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Slope deformations in eastern Moravia, Vsetín District (Outer Western Carpathians)

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ABSTRACT

The paper deals with slope movements activated by the extreme precipitations of July 1997. The research was centred on slope deformations in the Vsetín district, eastern Moravia, in an area belonging to the system of the Outer Western Carpathians. The Vsetín district was one of the most affected by the slope deformations with more than 500 localities of activated slope failures recorded so far. As to the character of the slope movements, landslides seem to prevail, together with earth flows and rockfalls. The slope failures disturbed the landscape infrastructure. The impact on the area of landsliding had the character of small natural hazards. The important landslide localities in the Vsetín district are presented and the human impact on landsliding is described.

Key words: slope deformations, Western Carpathians

1. Introduction

The slope movements are typical of the present-day geomorphological processes in the natural conditions of the the flysch Carpathians, which create a relief with the great intensity and slope deformations characteristic of landforms with dynamic devolopment. The slope deformations were caused by the whole spectrum of types of gravitational slope movements (see e.g. Nemčok, Pašek, Rybář 1974; Nemčok 1982). Activation of these movements is conditioned by geological and climatic conditions, topography and human activities. In the natural conditions of the Outer Western Carpathians, slope deformations arise under characteristic meteorological situations such as heavy rains and intensive snow thaw.

The extreme rainfalls in July 1997 were the main cause of the activated slope movements in the flysch rocks in the eastern Moravia. The slope deformations in some areas considerably disturbed the infrastructure of landscape. The Vsetín district (eastern Moravia) was one of the most affected by the slope movements with more than 500 localities of activated slope failures recorded so far. Research works in the mass movement areas have been organized and funded by the Department of Geology, the

Ministry of Environment of the Czech Republic. Geologists and geomorphologists from the Institute of Geonics, the Academy of Sciences of the Czech Republic and the Czech Geological Survey have collaborated and taken part in the registration and mapping of the slope deformations. Methods of geomorphological and engineering-geological mapping were used (Demek ed. 1972, Rybář et al. 1997) in the field works, and registered slope deformations were assessed on the basis of methodics in Hroch, Lochmann and Moravcová (1998). Within the framework of collaboration between our institutes and the Universities of Bologna and Urbino, Italian geomorphologists and geologists visited the mass movements localities in the Vsetín district and mutual discussion and the exchange of experiences in the field brought new knowledge to the evaluation of slope deformations (Kirchner 1998).

This paper gathers together the present state of our research using the published results (e.g. Kirchner, Krejčí 1998, 1999; Kirchner et al. 2000, Krejčí et al. 1999, 2000), is focused on the slope movements activated by the extreme precipitations of July 1997 and presents examples of landslide localities and the human impact which induced the landslides. Within the framework of the Institute of Geonics, the Academy of Sciences of Czech Republic, this research is supported by the Grant Agency of the Czech Republic grant project "Floods, landscape and people in the catchment of the Morava River" (grant no. IAA 3086903).

2. The disastrous floods in the Czech Republic, July 1997

In July 1997, two synoptic situations accompanied by extreme rainfall occurred over central Europe, and resulted in extensive floods over the eastern half of the Czech Republic. The afflicted territory had a total of over 3.10^9 cubic meters rain water within this short time period (Munzar, Ondráček and Táborská 1997).

The rainfall values in the period from 5 to 8 July were extremely high in eastern Moravia. A less severe rainfall situation occurred between 18 and 20 July. For example, 380 mm and 388.5 mm were gauged respectively in the towns of Valašské Meziříčí and Rožnov pod Radhoštěm during the first four critical days. These values are as much as four times higher than the average total value for July. The total July precipitation at the Valašské Meziříčí station were 497.6 mm (70 % of long-term annual average) and 549.6 mm in Rožnov pod Radhoštěm (60 % of long-term annual average) (Květoň, Srněnský and Veselý 1997; Řehánek, Kříž 1997). The Lysá hora Mt. station (Moravskoslezské Beskydy Mts.) had daily total precipitation, 234 mm on 6 th July. The highest daily total precipitation in the Czech Republic in the 20 th century at all, 240 mm was recorded at the station of Stará Červená Voda (northern Moravia) in 1903 (Munzar, Ondráček and Táborská 1997).

The floods that occurred during and after the first period of rain were particularly dangerous, and their extent was the largest in the 20th century. The floods caused massive damage to property, estimated at 2 billion USD and 50 human lives were lost. The severe rainfalls in northern and eastern Moravia in July 1997 triggered landslides recorded particularly in the flysch rocks of northern and eastern Moravia.

