S T U D I A G E O M O R P H O L O G I C A C A R P A T H O - B A L C A N I C A
ISBN 83-88549-56-1 VOL. XL, 2006: 107–118 PL ISSN 0081-6434
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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GEOMORPHOLOGIC HAZARDS IN THE CARPATHIAN FORELAND, TOLNA COUNTY (HUNGARY)

Abstract. Major geologic and geomorphologic hazards in the Tolna County of Hungary are landslides, floods and excess water inundations, soil erosion, and tectonic activities. The Tolna County is one of the most erosion-prone areas of Hungary. Locally, splash, sheet, rill, and gully erosion has removed the topsoil almost completely. Wind erosion is an equally serious potential hazard in the study area, predominantly in the Southern Mezőföld, where fluvial sediments are covered by a 112 m thick layer of wind-blown sand. As a result of human influences, topography has also been modified to a considerable extent, primarily as far as the shape, length, and angle of slope are concerned. The contribution of human activities to the formation of the observed valley asymmetry in the region can be regarded considerable. Another area of geomorphological hazard can be associated with fluvial action. Along the steep right bank of the Danube the Upper Pannonian sediment sequence consisting of alternating permeable and impervious layers is exposed and usually overlain by the Pleistocene or Upper Pliocene loess sequence or the Pliocene red clays. Because of earlier slumping and due to lateral erosion by the Danube the Upper Pannonian deposits are partly disturbed or partly buried under younger deposits. The Upper Pannonian sands are considered confined aquifers, and the water under pressure stored in them locally saturates the fossil slump-deposits lying above them, thus providing favourable conditions for slumping and landsliding.

Keywords: Hungary, geomorphologic hazard, landslide, soil erosion, flood

INTRODUCTION

Humankind has been fighting natural hazards for thousands of years. Some natural (climatic, hydrological) processes lead to well-known hazards. It has been the unavoidable experience of generations to face geological and geomorphologic hazards.

To provide a satisfactory definition for environmental and natural hazards is a difficult task. Natural hazards are defined by I. Burton and R. W. Kates

