60 cm) and its comparison with other telephone

Fig. 6: A partially buried telephone pole on dry valley bottom at the hamlet of Luskovica (state in the 1990s - Photo M. Stankoviansky)

poles in the near surroundings that were not buried, was approximately 1 m (Stankoviansky, 1997). The pit at the telephone pole made it possible to identify nine sediment layers of thickness ranging from 3 to 19 cm, separated by the thin intercalations of organic matter (decayed grass), while the total thickness of the deposit was 105 cm (Fig. 7). We suppose that these layers correspond with nine erosion-accumulation events or in other words with nine muddy floods that occurred at the place after 1961, when the telephone pole was erected. Thus, this deposit is unequivocally of the post-collectivization age (Stankoviansky et al., 1999). As this pit was excavated and interpreted in June 12, 1996 and there were no fresh deposits in the site, the muddy floods had to occur in the period 1961–1995. The repeated occurrence of muddy floods at the hamlet of Luskovica and the accompanying elevation of the valley bottom resulted in a significant change in its geometry. It was not changed only at places where yards of two houses, standing just on the way of this element, were situated. Mud deposited on yards was at all times removed by people living there.

One of key objectives of the current research is a calculation of the post-collectivization accumulation body volume. As to the ground plan, its contours were outlined and measured within the framework of detailed geomorphic mapping. Problems arose during attempts to fix its thickness. As already mentioned, older probing works were restricted to two probes, both located directly in the hamlet of Luskovica (one in the orchard and the other in the built-up area). This is why we focused on the upper part of the valley at present, lying on the field of Korytárka. Two pits were excavated in the summits

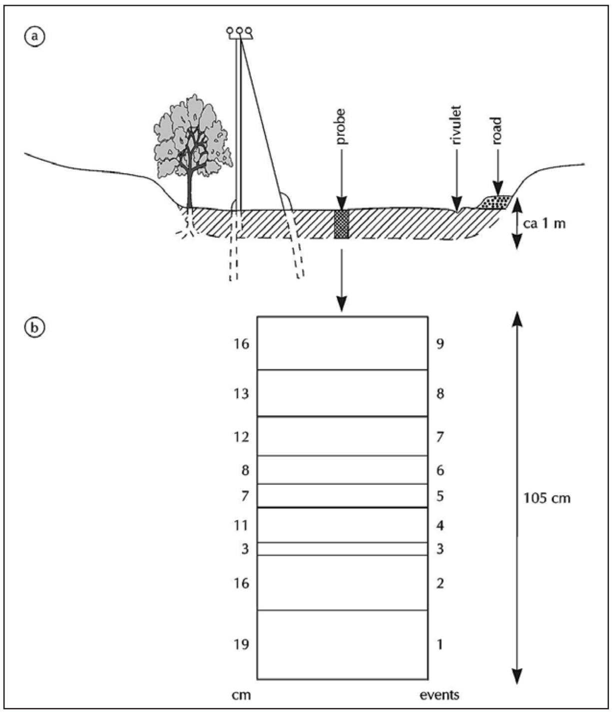

Fig. 7: Cross-profile of dry valley bottom at the hamlet of Luskovica with enlargement of test

of flat steps both in the ketlle-like valley head and above the contact of the field with the orchard situated at its lower margin (Fig. 8).

The pits as well as cores sampled by drilling from their bottoms showed that the valley floor fill up to a depth of 2 m is not stratified as the soil samples did not differ. We identified neither buried soil no any layer that would be able to distinguish the pre-collectivization body from the

Fig. 8: Probing works in the upper part of the dry valley (Photo M. Žiak)

post-collectivization one. This obviously relates to the fact that the sediment was homogenized due to both pre- and post-collectivization ploughing. To be able to find such traces, we plan to do more detailed probing works using an excavator and to open longitudinal and cross profiles (trenches) instead of point pits.

4.3 Attempt to date muddy floods and to reconstruct the meteorological, land cover and agrotechnical conditions of their formation

As we do not know the dates of nine particular extreme meteorological events that caused the formation of muddy floods resulting in the deposition of nine sediment layers, revealed during probing works in the valley bottom at the hamlet of Luskovica, we tried to lean on data from meteorological stations in Myjava and Krajné, provided by the Slovak Hydrometeorological Institute, Bratislava. In terms of methodology specified in the third chapter, we tried to choose a set of rainfall events with the potential to generate muddy floods in this site in the period from 1961–1995. In the first stage of data processing, we selected rainfall events with daily totals reaching at least 20 mm in both Myjava and Krajné meteorological stations (Figs. 9 and 10). Then we selected those of extreme events that were recorded at both stations and showed remarkable daily precipitation totals (in the case of the Myjava station also high rainfall intensity). Almost all of the selected events were caused by torrential rainstorms, only one by all-day rain. This set represented events with a purely meteorological potential to result in muddy flood generation. Finally, after excluding events that had no chance to cause intense erosion and hence muddy floods, due to land cover and agrotechnical conditions inappropriate for the occurrence of these phenomena, we gained a final, narrowed set of ten events that could have resulted in the formation of muddy floods (Tab. 2; these events are graphically presented also in the Figs. 9 and 10). This resulting set of events reflects significantly opinions of local residents; according to them, the muddy floods occurred practically only in the period when potatoes were grown in the Korytárka field (the growing season of potatoes is from April to September).

Though this approach decreases a set of potential relevant extreme events, it is far from unequivocal fixing the dates of particular muddy floods. In this situation, it would have been ideal to ascertain these dates from local institutions, individual citizens or from some regional branches of national workplaces that could have recorded damages caused by these events. Despite all our efforts (see Chapter 3), we failed to find out a single of searched dates. The last hope is the prospective response of local people to our article submitted recently for publication in the newspaper issued quarterly by the municipality of Krajné, with a request for their assistance in this matter. The step increases markedly our chance to address a much higher number of people than it was possible to do during the above-mentioned attempts.

Until now, we were successful neither in searching in records on particular crops sown or planted on individual cooperative fields in the respected years within the assessed period. In this context, the knowledge about the exact dates of extreme rainfall events is very important. If we should know them, it is possible (knowing precipitation rates of these events and particular crop) to calculate potential soil losses using the method introduced in the third chapter. Unfortunately, the oldest records that we have found so far originate from 1992. We managed to ascertain at least a crop rotation used on cooperative fields in the cadastral area of Krajné within the last two decades of the socialistic period (see above). This crop rotation was influenced by the fact that the local collective farm operated in the so-called potato region under the previous regime. The known crop rotation cycle could help to narrow, at least indirectly, the set of potential events of muddy floods. If at least one event associated with the presence of potatoes on the field of Korytárka could be ascertained, it would be then possible according to the regularity in crop rotation to learn in what years potatoes were introduced there and thus in what years muddy floods were very likely to occur at that site. The search for data on crops in the past years continues.

Date	R [mm][1]	RI [$mm.min^{-1}$][1]	R [mm][2]	Rain event[1,2]
18.4.1961	23.2	-	43.9	rainstorm[2]
27.6.1961	15.5	-	73.6	rainstorm[2]
4.7.1961	41.9	-	20.2	rainstorm[2]
31.5.1974	43.0	1.0	33.4	rainstorm[1]
30.6.1975	46.0	-	42.5	all-day rain[1,2]
14.6.1979	35.5	5.0	25.1	rainstorm[1]
16.6.1979	41.4	-	63.8	rainstorm[2]
24.9.1979	33.2	-	63.1	rainstorm[2]
13.8.1982	39.0	4.0	25.3	rainstorm[1,2]
4.6.1993	51.6	2.2	4.3	rainstorm[1,2]

Tab. 2: Narrowed set of extreme precipitation events resulting in the potential formation of muddy floods
1 - Myjava, 2 - Krajné

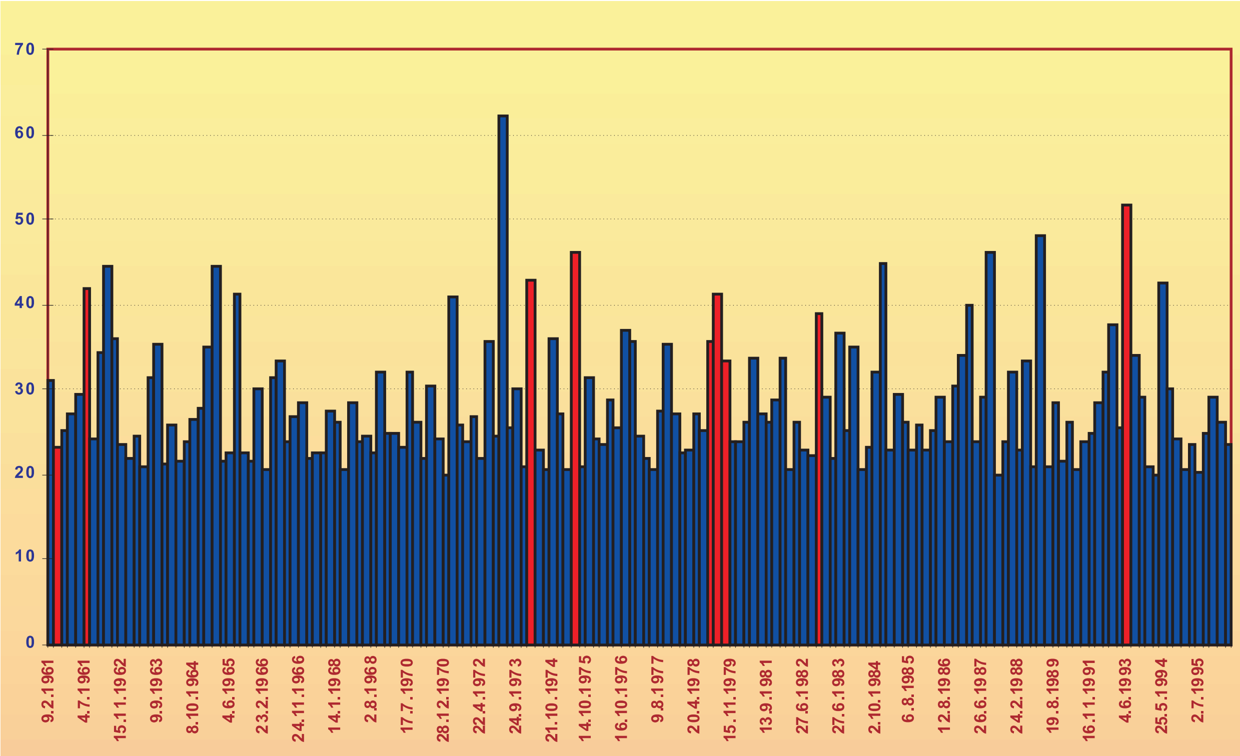

Fig. 9: Set of precipitation events with daily totals 20 mm and more (climatological station in Myjava)

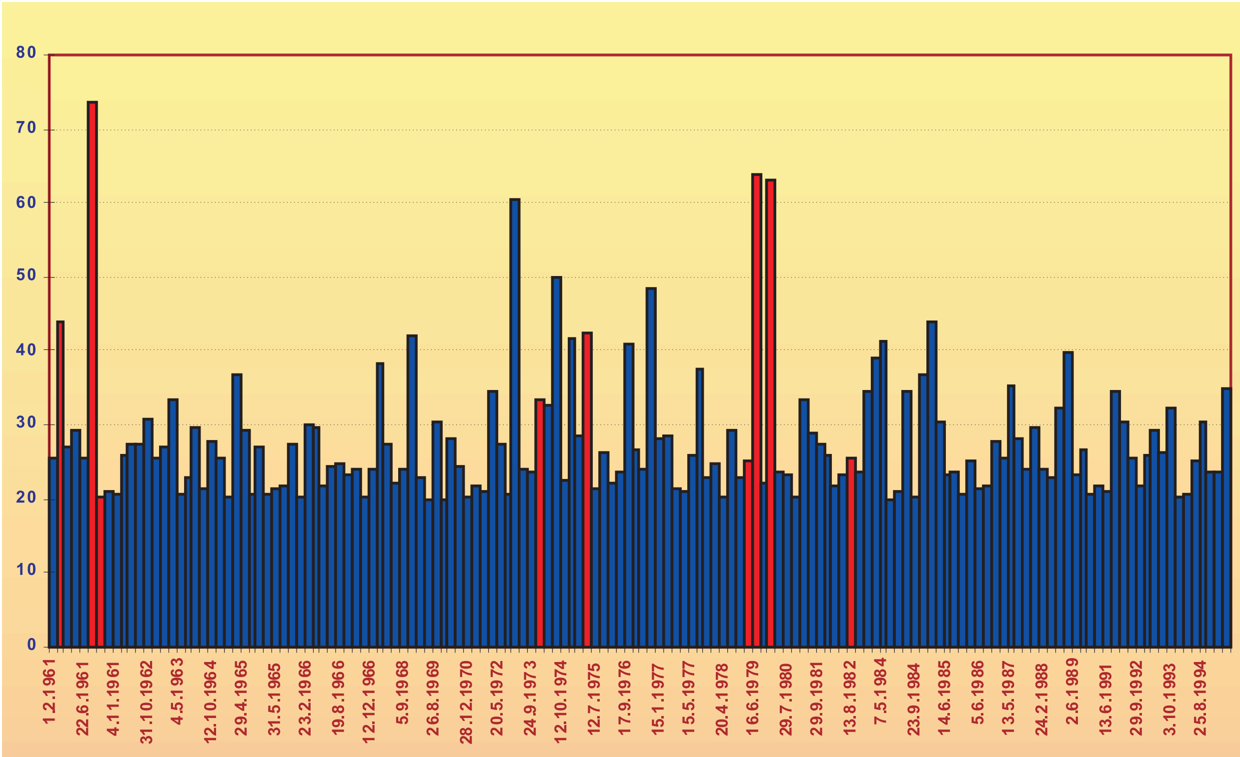

Fig. 10: Set of precipitation events with daily totals 20 mm and more (rain gauge station in Krajné)