The total damages from activated landslides reached about 30 millions USD in the Czech Republic.

3. Slope movements activated by extreme rainfalls in July 1997 in the Vsetín district

The Vsetín district (the eastern part of the Czech Republic, (Fig. 1) is characterised by mountain and highland relief of a mainly eroded and structurally denuded nature on the Mesozoic and Tertiary complexes of flysch rocks which belong to the mountain ridges of the Outer Western Carpathians (Czudek ed. 1972). In geological terms (Fig. 2), the southern and central parts of the district belong to the Magura Flysch Belt. The Vizovická vrchovina (Highland), the Javorníky Mts., the Hostýnské vrchy Hills, the Vsetínské vrchy Hills and the White Carpathians Mts. are formed by the Rača Unit and the Bystrica Unit (the small southern part of the district). The northern part of the district consists of the Outer Flysch Belt (the Moravskoslezské Beskydy Mts. consists of the Silesian Unit, the Podbeskydská pahorkatina Hilly land from the Subsilesian Unit). The flysch complexes are formed by alternating layers of claystones and sandstones. These kinds of rocks are little permeable, which means that their surface zone gets water saturated quickly. The layer bedding and tectonic fracturing also cause the formation of shear zones which controll slope movements. Other suitable materials for gravitational movements are loamy-stone, loamy-clay and loamy-sand sediments as well as thick unconsolidated residual mantles of weathered flysch rocks. The extreme precipitations in July 1997 resulted in both the origin of new slope failures and the activation of former slope movements (Kirchner, Krejčí 1998). As to the type of slope movement, landslides seem to prevail, together with earth flows and rockfalls. The slope movements (mainly

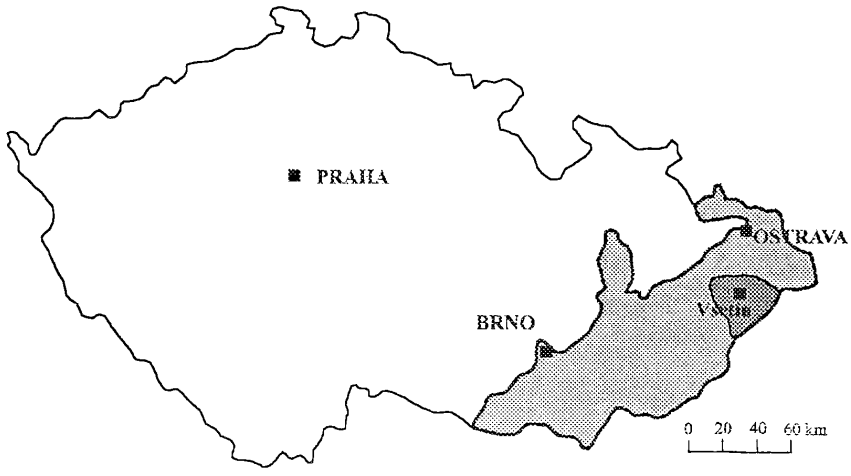

Figure 1: Schematic map of the Czech Republic with marked the Vsetín district, the Outer Western Carpathians and Carpathians Foredeep.

