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Geomorphological development of the lower part of the Vydra river basin

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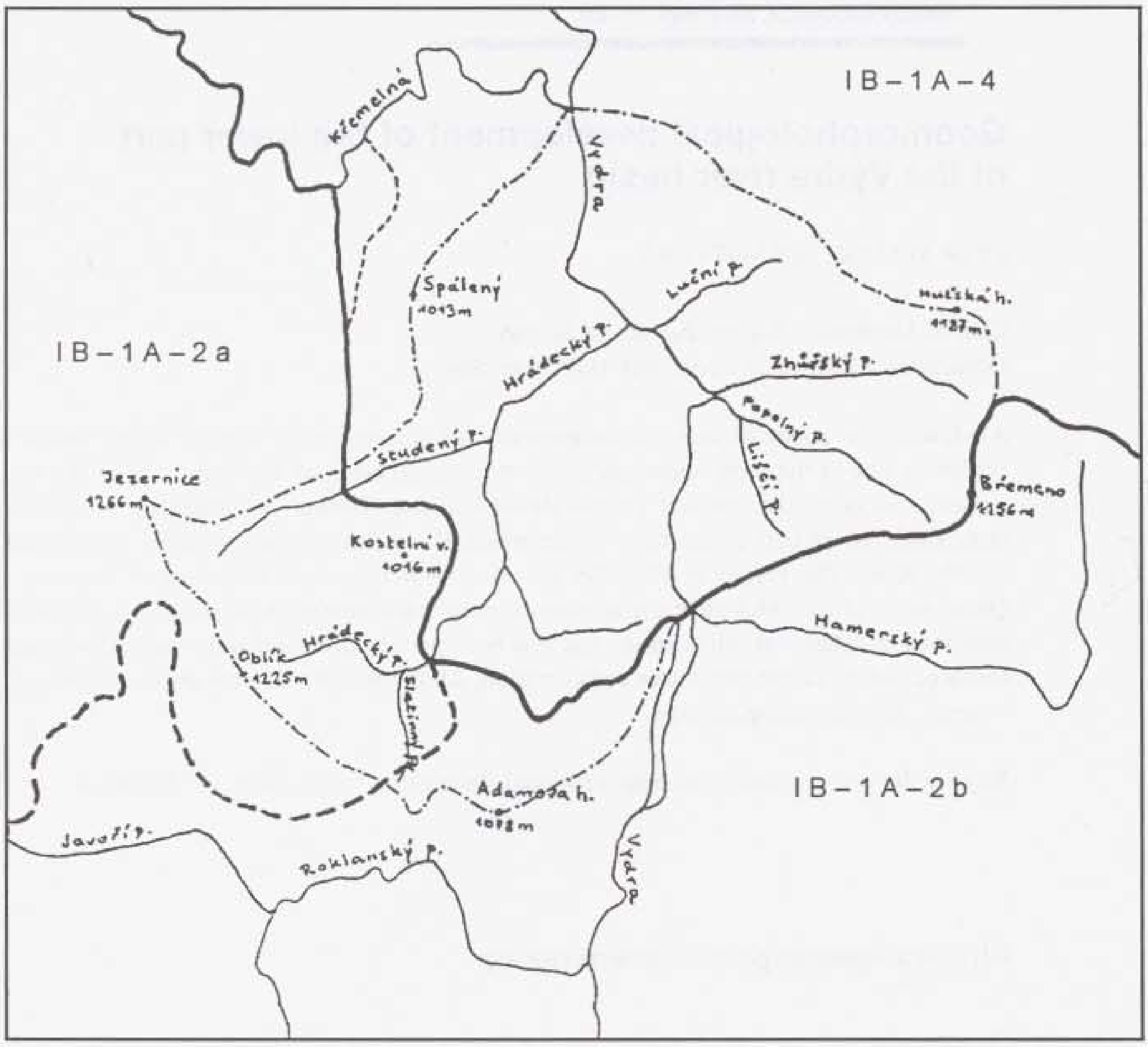
Abstract: The paper contains characteristics and description of surface forms which were studied in one of the most important geomorphological areas of the Šumava Mts. The authors present results of the detailed geomorphological investigation and mapping of genetically remarkable lower part of the river Vydra which flows through the Svojšská upland and the Kvilda plain. The region is characteristic of conspicuous manifestations of Neogene and Quaternary uplifts which gave rise to extreme erosional activity. Abundant cryogenic forms are described in detail, too. An attention has also been paid to structural and erosional- denudation forms occurring in the area under consideration. All the studied features are demonstrated in a synoptic geomorphological map.

Keywords: geomorphological map, erosional-denudation forms, Šumava Mountains

Physical-geographic characteristics

Orography

The surveyed area (Fig. 1) covers 38.5 km^2 of the lower part of the river Vydra from the mounth of the Hammerský brook down to the confluence with the river Křemelná. According to the geomorphological division of the Czech Republic (Czudek T. ed. 1972, Demek J. ed. et al.1987), the studied area belongs to a subunit of the Šumava plain. The Svojšská upland in the northen part of the mapped region exhibits erosional-denudation relief being furrowed by deeply incised valleys of the rivers Otava, Vydra, Křemelná, Losenice and their tributaries giving rise to steep intravalley ridges with elevations exceeding 1000 m a.s.l. (Huťská hora 1187, Křemelná 1125, Spálený 1013 m, Valy 1010). The Kvilda plain, which the southern part of the area belongs to, shows flat only locally slightly undulating relief that represents in the apical part of Šumava Mts the highest uplifted relics of an old denudation relief, i.e., Mesozoic-Paleogene peneplain. Flat relief is also demonstrated by wide shallow depressions. These were preserved because the backward erosion rejuvenated by the mountain range has not yet advanced that far. Isolated domes exceeding 1000 m a.s.l. developed on this large plateau (Velká Mokrůvka 1370 m, Blatný vrch 1367, Černá hora 1315 m, Poledník 1315 m, Stráž 1308 m, Tetřev 1260 m, Sokol 1253 m, Oblík 1225 m, Orel 1182 m).



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Legenda:

Provincie	Česká vysočina	Okrsek	IB-1A-2 Kvildské pláně
Soustava	I Šumavská		IB-1A-4 Svojšská hornatina
Oblast	IB Šumavská hornatina	Podokrsek	IB-1A-2a Prášilské pláně
Celek	IB-1 Šumava		IB-1A-2b Modravské pláně
Podcelek	IB-1A Šumavské pláně		

——— hranice okrsků

— — — hranice podokrsků

—·—·— hranice mapovaného území

Fig. 1: Orographic classification of the mapped area
Organické začlenění mapovaného území (podle B. Balatky)

Geological and tectonic setting

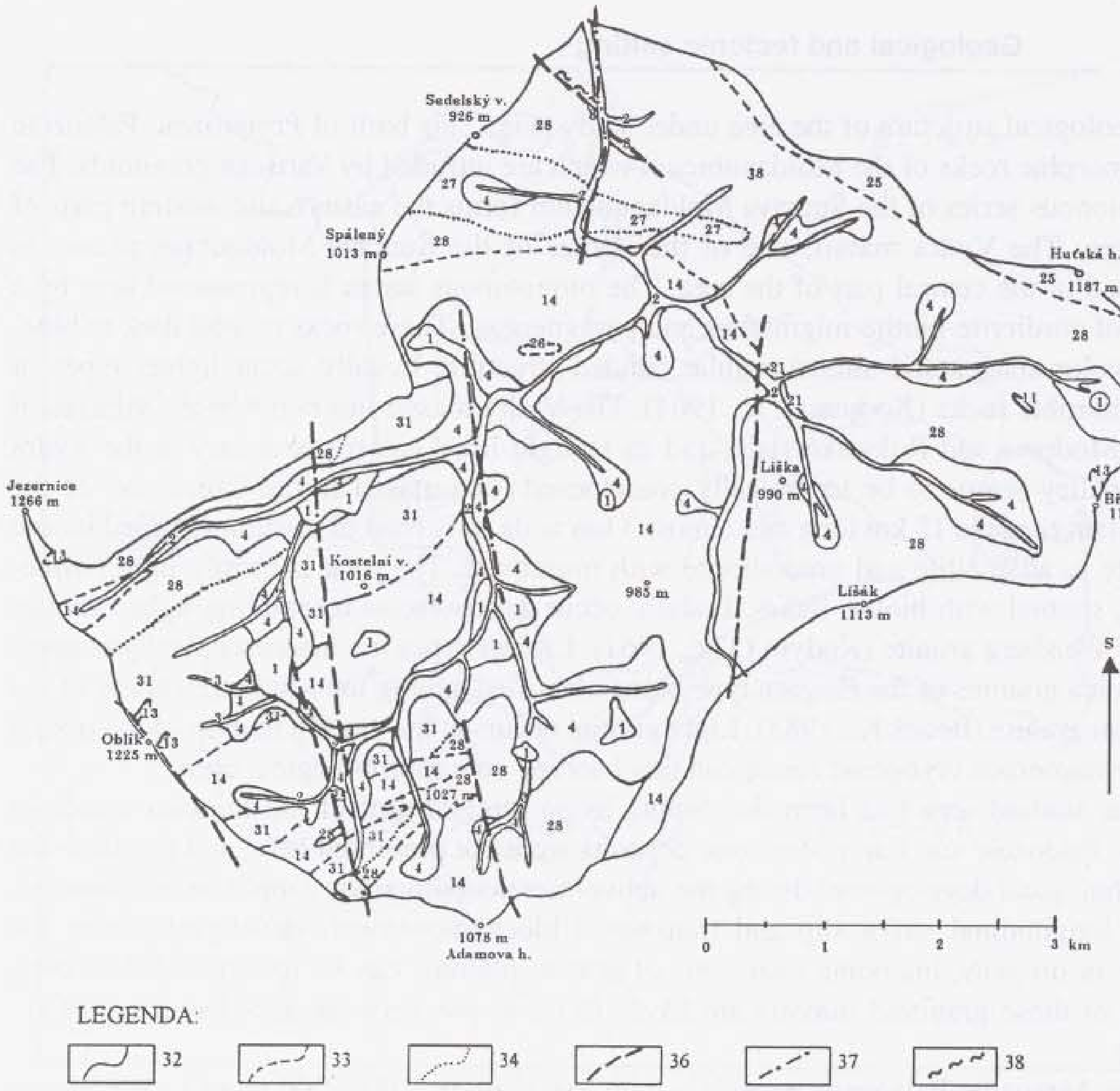
Geological structure of the area under study (Fig. 2) is built of Proterozoic-Paleozoic metamorphic rocks of the Moldanubicum which are intruded by Variscan granitoids. The monotonous series of the Šumava Moldanubicum forms the eastern and western parts of the area. The Vydra massif, one of the bodies of the Šumava Moldnubian pluton, is exposed in the central part of the area. The monotonous series is represented here by a zone of cordierite-biotite migmatites and paragneisses. These rocks exhibit dark to blue-grey color shades and almost regular banded structure. Locally occur lighter types of metamorphic rocks (Kodym O. jr., 1961). The Vydra massif lies between the villages of Srní, Modrava and Rokytské slatě, and its straight-lined eastern boundary in the Vydra river valley seams to be tectonically predisposed. The massif in the Czech part of the mountain range is 12 km long and almost 3 km wide. It is built of medium-grained biotite granite to adamellite and granodiorite with muscovite. The rock is mostly light (white-grey), spotted with biotite flakes. Locally occur darker facies resembling light varieties of the Weisberg granite (Kodym O. jr., 1961). Lighter types are macroscopically close to two-mica granites of the Eisgarn type being classified among the Mrákotín variety of the Eisgarn granite (Beneš K., 1983). Light granite occurs at the eastern margin of the massif where numerous cryogenic forms can be observed on a morphological crest.

The studied area had been developing as an integral unit of the Šumava mountain range. Paleozoic and Early Mesozoic deposits were not preserved here, and therefore the morphological development during the above-mentioned periods cannot be recostructed. Only longitudinal strike slip and transversal block movements developed during the Variscan orogeny, including intrusions of granite plutons, can be recognized. However, some of these granitoid massifs are likely to be of pre-Variscan age (Demek J. et al., 1965).

The Mesozoic-Paleogene peneplain with low altitude (100 – 200 m a.s.l.) is believed to have been the basal horizon in the neotectonic development of the Šumava mountain range. Slow arching of the mountain range took place since the end of the Oligocene till the Pliocene (mostly regional less contrasting movements of uplift character). Markedly intense movements of uplift character (including structural movements) occurred at the turn of Neogene and Quaternary periods. The Quaternary uplift of the mountain range in its mostly uplifted sections is, according to some authors (Kopecký A., 1983) equal to maximum 800 m (2/3 of the total uplift during the neotectonic stage).

The uplift of local structures was compensated by vertical erosion of rivers resulting from the readjustment of local erosional bases giving rise to conspicuous erosional forms in fresh crystalline rocks (Kopecký A., 1983).

The Šumava mountain range during colder climate in the Pleistocene became a periglacial area with local cirque glaciation. Solifluction and frost weathering led to the origin of cryoplanation plateaux, stone fields and debris flows. These processes were due to earlier exposure of the bedrock to weathering. Serial cross-sections (Fig. 4) may evoke an idea about morphostructures and their development in the mapped area.



