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## RELIEF OF THE SOUTH-EAST MORAVIA AND PROBLEMS OF GEOMORPHOLOGICAL CORRELATION OF THE WESTERN CARPATHIANS AND THE EASTERN ALPS

The significance of Moravia for correlation of continental and Alpine glaciations in Central Europe has been known for a long time and it seems to be suitable to extend the idea to the pre-Quaternary relief forms too. Particularly suitable for this purpose is the relief surrounding the Vienna Basin. This depression penetrates with its northern part into the Carpathians and with the south-west one into the Alps. Projects and constructions of geomorphological maps as the International Geomorphological Map of Europe, Geomorphological Map of the Carpathian and Balkan Regions (M. Pécsi 1977) and Map of Planation Surfaces of Carpathian and Balkan Regions (Resolution... 1975) demonstrate that this problem is not a matter for itself. The importance of correlation increases when the compared areas were dealt with according to different theoretical conceptions, and consequently, with different results. During the construction of geomorphological maps arises for example a danger of hardly reasonable time gaps on the contacts of geomorphological regions.

Looking at previous and present conceptions of denudation chronology of the Western Carpathians and the Eastern Alps, we can see considerable differences. The conception of three planation surfaces developed from the Upper Miocene till the Upper Pliocene is commonly accepted for the Western Carpathians (M. Klimaszewski 1965, E. Mazúr 1965). At present prevail tendencies to put the planation surfaces into still younger periods (E. Mazúr, J. Činčura 1975, L. Starkei 1975). For the Eastern Alps, on the contrary, the conception of many denudation levels is still valid. After the period influenced by the ideas of A. Winkler-Hermaden, who considered the relief of the area as very young, new investigations shift the age of summit parts of the relief to earlier periods. Generally is believed that in mountain areas, the development of present relief forms began after the Pyreneic phase (Eocene) by accumulation of a gravel cover built of allochthonous rocks of the Central Alps. This hypothetical relief termed the „Augensteinlandschaft“ dated from the Oligocene till the Ottnangian was the initial form of a more complex dissected relief, the „Raxlandschaft“, developed from the Oligocene to the Badenian. Preservation of surfaces from the period before thrusting of the youngest nappes can be explained partly by the slowness of movements, partly by the flatness of the overthrust plane (A. Tollmann 1968, H. Riedl 1977).

For the explanation of relations between the relief of the Western Carpathians and the Eastern Alps we can take into account in Moravia the correlative sediments building the youngest nappes, the deposits of the Carpathian Foredeep

and the Vienna Basin and the remnants of planation surfaces in the Pavlovské vrchy (Hills), Vizovická vrchovina (Highland) and in the Bílé Karpaty (Mts.).

The flysch nappes of the South-East Moravia were thrust in the Pyreneic, Savian and Styrian folding phases. The Vizovická vrchovina (Highland) and the Bílé Karpaty (Mts.) are parts of the older Magura nappe, the Pavlovské vrchy (Hills) of the younger Ždánice nappe. The nappes were formed as relief thrusts i. e. they were shifted over the subaerial erosional relief (Z. Roth 1975).

The development of the relief in the early-orogenic (pre-neotectonic) stage can be divided into two phases. In the first phase from the Eocene to the Lower Miocene after the thrusting of the Magura nappe the region, according to Z. Roth (1975), was uplifted to the altitude of 200–400 m. The local denudation relief was, according to the mentioned author, with great probability, in direct connection with the East-Alpine „Augensteinlandschaft“. In our opinion there is a certain difference, as the possibility of transport of the material from the Central Carpathians across the area of the Magura nappe has not yet been proved. The correlative sediments of this phase are the Ždánice-Hustopeče beds of Oligocene to Lower Miocene age. They are now regarded as molasse rather than as previously supposed flysch type sedimentation. Also the idea has been expressed that their sedimentary basin was rather a foredeep than a geosynclinal trough. The thickness of sediments ((2 500–3 000 m) suggests the greatest denudation of the nappe just in this phase.

In the second tectonically and paleogeographically complicated phase from the Lower Miocene to the Badenian the Ždánice nappe was formed and the Magura nappe was completed by thrusting over it. The structure, especially in the area of the present Vienna Basin suffered repeating movements accompanied by marine transgressions and regressions (see V. Špička 1966, 1972) and by the formation of synorogenic planation surfaces. This is demonstrated by the erosion surface (unconformity) on the bottom of the basin cutting both the Magura flysch and Ždánice flysch. The surface is fossilized by Lower Miocene deposits. Although buried, it is the oldest form in this part of the Western Carpathians. The Lower Miocene basal clastics, few hundred metres in thickness indicate the transport from the near rugged relief.

