

Morphostratigraphy of river terraces in the Eger valley (Czechia) focused on the Smrčiny Mountains, the Chebská pánev Basin and the Sokolovská pánev Basin

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ABSTRACT

The Eger (Ohře) River terraces originated in varied morphotectonic and climate-morphogenetic conditions that existed during the late Cenozoic evolution of the western part of the Bohemian Massif. In the area between the Smrčiny Mountains and the Sokolovská pánev Basin, these levels of the Eger River terrace system were identified (Table 1): the Pliocene terrace niveau B, the Cheb terrace (I), the Hradiště terrace (II), the Choječná terrace (III), Jindřichov terrace (IV), Nebanice terrace (V), Chocovice terrace (VI), Chotíkov Terrace (VII) and the recent flood plain (N). It was determined to be a morphostratigraphical system of 7 river terraces of Quaternary age. Older levels of fluvial sediments, occupying a still higher morphological position in the area between the Smrčiny Mountains and the Sokolovská pánev Basin, have been classified to the Pliocene. A comparison of terrace flights in the longitudinal profile of the Eger River between the Smrčiny Mountains and the Doupovské hory Mountains indicated that the Cheb terrace (I) in the Smrčiny Mountains is tectonically uplifted around 10 m in comparison with its level in the Chebská pánev Basin. In the Chlumský práh Horst area, the oldest Pleistocene terraces, which originated during the Tiglian stage, were uplifted by approximately 15 m. The Chebská pánev Basin originated at the intersection of the Eger rift and the Cheb-Domažlice fault zone and its river network is incised ca 40 m into the planation surfaces of the sedimentary basin. Both volcanic processes and frequent seismic activity in the region are associated with the Late Cenozoic tectonic movements. According to the current stratigraphical scheme of the Quaternary, the Eger terrace system was formed mostly by the Pleistocene (Table 2) during the Tiglian to the Weichselian stages.

KEYWORDS

river terraces; evolution of the Eger valley; neotectonic movements; Smrčiny Mountains; Chebská pánev Basin; Sokolovská pánev Basin

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1. Introduction

1.1 Theme and aims

The Eger River has a remarkable position among the streams of the Bohemian Massif because of the varied geological structure and palaeogeographical history of the whole catchment area. Conspicuous river valleys, terrace systems and related fluvial deposits originate in regions of neotectonic activity, combined with specific climate-morphogenetic processes (Balatka et al. 2015; Balatka and Kalvoda 2018). Geomorphological research on the Eger valley was aimed at landform evolution and morphogenetic evaluation of river terraces and further fluvial sediments. Particular attention was paid to the classification of the flight of Eger River terraces in the stratigraphical system of the Quaternary.

The aim of this research is to discover or verify locations of river terraces and other fluvial sediments in the Eger River valley between the Smrčiny Mountains and the Sokolovská pánev Basin (Fig. 1), to provide their morphogenetic evaluation and to suggest their correlation with the current stratigraphical classification of the Quaternary. The field research was focused on a documentation of the fluvial sediment exposures and a characterisation of the landform evolution in the Eger River valley and the surrounding area (Balatka and Kalvoda 2018). This geomorphological research confirmed the importance of the Eger terrace system in the assessment of the range of the Quaternary tectonic movements, especially in the area of the Chlumský práh Horst. The geomorphological analysis of the fluvial landscape in the Eger River valley enabled a creation of the longitudinal profile of the river terraces from the German border in the Smrčiny Mountains through Citice in the Sokolovská pánev Basin to Vojkovice in the Doupovské hory Mountains.

During the interpretation of the geomorphological analysis of the Eger River valley landforms, special attention was focused on the influence of neotectonic uplift on the terrace flights in the longitudinal profile. Primarily, the historical-genetic relationship between the older terrace levels evolved in the Chebská pánev Basin and the corresponding terrace levels in the Bohemian part of the Smrčiny Mountains and in the crystalline Chlumský práh Horst, which is asymmetrically extended in the Mariánské Lázně fault zone, was assessed.

The Eger River terraces originated during the varied morphotectonic and climate-morphogenetic conditions which existed during the late Cenozoic evolution of the western part of the Bohemian Massif. It is a substantial reason for a discussion about the morphostratigraphical correlation of the river terraces in the studied area of the Chebská pánev Basin and its neighbouring regions with the terrace system along the middle and lower course of the Eger River.

1.2 A brief review of earlier papers

The oldest works about the Eger valley were related to the Sokolovská pánev Basin, the Slavkovský les Mountains and the Doupovské hory Mountains (Wilschowitz 1917; Danzer 1922; Peter 1923). The Eger River terraces in the Chebská pánev Basin were addressed only by Engelmann (1920), who identified 5 terraces, whose relative surface heights above the valley floor reached 5 m, 10 m, 15 m, 20 m and 30 m. He also correlated the highest terrace flights in the Chebská pánev Basin with fluvial gravel in the Sokolovská pánev Basin at the relative height of 50–70 m and with the Eger terrace A in the lower valley of the Bílina River at the relative height of 170 m. However, this incorrect interpretation would imply that the oldest terrace of Eger would have a distinct divergence of 140 m in the upstream direction, which

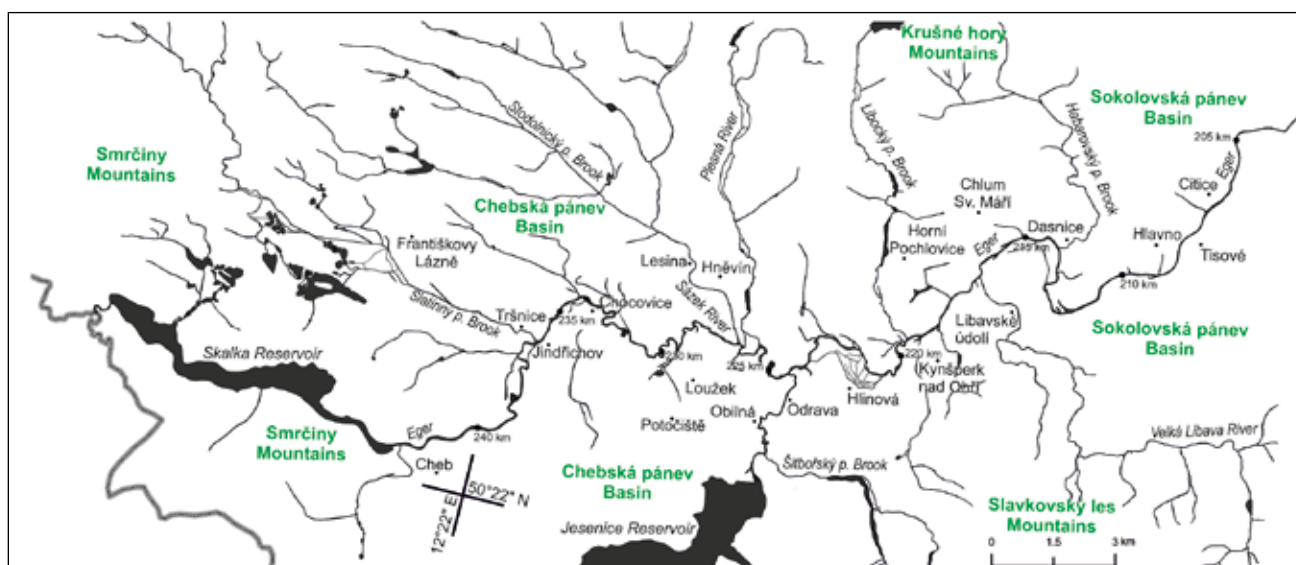


Fig. 1 Geographical position of the Eger (Ohře) valley between the Smrčiny Mountains and the Sokolovská pánev Basin.

is unrealistic. The studied area is also presented in Peter (1923), which describes 6 Eger River terraces between Kynšperk nad Ohří and Karlovy Vary. J. Peter identified the levels at the relative height of 50 m and 25 m as Quaternary terraces, while those at the relative height of 125 m, 100 m and 75 m as Pliocene terraces and the levels at the relative height of 175 m as terraces of Upper Miocene age. Nevertheless, the higher terrace levels at the relative height of 75 m to 175 m presented by Peter (1923) are in fact denudational plateaux and relics of local planation surfaces.

Complex geological research of the Chebská pánev Basin and parts of the Sokolovská pánev Basin, which took place in the second half of the 20th century, provided further substantial knowledge (Ambrož et al. 1958; Vrba 1959, 1981; Ambrož 1960; A. Kopecký 1960, 1966; Mazáč and Pokorný 1961; Kolářová 1965; Šantrůček et al. 1969, 1994). Ambrož et al. (1958) presented 10 terrace levels in the Chebská pánev Basin, whereas A. Kopecký (in Šantrůček et al. 1969) reported only 7 terrace levels in the same area, the highest one at the relative height of 30–35 m above the Eger valley floor. This author also correlated the highest terrace level with higher locations above the basin (relative height of 65 m) and in the area of former Chlum nad Ohří (relative height of 85 m). Their current position was explained by the young tectonic movements.

According to geological maps of the studied area (Škvor and Satran et al. 1974; Mlčoch et al. 1993; Müller et al. 1998), Eger fluvial sediments are of Pleistocene age. The complex studies of the Eger river terraces in the Chebská pánev Basin are presented by Kvaček (1987, 1989), who defined the localities of fluvial gravel-sand more accurately. This provided petrographic and granulometric analysis of the terrace sediments and documented them by several transverse profiles. Five terrace levels, the highest one in relative height of 17–25 m, were distinguished in this way. Their stratigraphical classification was derived from the older concepts mentioned above. Older publications concerning with the terrace system along the lower course of the Eger River are cited especially in the third chapter.

2. Methods

Geomorphological analysis of landforms was performed in focus on the palaeogeographical history of the studied region. Field works resulted in a detailed description of the identified localities with relics of fluvial sediments and in a set of graphical documentation. It especially concerns with a construction of a geomorphic sketch map, cross profiles and a complex longitudinal profile of the river terraces in the Eger valley. Geomorphological research was also supported by an evaluation of data presented in earlier regional papers about the fluvial accumulations.

