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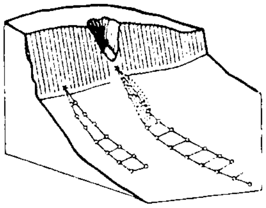
# EXCURSION GUIDE-BOOK

INTERNATIONAL SYMPOSIUM

# TIME, FREQUENCY AND DATING IN GEOMORPHOLOGY

CZECHO-SLOVAKIA
TATRANSKÁ LOMNICA - STARÁ LESNÁ
June 16-21, 1992

Bratislava 1992



International Geographical Union
Commission on Measurement
Theory and Application
in Geomorphology

Czecho-Slovak Committee
for the International
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Institute of Geography
of the Slovak Academy
of Sciences

# EXCURSION GUIDE-BOOK

Editors: Miloš Stankoviansky, Ján Lacika

## INTERNATIONAL SYMPOSIUM
## TIME, FREQUENCY AND DATING IN GEOMORPHOLOGY
## (STIFDIG)

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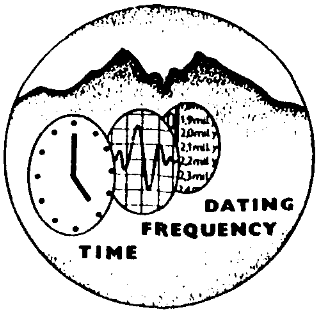

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Bratislava, 1992

## International Symposium on Time, Frequency and Dating in Geomorphology, Tatranská Lomnica - Stará Lesná, June 16-21, 1992

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# CONTENTS

**1st excursion day - Friday, June 19**

**I. Dating of glacial and glacifluvial landform and deposits in the Tatra Mts and their foreland** (Localities: 1,2)

**II. Landforms built of travertine, their dating and dynamics** (Localities: 3,4)

**III. Influence of neotectonics on development of river network changes in the Low Tatra Mts and the Popradská Kotlina Basin** (Locality: 5)

**2nd excursion day - Saturday, June 20**

**IV. Dating of glacifluvial landforms and deposits in the foreland of the Tatra Mts** (Localities: 6a, 6)

**V. Morphogenesis of amphitheatre-like deformation on the southern slope of the Low Tatra Mts** (Locality: 7)

Locality No.7: The Čertovica Saddle (The Low Tatra Mts)

**VI. Planation surfaces and eluvia in the Slovenské Rudohorie Mts** (Locality: 8)

**VII. Neovolcanic rocks and landforms and their dating** (Localities: 9, 10, 11)

**3rd excursion day - Sunday, June 21**

Locality No.11: Nová Baňa - Brehy. The youngest volcano in Czecho-Slovakia

**Appendix: Explanations to *enclosed maps:***

## Preface

Stankoviansky, M.

Aim of this excursion guide is to inform the participants of the International Symposium "Time, Frequency and Dating in Geomorphology" about the typical features of the relief of Slovakia with special regard to the themes expressed by the title of the Symposium.

The first, general part, presents a brief summary of morphostructural conditions of Slovakia with emphasis on the West Carpathians. Enclosed are the map of geomorphic units of Slovakia and the map of typological division of the relief of Slovakia, both on the scale of 1 : 500 000 and both forming part of symposium materials. Inclusion of this chapter was motivated by the effort to facilitate you the incorporation of the regional information touching the individual localities, within the overall context of geomorphic situation of the whole Slovakia.

Second part, that represents the core of the guide, contains detailed characteristics of geomorphic situation of the localities along excursion routes and their background. Excursion routes and concrete localities were chosen in a way that presents to the participants as many important morphostructures as possible on one side and on the other side also the results of the solutions of geomorphic and geological problems related to the question of dating. All eleven localities that you are going to visit during the two and a half day excursion are situated within the territory of the Inner West Carpathians that is geomorphicly the most interesting and esthetically most attractive region of Slovakia.

The excursion routes are as follows (Fig.1):

1st day - Friday, June 19:
The Tatra Mts - The Popradská Kotlina Basin - The Levočské Vrchy Mts - The Hornádska Kotlina Basin - The Kozie Chrbty Mts

2nd day - Saturday, June 20:
The Liptovská Kotlina Basin - The Low Tatra Mts - The Horehronske Podolie Furrow - The Slovenské Rudohorie Mts - The Poľana Mts

3rd day - Sunday, June 21:
The Zvolenská Kotlina Basin - The Kremnické vrchy Mts - The Žiarska Kotlina Basin - The Štiavnické Vrchy Mts - The Danube Lowland

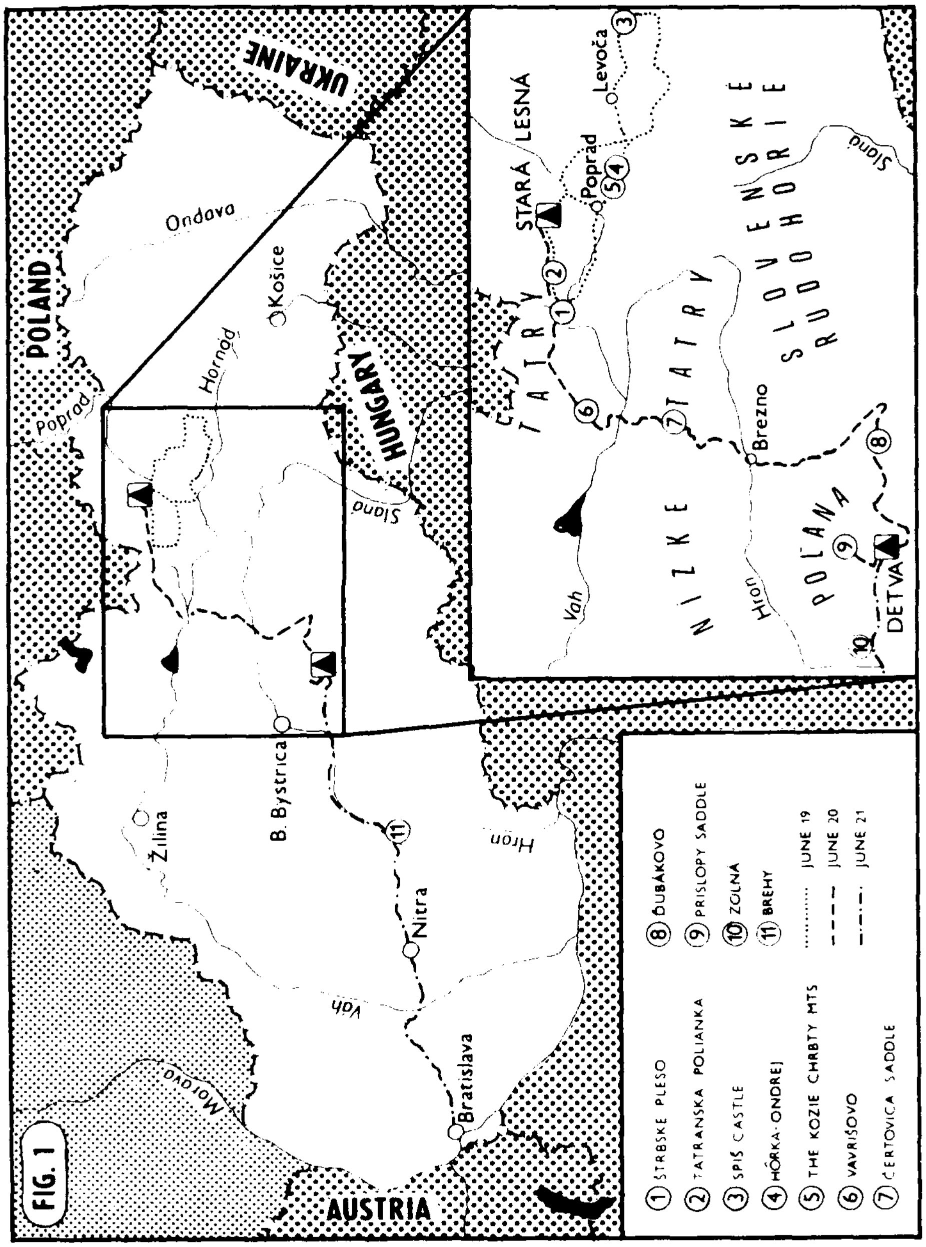


Fig. 1: Excursion routes

# Major geomorphic features of Slovakia with special regard to morphostructural conditions of the West Carpathians

Stankoviansky, M., Ondrášik, R.

The West Carpathians, within the Carpathian mountain arc, represent a special geomorphic province, even may be said a morphostructural megaform, of relatively self-contained position. The morphostructural individualization od the West Carpathians manifests itself in the form of an extensive, but relatively flat upwarp of an elliptic layout (Fig. 2). The ellipsis of the West Carpathians has a longer axis stretching in the direction WSW-ENE, above 400 km long, and a shorter one above 250 km long. Although the West Carpathian morphostructural ellipsis is considerably differentiated interiorly, as demonstrated later, outwardly, in contrast with the neighbouring morphostructural units, it differs very strikingly both morphologically, tectonicly, and by lithostructure. On the inner side, it is delimited very strikingly facing the Intra-Carpathian basins, namely the Great and the Little Danube Basins, and the Vienna Basin. In the outer side, the ellipsis of the West Carpathians is confined clearly facing the Hercynian epiplatforms of the Bohemian Massif and those of the South-Polish block by a continuous belt of depressions of the Carpathian Foredeep. Solely, in the NE the boundary of the West Carpathian upwarp is less sharp. It manifests itself morphologically and tectonicly, but not lithologically. The matter is the stretch between the Sandomierz Basin and the northernmost spur of the Great Danube Basin, in which the Flysch Belt connects the West Carpathians with the East Carpathians. Nevertheless, also here, however, a striking transversal depression is situated across the Flysch Belt in the area of the Nizke Beskydy Mts and is of a hillyland to bergland nature, with altitudes above sea-level about 500-600 m. The axis of this transversal depression includes an acute angle with the axes of the nappe-fold structure and is undoubtedly tectonic and younger than themselves.

From the viewpoint of detailed layout character of the West Carpathian morphostructure it is necessary to state that its course is about in 3/4 of the circumference relatively continuous, little zigzag, consequently literally close to an ellipsis. This phenomenon occurs along all the NW, N, E and SE circumference. Solely in the SW, in front of the Vienna Basin and the Little Danube Lowland the elliptic shape is impaired and the morphostructure of the West Carpathians runs out digitally by partial morphostructures to sub-Carpathian depressions, the ellipsis opens here. It cannot be out of question that this phenomenon connects with total movement tendency of the West Carpathian morphostructure.

A characteristic mark of **the West Carpathian Upwarp** is its extreme interior morphostructural differentation by a mosaic of two contrasted formations, namely positive and negative morphostructures ( mountain ranges - basins ). This interior

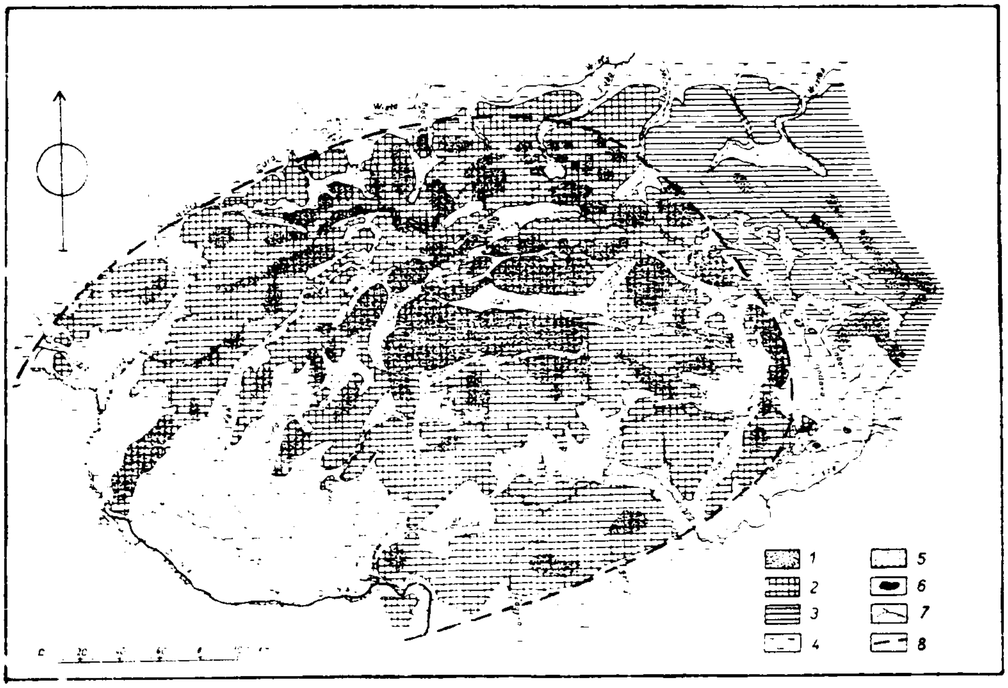


Fig. 2: Schematic map of the West Carpathian articulated upwarp (Mazúr 1965)
1-massive heigh macroforms, respectively massive top parts of individual rangers, 2-other middle mountainous relief of the West Carpathians, 3-middle mountainous relief of the East Carpathians. 4-Subcarpathian depressions, 5-intermontane basins and furrows, 6-stagnant water, 7-rivers, 8-rough border of the West Carpathian upwarp

morphostructural dissection of the West Carpathians is, however, subordinated to a unifying unit of higher order, i.e. to the West Carpathian Upwarp. This subordination manifests itself by the rise of altitute above sea-level of both contrasted morphostructural elements (mountain ranges and basins) from the fringes of the upwarp towards maximum inside the West Carpathians. Of course, the rise of the altitude of basins above see level is slower and ranges roughly from 150-200 m to 800-1000 m a.s.l., in positive morphostructures the altitude above sea-level increases from some hundreds of metres in the circumferential parts of upwarp up to over 2500 m in the core of upwarp - in the Tatry Mts. The discordant increase of altitude above see level of there contrasted morphostructures manifests itself in the core of upwarp by relative height differences of 1000-1500 m. Thus, it is the core of the West Carpathian Upwarp that is dissected most intensively.

Another mark of the dissected upwarp of the West Carpathians is its asymmetry, namely both in vertical and horizontal sense. The marks of asymmetry in vertical sense are closely connected with the layout and intensity of occurence of positive and negative structural wholes. The Inner Carpathians are substantially more intensively dissected than the Outer

Carpathians.

The most characteristic mark of asymmetry of the West Carpathian Upwarp is an extremely eccentric position of the summit of upwarp - the Tatry Mts in northeastern part of the West Carpathians. The Tatra maximum of upwarp is situated only about 90 km from the fringe of the West Carpathians. This asymmetric position of the summit of upwarp reflects also upon the pattern and layout of river system. The major rivers as the Váh, Nitra, Hron, Hornád, and Ipel̆ belong to the drainage basin of the Black Sea, and only the Dunajec and Poprad Rivers are directed to the Baltic Sea.

The West Carpathian dissected upwarp is divided into two morphostructural units of lower order, namely the block of **the Inner Carpathians** and the arc of **the Outer Carpathians** (Fig. 3). A very striking morphological boundary between these two morphostructures is an almost continuous belt of depressions bound to the course of the Klippen Belt. This manifests itself also as a striking boundary of subsurface structures - the so called Peri-Pieninian Lineament. It stretches along the northern circumference of the Malé Karpaty Mts, through the Považské Podolie Furrow, along northern circumference of the Fatra and Tatra Mts, where it is somewhat less conspicuous, and then it repeatedly deepens in the northeast between the Pieniny Mts and the Košická Kotlina Basin as the Spišsko-Šarišské Medzihorie Mts. In the east, it continues, then, as a striking depression in the Beskydské Predhorie Foreland separating already within the area of the East Carpathian structure the Vihorlat-Gutin structural unit from the Outer Flysch Belt. It is to be mentioned, it is true, that in this area, it is crossed by a striking subsurface disturbance delimiting the West Carpathians from the Pannonian Basin along the eastern side of the Slánske Vrchy Mts, event. the transversal disturbance of the Nízke Beskydy Mts, between the East Slovakian Lowland and the Sandomierz Basin. The morphostructural dualism is, in this way, another striking feature of the West Carpathians.

Characteristic for the Inner Carpathian block is a classical development of contrasted block to fold-block structures irregularly mosaically arranged. The spatial arrangement of these basic macro- and mesostructural elements of the Inner Carpathians has no marks of zonality, it cannot be derived, within the present-day morphostructural pattern, as a formation of fold, event. nappe-fold processes of the Mesozoic or Paleogene Era, but it is a formation of Neoid movements with prevalence of vertical movement. The differentiated neotectonic movement has formed here literally mosaic of positive and negative morphostructural forms, whether the matter be the older Paleozoic elements or folded and shifted Mesozoic formations, eventually volcanites. Axes of these Neoid blocks differ to various measure from the axes of pre-Neoid fold movements.

**The Inner West Carpathians** are divided, further, into five morphostructures of a lower order. They are as follows:

1. semimassiv structure of the Slovenské Rudohorie Mts,
2. Fatra-Tatra fold-block structure,
3. volcanic block structure of the Slovenské Stredohorie

Mts,
4. block structure of the Lučenec-Košice Depression,
5. block structure of the Slaná-Matra arc.

**The structure of the Slovenské Rudohorie Mts** is the oldest element of the West Carpathians, with striking marks of the Hercynian tectogenesis. It represents a relatively consolidated block, in which, at present, the interior differentiation takes place by rather exogenic processes than tectonic, and is characterized by extensive planation surfaces of the Neogene age.

**The Fatra-Tatra structure** is noted for a whole series of smaller crystalline cores with younger fold elements in a shape of positive morphostructures on the one hand, and for negative morphostructures with sedimentary formations of the Paleogene and Neogene ages on the other. It is in the Fatra-Tatra morphostructure where the differential tectonic movements reach their maximum.

**The structure of the Slovenské Stredohorie Mts** is built predominantly of volcanic masses overlying older elements, locally also Neogene sediments and is noted for an intensive fault structure with unevenly sinking blocks. The present-day macroforms are a reflection of neotectonic block movements and not of volcanic activity.

**The Lučenec-Košice Depression** represent a set of macro- and mesostructures conditioned predominantly by negative movements along the southeastern circumference of the Rudohorie block.

The last morphostructural element of the West Carpathians, on the confines of the Pannonian Basin, are positive horst structures bound to the inner volcanic arc. Although there are volcanic masses predominant here, it is necessary to emphasize repeatedly that as a macroform **the Slaná-Matra Arc** is conditioned by positive movements of blocks.

In contrast with the Inner West Carpathians, **the Outer West Carpathians** are noted both for their zonal course and a minor interior structural variety. By age and morphostructure, we distinguish here a relatively narrow **Peri-Pieninian Lineament** and the proper **Flysch Belt**. Although the Peri-Pieninian suture has substantially an anticlinorial interior structure, from morphostructural viewpoint it manifests itself as a structure projecting in a depression, what is strikingly suggested by its morphological nature.

The Outer Flysch Belt is marked for a nappe-fold structure, which is, however, desintegrated to a considerable measure by uneven block movements. Although traditionally the high Flysch massifs are considered as a product of selective erosion processes, there is a whole series of evidence that there are blocks positively moving here, the morphological individuality of which is often emphasized also by resistance of rocks. The development of contrasted negative and positive forms in the Flysch Carpathians does not reach, by far, the intensity in the Inner Carpathians, which is conditioned, to a considerable measure, above all by different physical properties of the Flysch substratum (greater plasticity).

As demonstrated, the structural nature of the West Carpathians is very varied, owing to a long and complicated development from the Paleozoic to present. The complicated tectogenic development consisting of several stages of very differentiated character has conditioned overlapping of some structural styles or structures within the present-day morphostructures it has conditioned their structural polygeneity.

The major features of relief of the West Carpathians are result of the Neogene, substantially Pliocene development. The major macroforms correspond to the so called neotectonic forms. The subaerial processes occured epicyclically under a strong influence of tectonic movements, and the lithological-structural properties as well as the influence of climate have manifested themselves only in the morphostructure. They have created morphosculptures (Mazúr 1976).

Geodynamic development of the West Carpathians in the Neogene was determined by the collision of continent-continent type between the north European platform and Carpathian-Pannonian block system. In the front of the orogeny, folding of the sedimentary fill of the flysch troughs took place. In consequence of the gradual subduction of the troughs, part of the sediments of the accretion wedge was separated and thrusted in the form of nappes on the platform foregland. Rotation and the related horizontal shifts of the blocks of the Carpathian-Pannonian system at the collision with the north European platform evoked an oblique convergence resulting in archlike form of the orogeny of the West Carpathians. Oblique convergence has decisively influenced the development of the intramontane basins in the West Carpathians. Subsidence maxima migrated from W to E, witha shifting trend of depocentres toward the backland area of the orogeny (Cicha et al. 1989).

This development in the contraction stage continued until the Lower to Middle Miocene. During the Middle Miocene the development began to change: extension with germanotypic tectonics started. The central parts of the Pannonian Basin started to sink intensely (evidence is provided by the thickness of the Neogene and Quaternary sediments) while the uplifting of the Carpathians continued (this is proved by the differentiated uplifts of the remnants of the Neogene planation surfaces and deeply incised valleys with the rests of the Quaternary terraces).

The following stage of extension was conducted also by an intensive volcanic activity, that resulted in the formation of extensive superimposed neovolcanite structures. It was precisely the stage of extension which substantially changed the former Paleoalpine structural plan of the West Carpathians.

**Morphostructures of the West Carpathians (CSFR)** (Mazúr 1976)

Explanations to Fig. 3

a) Boundaries between the Carpathians and Panonian Basins
b) Boundaries between the West and East Carpathians
c) Boundaries between the Inner and Outer Carpathians
c) Boundaries of the main morphostructural types in the frame of above mentioned morphostructural units

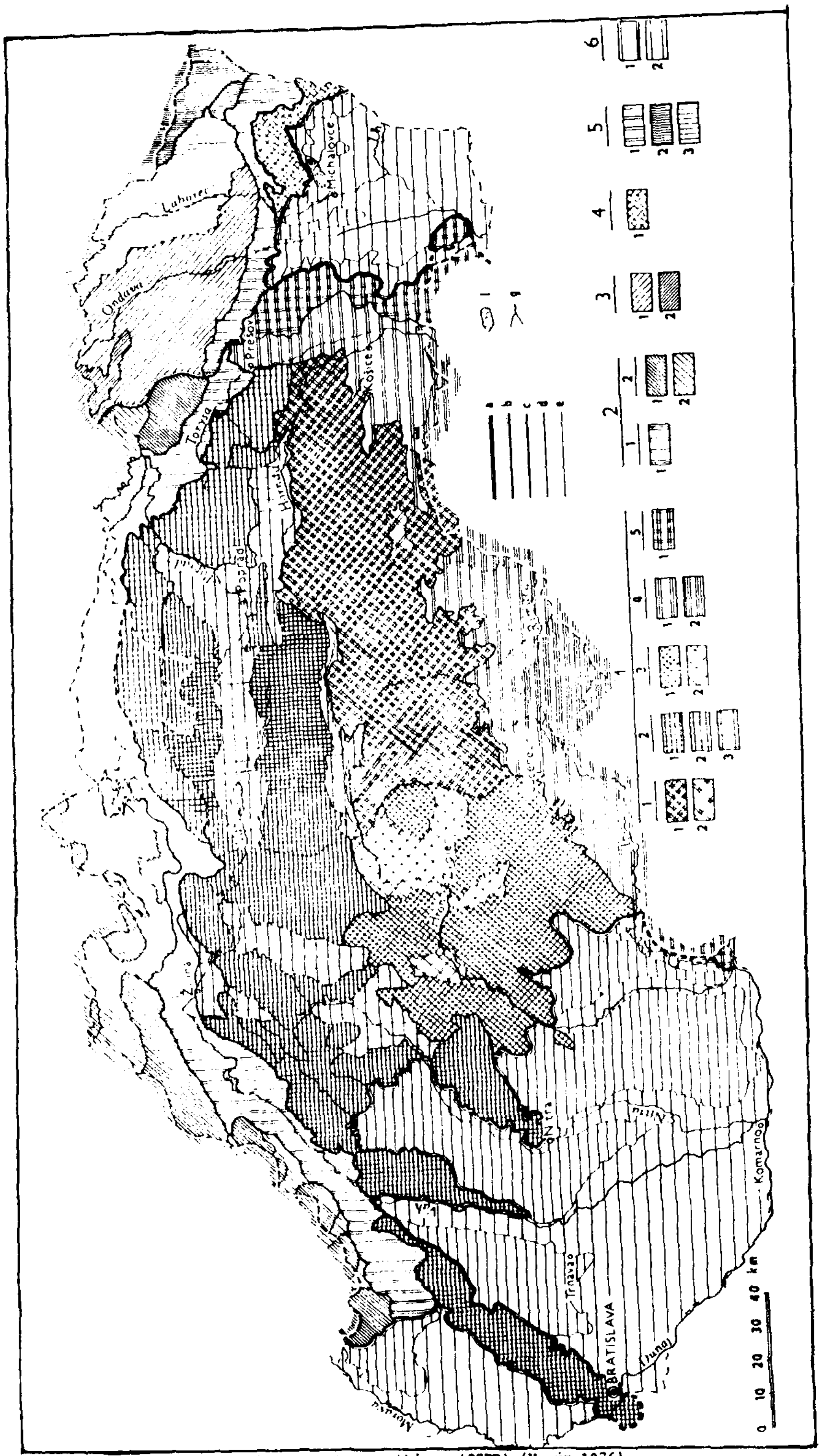


Fig. 3: Morphostructures of the West Carpathians (CSFR) (Mazúr 1976)

e) Boundaries of basic macromorphostructural units
f) Stagnant Water
g) Rivers
1. Morphostructures of the Inner West Carpathians
    1. Semimassive morphostructure of the Rudohorie type
        1. Semimassive moderately upwarped blocks
        2. Basin
    2. Fold-fault block morphostructures of the Fatra-Tatra type
        1. Positive morphostructures: horsts etc.
        2. Horsts of the Central Carpathian Flysch
        3. Negative morphostructures: grabens, morphostructural depressions - basins
    3. Volcanic block morphostructure of the Slovenske Stredohorie type
        1. Positive morphostructures: horsts and differentiated blocks
        2. Negative morphostructures: grabens, etc. - basins
    4. Morphostructural depression of the Lučenec-Košice type
        1. Negative morphostructures - grabens
        2. Moderately uplifted positive morphostructure in the frame of depression
    5. Block morphostructure of the Slaná-Matra type (Inner volcanic arc)
        1. Positive morphostructures - horsts
2. Morphostructures of the Outer West Carpathians
    1. Morphostructural depression of Peri-Pieninian Lineament (Klippen Lineament)
        1. Negative and intermediate fold-fault and intricate structures
    2. Fold-fault structures of the Flysch Carpathians
        1. Positive block morphostructures
        2. Intermediate morphostructures
3. Morphostructures of intervening belt - transversal depression of the Nizke Beskydy Mts
    1. Transversal depression through the Flysch Carpathians between the Sandomierz Basin and Pannonian Basin
    2. Positive morphostructural blocks

4. Morphostructures of the Inner East Carpathians
    1. Block structures of the Vihorlat-Gutin
5. Morphostructures of the Outer East Carpathians
    1. Morphostructural depression of Peri-Pieninian Lineament
    2. Positive morphostructural blocks
    3. Intermediate morphostructures of the Flysch Belt
6. Morphostructures of Pannonian basins (hinterland)
    1. Young, sinking morphostructures with aggradation
    2. Moderately uplifted positive morphostructures in the frame of the Pannonian depressions

## COMMENTARY NOTES TO EXCURSION ROUTES

### 1st excursion day - Friday, June 19

### I. DATING OF GLACIAL AND GLACIFLUVIAL LANDFORMS AND DEPOSITS IN THE TATRA MTS AND THEIR FORELAND (Localities: 1, 2)

Problems of dating of the glacial and glacifluvial landforms and deposits in the Tatra Mts and their foreland are solved by means of indirect dating methods. Elaboration of development schemes leans on the results of lithostratigraphic and biostratigraphic analyses and very efficiently used are the methods of detailed geomorphic research. Age of moraine ridges, glacifluvial fans and various polygenetic landforms was specified mainly according to their geomorphic position and selected mineral-petrographic characteristics of the deposits (degree of weathering, heavy mineral contents, particle size and morphoscopic properties of the deposits and the like). Evaluation of the findings of floristic, faunistic, pedological and archaelogical nature was realized too.

