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PLEISTOCENE THERMAL EROSION IN THE WESTERN PART OF CZECHOSLOVAKIA

I. Introduction

Although considerable progress has been done in the research of Pleistocene cryogenic hillslope processes and landforms in Czechoslovakia over the last 25 years, there is still little information available to the role of fluvial processes in periglacial environments. Our recent investigations concerning this problem are based on the valley shape, the river and slope deposits, as well as the character of the valley bottom and slope foot underlying the Pleistocene sediments; studied in numerous drill-holes, test pits and long excavations. The present report shows that linear (vertical) and lateral thermal erosion played, indeed, an important role in the evolution of Pleistocene valleys and in the modification of pre-Quaternary valleys in Bohemia and Moravia.

II. Thermal erosion

Thermal erosion results in the melting of ground ice, the removal of loosened material by flowing water and the origin of thermo-erosional features. Thus, thermal erosion is closely connected with normal mechanical erosion whose morphogenetic effects differ from place to place in permafrost areas. It can be said that it is in many regions much smaller than that of thermal erosion. Thermal erosion is acting in permafrost areas in all rivers. But its geomorphological effect controled by local conditions is variable and depends among others:

i) on the temperature of the runnig water and the temperature of the frozen ground;

ii) on the quantity, the mode of distribution and the type of frozen ground,

iii) on the composition and mechanical properties of the bedrock, notably on its jointing;

iv) on the quantity and the velocity of flowing water;

v) on the lenght of the annual period of thermal erosion;

vi) on the quantity of material supplied, not only from valleys slopes and river banks but also from the bottom of the river;

vii) on the tectonic regime of the area — uplift or subsidence — and on the rate of this tectonic movements. In many cases, the tectonics affect the type of thermal erosion as well as its share in the total activity of running water.

From the geomorphological point of view thermal erosion can be classified into two basic types: linear (vertical) thermal erosion and lateral thermal erosion. Both are interrelated and very often act together (T. Czudek — J. Demek 1973, p.

26). Under certain conditions the action of one type of thermal erosion dominates, under other conditions that of the second type. A lot of landforms created and/or conditioned by lateral thermal erosion as well as the rapid undercutting of river banks led many authors to conclusions that the thermal erosion operates predominantly laterally. In the conditions of present-day permafrost this opinion is correct especially in the case of larger lowland streams. But in many cases, mainly in areas of rapid uplift, the linear mechanical and linear thermal erosion dominate.

Both types of thermal erosion are known to be very effective. Examples from Arctic North America and Siberia in particular are startling. The frozen banks of the rivers Indigirka and Yana, for instance are in some places retreating at a rate of 10—25 m/year (S. S. Korzhuyev 1966, pp. 28—29). New gullies develop quickly, and the lenght of existing gullies may increase at a rate of several tens of metres/year. Numerous descriptions of the effect of thermal erosion in present-day permafrost areas have been presented in many papers and summarized especially by J. Dylik (1970), A. Jahn (1970, 1975), T. Czudek — J. Demek (1973) and H. M. French (1976).

III. Pleistocene thermal erosion and the evolution of valleys in the western part of Czechoslovakia

During the cold periods of the Pleistocene epoch Czechoslovakia was situated in front of the Scandinavian continental ice sheet and its western part in the proximity of Alpine glaciers. There is numerous direct and indirect evidence indicating the presence of Pleistocene permafrost on the territory of Bohemia and Moravia. The main arguments for this are:

i) post-cryogenic textures in unconsolidated fine-grained sediments;

ii) pseudomorphs of ice-wedges, the largest of them being 6,50 m deep and 11,25 m wide (Němčany near Slavkov u Brna, Central Moravian Carpathians);

iii) intensive deep frost weathering of massive rocks reaching along fissures to depths of more than 30 m;

iv) huge blocks of Tertiary and Pleistocene sediments transported in frozen state by the glacier in formerly glaciated areas of northern Moravia;

v) very frequent occurrence of climatically determined periglacial asymmetric valleys, dry valleys, dells, frost-riven cliffs and scarps, tors and cryoplanation terraces which can develop in seasonally frozen ground (where permafrost is lacking) but are —in such forms as found in Czechoslovakia— typical of zone with present-day perennially frozen ground.