Significant paleogeographical changes in the course of this phase took place also in the Karpatian and the Badenian (Old Styrian phase). Owing to repeated uplifts, a part of the basin filling was denuded and the development of planation surfaces reached over the flysch. The deposits of Karpatian were particularly reduced and the significant Intra-Miocene surface later dislocated by fault tectonics was developed. This development is exemplified also in the present relief of the Pavlovské vrchy (Hills). After the thrusting of the Ždánice nappe over the Karpatian sediments of the Carpathian Foredeep, the denudation and development of planation surface which was, at least, in the last phase shaped by marine abrasion (A. Ivan 1973) took place. The planation surface was buried under Badenian sediments, later dislocated along the cross faults and lastly resurrected in Upper Miocene or the Lower Pliocene. The correlative sediments of this planation surface are mainly basal clastics of the Lanzendorf series of the Badenian. It may be that the sporadic dark dolomites, according to I. Krystek and J. Tejkal (1968) of unknown provenience correspond to the black dolomites that are the key rocks of the „Augensteinlandschaft“.

The limestone klippe of the Pavlovské vrchy (Hills) provide a significant point for the correlation with the Alpine region too. The continuation of the hills

in Austria are the Leiser Berge, where H. Riedl (1960, 1977) found two planation surfaces on the limestone. The higher one (500 m) is a subaerial surface, formed in the Lower Miocene and it may be correlated to a certain extent, with the „Raxlandschaft“. The lower level (450 m) is the Badenian abrasion surface already mentioned. In the Pavlovské vrchy (Hills) due to analogous structural and paleogeographical conditions the Lower Miocene surface could develop, but its remnants have not been preserved. This results from the sandwiching of the Lower Miocene deposits between slices of the Jurassic limestone (Z. Stráník 1963) and from the great inclination of the thrust plane of the Ždánice nappe (Z. Stráník, E. Benešová, F. Pícha 1968, profile p. 98). The movements on the post-Badenian cross faults are also important. They throw doubt upon all conclusions inferred from the analysis of height of the surfaces. The basic changes in paleogeography and geomorphological development occurred in the Badenian during the young Styrian phase which initiated the late-orogenic (neotectonic) stage. The Vienna Basin has assumed its present ground plan (except the Hradiště Graben), bordered by distinct radial faults. The forming orographical units, the Pavlovské vrchy (Hills), Vizovická vrchovina (Highland) and the Bílé Karpaty (Mts.) have appeared, in comparison with it, as horsts. Generally however the anticlinal type of movements has prevailed.

The remnants of the Lower Miocene, the Badenian and the Pannonian deposits on cut folded structures suggest that the amount of denudation of the flysch was not great in the neotectonic stage. Most probably, due to repeated transgressions the denudation took place mainly in the Neogene sediments. The geomorphological reconstruction therefore should consider also the repeated burying and exhumation of the older relief. Particularly at the basin margins there are some resurrected surfaces on the narrow fault blocks in altitude close to younger planations.

Problematic is also the interpretation of correlative sediments in the Vienna Basin. Except the material from neighbourhood, sediments from the Bohemian Massif, great parts of the Alps and their northern forefield were brought here. Important is also fact that on the planation surfaces, owing to intensive modellation in Quaternary we do not find fossile weathering products and paleosoils. Nevertheless, especially the many-coloured layers in the Vienna Basin constitute the possibility how to precise the geomorphological development.

The planation surfaces of the investigated area are well preserved in the Pavlovské vrchy (Hills) and the lower southern part of the Vizovická vrchovina (Highland). Striking is especially the regional planation surface of 350 m, situated 160–190 m above the flood plains of the main water courses. In the Pavlovské vrchy (Hills) the surface cuts the faults disturbing the Badenian sediments. In the Vizovická vrchovina (Highland) deposits of the Pannonian age are preserved on it. H. Riedl (1960) in Leiser Berge ranged this surface into Upper Pliocene. According to H. Nowak (1969), in the Austrian part of the Carpathian Foredeep the surface has developed from the Pannonian till the Upper Pliocene. This conclusion is valid for our territory too, but here it is a complicated polygenetic surface in which also the pre-Pliocene exhumed elements could participate. This relief form is the most important from the viewpoint of the correlation of planation surfaces.