5. Conclusion

Investigation in the dry valley basin at the hamlet of Luskovica in the cadastral area of Krajné, the Myjava Hilly Land proved an enormous acceleration of water erosion processes due to large-scale land use changes associated with collectivization. It showed namely through a significant increase of geomorphic effectiveness of rainfall events. Extreme erosion in the valley bottom and on its sides resulted in intense muddy floods that deposited thick layers of sediments on its bottom. The accumulation body of a thickness of 105 cm consists of nine layers corresponding to nine muddy floods that occurred in the valley in the period 1961–1995. The identified repeated occurrence of muddy floods at the same site predestined this zero order agricultural catchment for an attempt to establish a sediment budget for it within a time scale of some decades. A perspective goal of this new research stage is to calculate soil removal during the individual, relevant, precisely dated extreme rainfall events, total soil removal during all investigated events, total sediment deposition and consequently total sediment export. For this purpose, we focused in the last period especially on the modelling of water erosion, on the estimation of the volume of post-collectivization accumulation body laid by muddy floods, on the attempt to date the events and to reconstruct meteorological, land cover and agrotechnical conditions of their occurrence.

The modelling of potential water erosion for 1955 and 1990 confirmed an almost double increase in the post-collectivization period in comparison with the period before the collectivization. However, the modelling of a hypothetical extreme rainfall event in post-collectivization conditions under a total daily precipitation amount of 45 mm and intensity of 5 $mm.min^{-1}$ suggested an almost six-fold increase of potential soil loss in comparison with the pre-collectivization period. Though the research directed at the calculation of the volume of the post-collectivization accumulation body revealed places of maximum deposition, it encountered with the limitations of common probing works and referred to a necessity of their significant extension. Analysis of precipitation data made it possible to define a set of extreme rainfall events that could be responsible for generation of muddy floods that deposited the above-mentioned nine layers of sediments. However, we have been not successful so far with the dating of muddy flood events on the basis of interviews with local institutions and individuals to be able to determine inequivocally which of the selected extreme rainfalls actually resulted in extreme erosion and thus also in the deposition of eroded material due to accompanying muddy floods. A similar situation we had to face with searching for data on crops grown on the respective cooperative fields in the concerned period. The investigation further continues in all indicated directions.

The presented results can be generalized also for other valleys of this type with a similar land use history and not only in the Myjava Hilly Land but also in other similar agricultural regions in Slovakia or in the neighbouring countries. This statement is supported by the fact that the same thicknesses of post-collectivization deposits were identified in the Považské podolie Basin (Stankoviansky, 1994) and even in the piedmont of the Ždánický les Mts. in the southern Moravia (Mederly, 1992; Obršlík, 2004a, b).

Acknowledgements:

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SEDIMENTOLOGICAL RECORD OF FLOOD EVENTS FROM YEARS 2002 AND 2007 IN THE DANUBE RIVER OVERBANK DEPOSITS IN BRATISLAVA (SLOVAKIA)

Jacek B. SZMAŃDA, Milan LEHOTSKÝ, Ján NOVOTNÝ

Abstract

The relationship between floods and their geomorphic effect is discussed in this article. Almost every flood event is registered in overbank alluvia. We investigated sediment structures and textures as responses to three flood events in 2002 and 2007 in the Danube River floodplain in Bratislava. The floods led to sedimentation mainly in the neighbourhood of the riverbank and on the roof of the natural levee. The 2002 spring flood has left lesser traces at the riverbank and bigger on the levee. The effect of 2002 summer flood was more equable. The effect of last flood (in 2007) manifested particularly in the close vicinity of the bank. Results show a relatively high variability of sedimentation processes during floods. The total amount of new sediments, their texture characteristics and spatial distribution do not depend only on the flood discharge, but also on the sources of floodwater and sediments in the river basin.

Shrnutí

Sedimentologický záznam povodňových událostí z let 2002 a 2007 v mimokorytových nánosech Dunaje v Bratislavě (Slovensko)

Příspěvek se zabývá vztahem mezi povodněmi a jejich geomorfologickým efektem. Téměř každá povodňová událost je zaznamenána v mimokorytových nánosech. V našem případě jsme zkoumali struktury a textury sedimentů jako odezvu tří povodní v letech 2002 a 2007 v nivě Dunaje v Bratislavě. Povodně vedly k sedimentaci zejména v blízkosti břehu řeky a na hřbetu agradačního valu. Jarní povodeň v roce 2002 měla menší efekt u břehu a větší na valu. Efekt letní povodně roku 2002 byl rovnoměrnější. Poslední povodeň – v roce 2007 – se sedimentačně výrazněji projevila jenom v těsné blízkosti břehu. Výsledky ukazují na poměrně vysokou variabilitu sedimentačních procesů při povodních. Celkový objem nových sedimentů, jejich zrnitostní charakteristiky a prostorové rozmístění nezávisí jen na povodňovém průtoku, ale i na zdrojích povodňové vody a sedimentů v povodí.

***Key words**: fluvial geomorphology, floods, vertical accretion, flood sediments, Danube River, Bratislava, Slovakia*

1. Introduction

Floodplains are formed by vertical accretion (whereby a river builds floodplain elevation through flood/vertical overbank deposition), processes of lateral accretion (whereby the river moves across the valley floor and lays sediments down behind it), in-channel deposition of fine sediment benches and by a combination of the above-mentioned processes. Vertical accretion is the most important cause to the present relief floodplain formation in alluvial river valleys and large alluvial plains with anabranching/anastomosing river planform. Floodplains that are dominated by vertically accreted fine-grained overbank deposits tend to be relatively flat and have significant topography, typically reflecting the reworking patterns. As the river overtops its banks, it loses power due to a greatly reduced depth and energy of the unconfined sheet-like overbank flow. Cycling flood couplet deposits reflect the rising and falling stages of floods. Different size of forms sets and different type of overbank deposits sets and combinations of them were deposited during flood (Allen, 1965, 1970; Brierley, 1991; Bridge, 2003; Miall, 1996; Zwoliński, 1992). Almost every flood event is registered in the overbank alluvia and the change of sedimentation is the effect of floodwater flow energy changeability in the channel and floodplain. Generally, three main phases of energy flow changes (rising, culmination and fall) are recognised in the flood (Allen, 1970) and thus the complete flood record can be expressed as a set of three layers – three unit cyclotheme, characterizing pensymmetrically the graded sequence (Mansfield, 1938; Klimek, 1974). Apart from this, three other kinds of flood flows velocity changes in overbank deposits are inscribed and are presented in terms of sediment record as follows:

(i) The flood rhythm - two layersets or two laminasets (Antczak, 1985; Mansfield, 1938; Szmańda, 2006). Semi-normally graded sequence consisting of two beds (laminas): coarse grained in the bottom and fine grained in the top.
(ii) The upward fining Bouma-like structure (Farrell, 2001) that is semi-normally graded poly-layerset sequence, similar to Bouma (1962) turbidities current deepwater clastic sediments.
(iii) The three unit cyclotheme consisting of lithofacieset (from bottom to top): a Horizontally Laminated Sand (Sh), a Ripple Cross-Laminated (Sr), Sand (S) and a Massive Mud (Fm). Fining upward of grain size composition can be noticed in this set (Bridge, 2003).

The aim of the article is to investigate sediment structures and textures as a response to three flood events in 2002 and 2007 in the Danube River floodplain (inter-dyke area) in Bratislava.

2. Study area and discharge during the 2002 and 2007 flood events

Lithofacial study of the Danube River overbank deposits was conducted on the floodplain in Bratislava. The area surveyed covers a fragment of several hectares of the Holocene Danube River lower I terrace (Ruszkiczay-Rüdiger et. al., 2005) in the inter-dyke floodplain – Figs. 1, 2 and 3 (Novotný et al., 2007). Geomorphological and lithological research (Novotný et al., 2007) showed that the Danube River channel pattern and lithology on this fragment represent an anabranching fluvial system (Wang et al., 2000). The present Danube River valley bottom has been strongly anthropogenically altered the meain reason being river channel regulations in the 18th and 19th centuries. The result is that the channel pattern was transformed from an anabranching multi-channel system to a single-channel canalised sinuous course (Pišút, 2002).

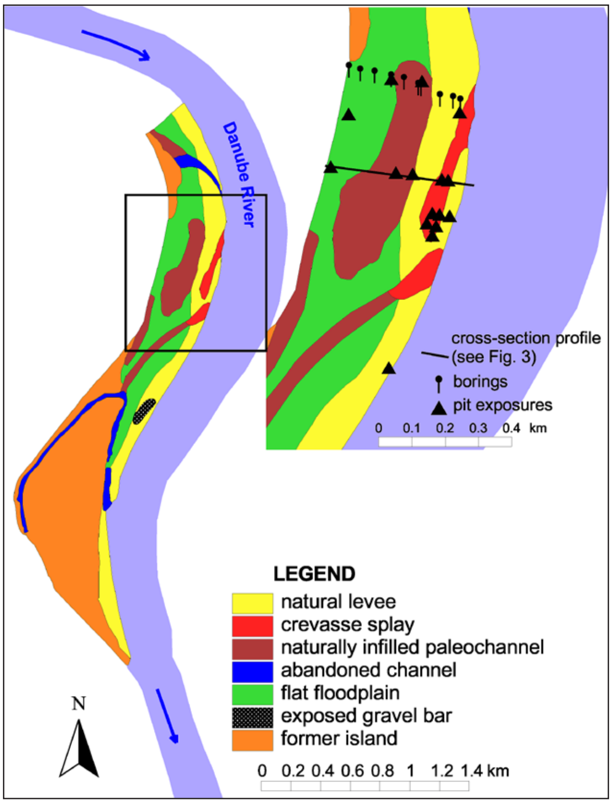

Fig. 2: Map of morphostratigraphic unit types, with the sites of sampling

Fig. 1: Location of the research area

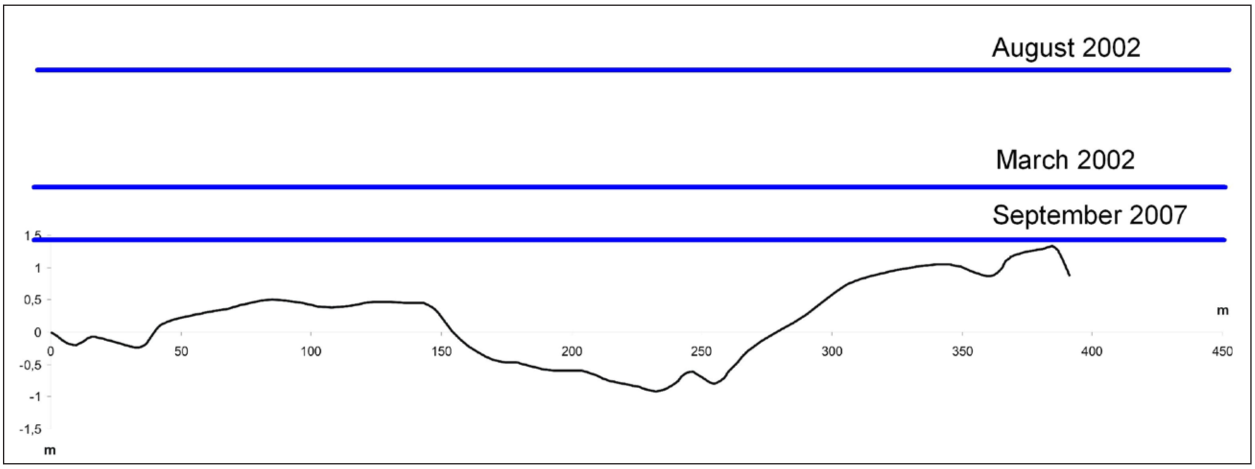

Fig. 3: Floodplain cross-section profile (for location see Fig. 2), with estimated levels of flood waters

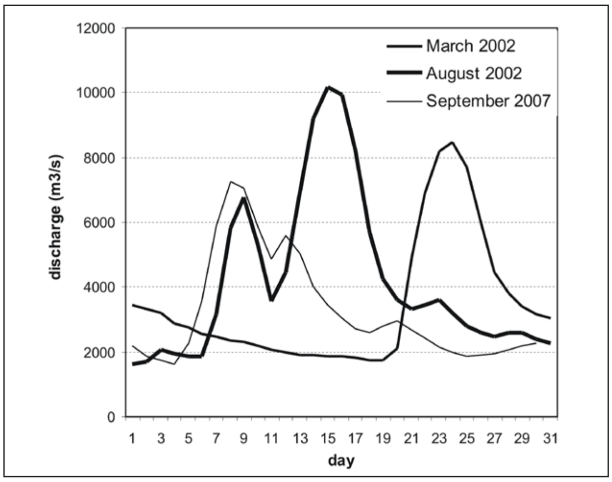

Fig. 4: Mean daily discharge of the Danube River in Bratislava (the gauging station Devin): floods in March, August 2002 and the flood of September 2007

At present time, the width of the Danube River channel study reach is about 350-400 m and the average annual discharge is 2,045 $m^3.s^{-1}$. The sedimentological response of three flood events was investigated (Fig. 4). The first of them happened in spring 2002 (24th March 2002), and its maximum discharge according to data from the Devín gauge station was 8,474 $m^3.s^{-1}$. The next flood event with a maximum discharge of 10,370 $m^3.s^{-1}$ (the Devín gauge station) came in summer 2002 (16th August 2002) and it was the second greatest one as to magnitude since 1920 when the hydrological records were introduced. The third, little flood event with a discharge of 7,238 $m^3.s^{-1}$ (the Devín gauge station) dates from summer 2007 (8th September 2007).

