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Soft rock pediments in South Moravia, Czech Republic

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Abstract

Soft rock pediments developed in South Moravia in some places as early as the Tertiary, in other places as late as the Pleistocene. Depending on local environmental factors the pediments developed either due to backwearing or downwearing. The most suitable conditions for the evolution of the Pleistocene pediments were during transitional periods between warm and cold climate phases and especially during periglacial conditions between cold and warm periods in the Middle and Late Pleistocene. In agricultural landscapes, the studied relief features continue to develop also at present.

Keywords: South Moravia, pediments, backwearing, downwearing, Pleistocene, Holocene

Introduction

Pleistocene soft rock pediments, often described as cryopediments (Czudek & Demek, 1970, 1976; Balatka et. al., 1974; Balatka & Sládek, 1975; Czudek 1988, 2005, 2008, Vandenberghe & Czudek, 2008) are well developed in the Czech Republic. They are broadly distributed in areas of epicontinental sediments of the Bohemian Cretaceous Basin (northern part of the Bohemian Massif), and marine deposits in the Western Carpathians of South Moravia. Pleistocene pediments in South Moravia have been studied in detail in the Central Moravian Carpathians, in the rolling, low country of the Dyjsko-svratecký úval Graben of the Carpathian Foredeep as well as in the Dolnomoravský úval Graben of the Vienna Basin (Fig. 1). The pediments developed in South Moravia on soft rock complexes are represented by folded or gently dipping marine strata (clay, claystone, marl, marlstone, fine sand and sporadic sandstone) mostly of Early and Middle Miocene age. Soft rock pediments often display gradients of only 0.5 to 2° (at the foot of the backslope mostly 2 to 4°, locally 7°). In South Moravia the width of the Pleistocene pediments attains in some places 1 km, usually not more than several hundreds of metres. The length of the pediment at the foot of the southwestern and western marginal slopes of the Central Moravian Carpathians reaches 15-20 kilomotres. In the Most Basin in northwestern Bohemia east of the town of Žatec e.g. only 0.5-2.0° sloping, well defined, Pleistocene pediments levelled Miocene and Cretaceous sedimentary rocks. They grade into Middle to Late Pleistocene terraces of the Ohře (Eger) River (Balatka & Sládek, 1975). In the Czech Republic Quaternary valley pediments, pediments at the foot of marginal slopes of upland regions, and pediments between Pleistocene river terraces can be found. At some localities, e.g. at the foot of the western marginal slope of the Central Moravian Carpathians east of the town of Židlochovice in the Dyjsko-svratecký úval Graben and in the Dunajovické vrchy Upland northwest of the town of Mikulov near the Czech-Austrian border (Fig. 1), the pediments began to develop as early as the Tertiary. In the massive (hard) rock environment of the Bohemian Massif in Moravia there are erosionial footslope surfaces mostly only up to 20-30 m in width which are assumed to result of parallel slope recession in the Pleistocene. These relief features merge into Tertiary pediments and/or low-angled valley sides. The origin of hundreds of metres wide pediments described by some authors as Pleistocene relief features (e.g. Chábera, 1984) in resistant, pre-Cretaceous rocks in the western part of the Bohemian Massif is hard to accept.

Geomorphological research in South Moravia has been facilitated by numerous boreholes, test pits, excavations and in some places more than 1 km long trenches. The results were

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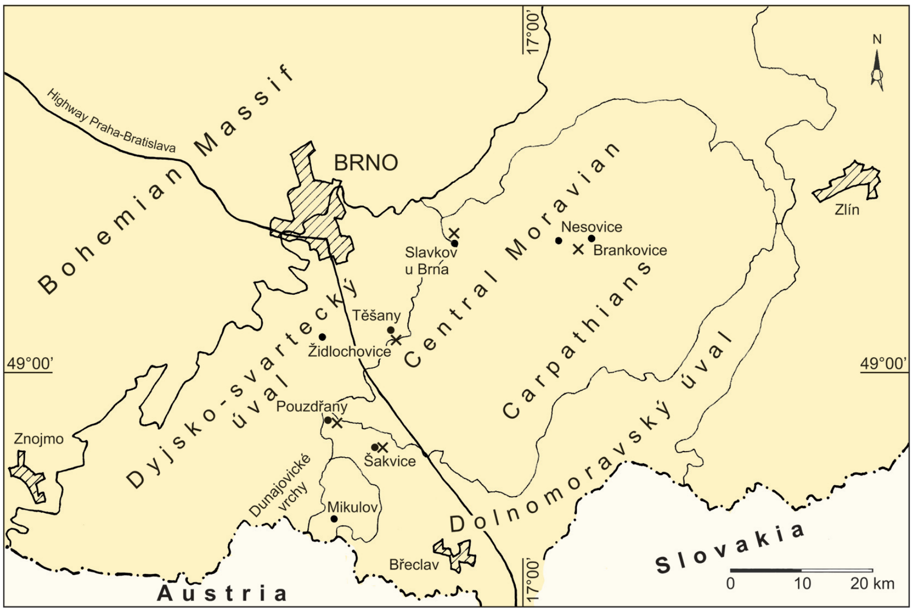

Fig. 1. Localities (X) of the described pediments.

discussed with geomorphologists and geologists including participants of the Meeting of Central-European Geomorphologists held in Vienna in 1994 during an excursion to South Moravia. Soft rock geology in South Moravia provides exceptional opportunities to examine the discussed relief features.

