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CHRONODYNAMICS OF THE LABE RIVER ANTECEDENCE IN THE DĚČÍNSKÁ VRCHOVINA HIGHLAND, CZECH REPUBLIC

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ABSTRACT. Geomorphological development of the antecedent Labe canyon-like valley in the Děčínská vrchovina Highland is described. The chronodynamics of the Labe deep-side erosion and its terrace system origin in the northern part of the Bohemian Massif as interference of climate-morphogenetic and neotectonic processes in the Upper Pliocene and the Quaternary are presented.

KEY WODRS: geomorphology, antecedence, Labe river

1. INTRODUCTION

The Labe canyon valley in the Děčínská vrchovina Highland (Elbsandsteingebirge) has been being formed since the Miocene in a morphostructurally complexly differentiated belt of tectonic active zones of the NW part of the Bohemian Massif. A pronounced deep- and back-side erosion of the Labe and of its tributaries started in the Pliocene and the present existing canyon valleys of the Děčínská vrchovina Highland are of Quaternary age.

The Labe valley in the Děčínská vrchovina Highland is cut into the lower situated E margin part of the Sněžnická hornatina Hills in the geomorphological district of the Děčínské stěny Walls. While in the S part the Labe canyon cuts across the higher situated relief in the neighbourhood of the Růžový hřeben Ridge (436 m), situated at the level of the Dolnožlebská vrchovina Highland surface on the opposite left river bank, the N segment of the valley follows the boundary between the higher Dolnožlebská vrchovina Highland and the lower situated level of the Arnoltická vrchovina Highland (Fig. 1). In connection with stronger uplifts of the S margins of the Děčínské stěny Walls, the depth of the valley incision, the height of which is in some places assymetrical in the lateral profile, reduces in a downstream direction from more than 300 m to about 200 m.

The structural denudational plateaux and ridges of the Děčínské stěny Walls are articulated by canyons and defiles mouthing into the Labe valley. During the Labe deepening into the Mesozoic sedimentary rocks, large rocks defiles were formed on the river valley slopes. In the Pleistocene, the Děčínská vrchovina Highland was repeatedly a part of the continental glacier foreground, [comp. Šibrava, Václ

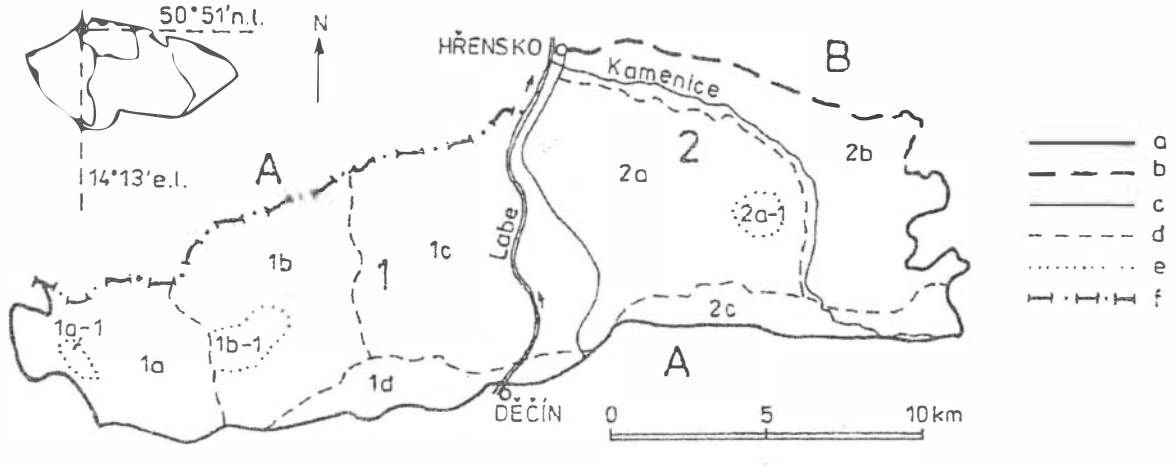

FIG. 1. Regional articulation of the Děčínská vrchovina Highland (modified according to Balatka 1995).
A. Děčínské stěny Walls (formed mainly by Cenomanian to Middle Turonian sandstone rocks): 1 Sněžnická hornatina Upland (1a Tiská vrchovina Highland (1a–1 Tiské stěny Walls), 1b Děčínskosněžnická hornatina Upland (1b–1 Děčínský Sněžník Mountain), 1c Dolnožlebská vrchovina Highland (in the southern part under the Upper Cretaceous sandstones there are crystalline rocks of the Lusatian granodiorites type outcropping in the Labe valley bottom), 1d Děčínské kuesty Kuestas); 2 Růžovská vrchovina Highland (2a Arnoltická vrchovina Highland (2a–1 Růžovský vrch Hill is a Tertiary volcanite of basaltic type), 2b Kamenická vrchovina Highland, 2c Olešská pahorkatina Hilly land); B. Jetřichovické stěny Walls (formed by Middle Turonian to Senonian sandstone rocks with fine occurences of basalt volcanite knobs). Graphical explanations: limits of geomorphological units: a – unit, b – subunit, c – district, d – subdistrict, e – part of subdistrict; f – state border between the Czech Republic and Germany.

1962; Kunský 1966; Šibrava, 1966; 1972], reaching in the periods of its maximal progression up to the N margin of the Bohemian Massif.

This paper proceeds to a correlation of the present known findings about the paleogeographical development of the NW part of the Bohemian Massif [for instance Moschelesová 1923; Grahmann 1933; Engelmann 1941; Král 1966; Šibrava 1966; 1972] and the results of the geomorphological analysis of landforms in the region of the Labe canyon-like valley in the Děčínská vrchovina Highland (Photo 1) and the system of Labe river terraces between the Bílina and the Kamenice River mouthing. This approach has enabled the reconstruction of the Labe antecedent valley origin in the Děčínská vrchovina Highland.

2. OUTLINE OF THE PALEOGEOGRAFICAL DEVELOPMENT OF THE DĚČÍNSKÁ VRCHOVINA HIGHLAND

The denudation after the Variscan orogeny caused in the NW part of the Bohemian Massif the development of a planation surface with a deep weathered lateritic crust on the surface of the crystalline rocks. Sinking of the Lusatian Sorbian

PHOTO 1. Canyon-like Labe valley in the Děčínská vrchovina Highland deepened mainly in sandstone rocks of Upper Cretaceous age. In the background there is the table mountain Grosser Zschirnstein (560 m a.s.l.). According to a viewcard from B. Balatka archive.

region in the Triassic caused the transgression of the epicontinental Jurassic séa from the N [Kopecký et al. 1963; Buday et al. 1961] which was closed in the Upper Jurassic by the Young Kimmerian Kelloway stage of the Alpine orogeny. The Bohemian Massif was getting uplifted and the Upper Cretaceous denudation removed the majority of the Jurassic sediments. Later on, due to tectonic faults during the Young Austrian phases of the Alpine orogeny, the territory of the present-day Děčínská vrchovina Highland became a depression through which the Upper Cretaceous sea penetrated into the Bohemian Massif [Klomínský 1994].