3. Methods

Overbank deposits of the above-mentioned flood events were identified by 10 borings, using handy soil driller and 20 pit exposures. The depth of borings varied from 60 to 350 cm (depending on the depth of gravel horizon), maximum depth of the pit was almost 2 m. Borings and pits served as sampling points to determine the processes and rates of vertical accretion using an allostratigraphic approach classified on the basis of the fluvial style (Miall, 1996). Sediments were classified using established methods (Brierley, 1991; Zwoliński, 1992; Marston et al., 1995).

4. Results

Lithofacial overbank deposits analysis

It is possible to observe the sedimentary records of the flood events from 2002 and 2007 in the overbank alluvia mainly in the neighbourhood of the riverbank. Thus, a special attention in our research was paid to the roof of the natural levee (Fig. 5), as well as to the bank profile (Fig. 6).

The large sandy sheet of overbank deposits was accumulated on the natural levee during the two floods in 2002 (Fig. 7). However, during the 2007 summer flood, small-sized and episodic landforms were deposited such as: sandy ribbons, sandy shadows, small-area sandy sheets (Fig. 8). The structure of alluvia deposited on the levee by the 2007 flood as a lithofacial profile is shown in Fig. 9A. We recognised two three-unit sequences making up the record of three flood phases on this profile. They are deposited above massive silt with isolated pebbles. The similar flood cyclotheme of overbank deposits was found on the bank profile (Fig. 9B). It is possible to identify three units of different lithofacial features in each of these layersets:

(i) The lower unit represents an initial, rising phase of the flood wave (Allen, 1970; Klimek, 1974) that is "rising of water stage and bank modification" (Zwoliński, 1992; The 1st phase). The lithofacies representing this unit:
  - the Massive Sandy Silt lithofacie (SFm) of 5 cm in thickness (Fig. 9A),
  - the roof part (2–3 cm thickness) of the Massive Sandy Silt lithofacie and the higher lying lithofacie of Massive Inversely Graded Fine Sands – Smi fragment 2–3 cm thick (Fig. 9A),
  - the organic matter layer with the Massive Silt admixture (C/Fm) thick a few millimetres (Fig. 9B);

Fig. 5: The roof of the natural levee overbank deposits structure

Fig. 6: The outcrop of channel overbank deposits

(ii) The middle unit is recording the phase of flood water rise and distribution (Allen, 1970; Klimek, 1974) or "floodplain inundation and initial deposition" (the 2nd phase) and "flood peak and widespread transport and deposition" (the 3rd phase) after Zwoliński (1992) that corresponds with the lithofacies of cyclotheme middle unit. The middle unit is represented by:
- the layer of 3 – 8 cm thickness of the Inversely Graded Massive Fine- and Coarse Sand lithofacie (Smi) and c.a. layer of 4 cm thickness of the Inversely Graded Massive Coarse Sand lithofacie (Smi) associated in roof with the Matrix-Supported Gravel lithofacie (Gm) on the levee lithofacial profile (Fig. 9A),
- the layer of 15 cm thickness of the Semi-Horizontally and Low-Angle Cross Laminated Medium Sand lithofacie (Sh/Sl), in the bank lithofacial profile (Fig. 9B);

(iii) The top unit of the flood cyclotheme is recording the fall of the flood wave and the clearing of flood basins (Allen, 1970; Klimek, 1974) or the two final phases recognised by Zwoliński (1992): "falling of water stages and height intensity of deposition" (the 4th phase) and "cessation of overbank flow and final deposition" (the 5th phase). The top unit is represented by:
- a few centimetre thick layers of the Massive Mud lithofacies (Fm) occurred in two cyclothemes on the natural levee profile (Fig. 9A),
- a few centimetre thick layers of the Massive Mud (Fm) lithofacies founded in the bank profile (Fig. 9B).

Apart from the layersets interpreted by us as three units of pensymmetrically graded flood cyclothemes, we also recognised other different types of lithofacial flood records.

The two-unit Semi-Inversely Graded Sandy Silt layerset is located in the bank profile at a depth of 25-50 cm (Fig. 9B). This layerset consists of the Massive Sandy Silt lithofacie (SFm) in the bottom and the Semi-Horizontally Laminated Sandy Silt lithofacie (SFh) in the roof. They were interpreted as a central unit (ii) of the three-unit flood cyclotheme (Klimek, 1974).

Moreover, two individual layers of lithofacie were identified. In the bank profile (Fig. 9B), the about 10 cm thick layer consists of the Semi-Horizontally up to the Low-Angle Cross Laminated Medium Sand litofacies (Sh/Sl). On the top of it, a several millimetre thick layer of organic matter (mainly grasses) with the Massive Silt lithofacie (C/Fm) admixture was deposited. However, in the natural levee profile (Fig. 9A), a 2 cm thick layer of the

Fig. 7: The sandy cover deposited on the natural levee during the floods in 2002

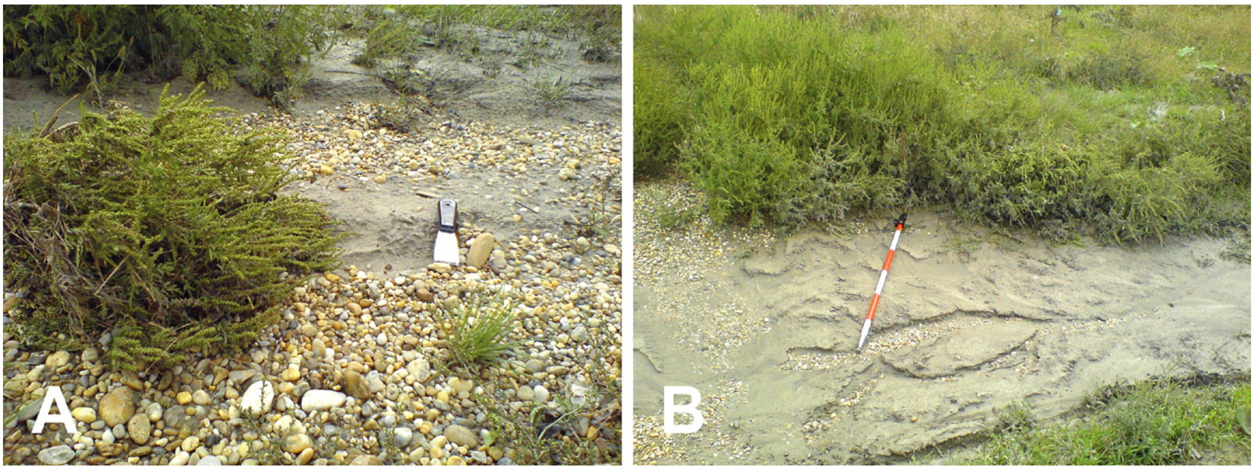

Fig. 8: The forms accumulated during the 2007 flood: A - sandy shadow and ribbons, B – small-area sand cover

Massive Silty Sand (SFm) was found. This arrangement of the lithofacies is not recording the complex phases of flow energy changes during the flood (Allen, 1970; Zwoliński, 1992), but in a horizontal plane it demonstrates the flow energy decrease along with the increase of a distance from the riverbank during a single flood (Allen, 1970; Bridge, 2003).

Correlation of the flood events with their lithofacial records

Taking into account the lithofacial features of analysed layersets and their position in profiles, the following correlation between them and flood events is assumed:

(i) The 2002 spring flood corresponds to the sequence of the three-unit flood cyclotheme SFm - Smi - Fm affirmed in the levee profile (Fig. 9A) as well as to the two-unit inversely graded sequence SFm - SFh in the bank profile (Fig. 9B).

(ii) During the 2002 summer flood, the three-unit flood cyclotheme Fm – Smi (Gm) - Fm situated in the levee profile (Fig. 9A) as well as the three-unit layerset C/Fm - Sh/Sl - SFm in the bank profile (Fig. 9B) were deposited. It should be underlined that this sequence is nearest to the three-unit flood cyclotheme described by Klimek (1974).

(iii) The Massive Mud (Fm) with organic matter (grass) was accumulated in the rising phase of the 2007 summer flood. Furthermore, the Horizontally Laminated Sand and Low-Angle Laminated Sand (Sh/Sl) were deposited in the culminated phase of this flood in the bank profile (Fig. 9B). Moreover, during this flood a Massive Silty Sand (SFm) layer of a low thickness was accumulated on the natural levee (Fig. 9A).

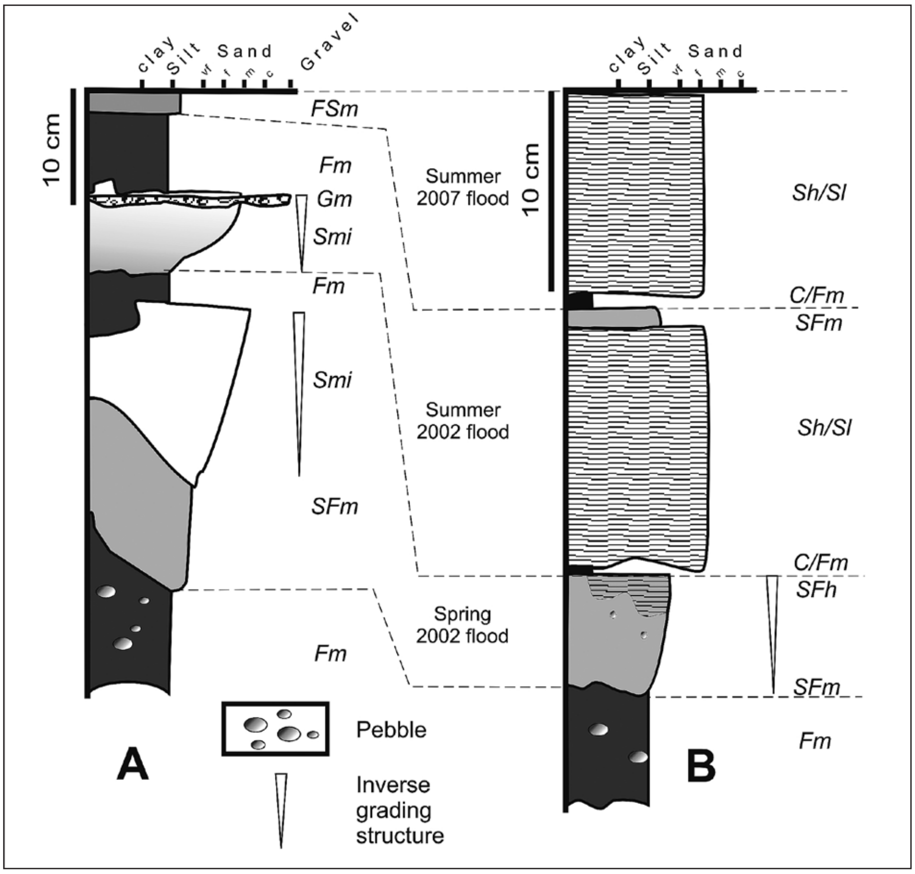

Fig. 9: Overbank alluvia lithofacial profile: A – natural levee lithofacial profile, B – channel bank lithofacial profile

5. Discussion

The interesting aspect of lithofacial analyses is that the characteristic layers i. e. the Horizontally Laminated Sand (Sh) and the Low-Angle Cross Laminated Sand (Sl) were situated in the bank profile. Their structure is similar to the deposition under high energy flow conditions of the "upper-regime flat bed" (Miall, 1996; Yagishita et al., 2004). It gives evidence of a high-energy flood flow entering the Danube River floodplain near the edge of the riverbank. This high-energy flow is likely to remain on a similar level almost all of the time of the flood duration. This hypothesis confirms the lack of grain size differentiation in these layers. However, the flow energy decreases already within a distance of several metres from the riverbank edge what is demonstrated usually by the alluvial deposition finer on a natural levee than on the bank edge. Moreover, flood flow energy is more diverse in the zone of the whole natural levee during all the time of individual flood event than near the bank edge. Thus, this is the evidence that in the levee structure cyclothemes SFm - Smi - Fm and Smi - Gm - Fm were registered during all flood phases of both (spring and summer) 2002 floods. In these cyclothemes, the rise of flood flow energy is also well recorded as expressed in the inversely graded lithofacies (Smi and Smi - Gm). Massive silt layers - covering sandy lithofacies that are semi-horizontally laminated or showing an inversely graded grain size sequence – are likely to indicate an immediate change of the flood flow conditions from high to lower energetic flow after flood culmination.