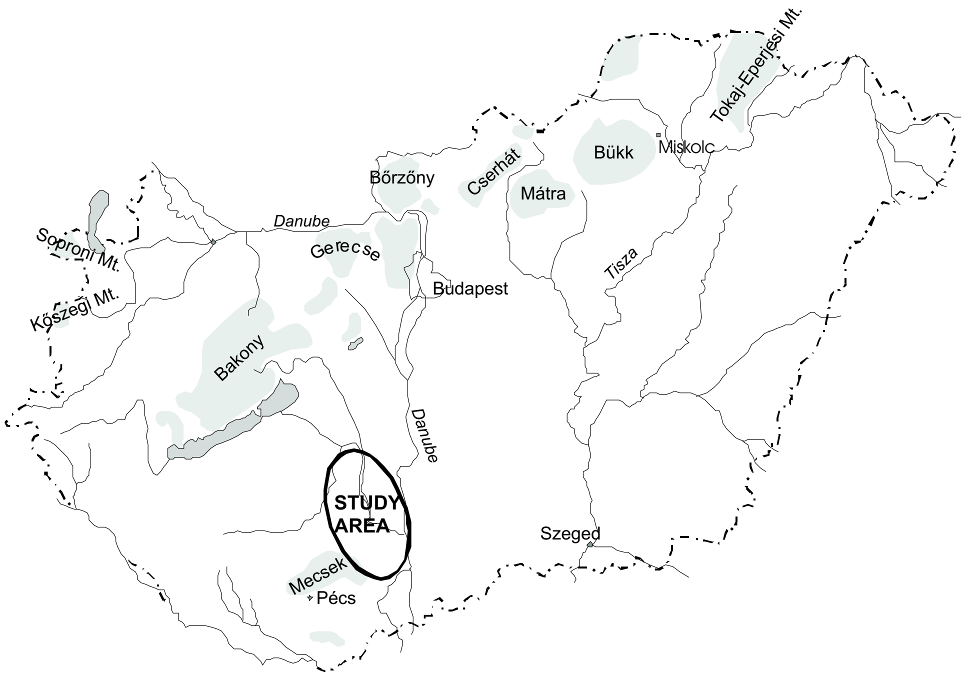

Fig. 1. Location of the study area, Tolna County in Hungary

(1964) as “those elements of the physical environment harmful to Man and caused by forces extraneous to him”. It is a common element of the various definitions that they draw a strict division between man-induced and naturally-occurring hazards. Traditionally, natural hazards have been seen as “Acts of God”. As human influence is spreading over the globe, any attempt at making a rigid distinction between Acts of God and Acts of Man is becoming increasingly difficult. For instance, flood problems may be exacerbated by natural climatic fluctuations as well as by human activities such as land drainage, river channelization and deforestation.

Although even in the 21st century the dependence on natural conditions is still remarkable, fortunately, in Hungary seldom occur major disaster events which make headlines in the media. Among the natural disasters, which are relatively common in Hungary, the following types take place with relatively high frequency:

— locally restricted meteorological phenomena (hailstorms, windstorms, wildfire);
— hydrological events of broader areal impact (droughts, floods, excess water inundations);
— minor destruction caused by tectonic activity (earthquakes, tremors, caved-in mining galleries);

— geomorphological processes in a stricter sense (slow processes like soil erosion and more rapid ones as various types of mass movement).

Among the above listed possible disasters the highest destruction is caused by the most frequently recurring floods and mass movements in Tolna County, therefore, the risk presented by these hazards are considered the greatest (Fig. 1).

GEOMORPHOLOGICAL HAZARDS

SOIL EROSION

The Szekszárd Hills is one of the most erosion-prone areas of Hungary. Splash, sheet, rill, and gully erosion has removed the topsoil almost completely in places (Photo 1–5). Based on erosion modelling studies, the magnitude of the various types of erosions can be up to 0.5 metres per 100 years under intense anthropogenic land use (H u s z á r 1998). The wind erosion is also a potential hazard in the investigated area, predominantly in the Southern Mezőföld, where fluvial sediments are covered by a thick layer of wind blown sand (L ó k i 2003). As a result of the anthropogenic effects, the relief has also changed to a great extent, primarily the shape, length, and angle of the slopes. It can considerably contribute to the observed asymmetry of the region's valleys.

Photo 1. Street wash (Photo by Sz. A. Fábián)

Photo 2. Eroded soil accumulated in a fan near Nagykónyi (Photo by Sz. A. Fábián)

Photo 3. Gully erosion on a slope of Tolna Hills near Nagykónyi (Photo by Sz. A. Fábián)

Photo 4. Erosion by flash flood in Nagykónyi. Street pavement was washed away (Photo by Sz. A. Fábián)

Photo 5. Debris accumulated by flash flood (Photo by Sz. A. Fábián)

The drainage pattern of Hungary is determined by the country's location in the centre of the Carpathian Basin. As a consequence, flood hazard is widespread over the lowland areas of the country and flood control is among the primary tasks of water management in Hungary. The natural drainage pattern has been modified significantly by large-scale channelization and land drainage measures, particularly in the second half of the 19th century (Lóczy and Juhász 1997).

Similarly to the overall situation in the Carpathian Basin, floods in Tolna County usually result from meteorological events in the surrounding mountains and occur some days later (Jakucs 1982). There are two times of the year when floods are most likely: one follows early spring snowmelt in the Alps and Carpathians, and the other is generated by early summer frontal rains all over the Danube catchments upstream.

There are two main types of flood which regularly occur along the Danube reach crossing the study area:

— Ice-jam floods occur when, as a consequence of dry continental or somewhat moister polar air masses conquer the Carpathian Basin and result in extreme low temperatures recorded over a longer period. This weather situation promotes the accumulation of large drifting ice-floes on the river. When particularly large amounts of ice pile up, a sudden rise in water levels result and inundations follow. As example the event on the Danube in March 1956 can be cited. An estimated amount of 186 million m^3 of ice accumulated along the Hungarian Danube section. Levee breaches in 200 m length took place in the area of Báta and more than 200 family homes were inundated.