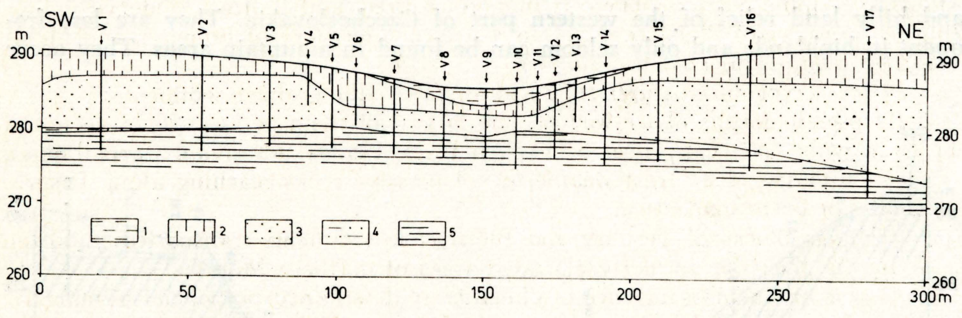
Permafrost occurred in Bohemia and Moravia not only during the Würm but also in former cold periods of the Pleistocene (J. Demek in J. Demek — J. Kukla ed., 1969, p. 39). Its thickness as well as the ice content were locally and obviously even in the individual cold periods different. Of widespread importance were here especially the relief and local geological conditions, the lithological rock properties in particular. The thickness of the Pleistocene permafrost on Czechoslovakia's territory is not sufficiently known at present. But according to recent investigations it attained at least several tens of metres. It is possible that it could attain even about 100 m under favourable conditions. Up to 60—70 per cent of permafrost by volume could consist of ice.

There are three basic morphographical valley types in the area described. These are:

1. broad open (dell-like) valleys;
2. deeply incised V-shaped valleys with a narrow bottom;
3. valleys with a broad bottom (box-like valleys).

The valleys are of different age and many of them originated in pre-Quaternary epoch. Some of them in the Bohemian Massif are even of Paleogene age. During the Quaternary an intensive modelling of older valleys and the evolution of new valleys can be observed.

In the development of the broad open valleys represented especially by dells (Dellen) and small dry valleys mainly processes of linear thermal erosion were important. These valleys are very frequent in Bohemia and Moravia and occur both in regions built of less resistant sediments and in solid rocks areas. Their sides are commonly asymmetric. The valleys mentioned form often a dense pattern in lowland and hilly land relief. During the Pleistocene the deepening and, owing to slope processes, the widening of older broad open valleys as well as the formation of small shallow dells and dry valleys in new places took place. From the character of the Pleistocene periglacial sediments on the bottom of the valleys described it follows that they were transported both by solifluction and running water. There are even cases that on the bottom of short broad open valleys occur channels filled-up with slope deposits whose cross-profile shows that they were created by linearly running water (T. Czudek 1971, p. 37, 1978, p. 72). In the Moravian Gate e. g. we established in drill-holes below the present-day broad open cross-profile of a dell a flat-bottomed box-like form (Fig. 1.) as well as knicks in the long-profile indicating fluvial action (T. Czudek 1973, pp. 10 – 12).

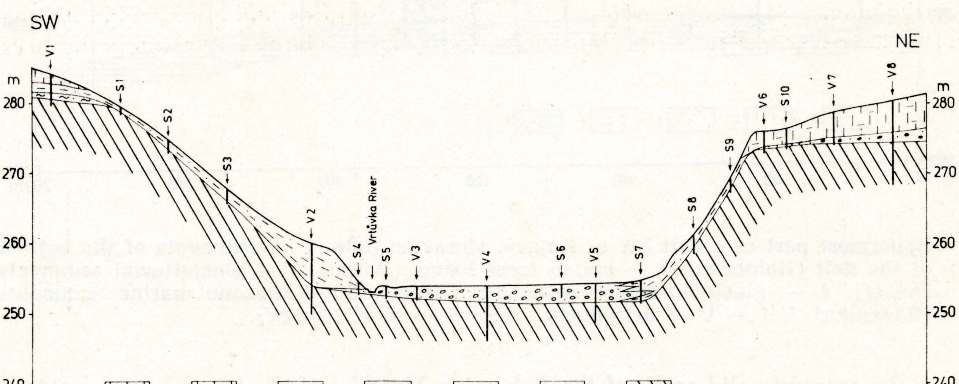


1. Uppermost part of a dell SW of Kujavy, Moravian Gate. 1 — sediments of the bottom of the dell (Holocene), 2 — eolian loess loams (Würm), 3 — glaciofluvial sediments (Saale), 4 — glaciolacustrine sediments (Saale), 5 — Miocene marine sediments (Badenian). V 1 — V 17 drill-holes. *(According to T. Czudek).*