The acquired data were used for the classification of the river terrace levels applying a method based on the reconstruction of the terrace levels in the longitudinal and transverse valley profiles. This complex method was already used by Q. Záruba in his work on the terrace system of the Vltava River (Záruba-Pfeffermann 1943; Záruba et al. 1977). The relics of the Eger River fluvial accumulations were recorded in the longitudinal profile, whose topographic base of the river level was measured in November 1949 with an average daily discharge of $7.32 \text{ m}^3 \text{ s}^{-1}$ in Citice (Vodohospodářská kancelář ministerstva techniky v Praze 1950). The reconstruction of the terrace levels in the longitudinal profile was based on the methodological approach called the equilibrium profile (Krejčí 1939). This method of characterising the terrace system builds on the assumption that the palaeo-thalweg and the surfaces of each major terrace level maintained stable gradients that correspond to the longitudinal profiles (Balatka et al. 2015). In the presented longitudinal profile, relics of the original surface (not reduced by erosion) and the base of the river terrace correspond to the state of equilibrium of the valley floor evolution. It means that a stream of certain discharge does not erode nor accumulate, so the only process that takes place is a transport of carried material. This state may be disturbed – as a consequence of tectonic movements, changes in the discharge regime and sediment supply – in the direction of net erosion or in that of net accumulation.

The regional research was essentially conducted in accordance with the current state of the stratigraphical division of the Quaternary (e.g. Gibbard and Cohen 2008; Gibbard et al. 2010). Previously used names of glacial periods in the Quaternary are presented in this work only as a mandatory referential statement on the timing of the occurrence of certain fluvial accumulation according to older publications.

The geomorphological record of the Eger valley evolution and its river terraces was significantly disturbed by the current character of settlement and by an intensive economical exploitation of the area. For example, the fluvial relief of the western part of the Sokolovská pánev Basin was completely degraded by anthropogenic activity. Numerous locations of the river terraces were destroyed by brown coal mining. Therefore, the fluvial sediments were preserved only on the Paleogene sediments and crystalline rocks. Waste areas of the river terraces of the Middle Pleistocene age were extracted in the Chebská pánev Basin and the Mostecká pánev Basin.

3. Key morphological patterns of the Eger valley

The source of the Eger River is situated in the Smrčiny Mountains. The river enters Czechia at the river km 263 (measured from the Eger River mouth to the Elbe



Fig. 2 Western side of the Chebská pánev Basin (in a view from the north to the south) with mildly incised Eger valley and upper part of the Skalka dam. In the background the Smrčiny Mountains are seen. Photo: Petra Štěpančíková

River). It reaches the Františkolázeňská kotlina Basin near the mouth of the Libský potok Brook in the south-western corner of the Chebská pánev Basin (50°23' N, 12°21' E). Then to the confluence with the Elbe, the Eger River follows the significant depression of the Krušné hory Fault and the subsequent Dolnooharská tabule Plateau in the tectonically subsided zone of the Bohemian Cretaceous Basin at the base of the Krušné Hory Mountains, while simultaneously epigenetically eroded the neovolcanics in the Doupovské hory Mountains and the České středohoří Mountains as well as the uprising crystalline plate of the Chlumský práh Horst between the Chebská pánev Basin and the Sokolovská pánev Basin. Originally, the Eger River followed the Krušné hory fault in its full length, since the confluence with the Elbe River was situated in the place of the present-day Ústí nad Labem until the Middle Pleistocene (Balatka and Sládek 1962, 1976). The length of the Eger River currently reaches 302 km with a catchment area of 5 614 km². The confluence with the Elbe River is situated near Litoměřice, which is before the Elbe River antecedent valley and fault gap, which cuts through the neovolcanics of the České středohoří Mountains.

The Eger catchment belongs to the Saxo-Thuringicum, which is a part of the Bohemian Massif built mostly by the metamorphosed rocks and Variscan granitoids (Chlupáč et al. 2002). It includes metamorphosed Paleozoic rocks of the Thuringen-Vogtland, the

crystalline complex of the Krušné hory Mountains and the Eger rift, Tertiary sediments and neoid volcanics (Mahel' et al. 1984). In the studied area, the Paleozoic rocks of the Thuringen-Vogtland are represented by quartz-mica schist, phyllitic mica schist with quartz layers, Cheb phyllite of Cambrian and Ordovician age and biotite granite of Late Paleozoic age (Škvor and Satran et al. 1975; Müller et al. 1998). The Eger valley and its surrounding area in the Hazlovská pahorkatina Hills (west of Františkolázeňská kotlina Basin) are built by porphyritic biotite granite and biotite hornstone. Phyllite and mica schist with layers of Vildštejn Formation protrude between Bříza and Hradiště (north-west of Cheb). The bedrock of the Chebská pánev Basin sediments is largely built by graywacke quartz-mica schists and white mica schists, which also surfaced in the Chlumský práh Horst and in the part of Eger valley leading to Hlavno.

Two depressions of the Eger Rift were created in the studied area, namely Chebská pánev Basin and Sokolovská pánev Basin. Chebská pánev Basin is filled by lacustrine and fluvial sediment of Eocene and Quaternary age (Fig. 2). Eocene clays, sand and gravel of the Starý Sedlec Formation fill the depressions of the crystalline complex and granitoids, which were affected by fossil weathering. The younger Nový Sedlec Formation is mostly of Oligocene age. The upper part of these layers contains volcanogenic sediments and lava bodies of olivine basalts (Ambrož 1958; Václ 1979). The Sokolov Formation was formed in the Lower Miocene. Its middle part contains a brown coal



Fig. 3 Landscape in the south-western part of the Chebská pánev Basin in a view from the Zelená Hora Mountain. Afforested ridges of the Slavkovský les Mountains (in the background) are delimited by fault- and denudation slopes along the Mariánské Lázně fault zone. Photo: Petra Štěpančíková

seam, which can be several tens of meters thick. The thickness of the upper part of the Sokolov Formation reaches up to 170 m (Cypris Formation) and it is built mostly by bitumen clays and sandstones.

The Chebská pánev Basin is situated on the crossings of the Eger rift and the Cheb-Domažlice graben. It consists of the Tertiary sediments, whose thickness reaches up to 400 m and it is significantly disrupted by many faults of several tectonic systems, such as Krušné hory system, Sudety system, Český les system and Jizera system (Václ 1979; Dobeš et al. 1986). Earthquake epicentres are closely connected to this area, which is the most seismically active region of the Bohemian Massif (Babuška et al. 2010). The western boundary between the Chlumský práh Horst and Chebská pánev Basin is created by the fault-slope of Mariánské Lázně fault zone (Fig. 3). The vertical range of the Cenozoic tectonic movements along the Mariánské Lázně fault, namely the subsidence of the Chebská pánev Basin and the uplift of the Chlumský práh Horst, is assumed to be 300–400 m (Malkovský 1976, 1979). The analysis of the neotectonic evolution of the Chebská pánev Basin by Peterek et al. (2011) confirmed the significant role of the Upper Pliocene and Quaternary tectonic movements.

In the Chebská pánev Basin, the lacustrine and fluvial sedimentation of the clay, sand and gravel of the Vildštejn Formation took place in the Pliocene and the Lower Pleistocene (4.5–1.5 Ma, Špičáková et al. 2000). According to the paleoflora analysis by Bůžek et al. (1985), the prevailing climate of the last lacustrine sedimentation shows the transition between the warm temperate (mean annual temperature 12–14 °C) and cold temperate climatic zone (6–7 °C). A diatrema with pipe filling near Podhrad originated in the Upper Pliocene. The younger parts of the Komorní hůrka Hill (503 m), which is built by the pyroclastic rocks and effusion of melilitic olivine nephelinite, are of Pleistocene age (L. Kopecký 1978; Šrbený 1982; Gottsmann 1999), and are the same age as the fluvial sediments involved in this study. The Quaternary age of the youngest active phases of the Komorní hůrka Hill was

confirmed by radiometric dating of its volcanic rocks, namely 0.85 ± 0.1 Ma up to 0.26 ± 0.05 Ma (Šibrava and Havlíček 1980) and 0.45–0.90 Ma (Wagner et al. 1998).

The Sokolovská pánev Basin has undergone a similar morphostructural evolution as the Chebská pánev Basin, since they used to be connected. In its longitudinal direction, the Sokolovská pánev Basin is enclosed by the significant fault-slopes of the Krušné hory Mountains (Krušné hory Fault) and Slavkovský les Mountains (Eger fault), which define the edges of the Eger Rift. Separation of these basins was caused by the Neogene uplift of the Chlumský práh Horst. Thus, the Chebská pánev Basin was occupied by the paleo-lake in the Pliocene, while the Sokolovská pánev Basin was no longer occupied by it. The surface of the Sokolovská pánev Basin is also built by the oldest sediments of Staré Sedlo Formation as well as by the neovolcanic rocks (L. Kopecký 1978, 1985; Malkovský 1979, 1980). Conspicuously varied relief of the Sokolovská pánev Basin was caused by the numerous tectonic outcrops of kaolinically weathered granitoid bedrock. In the northern edge of the Slavovský les Mountains (between Loket and Doubí), the Eger River created an epigenetic and antecedent canyon.

