Suppl. Geogr. Fis. Dinam. Quat.
II (1989), 51-62, 23 ff.

MOJMÍR HRÁDEK (*)

THE DANGEROUS ROLE OF DELLS IN AGRICULTURAL LANDSCAPES OF SOUTH MORAVIA (CZECHOSLOVAKIA) (**)

Abstract: HRÁDEK M., *The Dangerous Role of Dells in Agricultural Landscapes of south Moravia (Czechoslovakia).*

Dangerous processes are often associated with particular relief forms. In the hilly lands of the Bohemian Massif and the Western Carpathians, such forms include dells in which most erosion phenomena are concentrated. The dells represent natural catchments and form a relatively dense network. Problems arise when areas with numerous dells are subject to intensive agriculture. Many forms of cultivation have been carried out without respect to the relief. In spring when the soil is relatively unprotected and the winter snow is melting, slope processes become active. The incidence of snow-melt depends on slope orientation and weather conditions. During anticyclonic weather, snow sublimation dominates and there is little erosion, but during cyclonic weather, slope and nivation processes, such as supranival mudflow and subnival thermoerosion, intensify. The worst situation so far occured in 1981. The effects of nivation processes are aided by periods of rain. Such activity has greatly increased in the last three years when rainstorms have been more frequent. In some areas with a dense network of dells, the soil was destroyed down to bedrock. In addition to crop demage, a train was derailed, and in one dell, floodwater caused a bus accident, costing human lives. Overland runoff from the dells can contribute to the formation of destructive flooding, as seen in a few cases in 1988. Study of hazards associated with dells has been aided by geomorphological mapping and remote sensing techniques. The results were compared with data acquired with the method of mathematical modelling of runoff.

KEY WORDS: Dells, Nivation, Overland runoff, Soil erosion, Geomorphological hazards, South Moravia (Czechoslovakia).

Riassunto: HRÁDEK, *Il ruolo pericoloso dei solchi vallivi nel paesaggio agricolo della Moravia meridionale (Cecoslovacchia).*

Processi potenzialmente pericolosi sono spesso associati a particolari forme del rilievo. Nelle terre collinari del Massiccio Boemo e nei Carpazi occidentali tali forme comprendono numerosi solchi di origine periglaciale nelle quali sono concentrati la maggior parte dei fenomeni di erosione. I solchi rappresentano dreni naturali e formano una relativamente fitta rete. I problemi nascono quando aree con numerosi solchi sono soggetti ad agricoltura intensiva. Molti metodi di coltivazione sono stati usati senza tener conto del rilievo. In primavera quando il suolo è relativamente poco protetto e la neve invernale si sta sciogliendo, si attivano i processi di versante. Il ruolo della neve dipende dall'orientazione del versante e dalle condizioni meteorologiche. Durante le condizioni anticicloniche, la neve sublima e vi sono modesti processi erosivi, ma durante le condizioni cicloniche, i processi di nivazione e di versante, quali le colate fangose e l'erosione subnivale, si intensificano. La peggior situazione del genere si verificò nel 1981. Gli effetti dei processi di nivazione sono esaltati da periodi di piogge; tale attività si è molto incrementata negli ultimi 3 anni, in quanto i temporali furono più frequenti. In alcune aree con una fitta rete di solchi, il suolo fu spazzato via fino alla roccia in posto. Per di più, un treno deragliò e in un solco, le acque dilavanti causarono un'incidente ad un autobus, provocando la morte di persone.

Lo scorrimento superficiale dai solchi può contribuire alla formazione di esondazioni distruttive, come in alcuni casi nel 1988. Gli studi dei rischi associati ai solchi sono stati eseguiti con il rilevamento geomorfologico e le tecniche di rilevamento. I risultati raggiunti sono stati comparati con i dati acquisiti con i metodi di modellizzazione matematica degli scorrimenti.

TERMINI CHIAVE: Solchi vallivi, Nivazione, Scorrimento superficiale, Erosione del suolo, Rischio geomorfologico, Moravia (Cecoslovacchia).

The spring of 1987 and of this year in CSSR was characterized by a number of strong rainstorms, which caused marked physical damage and the loss of human lives. In the highland districts alone, of Zdár nad Sázavou and Jihlava, the results were a train de-railment, a bus accident, and the death of people in a water torrent. One of the main causes of these accidents, were processes which uncontrollably took place in the dells during the rainstorms. In the last few years there were recorded in these places, cases of erosion damage in the agricultural soil during the spring thaw of snow. This indicates, therefore, a great need to devote research to these landforms and their morphology, genesis, function and processes, which take place in them.

GENERAL CHARACTERISTICS

The term dell usually indicates a valley similar to depressed landforms in their various stages of development,

(*) *Ceskoslovenská Akademie Ved - Geografický Ústav v Brne.*
Presented at: Joint Meeting on Geomorphological Hazards, I.G.U., Firenze - Modena - Padova, May 28 - June 4, 1988.
(**) *The Author would like to give thanks to the persons in authority of the Institute of Geography of Czechoslovak Academy of Sciences in Brno, to the director Prof. V. Gardavský and the deputy director J. Přibyl, for enabling the publication of this article, and to Mrs. D. Majerová for help with its technical realization.*

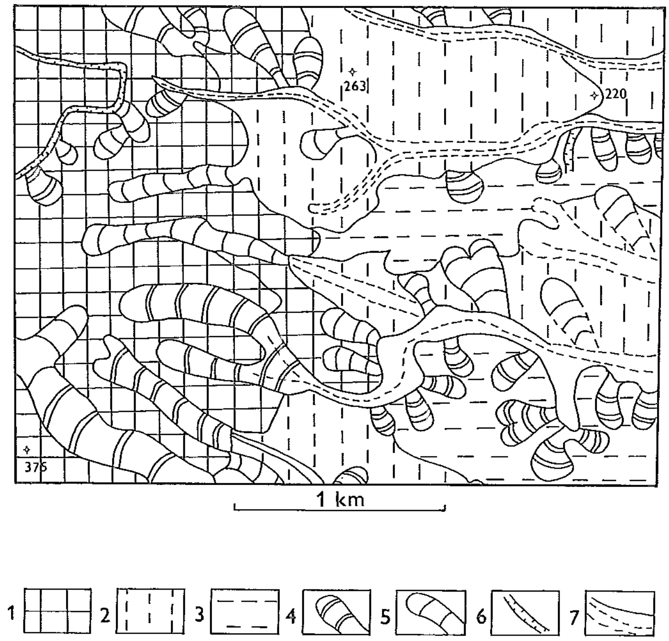

FIG. 1 - Simplified geomorphological map of the land joined to the Bohemian Massif and the Western Carpathians, including the density of dell patterns (according to DEMEK, 1959).
1. Highland relief of the Bohemian Massif, formed by ignious rock; 2. Lowland hill relief of the Western Outer Carpathian Depressions formed by loess; 3. Lowland hill relief of the Western Outer Carpathian Depressions formed by Miocene clays and sands; 4. Dells; 5. Dry valleys; 6. Gullies stabilized by vegetation; 7. Drainage pattern.