The paper deals with soft rock pediments at five localities – east of the village of Pouzdřany, between Nesovice and Brankovice villages and at the town of Slavkov u Brna (updated results from new geomorpholocical field research) as well as south of the village of Těšany and in the surroundings of the Šakvice village (new results).

Case studies at some localities of soft rock pediments in South Moravia

The Těšany locality

The village of Těšany is situated in the northern part of the Dyjsko-svratecký úval Graben close to the marginal slope of the Central Moravian Carpathians (Fig. 1). The terrain at this locality is underlain by Paleocene-Oligocene folded clay, claystone, fine sand and sporadic sandstone. On the uppermost part of the backslope remnants of more resistant marine gravel with sand (Middle Miocene, Early Badenian) are present (Fig. 2). The backslope (height 50 m, angle up to 8°) consists mostly of equally soft rocks as the footslope surface. This surface (width on the profile Fig. 2 930 m, gradient in the upper part 3-4°, in the lower part 0.5-1.5°) grades slowly into the valley bottom. On the backslope, the Pleistocene waste material is absent, and bedrock occurs below the 0.30 m thick Holocene soil. On the footslope surface only 0.30-0.50 m thick slope deposits can be found. The footslope surface is thus a typical soft rock pediment on folded Paleogene sedimentary rocks. The pediment near Těšany continues to the north-northeast as well as to south-southwest and its total length attains about 20 km. Small, mostly up to 10 m high inselbergs are present on its surface. The main process, which caused the origin of the pediment was the recession of the western marginal slope of the Central Moravian Carpathians. The fact that thopographic differences between the Central Moravian Carpathians and the lower landscape of the Dyjsko-svratecký úval Graben existed as early as the Tertiary (the marginal slope of the Central Moravian Carpathians must have been developing already at that time) together with the large width of the pediment in the surroundings of the village of Těšany (more than 1 km) tend to the opinion that the pediment must have started to develop already in the Tertiary. However, the distinction between the Tertiary and Pleistocene parts of the pediment is unknown. At this locality one can assume Büdel's (1977) concept of the 'traditional development', which has been accepted by many authors, e.g. French & Harry (1992), French (2007) and the author of this paper. The 'traditional development' ('traditionale Weiterbildung') theory was already mentioned earlier in Polish (Jahn, 1956, p. 377) and Russian geomorphological literature (Piotrovskij, 1964, pp. 56, 59).

The locality between Nesovice and Brankovice

At the foot of the southern valley side of the Litava River between the villages of Nesovice and Brankovice in the Central Moravian Carpathians (Fig. 3) a distinct, low-angled surface occurs. This surface extends from 300 m to 470 m in width (from the valley bottom to the backslope) and 2 km in length (along the bottom of the Litava River). Local geology consists of folded clay, claystone, fine-grained sand and sporadic with sandstone (Early Miocene, Egerian) of the Carpathian flysch zone. Shallow Pleistocene, now dry (except during heavy summer rains and snow melt), up to 8 m deep valleys (dells) divide the surface

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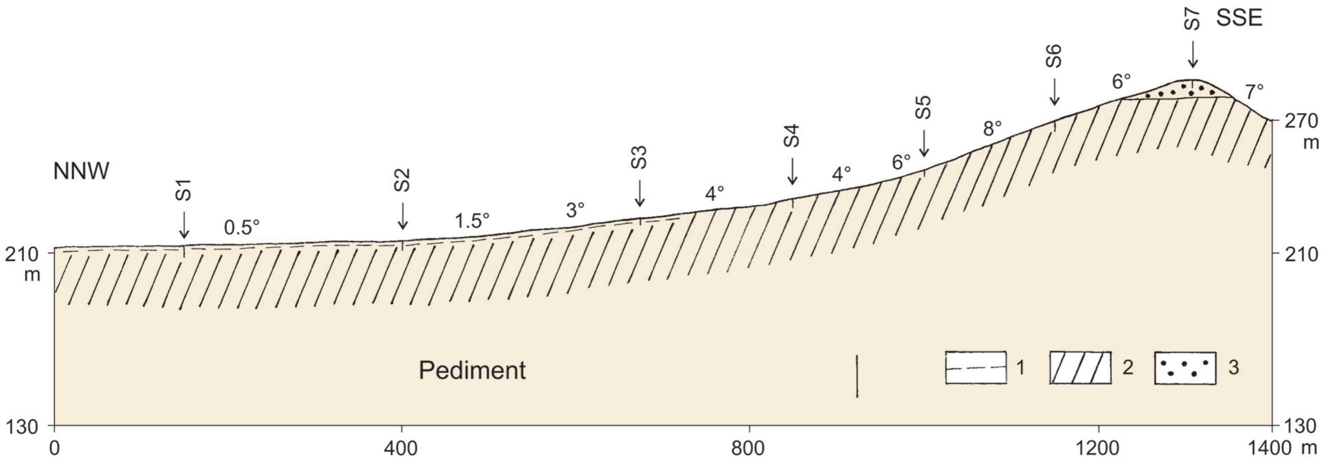

Fig. 2. Plio-Pleistocene pediment south of Těšany, northern part of the Dyjsko-svratecký úval Graben (49°02' N, 16°46' E). 1 – slope deposits (Late Pleistocene - Holocene); 2 – clay, claystone, fine sand and sporadic sandstone (Paleocene - Oligocene); 3 – gravel with sand (Middle Miocene, Early Badenian). S1-S7 test pits.

into five parts. These small valleys originated on the up to 60 m high and 12° angled backslope, which consists of the same soft flysch strata as the footslope surface. The footslope surface grades at angles of 3-5° continuously northwards either to the floodplain or to the low, 2-4 m high Holocene terrace of the Litava River. Only in one case (in the eastern part of the surface) a 8° angled slope exists. Due to a more resistant layer of sandstone, the footslope surface is at this place some 8-10 m higher than the immediate surroundings. The contact between the backslope and the low-angled footslope surface is marked by a distinct break of slope.

