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SOME PROBLEMS OF VALLEY DEVELOPMENT IN PLEISTOCENE DEPOSITS OF NORTHERN MORAVIA (CZECHOSLOVAKIA)

Abstract

The area of glacial deposits in northern Moravia represents a relief, the basic features of which developed in periglacial environment after the Saale Glaciation. Dells, dry valleys and broad river valleys are typical of the landscape. Some valley segments are connected to tectonic lines. In the valley development fluvio-thermal erosion processes played, indeed, a principal role. The report also presents a survey of the morphometry of asymmetrical valley segments on the basis of 1252 cross profiles with 33,718 numerical data, examined by computer.

INTRODUCTION

The paper discussed some problems of the Pleistocene valley development of lowland and hilly-land relief occupying a territory of about 1250 sq. km in the region of the Silesian Lowland especially its part the Hilly-land of Hlučín), the Ostrava Basin and the northern part of the Moravian Gate. The entire area was covered by the Elster and Saale continental ice caps with several oscillations of the glaciers (Macoun, 1980). Glacial, glaciofluvial, glaciolacustrine, fluvial and eolian deposits are the most prominent of the area. The thickness of the Pleistocene deposits in the territory is well variable from some metres up to approximately 100 m. The low relief with a dense drainage pattern attains mean altitudes up to 244 – 261 m (the total valley density is locally as many as 4 km/sq. km). Its present-day major elements developed under periglacial domaine in the presence of former permafrost after the retreat of the ice sheet of the Saale Glaciation sensu stricto. The Warta Glaciation did not touch our region. The thickness of the Pleistocene permafrost could attain in the region discussed about 100 m or also more; at least discontinuous permafrost existed as early as before the Matuyama-Brunhes boundary in Czechoslovakia (Czudek, 1982, p. 18).

There are three main valley categories in the studied area, such as dells, dry valleys and river valleys. A characteristic feature of these valleys is their striking slope asymmetry.

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DELLS

Dells form shallow weakly incised heads of dry valleys and lateral branches of the dry and river valleys. They can be very often difficultly distinguished from small-scale dry valleys or this distinction is practically almost impossible in many places. Since they merged continuously into dry valleys and because running water participated substancially in their development, they are classed by the author with the category of valleys (with the exception of dells on hillslopes – Hangdellen).

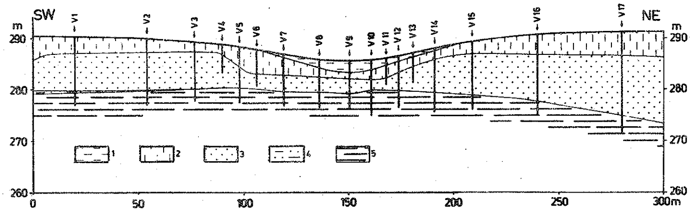

Fig. 1. Cross-profile of a dell SW of the village of Kujavy in the Moravian Gate

1. humus rich loams of the bottom of the dell (Holocene); 2. eolian loess loams (Vistulian); 3. glaciofluvial sediments, mainly sands (Saale *sensu stricto*); 4. glaciolacustrine sands and clays (Saale *sensu stricto*); 5. Miocene marine clays (Badenian); V1-V17 – borings

Dells tend to have usually a gentle bowl-like (broad open) transverse profile. The present lack of streams is attributed to consequent infiltration of the surface water to depth. There are even cases that a box-like cross profile (Fig. 1) occurs beneath the present-day shape of the dell. The length of the dells attains most often some hundreds of metres, locally even up to 1 km, their width 100 – 300 m and depth up to 10 m; the slope angle varies between 1° and 8°. In some places, dells are incised only into loess-like deposits (loess loams) but more frequently into the underlying strata built predominantly of glaciofluvial fine-grained sands. On the bottom of the dells below 1 – 2 m thick layer of deposits, resulting from present-day soil erosion on hillslopes, usually Late Vistulian filling occurs of about 1.5 m thick which indicates the role of running water (meltwater). In some dells these sediments could not be established.