through which there is not running a constant stream of water. Dells are linked to stream networks and therefore can be designated as initial drainage pattern segments (HRÁDEK, 1981). In the hillyland relief of Moravia, related to the Bohemian Massif and the Carpathians, dells are the landforms, which give this land it's characteristic appearance (fig. 1). They are found in rich number in lands built-up with all types of rocks - crystalline and sedimentary, solid and unconsolidated. In the valley patterns we usually distinguish between dry valleys and dells. Dry valleys are associated with river valleys, and dells are associated with both, either laterally or axially. In the Central European areas, the study of dells has been given marked attention. A number of foundational works have been produced in German (PENCK, 1924; SCHMITHENER, 1925; KELLERSOHN, 1952; NEFF, 1955; LUIS, 1961; SEMMEL, 1961 and others), Polish (KLATKOWA, 1965 and others), Hungarian (PÉCSI, 1924), and Czechoslovakian (DEMEK & *alii*, 1965; CZUDEK, 1971; HRÁDEK, 1981) and others literature. The research was largely aimed at clarifying the genesis of these landforms.

MORPHOMETRIC CHARACTERISTICS

Characteristic of dells are semi-closed landforms with convex slopes and concave floors. Particularly characteristic are the heads of these landforms, which usually spread-out and have a dish-like to kettle-like profile, depending on the stage of their development and relative relief. The depth of a dells is largely up to 10 m, and exceptionally, they can reach 15 or more meters. Quite often there occur twin-headed or asymmetrical dells with variously developed heights and slope angles. The most attention was given primarily to the dells which are agriculturally cultivated. These types of dells did not exceed a maximum slope angle of 20°. The natural gradient floor curve of the shorter dells is for the most part graded, and their maximal angle is dependent on the base level of erosion and relative relief, most-

FIG. 2 - An example of a dell with a step-like, terraced head. These modifications lower the risk of erosion and slow-down water run-off.

ly up to 20°. In longer dells, the long-profile can be stepped with one or a number of convex breaks. These profile breaks are conditional on either agricultural modifications of the original terrain or on the outcrops of more reistant layers, or ungraded development. Steeply inclined dell floors are frequently cut-through with younger gullies. It is possible to demarcate the axis of a dell on detailed topographical maps, like the axis of concave formations on the lines of parabolic points. In terms of the dimensions of the dells, the maximum ascertained length was 2 km and the maximum width, 0.5 km. The gradient curve amplitude of the floors of the largest dells, could be as long as 100 m.

GENETIC CHARACTERISTICS

There are a number of collected data, that date the development of dells primarily to the last glaciation of the Pleistocene (PÉCSI, 1964; KLATKOWA, 1965). The predisposition of dells in fracture zones of solid rock is assumed (LUKNIS, 1955). It is generally recognized that processes termed as nivation, in conditions of existing permafrost, share primarily in the origin of dells. The analysis of slope and floor deposits of the dells in the studied area showed that in an environment with little vegetation, the surface of the dell underwent frost weathering, frost heaving, cryogennic creep of wastes, cryoturbation, solifluction, and surficial and sub-surficial run-off of meltwater. The basic cause for the creation of dells was the proven existence of underground ice and ice veins, sharing in the formation of sorted and unsorted polygons, with the assumption of melting ice veins and the thermal activity of meltwater (CZUDEK, 1971, 1980; HRÁDEK, 1981). Dells represented in Pleistocene landforms, in which took place a gravitationally caused mass movement of material, loosened during the frost weathering from higher to lower lying parts of the landscape. Water and ice were the main transportation media. During the mass movement corrasion took place. As these processes loosened the material on the slopes, the floors of dells were being alternately covered by it, or deepened as the material was carried away. This described sequence of processes applies, however, only to the dells of hillyland regions, formed by solid rock, where their development was studied. Dells, lying within the area of continental glaciation or in grasslands, loess, and lowland regions had a quite different development (PÉCSI, 1964; KLATKOWA, 1965).

PRESENT FUNCTIONAL CHARACTERISTICS

In the Holocene, the intensity of the processes in dells markedly slowed-down. This is related to the development of forest and parkland vegetation in the landscape, which coherently covered the surface. The renewed action of these processes obviously relates to the colonization of the Central European forest lands from the 12th Century and to the agricultural cultivation. Parts of the land were deforested, changed into fields and mainly, during the spring, underwent the effects of slope processes. Immediately, therefore, after deforesting, basic antierosional protection for the terracing of slopes were established (fig. 2). As the analysis of slope deposits, deposited on the terrace showed, these modifications were effective (HRÁDEK, 1981). The activity of these processes takes place with the greatest intensity during the period when snow melts, and the conditions come closest to tundra conditions. Equally, rainstorms bring a threat of strong erosion later in the spring. Dells in the present hillyland landscape are landforms in which occur most often gravitationally caused water movement in open slope and valley geosystems. Water is the main transportational agent of wastes, both in solid and colloidal forms. With the formation of dells, there was an equally marked increase in the surface and number of slopes in the landscape, thus increasing the possibility of erosion. Besides this, a catchment function of the dell heads in the forming of concentrated water run-off, could be seen. Concentrated run-off can significantly contribute to the formation of floods. Thus, slope catena is naturally associated with fluvial catena.