The slow fall of flood flow energy after culmination representing cyclothemes fining upward like the semi-bouma sequence of Farrell (2001) or three – unit semi-normally graded cyclothemes (Sh-Sr-Fm) of Bridge (2003) was not observed.

6. Conclusions

Flooding is an important process that changes the morphology of the floodplain and thus also the entire riverine landscape. Understanding the behaviour, dynamics and effect of floods is essential both from the scientific as well as practical point of view. Floodplains in large alluvial plains are formed mainly by the process of vertical accretion. It is possible to identify and understand individual phases of flood according to the character of overbank deposits. Effect of three floods (two from 2002 and one from 2007) at a part of the Danube River floodplain in Bratislava was analysed. All cases resulted into sedimentation mainly in the neighbourhood of the riverbank and on the roof of the natural levee (up to 100 m from the bank). The 2002 spring flood had a lesser effect at the riverbank (up to 10 cm of mainly silt) and a greater effect on the natural levee (up to 30 cm of silt and sand). The 2002 summer flood had a more equable effect (up to 20 cm of sediments on the bank as well as on the natural levee), on the bank mainly horizontally laminated sand, on the levee complete flood cyclotheme (silt – sand – silt). On the bank, the structure of sandy sediments is mainly semi-horizontally laminated and on the levee, there is a complete 'flood cyclotheme' (three-unit layerset, characterizing a pensymmetrically graded sequence: silt – sand – silt). The last flood event (in 2007) affected sedimentation mostly in the close vicinity of the bank (up to 10 cm of sandy material) with only slight shadows of finer sediment far away from the bank-line being found.

The results show a relatively high variability of sedimen-tation processes during floods. The total amount of new sediments, their texture characteristics and spatial distribution do not depend only on the flood discharge, but also on the sources of floodwater and sediments in the river basin.

Acknowledgements

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ENDANGERMENT OF THE VILLAGE ČUNOVO (SLOVAKIA) BY LATERAL EROSION OF THE DANUBE RIVER IN THE 18TH CENTURY

Peter PIŠÚT

Abstract

Analysis of old maps enabled reconstruction of extremely dynamic channel changes of the Danube River along the part of its Slovak reach at the end of the 18th century. Prior to 1790, rapid development of a new Danube meander led to partial destruction of the small village Čunovo near Bratislava. Stone groynes were constructed to protect the undercut banks and to divert the flow into the new channel. Retreat of eroded banks at Čunovo over the periods 1783–1790 and 1790–1794 reached up to 432 and 229 m, respectively. Corresponding maximum rates of lateral erosion 57–72 m per year and/or 31–76 m during a single event are comparatively high in Central European conditions. Initiation and rapid development of the new meander were related to 1) increased river activity during the last onset of the Little Ice Age period, 2) serious channel changes after 1760 on the immediately upstream reach from Bratislava to Rusovce, 3) siltation of the Lesser Danube, but also to 4) local predisposition of the floodplain topography.

Shrnutí

Ohrožení obce Čunovo (Slovensko) laterální erozí Dunaje v 18. století

Výsledkem analýzy starých map je rekonstrukce extrémních dynamických změn koryta Dunaje v části jeho slovenského úseku na konci 18. století. Silné laterální erozi, která souvisela s rychlým vývojem nové zákruty Dunaje po r. 1783, padla do roku 1790 za oběť i část vesnice Čunovo u Bratislavy. Hydrotechnická protiopatření spočívala v ochraně podemílaného břehu kamennými valy a v odklonění proudu do nového koryta. Nárazový břeh čunovské zákruty ustoupil v období let 1783–1790 na nejvíce erodovaném úseku až o 432 m, v letech 1790–1794 pak ještě o dalších 229 m. To představuje poměrně vysoké hodnoty maximální břehové eroze od 57 do72 m za rok, resp. 31–76 m po přepočtu na jednotlivé vysoké vody. Vývoj nové zákruty souvisel se 1) zvýšenou aktitivou řeky v období posledního náporu Malé doby ledové, 2) se závažnými změnami koryta po roce 1760 na bezprostředně vyýše položeném úseku Dunaje mezi Bratislavou a Rusovcemi, 3) se zanášením koryta Malého Dunaje, ale také s 4) lokální predispozicí terénu nivy.

***Key words**: Danube River, historical maps, erosion rates, 18th century floods, Little Ice Age, Slovakia*

1. Introduction

Old maps as unique sources of data on the past landscapes have been increasingly employed in geosciences. Although they require some caution, for fluvial geomorphology they are priceless as to the knowledge of channel changes and dynamics prior to river channelisation (Hooke, Redmond, 1989; Pišút, 2002; Trimble, 2008).

The 18th and 19th centuries represent extremely important time periods as to historical maps. This is not only thanks to the progress in surveying techniques, but also because they depict landscape during probably the most pronounced climatic and land-use changes since the Middle Ages. In 1780s, the whole territory of Habsburg Empire was for the first systematically surveyed for military purposes. Unprecedented as to area covered / rich cartographic content, sheets of the Ist-IIIrd military surveys were secret until recently. Since they have been release to public (cf. Klein, 2003; Biszak et al., 2007), they attract attention of geomorphologists also in Slovakia. For instance, they are extremely useful for dating the periods of gullying (Stankoviansky, 2003). In 2006, also the maps from the collection of former Hungarian Locotenential Council (deposited in the National Archives of Hungary, as a part of Széchényi´s library) were released to public in digitised form on DVDs. This collection contains a large number of river maps and plans, which reflected local and regional problems mainly associated with flood protection, draining and increasing river use for navigation. They allow to study many natural and man-made channel changes and fluvial landforms, but also to better understand the cartographic content of regional and military maps.

This paper deals with a detailed analysis of some of the earliest (from 1790–1808) local manuscript large-scale maps from the above collection, concerning a particular small reach of the Danube River near Bratislava. Their comparison with both older (1783 – 4) and younger historical maps allows to reconstruct dynamic changes of the Danube channel, leading to partial destruction of the village of Čunovo.

2. Study area

Study area is situated downstream the Devín Gate Gorge by which the Danube River enters its subsident basin in the Danubian Lowlands (Fig. 1). It comprises around 5 kilometres of the river course (1850 – 1855) next to the Slovak capital Bratislava. Near the village of Čunovo, Mosoni Danube anabranch splits off from the Danube, creating the Szigetköz Island in Hungary. The river gradient at this stretch is still relatively steep (0.043‰). In the past, an average of approximately 600,000 m^3 of bedload and about 7 million tons of suspended load were annually transported through Bratislava. More detailed geological, geomorphological and lithological data on this reach can be found in another paper by Pišút (2002).

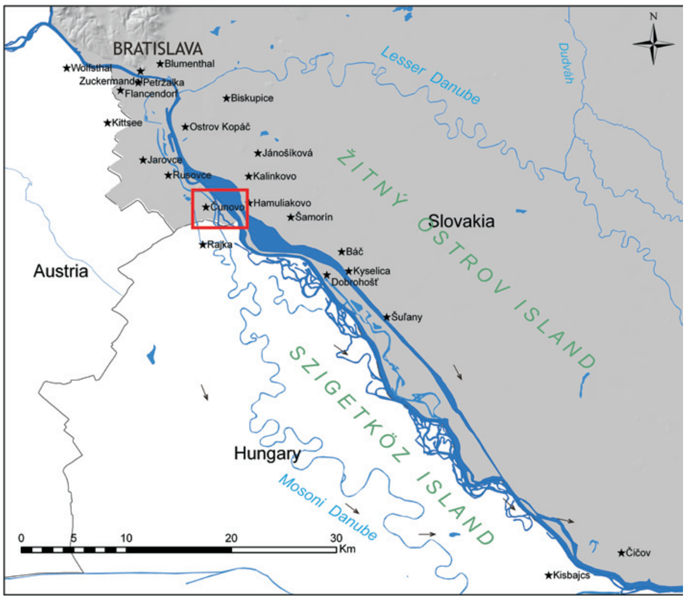

Fig. 1: Study area location

The discharge regime is directly influenced by snow-melt in the Alps with a high flow in summer and low flow in winter (respectively 33% and 18% of annual runoff). Mean annual discharge of the river is 2,024 $m^3.s^{-1}$, minimum and peak measured discharges amount to 570 and 10,400 $m^3\ s^{-1}$ (according to data from the gauging station in Bratislava, 1901–1950 period). The highest historical discharge can be approached from that estimated in Vienna (14,000 $m^3\ s^{-1}$) during the major flood of 1501. As to the flood regime, early spring floods tend to be associated with the snowmelt in the lower regions along the river upstream, and summer ones with the snowmelt and late spring to early summer rains over the higher Alps. Although the peak measured discharges are derived from the summer flooding (as in the disastrous flood of July 1965), late winter and early spring ice-induced floods represented the greatest hazard in the past. Dangerous ice floods originated more probably after a cold, snowy and long winter and/or sudden warming in the catchment area of the upper Danube (as in the 1784 flood; Munzar et al., 2005).

The originally small rural village of **Č u n o v o**, bordering on Hungary and Austria has been the southernmost city part of Bratislava since 1972. It is first mentioned in 1232 (*Chun*). After the dissolution of Austria-Hungary in 1918, Čunovo ceded to Hungary, but since 1947 it definitively became a part of the Czechoslovak Republic. In the 18^{th} century, Čunovo administratively belonged to the Moson County. In 1784 – 1787, the village consisted of 99 houses with a total population of 716 people (Horváth et al. 1982; Horváth, 1990).

The modern Danube (until 1990s) at this stretch was 300 m wide as a result of the mid-flow channelisation, realised in 1886 – 1896. At present, Čunovo is known for the large artificial water body of the same name – the Čunovo reservoir. With its area of 4,000 hectares, it is an important part of the Gabčíkovo hydropower plant. River corrections and realignment after 1886 and their ecological consequences are described elsewhere in detail (see references in Pišút, 2002 or Mucha [ed.], 2004).

3. Methods

To compare and quantify channel changes over time by map overlay (cf. Hooke, Redmond, 1989), historical map situations were georeferred into a commmon scale of the current Slovak projection system and datum S-JTSK Křovák East-North of National grid maps (map reference

18) in ArcMap 9.2 GIS software. This was not an easy task, since the floodplain topography changed beyond recognition over the past 250 years.

The sheets of 1825 „Danube mappation“ (map reference 14), unprecendented both in terms of accuracy and rich content, proved to be priceless in this reconstruction; they also served as a basis for geocoding of the 1834 map (map reference 15).

Several computer-based transformation methods have been developed to georeference the map sheets of military mappings. Nevertheless, in the Hungarian provincial system (for example in the IInd survey), errors greater than 200 m may occur (Timár et al., 2006). To minimise such errors, only minor sections of these maps depicting Čunovo and its surroundings were georeferred, using mainly street crossings and logging roads as control points.

In the case of 1790 to 1808 manuscript maps, the subjective approach of their author, Casparus Láb, must be taken into account. He surveyed and depicted water edges and hydrotechnic structures (= groynes, channel closures) with the highest accuracy possible, whereas evidently a lesser attention was paid to objects farther from the river or being not essential as to the map content (including the church in Čunovo). With respect to this, crossroads of the streets „Skýcovská“ and „Na hrádzi“, as well as the midpoint of minor channel closure next to the village proved to be the best benchmarks. Correction of transformation was undirectly checked by the position of Čunovo meander bank line on georeferenced maps, which should not cross the real edge of the former bank, preserved until today. With the aid of these points, the 1790 and 1800 maps (map references 5 and 11) were georeferred with a suggested transformation error of RMS < ± 10 m, which can be assessed from a comparision of known distances on the geocoded map. For instance, 100 Viennese ells (1 V. ell = 1.896484 m) on a graphic scale of the 1790 map corresponds to 185–188 in GIS. As shown in Tab. 1, displacement errors are comparatively small in most maps. Even in the first military map (1783–4), the RMS value of 33.167 m is much under the maximum rate of annual erosion during following years. Almost all maps were transformed using 1st Order Polynomial transformation.

Mean annual rates of erosion (m.year^{-1}) were derived from the distance of maximum bank retreat between 1784–1790 and 1790–1794, respectively. The cartographic evidence was verified and interpreted taking into account supplementary literature and field data, modern map topography and aerial photos.

