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ARTICLES

(ARTYKUŁY)

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RELATION BETWEEN TOPOGRAPHY AND STRUCTURE IN THE MORAVIAN AND SILESIAN PARTS OF THE WESTERN CARPATHIANS

MAIN RELIEF FEATURES OF THE MORAVIAN AND SILESIAN PARTS OF THE WESTERN CARPATHIANS AND ITS RELATION TO THE ADJACENT PART OF THE BOHEMIAN MASSIF

The topography of the Moravian part of the Western Carpathians is in a very close contact with the remarkably older relief of the Bohemian Massif that was consolidated during Variscan orogeny. The extensive planation surface of etchplain type in the eastern marginal part of the Bohemian Massif (Czudek and Demek 1970; Ivan and Kirchner 1995) generally inclined to the east, very contrasts with strong lithological control of forms in the Western Carpathians. The fronts of flysch nappes of the Outer Western Carpathians are situated, in some places, only about 5–8 km (35 km at the most) from foot of the eastern marginal slope of Bohemian Massif (Fig. 1). The fault at the western margin of the Carpathian Foredeep, along which the Bohemian Massif was uplifted, is parallel with the fronts of the flysch nappes (Stráník et al. 1993). The SE marginal slope of the Bohemian Massif was established in southern Moravia in Upper Eocene (Seifert 1992), in central and northern Moravia in Miocene. In the latter area a rotation of the system of Carpatho-Pannonian blocks was probably important factor in process of margin formation.

Actually, the topography of the Bohemian Massif continues to the east under Carpathians, first below the Outer Carpathian Depressions (the Foredeep) and then also beneath the Outer Western Carpathians (flysch nappes). The Bohemian Massif is supposed to extend under the Carpathians, as far as the