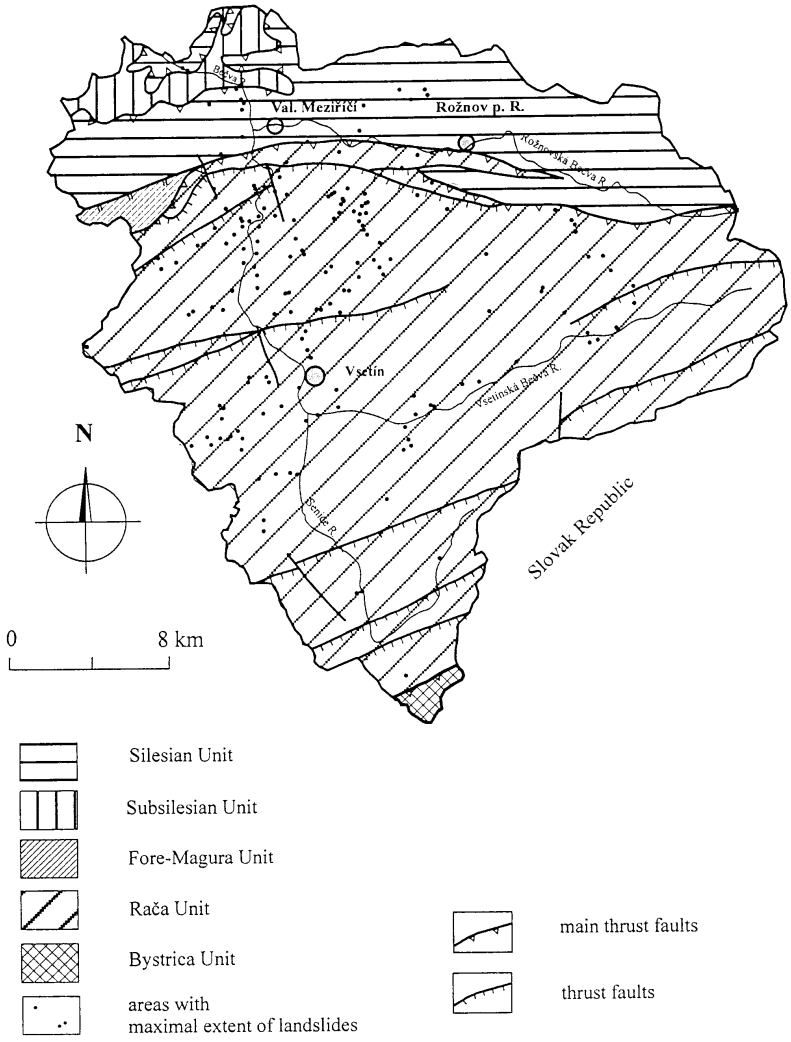

Figure 2: Schematic geological map of the Vsetín district with areas of maximum extent of landslides.

landslides) in some areas considerably disturbed the landscape infrastructure. In some places, the landslides endangered and disturbed peoples' homes, particularly so in the villages of Mikulůvka, Růžďka, both individual and entire recreational facilities, roads and local communications, the major railway to the Slovak Republic, local sources of drinking water, telephone cables, electrical supplies, a high pressure gas line, forest stands, gardens, orchards and pastures. Mass movements of mountain slopes have considerably endangered the water reservoirs of Bystřička, located in the deep Carpathian valleys. The impact of landsliding has the character of small natural hazards in the some damaged areas (Kirchner et al. 2000).

For the purpose of research, the landslides were classified in three categories (methodics of Hroch, Lochmann and Moravcová 1998 using the principles of Varnes 1984). Category III includes active landslides with damage to permanently inhabited houses, communications, large lands, etc. The mere classification in this category establishes the right for drawing funds from the Czech Ministry of Environment allocated to the research and consequent rescue of the area. In the Vsetín district (Photo 1), there were 86 landslides registered in Category III, 72 were recorded in other areas of the Czech Republic. Some localities still keep records on up to 6 separate partial landslides. Only 15 landslides of Category III were registered outside the sediments of the flysch belt of the Outer Western Carpathians, which indicaties the extraordinary predisposition of flysch sediments to the occurrence of dangerous geodynamic phenomena (Photo 2). There were more than 30 demolition orders issued for individual houses located in the landslide areas (Krejčí et al. 2000). The total number of landslides in all categories activated in the Vsetín district – as documented to December 1999 – amounts to over 500. In the majority of cases, the slope movements were activated as early as on Monday, 7 July 1997. Our research confirming that the fastest slides occurred between 7–8 July. Less intensive movements occurred due to the increased rainfalls in the period between 18–20 of July. The movements of extensive landslide areas were recorded until Autumn 1997. Inclinometric measurements in boreholes have been carried out in large selected landslides up to the present time.

3.1. Examples of landslide localities in the Vsetín district

We present the most extensive, and interesting from a research viewpoint, landslides in the Vsetín district (see e.g. Krejčí et al. 2000).

The landslide locality of Mikulůvka village is situated in the valley of Mikulůvka brook (a left tributary of the Vsetínská Bečva river), 8 km to NNE from Vsetín town. At least five houses and a cemetery in Mikulůvka village were endangered by an extensive landslide. The length of the activated landslide area amounted to about 600 m, its width being 300 m. Although the movement of the landslide front was originally considerably fast (1 to 2 metres per hour), the motion gradually stopped and the landslide calmed down. Geophysical research and drillings indicate that the phenomenon included the movement of deluvial loams and clays about 10 m in thickness.