4. Results

4.1 The Danube River at Čunovo in 1784

The map from 1783–4 (Fig. 2 – see cover p. 2) depicts Čunovo as a village, which had developed itself along the road leading to the river ferry. Two rows of streets on either side of the main streat formed a slightly extended central area. A Baroque church, built in 1783, stood slightly aloof the Danube mainchannel, on the NW edge of the village. Other important local buildings constructed of solid materials (in contrast to serf houses made of unburned bricks) were a manor house from 1765 –1770, and a landlord´s farmstead (*allodium*). The village extended close to the Danube R. bank; house parcels on either side of the village were approximately of the same length, about 170 m. The Danube R. mainchannel reached a considerable width of 500–600 m. There were 4 long, bare bars therein.

4.2 Endangerment of Čunovo by the formation of a new bend in 1790

According to the Latin map by G. Láb representing *„the Danube main channel and ravine of its banks next to the village of Čunovo“* (map reference 5), floodplain topography had dramatically changedn within only 7 years (Fig. 3). In the meantime, a brand new meander of the mainchannel with a hint of forming double bend developed there, with a radius of around 600 m and an average width of 306 m. Its rapid development was indirectly evidenced by a large unvegetated point bar with an area of 53 hectares. Bend development had fatal consequences for the Čunovo village: until 1790,

Date of the map	Number of sheets georeferred	RMS error of transformation (m)	Number of control points
1783-4	1 (outcrop)	33.166695	9
1790	whole map	< ± 10	2 (100 ells on map = 185-188 m in GIS)
1794	whole map	6.40337	5
1800	whole map	< ± 10	2 (100 ells on map = 194-197 m in GIS)
1808	whole map	19.03427	4
1811	2	10.34245	6
1825	4	0.17313-1.17377	10
1834	1 (outcrop)	4.92768	8
1856	3	0.38887-0.53457	4 corners of each sheet
1869-87	1 (outcrop)	8.6	8

Tab. 1: Accuracy and possible errors of the transformation of historical maps into the S-JTSK system

the river partially carried away one of two main streets, in total around a third of the village along with several houses. The eroded bank shifted up to the „sqaure“. Destruction preceding 1790 is not only indicated by short remnants of destroyed parcels, but also by a row of new houses (*nova Aedificia*), built in a safer position farther from the river. The map also showed 4 earlier groynes at river edge, which had been constructed prior to 1790 in a vain attempt to divert the dangerous flow (*...antiqua 4 lapidea calcaria*).

Projected remedial measures suggested to solve critical situation of the village were following:

i. immediate diversion of spillway from the cut bank by 6 new spur-dikes (*Neo erigenda lapidea 6 No Calcaria)*,
ii. deflection of the mainflow into a narrow channel located in the direction of the flood thalweg easterly from Čunovo. This should had be accomplished by the construction of 4 long groynes on the right-bank side-channel bar upstream the village (*d. Saepes in ordine 4 ponendae, que Insabulationem hic, ac aqua ad Ramum G promevebunt*). The groynes were really constructed after 1790. Three of them are depicted on F. Eperjessy map (map reference 6) in May 1792.

4.3 The Danube River at Čunovo in 1794

The map from 4 March 1794 (map reference 7) already shows the flow successfully deflected into a new, straighter channel about 150 m wide. Although it was carrying a major part of the flow (*Novus effectus Ramus per quem maxima vis aque descondit*), this channel still had not parameters sufficient for navigation of riverboats down- and upstream (*b. Ramus neo efformatus per quem ... parva quantitas aquae pro navibus sursum et deorsum comeantibus deserviens descondit*). This deficiency should had been rectified by little bar removal at its upper entrance by excavating a canal (*a. Canalis neo effossus pro aqua Danubiali allicienda et ad Ramum b. permovenda*).

Despite the subdivision of the mainstream into two wide channels, heavy lateral erosion still continued in the original bend as well. Since 1790, other 12.55 hectares of bank were carried away and a maximum shift of cut banks reached 229 m (Fig. 4).

For this reason, apart from 6 stone groynes built in the preceding years, the map also shows additional 7 groynes. These were already constructed by order of the Hungarian

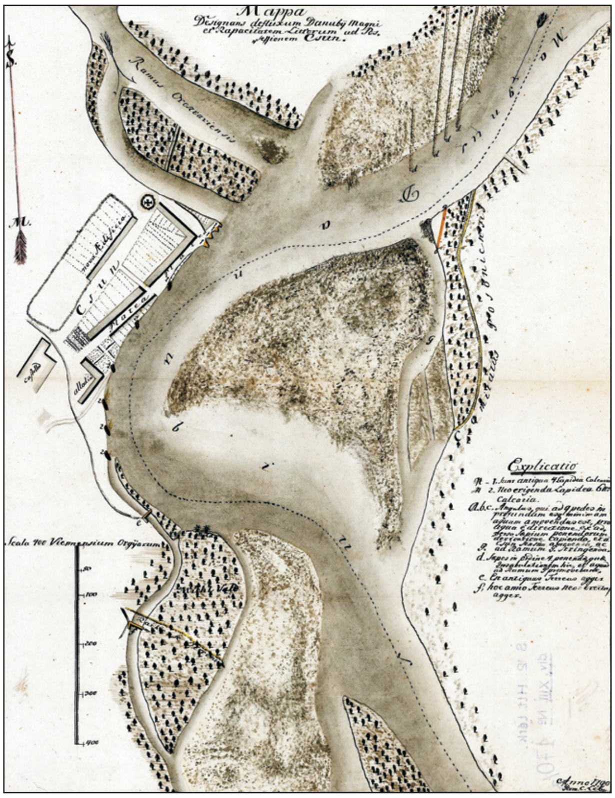

Fig. 3: Within only 6 years a brand new prominent meander of the mainchannel developed at Čunovo, partly destroying the village itself. Its rapid development is indirectly evidenced by the large unvegetated point bar. The 1790 manuscript map by Casparus Láb also shows detailed remedial measures intended to control erosion and to divert the dangerous flow

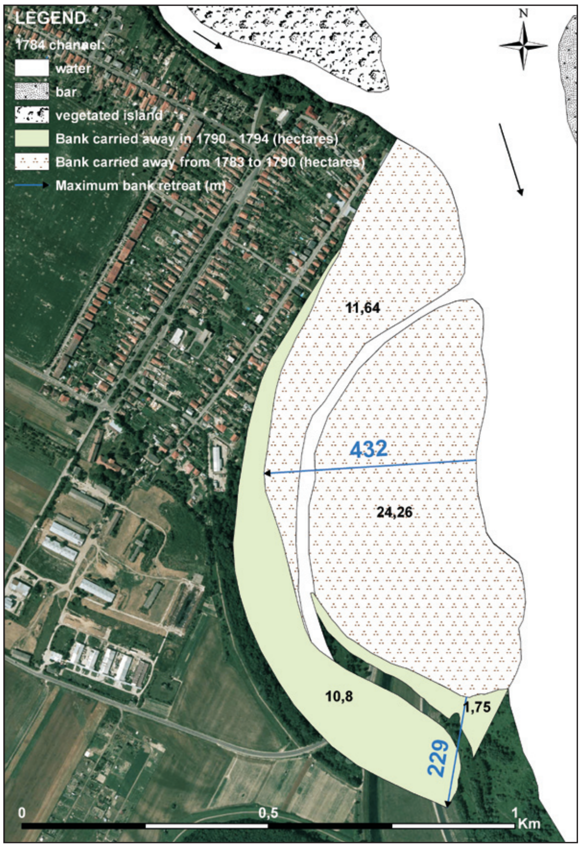

Fig. 4: Land carried away during the evolution of a new Danube bend in periods 1783–1790 and 1790–1794, respectively. Arrows designate the lines of maximum bank retreat (in metres) from which maximum bank erosion rates were derived

Locotenential Council, and three more remained to be built (*a.b.c.d.e.f.h. sun(t) 7 noviter ... contra Rapacitatem Ripparum posita Repagula, ubi adhuc 3 ponenda restant*). Following the map from 20 June 1794 (map reference 8; Fig. 5), these 10 new groynes were really completed during the next three months (*f. Repressoria Repagula No 10 recenter exstructa rapacitati aquae resistentia*).

4.4 The erosion event of January 1795

At the beginning of winter 1794/95, a major part of the Danube R. along the study reach froze over. It is documented by a particularly interesting map from 30 January 1795 (map reference 9). Accreted ice on either side of the loop upstream Čunovo dramatically narrowed the flow-through profile to only 60 m and deflected the current in a perpendicular direction toward the village, where the stream hit at full force (*e Glacies ad Rippam f aquam hac hyeme cum maxima vi perpendiculariter propellens*). On this single event lasting perhaps only a few days, additional rapid and catastrophic bank erosion occured, along a total length of 320 m and up to 29 m on the most badly eroded reach, having impaired one of the stone groynes (Fig. 6 – see cover p. 2). Therefore, six minor and one larger groynes began to be constructed immediately to control erosion (*f Hac hyeme 6 parvae, et unum majus lapideum repulsuale calcar contra rapacitatem nimiam Ripparum erigi inchoata*). Later on, by order of the Locotenential Council, the damaged groyne was restored and the undercut section was lined with stone revetments at a total length of 105 m, what is evidenced by the map from February 1796 (map reference 10).

Fig. 5: The map from 20 June 1794 already shows the flow succesfully deflected into a new, straighter channel. Nevertheless, heavy bank erosion was still continuing in the original bend, as well. Apart from 6 stone groynes, built in the preceding years, the map depicts additional 10 projected groynes

In 1795, a major part of the flow was already in the new channel and navigated by cargo boats (*b. Ramus novus Danubii, per quem Naves oneratae de et ascendere solent*; map reference 9).

4.5 Geomorphologically efficient high flows, floods and ice phenomena in the studied period

As to the action of major floods immediately preceding the period concerned, during June 1771 the flood water in Bratislava reportedly reached its maximum level since 1736. Ice-jam flood in February 1775 was one of the most disastrous of its kind in the 18th century (Tőry, 1952; Réthly, 1970). Several high flows of 1780s–1790s were compared to its culmination level, marked (Ballus, 1823) on the wall of the „Water Barracks" building in Bratislava (built in 1759-1763).

Nevertheless, major floods of 1780s as fluvial geomorphic factors have a specific position. This is in accord with general conditions of the 1781–1788 period in Central and Northern Europe, which was about 2 °C colder than the 1931–1960 period (Gisler, 1985). The most important facts about the floods in the studied period are as follows:

1783. Although the drifting ice on the Danube did not stop at Bratislava in the winter of 1782/3, the „flying ferry" (= local ferryboat, anchored on a long rope amidst the Danube R., commuting on the pendulum principle) had to be pulled ashore around 5 January. On 10 January, the water raised strongly and flooded the right-bank floodplain. On 14 February, the swollen water due to ice barrier flooded a part of the suburb Blumenthal. The „Flying" ferry was put into operation again on 22 February. A major „damage to banks" caused by the flood is reported from Rusovce village (Horváth et al., 1979).

On 7 December, bridges at Bratislava and Pest were dismantled due to the floating ice; on 23 December, the river was already hard frozen over in Pest. Zawadowski (in Réthly, 1970) mentions the December flood on the Danube R.

Disastrous flood in February/March 1784. Flood, which originated after a sudden thawing at the end of extremely hard, long-lasting and snowy winter of 1783/4 is one of the most important extreme examples of its kind in a number of European countries. Apart from the vast territory that was flooded, this event had extraordinary dynamics and record-high culminations. At the same time, it affected basins of many larger rivers. Flood parameters and damage extent were documented in detail in several papers (see e. g. Glaser, Hagedorn, 1990; Brázdil et al., 2003; Munzar et al., 2005 and references therein).

The Danube River basin was hit by this flood, too. During the movement of ice between 29 February and 7 March, low-situated parts of Vienna were flooded along with a number of villages in Lower Austria, resulting in a major damage to estates and livestock and claiming human lifes (Tőry, 1952; Réthly, 1970; Munzar et al., 2005).

In Bratislava, the river froze over as early as on 1 January. The fear of flood was felt in the town from 16 February. Since 25 February it rained heavily and the ice on the river was covered by half a cubit of water. In that winter, the Danube River was frozen for three months (only in the winter 1829/1830 it was icebound longer, for 99 days; Földes, 1896). Morning on 1 March broke the first ice barrier downstream the town, causing no damage. By the breach of the second one near the Zuckermandel suburb, the deflected powerful stream caused flooding of Blumenthal and swept away a boat with 13 people on board. Although there were only scattered ice blocks floating on the river on 2-3 February and smaller boats could navigate again, the water level rose so that on 6 March, houses near the pile bridge were already standing in water. On 10 March, the whole right bank was flooded up to the village of Kittsee (where three people drowned), although the water was already receding. Damages to banks are reported together with the order to repair the roads and bridges destroyed by the flood (Horváth et al., 1979). During this extreme flood, the side-channel closure (and dam) at Rusovce was breached again, as documented by the map from 1785 (map reference 2; Fig. 7 – see cover p. 3).

