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PLEISTOCENE CRYOPEDIMENTS AND CRYOPEDIPLAINS OF THE MORAVIAN-SILESIAN CARPATHIANS AND THE VIENNA BASIN (CZECH REPUBLIC)

Abstract. The Moravian-Silesian Carpathians are the westernmost member of the Western Carpathians in the south-eastern part of the Czech Republic. The small northern part of the Vienna Basin reaches into the Moravian-Silesian Carpathians from Austria and Slovakia. Extensive low-angled footslope surfaces are reported from many parts of the Moravian-Silesian Carpathians and Vienna Basin. Cryopediments (W a k o 1963) are gently inclined erosion surfaces developed at the foot of valley sides or marginal slopes of highlands and mountains by cryogenic processes in cold climates of the periglacial morphogenetic zone, mostly with the presence of permafrost. Cryopediments are rock-cut transportation surfaces which truncate geologic boundaries. Cryopediments develop due to the activity of a range of cryogenic processes whereby frost action, nivation and other processes extend the cryopediment upslope by a process of cryopediment back-scarp retreat. The geological conditions of the Moravian-Silesian Carpathians and Vienna Basin required the presence of Pleistocene permafrost during the origin and formation of cryopediments.

Key words: cryopediment, cryopediplain, the Moravian-Silesian Carpathians, Czech Republic

INTRODUCTION

Polish scientist professor Jan Dylik was the first who recognized, in 1957, that the bench like landforms in glacial deposits of older glaciations in Poland are analogue of the pediments in warm semiarid conditions. J. D y l i k (1957, p. 48) also correctly recognized similarity of geomorphological processes in semiarid warm areas and in dry periglacial environment. Aridity in both environments influences weathering and slope processes, which results in similar landforms. Pleistocene periglacial pediments are common landforms in the foothills of the Moravian-Silesian Carpathians (B a l a t k a et al. 1976; D e m e k 2013b).

THE MORAVIAN-SILESIAN CARPATHIANS

The Moravian-Silesian Carpathians are the westernmost member of the Western Carpathians in the south-eastern part of the Czech Republic (S t r á n í k et al.

1993 — see Fig. 1). The Moravian-Silesian Carpathians consist of highlands and mountains of the Outer (Flysch) Western Carpathians and the basins of the Carpathian Foredeep. Mountain ridges of the Outer Western Carpathians are composed of resistant massive sandstones, while foothills and depressions developed in soft shales and clays. Mountain ridges are rimmed by extensive Pliocene rock pediments (D e m e k et al. 2009).

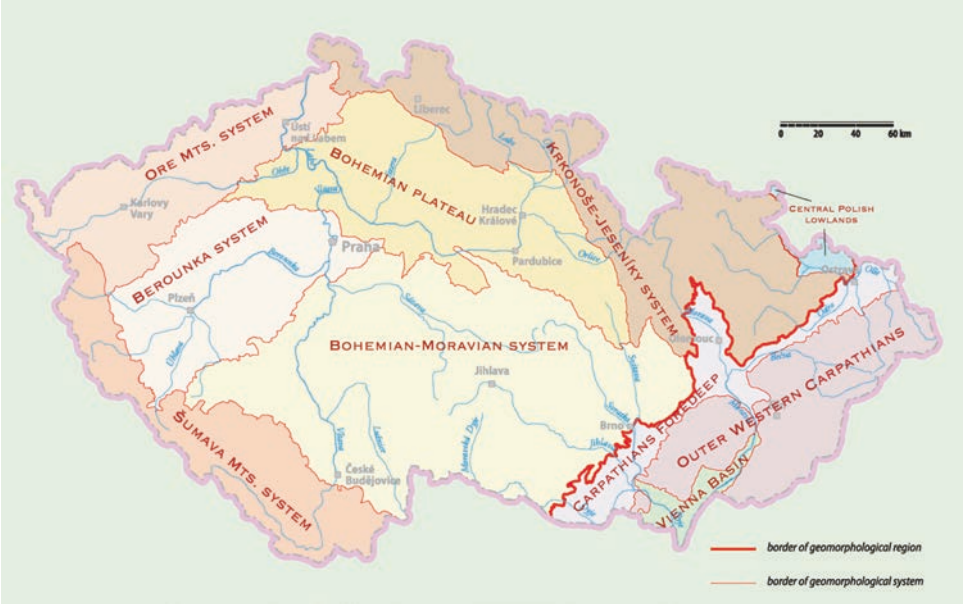

Fig. 1. Geomorphological regions and systems of the Czech Republic. The Moravian-Silesian Carpathians (Carpathian Foredeep and Outer Western Carpathians) and the Vienna Basin occupy the south-eastern part of the Czech Republic