4. Terrace system of the Eger River

One Pliocene terrace of niveau B and 7 terrace levels of the Quaternary age (Fig. 4) were discovered by the geomorphological analysis of the Eger River valley as well as by the evaluation of the previous research data and by the reconstruction method, which was used to assess the terrace system. The morphostratigraphical classification of the river terraces (Tables 1 and 2, Figures 5 and 6) was based on the parallel nature with the terrace system of the middle and lower Eger (Balatka and Sládek 1976; Balatka 1993; Tyráček 1995; Tyráček et al. 1985, 2004) and also on the correlation of the fluvial accumulations in the studied area with the Quaternary-geological system

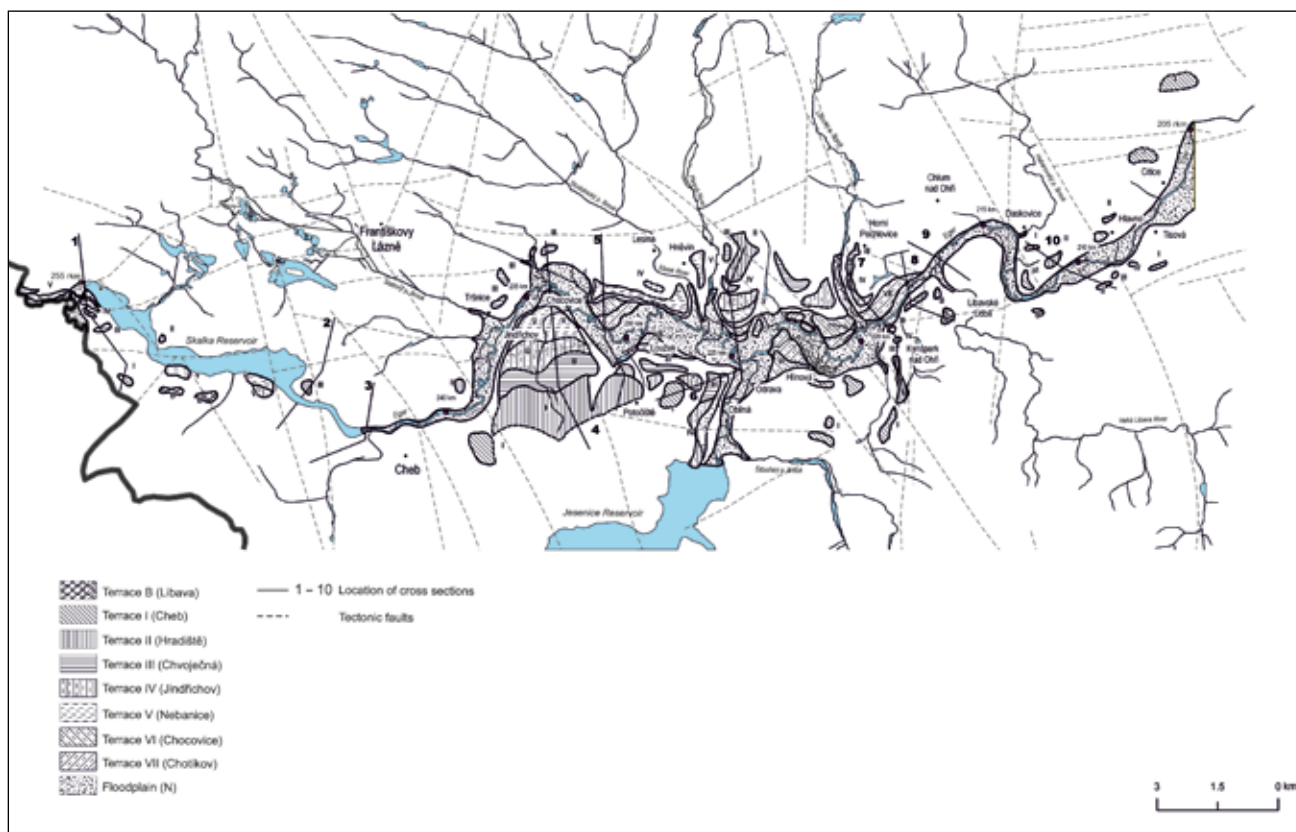


Fig. 4 Geomorphological sketch map of the Eger River terraces between the Smrčiny Mountains and the western part of the Sokolovská pánev Basin.

(e.g. Ambrož et al. 1958; Šantrůček et al. 1994; Balatka and Kalvoda 2008; Tyráček and Havlíček 2009; Balatka et al. 2010a,b, 2015).

The dependence of the terrace system structure on the morphotectonic and lithological conditions of the area, through which the river flows, can be clearly observed on the Eger River valley landforms. Since the Pliocene, the Eger River valley has been evolving in various kinds of relief, such as lowland, basin, upland, highland or mountain type of relief.

Neotectonic processes of the studied area took place in the Neogene and the Pleistocene, which was proven by the tectonic deformation of the Upper Pliocene – Lower Pleistocene Vildštejn Formation as well as by the structure and flights of the older terrace levels in the Eger River longitudinal profile (Fig. 7).

The Eger River flows through the studied area from the state border between the mouth of the Hraniční potok Brook and the vicinity of Citice in the length of 60 km (between river km 266 and 206), while crossing three geomorphological areas of the Krušné hory sub-province: the Smrčiny Mountains, the Chebská pánev Basin and the Sokolovská pánev Basin. The Eger River enters the rugged relief of the Smrčiny Mountains between the Hraniční potok Brook and the Libský potok Brook in the Hazlovská vrchovina Hills (Balatka and Kalvoda 2006; Demek and Mackovčín et al. 2006). In this area, the Eger River created a valley with a wide floodplain and meandering channel (Fig. 2).

However, it is presently hidden under the surface of the Skalka dam. The narrow erosion valley that was created by the Eger River immediately above Cheb is ca 85 m deep. On the other hand, the Eger River flows through a wide shallow valley with extensive flood plain and meandering channel in the Chebská pánev Basin between Cheb (river km ca 240) and the mouth of the Libava River (river km 216.8). This part of the Eger valley is incised 30–40 m into the planation surface of the oldest terrace, into that of the other fluvial deposits (Fig. 3) and also into the Vildštejn Formation of Pliocene and Lower Pleistocene age.

Between the mouth of the Libava River and Černý Mlýn (river km 209.2), the Eger River cuts into the crystalline complex of the Chlumský práh Horst creating a deep (ca 85–155 m) and asymmetrical valley. This epigenetic and antecedent valley intersects the morphologically significant zone of the Mariánské Lázně fault in the wider vicinity of Kynšperk nad Ohří. Near Černý Mlýn, the Eger River reaches the lower relief of the Tertiary sediments of the Sokolovská pánev Basin, namely the unit of the Svatavská pánev Basin. In the studied part of the Eger valley between the river km 265 and 148 (compare Figures 1, 4 and 7), the relics of Pliocene terrace of niveau B and heterogenous group of the Quaternary terraces were identified and documented. Their vertical distribution in the Eger River valley and morphostratigraphical classification is elaborated in Tables 1 and 2.

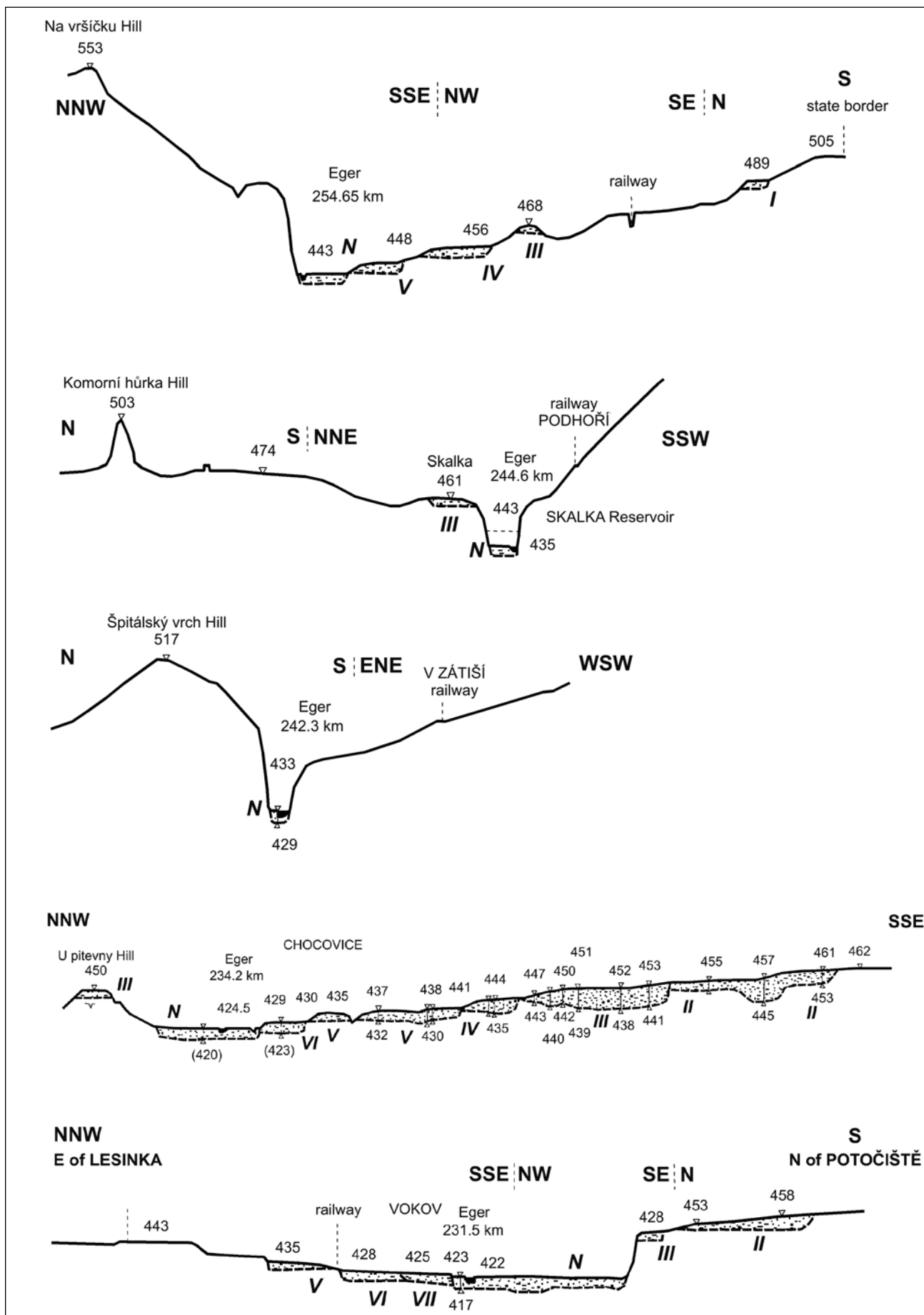


Fig. 5 Cross sections of the Eger valley and fluvial deposits between river km 254.65 and 231.50 (No. 1–5). Locations see in Fig. 4.