The landslide in the Růžďka village (7 km to N from Vsetín town, valley of Růždecký potok brook – right tributary of the Vsetínská Bečva river) in an area occurred on the left valley slope in the village of Růžďka and was to 800 m in length with its width ranging between 100–200 m. The landslide damaged five houses, local roads, gardens and the adjacent forest stand (Photo 3). This landslide, still active and very deeply founded, was the most destructive in the whole Czech Republic in 1997. In it, a 20 m thick layer of sandstones of the Beloveža Formation (Rača Unit) forced out the underlying bedrock claystones. The accumulation part of the landslide reaches a thickness of up to 30 m. The landslide front is situated right in the housing zone and its extremely destructive effect results from the structurally conditioned construction of the landslide body.

The landslide locality of Vidče – 1 km to SE from Zubří village and 3 km to W from Rožnov pod Radhoštěm town – is a most extensive landslide area which is partially

Photo 1: Western part of the Vsetínské vrchy Hills – typical flysch mountain relief with erosion-structural forms and slope deformations (surroundings of the Bystřička village). (Photo Karel Kirchner)

Photo 2: The landslide locality of Bystřička – upper scar of landslide is structurally determined – a syncline. (Photo Oldřich Krejčí)

Photo 3: Central part of large landslide with damaged buildings in the Růžďka village. (Photo Karel Kirchner)

Photo 4: Accumulation part of the large earth flow in the woody area of Brodská locality near the Karolinka village. (Photo Oldřich Krejčí)

affected by lateral fluvial erosion and can be found on the steep leftbank slope of the Rožnovská Bečva river, where a moving landslide of 250x400 m in size damaged the forest stand and a forest road, reaching with its accumulation part the river bed. In the case of further movements, there is a danger that the river bed would be narrowed or the water course totally blocked since the present movement of slide accumulation was a min. of 20 m from the river. In the motion were also sizeable sandstone benches in the lower part of the slope. This landslide is one of a very large fossil landslide area whose total length is about 900 m and which reaches the very upper parts of the mountain ridge, thus representing a great potential danger in the future because the river bed of Rožnovská Bečva might become blocked.

In the landslide locality of Bystřička (5 km to S from Valašské Meziříčí town, right valley slope of the Vsetínská Bečva river), two large landslides broke the railway between the towns of Valašské Meziříčí and Vsetín near the village of Bystřička on Monday, 7 July (Rybář et al. 1998). The accumulation front of one of them directly hit the railway track embankment, damaged rails, with the electrical mains trolley wires being taken down by falling trees. This landslide was structurally geologically controlled (a movement of the syncline core of the Rusava Member, Rača Unit). The lower parts of both landslides experienced severe water oversaturation of accumulated materials and the origination of earth and mud flows with a small runoffless depression. The movement of these flows down the steep slope heavily damaged the forest stand and raised a chaotic tangle of broken spruce trees in the accumulation part, thus forming an impervious barrier.

The landslide locality of Dušná (5 km to NE from Vsetín town, the upper part of Vsetínské vrchy Hills), the main scarp of an extensive landslide disturbed the road between Vsetín town and Malá Bystřice village near the Dušná pass. The total landslide length is more than 300 m and the width is about 100 m. The landslide area is very wet with some minor scarps and cracks. The landslide activity damaged some local ways, farmhouses, orchards, pastures and fruit trees. The landslide has a composite character with the sliding of partial blocks. The main movement is in the direction of the deluviofluvial depression axis (W-E) with a lateral motion component from NE. This partial segment of the landslide joins the main sliding mass in the depression. The total displacement during the whole landslide development is about 20 m (on the basis of geophysical prospecting). The active movement was compensated within the body of fossil landslide, because in the accumulation part there is no new evidence of displacement.

In the landslide locality of Brodská (Photo 4) near Nový Hrozenkov village, 15 km to E from Vsetín town, a landslide area with highly destructive effects in the landscape occurs in the left valley slope of the Malá Brodská brook (a right tributary of Vsetínská Bečva river) where a structurally conditioned earth flow (about 690 m in length and some 80 m in width – Rybář 1999). The slip blocked a forest road and destroyed a large grown-up forest. The impressive segregation area of the landslide is structurally geologically conditioned amounting to the height of 6–15 m. Flysch sediments started to move along the layer areas and fissure up to a distance of at least 100 m. The accumulation part of the landslide is about 100 m long and its height nearly 10 m. The lower part of the slip reached the brook bottom where it further proceeded along the

stream bed some 150 m. The landslide resulted in extensive damage to forest stands whose rescue is practically unrealistic from the viewpoint of area size and technical works (Kirchner, Krejčí 1998).