The dells are typical denudation landforms which in the absolute majority of cases acquired their contemporary basic features in the period of permafrost melting – towards the end of the Last (Vistulian) Glaciation. Some of them could start developing already earlier such as in the cold periods after the recession of the Saale ice sheet. It seems probable that in many cases (but not everywhere) the dells and also dells on hillslopes (Hangdellen) began to develop on ice-wedges and in places of higher ice content. Running water took active share in their evolution (MITT, 1959, p. 31; KATASONOVA, 1963, p. 95, 98 – 99; CHURSKA, 1965, p. 34, 51, 101) melting by its thermal effect the ground ice (CZUDEK, 1973, p. 12; 1979, p. 12; SVENSSON, 1982, p. 139 – 142) and carrying away the loosened material. Upon ice-wedges and in places of higher ground ice content originally gullies or shallow depressions could develop, which were the initial phase of the development of dells. The present-day shape of the dells is due mainly to periglacial mass-wasting; slope wash being of greatest, solifluction of smaller significance (comp. e.g. KLATKOWA, 1965, p. 112–113; KOSTRZEWSKI, 1971, p. 88–91).

DRY VALLEYS

Dry valleys are in the area described also widespread phenomena. They form the heads of river valleys and tributaries of these valleys on their middle and lower courses. Dry valleys attain usually lengths of up to 2–2.5 km, widths up to 500 – 600 m and depths mostly up to 20 m; the slope angles do not usually surpass 12 – 15°. Their cross section is dominantly broad open (broadly U-shaped), less often box-like. Their bottom lies for most of the year dry and beneath the Holocene deposits Upper Pleistocene (Vistulian) sediments are frequent with typical marks of deposits created by running water. The thickness of the Quaternary deposits of the valley bottoms attains roughly as many as 2–4 m. The dry valleys are incised into the underlying beds of eolian deposits i.e. mostly into highly permeable today glaciofluvial fine-grained sands.

Recent investigations suggest that dry valleys began to develop during the recession of the Saale ice sheet. Some of them seem to be conditioned by original landscape irregularities which appeared after the melting of the glacier as pointed out e.g. by KLATKOWA (1965, p. 108, 115) in Poland. The idea that many of them may have been initiated by former periglacial dells cannot be rejected. Unfortunately there is not sufficient quantity of factological material in the area investigated so far, which would allow a more exact dating of the individual stages of the development of dry valleys (and also river valleys) in the chronology of the Middle and Upper Pleistocene. From the present state of knowledge it follows, however, that in their development acted geomorphological processes in cold and humid temperate environment after the deglaciation of the area. The main processes were linear running water (especially fluvio-thermal erosion) and cryogenic slope processes.

RIVER VALLEYS

River valleys are in the area investigated by far not so frequent as dells and dry valleys. The river valleys (the largest of them – Odra and Opava – are not included) attain lengths mostly of up to 10 km, widths to about 1 km and depths mostly as many as 30 m. The angles of steeper slopes are mostly up to 16–20°.

Along the main water courses river terraces can be found. In some places, the fluviatile terraces are completely buried by slope and eolian deposits (Fig. 2). The river valleys have usually a flat-floored (box-like) cross profile and always a broad bottom, on the Odra River somewhere approximately up to 3 km in width (in average about 2 km). Some river valleys have distinct nearly orthogonal bends, indicating the influence of neotectonics.

The river valleys also began to develop during the retreat of the Saale ice cap when – similarly as during the recession of the Elster glacier – an intensive removal of the deposits along the water courses took place. They follow the original ground surface irregularities which appeared after the deglaciation of the area (glacial predisposition) and the older valleys from the pre-Saale and even pre-Elster periods. The valleys discussed originated due to downcutting and lateral erosion in periglacial and humid temperate environment; however, the geomorphological agents in cold regime of the Upper Pleistocene were responsible for their present-day major features.

