ČAG ČESKÁ ASOCIACE GEOMORFOLOGŮ

Geomorfologický sborník 16

MUNI Mendel University in Brno ÚGN




Sborník abstraktů konference

Stav geomorfologických výzkumů v roce 2018

Vílanec

25.–27. dubna 2018

Editoři:
Zdeněk Máčka, Jaroslava Ježková, Eva Nováková, František Kuda

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Editorial

Meetings of Earth scientists from Czechia, Slovakia, Poland and recently also from Hungary at annual geomorphological conferences „State of geomorphological research“ organized under auspecies of Czech Association of Geomorphologists have already become a tradition. Thus, we meet at already 18th international conference „State of geomorphological research in 2018“ from 25 to 27 April in the village of Vílanec near Jihlava in the heart of Bohemian-Moravian Highland.

Organization of the recent conference is a joint effort of several institutions placed in the city of Brno dealing with geosciences in some way:

- Department of Geography, Faculty of Science, Masaryk University;
- Institute of Geonics of the Czech Academy of Sciences, branch Brno;
- Department of Geology and Pedology, Faculty of Forestry and Wood Technology, Mendel University

Partner of the conference is National Geopark Vysočina.

Contributions both from basic and applied research in the field of geomorphology and related disciplines are being presented at the conference. We hope the conference, as in the last years, will become an inspiring event through exchanging ideas, knowledge and connecting people. The conference have become especially fruitful for presenting student research and meeting of young and senior researchers. Integral part of the conference is announcement of student award for excellent bachelor, master and doctoral thesis.

Postconference field trip in the region of the Geopark Vysočina will get participants familiar with basic features of the landscape as well as selected places of interest – castle Roštejn and adjacent geological exposition, stonemason company in Kaliště village, block fields and rock outcrops at Štamberk, Velkopařezitý rybník (pond) and finally Míchova skála, emblematic landform of the Geopark Vysočina.

We wish you pleasant time in Vílanec.

Zdeněk Máčka
on behalf of the organizational team

THE EFFECT OF POINT-BAR FORMATION AND BANK EROSION ON THE MORPHOLOGY OF THE LOWER TISZA RIVER, HUNGARY

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Alluvial rivers have been a widely studied subject of recent researches in geomorphology (Knox and Latrubesse, 2016; Wang and Xu, 2018), as their morphological changes afftect their human use, and also the risks and hazards. Key points in the morphological evolution of meandering lowland rivers are the bank erosion and the formation of bars, as they could indicate channel processes and equilibrium conditions of a reach. In recent years, several researches focused both on bank erosion (Piégay et al., 2005; Schuurman et al., 2016) and on the development of point-bars (Wang and Xu, 2016; Wang and Xu, 2018). According to Schuurman et al. (2016), spatially alternating bank erosion and point-bar growth are crucial in the development of meanders in rivers. While bars serve as sinks for sediments in alluvial rivers, bank erosion on the other hand is often the dominant source of sediments especially in modified watersheds (Shields et al, 2009). Bank erosion resulting from mass failure of steep banks is one of the most serious forms. The state of bars on the otherhand, are representative of the equilibrium of channels (Church and Rice, 2009).

The Tisza River in Hungary has been altered by various human interventions since the 19th century. It began with construction of embanked levees to control floods, artificial meander cutoffs and channelization to improve shipping and shorten the floodwaves, as well as recovering land for agricultural purposes. Later works included the construction of revetments and groynes to control the lateral erosion of the river. In the last fifty years, dams have also been constructed to support irrigation and to generate electrical power. As a result of these intensive human impacts, the channel processes seem to change. In a natural state (pre-19th c.), the Tisza had a meandering pattern with alternating point-bars. However, only some point-bars remain nowadays, the channel incises and bank erosional processes alter. The aim of the present research is to reveal the driving factors of recent point-bar formation and bank erosion, to determine the rate of these processes, and finally to give an evaluation on the channel evolution of the studied reach.

Our study was performed on the 89-km-long section of the Lower Tisza River (between Csongrád and the Hungarian-Serbian border). Here, the regulation works doubled the slope (2-4 cm/km) and reduced floodplain (from 10-20 km wide floodplain to just 1-5 km; Kiss et al., 2008).

To understand the role of point-bars and bank erosion in the morphological evolution of the Lower Tisza River, two approaches were applied. Firstly, to evaluate the long-term morphological changes of the river, military maps (since late 18th c.), hydrological surveys (1891-1999) including the planform and vertical cross-sectional parameters were applied. Based on this series of maps, the sinuousity, the width, the number and the length of point-bars were determined. Secondly, in selected study sites, the recent evolution of point-bars (at Csongrád and Ányás), and the rate of bank erosion (Csantelek 1-2, and Ányás) were measured and analyzed between 2013 and 2018 using an RTK GPS.

In a natural state, before the regulations, the sinuousity of the channel was high (with up to 30 meander bends), point-bars appeared in every bend, and the channel was realtively shallow (6-8 m).

Between 1891 and 1999, the channel experienced a 4 % increase in cross-sectional area in average, whilst its width reduced by 19 %, and the depth increased by 20 %. The narrowing of

the channel was as much as 52 % in some locations (e.g. at Csanytelek 2 study site). The cross-sections reflect, that where the bank erosion stopped by revetments the development of the point-bars continued, however due to the incision of the channel these point-bars melted into the banks and were colonized by trees, so finally they disappeared. Nowadays only 5 point-bars remain on the 89-km-long section. The results of our surveys showed that the point-bar at Csongrád is loosing sediments, in average 0.2 m/y. At the Ányás point-bar the upstream and downstream sections eroded by a similar rate of 0.2 m/y, however, there was deposition in the middle section. The difference between the studied point-bars is the existence of human impact: at the Csongrád site the revetment and groines altered the point-bar development, whilst at Ányás the bend develops withouth direct human impact, thus the point-bar accumulates. The rate of bank erosion is 1.0-1.2 m/y.

The Lower Tisza River like many rivers is adjusting its equilibrium in response to various human interventions (Kiss et al., 2008). The Lower Tisza experienced an increase in the specific stream power and increased flood height which are necessary conditions for increased erosion. The increased high water level coupled with lower low water level are conditions for increased bankline erosion (Rinaldi et al, 2008), and this is exactly what has happened on the studied sections: the rate of bank and point-bar erosion exceeds the rate of accumulation, referring to general channel incision. It suggest, that the originally meandering pattern of the river is transforming towards and ingrown meandering one.

Keywords: Bankline, point-bar, morphology, Lower Tisza River, erosion

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HOW THE NUTRIENT CONTENTS VARY AMONG HABITATS IN GRAVEL-BED RIVERS?

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Currently, we can find several studies examining the relationship between habitats and nutrient contents in rivers. Most of them reported that the nutrient supply is higher in later succession stages. This conclusion is based on the carbon, nitrogen or phosphorus contents, while micronutrients or physical properties are usually neglected. This study clarifies the relationships between habitats and properties of sediments of three submontane gravel-bed rivers in the Czech Republic (the Bečva, the Opava) and Slovakia (the Belá). For both Czech rivers renaturalized sections incurred after the flood in 1997 were selected, in case of Belá natural segment with minimal human impact (the channel patterns: Bečva – pseudomeandering channel, Opava – sinuous channel with bars, Belá – wandering channel). For each river 50 samples of subsurface layers were collected and the following physical-chemical properties were measured: soil reaction, conductivity, contents of organic and inorganic carbon, nitrogen, phosphorus, calcium, magnesium, sodium, potassium, manganese, iron, copper and zinc contents. The nutrient contents and physical properties vary among the rivers. Therefore data were standardized by range to allow analyze the differences between habitats (sparse vegetation, herbs, shrubs and tree vegetation in active channel and floodplain) in all rivers. For the comparison the differences the Kruskal Nemenyi test was performed. Our analysis showed that the soil reaction and organic carbon are the best variables to explain the differences between habitats. In later succession stages (floodplain and trees) is pH lower due to accumulation of organic matter and its decomposition. For the same reason the organic carbon content is higher in later succession stages. In potassium, copper and zinc contents we can find statistical significant differences between sparse vegetation and other habitats, but not between herbs vegetation and floodplain or shrubs and herbs vegetation. Variables like inorganic carbon, conductivity, manganese contents do not differ between the habitats.

Keywords: Bečva River, Belá River, Opava River, gravel-bed rivers, nutrients, habitats

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COMPLEX ASSESSMENT OF CHANNEL CHANGES AND BANK EROSION HAZARD ON THE SAJÓ RIVER (HUNGARY)

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The Sajó River (or Slaná in Slovakian) is a transboundary river of Slovakia and Hungary with a total length of 229 km, of which 124 km is located in the Hungarian territory. In the Hungarian territory it has an alluvial meandering channel type and shows one of the highest rate of free forming sub-reaches in compare with other alluvial rivers in Hungary due to the lack of extensive river engineering works.

In our previous studies (Bertalan and Szabó 2015; Bertalan et al. 2016) we intended to introduce our monitoring investigations on the recent trends of bank erosion processes. Selected bends of the most intensive shifting sub-reaches were analysed by UAV drone surveys. It turned out that several meters/year rate of bank retreat occurs in most of the sample areas. Contrary to the horizontal shifting we started to investigate the vertical profiles of river banks (Bertalan et al. 2018) by terrestrial close-range photogrammetry and Structure-from-Motion methods using a DSLR camera and RTK GPS.

With the purpose of understanding the changes of channel morphodynamics a detailed morphometric analysis had been carried out on the total Hungarian reach of Sajó River. The analysis was based on cartographic data, historical aerial imagery and digital ortophotographs in 8 time periods between 1952 and 2011. On the individual bend level several planform parameters had been calculated (i.e. chord, amplitude, radius of curvature). The rate of bank erosion/accretion and mean channel shift had been evaluated by the overlapping bank polygons and centerlines.

Keywords: channel morphodynamics, bank erosion, planform morphometry

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DATABASE OF GIANT LANDSLIDES FROM VOLCANIC ISLANDS - FIRST RESULTS

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Giant landslides on volcanic islands represent the largest formations which can be created in a single geological moment. Such landslides are distributed across the globe and have attracted a significant amount of research interest. Yet, no coherent attempts have been made to rationalise this information into a single online resource. This contribution summarises information about the structure of the recently created database of giant landslides on volcanic islands and presents some observations regarding the uncertainties inherent in the inventories. The database comprises information about giant landslides around the Atlantic, Pacific and Indian Oceans. Basic statistics of the giant landslides are presented. Using this database, it should be possible to interrogate the spatial and temporal patterns of land sliding and landslide reactivation as well as to better assess the hazard and potential risks posed by giant landslides on volcanic islands. It will be particularly interesting to see if any evidence can be found for global triggers, such as eustatic or climatic changes, instead of the more commonly expounded local triggers. Ultimately, it is hoped that the database will benefit both the geoscientific community and those agencies responsible for civil defence. The database is available from the giant landslides project webpage: https://www.irsm.cas.cz/ext/giantlandslides.

Keywords: giant landslides, bathymetry, global database, debris avalanche, slump

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Blahut J, Klimeš J, Rowberry M, Kusák M (2018) Database of giant landslides on volcanic islands – first results from the Atlantic Ocean. Landslides 15(4): 823–827. doi: 10.1007/s10346-018-0967-3

INVESTIGATION OF THE PERIODS OF SAND MOVEMENT WITH DIFFERENT DATING METHODS IN THE NYÍRSÉG, HUNGARY

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The Nyírség is the second largest sand dune area in the northeastern part of the Carpathian Basin. The Nyírség have been studying for over 100 years but geological and geomorphological research can still contribute to the understanding of the surface development of the area.
In the Carpathian Basin the Nyírség is the second largest sand dune area (ca. 4600 km^2), formed on the alluvial deposits of the Tisza River and its tributaries. At around 25 ka, fluvial processes terminated on the territory; and during the rest of the Pleistocene, aeolian processes prevaile. The strong north-westerly, northerly, north-north-easterly winds formed mostly blowouts, oval shaped sand hummocks and residual ridges. Parabolic sand dunes also evolved on a larger scale in the Nyírség.
The first significant sand movement in the Nyírség happened in the Upper Pleniglacial and the Late Glacial. The main landforms of the Nyírség developed at this time. The aeolian transformation of the land has not finished at the end of the Pleistocene. In the Holocene the sand moved within small area, mainly by anthropogenic impact.
Our aim is to clarify the age of the wind-blown sand movement periods, with different absolute dating methods (Radiocarbon dating method, OSL) and relative dating methods (palinolgical examinations, archeological finds).
We collected soil (Gyüre, Vásárosnamény, Kótaj), charcoal samples (Gégény, Kántorjánosi, Nyíradony, Nagyvarsány, Máriapócs, Petneháza, Gyüre and Lövőpetri) from many sand quarries which contain fossil soil layer for radiocarbon dating. For the OSL measurements samples were collected from Baktalórántháza, Gégény and Kántorjánosi sand quarries. For the palinological analysis we made five boreholes (Máriapócs, Nyírtanya, Nyírábrány, Vámospércs and Nyírlugos) and we visited an archeological excavation near Nyíregyháza-Oros.
Different age determination methods supported each other well. The age data support the results of previous researches. In the Nyírség the first major sand movements happened in the cold and drier period of the Upper Pleniglacial and Late Glacial (Baktalórántháza, Máriapócs, Lövőpetri, Nagyvarsány-Szabadságtanya, Gyüre, Petneháza, Nyírábrány). At the end of the Pleistocene the sand movements have not finished in the Nyírség (Gégény, Kántorjánosi).
Sand movement in the first half of the Holocene, in the Preboreal and in the Atlantic Phase took place due to climatic and anthropogenic effects also (Gégény, Kántorjánosi, Kótaj).
In the Subatlantic Phase, there were many little sand movement periods, mainly caused by anthropogenic impacts (Nyíradony, Nyíregyháza-Oros, Nyírlugos).

Keywords: Aeolian activity, OSL, radiocarbon dating, Pleistocene, Holocene, Nyírség, Hungary

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DELINEATING FLOOD EXTENTS WITHOUT HYDRODYNAMICS – YES OR NO?

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Traditional approach to delineating flood extents is through the hydrodynamic modelling procedures or geographic information systems (GIS). The former follow the the laws of physics describing the flow of water in channels and inundated areas (Murty et al., 2014). The latter is primarily based on the comparison of flood water surface elevations and the digital elevation model (DEM). Despite the absence of hydraulic connectivity and the omission of friction, such approaches have been successfully applied in multiple works for the identification of areas prone to being flooded (Wang et al., 2002, Zheng and Wang, 2006, Tonisson et al., 2008, Chau et al., 2013, McInnes et al., 2015, Seenath et al., 2016).
The AIZM model (Koli, 2013) is a GIS-based non-hydradynamic tool for delineating flooded areas based on known water surface elevations and DEM. Since the computation neglects hydrology and hydrodynamical aspects of flowing water, one could expect bad performance of the model. In order to evaluate the tool's ability to produce relevant outputs, it was tested using in 30 river reaches. The analysis was based on comparison of the modelled flood extents with those acquired from airborne imaging during real flood events that occurred in the Czech Republic in summer 1997, 2002 and spring 2006, and post-event field surveys. The input water depths were derived from flood marks' elevations.
The AIZM's performace was assessed taking into consideration the contribution of various river reaches' and the adjacent floodplains' characteristics to the flood extents' accuracy. The analysis allowed the identification of both the key limitations and the generally favourable conditions under which the AIZM model is able to deliver accurate outputs.
Based on the results, on of the main conclusions of this research is that the AIZM model can be a useful tool for the delineation os flooded areas in cases where only flood water surface elevations are available, for instance for reconstructions of inundations during past flood events, as well as for promt displaying in an operational use.

Keywords: AIZM, digital elevation model, flood inundation, flood marks, GIS

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TEMPORAL CHANGES OF DEBRIS FLOWS TRACKS IN THE ROHÁČSKÁ VALLEY, WESTERN TATRA MTS.

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This paper focuses on description and quantification of debris flows length and areal changes over time in the Roháčská Valley and its tributary valleys, Western Tatra Mountains, using remote sensing data. Aerial images taken in 1973, 1986, 2003 and 2015 were used to delineate the spatial extent of debris flow tracks and to define their initiation and deposition areas. Changes within the whole period 1973 – 2015 were quantified and a general trend in debris flows length and spatial extent was outlined. Selected morphometric characteristics (e.g. slope, aspect) for both the initiation and deposition areas were determined for the present debris flow tracks using the digital elevation model. All the derived attributes were subsequently studied in detail using statistical tools in order to describe the general character of debris flow tracks identified in the different parts of the study area.
About one hundred of debris flow tracks presently occur in the study area. The mean altitude of their initiation and deposition areas is about 1880 m a.s.l. and 1770 m a.s.l., respectively, whereas their mean slope is 43° and 35°. The area of the debris flow deposition zones have decreased by 15 % and 22 % during the period 1973 – 1986 and 2003 – 2015, respectively, which contrasts with observations from the High Tatra Mts.

Keywords: debris flow, remote sensing, morphometry, Western Tatra Mts.

PRECISION OF LANDSLIDE MONITORING TOOLS: A CASE STUDY OF DUNASZEKCSŐ, SOUTHERN TRANSDANUBIA

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Due to the changes in the world's climate and the increasing number of weather extremities, mass movements play more crucial role on Earth surface, as never before (Szabó 1996). Landslides are common on the right bank of the Danube River, between Budapest and Mohács, in Hungary. Landslides strongly influence the landform evolution of the whole area of the aforementioned region, however, the most severe landslides occurred at Dunaszekcső in 2008 and 2011 (Újvári et al. 2009, Bányai et al. 2014). Landslide movements might be triggered by different physical, geological, hydrological and meteorological factors. Their occurrence is preconditioned by loess layers, paleosols, steep slopes of the Danubian high bluff and they are triggered by extreme precipitation and the water level fluctuation of Danube River (Pécsi and Schweitzer 1995). Knowing that, it is quite challenging to find the most suitable tools and methods in order to explore a successful way to monitor and to describe the landslide's mechanism.