In order to present the cited problem diverse types of localities were chosen. Locality of the Štrbské Pleso Lake shows landforms and deposits of the Last Glaciation of the Tatra Mts. Locality Tatranská Polianka dedicates to the polygenetic landforms and deposits of various stades of the operation of glacifluvial processes. In the localities Nová Lesná and Vavrišovo we present the glacifluvial development in the Tatra foreland. The last two localities are characterized elsewhere.

### Geomorphic and Quaternary - geological characterization of the Tatra Mts and their foreland

Lacika, J., Halouzka, R.

All excursion localities are situated in the Podtatranská Kotlina Basin but genetically they are very closely bound to the Quaternary development of the Tatra Mts.

The Tatra Mts represent a strikingly positive morphostructure by which the West Carpathian Upwarp culminates. The Gerlachovský Štít Peak with altitude of 2655 m is the highest peak not only of the Tatra Mts but also of the whole Carpathian Arc. Geological structure of the Tatra Mts is not very complicated. The larger southern part of the mountain range build crystalline rocks, especially tectonicly very disturbed granitoids. Crystalline massif in the northen part is covered by a complex of Mesozoic rocks with nappe-fold structure. It is built mainly of dolomites and limestones.

The principal geomorphic phenomenon of the Tatra Mts is the Pleistocene glacial modelling. Activity of the glaciers formed in the Quaternary glacial epochs a glacial type of relief. On a markedly uplifted morphostructure developed a high mountainous, very dissected relief with numerous rocky landforms. Former mountain ridges were remodelled into sharp rocky and almost inaccessible ridges. In the individual ridges originated numerous separated peaks, rock towers and deep saddles. Between the ridges lie numerous glacially modelled valleys with cirques and "U" shaped troughs. They represent result of action of the valley glaciers as are at present time found in the Alps. Almost all Tatra valleys were glaciated. In higher part of the mountains, the East Tatra Mts, they reached even their foreland, in the West Tatra Mts their areal and volume range was smaller and also the present-day relief does not reach that degree of dissection and does not have that striking alpine character. The most expresive glaciers of the High Tatra valleys reached according to Lukniš (1972, 1973a) in the maximum of the Last Glaciation the following dimensions (length in km, thickness in m respectively): the Bielovodská Dolina Valley 13,0 and 280, the Kôprovská Dolina Valley 12,5 and 250, the Mengusovská Dolina Valley 10,7 and 200, the Studená Dolina Valley 9,8 and 220, the Javorová Valley 9,1 and 160, the Mlynická Valley 8,0 and 150.

Extent of the glaciation of the Tatra Mts in the Pleistocene document moraine ridges preserved in different stages. Moraines of older glaciations are in the stage of considerable destruction. Later they were covered by younger accumulation or their material was redeposited into younger moraine ridges. The best preserved were the moraine ridges of the Last Glaciation even though it did not reach the extent of the preceding (antepenultimate) main Riss glaciation.

Consistently with Lukniš (1973) we classify the accumulation related to the Last Tatra Glaciation into the alpine glacial Würm (the Vistulian or Vislian of the nordic stratigraphic scale), especially into its Pleniglacial and Late Glacial. It corresponds to the time interval of roughly 52,0-10,2 thousand years B.P (Halouzka 1989). More details will be given in situ.

After the retreat of the glaciers from the Tatra valleys a new phase of the landform development started. As it was acting only a short time it was not able to transform the glacial relief that still dominates. The main process is the destruction of the rocky forks by various gravitational processes, transport of the loosened material downwards and filling up the glacial valleys by these deposits. From among the main destructing processes let us cite the frost weathering and nivation. Material is transported by stone falling, snow and debris avalanches and also the rock falls, abrupt disintegration of whole blocks and massifs are not rare either. By this way the individual ridges were dissected into ribs and furrows making use of the tectonic predispositions. Transported material is deposited into extensive talus and snow and debris avalanche cones, that gradually disguise the original glacial relief. In the places of disappeared glaciers in cirques and troughs formed numerous glacial lakes. These gradually disappear as they are filled by the debris. Genetically cirque and moraine lakes can be distinguished. Specific type represents the Štrbské Pleso Lake (see text about locality No.1). A characteristic phenomenon of the rocky thresholds in the valley bottoms and in mouths of the lateral hanging valleys are the waterfalls.

On the southern slopes of the Tatra Mts originated specific landforms - rectilinear triangular fault slopes (faceted spur ends). They were formed along the fault bordering the mountains. Their inclination is 20 to 40 $^{\circ}$, they are consistently covered by periglacial debris and lack any signs of the glacial modelling.

Morphostructural antipode to the Tatra Mts is the Podtatranská Kotlina Basin. It is built of sediments of the Central Carpathian Flysch (Paleogene). Between the Tatras and the Podtatranská Kotlina Basin developed the most contrasting relief in the frame of the whole West Carpathians. Relative altitude of the Tatra peaks above the adjacent part of the basin exceeds 1600 m . Major part of the basin has hilly relief, only in the surroundings of Poprad an enclave of plain relief can be found. Basin hilly relief is bound to the alternation of broad valleys of the flows descending from the Tatras and low terraced and flat ridges bearing the covers of numerous generations of glacifluvial cones. The rivers Poprad a Váh forming hydrological and geomorphic axis of the basin are pushed by the Tatra tributaries towards south, nearer to the Low Tatra Mts. Inside the basin protrude several partial morphostructural units in the form of morphologically striking elevations. Specific territory is the contact of the basin with the Tatra Mts where there is a belt of subtatra communities serving for a recreation-therapeutic purposes. Tectonicly active morphological border is represented by a belt of foot-hills on a system of terminal moraines in the mouths of the main Tatra valleys. In many places the thickness of the accumulations exceeds 100 m. In downward direction the foot-hills pass to a glacifluvial hilly land. This geomorphic change manifests itself in the landscape by deforestation.

## Locality No. 1: Štrbské Pleso Lake. Stratotype region of moraines of the Last Glaciation in the Tatra Mts (Würm). Peats (Holocene)

### Geomorphic setting

Lacika, J.

Locality is in the highest situated community in the CSFR on a shore of the lake of same name in altitude of 1346 m. The community as well as the lake are on the surface of a massive complex of terminal moraines deposited under the mouth of the Mlynica and Mengusovská Dolina Valleys into the Podtatranská Kotlina Basin. Major of them is the Mengusovská Dolina Valley with more striking trough form and bigger moraine ridges. In the time of the Last Glaciation it was modelled by 10,7 km long and 250 m thick valley glacier. The smaller Mlynica Valley was reformed by a glacier 8,0 km long and 150 m thick. Territory around the lake is occupied by a hilly moraine that acquired its present-day morphographic features by additional destruction of moraines during melting of the dead ice buried beneath the moraine material. Through setting down of the moraine surface, originated three steps. In the highest one lies the kettle of the Slepé Pleso Lake. The medium one bears the largest Štrbské Pleso Lake and several kettles filled by peat. On the lowest step is the Nové Štrbské Pleso Lake . Its present existence is a result of anthropogenic intervention.

The Štrbské Pleso Lake is the largest Tatra moraine lake and the second largest on the Slovak side of the Tatra Mts. It occupies the area of 20,96 ha. The greatest measured depth reached 19,6 m. Mean depth is 6,63 m. Length of the shore line is 2350 m. Its genesis is combined. Partially it originated as a consequence of barring by terminal moraine and its subsequent deepening was caused by the melting of intramoraine dead ice. The lake is ecologically very instable and incorrect anthropogenic intervention might mean its emptying and disappearing. The community of Štrbské Pleso serves mainly for recreational and therapeutical purposes. Respiratory diseases are cured here. It is a basis for summer tourist trips, in winter time alpinic and nordic skiing is practiced here. In 1970 World Championship in nordic skiing disciplines was held here.

## Development of glaciation and stratigraphy of moraines

Halouzka, R.

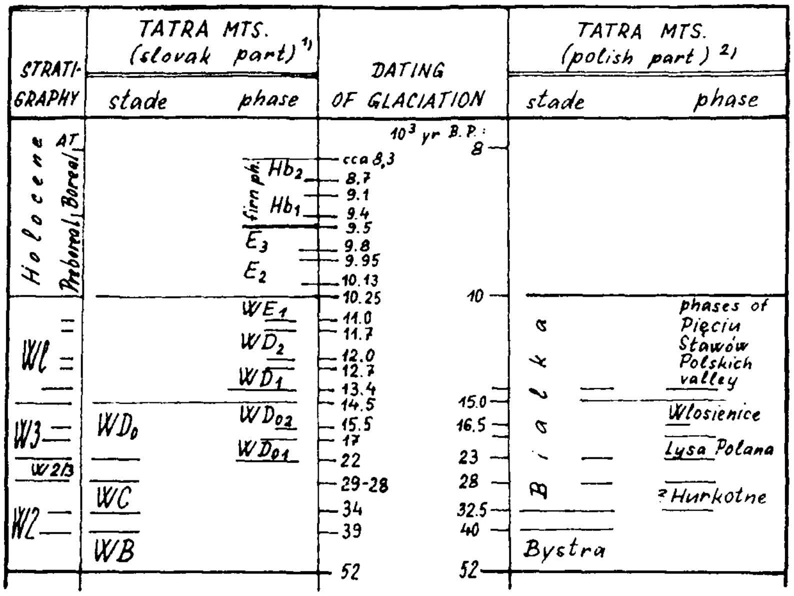
Region of the Štrbské Pleso Lake represents almost exclusively landforms and deposits of individual stades of the Last Glaciation. Title of this locality by complex stratotype is "Glaciation of the Štrbské Pleso Lake". Complex litho-morphostratigraphic unit of its determining deposits is entitled "Moraine formation of the Štrbské Pleso Lake" (Halouzka 1990, 1991, in print). Moraine deposits of this formation are divided in lower level into moraine "members", reflecting the stades of glaciation. Denotations of glaciation stades in the Tatra Mts (local names and stratigraphical abbreviations), introduced by Lukniš (1973a,b), was recently supplemented and unified (Halouzka 1989). In this sense it is possible to distinguish following moraine ridges and deposits (Lukniš 1968, 1973a, Halouzka in Gross at al. 1990, in Nemčok et al. 1990, 1991). Moraines and their boulder-block deposits in the region of locality reflect three **glaciation stades:**

1. maximum, i.e. B stade (Štósy) with WB moraines
2. submaximum, i.e. C stade (Tatranská Lomnica) with WC moraines
3. main recessional, i.e. $D_o$ stade (Veža) with $WD_o$ moraines (Lukniš 1973a,b, Halouzka 1977, 1989).

Geologically these moraines form deposits of three litho-morphostratigraphic units: member of the Štósy moraines Beds (maximum), member of the Tatranská Lomnica moraines Beds (submaximum) and member of the Veža moraines Beds (main recessional moraines). In a shortened working terminology they are denoted only as accumulations of WB (WC, $WD_o$) moraines.

Distribution of moraine accumulations in the region of the Štrbské Pleso Lake (see Fig.4) : (1) Accumulation of maximum WB moraines was preserved only from the glacier of the bigger Mengusovská Dolina Valley, i.e. in SE part of given region. (2) Ridges of the submaximum WC moraines (geomorphicly in the region the most important ones) take course in parallel direction (to ESE). The first belt is represented by the Varta (k.1060) high,

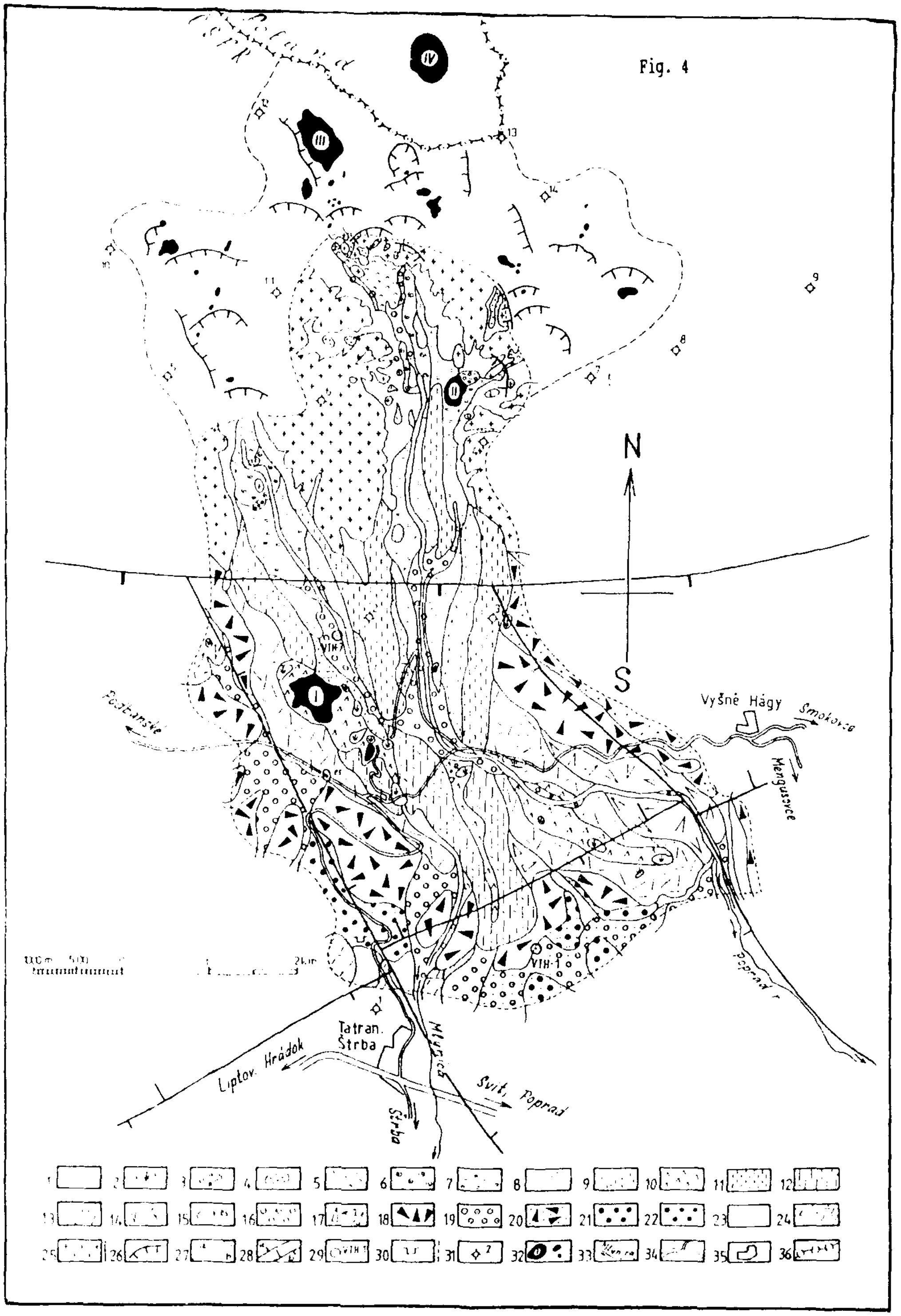
Tab. 1: Survey of dating of the Last Glaciation in the Tatra Mts.(Halouzka 1992)



1) R. Halouzka 1989 (modified 1991)
2) L. Lindner, J. Dzierżek, J. Nitychoruk 1990 (modified)

steep and at sides double ridge of terminal moraine, accumulation of which starts in the left side of the Mengusovská Dolina Valley. The second belt is formed by paralled ridge of a striking frontal moraine of the Mlynica glacier, its accumulation comes from the right side of the valley. This moraine ridge bars in the western and southern parts the lake basin of the Štrbské Pleso and Nové Štrbské Pleso Lakes and continues up to the flow of the Mlynica Brook.

The last (3) of the main moraines are the ridges of $WD_0$ moraines that are the best preserved and the longest ones among the moraines in the region of the Štrbské Pleso Lake. Even though their accumulations reach also the inside of the valley (central elevated belt of ground $WD_0$ moraine in the Mengusovská Dolina Valley) from the mouth of both valleys of the mountain range, in the relief there are characteristic continuous and long lateral to terminal moraine ridges.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Vyšné Hágy
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Mengusovce
Poprad
Tatran.
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Liptov. Hrádok
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Svit, Poprad
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Fig. 4

Fig. 4: Geological map of the Štrbské Pleso area (Halouzka 1992 - according Lukniš 1968, modified)
1 to 6: Holocene; 1-fluvial flood-pain sediments (redeposited loamy gravels to bouldery gravels), 2-peats (peat bogs); 3-proglacial meltwater deposits (sandy gravels),aggraded morainic basin in front of glacier; 4 to 14 - glacigenic gravelly boulder-block deposits of moraines of the Last Glaciation; 4-sediments of the neve or firn-glacier moraine ($Hb_1$ phase of deglaciaton),Boreal; 5-morainic sediments of $E_3$ phase (Preboreal); 6-morainic sediments of E phase (Preboreal); 7 to 9 - "Late Wurm" (late glacial part of Wurm or Vistulian glacial,Dryas age); 7-morainic sediments of $WE_1$ phase (Young Dryas); 8-morainic sediments of $WD_2$ phase (Middle Dryas); 9-morainic sediments of $WD_1$ phase (Old Dryas); 10 to 14 - pleniglacial of Wurm or Vistulian; 10-hummocky moraines (moraine hills or sag-and-swells topgraphy of moraines); 11-morainic sediments of $WD_{02}$ substade (Wurm 3 stadial); 13-morainic sediments of WC stade ("Wurm 2 stadials); 14-morainic sediments of WB (maximum) stade of the Last Glaciation ("Wurm 2" stadials); 15 to 16 - Wurm (Vistulian) glacial, undivided; 15-esker's gravelly sands (subglacial deposits); 16-glacifluvial bouldery gravels (bottom accumulation); 17-glacigenic gravelly boulder deposits (with blocks) of moraines of the Penultimate Glaciation (Riss Late or Wartian glacial); 18 to 19 - Riss Early s.l. (Saalian s.l.) glacial(s); 18-glacigenic gravelly boulder deposits (with blocks of moraines of the Maximum Glatiation; 19-glacifluvial gravels and bouldery gravels (with blocks), fan and terrace accumulation; 20-21-Mindel (Elsterian) glacials; 20-glacigenic weathered morainic sediment of they Old Glaciation; 21-glacifluvial weathered gravels and bouldery gravels (sandy and with blocks), terrace and fan accumulation; 22-glacifluvial strongly weathered gravels and bouldery gravels (with blocks and sand horizons), fan accumulation complex (Lower or Early Pleistocene, pre-Mindel); 23-undivided deluvial deposits (slope debris predominating), Quaternary; 24-Paleogenic flysch deposits, Zuberec-Formation: claystone (predominating) and sandstone (upper Eocene, upper Priabonian); 25-granite and granodiorite (Palaeozoic) 26-glacigenic valley steps in the cirque; 27-boundary limits of the: a) geological map, b) geomorphic scheme; 28-faults: a) fault dip, b) another f.d. in Quaternary (long line); 29-boreholes; 30-gravel-pit and sand-pit (locality Štrbske Pleso-south; 31-tops (of peaks); 32-erosional and morainic lakes; 33-streams; 34-roads; 35-village; 36-state border (frontier). Explanations to names of lakes: I-Štrbske Pleso Lake; II- Popradske Pleso Lake; III-Velke Hincovo Pleso Lake; IV-Czarny Staw Lake (in Poland). Explanations to names of tops (peaks): 1-Lieskovec (967); 2-Trigan (1481); 3-Pod Ostrvou (1446); 4-Ostrva (1926); Štrbske Solisko (2032); 6-Patria (2203); 7-Tupa (2276); 8-Končista (2535); 9-Gerlach (2655); 10-Furkotsky štit; 11-Satan (2416); 12-Kóprovsky štit (2367); 13-Rysy (2499); 14-Vysoka (2560)

Scheme and explication of the distribution of $WD_o$ moraines in the region of the Štrbské Pleso Lake: The most extensive are the watershed (Mlynica-Poprad) moraine ridges in the contact of the glaciers. They were accumulated from the space of the intervalley "tip" of the foot of the Patria Peak (k. 2203) from which they run toward SSE in the length of 5 km. Moraine belt has two sections - the ridge Trigan (k. 1481) and the ridge of the Spáleny Vrch (k. 1221). The first is a common contact lateral moraine of both glaciers. The second moraine ridge belongs practically only to the glacier of the Mengusovska Dolina Valley; the left one of the couple of ridges of the Spáleny Vrch is a continuation of the left side lateral moraine of this glacier (i.e. the ridge Pod Ostrvou - k.1446).

Finally, from $WD_o$ moraines of the exclusively Mlynica glacier exist nowadays only the moraines of two sections of right side lateral-terminal ridges running from the mouth of the Mlynicka Dolina Valley to SSE. First of all it is a big ridge oriented to the northern margin of the Štrbské Pleso Lake (ridge of the ski jump) and then a small ridge southerly from the Nové Štrbske Pleso Lake.

Described accumulations of $WD_o$ moraines are manifestations of the mentioned main recessional stade of the Last Glaciation and as such in the succession of its moraines in the given region relief (and also in other places in the High Tatra Mts) aggradate for the last time large and long moraine ridges. Detailed morphoanalysis in geological mapping of the Tatra Quaternary enabled to redistinguish, especially in the region of the Štrbské Pleso Lake, in the belts of $WD_O$ moraines two (eventually 3) partial frontal ridges (according to the mapping of Halouzka in 1990-91), apparently corresponding to the same number of oscillation of the glacier front of that time (?). Younger (eventually the youngest) oscillation of the $D_O$ stade of the Mlynická and Mengusovská Dolina Valley glacier must be then responsible for the fronts of big moraine ridges along the northern margin of the lake basin of both lakes. It is the ridge with the skijump near the Štrbské Pleso Lake and also the ridge of the Trigan (k.1481) near the Nové Štrbské Pleso Lake.

This finding is of essential importance in the question of more correct assessment of the stratigraphic position and age of origin of the lake basin of the Štrbské Pleso Lake (and subsequently also the proper lake in the basin). Author states only here that the newly obtained chronostratigraphic and time scale of the development of the Last Glacial in the Tatra Mts ( Halouzka 1989) gives us the age of the origin of the basin of the Štrbské Pleso Lake of about 16 thousand years B.P. (origin of the basin with dead ice). Then we suggest the origin of the lake after the melting of the dead ice at about 14 thousand years B.P. (i.e. at the beginning of the Late Würm glacial).

**Moraines of deglaciation phases.** During the following post-periglacial period of the Last Glaciation (i.e. during the Late Glacial and the older Holocene) only smaller glacial landforms and less extensive deposits of the individual deglaciation phases of recessional moraines were formed (this time as individual moraines of the separated Mlynica and Mengusovská Dolina Valley glaciers). These boulder-block moraine ridges are classified and denoted (Lukniš 1973a, b, Halouzka 1977,1989) in the following moraine sequence.

First of all there are moraines $WD_1$ and $WD_2$ (in the High Tatra foreland - i.e in the region of the Štrbské Pleso Lake). The following deglaciation moraines of the glaciers $WE_1$ and $E_2$, in lesser extent $E_3$ were accumulated (as it is typical for the whole south of the High Tatra Mts) only in the valleys of the mountain range. In our case in the Mlynická and Mengusovská Dolina Valleys (out of the Štrbské Pleso Lake region).

For these deglaciation moraines in the southern valleys of the High Tatra Mts generally holds that the front ridges of $E_1$ moraines were usually formed in valley mouths at the margin of mountains. But let us also note that the $E_3$ moraines (the youngest moraines of the real glaciers in the Tatra Mts) have then "retreated" in the majority of the High Tatra Mts valleys in Slovakia up to the glacier cirques in the valley heads. In the Polish side of the Tatra Mts where the cirques at the valley heads are lower situated than on our side these were totally deglaciated since the period of formation of our youngest glacier moraines i.e. $E_2$ and $E_3$ (according to the results of the lithofacial and palynological research and $C^{14}$ dating of the probe profiles in the bottoms of the cirque lakes).

Right in the valleys adjacent to the locality of the Štrbské Pleso Lake (i.e. Mlynická and Mengusovská Dolina Valleys) - in spite of the above mentioned general findings - the fill of the valley cirques is even younger than the $E_3$ moraines. The fill here consists almost exclusively from stone-block periglacial-moraine deposits, genetically understoond, the remnants of little firn glaciers. Sediments belong to the deglaciation cirque phase $Hb_1$ ( phase of so called firn moraine "WH" according to Lukniš); they are the most typical of the cirques of the Slovak High Tatra valleys.