The variability of the Pleistocene climate was manifested by the alternation of cold-climate and warm-climate periods. Especially during the last glacial period the climate in the Moravian-Silesian Carpathians changed repeatedly and rapidly. During the cold phases of the Pleistocene the Moravian-Silesian Carpathians were in the periglacial climatomorphogenetic zone. There is ample evidence of the Pleistocene cold climate and the presence of permafrost in the studied area such as post-cryogenic textures and ice-wedge pseudomorphs; thickness of the permafrost in the Moravian-Silesian Carpathians must have reached at least 220 m during the cold phases of the Pleistocene (R ů ž i č k o v á, Z e m a n 1992).

CRYOPEDIMENTS

The term cryopediments for the periglacial pediments was used for the first time by a Japanese scientist T. W a k o (1963). Cryopediments are very gently

concave erosional bench-like landforms that are usually cut into the base of valley sides or marginal slopes of highlands and mountains (C z u d e k, D e m e k, 1970; D e m e k 1972). Cryopediments developed by cryogenic processes in cold climates of the periglacial climate-morphogenetic zone, mostly with the presence of permafrost. Generally, only one level is recognized, although in some cases two (e.g. C z u d e k 2012) or even three levels developed. The total area of cryopediments and cryopediplains in the Czech Republic is 2071 km^2 (2.63% of the state territory – D e m e k et al. 2011). Cryopediments are common landforms in the Moravian-Silesian Carpathians (C z u d e k, D e m e k 1976). The general extent and spatial distribution of cryopediments and cryopediplains in the Moravian-Silesian Carpathians is shown on the 1 : 500,000 map of *Geomorphological conditions* (D e m e k et al. 2009).

CASE STUDIES

CRYOPEDIMENTS IN MIOCENE SAND – STUDY SITE AT VLASATICE IN THE BASIN OF THE DYJSKO-SVRATECKÝ ÚVAL

The site is situated in the lowland landscape of the basin of the Dyjsko-svratecký úval to the south from the city of Brno (Fig. 2).

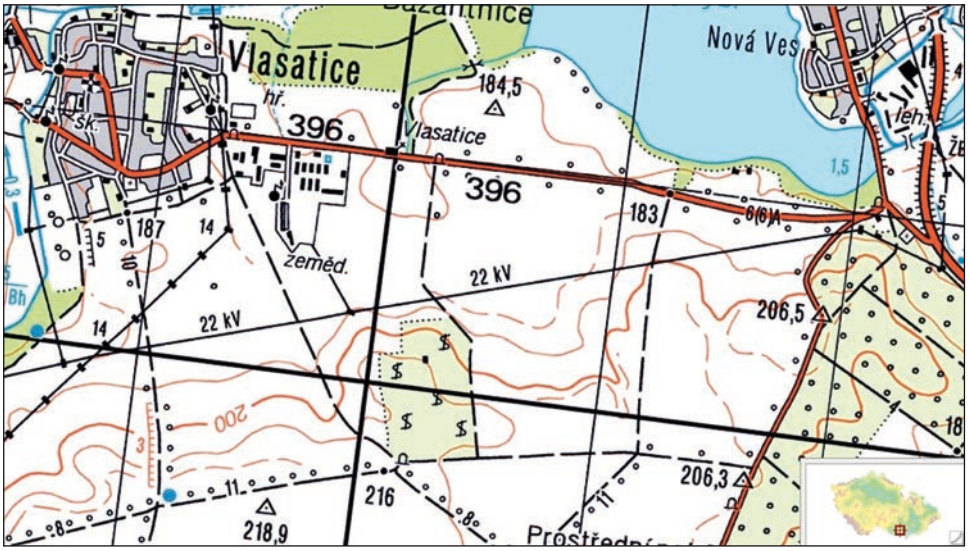

Fig. 2. Location of the cryopediment by the Miroslavka River near the village of Vlasatice. The level of the Lower Pleistocene river terrace (Günz) is 206 m a.s.l. The cryopediment forms a bench in the valley between the village of Vlasatice and the elevation point of 183 m a.s.l. on the road No. 396. Source: Army of the Czech Republic – Cenia Maps