Researchers used numerous methods for landslide monitoring at Dunaszekcső, such as DGPS measurements, tilt measurements and even remote sensing techniques with the intention of understand the nature of the landslides. Former researches covered only limited number of surveys and lasted for shorter time and did not provide information about the precision of the used tools. Despite of detailed measurements, our understanding on the mechanism of landslides are still scarce.

The methods of our research covers the whole investigated area by four widely used tools: DGPS, total station, analog theodolite and remote sensing. These tools have different operational principles, hence their precision differs as well. Our long-term monitoring using these tools covers ten years, which provide an outstanding source of data for define and compare the precision of the above-mentioned tools.

To identify the dynamics of the Dunaszekcső Landslide we used different grid networks. For analog theodolite we established 2.5×5 meter grid network (Bugya et al. 2011), in which altitudinal changes of the surface were measured from 2007 until 2008 approximately monthly. For DGPS and total station we established 5×5 meter grid network (Kovács et al. 2015). We measured X, Y and Z position of the points with total station in almost every third month. With DGPS we carried out nine measurements through the years. Paralelly, ERS, Envisat and Sentinel-1 based PSI and SBAS (interferometric stacking) measurements of the whole area was done. Stable scatterers were absent on the active landslide, due to the vegetation cover. Moreover, it is clearly seen also from field surveys that displacements were beyond the detection range of the above-mentioned C-band SAR sensors, since maximum unambiguous displacement of the surface has to be slower than quarter of the wavelength between acquisitions (Ferretti 2014).

As a result, we compared and demonstrated the selected tool's limitations and precision. Furthermore, we were able to notice the source of measurement inaccuracies. Considering the exact precision and limitations of the aforementioned tools, our data can provide a more precise insight into the mechanism of the landslide.

Keywords: monitoring, landslide, GIS, precision

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THE ICE-CONTACT ENVIRONMENT OF THE KUTNO MORAINES NEAR SŁAWOSZEW, NORTH-CENTRAL POLAND

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A commonly occurring feature of most glaciogenic convex forms of the Wartanian (late Saalian, MIS 6) in Central Poland is the internal structure formed mainly by accumulation of meltwater with a slight share of direct glacial accumulation. Sedimentation structures originated in this way are characterised by a great variety, which indicates a considerable diversity of features of sedimentation basins – variability of their conditions both in time and space. This is superimposed with the occurrence of deformation structures. Additionally, the fact that they are not remains of the most recent (Vistulian) but the penultimate glaciation increases the interpretation difficulties owing to transformations of the relief taking place for more than 130 thousand years: since the end of the Wartanian until the present day. It is the so called old moraine landscape (orig. ''krajobraz staroglacjalny").

This richness of internal structure in glaciogenic forms of Central Poland has been the cause of a lively discussion on the genesis of many of them. Many convex forms, initially interpreted as typical end moraines, were identified in later research as kames or other forms related to areal deglaciation (among others: Klatkowa 1972, Klajnert 1978, Rdzany 2009). In the event of the association of forms near Sławoszew, referred to as the Kutno Moraines (Lencewicz 1927), no detailed analyses of its internal structure have been conducted to date (except for geological charting), none of the oldest views on their end-moraine genesis have been verified and it became the primary aim of these studies.

Results of the conducted geomorphologic research (analysis of hypsometry, slope gradients etc.), particularly the clear asymmetry of slopes (with the southern slope being more steep) can indicate – in accordance with classical views on glacial relief (Klimaszewski 1978) – that these forms originated as a result of accumulation processes at the ice sheet front. Besides, the relief lacks elements which might indicate a connection with the most recent glaciation. However, its maximum extent is not far away – the distance of roughly 20-25 km. Analyses of the structures may indicate a contact of the northern slope with the active margin of the ice lobe, but the deformations are minor and few. The existing outcrops, especially those located in the three operating open-pit mines, allowed for lithofacial analysis to be conducted, which provided evidence for accumulational genesis of the studied forms. Therefore, there are no grounds for defining them as push moraines. They also reveal no features characteristic of kames (Baraniecka 1969).

A great abundance of sediment texture types was identified – from fine glaciolacustrine sediments to megaclasts (of up to even 2 m in diameter) – related to high energy water transport and movements of masses in the zone of close contact with the ice sheet front. Lithofacial analysis indicates a predominance of accumulation characteristic of outwash fans with a slight content of channel transport in the conditions of free fluvial flows. However, some flows were hyperconcentrated, while others were of debris flow type. A great lithofacial diversity may indicate irregular character of ice sheet melting, without a clearly ordered ablation rhythm. Besides, the geologic structure of the deeper substratum features no

indications whatsoever as to the formation of these end moraines in strict dependency on the sub-Quaternary and sub-Cainozoic bedrock.
Currently, the research results, despite allowing for significant conclusions to be drawn, still contain a number of issues which require explanation, therefore the research will be continued.

Keywords: old moraine landscape, end moraine, Kutno Plain, hyperconcentrated flow, debris flow

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ASSESSMENT OF DYNAMICS IN RECENT DEVELOPMENT OF A SINGLE-THREAD GRAVEL-BED RIVER (CASE STUDY OF THE POPRAD RIVER IN FORELAND OF THE HIGH TATRAS MTS.)

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The objective of the contribution presents the character and dynamic development of the Poprad River in the river section from Svit to state boundary with Poland with a total length of 87.5 river kilometers. The aim of the study was to identify morphological changes as a river bar area, bank width and lateral bank shift based on remote sensed data (1949, 1986, 2003 and 2014) in the GIS environment. The interpretation of the causes of morphological changes is based on an analysis of variability of four initiators: hydrological input, composition of riparian zone, forestation of catchment and human impact. Human impact has been identified as a dominant factor in changing the behavior of the river for last 65 years due to channelization from 7.8% (1949) to 30.6% (2014). The deforestation as an indirect human impact in the source zone of the river during period 2000-2012 is 10-times larger than in the period 1990-2000.

Keywords: river bar, bank line, multitemporal analysis, development, Poprad

PRELIMINARY MORPHOCHRONOLOGY OF TWO GLACIAL SITES AT THE BOHEMIAN FOREST (BAVARIAN PART)

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Reconstruction and prediction of climate change are an essential issues of the present-day geography. Data obtained by local glacial chronologies are used to reconstruct the Pleistocene environment and climate. This paper deals with morphology and morphometry of two sites influenced by the Pleistocene glaciation at the Bavarian part of the Bohemian Forest (Šumava) Mts. and both sites are placed in the Bavarian Forest National Park. Morphochronologies of both sites were determined according to analysis of accurate (LIDAR based) DEM. The first site is a stairways glacial cirque on the northern flank of Großer Rachel Mt. The cirque is situated below the ridge with a significant top plateau. Although not a lake is located at the bottom of the cirque, extended wetlands and peat-bogs can be connected with the overdeepening of the cirque floor. The second site is a glacial cirque on the eastern flank of Steinfleckberg Mt. The cirque is connected with the extensive ridge plateau from witch, probably, snow was deflated into the cirque. Wetlands and peat-bogs at the bottom of the cirque could implicate overdeepening of the cirque floor too. Hypothesis of the extensive glaciation, which assumes 7 km long glacier tongue, has been disproved by the comparison of a historically mapped moraine ridges and the DEM. Three morphochronological phases of the glacier retreat were determined in the northern cirque of Großer Rachel Mt. In contrary, two significant morphochronological phases of the glacier retreat and one older phase, which is not as significant as the previous were determined in the Steinfleckberg cirque.

Keywords: glaciation, Bavarian Forest National Park, morphology, morphometry

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GLACIER RETREAT AND SELECTED (GEO)ENVIRONMENTAL CHANGES IN THE CHURUP VALLEY, PERUVIAN ANDES

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The most heavily glacierised tropical range in the world – the Peruvian Cordillera Blanca - has been losing ice since the end of the Little Ice Age (LIA). The decline of the Churup glacier (9°28'18" S; 77°25'02" W) and associated processes are documented using the analysis of remotely sensed images (1948-2016), the Schmidt hammer rock test and lichenometric dating. It is shown that Churup glacier has lost the vast majority of its estimated LIA areal extent (1.05 ± 0.1 km^2) and with an area of 0.045 km^2 in 2016, it is expected that the complete deglaciation of the Churup valley is inevitable in the near future. Two principal zones are distinguished - Zone I being deglaciated since the LIA and Zone II deglaciated before the LIA. Recently exposed bedrock surfaces (Zone I) have shown higher R-values (54.2 - 66.4, AVG 63.3, STDEV 2.9) compared to pre-LIA exposed surfaces (46.1 - 59.3, AVG 50.1, STDEV 4.9), confirming the links to the duration of rock weathering. Colonisation of lichens rhizocarpon geographicum is observed on recently exposed surfaces in Zone I at elevations of up to 4,886 m asl; our results, however, show that the application of traditional lichenometrical dating in such an environment does not provide unconditionally reliable results. Finally, the characteristics of two zones are compared. It is concluded that recently deglaciated areas have undergone dynamic changes, which may, in turn, affect much larger areas (e.g., the influence on the water regime, initiation of long-runout slope movements), and need further appropriate scientific attention.

Keywords: Cordillera Blanca, tropical glaciers, deglaciation, lichenometry, rhizocaropon geographicum, Schmidt Hammer, Andes

HIDDEN PERIGLACIAL LANDFORMS OF TRANSDANUBIA, HUNGARY

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Surface periglacial features were described by authors in the last eighty years in Hungary. At least two main regions of these elements can be distinguished concerning their geomorphological position. Low mountainous regions (above 400 m asl) were affected strong cryogenic effects resulting cryoplanation walls or towers, terraces and slopes with block and debris fields (Székely 1977; Pinczés 1986). Lowlands, alluvial plains and fluvial terraces (below 300 m asl) of North-Western-Central Hungary are relatively reach in cryoturbations and other frost-related soil deformations (Fábián et al. 2014; Pécsi, 1997).

Thermal-contraction cracking of the ground usually forms a polygonal network as the most widespread and visible feature of permafrost areas (French 2007). The polygonal pattern of ice or sand wedges could be simply identified using aerial photography or even high-resolution satellite imagery (Levy et al. 2010; Ewertowski et al. 2016). These crop-marks are periodically visible as differences in the vegetation cover. However, in our case, they could also be identified on the bare agricultural fields during the winter period. The visibility of the polygon edges is influenced by the thickness of the Quaternary cover, soil moisture differences, the contrast in the surface lithology of the filling and host materials, vegetation type, cultivation and erosional processes and also the meteorological conditions during image acquisition.

Formerly, polygons were rarely reported in Hungary based on field observations studying profiles in opencast mines (Pécsi 1997; Kovács et al. 2007). A project for 'analysing thermal contraction crack polygons from satellite imagery using GEOBIA' was started to study polygonal patterns of the Kemeneshát mesoregion. The main goal was to explore the spatial arrangement and geometric characteristics of this complex landforms. Samples were also taken from a profile of a gravel pit for further laboratory investigation, as optically stimulated luminescence dating and particle-size distribution analysis.

The polygon network exploration was based on WorldView-1 panchromatic images with 0.5 m horizontal resolution. The image analysis and post-processing of the prepared vector dataset were carried out using GIS software. Parallel, other satellite images were explored on Google Earth using the 'Historical Imagery' function to detect the forms on further satellite images between 2006 and 2017. The satellite image-based mapping was completed with a pilot study using ground penetrating radar method and an experimental mining surface mapping with drone images, as well.

The results show that the delineated polygons mostly have five-seven edges, the most frequent sizes vary between 13–23 meters, the biggest polygons reach the 50–60 meters diameter and the edges intersect with angles between 110–130°. Based on these characteristics we found that from the categories of Ewertowski et al. (2016) the irregular, small, non-orthogonal polygons are most representative of the Kemeneshát mesoregion. The obtained values show a strong similarity with relict forms found in other regions of Europe (Bertran et al. 2013; Ghysels & Heyse 2006). Preliminary results on numerical ages of relict sand wedges suggest that thermal contraction cracking occurred between 23 and 16 ka. Similar ages of a relict sand wedge polygon were announced on another study site in North-Central Hungary (Fábián et al. 2014).

Keywords: periglacial zone, polygonal network, relict sand wedge, fluvial gravels, Kemeneshát, Hungary

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THE PROBLEM OF IDENTIFYING ESKERS AND THEIR MORPHOLOGY IN CENTRAL POLAND

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Eskers are fluvioglacial forms which are predominantly long, narrow and sinuous. They are formed in subglacial or englacial tunnels, in ice-walled supraglacial channels, subglacial cavities and subaerially or subaqueously at tunnel or channel mouths (De Geer 1897, Brennand 1994, Warren and Ashley 1994). Subglacial tunnels, in which eskers are created can be divided into N-channels, which are cut in the substratum by meltwater, and R-channels – cut in the bottom of a glacier or ice sheet. Eskers can be formed simultaneously along a long fragment of a glacial tunnel or time-transgressively during the recession of the ice margin (De Geer 1897). Eskers are mostly built of sands and gravels deposited from flows which were often under hydrostatic pressure.

Identification of eskers, determination of their morphological and sedimentologic features and reconstruction of the conditions of their origination provide a great deal of information on the drainage system, dynamics and conditions of ice sheet deglaciation. Identification of eskers in Central Poland and more detailed research into them took place during the preparation of the Detailed geological map of Poland at the scale of 1:50 000 and regional research (e.g. Baraniecka and Sarnacka 1971, Michalska 1971, Jaksa and Rdzany 2002, Frydrych 2016). A significant problem in identification of eskers in the Polish Lowlands is their complex genesis. Most of them are formed within glacial tunnels, which are then remodelled into open channels (Michalska 1971, Fard and Gruszka 2007). This creates a problem with genetic classification of forms, which are sometimes indicated as eskers, crevasse forms or even kames.

Based on the Detailed geological maps of Poland, a review of eskers in Central Poland, within the extent of the Warta glaciation, includes about 70 eskers built of over 300 smaller forms. Eskers of Central Poland, which were formed during the Warta glaciation (late Saalian, MIS 6) are characterised by considerable disintegration in comparison with forms which originated during the Vistulian glaciation (Last Glacial Max., MIS 2). Single forms were divided into sections: from several to about a dozen, of < 1 km in length, which makes it difficult to reconstruct the primary esker features. Location of most eskers along river valleys, which most probably use old tunnel channels, indicate the presence of conditions in which eskers could easily undergo erosion and division into segments. It cannot be ruled out that some forms were created time-transgressively during subsequent stagnation of ice margin and formed the so-called short beads (Warren and Ashley 1994). In the further part, sets of such sections which constitute a single form will be called esker sequences.

The average length of identified esker sequences in Central Poland is 3.5 km, and the longest one is 10 km. The longest, uninterrupted fragment of an esker is located in the sequence of the Grójec esker and is ca. 7 km long. The width of the forms ranges between 1.5 km and ca. 100 m. The mean elongation of eskers, expressed as the ratio of the length to the width is 7.2, and the maximum value is 16.5. In Central Poland, only a few visibly sinuous forms were identified. It seems that the morphology of some forms was transformed by the later processes of accumulation and erosion. The distribution of esker orientation is bimodal, and the largest number of eskers are oriented NW-SE and NNE-SSW, which is related to the direction of ice sheet movement in different ice streams.

In terms of morphology, eskers of Central Poland are slightly different than eskers described in the areas of Canada or Scandinavia, where these forms reach several to several dozen kilometres in length, and are usually much better marked in the landscape and more clearly sinuous. It is related to the different substrata, on which they were formed, and the subsequent relief transformation. In Central Poland, eskers were mostly formed in tunnel channels, cut in a soft bed, where the proper part of the esker was created. It was then overlaid with sediments from an open channel or crevasse, which could result in broadening of the form and masking its sinuous character.

Keywords: eskers, morphology, Warta Glaciation, Central Poland

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PARAMETERS, LONGITUDINAL DISTRIBUTION AND DYNAMICS OF LARGE WOOD IN A MEDITERRANEAN EPHEMERAL STREAM

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Many scientific papers have acknowledged the importance of large wood (LW) in the geomorphic functions of rivers and streams and its unique benefits for aquatic biota (e.g., increased habitat heterogeneity, providing source of food, creation of refuges for aquatic organisms). Although LW has been intensively studied in forested basins of humid temperate climates, data on LW patterns coming from different fluvial environments are scarce. We investigated the dimensions, characteristics, longitudinal distribution, and dynamics of LW along a 4.05-km-long reach of an ephemeral channel typical of semi-arid European Mediterranean mountainous landscape (Sfakiano Gorge, Crete, Greece). We analysed a total of 795 LW pieces, and the mean observed abundance of LW was generally lower (14.3 m^3 per hectare of active valley floor or 19.6 LW pieces per 100 m of stream length) than is usually documented for more humid environments. The number of LW pieces was primarily controlled by trees growing on the valley floor, whereas LW recruitment from steep adjacent hillslopes was less important. The valley floor width and the distance from the coastline (the moisture gradient) played crucial roles in the distribution of living trees as the main source of LW for the studied channel. These living trees acted as important LW supply agents (by tree throws or the supply of individual branches with sufficient LW dimensions) and flow obstructions during large flood events, causing storage of transported LW pieces in jams. However, the downstream transport of LW is probably episodic, and large jams are likely formed only during major floods of >10y recurrence interval; after more than 15 years, we still observed significant imprints of the last major flood event in 2000 on the present distribution of LW. The geomorphic function of LW in this dry fluvial system can be perceived only as a spatially limited stabilisation element for sediments, which was documented by the occurrence of a low-frequent LW steps and jams that accumulated coarse clastic material. The observed arrangement of LW pieces suggests that some jams act as flow obstructions during high flow events.