The Děčínská vrchovina Highland is a part of the Lusatian facial region of the North-Bohemian Cretaceous basin. On its surface, there are rocks of the Lusatian Pluton, Upper Cretaceous sediments and Tertiary volcanites intrusions. During the supreme phase of the Saxonian faulting in the Tertiary, the sedimentary filling of the Cretaceous basin was broken by uplifts and sinking into several independent, mutually shifted blocks. The Děčínská vrchovina Highland morphostructure was formed in the area of the crossing of two important and long-term active tectonic zones [Moschelesová 1923; Präger, Lemke 1967; Thurm 1973; Rather and Wagner

1975]. They are the NW–SE oriented Labe lineament and the fault zone situated along the eastern margin of the Krušné hory Mountains, oriented in the monitored region in the W–E direction. It includes the so–called Děčín– and the Česká Kamenice–fault fields. The repeated activation of that zone has been doing since the Tertiary [Malkovský 1976; 1979], while that of the Labe lineament probably started in the Proterozoic.

Between Děčín and Hřensko, the crystalline rocks are uncovered on the bottom and in the lowest parts of the Labe canyon–like valley slopes between the N margin of Loubí Village and the Studený potok Brook. They are Lusatian granites with mantle relics under the shape of metamorphosed sediments of Proterozoic, eventually of Lower Paleozoic age. There are phyllites and phyllitic greywackes passing into sillimanitic gneisses with quartzite, horn–stone and amphibolite fillings. The northernmost part is formed by medium-grained, partly oriented biotitic granodiorite.

Cretaceous sediments are represented in the Labe canyon valley between Děčín and Hřensko in the stratigraphic range Cenomanian – Coniac with a maintained thickness of the Cretaceous groups of layers 300 m in average. Gravel sandstones and conglomerates, medium to coarse grained sandstones of the Cenomanian age with a thickness of up to 90 m form mainly the lower and milder parts of the Labe valley slopes. On the basis of Turonian sediments, clayey–limy marlite sandstones have developed, and in the upper layers, sandy sedimentation is prevailing. Fine–grained kaolinic sandstones pass into coarse–grained sandstones. Above them, a monotonous group of beds of mostly yellowish, finely to medium grained quartz block sandstones developed. In the highest relief position of the Jetřichovské stěny Walls, there are yellow–brown block sandstones of Coniac age.

The Bohemian Massif uplift in the Lower Tertiary that formed a vault with its top in central Bohemia and, thus conditioned, the origin of the centrifugal river network [Engelmann 1941; Balatka and Sládek 1962a; 1975 and Malkovský 1976; 1979] is, in the monitored territory, documented by a strong denudation of the Cretaceous sediments. As a consequence of the Neogene Saxonian block movements, this Lower Tertiary river network was largely transformed, mainly by the uplift of marginal mountain ranges of the Bohemian Massif. The outflow of rivers of the W and N part of Bohemian Massif via the Krušné hory Mountains planation surface to the Leipzig Basin to the Eocene Saxonian sea continued probably even in the Lower Miocene [Malkovský 1979] and was interrupted by a later uplift of the Krušné hory Mountains. The intermountain belt in the region of the present–day Děčínská vrchovina Highland was formed, probably as recently as in the Middle Miocene, as the Labe bend with block structure enabling the outflow of the principal river of the new water courses network of the greater part of the Bohemian Massif to the Northern Sea.

In the Neogene, the České středohoří Mountains were practically the extension of the basin on the fault zone E of the Krušné hory Mts. After the retreat of the Miocene Lusatian sea from the NW margin of the Bohemian Massif, the Děčínská vrchovina Highland region had a tendency to secular uplift. Nevertheless, the Labe bend northwards from Ústí nad Labem has been maintained in different paleogeo-

graphical conditions since the Paleogene up to the present day. The Upper Mesozoic elongated shelf sea gulf with facially prevailing delta sedimentation is thus copied by the relief of the headland of the Bohemian Cretaceous Basin along the Labe up to the Dresden part of the North–German Lowlands.

The Saxonian orogenetic processes were manifested in the NW part of the Bohemian Massif equally by volcanic activities [Kopecký et al. 1963]. In the region of the Děčínská vrchovina Highland, the oldest Upper Oligocene phase of volcanic activities includes probably the Holý vrch Hill (529 m) situated SSW from the Děčínský Sněžník Mountain. The Miocene volcanites are situated only eastwards from the Labe, where they often form marked elevations. Large intrusions of volcanic rocks into Cretaceous sediments occurred there causing solidification of sandstone blocks by contact and hydrothermal metamorphosis. Flue and lode fillings often do not rise to the surface, locally they mildly vault the upper layer sediments and are progressively uncovered by selective denudation.

The right–side affluents of the Labe, Ploučnice and Kamenice Rivers, were formed in connection with the Miocene uplift of the Lusatian Ridge along the Lusatian Fault [Gregor 1959; Gregor and Tesařík 1959]. In the Pliocene and in the Quaternary, the Ploučnice River got antecedently cut into the volcanic rocks of the České středohoří Mountains. As a consequence of severe Labe erosion, the lower valley of the Kamenice River got deeply cut into the Cretaceous sediments during this period [Glöckner 1964; 1967; Balatka and Sládek 1978].

Structural–denudational planation surfaces of the Arnoltická vrchovina Highland in altitudes above 280 m acting as watershed table ridges of subsequent Labe courses are relics of the Pliocene relief between Děčín and Hřensko [Kalvoda and Zvelebil 1983a,b]. The Arnoltická vrchovina Highland is dissected by faults especially at its margin, while in its rock complexes layer folds of 3 to 7° in the direction NE–SW, NW–SE and N–S can be seen. The elevation between the Brtníky, the Růžovský vrch Hill up to the Růžový hřeben Ridge northwards from Děčín has a synclinal character. Oscillations of the Cretaceous sediments thickness, due to local conditions of their sedimentation do not exceed tens of metres. Westwards from Dolní Žleb, sandstones are bedded quasi–horizontally, their tectonic inclination, mainly of 2 to 4° to NNE, is nevertheless documented in the Labe valley.

The fault zone, on which the Labe antecedent valley has developed, links to the Middle Saxonian fault system with the predominant NW–SE orientation. When comparing relative heights of the boundary between the Middle and the Lower Turonian above the left and the right Labe banks, the primary assymetry of the antecedent valley should be taken into consideration [Lamprecht 1935; Kalvoda 1980 and others]. The left–bank west block of the Děčínská vrchovina Highland has been probably uplifted in its middle and northern part less than the block of the Labe margin of the Arnoltická vrchovina Highland. The main stages of these uplifts occurred in the Upper Pliocene and in the Lower Pleistocene, when the Labe incision into the Mesozoic block sandstones and their crystalline basement reached minimally the depth of 300 m.

The graded to mildly undulated relief of the Děčínská vrchovina Highland region was formed in the Tertiary mainly in subtropical climatic conditions. Since the be-

ginning of the Quaternary, however, this relief has become a part of the continental glacier foreland. Changing climate–morphogenetical processes, alternating between semiarid very cold glacial and humid, mildly warm interglacial periods led, together with tectonic uplifts, to a progressive deepening of the Labe and of its affluents and to the present–day canyon valleys development.