Drill holes and test pits indicated that outside the small dry valleys (dells), the Quaternary waste deposits on the surface vary in thickness from 1 m to 1.50 m, but in the scarp foot zone the bedrock is usually closer (0.50-0.80 m) to the ground surface. On the lowermost segment of the surface, in the area of the transition to the low river terrace or to the floodplain, the scree (clay, fine sand, loessial loam) is in some places up to 4 m thick. But on the backslope it does not exceed 0.30-0.50 m. The small thickness of Quaternary mass wasting material, the considerably lower gradient of the footslope surface than the Early Miocene strata, and the presence of a small remnant of the Middle Pleistocene fluvial gravel (25 m above the river bed in a small area and up to 0.9 m thick) in the eastern part of the locality indicate the erosional origin of the low-angled footslope surface, the pediment.

The present-day topographic differences of the bedrock underlying Quaternary sediments indicate that the pediment surface is not the base of a river terrace, but a surface developed due to a few metres downwearing after removal of the terrace

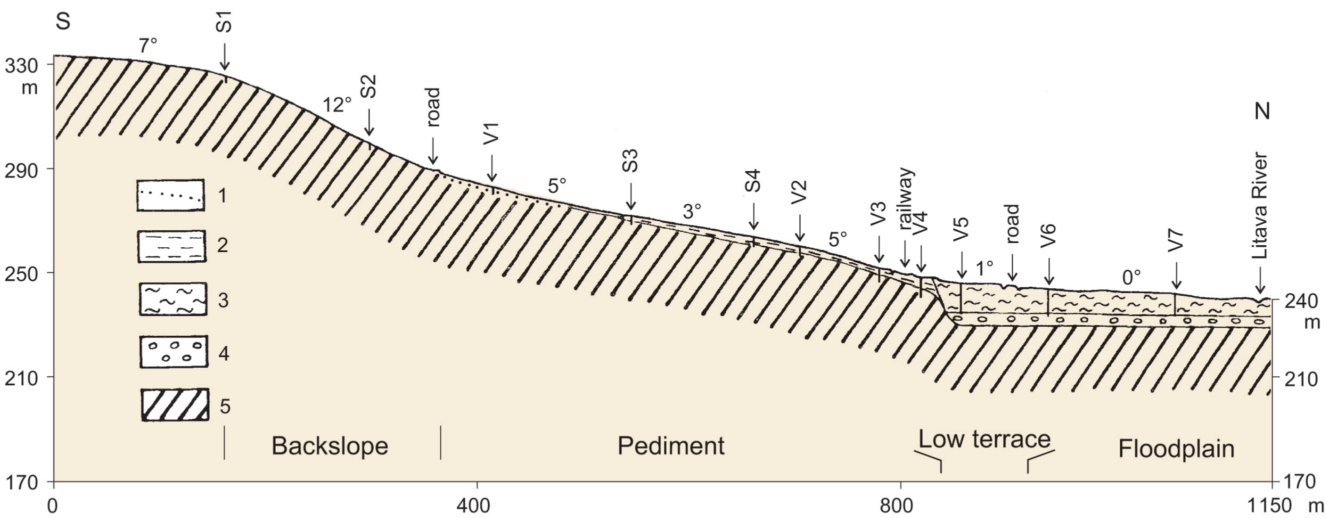

Fig. 3. Pleistocene pediment between Nesovice and Brankovice, northern part of the Central Moravian Carpathians (49°09' N, 17°06' E). 1 – slope deposits (Holocene); 2 – slope deposits (Late Pleistocene - Holocene); 3 – overbank deposits (Holocene fine sand, silt and clay); 4 – gravel and sand of the Litava River floodplain (Late Pleistocene - Holocene); 5 – clay, claystone, fine sand and sporadic sandstone (Early Miocene, Egerian). S1–S4 test pits, V1–V7 boreholes.

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gravel. An indication for such a downwearing of the ground surface can be seen in the coalescence of adjacent dells sides and consequently in the irregular lowering of their interfluves by mass movement processes, particularly gelifluction and sheet wash activity. Thus, the gently sloping pediment in the Litava River valley represents a younger surface than the 25 m high Middle Pleistocene fluvial terrace. On the backslope zone there are no traces of a former river terrace. Based on evidence from borings, test pits and field studies, this part of the pediment developed as the result of recession of the southern side of the Litava River valley. The extent of the parallel retreat is supposed to have been as much as 100 m . For this reason the resulting surface of the pediment at this locality can be considered as a composite pediment. The larger part (width) of the pediment developed during downwearing, a smaller section (near the backslope) resulted of backwearing. However, it can not be excluded that these geomorphic processes operated simultaneously.