In the present agricultural landscape, these dell functions were not taken into appropriate consideration. With

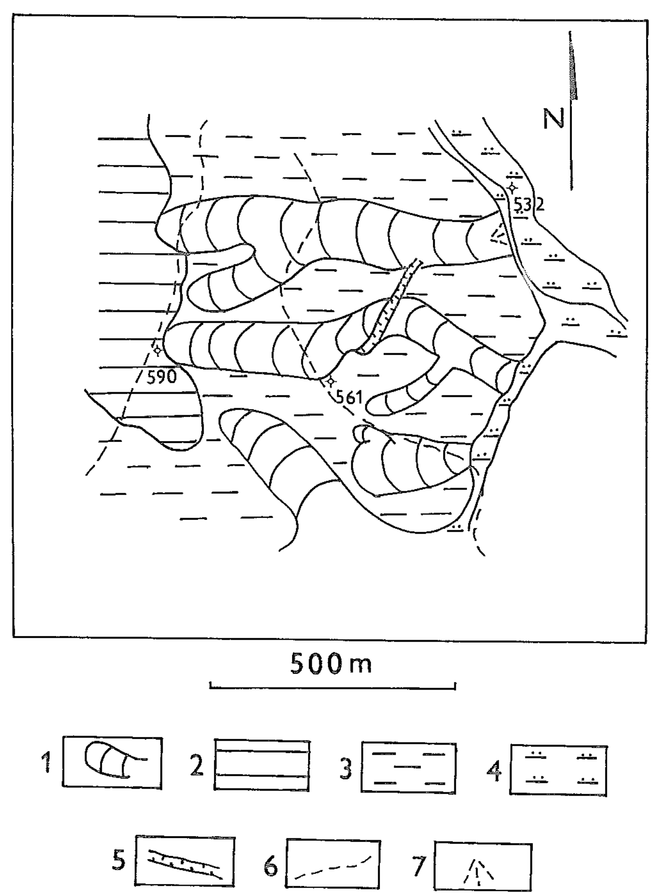

FIG. 3 - Pattern of the dells in the studied area NW of Bystrice n.P. 1. Dells; 2. Flat of levelled surface; 3. Gentle slopes; 4. Flood plains; 5. Artificial cuts; 6. Roads and paths; 7. Alluvial fans.

insufficient protective modifications, they were designated to the category of large-field production systems. The original arrangement of land parcels, done according to configuration relief, was replaced by extensive consolidation of field areas, useful only for flat surfaces.

DATA FROM THE STUDIED REGION

The dangerous role and geomorphological hazard of dells has been observed in much detail and over a long period of time in the region of the Czech-Moravian Highlands, especially the area surrounding the town of Bystrice nad Pernstejnem, where the hillyland relief contains dense patterns of these landforms. This region was under regular observation, complete with geomorphological mapping of the landforms and phenomena in the formation of the slope and fluvial processes. The maximum elevation above sea-level reached 700 m, relative relief to 100 m, and the mean value of the slope angle is 3,4°. The divides are formed by flats or wide ridges; slopes are for the most part gentle, and valley floor breadth measures up to 100 m. Dells from the neighbouring basins often meet in saddles on the divide; between some of them there are flat outliers. In this region dells and dry valleys are the main landforms softly furrowing the valley sides and giving to the region it's typical undullated appearance.

In evaluating the role of the dells, it is equally important to know some of the average long-termed climatic data characterizing the climate of the wider area, especially the temperatures in the period of thawing snow and precipitation in the summer months.

The area surrounding Bystrice nad Pernstejnem lies in a moderately humid, moderately warm region and during the period from 1901-1950, the annual precipitation amount was 651 mm, with a maximum rainfall in the summer months. The average monthly rainfall in May was 64 mm, in June- 78 mm, in July- 77 mm and in August- 80 mm. The mean annual temperature was 6,5° C; —3,9° C in January, —2,5° C in February, and 1,4° C in March.

A group of dells and dry valleys NW of Bystrice nad Pernstejnem was chosen for long-term research. Their heads interposed with the edge of a flat surface, 600 m above sea-level, and a flat ridge which projected from it (fig. 3). A few of the dells are twin-headed, some have a transversal asymmetrical profile. The lengths are ranging up to 800 m, the widths up to 200 m, and depths of up to 10 m. The maximum slope angles for the heads of asymmetrical dells is 20°, and for gentle slopes it is about 8°. The floors incline between 5-8°. The steeper slopes face south to SE.

The studied area is formed of pencil biotite gneisses. Crystalline rocks weathered on the surface are sandy and fragmented. The remaining products of weathering-older, coloured clays, were preserved in fragmentary form. The sides of the dells are covered with debris and sandy slope loams 0,2-1 m thick. The weakest density of the cover is in the upper convex part of the slopes. On the dell floors there is as much as 2 m of accumulated sandy material and debris, and loamy material of the Pleistocene, Holocene, and Present age. Their origin were explained above. Pleistocene and Holocene debris are divided by a whitish podsol A_2 horizont and B horizont of iron and manganese hydroxide.

The studied region is regularly cultivated by agricultural state farms. The land with dells was divided-up into a number of large parcels. Most often the fields are planted with grains, potatoes, corn, flax, and mixtures of grain with legumes for feed. Part of the grain is sown in the autumn as winter wheat. The road network was reduced in this area. The main road between the two agricultural establishments, cut cross-wise across most of the dells. The artificial drainage pattern of the surface is insufficient. A number of anti-erosion control modifications were abolished, such green tracts with trees on a few of the dell floors, and terracing. The land was drained by a system of drainage pipes and wells.

PRESENT DAY PROCESSES IN DELLS

In the course of twenty years of observation and research, a whole series of processes occurring in the dells has been registered. In certain years, the intensity of these processes have shown dangerous implications. It has been confirmed that the intensity of the processes are influenced by both climate in the seasonal year, and the way the land is cultivated. Intensive processes can take place during the melting of snow in February and March, or in the late spring months and the beginning of summer, when there is usually significantly larger rainfall amount. The course of the weather is strongly influenced by the circulation of air masses during the cyclonal and anticyclonal situations. In terms of the manifestations of these situations, the amount of rain

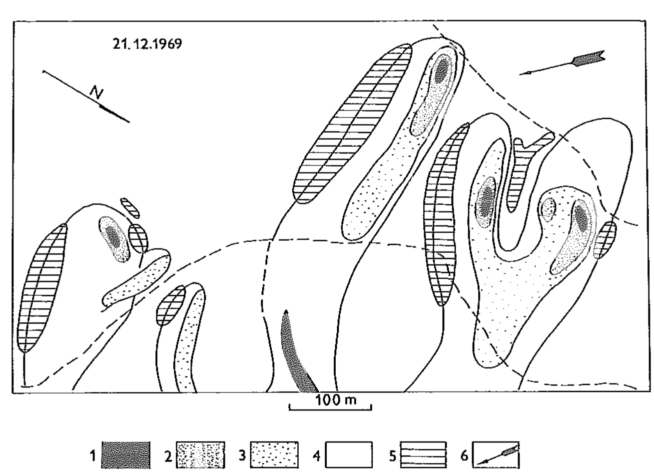

FIG. 4 - Map of snow-cover distribution on the dell slopes in December 1969.