The cryopediment developed in the Miocene (Badenian) sand in the valley of the River Miroslavka (right tributary of the Jihlava River). The cryopediment is situated between the river terrace of the Dyje River (Early Pleistocene — Günz — Havlíček, Stráník 1988) and the terraces of the Miroslavka River (Late Pleistocene — Fig. 3). The length of the cryopediment ranges from 0.4 km to 1 km. The markedly steeper back slope (dip from 9 to 4 degrees) is formed by Miocene sand (Badenian). The cryopediment, dipping from 2 to 1 degree, is separated from the steeper back slope by a relatively rapid change of the slope angle. The gentle surface of the cryopediment is covered by a thin layer of Quaternary slope deposits (borings No. S1 and S2). The presence of permafrost was necessary for the cryopediment to develop because of the porosity and permeability of the Miocene sand.

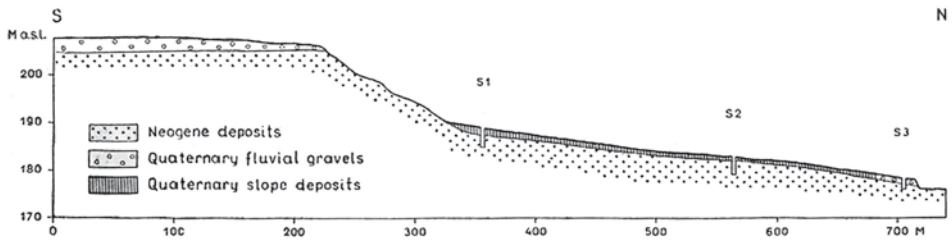

Fig. 3. Cross-section through the cryopediment in the valley of Miroslavka River near the village of Vlasatice (south of the city of Brno)

CRYOPEDIMENTS IN MIOCENE CLAYS — STUDY SITE AT HILLS OF DUNAJOVICKÉ VRCHY

The site is situated in the basin of Dyjsko-svratecký úval, north-west of the town of Mikulov near the state border between the Czech Republic and Austria (Fig. 4). The hills of Dunajovické vrchy represent a low breached dome with a central depression (combe) rimmed by two asymmetric ridges (Fig. 5). The term combe is used to describe central depression carved along the crestline of breached tectonic dome by river action and widened by back-wearing of infacing scarps of asymmetric ridges during the development of Pleistocene cryopediments.

Cryopediments developed in the central depression (combe) and in the Miocene clays of a parallel depression near the village of Dolní Dunajovice (Fig. 4). The length of the cryopediments reaches 2.0 km. The dip of back slopes is 15°; the dip of cryopediments at the foot of back slopes is 4° and 1° in the lower parts.

Cryopediments of Dunajovické vrchy are transportation surfaces developed in bedrock — Miocene clays covered mostly, and solely, by black soil (Demek 2013a). In many places even black soil is missing due to soil erosion accel-

Fig. 4. Location of the hills of Dunajovické vrchy – NW of the town of Mikulov at the state border between the Czech Republic and Austria. Source: Army of the Czech Republic – Cenia Maps