1785. The Danube River became iced over in Bratislava only on 1 March. On 21 March, the ice began to move and broke without causing any damage. The Danube R. burst its banks again between 22 and 29 April, flooding low-lying banks and later also some parts of the town. The third high flow between 20 and 28 June caused damage to Bratislava but mainly to crops grown on the Žitný ostrov Island, where many houses collapsed. In July, the lower Váh R. basin and a part of the Žitný ostrov Island were flooded again (Réthly, 1970), although this flood could have been related to high flow on the Váh River.

Year 1786. The Danube froze over in Bratislava on 8 January. Ice flood on the Upper and Middle Danube is mentioned by Tőry (1952). The river overflowed its banks again between 26 June and 5 July. On 29 June, the „flying ferry" had to be pulled out ashore. High flow also occured in Austria and Hungary. The flood caused no much damage.

The third high flow occured on 6 and 7 August. Water began to rise also on 20 August. On 22 August, the Danube overflowed and flooded the right bank up to Kittsee, breaking the traffic connection to Vienna. This was reportedly already the fourth high flow of the year. The Danube was also in flood in Hungary (Réthly, 1970). In Austria, this flood is listed among the 7 highest (since 1000) with a peak discharge exceeding that recorded during the flood in 1899, i. e. over 10,870 $m^3.s^{-1}$ (Fekete, Láng, 1967).

On 22 December, numerous ice blocks appeared in Bratislava, so that on next day the „flying bridge" was taken apart (Prešporské Noviny, No. 102, from 30 Dec.).

Major flood in November 1787. Extremely high flow occurred on the Danube R. between 28 October and 14 November. Also this flood is listed among the 7 highest in Austria (Fekete, Láng, 1967), with a peak discharge of 11,800 $m^3.s^{-1}$ according to Horváthová (2003). It caused much material damage and a number of people were drowned.

On 31 October, the stream in Bratislava was already so fast running and powerful that it pulled down a minor bridge on the left bank. Low-situated suburbs and city islands were all flooded (Ballus, 1823; Portisch, 1933). The continually rising water broke the Vienna highway embankment (see also map reference 3) and flooded the right bank up to Rusovce through the openings. Traffic connection was broken for at least 8 days. Water caused much damage to boat mills of the town. On the Žitný ostrov Island, dykes broke at Hamuliakovo, Kalinkovo, Jánošíková and Bodíky villages (Földes, 1896, Gyalókay, 1978). Dyke failure at Rusovce is documented by another map of G. Jáczyg (map reference 4). In Austria, water penetrated the Vienna downtown (Tőry, 1952); its culminating level is documented by flood-marks in Hainburg and Marchegg (Horváthová, 2003). Also Rába and Rábca Rivers in Hungary run out of banks and the town of Győr was flooded. In Pest and Buda, water peaked by 5.9 m above „the ordinary level".

Floods of 1788. After a comparatively mild winter of 1787/88, the „flying ferry" was put into operation on 1 March 1788. According to a remark on the 1792 map by F. Eperjessy (map reference 6), the geomorphologically effective high flow occured again in November that year. On that occasion, two of a half-silted upstream entrances of the Hamuliakovo side channel opposite to Čunovo were reactivated by the stream (b.b. *Rami antea obsabulati, A^o vero 1788 Mense 9^{bri} interventa exundatione adaperti occasione qua in loco*). Probably the same flood resulted also in the breach of the left-bank dyke next to Hamuliakovo village (Földes, 1896). The flood on the Middle Danube is also mentioned by Tőry (1952). According to Réthly (1970), the „flying ferry“ of Bratislava was pulled ashore on 29 November again, when the river began to be covered by ice and it completely froze over there on 20 December. The month of December was in this winter the coldest one in the period 1775–2000 (Brázdil et al., 2003).

Floods in 1789. The Danube was frozen over in Bratislava until mid- January (Horváth et al., 1979). Warming resulted in ice flooding causing much damage to Szigetköz and Žitný ostrov Islands. On the latter, many communities were cut off by water for 13 days. In the villages Dobrohošť, Báč, Kyselica only few houses remained intact. On 14 January the Danube overflowed the banks also at Flancendorf and Wolfsthal. Also at the beginning of February, ice blocking caused a great damage to the right bank, where a dyke breached at Rusovce and a vast area was flooded up to Jarovce village. In Rusovce, Rajka and Bratislava 45, 128 and 56 houses collapsed, respectively (Réthly, 1970). One of these ice floods caused breach to the left-bank embankment at Kalinkovo village. These sections were repaired in 1792 (Földes, 1896; Gyalókay, 1978).

High flow also occured between 26–29 August 1789, when the right bank up to Rusovce was flooded again (Réthly, 1970).

Ice flood in 1790. Though Réthly (1970) gives no data on river ice for this year, according to Varga (in Juhász, 1996), the ice thickness in Bratislava should have had reached 120 cm in hard winter. The ice set to movement at the end of the month, and the ice barrier caused the flooding of Komárno and the lower Žitný ostrov Island. In Kolárovo, 180 houses collapsed, communities Čalovec and Kameničná were almost completely destroyed. In that year, the ferryboat between the municipalities Biskupice and Kittsee ceased to exist due to channel changes and frequent floods in previous years, although it had been in operation since medieval times (Püspöki-Nagy, 1969).

Hydrological events from 1791 to 1794. In ***1791***, high flow might have occured at Čunovo in summer (as it was in June in Buda, Hungary; Réthly, 1970). In ***1792***, along the Bratislava reach, the drifting ice came to a standstill on 14 January. It began to move again on 29 January, causing a lot of damage. Evidenced by a remark on F. Eperjessy map (map reference 6), one of the additional upstream entrances of the Hamuliakovo side channel opposite to Čunovo was produced during this flood (*Ultima glaciali exundatione A^{o} 1792 Mense Januario interventa efformatum novi rami orifitium*). On 22 February, ice appeared on the river again. It moved around 11 March. In ***1793***, drifting ice occurred on the Danube since 8 January. After it had moved without any damage on 27 February, the „flying ferry“ began to commute again. In ***1794***, the Žitný ostrov Island was flooded around 31 August (Réthly, 1970).

The frozen Danube in winter 1794/1795. Despite the lack of literary data for January (cf. Réthly, 1970), there was ice on the Danube prior to 30 January 1795, as documented by the erosion event at Čunovo (map reference 9).

In the cold winter of 1794/95, the river at Bratislava froze at some places down to the bottom. It began to swell strongly on 20 February. The ice moved and at several places (e. g. next to Hamuliakovo village) it piled up. On 24 February, the river overflowed its banks. On 6 March, the right bank upstream of Rusovce up to the Vienna highway was flooded and covered with ice floes. Three days later, the ice eventually cracked and receded without causing substantial damage. On 21 March, the „flying ferry“ started to commute again. Probably the same high flow is also documented from Hungary (Réthly, 1970), the flood on the Middle Danube is mentioned by Tőry (1952), as well.

5. Discussion

Major determinants of the rapidly developing new Danube bend at Čunovo were following:

i. increasing surface runoff in the 18th century within the whole Upper Danube basin, as a consequence of introducing new agricultural techniques and crops, as well as changes in forest management;
ii. icreasing lateral activity of European rivers, including the Danube, related to the last onset of the Little Ice Age, approximately after 1753 when cold winters with large amounts of snow became more frequent and also the frequency of floods in summer season increased;
iii. serious natural and human-induced changes of local scale which occured on the Danube stretch at Bratislava after 1760;
iv. predisposition of local topography at Čunovo.

All these factors dramatically increased lateral activity of the Danube mainchannel downstream of Bratislava in the 1780s.

From the list of high flows, floods and ice phenomena cited in chapter 4.5 it follows that he Čunovo bend was shaped by at least *14 geomorphologically effective floods between 1784–1790 and by 3 additional high flows in 1790–1794* (prior to January 1795). During the first phase, some of the largest floods of this perod occured: in 1784, 1786, 1787 and 1789. Moreover, two of them (1787, 1788) appeared in an “out-of-season” period of the year (autumn). The flood in November 1787 not only had a character of at least 100 yr flood with the major destructive force, but water also reached the record-high level (at least since 1777, when the Vienna embankment had been completed). The floods in 1780, 1784, 1787 and 1789 also repeteadly destroyed the dyke and the side-channel closure at Rusovce, constructed after 1773.

If we calculate the ideal rates of bank retreat or total area carried away falling on a single high flow event, we find out that lateral erosion peaked in the period from 1790 to 1794 (Tab. 2). This can be explained by the fact, that after the initial stage of rapid growth by extension, i. e. until 1790, a critical value of the r/w ratio (= radius of channel curvature to its width) was reached. From this moment on, the channel planform alone exerted considerable control over the subsequent direction downstream and over the rates of lateral migration (Hickin, 1974).

Period	Maximum bank retreat (m)	Total eroded area (hectares)	Minimum number of high flows	Maximum lateral erosion per year (m)	Maximum lateral erosion per single event (m)	Maximum area carried away during 1 event (ha)
1784-1790	432	35.90	14	72	31	2.24
1791-1794	229	12.55	3	57	76	4.18

Tab. 2: Dynamics of lateral erosion

Synchronously, the Čunovo meander development was also largely affected by *channel changes, which occured at the immediately upstream located reach of Bratislava*. Ice floods in 1766-1768 accelerated natural shift of the mainchannel at Pečňa Island upstream of Bratislava (Pišút, 2002). This iniciated construction of an artifitial levee from Wolfsthal to Bratislava, a so called Vienna highway, which also resulted in the blockage of more than 200 m wide ("*Croatian*") side-channel in 1777. These corrections led to a significant shortening and straightening of the Danube at Bratislava. Expected response of the river to this was local bottom erosion and decrease of groundwater level which help to explain the sudden shallowing and silting of the *Mühlauer Donau Arm* (Mill channel), the main of two upper mouths of the Lesser Danube, in 1779–1784. This resulted in the cessation of flow through this anabranch, whereas more water was diverted into the „Major“ Danube itself.

Flow concentration into the shortened channel also accelerated the double bend cut-off at current rkm 1862–1864 in 1780. The mainchannel itself gradually began to enlarge there from 165 m in 1774 to 339 m in 1816 (Pišút, 2002).

Also the blockage of the Rusovce secondary channel after 1773 contributed to increase the stream power immediately upstream of Čunovo. A several kilometres long, quite straight section of the main flow shown on the 1783–4 map (Fig. 2) was actually an unstable transitive stage closely prior to the formation of new mainchannel sinusoids, represented by the curve at the Kopáč island (Pišút, Timár, 2007) and farther downstream by the Čunovo meander itself.

Downstream of Čunovo, along the reach Kalinkovo - Šuľany, the increasing lateral activity cf. since 1788 was synchronously reflected by growing accounts on rapidly retreating banks and related damage to dikes (Földes, 1896). Six large meanders shown on the map by Mikovíni (1735) and minor meanders at Bodíky (rkm 1824–31; Pišút, 1995) had all been cut-off after 1778. Instead, numerous unvegetated bars appeared in the widening mainchannel as a sign of channel overenrichment with bed load (Pišút, 2006).

Another evidence of increased lateral activity in the 1780s is from the stretch between the villages Kis Bajcs and Čičov (at the rkm. 1799–1802). The first reference upon the rapidly developing Danube bend, which carried away banks and destroyed dykes at the border of Komárno and Győr counties dates back to 1781. During the following years, two pronounced meanders developed there, which had not existed at all or only were at an early stage of development in 1783–4 (Szabó et al., 2004). Both were artificially cut off in 1798. Relics of abandoned meander loops on either river banks are the current reserve Čičov oxbow in Slovakia, and paleomeander next to the Bajcs village in Hungary (Timár, Pišút, 2008).

Changes in fluvial regime due to changes in large-scale atmospheric circulation patterns, associated with the increasing major flood events in Europe during this period, have been identified e. g. in Britain, where unusual high run-off and particularly severe flooding between 1760–1792 resulted in marked channel entrenchment in the Tyne river basin (Macklin et al., 1992). In the Oulanka River, Finnland, a major snow-melt and ice floods were responsible for the formation of unusually high scroll bars between 1770–1840, with the timing of peak floods to the 1780s (Koutaniemi, 1987). Similar gravel accumulations dated to the 1790s and 1820s originating from major point bars were also recognised on the Slovak Danube (Pišút, Timár, 2007). Also in the Upper Danube and its important tributaries, old maps show mid-channel bars and a tendency of initial braiding in the sinuous Danube reach during the 18th and at the beginning of the 19th century (Buch, Heine, 1995).