KVARTÉR, holocén: **1** – rašeliny, **2** – fluviální písčité hlíny, hlinité písky a štěrky, **3** – deluviofluviální hlíny, písčité hlíny a hlinité písky,
holocén – pleistocén: **4** – deluviální a deluviálně soliflukční sedimenty (hlinitopísčité, hlinitokamenité),
PALEOZOIKUM, magmatity: **8** – biotitický žulový porfyr, **11** – leukorátní drobnozrnná až středně zrnitá biotitická žula, **13** – středně zrnitá až hrubozrnná porfyrická biotitická žula (weinsberský typ), **14** – středně zrnitá až hrubozrnná biotitická žula (varianta weinsberského typu),
PALEOTOIKUM – PROTEROZOIKUM, moldanubikum: **21** – kvarcit a kvarcitická rula, místy s polohami erlánu a leptynitu, **25** – masívní biotitická a sillimaniticko-biotitická pararula, s přechody do silimaniticko-biotitické migmatitizované pararuly, **26** – masívní světlá biotitická pararula, s přechody do sillimaniticko-biotitické migmatitizované paparuly až leukokrátního migmatitu, **27** – sollimaniticko-biotitická migmatitizovaná pararula převážně páskovaná, s přechody do masívní biotitické pararuly, **28** – cordieriticko-biotitická silně migmatitizovaná pararula převážně páskovaná, až migmatit stromatitového typu, místy s muskovitem a sillimanitem, **31** – masívní drobnozrnný až středně zrnitý cordieriticko-biotitický migmatit (anatexit) s přechody do biotitické pelové ruly,
32 – zjištěná hranice hornin, **33** – pravděpodobná, přesně nezjištěná hranice hornin, **34** – petrografický přechod hornin, **36** – zlom předpokládaný nebo nepřesně lokalizovaný, **37** – zlom předpokládaný, zakrytý mladšími útvary, **38** – mylonitová uóna.

Fig. 2: Synoptic geological map of the lower part of the Vydra river basin
Přehledná geologická mapa dolního povodí Vydry (podle geologické mapy ČR, list 22–23 Kašperské Hory)

Drainage pattern

Change in the character of stream pattern resulted from a fast uplift of the central part of the Šumava Mts in Quaternary times. Its prolonged development before the Neogene, due to low rivers gradient and dry climate gave rise to broad valleys in shallow depressions. Simultaneously with the uplift of the area and deformation of the peneplain, the drainage pattern became more complex and contrasting due to increasing unbalance of river gradients (Fig. 3) accompanied by small waterfalls linked with more resistant rocks.

A broad and shallow valley depression south of Srní, which is nowadays flown through by the Hradecký brook, represents a relic of the old drainage pattern. The present river Vydra originated due to a head erosion and by beheading of older streams. The river Vydra near the Turnerská cottage flows through almost a canyon-like valley which above the cottage turnes sharply from N-S direction to the NE and then immediately to the NW. These changes are strictly controlled by predominating strike of fractures in the bedrock. The river itself selected the most frequent strike of fractures for its bed.

The river Vydra is the main stream in the mapped area. It rises on the NW slope of Luzný (Lusen, 1373 m a.s.l.) at an altitude of 1215 m a.s.l. From its spring area it flows through a broad shallow valley, but below Březník the valley suddenly becomes narrow with steep slopes and then the narrow valley gradually opens to the north and the stream flows into a depression near Modrava. After Modrava the valley again narrows. Changes in valley profiles are followed by changes in river gradients (Fig. 3).

The gradient on the slopes of Luzný is equal to 39.2 %, in the valley south of Březník 9.8 %, between Březník and Modrava 20.7 % and between Modrava and Antýgl 17.2 %. Below Antýgl, the river gradient increases and the valley cuts deeper and its slopes become steeper. The river bed is full of granite boulders and blocks which resulted from frost weathering of granite of the Vydra massif. The river stretch between the Hálkova cottage and the mouth of the Hrádecký brook shows a gradient of 56.6 %. Here, the granite blocks are 3 – 5 m large giving rise to violent rapids. Numerous eversion forms can be observed in the river bed flowing through migmatites. In further section, up to the mouth of Křemelná river, the gradient becomes slightly low and the valley gradually broadens (Fig. 4) being also deeper. A total lenght of the river Vydra up to the confluence with the river Křemelná is 23.1 km, whereas the catchment area is 146.2 km^2 large. The average annual flow of the river Vydra measured at Modrava is equal to 3.44 m^3/s. More important right-hand tributaries are the Ptačí brook (lenght 5.0 km, average gradient 39.8 %), Černohorský brook (4.1 km; 42.4 %), Filipohuťský brook (4.5 km; 37.3 %), Hamerský brook (9.1 km; 23.2 %), Popelný brook (3.1 km; 97.1 %), Zhůřský brook (3.6 km; 97.5 %) and Luční brook (1.9 km; 105.8 %), the left-hand tributaries include: Březnický brook (2.6 km; 60.8 %), Cikánský brook (1.8 km; 21.1 %), Roklanský brook (13.9 km; 20.6 %) and Hrádecký brook (7.2 km; 53.9 %). Sinistral tributaries have generally lower gradient, whereas dextral tributaries are mostly short and steep.

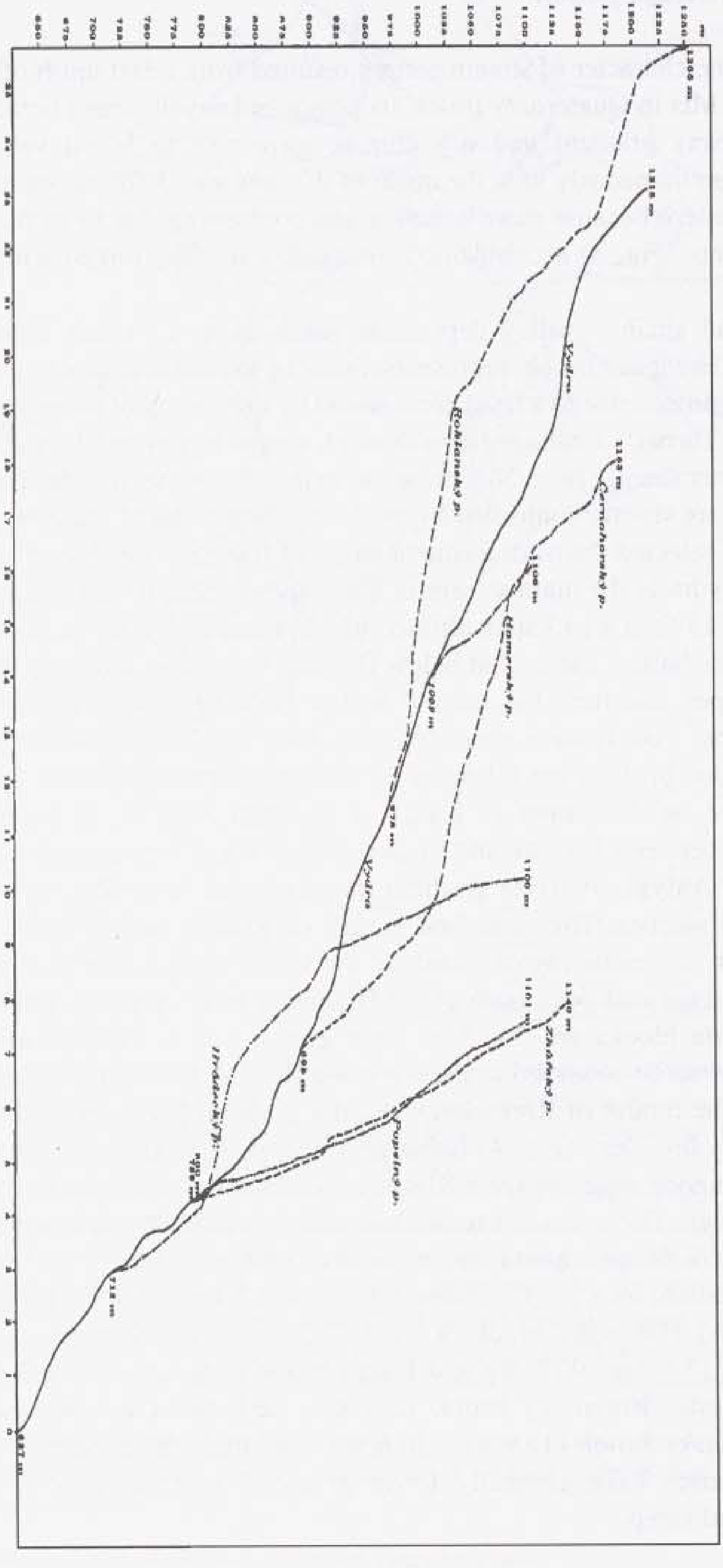


Fig. 3: Longitudinal section of the river Vydra and its tributaries
Podélný profil říční soustavy Vydry (20x převýšeno)

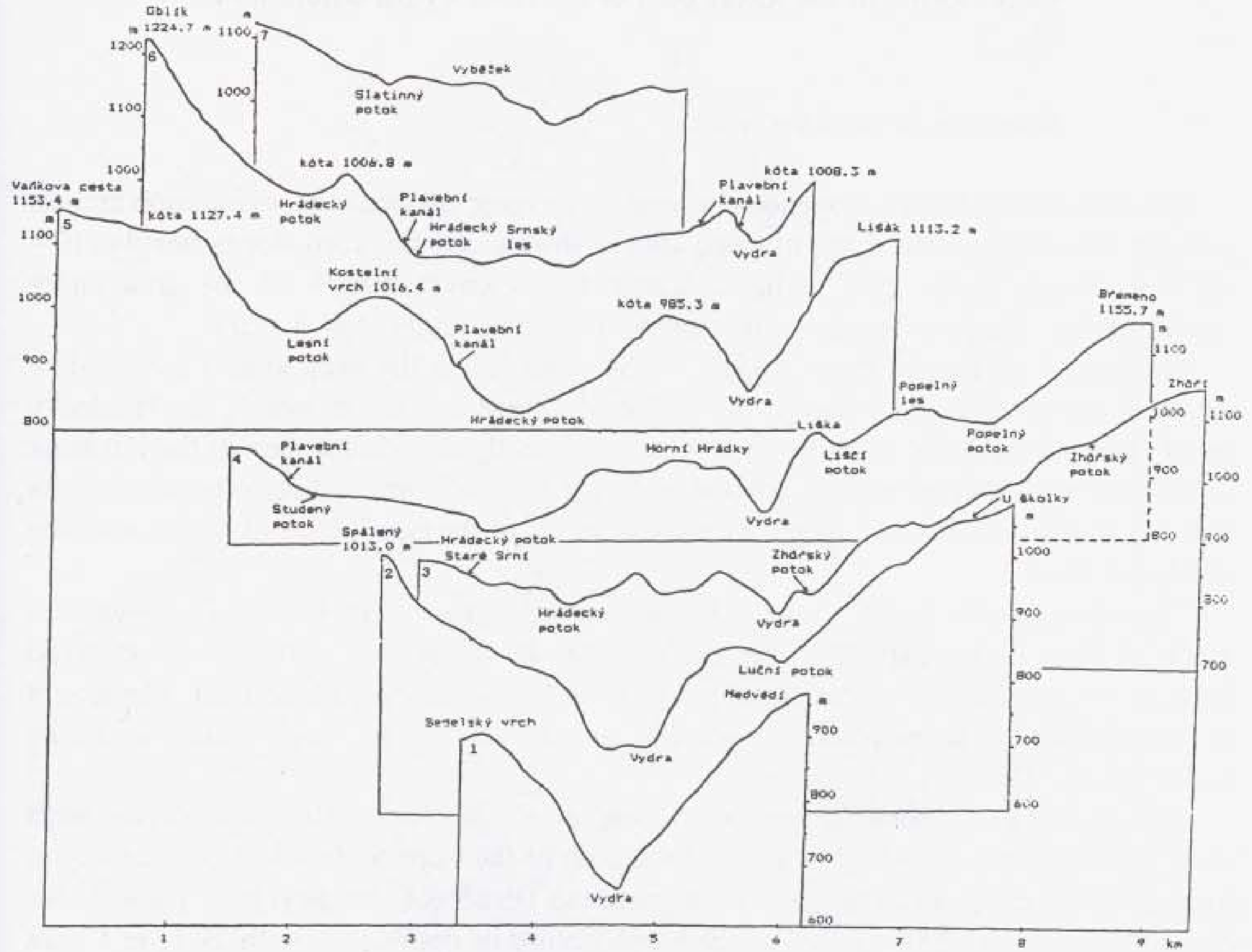


Fig. 4: Serial cross sections of the lower part of the Vydra river basin
Sériové příčné profily dolního povodí Vydry (5x převýšeno)

Relief forms in the lower part of the river Vydra catchment

(Fig. 5)

Structural forms of the relief

Forms resulting from endogenous processes (tectonic dislocations, exfoliation arches, jointing, lithology) occur in the mapped area as structurally denuded slopes steeply (10 – 20°) or sheerly (over 20°) inclined. These forms cover 1.8 % of the area under consideration. They are mostly connected with inferred faults of N-S strike.

The largest surface of these slopes can be observed in the deep almost canyon-like valley of the river Vydra between the Hálkova cottage and the mouth of the Hrádecký brook. Morphologically most prominent are structurally denuded slopes on the left bank of the river Vydra, at the eastern hillside of the range near Horní Hrádky (elevation points 960.1 m and 886.0 m a.s.l.) which extends as far as to the confluence of Vydra with the Hrádecký brook.