Keywords: large wood, ephemeral stream, Mediterranean, Crete

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STRUCTURAL, TECTONIC AND GEODYNAMIC ENVIRONMENT OF LITOMĚŘICE THERMAL ENERGY BOREHOLE

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A thermal heat powerplant using deep boreholed is planned in the area of former military barracks in Litoměřice. The project has a twofold aim: a practical one and a research one. The practical is providing heat source for the Litoměřice city heat station, and the research aim is to allow deeper insight into environment of 5 km bedrock. While the benefit for the city in the form of heat station is clear, some doubts remain concerning the influence of drilling and hydraulic stimulation on the tectonic and seismic stability of the region.
To cope with this problem, a set of networks monitoring the seismicity and movements on tectonic faults was established. The seismic network, using both traditional seismographs and innovative 6way Rotaphones, is under construction. The 3D monitoring of tectonic movements using automated TM-71 devices is already operational to ensure assessment of the background, pre-drilling state, to be compared with the data obtained during the drilling and stimulation.
In the scope of preparatory works, a morphostructural analysis of the surroundings of the proposed borehole was performed, consisting of morphometric analyses (including analysis of lineaments, valley profiles and slope characteristics), lithological analysis, and analysis of tectonic lines and faults. The results were used to characterize the structural and tectonic settings of the borehole surroundings. Finally, a study of current geodynamic phenomena in the area of interest was performed. The slope stability and landslide occurrence was investigated, and the record from the 3D fault monitoring was analysed.
Preliminary results of monitoring of 3D movements on the tectonic faults and seismicity during the pre-drilling observation period show, that while there are certain traces of geodynamic activity, generally the area is rather stable.

Keywords: morphostructural analysis, fault monitoring, hydraulic stimulation seismicity, České Středohoří

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DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATIONS CONTROLLED BY THE STRUCTURE OF FLYSCH NAPPE OUTLIER: INSIGHTS FROM LARGE SCALE ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY AND LIDAR MAPPING

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The flysch nappe outliers propose a convenient structural background prone to the evolution of deep-seated gravitational slope deformations (DSGSDs). The study area of Palkovické hůrky hills represents an isolated nappe outlier of Carpathians flysch nappes (Czech Republic). Large-scale geomorphological mapping based on the field survey and interpretation of LiDAR data documents occurrence of various types of slope deformations including two cases of DSGSDs. With the aim of detection of DSGSDs main controlling factors, multidisciplinary investigation has been performed. The detailed structural measurement detects folded brachysynclinal structure composed of jointed lithologically differenced strata creating specific step-like topography. In the case of study area, innovative approach to morphotectonic assessment with the use of new high-resolution LiDAR data approved high tectonic disruption with significant morphogenetic influence. Four specific localities have been subjected to complex geophysical sounding. Kilometre-scale electrical resistivity tomography (ERT) profiles with the depth of penetration reaching the limits of this method were lead across whole gravitationally disrupted ridges. Such extensive geophysical survey has clearly described overall structural conditions. ERT has detected alternation of lithological units and wide range of folding and tectonic disruption. Significant folded plastic claystone beds underlying rigid sandstone blocks have been discovered. Finally, ERT has confirmed existence of deep seated sliding and sagging of such massive and defined its extent, depth and internal structure. We consider the complex structural condition with existence of lithological boundaries, tectonical disruption and folding to be the main controlling factors of DSGSDs evolution.

Keywords: deep-seated gravitational slope deformations, electrical resistivity tomography, flysch, nappe outlier, Palkovické hůrky hills, Outer Western Carpathians

RECONSTRUCTION AND DIGITAL MODELLING OF ROCKFALL EVENT WITHIN A FORESTED SLOPE – A CASE-STUDY FROM BYSTRZYCKIE MTS. (CENTRAL SUDETES, POLAND)

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Rockfalls can be recognized as one of the most spectacular types of mass movements, well described in geomorphological literature. Rockfall studies concentrate on high mountains areas such as the Alps (e.g. Sellmeier 2015, Messenzehl et al 2017) or any other zones characterized by high relief energy and existence of rockfall source areas – rock walls. Contemporarily, these studies usually deal with the methodical aspects of digital modelling of possible rockfall trajectories, usually in context of public safety maintenance (e.g. Dorren 2015, Sellmeier 2015, Sellmeier and Thuro 2017). Also, many authors focus on the protective role of trees within rockfall transit and deposition area, as they can stop falling blocks or considerably reduce their velocity (e.g. Perret et al 2004, Dorren et al 2007).

Within the Polish part of the Sudetes region, rockfalls cannot be considered as a commonly observed phenomena. For example, there are no publications concerning contemporary events of rapid downslope movement of a big single block or group of blocks. However, there are publications which focus on the dynamics and development of scree slopes containing rock debris (Remisz, Bijak 2011, Remisz 2012). Hence, the possibility to observe and study in detail the effects of rockfall involving a single block within a forested slope shall be considered interesting.

The presented case study concerns an event of rockfall, which took place in February 2017 on the left slope of Bystrzyca valley nearby Młoty village (Bystrzyckie Mts, Central Sudetes). It resulted in gravitational downslope movement of a single block of approximate size of 2.4×1.3×1.2 metres, which did not reach the valley bottom but stopped on a single tree stem in the distance of 49 metres from the source area. The block caused severe damage to a few young trees and bushes as well as created a number of impact pits within the slope surface.

The main field work, conducted in March 2017, included detailed photographic documentation and laser rangefinder measurements of the rockfall site. The latter, combined with the use of high-resolution LiDAR-based digital terrain model, enabled the detailed cartographic presentation of the study site. Additionally, electrical resistivity tomography (ERT) and electromagnetic (EM) measurements were done in order to provide an additional information on the subsurface conditions of the study area (including an estimation of the depth of slope scree cover). The photographic documentation of the study site was done once again one year later, focusing mainly on the remnants of microrelief created by the moving block. Digital photography dataset was used as an input in the process of creating 3D models of block and selected pits. The models were created with use of Structure from Motion (SfM) techniques in AgiSoft Photoscan software. Analyses of the models enabled one to estimate weight of the block– 3.2 tons. Secondly, a comparison of the 3D models of pits gives brief insight on permanence of these forms.

The results of field observations, mapping and SfM modelling are presented in combination with the results of rockfall numerical modelling, which was conducted with use of RocPro3d software and resulted theoretical trajectories of block movement.

Keywords: rockfall, mass movements, numerical modelling, Structure from Motion. Bystrzyckie Mts., Central Sudetes,

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TRANSPRESSIONAL BASE OF THE CUESTA MORPHOTECTONICS IN EASTERN PART OF THE BOHEMIAN PLATEAU (CZECHIA)

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The goal of this contribution is to proclaim the role of transpressional processes on the morphotectonics in eastern part of the Bohemian Plateau. Structural arrangement with morphological effect of this area is traditionally explained by the system of the synclines and anticlines supplied by the faults or the horsts and grabens (eg. Frech, 1904; Žůrek, 1963; Malkovský, 1980). Malkovský (1987) outlined the transpressional arrangement without direct evidences. Adamovič & Coubal (1999) introduced that tectonic style of the folds combined with reverse or possibly strike-slip faulting indicates that the formation of these structures resulted from an intensive, approx. NE–SW orientated compression. Valigurský & Čech (2003) and Čech et al. (2011) speculated over the (half)graben pattern of the Ústecká Furrow formed by a system of rhomboidal inclined blocks and surrounded by the (half)horst/cuesta ridges. They described the phases of compression and extension without real structural fieldwork evidences in this area.
The area of research associates three fault zones – the Jílovice Fault zone, the Semanín Fault zone and the Kyšperk Fault zone. The researched methods include the tectonograms of the striated fault planes, paleostress analysis, analysis of joint sets and reflection seismic survey. There were determinated thrust faults, reverse faults and strike-slip faults due to oblique or subhorizontal striation. The distribution of maximal normal stress σ_1 appears in a concordance to the continual joint sets in the direction esp. NW–SE, NE–SW, NNE–SSW, ENE–WSW and E–W. The direction NW–SE also coincides with the intensity of uplift varied along the length of the ramp in the Orlické hory Mts. ridge (Różycka & Migoń, 2017). The reflection seismic profile shows positive "flower structure" in e. vicinity of the Semanín Fault zone. A combination of the direct evidences of thrust/reverse faults and strike-slip faults gives a conception of transpressional features. The thrust/reverse faulting accompanied by strike-slip fauls led to a progress of inclined and rotated blocks – cuestas. The phase of compression was replaced by an extension documented by conjugate normal faults or tension fractures.

Key words: transpression, joints, morphotectonics, Bohemian Plateau

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C-14 DATING OF BIOSPHEROIDS – NEW PERSPECTIVE FOR SOIL AGE DETERMINATION

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Age determination of paleosoils is useful for the studies of archeology, soil development, climate change, paleoenvironmental and landscape evolution research. C-14 dating of paleosoils is a challenging task as ordinary soil organic matter (SOM) does not give a realistic C-14 age of the birth or the burial of a soil layer as SOM is normally accumulated over hundreds or even thousands of years. If one could not find some macrofossil remains in the discovered soil horizon then the age determination is always a matter of debate. On the other hand secondary carbonates in soil could provide detailed information about the paleoenvironmental and climate conditions in the past.
In this study we have investigated the earthworms produced biospheroids as a possible material for soil C-14 dating. Recent studies suggested that earthworms consume preferably fresh organic matter during their life in the soil, which means the products of their digestion would contain rather recent organic carbon instead of the aged carbon from the SOM fraction.
Although biospheroids are rather small (diameter < 2mm and mass < 5 mg) pure calcite granules, the state-of-the-art accelerator mass spectrometry (AMS) technique gives the possibility of their radiocarbon dating at the AMS Laboratory of the Institute of Nuclear Research of HAS (Atomki).
We have investigated 8 different recent topsoil samples collected at 5 different localities in the Hajduság area (Hungary). Biospheroids were carefully collected form each soil samples and 2-3 granules were used for C-14 dating of the individual soil samples. Results confirmed that biospheroids mostly contain young (max age 30 years) organic carbon, which gives realistic (zero) C-14 age for the top soils.

Keywords: C-14, biospheroid, paleosoil, soil

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LARGE WOOD BUDGET AND TRANSPORT IN THE DYJE RIVER CORRIDOR

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This contribution is focused on the issue of large wood budget and transport in the river affected by hydropower generation. The paper presents the result of monitoring of riparian forest and large wood in the river channel and floodplain of the River Dyje between the dams of water reservoirs Vranov and Znojmo. The natural development of the Dyje River corridor including the transport of large wood and obviously also sediments, is influenced by the existence of the Vranov water reservoir and the energetic regime of water flows below the dam and its integral hydropower generation.
Hazardous riparian trees and their input into the river corridor were monitored in 36 reaches of the floodplain and the river channel, each 200 m long. Furthermore, the input and the output of large wood by floods were monitored in the river reaches. Trees and large wood were marked by alluminium tags and localized by GPS. At the same time the large wood floated to the dam of the Znojmo water reservoirs were documented.
As the observation shows, the number of large wood in detected area is nearly constantinous in examined time – it rather goes down. This does not mean that there are no changes indeed. It could be more exactly described as a state of dynamic balance, where annual loses of dozens to hundreds of pieces are replaced by supplement of new large wood. A mobility of large wood floated to the Znojmo reservoir dam is rather continuous in small amount of pieces, however in the area between Vranov and Znojmo the great capture potential is obvious. A floating wood is trapped at shores, often hooked by trees or older large wood there. Comparing numbers of alochtonnous pieces in observed areas with numbers of pieces floated to the dam, it can be estimated, that roughly 10 – 20% of large wood can be flooded to the dam. Similar situation happened during the flood in 2006, when the only one fifth of large wood floated to the dam of the Znojmo water reservoir. The rest of large wood was captured in riparian vegetation.
The most of the floated large wood came from the area 5 to 11 km away from the dam of water reservoir Znojmo. However some smaller pieces were transported from the area more than 35 km away. Floating of a large wood was time variable, while more significant movement of the large wood started in July 2013, when the level of 1,5-year flood was reached.

Keywords: wood budget, riparian trees, large wood, floods

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SECONDARY GEODIVERSITY AND CULTURAL HERITAGE ON EXAMPLES FROM THE ARCHDIOCESE OF OLOMOUC

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In the relief of the cultural landscape of the Central European area, the historical role of man as a decisive factor of dynamic changes is emphasized. Human activities influence natural geomorphological processes and they often induce the new ones. These include anthropogenic processes that form anthropogenic (or so-called technogenic) landforms.
The origin and formation of the distinctive anthropogenic landforms are often related to the driving forces of particular cultural periods, war events or technical and scientific development. These landforms form an important part of the historical landscape, they increase the overall landscape diversity and they represent so-called secondary geodiversity. Identification, assessment, observation, and explication of these landforms are necessary for the complex perception of natural and cultural heritage and they help to understand the role of secondary geodiversity features within the landscape diversity.
One of the public interests of the Czech Republic is the interest on the material cultural heritage, respectively cultural values formed in the past that influence the living space of present and future society. Material cultural heritage includes (among others) the sites with man-made features or features of combined origin (both natural and man-made) that have exceptional world value from the historical point of view. According to this, historical anthropogenic landforms can be also classified as specific cases of material cultural heritage.
The first aim is to assess secondary geodiversity which is represented by particular anthropogenic landforms, anthropogenic processes, and influences of human activities on the relief. These secondary geodiversity features have also a historical significance, they increase the overall landscape diversity and some of them form a part of geomorphological heritage which can be defined as those components or features of primary (natural) and secondary (man-made or anthropogenic) geodiversity which are of significant value to humans, including scientific research, education, aesthetics and inspiration, cultural development, and a sense of place experienced by communities.
The contribution presents the examples (specific sites with historical anthropogenic landforms) from the central and western part of the Archdiocese of Olomouc including the assessment of their geohistorical importance, their significance for landscape memory and their potential for geotourism and educational purposes.

Keywords: secondary geodiversity, cultural heritage, central Moravia

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SLOPE DEFORMATION MAP AROUND THE HIGHWAY D8 BETWEEN VILLAGES DOBKOVIČKY AND PRACKOVICE NAD LABEM – UPDATED FOR APRIL 2016

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The presented landslide inventory map was part of the report prepared for the Czech Ministry of Transportation in 2016 (Stemberk and Mašín ed. 2016). The main aim of the report was to analyze causes of occurrence of the landslide from June 2013, which damaged 200 m of almost finished highway crossing the volcanic mountain range of the České středohoří. The landslide inventory mapping described distribution and state of activity of all types of landslides based on their morphological imprint.
The study area is located on the east slope of the Elbe River with the ridge top built by volcanic rocks (basalts) which overlay Mesozoic sediments (clay stones, lime stones). Since 1970´, scientific research showed that the area is subject to deep-seated rock block spreading slope deformations as well as variety of shallower landslides. Despite of that highway was built across this highly susceptible area. Its completion was seriously delayed by the June 2013 landslide.
The mapping was done in a filed using 1:10,000 scale topographic maps as well as detailed digital elevation model derived from LiDAR measurements as topographic base information. Field works were conducted during March and April 2016 and confirmed already well documented fact that the area under study is subject to development of different landslide types. They include deep-seated (>40 m deep) rock blocks spreading, shallow to medium-deep landslides as well as minor rockfalls. Landslide distribution is not random since the deep-seated deformations form suitable conditions for occurrence of other landslide types, which develop on steep slopes of their source areas and toes. Other important landslide occurrence conditions are accumulation of underground water, deep-ward stream erosion and alternation of the slope stability conditions by quarries. Large number of mapped landslides exhibits evidences of recent activity testifying the high dynamics of slope development within the study area, which is also strongly affected by ongoing (March 2018) operation of the quarry. Intensive agricultural use of the study area is capable of erasing morphological evidences for low-magnitude (short vertical and horizontal movements) landslide movements, which was illustrated by several cases, when historically documented landslides (e.g. in 2010) was impossible to identify during the field mapping. Therefore, it is important to keep in mind that the presented map does not contain records of all historically identified landslides within the study area. It represents temporarily constrained historical landslide inventory map which needs to be updated to provide reliable information about development of the stability conditions within the study area.

Keywords: landslides, rock block spreading, engineering geomorphology, vulcanic rocks, landslide mapping

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DETECTION OF VALLEY HEADS FROM DIGITAL ELEVATION MODELS

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Valley heads are the one of the most dynamic parts of landscape with their importance in geomorphology, geology, hydrology, ecology, biology and other scientific and engineering disciplines. The delineation of valley head areas is always problematic, as the valley head depression slightly continues to surrounding parts of the landscape (landforms), i.e. valley floors, valley slopes and upper parts of ridges. Nevertheless, the exact position and delineation of valley heads is useful in some geomorphological applications, such as mapping or creating elevation profiles for further analysis, as the properties of more valley heads should be always comparable.

