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L A N D F O R M E V O L U T I O N I N M O U N T A I N A R E A S
Recent geomorphological hazards in Carpatho-Balcan-Dinaric region

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GEOMORPHOLOGICAL ASPECTS OF NATURAL HAZARDS AND RISKS IN THE CZECH REPUBLIC

Abstract. The contribution describes geomorphological aspects of natural hazards and risks, especially floods and slope movements (landsliding), which were been induced by rainfall in the July 1997 in Moravia and in the August 2002 in Bohemia. Geomorphological hazard studies in flood- and landslide-affected areas were typical examples of research in which a combination of detailed field investigation and theoretical interpretation was required. Selected results of geomorphological observations from affected areas and some methodological experiences related to geodynamic aspects of natural hazards and risks are summarized.

Key words: natural hazards, risks, floods, slope movements, geomorphology, Czech Republic

INTRODUCTION

Hazards and disasters have become a central concern of geography. Natural hazards are defined as those elements of the physicals environment harmful to mankind and caused by forces extraneous to him. Geomorphological hazards are part of a larger group of natural hazards, including e.g. floods, slope movements, soil erosion, water quality risk, desertification, sudden weather changes and wildfires. Geomorphological hazards are apprehended as a possible occurrence of extremely dynamic or large-area destructive geomorphological process in a particular place and time (e.g. Panizza 1986; Kalvoda 1996). Research into geomorphological hazards could be understood as an opportunity for the preparation of conceptual models and for the understanding of general principles of the origin of natural disasters (Goudie and Kalvoda 1997). In hazardeous areas rapid events occur especially in disequilibriated geomorphological systems. Natural hazards studies are essential for a better understanding of ecosystem protection and the relationship between the environment and human health. Priority

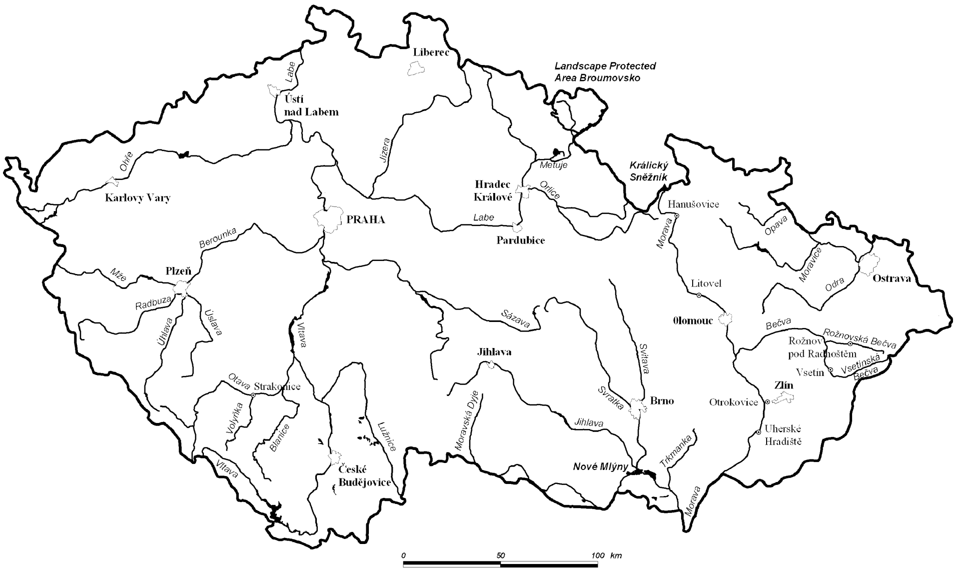

Fig. 1. Schematic map of the Czech Republic with the described localities

theme of physical geography is the studying of the stability and resistance of the environmental systems to the disturbances of the frequency, size and extent of natural events and processes (e.g. Kalvoda 1996, 2003).

The application of geomorphological research results in assessing the present dynamics of landscape changes Central European region of the morphostructural contact of ancient Hercynian Orogene on one side and young Alpine and Carpathian Orogene on the other side, including natural hazards and risks. Recent events of extreme hazardeous phenomena in the Czech Republic were: a) active morphotectonics, b) slope movements and/or landslides, c) accelerated soil erosion and d) floods. In this paper are summarized selected results of geomorphological observations connected with recent extreme floods (1997 and 2002) in the Czech Republic and some methodological experiences related to geodynamic aspects of natural hazards and risks (Fig. 1).