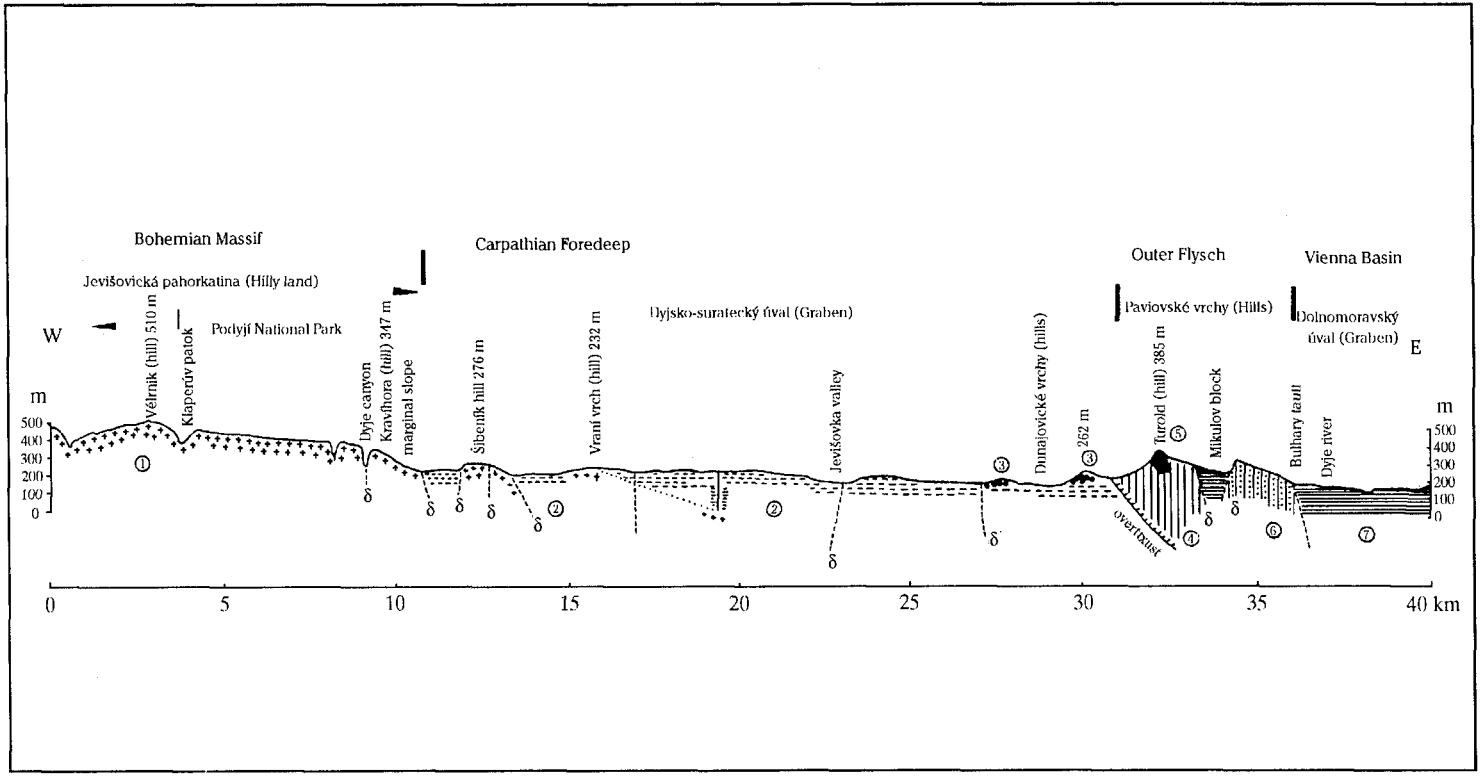

Fig. 1. Profile across southern part of Bohemian Massif and adjacent part of West Carpathians: 1 — biotite granite, 2 — Miocene sediments in Carpathian Foredeep, 3 — Miocene basal conglomerates (Lower Badenian), 4 — Cretaceous — Lower Paleogene flysch, 5 — Jurassic limestone (klippes), 6 — Upper Paleogene flysch, 7 — Miocene sediments in Vienna Basin

Ryc. 1. Przekrój przez południową część Masywu Czeskiego i fragmentu Karpat Zachodnich: 1 — granit biotytowy, 2 — osady mioceńskie Zapadliska Przedkarpackiego, 3 — podstawowe zlepieńce mioceńskie (dolny baden), 4 — flisz kredowo-dolnopaleogeński, 5 — wapienie jurajskie (Pas Skalicowy), 6 — flisz górnopaleogeński, 7 — osady mioceńskie Basenu Wiedeńskiego

Klippen Belt where there was an underthrusting below the system of Carpathian-Pannonian blocks. The Klippen Belt as a surface manifestation of a collision is, at the same time the frontier between very different topographies of the Outer and Inner Western Carpathians. According to Roth (1980) the Outer Western Carpathians are no separate litospheric block but rather an oblong allochthone which is probably rootless.

Investigations of the topography of the Moravian part of the Western Carpathians as a part of the Alpine–Carpathian intercontinental orogen must, for that reason, be concerned not only with their relatively young relief formed by sediments of the accretion wedge and the foredeep, but also with the old, partially pre-collision paleoreliefs of the subsided and buried basement of the former passive continental margin. These paleoreliefs are of importance because of two of their aspects. First, in the prospection for and extraction of raw minerals, above all coal (in the Upper Silesian Basin) and oil and gas (Krejčí et al. 1994). Second, the marginal part of massif "had experienced, since Late Cretaceous, more conspicuous and more differential vertical displacements then other parts of the platform" (Roth 1978, p. 350), and the movements of autonomous basement blocks exerted much influence on the development of forms on flysch and molasse sediments of the Western Carpathians.

The area of the Moravian and Silesian part of the Western Carpathians is 11,112 km^2 and its width between the eastern foothill of Bohemian Massif and the Klippen Belt (already in Slovakia) is about 90 km in southern Moravia and 70–80 km in northeastern Moravia. A special role in the relief of Moravia is the one played by Dolnomoravský úval (Graben) (965 km^2) in the northern salient of the Vienna Basin which constitutes a partial structure of the complicated and vast Pannonian Basin. The Vienna Basin is an important connecting link between the Western Carpathians and the Eastern Alps and its formation has caused the fact that the South Moravian and the Central Moravian Carpathians (including Pavlovské vrchy — Hills) and the Chřiby (Highland) form a more or less isolated zone, in nearly a complete separation from the more compact parts of the Magura flysch adjacent to the Klippen Belt.