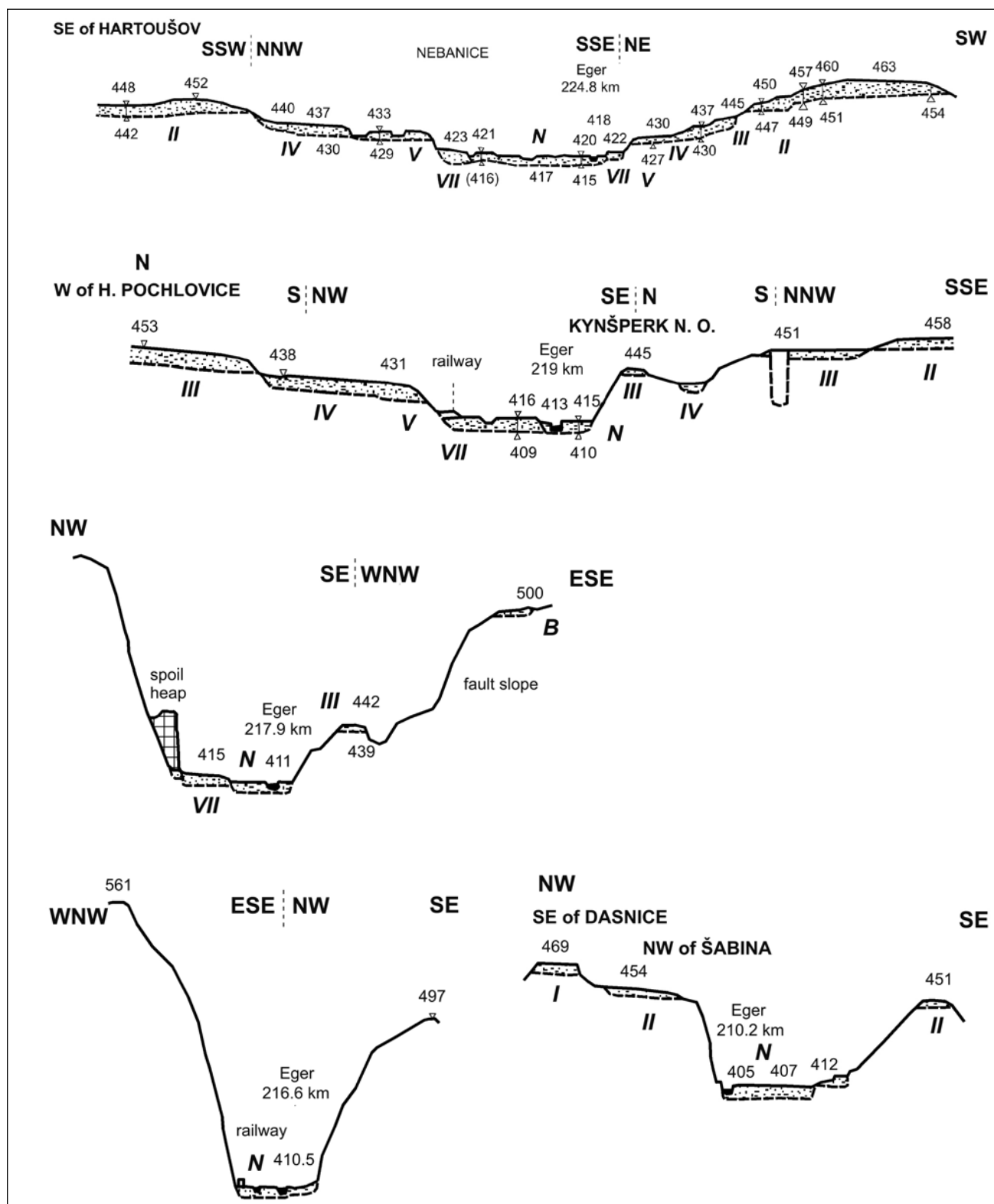


Fig. 6 Cross sections of the Eger valley and fluvial deposits between river km 224.80 and 210.20 (No. 6–10). Locations see in Fig. 4.

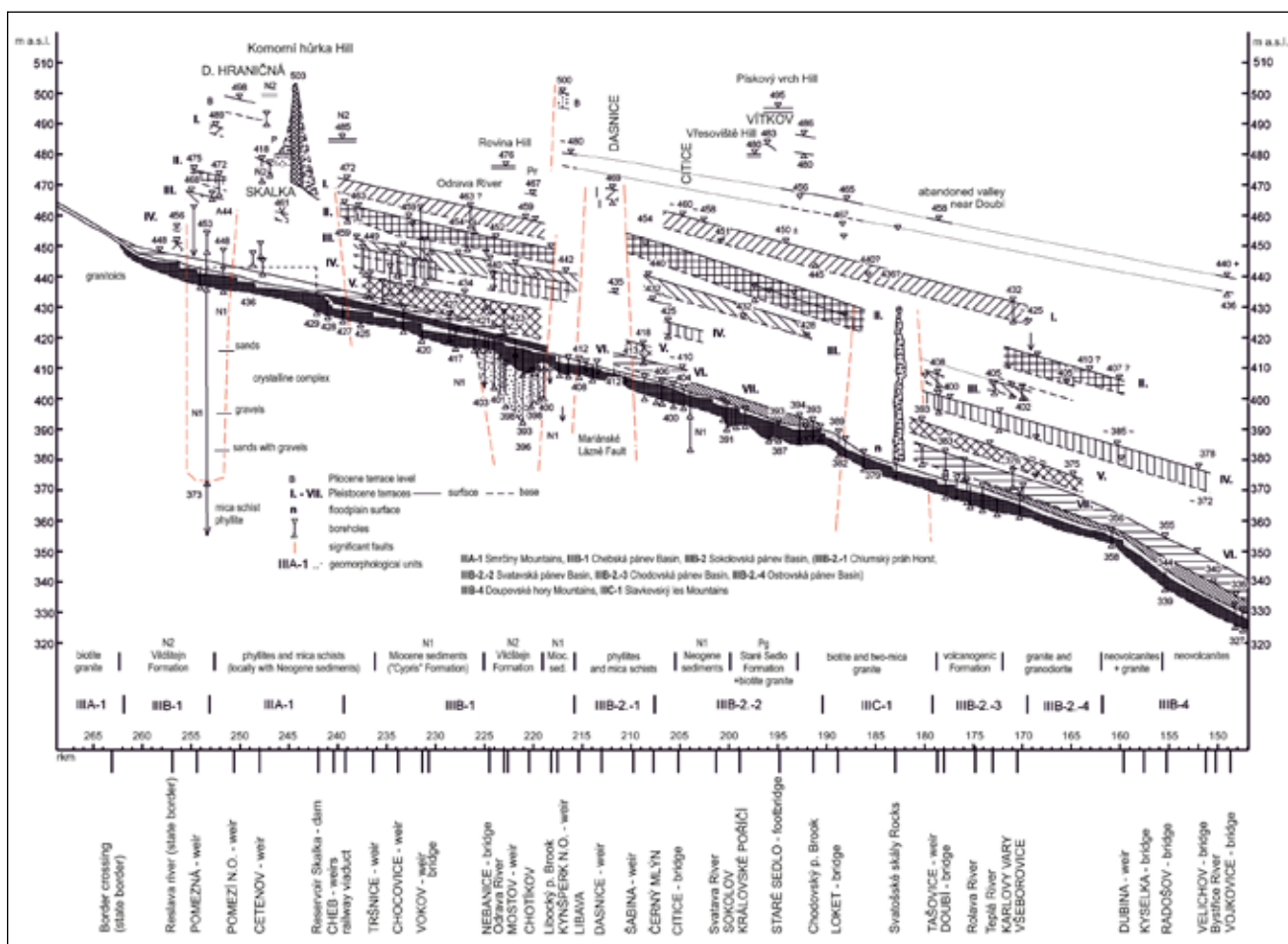


Fig. 7 A longitudinal profile of the Eger River terraces between the Smrčiny Mountains and the Doupovské hory Mountains.

4.1 The Pliocene terrace niveau B

Several small localities of the oldest and the locally highest terrace niveau B were identified. Its name and stratigraphical classification in the Pliocene correspond with the terrace niveau B in the Mostecká pánev Basin at the foot of the Doupovské hory Mountains (Balatka and Sládek 1976). The two highest localities of the terrace niveau B (in the direction against the Eger River flow) are situated near Dolní Hraničná. The first one was found on the right valley slope in Dolní Hraničná and the second one is 500 m east of the same village. The relic of the 2 m high terrace gravel covers the moderately angled slope at 492–498 m a.s.l. (56–61 m above the former Eger River level, Fig. 8). Mlčoch et al. (1993) and Müller et al. (1998) classified these gravel localities to the Günz. The bedrock of the fluvial sediments is formed by quartz-mica schists and by the sediments of the Vildštejn Formation.

Another locality of the niveau B was found in Chlumský práh Horst, north-east of the road from Kynšperk nad Ohří to the Libava River valley. This small moderately angled platform consists of quartz-mica schist bedrock, which is covered by coarse sub-angular gravel and sharp-edged fragments of quartz, quartzite, phthanite and brownstone (15–30 cm) with sporadic appearance of well rolled

boulders. A larger block of quartzite ($2.0 \times 1.2 \times 0.3$ m) was also found, as well as the crystalline bedrock that was uncovered in the 3m deep exposure. This locality is situated at 495–500 m a.s.l., which corresponds with the relative height of 83–88 m above the Eger River. The excavation described by Kvaček (1987, 1989) consist of a 1.5m thick layer of sandy (loess?) loam covering a 1.5 m thick layer of clay gravel, which was situated on the top of the clay regolith of the crystalline complex. The sediments discovered in this location are alluvial rather than terrace sediments and were probably accumulated by the Libava River. Šantrůček et al. (1994) presented these sediments as “the fluvial sand gravel of the Upper Pliocene age”, while Kvaček (1987, 1989) was of the opinion that the same sediments (with a question mark) originated in the Donau glacial stage, so that they are of Pleistocene age. However, if it really was the oldest Pleistocene terrace (I), it would have been uplifted by ca 50 m during the Quaternary. According to Šantrůček et al. (1994), the small accumulation of gravel located above the left slope of the Libava River valley at 480 m a.s.l. (relative height of ca 70 m) and an even smaller gravel accumulation ca 1 km south-west of Šabina at 475–480 m a.s.l. (relative height of 70–75 m) are also of Upper Pliocene age.