3. Fluvial Sediments and Labe Terraces in the NW Part of the Bohemian Highland

With some exception, river terraces in the Labe canyon are not maintained in the Děčínská vrchovina Highland. For that reason, attention was paid also to the Labe valley in the N part of the České středohoří Mountains. In the observed segment of the Labe valley, fluvial sediment occurrences were divided into 7 terrace groups (Fig. 2). The highest situated gravels of a varied petrographic composition are maintained near Budov (altitude of 320 m, relative height above the Labe level 188 m, Hibsch 1904a,b; Král 1966). According to our findings, quartz and basalt boulders occur only rarely in deluvial sediments on the basalt mass platform at altitude 313 to 314 m. Stratigraphically important occurrence of fluvial sediments near Stříbrníky has the denuded surface of sands and gravels of Ohře origin at altitude 275 to 265 m (142 to 132 m of relative height). After the paleontological finding of a tooth of the elephant Archidiskodon meridionalis [Liebus 1929], this locality was linked to the Lower Pleistocene. The high position of those sediments was explained by tectonic uplifts of the territory [Engelmann 1938; Král 1966; Šibrava 1972]. After a reexamination of the paleontological findings, these sediments are considered as being of the Upper Pliocene age [Kočí et al. 1991].

The Upper Pliocene age is linked also to the fluvial sediments near the Labe canyon edge near Belveder by Labská Stráň in the Děčínská vrchovina Highland [Beck and Hibsch 1895; Grahmann 1933]. These mostly quartz and quartzite gravels contain the rock material of the Ploučnice and Vltava region origin [Klein et al. 1967]. Strongly clayey sands from the Cretaceous sandstones eluvium contain different ratios of relatively well wrought boulders of quartzes, less frequently quartzites and lydites, of sizes inferior to 3 to 5 cm. Sporadically, there are greater boulders and poorly wrought basalt and sandstone boulders with a diameter superior to 0.5 m in the longer axis. A small terrace plateau of a size approximately 130 × 90 m at the right bank edge of the Labe canyon is situated at the foot of the Pliocene valley right slope 10 to 15 m under the level of the planation surface. Southwards from the described locality, near Belveder, there is a small sandstone plateau at 293 m (on a slightly separated margin block) situated at the level of the Pliocene terrace base. This plateau is deepened more than 50 m into the level of a marked structural denudational plateau with the geodetical point 346 m southwards from Labská Stráň. If the sediments are stratigraphically identical with those of Stříbrnice, the altitudinal position of the Belveder sediments (296 to 293 m, resp. 178 to 175 m of relative height) is the result of a tectonic uplift of the territory of about 40 m when compared with the presupposed position of the Pliocene river valley bottom.

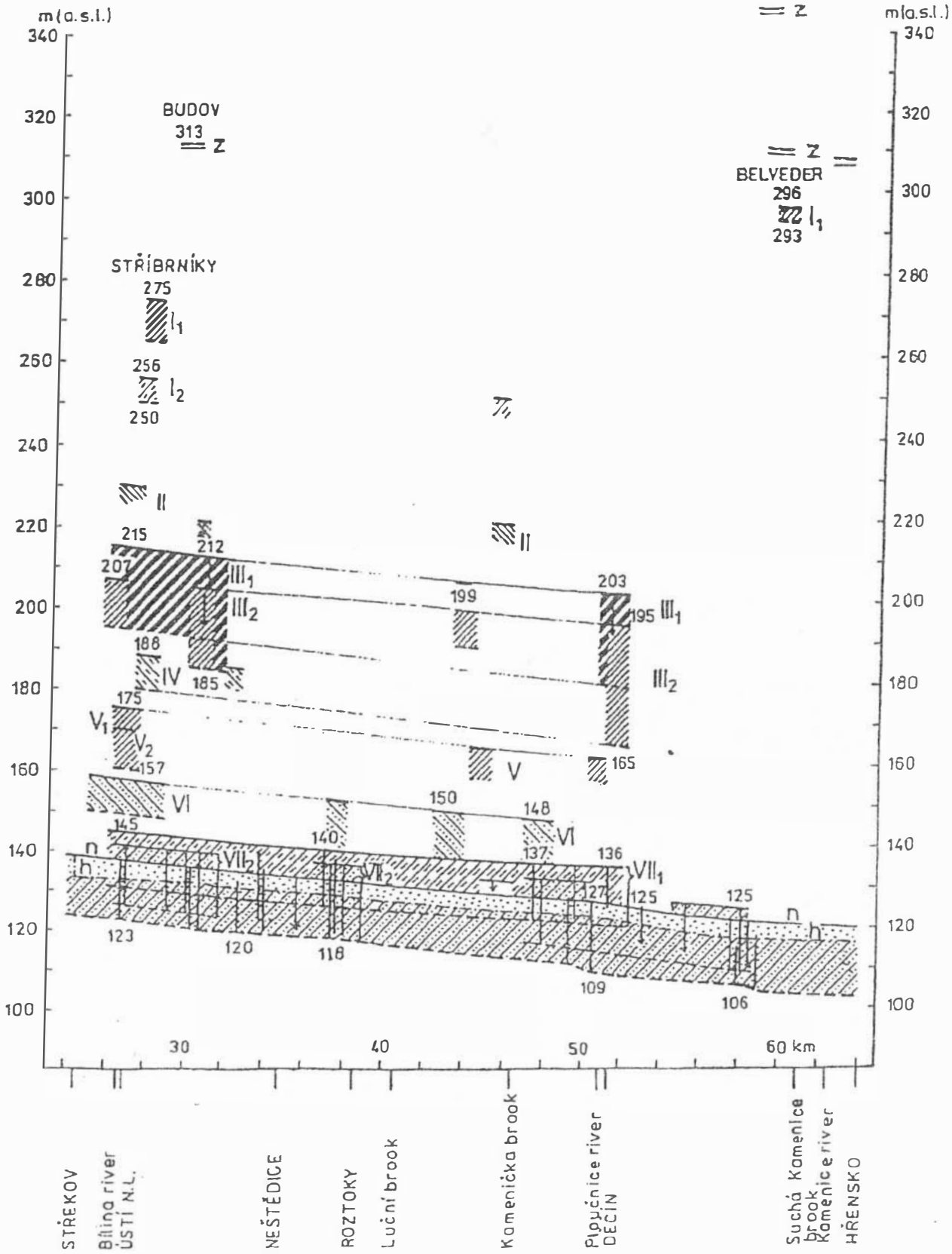

FIG. 2. Longitudinal profile across the Labe terraces between Ústí nad Labem and Hřensko. Z – planation surfaces, I_1 ... VII_2 – fluvial gravels and river terraces of the Pliocene and the Quaternary age; n – alluvial plain level; h – river level; full – terrace surfaces, dashed – terrace bases, dashed and dotted – the Labe level.

While the Stříbrnice locality I_1 in the Most Basin [Balatka 1995], the occurrence of lower situated sandy gravels at the Mariánský vrch Hill in Ústí nad Labem (256 to 250 m, resp. 123 to 117 m of relative height) corresponds in the Most Basin to the terrace I_2 (the Vysočany one), considered equally as of the Upper Pliocene age [Tyráček et al. 1985].