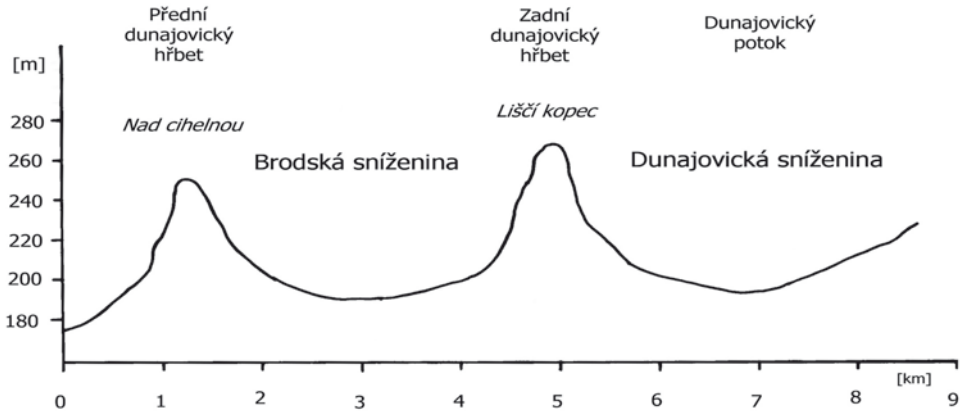

Fig. 5. Cross-section through the hills of Dunajovické vrchy with the central depression (Brodská sníženina) rimmed by two asymmetric ridges (Přední Dunajovický hřbet and Zadní Dunajovický hřbet) and parallel depression of Dunajovická sníženina, with cryopediments at the bottoms of both depressions

erated by human activity and Miocene clays appear directly on the surface. A thin cover of Pleistocene colluvial-aeolian deposits was found in some places in the lower parts of the cryopediments. Cryopediments are bounded on the Late Pleistocene gravel layer of floodplains.

Fig. 6. Cryopediments in the central depression (combe) of Brodská sníženina (Photo J. Demek)

TROUGH OF THE POPICKÁ SNÍŽENINA WITH CRYOPEDIMENTS LEVELLING FLYSCH DEPOSITS OF THE ŽDÁNICE-HUSTOPEČE FORMATION

The longitudinal trough of Popická sníženina in the Vienna Basin is situated to the west of the town of Velké Pavlovice (Fig. 6). The trough developed in psammitic and pellitic deposits of the flysch Ždánice — Hustopeče Formation (Eger — Eggenburgian) of the Ždánice unit of the Outer Group of Carpathian nappes. In the SW part of the trough the cryopediments developed at the foot of two isolated hills — Šakvický kopec (203.8 m a.s.l.) with the village of Šakvice and Přítlucká hora (292.5 m a.s.l.) with the village of Zaječí on the top. Remnant of the fluvial terrace of the Dyje River (Early Pleistocene — Havlíček, Stráník 1993) is preserved on the flat top of Šakvický kopec. The back slope of the cryopediment exhibits the dip of 5°. The break of slope divides the back slope and its surrounding cryopediment.

The dip of the cryopediment at the foot of the back slope is 4°, while at its lower part it decreases to 0.5° at the railway. The length of the pediment is 0.8–1.0 km (Fig. 7). Several kilometers-long excavations for pipelines and other