At the foot of the slopes of the dry and river valleys gently sloping erosional surfaces (angle of slope mostly 1 – 4° and width most often up to 100 m, locally even 200 m) occur in several places in the region of the Hilly-land of Hlučín. In most cases these landforms can be considered Upper Pleistocene cryopediments.

FLUVIO-THERMAL EROSION

Fluvio-thermal erosion results in the melting of ground ice, the removal of loosened material by running water and the origin of thermo-erosional relief features. While in contemporary permafrost areas the effects of fluvio-thermal erosion in fashioning the valleys are relatively well known, in the regions of Pleistocene permafrost this problem has not been studied sufficiently so far. But owing to the pioneer papers by BÜDEL (1969), DYLIK (1969) and JAHN (1970) these questions have become actual even in Central Europe. The author's geomorphological investigations of the Pleistocene fluvio-thermal erosion in Bohemia and Moravia (western part of Czechoslovakia) are based on the valley shape, the river and slope deposits as well as the character of the valley bottom and slope foot on the deposits of the continental glaciation studied in numerous borings, test pits and long excavations. The present investigations have shown that linear (vertical) and lateral thermal erosion played, indeed, a principal role in the origin of Pleistocene valleys and in the modification of the pre-Quaternary valleys in Czechoslovakia. Both types of fluvio-thermal erosion acted together but under certain conditions the action of one type of thermal erosion, under other conditions that of the second type dominated.

In the origin of bowl-like valleys (dells and dry valleys) linear thermal erosion prevailed, though in many cases lateral shifting of the axes of these landforms and

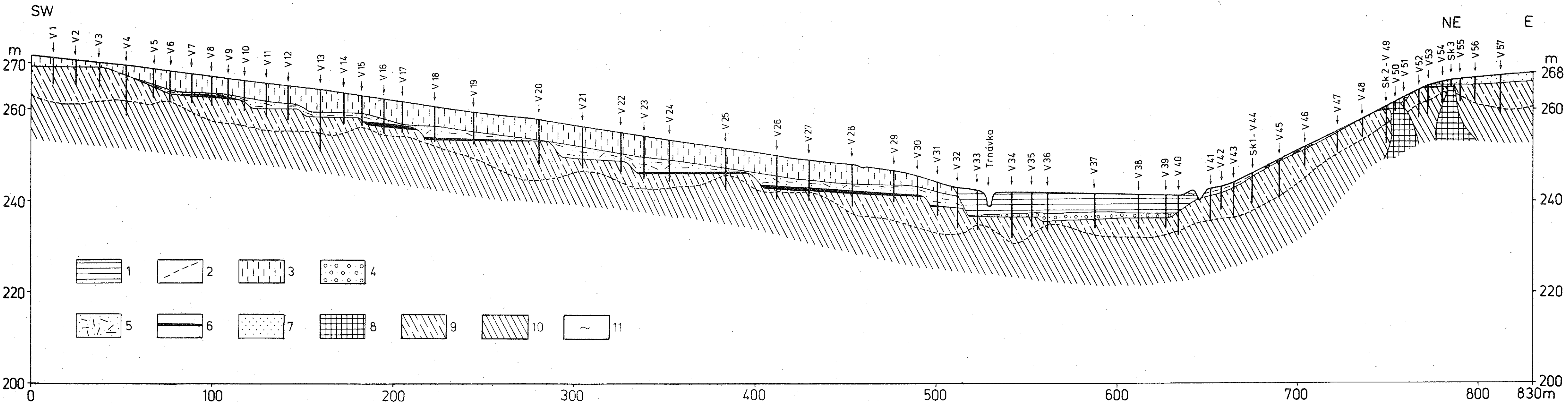

Fig. 2. Valley of the Trnávka River near the village of Trnávka in the Moravian Gate