Several attempts have been made to recognize these features automatically in the past. Tribe (1991) developed a new automated method to derive spatial extent of valley heads in GIS from digital elevation models. This tool has been examined in multiple landscape types (alpine mountains, mid-mountains, highlands and lowlands) across Central Europe using digital elevation models with different quality. However, the results were not convincing, when some valley heads were detected in wrong places and some weren´t detected at all. Jasiewicz and Stepinski (2013) introduced a new GIS raster algorithm called Geomorphons for landform classification, comparing relative height of adjacent cells in a moving window. In this classification system, the hollow category is similar to a valley head, but the results of Geomorphons algorithm depend on the raster resolution of digital elevation model used for the analysis. Both above-mentioned papers were an inspiration to make a new universal method for automated recognition of valley heads from digital elevation model in GIS using a moving window.

During the creation process by testing each step in different landscapes and raster resolutions used, following remarks came up: (1) High-resolution digital elevation models are not suitable for automated recognition of valley heads, because the surface details cause bias. Thus, a generalization process should be performed and the cell size should be larger than 30 m. (2) It is necessary to use suitable size of the moving window, which should be greater than just 3x3 cells taking in account only surrounding cells. At least two surrounding rows and lines of cells should be used for consideration of surface shape in the neighborhood of the central cell, depending on the raster resolution. (3) The only reliable result of valley heads automated delineation is a point dissecting the valley head and adjacent valley floor. All attempts of automated recognition of valley head area or borders on the basis of slope and curvature changes couldn´t be considered universal, because some results were confusing in different landscape types.

Keywords: valley heads, GIS, digital elevation model

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LOCAL GEOHERITAGE: ITS POTENTIAL FOR GEOTOURISM AND EDUCATIONAL PURPOSES (CASE STUDY: LOMNICKO AND DEBLÍNSKO, SOUTH MORAVIA, CZECH REPUBLIC)

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Geodiversity, respective its valuable part, geoheritage, is considered and recognized as important resource for the geotourism, geoeducational and recreational purposes. In the Czech Republic, there are a lot of examples of such use of geoheritage (sandstone rock cities (e.g. Elbe Sandstones), karst areas (e.g. Moravian Karst), mountains (e.g. Krkonoše), which is usually significant on the national level, it enables geotourist and recreational activities and support economic development on the regional and national level. However, in the local scale, geodiversity (respectively local geoheritage, or particular geosites and geomorphosites) also serves the above mentioned purposes. Maybe these landscapes or landforms are not so breathtaking, extensive or unique, but they also possess the potential for the tourist and recreational purposes and their possible further development. These areas offer an alternative to the traditional tourist destinations that are often overcrowded and overloaded, especially during holidays and weekends.

Generally, three levels of geoheritage's importance can be described (with examples from the Czech Republic): 1) global geoheritage: UNESCO WHS or Global geoparks (Bohemian Paradise), 2) National geoheritage: National Parks, National Geoparks, PLAs, National Nature Monuments or National Nature Reserves (e.g. Elbe Sandstones National Park, Moravian Karst PLA, Vysočina National Geopark, Panská skála National Natural Monement), 3) Regional/local geoheritage - locally important geosites and geomorphosites, usually with lowest category of legal protection (Nature Reserve or Nature Monument or Natural Park) or without protection.

Both study areas (Lomnicko and Deblínsko) can be included into the third level. They are situated in the outskirts of Brno and they can be considered the recreational and touristic background of the city, however, they are not so used for these purposes due to the existence of other traditional and favourite tourist destination north of Brno - Moravian Karst PLA. Both areas are well accessible and equipped with several marked tourist paths, basic tourist facilities (shelters, information panels with maps) and tourist infrastructure in the villages and towns. The short distance from Brno city makes these areas important for the short-term (one day) recreation and tourism development and it is a friendly alternative to the overcrowded Moravian Karst.

Lomnicko represents a harmonic landscape with well conserved natural features. Geologically it is relatively monotone (Proterozoic gneisses covered by Quaternary sediments), but thanks to the intensive periglacial and cryogenic processes in the Pleistocene, the morphological diversity of the area is very high (tors, ridges, castle-koppies, structural ridges, block accumulations and flows, nivation depressions, cryoplanation terraces, frost-riven cliffs, abri, rims) and it belongs to best preserved areas with periglacial and cryogenic rock landforms in the Czech Republic. Cultural features are represented by traditional agricultural and sacral objects with use of local material. The Jewish cemetery in Lomnice is declared as Cultural

Monument. In the open landscape, the small sacral objects are common (crosses, small chapels etc.).
Deblínsko is characterized as diverse landscape with mosaic of fields, forests, meadows and ancient orchards. Geology (respectively lithology) of the area is very varied (Proterozoic gneisses and phylites, Devonian limestones, siliciclastics sediments of Carboniferous age, Miocene and Pliocene freshwater sediments, Badenian marine sediments, Quaternary fluvial and eolian sediments), which influence the morphodiversity: the most important landforms of the area are deep incised valleys, karst forms, various rock formations of cryogenic origin and old abandoned quarries. Cultural features are represented especially by long mining history (ores at Bílý potok valley, limestone extraction, old lime kilns, kaolin extraction) and use of water resources (e.g. mills on the Svratka River and its tributaries).
As shown in these and many other cases, local geohetitage has a potential for geotourism and geoeducational purposes. This potential is based on the particular values of the local geoheritage (respectively locally important geosites and geomorphosites):
1) High scientific, conservation and educational values: landforms and processes are illustrative, visible and simple to understand and can be used for environmental education by local schools; integrity or conditions of landforms are relatively good which can be affected by lower amount of visitors and less intensive use of them,
2) Added values: close links to the landscape and culture: ecological, historical or archaeological values, artistic and literature values, geomythological aspect, relations to the historic landuse, the traces of the landscape memory, local materials used for local buildings and constructions,
3) Economic and tourist value: accessibility, presence of tourist infrastructure or background for short-term visits, financial availability (local geoheritage - local prices),
4) Number of visitors and knowledge/popularity of the site/area: local geoheritage is not so well-known and popular and the number of visitors is not so high as in the case of national and global geoheritage, so it offers a friendly and nice alternative for visitors that are looking for something new, original, calm and not so overcrowded at the same time,
5) Stronger feel of local identity: local products, authentic local people, folklore and services.
The question is if the further and more intensive development of geotourist activities can or cannot endanger these harmonic landscapes and its geodiversity features. Nevertheless, the use of local geoheritage for educational purposes is desirable, because this part of environmental education is not so developed and geodiversity, geoeducation and related features are not even mentioned in the Conception of environmental education and enlightenment of the South-Moravian Region.

Keywords: geotourism, geoheritage, geoeducation, Lomnicko, Deblínsko, Czech Republic

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URBAN GEOTOURISM – PROMOTING GEOHERITAGE WITHIN TOWNS AND CITIES

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Geotourism is defined as a form of nature tourism that focuses on landscape and geology, but also on the biotic and cultural features that are linked to the abiotic nature. Generally, it should be geologically based, environmentally educative, sustainable and locally beneficial and it should ensure tourist satisfaction (Dowling and Newsome eds., 2010). Traditionally, it is developed and appreciated as an effective tool for promoting geoheritage in rural areas, however, the importance of geodiversity in towns and cities has been already recognized and urban geoheritage is also considered a significant resource for tourist and educational activities (e.g. Hawley 1996, Robinson 1982). Geotourist products within urban areas thus represent a relatively new type of attractiveness and they are viewed as a fresh alternative to the traditional urban tourist destinations (London Geodiversity Partnership 2014, Reynard et al. 2017). The growing interest in urban geotourism (respectively in promoting geological and geomorphological heritage in towns and cities) is supported by numerous case studies (e.g. Rodrigues et al. 2011, Palacio-Prieto 2015, Pica et al. 2017, Zwolinski et al. 2017, Kubalíková and Bajer 2018).
The contribution presents specific role of geodiversity and geoheritage in the urban areas (e.g. its importance for the urban development and influence on the situation of significant buildings or communications, its potential for tourism, education and recreation) and stresses the main reasons why should be urban geotourism developed. As the urban geoheritage is closely related to the human activities (respectively geohistorical, cultural, artistic and architectonical aspects), some specific issues and features that are usually included into urban geoheritage are discussed. Consequently, particular activities that can be developed for the promotion of geoheritage in towns and cities are proposed and the examples from Brno city (Czech Republic) are presented.

Keywords: geotourism, geoheritage, urban geosites and geomorphosites, Brno, Czech Republic

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RENYI MULTIFRACTAL DIMENSION OF DRAINAGE PATTERN (BLUE NILE BASIN, ETHIOPIA): A NEW METHOD OF MORPHOSTRUCTURAL ANALYSIS?

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The Western part of Ethiopia, including the Ethiopian Highlands and Main Ethiopian Rift, is among the most tectonically influenced areas in the world. This area has been influenced by sea transgressions, tectonic uplift, episodic volcanism and the opening of the rift systém. These very dynamic endogenous processes have led (along with the intense activity of exogenous processes) to the emergence of a very complicated landscape, in which traces of long and varied development have been recorded. Based on the multifractal analysis of the valley networks in the Ethiopian Highlands can be assumed, that the valley networks depicted using SRTM DEM data are multifractal objects. The Rényi multifractal dimension was used for a morphostructural analysis of the landscape using the SRTM DEM raster data (30 m pixel size) and for to distinguish trellis valley networks in the neotectonically affected eastern part of the Ethiopian Highlands from dendritic valley network in the western part of the Ethiopian Highlands without the influence of neotectonics, where an older senile landscape are located. The higher values of the Renyi multifractal dimension (the monofractictal dimension did not fall below 1.75 for the scale exponent $\alpha = 10$, and below 2.55 for the scale exponent $\alpha = -10$) reached: a) trellis valley networks in the juvenile neotectinically affected landscape; b) areas with active depth (inclination of valley slopes > 45 °) and fluvial back erosion; c) areas with river piracy tendencies; d) areas with mass movements; e) areas with earthquakes; f) areas with a high incidence of faults in the bedrock. On the other hand, the lower values of the Rényi multifractal dimension (monofractal dimensions did not exceed 1.7 for scale exponent $\alpha = 10$, and did not exceed 2.55 for scale exponent $\alpha = -10$) reach: a) dendritic valley networks without structural influence; b) older areas, so-called senile landscape without neotectinic effects; c) valleys with exceptionally wide valley bottoms; d) areas without faults in the geological bedrock. The Renyi multifractal dimension of the valley network method can be used for morphostructural analysis of landscape using remote sensing. However, it can be used to complement the common methods of landscape analysis e.g. together with the following methods: mapping landscape shapes, analysing linear landscape features, and analysing the longitudinal profiles and valley cross-sections profiles.

Keywords: Renyi multifractal dimension, fractal, valley network, Ethiopian Highlands.

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RECENT PROGRESS IN GEOMORPHOLOGICAL APPLICATIONS IN MONTANE TOURISM

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In connection with the growing tendency of society to devote itself to local history and local sights, disciplines and methods dealing with montane landscape survey has begun to be very exploited. The municipalities as well as private companies or non-profit organizations have sensed the possibility of saving an ancient montane heritage and attracting new potential tourists. Because the montane heritage is largely made up of montane relief forms, the geomorphological survey with modern research methods often play a major role in designing projects. When accessing old quarries, underground mines or spoil heaps for tourists, various geomorphological of even speleological methods are being used, i.e. speleological mapping by using laser systems and software, geomorphic mapping (even underground geomorphic mapping), DEM of underground mining chambers creation, LIDAR data processing and recent relief imaging, GIS software analyses, creation of map compositions, dating of geomorphic forms and processes, geophysical survey using different methods etc. This contribution shows the recent examples of using of above mentioned methods on examples from Krušné hory Mts., Nízký Jeseník Highlands and Ostrava basin.

Keywords: montane tourism, geomorphology, LIDAR, applications

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GRAVEL-BAR DYNAMICS OF THE PROTECTED MULTIPLE-THREAD REACH OF THE MORÁVKA RIVER

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The poster deals with gravel-bars dynamic of the multiple-thread channel reach of the Morávka River in the Czech part of the Carpathian Mts. The Morávka River has undergone a rapid change in the last 50 years, particularly in connection with the transition from the originally multiple-thread to single-thread channel. In the area of the Skalická Morávka National Nature Monument (NNM), a short reach is still preserved with close-to-natural processes of multiple-thread channel pattern. The multiple-thread channel reaches are characterized by high dynamics of gravel bars. Such reaches are affected by large amounts of supplied coarse sediment and occurrence of frequent floods which remobilise coarse sediments (Gurnell et al. 2009). In the Morávka River preserved multiple-thread channel reach, periodically disturbed gravel-bars are protected as habitat of rare and endangered species (e.g. *Myricaria germanica*, *Equisetum variegatum*, *Equisetum hyemale*, *Calamagrostis pseudophragmites*, *Equisetum ramosissimum*). In the last two decades, agradually decreasing trend of gravel-bars dynamic was observed. This trend is connected with sediment deficit, which reflects decreased supply from the upper part of the basin. Moreover, decreased frequency of flood events decreases intensity of sediment transport and makes difficult to periodically disturb surfaces of gravel bars. This state resulted from the construction of the Morávka Valley Dam, the Vyšní Lhoty weir and other anthropogenic impacts as torrent control works and gradual afforestation of the mountainous part in the Morávka River basin since the 19th century.

In this investigation, planform changes of gravel bars in multiple-thread channel in the Skalická Morávka NNM were assessed using available aerial photos from the years 2000, 2003, 2006, 2009, 2012, 2014 and 2016. The gravel-bar surfaces were divided into two groups: (i) the potentially mobile and (ii) stabilized gravel bars (as vegetated islands). The potentially mobile gravel bars included bars without vegetation or slightly covered by vegetation (with two years maximum age of bushes and trees). The potentially mobile gravel bars have a possibility for re-flushing of coarse sediment material. They represent a habitat for rare and endangered species, which are under protection in the Skalická Morávka NNM. The second group of gravel bars were represented by the stabilized bars fully covered by vegetation (with two years minimum age of bushes and trees), where the disturbances affected by higher flows or floods had limited effect on mobility of coarse material deposited in bars. The set of aerial photos allowed the identification of the potentially mobile gravel bars (without vegetation cover) and stabilized gravel bars (as islands or vegetated gravel bars) in the Skalická Morávka NNM. These groups were identified in the ArcGIS ArcMap 10.1 by polygons.

The results shown, that the largest spatial extent of potentially mobile gravel bars was in 1955 before the construction of the Morávka Valley Dam and the Vyšní Lhoty weir. The small decrease of potentially mobile gravel bars occurred in 2000, where obvious impact of the Vyšní Lhoty weir and Morávka Valley Dam already appeared. However, there was an important hig-magnitude flood event in 1997 (with culmination of discharge 191 m^3/s), which certainly influenced the distribution of potentially mobile and stabilized gravel bars. The massive loss of the area of potentially mobile gravel bars was observed between 2000-2016,

when the area of potentially mobile gravel bars decreased about 85% and spatial distribution of stabilized gravel bars increased about 77%.
This trend of decreasing of potentially mobile gravel-bars area did not change by the flood in 2010 (with culmination of discharge 187 m^3/s). The area of the stabilized gravel bars still increased. The increase was caused by rapid succession of vegetation, which effectively stabilized gravel bars and protected their surface from disturbations caused by higher flows and floods. This state was connected with the transformation of multiple-thread channel morphology and change of original close-to-natural conditions. The management measures are needed to improve the current state of the Skalická Morávka NNM.

Keywords: gravel-bars dynamic, multiple-thread channel pattern, the Morávka River, the Moravskoslezské Beskydy Mts.

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GEOMORPHIC SURFACES ON THE SLOPES OF THE PÉCS BASIN

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The Mecsek Mountains in southwestern Hungary rises 250–300 m above the Transdanubian Hills (highest point: Zengő, 682 m). The origin of the Pleistocene Pécs Basin in its southern foreland is related to the Mecsekalja Dislocation Zone. This basin is wedged in east-west direction in between the Mecsek Mountains and the South-Baranya Hills. The characteristic features in the northern and southern slopes of the basin are geomorphic surfaces and their remains at different elevations. Their evolution is closely related to the basin's periodic subsidence, or the earlier abrasion and pedimentation processes. Our objective is to find a relationship between the previously identified geomorphic surfaces on the western slopes of the Mecsek Mts (Jakab Hill, SW). For geomorphological mapping of the study areas Hungarian EOV topographic maps were applied at 1:10000 and 1:50000 scales complemented with field study and GIS (ArcGIS Pro) software. At lower elevations (under 500 m) three geomorphic surfaces (350–380 m, 280–300 m, 240–270 m) were formed mainly on Triassic sandstones and limestones. These abrasion surfaces have been dated to the Miocene, further shaped as a pediment in the Late Miocene. At this time, the Pécs Basin divided the Mecsek Mts from the South-Baranya Hills, formerly the glacis of the mountains. The western consequent streams are the most characteristic features on the pediment. The lowest interfluve is the base level of the Pécs Basin. The basin was formed by the subsidence of three sub-basins (the Zók, Pellérd and Nagyárpád Basins). The south-directed consequent watercourses dissecting the glacis were captured by the subsidence of the basin and their flow direction was changed (obsequent valleys) on the southern edge of the basin. The geomorphic maps of the northern slopes (Kozármisleny and Málom) were georeferenced in ArcGIS Pro software to help in the observations and we also used digital elevation model for the analyses. The geomorphic surfaces from this area are younger and appear at lower elevations than in the Mecsek Mts. Typically the surfaces appear between the basin floor (at 120 m) and the highest surface (200–220 m) at 130–140 m, 150–160 m, 170–180 m and 180–190 m elevations. The most recent study area is in the western section of the basin (around Boda). We observed the southwestern slopes of Jakab Hill and mapped the geomorphic surfaces. Compared to the higher surfaces (320–200 m) those at lower elevations were more difficult to identify, because the slopes between the surfaces were planated through intensive agricultural cultivation. This is also the oldest and widest part of the basin. The axis of Jakab Hills tilts to the southwest. The higher geomorphic surfaces (200–230 m, 160–180 m) can be detected on geomorphological maps because the derasional valleys related to erosional valleys only reach the slopes between the surfaces. The elevations of surfaces are related to the higher geomorphic surfaces in the middle and southeastern sections of the basin.