REGIONAL CASE STUDIES OF EXTREME FLOODS AND RELATED PHENOMENA

Reconnaissance works and field mapping performed in the Opava, Bečva and the Morava River basins after the 1997 summer floods and in the Otava River basin after the August 2002 floods show that river basins respond in different ways. Differences in relief changes depend on variations in spatial and time distribution of rainfall and variable geological and geomorphological conditions (Vilímek and Langhammer, in print). The comparison of overflow during the 2002 flood in Bohemia and spatial scope of flood plains around the Volyňka, Blanice, and Otava River proves dependence on rainfall. The upstream Blanice River was affected by rainfall to a higher extent than the Volyňka and Otava River and in parts of the Blanice valley, overflow significantly exceeded flood plains limits. The Otava and Volyňka River were in completely different conditions. Major overflow almost copying the scope of flood plains was found on the Otava only on its track below the Volyňka confluence. Villages are built on adjacent hills of the valley leaving the flood plains undeveloped. Therefore, floodwaters did not cause any significant damage. Lateral erosion and accumulation processes were detected on the Losenice River (the area of intensive rainfall) and on downstream Volyňka in localities affected by major anthropogenic activities around influx to the town of Strakonice.

Different watercourse tracks trigger variable geomorphological processes depending on the stream gradient, amount of flowing water, inclination of adjacent slopes etc. Moreover, enormous precipitations affected river basins formed by different types of rocks. It is useful to stress the processes of relief changes ongoing on tracks of a steeper gradient (mostly in upstream areas) where unabsorbed water flows fast from hills to channels. Due to steep-sided

Photo 1. Railway station in the Northern Moravia destroyed by the Desná River during flood in summer 1997 (Photo from the Archive of the Agency for Nature Conservation and Landscape Protection of the Czech Republic)

valleys, the overflow scope is limited, bed erosion prevails over lateral erosion, and loose sediments are washed away from the valley network. During the floods, bed erosion affected mostly the most upstream parts of main watercourses and their tributaries. During four days (July 5th to 8th,1997) the Meteorological Station situated at the bottom of deep incised the Morava River valley in the mountain range Králický Sněžník measured 550 mm of precipitation. The following flood hazard in known as 1000-year-flood discharge. Linear water erosion prevailed in upper reaches of the Morava River. Free debris of the Holocene and Pleistocene age at the bottom of V-shaped valleys and ravines was washed away and hard bedrock (gneiss) was exposed. In some places large block of gneiss were torn away along fissures from bedrock at exposed bottoms of ravines and moved downstreams. Debris formed large alluvial cones at confluences (Demek and Kopecký 1998).

In some places a stream incision into the rocky bed was detected. During above mentioned hazard 1997 in the Upper Morava River watershed the river incised into hard bedrock and the river bed became deeper by 0.3 m (Demek and Kopecký 1998). The incision and undercutting of valley slopes caused landslides in lower parts of high valley sides. During the flood in the year 2002, sediments clearing was performed on the upstream Úhlava River and its tributaries and in the year 1997 on tributaries of the Nedvědička River affected in the period 5.07.–7.07.1997 by relatively less intensive precipitations. Incision into the loose bedrock of the Nedvědička right-hand tributary close to the Spálený mlýn could also be caused by tectonic predispositions. Bed erosion also steepens valley slopes making them less stable than prior to floods, which due to gravitation and changes of saturation conditions leads to small landslides. Sheet erosion was also detected on short and steep slopes. Due to surface wash once rocks and soil are saturated by water, great amounts of soil and weathering residues may be carried away from river basins and transported to channels. Watercourses cutting through deep ravines could thus be even blocked.

Flat flood plains usually appear in areas of a milder watercourse gradient in broadened valleys. In bends, lateral erosion affects banks and the property could be damaged. The largest floodplain in Czech Republic — the Morava River floodplain was totally flooded during the 1997 flood. The flood water covered the whole historical floodplain as documented by the comparison of the flood limit and of spatial extent of Holocene fluvisoils. Due to dense net of settlements (including large towns as Hanušovice, Litovel, Olomouc, Otrokovice, Uherské Hradiště, etc.) situated in the Morava River floodplain came to lost of lives and to extreme damages. Many bridges, roads, railways, river embankments and houses were torn away. Such situation could be also documented on the Rožnovská Bečva River around the town of Rožnov pod Radhoštěm in the Moravskoslezské Beskydy Mountains. Below the Prostřední Bečva village, lateral erosion pulled down a bridge pillar and thus a whole bridge. Lateral ero-

Photo 2. River bed of the Bečva River in the Moravian Carpathians after flood in summer 1997 (Photo from the Archive of the Agency for Nature Conservation and Landscape Protection of the Czech Republic)

sion of concave banks also damaged a railway embankment by the Kalovice village. On the contrary, in the Otava River basin in southern Bohemia, no significant flood plains damage was detected in the area between Strakonice and Písek towns, because settlements were built outside the inundation area and the bridge connected to the embankment close to the Písek town had a sufficient flow capacity. There also was another bridge vault in the road embankment allowing for a free flow of water running outside the channel through flood plain.