PRE- AND SYNCOLLISION RELIEFS OF THE BOHEMIAN MASSIF UNDER THE OUTER CARPATHIAN DEEPRESSIONS AND OF THE OUTER WESTERN CARPATHIANS

The importance of the paleorelief as a very complicating factor in subsurface mining of black coal has been known in the Upper Silesian Basin for a long time already, while it is a relative nevelty in the prospecting for oil and gas deposits (Bezvodová and Zeman 1983). The investigations have shown that some parts of the paleoreliefs are also buried remnants of planation surfaces, probably of etchplain type, with many remnants of deep weathering

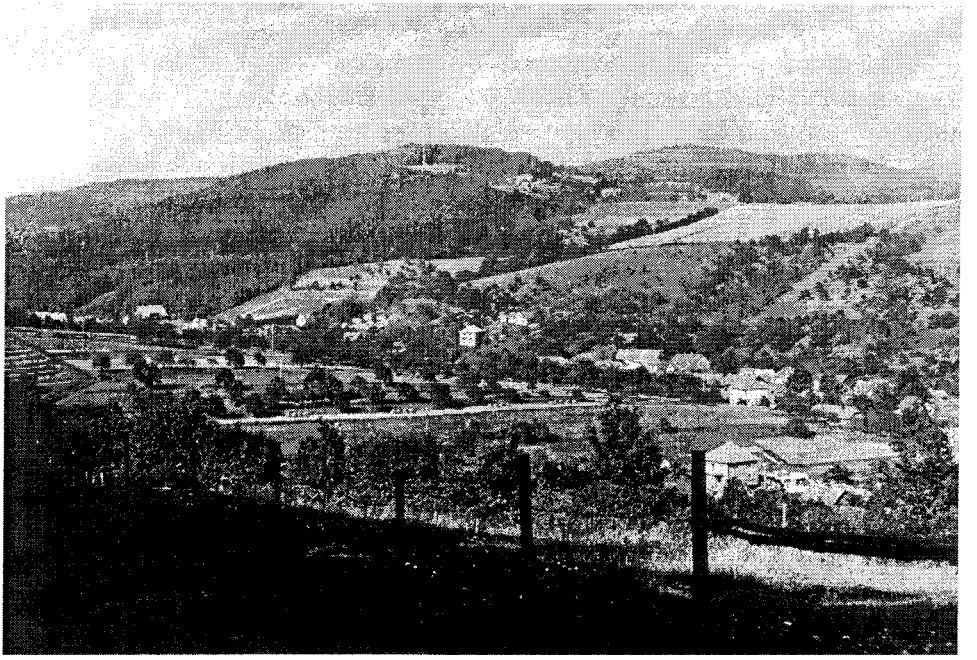

Photo 1. Soutwestern part of the narrow anticlinal ridge Komonec (about 600–700 m) in the Vizovická vrchovina (Highland), northeast of the Luhačovice spa, in the partial Rača nappe in the Magura flysch. The ridge formed consists of resistant Luhačovice sanstone (Eocene) the topography with prevailing gentle slopes developed on less resistant claystones of Zlín Formation of the Rača nappe. Photo M. Hrádek

Fot. 1. Południowo-zachodnia część wąskiego antyklinalnego grzbietu Komonec (około 600–700 m) na Wyżynie Wizowickiej, położonego na północny wschód od uzdrowiska Luhačovice. Część nasunięcia Rača w obrębie fliszu magurskiego. Grzbiet zbudowany z odpornych eoceńskich piaskowców luhaczowickich. Łagodne zbocza są założone na małoodpornych mułowcach formacji Zlin nasunięcia Rača Fot. M. Hrádek

profiles. In the Upper Silesian Basin the formation of these probably Mesozoic weathering products, described as red beds, of as much as 230 m of thickness (Dopita et al. 1997), has brought about the disappearance of coal seams. To the contrary, in central Moravia there are exploitable oil deposits in deep weathering products of crystalline rocks overlapped by Neogene sediments and by flysch nappes (e.g. Krejčí 1988). Another phenomenon, frequent but most controversial, which has been paid much attention to, are the paleovalleys of up to 1,000–500 m of depth filled with sediments of different age. They are not recognizable in the present topography of the Western Carpathians beeing hidden by sediments of the Carpathian Foredeep and flysch nappes. In the Upper Silesia Basin the sedimentary filling is mostly of Miocene age (Ottnangian, Badenian) but in southern Moravia of Paleogene age (Jiříček 1993). Some

Photo 2. Pulčínské skály (733 m) in southwestern part of the Javorníky Mts, Rača nape, Magura flysch. Margin of rock city with many tors, boulders, fissure caves and microforms (honeycombs) in the resistant middle to coarse-grained sandstone of the Eocene age. Photo K. Kirchner

Fot. 2. Pulčínské skály (733 m) w południowo-zachodniej części Jaworników, nasunięcie Raczy, flisz magurski. Obrzeże miasta skalnego z formami skałkowymi, blokowiskami, jaskiniami szczelinowymi i mikroformami typu „plastra miodu" w obrębie odpornych średnio- i gruboziarnistych piaskowców eoceńskich. Fot. K. Kirchner

authors prefer even the Cretaceous age of the sediment. In the presently uncovered part of the Bohemian Massif only Miocene (Badenian) sediments can be found in some river valleys. But the close relation between present valley pattern in marginal part of the Bohemian Massif and some buried valleys below Western Carpathians is quite apparent.