Three large castle koppies resulted from intense cryogenic processes. Their walls as much as 40 m high steeply fall into the Vydra river. Some frost cliffs can be observed between the castle koppies but the slope is locally covered by a block-field. The lenght of this structurally denuded slope including its part covered by block-field is 2 km, its width is 150 – 200 m.

Structurally predisposed slopes on the opposite right bank of the river Vydra start more downstream, about 250 m above the mouth of the Popelný brook. Here, the slopes line an incised meander of the river Vydra near the Turnéřská cottage (Photo 1.), and also occur along the last 200 – 300 m of the brook before its confluence with the river Vydra in valleys of Popelný and Zhůřský brooks. Some rock outrops about 20 – 30 m high can be seen straight above a road running along the right-hand river bank. A number of frost cliffs occur above these rock exposures. The broadest (max. 350 m) part of the slope occurs at a locality called Na stoupách, NW od the Turnerská cottage. The total lenght of the slope is 1200 m. The slope towards the NW is covered by a large rock field.

Structurally modelled slopes of lesser extent occur on both banks of the river Vydra, and also downstream below the mouth of Hrádecký brook. All slopes along the Vydra river valley show an inclination above 20° which led to faster surface degradation and exposure of the bedrock. Rock outcrops were then considerably remodelled during glaciation. Another factor influencing the origin of the above-mentioned forms was the activity of the river Vydra which is deeply incised scouring the adjacent slopes and transporting the desintegrated and weathered material. The orientation of slopes is controlled by the river Vydra water route.

Other three localities of structurally predisposed slopes occur on relics of exfoliation domes. They form a continuous almost one kilometer long and 150 – 200 wide strip of NNW-SSE strike in forests near the Horní Hrádky village, about 500 m above the highway connecting Srní and Antýgl (i.e., NW slopes of the elevation point 985.3 m), then the northern slope of Kostelní vrch (1016 m a.s.l.), and finally the southern and southeastern slope of Spálený (1013 m a.s.l.). All three localities were affected by intense glacial processes which gave rise to frost cliffs (as much as 30 – 40 m high near Horní Hrádky) and blocky colluvium. The slopes on Spálený exhibit steep to sheer inclinations.

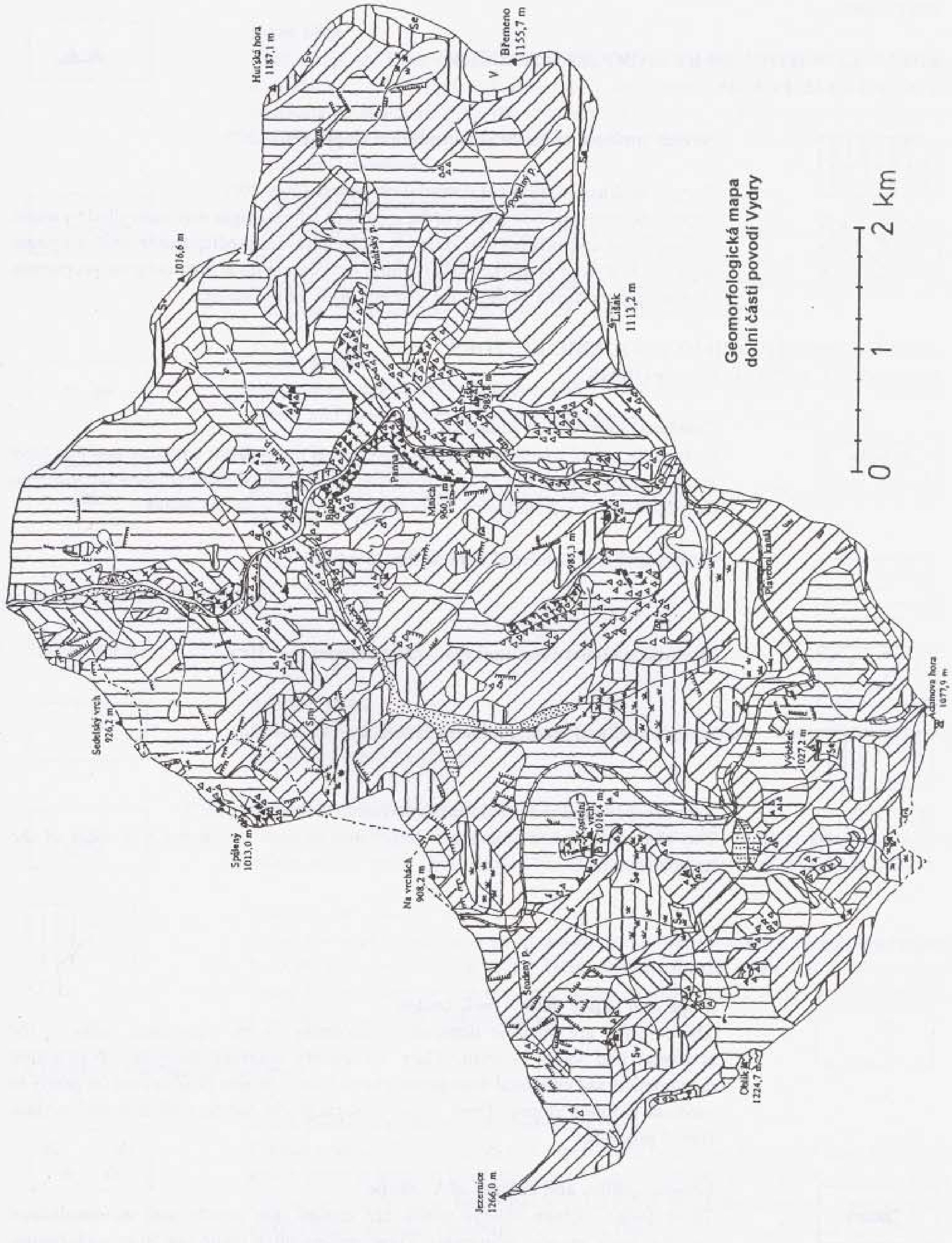
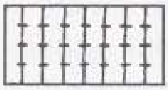


Fig. 5: Geomorphological map of the lower part of the Vydra river basin

Legend and definition of forms used in the detailed geomorphological map of the lower part of the Vydra river basin

FORMS CONDITIONED BY ENDOGENIC FACTORS
STRUCTURAL FORMS



Steeply inclined structural denudation slopes (10 – 20°)

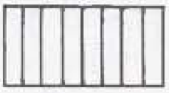
Steeply inclined structural denudation slopes (over 20°)
These categories include slopes or their parts of which origin was controlled by mode of deposition and lithology of relevant rocks, tectonic predisposition and/or system of joints. The slope is marked as structural denudation form providing the proportion of structural elements in the slope exceeds 40 % of the surface.

FORMS CONDITIONED BY EXOGENIC FACTORS
EROSIONAL DENUDATION FORMS

Erosional denudation plains (0 – 2°)
Parts of the relief which originated regardless of the bedrock structure and that have inclination not exceeding 2°. The following plains can be distinguished according to their position: V – peak plains, Sv – slope plains, Se – saddle plains

Gently inclined erosional denudation slopes (2 – 5°)

Medium inclined erosional denudation slopes (5 – 10°)



Steeply inclined erosional denudation slopes (10 – 20°)

Very steeply inclined erosional denudation slopes (over 20°)
The above-mentioned slopes are considered to have originated regardless of the bedrock structure

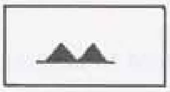
Fluvial forms

Slope and valley dells – rock-basins
These forms are shallow depressions occurring in the uppermost parts of the erosional and valley system. They are mostly rimming margins of structural denundation and erosional denudation plains. They can also be observed on gently to medium inclined slopes. Their origin is particularly due to suffosion and surface fluvial processes

Erosion gullies and ravines of V- shape
These forms include valleys which are incised into mostly soft unconsolidated material (rock mantle, deluvium). These gullies often come out from rock-basins. They originate due to vertical erosion and become elongate due to backward erosion. Cross-sections are of V-shape

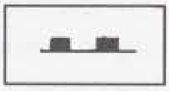
Prominent rock steps in streams

Cryopediments and their forms



Frost cliffs
Rock step in slope which originates through frost weathering and surface degradation. Rock walls of frost cliffs are vertical or almost vertical and/or overhanging depending on the structure of relevant rocks (particularly joints or bedding planes). This category also involves the rock outcrops remodelled by cryogenic processes

Cryoplanation terraces and plains
These forms include rock surfaces which originate through destruction and retreate of a frost cliff on marginal planes of L joints in slopes. Their surface is usually covered with products of frost weathering which are also transported on their face. The peak cryoplanation plain represents then their advanced stage.

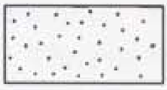


Castle koppies
Large often rugged rock exposures with vertical walls which occur on apical parts of domes and rounded crests. Their length considerably exceeds their height.

Isolated rock forms
Rock outcrops which stick out from the surrounding surface. They are smaller than the rock koppies

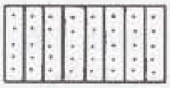
ACUMULATION FORMS

Fluvial forms



Alluvial plain
Recent accumulation domain of the river formed by loose (unconsolidated) sandy and loamy-sandy sediments

Dejection (alluvial) cones
Accumulation forms originating due to fluvial activity in valley mounths, erosion gullies and ravines. They usually have a triangular shape (in plan)



Valley floor run-off
These forms are constituted by unconsolidated material washed up by flood waters from the upper parts of the relief. These deposits fill the upper and middle parts of valley floors. Their surface is gently inclined relative to the valley axis and usually gradually passes into adjacent slopes

Cryogenic and solifluction forms

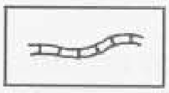
Block-fields (continuous and discontinuous)
Greater amount of rock blocks and angular rock fragments separated from rock walls which cover at least 50 % of the surface. Gravitation and slope processes play major role in the formation of block-fields. Continuous block-fields are as much as a few metres thick whereas discontinuous block fields have randomly distributed blocks over the surface

ANTHROPOGENIC FORMS

Terrace fields, anti-erosion walls and rock accumulations
Anthropogenic steps (walls) originated through human activities related to farming. Only forms being more than 1 m high and 50 m long are mapped

Anthropogenically reshaped relief
Larger areas remodelled by any human activity (landscaping, site development for construction, etc.)

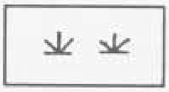
Loam pits



Canal for floating timber

OTHER FORMS

Springs



Peat bogs

Lakes (natural, man-made)

Erosional denudation forms of the relief

Erosional denudation plains and slopes

Erosional denudation plains are distributed over the entire studied area covering 1.2 % of the total surface. However, most abundant are in the eastern part. Three types of plain can be distinguished according to their position: peak, saddle and sloping. The most abundant are the saddle erosional denudation plains, whereas sloping plains are slightly less frequent and the least abundant are the peak plains.

Two thirds of erosional denudation plains occur on dividing ridges in marginal part of the mapped area (Photo 2.). Erosional denudation plains exhibit a variety of shapes. The peak and sloping plains are mainly oval or elliptical. The saddle plains are mostly narrower towards their central part and broader towards their marginal parts. Their areal extent of plains varies between 1 and 18 hectares.

Erosional denudation plains can be divided into two groups according to their altitude above sea level. The first group includes plains of an altitude of 1015 m ≤ 45 m which occur mostly in the western part of the area. They are mostly small (1 – 3 ha) and have a saddle character. The other group involves plains occurring at altitudes of 1150 m ≤ 35 m. These are the largest plains observed in the studied area. The largest one is the peak plain on Břemeno which exhibits an elliptical shape being 650 m long and 250 – 400 m wide. This plain together with northerly lying plains on Zhůř and Huťská hora is part of a system of plains situated on the Vydra (and Hamerský brook) and Losenice divide to which also belong plains of Zhůřské slatě, Ranklovská rovina and Mezilesní slať which lie already outside the mapped area.

The plains are usually surrounded by gently inclined slopes (2 – 5°) which transit into steeper slopes. This configuration may support a hypothesis that these plains are relics of an old levelled relief which was broken and shifted into various heights.

Erosional denudation slopes, which cover considerable part of the mapped area, form four categories according to their angle of slope: 2 – 5°, 5 – 10°, 10 – 20° and over 20°. The change in slope angle is usually gradual with the exception of western slopes of the Vydra river valley between the mouth of Hrádecký brook and Kramlový Mlýn, and eastern slopes of the Oblík massif. The most abundant morphological form in the mapped area are slopes having angles 10 – 20° and 5 – 10°.

Gently inclined erosional denudation slopes (2 – 5°) constitute 12.6 % of the area under consideration. They occur in form of a discontinuous strip which is built of dividing ridges and their forks at the southern and eastern boundary of the area. Gently inclined slopes are usually linked with plains and together with them seem to form a denudation relic of the old levelled relief. These gentle slopes transit gradually towards the central part of the catchment into slopes with medium angles. Gently inclined slopes can also be seen in broad and shallow valleys (often filled with peat moors) in the Hradecký brook catchment which may be relics of pre-Quaternary drainage pattern.