Table 1 Vertical distribution of Neogene fluvial sediments and Quaternary terraces (surface/base in metres above river bed) in the Eger River valley, Czechia.

Neogene sediments and river terraces	Chebská pánev Basin Balatka et al. (this paper)	Chlumský práh Horst Balatka et al. (this paper)	Doupovské hory Mountains Balatka (1993)	Mostecká pánev Basin (western part) Balatka (1993)	Mostecká pánev Basin (Žatec area) Balatka and Sládek (1976)	Bílina River (Hostomice area) Balatka (1995)	Elbe River (Ústí nad Labem area) Balatka (1995)
A	–	–		116/110	197/190		
B	–	88/~83		122/125	–		
I	43/~38	61/58	67/63	71/65	I ₁ 124/118 I ₂ 116/107 I ₃ 103/96	I ₃ 79/77	I ₁ 138/128 I ₂ 119/115
II	35/30	48/~45	II ₁ 58/53 II ₂ 50/47	II ₁ 64/58 II ₂ 62/58	II ₁ 96/90 II ₂ 89/84 II ₃ 83/79	II ₁ 72/65	II ₂ 93/77
III	25/19	30/~24	III ₁ 41/~ III ₂ 36/33	III 47/43	III ₁ 70/63 III ₂ 66/59	III ₁ 55/53 III ₂ 43/36	III ₁ 78/58 III ₂ 70/58
IV	21/14	26/~20	IV ₁ 29/24 IV ₂ 22/~	IV ₁ 40/36 IV ₂ 39/34 IV ₅ 20/15	IV ₁ 60/56 IV ₂ 55/51 IV ₃ 51/45 IV ₄ 48/45 IV ₅ 45/41	IV ₁ 27/23 IV ₂ 21/18 IV ₅ 17/10	IV ₁ 51/42
V	13/6	13/6	15/~	V ₁ 17/9 V ₂ 14/9	V ₁ 37/30 V ₂ 33/30	V ₁ (~10/~ V ₂ 5/~2	V ₁ 38/23 V ₂ 33/23
VI	6/~0	7/3	7/0	VI ₁ 12/6 VI ₂ 8/1 VI ₃ 5/1	VI ₁ 26/20 VI ₂ 23/17 VI ₃ 20/15 VI ₄ 17/12	VI ₁ 3/~6	VI ₁ 20/12 VI ₂ 16/11
VII	3.5/~3	~4/~4	–	–	VII ₁ 14/10 VII ₂ 8/2 VII ₃ 6/2	–	VII ₁ 8/~4 VII ₂ 4/~14
N flood plain	1.5/~3	1.5/~4	2/~5	2~3/~4	3/~3		

Therefore, the sediment relics of the oldest terrace niveau B were preserved only in the morphostructural zones of the Smrčiny Mountains and the crystalline Chlumský práh Horst offsets, which have been uplifted during the Upper Cenozoic. The locations of the terrace niveau B in the Smrčiny Mountains with their surface at 61 m above the river level are almost at the same level as the highest location of the Vildštejn Formation in the surrounding area. The surface of the terrace niveau B is ca 10 m higher than the surface of the oldest Quaternary terrace (Cheb terrace, I) and also ca 10 m higher than the highest planation surface of the Vildštejn Formation in the Chebská pánev Basin around the Eger River valley. The top of the Pleistocene volcano Komorní hůrka Hill is situated slightly higher than the surface of the terrace niveau B (503 m a.s.l., Fig. 9). The Chlumský práh Horst is another significant area of the terrace niveau B. Besides the already described location of the highest level with its surface at 88 m above the river level (Fig. 10), many other small accumulations of these fluvial sediments were preserved here. The surface of these relics is up to 20 m lower than the highest levels and their body consists of a coarse clay gravel with imperfectly rolled

clasts. The highest situated accumulation of the terrace niveau B in the area of the Chlumský práh Horst is located ca 25–30 m above the highest levels of the terrace niveau B that was formed on the sedimentary rocks of the Vildštejn Formation.

4.2 The Quaternary terraces

The Eger River has formed only sporadic and small terrace sediments in the Smrčiny Mountains. On the other hand, it has created large and continuously developed terraces in the Chebská pánev Basin. In the tectonically uplifted morphostructure of the Chlumský práh Horst, the rare relics of the higher (and therefore older) terrace levels exhibit a significant increase of its relative heights in comparison to those of the Chebská pánev Basin. Geomorphological analysis of the Eger River valley fluvial landscape, using the reconstruction method in the valley profiles, along with the previously published data, were used to assess the terrace system with these levels (Figures 4, 7 and Table 1): Terrace I (Cheb), Terrace II (Hradiště), Terrace III (Choječná), Terrace IV (Jindřichov), Terrace V (Nebanice), Terrace VI (Chocovice), Terrace VII (Chotíkov) and N (recent flood plain).

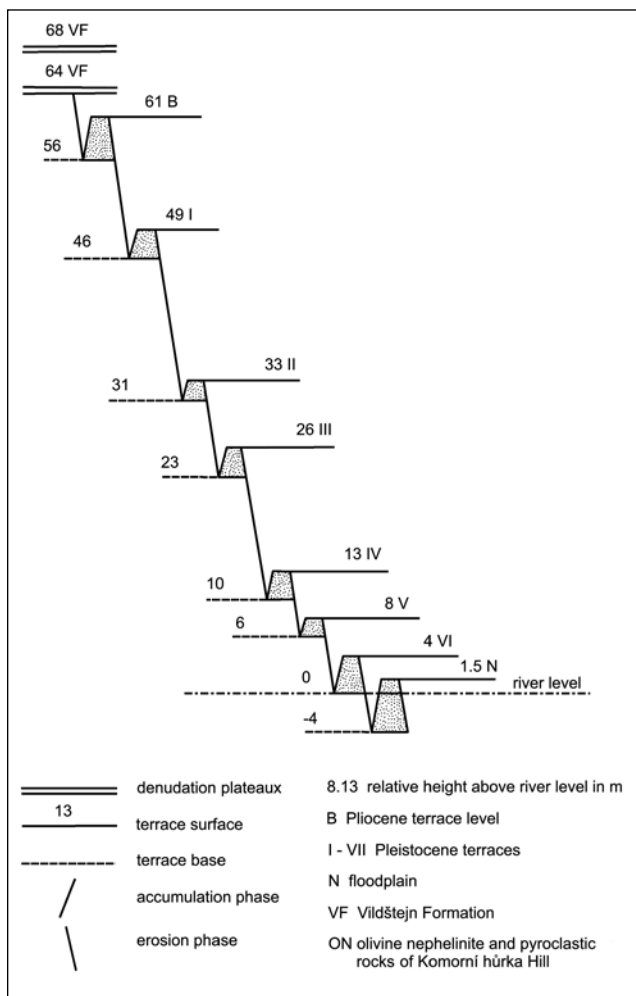


Fig. 8 Graphical scheme of successive incision of the river during the Eger valley evolution in the Smrčiny Mountains and the Františkolázeňská kotlina Basin (the section between river km 257–251).

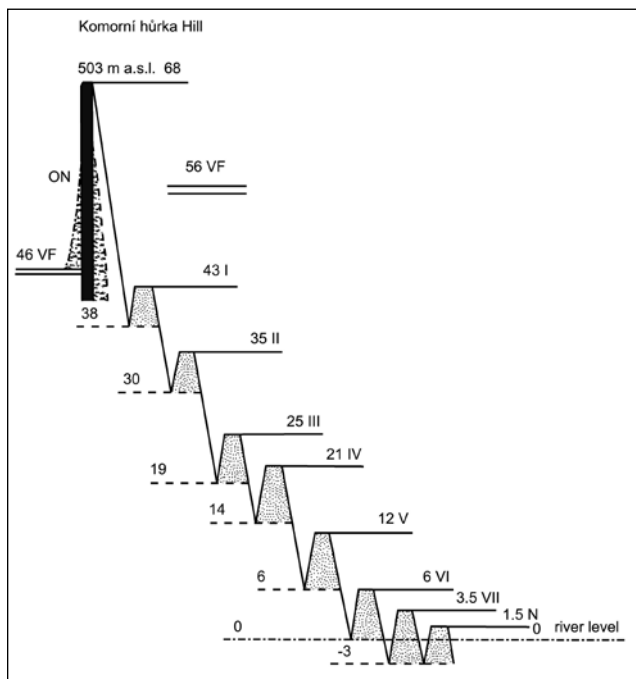


Fig. 9 Graphical scheme of successive incision of the river during the Eger valley evolution in the western part of the Chebská pánev Basin (river km 245–237). Explanations see in Fig. 8.