The Slavkov u Brna locality

In the Central Moravian Carpathians at the town of Slavkov u Brna (Austerlitz), a distinct low-angled footslope surface, which is sloping southwards to the valley bottom of the Litava River, can be found (Fig. 4). The backslope and the footslope surface at this locality are also underlain by the same soft marine strata (clay, claystone, fine sand and sporadic sandstone) of the Early Miocene (Karpathian) age. The maximum width of the surface attains 1 km, its extent from west to the east 2.5 km. The backslope ranges in height from 40 to 60 m and at angles usually between 10-14°. Besides frequent dry slope dells, traces of many small, mostly Holocene landslides are present on the backslope. Short, up to 250 m wide and 5-15 m deep flat valleys of the 'Hangdellen' type, and the main 30-40 m deep valley along the road Brno - Rousínov dissect the backslope. Quaternary deposits underlying the soil are normally only 0.20-0.40 m thick on the slope.

The footslope surface at the site Slavkov u Brna consists of two parts (Fig. 4). The higher part varies in slope angle from 1° to 7°. The lower part consists of a nearly horizontal to gently sloping (0.5-2.0°) erosion surface. Less than 1° sloping Quaternary soft rock pediments are also known from other countries, e.g. Poland (Rotnicki 1974). The contact between the upper part of the footslope surface and the backslope is mostly well defined (as shown in Fig. 5), while that between the higher and lower parts of the footslope surface is less clear. The topographic differences at the contact between both parts of the footslope surface are up to 4-10 m. On the lower part of the footslope surface the dells are only 2-4 m and up to several hundreds of metres wide. The upper part of the surface gradually grades into the surface of the higher (14 m above the Litava River) Late Pleistocene terrace, the lower part grades into the lower Late Pleistocene terrace (4-6 m above the Litava River). Numerous test pits, drill holes, and about 100 m long trenches indicated that the upper section of the footslope surface is covered by only a 0.40-1.20 m thick veneer of scree derived from the backslope. However, in many places these waste deposits are completely absent and the Holocene soil there is directly on bedrock. A similar situation have been observed on the lower (younger) part of the surface, although at the contact with the lower, Late Pleistocene river terrace the slope deposits (clay, fine sand and loessial loam) reach a thickness of 2 m to 2.30 m. This proves the erosional origin of the footslope surface, i.e. the pediment.

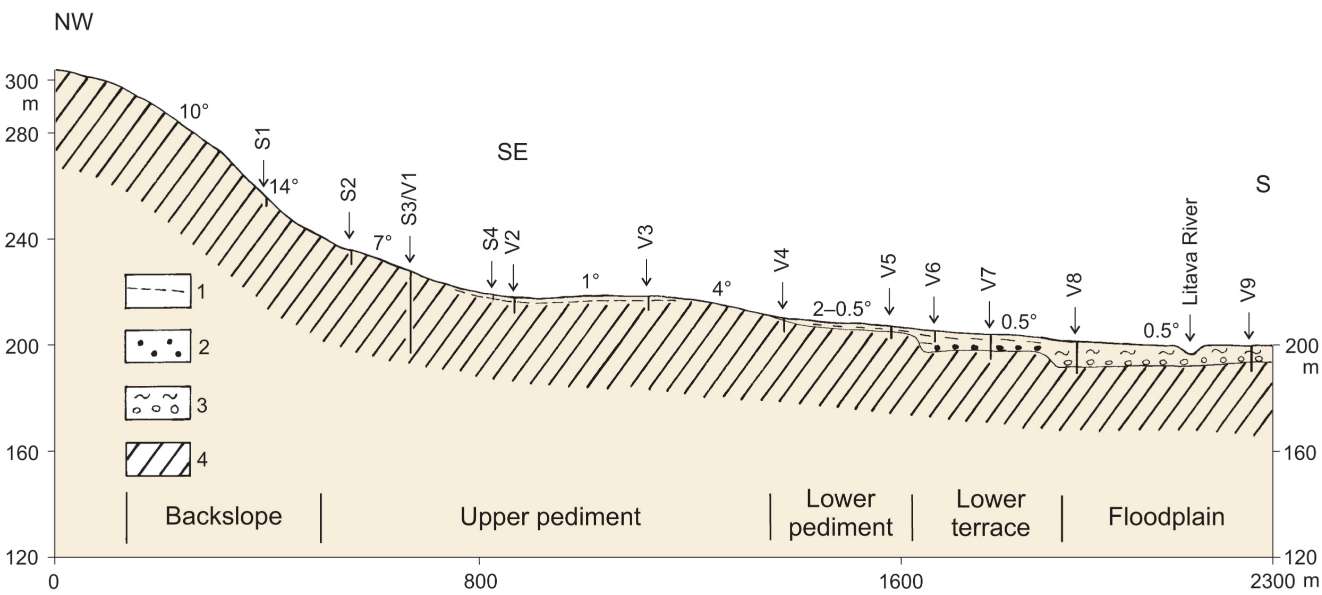

Fig. 4. Pleistocene pediment at Slavkov u Brna (eastern part), northern part of the Central Moravian Carpathians (49° 09' N, 16° 53' E). 1 – slope deposits (Late Pleistocene - Holocene); 2 – gravel of the lower Late Pleistocene fluvial terrace; 3 – floodplain deposits (fine sand, clay and silt) and gravel of the Litava River (Late Pleistocene - Holocene); 4 – clay, claystone, fine sand and sporadic sandstone (Early Miocene, Karpathian). S1–S4 test pits, V1–V9 boreholes.

Fig. 5. Backslope with a sharp knick and upper section of the Pleistocene pediment with an artificial lake at Slavkov u Brna (western part), northern part of the Central Moravian Carpathians.