Medium inclined erosional denudation slopes (5 – 10°) are abundant constituting 36.5 % of the mapped surface. They mostly form a gradual transition from gently inclined slopes on flat divides to steeply inclined erosional slopes. These slopes also form a broad and shallow valley depression south of Srní where are linked with the alluvium of the

Hrádecký brook and then with gently inclided slopes of a peat bog in the Srnský les (forest) and upward pass into slopes with steep angle. A wide and flat ridge near the Horní Hrádky village represents morphologically significant part of the entire area. Medium inclined slopes form there an isolated area (1 800 m long, max. 1000 wide) surrounded by steeply dipping slopes. Some islets of gently inclined erosional denudation slopes can be seen in the highest parts of the ridge (elevation points 985.3 m and 930.3 m a.s.l.). They may represent denuded relic of an old levelled surface at lower altitude (which is supported by the elevation above sea level which is close to that one of erosional denudation plains at 1015 m ≤ 45 m).

Erosion gullies start to develop on gently inclined slopes. The continuity of slopes is disturbed and accompanied by reduction of their surface as a result of continuing headward erosion together with suffosion processes which permanently keep shifting shallow dry little dells inward the slopes.

Steep erosional denudation slopes (10 – 20°) cover 40.3 % of the total surface of the studied area, thus being the most abundant element of the relief. They occur mostly in central parts of the valley slopes. Even on these slopes exist shallow dry little dells but are much less abundant relative to the above-mentioned slopes. They are furrowed by erosion gullies and ravines created by streams. Locally occur discontinuous rock fields. Regardless of steep inclinations, some signs of earlier farming activities can be observed on these slopes (terrace fields and pastures) particularly in the neighbourhood of abandoned villages – Zelená hora, Zhůří, Jelenov and Buchingrův dvůr.

Steeply inclined erosional denudation slopes (over 20°) constitute 6.5 % of the total surface of the area under study. They mostly occur in lower sections of deeply incised valleys or canyons of the river Vydra and its tributaries (Hrádecký brook, Zhůřský brook and Popelný brook). They can also be seen in the esatern part of the Oblík massif where they form a sharp transition between planed relief in the area of Kostelní vrch (about 1 000 m a.s.l.) and on a flat dividing ridge about 1150 m a.s.l. Rock exposures on these slopes suffered from frost weathering which gave rise to frost cliffs and rock fields.

Cryopediments and their forms

Abundant meso- to macroforms resulting from cryogenic processes can be observed in the mapped area (parallel backwearing of steeper parts of slopes and subsequent development of erosional denudation base of slope surface due to intense frost weathering and subsequent surface degradation). These forms include frost escarps, scrubs, cryoplanation terraces and apical cryoplanation plateaus.

Two peak cryoplanation plateaus were identified in the surveyed area. One of them occurs in the uppermost part of Oblík (1225 m a.s.l.; Photo 3.). It is about 300 m in diameter and its inner vertical range is equal to 14 m. Its northern boundary is rimmed with three frost cliffs under which the plateau passes into steeply inclined slope where outcrops of granite with migmatite mantle can be seen. Another frost cliff occurs at the southeastern margin of the plateau. An isolated rock about 7 m high, disturbed by a frost fissure, occurs on the cryoplanation plateau. The plateau is covered by a thin layer of detritus maximum 50 cm thick which contains blocks of mostly migmatite and rarely granite as much as 1.5 m large. Numerous fallen trees argue for thin layer of soil.

Another peak cryoplanation plateau lies on Kostelní vrch (1016 m a.s.l.) at an altitude between 1000 and 1016 m a.s.l. Its bedrock is built of migmatites. The plateau is of elliptic shape with its longer axis being 250 m long. The plateau on its SE and SW borders is terminated by two frost cliffs. Two rock exposures which suffered from cryogenic reshaping can be seen at the western boundary of the plateau. Two torsos which remained after cryoplanation processes, occur straight on the cryoplanation plateau. One of them is an isolated rock about 8 m high which desintgrated into two 2 metre large blocks in the eastern part of the plateau. Another isolated rock in the western part of the plateau can be defined as a castle koppie since its horizontal dimension exceeds its vertical dimesion (5 – 15 m). This castle koppie is trending N-S and exceeding the cryoplanation plateau across the steeply inclined slope which surrounds the plateau. The blanket of detritus on the plateau is slightly thicker than that at the former locality (about 1 m). Two mature cryoplanation terraces were identified on the eastern slopes of Oblík (750 m E and 600 NE of the crest). Their stage is formed by a rock escarp.

The frost cliffs appear to be the most abundant cryopediment forms in the surveyed area. They occur at the following localities: river Vydra valley between the Hálkova cottage and Čeňkova Pila village, lower stretch of the Zhůřský brook and Popelný brook, western edge of a flat crest near Horní Hrádky, then Kostelní vrch (1016 m a.s.l.),

Liška (900 m a.s.l.), Spálený (1013 m a.s.l.) and Oblík (1225 m a.s.l.). The shape, size and distribution of mesoforms originated through cryogenic processes were to large extent controlled by systems of joint planes in the bedrock. The investigation of the above-mentioned forms versus trends in joint planes has been an integral part of the field work.

Frost cliffs on the Kostelní vrch (1016 m) occur on its northern slope. The most prominent rock form is a castle koppie which is 75 m long, trending SSE-NNW and is being terminated in the north by a wall as much as 15 high, oriented E-W. The cliffs occur at two altitudes (995 and 975 m a.s.l.), their heads facing N to NNE and their height reaches 3 – 12 m. Their morphology was influenced by orientation of the Kostelní vrch slope which was exposed to the north thus open to cold and harsh climatic conditions.

A large isolated rock, as much as 25 m high, occurs on a crest which extends from the Kostelní vrch to the west, The rock is about 150 m away from the summit at an altitude of 1000 m a.s.l This isolated rock shows only of few joints and therefore only large blocks, about 5 m large, originated during its desintegration. Two towers can be observed in its uppermost parts.

Altogether 203 measurements of joint planes strike were done on the apical cryoplanation plateau and the northern slope of the Kostelní vrch (see Fig. 6.). Two systems of joints can be seen on the diagram. The primary system is dominant, whereas the secondary one is much less abundant. The S joints have strike 160 – 170°, whereas the Q strike is doubled (60° and 80°). Rectangular jointing reflects the primary system which can be observed in the field. The duplication of Q strike results in gently arched course of frost cliff walls on the northern slope of Kostelní vrch. The S strike controlled the orientation of castle koppie being also evident in rugged morphology of local frost cliffs. The secondary system consists of joints trending 10° to 110° but it is much less abundant and therefore its role in morphology of the relief is much less prominent.

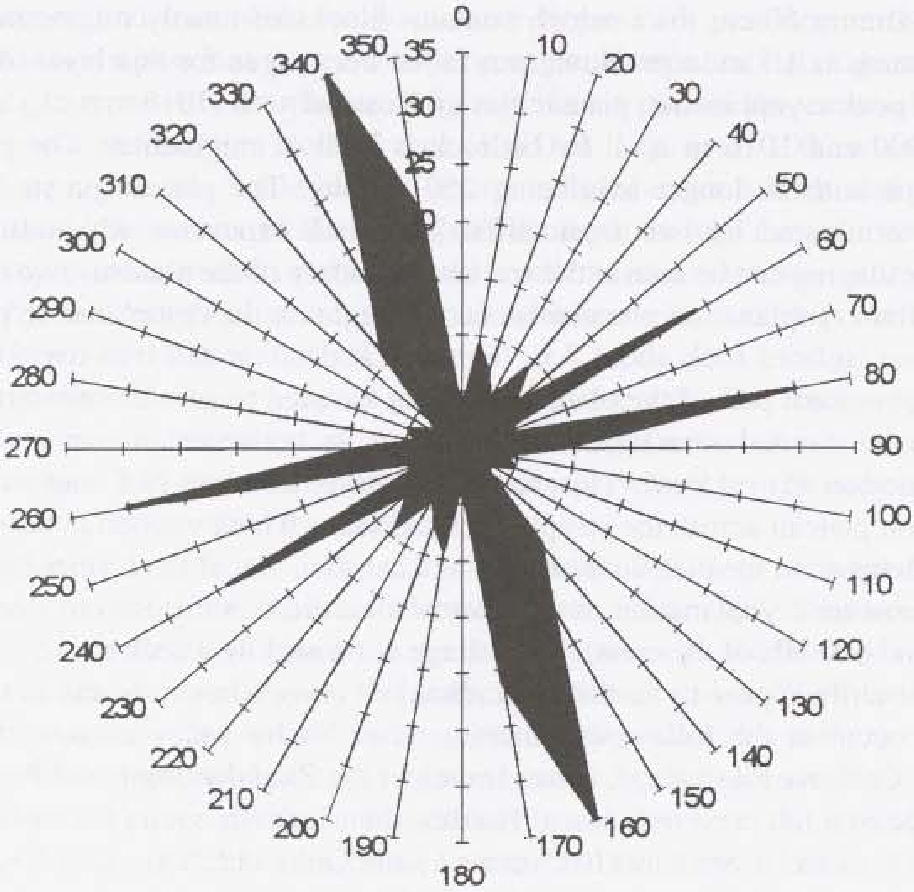


Fig. 6: Cloose's rosette of 203 strikes of joint plane measured on Kostelní vrch
Cloosova růžice 203 směrů puklinových ploch na Kostelním vrchu

The western edge of a flat crest near Horní Hrádky above the highway connecting Srní and Antýgl represents one of the most notable rock forms modelled by cryogenic processes. Local frost cliffs occur on granite outcrops of the Vydra massif forming a strip about 750 m long, trending NNW-SSE . The strip begins 350 m NW of the „Kamenný dům" resthouse. Initially, the cliffs occur at two horizons. Their walls are 4 – 7 m high and their heads are oriented towards WSW to SW. However, two steps of cliffs are not developed along the entire length of the above-mentioned strip because the height of the upper step becomes greater towards SSE, whereas the lower step dies out.

A large frost cliff (80 long and max. 30 m high) can be observed about 200 m west of the „Kamenný dům" resthouse. It is also very wide (30 m) but was split in two parts by a longitudinal frost joint. Another 35 m high and 60 m long cliff occurs about 30 m away from the latter one. The hight of cliff walls locally decreases (5 – 12 m), and two steps can again be observed. These cliffs are characteristic of abundant horizontal joints which gave rise to horizontally lying „benches" (i.e., blocks of which length and width are greater than their thickness).

Other three large frost cliffs (35 – 40 m high, Photo 4.) lie about 250 m SSW of the „Kamenný dům" resthouse. Horizontal joints are much less abundant giving rise to large blocks as much as 5 m in size, and some rock overhangs originated. Rock walls are very rugged.

Frost cliffs continue from this site for another 100 m to the SE being terminated by a dry small dell west of the elevation point 985.3 m. Altogether 233 measurements of strike of joint planes were done on frost cliffs at this locality (Fig. 7.). Two conspicuous systems of joints can be seen on the diagram. The first one is concurrent with the primary system observed on the Kostelní vrch: S joints run 170°, whereas Q joints run 80°. The strike of S joints was critical for the development and orientation of cliff walls since it mostly runs NNW-SSE to NW-SE. The second system of S joints is doubled: 20° and 40°; the Q joints run 100 – 110°. The second system is more abundant but which system is primary is difficult to establish. Because of these systems of joints the course of frost cliffs is not straight-lined, and some short forks protrude from extra large cliffs.