There are not only the quoted (firn) deposits in the numerous glacier cirques of the system of the Mengusovská Dolina Valley. Also, though in lesser extent, besides sediments of the youngest moraines $E_3$ (lower cirque of the Zlomisková Dolina Valley) the youngest and purely periglacial (nival) deposits from the last cirque phase of deglaciation of the High Tatra Mts (i.e. $Hb_2$ phase, after Lukniš's denotation phase "h") were proved - they form the Postglacial protalus ramparts (cirque of the Veľké Hincovo Pleso Lake).

**Summary** (moraines in the region). The Štrbské Pleso Lake region in the High Tatra Mts is geomorphic-geological stratotype locality of a complex of moraines and moraine deposits of the Last Glaciation (Würm, Vistulan or Vislian) for the whole Tatra Mts. In the southern part adheres a ring of denudation remnants of moraine deposits of so called maximum glaciation (Older Riss, Saalian) including stratotype locality Štôla. In the western side of the region come out to the surface in the stratotype locality Rakytovec also moraines of so called Penultimate Glaciation (Younger Riss, Vartian) from beneath the moraines of the Last Glaciation. Margin of all moraines of the southern part of the regions surround glacifluvial accumulations (cones and terraces) of various ages.

Beside the moraines (eventually glacifluvial material) the region is characterized also by the peat directly in the lake basin of the Štrbské Pleso Lake, but they were very reduced by building works. The processed profile of the peat bog near the Štrbské Pleso Lake (Krippel 1986) contains the Holocene peat from the Atlantic, Subboreal and Subatlantic periods.

A map reconstruction of the paleogeographic development of the last glaciation in this territory (see Fig. 5) is added to the described geological and morphological situation.

From the commentary we choose: Since the known beginning of the Last Glaciation in the Tatra Mts (about 52 thous. years B.P.) the Mlynická and Mengusovská Dolina Valley glacier formed below the valley mouth in the foreland of the High Tatra Mts more or less common body in the course of three main stades of the Wurm Pleniglacial (WB WC, $WD_o$). The overall trend of its direction: from the turn to the left in the time of maximum (WB) to transfer to the right (WC) and finally to concentration to the central common body ($WD_o$). The lake basin was deglaciated only by the recession of the glacier front between two substades of $WD_o$ moraines. Recession of the two, since then divided, glaciers into the position of the beginning deglaciation phases of Late Glacial of Wurm (approx. 14 thousand years B.P.) apparently meant also melting of the dead ice in the basin and the origin of the Štrbske Pleso Lake. Deglaciation phases of the glaciers of both

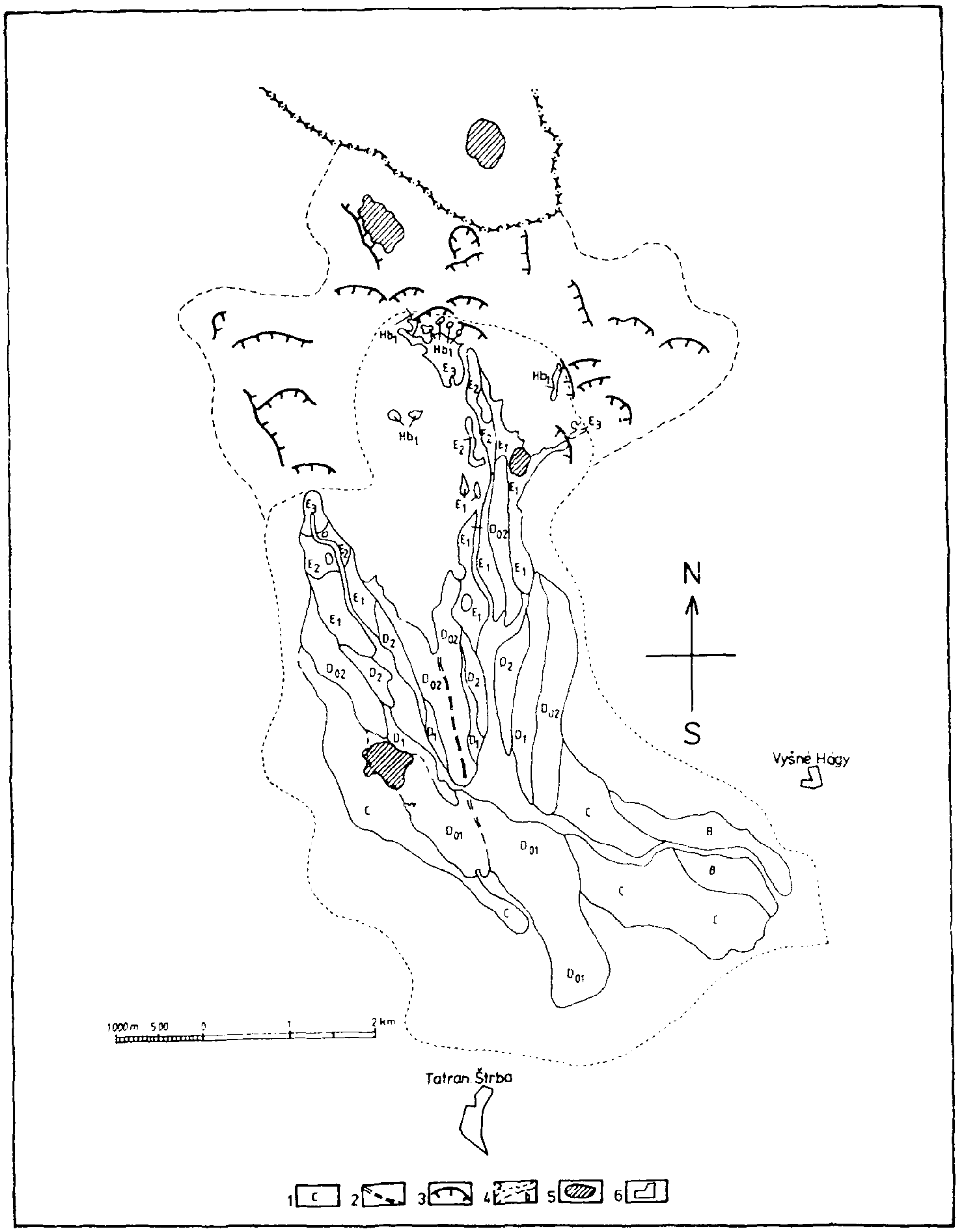


Fig. 5: Paleogeographical map of the Last Glaciation in the Štrbské Pleso area (Halouzka 1992)
1-stades and phases of the Last Glaciation in area; 2-dividing line between two glaciers; 3-glacigenic valley steps in the cirque; 4-boundary limits of the : a) paleographical map, b) geomorphic scheme; 5-main recent lakes; 6-village.

valleys were represented by the position of the fronts of the glaciers first in the foreland (phases $WD_1$,$WD_2$), then in the valley trough ($WE_1$, the Holocene phases $E_2$ and $E_3$) and in cirques (partially $E_3$, firn glaciers of the phases $Hb_1$ or $Hb_2$). Thus the authentical glaciers disappeared from the valleys near the locality and from the High Tatra Mts in general about 9500 years ago and the firn glaciers disappeared more than 8000 years ago. Approximately since then (8000 year B.P.) the formation of peat bogs (since Atlantic) is dated.

Age of the landforms and deposits of the described moraines of the last glaciation in the locality (and in the Tatra Mts in general) was assessed in the Slovak part of the mountain range by indirect methods. The way of indirect assessment when the time scale of the Last Glaciation in the Tatra Mts was schemed, is analyzed in the corresponding author's lecture in the Symposium. This Guide contains only the resulting dating survey of the last glaciation in the Tatra Mts (Tab. 1) by Halouzka 1989, partially revised in 1991).

## Locality No. 2: Tatranská Polianka (Great Yellow Wall). Periglacial polygenic accumulations of Pleistocene age.

Halouzka, R.

The instructive section of Veľká žltá stena ("Great Yellow Wall") can be seen at the junction of the Velická Dolina Valley with the High Tatra foreland, close to Tatranská Polianka, in altitude 1030 m.

The 60 m high wall rose as a result of the catastrophic flood in 1813. It consists of granodiorite gravel, boulders and debris. The whole succession was divided into 18 beds grouped into three complexes (Fig. 6).

The lower complex (from bottom to top they are beds S,R,P,O,N), almost 40 (30) m thick, considerably weathered, consisting of rounded gravel and boulders, is most likely of Early Mid-Pleistocene age. The strong weathering is explained by the derivation of the gravel from the Neogene weathering crust, which in the little dissected mountains before the upheaval of the Tatray might have been up to several tens of meters thick.

The middle complex, 10 (20) m thick (beds N, and mainly M, L, K), contains mostly in the matrix of considerably weathered gravel and pebbles, scattered fresh gravels and boulders. This complex is separated from the substratum by a sharp erosion surface. The weathered gravel was redeposited from the underlying beds, i.e. from the higher parts of the underlying Early Mid-Pleistocene alluvial fan, when the Brook Velický Potok cut into the non-weathered granodiorite, and washed out the top part of the same Early Mid-Pleistocene fan below the foot of the slope. The middle complex is most likely of Later Mid-Pleistocene age (i.e. from the periods of maximum glaciation of mountains).

The upper complex is 10 m thick. The amount of gravel and less rounded blocks increases towards the top. With the exception of G and A beds, it is characterized by solifluction structure.

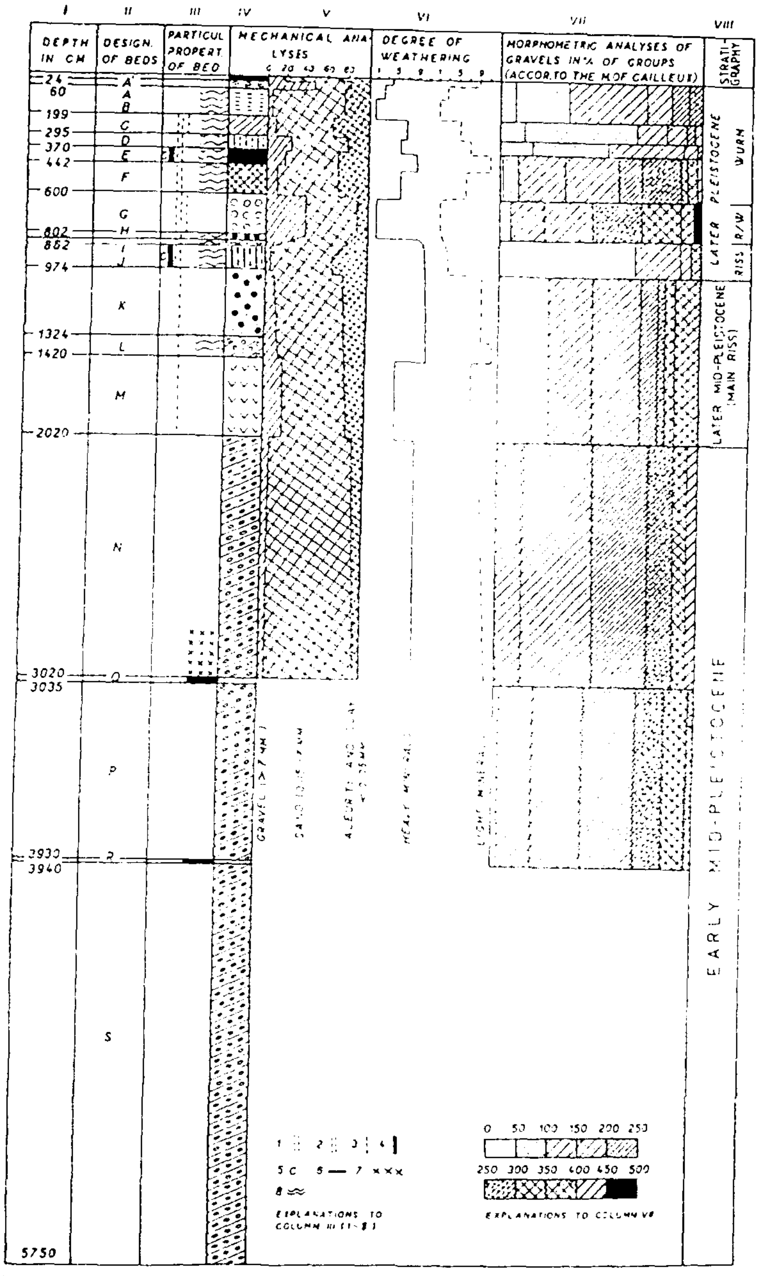


Fig. 6: Veľká žltá stena section in Tatranská Polianka (Lukniš 1967, 1973 - partly modified by Halouzka 1992)

Groups of the Iz gravel according to Cailleux. Explanations to column III (1-8): 1-non-weathered gravel strongly predominating; 2-non-weathered gravel and strongly weathered gravel are roughly equilibrated; 3-non-weathered gravel scattered in the mass of weathered gravel; 4-fossil soil sediment; 5-occurrence of charcoals; 6-accumulation of kaoline; 7-coagulation of the Mn compounds; 8-solifluction structure.

The G bed contains solid, comparatively finer gravel, well rounded by water transport, without any traces of solifluction; therefore, it is generally considered as dating from the Interglacial.

The G bed divides the upper complex into three parts: (a) The lower solifluction layer. In its lower part there is a soil relic with charcoals displaced by solifluction. (b) Interglacial fluvial sediments. (c) A 6 m thick layer of predominantly rounded solifluction gravel-bouldery debris. Assumption of the stratigraphy of the upper complex beds is Latest Mid-Pleistocene and first of all Late Pleistocene.

Parallelization in High Tatra Mts.:

| | |
|---|---|
| upper complex (partly) ............ | moraines of the:<br>-Late Glaciation<br>-Penultimate Glaciation |
| middle complex (partly) ........... | moraines of the Maximal Glaciation |
| lower complex (partly) ............ | moraines of the Old Glaciations(s) |

Genesis of the accumulations and landforms on the locality: relation to flow-migrations of the Brook Velický Potck on the mountains foreland. Development of processes: fluvial erosion proceeding to the beginning of the Middle Pleistocene; fluvial and first of all periglacial polygenic accumulation during the whole Middle and Late Pleistocene periods; might postglacial fluvial erosion of the brook.

The profile through the Veľká žltá stena indicates the complicated formation of the foothill accumulations in the Inner-Carpathian depresions.

[Compiled according Lukniš 1967 and Halouzka 1979; modificated, with supplement].

## II.LANDFORMS BUILT OF TRAVERTINE, THEIR DATING AND DYNAMICS

(Localities: 3,4)

**Locality No. 3:** The Spiš Castle

### Geomorphic setting of the Spiš Castle (the Hornádska Kotlina Basin)

Stankoviansky, M.

The Spiš Castle is situated in the eastern part of the Hornádska Kotlina Basin.

The Hornádska Kotlina Basin is an intramontane landscape unit of the Fatra-Tatra region. It forms a striking morphological depression of elongated form in W-E direction. In the north it is bordered by the Levočské Vrchy Mts and the Kozie Chrbty Mts, in the west and southwest by the Low Tatra Mts, in the south by the Slovenské Rudohorie Mts and in the east by the Branisko Mts. The basin is built of the 400-800 m thick complex of the Central

Carpathian flysch and basal transgressive conglomerates, breccias and sandstones of the Eocene age. The basin is limited by faults of NW-SE and W-E directions. Along the N-S transversal faults springed mineral waters that formed numerous travertine mounds by the end of the Pliocene and in the Pliestocene. The Paleogene complexes along the River Hornád and its tributaries are covered by the Quaternary alluvial material. Relief energy of gently modelled relief in the western part is 30-100 m, that of more dissected relief in the eastern part is 100-180 m, in places also more than 200 m. Maximum altitude is 672 m (the Medvedie Vrchy Hills), minimum 380 m (flood plain of the Hornád River near Spišské Vlachy).

Rough features of the Hornádska Kotlina Basin originated before the Paleogene and their formation was finished by later tectonic movements. Detailed formation of relief was influenced also by exogenic geomorphic processes, above all by gravitional, pluvial and fluvial processes. On the soft claystone layers, especially in the western and northwestern part of the basin in the section of Spišský Hrhov - Behárovce, denudation process created a smooth, shallow-modelled relief. Higher relief energy is linked to more resistant sandstone layers. In some places preserved the rests of the Upper Pliocene bottom of the basin, so called river level, that was in the Quaternary dissected by the River Hornád and its tributaries into a system of flat ridges. River terraces accompany the River Hornád in the western and central parts of the basin.

The Hornádska Kotlina Basin includes the following subunits: Vikartovská Priekopa Graben, Hornádske Podolie Furrow, Medvedie Chrbty Hills and Podhradská Kotlina Basin. Important phenomena of the basin are also planar and rotational landslides especially on the claystone-shale rocks in the Podhradie part of the basin.

## Significance of travertine deposits of the Spiš region for the Late Tertiary and Quaternary relief development

Ložek, V.

Travertine deposits of different age provide important evidence for the chronologic sequence and intensity of various geomorphic processes, particularly for erosion and karstification. This is based on the fact that the travertine formed predominantly during moist and warm phases, i.e. in the Pleistocene interglacials incl. the Holocene as well as in the Late Tertiary. Therefore deposits of different age are characterized by a different grade of destruction. This makes possible not only to date particular travertine deposits but also to trace the history of various geomorphic processes. In the area of Spiš five groups of travertine deposits were distinguished on this basis (Fig. 7):

Drevenik Group /Late Tertiary-Pliocene/: The original form of deposits is largely changed by erosion and intensive karstification associated with terra rossa formation; marginal parts are strongly affected by cambering leading to formation of "rock cities".

Pažica Group /Final Pliocene-Early Pleistocene/: marginal parts are rather strongly affected by cambering; karstification and surface degradation are markedly developed, but terra rossa occurs only locally. There are karst pipes with fills showing a complicated stratigraphy including different interglacial horizons.

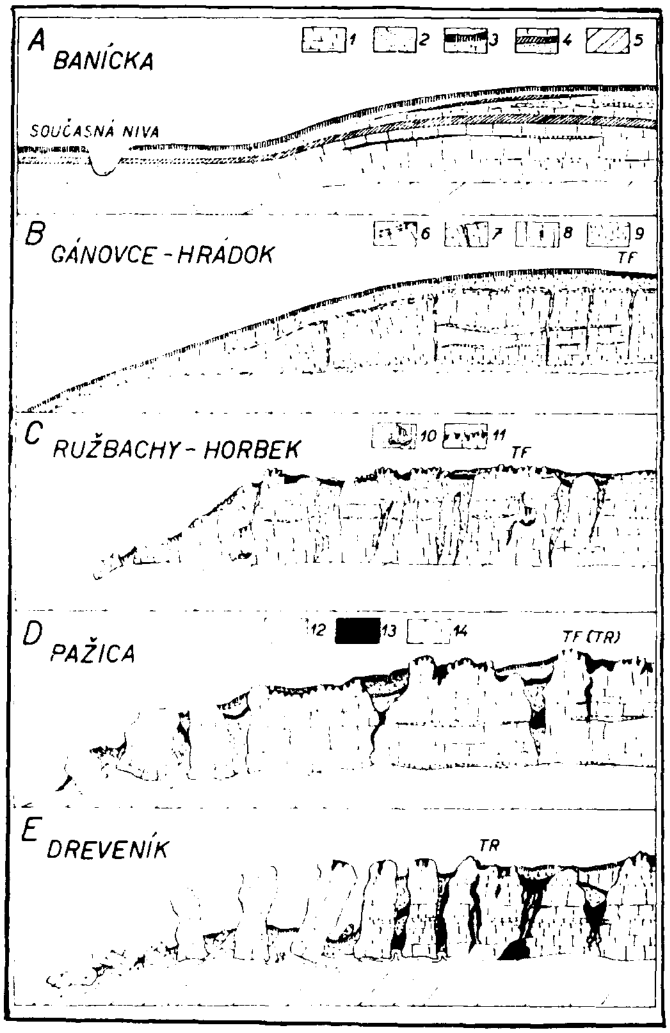


Fig. 7: Groups of travertines by relative age (Ložek 1973)
1.solid travertines, 2.loose calcareous tufa, 3.surfacial rendsina, 4.buried rendsinas, 5.base of travertines, 6.frost ruffling of solid travertine surface, 7.cracks in travertines, 8.loess, 9.loamy-stony debris, 10.small caves with dripstone formations, 11.karren, 12.loess-like fill in caverns, 13.terra fusca (TF), terra rosa (TR), 14.base failures.

Ružbachy-Horbek Group (Middle Pleistocene): Karst processes are represented by small caves and a well-developed terra fusca, marginal parts are affected by erosion and minor cambering processes.

Gánovce-Hrádok Group /Last Interglacial/: The original form of deposits is rather well preserved, there are minor traces of karstification, the surface is mostly affected by frost weathering and bears fully developed rendsina soils or in favourable level places a shallow terra fusca.

Hozelec-Banicka Group /Holocene/: The original form is fully preserved, the surface is fresh bearing only shallow rendsinas, often in initial stages. Karst processes occur only as subrosion due to changing activity of springs which formed the deposits in question.

## Travertines of the Spiš Castle Hill - Biostratigraphic dating

Ložek, V.

The huge Spiš Castle is situated on a travertine cover outlier forming the northernmost part of the travertine complex of Drevenik-Ostrá hora-Spišský Hrad. The travertines are mostly recrystallized and thus poor in fossils which have been preserved only locally in certain horizons. Their dating is based on leaf impressions which according to the determination of Nemejc belong in part to tree genera occurring in Central Europe as Quercus, Ulmus, Fraxinus or Acer, and in part to extinct taxa as Gingko, Torreya, Juglans, Celtis, Liquidambar, Parrotia, Zelkowa and Cercidiphyllum which partialy survived only in remote areas of Eurasia. Also Fagus and Alnus are represented by ancient forms. Out of Mollusca only Granaria frumentum /Drap./ has been identified since the great majority of shells were strongly affected by diagenetic changes of the travertine rock.

The above plant assemblage provides definite evidence that the travertine complex in question is of pre-Quaternary age. It differs markedly from all floras recorded in other travertine sites in the Spiš region which include Quaternary assemblages only - from early Pleistocene interglacials to the Holocene. The combination of tree taxa cited above indicates the Pliocene age without more detailed chronostratigraphic placement. There are also no records available which might give evidence whether these travertines formed during a longer or shorter time span, i.e. probably during several climatic cycles existing also in the Late Tertiary, however in a less dramatic form than during the Quaternary.

This biostratigraphic dating is supported by other lines of evidence, particularly by considerable destruction of the travertine body due to gravitational displacements on semisolid underlying rocks as well as by intensive karstification. Of particular importance are fills of karst cavities consisting of strongly developed terra rossa with bean ore. In this context it is worth mentioning that also the travertine itself shows a very intense diagenetic lithification which is characteristic of Tertiary spring limestones.

In addition, we must mention a karst pipe exposed in the abandoned quarry of Ostrá Hora, sedimentary fill of which includes an interglacial molluscan fauna with the index species Drobacia banatica /Rssm./. The molluscan assemblage suggests a pre-Eemian age of this Interglacial.

In the eastern vicinity of the Spiš Castle a huge travertine mound called Sobotisko is situated which includes a molluscan fauna as well as a small-sized Middle Palaeolithic industry indicating that this travertine body formed itself in a warm phase of the younger half of the Pleistocene, according to the U/Th-dating probably in the Penultimate Interglacial. In contrast to the Drevenik Complex, the travertine mound of Sobotisko shows no disturbances by gravitation and its karstification is also much less intense. Its surface has a fresh character since the travertine deposit has rather steep slopes which were obviously uncovered during the phase of overall sheet erosion at the beginning of the last pleniglacial phase.

## Gravitational disintegration of the Spiš Castle Hill

Malgot, J.

The Spiš Castle - The National Cultural Monument - belongs to the most extensive Central European castles. It was founded in 1120. Its constructing development was complicated. The castle was abandoned in 1780 , after the fire. At the present time is in reconstruction - the castle walls are reconstructed, several objects of the castle are under conservation and also the rock walls the castle stands on are being statically stabilized.

The Spiš Castle is standing on travertine mound (Fig. 8) that is a part of the Podhradská Kotlina Basin. The basin has developed as an inversion depression on anticlinal of claystone-sandstone complex of the Central Carpathian flysch (Palaeogene) in the surroundings of Spišské Podhradie. From otherwise smooth modelled relief protrude striking elevations of travertine mounds of Drevenik, Spišský hrad, Ostrý vrch, Sobotisko, Pažica and Sivá brada, that were created in the Pliocene up to the Pleistocene from mineral waters springing to the surface along the tectonic faults. Travertine mound of the Spiš Castle has, according to the degree of failing and karstification, probably originated similarly to the oldest mound of Drevenik, by the end of the Pliocene, while it is possible to suppose that the development of its upper travertine layers continued also in the Older Pleistocene (see Ložek). The youngest mound in the given region is the hill of Sivá brada with still active mineral springs.

Base of the travertine bodies is formed by the Palaeogene complex of the Central Carpathian flysch in transitory sandstone development where the sandstones and marly claystones alternate in an approximate ratio of 2 :1 (Fig. 9). Direction of flysch layers in the surroundings of Drevenik has a gentle inclination to SW and SSW, of approx. 5-10 °.