A contribution to the solution of the question of the foundation period of the Labe valley in the České středohoří Mountains and in the Děčínská vrchovina Highland are the findings of rocks and minerals (for instance Krkonoše Mountains chalcedonies and aucarites, the Brdy Mountains ferrous quartzites and moldavites) evidently of Bohemian Massif origin in the Labe sediments in the neighbourhood of Dresden considered as Upper Miocene [Rost et al. 1979], or Pliocene ones [Genieser 1962 and others]. These fluvial sediments probably correspond to A terraces of Grahmann (1933) and Engelmann (1938) and at present they are assigned to the upper part of the Lower Pliocene [Bouška 1994; Bouška et al. 1995].

The altitudinal position of the so-called postvolcanic planation surface in the České středohoří Mountains (375 to 650 m, [Král 1966]) indicates that the Labe valley was founded there probably in the Upper Miocene, or possibly in the Lower Pliocene, that is before the beginning of intensive differentiated uplifts of the České středohoří Mountains neovolcanic horst. At present, the Labe valley is incised into the lowered zone between differently uplifted blocks. Equally in the territory of the Děčínská vrchovina Highland, the Labe took the position of the lowest situated sandstone block at the contact of the Dolnožlebská and the Arnoltická vrchovina Highland, and before the period of the main tectonic movements, [comp. Moscheles 1920].

Among the evident Pleistocene terrace levels, beside the valley Labe terraces only the IIIrd terrace [Král 1966], the so-called Neštěmice one of Šibrava (1972), is continuously developed. The gravel surface is situated maximally 80 to 85 m above the river (III_1), locally a 5 to 7 m lower erosion level (III_2) is developed. The terrace sediments are maximally 27 m thick [Růžičková 1968]. The stratigraphically key locality in Děčín (near the hospital, Foksche Höhe) with a significant group of beds of proluvial, glacilacustrial and fluvial sediments corresponds, according to Šibrava (1967, 1972), to the cataglacial phase of the first glaciation (Menap, Günz), as well as to the anaglacial phase of the first Elster glaciation (Mindel 1). The same author indicates a relatively low level of the old valley bottom at the height of 40 to 50 m above the present-day water level. The position in the lateral profile proves that the localities of the IIIrd terrace have not been affected by evident tectonic movements.

The IVth terrace includes gravels only in Ústí nad Labem – Střekov at altitude 188 to 179 m (55 to 46 m of relative height). Exceptionally, sediments of the Vth terrace – the Nebočady one according to Šibrava (1972) – with the surface in Ústí nad Labem – Střekov at 42 m, are also maintained near Nebočady 37 m above the Labe level. This terrace with the supposed double constitution of sediments corresponds to both Elster glaciations (Mindel 1 and Mindel 2, Šibrava 1972). The VIth terrace (the Ústí one according to V. Šibrava 1972) occurs sporadically with the

surface at 20 to 24 m and the basis 16 to 18 m above the river [Růžičková 1978]. The sediments of this terrace are assigned both to the second Elster glaciation and to the cold oscillation of the Elster–Saale interglacial [Šibrava 1972]. Its geomorphological shape is therefore younger than the Elster glaciation.

The continuously developed terraces of the VIIth group are characterized by a complicated structure. The highest level (VII_1) with the surface at 10 to 13 m above the river corresponds to the main terrace of Růžičková (1978) and the Travčice terrace of Šibrava (1972); stratigraphically, it belongs to the Saale glaciation (Drenthe, Riss 1). The lowest step with the level at 6 to 8 m above the river is interpreted as the Warthe one (Riss 2), the gravels under the Holocene alluvia of the alluvial valley are of Weichsel (Würm) age.

The base of the terrace VII_1 is situated, according to drills, mostly 3 to 4 m under the river level; the rock basement of the terrace VII_2 has two levels – the higher one at 7 to 9 m and the lower one at 10 to 14 m under the river level. In rare cases, the drills discovered a sediment base under the terrace VII_1 level nearly at the level of the deepest position of the terrace VII_2 basis. The lowest positions of the base are developed in the overdeepened furrow, the genesis of which is probably connected with the intensive erosion after the retreat of the Saale glacier, when, after accumulation of gravels of the VIth terrace, the valley got deepened by 35 m at least. Coarse to boulder gravels of the basal positions of the furrow filling contain mainly rocks of local origin. The earlier authors [Hibsch 1899, Grahmann 1933 and others] supposed that Würm gravels under the Holocene alluvia lay on the Riss terrace sediments.

The surface of the alluvial plain (3 to 4 m of relative height) presents, together with the river level, an increased inclination in the upper part of the Labe canyon, that is, in places, where the river gets incised into the Cretaceous sedimentary rock crystalline base. The Labe water–level inclination in the 7 km long segment beneath the Ploučnice mouthing is 0.71‰, in the lower situated segment only 0.25‰ and above the Ploučnice mouthing 0.38‰.

4. The Origin of the Labe Canyon–Like Valley

The geomorphological analysis discovered in the Labe canyon–like valley relics of erosion–denudational levels, the bases of which can be interpreted as partial level of the river network deepening in the Quaternary [Kalvoda and Zvelebil 1983a,b; Zvelebil 1989]. This erosion–denudational levels have only local significance, when evaluated with the help of the relative heights above the present–day valley bottom. The comparison of the position of the erosion–denudational levels relics between Děčín and Hřensko with the Labe terrace system between the Bílína and the Kamenice River mouthing, and with the other Quaternary geological data, offers, nevertheless, relatively reliable information about the course of the river network deepening in the Děčínská vrchovina Highland [Balatka and Kalvoda 1995]. Retaining profiles were elaborated in that sense mainly in the W part of the Arnoltická vrchovina Highland between the mouthing of the Studený potok Brook and the Suchá Kamenice Brook, that is on the right side of the middle part of the Labe

valley. The correlation of the geomorphological situation with the engineering geological conditions has shown in addition [Kalvoda and Zvelebil 1989; Zvelebil 1989] that the presently active deeply founded sliding slope movements and occasional catastrophic rockfalls occur in the belts with relics of fossil disintegrated masses of destructional landforms of the progressively enlarged Labe valley.

In the Upper Pliocene, the Arnoltická vrchovina Highland between the Suchá Kamenice and the Studený potok Brooks had a mildly undulated relief with a more marked elevation of the basalt knob of the Arnoltický vrch Hill. The lowest level of the basalt planation surface represents the erosion–denudational level A, the lower part of which corresponds to the ba
The relic of this terrace with its surface at 178 m of relative height is maintained above the Labe valley margin northwards from the Belveder site near Labská Stráň. The Labe deep–side erosion, followed by back–side erosion of the subsequent water courses, started only after the terrace I_1 deposition, which could also have come from the right–side Labe affluents in the Děčínská vrchovina Highland. In the Upper Pliocene, the Labe somehow passed more northwards than in the Quaternary, probably across the territory of the Kripenbach Brook lower course.

In the Labe valley segment between the Studený potok Brook and the Suchá Kamenice River, there are maintained on the slopes other relics of partial levels of river deepening in the following way (see Fig. 3): base of erosion–denudational level B at altitude 252 m, 134 m of relative height; level C – altitude 226 m, 108 m rel. h. and level G – altitude 102 m, −16 m of rel. h. above the river surface. On the accumulation landforms, there are probably relics of the temporary river valley bottom of the level Fo at 148 m, resp. at 30 m; of the level F at 131 m resp. at 13 m and of the level G+1 at 116 m of altitude and at −2 m of rel. h.