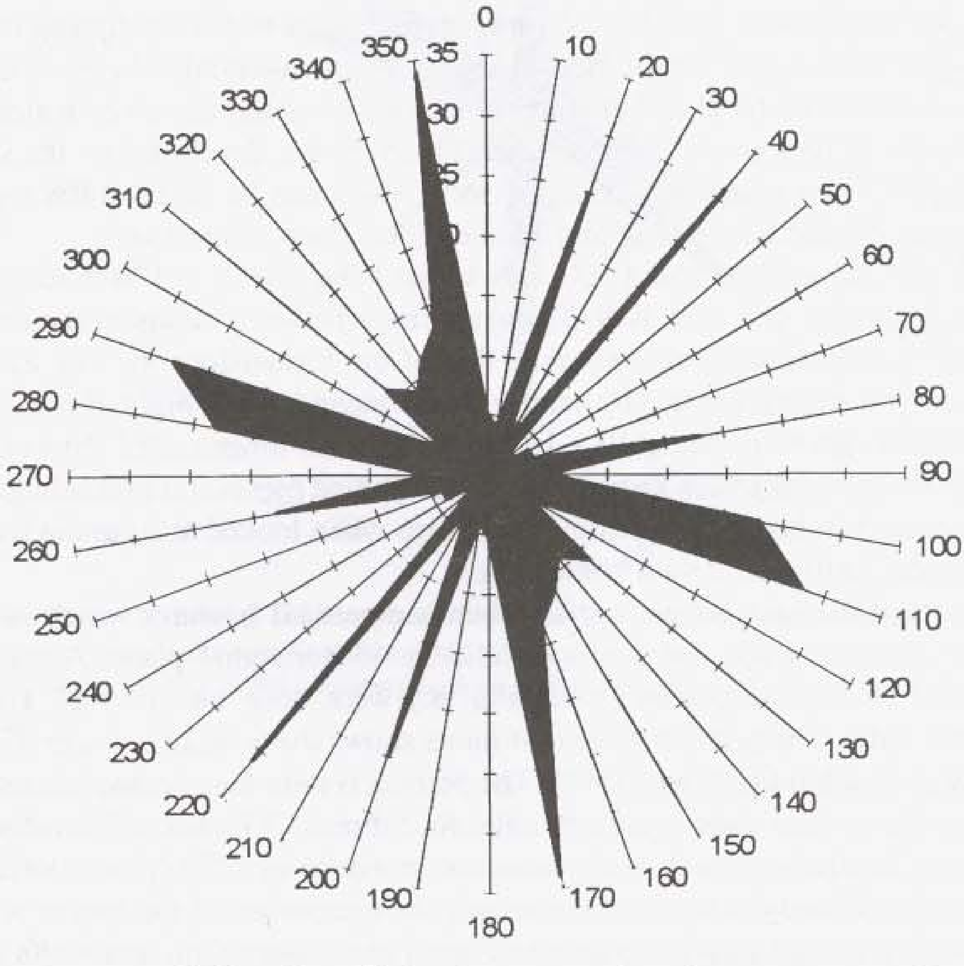


Fig. 7: Cloose's rosette of 233 strikes of joint plane measured on the west crest near Horní Hrádky (at Kamenný dům resthouse)
Cloosova růžice 233 směrů puklinových ploch na záp. straně hřbetu u Horních Hrádků (u penzionu Kamenný dům)

An elongate flat crest is terminated by an elevation point 985.3 m a.s.l. The above-mentioned strip of cliffs is located at its western edge. The crest is divided into two branches extending to the SW and SE. A rock koppie occurs on the SW rounded crest. Its dimensions are 50 x 20 m and hight reaching as much as 30 m (Photo 5.). The koppie is dissected by joints to form single rock towers. Several frost cliffs in the slope are adjacent to these rock towers. Locally can be observed „benches" in vertical position which are due to abundant vertical joints (Photo 6.). An isolated rock at an elevation of 978 m a.s.l. is situated on the crest SE of the elevation point 985.3 m. It is 5 m high with 10 x 4 m plan. A cryogenically remodelled exfoliation dome with flanks dipping to the NW is exposed at two sites about 50 m SE of the isolated rock in places where the slope begins to incline more steeply.

Another area with abundant frost cliffs confined to the Vydra granite massif is on the rounded crest above the left bank of the river Vydra. It extends to the N from flat relief near Horní Hrádky. Three large rock koppies originated on this crest, the length of which is less than 2 km. Numerous cliffs can be seen on the eastern slope of the crest. The rock koppie which is about 150 m long and as much as 40 m wide culminates at the elevation point 960.1 m. Its longer axis runs N-S. The hight of walls along its eastern side is greater (40 m) and descends to the river Vydra, whereas the western walls of the castle koppie are maximum 25 m high. This asymmetry is due to the inclination of joints which are dipping to the W.

This rugged rock koppie can be classed among types with doubled system of S and Q joints. A rock field with blocks of granite as much as 3 m large lies on both slopes below the rock koppie. A rock tower called Mnich (Photo 7.) has developed on the summit of the rock koppie. Two perfectly developed rock bowls can be seen on the top of rock tower. They are 50 and 65 cm long and 15 and 40 cm deep, respectively.

Another rock koppie lies about 500 m N of the latter one. It is 120 m long and 10 – 20 m wide. Its longer side runs N-S. The asymmetry between hights of the eastern and western wall is even more prominent than that of the former locality. The eastern wall consists of several steps separated by narrow ledges having a total hight of max.45 m. The western wall has two steps being 10 – 15 m high. A rock tower called Panna (Photo 1.) dveloped on the top of the rock koppie. It is accompanied by several protruding blocks of rock as much as 5 m high, so the whole rock form when looked at from the river Vydra resembles a real fortification with battlement.

Some parts of the rock koppie contain abundant vertical fractures which gave rise to benches 40 – 80 cm thick that are perpendicular to horizontal plane. Altogether 214 measurements of fracture planes strike (Fig. 8.) were done on this rock koppie and adjacent frost cliffs. The primary system of joints shows the S strike equal to 0°, whereas the Q strike is doubled (110° and 130°). The second system has a conspicuous strike of 50°, whereas the system almost perpendicular to it shows 150° strike. The latter is much less abundant. Similar results showed measurements done by J.Votýpka in 1972.

The S strike of the primary system controls the orientation of the longer wall of the rock koppie. The second fracture system can mostly be observed on frost cliffs occurring on the slope below the rock koppie. The sloping crest, which accommodates on its top the above-mentioned rock koppie, turns to the west and the river Vydra forms a superinduced meander around the koppie.

Another rock koppie occurs about 750 m to the NW. This rock form is trending NNE-SSW, being 70 m long and 10 – 20 m wide. Its eastern wall falling down to the river Odra is 30 – 40 m high, whereas the western wall is only 5 to 20 m high. The whole form is dominated by a rock tower called Baba. The rock tower is separated into two parts by a widened frost crack. Its eastern part is 40 m high. Some overhanging blocks protrude from the walls of the rock tower. The rock caverns seem to be most abundant among microforms of the relief.

Some rounded blocks can also be observed on the above-described rock koppies. They are, due to selective erosion and fracturing, connected with the bedrock by only a small plane (Photo 9.). These forms, however, are not loggan stones as erroneously quoted in

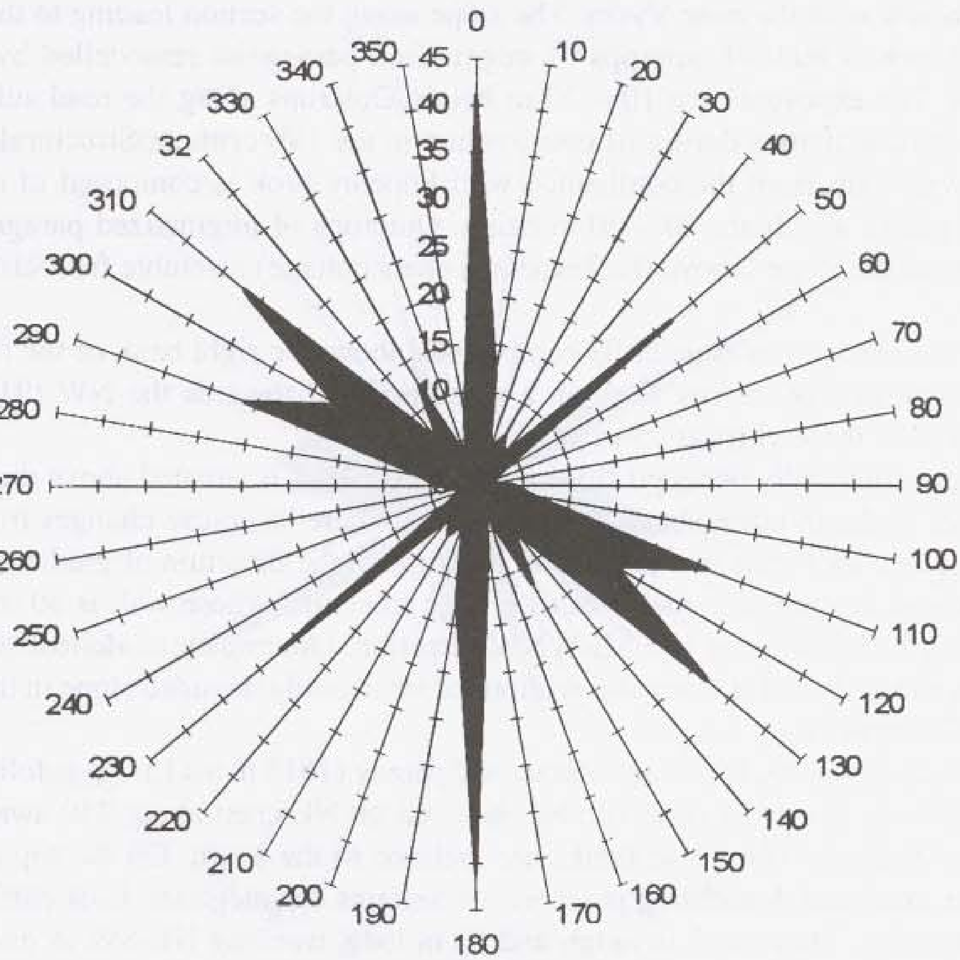


Fig. 8: Cloose's rosette showing 214 joint plane strikes measured in the neighbourhood of the rock form Panna above the river Vydra near Turnéřská chata cottage
Cloosova růžice 214 směrů puklinových ploch v okolí skalního útvaru Panna nad Vydrou u Turnéřské chaty

tourist guides and panels at tourist trails of the Vydra region because they are firmly connected with the bedrock (Rubín J., Balatka B. et al, 1986).

Numerous frost cliffs can also be seen on a rounded crest called Liška (990 m a.s.l.). The cliffs occur straight on the crest top as well as on its western slope. Their heads are oriented to the east, being 5 to 15 m high. Cliffs on the slope originated on an outcrop of migmatite exfoliation dome whose flanks are dipping to the NE.

Other occurrences of frost cliffs lie on SW slopes of the Černé stráně crest (982 m a.s.l.). They are inclined towards the Popelný creek. The cliffs form a 350 m long strip of ESE-WNW direction. They are of rather smaller dimmensions (their walls are 5 – 15 m heigh) being confined to migmatites. They form two steps.

Numerous frost cliffs exhibiting two steps can also be observed on slopes above the right bank of Zhůřský brook. They are arranged in a lenght of 600 m at an altitude of 920 – 960 m a.s.l Their walls are 5 – 18 m heigh.

Outcrops of migmatized paragneiss remodelled by cryogenic processes dominate above the right bank of the river Vydra (below Hálkova cottage as far as to Čeňkova pila). No frost cliffs exist on granite outcrops because intense frost weathering led to complete desintegration of granite into large blocks, locally as much as 5 m in size, which form rock fields. A structurally denuded slope begins about 250 m west of the confluence of

Popelný brook with the river Vydra. The slope along the section leading to the mouth of Popelný brook is built of outcrops of migmatized paragneiss remodelled by cryogenic processes. The exposures are 10 – 20 m heigh. Outcrops along the road suffered from anthropogenic activities during its construction in the 19^{th} century. Structurally denuded slope downstream from the confluence with Popelný brok is composed of outcrops of quartzite gneiss which are 20 – 30 m heigh. Outcrops of migmatized paragneiss in the upper part of the slope (above the Turnéřská chata cottage) resemble frost cliffs.

Other occurrences of frost cliffs can be seen above the right bank of the river Vydra, 0.3 km south of Buchingrův Dvůr in a slope oriented towards the NW (910 – 940 m a.s.l.). Walls of these cliffs are 5 m heigh.

Another structurally denuded slope about 400 m long is situated above the right bank of the river Vydra in place above Kramlův Mlýn where its course changes from the NW to the N. The rock forms two protracted outcrops in the direction of gradient which can be considered inexpressive rock ribs of a large frost cliff whose wall is 30 m heigh and 100 m long being oriented in ESE-WNW direction. Outcrops remodelled by cryogenic processes can be found at other two sections of structurally denuded slope in the direction towards Čeňkova Pila.

Abundant cryogenic forms also occur on Spálený (1013 m a.s.l.). An exfoliation dome remodelled into two frost cliffs can be observed on NE crest about 250 away from the summit of Spálený. The dome flanks are inclined to the south. On the top of Spálený, there is an erosional denudation plain which contains desintegrated frost cliffs on its NE and SE margins. They are 2 m heigh and 10 m long, trending NE-SW. A discontinuous rock field can be seen below the frost cliffs

The southern and southeastern slope of Spálený has structurally denuded character. Strong congelifraction and gelivation processes resulted in desintegration of frost cliffs and formation of rock field and several rock-streams. Rock outcrops occur at two altitudes. Altogether 90 measuremets of strike of fracture planes were done on frost cliffs of the Spálený area. More measurements were impossible to perform because of desintegration and shifting of blocks. Two systems of joints can be seen on a plot shown in Fig. 9. The primary system exhibits strikes of 340° and 60°, whereas the secondary system shows strikes of 0° and 100 – 110°. Another strike is equal to 130°. The diagram is difficult to interpret because of limited number of measurements.

Altogether 740 measurements of fracture planes were performed at four localities: Kostelní vrch (1016 m a.s.l.), western edge of the crest near Horní Hrádky, in the vicinity of rock form called Panna above the river Vydra near the Turnéřská chata cottage and on Spálený (1013 m a.s.l.).

Fracture planes were actually measured on granite of the Vydra massif (Horní Hrádky, Panna) and on migmatite along the contact with granite (Spálený, Kostelní vrch). Fracture systems on single diagrams do not considerably differ from each other. The granite intrusion during its ascent and crystallization affected the surrounding rocks to such a degree that even fracture systems along the contact with granite show the same strikes (Figs 6 – 9). Two fracture systems plotted on digragrams indicate that during the magma cooling of the granite massif a change in direction of oriented pressure occurred which gave rise to two systems of joints.