There is no geologic evidence for tectonic subsidence at the foot of the backslope at the locality of Slavkov u Brna. The occurrence of lateral erosion of the Litava River can also be excluded. This suggests that the footslope surface developed as a pediment. Backslope recession was mainly due to the large number of flat slope valleys (slope dells – 'Hangdellen'). Geomorphic processes acting on the pediment included surface runoff, sheet wash and gelifluction. These processes transported fine-grained material derived from the backslope, and lowered the pediment surface. Available data indicate that the most intensive removal of the material was in the axes of flat valleys (dells) dissecting the backslope and pediment. It can be concluded that while the recession of the backslope led to the origin of the pediment, the present-day shape of this surface must be attributed to the downwearing processes. The origin of the lower section of the pediment appears to be caused by climate episodes with higher humidity. Valleys and dells incised into the pediment and running water due to lateral erosion (planation) lowered the fringe zone of the pediment and thus caused the origin of its lower part. A more precise age of this process can not be specified due to the lack of reliable knowledge of the age of the river terraces. One can only conclude that the footslope surfaces at Slavkov u Brna are pediments developed mainly in cryogenic periods of the Late Pleistocene.

The Pouzdřany locality

The locality 0.5 km east of the village of Pouzdřany in the southwestern part of the Dolnomoravský úval Graben (Fig. 6) together with the surroundings of the Šakvice village represents a typical example of a pediment developed after the origin of the 40 m high Middle Pleistocene river terrace. Similar examples can be found at other localities in the western part of the Czech Republic e.g. in the Bohemian Cretaceous Basin as well as in the Most Basin. At the locality of Pouzdřany Eocene up to Early Miocene (Eggenburgian) folded clay, claystone, fine sand and sandstone occur. The width of the pediment, which developed as a result of parallel backslope recession, reaches 270 m, the gradient is 1-3° and the thickness of the colluvium is up to 1-1.4 m. The transition from the backslope to the pediment is continuous without any marked knickpoint or

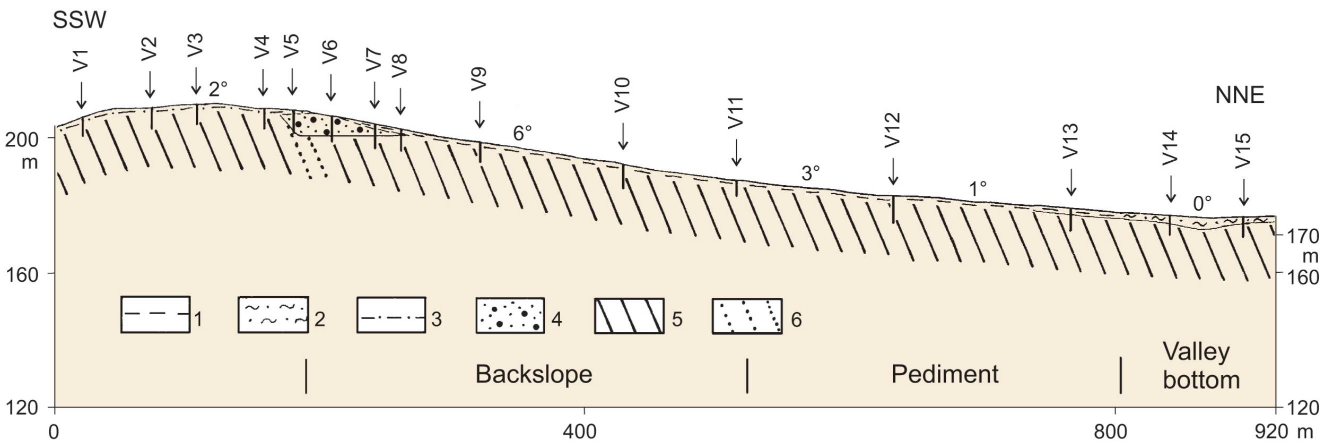

Fig. 6. Pleistocene pediment east of Pouzdřany, southwestern part of the Dolnomoravský úval Graben (48°56' N, 16°39' E). 1 – slope deposits (Late Pleistocene - Holocene); 2 – fluvial deposits (mainly Holocene clay and fine sand); 3 – regolith on the watershed (Late Pleistocene); 4 – fluvial sand and gravel of the Svratka River terrace (Middle Pleistocene); 5 – clay, claystone and fine sand (Eocene - Early Miocene, Eggenburgian); 6 – sandstone (Eocene - Early Miocene, Eggenburgian). V1–V15 boreholes.

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scree. The backslope is 20 m high with an angle of 6°. The described pediment passes into the pediment at the foot of the southwestern marginal slope of the Central Moravian Carpathians which spreads to the southeast at a distance of 15 km.

The Šakvice locality

The village of Šakvice in the southwestern part of the Dolnomoravský úval Graben (Vienna Basin) is situated on the 40 m high terrace of the Dyje (Thaya) River (Fig. 7). The Middle Pleistocene terrace consists of pebbles, usually below 5 cm in diameter. The terrace is surrounded by 10-18 m high and up to 5° inclined slopes passing slowly into typical erosional footslope surfaces with slope angles varying from 0.5-3°. A 0.5-1 m thin veneer of surficial material covers the pediments. Like at the locality of Pouzdřany, the Early Miocene (Eggenburgian) folded marl and marlstone *in situ* occur in some places directly below the 0.3-0.4 m thick Holocene soil. North of the terrace the pediment surface passes without any break of slope into the nearly horizontal pediment at the foot of the southwestern marginal slope of the Central Moravian Carpathians. In the eastern part it passes into the floodplain of the Štinkovka River and in the southern and western part it grades into the lower Late Pleistocene Dyje (Thaya) River terrace (Fig. 8). A similar situation can be observed around the 16 m high inselberg Šibeniční vrch (196.4 m) built of Early Miocene coarse-grained conglomerates (Fig. 8). The pediment developed due to the backwearing after the origin of the 40 m high Middle Pleistocene terrace of the Dyje (Thaya) River.