Keywords: geomorphology, Mecsek Mts., Pécs Basin, geomorphic surfaces, GIS

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FINE WOOD MOBILITY IN THE SUČÍ STREAM

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The aim of this research was to evaluate mobility of fine wood in two morphologically distinct sections of the Sučí stream (Podbeskydská pahorkatina Hilly land). The Sučí Stream begins at the northwest foot of the Ondřejník Massif at an altitude of 550 m asl. and its length is 1.5 km. Mean channel gradient is 10.8 %. I installed 60 twigs of three different lengths (20, 30 and 40 cm) into the incised section and into the morphologically contrasting section with predominant accumulation processes. The upstream accumulation section has a lower average channel gradient (3.8 %) and the flow is usually split up into more flowpaths within relatively flat valley floor after heavy precipitation. On the other hand, the downstream deeply incised section has a higher average gradient of the channel (9.9 %).
The field works included repeated measurements of the transported distance of the twigs and their changes in orientation with respect to flow direction. The evaluation of transport took place between 5. 5. 2017- 4. 10. 2017 together with observation of precipitation amounts and discharges at nearby gauging stations. The results showed that within one stream in two sections close to each other, there may be great differences in fine wood mobility. The mobility of fine wood was lower in the incised section and the wood was transported only after significant rainfall (3day maximum precipitation amount of 65.5 mm). During the long-term monitoring, larger-size categories of the twigs were transported after a 3day maximum precipitation amount of 76.5 mm. For the first measured event, only the accumulation section confirmed the assumption that shorter pieces will be transported over longer distances. The twigs in this section were mobile even during relatively low flows during the long-term monitoring. During this monitoring, I did not record any threshold for precipitation that would be necessary for initial mobility in this section. The longest transported distance in the accumulation section was 17.8 m and 44.7 m in the incised section. The stabilization of the twigs in the riverbed by river wood was an important factor for potential mobility. The presence of river wood in the riverbed was the most important element for fine wood storage, preventing its mobility. In both sections the trend of fine wood storage with a parallel orientation with respect to flow direction prevailed.

Keywords: river wood, fine wood mobility, Sučí stream, Podbeskydská pahorkatina Hilly land

RECOGNIZING LANDFORMS OF INTERNATIONAL SIGNIFICANCE

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Landforms are a key component of geoheritage and are decisive for geodiversity of an area. However, landforms have a very special status within geoheritage as they combine inheritance and dynamics (Coratza and Hobléa 2018), unlike rock outcrops or fossil sites. This dual character of landforms is reflected in the wording of criterion (viii) for natural UNESCO World Heritage which specifies that World Heritage properties have to be 'outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features'. This very general statement raises several questions which seem not easy to be unequivocally answered. How to define 'significance' in the context of landforms and processes contributing to the development of landforms? How to define it in respect to various levels of inquiry, from local to international? Is it possible to evaluate 'significance' objectively, to avoid biased approach and minimize individual preferences? Are there thresholds of significance beyond which a truly international significance can be claimed?
In fact, 'significance' may be variously understood (Migoń 2014). Landforms may be significant for the science of geomorphology itself, playing an important part in our attempts to understand how the Earth's surface evolves. They provide the record of the evolution of the Earth surface in different time spans, from the most recent past (e.g. history of deglaciation since the Little Ice Age, recorded in the assemblages of moraines and outwash sediments) through the Quaternary (e.g. evolution of dune fields in world's deserts or the origin of flights of raised marine terraces on oceanic islands and tectonically rising coasts), to longer periods, even back to the Mesozoic as is the case of the Fennoscandian Shield. Some landform assemblages record the past better than others and those which do this best, are clearly of the highest significance. Another, but closely related reason of significance resides in the role of a type locality played by a landform/landscape. Some landforms, due to their clarity, accessibility, size etc., became a subject of detailed studies which then, as the science of geomorphology evolved, gained the status of a 'classic'. This is reflected in the common practice to draw parallels to such localities in subsequent studies carried elsewhere in the world. Examples of such 'classic' geomorphic features include the cockpit karst of Jamaica, star dunes of the Sonoran Desert, pingos of the Mackenzie Delta, raised coral reefs of Huon Peninsula (New Guinea), tors of Dartmoor (England), or the great escarpments of South Africa. Certain geomorphic localities are sites of 'milestone' discoveries in the history of Earth Science. Channeled Scablands of northwest US represent an area where the existence of glacial megafloods was realized for the first time, whereas the Meteor Crater in Arizona helped to understand the reality of extraterrestrial impacts. Often these 'classic' localities are more thoroughly researched than others and hence, better understood and presented as model examples of a certain type of landforms. The significance may also be associated with the sheer size of certain landforms. Huge size tends to be presented as natural curiosity but science helps to go beyond a mere fascination with grandeur, offering insights into the power of certain land-forming processes. Finally, an issue of uniqueness of certain landforms

emerges. Although processes that shape the surface of the Earth are universal and governed by basic principles of physics and chemistry, combinations of factors behind landscape evolution in any given place may be nearly endless, resulting in physical landscapes with no or little parallels elsewhere.

Landforms may be also significant for reasons not directly related to geomorphology itself. In the context of biology, while not necessarily significant in their own right, landforms may crucially underpin the course of biological and ecological processes, contribute to the high degree of endemism, explain the mosaic of habitats and specific environmental adaptations among the living world. Likewise, in the cultural heritage context landforms are the necessary background of many cultural landscapes or inseparable components of sites of special cultural, religious, or historical significance. The spiritual significance of isolated hills and mountains is common to many cultures in the world and in specific instance the sacred status of a mountain goes hand in hand with scientific significance (Uluru in Australia is one example). Further examples of these linkages are provided by human modifications of extraordinary badland landscapes, military architecture which uses residual landforms, caves and shelters with rock art or urban layouts guided by landform configuration.

Leaving science aside, landforms may be considered significant by the general public for reasons rather different than those named above although some common points remain. Grand examples of certain natural phenomena always attracted attention and the quest for 'World records' drives many people to particular localities. However, the best examples of a kind are not necessarily the biggest ones. Clarity of expression may be more important than size and one may think about situations where too big a size negatively impacts the ability to appreciate the whole landform in the context. Another factor contributing to significance for general public is accessibility. Thus, for many the Niagara Waterfall would probably be more significant, and better recognized, than more remote examples even if they are bigger and their surroundings less altered anthropogenically.

Keywords: geoheritage, geotourism, World Heritage, Geoparks

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MORPHOTECTONICS OF THE SOWIE MOUNTAINS BLOCK, SW POLAND, REVISITED – INSIGHTS FROM LIDAR DEM

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The Sowie Mountains in the central part of the Sudetes have played an important role in morphotectonic studies of the mountain range. Due to clarity of its mountain front associated with the Sudetic Marginal Fault they attracted significant attention in the 1990s and several benchmark papers have been produced (e.g. Krzyszkowski and Pijet 1993, Krzyszkowski et al. 1995, Krzyszkowski and Biernat 1998, Krzyszkowski and Olejnik 1998). They included pioneering studies of geomorphometry of the mountain front and strong claims were made that uplift of the mountains relative to the foreland was continuing in the Quaternary which was at variance with views offered before. In the 2000s further work focused on morphometric properties of drainage basins in the elevated mountainous block (Badura et al. 2005, 2007). However, source materials for these studies were contour maps at 1:25,000 scale, later digitized to allow calculations of drainage basin parameters. Realizing various inaccuracies of those background cartographic materials and smoothing of contours on pre-1945 maps, potentially hiding small-scale geomorphic features of morphotectonic significance, a new look at the old problem was attempted, making use of high-resolution LiDAR data. In addition, the spatial context of the study was extended to include the south-western mountain front of the Sowie Mountains which escaped attention in morphotectonic studies before, apparently due to an assumption that it is not a tectonically-controlled feature but reflects different erodibility of bedrock (gneiss versus sedimentary rocks).

The following landforms and geomorphic features were analysed or re-analysed using LiDAR dataset: morphometric features of both the north-eastern and south-western mountain front, selected drainage basin parameters and longitudinal profiles of rivers crossing the mountain fronts. The qualitative component of the analysis includes examination of slope map in order to identify potential markers of differential uplift such a remnants of pre-faulting planar topography, truncated terraces and triangular facets along mountain fronts.

The key conclusion emerging from the study is that morphometric properties of both mountain fronts are similar which may be interpreted in at least two ways. The first interpretation holds that the SW mountain front is also an active structure and the Sowie Mountains are bordered by normal faults with considerable throw (~500 m at least) on both sides. Alternatively, one may argue that geomorphometric characteristics of fault-generated mountain fronts and bedrock-controlled escarpments may be strikingly similar and hence, geomorphometric parameters do not play such a discriminating role as usually assumed.

Keywords: morphotectonics, geomorphometry, morphometric indices, tectonic landforms, mountain fronts, Sowie Mountains, Sudetes

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INFLUENCE OF EVAPORATION ON SOIL MOISTURE VARIABILITY IN MULTI-LAYERED FLOODPLAIN SOILS

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Floodplain soils, due to their high spatial variabilities in texture, organic matter content and water retention capacities, fundamentally influence soil productivity and successful cropland cultivation and agricultural activities. A former study by Nanson and Croke (1992) pointed out that point bars and shale-and-ridge topographies on floodplains indicate extremely heterogeneous (Thayer and Ashmore, 2016), multi-layered textural pattern that markedly influences local moisture dynamics. Similar landforms of these types are common along the Hungarian reach of the River Drava (a border river between SW Hungary and Croatia). Soils, developed on these sediments, react location-specifically to extreme drought periods and a groundwater table depth changes according to their elevation above the river, groundwater level dynamics, and soil textural properties. Falling groundwater table elevations, partly due to the incision of the river and climate change, have been observed on the Drava floodplain over the past decades. The increasing drought hazards and falling groundwater table levels may pose substantial risk on the area and the local water dynamics. Moisture shortage in the shallow rhizosphere and the increasing depth of the capillary fringe zone directly influences forest vitality and crop yields in the area (Fodor-Rajkai 2004). To estimate the water balance of the deeper soil horizons, moisture dynamics of the vadose zone can be accurately estimated by numeric models (Kandelous- Simunek 2010, Le Bourgeois et al. 2016). To analyze the location-specific influence of texture on moisture dynamics, 19 study sites of 30 to 70 hectares were selected based on landforms and ortophotos. Five soil surface textural types (STT) were identified at the 19 sites. With the help of the PCA (Principal Component Analysis) the drought-sensitive sites of the studied portion of the Drava floodplain were identified. With HYDRUS-1D model simulations the impact of groundwater table depth on the temporal changes of moisture content of the rhizosphere was analyzed. Model runs were carried out at three different groundwater table depth for each study site. Results were statistically analyzed and compared by PCA. The inverse HYDRUS-1D models were validated for five different soil textures. The impact of evapotranspiration on moisture dynamics was also estimated at two sites on the floodplain (Cún-1 and Cún-2). To assess the impact of evaporation on moisture conditions the Antal-, Meyer-, Turc-, Thornthwaite- and Penman-methods evaporation calculation methods were employed. According to our findings, areas of extreme drought risk primarily corresponded with the sandy-textured surfaces. These drought prone areas totaled 59.69% of the entire studied area at the long-term mean groundwater table depth. When groundwater table depth was lowered by 1 meter, the percentage of drought affected areas increased to 79.61%. The results of the inverse model runs indicated that the monthly Penman model estimations provided the best match between measured and modeled soil moisture time series at a depth of 25 cm. However, at the depth of 70 cm the monthly Penman and the Thornthwaite parametrization performed equally high level and showed best correspondence with the measured results.

Keywords: multi-layered soils, evaporation, soil moisture, Hydrus 1D, floodplain, drought hazard, degradation

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THE ROLE OF INVASIVE SPECIES IN INCREASING RIPARIAN VEGETATION DENSITY AND THEIR EFFECT ON FLOODING (MIDDLE AND LOWER TISZA RIVER AND MAROS RIVER, HUNGARY)

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A basic condition of effective flood protection is to provide the rapid and unobstructed conveyance of floods. This may be hampered by dense vegetation, since increased surface roughness affects the flood conveyance of the floodplain, as it alters flow conditions and significantly slows floods down (Straatsma et al., 2008). In the last century, the land use of the floodplain of Hungarian rivers changed considerably, as meadows, pastures and arable lands have been replaced by forests, besides surface roughness has further been increased by invasive species, such as false indigo (Amorpha fruticosa), wild cucumber (Echinocystis lobata) and riverbank grape (Vitis riparia), having been spreading rapidly since the 1980s, causing indigenous species to be excluded from the floodplain (Sándor and Kiss 2007).

The aim of the present research is to determine the extent to which Amorpha fruticosa increases vegetation density, thereby modifying surface roughness (Manning's n). In addition, we attempted to model how the removal of A. fruticosa would change the flood conveyance of the floodplain.

To determine vegetation density, we used the method (Parallel Photographic Method) from Warmink (2007), which gives the proportion of area occupied by vegetation within a given volume unit. The basis of this method is that photographs are taken of the vegetation in front of a large white screen, which when converted into black-and-white images gives the proportion of vegetation represented by black pixels. The impact of A. fruticosa on vegetation density was calculated by removing it from the black-and-white images. The results therefore show the extent to which vegetation density would decrease if A. fruticosa was cleared from the floodplain. The photographs were taken in the winter period when trees were leafless, since (1) leaves could multiply the proportion of black pixels, and (2) floods typically occur during the winter and early spring period.

The results suggest that the contamination of a given area by A. fruticosa depends largely on the land-use of that area. There are major differences between the sample areas in land-use changes since the 18th and 19th century. On the floodplains of the Lower Tisza River and Maros River, meadows, pastures and arable lands virtually disappeared, while nowadays forests occupy almost all (86%) of the floodplain. In contrast, along the Middle Tisza River forests occupy smaller areas (50%) and the proportion of meadows and arable lands (43%) is still considerable, however 88% of the latter are contaminated by A. fruticosa.

The results of the photo-based method show that on meadows, pastures and arable lands the presence of A. fruticosa increases vegetation density by 100%. In forest plantations, it contributes 20-40% while in natural riparian forests, it contributes 15-16% to vegetation density. These differences could be explained by the fact that on pastures and arable lands, A. fruticosa could spread easily due to lack of shadowing, while in forests the shade of large trees impede A. fruticosa to advance into them, it only forms denser stands on the verges of the forests.

The values of vegetation density were used in a HEC-RAS model to simulate a record high flood (in 2006) on the floodplain of the Lower Tisza River with different vegetation covers. The results suggest that the clearing of the vegetation in patches would not cause any

significant changes in flood conveyance and peak levels. Although the flood flow would accelerate in the upstream sections of the cleared areas, in the downstream sections the flow would be impounded because of denser vegetation. Therefore, these two effects would extinguish each other. Accordingly, clearing of longer sections of the floodplain would lead to more effective results.

Keywords: Vegetation density, invasive species, Amorpha fruticosa, Parallel Photographic Method, HEC-RAS

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INTEGRATED SPATIAL ASSESSMENT OF WIND EROSION RISK IN HUNGARY

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Wind erosion susceptibility of the Hungarian soils was mapped on national level integrating three factors of the complex phenomenon of deflation (physical) soil (features), wind (chracteristics), landuse/landcover). Results of wind tunnel experiments on erodibility of representative soil samples were used for the parametrization of countrywide map of soil texture compiled for the upper 5 centimeter layer of soil, which resulted in a map representing threshold wind velocity exceedance. Average wind velocity was spatially estimated with 0.5' resolution using the Meteorological Interpolation based on Surface Homogenized Data Basis (MISH) method elaborated for the spatial interpolation of surface meteorological elements. The probability of threshold wind velocity exceedance was determined based on values predicted by the soil texture map at the grid locations. Ratio values were further interpolated to a finer 1 ha resolution using sand and silt content of the uppermost (0-5 cm) soil as spatial co-variables. Land cover was also taken into account excluding areas which are not relevant from the aspect of wind erosion (forests, water bodies, settlements etc.) to spatially assess the risk of wind erosion.

The outcome of wind speed exceedance calculations was the probability value of wind velocity exceeding critical values on an hourly level during the observed 13 years in each point of the grid network (Fig. 5). According to the map, spatial variability is relatively high throughout the country. Values in general range from 0% to above 2.5% in relation to wind climatology, landscape, soil properties and land cover.

According to the categorized wind-erodibility map five distinct territories can be identified in the country with typically higher wind erosion risk:

1. The Nyírség is an ancient alluvial fan, its area is about 5,100 km^2 and consists of mainly sandy soils and its different variant. About one third part of the area are covered by forests (mainly the eolian forms), but there is difference in this regard in regional distribution, because territories covered by sandy loam, loam and silty loam are under agricultural cultivation and are more endangered by wind erosion.
2. The Duna-Tisza Interfluve is about 10,000 km^2 and also consists of sandy soils and its variant. A significant discrepancy to the Nyírség that this area is poorer in precipitation (500-550 mm) and there are drought periods in many years. As a consequence of its dryer climate, its forest cover is sparser than in Nyírség.
3. The glacis in the foreground of the Transdanubian Mountains are affected by wind erosion because of mainly two reasons. In one hand they are covered by sandy soils, on the other hand the wind velocity is the highest in Hungary – because this region is exposed perpendicularly to the dominant winds blowing from northwest.
4. The Inner-Somogy is about 3,000 km^2. However, it has more precipitation, than Nyírség and Duna-Tisza Interfluve, according to the alluvial fan origin of the area, it is also covered by sandy soils, which make it more endangered by wind erosion.