1. flood plain deposits: loams, sands, clays (Holocene); 2. slope deposits: loams and clays (Holocene); 3. eolian loess loams (Vistulian); 4. sands and gravels with clay interbeds of the valley bottom (Late Vistulian); 5. redeposited glaciofluvial sediments, mainly sands and clays (Pleistocene); 6. sands and gravels of the buried river terraces (Pleistocene); 7. glaciofluvial deposits, mainly sands and clays (Saale *sensu stricto*); 8. igneous rocks (Cretaceous); 9. clays, rarely with sandstone interbeds (weathering products of Cretaceous rocks); 10. claystones, rarely with sandstone interbeds (Cretaceous); 11. anthropogenic deposits; Sk 1-Sk 3. test pits; V1-V57 — borings

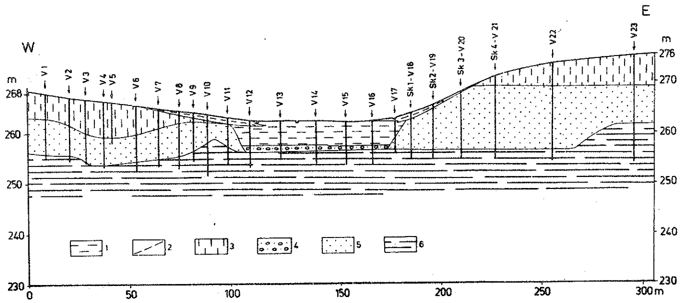

Fig. 3. Valley SSW of the village of Bílov in the Moravian Gate

1. flood plain deposits: clays, silts and sands (Holocene); 2. slope deposits: loams (Holocene); 3. eolian loess loams (Vistulian); 4. sands and gravels of the valley bottom (Late Vistulian); 5. glaciofluvial deposits; mainly sands (Saale *sensu stricto*); 6. Miocene marine clays (Badenian); Sk 1-Sk 4. test pits; V1-V23 – borings

slope undercutting occurred due to asymmetric action of periglacial slope processes (CZUDEK, 1979, p. 17; 1980, p. 11; 1982, p. 21–22).

Most distinct marks of lateral fluvio-thermal erosion can be observed in flat-floored river valleys. The width of the bottom of these valleys surpasses many times the depth of the valleys; the bottom is somewhere up to 100 times broader than the present river channel. Numerous cross profiles based on many borings and test pits have shown that the bottom of the river valleys is below the gravels of Vistulian Period (and even the former bottom from the period before the Saale Glaciation *sensu stricto* as illustrated in figure 3) on the whole fairly flat (though dissected by shallow stream channels). The former braiding channels can be found in various places even in close proximity of valley sides. The gravels of the valley bottom are often directly adjacent to bedrock of the slopes which are considerably steep here (usually more inclined than in the middle and upper slope segments). Even an asymmetrical development of fluviatile terraces (Fig. 2) and distinct shifting of the valley axes on a distance of more than 200 m can be observed; in one profile at a relatively low-order streamflow on a distance of as many as 530 m (CZUDEK, 1973, p. 40; 1980, p. 13–14). Upper Pleistocene lateral thermal erosion often acting evidently simultaneously with the downcutting over the entire width of the valley floor has been decisive for the present-day major features of the river valleys in the area investigated in northern Moravia.

VALLEYS AND QUATERNARY TECTONICS

Distinct orthogonal bends van be observed at some river valleys in the studied area. In places of the bend of the valley from on direction into another, there are always short dry valleys following directly the direction of the section of the main valley before and after the valley bend. In the surroundings of the village of Píšť in the Hilly-land of Hlučín a distinct rectangular valley pattern occurs. Such valley features are characteristic of areas with block tectonics. But even in some other rectilinear river valley segments without orthogonal bends, there is tectonic instability either proved or supposed by geophysical and geological methods. As follows from geophysical research, the surface of the Paleozoic rocks in the region of the Silesian Lowland in depths of several hundreds of metres is broken into blocks bordered by faults (VÁCA, 1977, p. 184–186). These faults along which differential movements of the individual blocks of Paleozoic rocks took place in the pre-Neogene and Neogene Epochs continue even in the Quaternary. They manifest themselves through the Miocene and Quaternary deposits as far as to the land surface and influenced the development of valleys.