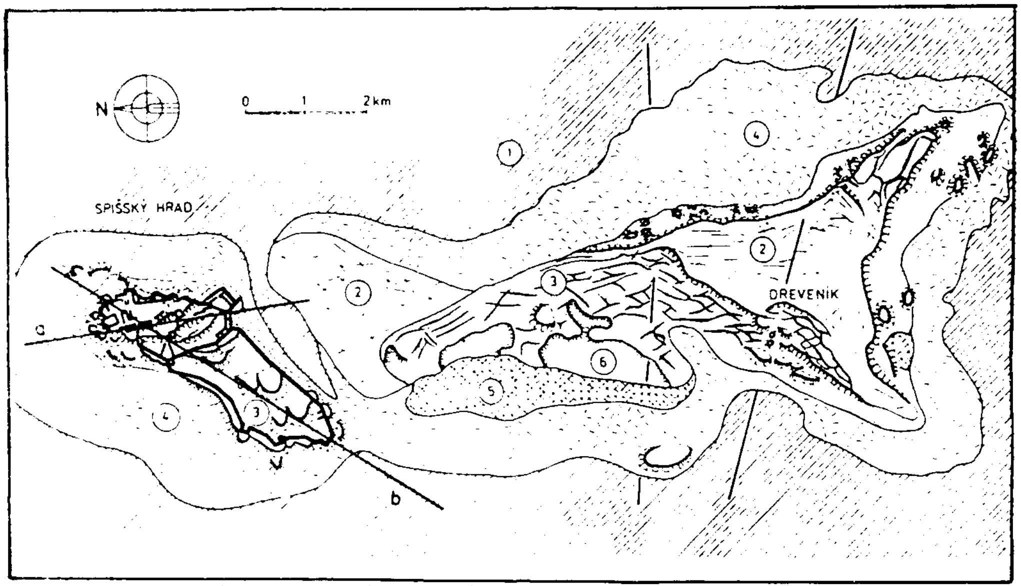


Fig. 8: Map of slope failures on the Spiš Castle Hill and the Drevenik Hill (Nemčok, Svatoš 1974) 1-sandstones and marly claystones of Central Carpathian Flysch (Paleogene), 2-traverine bodies, 3-block fields, 4-slope with individual blocks, 5-waste dumps, 6-travertine quarry.

Fig. 9.

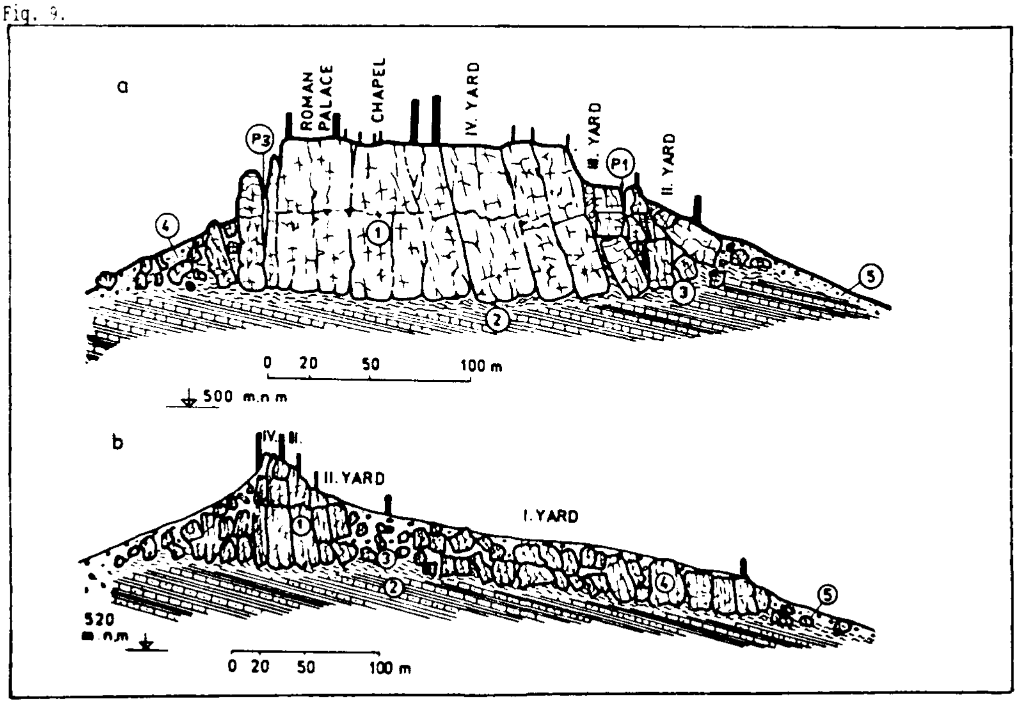


Fig. 9: Geological profiles of the Spiš Castle Hill (Fussganger 1985)
1-travertine (Pliocene-Pleistocene), 2-marly claystones and sandstones (Paleogene), 3-contact plastic creep zones, 4-separated blocks in block fields, 5- slope debris, P3-dilatometers fitted.

The original dome-shaped form of the travertine bodies has been destroyed to a considerable extent, so that today remained from former travertine mounds only denudation torso either in the form of rocky klippes (the Spiš Castle) or flat tables with steep and high marginal rocky walls (Dreveník). This destruction was caused mainly by gravitational subsurface creep movements of rigid travertine bodies on plastic base, along which also in lesser extent the karst, weathering and denudation processes took part. Also an intensive periglacial freezing of travertines, mainly in their contact with plastic flysch base had certain influence in the initial development of the creeping block failures as early as in the Pleistocene. Separation of travertine body into blocks during the periglacial climate probably emphasized also the extension of ice fill in the joints and cracks. According to geophysical research the thickness of the travertines in the Spiš Castle was orientatively found to be of 34-44 m and 29-33 m in the 2nd and the 1st courtyards respectively.

Travertine body of the Spiš Castle Hill is, generally speaking, strongly failed by a system of joints and cracks and the most striking ones are oriented to NW-SE while the less continuous, though also numerous cracks run also in the NNE-SSW direction. The biggest crack wide 0.5-1.6 m in NW-SE direction practically divides in halves the travertine mound with the central part of the castle and it also has provoked the origin of a cracky, so called Temná Jaskyňa (Dark Cave). According to the speleological exploration (Cebecauer, Liška 1972) the length of the cave is 60 m and its height is 30-35 m. Its dripstone formations are considerably weathered. Another cracky, similarly oriented underground space, though much smaller is under the western part of the 3rd courtyard. It is accessible directly from the 2nd courtyard but only in the length of 7-10 m, while there is an assumption that it runs also across the castle to both its margins. The oldest known cave is the so called Podhradská jaskyňa (Undercastle Cave) situated in the southern part near the castle entrance gate under the so called Perúnova skala (Perun's Rock).

From the above mentioned text it is obvious that the castle klippe is broken into blocks that slowly incline, sink and slide on their relatively plastic flyschoid base. The castle walls built on such mobile travertine blocks are in different ways failed, separated and shifted down the slope.

In order to observe the present development of the creep movements in 1980 in the Spiš Castle, 3 mechanical-optic dilatometers of the TM-71 type ( Fussganger 1985) were installed. The first apparatus was introduced in the open crack in the western side of travertine block, so called Perun's Rock, about 25 m northward from the entrance tower gate, second apparatus in the 2nd courtyard in the crack betwen one of transversal castle walls and the NW peripheral wall and the third apparatus was put between the separated towerlike travertine block and N margin of the castle klippe under the Roman palace (Fig. 9).

Results of measurements in the 1980-83 period in the first apparatus showed that the loose marginal block (the Perun's Rock) is shifting away from the crack in ESE direction at a velocity of 0,1 mm/year and simultaneously lifting by the same speed. Uplift on the measured side means though that the block on the opposite E side sets down in the space of the Undercastle Cave. According to the total perpendicular width of the crack (74 cm) failing above also the castle wall of the 2nd - 3rd interyard we can see that the found velocity of the creep movement is small at the present time.

According to the known historical data of the construction of the central upper parts of the castle in the years 1249-1270, i.e. ca 720 years ago the development of the crack to the present width should be corresponded by the mean block movement of 1,03 mm/year. Therefore it is possible to suppose that the essential component of the block movement in this place was the setting into the cave space that probably occurred in the form of faster jumps. It might have been caused also by an explosion of the castle powder-magazine under the castle tower during the fire on April 27, 1543.

Apparatus No. 2 (Fussgänger 1985) detected, that the 23 cm wide crack separating NW peripheral castle wall is widening by mean velocity of 1,13 mm/year in N-NW direction. There is an interesting date that the crack opening time into the present width of 23 cm at the measured mean velocity (1,13 mm/year) derived by means of reverse calculation gives the result of 203 years i.e. exactly the year 1780 when there was the last fire in the castle and it was not reconstructed any more and left abandoned.

Apparatus No.2 continues measuring of the movements up to the present time. According to the personal information of Ing. B. Košťák (Institute of Geology and Geotechnics, Czecho-Slovak Academy of Sciences, Prague) who has installed the measuring apparatuses, the crack widens gradually in northly directions by the velocity of 0,97 mm/year. Peripheral wall is rising relatively by 0,28 mm/ year, what is explained by its tilting.

Geologicaly very rapid movement of individual blocks have caused serious damages on the castle cbject. It caused the fall of certain peripheral castle walls, numerous cracks in the walls and twisting of supporting columns in the rooms below the citadel. Due to block movements one of the two bricklayed towers fell in the past, travertine blocks tilted together with walls and rooms in the eastern part of the interyard (Malgot et al, 1988).

Correction of the object, which is founded on moving blocks, is very complicated. It is impossible to solve this problem without a detailed mapping and documentation of all cracks, along which occurs the gravitational disintegration of the castle subsoil. It is necessary to allow dilatation in places, where gravitational failure takes place in the masonry. It would be useless to treat these walls, because they would fail again in time. It is technicaly possible to make a permanent treatment and completion on the Spiš Castle only of those castle parts which are founded solely on one block. For their protection it is possible to build from the outer side 2-3 stabilizing fulcrums.

A positive role will play also antiweathering measures, which are presently made there by the Enterprise Geological Survey Spišská Nová Ves. Indispensable are also jointing of the masonry and its strengthening by grouting. Shallow anchors and surface grouting are made where surface dropping off, crumbling and falling of fragments from the rock walls threaten the security of pedestrians.

## Locality No. 4: Hôrka-Ondrej

### Geomorphic setting of Hôrka-Ondrej (SE part of the Popradská Kotlina Basin)

Stankoviansky, M., Halouzka, R.

Locality No. 4, travertine mound in the cadastre of the community Hôrka-Ondrej is situated at the SE border of the Popradská Kotlina Basin, concretely in its part the Vrbovská Pahorkatina Hills, near the foot of the Kozie Chrbty Mts.

From the geological point of view the given part of the basin is built of the Central Carpathian flysh complexes (Paleogene) and the Quaternary sediments. Deep base is built of the Mesozoic formations of the Križna and the Choč nappes (limestones, dolomites and others).

Typical feature of the territory around the locality are numerous mounds bound on fault zone WNW-ESE direction, active in the Quaternary, above all in the youngest period of the Middle Pleistocene and in the Upper Pleistocene with manifestations in the Holocene, as well. The main fault is the Gánovce fault (mostly following the course of the Gánovský Potok Brook with numerous travertine mounds; parallel fault is the Švábovce fault, running through our locality (Hôrka-Ondrej); it is situated about 600-1000 m northward from the Gánovce fault. Travertine mounds in Gánovce are world wide famous for rich finding places of mammalian bones and fossil plants and especially of the finding of the Neanderthal man's brain casting - the man of the last Interglacial period.

Knowledge of the Quaternary mapping shows that the Poprad River flowed in direction to Gánovce and farther to ESE during formation of upper (III.) and main (II.b) steps of middle terraces, that means till the last sedimentation cycle of the Middle Pleistocene (till the younger Riss).

The Poprad River flowed probably (?) to the present Hornád River valley what would represent direction towards South, into the Danube drainage basin.

Shifting of the Poprad River to the present flow on NE (Poprad, Kežmarok and further toward the Dunajec River in Poland) is result of young tectonics.

More detailed information on the paleogeographic development of wider background of this locality can be found in the chapter on the Kozie Chrbty Mts (Locality No. 5).

## The Hôrka-Ondrej travertine mound - Biostratigraphic dating

Ložek, V.

The travertine mound in Hôrka-Ondrej, called Smrečányiho skala (Smrečányi's Rock) represents one of the small travertine bodies typical for the Gánovce area. Its depositional sequence has been exposed in an abandoned quarry where particularly solid heavy-bedded travertines were exploited so that only these parts of the deposits consisting of loose or thin-bedded tufas have remained preserved. Throughout the travertine sequence a small-sized Middle Palaeolithic industry occurs which is at present investigated by systematic excavations of the Archaeologic Institute of SAS showing in detail the structure of the travertine mound . The travertines are rather rich in molluscan shells and mammalian bones and teeth, which fact is of prime importance for the dating of this deposit as well as for the reconstruction of environmental conditions during the sedimentation of particular layers.

The travertine mound consists of 3 strata groups : the lower series is developed as thin-bedded travertines with semi-solid interlayers and thin humic horizons that are exposed in the entrance area. Molluscan shells are concentrated in humic horizons and predominantly belong to terrestrial open-ground tolerant species living also at present in dry segments of forming travertine mounds, e.g. at Sivá Brada or Banicka near Hozelec. More westerly these thin-bedded travertines grade into loose tufas with clay intercalations. Their molluscan assemblages are dominated by marshland species of open country, however, the presence of Vertigo moulinsiana /Dup./ in the basal layer documents that the complex in question formed under early interglacial conditions. The uppermost horizons of this series are exposed at the southern margin of the mound in the western part of the section and include a number of woodland (e.g. Acicula polita/Htm./) and xerothermic elements (e.g. Cepaea vindobonensis/Fer./) which are indicative of Interglacial climatic optimum.

The middle series of solid heavy-bedded white travertines has been preserved only as minor remainders in marginal parts of the mound. Formerly, in blocks separated by quarrying impressions of oak leaves /Quercus/ and fragments of interglacial snails incl. the index species Drobacia banatica /Rssm./ were collected. At the boundary between the lower and middle series on large bedding planes numerous impressions of Salix caprea and birch were exposed during archaeologic excavations.

The upper series is best preserved along the northern margin of the mound, particularly in the NW section. Its basal layer overlying immediately the compact travertines of the middle series consists of black clayey loam with a calcareous intercalation including numerous shells of Bradybaena fruticum /Mull./ and Euomphalia strigella /Drap./ indicating a parkland. This layer is covered by a sequence of loose tufas including in its lower layers a woodland assemblage of culminating interglacial with several index species as Drobacia banatica /Rssm./, Discus perspectivus /Muhl./ and Cepaea vindobonensis

/Fér./. The latter suggests that even during this woodland phase patches of open country were persisting. Towards the top this snail assemblage grades into a parkland fauna with Bradybaena, Euomphalia and Chondrula tridens /Müll./, the latter being a steppe element indicating forest-steppe environments.

The central part of the travertine body is developed as a spring cone consisting of periclinal beds of solid travertines strongly corroded by spring water. These were formerly covered by thick heavy-bedded travertines which were mined out. In the western and northern part of the mound there are deep kettle-shaped hollows filled up by strong brown lime-deficient clay consisting of sorted material coming from the Palaeogene bedrock. These features probably represent spring "craters" similar to those in Vyšné Ružbachy or in Liptovský Sliač, later filled up by spring mud. We might suppose that such infills formed themselves at least partly during the course of travertine formation.

The original surface of the travertine deposit has been preserved only in the lateral wall of the entrance area. Eroded travertines of the basal series here are covered by scree consisting of solid travertine boulders /deriving from the middle series/ with light brown loess-like matrix. This grades upwards into a yellowish loess-like loam including a pleniglacial molluscan fauna with numerous Pupilla loessica Lžk. and Succinea oblonga Drap. thus representing an equivalent of the youngest loess in lower-lying areas. The uppermost member consists of travertine scree with black rendsina matrix and a well developed deep rendsina soil at the surface. These Holocene strata include also a predominantly steppe fauna with abundant Chondrula tridens /Mull./. Woodland elements are poorly represented by Cochlodina cerata /Rssm./ only.

Composition of fauna as well as the intensity of destructional processes affecting the travertine body suggest that this deposit formed in one of the Young Pleistocene warm phases, probably during the Last Interglacial /Eemian/ representing thus an equivalent of the famous site of Gánovce in the vicinity.

## The Hôrka-Ondrej travertine mound - Archaeological dating

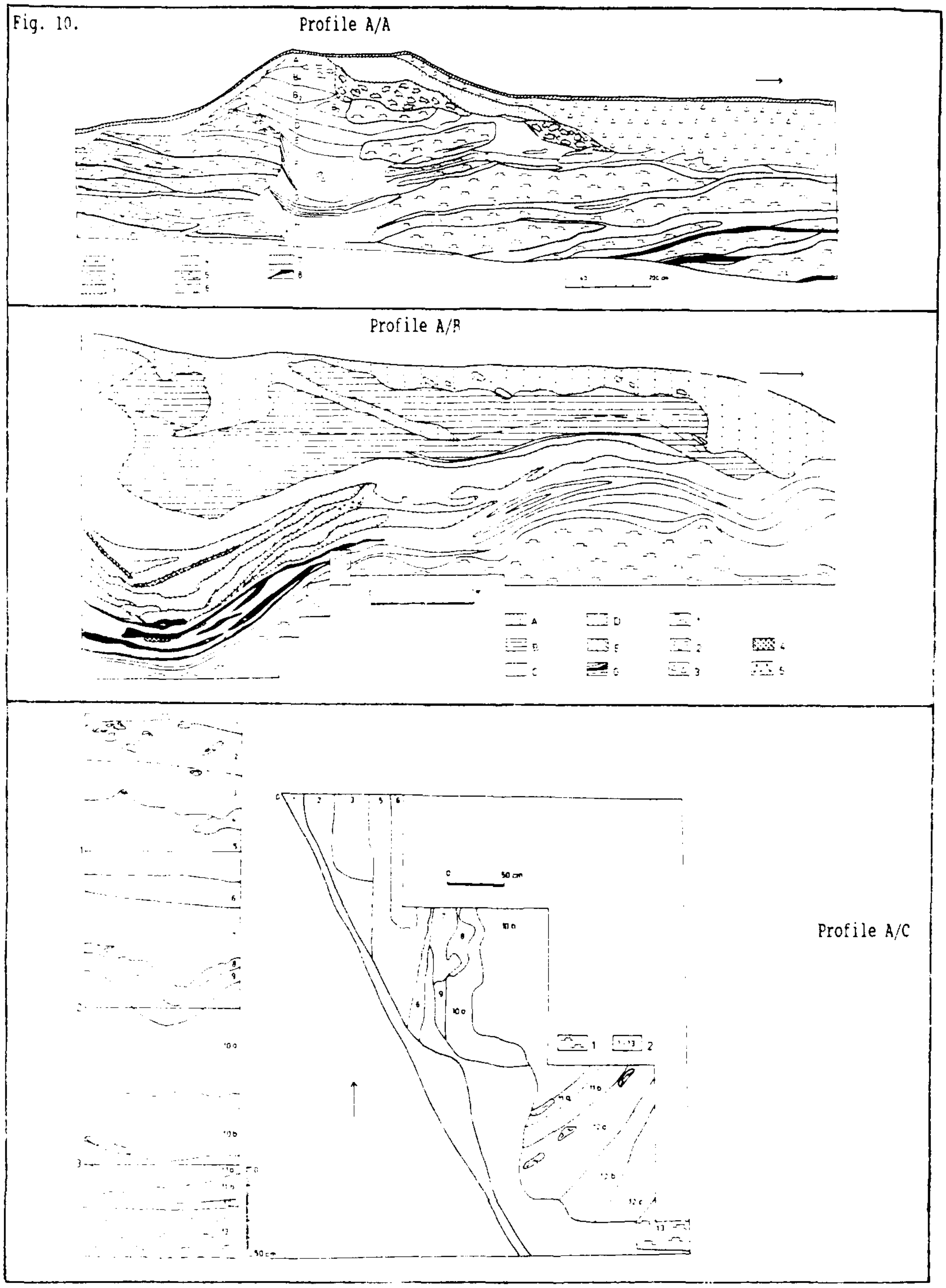
Kaminska, Ľ.

The first reconnaisance survey at Hôrka-Ondrej was done by Prošek and Vlček followed by a brief trial excavation of Bánesz and Barta in 1961.

The above surveys detected 4 (5) cultural layers with Mid-Palaeolithic instruments in one profile. Based on its fauna analysis the travertine was backdated to the culmination of the latest interglacial period (Riss-Würm, Eem). Sporadically documented was its settlement from the earlier Bronze Age by the people of the Otomani culture.

The locality was seriously damaged in the past by the quarry extracting firm travertine blocks. Relatively undamaged were left loose travertine layers and clayey sediments filling up the

Fig. 10.



Profile A/A

Profile A/B

Profile A/C

Fig. 10: Profiles of travertine in Hôrka-Ondrej (Kaminská 1992)
PROFILE A/A: 1-loamy layers, 2-travertine, 3-humus, 4-light grey loam with tiny pieces of travertine, 5-dark black loam with pieces of travertine, 6-dark grey loam with tiny pieces of travertine, 7-light brown loam with medium sized pieces of travertine, 8-gray black layers; PROFILE A/B: A-LAYER A, B-LAYER B, C-LAYER C, D-LAYER D, E-LAYER G-LAYER G, 1-travertine, 2-fragments of travertine, 4-burn down positions, 5-coals; PROFILE A/C: 1-solid travertine, 2-profile layers

depressions in the travertines, as well as the superposed covering layers.

A systematic archaeological excavation at Hôrka-Ondrej started in 1987. At present, works are under way in several places which made it possible to uncover relics from a relatively long period of time of travertine and clayey sediment formation (Fig. 10).

The most ancient documents testifying man's settlement in this locality come from the area of a fireplace uncovered under a travertine layer dating from the top interglacial period. They include quartz splinters and overburnt animal bones.

Later phases of settlement are documented by numerous finds of split stone industry in both travertine and clayey layers dating from the close of the Interglacial when the territory of the Spiš region had the character of a park-like forest-steppe landscape. The same time horizon, or one of its phases, can be attributed also to the other fireplace found.

The so far acquired split stone industry has a mid-Palaeolithic character. It was produced mostly from the local quartz. The splitting of the artifacts in this place is testified by numerous finds of quartz splinters and chips. Less used was radiolarite whose sources are not found in immediate vicinity of the locality. Chief types of this industry are scrapers of various forms (arched, straight, angular etc.). Those made from radiolarite often carry traces of planar retouch, especially of the bottom side. Other types of tools include points, however, more frequent are pointed splinters both retouched and non-retouched. In spite of some Late Palaeolithic types of tools (scraper, steeply retouched blade), the split stone industry from Hôrka-Ondrej can be associated with the Mousterien culture.

The latest finds discovered so far at the locality Hôrka-Ondrej date from the Early Bronze Age and belong to the subjects of the Otomani culture (Kaminská, in print).

## III. INFLUENCE OF NEOTECTONICS ON DEVELOPMENT OF RIVER NETWORK CHANGES IN THE LOW TATRA MTS AND THE PODTATRANSKÁ KOTLINA BASIN (Locality: 5)

### Locality No. 5: The Kozie Chrbty Mts (Hozelec)

Jakal, J.

The Kozie Chrbty Mts (Fig. 11) represent a striking asymmetric horst of very young age, in the south separated from the Low Tatra Mts by the Hranovnicka Priekopa Graben and in the north bordering with the Podtatranská Kotlina Basin (Sub-Tatra Basin). Its highest mount Filagória reaches 1255 m altitude, towards east it narrows and submerges under the Palaeogene of the Podtatranská Kotlina Basin in the part of Dúbrava (the Vikartovský Chrbát Ridge).

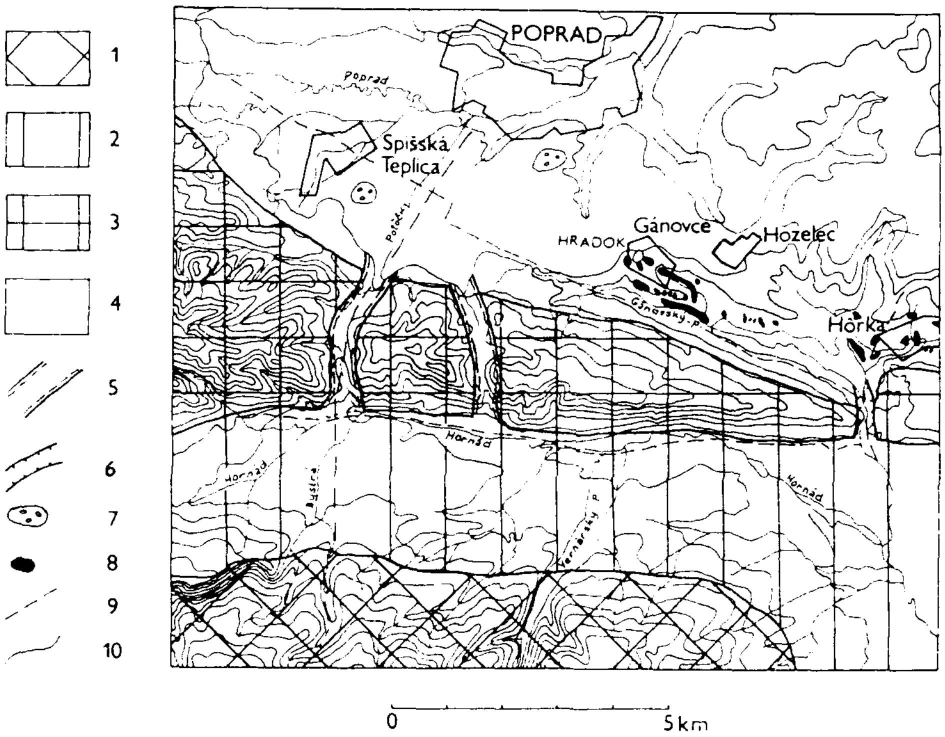


Fig. 11: Geomorphic sketch of the Kozie Chrbty Mts region
1.vaulted horst The Low Tatra Mts, 2.graben (The Hornádska Kotlina Basin), 3.horst (The Kozie Chrbty Mts), 4.morphotectonic depression (The Podtatranska Kotlina Basin), 5.old abandoned valleyes, 6.gaps, 7.finds of Upper Pliocene-Old Pleistocene gravel, 8.freshwater limestone mounds, 9.faults, 10.contour lines-interval 40 m

The territory of the Kozie Chrbty Mts was affected by very young tectonic movements, that evoked the change in organization of the river network and influenced the geomorphic development of the neighbouring regions.

The Kozie Chrbty Mts are subsequent mountain range built of the rocks of the Choč nappe. Rocks of melaphyre series (Carboniferous-Permiam to the Lower Trias) are prevailing, and especially melaphyres, porphyres, porphyrites, varied sandstones, quartizites, shales and arkoses are represented here. In the central and western parts of the Kozie Chrbty Mts appear also sandstones and dolomites of the Middle Trias.