5. The Transdanubian loess region is also situated in the Transdanubian region and consists of loess. The productivity of the soils formed on them is outstanding, so the dominant land use is arable lands. This territory is also exposed perpendicularly to the winds blowing from northwest, which together with the seasonally uncovered and extended agricultural areas make it more susceptible to wind erosion.

Keywords: Hungary**,** SAGA**,** spatial soil data**,** wind erosion mapping, wind velocity data

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DENDROGEOMORPHOLOGICAL ANALYSIS OF THE LANDSLIDE ACTIVITY IN JABLŮNKA (OUTER WESTERN CARPATHIANS, CZECH REPUBLIC)

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This contribution introduces new data about the landslide activity in the flysch relief of Outer Western Carpathians in Jablůnka. This area is known for its instability but no comprehensive data exist about historical landslide activity. In the chosen locality we investigated its activity with 106 tree cores of Picea abies (L.) Karst. The analysis was based on the existence of reaction wood and abrupt reduction in annual tree ring width. We have compiled six-year chronology with the oldest one in 1941. Moreover, maps of spatio-temporal reconstruction of movements were created for these years and the locations of the largest activity were determined. Landslide activity poses a threat to human life, property and the environment. Therefore, more attention should be paid to these phenomena.

Keywords: dendrogeomorphology, landslide, Outer Western Carpathians

CHANGES OF THE HYDRODYNAMICS CONDITIONS IN THE BRAIDED RIVER

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The work focuses on the understanding of the basic hydrodynamic conditions along the braided gravel-bed river Ochotnica. Measurements were carried out in a braided section which was morphologically active and were carried out in the period from 2003 to 2014 at specific locations. The study focuses on the flow velocity measurements, which were carried out for different flow conditions, and the determination of the basic hydraulic parameters shear velocity, bed shear stress, Reynolds number, and Froude number. The gravel material was also examined to determine the characteristic grain sizes.
The conclusions from our work are following:
1. Under flows with high water level, the center and right channel of the Ochotnica River were conveying water, which resulted in the formation of active gravel bars. During periods of low flow (low water levels), those two channels were morphologically inactive.
2. During low flow conditions, a pool behind the right gravel bar was filled with water was filled with water and the water was present all time in the pool even if all channels were conveying water. This suggests that the channels are hydraulically connected through the alluvial gravel bed of the river.
3. The shear stress and hence the Shields-parameter depends highly on the flow velocities, as they were used for the calculation of the shear velocity [a question: how reliable are these estimates]. Bed shear stress and Shields parameter were highest, were flow velocities were largest and the water depth had not such a big effect on these two parameters.
4. The study shows that despite the disturbance of the river channel through engineering works, the river returns to its characteristic morphology rather fast.
5. The anthropogenic influence on the river bed must be seen critically. The local road caused the reduction of the grade line of the bars and their natural structure was disturbed. However, it also caused an increasing grade line at the side channel, which acts as a barrage and stops water flowing into these structures.

Keywords: braided river, shear stresses, Froude number, Reynolds number

COARSE CLASTIC DEPOSITS IN THE BOHEMIAN MASSIF – CARPATHIAN FOREDEEP CONTACT AREA SOUTH OF ZNOJMO (CZECH REPUBLIC – AUSTRIA): RECENT CHANGES IN THE REGIONAL PALEOGEOGRAPHY

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Various occurrences of coarse clastic sediments, especially gravels, are preserved in the subjected area belonging to boundary region between the Bohemian Massif and the Alpine-Carpathian orogenic system both from sedimentological (incl. stratigraphical) and geomorphological points of view. Some 10–15 different types of gravel could be distinguished coming from the Miocene – Pliocene – Quaternary periods. Miocene deposits of the Carpathian Foredeep and Quaternary alluvial fan and terrace system of the Dyje / Thaya River are more known from previous research. However, mutually similar sites stretching nearly 20 km from the Šobes meander of the sharply incised Dyje River in the higher crystalline terrain of the Bohemian Massif (Podyjí National Park) in the NW via a specific wide depression at the SE margin of the Massif toward flat summits of the higher rugged water divide area of the Heidberg Upland within the lower Foredeep in the SE were largely omitted or inconsistently classified during geological mapping both on the Czech and Austrian sides of the area. Stratigraphically, the gravels are likely of Pliocene age. However, the beginning of Quaternary period as a time of their origin cannot yet be fully excluded.
Basic sedimentological (petrology, heavy minerals) and geomorphological characteristics (relief setting variability) of this extraordinary sedimentary belt were investigated. The occurrences are located in quite levelled altitudes of 315–270 m, some 60–120 m above the present-day base level of erosion. A dominant part of its sedimentary content was redeposited from Miocene of the Carpathian Foredeep, most likely the Lower Badenian Formation, derived from the nearby Dyje / Thaya pluton of the Bohemian Massif (quartz, quarzite, aplite, pegmatite, granite) but some portion of the rock material corresponds to the Moravicum and even Moldanubicum (graphitic quarzite, gneiss, amphibolite) exposed in the present-day incised Dyje / Thaya River canyon more to the NW, thus plausibly evidencing: (1) significant clastic transport from those more distant units of the Bohemian Massif within the valley; and (2) later abrupt change of the SE striking stream from the Šobes meander toward the town of Znojmo in the NE, possibly driven by conjugated NE–SW and N–S lineaments of the Waitzendorf Fault system parallel to the Bohemian Massif – Carpathian Foredeep boundary. This stream redirection was either conditioned by active Quaternary tectonics or by mere passive stream adjustment to old lines within this fault zone. In case of the former possibility, more striated slickensides were found out in the valley section between Šobes and Znojmo to support potential recent tectonic influences, however, their structural evaluation has not yet provided unequivocal plausibility of this evolutionary variant.

Keywords: gravel variability, Miocene – Pliocene – Quaternary period, basic sedimentology, possible source, paleogeography, Waitzendorf Fault System, Bohemian Massif – Carpathian Foredeep contact area

UAV TECHNOLOGY FOR LANDSCAPE CLASSIFICATION AND MAPPING

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Geomorphological mapping requires the collection of primary landform data and depends on scale and changes in the studied object's attributes. Landform identification is normally based on the object classification framework using field work and remotely sensed data with temporal and spatial accessibility, flexibility and accuracy. Miřijovský and Langhammer (2015) emphasize the great reliability of UAV (Unmanned aerial vehicle) in fluvial geomorphologic research and illustrate differences between standard schematization of study area during classic field research with errors from subjective observation and UAV mapping. The main aim of this paper is to present possibilities of UAV technology for the identification and mapping of fluvial landforms and analysing of the point cloud density after vegetation filtration in fluvial geomorphic research. Data acquisition for riverine landscape mapping using a low-cost UAV outlay is divided in to 5 main steps (Rusnák et al. 2018): (i) reconnaissance of the mapped site - identification of potential problems and dangers in flight mission, takeoff and landing points; (ii) pre-flight field work - the placement and targeting of ground control points (GCPs) for precise georeferencing; (iii) flight mission - aerial imaging of the study area; (iv) quality check and processing of aerial data - data accuracy assessment and software data processing and (v) operations above processed layers and landform (object) mapping (extractions) - comprising visualization, landform identification and morphometric analysis. The essential field research elements of legislative processes and UAV permission and regulations were certified prior to the flight; and these are designated step zero (0).
For monitoring of the selected Belá River reach was used UAV system from HiSystem company: HEXAKOPTER XL with 6 rotors and Sony NEX 6 camera with 16-50 mm lens. Spatial referencing was performed with 38 control points (GCP- Ground Control Point) targeted by RTK GPS Leica Zeno 5 with GG03 antenna and accuracy of 11 mm. For data processing was used Agisoft PhotoScan software, which operates on the principle of SfM algorithm. Advantages of this method is high level of automation and UAV photogrammetry provides accurate data with high resolution, affordable acquisition cost and represent the less time-consuming data collection technique. Total geometry error was 80 mm and RMSE (root mean square error) after aligning all the images it was 60.121 mm (x coordinate), 43.7584 mm (y coordinate) and 29.46 mm (z coordinate). The Belá River is subdivided into two reaches; (1) the northern reach dominated by gravel bar and island areas with woody debris accumulated in abandonment arms created by material accumulation up to 1 m above present river flow and (2) the reach in the lower part is affected by anthropogenic creation of a small hydropower plant and artificial canal with evident secondary channel incision. Proficient automated classification (supervised Maximum Likelihood Classification) was achieved for the "vegetation" and "gravel bar" classes and lower accuracy of water class due to vegetation class cover overhanging the bank line, visible bedrock under the water level classified in the bare-surface class and the gravel channel bed in the gravel-bar class was observed. SfM algorithm creates an envelope surface model with vegetation cover and for that the resulting point cloud was semiautomatic classified in the software Terrasolid - Terrascan (Microstation), in the following six classes: high vegetation (over 5 m), medium vegetation (from 1.5 m to 5 m), small vegetation (from 0 2 m to 1.5 m), topographic surface and water surface. Classification of point clouds increases the accuracy elevation model, but on the other

hand, does not capture the real terrain and topography under the vegetation. Sparse vegetation canopy allows capturing the surface of the ground, but with a significantly lower point density and therefore it is necessary to evaluate the quality, thus obtained elevation model. The average density of points the most significant drop in the category floodplain (from 131.7 points per m^2 to 2.8 points per m^2), wherein the density of points is increased with increasing height of the vegetation (Rusnák et al. 2018). In the areas with dense vegetation is obvious significant loss of information of the surface height. Multiple imaging by classic nadir images combined with oblique and horizontal ground imaging is crucial in mapping bank height, bank line, bluffs and valley walls. The accuracy of the applied classic approaches to bank delimitation from aerial photos in both models and orthophotos is severely affected when the banks are inclined at an angle rather than forming a vertical cliff. It is therefore important to create a methodology which applies landforms delimitation in 3-dimensional space; employing 3D assessment of landscape objects rather than classic planar geoscience analysis in GIS.

Keywords: UAV, fluvial landscape mapping, workflow, point cloud classification, vegetation separation, UAV photogrammetry

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STREAMS AND LAKES OF THE NELSON ISLAND, SOUTH SHETLAND ISLANDS, ANTARCTICA

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Nelson Island is located in the South Shetland Islands and covers area around 150 sq. km. Nelson Island lies only 400 m from the King George Island across the Fildes strait.
Vast majority of Nelson Island is glaciated. Sparse unglaciated areas are located along the coast. We situated our research to the northernmost largest unglaciated area adjacent to the Fildes Strait. We used combination of GNSS mapping and studying aerial photos from the period 2005-2016 to map all the streams and lakes located in this unglaciated area. Longitudinal profiles of all streams were constructed using GNSS. We georeferenced and vectorised aerial photos to establish tables containing data of all streams and lakes, containing their length, elevation, area etc.
We plan to use presented data for detailed geomorphic survey of geomorphic forms and processes connected with fluvial environment and to select spots for obtaining samples of sediments from the lake bottoms in oncoming seasons.

Keywords: stream, lake, longitudinal profile, deglaciation, Antarctica

CARSTIFICATION POSSIBILTIES IN THE TRANSITIONAL FACIES OF THE BOHEMIAN CRETACEOUS BASIN – EVALUATION OF EXISTIG RESEARCHES

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The Bohemian Cretaceous Basin (BCB) is one of the most important hydrogeological structures in this country, with huge sources and storages of underground water. Despite of this importance, in many BCB areas it hasn´t been studied yet, how well-permeable pathways arise. The doyen of Czech hydrogeology Prof. Hynie described some of the hugest springs to be of karst origin and as the most permeable area he described the so-called transitional facies between shallow-water sandstones and deep-water marlstones. In many BCB areas with huge springs we can find thin sandstones and siltstones layers with high carbonate content even in stratigraphical levels corresponding with aquifers. Karstification process is not associated only with well-dissoluble rock, e.g. limestone but it can also be found in other rocks like quartzites or silicaclastics rocks with carbonate matrix.
The content of this presentation is the evaluation of the previous work results in this field. My research is focused on Vysokomytska and Ustecka synclinal area. 160 samples were taken from borehole cores and rock outcrops in this area. Cores were taken from intervals where: (i) high carbonate content was expected, (ii) conduits and enlarged fractures were observed, (iii) inflows to boreholes were determined by well logging. Calcium carbonate content was determined by calcimetry in cores. Cores were leached in hydrochloric acid to observe the degree of disintegration. Polished sections were prepared from selected core Ca, Si, Na, K, Al content was automatically mapped by microprobe to visualize the calcium, silica, feldspar and clay mineral distribution in cores.
Leaching in hydrochloric acid is an accelerated simulation of natural processes of dissolution by acidic solutions. In many aquifers in BCB there are thin calcite-rich layers which disintegrates after leaching calcite. Leaching of the samples in acid led to the decrease of sample strength, sometimes to their desintegration. Leaching experiments showed that the carbonate content is an important but not the only driving factor in the karstification process.
In sediments with detrital quartz admixture the total disintegration mostly occurs between 35-50% $CaCO_3$ content depending on insoluble material contacts. In sediments with precipitated silica even calcite content 80% may not be sufficient for material to disintegrate after leaching, and disintegration occurs mainly on fractured zones.

Keywords: Bohemian Cretaceous Basin, karst, carbonate content, marlstone, leaching experiments

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POSSIBILITIES FOR SUSTAINABILITY OF THE MULTIPLE-THREAD MORÁVKA RIVER CHANNEL IN THE SKALICKÁ MORÁVKA NATIONAL NATURE MONUMENT

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The originally multiple-thread Morávka River channel located in the piedmont of the Moravskoslezské Beskydy Mts has undergone a morphological change in the last 50 years, particularly in connection with the narrowing of active channel and incision. One exception is a short channel reach with preserved close-to-natural state of multiple-thread channel, where lateral erosion and channel migration during flood discharges occur. This short reach is included in protected landscape area of the Skalická Morávka National Nature Monument (NNM) in order to preserve typical Carpathian piedmont river channel with a habitat for endangered species of fauna and flora. However, a gradual channel transformation has been observed in this preserved multiple-thread river reach in the last two decades.
The main aim of this research was to define the possibilities of restoration measures to keep and protect the multiple-thread river pattern in the Skalická Morávka NNM. The research included (i) the analysis of close-to-natural multiple-thread channel reach dynamics, (ii) the evaluation of the bed-load transport intensity as one of the main factor generally influencing sustainability of multiple-thread river pattern and (iii) the assessment of dominant discharges for bed-load transport in the Skalická Morávka NNM. The spatiotemporal channel dynamics in the Skalická Morávka NNM were assessed using available aerial photos taken between the years 2000-2016. The volume of bed-load transported sediment during 20- and 1-year recurrence interval discharges was estimated by the analysis of repeatedly measured cross-sections during the years 2005-2015 in the 0,9 km long channel reach in the upper part of the Skalická Morávka NNM and recorded discharges. The BAGS model (Bedload Assessment in Gravel-bed Streams, published by the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station) was used to ascertain dominant discharges for bed-load sediment transport in the Skalická Morávka NNM. Additionally, the analysis of man impact on water and sediment distribution in the fluvial system of the Morávka River was realized.
The results showed that large volume of sediment was stopped in the upstream part of the Morávka basin by the Vyšní Lhoty weir and by Morávka Water Reservoir. However the presence of check dams in small tributaries together with increase in forested area during 20th century declined sediment production in the headwater parts. Based on the calculations, ca. 20000-25000 cubic meters are missing in the 0,9 km long channel reach in the upper part of the Skalická Morávka NNM. This volume of sediment material was eroded by discharges with 20-year recurrence interval in the year 2010 and it will be necessary to adding of this amount of sediment. On the other hand, the Morávka River needs sufficient amount of gravels (up to several thousand cubic meters) during individual higher-flow (with 1~2-year recurrence interval discharge) events to prevent from further incision and channel narrowing. Other actions as artificial disturbations of gravel-bar surfaces and artificial flooding are recommended because intensive succession of tree vegetation was observed on the gravel bars. This succession affected mobility and re-flushing of sediments in the close-to-natural multiple-thread channel in the Skalická Morávka NNM.

Keywords: multiple-thread channel, gravel-bed river, incision, river restoration, protected landscape area, Morávka River, Moravskoslezské Beskydy Mts.

QUATERNARY TECTONIC ACTIVITY ON THE MARIANSKE LAZNE FAULT (CHEB BASIN, WEST BOHEMIA) AS REVEALED BY 3D TRENCHING AND GEOPHYSICAL SURVEY

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Mariánské Lázně fault (MLF) is a NW-SE striking, morphologically pronounced structure in western Bohemian Massif, which controls the eastern limit of the Cheb-Domažlice graben. The northern segment of the MLF limits the western mountain front of the Krušné hory Mts towards the eastern limit of the Cenozoic Cheb basin, which is superimposed on the western part of the NE-SW trending Eger Rift. The Cheb basin is famous for Quaternary volcanism, present-day earthquake swarm seismicity (max. ML=4.6) and mantle-derived CO_2 emanations. We carried out paleoseismic survey at the Kopanina site to decipher Quaternary tectonic activity of the MLF and to look for potential large surface-rupturing prehistoric earthquakes that would be responsible for the morphology of the fault scarp/mountain front of Krušné hory Mts. We performed 3D trenching (fault-parallel and fault-crossing trenches), which was preceded and accompanied by geophysical survey to specify the trenching site and to extend geological structures revealed from trenches more to the depth. The presented 2D and 3D geophysical survey included electric resistivity tomography and ground penetration radar. Seven excavated and six hand-dug trenches revealed a complex geology and deformation probably as a result of right-lateral transpression during Late Quaternary. The MLF seems to be expressed here by several fault splays active during different geological times. The youngest fault displaced and deformed Holocene deposits of the age interval 5.3 - 1 ka BP, which is the youngest proved surface faulting in central Europe, reported so far. The youngest observed faulting occurred during two earthquakes of suggested minimum magnitude Mw=6.3 – 6.5.