Probably at the end of the Pliocene, the Labe cut into the level of 134 m of relative height above the present water surface, that is on the basis of the erosion–denudation level B. In the Prätegelen (Donau), the accumulation terrace I_2 was originated with a maintained surface at 123 m of relative height near Děčín. At that time, the Labe valley was probably partially gravelled. The terrace I_2 downstream of the Labe course significantly diverges from the alluvial plain and with younger terraces. It proves the assymetry of the tectonic uplift amplitude with its maximum in the SE part of the Děčínská vrchovina Highland [comp. Grahmann 1933].

In the Tegelen, the Labe was probably incising and reached the base of the erosion–denudational level C (that is 108 m of rel. h.), later at the base of the erosion–denudation level D (92 m of rel. h.). This base corresponds to the level of the fault caves bottom northwards from the Belveder site near Labská Stráň [Kalvoda and Zvelebil 1989]. After the stage of deepening, the Labe valley was, during the Lower Günz, gravelled in a thickness exceeding probably 20 m, which corresponds in the neighbourhood of Děčín to the river terrace II with its surface at 220 m.

Before the formation of the IIIrd terrace, the Labe reached through deep–side erosion the level of the base of the erosion–denudational level E (64 m of rel. h.) and later even the level of 43 m of rel. h. (near Děčín the altitude of 165 m,

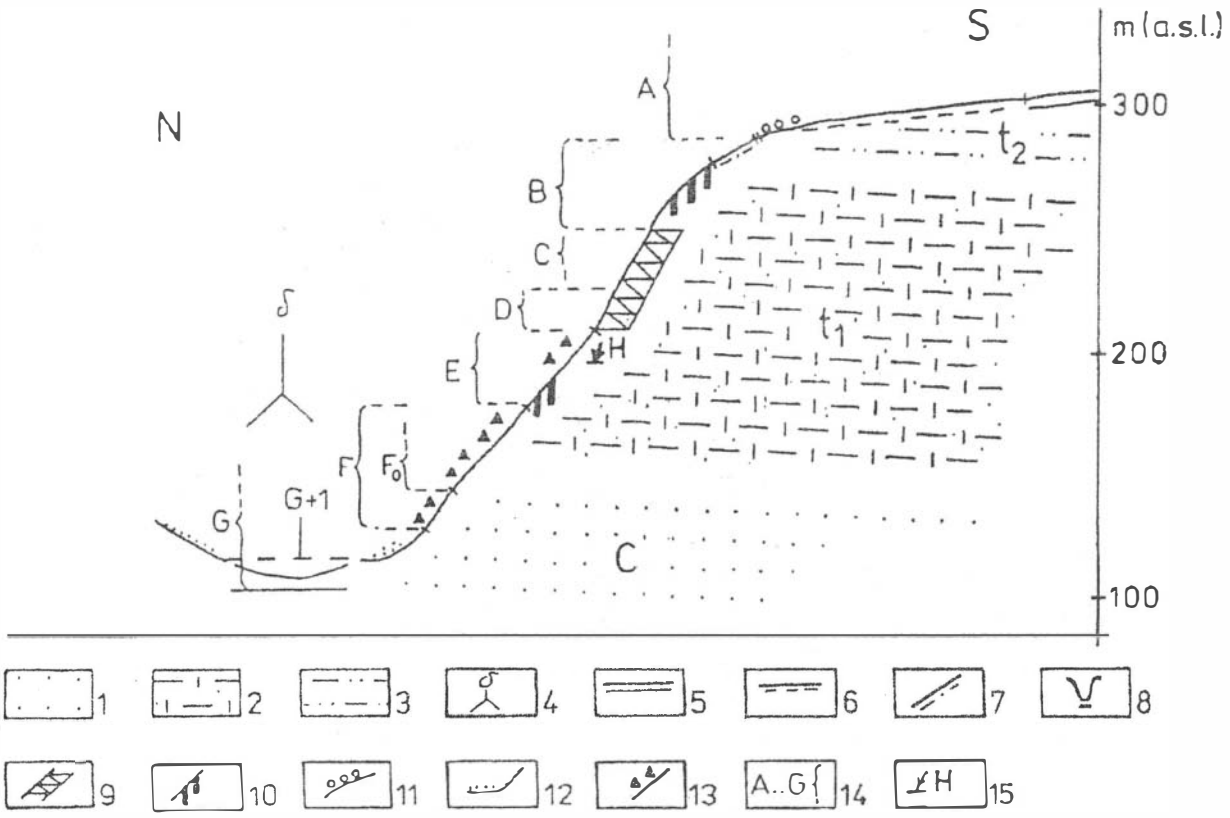

FIG. 3. Scheme of erosion denudational zones of the middle part of the Labe canyon valley (modified according to Kalvoda and Zvelebil 1983a,b; Zvelebil 1989): Explanations: 1 – 3 Upper Cretaceous sandstones, local siltstones: 1 – Cenomanian (C), 2 – Lower Turonian (t_1), 3 – Middle Turonian (t_2); 4 – fault zone; 5 – 10 destructional landforms: 5 – belevelled surface of Pliocene age under the form of denudational plateaux with an inclination of 0 to 2°, 6 – mild denudational slopes with an inclination of 2 to 5°, 7 – erosion denudational slopes with an inclination superior to 5°, 8 – overdeepened Labe bed bottom, 9 – step-type rock relief, 10 – articulated disintegrated rock relief; 11 – 13 – accumulation landforms: 11 – river terrace of Pliocene age, 12 – alluvial plain, 13 – slope sediments and accumulations of subrecent and recent rockfalls; 14 – identification and vertical extent of erosion–denudational zones, 15 – base of fissure and fault cave systems.

the terrace I base according to Grahmann 1933, equally Šibrava 1972). It can be presupposed that the valley was getting enlarged not only by erosion, but also by rockfalls, landslides and the other slope movements of weathered masses. According to Šibrava's interpretation (1972), the nearly 30 m thick accumulation of the IIIrd terrace was due to the Labe blocking by the continental glacier in the region of Meissen in the Menap and in the first stage of the Elster (Mindel). During the Elster, the maintained terraces IV and V were formed between Litoměřice and Děčín.

A geomorphologically very significant stage of deep erosion went on during the Holstein interglacial. The canyon valleys of the Labe affluents were constituted at the same time. The deepening of water courses together with warm and humid climatic conditions activated at the same time slope movements that transformed

the valleys' lateral profiles. The deep-side erosion went on in several stages even during the Saale glaciation, so that in the Eem interglacial, the Labe valley bottom in the Děčínská vrchovina Highland got cut on the basis of the erosion–denudational level G even upto 16 m below the present-day river level.

The accumulation of the VIth terrace is connected with the Drenthe stage and that of the terrace VII_1 (with its base at 3 to 4 m below the river level) with the Warthe stage of the Saale glaciation. In the Saale glaciation period, the Labe valley was again filled up by river sediments that got eroded during warmer fluctuations. The stages of removal of those sediments probably represent the bases of the erosion–denudational levels F_0 (30 m of rel. h.) and F (8 to 18 m of rel. h.) modifying accumulation landforms. The modellation of the valley was also largely due to the lateral erosion and slope movements.