— Ice-free floods are less destructive but more common events. They are caused by high-intensity rainfalls or rapid snowmelt (Nemes 1994). One of the most recent flood waves of this kind passed on the Danube in August 2002, when daily precipitations in the Austrian Alps reached 30–50 mm. Immediate interventions became necessary exclusively along the sections above Budapest, along the lower reaches no critical situation was reported.

It is characteristic how the sparse population was able to coexist with the natural hazard. Their lifestyles were adjusted to the presence of water and thus they were relatively immune to flood hazard. Man and river maintained a balanced relationship before channelization measures. The utilization of seasonally inundated areas, called floodplain economy (Andrásfalvy 1973, 2000), ensured for the population that they could take advantage of flooding, cutting through the point bar systems at intervals and conducting water to the backswamps, which could be used as orchards, meadows or pastures. Naturally, during channelization such gaps had to be filled and the traditional utilization of the floodplain ceased to function.

The sedimentation in and organic filling of the active floodplain contributes to record flood levels. Nowadays water management faces the dilemma of how to design flood control: whether through the constant increasing of levee heights or creating new flood reservoirs partly relying on the restorable remnants of the traditional floodplain economy. The safety of the population calls for a decision in this matter in the near future.

For the implementation of a new flood-control strategy geomorphological, hydrological, environmental and human geographical investigations are needed. The particular tasks to be fulfilled are the following:

— to reconstruct the Holocene evolution of the Danube floodplain based on detailed geomorphological mapping;
— to establish the rate of sedimentation in the floodplain, monitoring changes since the beginning of channelization;
— to reveal the variations of sedimentation on the different floodplain landforms and to establish the relationship between sedimentation rate and distance from dykes;
— to study the historical changes in forest cover in the mountainous part of the catchment;
— to map the distribution of natural levees in order to find opportunities for removing dykes and substitute them with modified natural levees;
— to map the geoecological conditions of the floodplain;
— economic and human geographical investigations to reveal the social impact of flood control measures.

LANDSLIDES

Landslides in the studied hill region are concentrated in areas where relative relief is sufficiently high. This is the situation along the Danube bank where stream undercutting has produced relatively high bluffs. In Tolna County two high bluff sections considered more or less active can be distinguished: the Dunaföldvár bluff and the Dunakömlőd-Paks bluff. The bluffs generally consist of Late Miocene (Upper Pannonian) marine-lacustrine clay silts, sands and sandstones, Pliocene terrestrial sands and red clays as well as a 20–80-metre thick Quaternary loess sequence with interbedded sands and paleosols.

Interpreted from their lithostratigraphy and geomorphologic conditions, the following stability types of high bluffs can be distinguished:

1. banks directly eroded;
2. banks with a foreground and including unstable sediments;
3. banks protected by foreground deposits and fluvial sediments.

In the case of type 1 and 2 the bluffs are unstable, and have been considerably damaged or endangered by mass movements. In the case of type 3 the bluff is devoid of mass movements. Naturally, the types listed above are combined in many cases resulting in mixed forms (Karácsonyi and Scheuer 1972).

One of the most important factors is the hydrological situation of high bluffs. The Danube has a water level fluctuation in a range of nearly 10 metres. The high water levels influence natural seepage, the springs of ground and artesian water at the foot of the bank, which is inundated during higher water stages.

Along the steep bank of the Danube in some places even the Upper Pannonian sediment sequence consisting of alternating permeable and impervious layers becomes exposed. It is usually situated below the Pleistocene or Upper Pliocene loess sequence or the Pliocene red clays. Because of earlier slumping and due to lateral erosion by the Danube the Upper Pannonian sediments are partly redeposited, occur in a disturbed stratification, or partly buried under younger deposits. The Upper Pannonian sand deposits are confined aquifers, and their water under pressure locally moistens the overlying fossil slump deposits, thus providing favourable reconditions for the reactivation of slumps and the generation of new landslides. During spring–summer floods the river will inundate the surface to the level of the springs issuing at the base of the bluff, so that the springs will swell and the groundwater table will locally rise. This circumstance is noteworthy because, as shown by the pertinent data, slumps and earthslides can be expected to take place, particularly after prolonged high-water stages of the Danube (Pécsi et al. 1979).