Keywords: Quaternary tectonics, geophysical survey, earthquakes, trenching, Cheb basin, Mariánské Lázně Fault

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TRACES OF INCREASED HYDROGEOMORPHIC ACTIVITY IN THE EASTERN SUDETS DURING THE PERIOD 2007–2014

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Debris flows, debris floods and gully erosion belongs among the most frequent natural hazards occurring in the Central European mid-mountain regions. Since the 1997 disastrous floods, several low- and high-magnitude events of increased hydrogeomorphic activity have caused damages on vegetation, forest roads, railways, etc. This contribution brings an overview of debris flow/flood events and gully erosion activity in the northern part of the Eastern Sudetes during the last 10 years. The selected events were investigated based on documented materials, geomorphic mapping, orthophoto analyses, dendrogeomorphic dating, and analysis of meteorological data. Particularly, the 2010 debris flow event in the Hrubý Jeseník Mts. and recent gully erosion (2007–2014) in the Zlatohorská vrchovina were investigated in detail.

At least eight debris flow paths (50–500 m long; 2–10 m wide; 0.5–2 m deep) developed or were reactivated during the rainstorm (79.3 mm/day) in May 2010. The most destructive spatial imprint was recorded in the Klepáčský potok stream where the transport of large woody debris occurred simultaneously resulting in considerable damages on riparian vegetation and check-dam structures. Increased gully erosion since 2007 was documented near the Mikulovice city (maximum investigated gully incision was 154 cm during the extraordinary rainstorm with the intensity of 41.3 $mm.h^{-1}$ in May 2014) causing damages on railway structures and floodplain area. Based on the data synthesis, three general factors responsible for an increased effect of hydrogeomorphic activity were found: (i) occurrence of more intense rainstorms (even though the intensification is hardly to be evidenced); (ii) natural and/or anthropogenic disturbance at the study site preceding the disastrous event (windstorm caused the large wood recruitment into the channel resulting in bigger damage caused by debris flow in the case of the Klepáčský potok stream; previous flood countermeasures changed the runoff contributing area which increased the gully incision and widening in the case of gully network near the Mikulovice city); (iii) tectonic-geological predisposition (the most frequent debris flow activity occurs in the area of deep-seated rockslides; increased gully erosion occurred in highly erodible glacifluvial deposits).

Keywords: debris flow, gully erosion, dendrogeomorphology, precipitation data, Eastern Sudetes

RIVER TERRACES IN THE FORESTED HEADWATER CATCHMENT OF ČERNÁ OSTRAVICE RIVER

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Reconstruction of the development of the fluvial terraces in midmountain forested areas is problematic due to the limited extent of the fluvial terraces, dense vegetation cover or incompleteness of the fluvial archives. Most of the studies are focused on the downstream valleys (Bridgland et al., 2017; Lewin et al., 1995; Schumm, 1981; Starkel et al., 2007) and only few studies are focused on the headwater streams (Collins et al., 2016; Pierce et al., 2010; Scherler et al., 2016). Černá Ostravice river represent uniquely well preserved terrace system at the highest part of Moravskoslezské Beskydy Mts. In order to reconstruct the evolution of the valley floor we use the LiDAR data, field survey, geophysical sounding, sedimentological analyses and absolute dating. In accordance with the results we provide approximately 8 –kyr record of the development of the fluvial system. Therefore we have opportunity to capture the environmental and human-introduced changes of the upstream fluvial system. In accordance with the results we identify 5 different phases of the landscape evolution. The minimal age of the oldest accumulation phase (P1) is ~8 ka. Dominance of the fine massive sedimentation suggests intensive sheet erosion. We assume occurrence of the incision phase (P2) caused by increase of the precipitation and natural change of the vegetation cover over the Atlantic. In the accumulation phase (P3) over Subboreal dominates the coarse accumulation, it is probably linked with the increase of the precipitation. Over the Subboreal/ Subatlantic transition occurred another phase (P4) with the high magnitude of the event or events which caused resedimentation and accumulation of the organic debries. Over last 400 years the fine overbank sedimentation is prevailing. This evolution phase (P5) could be linked with the shepherd activity and deforestation in the watershed due to the Wallachian colonisation. Present incision phase (P6) could by linked with the direct and indirect changes of the fluvial system. Almost pristine watershed underwent climate controlled development till the beginning of the 17th century when the human activity prevailed, affect the fluvial system and change the sediment budget. Reconstruction of the morphostratigraphy of the headwater stream at the midmountain forested area provides insight into dynamic, sensitivity and functioning of the headwater midmountain fluvial system over Late Quaternary.

Keywords: stream, river terraces, morphostratigraphy, Moravskoslezské Beskydy Mts., Wallachian colonisation

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GEOMORPHOMETRY AND POSTGLACIAL EVOLUTION OF THE PEŁCZNICA VALLEY GORGE (WAŁBRZYCH UPLAND, SUDETES)

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The main goal of this work was to provide geomorphometric description of one of distinctive narrow (i.e. gorge) valleys located in the marginal part of the Middle Sudetes, in the Wałbrzych Upland, the Pełcznica River valley. The analysed part of the Pełcznica Valley represents a transitional section of the drainage system that connects the intra-mountain depression of the Wałbrzych Basin with the Sudetic Forefield. The area exemplifies of one of the characteristic features of the Sudetes' relief described by Jahn (1980), i.e. the fact that the morphological axis of the Sudety range is composed of intra–mountain basins, not mountain ridges. In the Neogene this area, like the other parts of the Sudetes, was subject to tectonic uplift, which took place mainly along the Sudetic Marginal Fault (SMF) and old secondary dislocations of Variscan origin. The period preceding the Neogene block movements was recorded in this part of the Sudetes in the form of extensive denudation surfaces (leveling 400–600 m a.s.l.) above which resistant ridges and dome- like shaped monadnock hills rise.
The gorge of the Pełcznica valley was probably initiated during the period of the Neogene tectonic activity of the Sudetes (Szczepankiewicz 1954). However, the development of the valley during this period and a link to the network of a pre–Quaternary drainage system is difficult to determine. The Pełcznica valley within the Wałbrzych Upland crosses latitudinally oriented, strongly jointed, folded structures of the Świebodzice depression, which is a Paleozoic tectonic basin filled with coarse clastic deposits of Devonian and Lower Carboniferous age. They are mainly polymictic and gneiss conglomerates and greywackes. The valley itself is carved within a conglomerate series from the Lower Carboniferous period. On flattenings adjacent to the gorge, there are preserved patches of glacial deposits (tills with erratic blocks), indicating that during the Pleistocene the entire area was covered the Scandinavian ice–sheet, for the last time during the Odranian, i.e. maximum stage of Saalian Glaciation. The development of the valley in its modern form should therefore be connected with the postglacial period, i.e. since the deglaciation of the last ice-sheet that covered the area of the Wałbrzych Upland (Krzyszkowski, Stachura 1998a, 1998b).
Field mapping and geomorphometric analysis based on high-resolution DEM derived from LiDAR data allowed one to distinguish three different zones in the gorge reach of the Pełcznica valley. The primary parameters characterizing these zones are as follows:
– Upper Zone: L – 0.6, S – 7.3, W – 37, D – 45–55, SI – 20–30,
– Middle Zone: L – 1.1, S – 22.7, W – 22, D – 70–75, SI – 30–45,
– Lower Zone: L – 1.1, S – 13.4, W – 82, D – 60–70, SI – 25–40,
where: L – length (km), S – Mean valley floor slope (‰), W – Mean valley floor width (m), D – Valley depth (m), SI – Mean valley slope inclination (º).
The above data indicate that the middle section of the Pełcznica gorge valley has the character of a narrow and deep incised erosional ravine. It seems that the nature of this section is not related to the diversity of the bedrock. Both polymictic conglomerates and gneissic conglomerates crop out in this section of the gorge. Presumably in this section the Pełcznica river overcomes a block structure which shows greater tectonic activity than the neighbouring areas. This fact is confirmed by geodynamic observations recently carried out in the Książ Castle by Kaczorowski & Wojewoda (2011), Kasza et al. (2017). Postglacial uplift of this part

of the Wałbrzych Upland was greater than postulated earlier by Krzyszkowski & Stachura (1998b) and probably reached 40–50 m.
During the Late Pleistocene, on the slopes of the gorge of Pełcznica, intense weathering and mass–wasting processes occurred in periglacial conditions. Their effect was the origin of scree-slopes and debris talus on the valley sides which reach the bottom of the valley. These processes (weathering of rock outcrops, rock fall), due to the significant relief energy and high slope inclinations, also occur nowadays, although their intensity and rates are lower.

Keywords: fluvial erosion, gorge valley, periglacial mass–wasting processes, Pleistocene, Sudetes

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PALAEO-TEMPERATURE RECONSTRUCTED FROM RELICT SORTED PATTERNED GROUND IN THE KRKONOŠE MTS.

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Palaeo-temperature reconstructions utilizing periglacial sorted patterned-ground features are challenging because these landforms can develop over a considerable temperature range. Consequently, most inferences made so far have been purely qualitative, and as such, they have been frequently considered as unreliable. However, theoretical and experimental studies have demonstrated that patterned-ground geometry depends on temperature conditions at the time of its initiation. The size of sorted patterns is controlled by the frost depth in seasonally frozen regions and the thaw depth in permafrost areas, and their diameter-to-sorting depth ratio is constant, of c. 3.1 to 3.8 under subaerial conditions (e.g. Ray et al., 1983; Hallet and Prestrud, 1986). Accordingly, temperature conditions at the time of patterned-ground formation can be inferred via the sorting depth, which closely approximates former frost or thaw depth.

In this contribution, we introduce a novel procedure designed to infer palaeo-temperature and palaeo-permafrost conditions prevailing at the time of the initiation of sorted patterned ground, which we demonstrate on the example of the Late Glacial or Early Holocene large-scale sorted nets located on the Luční pláň Plateau in the Krkonoše Mts., Czech Republic.

The median diameter of the investigated sorted nets is 4.15 m and the estimated median sorting depth achieves 1.18 m, which is well consistent with our electrical resistivity tomography soundings and earlier observations in excavations at the study site. The median modelled air thawing index is 285 °C.days with interquartile range of 164 °C.days to 478 °C.days. The median mean annual air temperature (MAAT) was calculated to be –8.3 °C with interquartile range of –10.0 °C to –6.5 °C. The sorted patterns likely formed under continuous to discontinuous permafrost conditions because c. 55 % and c. 44 % of the probability distribution of MAAT is below –8.0 °C and –1.5 °C, respectively (sensu Gruber, 2012).

Clearly, the presented method is able to provide palaeo-temperature and palaeo-permafrost estimates for sorted patterned ground, but we believe it also is applicable on other periglacial structures indicative of the base of palaeo-active layer.

Keywords: palaeo-temperature reconstruction, active layer and permafrost, sorted patterned ground, ground thermal modelling, Central Europe

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REDUCING FLASH FLOOD HAZARDS IN SMALL BASINS USING OPEN-SOURCE GIS ANALYSIS

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The study is focused on the use of hydrologic modelling on small and casual streams. For implementation of this study the Prostřední Pořící municipality was used. Two basins in the north-east and south-east part of the municipality were evaluated. The main purpose of the hydrologic modelling is to lower costs in the realisation phase of the flood protection project. The basic inputs are Digital Terrain Model, land use, information about precipitation in the area and field survey. We used existing methodology for estimating the rate of the flash flood hazards. For own hydrologic modelling and application of GIS we used freeware and open-source programs (QGIS, GRASS GIS and HEC-HMS). The hydrologic modelling confirms recorded fluvial processes in the terrain. Next the discharge series were obtained for N-year precipitation periodicity in the pour points of interest. The outputs of the study can be used for effective localization and design of flash flood protection to mitigation flash flood hazards.

Keywords: flash flood protection, Prostřední Poříčí, QGIS, GRASS GIS, HEC-HMS, hydrologic modelling, Digital Terrain Model, discharge series

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EXCURSION GUIDE

Author of the text: RNDr. Lucie Kubalíková, Ph.D.

Field Trip 27th April 2018: Geo(morpho)sites/natural and cultural heritage within Vysočina Geopark

Itinerary:

1) Roštejn Castle look-out tower: overview of the Vysočina Geopark landforms
49°15'08.339"N, 15°25'34.202"E
9:30 – 10:00
Parking is possible in front of the castle.

2) Geological exposition near Roštejn Game Park: introduction to regional geology and petrography
49°14'54.003"N, 15°25'30.716"E
10:00 – 10:40
It is possible to walk from the castle to the exposition through the Roštejn game park using the yellow marked path (respectively educational trail "Roštejnská obora") or park a car directly in front of geological exposition.

3) Kaliště - Máca Stonemason Company: demonstration of stone cutting and polishing
49°14'48.258"N, 15°17'38.221"E
11:15 – 12:15

Parking is possible in front of the buildings.

4) Štamberk and stone field Natural Reserve: rock formations, boulder fields and streams, remnants of quarrying (Řásná quarry)
49°12'35.792"N, 15°22'56.983"E
13:00 – 14:30

Parking is possible along the local communications of Lhotka municipality. From Lhotka, we are going to follow green marked path up to Štamberk castle ruins and then continue on the blue marked path to the Řásná quarry. The length of the trail is approximately 2 km with superelevation of 100 m. The return along the same path.

5) Pařezitý rybník and Míchova skála: medieval pond with surrounding wetlands, rock formations 49°13'44.961"N, 15°22'55.962"E
15:00 – 17:00

Parking is possible on the parking place next to the pond. From here, we are going to follow red and green marked path (partly along with educational trail "Velkopařezitý rybník") up to Míchova skála, cca 2.5 km with superelevation of 100 m. The return along the same path or with an alternative – blue marked path, respectively educational trail around the pond (the diversion at Javořický potok)

Brief information about the visited sites

1) Roštejn Game Park (Roštejnská obora Natural Reserve), Roštejn Castle, Geological exposition at Roštejn Game Park

Roštejnská obora Natural Reserve

Natural Reserve was declared in 1977 and on the area of 31,9 ha it protects one of the largest natural beech forest of Bohemian-Moravian Highland. Besides the mighty beeches, the elms, acers, lindens and ashes can be found here as well as numerous protected and threatened species of plants and animals.

Bedrock consists of a fine grained muscovite-biotite Moldanubian granite. The main landforms are represented by cryoplanation surface, castle koppies and block accumulations. The Roštejn Castle was constructed on the rocky rampart on the cryoplanation surface. The surrounding slopes are covered with block accumulations which are affected by congelifluction. Other frost cliffs are situated east and south-east from the castle and they are accompanied by debris and stone/boulder fields. The granites have typical block-bedded disintegration. Granite blocks are cut by thin quartz veins which often weather out.

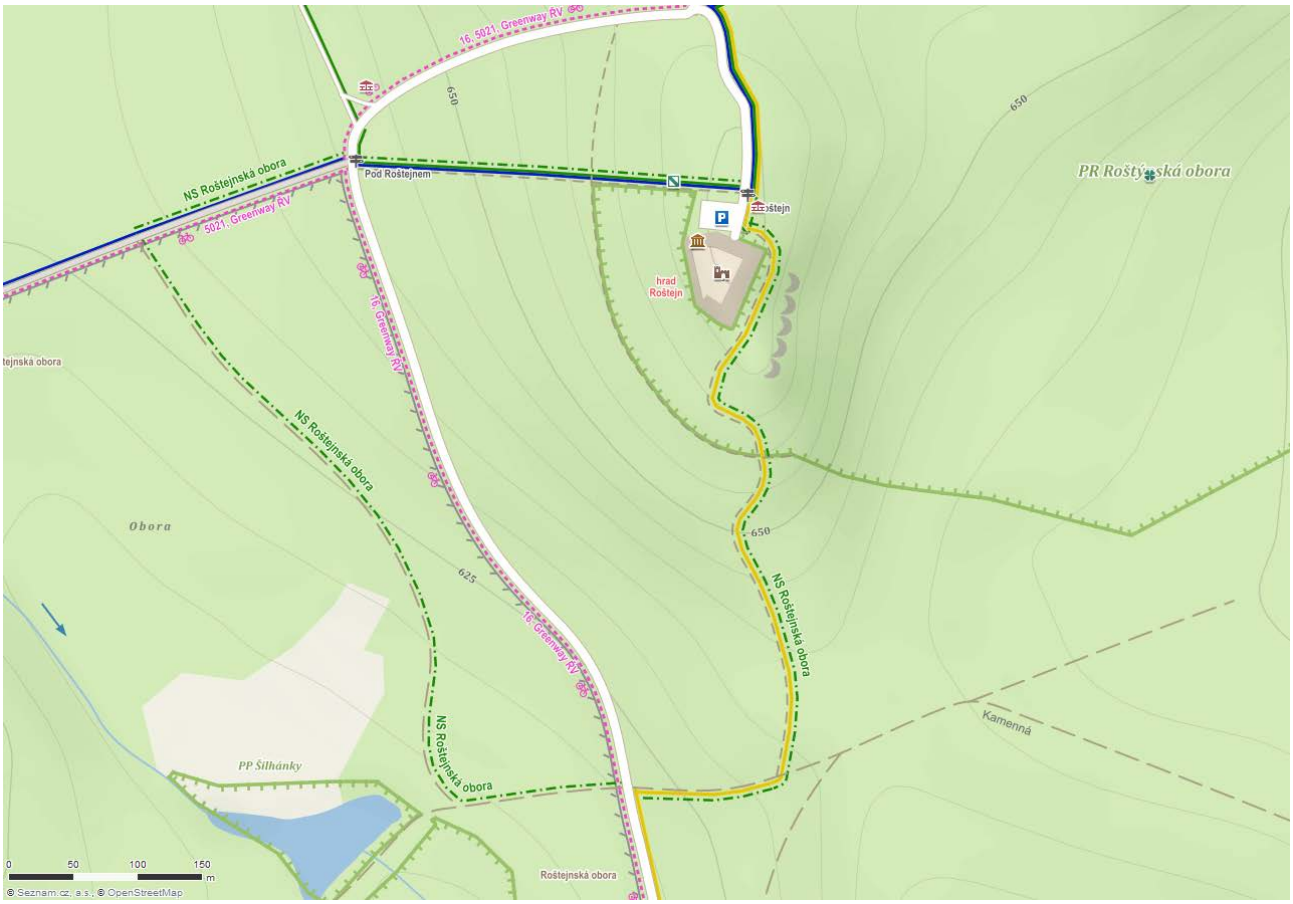

Fig. 1: Close surroundings of the Roštejn Castle (source: mapy.cz)

Roštejn Game Park (126.9 ha) was established at the end of the 16th century and it belongs to the oldest game parks in the Czech Republic. The game species varied in the past, in present days, the moufflons, fallow-bucks and wild pigs live here. The entrance to the game park was possible through the gates of which only Western was preserved. Historically important are

the original granite columns used for construction of a fence with a total length of 4 917 m. In 2006, a new game park for high game (116 hectares) was set up in the vicinity of original game park. There is a marked circular educational trail from the castle, which is about 2 km long (a 45-minute walk).