VALLEY ASYMMETRY

A typical feature of the dells, dry valleys as well as river valleys is their slope asymmetry. In this paper such a type of asymmetry is described in which the opposite sides have approximately the same height above the valley bottom but a markedly different inclination (asymmetry in slope inclination). This type of asymmetry is most widespread and has been studied mainly in the northern part of the Moravian Gate and in the area of the Hilly-land of Hlučín. Almost each valley is in the area investigated asymmetrical at least in one segment. The asymmetry starts somewhere in the very beginning of the valley, the valley being incised there even only 2 m, but in particular from depths of 3–4 m. The steeper slopes are oriented predominantly towards the west directions even in the uppermost valley sections. An alteration in the exposure of the steeper slope downstream in such a way that the slope would have in the uppermost and upper segments a "cold" exposure and in the middle and lower courses a "warm" exposure cannot be observed. There is also no evidence that small valleys would be characterized by a cold, and larger valleys by a warm exposure of the steeper slope or on the contrary. There are usually eolian loess loams even more than 5 m thick with traces of solifluction and sheet wash on gentle slopes. In the substratum of eolian deposits the uppermost layers of the sediments of continental glaciation are disturbed by cryogenic slope processes. On the steeper sides of asymmetrical valleys the loess deposits have a considerably smaller thickness or they are absent. Periglacial slope deposits form there only a thin veneer or they do not occur at all.

For more detailed knowledge of the asymmetry in slope inclination 284 localities were measured in the northern part of the Moravian Gate and 968 in the region of the Hilly-land of Hlučín. In the first area 6532 numerical data were obtained, in the second one 27,186 numerical data were statistically examined on Hewlett-Packard 9825A computer. Some of these mathematical treatments are given below. Several geological cross profiles were also compiled, based on numerous borings and test pits.

The average value of the index of asymmetry (index of asymmetry was computed for each cross profile by dividing the average angle of the steeper slope by the average angle of the gentler slope) in the northern part of the Moravian Gate amounts to 2.53, the mean difference of asymmetry (the average angle of the steeper slope minus the average angle of the gentler slope) to 5.2. The relatively low indices – varying between 1.25 and 3.0 occurring in 80.28% of the total