1. Snow depth greater than 0,3 m; 2. Snow depth 0,3 m; 3. 0,2 m; 4. 0,1 m; 5. Less than 0,1 m; 6. Direction of wind.

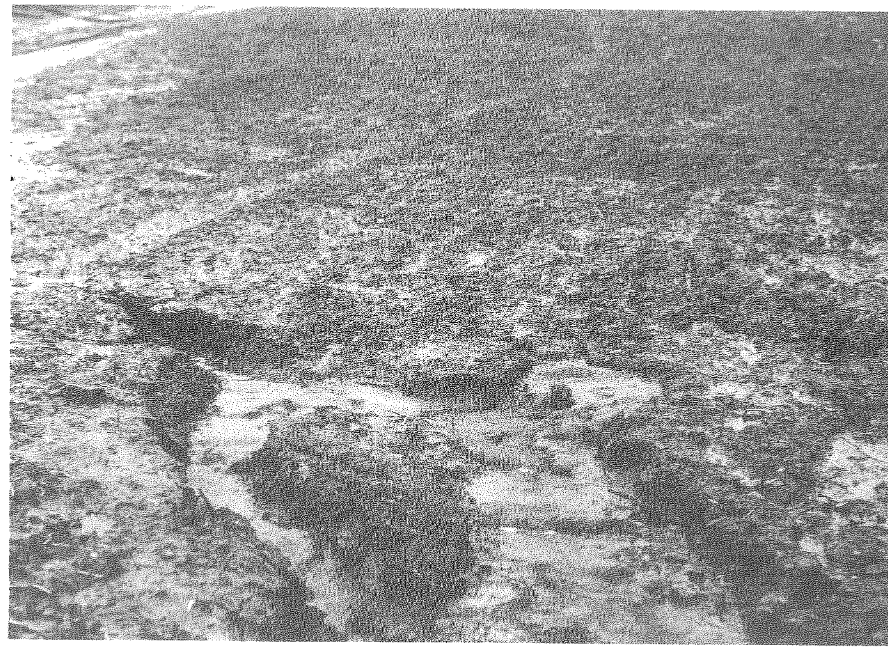

FIG. 5 - Erosion of soil by ground water seepage from damaged drainage pipe (March 1981, Bystrice n.P.).

and snow precipitations, the temperature changes in spring months, and the prevailing wind direction, have the greatest influence on the intensity of these processes. The intensity of the processes are further influenced by the state of the surface with the dells; whether the ground cover is vegetational (with natural or artificial agricultural cover), whether the vegetational cover is dense or sparse and how the soil was cultivated, either downslope, or with parallel contour lines. Of equal importance is the maintenance of surface drainage patterns in a good condition, and infiltration ability of the soils, and rock permeability.

The most dangerous situation occurs when the negative effects of weather combines with the surface barreness or insufficient vegetational cover. At this point a cascade reaction of causal processes conditioned by gravitational mass movement occurs. Such a situation, not lacking a certain amount of randomness, occurred in the studied region in the beginning of spring 1981 and at the end of spring and at the beginning of summer 1987. This phenomenon occurs locally almost every year in the wider area.

FIG. 6 - Ground water seepage from damaged drainage pipes have lateral thermoerosional effects on the rill walls.

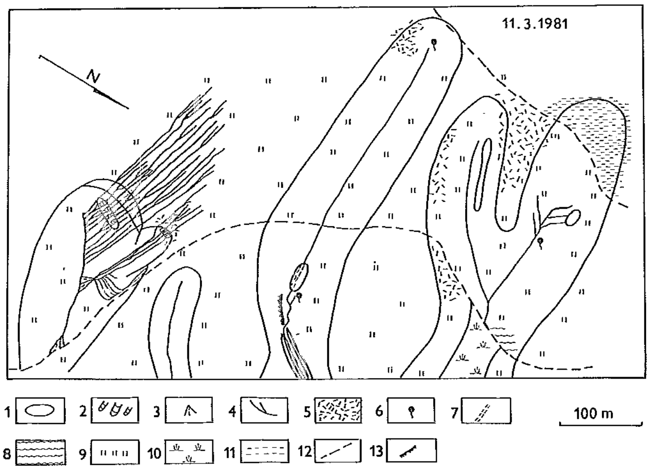

FIG. 7 - Map showing the course of thawing in the dells in a high pressure period during an anticyclonal situation (March 1968).
1. Snow patches; 2. Places with slushy soil; 3. Periodic seepage of ground water from demaged drain pipes; 4. Erosion rills; 5. Subnival maltwater channels; 6. Places abundantly covered by stones as a result of frost heaving; 7. Places flooded by meltwaters; 8. Places overgrowen by winter wheat; 9. Places with ploughed surfaces; 10. Grassy growth; 11. Stubble-fields; 12. Roads.