Roštejn Castle (Rosenstein)

The late Gothic castle (the first written mention in 1353 but built a few years earlier) rises on a rocky hill (677 m) near the village of Doupě. It was constructed by the lords of Hradec, but during the history, the owners changed (Slavats from Chlum and Košumberk, Liechtensteins from Kastelkorn and Podstats from Liechtenstein). In 1915, the lightning struck the Gothic tower, and the castle subsequently burnt down. It was repaired over the next few decades, part of the castle was opened to the public in 1969, and other spaces were made accessible in the 1980s. In 1991, a new exhibition Stonemasonry at Vysočina (Bohemian-Moravian Highland) was opened and currently the castle is owned by the Vysočina Region and administered by the Vysočina Museum in Jihlava.

The dominant feature of the castle – the original Gothic heptagonal tower, 48 meters high – is accessible to visitors and it provides a great view of the region. In the castle, the illustrative examples of relationships between abiotic nature, living nature and human activities can be observed (use of granite outcrops within the castle construction, incorporation of outcrops into buildings, building stone usage, problems of water sources - wells at the castle, etc.).

Fig. 2: Roštejn Castle: an example of incorporation of outcrops into buildings (Photo: Z. Máčka)

2) Kaliště - Stonemason Company: demonstration of stone cutting and polishing

Family company Granit Máca Ltd. has been engaged in the extraction and processing of granite for several generations. The granite type Mrákotín (of grey and yellow colour) is extracted in the quarry of Panské Dubenky and then processed in Kaliště.

Stonemason Company in Kaliště (Granit Máca Ltd.)

The stonemason company is situated about 450 m northwest of the municipality near the Bělohradský pond. The enterprise belonging to the Máca family allows the granite to be cut, polished, jetted, bush-hammered (bush-hammering is a mechanical treatment of visible surfaces of stone). On programmable circular saws it is possible to process granite even in rounded shapes. The company deals with rough and clean stone production (cobblestones, staircases), production of architectural elements (fountains, columns, pillars) and noble stone production (paving, tiling).

Fig. 3: Granite Mrákotín Variety – from the quarry of Mrákotín near Telč (photo: P. Bokr, source: http://fotoarchiv.geology.cz/cz/foto/17132/)

Kamenolom Panské Dubenky is situated east of the Route n. 409 leading from Panské Dubenky to Domašín. The access is possible from the Perka colony (derived from the word "perk" - coarse sand-gravel from granite). The extracting is done by blasting granite blocks. The local, commonly used name is the Máca quarry, according to the traditional stonemason family of Máca, which also carries out the quarry. In the quarry, there is a rough stone production, blocks of stone designed for processing of fine stone products are transported to a stonemason workshop in Kaliště. The quarry is accessible only with the permission of the owner. The site is in the database of Important geological sites (kept by Czech Geological Survey – http://locality.geology.cz) and it is formed of the fine- and medium-grained muscovite-biotite granite (so called Mrákotín Variety), typical for the Eastern part of the Moldanubian pluton. The foliation planes are covered by biotite aggregates and xenolite

accumulation. System of fractures is comparatively complicated and three orientations can be observed. This granite body demonstrates well the development of granite intrusion.

3) Štamberk and stone fields, Řásná quarry

Štamberk and stone fields Natural reserve

Natural reserve was declared in 1982 and it is situated in the altitude of 610–717 m. The reason for declaring were the ecosystems of beech forests with specific and threatened species and remarkable geomorphological phenomena, above all, the rock outcrops and frost cliffs with frost weathering features, block accumulations and boulder stream.

The bedrock consists of muscovite-biotite granite (type Číměř). The rock outcrops were influenced by weathering already during the Tertiary tropic climate (rounded boulders, karrens), frost weathering during Pleistocene (frost cliffs, caverns, boulder fields, debris heaps) and weathering during current humid climate (rock niches). Hieroglyphic mosaic niches represent a unique phenomenon within the site.

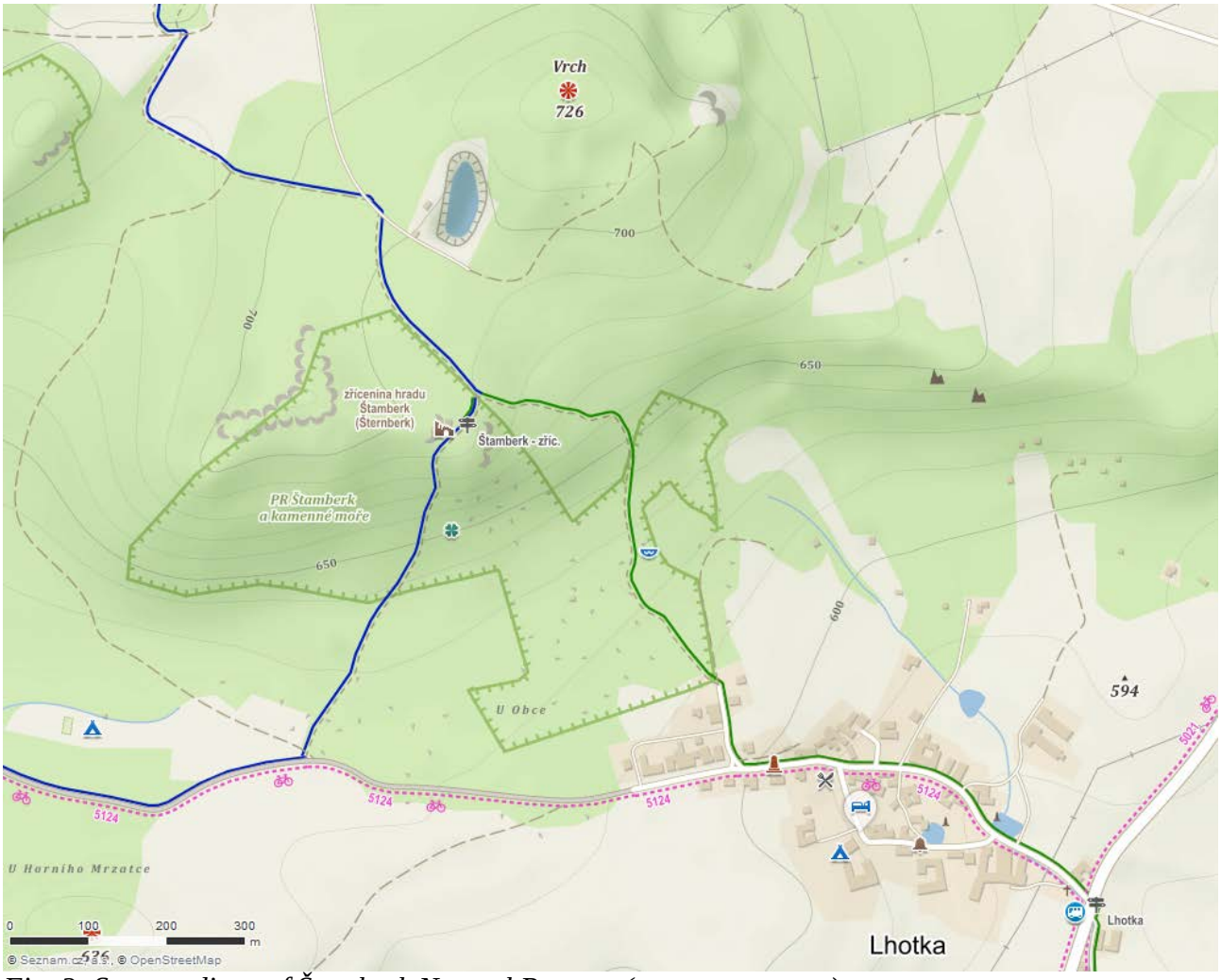

Fig. 3: Surroundings of Štamberk Natural Reserve (source: mapy.cz)

Within this site, the ruins of the medieval Štamberk Castle can be found. From this castle, only the torso of the palace wall, remnants of the guard tower and other walls (the largest wall: 10 m tall and 3 m wide), valleys and ditches are preserved. The castle was probably built by Jaroslav of Šternberk in the second half of the 13th century (in the written documents it was first mentioned in 1356 when it was sold to the lords of Hradec). Later, during the Hussite wars, it was conquered and hardly damaged. The castle is connected with folk tales and legends about the Templars, their treasures hidden in the rocks and the secret corridors leading to Telč or to Roštejn Castle.

Fig. 4: Probable appearance of the Štamberk Castle and the ruins today (source: https://www.rasna.cz/lokality_hrad_stamberk.html, http://mapio.net/pic/p-52652020/)

Lom Řásná

Abandoned quarry is situated approximately 400 m north-west of the ruins, on the southwest slope of the Vrch Hill. It is partly flooded with natural lake. It is a typical locality of one of the distinctive varieties of two-mica granites of the Mrákotín type (medium-grained, slightly porphyric biotic Mrákotín granite (Variety of Řásná)). The rock has a medium-grained texture with the appearance of distinct potassium feldspar phenocrysts. Extensional fracturing of this rock is common, sometimes with quartz filling.

The granite has been quarried here mainly for decorative and construction purposes. Stone quarrying dates back to the eighteenth century, granite was initially broken from the surface boulders and accessible outcrops, from 1923, the classical quarrying process started. Its porphyric appearance contributed to its popularity together with good physical-mechanical qualities. For decorative purposes, the rock was mainly used in Moravia, most often in Brno. Prague is well-known for its use in the metro stations: Main Train Station and Smíchov Train Station. Quarrying was terminated in 2009.

4) Velkopařezitý Pond a Míchova skála Rock

Velkopařezitý Pond (Velký pařezitý Pond)

Natural Reserve is situated 1.5 km north-west from Řásná municipality, the reason for declaring is a preservation of relatively large complex of oligotrophic pond, wetlands and peaty bogs in Jihlava Hills. The bedrock consists of granite. The peat layers reach the thickness of 4.5 m (rarely 5 m, the deepest within the area) and they were exploited in the past. The peat bog originated during Upper Pleistocene and the Holocene. The present organic sediments are formed by dark brown to black, respectively brown-black peat, on the base, there are individual occurrences of gray impermeable clays. In particular, moss, peat-wood and sedge-wood humolites are present. These types of sediments are most commonly found at altitudes from 515 to 715 m. In the case of the Velkopařezitý Pond, the peat is partially hidden under the water surface. Many occurrences of organic sediments have been devastated by local exploitation and melioration due to their location in relatively easily accessible areas.

The pond was founded by Zacharias of Hradec in 1565 and originally it served as a water resource for Telč. For this purpose, the water from the pond was drained by artificial ditch from the Jihlava basin to the Telčský brook in the Dyje basin. Since the founding of the pond, numerous tree stumps of the original forest have been preserved on its bottom, which gave the name to the pond. Currently, the pond is used for very extensive fish farming.

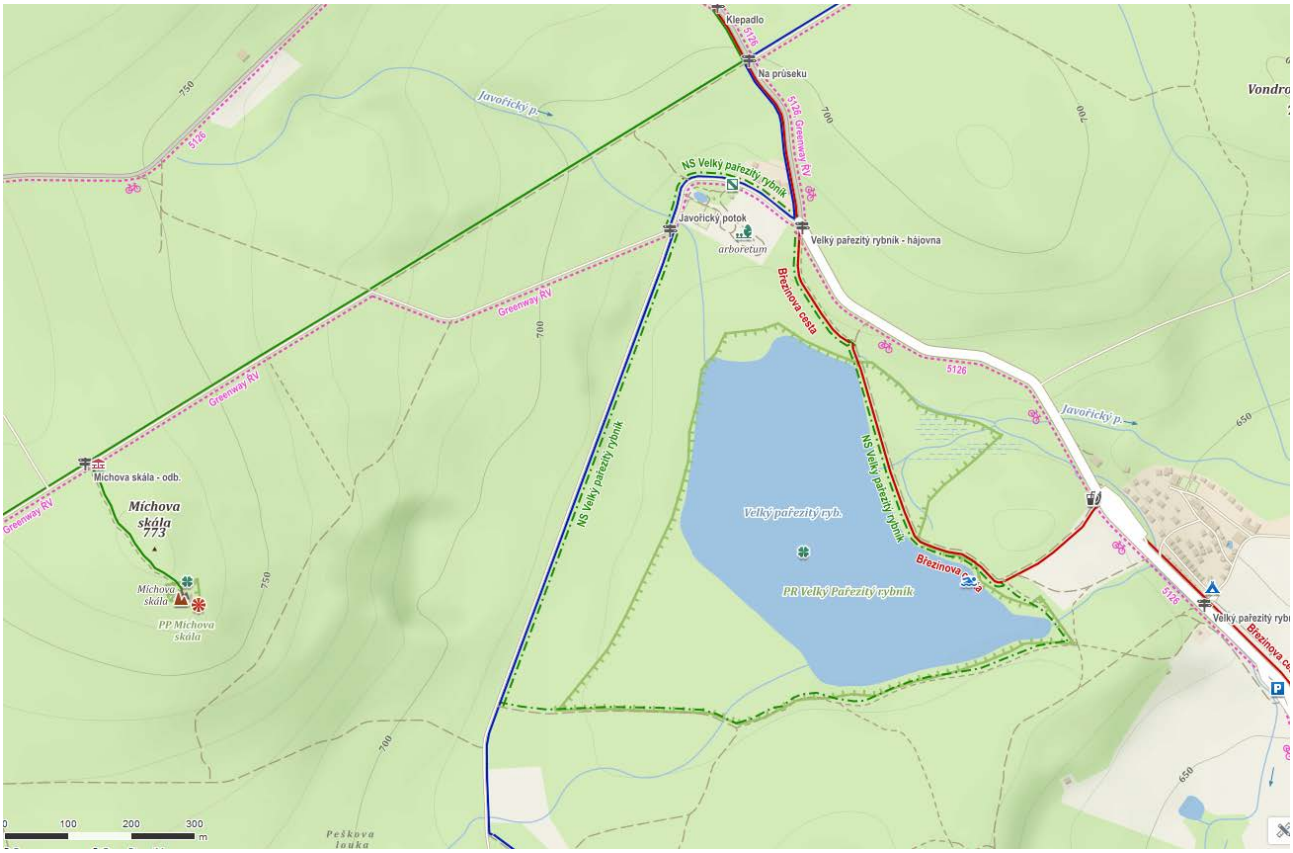

Fig. 5: Surroundings of the Velkopařezitý Pond Natural Reserve (source: mapy.cz)

Míchova skála (Míchova Rock)

The symbol of Vysočina Geopark, Míchova Skála (Rock), is situated in the altitude of 765–774 m. The Natural Monument was declared in 1984 as one of the best preserved examples of the rock outcrops influenced by tropical weathering in Neogene and frost weathering during Pleistocene.

The rock outcrop has the character of two rock towers and frost cliffs, it is surrounded by block fields and debris heaps on original cryoplanation surfaces. The dimensions of the east rock tower are 26 x 21 m, the western tower 21x19 m and the height is approximately 13 m. Concerning the diversity of mezoforms and microforms, there are different types of honeycombs, rock niches, numerous overhangs and fissure caves. Panholes (weathering pits) with drainage channels were also observed. The aforementioned phenomena were only slightly disrupted by the recent rock fall.
Due to the fire of the forest in 1980s, the spectacular view was opened and the outcrops serve as a look-out.

Fig. 6: Míchova skála (Rock) was used for the logo of Vysočina Geopark (source: http://www.dedictvivysociny.cz/priroda/zvlaste_chranena_uzemi-11/prirodni_pamatka-39/?id=211, http://www.telc.eu/turista_a_volny_cas/priroda/narodni_geopark_vysocina)

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