Development and age of the pediments

In soft sedimentary sequences of South Moravia the discussed pediments originated in a wide time scale from the Late Tertiary to the Holocene. This opinion is based on the fact that the relief features are topographically situated between the Middle Badenian sediments at the highest point of the region (Urban 360.6 m a.s.l) and the Holocene floodplains. Thus, the pediments developed under quite different climate conditions (Garleff et al., 1988, Brunotte & Garleff, 1989). As the pediments grade into the surface of the river terraces and/or to the valley bottom, it is generally accepted that they must have been formed during the same period as the river terraces (e.g. Beck, 1989). However, the knowledge of the geologic contact between the bedrock surface of the pediment and the fluvial relief forms (terraces and/or valley bottoms) is limited. The present data from the Czech Republic indicate the following two possibilities. First, the pediment began to develop earlier than the river terrace; in this case the terrace is cut into the outer part of the existing pediment (Figs. 4, 7). Second, the pediment started to develop after the accumulation of the fluvial terrace (in cases where the pediment exists between Pleistocene river terraces, after the origin of the lower terrace).

The problem in South Moravia is the absence of more precise terraces dating. Loess complexes with fossil soil horizons are missing on the described pediments possibly due to the rapid development of the soft rock pediments. The loess deposits might have been eroded during and/or shortly after their sedimentation. Available data indicate that the terrace at the locality of Pouzdřany can be considered to be of Middle Pleistocene age. The terrace in the eastern part of the locality between Nesovice and Brankovice as well the highest terrace at the locality Šakvice are of Middle Pleistocene whereas both terraces at Slavkov u Brna are of Late Pleistocene age. Very likely, the Pleistocene pediments in South Moravia must have developed as early as the Early Pleistocene. Major features, however, originated in the Middle and Late Pleistocene. The theory of the 'traditional development' by Büdel (1977), discussed also e.g. by French & Harry (1992) and French (2007), has been accepted for the Těšany locality and for the region northwest of the town of Mikulov in the Dunajovické vrchy Upland. The development of the described phenomena as well

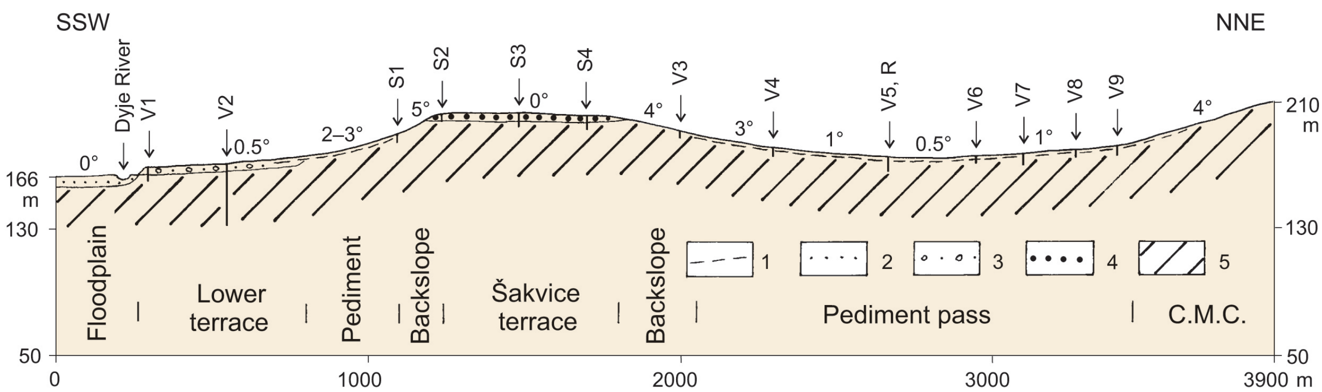

Fig. 7. Pleistocene pediments in the surroundings of Šakvice, southwestern part of the Dolnomoravský úval Graben (48° 54' N, 16° 43' E). 1 – slope deposits (Late Pleistocene - Holocene); 2 – floodplain deposits of the Dyje (Thaya) River (Late Pleistocene - Holocene fine sand and gravel); 3 – gravel and sand of the lower Late Pleistocene terrace of the Dyje (Thaya) River; 4 – gravel and sand of the Šakvice terrace of the Dyje (Thaya) River (Middle Pleistocene); 5 – folded marl and marlstone (Early Miocene, Eggenburgien). S1–S4 excavations, V1–V9 boreholes, R – Brno - Břeclav Railway, C.M.C. – southwestern marginal slope of the Central Moravian Carpathians.