Bank erosion rates and channel migration are also a complex function of stream size, sediment size (D_{50}) at the base of the outer bank, its height and on-bank vegetation. The descriptive part of the Ist military mapping characterises the Danube at Rusovce in 1783–4

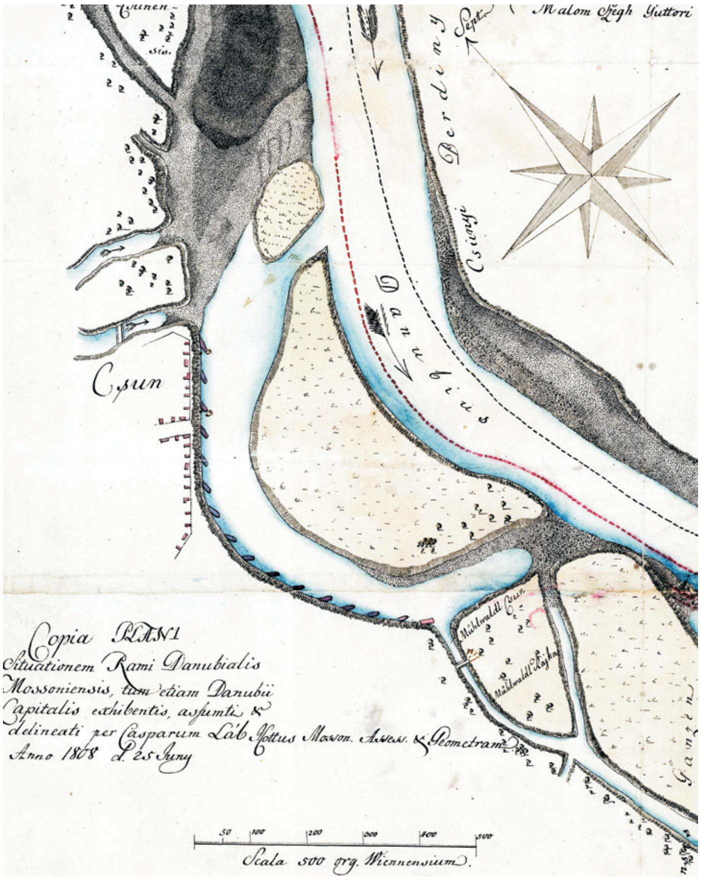

Fig. 8: The map from 25 June 1808 showing the Čunovo meander after its abandonment. Until 1796, a total of 16 stone groynes up to 40 m long were constructed to protect the Čunovo undercut banks

as *„1000 or more steps wide, it has rapid flow, banks 2 and more ells high... Its rapacious stream along with sandy bottom cause that almost every flood destroys islands and establishes new ones.*“ (Klein, 2003).

The rapid bank migration at Čunovo can also be partially explained by the *local floodplain configuration*, particularly by the position of a minor parallel right-bank channel (Fig. 3). It separated the island „Mill Forest“ (*Muhl Wald*), with two mills powered by the fastest stream in a heavily eroded part of the loop. The mills were accessible through an earthen closure (*antiquus Terreus agger*), but due to the proceeding erosion, the closure was planned to be replaced by a new one downstream (*hoc anno Terreus neo=erectus agger*). In 1790, the channel was already located closely beyond the mainchannel cut bank, only separated from it by a narrow strip of land. After this had been ultimately carried away, the bank line was shifted by a significant „jump“, since the original bank of the side channel immediately became a new mainchannel bank.

The calculated rates of bank retreat (= of lateral erosion) are consistent with the previous data from the Bratislava reach (Pišút, 2002). Mean rates in the period from 1712–1753 averaged 11.7 m.year^{-1}, reaching from 4.84 to 16.48 m.year^{-1}, in dependence upon the position and developmental stage of the bends. In following period (1753–1774) it was 7.46 m.yr^{-1} (2.75–11.96 m), but during the next period (1774–1779) of serious channel changes, the mean rates of erosion increased up to 37.03 m.yr^{-1}. (Pišút, 2002), the values reflecting the increasing river activity with peak values at Čunovo since 1780.

Comparable rates are reported from the Čičov meander whose banks retreated of at least 10 m only from the spring to November 1790 (Gyulai, 1896).

Active development of the Čunovo bend was confined to years 1783–1795. After its abandonment, the Čunovo meander quickly silted up. In 1808 (Fig. 8), both entrances of the channel were already almost filled with deposits and the surface area of water body shrinked almost to a half. Four decades later it represented less than one fourth of the original mainchannel width from 1790 (Fig. 9 – see cover p. 3).

6. Conclusion

The set of amazing old large-scale maps shows the rapid channel changes of the Danube River at the small village of Čunovo (Slovakia). Several maps were surveyed by the same person - Casparus Láb, the then official surveyor of Moson County.

Detailed analysis of the above maps revealed an until now completely unknown episode in the life of Čunovo village, which was undermined and partially carried away by the river in 1783–1794.

Apart from Petržalka and other destructed and/or relocated settlements (Pišút, 1995; 2006), Čunovo provides another "textbook" example of riverside village, being endangered by heavy lateral erosion during the last onset of the Little Ice Age.

Due to the devastating effects of extreme floods, reaction of regional authorities (Moson County) to heavy erosion had been both belated and insufficient and thus a part of the village was washed away. In 1790, expensive hydrotechnical remedial measures including two types of groynes had to be adopted to protect the undercut banks and to divert the flow. Most works were undoubtedly done by serfs from Čunovo itself and by residents of adjacent villages in the same county, as it was a common practice elswhere (Földes, 1896). Despite the successful mainstream deflection into a new channel, heavy lateral erosion still continued also in the original bend, so that the Locotenential Council as Habsburg´s central supervisory authority for Hungarian Kingdom, had to become involved. Eventually, a total of 16 solid stone groynes up to 40 m long were constructed to protect the undercut banks at Čunovo until 1796. Their remnants incorporated into the former bank should exist in the field until today, though obscured by secondary sediments and slope processes.

Out of the original Danube meander, only a small part of its bottom and point bar remained intact until present. Its major part was lost by the construction of the Gabčíkovo hydroelectric plant in the 1980s–1990s. Similarly as additional river forms from the same period (e. g. the Kopáč Island or the Čičov oxbow), also the remainder of the Čunovo palaeomeander represents an important nature monument, illustrating the highly energetic Danube River system of Little Ice Age period. Undoubtedly, it deserves legislative protection aimed at the conservation of the original river form and related floodplain forest vegetation. Another evidence of serious environmental changes in 1784–1794 is the current planform of the Čunovo city part, strongly determined by the disastrous event.

After a relatively calm period in the1980s, floods in Slovakia are becoming a significant determinating factor in the urbanised landscape again (Minár et al., 2005). This contribution illustrates a major potential of the historic maps to better understand destructive effects of the past extreme runoff events.

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3. Relations Plan über Den, durch das grosße Wasßer in Monath Novemb. 1787, beschädigten Flanschendorffer Fahr-Damm. Georg Jáczyg, 1788, 35.5 x 25 cm, sign. S12 D13 No129.
4. Relations Plan über die beschädigte Dämme bez Carlburg in Monath Novembr. 1787. G. Jáczyg, 1787, 21 x 31.1 cm, National Archives of Hungary, collection of manuscript maps, sign. tk 2524.
5. Mappa Designans defluxum Danubii Magni et Rapacitatem Littorum ad Possessionem Csun. C. Láb, 1790. 34.5 x 47 cm, sign. S12 D13 No 170:3.
6. PLANUM Repraesentans Capitalem Danubium una cum in, et efluentibus ramis, per terrena Szemeth, Gutor, et Csuny defluentem, ac una indigitans periculum, quod possessioni Gutor ex continua succussione ripparum, et demolitione aggerum im(m)inet, modalitatem insimul remonstrans, qualiter p(rae)mentionato periculo obviari possit.... Franciscus Eperjessy, May 1792. 70.5 x 51 cm, sign. S12 D13 No 200.
7. MAPPA Capitalis Danubii ad Csuny, et operationum Hydraulicum. Casp. Láb, 1794, March 4, 21.5 x 37 cm, sign. S12 D13 No 233.
8. PLANUM Geometricum Danubii Capitalis ad Csúny in I(nclyto) Co(mi)t(a)tu Mosonien(sis). Casp. Láb, 1794, June 20, 32 x 42 cm, sign. S12 D13 No 234.
9. PLANUM Geometricum Capitalis Danubii ad Possessionem Csún I(nclyto) Co(mi)t(a)tui Mosonien(si) adjacen(tem). C. Láb, 1795, January 30. 47 x 36.5 cm, sign. S12 D13 260.
10. MAPPA Geometrica Capitalis Danubii ad Pos(se)s(io)nem Csún I(nclyto) Co(mi)t(a)tui Mosoniensi ingremiatam. C. Láb, 1796, February 10. 56.5 x 44 cm, sign. S12 D13 269.
11. MAPPA Orificium Rami Mossoniensis, et Capitalem Danubium p(rae)terfluen(tem) rep(rae)sentans. C. Láb, 1800, March 13. 43.5 x 34.5 cm, sign. S12 D13 No313.
12. Copia PLANI Situationem Rami Danubialis Mossoniensis, tum etiam Danubii Capitalis exhibentis, assumti et delineati per Casparum Láb ... 25 June 1808. 64 x 70 cm, sign. S12 D13 No 367.
13. HIYDROTECHNISCHE Karte des Donaustroms von der Unter Oesterreichischen Gränze. Stanislaus Heppe, 1811, sign. S12 D11 No 74:6 and 7.
14. THE DANUBE MAPPATION, sheet NW XIII VIII 8. Samuel Forberger, 1825. 76.5 x 61.5 cm (http://www.dunamappacio.hu/online).
15. HYDROGRAPHISCH HYDROTECHNISCHE ÜBERSICHTS KARTE Von der Donau Strom Strecke zwischen Theben und Gutor. July to December 1834. 214 x 65 cm, sign. S12 D11 No 0091:02.
16. CADASTRAL MAP of the village Čunovo, 1856. Dorf SARNDORF ungarisch CSUNY in Ungarn Oedenburger District Wieselburger Comitat 1856. Total of 10 sheets, surveyed by Johan. Hedanek. Central Archives of Geodesy and Cartography, Bratislava.
17. MILITARY MAP (IIIrd Franciscan-Joseph´s) survey, sheet PRESSBURG und HAINBURG, Zone 13 col. XVI. Surveyed between 1869–85 (Biszak et al., 2007).
18. NATIONAL GRID MAP (Základná mapa) of ČSFR 1 : 10 000, sheets 44-24-18, 44-24-19, 44-24-23, 44-24-24.

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INTERNATIONAL CONFERENCE „STATE OF GEOMORPHOLOGICAL RESEARCH IN THE YEAR 2008“

Zdeněk MÁČKA

The ninth annual conference of the Czech Association of Geomorphologists (CAG) was held from 3 to 5 July 2008 in Šlapanice near Brno. The aim of the meeting is traditionally the reflection of research activities and new developments achieved by the Czech geomorphological community in the past year. From the modest former meetings of Czech and Slovak geomorphologists, originally organized by geomorphologists from the Ostrava University in the years 2000 and 2001, the conference evolved during the following years into a much-favoured scientific meeting, which is attended apart from Czech researchers by a growing number of foreign geomorphologists, mainly from Slovakia and Poland. This year of the serial was jointly organized by three geographical institutions from Brno – Department of Geography, Faculty of Science, Masaryk University; Centre of Environmental Geography, Institute of Geonics, Academy of Sciences of the Czech Republic; Department of Landscape Ecology together with Department of GIS Applications, The Silva Tarouca Research Institute for Landscape and Ornamental Gardening. The conference was held in the University Centre Šlapanice of Masaryk University. This year's meeting was attended by a large number of participants from the neighbouring countries and by many postgraduate students. More than a half of the participants arrived from Poland or Slovakia, i.e. from countries geographically nearest to the Czech Republic, which the Czech geomorphology has traditionally the tightest contacts with. Restrainedly and with pleasure, we can claim that the CAG conference has evolved into the largest tripartite meeting of central European geomorphologists.

During the first two days, conference papers were presented in two parallel sessions that were further divided into thematic blocs. On the third day, a field excursion was organized, which was devoted to the evolution of landforms at the southeastern margin of the Bohemian massif. The first day of the conference meeting was opened by four invited lectures given by our leading researchers in the discipline Prof. Jaromír Demek (The significance of geomorphology for the study of landscape) and Prof. Jan Kalvoda (Geomorphological aspects of global changes in endogenic hazards and risks) and by foreign guests Prof. Kazimierz Klimek (Past and present catchment–floodplain interaction – Osoblaha/Osobłoga, Eastern Sudetes and Foreland) and Prof. Jozef Minár (Morphostructures of the Western Carpathians in the light of the newest geological and geophysical evidence). The book of abstracts was distributed during the conference and a possibility to publish full texts of the conference papers was offered to active conference participants in the journals Moravian Geographical Reports and Geomorphologia Slovaca et Bohemica. The conference agenda was divided into the following thematic blocs: historic geomorphology and morphotectonics, fluvial processes and forms, glacial and periglacial processes and forms, slope processes and forms, geoinformatics in geomorphology and miscellaneous. The number of oral papers and posters presented at the conference was 60 and over 20, respectively, and the number of participants was over 80. Nine papers were presented at the session of historic geomorphology and morphotectonics, which were devoted to morphostructural analysis and morphotectonic response in the landforms of smaller areas and large geomorphological regions. Eighteen papers were presented at the session of fluvial processes and forms. Traditionally great attention was paid to historical changes of river channels and their floodplains, morphological differentiation of river landscapes and transport and deposition of fluvial sediments, including its human modification (influence of road networks, impact of water reservoirs). Seven papers were presented at the session of glacial and periglacial processes and forms, which were mainly devoted to the glaciation of our marginal mountains (Krkonoše, Šumava), partly also to the continental glaciation of Poland. Slope processes and forms were discussed in 10 papers. Most attention was paid to landslides and debris flows and their impact upon the landscape. This year, more papers related to the topic of geoinformatics and its application in geomorphology, so a special session had to be opened, which contained 7 papers. The papers covered variegated topics including geomorphological information systems, assessment of the precision of digital terrain model or utilization of GIS in analysing soil erosion on arable land. Some of papers were of specific theme and for them the session of miscellaneous was opened, in which issues such as karst investigations, results of biogemorphological research or theoretical and methodological problems were discussed.