In areas of solid rocks of the Bohemian Massif and the Western Carpathians dells developed in places of greater jointing or where shallow terrain depressions might have already occurred. In these places, there were, owing to greater moisture, favourable conditions for the development of larger ground ice masses. Even in regions consisting of soft Neogene and Quaternary sediments Pleistocene dells and dry valleys originated in former relief depressions and greater ground ice occurrences. On ice-wedges and larger ice lenses first gullies developed due to thermal erosion of linearly running water which may in many cases be considered the initial phase of the evolution of the dells. Owing to linear flowing water (mainly vertical thermal erosion) these landforms were deepened and broadened by mass wasting processes. In many cases lateral shifting of the axis due to asymmetric action of slope processes and undercutting of the sides of dells and dry valleys by thermal erosion took place. Lateral thermal erosion co-operated accordingly in the origin of valley asymmetry.

Deeply incised V-shaped valleys with a narrow bottom are widespread in the highlands and especially mountains of the Bohemian Massif and the Western Carpathians. These valleys are even several hundreds of metres deep and characterized by a lack of morphologically expressed fluvial terraces. The terraces are usually buried by slope material. In many V-shaped valleys (in mountain regions in particular) there were mostly not favourable conditions for the development of river terraces. This is connected with a very intensive uplift which could to a considerable extent obscure the climatically conditioned phases of a certain stability and activity in valley incision. Due to intensive tectonic uplifts at the end of the Tertiary and in Pleistocene the valleys described exhibit distinct features of forms created by rapid down-cutting. In the Krkonoše Mts., the Krušné hory Mts., the Hrubý Jeseník Mts. and the Moravskoslezské Beskydy Mts. for instance the intensity of the Pleistocene deepening of the valleys can be established with at least 300 and/or 400 m. The disturbance of the bedrock by frost (widening of the original fissures) in the valley bottom and lower slope parts seems to be greater than on the surrounding watershed ridges. In the development of the V-shaped valleys during the Pleistocene mainly normal mechanical erosion as well as thermal vertical erosion took share. The lateral erosion was of less importance in the general aspect of these valleys.

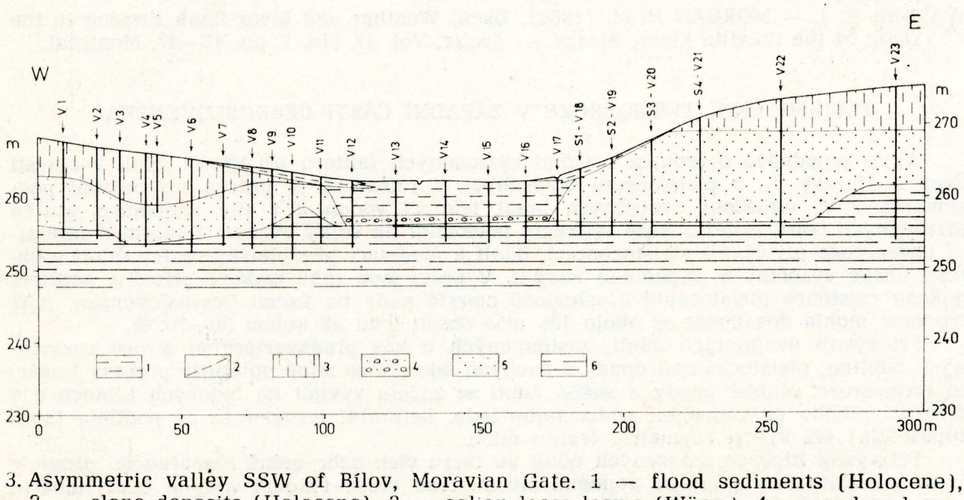
The valleys with a broad bottom (box-like valleys) are typical of the lowland and hilly land relief of the western part of Czechoslovakia. They are less frequent in highlands and only seldom can be found in mountain areas. They occur