THE PROCESSES AND SPECIFIC FEATURES OF THAWING SNOW

The intense processes connected with the thawing of snow depend, in part, on the amount and distribution of snow, exposure of the slope, and the weather factor in the situation. The depth of snow on the slopes of dells is usually uneven. On the one hand, the influences of exposure to the direction of the prevailing wind in times of snow precipitation can be seen; on the other hand, the influence of sunlight exposure. In the studied region NW currents dominate and therefore the deepest to twice as deep snow cover is usually on the leeward sides, which have concurrently warm exposure to the south and SE. The depth of the snow on these slopes is 0,3-0,7 m (fig. 4). The thinnest snow layer in the remaining spots quickly melts at the beginning of the thawing and only snow patches remain on these leeward slopes. The further progression of thawing snow influences the weather situation and exposition of the leeward slopes. The process of thawing is different in clear, sunny weather in the high pressure areas above Central Europe and in the rainy weather during the cyclonal situations with wet frontal flow. In the first case, a great difference between daytime and nightime temperature can be seen. The daily maximum temperature reached at the beginning of March during the aforementioned observed years was 22° C with a nightly minimum of —9° C. There was a sublimation of snow on the isolated leeward slopes. Small trickles of water with small erosional effects ran from the edge of the snow patches. The soil in the surroundings was thawed to a depth of 5 cm. The wet soil around the snow patches was a contrast to the dry surface of the rest of the dell. During this period there was recorded the seepage of groundwater running out of damaged drainage pipes (fig. 5). If the surface of the soil is frozen, especially in the morning hours, the running water acts thermoerosionally on it's surroundings and form a lateral sapping into the walls of the rills, which are draining away (fig. 6).

For a number of days after this weather situation, the snow thawed without causing damage and with only insignificant erosion damage, but only on the leeward slopes (fig. 7).

Snow thawing in the dells takes place much more intensively during a weather situation in which there forms above Central Europe a frontal flow with rainfalls from the ocean, as in the beginning of March 1981. At that time the soil was still frozen and the surface under slush. On the lee-

FIG. 8 - Intense activity of slope processes during rainy thawing after a cyclonal situation in March 1981 NW of Bystrice n.P. In the background snow patch with tongues of mudflow; in the foreground, alluvial fan.

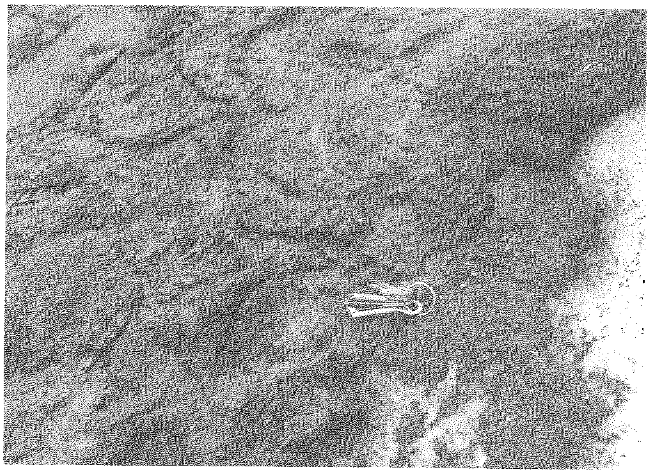

FIG. 9 - Mudflow tongues on a snow-patch surface (March 1981, Bystrice n.P.).

FIG. 10 - Rain water and water from thawing snow has significant thermoerosional effects, which formed rills cutting through the surface of mudflow tongues (Bystrice n.P. March 1981).

ward slopes, snow patches up to 50 m long and 7 m wide and approximately 0,3 m deep, remained. Water from the melted snow and the rainfalls cut rilled patterns with a depth of up to 10 cm on the slopes. Parallel patterns made up of rills were expressly contingent on the direction of the rows of winter wheat and tractor tracks. During the rains, streams of sandy loam material and rock fragments washed up onto the snow patches by running water, ran in tongues along the snow surface. Mudflow ran through the snow patches and accumulated on the slopes down under the them (figg. 8, 9). Concentrated water flows from rills above the snow patches caused thermoerosion on the firn surface and dug furrows as deep as the snow base (fig. 10). Water, which ran out from the rills, accumulated fine to coarse debris material into alluvial fans, which joined to the continuous accumulation on the dell floors. Further, large alluvial fans were found in places where dells cut across the road, which acted as a dam (fig. 8). From the most damaged dell, with an area of 2,4 hec., soil was carried, with the melting of the snow, about 8 m^3 into both alluvial fans. During intense rains, the rest of the snow quickly disappeared and dense braided patterns of erosion furrows up to 0,4 m wide and 0,3 m deep, remained on the slopes. The convex parts of the leeward sides, above and below the snow patches, was the most damaged. Tongues of mudflow material remained lying on the surface of the slope and the flow no longer continued, not even after further rain falls (fig. 11). This partly sorted and layered material was washed onto the dell floors by running rain water. During chance clear nights, when the temperature falls below freezing, the surface of the slopes were covered by a layer of pipkrake and in the course of the day, as the temperatures increased, there was left a creeping of soil particles. Rainfall during the period after the snow thawing caused further sapping and increased erosional rills and furrows. The damage resulting to the soil as well as to the grain from the processes during the snow thaw, were in this case significant. It showed that the range of processes which act during the course of rainy thawing is rich and it's effects altogether harmful. The intensity of the processes on the steep leeward slopes greatly heightened the activity of the processes on the gentle opposite slopes (fig. 12).

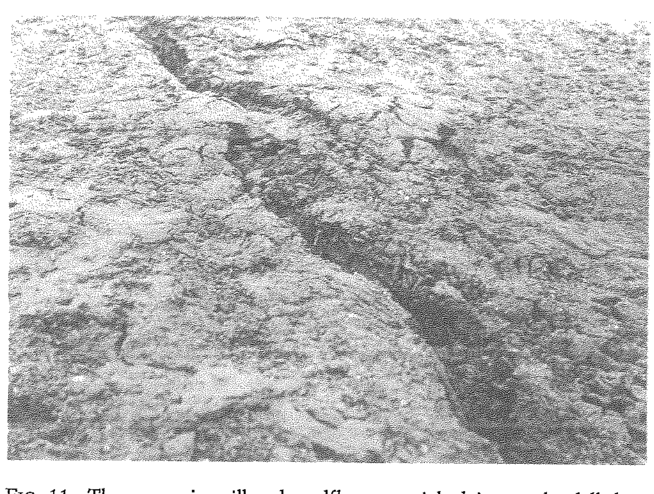

FIG. 11 - Thermoerosion rill and mudflow materials, lying on the dell slope surface after the snow thawed (Bystrice n.P., March 1981).