Interpretations of the buried forms are being widely discussed and they differ from one another by the stress on subaerial, subaquatic (submarine canyons — Pícha et al. 1978) or tectonic processes (grabens or tectonically predisposed valleys), but also on the importance that is being attached to the way of formation of the flexure bend of the eastern margin of the Bohemian Massif. It is probable that in various parts of the flexure and in different periods the role played by the individual factors was different, the variance including dominant normal block faulting (e.g. in the Moravská brána — Gate) as well as erosion exemplified by the buried dendritic valley pattern and above all, by valley cutting of the thick platform cover of Jurassic sediments in the Nesvačilka Graben (Jiříček 1993).

OUTER CARPATHIAN DEPRESSIONS

The Outer Carpathian Depressions generally form a belt of low topogarphy of SW–NE direction, made by three relatively wide shallow flat bottomed depressions with broad floodplains, river terraces and important hydrographic knots (the Dyjsko-Svratecký úval (Graben), Hornomoravský úval (Graben) and Ostravská pánev (Basin); separated by two narrow depressions (Vyškovská brána — Gate) and Moravská brána (Gate), very important for traffic and transport, drained longitudinally and situated on transversal elevation axes (NW–SE). The narrowest part of gates are crossed by important watersheds, in the Moravská brána (Gate) by the Main European Watershed between Danube and Oder Rivers. The most pronounced Moravská brána (Gate) has been interpreted as typical graben (Czudek and Dvořák 1989). Along southeastern margin of the Bohemian Massif there are elevations of basement rocks mounting on the flat bottom of the Outer Carpathian Depression and forming conspicuous hills (some are typical granite inselbers) or small horsts (Ivan and Kirchner 1995). In the eastern parts of Outer Carpathian Depressions there are also isolated hills or low ridges but formed by Miocene Litothamnion limestone or by Badenian gravels. In the Dyjsko-Svratecký úval (Graben) they are surrounded by extensive cryopediments.

Beyond the general SW–NE orientation of the zone of the Outer Carpathian Depressions there is the Hornomoravský úval (Graben) of NW–SE direction penetrating far into the Bohemian Massif filled with Miocene and Pliocene sediments (Růžička 1973, 1989). Structure and composition of sediments together with Quaternary river terraces suggest very young tectonic movements as well as possible former connection with Vienna Basin. The thickness of Pliocene sediments is as much as 230 m. Their lower part is formed by reworked products of deep chemical weathering coming from the Bohemian Massif (Růžička 1989). In terms of morphotectonics the Hornomoravský úval (Graben) constitutes a double graben with axial horst formed in part by crystalline rocks. The margins of the grabens display also the N–S to NNW–SSE direction suggesting the more complicated structure. In the north the graben is closed by the Bušín cross fault indicating a connection with Králická brázda (Furrow), constituting the southern end of the Klodzko Basin (in Poland).

OUTER WESTERN CARPATHIANS

The Outer Western Carpathians are characterized by transversal segmentation as consequence of NW–SE faults that continue there from the Bohemian Massif and by differentation of topography and of geological structure dimininishing towards SE to the interior of the orogene (Ivan 1987). This can be observed

in its most complicated form at the western marginal part of the Carpathians, e.g. in the Pavlovské vrchy (Hills) and in the Podbeskydská pahorkatina (Hill land). The lithology of the region is extremely variable with many resistant remnants of the Jurassic limestone (klippes) or paleovolcanites (teschenite) forming distinct topographic elevations. The western margin of the Podbeskydská pahorkatina (Hilly land) facing the Moravská brána (Gate) is formed by horst of Malenik (479 m) that is a geomorphological part of the Outer Western Carpathians although made of folded Upper Paleozoic sediments of the basement of the Bohemian Massif. In the Litenčická pahorkatina (Hilly land), east of the Vyškovská brána (Gate) have been drawn into the neotectonic uplift of the Central Moravian Carpathians the Ottnangian sediments (Miocene) of Carpathian Foredeep. To the contrary, the eastern part the Outer Western Carpathians adjoing to the Klippen Belt is formed in its complete length by considerably lithololologically homogenous flysch of partial units of Magura nappe, with the corresponding rather uniform topography.