TYPES OF HIGH BLUFFS AND THEIR GEOMORPHOLOGICAL PROPERTIES

Along the Dunaföldvár high bluff the Danube undercuts by lateral erosion an isolated loess-mantled section of the Mezőföld Plateau. Near the Dunaföldvár bridge, the bluff is 15–25 metres high and almost vertical. South of the Dunaföldvár bridge the bluff is vertical and 30–50 m high. The major slice slide of 1970 occurred in this section. The landsliding took place south of the bridge and deformed the channel of the river, the upwarped material developed into an "island arc" within the channel. Hydro-geological investigations revealed the geological and geomorphologic conditions in the area and the causes of landsliding (Pécsi 1971; Schweitzer 1978).

The meander of the Danube in front of the Paks-Dunakömlőd high bluff was regulated in 1854 and directed into an artificial channel. Before the channelization of the river and road and railway constructions the river had very intensively eroded the bank along this reach. In several places remnants of fossil and recent sliding may be observed side by side (Fodor et al. 1981).

ACTIVE LANDSLIDES

There are relict landforms of previous slides in the area of Szekszárd Hills (Fig. 2). Besides these several currently active mass movements are observable that are renewed through complicated interactions of natural and anthropogenic factors. These movements present a geomorphological hazard nowadays.

1. A slide occurred at an approximately 50 metre long and 15–20 metre wide section in the Porkoláb Valley at Szekszárd in March 2000. In consequence of the slide a road-section was damaged. The earth movement can be described as a flexural slip and was followed by a minor rotational slump affecting reddish brown clay. The large amount of precipitation in 1998 and 1999 considerably contributed to sliding. The rainy weather increased ground water pressure, which

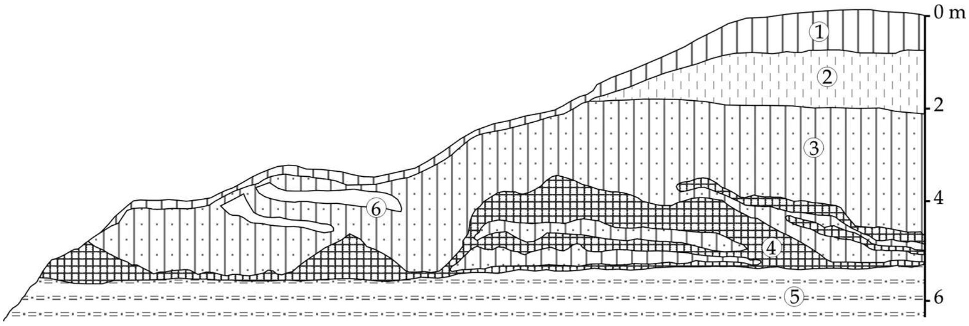

Fig. 2. Cross section of the fossil landslide at Hidaspetre, Szekszárd Hills (by Sz. A. Fábián and G. Varga). 1 — recent soil, 2 — loess, 3 — loessy sediments, 4 — red clay, 5 — Pannonian clay, 6 — paleosol remnants

triggered sliding. The area is covered by loess deposits of various origin. The problem of landslide hazard cannot be simply solved by draining groundwater from above the sliding plane. Rainwater flow also affected the region behind the slumped mass and pipes collapsed in the loess sequence and, consequently, stability was further reduced (VITAQUA 2002).