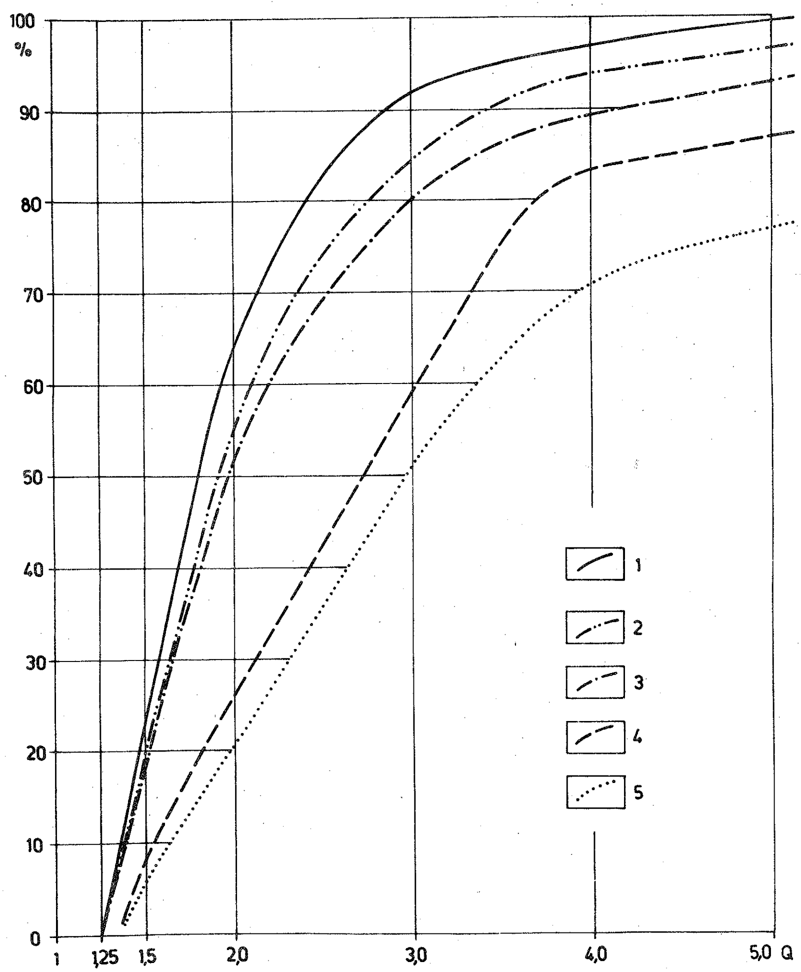

Fig. 4. Cumulative curves of asymmetry indices in the northern part of the Moravian Gate

1. small valleys; 2. all valleys without Odra River; 3. all valleys including the Odra River; 4. large valleys without the Odra River; 5. large valleys including the Odra River valley

indices – are typical. In larger valleys the index is greater, on average, than in smaller ones (Fig. 4). This is also valid for the region of the Hilly-land of Hlučín. The average angle of the steeper slopes in the northern part of the Moravian Gate amounts to 9,4°, the average length to 80.6 m, the average angle of the gentler slopes to 4.2°, the length to 183.6 m. The mean length of the asymmetrical valley segments is 771 m, the valley depth 13.8 m, the width of the valley bottom (without the Odra River) 100 m. The steeper sides are most often oriented towards the W (83 times), NW (64 times) and SW (53 times). Altogether 70.42% of all steeper slopes are accordingly facing towards the western directions. The asymmetrical sections with steeper sides faced towards the SW, NW and W are also the longest, the segments with SE and N-facing steeper slopes are the shortest.

In the region of the Hilly-land of Hlučín the average index of the studied asymmetry amounts to 1.93, the mean difference of asymmetry to 4.3. Indices ranging between 1.25 and 3.0 are most frequent; they form 92.67% of the total indices. The average angle of the steeper slopes is 9.8°, the length 57.2 m, the average angle of the gentler sides amounts to 5.6°, the length to 113.1 m. The mean length of the asymmetrical valley sections amounts to 333 m, the valley depth to 9.2 m, the width of the valley bottom to 42 m. The steeper slopes are most often oriented towards the NW (229 times), W (182 times) and SW (151 times), i.e. 58.06% of all steeper slopes. Analogous situation is even in other regions of the western part of Czechoslovakia (Fig. 5). The asymmetrical valley segments with steeper sides facing towards SW, NW and W are also the longest, the shortest are segments with exposures of steeper slopes towards the SE and E.

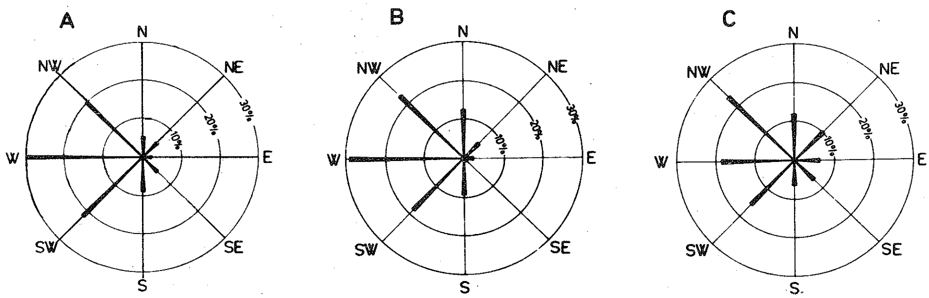

Fig. 5. Frequency of asymmetrical valley segments plotted against the orientation of steeper slopes
A – eastern part of the Nízký Jeseník (Highland); B – northern part of the Moravian Gate; C – Hilly-land of Hlučín