From the geomorphic point of view the eastern part of the

Dubrava territory represents an unilaterally inclined horst towards north with strikingly steep southern and more gently inclined northern slopes. The ridge is cut by two old deep valleys (region of Kvetnica and Vysoká) that were drained in antecedent position by the brooks Bystrá and Vernársky Potok in the Upper Pliocene. These flows came from the Low Tatra Mts tended to the north across the present Hranovnicka Priekopa Graben along the horst valleys and flowed in the River Poprad. The change in the development of the river network was noted as early as in 1909 by Sawicki. The gravel alluvia of these rivers in the northern foothill of the horst in the region of Spišská Teplica found Roth (1937) and took them for Upper Pliocene to Middle Quaternary. Old gravels of the flows of the Low Tatra mountains in several places of the Podtatranská Kotlina Basin were described by Lukniš (1973). A typical example here is the profile in an former brick yard in Poprad with a characteristic low layer of strongly weathered tiny gravels coming from the Low Tatra Mts, containing melaphyres and Verrucano sandstones (Fig.12).

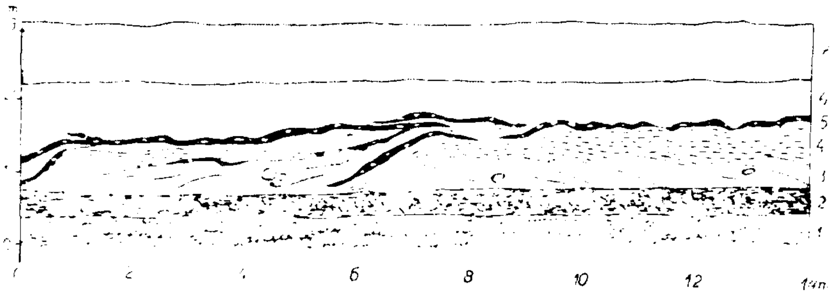


Fig. 12: Profile of the south wall of the Poprad brick yard (Lukniš 1973)
0-40 cm (layer 1): loamy gravel, prevailingly intensively weathered, tiny 1-7 cm, occasionally 20 cm; sandstone of verrucano with sandy disintegration; disintegrated melaphyres and porphyrites 40-80 cm (layer 2): dark to black clayey loam, colored by manganese compounds. 80-180 cm (layers 3-4-5): loamy-clayey solifluctioned light yellow brown loess loams with round stones of vein flints (3), darker solifluctioned grey brown loess loam with solifluctioned intercalations of clayey loam and flysch rocks fragments (4), uneven surface of layer dragged to higher layers. 135-180-220 cm (layer 6): loess loam with scales of mica with indication of startification. 220-310 cm (layer 7): recent soil

Both abandoned valleys running across the horst were here during the Quaternary probably witnesses of such an intensive sink of the Hranovnicka Priekopa Graben and uplifting of the horst of the Kozie Chrbty Mts along the faults of the subsequent direction that destroyed the old consequent river network on the northern slopes of the Low Tatra Mts. Younger rivers network with subsequent axis of the River Hornád adapted to the younger tectonic forms was created (Lukniš 1973).

In the following geomorphic development stage the Gánovsky Potok Brook formed along the transversal fault a transversal valley in eastern part of the horst. It proceeds by headward erosion through the northern margin of the horst to the Poprad drainage basin. It captured the little brook flowing from the Kvetnica Valley. In the Holocene stage of vertical erosion the

Gánovský potok Brook deepened its bed by more than 10 m in what was once a flat watershed.

Bottom of the Hranovnícka Priekopa Graben where the Gánovský Potok Brook, flows in lies 100 m lower than the bottom of the Podtatranská Kotlina Basin where by headward erosion it penetrates to the flat watershed between the Baltic and Black Seas drainage basins. Capture of the River Poprad might have meant in further development some striking changes of the river net in the Podtatranská Kotlina Basin.

Northly from the monoclinal horst Dúbrava manifest striking longitudinal fault lines of WNW-ESE direction and transversal NNE-SSW faults dissecting the Palaeogene bottom of the Podtatranská Kotlina Basin into a mosaic of smaller blocks. There are numerous mineral springs bound to these faults, and fresh water limestones in the form of travertine mounds have deposited here. They are Quaternary, most frequently Riss-Würm to recent travertines with well preserved rests of fauna and flora and archaelogical artifacts.

Travertine mound Hrádok in Gánovce (originally a mound 15 m high , diameter 120 m) is known for the finding of the casting of the brain cavity fill of the Neanderthal man.

Comparison of the flora of the Gánovce travertine and the Pod Borom peat bog lying on the Riss terrace with the use of palynological analysis (Krippel 1961) shows the similarity of flora developing during the whole Riss-Würm Interglacial that has preserved in both localities. Presence of pollen of Juglans that have never grown in this region during the Holocene and the absence of the pollen of beech that appeared here in the Holocene, facilitate the age classification of the peat bog and the age of the Gánovce travertine formation into the Riss-Würm Interglacial.

The solid travertines are mostly extracted. It was used as a decorative and building material.

## 2nd excursion day - Saturday, June 20

## IV. DATING OF GLACIFLUVIAL LANDFORMS AND DEPOSITS IN THE FORELAND OF THE TATRA MTS - continuation. (Localities: 6a, 6)

### Locality No. 6a: Nová Lesná. Glacifluvial sands of the valley of the Studený Potok Brook

### Stratotype locality of the Nová Lesná stage and beds (? Biber).

Halouzka, R.

This locality was a new large sandpit above Nová Lesná in the seventies. Locality lies in the foreland of the High Tatra Mts within the sedimentation reach of the Studená Dolina Valley, on the right bank of the Studený Potok Brook in altitude 825 m.

The section of the new sandpit was exposed in thickness of 10-12 m and displayed a sequence of loamified sand and gravel (mostly fractions approx. 1 mm and 2-5 mm), with a subordinate amount of minute gravel (approx. 1 cm fraction), locally with rare pebbles of medium-sized gravel (2-5 cm in diameter), and quite sporadically with coarse grained pebbles (7-10 cm or, in the case of blocks, up to 30 cm in diameter). Granitoid rocks largely predominate, although quartzites and other rocks also occur. The medium and coarse grained gravel fraction, nearly always consisting of granitoids, is completely weathered and disintegrated. The sediments are compact and a little cemented.

| strati-graphy | | ALPS: | | TATRA MTS.: Glaciations: | Glacial: | Chronostratigraphic / Lithostratigraphic units |
|---|---|---|---|---|---|---|
| Pleistocene | Middle | Riss | Late | Rakytovec (Penultimate - P1) | $R_B$ | Rakytovec stage (Rakytovec moraines Beds; gf gravel accum.) |
| | | | | Štôla ((Maximal-MX) | $R_A$(max.) | Štôla stage (Štôla moraines Beds; of gravel accum.) |
| | | | Early | Smokovec (Old - O) | M | Smokovec stage (Sm.moraines Beds; Vavrišovo sandy gravels Beds - gf) |
| | | Mindel<br>Günz | | - glaciation | -glacial | Gerlachov-Východná stage (Gerlachov-Východná gravels and sands Beds-gf) |
| | Old | Donau | | - glaciation | -glacial | Hybe stage (Hybe sand-gravels Beds-gf |
| | | Biber | | - ? glaciation | -glacial | Nová Lesná stage (Nová Lesná sands Beds - ? gf) |

Tab. 2: Survey of pre Würm sediments of the Tatra Mts (by Halouzka 1990, 1991 and in:Nemčok et al.1991)

The sediments of this accumulation have been found with thickness of 5,8 m and lying on dark brownish-grey Paleogene shales up to a distance of 1 km from the locality. In the new sandpit area the sedimentary conditions are the same as described above, only sandy-gravel sediments are thicker.

These sediments are interpreted as glacifluvial oldest accumulation ( Lukniš 1968, 1973a and others) and stratigraphically these are ranged ( Halouzka 1990, 1991 in print, in Nemčok et al. 1991) to the earliest Pleistocene (? Biber). That is stratotype locality of the so-called Nová Lesná sand beds, which are the base of Tatra Pleistocene.

Sedimentary petrographic characteristics (by Horniš):

Grain size: relatively sorted sediments, with a portion of sandy and silty fractions making up more than 50 %.

Petrography (pebbles): gravel consists of granite. Pebbles are well worn in fractions over 30 mm and mostly fragmentary in finer grained fractions, with abundant isolated quartz grains.

Heavy minerals: opaque minerals are dominant; apatite and minerals of the epidote-zoisite group are abundant. Chlorite,

amphibole, biotite, and zircon are subordinate.
[Compiled according Halouzka 1979; modificated].

## Locality No.6: Vavrišovo. Glacifluvial gravel of the Belá River

## Stratotype locality of the Vavrišovo sandy gravels beds (Mindel).

Halouzka, R.

The locality lies in the foreland of the West Tatra Mts, in front of the mouth of the Jamnická-Račková Dolina Valley and on the right side of the Belá River in altitude 735. The exposure displays a thick sequence of glacifluvial gravel forming a terrace accumulation of the former confluence region of the Belá River with the Račková Brook, which drains the Jamnická-Račková Dolina Valley.

The exposure shows a section about 14 m high in the gravel sequence: sandy to partly loamified gravel of various grain size, mostly to coarse and very coarse grained or boulders, particularly with blocks (averaging 40 cm and rarely 60-70 cm in diameter) in lower portions. Granitoid rocks absolutely predominate, forming especially glocks and being followed by less abundant crystalline schists, various quartzite, and brown sandstone. Both granitoids and crystalline schists as well as sandstones are sometimes strongly weathered, especially in the section's lower part.

In the gravel sequence of the exposure lies about 10 m thick weathering horizon which contains more clayey, completely weathered granite and black Fe-Mn spots. This horizon indicates a warm oscillation in the gravel accumulation. The lower part of the gravel sequence is more weathered than the upper one.

The gravel accumulation base (i.e. approximately 728 m a.s.l.) lies some 26-30 m above the level of the the Belá River (Fig. 13 ). The thickness of gravel in the section's terrase plain may attain a value of up to 35 m. This doubled gravel accumulation is ranged to the Mindel (Gross et al. 1978, Halouzka in Gross et al. 1980, Halouzka 1979).

Sedimentary petrographic characteristics (by Horniš):
Grain size: very poorly sorted, sandy and fine fractions very subordinate.
Petrography (pebbles): various composition - granite, quartzite and silliceous sandstone; metamorphic rocks include phyllite and metaquartzite. The coarsest fraction (over 30 mm) contains well worn pebbles; only granites (partly weathered) are semiangular in places. Fine fractions are dominated by fragmentary grains prevailing granite; the finest fractions contain isolated quartz grains.
Heavy minerals : opaque minerals predominate. Amphibole and apatite are abundant, followed by minerals of the epidote-zoisite group. Biotite, zircon, rutile and chlorite vary from subordinate to sporadical.
[ Compiled according Halouzka 1979; modificated].

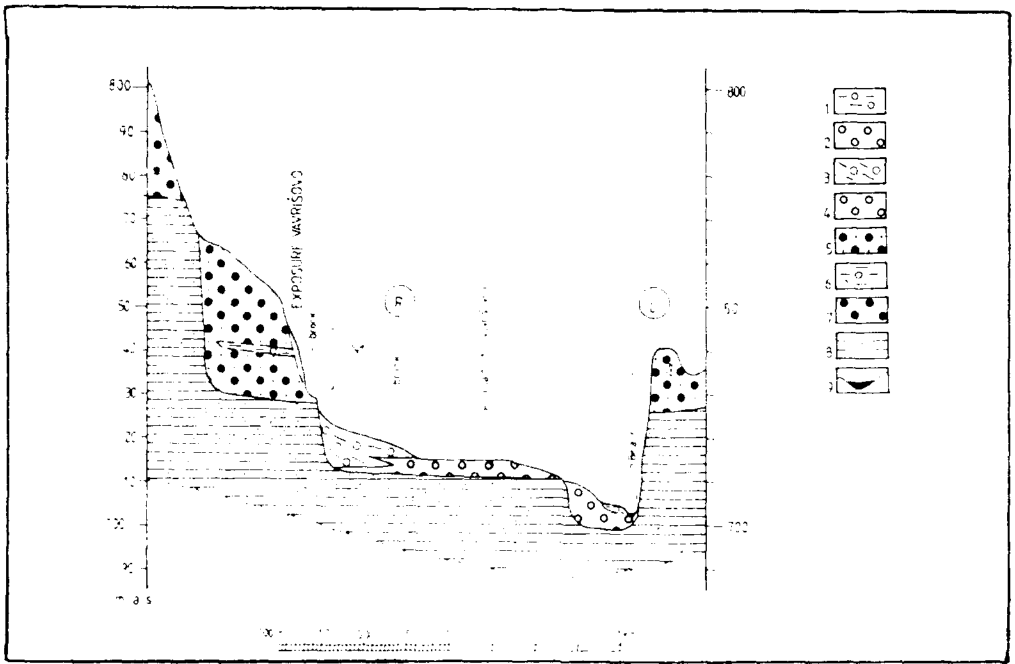


Fig. 13: Geological section through the Bela River Valley near Vavrišovo (Halouzka 1992)
1-fluvial flood-plain sediments (redeposited loamy gravels to bouldery *gravels*), *Holocene*; *2-glacifluvial* sandy gravels to bouldery gravels (bottom accumulation), Wurm; 3-alluvial fan accumulation (loamy-sandy gravels), Riss Late; 4-glacifluvial sandy gravels to bouldery gravels (terrace accumulation), Riss Late; 5-glacifluvial complex of weathered sandy gravels to bouldery gravels (doubled terrace accumulations), Mindel; 6-clayey and silty sands with strongly weathered gravels (pebbles), Mindel (Intermindel); 7-glacifluvial complex of strongly weathered gravels (pebbles) to bouldery gravels, Gunz; 8-Paleogenic flysh deposits of Zuberec-Formation:claystone (predominating) and sandstone (upper Eocene, upper Priabonian); 9-river channel

## V. MORPHOGENESIS OF AMPHITHEATRE-LIKE DEFORMATION ON THE SOUTHERN SLOPE OF THE LOW TATRA MTS (Locality: 7)

### Locality No. 7: Čertovica Seddle (The Low Tatra Mts)

### Geomorphic characterization of the Low Tatra Mts with regard to amphitheatre-like deformation

Stankoviansky, M.

The Low Tatra Mts, situated in central Slovakia, represent the second highest mountain range of Czecho-Slovakia (2043 m a.s.l.). It has the largest area of the so-called core mountains within the West Carpathians (about 1 240 $km^2$). The lenght of mountains in the W-E direction is 75 km, maximum width is 25 km. The Low Tatra Mts is divided into two geomorphic subunits: the

Ďumbier Tatra Mts (higher western part) and the Kráľova Hoľa Tatra Mts (lower eastern part).

From the morphostructural viewpoint, the Low Tatra Mts represent a positive morphostructure - vaulted horst, with a fold-block structure. It is bordered by negative morphostructures in the north and south, and by positive ones, but relatively less uplifted, in the west, east and north-east.

Values of positive vertical neotectonic movements in the Low Tatra Mts, proceeding by stages and differentially, range from 900 to 2 000 m (Mazúr, Kvitkovič 1980). The original morphostructure had been epicyclically destructed by subaerial processes from its foundation after each renewal of the tectonic movements. In connection with the intensive destruction of the relief, remnants of the planation surfaces developing over periods of relative tectonic inactivity can be found only exceptionally. The remnants of the so-called middle-mountains level from the Pannonian are the best preserved; by Mazúr (1965) it is possible to find them on the top parts of lateral ridges of about 1 200-1 400 m a.s.l. In the north-east and southwest remnants of this level drop to about 900-1 000 m a.s.l.

Evidence for uplift of the Low Tatra Mts during Pleistocene can also be found, among others, in the parallelism of 9 horizontal cave levels in the Demanová Valley cave system with the Vah River terraces (Droppa 1972), in breaks on valley slopes and in the presence of terrace remnants in several valleys. The present-day vertical movement of the Low Tatra Mts by Kvitkovič, Plančár (1975) ranges from +0,5 to +1,5 mm annually.

The fundamental geological building unit in the Low Tatra Mts is its crystalline core (Proterozoic metamorphic and Variscian granitic rocks) in asymmetrical position. The core is uncovered in the region of the central ridge as well as along the southern slopes of the mountains. In the north and north-west the crystalline core is overlain by Mesozoic sedimentary rocks of the Tatride unit and nappes (predominantly limestones, dolomites, marlstones, shales, quartzites and interlayers of melaphyres).

The relief of The Low Tatra Mts has a massive character. Its fundamental morphological element - "spine", is represented by the central ridge. From the central ridge to the north and south lateral ridges (forks) extend, separated by deep valleys. Hence, the ground plan of the mountains has a "riblike" character. From the relief types, according to classification by Mazúr (1980), alpine relief, glacio-alpine and above all fluvially dissected forked relief prevail.

Both the alpine and glacio-alpine relief types are bound to crystalline structures, characteristic by weak lithologic influences. This relief type can be found in a substantial part of the central ridge as well as in the upper portions of some of the forks.

The fluvially dissected forked relief is marked by two different varieties, expressing different lithologic-structural conditions. The forks in the southern part of the mountains as well as upper parts of the northern ones near the central ridge, built of crystalline rocks, are due to weak lithologic influence smoothly modelled, rounded, locally flat. On the contrary, the forks in the northern part of the mountains on the nappe-fold structure are (in connection with strong lithologic influence) marked by the sharply modelled landforms, above all by structurally conditioned monoclinal crest and hog-backs, which are bound to limestone - dolomitic formations (Stankoviansky 1984).

Satellite images revealed an extensive deformation on the southern slopes of the Low Tatra Mts. This amphitheatre-like deformation is situated in the crystalline terrain.

The territory was geologically mapped on the basis of the documentation of exposures and results of mining and bore holes. Recently also an ample geological research was carried out here. Interpretation of the result of geophysical research of deeper geological structures is subject of discussion. Reconstruction of the development the deeper lithosphere during the Alpine orogenesis and in the case of crystalline also pre-Alpine stages of geological structures are taken as a basis.

We are presenting you for discussion two interpretations of the investigated phenomenon. Both interpretations are rather speculative.

## Interpretation of investigated phenomenon as a gravity nappe

Pospišil, L.

During the Tertiary period the south western part of the Low Tatra Mts had presumably the character of a horst whose relatively fast uplift had been caused by active deformations

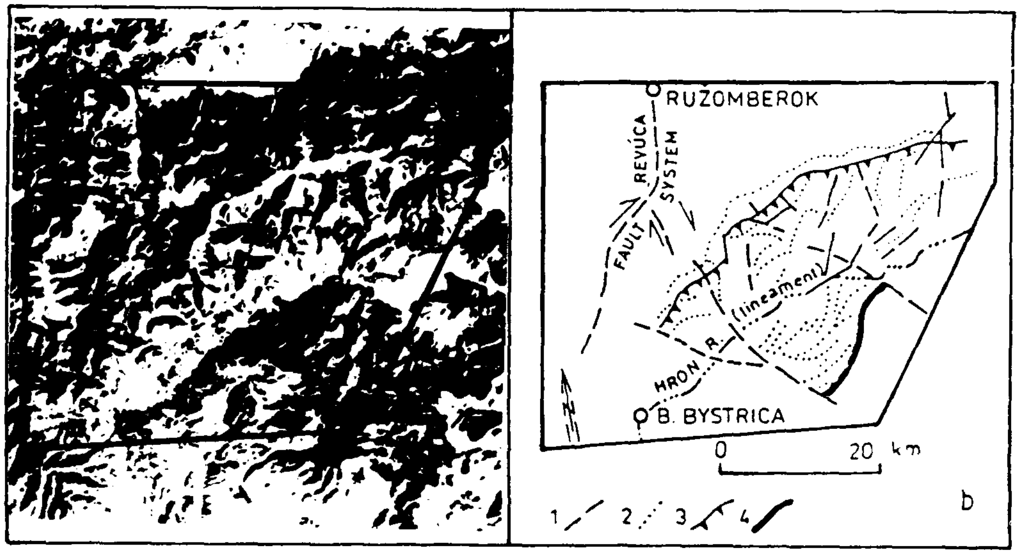


Fig. 14: Area of the southern slopes of the Low Tatra Mts
a) Part of the Landsat image
b) Interpretation of structural elements. 1-faults and fracture zones, 2-ridge axis, 3-gravity nappe scarp, 4-boundary of the gravity nappe relict

within the fundament (Fig. 14). Complicated faults or fracture systems of great diversity (Revúca, Hron, Mýto-Tisovec tectonic systems), many of them of the strike-slip character, the expressive dissection of the relief, and numerous geodynamic features, outline the intricate geologic environment and complicated Late Alpine development of the whole structure.

Author ascribes this structure with a character of extensive deformation to a group of gravity nappes.

## Analysis of geodynamic processes

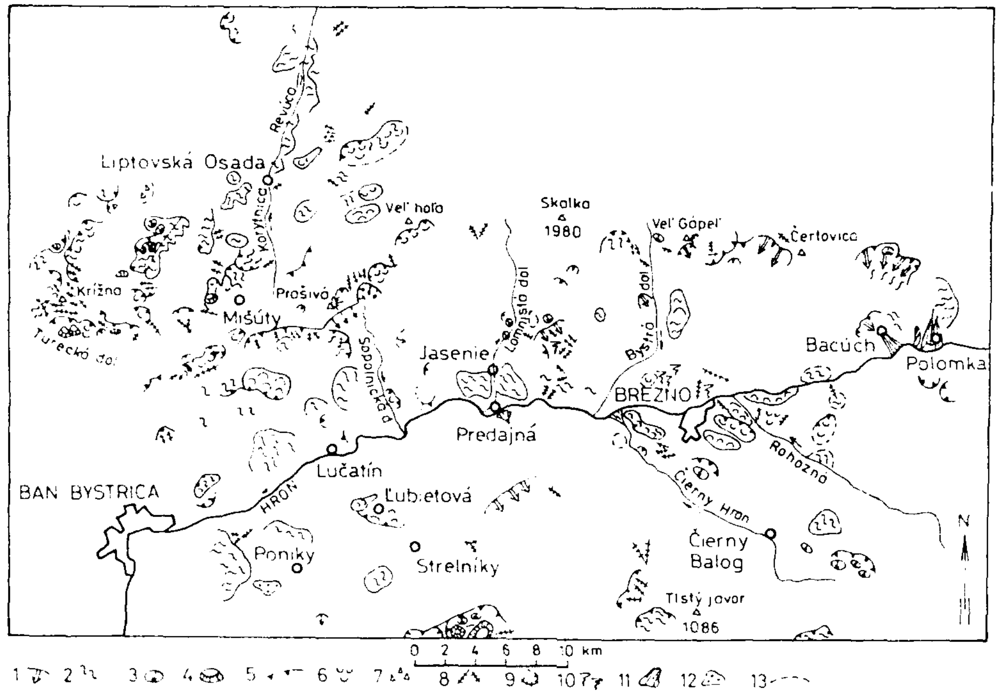
Important secondary factors demonstrating the dynamics of the geologic environment are the geodynamic phenomena. The following were object of interest (Fig.15): 1. Slope deformations (creep, slide and fall gravity deformations, taluses, block disintegration and block fields), 2. Erosion elements (gully and sheet erosion, erosion edges), 3. Surface karst phenomena, 4. Forming of proluvia, 5. Weathering. Results were completed, with local slope failures (after Nemčok, 1982).

## Analysis of faults and fractures

The Late Alpine movements (Sarmatian to Quaternary) resulted in the general uplift of the West Carpathians with expressive differentiation of movements of individual blocks along transcurrent faults, mainly of the NE-SW direction. This movement in the principal direction of horizontal stresses from the south resulted in the motion of the central and eastern part of the West Carpathians to the north and northeast. Two areas with different uplifting-subsiding tendencies were distinguished in the studied region: 1. the subsiding Hron River valley from ENE to WSW following the past-Palaeogene megasynclinal depression and the adjoining depressions, 2. the elevation area of the Low Tatra Mts and Veľká Fatra Mts and the northern part of the Veporske Vrchy Mts. The fault and fracture zones are best characterized by the configuration of the drainage systems, sporadically facetted slopes. The principal direction of prevailingly linear tectonic zones, dislocations and shorter fault-fracture elements were interpreted and distinguished (Fig.16). (Fig.17 represents combination of Fig. 15 and 16).

The most important faults are considered the following (Fig. 18 ):the Revúca fault zone (NNW-SSE) with dextral slip character, the Hron River fault system (WSW-ENS) with dextral slip character and large seismicity and the Mýto-Tisovec fault system. All the tectono-structural features are indicated by the characteristic valley network pattern, spring lines, erosional features, morphostructures, etc.

It is rather impossible to explain identified structure of gravity nappe in the whole time and space development with present knowledge level. It is possible though to point at some influences that had to exist in the origin of such structure. Paleogeographic analysis (Fig. 19) of the Tertiary development showed, that the uplift tendency of the whole region in relation to its surroundings until the Oligocene . This movement though pulsative had presumably in its last stage an enormously rapid


Liptovská Osada
Revúca
Korytnica
Veľ hoľa
Skalka
1980
Veľ Gápeľ
Čertovica
Križno
Prošivô
Mišúty
Turecká dol.
Sopotnica
Lomnistá dol
Bystrá dol
Jasenie
Bacúch
Polomka
BREZNO
Predajná
Rohozná
Lučatín
Čierny Hron
BAN BYSTRICA
HRON
Ľubietová
Čierny Balog
Poniky
Strelníky
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1086
N
0 2 4 6 8 10 km
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Fig. 15.↑

↓ Fig. 16.