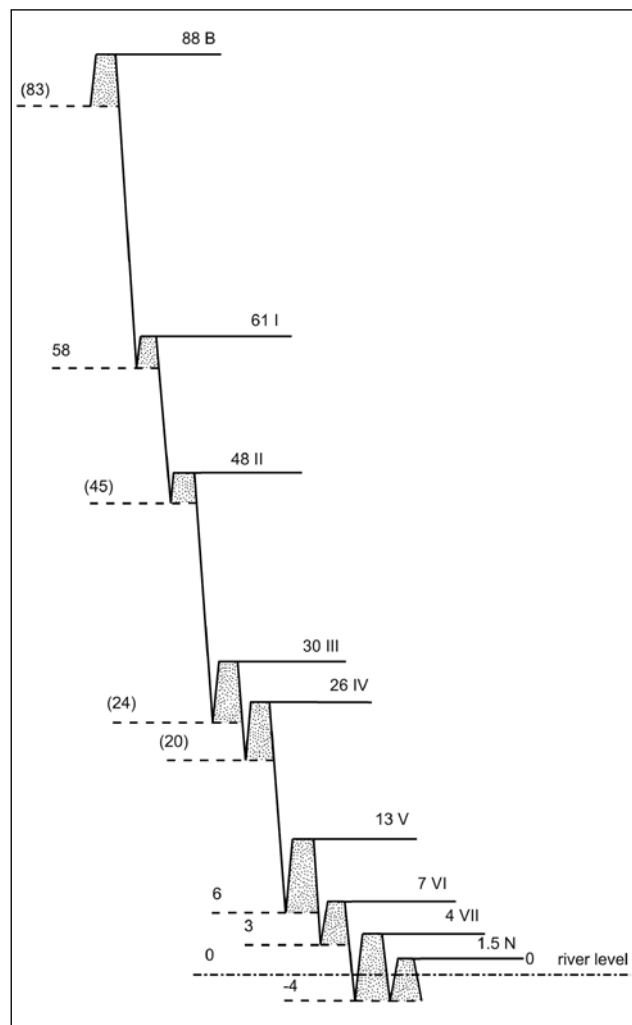


Fig. 10 Graphical scheme of successive incision of the river during the evolution of Eger valley in the Chlumský práh Horst (river km 218.5–209.7). Explanations see in Fig. 8.

Terrace I (Cheb)

In the Chebská pahorkatina Hills (which is a part of the Smrčiny Mountains), a small slightly angled platform west of Hraničná with its surface close to the 490 m contour line (thus at 49 m above the Eger River level) was classified as Terrace I (Fig. 8). This relic of the gravel is 2 m thick (Ambrož et al. 1958) and it covers the sediments of the Vildštejn Formation. Mlčoch et al. (1993) classified these sediments to the Günz. In the western part of the Chebská pánev Basin, another location of Terrace I was found near the railway station, on the platform located at 470–472 m a.s.l. (relative height of 41–42 m), which was also classified to the Günz by Šantrůček et al. (1994). This terrace level also includes 5 m high gravel on the significant platform north-west of Potočiště at 460–463 m a.s.l., thus at 40–43 m above the river. Furthermore, two small accumulations of gravel are situated at the Terrace I level near the Hlínová and Dobříš at 455–459 m a.s.l., whose bedrock consists of the Vildštejn Formation sediments.

In the Chlumský práh Horst area, a small dorsal location 1 km south-east of Dasnice with its surface at 469 m a.s.l. is classified as Terrace I. Coarse clay sand with sub-angular boulders and fragments of quartz,

strongly weathered phylites, mica schists and gneiss, quartz and ferric sandstone and conglomerate were found in the 3 m deep sand pit. Assuming the continuous flight of the Eger River terraces in its equilibrium longitudinal profile, this accumulation of gravel is located 15–20 m above the Terrace I level.

Presented locations of Terrace I including the alluvial gravel of the same level are situated almost at the same altitude as the planation surface of the Vildštejn Formation sediments (Upper Pliocene – Lower Pleistocene). The accumulation of Terrace I sediments probably occurred after the retreat of the Pliocene-Lower Pleistocene paleo-lake. Therefore, this Cheb Terrace is classified to the Tiglian stage of the Pleistocene (Table 2). According to Škvor and Satran et al. (1974), these accumulations outside of the Chebská pánev Basin (using the then stratigraphical classification) are of Günz – Donau age. A. Kopecký (in Šantrůček et al. 1969) classified the highest terrace accumulations east of Cheb to the old Donau – oldest Günz. In the Sokolovská pánev Basin, the sand gravel accumulations on the left bank of the Eger River between Citice and Svatava with their surface at 455–460 m a.s.l., thus in a slightly lower position (ca 5 m) than the accumulation near Dasnice, are

Table 2 Morphostratigraphy of terrace deposits of the Eger River (the Chebská pánev Basin and neighbouring regions) and their correlation with fluvial sediments in the middle and lower located sections of the Eger valley up to the Elbe River confluence area.

European stratigraphical stage divisions of the Quaternary (Gibbard and Cohen 2008; Gibbard et al. 2010)	EGER Chebská pánev Basin and neighbouring regions (Balatka and Kalvoda 2018; Balatka et al., this paper)	EGER Doupovské hory Mountains (Balatka, 1993) and Mostecká pánev Basin (Balatka and Sládek 1976; Balatka 1995)	EGER Mostecká pánev Basin (Tyráček 1995, 2001; Tyráček et al. 2004; Tyráček and Havlíček 2009)	ELBE Ústí nad Labem area (Balatka 1995; Balatka and Kalvoda 1995; Kalvoda and Balatka 1995)
Holocene Late Pleistocene Weichselian 0.12 Ma	Alluvial deposits Chotíkov Terrace (VII)	Rock bottom and alluvial deposits VII ₃ –VII ₁	Thalweg gravel VII ₃ –VII ₁	Rock bottom and alluvial deposits VII ₂ –VII ₁
Middle Pleistocene Saalian (Warthe, Drenthe) 0.20 Ma	Chocovice Terrace (VI)	VI ₄ –VI ₁	VI ₄ –VI ₁	VI ₂ –VI ₁
Middle Pleistocene Saalian (Wacken, Fuhne) 0.38 Ma	Nebanice Terrace (V)	V ₂ –V ₁	V ₂ –V ₁	V ₂ –V ₁
Middle Pleistocene Elsterian Cromerian 0.78 Ma	Jindřichov Terrace (IV)	IV ₅ –IV ₁	IV ₅ –IV ₃ IV ₂ –IV ₁	IV ₁
Early Pleistocene (Bavelian, Menapian, Waalian, Eburonian) 1.78 Ma	Chvoječná Terrace (III)	III ₂ –III ₁	III ₂ –III ₁ II ₃	III ₂ –III ₁
Early Pleistocene Tiglian 2.58 Ma	Hradiště Terrace (II) Cheb Terrace (I)	II ₂ –II ₁ I ₄ –I ₁	II ₂ –II ₁ I ₄ –I ₁	II ₁ I ₂ –I ₁
Neogene Pliocene 5.30 Ma Miocene	Niveau B	Niveau B Niveau A		

presented by Škvor and Satran et al. (1974) also as Terrace I. Nevertheless, they are currently covered by the spoil heaps of the coal mines.

Terrace II (Hradiště)

The highest location of Terrace II (in the direction against the Eger River flow) was discovered on the small residual platform at 469–472 m a.s.l. (up to relative height of 32 m), which is covered by 1–4 m thick sand gravel. According to the borehole data, these deposits are situated on the weathered phyllites (Rousek 1960). The Terrace II has developed continuously between Cheb – Hradiště and the Odrava River valley south-east of Loužek in the Chebská pánev Basin. The surface of Terrace II is situated at 463 m and its base at 458 m a.s.l. near Hradiště, while the surface of this terrace east of Dolní Dvory is at 460 m and its base at 455 m a.s.l. and the surface of that south of Loužek is at 455 m and its base at 450 m a.s.l. South and south-west of Chvoječná, the surface of Terrace II is located at 455–460 m a.s.l. The thickness of its gravel varies mostly between 2.5–6 m. The terrace surface descends slightly to the north and gradually blends with the surface of Terrace III.

Terrace II surface was found at 458–453 m a.s.l. near Potočiště. According to Kvaček (1987), these sediments belong to the Vildštejn Formation. On the other hand, Šantrůček et al. (1994) classified sand gravel found in these locations as the older Mindel. The locality near Loužek, whose surface is situated at 450–455 m a.s.l., is the last occurrence of Terrace II in the eastern part of the Chebská pánev Basin. Alluvial clayey sand gravel (2–5 m thick) south of Hartoušov with the surface at 448–452 m a.s.l. corresponds to the level of the Eger Terrace II. The localities of the Hradiště Terrace in the Chebská pánev Basin were presented by Kvaček (1987) mostly as of Günz age. While according to A. Kopecký (in Šantrůček et al. 1969), these locations of Terrace II are of Lower Pleistocene age.

Sand gravel 0.5 km north-west of Šabina at 454–450 m a.s.l. (relative height of 48–44 m), which is presented as of Günz age by Šantrůček et al. (1994), is assigned to Terrace II in the area of the Chlumský práh Horst. Quartz and crystalline gravel (diameter of 15–40 cm) 2–3 m in thickness are located on the narrow ridge on the right bank of the Eger River. The geological map in Šantrůček et al. (1994) also reported that the small relic of Terrace II north of Hlavnov at 450 m a.s.l. is of Günz age. In the eastern part of the Chlumský práh Horst, these locations of Terrace II are situated at 15–20 m higher altitude (Fig. 10) than that of the (suspected) flight of the equilibrium longitudinal profile of the Eger River terraces.

Terrace III (Chvoječná)

Terrace III has been exceptionally preserved in the area of the Smrčiny Mountains. The small locality at 468 m a.s.l. (relative height of 26 m) containing fragments and sub-angular boulders of quartz and

crystalline complex was identified south-east of the Reslava River and the Eger River confluence. The small residual platform near Skalka (461 m) is covered by a 1–2 m thick gravel, which is situated on the top of the phyllite eluvium (Rousek, 1960). In the Chebská pánev Basin, Terrace III has evolved between the northern part of the Hradiště area and the Odrava River valley south-east of Loužek (Fig. 9). To the west, the surface of the terrace is located at 453 m a.s.l., at 450–452 m a.s.l. near Chvoječná and its base is at 438–442 m a.s.l. The maximum thickness of the sand gravel (11–14 m) represents the recessed furrow of the terrace base. The surface of the small and narrow locality with a relic of sand gravel near Loužek is situated at 446–448 m a.s.l.

North of Obilná, the fluvial sediments on the left slope of the most downstream part of the Odrava River valley were excavated in the sand pit, which uncovered 2–3.5 m thick terrace gravel sands and sand gravel. These accumulations cover finer-grained sand gravel, which contain layers of course sand and clay lenses of the Vildštejn Formation. This sand pit revealed 5–7 m thick terrace sediments. The highest part of the currently abandoned sand pit reaches the level of Terrace III (max. 448 m), whereas the pre-dominant parts belong to Terrace IV (max. 440 m). According to Kvaček (1987), the main part of these sediments is of Mindel age, while the lower parts belong to the Riss.