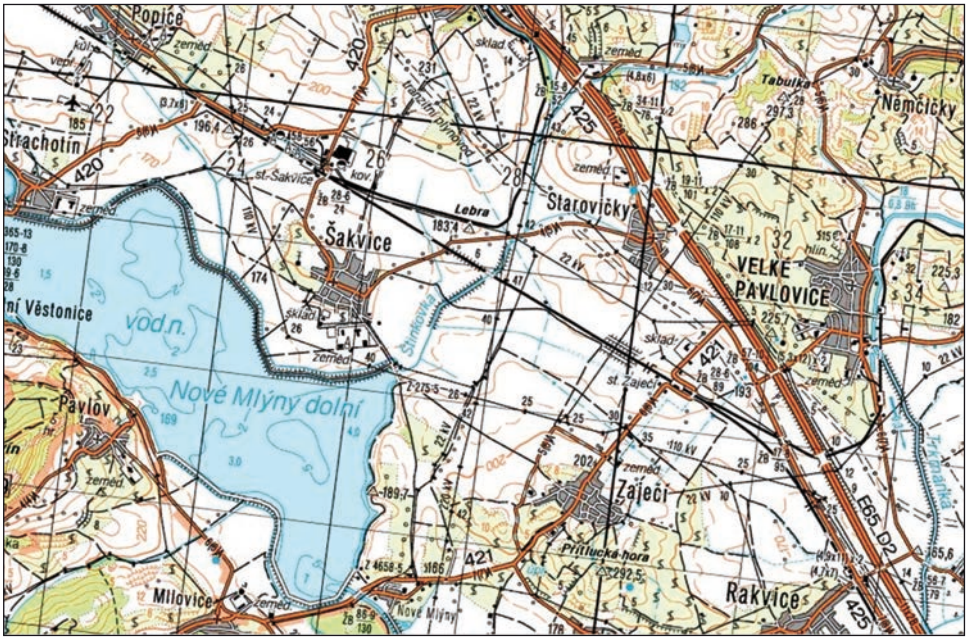

Fig. 6. Location of the trough of Popická sníženina in the Vienna basin to the west of the town of Velké Pavlovice at the foot of the Central Moravian Flysch Carpathians (upper right corner). The lower cryopediments developed by the retreat of border slopes at the bottom of the troughs-around the current railway line (= Lebra 183.4 m a.s.l.). Source: Army of the Czech Republic — Cenia Maps

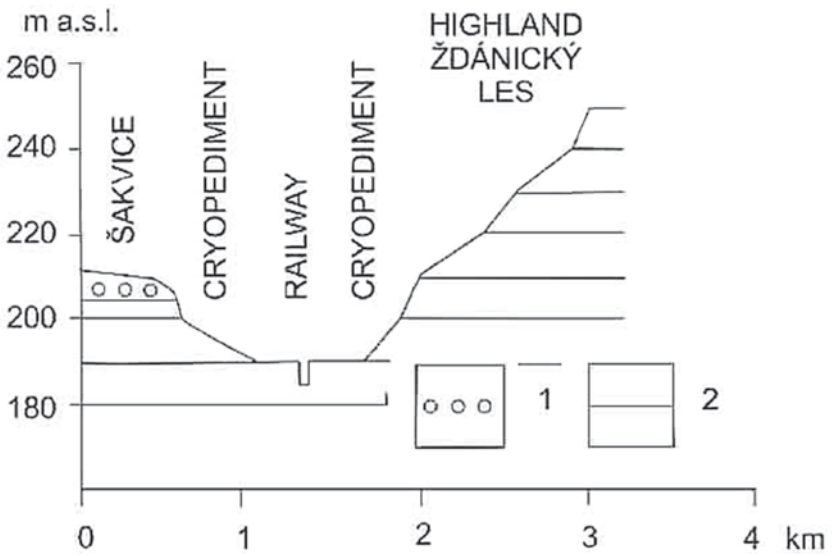

Fig. 7. Cross-section through the Popická sníženina with cryopediments. Explanation: 1. river terrace gravel of the Dyje River (Early Pleistocene), 2. flysch rocks of the Ždánice — Hustopeče Formation (Eger — Eggenburg) of the Outer Group of the Carpathian nappes

exposures have shown that the surface of the pediment is covered only by black soil (Fig. 8). The pediment grades to the gravel of the floodplain of the Štinkovka River. In the NE part of the through of Popická sníženina cryopediments developed at the foot of a marginal slope of the Ždánický les (a highland part of the Central Moravian Flysch Carpathians). Cryopediments at the foot of the Central Moravian Flysch Carpathians in the vicinity of the town of Velké Pavlovice developed in two levels divided by a low scarp due to Quaternary neotectonic movements.

Fig. 8. Exposure on the cryopediment near the village of Šakvice. Thin layer of black soil on the levelled flysch deposits (the Ždánice — Hustopeče Formation of the Ždánice unit of the Outer Group of Carpathian nappes) (Photo J. Demek)

CRYOPEDIPLAIN

Coalescence of several cryopediments produced a cryopediplain. It is a relatively smooth bedrock surface with gently concave profile. The largest cryopediplain in the Moravian-Silesian Carpathians developed by the coalescence of many cryopediments at the foot of the Central-Moravian Flysch Carpathians to the south of the city of Brno (Fig. 9). This cryopediplain is a complex rock- cut surface that truncates Neogene deposits (clays, sands) of the Carpathian Foredeep and also flysch rocks of the Ždánice group of Outer Western Carpathian overthrusts (Fig. 10).