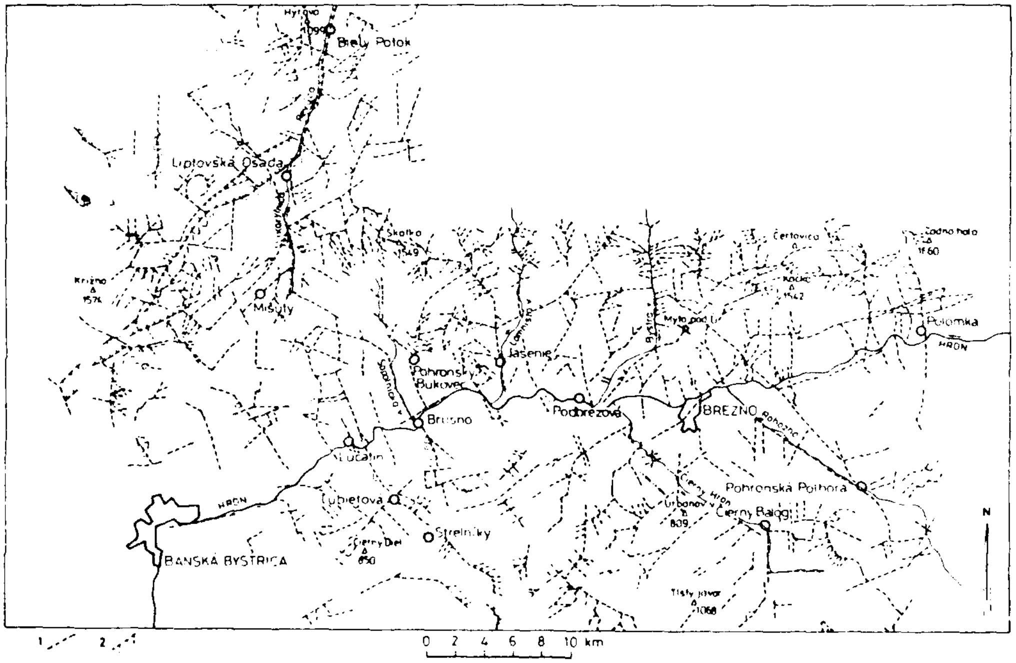
Biely Potok
Liptovská Osada
Korytnica
Križno
Mišúty
Sopotnica
Pohronský Bukovec
Jasenie
Brusno
Podbrezová
Bystrá
Čertovica
Polomka
HRON
BREZNO
Rohozná
Pohronská Polhora
Čierny Hron
Čierny Balog
Lučatín
Ľubietová
Strelníky
BANSKÁ BYSTRICA
HRON
Tlstý javor
N
0 2 4 6 8 10 km
1 2

Fig. 15: Analysis of geodynamic phenomena (Pospišil in Halmešova et al. 1990)
1-slope deformations general, 2-talus creep, 3-block rifts,block fields, 4-individualized blocks, 5-scarps, 6-landslides, 7-alluvial fan, 8-gully erosion, 9-erosion edge, 10-sheet erosion, 11-proluvial cones, 12-sinkholes,karst valleys, 13-open cracks

Fig. 16: Tectonic analysis of the southwestern slopes of the Low Tatra Mts (Pospišil in Halmešová et al. 1990)
1-faults and fractures, 2-faceted slopes

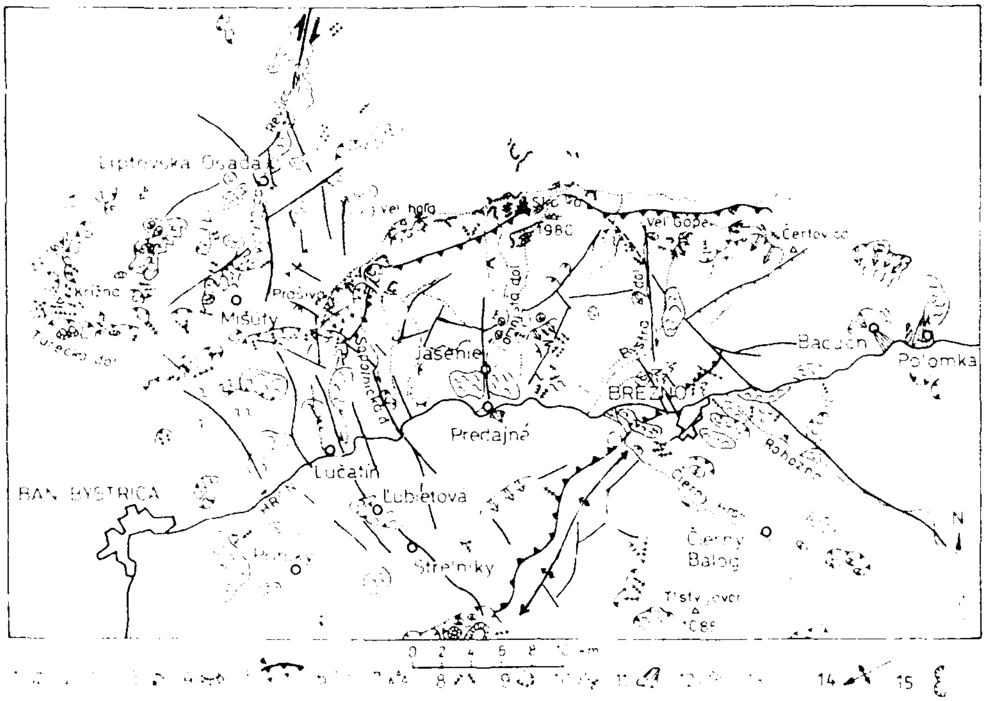

Fig. 17: Tectonic map completed by dynamic phenomena in the southern slopes of the Low Tatra Mts area (Pospišil in Halmešova et al. 1990)
1-13-see fig.16; 14-axis of anticlinal zone, 15-local slope deformation analyzed by Nemčok 1983

course. Decisive role here was perhaps the one of horizontal movements of the Carpathian blocks along the faults in the directions of SNS-WSE and NE-SW (J. Nemcok 1984, L. Pospisil et al. 1985) that are observable also in satellite images. The Lower Miocene age of these movements responds to the dynamic conditions that existed at that time and might have continued minimum until the Sarmatian.

In the sense of denudation chronology (conservation of tiny rests of middle-mountain level from Pannonian (Mazúr 1965) the age of gravity nappe is derived as Pre-Pannonian. The Pliocene sediments in lakes of the Paleo-Hron River valley (Nemčok 1957) have originated already after the partial consolidation of gravity nappe. The fact, that planation surface rests preserved

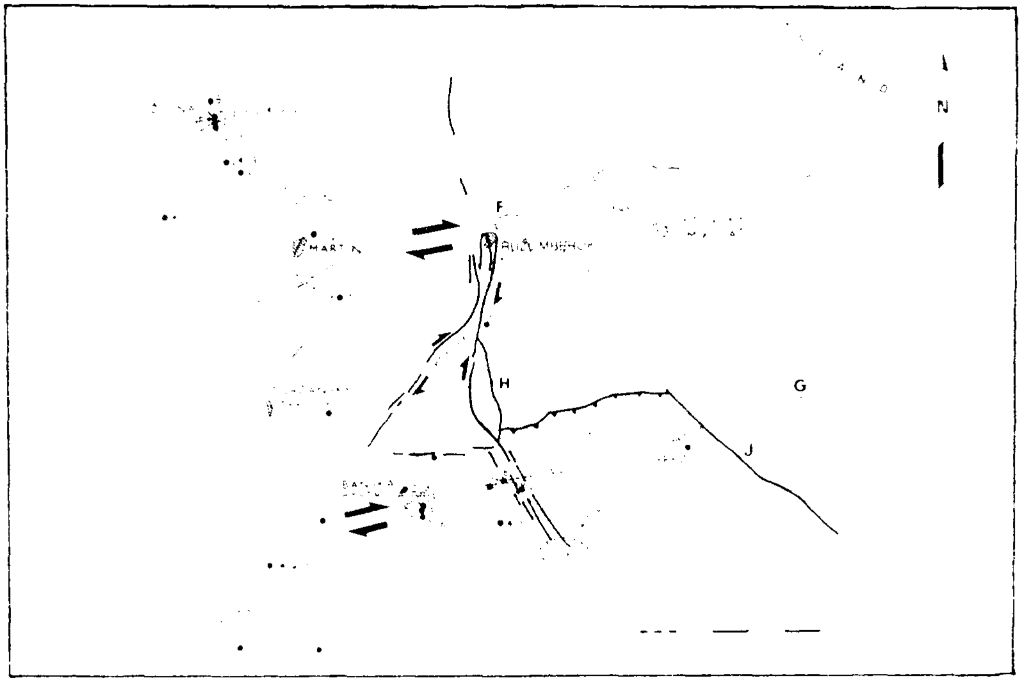

Fig. 18: Dynamics of the fault systems of the gravity nappe area and its surroundings (Pospisil in Halmešova et al.1990)
1-gravity nappe (Klinec et al. 1985), 2- central zone of Poľana volcanoes, 3-wrench fault of the first order, 4-faults, 5-direction of the first order sesmic energy attenuation, 6-eartquake epicentres,

in very different altitudes in the mountains indicate activity of fault systems until the Quaternary, and that is testified by the piracy of the Jaseniansky Potok Brook.

Seismotectonic and magnetotelluric data

The Hron tectonic zone (Klinec et al. 1985) is of essential importance in the formation of the gravity nappe. The earthquake occurrences along the Hron tectonic zone give evidence that the boundary is active even today. In the section between the towns of Banska Bystrica and Brezno, bound by the Revuca and the Myto-Tisovec fault (Fig. 20a ), the focal depths reached 10 km. Based on the fault plane solutions, the character of movements was found to be horizontal displacement (Pospisil et al. 1985) and it can be assumed that it was a right-lateral strike slip.

The new magnetotelluric data on transcarpathian profile 2T (Varga, Lada, 1988, Hajdova et al. 1990) provide a picture completely different from the geological so far assumed (Fig.20b ). In that way the new data and criteria for verification of the gravity nappe and the Hron lineament were gained.

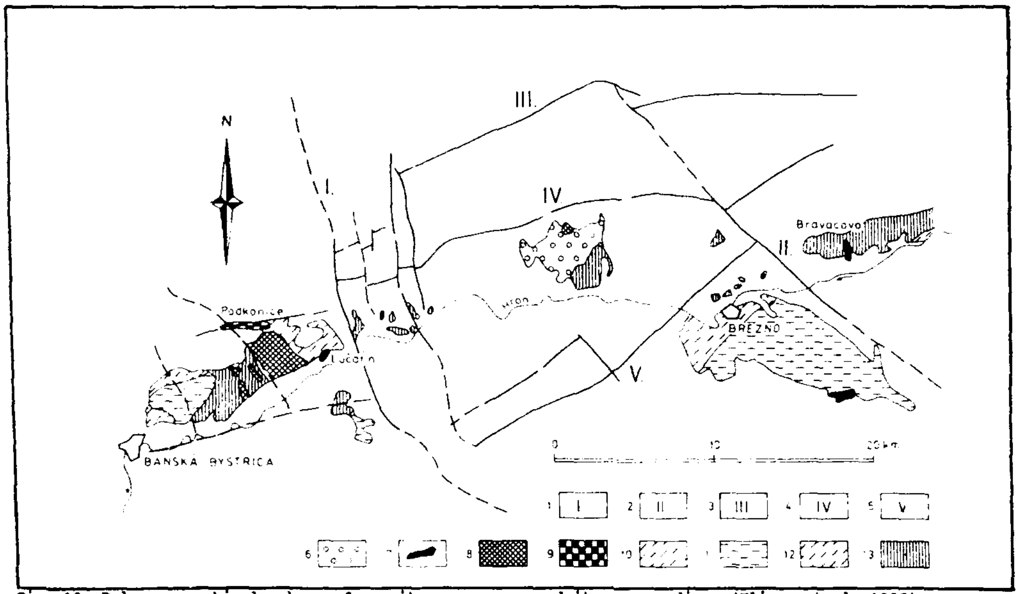

Fig. 19: Paleogeographical scheme of gravity nappe area and its surroundings (Klinec et al. 1985)
1-the Revúca fault system, 2-the Mýto faults system, 3-the Low Tatra Mts fault system, 4-the Hron River fault system, 5- the Čertovica fault system, 6-the Vajsková conglomerates, 7-sediments of motley series (the Polhora development of Paleogene, the Pre-Lutetian age), 8-dolomitic conglomerate facies, 11-claystone lithofacies, 12-regressive facies of the Oligocene (the Upper Hron Valley development of Paleogene, Lutetian-Oligocene), 13-gravel (Pliocene)

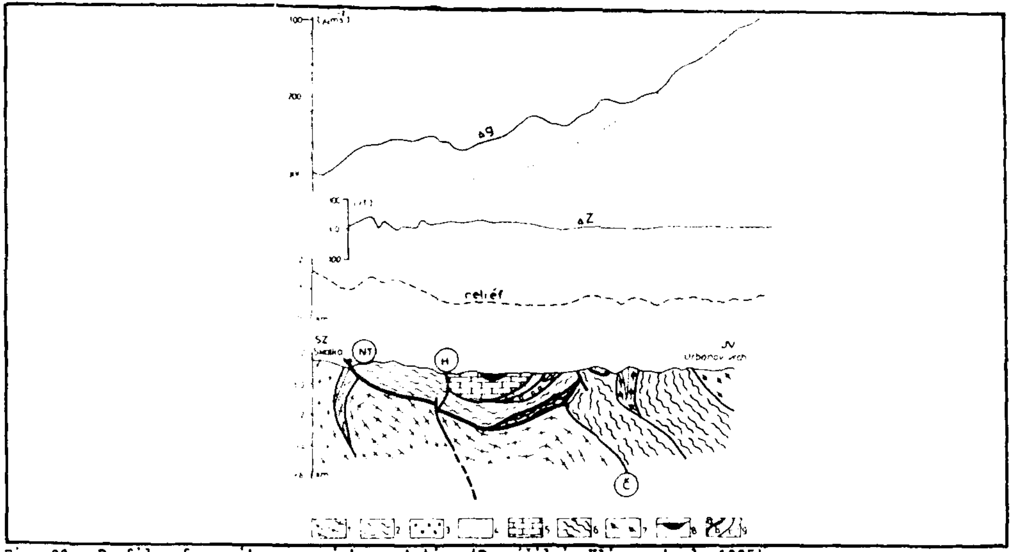

Fig. 20a: Profile of gravity nappe interpretation (Pospišil in Klinec et al. 1985)
1-granitoids, 2-crystalline schists, 3-sandstones,conglomerates,rhyolites (Permiam), 4-quartzites and carbonates of the lower tectonic unit, 5-carbonates and melaphyres of the upper tectonic unit, 6-mica schists,amphibolites, 7-gneisses,migmatites, 8-the Vajsková conglomerates, 9a-basement of the gravity nappe, 9b-dislocations of higher order, 9c- dislocations of lower order, NT-the Low Tatra Mts fault system, H-the Hron River fault system, Ć-the Čertovica fault system

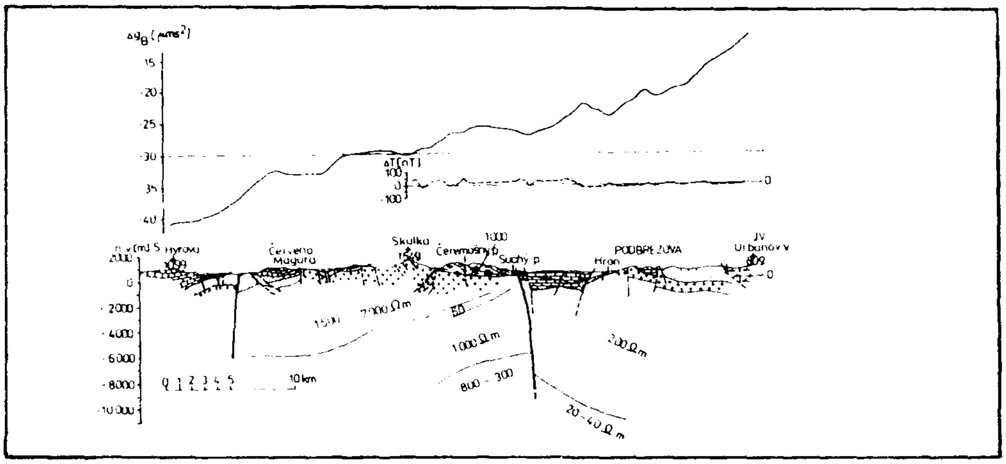

Fig. 20b: Geological cross-section through the Low Tatra Mts with results of geophysical investigations (Varga,Lada 1988, modified by Pospišil)
$\Delta g_B$-gravity anomalies curve, $\Delta T$-magnetometric anomalies curve, ohmm-geolelectric resistivity values

## Interpretation of investigated phenomenon as a near fault deformation

Ondrášik, R.

In contrast with the above quoted opinion the author (Ondrášik 1990) considers this amphitheatre-like deformation with scarps (similarly to other in the Low Tatra Mts and in other parts of the West Carpathians) as a near fault deformation related to the stress relics and extension of the upper crust since the Middle Miocene. As a consequence the movement of the upper crust of the Inner West Carpathians along the inclined discontinuity zones and the linked listric faults took place (Fig. 23). Inclined discontinuity zones had originated during the overthrusts in the preceding stages of contraction (Upper Cretaceous to Lower Miocene). Crystalline nappe that is above considered as gravity one can be taken for autochthonous mantle of granitoids or it might be an overthrust.

Extension in the upper part of lithosphere with manifestation of so called germanotype tectonics is related to asymmetrical vaulted uplift of the Inner West Carpathians from Middle Miocene as the majority of geologists and geomorphologists agree. The most uplifted is the outer margin of the Inner West Carpathians, and the least uplifted is their inner margin. The varied regime of uplift and the related changes of horizontal tension in various depths are probably balanced out by the plastic deformations in the zone of lower seismic velocity in the depth

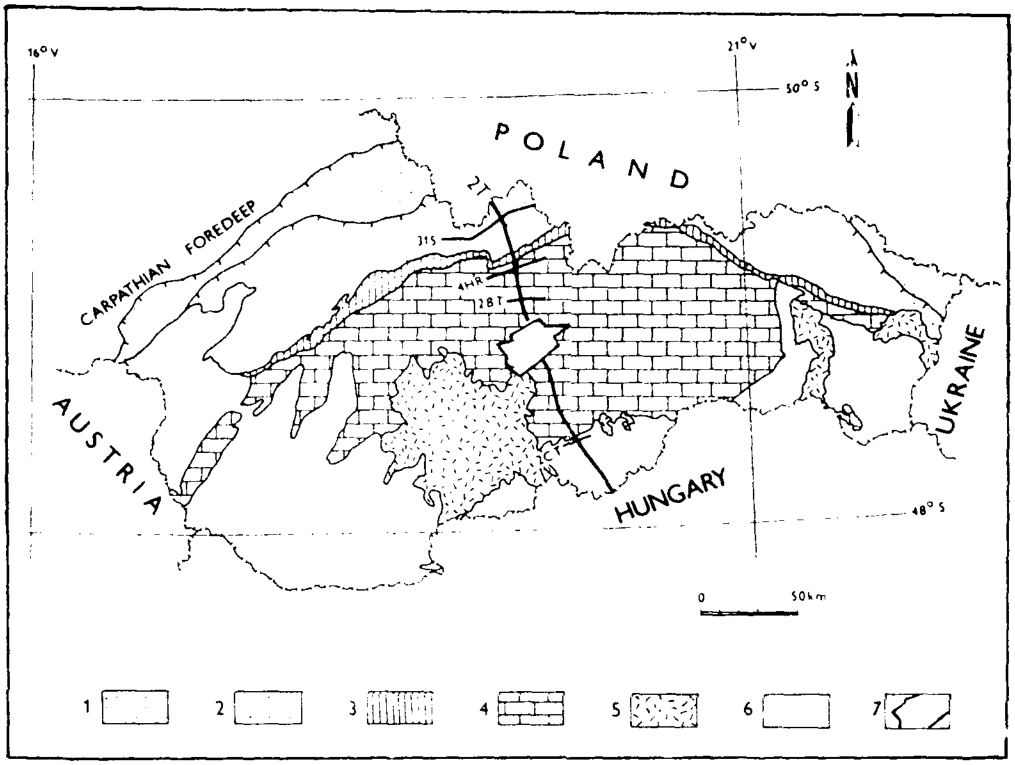

Fig. 21: General geological map of Czecho-Slovak West Carpathians and situation of seismic profile 2T (Tomek et al.1989)
1-outer of Krosno flysch, 2-inner of Magura flysch, 3-Pieniny Klippen Belt, 4- Inner Carpathian (undivided), 5-Miocene subduction volcanics, 6-Neogene, 7-situation of deformation under study

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Fig. 22a: Joint time section (non migrated) obtained from the data recorded along profile 2T. Selected reflection segments, local diffractions, Horizontal vs vertical approximate length ratio is 1,5:1 (Tomek et al. 1989)

Fig. 22b: Idealized geological section through the West Carpathian crust along profile 2T (Tomek et al. 1989) Lower European plate 1-upper crust with sedimentary cover of the European plate (Brunnia) passive margin. 2-lower crust of the European plate (Brunnia) passive margin, 3-subdiction accretion complex of the Krosno sea. The Upper Carpathian-Pannonian plate, 4-Neogene of the Lučenecko-Rimavská Kotlina Depression, 5-inner subduction accretion complex of Magura. 6-Pieniny Klippen Belt, 7-Inner-Carpathian (Podhale) Paleogene, 8-Subtatricum, 9-Mesozoic envelope of Tatricum, 10-granitoid rocks of Tatricum, 11-crystalline schists of Tatricum, 12-upper crust of Tatricum or of other crystalline complex beneath Tatricum, 13- lower crust of Tatricum, 14- North Veporicum, 15-granitoid rocks of Veporicum, 16-South Veporicum, 17-Gemericum, 18-Silica nappe, 19-Moho discontinuity, 20-overthrust fault

Fig. 23: Schematic kinematic model through the West Carpathians (the Ondrášik's interpretation of the profile of Tomek et al. 1989 - see Fig. 22)
C-crystalline, Fo-outer flysch, arrows show direction of movement in neotectonic stage

Fig. 22a.

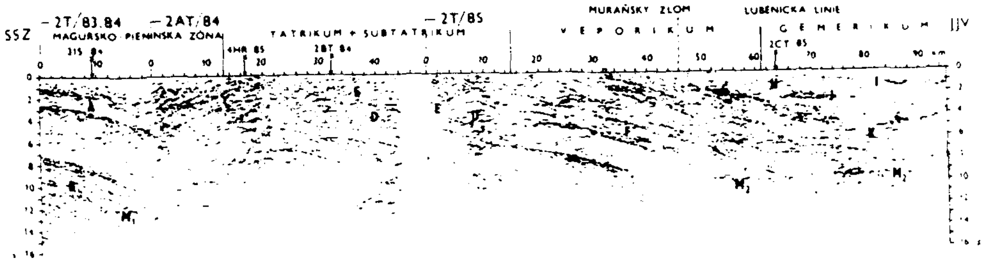


Fig. 22b.

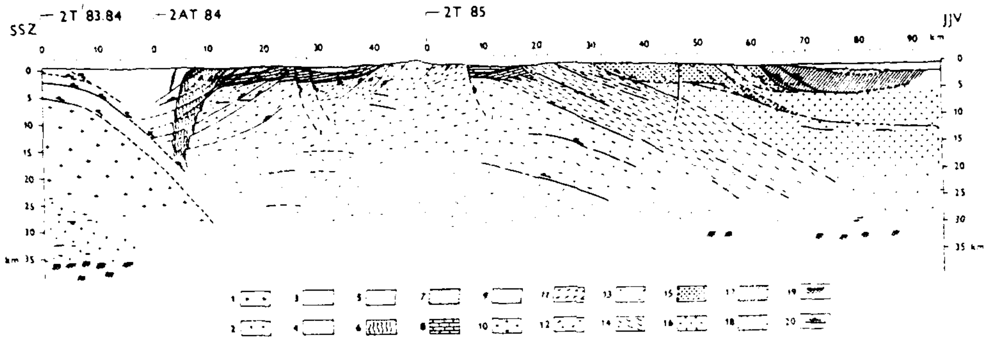
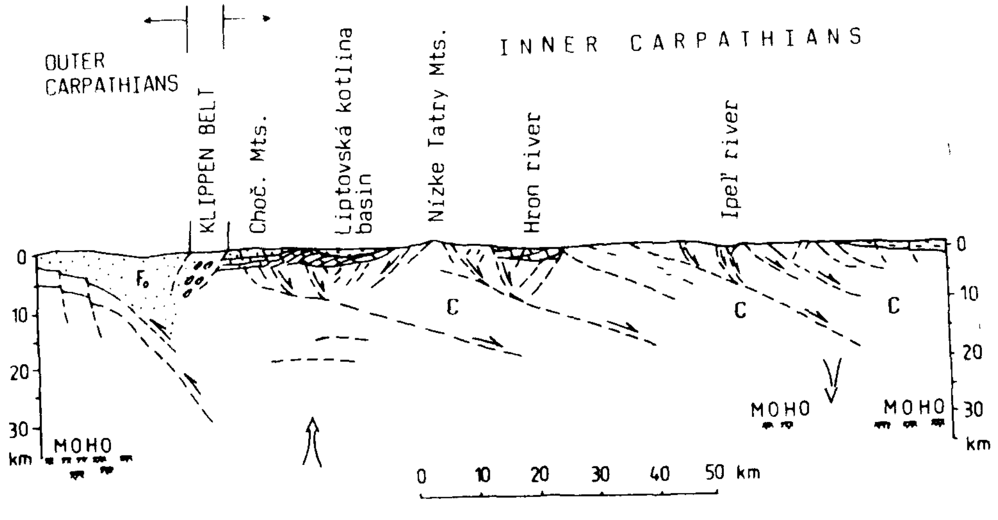


Fig. 23.



of 10 - 17 km while over this zone occurs fragile disturbance accompanied also by seismic tremors. Foci of the earthquakes in the territory of the West Carpathians were identified in the majority of the cases in the depth less than 10 km and their energy was less than 6.5 Magnitudo (Zátopek 1979).

The quoted interpretation admits also a possibility that some basins in the Inner West Carpathians in the initial stage of the development might have originated in prevailing horizontal tectonic pressures in relation to the lateral strike slips as "pull-apart" basins. But the main phase of the development of basins as pronounced geomorphic features has occured since the Middle Miocene.

Notice: Fig. 23 represents Ondrášik's inpretation of data (Fig. 22a) recorded along profile 2T (Fig. 21) in comparison to interpretation by Tomek et al. (1989) (Fig. 22b).

## VI.PLANATION SURFACES AND ELUVIA IN THE SLOVENSKÉ RUDOHORIE MTS

(Locality: 8)

### Locality No. 8: Ďubákovo

Ondrášik, R.

In several mountain chains in the Central Slovakia, formed prevailingly by Pre-Mesozoic crystalline rocks and granitoids, the remnants of planation surface (etchplain) dissected by deeply cut valleys occur. Classically is this planation surface developed in the western part of the Slovenské Rudohorie Mts, in wider surroundings of Detvianska Huta. The rests of eluvia and redeposited weathered material are found. Remnants of eluvia are irregularly preserved in the form of sandy loams and loamy-stony soils. Towards the bedrock they slowly change into tectonicly impaired schists, gneisses and granitoids that vary from intensely weathered to those untouched by weathering. Also the gouges of detected thickness up to 2 m (Ondrášik et al. 1987) occur. In exposed parts of the hills and slopes only slightly weathered granitoids appear in the surface and the rocky relief occurs.