The remnants of surface of 270 m, which have already certain relations to the valley pattern, can be found in places under the level of 350 m. Somewhere they have the features of pediments. The position closely above the highest river

terraces suggests Upper Pliocene age. The smaller extent is due to extensive development of Pleistocene cryopediments. They form mostly the bottom of basins connected with short water gaps or pediment passes. In places the destruction of the older relief was so intensive, that we may speak about cryoplain accompanied by residual hills quite analogic with inselbergs. The development of cryopediments was expressively controlled by lithology. They can be found mostly on weak Neogene deposits or moderately consolidated flysch claystones. This dependence somewhere resulted in relief inversion of the same type as that developed in the Bílé Karpaty (Mts.) in the Tertiary.

Substantially more complicated problems are met with in highland and mountainous relief. The state of their research in our country was described by J. Demek et al (1965), T. Czudek, J. Demek and O. Stehlik (1965) and J. Demek (1976). As a rule it is difficult to determine even the number of planations. Dating, when it is proposed, rests mostly on analogy with other regions. Except the idea of Miocene abrasion, all previous conceptions have their starting point — regardless whether they come to the conclusion of single dislocated planation surface (J. Krejčí 1944) or of number of levels — exclusively in tectonic causes. For example A. Winkler-Hermaden (1957), on the basis that in the Vienna Basin the compressional tectonics is separated from the tensional one, adds to every folding phase two planation surfaces. But the basic presumption was modified by new research (V. Špička 1966). In earlier works uniform lowering of all surfaces is also tacitly anticipated. Climatic aspects of planation surfaces were not considered at all.

It is necessary to say that only little interest is devoted to the higher flysch relief at present. From the Wienerwald where the geological structure is similar to mountain areas of the flysch Carpathians in Moravia, A. Winkler-Hermaden in his comprehensive book only briefly quotes G. Götzinger, who distinguished three more distinct levels in 520 m, 560—570 m and 600—620 m and less striking planations in 760—780 m and in 800 m. The highest surface is according to A. Winkler-Hermaden of the Lower Pannonien age.

The above mentioned difficulties can be demonstrated on the Bílé Karpaty (Mts.). The structure of the Neogene deposits at the southwest termination indicates a brachyanticlinal closure, from which the height of mountains increases successively towards NE. In the south-west part of the mountains, east of the city Strážnice, we can find two planation surfaces in the axial part which are difficult to distinguish. The lower one is accompanied by fault steps at the outer edge. On the contrary, in the highest parts, e. g. in the surrounding of the Velká Javořina (970 m), at least 5 levels (820—880 m, 650 m, 500—550 m, 450 m and 380—420 m) may be determined on the morphographical basis.

However, the genetic and chronologic considerations are complicated at least by three factors: 1) cross faults of NW-SE direction, reflecting movements of the deep platform basement; on the faults topographical steps are developed in some places, 2) according to P. Grecula — Z. Roth (1978) a Tertiary subduction zone passes under the Bílé Karpaty (Mts.); that might be in connection with the manifestations of young longitudinal tectonics found by J. Moschelesová (1923); 3) at present it is not possible to relate definitely any planation surface of the Bílé Karpaty (Mts.) with the surface of 350 m in the Vizovická vrchovina (Highland), which forms a part of their western forefield.

This article could not discuss all the problems, e. g. the influence of folding phase migration etc. Nevertheless our analysis shows that the forms analogic with

the „Augensteinlandschaft“ and „Raxlandschaft“ have not been preserved in the present relief in Moravia. However, it is possible to find them in the sedimentary record of the Neogene basins. For the correlation of the relief of the Western Carpathians and the Eastern Alps only the lowest present time planation surfaces time may be considered. The research of the highland and mountain relief has not advanced sufficiently till now.

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## S o u h r n

### RELIÉF JIHOVÝCHODNÍ MORAVY Z HLEDISKA GEOMORFOLOGICKÉ KORELACE ZÁPADNÍCH KARPAT A VÝCHODNÍCH ALP

Současné denudační chronologie Západních Karpat a Východních Alp jsou velmi rozdílné. Pro jejich korelaci, potřebnou z hlediska tvorby přehledných geomorfologických map a z toho, že se u nás začínají objevovat termíny alpské geomorfologie (Z. Roth 1975), má význam hlavně reliéf po obvodu Vídeňské pánve. Dnešní reliéf flyšových Karpat jv. Moravy je svým založením sice starý, pro korelaci lze však uvažovat jen mladší, dobře zachované povrchy pahorkatin a některých vrchovin. V členitých vrchovinách a zejména hornatinách nedospěl výzkum ještě dostatečně daleko. Prvky analogické s tzv. „Augensteinlandschaft“ a „Raxlandschaft“ lze u nás hledat hlavně v diskordancích a korelátních sedimentech neogenních pánví.