2. Active surface movements are clearly observable along the slopes of the Decs hill used as a vineyard. The hill is located at the extreme eastern margin of Szekszárd Hills facing the Sárköz floodplain, approximately 8–10 km south of the city of Szekszárd. The terrain is characterized by relict landforms of fossil slides,

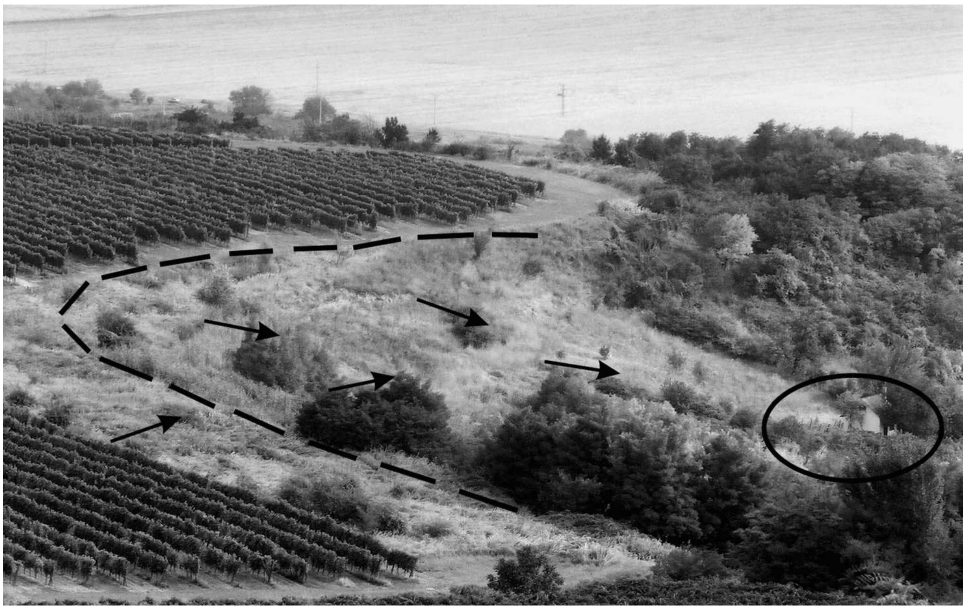

Photo 6. Recent mass movement at Decs, Szekszárd Hills (Photo by K. Lampért)

arched rupture fronts and typical landforms of a loess region (hollow roads, ravines, loess ruptures). During large-scale landscaping measures pseudoterraces and scarps were created. Surface movement occurred along a steep slope, probably at a rupture front of fossil slide at the altitude of 160–170 m. The human activity was also instrumental in the reactivation of the process. Principally excavation and intensive economic activity altered the drainage system. Rainwater infiltrates deeper and more rapidly if the ground surface is left unvegetated. This slide moves slowly and periodically. Snow melting and heavy rainfall accelerate; arid periods hinder the movement (Szabó 1995).

A characteristic depression appears behind the slumped surface where water is collected during and after rainfall the surrounding more elevated surfaces. The water infiltrates into the slip face which causes further mass movements. Wetland indicating vegetation is observable at several places at different altitudes along the margins of the hills. This point to the reshaping of the area by mass