Environmental specialists repeatedly argue that the 1997 floods on the Morava River had such devastating effects due to anthropogenic modifications of landscape. However, it is evident that floods could not be avoided due to extreme rainfall conditions. The scope of damage on property is mainly determined by the scope of development in inundation areas and not by deforestation of upstream areas or similar men activities. M. Hrádek (2000) stated that improper anthropogenic interventions into landscape have only a small impact on major ("catastrophic") floods and their scope and consequences. For example, the 2002 catastrophic floods was triggered mainly by high soil and rock saturation after the first precipitation episode (6.08.–7.08.2002), which is a purely natural factor.

V. Vilímek and J. Langhammer (in print) suggest that it is beneficial to build storage sedimentation reservoirs in upstream areas. During the 2002 hazard

Photo 3. Landslide cause by lateral erosion of the Bečva River in the Moravian Carpathians during flood in summer 1997 (Photo from the Archive of the Agency for Nature Conservation and Landscape Protection of the Czech Republic)

Photo 4. Accumulation part of the catastrophic landslide Brodská near the town of Vsetín in the Moravian Carpathians cause by heavy rain in summer 1997 (Photo by O. Krejči)

in the Southern Moravia great help were dry polders along lower reaches of the Trkmanka River and the Dyje River. Even lowland water reservoirs Nové Mlýny protected the town of Břeclav from flooding and respective damages. They reduce the scope of overflow and blockage of narrowed profiles, e.g. under bridges. It also is very often useful to enable rivers to overflow freely in undeveloped flood plains and not to impede such overflow even when agricultural crops are at risk. For example, the Vsetínská Bečva River above the town of Vsetín is limited by a mound impeding its outflow to flood plains.

A sensitive approach to extreme or even catastrophic situations in nature is suggested (Kirchner 2005; Kirchner and Krejčí 2005; Kirchner et al. 2000; Vaishar et al. 2000; Kolejka 2003). The extreme precipitation in July 1997 activated slope movements in the flysch relief of the Outer Western Carpathians in eastern Moravia. The slope movements originated new landslides, activated potential slope deformations and markedly remodelled the topography. Slope failures disturbed the landscape infrastructures on the many places especially in the Vsetínsko and Zlínsko Regions. The impact of area by landsliding was of the character of small natural disasters. The situation was an impuls for a detailed geological and geomorphological research and mapping of slope deformations (Kirchner and Krejčí 2002). In the Vsetínsko Region, where slope movements influenced very intensively and destructively, more than 1,500 landslide phenomena were documented with a total number of slope deformations in the Outer Flysch Carpathians in Moravia amounting to 3,700 as to April 2001 (Krejčí et al. 2002). Slope movements (especially landsliding) are important geomorphological hazard in the highland and mountain flysch relief in the Moravia and Silesia. Base on systematic registration and mapping of slope failures, the slope-failure susceptibility maps (scale of 1 : 10,000) are constructed in the affected areas. This maps should play a principal role in making new town and country planning (Rybář and Stemberk 2000).

It is important to proceed case by case and methodologically drawing on the following principles (Vilímek and Langhammer, in print): 1) to respect the course of natural processes and leave space for a long-term natural relief and landscape evolution, 2) where protection of residential zones, infrastructure, historical and archaeological sites etc. by technical means is indispensable, it is important to proceed cautiously to minimise negative effects on nature, 3) designers of new buildings should consider the suitability of particular sites taking into account possible hazards and risks, e.g. risks of flooding, landslides and earthquakes. It is important to file records on landslides and other sudden or slow recent geodynamic processes in river basins and specify their relations to geomorphological processes ongoing during floods. Although

Photo 5. Flooded floodplain of the Morava River during summer flood 1997. Patterns of abandoned river meanders are clearly seen (Photo from the Archive of the Agency for Nature Conservation and Landscape Protection of the Czech Republic)

Photo 6. Totally flooded floodplain of the Morava River between towns of Napajedla and Otrokovice in the central part of Moravia during flood 1997 (Photo from the Archive of the Agency for Nature Conservation and Landscape Protection of the Czech Republic)

many indications of past floods tend to disappear in the course of time, some relief patterns caused by erosion or accumulation processes can be identified even after longer periods of time, e.g. significant erosion steps, channels shifts, or slope deformations.