On the third day of the conference, a field trip was organized by coach to three localities southeast of Brno at the margin of the Bohemian massif. The first visit was paid to the locality of Ledové sluje (Ice Caves) with outstanding deep-seated slope deformation and pseudokarst features and discussed were also the problems of the Dyje river development. In the following locality of Hostěradice, the conference participants visited medieval cellars excavated in the Lower Miocene sandy marine deposits, where new findings on morphotectonics of the area were presented. Visit to the last locality was devoted to the relationship between Miocene marine transgressions and landscape evolution in the Vedrovice locality where outcrops of the marginal facie of Lower Miocene sea were shown to the participants.

Professor Jaromír Demek is explaining the geomorphological development of the Dyje River in The locality of Ledové sluje (Ice caves) in the Podyjí National Park during field excursion (Photo: M. Havlíček)

I have been attending the CAG conferences since the very beginning, and therefore I can observe what changes the Czech geomorphology has gone through in terms of its scope and how the attendance of the conference increased during the last decade. Whereas some of research themes are evergreens in the Czech geomorphology (e.g. morhostructural analysis, slope processes), other ones have newly emerged and established a firm position already. Perhaps the most important change is a shift from long-term landscape development studies in large areas to works focused on smaller forms (slope, fluvial, glacial and periglacial) and shorter time intervals; indeed the Czech geomorphology has been recently exploring new spatial and time scales. The shift in the thematic orientation of Czech geomorphological research is best reflected in the titles of conference sessions, which follow the selected disciplines of dynamic geomorphology. According to my personal view, a great progress has been achieved for example by geographers from the Ostrava University in the research of slope forms and processes in the Moravian part of the Carpathians and abroad. Another newly established field of research at Charles University in Prague is devoted to the glacial and periglacial geomorphology of the High Sudetes Mountains. This research is conducted by young scientists who are surrounded with small teams of undergraduate and doctoral students. Czech geomorphology also focused on geomorphological hazards during the last decade, and on a greater utilization of geoinformation technologies (digital terrain models), geophysical methods and sedimentological analyses of correlate sediments. Nevertheless, it is necessary to admit that the Czech dynamic (process) geomorphology is still delayed behind the world's scientific community, which is evident for instance from the comparison with papers presented at the conference by Polish geomorphologists. Apart from the new research directions, the Czech geomorphology continues in the traditional research topics – e.g. morphostructural analysis, study of morphotectonic process or regional geomorphological investigations. My positive perception from the conference is a finding that foreign working experience is not only the case of several individuals but becomes still more usual among many young Czech geomorphologists including postgraduate students.

After a year, the conference brought together almost all Czech geomorphologists and a large number of their colleagues from abroad. I believe that this meeting from the series of conferences held by the Czech Association of Geomorphologists was motivating, enriching and at the same time a pleasant experience. I also hope that the conference helped to present the Czech geomorphological research beyond the boundaries of our rather small domestic arena and brought enriching research impulses from our foreign neighbours.

INSTRUCTIONS FOR AUTHORS

Moravian Geographical Reports publishes the following types of papers:

Original scientific papers are the backbone of individual issues of the journal. These theoretical, methodological and empirical contributions from Geography, as well as regionally-oriented results of empirical research from various disciplines, usually will have a theoretical and a methodological section, and should be anchored in the international literature. We recommend following the classical structure of a paper: introduction, including objectives and the title and other details of a grant project, when applicable; theoretical and methodological bases; empirical part of the work; evaluation of results; and discussion, conclusions and references. Scientific papers will also include an abstract (up to 500 characters) and 3 to 8 keywords (of these a maximum of 5 general and 3 regional in nature). With the exception of purely theoretical papers, it is desirable that each contribution has attached colour graphic enclosures, such as photographs, diagrams, maps, etc., some of which may be placed on the second, third or fourth cover pages. Papers on regional issues should contain a simple map indicating the geographical location of the study area. The maximum text size is 40 thousand characters, plus a maximum of 3 pages of enclosures. The number of graphic enclosures can be increased by one page provided the text is shortened by 4 thousand characters.

All scientific papers are subject to a peer review process, with two anonymous independent reviewers (one of whom preferably would be from outside the Czech Republic) appointed by the Editorial Board. The criteria for the review process include the following: an evaluation of the topicality and originality of the research problem; level of theoretical and methodological understanding of the problem; the methods used; the relevance of sources and references to the literature; and contribution to the development of the scientific area under study.

Scientific communications are meant to inform the public about current research projects, scientific hypotheses or findings. The section is also used for discussion of scientific debates or refining scientific opinions. Some contributions may be reviewed at the discretion of the Editorial Board. The maximum text length of a scientific communication is 12 thousand characters.

Scientific announcements present information about scientific conferences, events and international cooperation, about journals with geographical and related issues, and about the activities of geographical and related scientific workplaces. The scientific announcements preferably will be published with colour photographs. Contributions to jubilees or obituaries of prominent scientific personalities are supplied exclusively by request from the Editorial Board. The maximum text length of a scientific announcement is 5 thousand characters.

Moravian Geographical Reports also publishes reviews of major studies in Geography and other related disciplines, published as books or atlases. The review must contain a complete citation of the reviewed work and its maximum text is 3.5 thousand characters. Normally, graphics are not included.

More detailed instructions can be found at ***http://www.geonika.cz/EN/research/ENMgr.html***

The journal Moravian Geographical Reports is monitored in the SCOPUS database. Information about the journal can also be found on other web sites, such as the site of the American Geographical Society Library ***(http://www.uwm.edu/Library/AGSL/)*** or the site of the University of Colorado at Boulder ***(http://www.colorado.edu/geography/virtdept/resources/journal/journals.htm)***.

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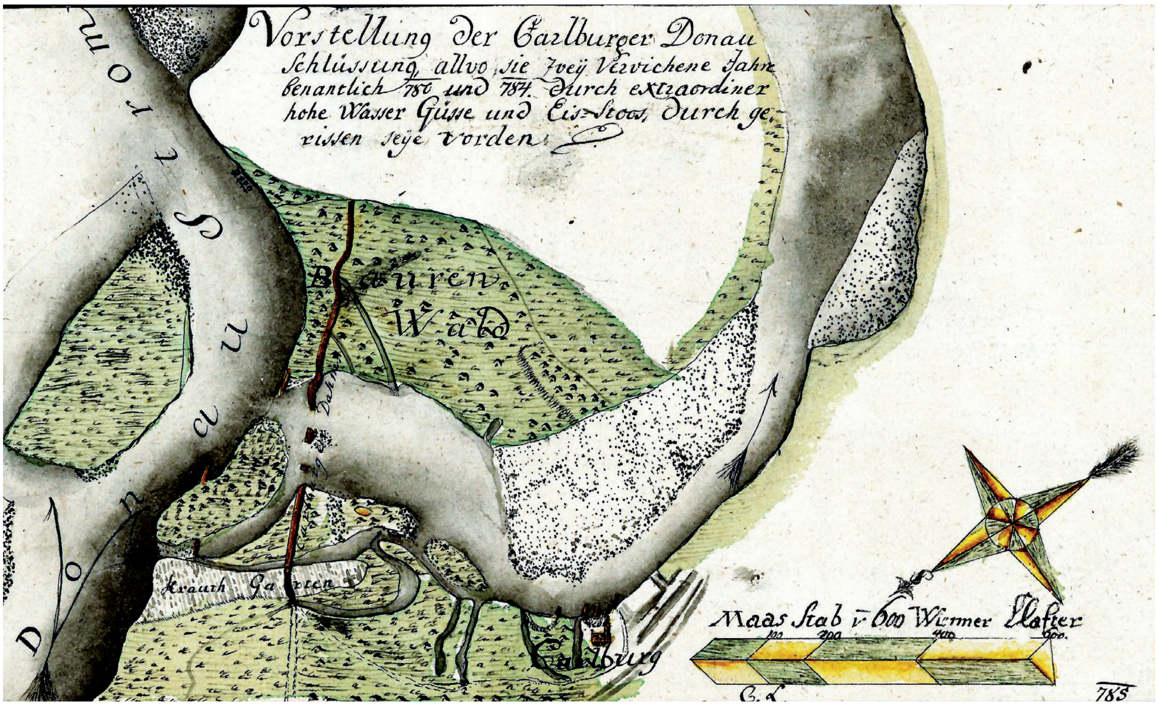

Fig. 7: Breaches to side-channel closure (and dike) at the village of Rusovce (Carlburg), illustrating the destructive force of 1780 and 1784 ice floods. Heavy lateral erosion in re-activated channel during these floods was also indirectly evidenced by extensive unvegetated point bars

Fig. 9: The Danube floodplain between Čunovo (Sarndorf) and Hamuliakovo (Gutor) in 1834 with the Čunovo abandoned side-channel

Illustrations related to the paper by P. Pišút

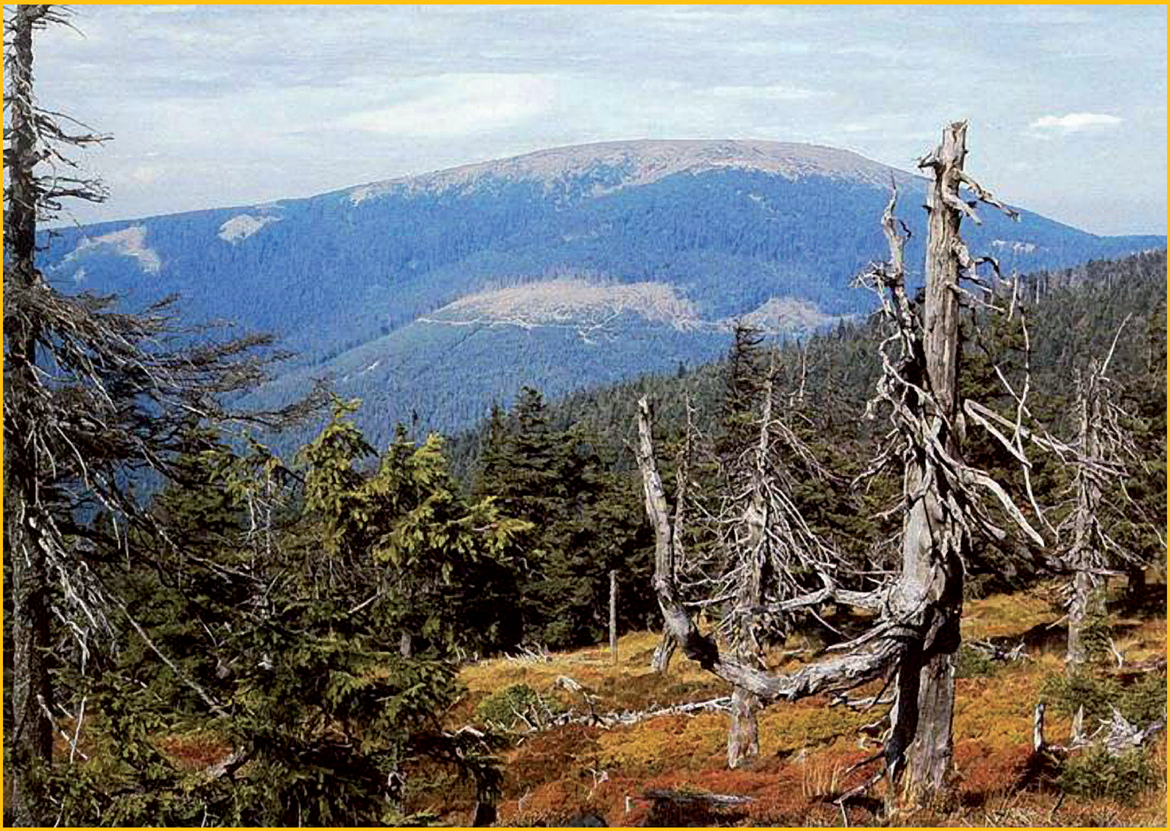

Fig. 2: The impact of altitude on vegetation on the slopes of Králický Sněžník Mt. (1423.7 m a.s.l.). The top of the mount reaches above the upper timberline (source: Archive VUKOZ)

Fig. 3: The Labe R. canyon through the Děčínská vrchovina Highland with the developed valley phenomenon (source: Archive VUKOZ)

Illustrations related to the paper by J. Demek