The most striking manifestations of the transversal segmentation and of the basement — caused influence are the quer depressions of Jablunkovská brázda (Furrow) and Fryštácká brázda (Furrow). Both of them are "blindly" ended in the SE in area where on an important fault (the sub-Beskydy step) the buried basement surface of the Bohemian Massif is sunken suddenly, by about 2 km, and where the flysch nappe thickness increases correspondingly. The sub-Beskydy step, however, does not make itself in the present surface topography. The Fryštácká brázda (Furrow) constitutes a direct continuation of the Hornomoravský úval (Graben). On its bottom can be found remnants of the lower niveau of planation surface, not dated more in detail so far. The development of the nappe struture of the Outer Western Carpathians is a clear polarization, by progressive thrusting of flysch nappes over foreland and by a longitudinal shift of orogenic phases along line of thrusting from west to east (Jiříček 1979). The flysch nappes were undergoing an intensive synorogenic denudation as early as during their folding and thrusting. This is evidenced by basal Eggenburgian clastics (Lower Miocene) that are unconformably deposited on erosionally planned structures of the older Magura flysch (under the thick Neogene sediments filling the Vienna Basin) and by Badenian sediments (Middle Miocene) on the planned folded structures of the younger Ždánice nappe that has been thrusted over Karpatian sediments (in Pavlovské vrchy — Hills) and Ždánický les (Highland). According to Roth (1975), the Magura nappe there is an erosional nappe. The subaerial topography developed in altitude 300–400 m is analogical Augensteinlandschaft of to Lower Miocene age occuring in the Eastern Alps (Tollmann 1968). The more detailed research of the problem is necessary.

In the southern and central Moravian part of the Western Carpathians there exist great differences between topography on less resistant and not typical (molasse-like) flysch of the Outer Flysch Belt (Ždánice and Pouzdřany nappes)

adjoing to the Foredeep and that on the generally more resistant and typical rocks of the Inner Flysch Belt (Magura and Foremagura nappes) adjoing to Klippen Belt. Along front of Magura nappe in the Chřiby (Highland) the difference is attenuated by strike-slip fault. The vast Magura nappe consist of several partial units, the innermost of them, the Bílé Karpaty unit is at present considered as individual nappe (Potfaj 1993). The Bílé Karpaty nappe is situated direct over collision zone and consist of free blocks (Roth 1980). The block of nonfolded flysch with subhorizontal structural surface within the nappe structure can be probably explained by this location. In the Bílé Karpaty Mts and Hlucká pahorkatina (Hilly land) where the large scale relief inversion has been developed, there are also small neovolcanic forms representing the sills, dykes and also a cedar-tree laccolith in surroudings of the town Uherský Brod. The intrusion probably connects with the Nezdenice fault (NW–SE) crossing the Magura nappe. The hills formed by basalt and trachyandesite rocks probably of Badenian to Sarmatian age (Přichystal 1993) are mostly strongly destroyed by mining activity.

In northern Moravia and in Silesia both Silesian and Subsilesian nappes belong to Outer Flysch Belt and the width of the Magura nappe is reduced here. The differences between topography of the Outer and Inner Flysch Belts are less distinct there. Owing to denudation of the part of higher Silesian nappe interesting tectonic windows and half windows developed in rocks of the lower Subsilesian nappe.

In the highest flysch mountains, Moravskoslezské Beskydy and Javorníky, the existence of summit planation surface (Sarmatian ?) continues to be put in question (Menčík et al. 1984), which is even more supported by what is known about importance of the Quaternary gravitational processes (spreading) of massive sandstone ridges, in a situation where the condition of preservation of planation surfaces should have been the most favourable theoretically. For instance in the Javorníky Mts the summits surfaces are flat anticlines interpenetrated by a system of axial faults. The complete massif is loosened there by the deep creeping with sizeable rock slides and fissure caves. The gravitational disintegration is also indicated by the vast subterranean cavities found in the summit parts of ranges of the Moravskoslezské Beskydy Mts (the mountains of Kněhyně (1,257 m), Lukšinec (899 m) and Radhošť (1,129 m), of the Hostýnské vrchy Mts (Křížový vrch (Hill, 670 m), of the Vizovická vrchovina (Highland) (Kopce 699 m) and the Javornky Mts (Hradisko 773 m).