Along the faults and disrupted zones weathering reaches the depth of several tens to hundreds of meters, as it was found for example in exploration galleries and in foundation ground of the valley dams on the rivers Ipeľ and Slatina. The sketch profile of the remodelled planation surface shows Fig. 24.

In the western margin of the planation surface on granitoids lie pyroclastics and andesites of the Poľana Mts. Mišík et al. (1985) dates them Baden-Sarmatian (i.e. 11 to 16 million years).In a cut of a road in the basement of neovulcanites sandy loams of granitoid eluvium were discovered (Ondrášik 1973).

In the southeastern piedmont of plateau and in the contiguous part of the Lučenecká Kotlina Basin are 10-20 m thick eluvia of schists with primary kaolin complexes that are covered by river sediments of the so called Poltar formation thick up to 100 m.

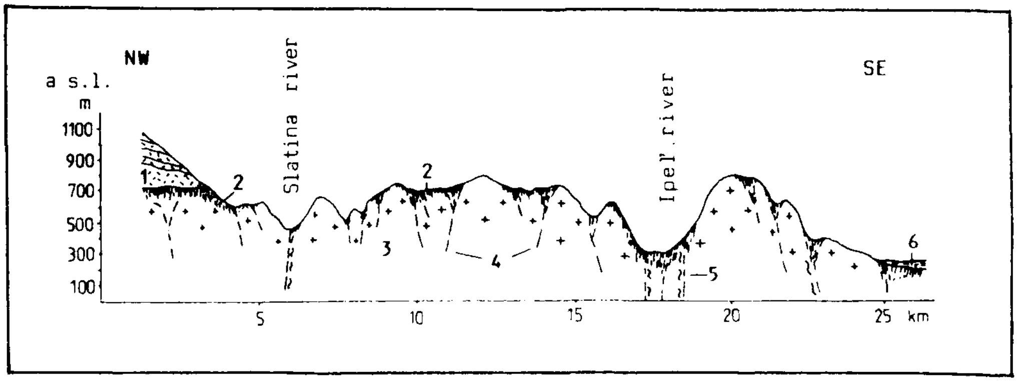


Fig. 24: Schematic profile through planation surface in western part of the Slovenske Rudohorie Mts (Ondrašik 1973)
1-neovolcanic rocks of the Poľana Mts, 2-remnants of Neogene eluvia, 3-granitoides, 4-local faults, 5-regional faults zones, 6-gravels and clays of the Poltar Formation

Gravel prevailes, in basal part of strata group numerous layers of secondary kaolin clays occur. In these, besides prevailing kaolinite also montmorillonite, illite, and halloyzite occur (Kraus 1989). Kraus (l.c.) dates the basal part of the formation into Pontian (5 - 7 million years). Source territory of sediments is supposed in the mentioned planation surface (etchplain).

Kraus (1989) dates period of formation of kaolin eluvia into Palaeogene and Lower Miocene. Eluvia were formed on the planation surface in the conditions of warm subtropic to tropic climate. There are many reasons to suppose that the development of thick eluvia continued also in younger Neogene during volcanic activity. But in that time probably great part of plateau was temporarily covered by pyroclastic material (Lukniš 1964). Resedimented products of weathering in southeastern piedmont testify an intense erosion of these Neogene eluvia at the end of Miocene (in Pontian) and in Pliocene, when according to Mazúr (1964) and Lukniš (1964) pronounced tectonic archlike rise of the territory and its tectonic differentiation with vertical erosion occurred. Tectonic differentiated movements and pronounced cooling of the climate did not offer favourable conditions for further development of eluvia, on the contrary, they were reduced. At the present time the lower horizons of former thick eluvia occur only on the remnants of the planation Neogene surfaces as well as on the hanging walls of tectonicly active faults, on tectonicly impaired zones and in the bottom and on the slopes of the valleys where they are covered by Quaternary formations especially fluvial and proluvial sediments. Fluvial sediments thick 4-8 m occur in the bottom of the valleys. They are dated into Würm and Holocene. At the mouths of lateral valleys developed proluvial cones. Their thickness in the upper valley of the river Ipeľ was found up to 35 m (Ondrášik et al. 1990) Sandy and loamy gravels and loams prevail. Also a layer of peat was found but as it was sterile, it was not possible to determine its age.

Velocity of the differentiated tectonic movements is estimated only on the basis of indirect geomorphic data like altitude differences of the planation surfaces, abrupt changes of longitudinal profiles of water flows cut into lithologically quasi-homogeneous complexes. Maximum observed earthquakes reach intensity up to $4^{\circ}$ MSK (Procházková et al. 1978). Mean velocity of differentiation movements is estimated to hundredths of mm per year. But the direct evidence of its real course is missing so far. In relation to the project of pumped storage plant a geodetic net of observation points were constructed in 1989 in the territory of interest on the opposite wings of active faults. Measurements are carried out once a year.

# VII. NEOVOLCANIC ROCKS AND LANDFORMS AND THEIR DATING

## Geochronology of the Slovak neovolcanic regions

Lacika, J.

Beyond the locality Ďubákovo enters the excursion route into the regions of Central Slovakian neovolcanites that have been abundantly geochronollogically investigated. Volcanic activity in the given regions is linked with tectonic disintegration of the inner margin of the Carpathian Arc that is probably a consequence of the upward movement of mantle diapir. Margin of the West Carpathians has disintegrated into a system of tectonic elevations and depressions, individualized by systems of faults. The crossing points of the fault deformations became the access roads for the volcanic matter towards the earth surface and in many cases also to the geomorphic manifestations of volcanic activity. Eruptions have manifested themselves in various volcanic centres and in various stages. Volcanic structures have developed in close relation to the formation of morphostructural plan of the whole region. Products of volcanism mostly formed stratovolcanoes or filled deepening volcanotectonic depressions. After the formation of volcanic structure occurred rapid exogenic destruction. On denudated volcanoes either the products of younger phase of volcanic activity were deposited or new eruptions manifested themselves and their intense denudation went on. Post-volcanic exogenic erosion of initial volcanic landforms took place in close dependence from morphostructural position of denudated volcano. The Štiavnica stratovolcano is an example of denudated, very exposed position on uplifted horst. That is why we are finding it nowadays in the stage of strong transformation and denudation up to the level of neovolcanic pre-Tertiary basement. Stratovolcano of the Poľana Mts is just opposite case , its less exposed position facilitated the preservation of various morphographic indices of the original stratovolcano. Within the frame of Central Slovakian neovolcanic complex it is possible to divide two basic structural units, discernible by the extent, age as well as petrographically. The older and as to the area, the much more extensive one originated in the Miocene. It is formed from the andesite and rhyolite products of volcanism.

They mostly build the whole massifs and mountains. The younger part of the complex is represented by the products of basalt volcanism, activated in the Pliocene and Pleistocene. They participate in the structure of the complex by a very small proportion in a form of isolated and small bodies.

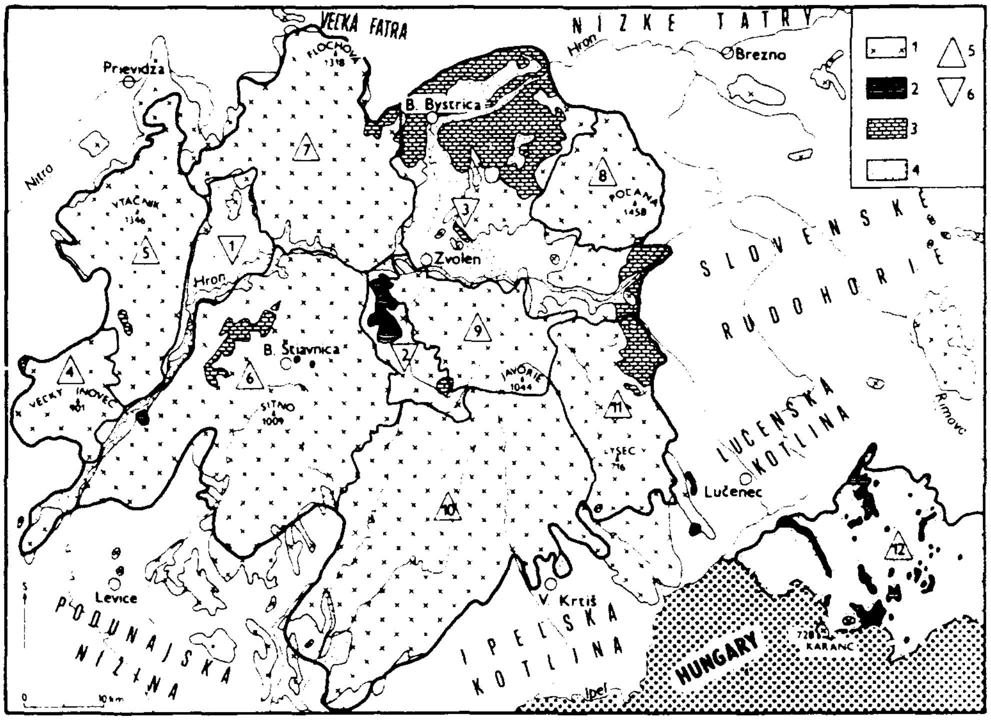


Fig. 25: Neovolcanic region of Central and Southern Slovakia
1-andesites and rhyolites, 2-basalts, 3-pre-Tertiary rocks, 4- Tertiary sediments, 5- mountains: △4-Pohronský Inovec Mts, △5-Vtáčnik Mts, △6-Štiavnické Vrchy Mts, △7-Kremnické Vrchy Mts, △8-Poľana Mts, △9-Javorie Mts, △10-Krupinská Planina Mts, △11-Ostrôžky Mts, △12-Cerová Vrchovina Mts; 6-Basins: ▽1- Žiarska Kotlina Basin, ▽2-Pliešovská Kotlina Basin, ▽3-Zvolenská Kotlina Basin

## Andesite and rhyolite volcanism and its dating

Lacika, J.

Products of andesite and rhyolite volcanism built seven mountains of the Slovenské Stredohorie Range (The Poľana Mts, the Kremnické vrchy Mts, the Vtáčnik Mts, the Pohronský Inovec Mts, the Štiavnické vrchy Mts, the Krupinská Planina Mts, the Ostrôžky Mts). Besides, isolated they occur also in the neighbouring geomorphic units (the Slovenské Rudohorie Mts and the Danube

Lowland) and in intramontane basins (the Zvolenská Kotlina Basin, the Upper Nitra Basin, the Pliešovská Kotlina Basin, the Ipeľská Kotlina Basin).

The Miocene volcanism is diversified with representation of extrusions as well as intrusions. Explosion products prevail over the effusive rocks. The most frequent is the stratovolcanic structure. The developmental scheme of andesite and rhyolite volcanism is leaning on the results of the detailed basic research and numerous dating analyses of different nature. Especially successfully applied were the geological methods of dating. Biostratigraphic research is based mainly on palynological evaluation of numerous samples ( Planderová in Konečný et al. 1983), collected from the sediments between volcanic sedimentary cycles in intramontane basins. They were verified by correlation with similar analyses of the neighbouring regions of the West Carpathians and Paratethys. They offer valuable data on time-spatial changes of the Miocene paleoclimate and paleorelief. For example according to the reconstruction of the Lower Sarmatian flora Planderová interpreted the height of caldera slope of the Štiavnica stratovolcano.

To the exact definition of the development of the Miocene volcanism considerably contributes the method of lithofacial analysis. In the frame of the whole complex tens of lithofacial units were distinguished, age of which was interpreted according to their position in relation to the neighbouring units, dated by other methods. There are also numerous results of radiometric datings (Table 2). Two basic methods were used - K/Ar method and fission track method. Geomorphic method of dating is not quiet applicable for the Miocene part of the neovolcanic complex for the absence of precisely interpreted remnants of the Neogene relief in the West Carpathians. Initial volcanic relief was strongly eroded and the volcanic morphostructures were transformed into horst morphostructures. Original volcanoes manifest themselves only passively, through the structural and lithological characters of the rocks. Duality of the rocks according to the geomorphic value, presence of resistant effusive rocks along the less resistant, explosive ones find a very suitable environment on the stratovolcanic structures. Post-volcanic rocks, propylitisation and quartzification participate in the relief form. Prepared intrusive bodies often rise as elevations.

By mutual correlation of the results of numerous geochronological analyses the following developmental scheme was elaborated:

Beginning of the oldest volcanic activity in the given region was biostratigraphically proved in the Lower Badenian. In the southern margin of the Krupinská Planina Mts occurred a tectogenic reversion in the development and in the border line of the two new morphostructures centres of andesite volcanism were activated. With little delay originated more northly lying centre Lysec in the Ostrôžky Mts. In the Middle Badenian the volcanism extended also to the northern part of the region , where three big and one smaller stratovolcanoes were formed. Products of stratovolcanoes were redeposited on the outer volcanic slopes, in the shore zones of the Badenian sea or they

Tab. 3: Radiometric dating of andesite and rhyolite rocks in Central Slovakia

| No. | LOCALITY<br>rock | method | age (mil years) |
|---|---|---|---|
| | The KRUPINSKÁ PLANINA Mts. and The OSTRÔŽKY Mts. | | |
| 1. | HRUŠOV•<br>pyroxene andesite | K-Ar | 18,5 ± 0,9 |
| 2. | LYSEC-HILL•<br>amphybole andesite | K-Ar | 18,2 ± 0,8 |
| 3. | CEROVO•<br>andesite breccia | K-Ar | 17,3 ± 0,8 |
| | The ŠTIAVNICKÉ VRCHY and THE POHRONSKÝ INOVEC Mts. | | |
| 4. | BANSKÁ ŠTIAVNICA••<br>*granodiorit* | Fiss.Track | 17,1 ± 0,4 |
| 5. | TANÁD-HILL•<br>pyroxene andesite | K-Ar | 17,0 ± 0,5 |
| 6. | PASTIERSKA-HILL••<br>amphibole-biotite andesite | Fiss. Track | 15,3 ± 0,3 |
| 7. | SABOVA SKALA-HILL••<br>rhyoilite volcanic glas | Fiss. Track | 14,3 ± 1,4 |
| 8. | RUDNO NAD HRONOM••<br>rhyolite | Fiss. Track | 12,3 ± 1,0 |
| | The KREMNICKÉ VRCHY Mts. | | |
| 9. | KORDÍKY••<br>amphybole andesite | Fiss. Track | 16,2 ± 0,6 |
| 10. | HORNÝ TURČOK•<br>pyroxene andesite | K-Ar | 15,2 ± 1,0 |
| 11. | STARÁ KREMNIČKA•<br>rhyolite | K-Ar | 11,2 ± 0,3 |
| | The POĽANA Mts. and The JAVORIE Mts. | | |
| 12. | BREZINY•<br>pyroxene andesite | K-Ar | 16,7 ± 1,2 |
| 13. | ZVOLENSKÁ SLATINA••<br>amphybole andesite | Fiss. Track | 16,6 ± 0,3 |
| 14. | STARÁ HUTA•<br>amphybole andesite | K-Ar | 16,4 ± 0,6 |
| 15. | DETVA••<br>pyroxene-biotite andesite | Fiss. Track | 13,6 ± 0,4 |
| 16. | KYSLINKY••<br>rhyodacite | Fiss. Track | 13,0 ± 0,3 |
| 17. | STRELNÍKY••<br>rhyodacite tuffs | Fiss. Track | 12,9 ± 0,4 |

• Bagdasarjan et al. 1970

•• Repčok 1981

filled subsided volcanotectonic depressions among the stratovolcanos. In the Upper Badenian started the stage of intense denudation of the volcanic forms that was gradually replaced by the stage of depression deepening and extrusive volcanism. Effusions filled in the calderas of the volcanoes and they often oozed over the borders to fill in the paleovalleys on their peripheral slopes. In the Lower Sarmatian the eruptive centres again activated. In the Poľana Mts formation of new stratovolcano of central type took place. The Štiavnica stratovolcano and Javorie shifted the eruptive activity from the centre to the slopes of the volcanoes. Numerous lava streams reached even the border parts of the Sarmatian sea. In the Upper Sarmatian again occurred the deepening of volcano-tectonic depression. Renewed tectonics manifested itself in the individualization of the horsts. In the Pannonian basalt-andesite volcanism becomes active. It took part in the formation of one stratovolcano and numerous forms of intrusions in the Kremnické Vrchy Mts. In the remaining parts only isolated volcanic activity manifested. In the Pliocene and Quaternary stressing of basin-mountainous contrast relief occured and the contemporary appearance of the valley net was formed.

## Locality No. 9: The Prislopy Saddle (the Poľana Mts)

### The best preserved stratovolcano in the West Carpathians

Lacika, J.

The Prislopy Saddle lies in the Poľana Mts in the southern border of its central depression. The mountain chain might be characterized as a multi-phase formed Miocene stratovolcano with its inner structure complicated by central intrusions. In the structure of the mountains two superimposed stratovolcanoes were discerned. The older one, Lower to Middle Badenian was exogenously eroded and denudated to large extend before the Sarmatian. To its strong denudation contributed the deepening of the volcanotectonic depression in the southern periphery of the volcano where the volcanoclastics and lava were directed. After the Sarmatian volcanic activity the local eruptive centre calmed down and did not activate any more. The Sarmatian stratovolcano was again exogenously eroded but not to such extent as not to preserve some gross relief features of the original volcanic form until the present time.

Visually most easily interpreted , on the maps and on the radar image, is the central depression taken for caldera (Fig. 26). The opinions of the geologists on the type of caldera here differ so far. Some of them consider it the consequence of emptying of the magmatic reservoir under the eruptive centre of stratovolcano. There are also defendants of the development of the depression by erosive extension of the summit crater. A collapse in the first developmental stage we can not exclude. Resulting depression was then remodelled and extended by erosion. Radar image clearly shows the role the fault tectonics played in the formation of the depression. Northern peripheral ridge of caldera forms with its eastern continuation an angle that is very close to the right and its course is apparently linear. In the environs it is linked with the valley network determined by the fault system of SW-NE direction. In the given direction also the superimposed section of the Hačava Valley that is now draining the caldera was formed. Southern delimitation of the central depression is probably of erosional origin according to its form. The peripheral ridge of the depression almost in all its length exceeds the 1000 m altitude above sea level. It drops under this contour line only in the point of the locality. The Príslopy Saddle is the only outstanding depression linked to the tectonic dislocation. Interesting geomorphic situation occurs under this saddle where the radar image of geological situation and the form of the valley network indicate presence of larger gravitational deformation. Similar forms can be found also inside the caldera, where they deform its comparably steep peripheral slopes. Their height over the depression bottom reaches 400 to 500 m. In the sea level altitude of around 1000 to 1100 m occurs in larger area a determined type of relief in the form of inclined plateaus, rounded hills and gentle slopes. Some elevation are probably linked prepared intrusions in the centre of stratovolcano. Valley network inside caldera is clearly radially centripetal.

Also the peripheral part of the Poľana Mts preserved some morphological features of the original stratovolcanic structure. The most striking one of them is the form of the valley network that is radially centrifugal, especially in the southern foothill of the mountains. The course of the intervalley ridges is almost perfectly linear, that is step-like only in its details depending on the presence of more resistant effusions as compared to less resistant products of explosive volcanism. Influence of the passive structure is apparent also in the longitudinal profiles of some peripheral valleys with steps and waterfalls.

Genesis and post-volcanic geomorphic development can be well presented on the basis of morphostructural position of the Poľana Mts. The local eruptive centre activated itself in the crossing of two important fault systems. The SW and NE direction of the first of them can be well observed in the texture of the valley network. The second, almost rectangular to the first is also well projected in the valley network and at the same time it is identifiable in the step-like declining of the Slovenské Rudohorie Mts. into the Zvolenská Kotlina Basin. Transitory position of the Poľana Mts between the negative morphostructure of the Zvolenská Kotlina Basin and the positive semimassive unit of the Slovenské Rudohorie Mts can explain the relatively low degree of exogene destruction. It presents the Poľana Mts in less exposed situation from the point of view of the activity of erosion-denudation processes. Opposite case is the already quoted of the Štiavnica stratovolcano, that due to its long time horst situation is much more eroded.

Development scheme of the Poľana Mts:

In the region of the Poľana comparably great number of geochronological analyses were carried out, the massif was submitted to a detailed geological investigation and recently also more intense geomorphological study was started. Especially geological dating measurements correspond to each other in an admissible extent. More problematic is the geomorphic interpretation of the age of the local neovulcanites eventually the origin of stratovolcano. According to radiometry the higher layers of the stratovolcanic construction are the Sarmatian age. If we admit that the usual scheme of cyclic planation of the West Carpathians after Mazúr and Lukniš is still valid, we have to find in the mountains relief the rests of the Pannonian planation surface. But it is absent. Therefore either the age interpretation of the stratovolcano after the Sarmatian is incorrect and the volcano was active after the Pannonian planation or this scheme is not valid for the Poľana Mts and stratovolcano really originated in the Sarmatian. We rather

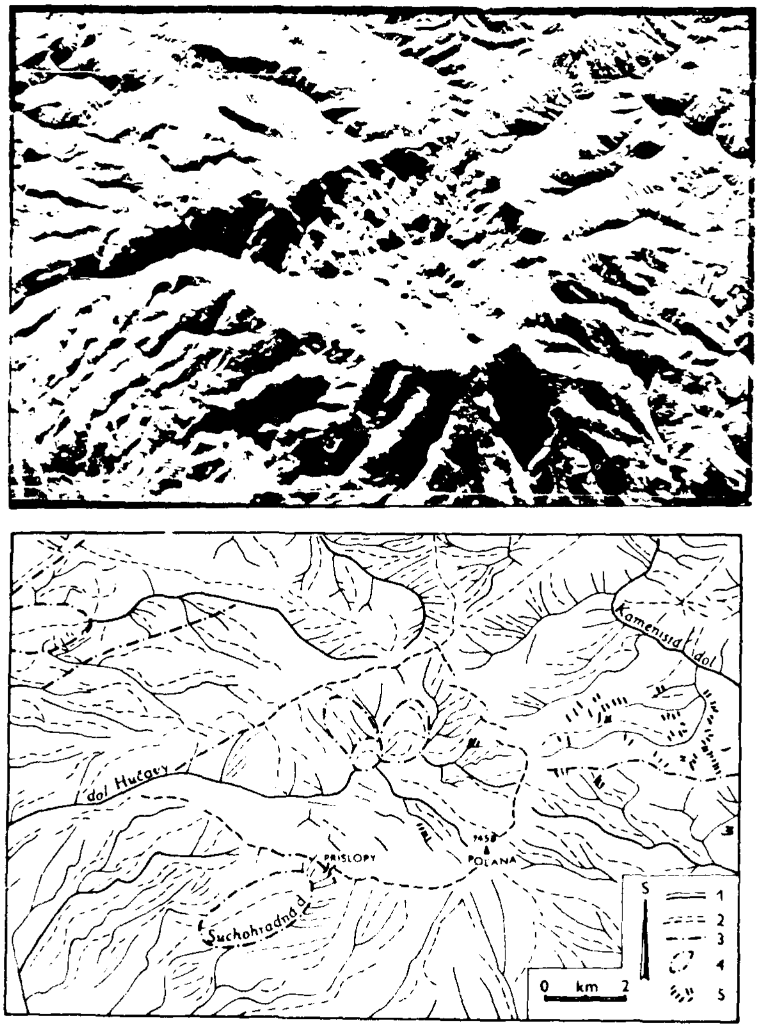


Fig. 26: Radar image of Poľana Mts and its interprtetation (Lacika in Jakal et al. 1992)
1-valley lines, 2-crest lines, 3-others linear dividing marks, 4-non-linear dividing marks, 5-micro dividing marks

support the second version, i.e. we support the credibility of the radiometric analyses. Doubt has been cast on the cited geomorphic conception in various places of the West Carpathians, it is probably more complicated and the individual stages of planation in the Neogene did not necessarily have to have the same proceeding in the same time and intensity. This problem is still open and gains importance from the point of view of further geomorphological development in Slovakia.

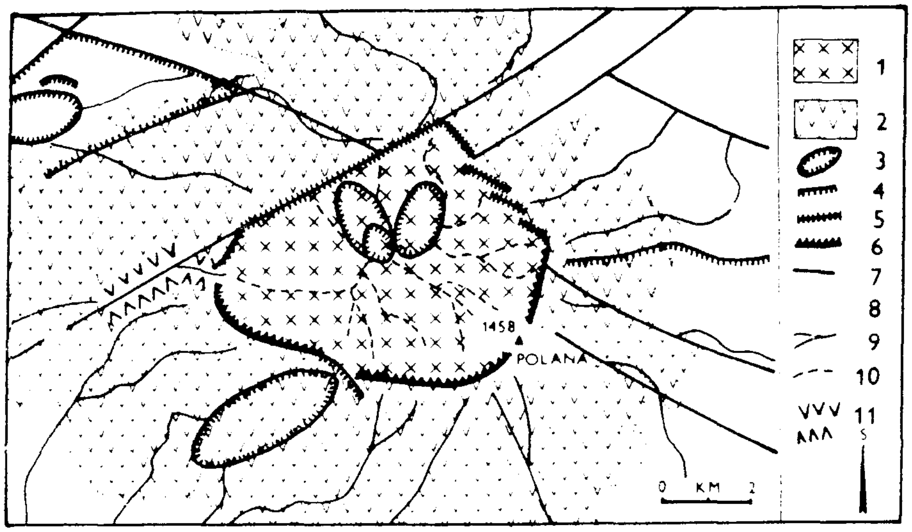


Fig. 27: Morphometric scheme of the Poľana Mts (Lacika in Jákal et al. 1992)
1-caldera of stratovolcano, 2-periphery of stratovolcano, 3-indication of gravitational disturbances or demostration of passive structure in relief, 4-indication of tectonical disturbances on the crest-valley systems, 5-indication of tectonic bordering of caldera, 6-indication of erosional bordering of caldera, 7-indication of morphostructural dividing marks not related to crest-valley systems, 8-erosional border of stratovolcano, 9-valley lines of radial excentrical texture of periphery, 10-valley lines of radial concentrical texture of caldera, 11- through-like valley of the Hučava river draining caldera

## 3nd excursion day - Sunday, June 21

### Locality No. 10: Zolná. Fossil Lahar

Dublan, L.