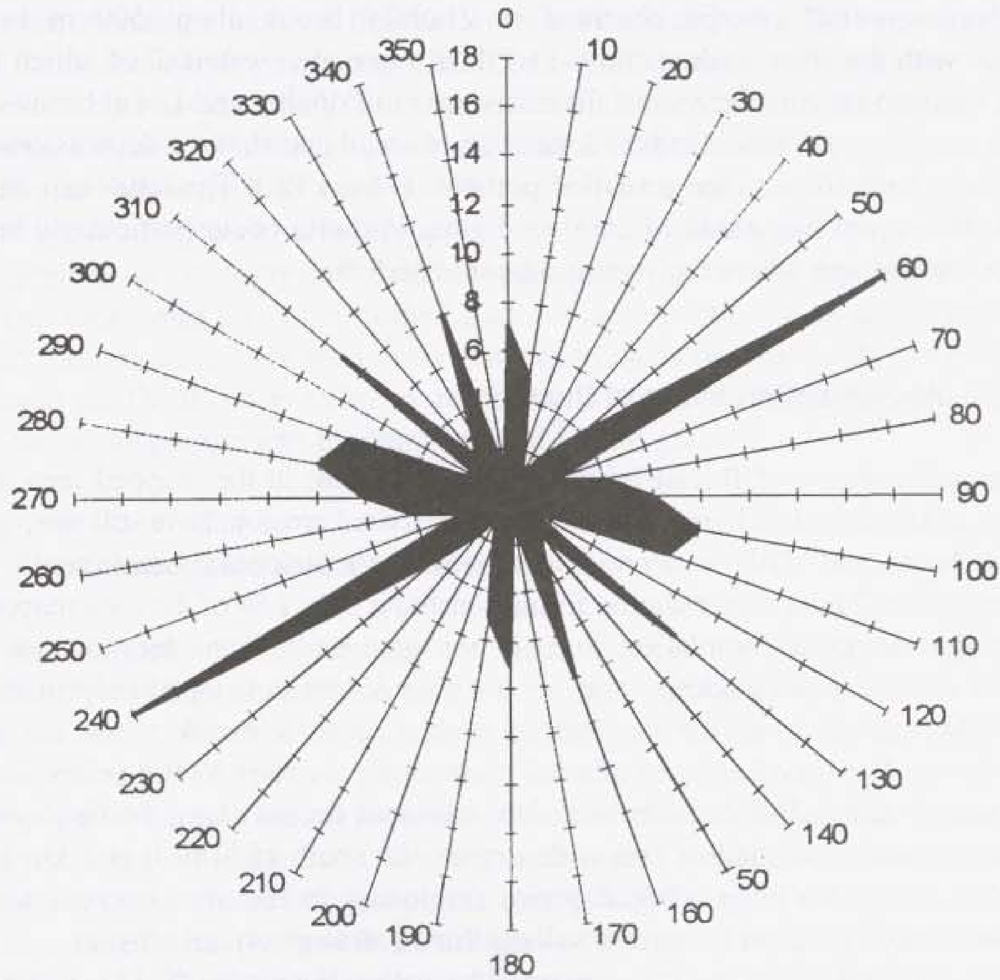


Fig. 9: Cloose's rosette demonstrating 90 strikes of joint plane measured at Spálený
Cloosova růžice 90 směrů puklinových ploch na Spáleném

Fluvial erosional forms

Spring areas of some streams form either valley or slope drainage dells. Altogether 21 dells were identified in the mapped area. About two thirds of them are slope drainage dells and one third are valley drainage dells.

Erosion furrows and gullies of V shape are other morphological forms occurring in the mapped area. They resulted from Holocene erosion. Erosion furrows come out straight from slope drainage dells.

Deeply incized canyon-like valleys of the river Vydra between Antýgl and Čeňkova Pila, Popelný and Zhůřský brooks and the lower part of Hrádecký brook originated due to backward and vertical erosion. These valleys have steep slopes, very narrow bottoms and the streams locally cut into the bedrock having steep gradient with rare nicks which form cascades and small waterfalls.

Lower sections of valley slopes are steeper and from the upper parts are separated by distinct slope cuts. Slopes are often covered with blocks of rock which originate through frost weathering of numerous rock outcrops. These large boulders block the river beds of Vydra and the lower section of Hrádecký brook giving rise to numerous rapids (Photo 10.).

The highest waterfall can be observed in Zhůřský brook about 500 m before its confluence with the river Vydra (Photo 11.). It is a two-step waterfall of which the total height is almost 5 m. Smaller waterfalls also occur in Popelný and Luční brooks.

Evorsion activity of water leads to formation of small and shallow depressions in river bed of mostly oval shape – the so-called potholes (Photo 12.). The latter can be seen in river bed made up of migmatite of the river Vydra. Potholes occur particularly below the Hálkova chata cottage where the river gradient is 56.5 %.

Accumulation forms of the relief

Accumulation forms of fluvial origin are generally rare in the mapped area since the lower parts of streams, which originated through backward erosion, have still steep gradient, except the broad and shallow depression of nowadays Hrádecký brook south of Srní. Consequently, the fluvial accumulation forms constitute only 1 % of the total mapped area.

The major fluvial accumulation form in the area under consideration are alluvial plains. The alluvial plain in deep valley of the river Vydra developed only in the valley opening downstream from the confluence with Hrádecký brook when the gradient becomes lower. The total lenght of alluvial plain along the river Vydra valley is equal to 1200 m, max. width is 160 m. More abundant alluvium occurs along the Hrádecký creek in the above-mentioned shallow and wide depression south of Srní. It is 2 km long and 80 – 150 m wide. No large alluvial plains originated in the area because almost all streams have steep gradient in narrow valleys due to strong vertical erosion.

Another accumulation form is represented by valley floor run-off. Three occurrences of this type of form were found in the mapped area. Two of them can be observed in a broad and shallow valley depression south of Srní on the Hrádecký and Studený brooks, shortly before their confluence. A wash-depression originated in the upper part of the Hrádecký brook above a canal for floating timber. The depression is 350 m long and 150 wide.

Dejection cones should also be mentioned. Only three of them exist in the entire area. They occur in the river Vydra valley in places of confluence with smaller streams where valley bottom is widened. They are morphologically inexpressive.

Cryogenic and solifluction accumulations

This group includes accumulation forms composed of rock fragments and blocks of cryogenic origin. Continuous rock fields can be found particularly on steep slopes in canyon part of the river Vydra valley. They consist of medium-grained biotite granite which desintegrated along fractures into rectangular blocks.

The best developed rock field occurs on the right bank of the river Vydra 0.4 km NW of the Turnerská chata cottage (Photo 13.). It is 300 x 200 m in size consisting of angular blocks on average 1.5 m large, locally as much as 3 m in size. Another continuous rock field can also be observed on the oposite bank between rock forms called Baba, Panna and Mnich where blocks are as much as 5 m large.

Smaller continuous granite rock fields exist on southern slopes of Spálený, and then 1.5 km SW of Oblík above a slope drainage dell. Discontinuous rock fields are more abundant being not so closely related to the Vydra granite massif. Among accumulations consisting of granite blocks, a system of discontinuous rock fields on the western slope of flat crest near Horní Hrádky and below the highway Srní – Antýgl is most prominent. Desintegrated granite blocks form accumulations on valley slopes of the Hrádecký brook and the river Vydra.

Desintegration of strongly migmatized paragneiss gave rise to blocks forming discontinuous rock fields on slopes of the Lišák-Liška crest and also on slopes of Popelný and Zhůřský brooks valleys. A group of a few occurrences of rock fields can be seen on eastern slopes of Oblík near Vaňkova road. Local rocks consist of medium-grained cordierite-biotite migmatite and medium-grained biotite granite.

Anthropogenic forms of the relief

The whole mapped area lies nowadays in the Šumava National Park, and partly in its 1st zone (strictly natural). In addition to the preserved natural systems, there also exist anthropogenic forms of various age and origin. The road on the right bank of the river Vydra was constructed in 1888.

Anthropogenic forms related to construction of roads: There exists a network of asphalt, paved, unpaved roads and old abandoned roads. The roads locally run in slope cuts, on made-up ground and in some places they must have been strenghted.

Anthropogenic forms derived from military activities: Such forms can be observed on Huťská hora (1187) where straight on the top there is an abandoned facility of the former radiolocation station, and 1 km SE of this site in the area of the former village of Zhůří are abandoned barracks.

Anthropogenic forms related to farming: Farming on larger areas took place until 1945 when the German population was ousted. The present farming activities are less intense than those before 1945. Some terraces, antierosion walls and rock heaps were preserved to resemble earlier rural activities.

Anthropogenic forms derived from activities of water management: The most prominent work of this type is represented by the so-called Plavební (Vchynicko-tetovský) kanál, actually a canal for floating timber. It was constructed in the years 1799 – 1800 to transport timber and to avoid rapids on the river Vydra. Nowadays it serves together with water reservoir of Sedlo as a water supply for hydroelectric power station Vydra. Another small hydroelectric power station Čeňkova Pila is supplied from a canal constructed close above the confluence of the rivers Křemelná and Vydra. Two former mill races can be observed: near the Kramlův mlýn on the river Vydra and near the abandoned mill on Hrádecký brook below Srní.

Anthropogenically remodelled relief of human settlements: The mapped area is poorly populated. The first settlements were established as late as in the 18th century having been connected with tree-cutting. The only present community is Srní which is an important recreation centre and camping site. There are some other settlements and several lonely houses used nowadays for recreation. Some ruins of former settlements and buildings can also be seen in the area.

Anthropogenic forms related to mining: Only two small clay pits occur in the mapped area: near Horní Hrádky and at Tříjezerní slať. The latter provides an outcrop with signs of solifluction.

Other forms of the relief

Numerous peat bogs (highmoor bogs) originated in Šumava after the retreat of continental glacier. Peat bogs are bound to outflows of poorly mineralized groundwaters. Nine highmoor bogs were identified in the mapped area. They occur in valleys, on slopes and also on groundwater divide (dividing crest). The majority of peat bogs occur on tectonic dislocations and joints which has been proved by field observations when peat bogs rest on inferred faults (e.g., Tříjezerní slať, valley highmoor bogs at Studený and Hrádecký brooks).

Also worth to be noted are local springs which were discovered during the mapping. Out of five springs, four rise on steeply inclined erosional denudation slopes.

Origin of the relief of the lower part of river Vydra basin

The most important phenomena controlling the relief features in the mapped area are the intense vertical erosion due to tectonic uplift which occurred at the turn of Tertiary and Quaternary epochs and Pleistocene cryogenic modifications of the local morphology.

Relics of old levelled surface from the end of Cretaceous era are preserved in the southern and southeastern parts of the mapped area, and also at the northern border of geomorphological unit of the Kvilda plain. Erosional denudation plateaux occur here at two altitudes (Demek J.ed. et al., 1987). A shallow valley depression south of Srní flown through by the Hrádecký creek is obviously a relic of the old relief prior to its rejuvenation at the turn of Tertiary and Quternary epochs.

Striking increase in the intensity of vertical erosion occurred in the course of the Tertiary and Quaternary due to tectonic uplift of the whole area. This uplift resulted in change of the Tertiary drainage pattern. The river Vydra through backward erosion captured near Antýgl the Hamerský brook which originally flew to the east and emptied into the present Hrádecký brook. The uplift also resulted in formation of deep valleys with steep river gradients. In the case of the river Vydra, the valley is almost a canyon with steep slopes locally built of rock walls as much as 40 m heigh and with eversion forms in the river bed. The majorityy of steeply inclined structurally predisposed slopes are also confined to the river Vydra.

Cryogenic modification of the relief took place in the Pliocene. Cryogenic forms in the studied area again occur along the river Vydra and then along the Zhůřský and Popelný creeks, in the uppermost part of Kostelní vrch (1016 m), Spálený (1013 m), Oblík (1225 m) and on the western edge of the flat crest near Horní Hrádky. These forms originated in places where the bedrock was exposed to denudation and erosion and also due to vertical erosion of local streams. The uppermost parts of Oblík and Kostelní vrch suffered from cryoplanation which gave rise to cryoplains. Large castle koppies originated as a result of cryogenic processes on morphological crest of the granite massif above the left bank of the river Vydra near the Turnerská chata cottage.

Fluvial accumulation forms are rather rare in the mapped area because of intense vertical erosion and steep river gradients. They are represented by alluvial plains, dejection cones and run-offs. These occur along the river Vydra and Hrádecký brook in places with low gradient.

Peat bogs begun to originate at the end of Pleistocene on newly arosen outflows of groundwater. They occur in valleys, on slopes and divides.

The impact of anthropogenic activities on the landscape in the lower part of the river Odra basin was rather negligible which is supported by the fact that besides urban forms, the most striking anthropogenic forms are water works. The whole area is nowadays an integral part of the Šumava National Park which considerably contributes to preservation of the local landscape and its characteristic forms.

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GEOMORFOLOGICKÝ VÝVOJ DOLNÍ ČÁSTI POVODÍ ŘEKY VYDRY

Résumé

Stať se zabývá podrobnou charakteristikou povrchových tvarů se zvláštním zřetelem na vznik a vývoj kryogenního reliéfu na převážně žulovém podkladu masívu Vydry.

První část představuje stručnou fyzickogeografickou charakteristiku, která zahrnuje orografický přehled a začlenění území. Následuje současný pohled na geologické a tektonické poměry. Vzhledem k tomu, že tato oblast byla v neogenu a kvarteru velice intenzivně vyzdvihována, což mělo za následek razantní oživení hloubkové eroze, je v hydrografické části provedena směrová a spádová analýza vývoje příslušné části říční sítě.