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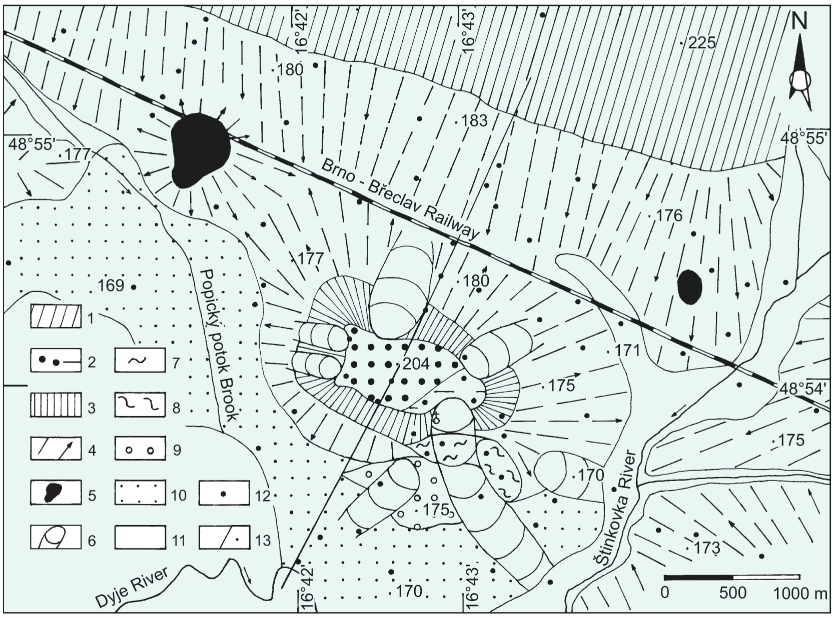

Fig. 8. Pleistocene pediments in the surroundings of Šakvice, southwestern part of the Dolnomorvaský úval Graben. 1 – southwestern marginal slope of the Central Moravian Carparthians; 2 – Middle Pleistocene Šakvice terrace of the Dyje (Thaya) River (in the eastern part fluvial gravel and sand eroded); 3 – backslope of the pediment around the Šakvice terrace; 4 – Pleistocene pediments; 5 – inselbergs (Šibeniční vrch 196.4 m in the W part, and Lebra 183.3 m in the E part of the map); 6 – shallow dry valleys (dells); 7 – surface on aeolian sand; 8 – sand dune; 9 – higher Late Pleistocene terrace of the Dyje (Thaya) River; 10 – lower Late Pleistocene terrace of the Dyje (Thaya) River; 11 – floodplains; 12 – selected boreholes and excavations; 13 – geological profile (see Fig. 7) and elevation points in metres a.s.l. The village of Šakvice occurs in the E part of the Šakvice terrace.

as cryoplanation terraces in the mountains and uplands of the Bohemian Massif and the Carpathians were favoured by the impermeability produced by the presence of permafrost (see e.g. Thorn & Hall, 2002). Pleistocene pediments are considered to have originated mainly at transitional phases between warm and cold periglacial conditions and especially during periods between cold and warm times when snowmelt (Gullentops et al., 1993), permafrost degradation or thawing of seasonally frozen ground together with an incomplete vegetation cover prevailed. The vegetation was of course very important (if not more than the permafrost) in the development of the landscape. Unfortunately more precise data are from the area described absent at present.

Agricultural lands of the Czech Republic experienced an enormous increase of soil erosion in 20th century. A number of boreholes (17) on the bottoms of the dells dissecting the composite pediment at the locality of Nesovice-Brankovice villages indicated the presence of an up to 2.4 m thick accumulation cover of recent soil erosion material. In contrast, on the pediment surface outside the dells, the Holocene soil is mostly about 1 m thick. This is one of the indicators that pediments in agricultural lands of the Central Moravian Carpathians continue to develop also at present. The main periods of such a development are during snow and frozen ground thawing at the end of the winter when the processes resemble Pleistocene periglacial processes with a high degree of seasonality. Development also occurs during heavy rainfall from May to August. During the short, heavy rainfall on 25 May 2010, surface runoff over an area of up to 200-300 m in width even destroyed the wall of the garden of the Slavkov u Brna chateau at a length of 62 m.

Human activity since the Neolithic, but mainly since the middle of the last century caused the removal of large amounts of regolith from the backslope and from the surface of the pediments. Man-made morphological effect of landscape downwearing was controlled mainly by local relief conditions. Many Pleistocene dells are partly or completely covered by colluvium at present. This view is supported also by a large thickness of overbank deposits of the Litava River at the locality of Nesovice - Brankovice that reaches 6-10 m in the 300-500 m wide floodplain. It is suggested that high slopes (backslopes) have retreated, less inclined slopes (pediments) are being lowered at present, and that the present-day land forming processes strongly influenced by man act in the same direction as in the Pleistocene periglacial environment (Czudek & Demek, 1976).

Conclusions

South Moravia, an area of Early to Middle Miocene soft rock territory (clay, claystone, marl, marlstone, fine sand and sporadic sandstone), is a classic area of pediments. These landforms originated as early as in the Tertiary (after the Badenian) and 'traditional development' took place through the Quaternary. However, in many places the pediments are younger than the fluvial terraces and there is no doubt that they started to develop also as late as the Middle and Late Pleistocene.