Cryogenic and periglacial modelling processes were again prevailing in the Weichsel glaciation period (Würm). At the same time, the sedimentation of the river terrace VII_2 went on. After deposition of these terrace sediments there came a period of deep–side erosion that reached the level approximately 1 m below the present–day Labe river surface. On the base of this erosion–denudational level G+1, there are Holocene gravels or alluvial plain sands and soils with the surface at 1 to 6 m of rel. h. During the postglacial period, huge loamy–sandy to bouldery accumulations of the lower slope part were formed. A number of brooks, now no longer in existence, deepened the lateral short valleys and erosion cuttings mainly in the more humid Holocene periods.

A unique phenomenon of the Labe antecedent valley development in the NW part of the Bohemian Massif is undoubtedly its repeated filling up by fluvial, slope and other sediments of Quaternary age of a thickness of several tens of metres. During the main stages of the river erosion, these sediments, including landslide and rockfall accumulations, were transported towards NW outside the region of the Bohemian Massif. Slope movements on the sides (Photo 2) and river erosion of the Holocene sediments of the Labe valley bottom in the Děčínská vrchovina Highland continue at present, too.

5. Conclusion

The relics of the Neogene relief, mainly the structural denudational planation surfaces, are maintained in the monitored part of the Děčínská Highland up to an altitude of 346 m. During the deepening of the Labe and of its affluents due to the secular tectonic uplift of the Bohemian Massif, there was, since the Pliocene, an influence of the morphostructural plan of fault zones in the Mesozoic sedimentary rocks. The chronodynamics of the development of this part of the Labe canyon valley is shown in Tab. 1.

This scheme indicates that the deep–side erosion of the Labe river network in the Děčínská vrchovina Highland had already exceeded 50 m in the Pliocene. Since the formation of the terrace I_1 near Labská Stráň, the Labe got deepened by a further 180 to 200 m, while its present rock bottom could have already existed in the Drenthe stage of the Saale glaciation, but at least in the Eem interglacial.

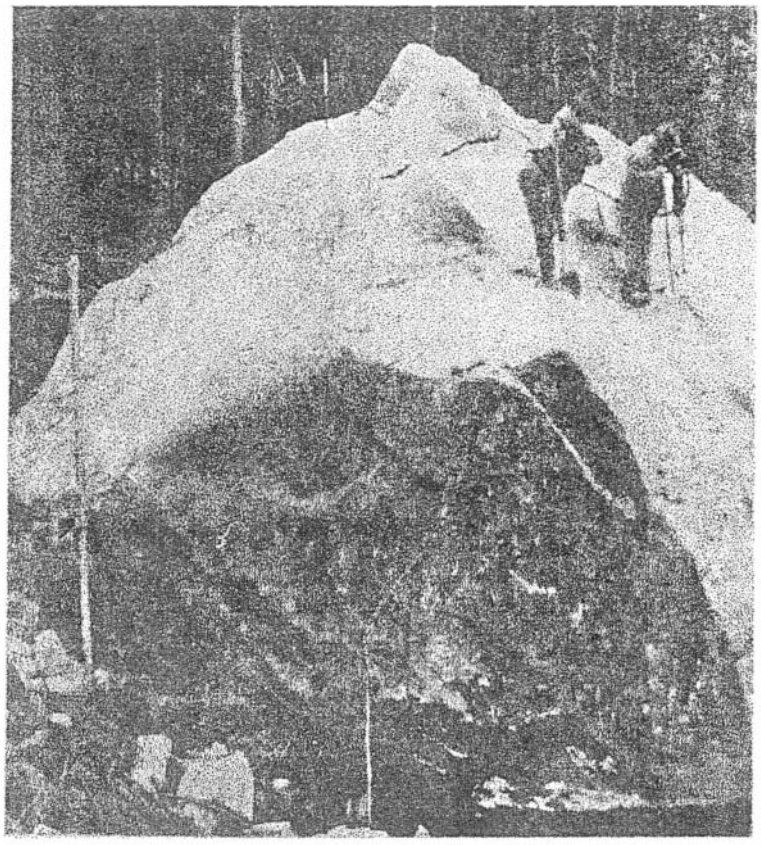

PHOTO 2. Sandstone block (volume 310 m^3) that stopped only several dozens of metres above the Děčín – Hřensko road during the catastrophic rockfall in 1978.
Photo: J. Zvelebil.

Nevertheless, the principal question is the evaluation of the chronodynamics of those phenomena (including absolute dating, [comp. Záruba et al. 1977; Tyráček et al. 1985; Kočí et al. 1991; Tyráček in Klomínský 1994; Balatka 1995]) and its interpretation in the context of the paleogeographical development of the Bohemian Massif and of the region of the North–European continental glaciation in the Quaternary. From the presented results of the geomorphological analysis it follows that it is necessary to perform 1) dating of terraces I_1 and I_2 with their surfaces at 178 m and 123 m respectively above the present Labe level; 2) determination of the period of origin of the base and of the accumulations of the IIIrd river terrace sediments and their time correlation with the stage of progression of the continental glacier in the Lower Pleistocene; 3) a more precise determination of the time and phases of the marked deep–side erosion since the Holstein to the Eem interglacial; 4) confirmation of the time correlation of the river terraces VI and VII_1 formation with the stages of the Saale glaciation.

TABLE 1.Course of the antecedent deepening of the Labe canyon–like valley in the Děčínská vrchovina Highland

Stratigraphic period according to the continental (Alpine) classification	Geological age (in 10^6 yr)	Chronodynamically significant data about the Labe valley relief development in the Děčínská vrchovina Highland
	–5.30–	Denudation of Turonian sandstones on the surface of the "basaltic" planation surface in conditions of warm humid climate. Formation of the river accumulation terrace A with its surface at 188 m and its basis at 183 m of relative height (resp. surface/base figures below) near Ústí nad Labem.
Pliocene		Base of the erosion–denudational level A, 175 m of rel.h.(all details from the region between Suchá Kamenice and Studený potok Brooks). Formation of the terrace I_1 (142/132 m near Ústí nad Labem, 178/175 m near Labská Stráň).
	–1.80–	Base of the erosion–denudational level B,
Tegelen (Donau 1)		134 m of rel. h. Formation of the terrace I_2 (123/117 m near Ústí nad Labem).
	–1.64–	Secular tectonic uplift and progressive cooling
Eburon (Donau 2)		of the climate. Base of the erosion–denudational level C,
Wall		108 m of rel. h., and D, 92 m of rel. h.
Menap (Günz 1)		Formation of the terrace II (97/81 m near Ústí nad Labem and 85/80 (?) m near Děčín).
	–1.05–	Base of the erosion–denudational level E,
Bavel (Günz 2)		64 m of rel. h. Formation of the terrace III_1 (82/62 m near Ústí nad Labem, 81/58 (43) m near Děčín).
	–0.85–	Warm spell and humid climate in the interglacial,
Cromer (Günz/Mindel)		stage deepening of the Labe and its affluents. Formation of the terrace III_2 (75/62 m near Ústí nad Labem, 73/58 (43) m near Děčín).
Elster 1 (Mindel 1)	–0.55–	Formation of the terrace IV (55/46 m near Ústí nad Labem).
Elster 2 (Mindel 2)	–0.47–	Formation of the terrace V_1 (42/27 m near Ústí nad Labem, 37/32 m near Děčín) and V_2.
	–0.43–	Strong deep–side erosion with progressive Labe