Unlike that, there are many new pieces of knowledge on cryopediment-typed piedmont planation surfaces (Czudek 1997). They are the most spread in the Outer Carpathian Depresions, less in flysch hilly lands. The vast cryopediments are likely to have originated from the continued slope retreat and from the lowering of pre-Quaternary pediments. In the southern part of the Hlucká pahorkatina (Hilly land) made of low resistant flysch of the Bílé Karpaty unit tiny cryopediment basins were formed on anticlinal structures while the internal topographic elevations have been started on synclinal structures (relief inversion).

DOLNOMORAVSKY ÚVAL (GRABEN)

The relief of the Dolnomoravský úval (Graben) was formed on Neogene sediments of the Vienna Basin, i.e. of structure that has been superposed on the folded and overthrusted Magura nappe. The depression was started in Badenian in connection with a left-lateral strike slip as a pull-apart basin limited by steep normal faults (Roth 1980; Burchfiel and Royden 1982). The sedimentary filling is more than 5,000 m thick. During later stages of the overthrusting the structure was carried on the top of nappe as a piggy-back basin (Krejčí et al. 1994). In the youngest partial grabens of Hradišťský příkop and Kútský príkop situated along longitudinal axis of the basin, it was followed in the Upper Pleistocene (Mindel, Riss), by a stage of fluvio-lacustrine sedimentation (Baňacký 1993; Havlíček 1977). These grabens have been separated from each other by eastern part of a ring structure to the north of the town Hodonín (Ivan et al. 1994) that was in the uppermost Pleistocene partially buried by eolian sands as much as 35 m of thickness.

SLOPE PROCESSES

Gravitational slope processes and their manifestations are generally represented above all in the Outer Western Carpathians. As early as in sixties their extent and their impact upon economic activities have led to the formation of a central register that has subsequently supplemented by research performed for the purpose of file-keeping and of detailed geological and geomorphological mapping. Within the limits of the former Czechoslovakia a brief survey of the problems in question is presented in paper by Hrádek et al. (1995).

In 1997, in connection with the very intensive summer rainfall, many old landslides became activated and vast new ones were started, moreover in conjuction with massive flooding. In many places the slope masses still continue sliding. At various locations the slide movements of slopes and the floods acquired the character of local disaster and caused sizeable economic losses as well as ecological damage of the order of thousands of millions crowns. In consequence of this event there were about 450 significant landslides monitored in the Moravian part of the Carpathian flysch so far, which number is likely to increase. Investigations of the consequences of these processes still go on.

At present, the largest activated landslide area in the Moravian part of the Western Carpathians there is in the Vsetinské vrchy Mts in the valley of the Byštřička river. The different types of slope deformations affecting both deluvial deposits and bedrock (Beloveža Formation of the Rača unit in the Magura Flysch of the Middle Eocene–Paleocene age) are occuring in area of 4 km × 1.2 km. In the village Růžd'ka in the eastern part of the Vsetínské

vrchy Mts, also in the Beloveža Formation, the huge landslide (800 m in lenght and 200 m wide) has destroyed many buildings and roads. In the deep-seated deformation about 20 m thick sandstone block displaces the underlying claystones. The thickness of the material in the accumulation area is about 30 m.

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STRESZCZENIE

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ZWIĄZKI POMIĘDZY RZEŹBĄ I STRUKTURĄ MORAWSKIEJ I ŚLĄSKIEJ CZĘŚCI KARPAT ZACHODNICH

Rzeźba Karpat Zachodnich na terenie Moraw pozostaje w ścisłej relacji do znacznie starszego Masywu Czeskiego, uformowanego podczas orogenezy waryscyjskiej. Karpaty Zachodnie na terenie Republiki Czeskiej zajmują powierzchnię 11 112 km^2. W pracy omówiono ogólne związki rzeźby ze strukturą geologiczną Masywu Czeskiego i Karpat Zewnętrznych łącznie ze strefą obniżeń tektonicznych. Zwrócono również uwagę na rolę głównych procesów geomorfologicznych, zwłaszcza ruchów masowych we współczesnej ewolucji rzeźby.