Lahars are the characteristic lithogenetic type of volcano-sedimentary geological bodies that occur in the slopes and foothill of the polygenetic Poľana stratovolcano. Their development is linked to the border between the Lower and Middle Sarmatian. Expressed in radiometric dating it is the section delimitated by 12.74 - 12.65 million years. Stratovolcano was in that time in the stage of explosive-extrusive activity of the

Mts. Peleé type producing a larger amount of clastics. This material created a stratified volcanic cone - source of fragmentary substances for the formation of lahars. They originated through the loss of the stability of the slopes saturated with water during intense rains periodically repeated in then existing Mediterranean climate.

Term lahar is accepted in the sense of van Bemmelen (1949) who defined it as a deposit resulting from mass transport of fragmentary volcanic material mobilized by water on volcano slope.

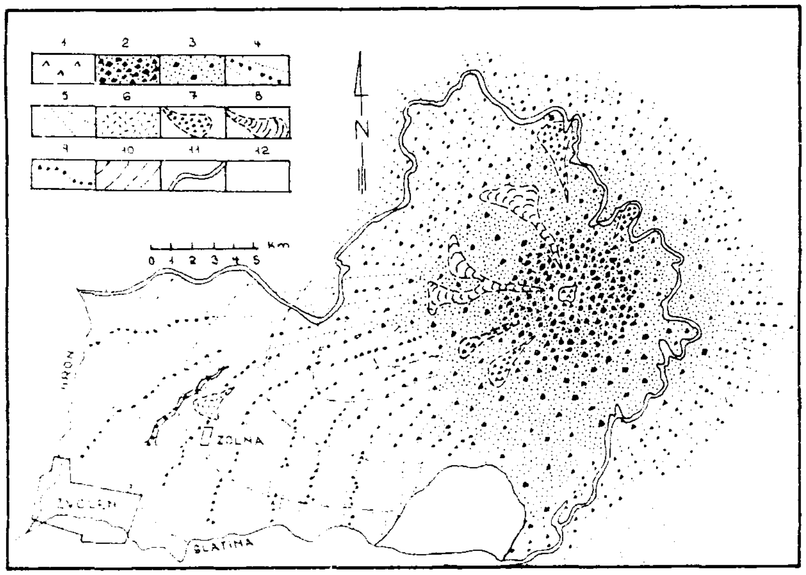


Fig. 28: Polana stratovolcano in the stage of lahar formation of Lower-Middle Sarmatian age (Dublan 1992) 1-extrusive bodies near crater, 2-central volcanic zone, 3-temporary zone of volcanic slope, 4-external volcanic zone of alluvial cone-region of development of braided channels, 5-region of prevailing sanding facies of alluvial cone, 6-Zolná lahar, 7-pyroclastic flows, 8-lava flows, 9-braided channels, 10-probable extent of alluvial cones fan, 11-actual extent of Polana volcanic rocks

Zolná lahar is a typical representative of the genetic type of lahars, exclusivity of which is given by the presence of opalesced tree trunks in the lower part of the body. Trunks, branches and other plant material was swallowed by the tumbling lahar and then petrified in diagenetic processes.

According to the analysis of microscopic structure of wood, all tree trunks occurring in lahar belong to Ulmus sp. gender i.e. elms. There is an interesting finding that some trunks were invaded by decay even before the fossilization of the wood started.

Besides elms we detected also impressions of weeds, leaves and tree branches. Among them other communities like Acer, Quercus, Byttneriophyllum and Cyperus chavannesi Heer (Sitár in Dublan 1992) were identified. As a whole they probably represented a biotope of alluvial forest.

In other localities of the same time interval sporomorphs coming from mixed forests of volcano mountain crests are known. These are identifiable mainly through the species of Abies, Picea, Cedrus, Pinus (Planderová in: Konečný et al.1983).

The quoted facts testify the presence of vertical vegetation zonality as well as the expressive relief dynamics.

These data combined with the analysis of the geological structure prove that the relative difference between the erosive base of the volcano foothill lowlands and its summits was about 1500 m.

These are the basic conditions for the formation of alluvial cone, sedimentation of which was accompanied by catastrophic invasion of lahars. One of its representative is the Zolná lahar.

Mobilized tuff material of the Zolná lahar had tumbled down into the lowland region. Along its movement on the surface of the proluvial cone it utilized the braided channels, swallowing part of boulders of the bottom of erosive river-beds and penetrated through the biotope of the alluvial forest at the foothill. Caught tree trunks were drawn into lahar with subparallel arrangement in the height and distance of about 1 m from the lahar base.

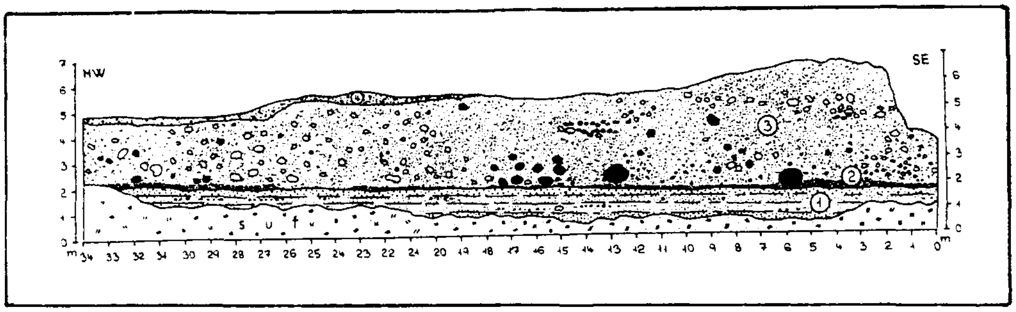


Fig. 29: Schematic profile of Zolná lahar outcrop (Dublan 1992)
1-epiclastic sandstones, 2-basal part of lahar with yellow grey tuff, 3-basal part of lahar (98% of bulk)-tuff with fragments and andesite boulders. The tuff material mixed from rhyolite and andesite. The position of wood is represented in the section, 4- overlying epiclastic sandstones with andesite fragments

Lahar deposited itself on the surface of alluvial cone in the distance of about 12-15 km from the point of its mobilization of volcano slope.

Directions of the transport of cone sedimentary material, erosion channels and trunk arrangement is parallel.

In the next period lahar was covered by continuing sedimentation of alluvial cone the development of which was interrupted until the final effusion stage of the development of stratovolcano. During this stage originated a fortified stratovolcano protected by an armour of lava flows.

Since then until the present time, i.e. about 12.4 million years is the volcano calm and submitted to the ongoing erosion.

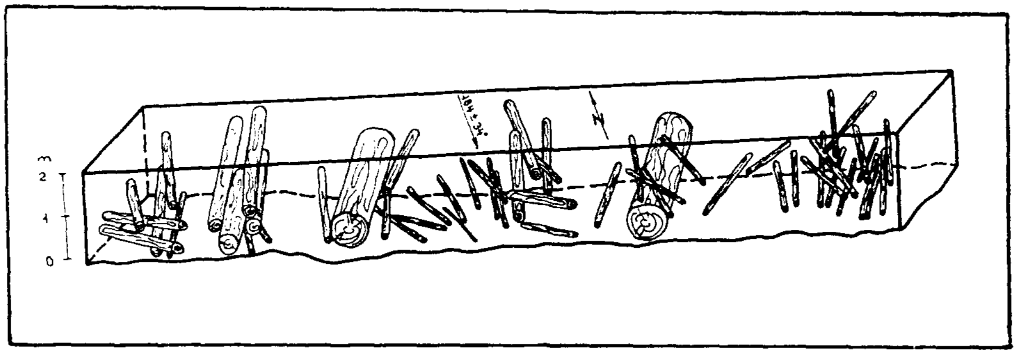


Fig. 30: Detailed block diagram of Zolná Lahar (Dublan 1992). It shows distribution of wood in a place of maximum accumulation. Lower border of diagram is identical with lower border of lahar

## Basaltic volcanism and its dating

Lacika, J., Halouzka, R.

The course of basaltic volcanism in the West Carpathians took place in the Pliocene and Pleistocene in two volcanic regions: South Slovakia (the Cerová Vrchovina Mts and the Lučenecká Kotlina Basin) and Central Slovakia (the Štiavnické Vrchy Mts and Pliešovská Kotlina Basin). Less numerous occurrence of its products is in the Central Slovakia region, where they are classified within the neovolcanic complex. Region of South Slovakia has more frequent occurrence of the basalts where they are surrounded by neovolcanic rocks of the Tertiary sedimentation cycles.

Basaltic volcanism is diverse, represented by extrusions and intrusions. It manifested itself by explosions and effusions. Partially identical and partially different dating methods were applied in the dating of its products. Method of fission track proved to be useless as it did not correspond to the results of other analyses. K/Ar method (Bagdasarjan et al. 1968 and 1970, Balogh et al. 1981 and 1987, Kantor and Wiegerová 1981) was applied more successfully. There were problems only with the interpretations of ages of the youngest basaltic products, for instance in the locality Brehy. Besides radiometric methods of dating results of lithostratigraphic, biostratigraphic and paleomagnetic dating analyses are at disposition. For instance in the locality Hajnáčka in the Cerová Vrchovina Mts the age of the local basaltic volcanoclastics was estimated by means of the findings of skeletons of fossil vertebrae (Fejfar 1964).

Initial volcanic forms created by basaltic volcanism are preserved in their transformed form also in the contemporary relief. Their genetic relationship to the surrounding by age defined relief (planation surfaces, fluvial terraces) increases the efficiency of application of geomorphic methods of basal dating. In that sense the products of basaltic volcanism in the Cerová Vrchovina Mts were the best processed (J. Lacika 1990).

According to the results of dating analyses the following development scheme of the course of the basaltic volcanism in the

Tab. 4: Radiometric dating of basalts in Southern and Central Slovakia

| No. | LOCALITY | Method | Age (mil years) |
|---|---|---|---|
| The CEROVÁ VRCHOVINA and The LUČENECKÁ KOTLINA Basin | | | |
| 1. | ŠURICE**<br>nepheline basanit | Fiss. Track | 7,8 ± 0,3 |
| 2. | HAJNÁČKA**<br>nepheline basanit | Fiss. Track | 7,5 ± 0,3 |
| 3. | MAŠKOVÁ***<br>alcalic basalt | K-Ar | 7,45 ± 0,4 |
| 4. | PODREČANY***<br>nepheline basanit | K-Ar | 7,15 ± 0,23 |
| 5. | ŠOMOŠKA*****<br>alcalic basalt | K-Ar | 4,59 ± 0,52 |
| 6. | MEDVEŠ****<br>alcalic basalt | K-Ar | 3,81 ± 0,27 |
| 7. | HAJNÁČKA-CASTLE*<br>nepheline basanit | K-Ar | 2,75 ± 0,44 |
| 8. | BULHARY***<br>nepheline basanit | K-Ar | 2,57 ± 0,08 |
| 9. | VEĽKÉ DRAVCE*<br>nepheline basanit | K-Ar | 1,62 ± 0,32 |
| 10. | RAGÁČ*<br>alcalic basalt | K-Ar | 1,35 ± 0,32 |
| The ŠTIAVNICKÉ VRCHY Mts. and The PLEŠIVSKÁ KOTLINA Basin | | | |
| 11. | KYSIHYBEL*<br>nepheline basanit | K-Ar | 8,08 ± 0,58 |
| 12. | KALVÁRIA*<br>alcalic basalt | K-Ar | 7,29 ± 0,41 |
| 13. | OSTRÁ LÚKA**<br>alcalic basalt | Fiss. Track | 7,10 ± 0,7 |
| 14. | BREHY*<br>nepheline basanit | K-Ar | 0,53 ± 0,16 |

| | |
|---|---|
| * | Balogh et al. 1981 |
| ** | Repčok 1981 |
| *** | Kantor - Wiegerova 1981 |
| **** | Balogh et al. 1987 |
| ***** | Balogh et al. 1992 |

West Carpathians was elaborated:

After the Sarmatian, volcanic activity in the whole West Carpathian area was clearly reduced. In the Pannonian a transitory stage from andesite to basaltic volcanism in the form of eruptions of basaltoid andesites in the Vtáčnik and the Kremnické Vrchy Mts took place.

The oldest products of basaltic volcanism were radiometrically identified as the Pontian . In that period intrusive bodies surrounding Banská Štiavnica in the Štiavnické Vrchy Mts were formed. The Upper Pliocene was considered so far a period of relative tectonic consolidation that manifested itself in the formation of planation system - river system of levelling. In the southern border zone of the West Carpathians according to the occurrence of the volcanic manifestations increased tectonic activity must have operated. The most frequent centres of basaltic volcanism in the Upper Pliocene can be found in the Cerová Vrchovina Mts. According to the geochronological analyses, since the beginning of the Quaternary at least three stages of tectonic activity occurred. Eruptions of basaltic volcanism in limited extent occurred also in the Pleistocene, in three regions: The Štiavnické Vrchy Mts the Pliešovská Kotlina Basin and in the Cerová Vrchovina Mts. In the Lučenecká Kotlina Basin the Pleistocene volcanic activity was not proved. In the Cerová Vrchovina Mts was detected according to radiometric dating and geomorphological position an Old Pleistocene eruption centre of Veľký Bučeň and Ragáč, and the Old to Middle Pleistocene maars in Hodejov and Fiľakovo. In neovolcanic region of the Central Slovakia basaltic bodies Ostrá Lúka and Brehy have a proved Pleistocene age. In Ostrá Lúka in the north of the Pliešovská Kotlina Basin is an effusion of basalts laid on the gravels of so called plateau terrace of the river Hron that formed on then existing confluence with the flow draining the Pliešovská Kotlina Basin (Halouzka in: Konečný et al. 1983, 1986 and Halouzka 1986).

This superposition of the lava flow to the highest and oldest step in the terrace system in the Pannonian-Carpathian region (T IX) as well as dissection of the original lava front facilitated the classification of the local basalts into the Quaternary, to the basal part of the Pleistocene (? biber). The age of the effusion has not been radiometrically assessed yet , but it should not be more than 1.5-1.8 million years. The lava flow of the locality Brehy covers the lowest and the youngest gravel accumulation of the river Hron, of the so called third central terrace (T IIa) as asserts Halouzka 1986.

## Locality No. 11: Nová Baňa - Brehy. The youngest volcano in Czecho-Slovakia

### Geomorphology and volcanic activity

Lacika, J., Šimon, L.

The locality presents the youngest manifestations of basaltic volcanism and volcanism in general in Czecho-Slovakia. It is situated on the left side of the river Hron near the city of Nová Baňa. It is a part of the volcanic-horst mountains of the Štiavnické Vrchy Mts.

From the geological point of view the locality of Brehy is situated in the peripheral part of the strongly denudated Štiavnica stratovolcano. The central part of the original volcanic form lies in the NE direction in the region of the city of Banská Štiavnica. The stratovolcano was formed between the Lower Badenian and Middle Sarmatian. In the following development it was tectonically uplifted and transformed into the horst morphostructure. Valley of the river Hron is an important geomorphological and structural element of the surroundings of the locality, based on the fault system of approximately NNE-SSW direction. In the space under Nová Baňa, the Hron valley expands into a small basin. Its origin is probably determined by crossing of fault system of various directions. The surroundings of the locality are built prevailingly by the products of the Badenian andesite volcanism with numerous manifestations of hydrothermal transformation. The proper locality is formed by the products of basaltic volcanism, basanites and basaltic volcanoclastics. They are assigned to three lithological units: 1.lava flows of basanite, 2. interbedded lava flows and air fall tephra layers, 3. pyroclastic rocks (scoria and fall deposits, pyroclastic bombs).

Volcanic activity in the locality according Šimon took place in about two stages. During the first, effusive stage, poured from the advective crater several sandwiched partial lava flows. In the second, eruptive stage, in the place of the cited crater formed small, though morphologically very pronounced cinder cone with alternated layers of tuffs and lava. In the contemporary relief it creates elevation of the Pútikov Vŕšok Hill (k. 432).

Lava flows manifest themselves morphologically as plateau steplike slope lying between the bottom of the valley of the river Hron and the foothill of the volcanic cone. There is observable at least a four step system in the relief arranged in to the form of fan 3 km long. The lava effusion partially filled the above cited basin and disguised its original morphographic expression. It influenced the valley system in the proximate surroundings lava has blocked the way to both lateral valleys and forced a change of their course in the lower sections. In one of them on the basis of the character of the local accumulation it is possible the suppose a contemporary blocking of the flow and a short-time existence of a small lake. It is fairly probable that the basalts affected also the adjacent part of the flow of the river Hron even if we do not find them in the right bank.

## Geology of Quaternary

Halouzka, R.

Evidence of a short-term flow blocking were found in the sediment analyses in the adjacent parts of the valley. Up to the Žiarska Dolina Valley is present loam-sandy alluvium in gravel accumulation (Halouzka in Lexa et al. 1986). Besides also an anomalous occurrence of the next erosion-accumulative step over the potential block in Žiarska Kotlina Basin is the indication of the blocking of the river Hron by basalts. This step is as to his position younger than the bottom gravel accumulation of the river Hron.

Repeated effusions of basalts in the locality Brehy mostly cover in the river Hron gravels. Analysis of the quarry profile provides evidence only of the direct superposition of the basalts on the terrace gravels interpreted as the lowest terrace of the river Hron - step T IIa, Its age is assessed in the Younger Riss (Halouzka in: Kanda et al. 1986). The base of gravels is in the relative altitude 0 to 2 m above the level of the river. Lava flow surface exceeds the level of the valley flood plain by 20 to 30 m in the margin and 50 m further from the flow front. Columnal nepheline basanites build basal part of lava flow in upper part of the section occur more frequently volcanoclastics and basaltic pumica. Samples for the paleomagnetic and radiometric age dating of the basalts were collected in the quarry. According to the paleomagnetic characteristics the samples were classified in positive polarity of the Brunhes epoch. Radiometric dating by K/Ar method assessed the age of basalts on 0.53±0.16 million years, that contradicts the results of other geochronological analyses. The real age of basalts must be younger. It seems that

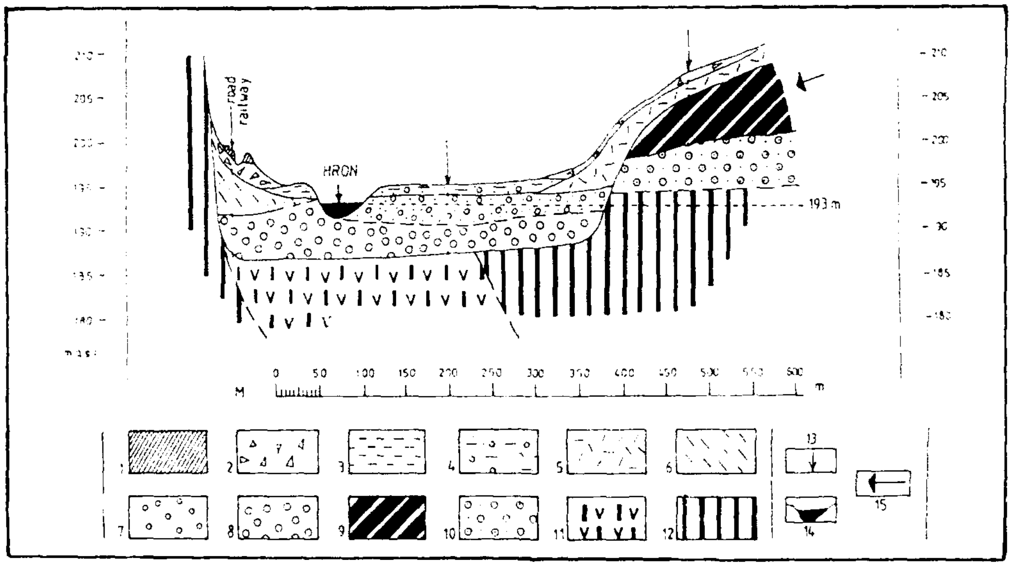


Fig. 31: Geological section through the Hron River valley near Nová Baňa-Brehy (Halouzka 1992 - compiled according profile in map 1:5000 - in Kanda et al. 1986)

1-man-made ground deposits, 2-debris, 3-fluvial sandy loams, 4-fluvial sandy loams with gravel, 3-4-alluvium in the flood plain, 5-polygenic slope loams (surface wash), 6-polygenic slope sandy loams (surface wash), 2,5,6-deluvial (slope) sediments, 1 to 6-Holocene, 7- fluvial gravel and sands, 8-fluvial sandy gravel, 7 to 8-Late (Upper) Pleistocene, Würm (bottom accumulation), 9-nepheline basalts, 10-fluvial sandy gravel (terrace accumulation), 9 to 10-Middle Pleistocene, Late Riss, 11-andesitic volcanoclastics (tuff), 12-andesites, 11 to 12-Miocene (Badenian), 13-resistivity sounding probes (geophysical survey), 14-river channel, 15-lava flow direction it is not possible to apply the given methods , therefore the analyzed samples must be younger than 0,4 million years.

The age of the basalts in locality Brehy was more exactly assessed by means of a borehole near the village Tekovská Breznica (Karolus, mapping 1971). According to the sedimentary-petrographic analysis of D. Minaříková the basal gravels and the lava flow were compared with analogous accumulations in the near terraces of the river Hron. Accordance was confirmed especially in association of heavy minerals. Determination of the age of basalts from above is facilitated by the complex of loams. Its basal part consists from interglacial soil of brunisol type and soil sediments.

Age assessment of the basalts in the locality Brehy is assisted also by some supraregional relations, especially in the direction towards the Podunajská Nižina Lowland. In the lower Pohronie Region the complex research and mapping (including analyses of boreholes) of the Quaternary proves the presence of basalts of Brehy type exclusively in gravel accumulations of the lowest terraces T IIa and in a bottom accumulations (i.e. Younger Riss and Würm) Halouzka, 1973 and 1982 . They were not found in older accumulations. Tuff thin layers in the loesses of the Komjatice near Nitra brick-yard ( Vaškovský, Karolusová 1969, Schmidt 1972) and the Levice-Monako brick-yard (Kukla Ložek, Halouzka 1982) show, also after revision, the Riss age (not the Mindel).

## Determination of stratigraphy and age of basalts in the locality

Halouzka, R.

Basis is the position of basalts. Basement terrace gravel of the river Hron are according to the morphoalysis and morphometry, lithological and sedimentary-petrographic character (all in the wide regional comparison) classified to the youngest middle terrace (T IIa), with accumulation of the Younger Riss. The soil layer covering basalt than facilitate to classify them more accurately into the final stage of the Younger Riss (event. beginnig of the last Interglacial). According to the general dating of the sedimentary cycles of the Quaternary it responds to the age of approximately 130-160 thousand years B.P. The suggested age does not contardict either the measured data of palaeomagnetism (positive polarity) or the K/Ar dating values (< 0,4 million years B.P.). It is the youngest effusive volcanic activity (body and form) in the West Carpathians and in Czecho-Slovakia in general. The older effusion have probably been oriented toward Brehy and the younger ones to Tekovská Breznica.

## Appendix - Explanations to enclosed maps

### Geomorphic units (Mazúr, Lukniš 1983)

The presented division of the surface of Slovakia was based on the objective to achieve a delimitation of surface units as unrepeatable individuals. A typologic or genetic division is not treated here, it is a subject of individual or specific division according to Rodoman (1956), and/or Grigg (1965). Moreover, it is necessary to emphasize here that division was not limited to traditional orographic standpoint which permitted to consider only some properties of relief, but it had started from a much larger general geomorphic basis with a complex conception of the relief.

From the very nature of the geomorphic regionalization, as a scientific method the aim of which is to give a cartographic conception of the spatial distribution of geomorphic units (individuals) of different taxonomic levels occuring in the natural region, it is indispensable to rely both on systemization of geomorphic surfaces and on the criteria of the territorial delimination of these surfaces and thus bring the resulting picture as close as possible to the reality.

Methodically authors started from the so-called analytical regionalization with the aim to classify and delimit the geomorphic surfaces as unreapeatable individuals into a taxonomic system. The individuals of each element of this system is given by the form, contents and situation.

The map of relief types in Slovakia prepared on the scale of 1:200 000 and generalized to the scale of 1:500 000 was the material on the basis of which the regional division of Slovakia was carried out. Then authors used nowadays abundant geomorphic literature with map documentation, geological maps on the scale of 1:200 000, map of morphostructures of the West Carpathians and, naturally, their own knowledge of the terrain.

Classification of geomorphic units comprises 8 levels. It starts from the global Alpine-Himalayan system, through the subsystem of the Carpathians and the Pannonian Basin; in the third level it distinguished provinces; in the fourth - - subprovinces; and in the fifth it provides a definition of geomorphic regions. Under region authors understand a surface with a considerable degree of homogeneity (from the morphostructural standpoint). In the sixth level the basic geomorphic units (macroforms) are defined distinctly spatially, being homogeneous not only from the morphostructural viewpoint, but also from that of morphography and exogenic sculpture. In the seventh and eighth levels subunits were delimited with the highest degree of homogeneity from the viewpoints of surface morphography, genesis and detailed aspect.

## Typological division of relief (Mazúr 1983)

Constructing this map three aspects of relief have been evaluated, such as the morphostructural viewpoint, the morphosculpture and the morphometry. The morphostructural viewpoint is based on the evaluation of movement tendency (positive or negative) of the earth crust on the structural types and lithological properties. Therefore, it considers relief types conditioned directly by tectonic movements (active structure), or derived secondary types resulting from deposition condition and lithology (passive structure). Based on these criteria, author established a five-stage classification of 17 types of morphostructural relief which are expressed on the map by varicoloured structural shadings in the legend lines.

Morphosculptural viewpoint is based on the genesis of relief conditioned by exogenic processes. Author, using a three-stage classification, has established 25 genetic types of sculptural relief which are expressed by basic coloured shandings in the legend columns. The morphometric aspects, relief amplitude, medium angle of slope and relevant hypsographical steps are expressed in the 3rd stage of classification of sculptural relief by respective morphometric terms (from plain via undulated plain, hilly land to highland). By arranging the classified types into a matrix, relief stages occuring in the territory of Slovakia appeared real. For the cartographic shaping a method was chosen that combined basic coloured shadings and structural rasters so, that the resulting map expresses the plasticity of relief at the level of macroforms and at the same time also their inner typological differention at the level of mesoforms.

Typological division of relief of Slovakia was prepared on the scale of 1:200 000. The presented map on the scale of 1:500 000 is a derived generalization of more detailed maps mentioned before.

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