2. Box-like valley of the Vrtůvka River near Velká Bystřice, Nízký Jeseník (Highlands). 1 — loess (Würm), 2 — loess with fragments of Lower Carboniferous rocks (Würm), 3 — slope deposits: loams and debris (Würm), 4 — sediments of the valley bottom (Holocene — Würm), 5 — terrace sediments (Young Pleistocene), 6 — fossil weathered material (caolinitic clay) redeposited in the Pleistocene, 7 — bedrock — mostly shales (Lower Carboniferous). S 1 — S 10 test pits, V 1 — V 8 drill-holes. *(According to T. Czudek and M. Hrašna).*

in various rocks and their typical feature is a flat broad bottom, the dimensions of which usually exceed the depth of the valley (Fig. 2.). The rivers are underfit, their bottoms being even more than 100 times broader than the present river channel. It follows from numerous drill-holes that the base of the fluvial deposits is on the whole fairly flat in the cross-profile. The basis of terrace gravels and sands exhibits the same character or is slightly inclined towards the valley axis. Shallow depressions (one or several) occur in the bedrock underlying the sediments of the valley floor. These former braiding channels are to be found in various places; even in close proximity of slopes and inside the gravel body, too. The character of accumulation of the Pleistocene sands and gravels point also to their removal not only down-streams but even in lateral direction. There, where no talus occurs, the Quaternary sediments of the valley bottom are directly adjacent to the bedrock of the slope, which is here considerably steep (usually more inclined than in the other slope parts). A similar situation indicating lateral erosion exist in the case of river terraces. In places where talus exists at the foot of the slope several types of relationships between the Pleistocene gravel-sand series of strata of the valley floor and the slope deposits were established. The effects of lateral erosion were accordingly strongly affected by the action of periglacial slope processes. Although box-like valleys must have existed in many areas of the western part of Czechoslovakia as early as before the Quaternary, the Pleistocene lateral erosion often occurring evidently together with the deepening of valley bottoms has been decisive for their present-day shape. It is not excluded and has not been exactly proved for the moment, that lateral erosion was supported by icings. Their presence during the cold Pleistocene periods is beyond any doubt in Central Europe.

Pleistocene lateral erosion (especially thermal erosion) is responsible not only for the development of present-day flat broad valley bottoms. In many cases, a distinct shifting of the valley (often by as much as several hundreds of metres) owing to asymmetric action of slope processes can be observed. This is indicated by the often asymmetric development of the river terraces. An example can be the Trnávka River valley in the Moravian Gate where 9 buried Pleistocene terraces



3. Asymmetric valley SSW of Bílov, Moravian Gate. 1 — flood sediments (Holocene), 2 -- slope deposits (Holocene), 3 — eolian loess loams (Würm), 4 — sand and gravel of the valley bottom (late Würm), 5 — glaciofluvial sediments (Saale), 6 — Miocene marine sediments (Badenian). S 1 — S 4 test pits, V 1 — V 23 drill-holes. *(According to T. Czudek).*

were found on the left (E-facing) side at a distance of 5 km from the valley head. The lenght of the lateral shifting of the valley axis towards the steeper (W-facing) slope is about 530 m. Pleistocene lateral thermal erosion took also share in the development of asymmetric valleys (Fig. 3.) which belong to the typical features of the relief in the western part of Czechoslovakia.

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PLEISTOCENNÍ TERMOEROZE V ZÁPADNÍ ČÁSTI ČESKOSLOVENSKA

Autor pojednává o jednom z velmi významných faktorů při vývoji údolí v oblasti Čech a Moravy, tj. o pleistocenní termoerozi. Termoeroze je proces rozpouštění podzemního ledu, odnášení uvolněných hmot tekoucí vodou a s tím spojeného vzniku příznačných tvarů reliéfu. Naše výzkumy poukazují na velký význam lineární a laterální termoeroze při vývoji pleistocenních údolí a modelaci předpleistocenních údolí v oblasti České vysočiny a Západních Karpat. V práci jsou také podány přímé a nepřímé důkazy existence pleistocenní dlouhodobě zmrzlé půdy na území Československa, jejíž mocnost mohla dosahovat až okolo 100 m a obsah ledu až kolem 60—70 %.

Při vývoji úvalovitých údolí, zastoupených u nás předkvartérními široce rozevřenými údolími, pleistocenními úpady a suchými údolími se silně uplatnily procesy lineární termoeroze. Mnohé úpady a suchá údolí se začala vyvíjet na ledových klínech a v místech většího nahromadění podzemního ledu. Laterální termoeroze se podílela (spolupůsobila) při vývoji asymetrie těchto údolí.

Při vývoji hluboce zařezaných údolí ve tvaru více nebo méně rozevřeného písmene V se v pleistocénu uplatnila zejména mechanická eroze tekoucí vody a také lineární termoeroze. Boční termoeroze měla pro celkový vzhled těchto údolí menší význam.

Pro dnešní tvářnost neckovitých údolí byla rozhodující laterální termoeroze, probíhající zřejmě často za současného termoerozního prohlubování údolních den. Není vyloučeno, že boční termoerozi podporovala i náledí.