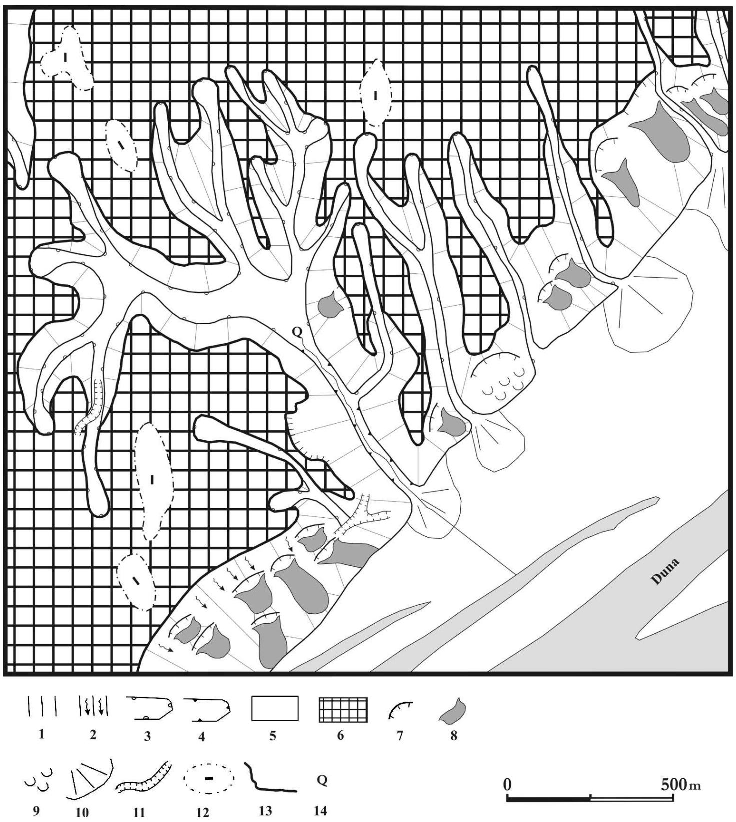

Fig. 3. Geomorphic map of recent mass movements between Báta and Dunaszekcső settlements (by Sz. A. Fábián and K. Lampért). 1 — slope, 2 — slope with gully erosion, 3 — derasional valley, 4 — erosion valley, 5 — floodplain, 6 — loess plateau, 7 — scarp, 8 — toe of a fossil landslide, 9 — creep, 10 — talus, 11 — loess valley, 12 — loess doline, 13 — stream, 14 — spring

movements. The fissures among debris slowly widen into cracks. The rainwater running off along slopes broaden and deepen these cracks, thus initiating gully and rill erosion. Similar gullies developed on the steep edge of the slope with slide in the summer of 2005, when heavy rainfall took place within a short period. The gully also threatened the nearby cellar buildings. Gully erosion, expanding of ravines and extensive dissection of relief has a significant contribution to soil removal in the loess covered area. Opened ditches serving to conduct surface water and surfaced roads have been damaged in the study area. The intensification of piping under solid pavement lead to forming at least a metre and a half deep caverns locally. The resulting network of underground channels caused significant damage to the vineyards nearby. The rows of vines-stocks are tilted downslope as a clear consequence of creep and more rapid types of mass movement. It is clearly observable that a section with some ten metres of rows moved over one year (Photo 6).

Surface subsidence in downslope direction is also indicated by the tilting of vines. The depression may show the main direction of subsurface water flow. It starts from a deep ravine that recedes to the top and has a consequence of the processes at the studied area (Fig. 3). The deranged surface is characterized by collapses of loess pipes and tunnels, deep gullies, continuous collapse of ravine side walls and developing of loess ruptures.

As a consequence of the presence of higher slope classes, unconsolidated surface material and the undercutting action of the Danube River, Tolna County is exposed to a wide range of geomorphological hazards.

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STRESZCZENIE

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ZAGROŻENIA GEOMORFOLOGICZNE NA PRZEDPOLU KARPACKIM, TOLNA, WĘGRY

Do głównych zagrożeń geomorfologicznych na obszarze Tolna na Węgrzech zaliczono osuwiska, powodzie, erozję gleb oraz aktywność tektoniczną. Jest to obszar najintensywniej modelowany przez współczesne procesy erozyjne w skali Węgier. Pewne tereny są całkowicie pozbawione pokrywy glebowej wskutek działania rozbryzgu, spłukiwania powierzchniowego i bruzdowego i erozji wąwozowej. Erozja wietrzna (eoliczna) jest również poważnym zagrożeniem zwłaszcza na obszarze południowego Mezőfoldu, gdzie osady fluwialne są okryte 112-metrową warstwą piasków pochodzenia eolicznego. Pod wpływem antropopresji lokalna rzeźba jest w znacznym stopniu zmieniona. Zmianie uległy kształty stoków, ich długość i nachylenie, a doliny uzyskały profile asymetryczne.

Inne zagrożenia występują podczas powodzi, zwłaszcza na stromych prawobrzeżnych zboczach Dunaju. Zbocza zbudowane z osadów górnopannońskich zawierają na przemian warstwy przepuszczalne i nieprzepuszczalne. Na nich spoczywają osady plejstoceńskie lub górnoplioceńskie, częściowo zaburzone lub fosylizowane przez młodsze serie osadowe. Górnopannońskie piaski stanowią warstwy wodonośne, a woda w nich zawarta sprzyja uruchamianiu procesów osiadania i osuwania.