In the landslide locality of Vaculov - Sedlo (8 km to NE from Vsetín town, valley of Bystřička brook – right tributary of Vsetínská Bečva river), the most extensive activated landslide area in the Outer Flysch Carpathians in Moravia at the present can be found in the right valley slope of the Bystřička brook, the length of the landslide area is 4 km, width 1.2 km (Photo 2). There are various types of slope failures which affect both deluvial sediments and the bedrock. Thick landslide accumulations alternate with water logged depressions (the existence of a small lake). The open parent rock links up with fissure caves and pseudokarst dolines. Many lonely houses and special-purpose roads were damaged and particular losses were seen on the soil cover in meadows, pastures and forests. Sizeable blocks of bedrock proceed into the streambed of the Bystřička brook and a name-less brook, which are gradually being blocked.

3.2. Human impact inducing the landslides

Landslide localities have their specific features which – apart from the natural prerequisites – also include factors caused by human activities. Human impact is an important agent leading to the origin of slope movements in the Vsetín district. The kinds of human influences relating to the development of landslides were investigated. We selected a set of 201 landslides in the Vsetín district with the complete characterization of causes.

Human impact induced landsliding in 42 cases only. It is possible to recognize several types of human activities which are directly or indirectly responsible for landslide activity on slopes. In many cases the causes acted in combination. Landslides were classified on the basis of the main causes: – 22 landslides originated as a consequence of additional moistening of slopes by overland flow running especially from paths located above the landslide area, – 10 landslides were caused by earth cuts of the roads, – 10 landslides were induced by changes of land use. The land use changes include a conversion of forests to grassland and arable land, intensification of grazing and building of recreational objects (cottages, gardens). The additional inflow of water on slopes was caused especially by unsuitably located paths, damaged or unsuitably designed sewerage drainage, excavations of telephone cables, water supply lines, gas pipes lines and with non-compressed filling.

4. Conclusion

The activity of slope deformations (mainly lanslides) in the Vsetín district is conditioned by geological control as well as by character of relief of this dissected mountain and highland of the Carpathian area. Heavy rainfalls in July 1997 were the main impulse of the activation of slope movements. The Vsetín district (eastern Moravia) was one of the most affected by the mass movements, more than 500 localities of activated

slope failures have been recorded here up to the present. The effecting of landsliding in the Carpathian landscape had the character of small natural hazards in some areas. To stabilise the slope deformations and recover the losses will take a long time. The registration of landslides is being processed, the extensive landslide localities will be studied in detail in order to bring into being rescue measures that would correspond with the extent of the damage to houses and landscape losses. The research of slope deformations in the Vsetín district will continue within the framework of a special project of the Geological Research Institute and of a grant project of the Institute of Geonics, the Academy of Sciences of the Czech Republic, Brno Branch. Landslide areas will be registered (on maps of scale of 1:10 000) and classified in categories by the degree of landslide danger and intensity of its occurrence. From the viewpoint of geology and geomorphology as sciences, the achieved results are expected to enable a certain adjustment of present geological maps and the appropriate evaluation of the role of slope failures in the slope development of mountain ridges of the Outer Western Carpathians.

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SVAHOVÉ DEFORMACE NA VÝCHODNÍ MORAVĚ, OKRES VSETÍN (VNĚJŠÍ ZÁPADNÍ KARPATY)

Résumé

Práce se zabývá svahovými pohyby, které byly aktivovány extrémními srážkami v červenci 1977. Výzkum byl zaměřen na svahové deformace v okresu Vsetín na východní Moravě, tedy na oblast náležející systému Vnějších Západních Karpat. Okres Vsetín má více než 500 registrovaných lokalit svahových deformací, mezi nimiž převažují sesuvy, bahnité proudy a skalní řícení. Aktivita svahových pohybů je zde podmíněna geologickou stavbou a členitým reliéfem této horské oblasti Karpat.

Svahové pohyby porušily infrastrukturu krajiny a vliv sesouvání má charakter malých přírodních ohrožení. Je popsán též účinek člověka na sesouvání a možnosti stabilizace svahových deformací. Jejich vybrané lokality budou podrobně sledovány s ohledem na záchranná opatření i na určení úlohy svahových pohybů při vývoji svahů ve Vnějších Západních Karpatech.