Stěžejní částí práce je kapitola věnovaná tvarům reliéfu. Strukturní tvary podmíněné tektonickými poruchami, exfoliačními klenbami, puklinatostí a litologickými vlastnostmi hornin jsou zastoupené především strukturně denudačními svahy o různé sklonitosti (viz geomorfologická mapa).

Procentuálně větší část území zaujímají erozně denudační tvary prezentované denudačními plošinami a různě ukloněnými svahy. Nejrozšířenější jsou svahy o sklonu 10 – 20° a 5 – 10°, které jsou většinou rozčleněné erozními rýhami a stržemi svahových toků.

Pro zkoumané území je charakteristický velký výskyt kryogenních mezo a makro tvarů vznikajících kryopedimentací. Vyskytují se zde především mrazové sruby a srázy, svahové a vrcholové kryoplanační plošiny (kryoplény) a skalní hradby. Za účelem vysvětlení morfologie, polohy a směrového rozložení kryogenních tvarů byla provedena puklinová měření a vyhodnocena v diagramech.

Přehledně je vysvětlen vznik a vývoj fluviálních erozních a akumulačních tvarů a kryogenních akumulací. Na závěr je provedena genetická klasifikace vyskytujících se antropogenních tvarů reliéfu.

Část podávající současný pohled na vznik a vývoj reliéfu povodí dolní Vydry a určující rozhodující modelační faktory tohoto území uzavírá celou stať.

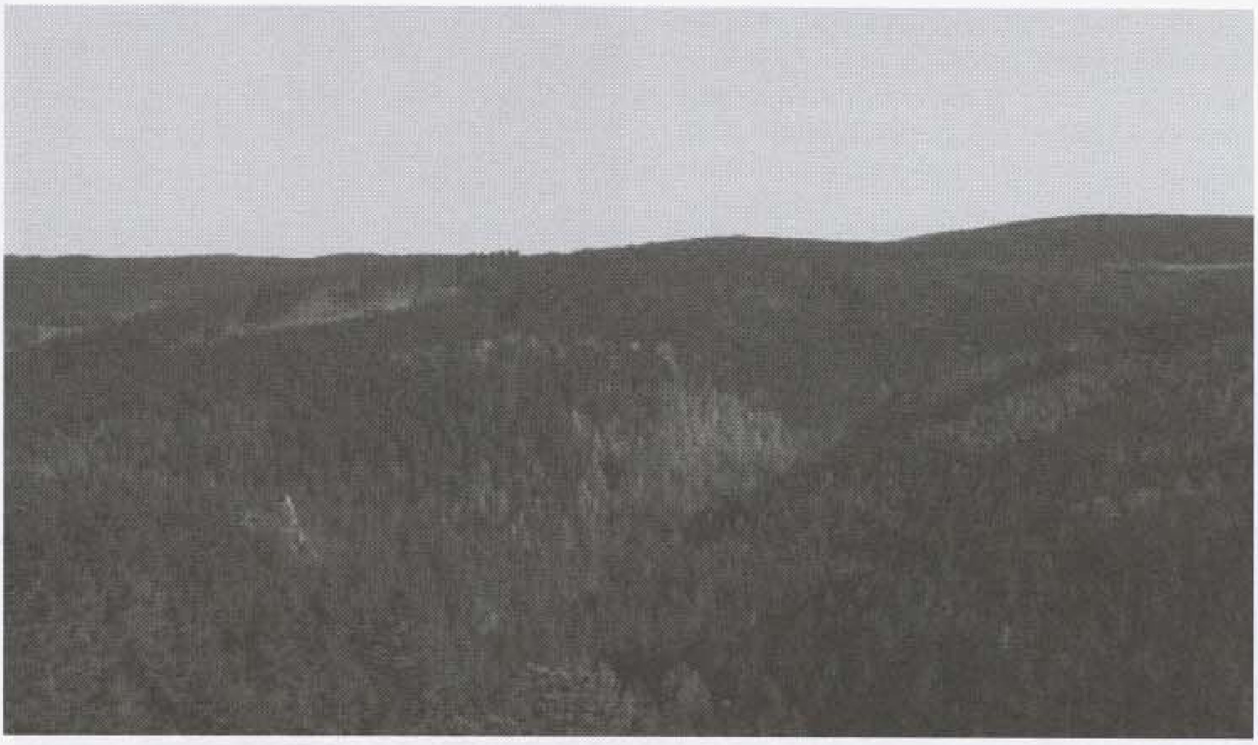

Photo 1: A view of incised meander of the river Vydra near the Turnéřská chata cottage and head of canyon-like valley of Zhůřský brook looked at from elevation point 960.1 m a.s.l. near Horní Hrádky. To the left there is the Panna rock tower, to the right Huťská hora (1187 m a.s.l.)
Pohled na zaklesnutý meandr Vydry u Turnéřské chaty a závěr téměř kaňonovitého údolí Zhůřského potoka z kóty 960,1 m u Horních Hrádků, vlevo skalní věž Panna, vpravo Huťská hora (1187 m)

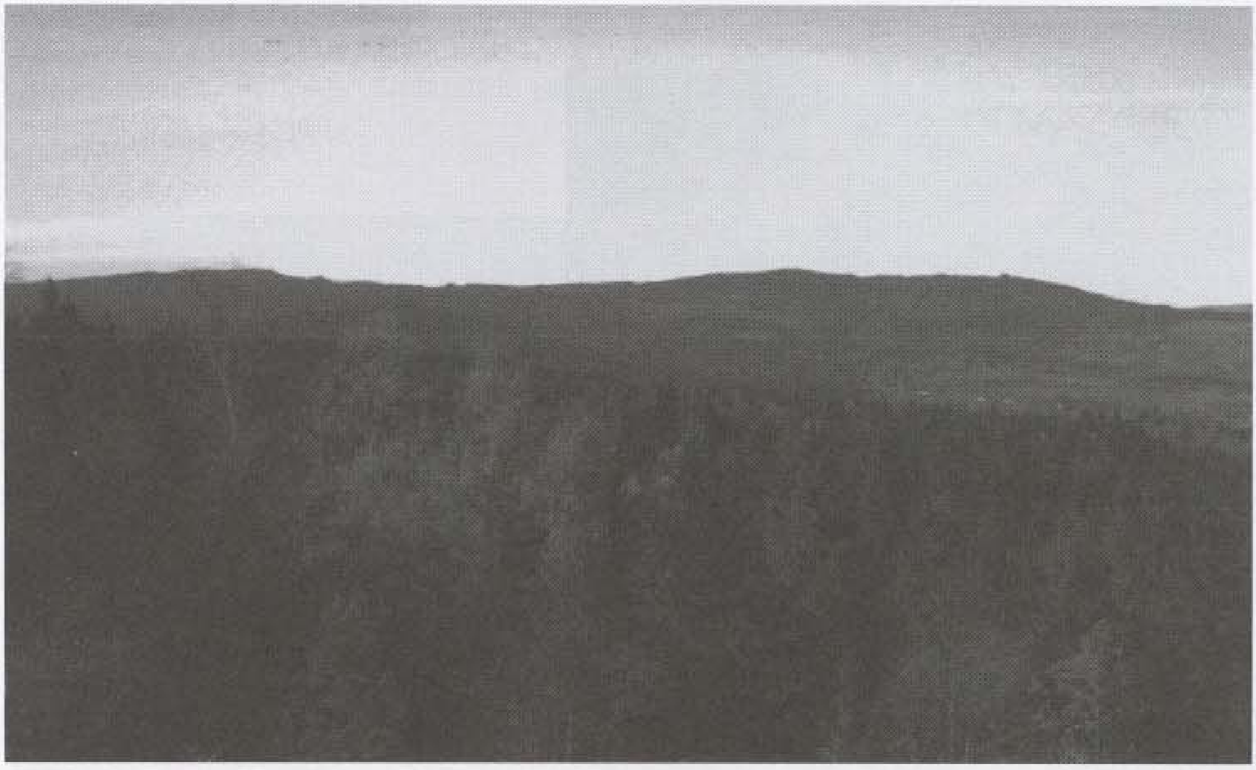

Photo 2: Flat dividing crest at southwestern border of the mapped area: to the left there is Oblík (1225 m a.s.l.), to the right Jezernice (1266 m a.s.l.), at lower altitude the Kostelní vrch (1016 m a.s.l.) can be seen on the left side
Plochý rozvodnicový hřbet na jihozápadním okraji mapovaného území: vlevo Oblík (1225 m), vpravo Jezernice (1266 m), v nižší výškové úrovni vlevo Kostelní vrch (1016 m)

Photo 3: Peak cryoplanation plain on Oblík (1225 m a.s.l.
Vrcholová kryoplanační plošina na Oblíku (1225 m)

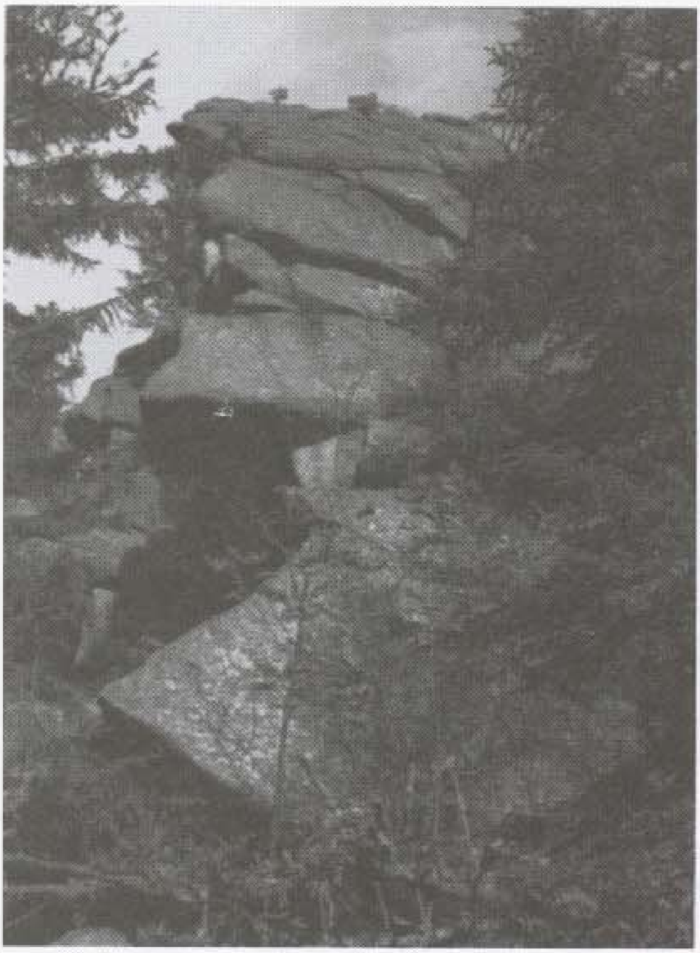

Photo 4: Large frost cliff (250 m SSW of "Kamenný dům" "resthouse") with wall 40 m heigh
Mohutný mrazový srub (250 m JJZ od penzionu „Kamenný dům") se stěnou vysokou 40 m

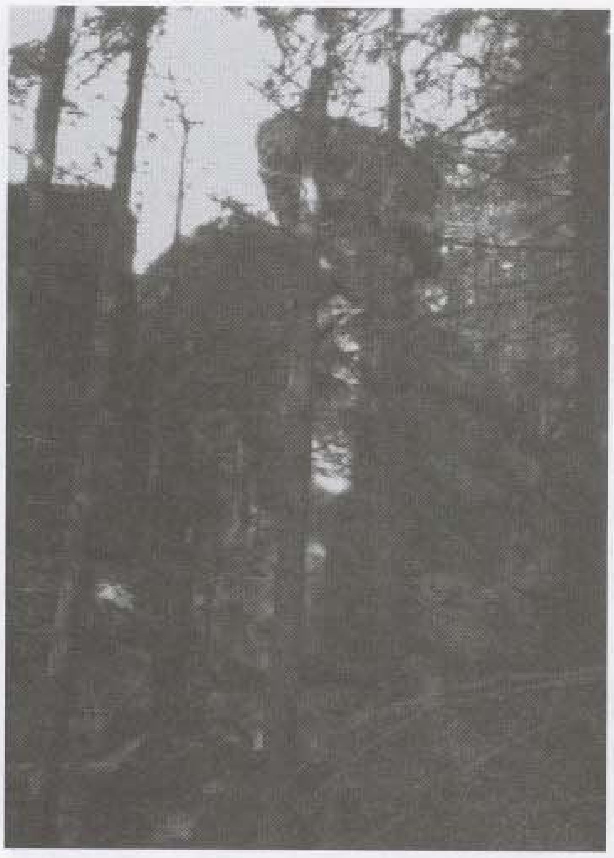

Photo 5: A castle koppie (0.5 km south of elevation point 985.3 m a.s.l. near Horní Hrádky) dissected by frost clefts into rock towers
Skalní hradba (0,5 km již. od kóty 985,3 m u Horních Hrádků) rozčleněná mrazovými puklinovými rýhami ve skalní věži