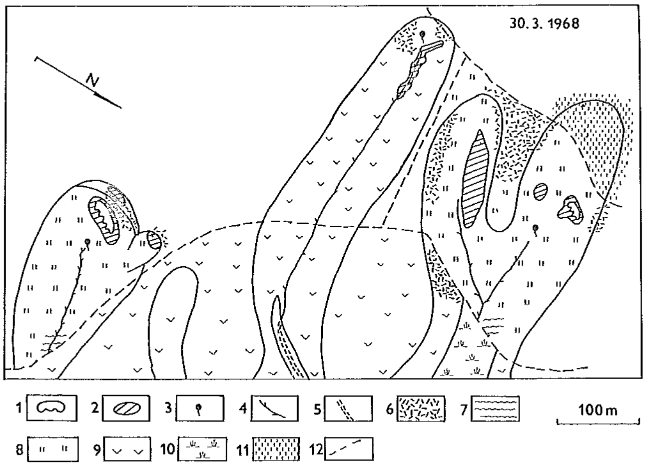

FIG. 12 - Map showing the course of thawing in the dells after a cyclonal situation with wet frontal flow (March 1981).
1. Snow patches; 2. Tongues of mudflow; 3. Alluvial fans; 4. Erosion rills; 5. Places abundantly covered by stones as a result of frost heaving; 6. Periodic seepage of ground-water from demaged drainage pipes; 7. Subnival meltwater channels; 8. Places flooded by water from thawing snow; 9. Places overgrown by winter wheat; 10. Grassy growth; 11. Stubble fields; 12. Roads; 13. Steps of agricultural terraces.

THE DANGEROUS PROCESSES OF SPRING RAINSTORMS

Until 1986 the damage in the studied region was recorded only after the spring thaw. In 1987 there was marked damage done in a later period, during May and June. But even these situations had their beginnings in the early spring. The thawing snow did not bring about any damage, but the winter season was noticeably prolonged and there were still hard frosts in March. This led to late agricultural work and sowing. In the beginning of May the agricultural growth was quite undeveloped and sufficient ground cover did not form. From the beginning of May, in the area surrounding Bystrice nad Pernstejnem, there was intense storm activity and strong rainfalls began. In the course of two months there were 7 short-term cloud bursts, which lasted a maximum of up to 35 minutes. The total rain amount during these downpours was 103 mm, with a maximum one-time amount of 50 mm. The total precipitation amount for the two months was 150 mm. Rain wash and erosion processes were noticed mainly in the dells (fig. 13). The intensity of the processes

FIG. 13 - Intensive slope processes in the dells NW of Bystrice n.P. after a rainstorms in May and June 1987.

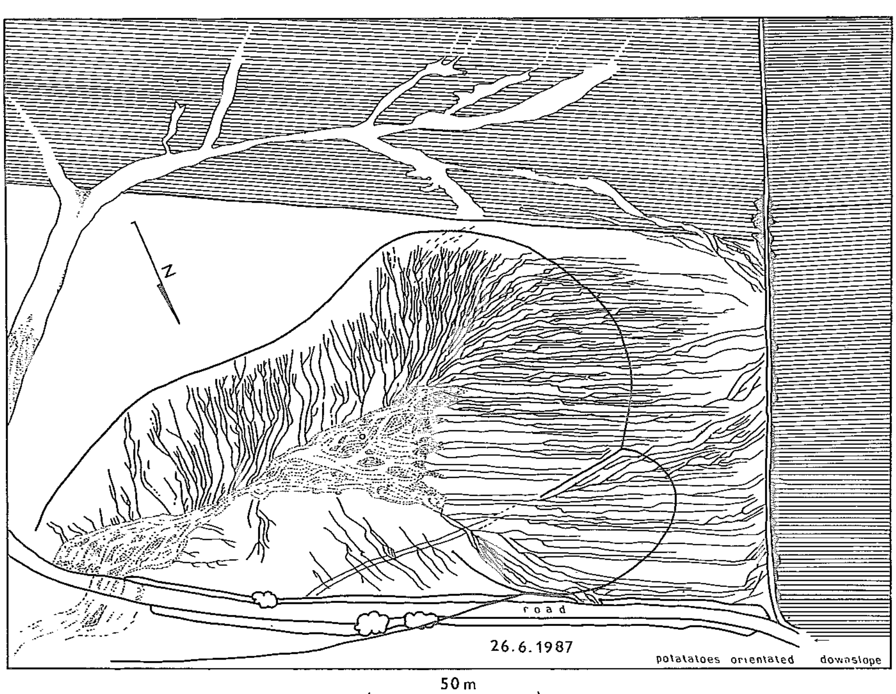

FIG. 14 - Dense dendritic rill pattern in the microbasin of dell head resulting from rainstorms in May and June 1987. The rill pattern is influenced by the direction of the furrows in the neighbouring potatoe field through which ran a large amount of water from a long, gentle slope. A different erosion pattern formed in the neighbouring dell, where there was protective influence of vegetation (potatoe).

was strengthened by the insufficiencies in cultivation, poor arrangement of erosionally dangerous plants, and insufficient systems of surface drainage. In the dell heads, fan-like concentric systems of erosional grooves formed, which constantly deepened during the following downpours (fig. 14). In two months, gullies of up to 1,6 m deep formed on the dell slopes (fig. 15).

Markings from sheet erosion and downward cutting was ascertained on the dell floors, as well as, accumulation. Sheet erosion in the strips took place on the dell floors with a straight profile slope angle up to 10°. The width of these strips were 1,5-8 m, depending on the floor width, with a depth up to 0,3 m. Sheet erosion with deep downward cutting and a furrow depth of up to 1,7 m, occurred in the seg-

FIG. 15 - Pattern of parallel erosion rills, up to 1 m deep on a dell slope (Bystrice n.P., June 1987).