The Hewlett-Packard 9825A computer was also used to examine, for instance, the linear correlation between the index of asymmetry and the length of asymmetrical valley sections, furthermore the relationship between the index of asymmetry and the valley depth, its width and the width of the valley bottom. The correlation coefficients are demonstrated in the following table. The medium-high degree of the linear relationship of the index of the asymmetry in slope

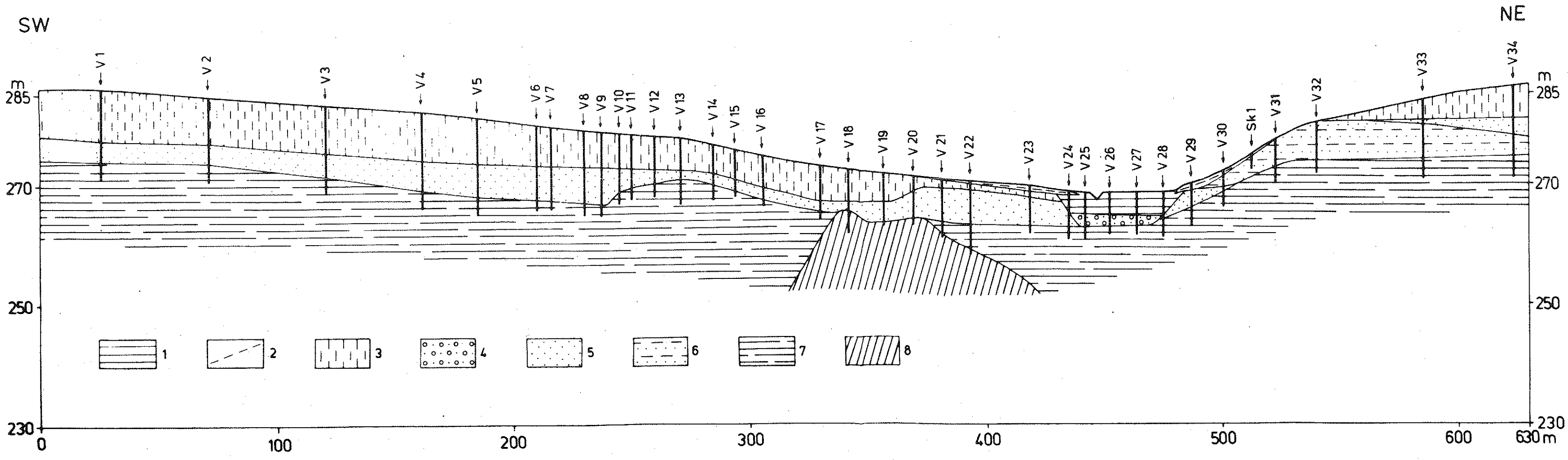

Fig. 6. Asymmetrical valley NE of the village of Stachovice in the Moravian Gate

1. flood plain deposits: loams and clays (Holocene); 2. slope deposits: loams (Holocene); 3. eolian loess loams (Vistulian); 4. sands and gravels of the valley bottom (Late Vistulian); 5. glaciofluvial deposits, mainly sands and clays (Saale *sensu stricto*); 6. glaciolakustrine sands and clays (Saale *sensu stricto*); 7. Miocene marine sediments, clay with sand interbeds (Badenian); 8. Lower Carboniferous greywackes and shales; Sk 1. test pit; V1-V34 – borings

inclination to the width of the valley bottom points to the role of lateral erosion in the development of slope asymmetry.