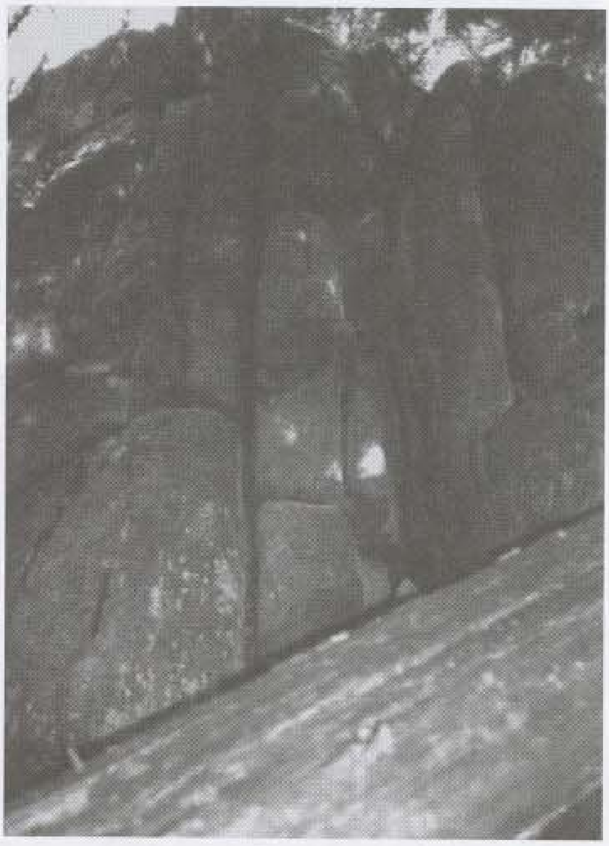

Photo 6: A frost cliff 0.5 km NW of Rokyta. Its wall is formed by vertical benches due to abundant vertical joints
Mrazový srub 0,5 km SZ od Rokyty, jehož stěna je vlivem zvýšené frekvence vertikálních puklin tvořena svislými „lavicemi"

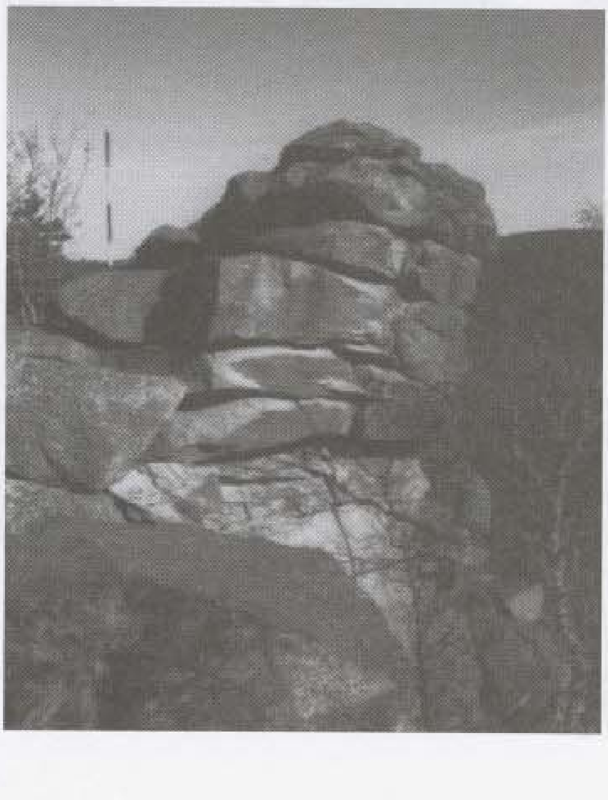

Photo 7: Rock tower called Mnich (960,1 m a.s.l., 0,5 km north of Horní Hrádky) with two rock bowl on the top
Skalní věž Mnich na kótě 960,1 m (0,5 km sev. od Horních Hrádků) na jejímž vrcholu jsou dvě dokonale vyvinuté skalní mísy

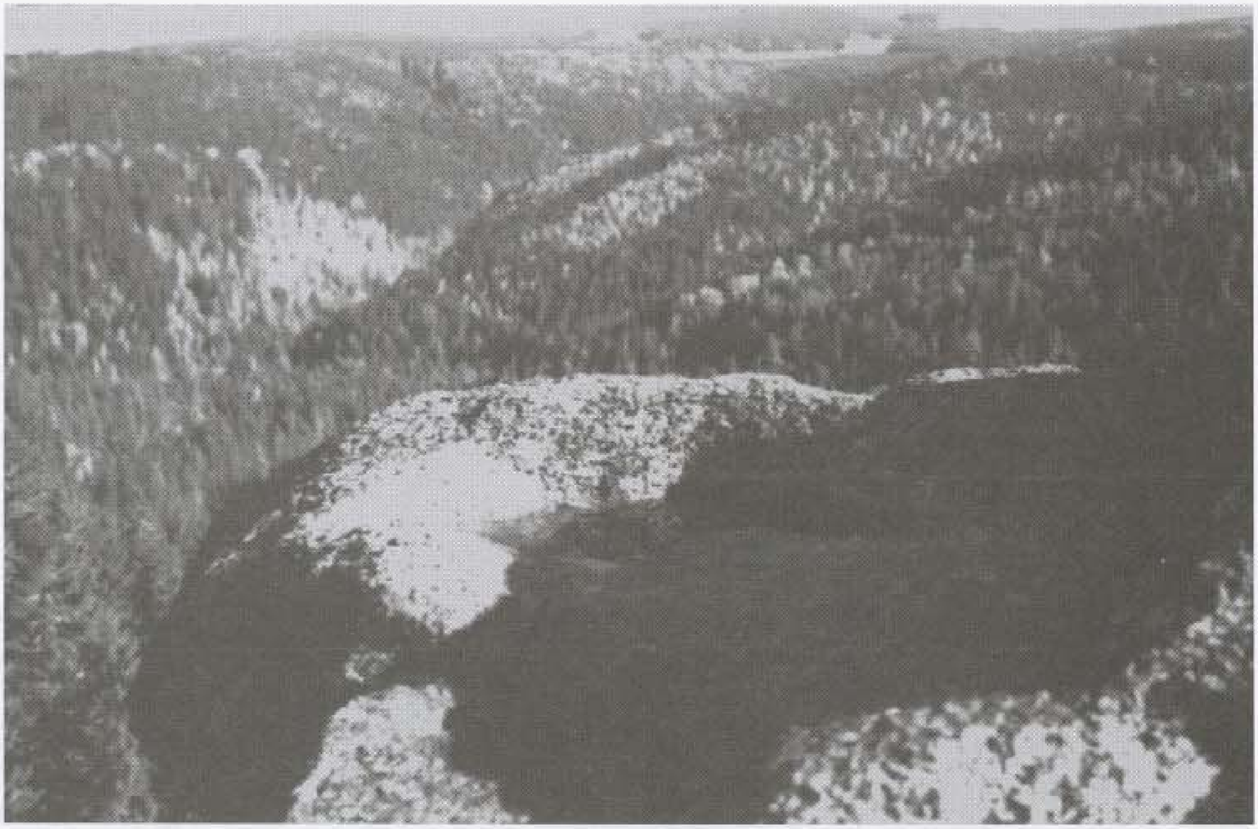

Photo 8: Rock bowl with groove on the top of the rock tower called Mnich
Skalní mísa s odtokovým žlábkem na vrcholu skalní věže Mnich

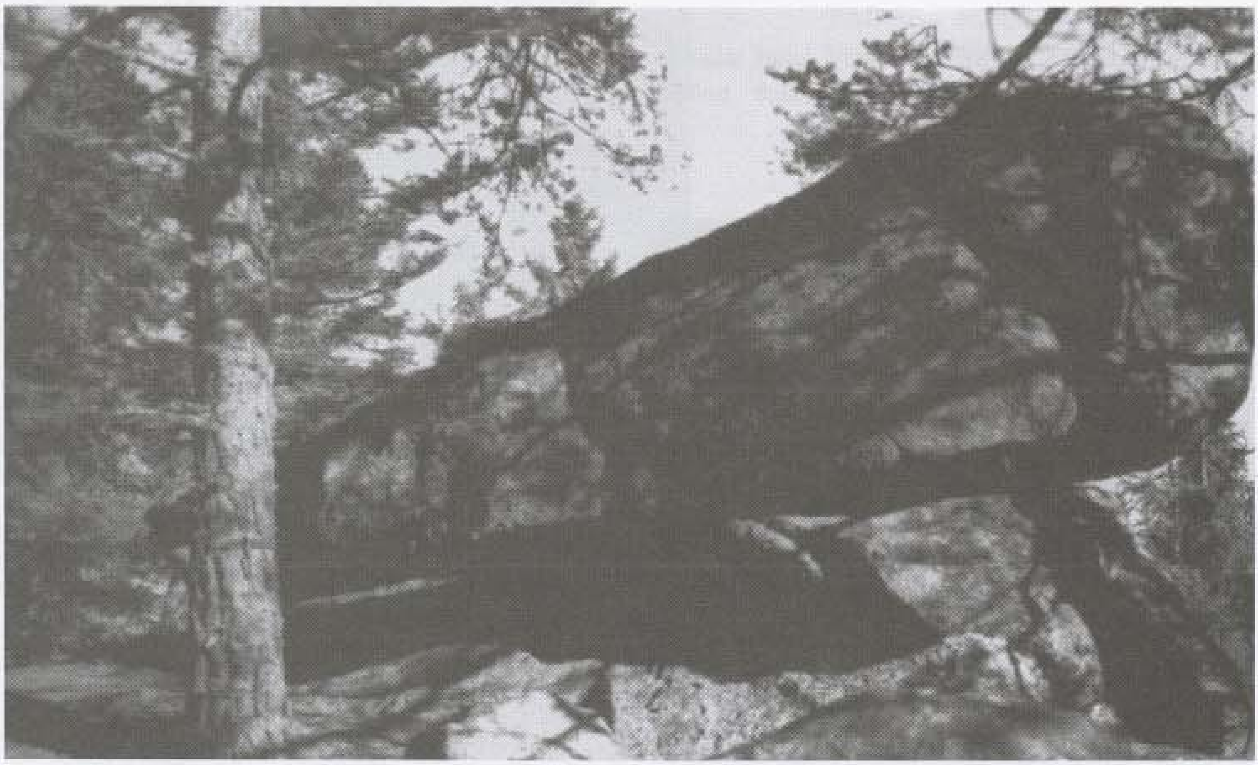

Photo 9: Rounded block on the top of castle koppie near Horní Hrádky which originated due to selective erosion. It is connected with the bedrock through small face
Zaoblený blok na vrcholu skalní hradby u Horních Hrádků spojený v důsledku selektivní eroze s podložím jen malou plochou

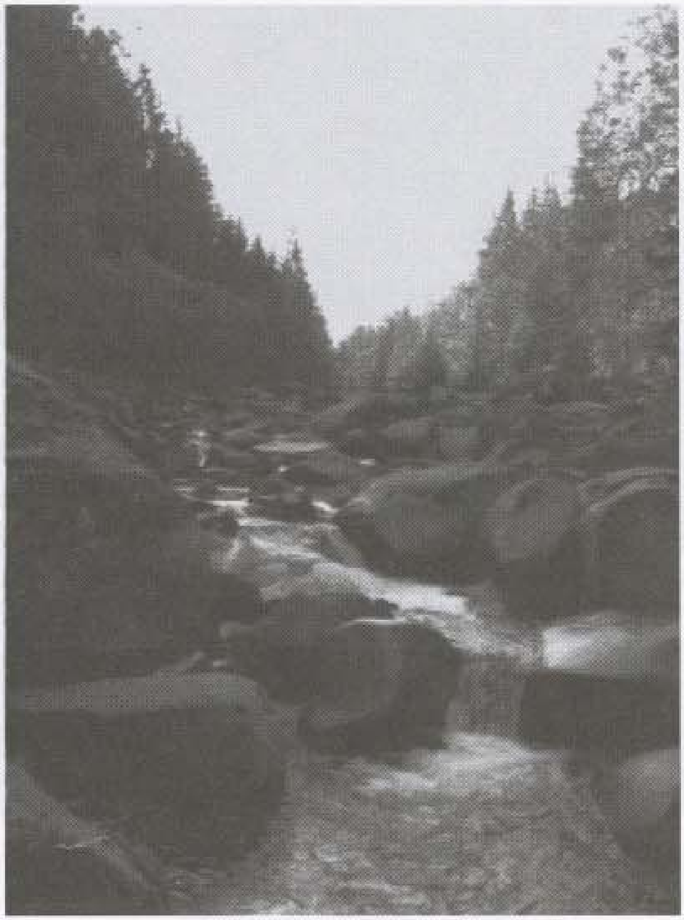

Photo 10: Granite blocks as much as 5 m large in the Vydra river bed create rapids in stretch below the Hálkova chata cottage
Granitové bloky o velikosti až 5 m vytvářejí v korytě Vydry v úseku pod Hálkovou chatou četné peřeje

Photo 11: Waterfall on Zůřský brook, 500 m from its confluence with the river Vydra
Vodopád na Zhůřském potoce 500 m před ústím do Vydry

Photo 12: Potholes in solid migmatite exposed in the Vydra river bed near the Turnéřská chata cottage
Obří hrnce v kompaktním migmatitu vystupujícím z koryta Vydry u Turnéřské chaty

Photo 13: Rock field above the right bank of the river Vydra (0.4 km NW of the Turnerská chata cottage) consisting of granite blocks 1 – 3 m large
Kamenné moře nad pravým břehem Vydry (0,4 km SZ od Turnéřské chaty) tvořené žulovými bloky o velikosti 1 – 3 m