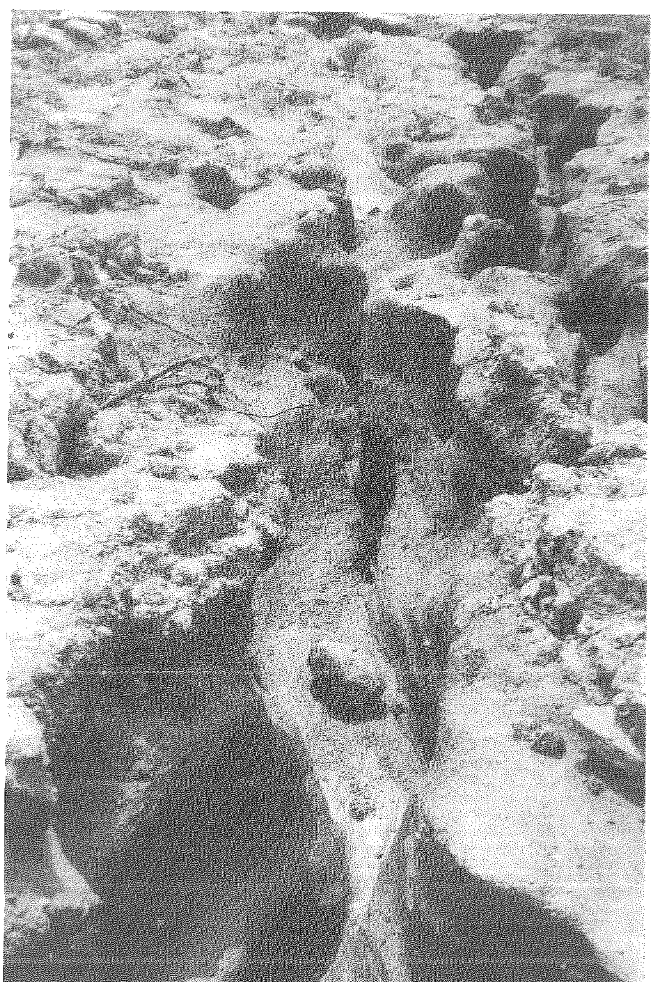

FIG. 16 - Erosion gully on a dell floor in gley soil up to 1,7 m deep (Bystrice n.P., June 1987).

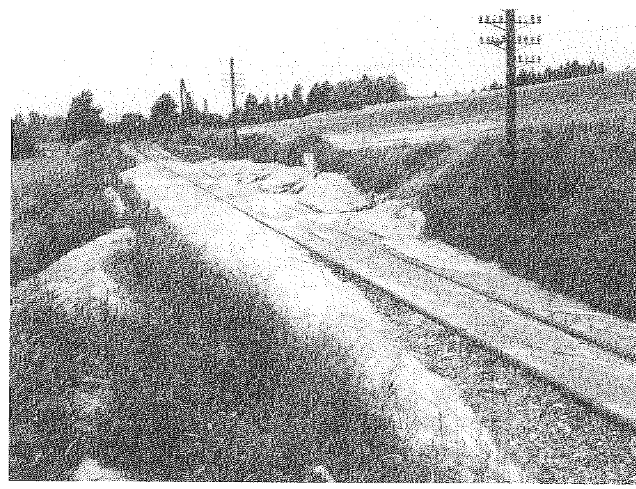

FIG. 17 - An alluvial fan of material carried from the dell floor onto a railroad track caused a train derailment and transportation breakdown (June 1987, area surrounding Bystrice n.P.).

FIG. 18 - The upper part of a catchment area in the hill relief of the Czech-Moravian Highlands and surface with shallow undulation of dells. After a strong evening rainstorm, the lower part of this short funnel-shaped catchment was hit by strong flooding, during which two people died. A stopped-up pipe culvert, draining the highway embankment and water overflowing the dell floors onto the fields, shared in the catastrophe (Kozlov, April 1988).

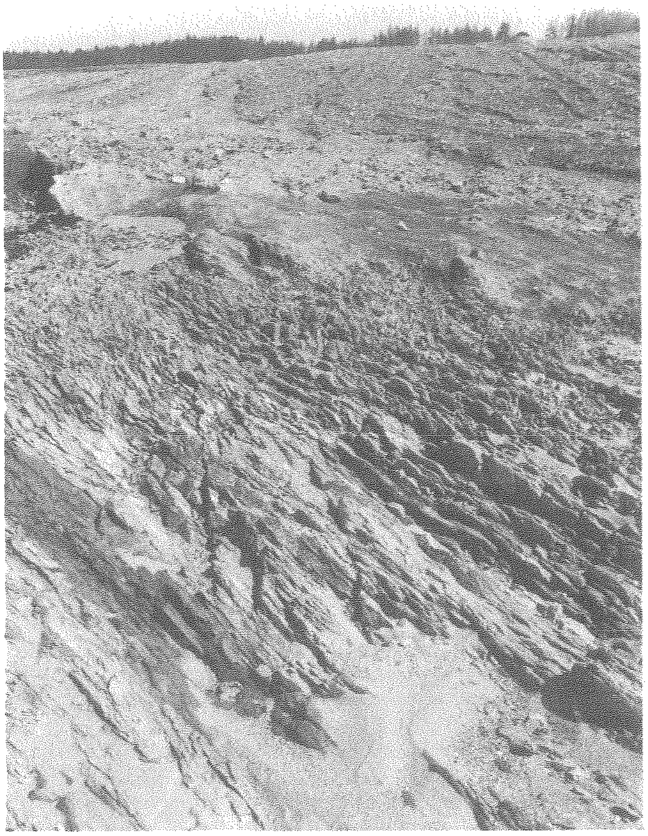

FIG. 19 - At the point of convex break on the dell floors, light soil was removed by strip erosion to the level of gneissic bedrock (Kozlov, April 1988).

ments with convex profile breaks (fig. 16). Material was accumulated and alluvial fans deposited in the dish-like heads and floor segments with concave profiles. The floors of dell heads were covered by alluvial fans with tens of cubic meters of bed load (fig. 16). The measured amount of washout in comparison to the snow thaw of 1981, was two to three times higher. The largest fans formed where the dells were transversely intersected by roads or train tracks. This matter acted as a protective barrier and protected the removal of soil from the field. The same thing occurred in the dells whose sides and floors were terraced; an important protective balk emerged. It's grassy belt was able to disperse the concentrated water flow, causing the downward cutting, and transform it into less harmful sheet wash and accumulation of carried-off material.