Fig. 9. Cryopediplain around the village of Moutnice south of the city of Brno. Source: Army of the Czech Republic — Cenia Maps

Fig. 10. Very flat surface of the cryopediplain in the vicinity of the village of Moutnice (SE from the city of Brno) (Photo R. Demek)

DISCUSSION

Cryopediments are Quaternary landforms developed in the cold periods of the Pleistocene. Processes responsible for carving cryopediments were frost creep, frost heaving, nivation, congelifluction (solifluction over the permafrost table), rill erosion, piping, dell formation (dells acted as main lines of material removal) and backwearing of the back slope (D e m e k 1980). Cryopediments are younger than the Early or Middle Pleistocene river terraces (as evidenced at the localities of Vlasatice and the trough of Popická sníženina at Šakvice). The presence of water was essential during the formation of cryopediments. Availability of liquid water in the summer period is a very important factor for the formation of cryopediments in generally dry periglacial environment. Therefore important role is played by snow-drifts at break of slopes, that last for the most of the summer (Fig. 11). In the summer period, the thaw water from snow-drifts activates the whole complex of cryogenic processes carving the cryopediment. Melting of the snow-drift during the high summer supplies meltwater necessary for the cryogenic processes on the cryopediment. Sapping of the back-scarp causes its backwearing. Backwearing of valley or marginal slopes is the main process of cryopediment formation. The backwearing of valley slopes and border slopes of troughs was the primary reason for the widening of river valleys and troughs and the formation of benches. Downwearing in the periglacial conditions is difficult due to the position of the permafrost table near the surface.

Fig. 11. Snow-drift and nivation features in the break of slope at the foot of a back-scarp in the contemporary cryosphere of the Southern Siberia that persist in sunny summer. Note the nivation hollow and sapping of the foot of the back-scarp (Photo J. Demek)

H. French (1996) supposes that cryopediments are inherited landforms and cold-climate processes acted on a pre-existing pediment morphology. Pliocene pediments are widely distributed in the Moravian-Silesian Carpathians and in some areas cryopediments actually neighbour on Pliocene pediments (Demek et al. 2009). But most cryopediments of the Moravian-Silesian Carpathians are Middle- up to Late Pleistocene landforms as they occur in lower positions in respect to the highest Pleistocene river terraces and grade to low river terraces or directly to the gravels of valley bottoms. Cryopediments form the lowest level of pediment system of the Moravian-Silesian Carpathians which in some cases is even buried by bajada gravel (Demek et al. 2011). According to author´s experience, permafrost is necessary for the formation of cryopediments. First, permafrost table serves as an impermeable layer for water and, secondly, it supports high activity of cryogenic processes. Cryopediments formed very rapidly during a short period of time in the Middle and Upper Pleistocene. Large amount of material was removed by cryogenic processes over a very short time and in some cases even led to relief inversion. Pleistocene (Würmian) loess cover on cryopediments is limited to isolated patches only (Stráník, Havlíček 1993). Cryopediments predominantly served as transport surfaces. Interestingly, only thin congelifluction and slope deposits were found in the studied area. Congelifluction and sheet-wash must have acted as transport medium on the cryopediments with a dip of only 1°. Also, no features typical for a deep active layer were found on the cryopediments.

T. Czudek (2011) proposed the idea of two different modes of the origin of Pleistocene cryopediments in the Central-Moravian Carpathians – the backwearing and downwearing of flysch slopes. In reality the main process of carving of cryopediments is the backwearing, locally supported by the lateral planation by rivers and dell activity. Also the idea that the cryopediments in the Moravian-Silesian Carpathians were shaped continuously from the Pliocene to the Holocene (Czudek 2011, p. 15) is not correct because of the neotectonic movements (Vyskočil 1984; Musil 1993) and variable climate of the Pleistocene. Cryopediments are usually separated from the Pliocene pediments by erosional scarps. The latest paper of T. Czudek (2012) only repeats earlier statements and brings nothing new, even for discussion.

CONCLUSION

Cryopediments are the lowest and youngest member of the pediment system of the Moravian-Silesian Carpathians. Cryopediments are mostly separated from the Pliocene pediments by erosional scarps due to neotectonic movements and variability of Pleistocene climate. Cryopediments are Quaternary landforms, not Pliocene pediments remodelled by cryogenic processes. Their location, extent and time of development indicate that formation of the cryopediments required

presence of permafrost. The major process that carved cryopediments was the backwearing of back-scarps.

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