	Index/length of asymmetr. valley segments	Index/depth of valleys	Index/width of valleys	Index/width of valley bottoms
Northern part of the Moravian Gate	0.327	0.127	0.613	0.611
Hilly-land of Hlučín	0.270	0.276	0.668	0.431

Although asymmetry in slope inclination began to develop in the area described as early as in the cold periods of the Pleistocene before the Saale Glaciation (CZUDEK, 1973, p. 32) – comp. also figure 6 in this paper – its present-day major elements originated after the retreat of the glacier of the last stage of the Saale Glaciation *sensu stricto*. In the majority of cases the slope asymmetry evidently developed contemporaneously to the downcutting of the valleys (FRENCH, 1971, p. 727, 729). The asymmetry is climatically controlled and acquired its present shape during the Late Vistulian times under periglacial conditions.

Among the causes of the origin of the climatically controlled valley asymmetry eolian sedimentation can be eliminated as dominant agent since the asymmetry began to develop as early as before the eolian periods of the Vistulian Epoch. The asymmetry developed even during the loess phases as well as after the accumulation of eolian deposits. At the early stage the eolian processes contributed to the enrichment of the glaciofluvial sandy deposits of the continental glaciations by fine-grained material which promoted the activity of slope processes. In cases of greater accumulation of eolian deposits a certain "fossilisation" of the underlying sediments took place.

The valley asymmetry developed in the area described owing to the differential effect of periglacial slope processes operating upon valley sides of varying orientations as well as to the lateral erosion, mainly to fluvio-thermal erosion during the various phases of the periglacial climate cycle. The author's opinion that the different cryogenic mass-wasting of opposite valley sides was caused by their differential thermal balance and effectively supported by snow patches, is in agreement with many workers.

Field observations carried out during many years suggest that in agricultural areas (completely prevailing in the territory described) the valley sides are developing unequally even at present. The main period of such a development is that of snow and frozen ground melting at the end of the winter when the geomorphological agents are similar to periglacial ones. The present-day development trends to a greater denudation of gentle slopes which manifests itself by further emphasizing of the Pleistocene asymmetry. Simultaneously, the asymmetry develops in new places.

CONCLUSIONS

1. The major relief features of the area described developed in the periglacial morphoclimatic system after the deglaciation of the territory.
2. A considerable number of dells began developing on ice-wedges and in places of higher ground ice content. In their evolution running water besides mass-wasting – especially slope wash – participated to a considerable extent (they are consequently a mixed product of running water and slope processes).
3. It is possible that some dry valleys are linked to original landscape irregularities which appeared after the retreat of the Scandinavian glaciers and many of them have developed in places of former periglacial dells.
4. The river valleys are linked to the depressions in the original glacial relief and to older drainage axes from pre-Saale and/or pre-Elster periods.
5. Linear and lateral fluvio-thermal erosion were the principal factors in the geomorphological activity of running water. Both types of thermal erosion operated together in all valleys. However, in the development of dells and dry valleys linear thermal erosion predominated. Most distinct marks of Upper Pleistocene lateral fluvio-thermal erosion occur in flat bottomed river valleys.
6. At the foot of the slopes of the dry and river valleys cryopediments can be found.
7. Some valley segments (usually of river valleys) are connected with tectonic lines manifesting themselves to the land surface through the Miocene and Pleistocene deposits from depths of several hundreds of metres.
8. The valleys portray a striking asymmetry of their slopes. This asymmetry developed owing to the differential effect of periglacial processes (due to different insolation as well as moisture conditions caused by snowfields) operating upon opposite valley sides and due to lateral erosion, mainly fluvio-thermal erosion, in different climatic phases of the periglacial environment. It acquired its present aspect in the cold climatic regime during the Late Vistulian times.

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