Besides the damage to the agricultural growth, there were accumulations of bed loads and concentrated run-off threatened human lives. An alluvial fan, deposited on the railtracks, caused a train derailment and a transportation breakdown (fig. 17). Two people drowned in a bus that was turned over by the torrent. Along with the erosional dangers, further dangerous functionings of dells could be seen in the formation of concentrated water currents running along the dell floors and dry valleys. Beside other factors, these cur-

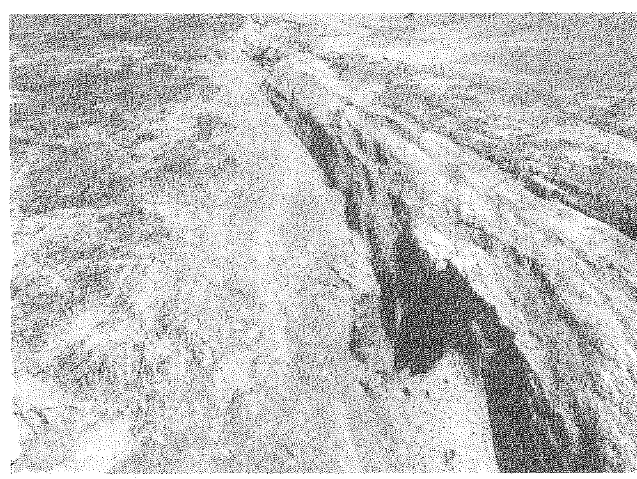

FIG. 20 - Flood bank markings after the flood in the central part of the short catchment. The slope of the terrace on the dell floor was soaked with water and suffered planar slide (Kozlov, April 1988).

FIG. 21, 22 - The system of drainage pipes and wells could not prevent the overland flow from the dells (Kozlov, April 1988; Bystrice n.P. June 87).

rents, dependent on the transformational abilities of the basins, contribute to the formation of floods. The dense pattern of the dells lowers this transformational ability of the basins. This dangerous situation was expressly seen in the spring 1988 in the short tributary basins of the Jihlava River. This basin had already been troubled by intense rainstorms, with a rainfall of cca 100 mm, in the last half of April. The ground of the largest part of the basin was bare and not planted. The overland flow here concentrated on the dell floors, where it caused surface strip washout and gully erosion at the point of convex break of the long-profiles (fig. 18). In some places the bedrock was thrown about the broad strip (fig. 19). Transformational ability of the basins in this season was considerably lowered. The threshold values of the overland flow and discharge in the channel were exceeded and this produced flooding, which seriously damaged many homes and 2 people lost their lives.

The efforts invested in agricultural large scale manufacturing production and the conforming of the landscape toward those purposes, were negative factors in this critical situation. The original functioning anti-erosion control modifications, mainly grassy strips on the dell floors, terraced floors and slopes, the pattern of drainage conduits, small ponds, etc., were discontinued. Pipe and well drainage were insufficient for the needs because they were unable to handle the overland flow from water precipitations (figg. 21, 22).

Unsuitable land cultivations and the placement of erosionally dangerous plants in exposed places (fig. 23), supported the formation of an erosionally dangerous situations, concentrated run-off from dells and flooding. In such situations, dells act as miniature basins (microbasins).

GEOMORPHOLOGICAL HAZARDS OF DELLS AND THEIR RESEARCH METHODS

It has been seen that dells are a functionally unstable geosystem and can contribute to the formation of dangerous situations and natural catastrophe. In applying these functions, two factors contribute. On the agricultural side, it is the trend to increase production. The results of this trend is the placement of landscapes with dells into the large field production system, without proper erosion control measures. Further, is the negative trends in weather developments, which in terms of cyclical oscillations, comes into season with more frequent cases of erosionally dangerous situations (KOTRNEC, 1986). The period of this oscillation is ca 15 years. The peak of the present oscillation should take place in 1991. This statistically established assumption confirms the yearly increase in the number of dangerous erosional events. One can therefore assume, that there will be an increase in the dangers and risks, which the network of dells threaten, in the hillyland areas. While the patterns of ancient gullies no longer play a dangerous role in the results of stabilization of vegetations, dell erosion is starting to take that place in full measure. Both gully and dell erosion have their historical causes (STEHLÍK, 1981).

FIG 23 - Poor orientation of the furrows on the potatoe fields heightened the danger of erosion and overland flow from the dells (Kozlov, April 1988).

In geomorphological research on the hazards of dells, there are two possibilities. One of them is to take advantage of geomorphological mapping, in either classical forms, or with the use of remote sensing analyses. The second possibility is to use the numerical mathematical statistical methods and mathematic modelling.

Detailed geomorphological mapping was used i.e. during the recording of dangerous erosional situations. Dells represent suitable objects for general and detailed geomorphological mapping. The function of registration of erosional phenomena, slope activity, and fluvial processes can suitably compensate for air photos or satellite images. With geomorphological mapping it is possible to establish the exact formation and arrangement of the pattern or system of dells in the landscape, and with that, contribute to planning and the actualization of anti-erosion control safeguards. The density of the dells in a chosen grid can be calculated, by a known formula, from the mapped patterns. The density of the dells, themselves, give certain information about potential soil erosion. For example, up to this point, it is unknown how to differentiate the density of dells found in regions composed of various rocks. It would be interesting, for example, to compare the data on dell density in crystalline rocks with data in density in Carpathian flysh rocks, where it is known that slope processes occur much more intensively. On the basis of density of the dells, it would be possible to classify basins endangered by erosion and flooding, those with low transformational abilities in the forming of floods.

In view of the oscillation of dangerous erosional phenomena associated to climatic changes, it would be definitely possible to make a prognosis of erosion according to weather change and then organize a warning system for the inhabitants of the area.

The use of data on dell density in calculating the potential and actual erosion and soil removal, stamming from the general relationships of empirical erosion models, is not very useful, in view of the fact that they can be replaced either by data on the average sloping of the basins (i.e. according to Herbst's methods), or the slope angle coefficient factor in the chosen grid. Direct measurements and calculations of run-off water and soil washout from agriculturally cultivated dells in various regions always come up against technical problems.

CONCLUSIONS

Dells in Central European hillyland landscapes represent an important member in the gravitationally caused transfer of material and energy. This transfer is influenced by the interaction between climate and the managerial activity of man in the landscape. The results of this unstable role of the dells is the real danger of the formation of catastrophic erosional and flood situations. The goal of this work on the basis of long-term observation, is to point out these dangers and the necessity of including dells among the landforms which need appropriate attention. Geomorphological research and mapping can contribute proposals and develope effective anti-erosion control safeguards.

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