Special case are flash-floods. They have limited spatial extent, but they can have important gemorphic consequences and cause heavy property damages. Several examples have been described by J. Demek and J. Kopecký (1997) from the Landscape Protected Area Broumovsko. For example the flash-flood from 11.07.1995 caused by thunderstorm from 12:40 to 2:10 PM with precipitation 67 mm caused extremely intensive sheet flood and gully erosion. The landscape changes (gully erosion, landslides, debris accumulation, etc.) during this short event were greater than in preceding 50 to 60 years.

DISCUSSION OF METHODOLOGY

Geomorphological hazard studies are typical examples of research in which a combination of detailed field investigation and theoretical interpretation is required. Another feature of geomorphological studies of environmental hazards is the appreciation of their sheer diversity (comp. Demek and Kalvoda 1992; Kalvoda 1993; Kolejka 2003). In the past there has been a tendency to concentrate attention on extreme natural events and phenomena. However, there is also a great array of long-term geomorphological changes that occur in the environment, which can cause a degradation of the nature (Goudie and Kalvoda 1997). Urgent examples are hazards that arisen as result of global (or regional) warming. Such long-term changes of the environment have a major influence on the location, incidence and severity of geomorphological hazards and risks.

Despite causing serious or even irredeemable losses, floods should be viewed as natural phenomena of landscape evolution. In the past, floods formed part of relief development and the scope of flood plains and sediments characteristics prove that floods used to be locally even more severe. Cases of recent floods inundating broader areas than in the past could be attributed to locally retained water due to unsuitably situated facilities or to extreme precipitations in a particular local river basin. To prevent damage, it is vital to study flood causes and consequences on the regional level and to tackle the problems of local enormous erosion or overflow. In areas marked by significant property damage, it is necessary to find out whether it is caused by improperly situated facilities or relatively objective causes, like extreme discharge values.

Since a certain period of the late Quaternary, human activities have been changing the resilience of the natural environment to maintain the evolutional trends and the integrity of this dynamic global system. Therefore, a comparison of regions with a different extent and history of anthropogenous impact (e.g. Kalvoda and Demek 1991; Kalvoda et al. 1994, 1997; Kalvoda 1998a, b) enables the discovery of the participation of human society on global changes of the natural environment. This correlation contributes to the preparation of (prognostic) models of the dynamics of changes of the natural environment. The present-day physical, chemical and information technologies ensure a higher order of sampling, archiving and processing of data obtained by field monitoring and measurement or by laboratory research. A certain degree of knowledge of the natural process dynamics can then be used also for the purpose-aimed expert systems, for instance for preparation and testing of prognoses and predictions of hazards processes and events.

CONCLUSIONS

Global geomorphological research of flood situations proves that floods should be respected as general and usual natural phenomena forming part of a long-term landscape evolution. Respecting natural processes and phenomena of various spatial and time scales, it can be implement an effective geoecological strategy of natural hazards prevention and clearance of consequences of sudden or catastrophic geodynamic events. Applying the methods of geomorphological research, it can be ensured a comprehensive approach to hydrographic network development, broaden possibilities of reconstruction of past natural catastrophes, and support forecasting efforts in hazardeous regions.

Geomorphology is progressively developing specialization of physical geography and earth sciences as a whole, which are focused on research of the origin and intensity of changes and the evolution of landforms. Multidisciplinary teams have developed (e.g. Demek and Kalvoda 1991; Kalvoda and Mercier 1996; Kalvoda and Rosenfeld 1998; Košťák et al. 2000; Rybář et al. 2000; Stemberk et al. 2000) which focus on monitoring of recent geodynamic phenomena and interpreting, correlating and synthesizing measurements with the aim of understanding the dynamics of landform evolution and changes of the natural environment on local and regional scales. The increasing exposure of people to hazardeous events and processes needs an evaluation of the integrated risk management. This process of considering the social factors involved in risk analysis is decisive to minimise health and life damage and economic consequences of disasters, hazard events and phenomena.

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STRESZCZENIE

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GEOMORFOLOGICZNE ASPEKTY ZAGROŻEŃ NATURALNYCH I RYZYKA W REPUBLICE CZESKIEJ

Praca omawia zagrożenia związane z występowaniem powodzi i ruchów masowych spowodowanych opadami w lipcu 1997 na Morawach oraz w sierpniu 2002 w Czechach. Zagrożenia geomorfologiczne określano na podstawie szczegółowych badań terenowych i ich interpretacji. Kartowanie skutków powodzi w roku 1997 wykonano w dorzeczach Opawy, Beczwy i Morawy, a w roku 2002 w dorzeczu Otawy. Udokumentowano pogląd mówiący, że skutki wielkich powodzi wywołanych ekstremalnymi opadami były zróżnicowane w skali regionalnej. Wcześniejsze antropogeniczne przekształcenia rzeźby dorzeczy spowodowały zintensyfikowanie procesów i zwiększoną transformację form w okresie powodziowym.