A few small locations of Terrace III in the form of alluvial gravel were recorded on the left bank of the Eger River. These accumulations were presumably deposited by the tributaries of the Eger River. Approximately 3 m thick gravel sand covers a small residual platform at 447.5 m a.s.l. near Tršnice. Šantrůček et al. (1994) sets their origin, as well as that of the close locations of the gravel sands south-west of Doubí (449 m) and between Třebeň and Lesina (450–447 m), to the younger Mindel. The same authors consider the gravel north-west of Chotíkov to be the alluvial accumulations of Günz age.

In the Chlumský práh Horst (Figures 7 and 10), the gravel of the Libocký potok Brook near Horní Pochlovice (max. 453 m) also has an alluvial origin. Clayey quartz, slate, phyllite and gneiss gravel (7–10 cm in diameter) were found in the 6m deep sand pit south of the previously mentioned location. The narrow ridge above the right bank of the Eger River north-east of the Kynšperk nad Ohří is covered by the 3 m thick gravel of Terrace III with its surface at 442 m a.s.l. A small locality of the gravel accumulations at 435–440 m a.s.l. near the Černý Mlýn was also categorised into this level.

Terrace IV (Jindřichov)

The highest upstream appearance of the Eger (Jindřichov) Terrace IV was found south-east of the Reslava River mouth. This denudation relic is situated on the small ridge at 456 m a.s.l. (relative height

of 13 m) and it includes dispersed boulders and fragments of the quartz and crystalline complex. A small locality of this terrace level (with the erosionally lowered surface at 456 m a.s.l.) was also found on the right bank of the Skalka dam 1 km west-north-west of Skalka. In the Chebská pánev Basin, Terrace IV occupies a large area between Jindřichov and the northwestern vicinity of Chvoječná. The surface of this terrace descends from 445–448 m a.s.l. (max. relative height of 40 m) to 440–445 m west of Chvoječná, where its base was located at 430–435 m a.s.l. Moderately coarse sand gravel (5–12 cm in diameter) with layers of pea gravel and coarse sand was uncovered in the 4–5 m deep sand pit south-east of Jindřichov. The upper layers of these fluvial sediments were significantly churned by frost patterns (palsas).

The southern part of the location near Obilná at the lower valley of the Odava River (surface max. 440 m), which extends to the rock exposure of the mentioned sand pit, was also classified as Terrace IV. On the left bank of the Eger River, the localities of Terrace IV were found north-west of Lesinka (440–442 m), north of Nebanice (442 m) and Chotíkov (434 m) and north-west of Dolní Pochlovice (440 m) above the left bank of the Libocký potok Brook. In the eastern part of the Chlumský práh Horst, a denudation relic (up to 1 m) of small and partly sub-angular gravel near Černý Mlýn with its surface at around 430 m a.s.l. belongs presumably to Terrace IV as well. In the longitudinal profile of the Eger River, Terrace IV does not show any significant anomalies in the area of the Chlumský práh Horst, although its relics form (probably) two altitude levels at up to 431 m and 425 m a.s.l.

Terrace V (Nebanice)

In the area of the Smrčiny Mountains, Terrace V is represented by the gravel accumulation on the left bank of the Eger River valley above the Reslava River mouth. Mlčoch et al. (1993) is of the opinion that this accumulation is of Riss age. On the right bank of the Eger River ca 0.5 km east of the Reslava River mouth, the location of sub-angular boulders and mostly quartz fragments at 451 m a.s.l. (relative height of 6–8 m) were classified as Terrace V. The same applies to the denudation relic of the gravel accumulation on the coastal abrasion cliff of the Skalka dam, which was found ca 1 km west-north-west of Podhoří (the surface is at 446–447 m a.s.l., the base discovered by boreholes is at 442–444 m). On the abraded bank of the Skalka dam, sand gravel (quartz, quartzite, gneiss, basalt) was discovered under the deluvial sediments at ca 3–4 m above the back water level (443 m a.s.l.).

In the Chebská pánev Basin, Terrace V has preserved itself on the large area inside the bend of the Eger River valley, which is located east and north-east of Jindřichov. The surface of this terrace is at 440 m a.s.l. near Jindřichov and at 436–437 m a.s.l.

north-west of Chvoječná. The base of this 5–8 m thick sand gravel was discovered by numerous boreholes on the west at 335–330 m a.s.l. Similarly to the surface, the base of this terrace continuously descends to the north and develops into lower Terrace VI. The moderately coarse sand gravel (5–12 cm in diameter; max. 25 cm) mostly of quartz and quartzite was excavated in the former sand pit (4–5 m deep) south-east of Jindřichov. The sand gravel was found in the sand pit at the north-east edge of Jindřichov. These accumulations are significantly frost-churned on the surface and they also contain frost wedges filled with coarser gravel (15–20 cm). In addition to the frequent quartz, weathered phyllites, gneiss and sporadic granites and basalts were also represented. The 80–100 cm thick layer of pellodite, leafy jointed silt and clayey sand was also found in this profile.

The surface of the narrow Terrace V north and north-east of Loužek is situated at 430 m a.s.l., while its decreased north-eastern part reaches the level of Terrace IV. On the left bank of the Eger River, the large gravel-sand plateaux, between the vicinity of Třídvoří and Vrbová (surface at 435–433 m), was also identified as Terrace V. Several currently abandoned sand pits, 2.5–4 m in depth, were established in Terrace V near the north edge of Nebanice (above the railway). These gravel sands were significantly churned by cryogenic processes (Ambrož 1958). According to the borehole data, the thickness of these terrace sediments varies between 1.7–3.8 m. The geological map 11-14 Cheb (Šantrůček et al. 1994) classifies most of the discovered localities of Terrace V to the young Mindel, while some of them to the older Riss.

Terrace VI (Chocovice)

In the Smrčiny Mountains, Terrace VI (the surface at 5–7 m above the Eger River level) was rarely identified. A few accumulations, which do not have the form of a terrace, were located by the boreholes under the deluvial sediments. These deposits are situated, for example, at the river km 258 at 448 m a.s.l. and on the right bank of the Skalka dam ca 1.3 km west of the village Skalka. Sand gravel, which was located by the boreholes in the vicinity of Cheb (for example with the surface at 437.5 m and the base at 432.6 m a.s.l., Šantrůček et al. 1994) could not be verified due to the current built-up area.

In the Chebská pánev Basin, Terrace VI was preserved at the northern edge of the large fluvial terrace accumulation near Chocovice, thus inside the extensive bow of the Eger River valley. Its surface is located at 428–431 m and its base at 426 m a.s.l. An even larger locality of the Chocovice terrace was found north of Vokov with its surface at 423–427 m a.s.l. North of Nebanice, Terrace VI is represented by the southern part of the gravel sand accumulation located above the railway. Its surface is situated at 425–426 m a.s.l. The surface of the rather extensive Terrace VI locality near Chotíkov (below the railway, 3 m above the

flood plain) is at 420–423 m a.s.l. The sand pit (only 3 m deep) near the eastern edge of the village, was founded in the medium coarse to coarse sand gravel (5–10 m in diameter), which is built mostly by the quartz and quartzite.

In the Chlumský práh Horst, the denudation relics of the gravel are located at the level of Terrace VI. The surface is at 415–420 m a.s.l. (base at 409–411 m a.s.l.) south-west and west of Chlumeck. These accumulations are, according to Šantrůček et al. (1994), of young Mindel age. Scattered gravel at the higher level (up to ca 430 m a.s.l.) corresponds to the already lowered Terrace VI. Note that the geological map by Šantrůček et al. (1994) marks this gravel locality over an unreasonably large area and, moreover, at the altitude of 450–433 m. Thus, it should also contain the levels of Terrace IV and V.

Terrace VII (Chotíkov)

The occurrences of Terrace VII, with its surface not more than 3.5–4 m above the river level, are closely connected to the sediments of the valley floor, with which this terrace usually shares its base. In numerous places, the surface of Terrace VII continuously evolves into the surface of the flood plain. The longitudinal profile of the Eger River valley demonstrates (Fig. 7) that Terrace VII follows the river (and flood plain) only in the Chebská pánev Basin, i.e. Terrace VII appears below the slope change near Cheb. Its surface is situated at 431–433 m, while its base is at 425–427 m a.s.l. Particularly, this terrace was located near Chocovice with its surface at 428 m and its base at 423 m a.s.l., near Vlkov and Třídvoří (424 m) and near Nebanice and Chrtíkov with its surface at 418–419 m and its base at 414 m a.s.l. In the Chlumský práh Horst, the extensive locality of Terrace VII (surface at 415–417 m) is situated at the entry of the Eger River to the horst near Dolní Pochlovice. The lowered parts of Terrace VII surface are locally covered by the relics of the Holocene flood clay.

Recent flood plain and valley floor

The sedimentary filling of the current valley floor of the Eger River is formed by two layers: the lower mostly sandy gravel and gravel sands of Upper Pleistocene age and the overburden mostly sandy loam and loamy sands of Holocene age. The course of the valley floor bedrock is often characterised by a significantly uneven slope ratio. The surface of the flood plain demonstrates a change of its gradient below the Špitálský vrch Hill (between river km 242–241) in the north-western part of Cheb, i.e. approximately at the entrance of the river to the basin. This gradient step of the river, which is being shifted in the upstream direction by back erosion, is lithologically conditioned by the more resistant quartzite mica shists that form the valley slopes up to the north-eastern vicinity of Cheb (river km 238–239). Two fault systems with a NW–SE direction, which cut the Eger

River valley at the river km 241 and 239, were also important for the formation of this gradient step of the river.