Holstein (Mindel/Riss)		deepening up to the present level of the river bottom; activation of slope movements on the valley slopes.
Saale, stage Drenthe (Riss 1)	−0.30−	Formation of the terrace VI_1 (24/16 m near Ústí nad Labem), the terrace VI_2 is not maintained.
	−0.20−	The region of the Děčínská vrchovina Highland is the foreground of the continental glacier, strong influence of periglacial processes.
Saale, stage Warthe (Riss 2)		Formation of the terrace VII_1 (12/−2 m near Ústí nad Labem, 13/−3 m near Děčín). Base of the erosion–denudational level G, −16 m of rel. h. between the Studený potok Brook and Hřensko. After gravelling of the valley, bases of the erosion–denudational levels F_0 and F, 30/13 m of rel.h., were formed on accumulation landforms.
	−0.13−	Considerably warmer and humid climate of inter-
Eem (Riss/Würm)		glacial, intensive transport of Quaternary sediments, erosion, slope movements.
Weichsel, early and high (Würm 1, 2)	−0.10−	Formation of the terrace VII_2 (8/−10 m near Ústí nad Labem, 8/−14 m near Děčín).
	−0.04−	Base of the erosion–denudational level G+1, −2 m of rel. h.
Weichsel, late (Würm 3)		Slope developement in the periglacial climate, later progressive warming.
	−0.01−	Formation of alluvial accumulations (4/−3 m near Ústí nad Labem and Děčín).
Holocene		Frequent rockfalls and landslides. Occasional sedimentation, especially since the Atlantic period, of inundational soils and sands, anthropogenous
	−0.00−	modelling of the relief.

REFERENCES

Balatka B. (1995), *Terasy střední a dolní Bíliny – spojovací článek terasových systémů Ohře a Labe*, Sborník ČSG **100**, 4, Praha, 249–267.

Balatka B. (1995), *Regionální členění reliéfu Děčínska*, Sborník ČSG **100**, 3, Praha, 241–244.

Balatka B., Kalvoda J. (1995), *Vývoj údolí Labe v Děčínské vrchovině*, Sborník ČSG **100**, 3, Praha, 173–192.

Balatka B., Sládek J. (1962a), *Říční terasy v českých zemích*, Naklad. ČSAV, Praha, 578 p.

Balatka B., Sládek J. (1962b), *Terasový systém Vltavy a Labe mezi Krulupy a Českým středohořím*, Rozpr. ČSAV, Ř. mat.–př. Věd **72**, 11, Praha, 62 p.

Balatka B., Sládek J. (1975), *Geomorfologický vývoj dolního Poohří*, Rozpr. ČSAV, Ř. mat.–př. Věd **85**, 5, Praha, 70 p.

Balatka B., Sládek, J. (1978), *Ke geomorfologii řečiště dolní Kamenice*, SČSSZ **83**, 2, Praha, 143–149.

Beck R., Hibsch J.E. (1895), *Erläuterungen zur geologischen Spezialkarte des Königreichs Sachsen*, Section Grosser Winterberg – Tetschen. Leipzig, 81 p.

Bouška V. (1994), *Moldavites. The Czech Tectites*, Praha.

Bouška V., Mottl V., Rost R., Ševčík J. (1995), *Moldavites from the Cheb Basin*, Věstník ČGÚ **70**, 3, Praha, 73–80.

Buday T. et al. (1961), *Tektonický vývoj Československa*, Academia, Praha, 254 p.

Engelmann R. (1938), *Der Elbedurchbruch – Geomorphologische Untersuchungen im oberen Elbegebiet*, Abhandg. d. Geogr. Ges. Wien **13**, 2, Wien, 1–38.

Engelmann R. (1941), *Krustenbewegungen und morphologische Entwicklung im Bereich der Böhmischen Masse*, Mitt. d. G. G. Wien **84**, Wien, 179–196.

Genieser K. (1962), *Neue Daten zur Flussgeschichte der Elbe*, Eiszeitalter und Gegenwart **13**, Öhringen/Württenberg, 141–156.

Glöckner P. (1964), *Geomorfologická mapa povodí Kamenice*, Dipl. pr. Kat. fyz. geogr. a kartogr. PřF UK, Praha.

Glöckner P. (1967), *Terasy labské Kamenice*, SČSSZ **72**, 4, Praha, 281–295.

Grahmann R. (1933), *Die Geschichte des Elbetales von Leitmeritz bis zu seinem Eintritt in das norddeutsche Flachland*, Mitt. d. Ver. f. Erdkunde, NF, Dresden, pp. 132–194.

Gregor T. (1959), *Terasy řeky Ploučnice od České Lípy až k jejímu ústí do Labe*, Dipl. pr. Kat. fyz. geogr. a kart. PřF UK, Praha.

Gregor T., Tesařík K. (1959), *Terasy řeky Ploučnice*, SČSSZ **64**, 4, Praha, 303–323.

Hibsch J.E. (1899), *Versuch einer Gliederung der Diluvialgebilde im nordböhmischen Elbthale*, Jahrbuch d. K. k. Geol. Reichsan. **49**, Wien, 641–648.

Hibsch J.E. (1904a), *Geologische Karte des Böhmischen Mittelgebirges*, Blatt V (Grossprisenen), Wien, 126 p.

Hibsch J.E. (1904b), *Geologische Karte des Böhmischen Mittelgebirges*, Blatt IV (Aussig), Wien, 80 p.

Kalvoda J. (1980), *Výzkum stability skalních stěn podél silnice Děčín – Hřensko. II. Morfogenetická analýza příčin vzniku recentních skalních řícení v údolí Labe mezi Děčínem a Hřenskem*, Díl. výzk. zpr. ÚGG ČSAV, Geofond, Praha, 33 p. + 16 encl.

Kalvoda J., Zvelebil J. (1983a), *Dynamika a typy porušování svahů při vývoji údolí Labe v Děčínské vrchovině*, Acta Montana **63**, Praha, 5–74.

Kalvoda J., Zvelebil J. (1983b), *Porušování skalních svahů údolí Labe v Děčínské vrchovině*, Sb. pr. Geogr. úst. ČSAV **1**, Brno, 163–173.

Kalvoda J., Zvelebil J. (1989), *Vývoj skalních svahů a pseudokrasových jeskyní údolí Labe v Děčínské vrchovině.*, Sborník "Symposium o krasu Sudetské soustavy", Knih. České speleolog. spol., sv. 10, Praha, pp. 112–126.

Klein V., Opletal M., Pražák J. (1967), *Vysvětlující text k základní geologické mapě 1 : 25 000, list M – 33 – 41 – A – c (Königstein) a M – 33 – 41 – A – d (Hřensko)*, Geofond, Praha.

Klomínský J., Edit. (1994), *Geologický atlas České republiky. Stratigrafie*, ČGÚ, Praha.

Kočí A., Růžičková E., Kadlec J. (1991), *On dating of the Labe river terraces in the environs of Ústí nad Labem*, Věstník ÚÚG **66**, 1, Praha, 43–49.