Pleistocene pediments originated on identical lithology as the result of different geomorphic processes – backwearing or downwearing. These geomorphic processes have been controlled by local environmental conditions. Both modes of the origin of the pediments acted together, but their effect on the relief development was different. The major process which caused the origin of the pediment between Nesovice and Brankovice villages was the downwearing of the river terrace and its underlying flysch strata due to the development of small, shallow, at present dry valleys (dells). At Slavkov u Brna (Austerlitz) the major process of pediment development was the parallel recession of the northern valley side of the Litava River caused mainly by particularly numerous slope dells ('Hangdellen'). The lower (younger) part of the pediment originated as a result of the lowering of the marginal part of the older (higher) pediment mainly by lateral erosion (planation). This process was triggered by a climate change leading to higher humidity. The thin veneer of waste material (the Holocene soil often lies directly on bedrock), the low gradients and a rapid development are typical of the South Moravian pediments. In the Dyjsko-svratecký úval Graben between Židlochovice and Těšany as well as in the south-western part of the Dolnomoravský úval Graben of the Vienna Basin in the surroundings of Šakvice, the coalescence of individual pediments took place. In the surroundings of Šakvice village the pediments are at the foot of the southwestern marginal slope of the Central Moravian Carpathians, around small inselbergs as well as around the isolated remnant of the Middle Pleistocene Šakvice terrace of the Dyje (Thaya) River.

The pediments developed mainly in warmer and wetter climate periods during the Middle and Late Pleistocene. Permafrost was not necessary for their origin in South Moravia as the region is built-up mostly by unpermeable sedimentary rocks. However, deep seasonally frozen ground will favour development. Pediments in agricultural lands are also shaped at present. Finally, it should be noted that they developed from the Tertiary to the Holocene.

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References

Balatka, B., Czudek, T., Demek, J., Ivan, A. & Sládek, J., 1974. Geomorfologické poměry Pavlovských vrchů a jejich okolí (Geomorphology of the Pavlovské vrchy Hills and their surroundings, Czechoslovakia). Sborník Československé společnosti zeměpisné 79: 1-10.

Balatka, B. & Sládek, J., 1975. Geomorfologický vývoj dolního Poohří (Geomorphological development of the lower part of the Ohře River Basin). Rozpravy Československé akademie věd, ř. mat. a přír. věd 85: 1-70.

Beck, N., 1989. Periglacial glacis (pediment) generations at the western margin of the Rhine Hessian Plateau. Catena Suppl. 15: 189-197.

Brunotte, E. & Garleff, K., 1989. Structural landforms and planation surfaces in southern Lower Saxony. Catena Suppl. 15: 151-164.

Büdel, J., 1977. Klima-Geomorphologie. Gebrüder Borntraeger (Berlin-Stuttgart), 304 pp.

Czudek, T., 1988. Kryopedimente – wichtige Reliefformen der rezenten und pleistozänen Permafrostgebiete (Cryopediments – important relief forms in contemporary and Pleistocene permafrost environments). Petermanns Geographische Mitteilungen 132: 161-173.

Czudek, T., 2005. Vývoj reliéfu krajiny České republiky v kvartéru (Quaternary development of landscape relief of the Czech Republik). Moravské zemské muzeum (Brno): 238 pp.

Czudek, T., 2008. Kryopediment v údolí Litavy východně od Bučovic, Středomoravské Karpaty (Cryopediment in the Litava River valley east of Bučovice, Central Moravian Carpathians). Geologické výzkumy na Moravě a ve Slezsku 15: 8-12.

Czudek, T. & Demek, J., 1970. Pleistocene cryopediments in Czecholsovakia. Acta Geographica Lodziensia 24: 101-108.

Czudek, T. & Demek, J., 1976. The slopes of the Central Moravian Carpathians: periglacial or temperate? Studia Geomorphologica Carpatho-Balcanica 10: 3-14.

French, H.M. & Harry, D.G., 1992. Pediments and cold-climate conditions, Barn Mountains, unglaciated Northern Yukon, Canada. Geografiska Annaler 74 A: 154-157.

French, H.M., 2007. The periglacial environment. John Wiley & Sons, Ltd (Chichester), 458 pp.

Garleff, K., Brunotte, E. & Stingl, H., 1988. Fußflächen im zentralen Teil der Hessischen Senke (Piedmont glacis in the central part of the geological structure 'Hessische Senke', Western Germany). Berliner Geographische Abhandlungen 47: 63-76.

Gullentops, F., Janssen, J. & Paulissen, E., 1993. Saalian nivation activity in the Bosbeek valley, NE Belgium. Geologie en Mijnbouw 72: 125-130.

Chábera, S., 1984. Údolní pedimenty na dolním toku Volyňky (Valley pediments in the lower segment of the Volyňka River). Sborník Jihočeského muzea v Českých Budějovicích, přír. vědy 24: 67-71.

Jahn, A., 1956. Wyżyna Lubelska – rzeźba i czwartorzęd (The Lublin Upland – relief and Quaternary). Państwowe Wydawnictwo Naukowe (Warszawa), 453 pp.

Piotrovskij, M.V., 1964. Problemy formirovanija pedimentov (Problems of pediment development). *In:* Gerasimov, I.P., Meshcheryakov, Y.A., Vostryakov, A.V., Gorelov, S.K., Dumitrashko, N.V., Korzhenevsky, A.A., Naumov, A.D. & Timofeyev, D.A. (eds): Problemy poverchnostej vyravnivanija (Problems of palantion surfaces). Izdatelstvo 'Nauka' (Moskva): 50-65.

Rotnicki, K., 1974. Slope development of Riss Glaciation and moraines during the Würm, its morphological and geological consequences. Questiones Geographicae 1: 109-139.

Thorn., C.E. & Hall, K., 2002. Nivation and cryoplanation: the case for scrutiny and integration. Progress in Physical Geography 26: 533-550.

Vandenberghe, J. & Czudek, T., 2008. Pleistocene cryopediments on variable terrain. Permafrost and Periglacial Processes 19: 71-83.