Kopecký L. et al. (1963), *Vysvětlivky k přehledné geologické mapě ČSSR 1 : 200 000, M – 33 – IX*, Praha.

Král V. (1966), *Geomorfologie střední části Českého středohoří*, Rozpr. ČSAV, Ř. mat.-př. Věd **76**, 5, Praha, 66 p.

Kunský J. (1966), *Terasový systém labský a jeho vztah ke čtvrtohornímu zalednění kontinentálnímu a horskému*, Acta Univ. Carol., Geogr. **2**, 1–2, Praha, 21–22.

Lamprecht F. (1935), *Gesteins und flussbedingte Grossformen des Elbsadsteingebirges*, Mitt. d. Ver. f. Erdkunde zu Dresden **9**, Dresden, 111–157.

Liebus A. (1929), *Über die säugetierfauna der Quartärablagerungen aus der Umbegung von Ausig a.d.E.*, Lotos **77**, Prag, 121–150.

Malkovský M. (1976), *Saxonische Tektonik der Böhmischen Masse*, Geol. Rundschau **65**, 1, Stuttgart, 127–143.

Malkovský M. (1979), *Tektogeneze platformního pokryvu Českého masívu*, Knih. ÚÚG, 53, Praha, 176 p.

Moscheles J. (1920), *Das Böhmische Mittelgebirge*, Zeitschr. f. Gess. f. Erd. zu Berlin 1920, Berlin, 24–59, 117–146.

Moschelesová J. (1923), *Morfologické důkazy nejmladších tektonických pohybů v severozápadních Čechách*, SČSSZ **29**, Praha, 132–134.

Präger F., Lemke F. (1967), *Anlage einer geologischen Speziallinie "Elbtalgraben"*, Vermessungstechnik **15**, 6, Berlin, 229–231.

Rather V., Wagner A. (1975), *Kleintektonische Bewegungen als Ursache der Höhlenbildung im Elbtal zwischen Wehlen und Posta*, Die Höhlenforscher **7**, Dresden, 21–25.

Rost R., Nicht H., Wagner H. (1979), *Moldavite aus der Umgebung von Dresden, DDR*, Čas. mineral. geol. **24**, 3, Praha, 263–271.

Růžičková E. (1968), *Zpráva o petrografickém výzkumu v oblasti Českého středohoří a mapování na listu Ústí n Labem – západ*, Zpr. geol. výzk. 1966, Praha, pp. 333–335.

Růžičková E. (1978), *Význam sedimentů středního pleistocénu pro stratigrafii kvartéru v oblasti Českého středohoří*, Rigor. pr., PřF UK, Praha, 91 p.

Šibrava V. (1966), *Das Pleistozän im Bereich des Elbetalgrabens auf dem Gebiet der ČSSR*, Geologie **15**, 1, Berlin, 67–78.

Šibrava V. (1967), *Study on the Pleistocene of the glaciated and non-glaciated area of the Bohemian Massif*, Sb. geol. věd, ř. A **4**, Praha, 7–38.

Šibrava V. (1972), *Zur Stellung der Tschechoslowakai im Korrelierungssystem des Pleistozäns in Europa*, Sb. geol. věd, ř. A **8**, Praha, 1–218.

Šibrava V., Václ J. (1962), *Nové důkazy kontinentálního zalednění severních Čech*, Sb. geol. věd, ř. A **11**, Praha, 85–91.

Thurm H. (1973), *Untersuchung des vertikalen und horizontalen Bewegungsverhaltens der Erdkruste im Testgebiet Elbetalzone*, Vermessungstechnik **7**, Berlin, 267–271.

Tyráček J., Minaříková D., Kočí A. (1985), *Stáří vysočanské terasy Ohře*, Věst. ÚÚG **60**, 1, Praha, 77–86.

Záruba Q., Bucha V., Ložek V. (1977), *Significance of the Vltava terrace system for Quaternary chronostratigraphy*, Rozpr. ČSAV, Ř. mat.-přír. Věd **87**, 1, Praha, 1–90.

Zvelebil J. (1989), *Inženýrskogeologické aspekty vývoje skalních svahů v Děčínské vrchovině*, Kandid. dizert. pr., ÚGG ČSAV, Praha, 282 p.

CHRONODYNAMIKA VÝVOJE ÚDOLÍ LABE V DĚČÍNSKÉ VRCHOVINĚ, ČESKÁ REPUBLIKA

Jan KALVODA a Břetislav BALATKA

V pleistocénu byla Děčínská vrchovina opakovaně součástí předpolí kontinentálního ledovce, který v obdobích maximálních postupů zasahoval až na severní okraj Českého masivu. Rekonstrukce chronodynamiky reliéfotvorných procesů a jevů při vývoji údolí Labe v mladším kenozoiku je založena na geomorfologické analýze sledované části Děčínské vrchoviny a na její korelaci s terasovým systémem Labe mezi ústím Bíliny a Kamenice a s dalšími kvartérně geologickými údaji.

Při zahlubování říční sítě do kerně rozlámaných křídových sedimentů Děčínské vrchoviny se erozní svahy vyvíjely na úkor plochy zarovnaných povrchů neogenního stáří. V mladším pliocénu byla na mírně zvlněný reliéf uložena aluviální terasa I_1, jejíž relikt s povrchem 178 m relativní výšky se zachoval nad okrajem labského údolí u osady Labská Stráň. Patrně koncem pliocénu se Labe zařízlo na úroveň 134 m rel.v. nad současnou hladinou, která je dnes u Hřenska ve 117 m n.m. V prätegelenu (donau) vznikala akumulační terasa I_2 se zachovaným povrchem ve 123 m rel. v. u Děčína. V tegelenu se Labe zahloubilo pravděpodobně až na 92 m rel. v. a ve starším günzu vznikla říční terasa II, jejíž povrch je v okolí Děčína 220 m n.m. Před vznikem III. terasy dosáhlo Labe erozí úroveň 43 m rel.v. Téměř 30 m mocná říční terasa III byla vytvořena patrně v obdobích zahrazení toku Labe pevninským ledovcem u Míšně v menapu a v 1. fázi elsteru (mindel).

V holsteinském interglaciálu působila morfologicky velmi výrazně hloubková eroze, která pokračovala v několika etapách i během sálského zalednění. Proto již v eemském interglaciálu bylo dno údolí Labe v Děčínské vrchovině až 16 m pod dnešní hladinou řeky. Zachované relikty akumulace VI. terasy souvisí se stadiem drenthe a terasy VII_1 (s bází 3–4 m pod hladinou řeky) se stadiem warthe sálského zalednění. Tyto fluviální sedimenty byly v teplejších obdobích erodovány. Během viselského zalednění (würm) proběhla sedimentace terasy VII_2. Následující etapa hloubkové eroze dosáhla úrovně přibližně 1 m pod současnou hladinou Labe. Na tuto bázi byly uloženy holocenní štěrky a písky údolní nivy.

Při hloubkové erozi probíhalo v kvartéru na odkrývaných skalních masivech pískovců Děčínské vrchoviny intenzivní zvětrávání. Převážně podél ploch diskontinuity vznikaly svahové pohyby, které na některých lokalitách pokračují i v současné době.