The bedrock of the valley floor sediments does not have (according to boreholes) an equilibrium longitudinal profile. Locally, significant differences in sediment thickness were discovered. Similarly to the surface of the flood plain, the gradient step of the valley floor bedrock was found below the dam of the Skalka Reservoir, i.e. at the entry to the Chebská pánev Basin from the crystalline complex of the Smrčiny Mountains. Another slight increase of the valley floor sediment thickness (about 2 m) appears between the river km 233.5–232, i.e. on the lithological boundary of the Vildštejn Formation (Upper Pliocene – Lower Pleistocene) and the Miocene Sokolov Formation.

A significant change of the valley base gradient was found in the foreground of the Mariánské Lázně Fault (Vrba 1959), where the thickness of the valley floor sediments rises up to about 5 m above the adjacent sections. The sand gravel of this location covers the sediments of the Vildštejn Formation, which fill the tectonic depression in the Miocene accumulations of the Cypris Formation. The lowest point of the Vildštejn Formation base is situated at 393 m a.s.l., i.e. 26 m under the flood plain surface. Right before the Mariánské Lázně fault, the base of the valley floor sediments creates a distinct elevation, which causes the reduced thickness of the sediments (4 m), i.e. it is situated ca 3 m under the river level. Further below the Mariánské Lázně fault, the course of the Eger River valley floor returns to the level, which correspond to its gradient above the mentioned anomaly. The smaller thickness of the valley floor sediments (between river km 220–211) was found on the most elevated part of the Chlumský práh Horst.

In the foreground of the Mariánské Lázně fault, the tectonic trench, whose floor lies 26 m under the flood plain surface, creates a depression in the overburden sediments, which reaches up to 8 m (Vrba 1959). Usually, the thickness of these overburden Holocene sandy loam and clay sands vary between 1–2 m. The underlying sediments are 3–5 m thick (Vrba, 1959) and they contain granularly heterogeneous sands with quartz boulders (3–8 cm in diameter) and of the basal coarse gravel (5–12 cm in diameter, up to 25 cm). In between the two strands of the Mariánské Lázně fault (river km 219.5–217), both Miocene and Vildštejn sediments were uplifted up to 450 m a.s.l. (relative height of 35 m). Considering that Terrace III (the surface at 442 m a.s.l. in the area of the Chlumský práh Horst) does not show marks of the tectonic disruption, it can be stated that the uplift took place in the Lower Pleistocene.

The longitudinal profile of the Eger valley floor (Fig. 7) is substantially connected to the lithological, tectonic and geomorphological conditions of the studied area. The more distinct anomaly of the gradient

occurs in the incised part of the Eger valley in the Hazlovská vrchovina Hills (Smrčiny Mountains). Here, between river km 266–260, the average gradient of the valley floor reaches 3.33‰. In the area of the Františkolázeňská kotlina Basin, between river km 258.6–252.6, the average gradient of the valley floor reaches 1.00‰. In the Chebská pahorkatina Hills, between the vicinity of Bříza and the north-western edge of Cheb (river km ~252.6–240), the average gradient of the Eger valley floor reaches only 0.833‰. It is therefore smaller than that of the Františkolázeňská kotlina Basin. This low gradient value corresponds to the conditions of the significantly meandering channel and the wide flood plain, which evolved here before the construction of the Skalka Reservoir. Between the Reslava River mouth and Skalka, the mean gradient of the floodplain axis is 1.571‰, while the channel gradient reaches 0.846‰. A markedly increased gradient of 5.00‰ occurs in the ca 1 km long section of the valley under the dam of the reservoir and in several weir locations. In the Chebská pánev Basin (river km 240–217), the gradient of the meandering river level is 19 m to 23 km, which corresponds to the mean gradient of 0.826‰. However, the average gradient of the valley (flood plain) axis is 1.58‰. The significant change of the river level gradient (1.418‰) occurs in the area of the Chlumský práh Horst (river km 216.8–209.2). Subsequently, this gradient decreases in the western part of the Sokolovská pánev Basin (river km 209.2–206.6) to 1.05‰.

Morphostructural characteristics of the valley and the analysis of the gradient conditions of the Eger River level implies, that the increased river level gradient in the Hazlovská vrchovina Hills was caused by the smaller discharge of the river and also by the more resistant rocks of the Smrčiny Mountains massif, which are located in the tectonically uplifted area in the proximity of the Chebská pánev Basin. The balanced gradient conditions of the Františkolázeňská kotlina Basin and of the subsequent section of the Chebská pahorkatina Hills correspond to the presence of the less erosion resistant rocks. The lithologically conditioned section of the increased river level gradient (ca 5‰ to 1 km) occurs before the entrance to the Chebská pánev Basin above Cheb. The balanced gradient of the Eger river level in the Chebská pánev Basin, based on the resistant and homogenous basin sediments of the Cypris and Vildštejn Formation, is not substantially influenced by the river meandering. The increase of the river level gradient in the Chlumský práh Horst corresponds to the Quaternary uplift of the crystalline block between the Chebská pánev Basin and Sokolovská pánev Basin at the Mariánské Lázně fault. The average gradient of the Eger River meandering channel in the Chlumský práh Horst (1.418‰) is similar to the gradient of its flood plain axis in (1.58‰) and above (1.571‰) the Chebská pánev Basin.

5. Discussion

The correlation of the Eger River terraces between the Smrčiny Mountains and the Sokolovská pánev Basin and the terrace system of the middle course of the Eger River valley is based on the research made in the Doupovské hory Mountains (Balatka 1993) and in the Mostecká pánev Basin (Balatka and Sládek 1976; Tyráček 1995). The evaluation of these findings, together with that of the terrace system of the lower Eger River course (for example Balatka and Sládek 1976; Tyráček 1995, 2001; Tyráček et al., 2004), the Elbe between Děčín and Hřensko (Balatka and Kalvoda 1995; Kalvoda and Balatka 1995) and the central part of the Bohemian Massif (Balatka and Kalvoda 2008, 2010; Balatka et al. 2010a,b, 2015) are used to suggest the classification of the Eger River terraces in the studied area into the stratigraphical system of the Quaternary (Tab. 2).

Because of the significant river channel meandering, only 6 Eger River accumulation terraces have evolved in the Chebská pánev Basin (Fig. 7, Balatka and Kalvoda 2018). The relative height of their surfaces reaches up to 25–30 m, while their thickness is mostly 4–6 m, rarely 8–10 m. The surface of the highest preserved level (Terrace II) is embedded 10–25 m into the platform surface of the Vildštejn Formation, which originated in the Lower Pleistocene. Presumably, the stratigraphical classification of the Vildštejn Formation corresponds to that of Terrace I in the lower course or the Eger River valley. In comparison with the terrace system of the Sokolovská pánev Basin, the equivalent terraces of the Chebská pánev Basin are situated at a significantly lower level, namely there is a 25 m difference in the case of Terrace II and a 8 m difference in that of Terrace V. This was caused by the neotectonic uplift of the asymmetric Chlumský práh Horst (Figures 7 and 10).

In the Sokolovská pánev Basin, through which the Eger River flows in the length of 55 km including the 10 km long fault gap in the granodiorite of the Slavkovský les Mountains, the 10 levels of the river accumulation terraces were discontinuously preserved. The highest terrace levels (up to relative height of 101 m) have marks of tectonic deformation. The fold deformations of the Tertiary sediments and of the overburden terrace sand gravel were found in the exposures of the brown coal mines. Their formation was most likely caused by the Quaternary tectonic movements (e.g. L. Kopecký 1978, 1985). Due to the greater uplift of the northern part of the Sokolovská pánev Basin along the Krušné hory fault, which includes the lacustrine sediments covering the edge of the granites of the Slavkovský les Mountains, the Eger River channel took a position along the southern edge of the basin in the Neogene. Only small relics of the terraces have been preserved in the deep epigenetic and fault gap valley of the Eger River at 50–58 m and 40–44 m above the river (Čtyrský 1996). In its middle

course, the Eger River flows through the Mostecká pánev Basin in a 39 km long section, which is characterised by the deeply incised valley (over 400 m) cutting the Doupovské hory Mountains. The river level gradient has a higher value in this area (2.03‰ on average, maximum 6.9‰). Locally, the river also erodes the crystalline bedrock of the neovolcanites.

The Doupovské hory Mountains represent a tectonically active volcanic block of the Eger rift, which has been gradually uplifted since the Lower Miocene up to the present (L. Kopecký 1985). The rate of this uplift is estimated at 200–300 m. In the Doupovské hory Mountains, the Eger River valley was created during the Neogene in the zone of the tectonic bend between the lava flows, which descends from the centre of the volcanic massif in a northward direction and the volcanic bodies, which face away from the fault slope of the Krušné hory Mountains in a southward direction (Balatka 1993). In this part of the Eger River valley, the incomplete river terrace system of the 9 levels shows a significant convergence in the direction against the river flow (ca 30 m at the highest levels). Therefore, the river flows approximately at the level of Terrace VI at its entry to the Doupovské hory Mountains below Karlovy Vary. The surface relics of the oldest Quaternary Terrace I are situated at 71–54 m above the river. However, its lowest situated surface (near the mouth of the Bystřice River) was found at 106 m above the river.

In the western part of the Mostecká pánev Basin, the course of the oldest terraces shows a tectonic uplift of ca 15–20 m in the longitudinal profile. The highest channel gradient of the Czech section of the Eger river valley is connected to the uplifted block (horst) of the crystalline complex along the Sřezov fault. This gradient reaches up to 10‰ (Balatka 1993). The distinctive fold deformations with a brachyanticline shape, which affected the Miocene clays and coarse sandy gravel, were found in the sediments of Terrace III and IV near the Sřezov fault. These deformation structures were created mainly by frost and by the extrusion of the underlying clays into the terrace sediments during a period of periglacial climate in the Pleistocene, although the neotectonic movements of the basin bedrock could also play their role (L. Kopecký 1978, 1985).

The stratigraphical system of the Eger River terraces in the Mostecká pánev Basin was created by Tyráček (1995, 2001). Its correlation with the Elbe terrace system was made using the terrace system of the lower course of the Bílina River (the older levels, Balatka 1995) and that of the lower course of the Eger River (the younger levels, Balatka and Sládek 1976). The richly segmented structure of the terrace system in the Mostecká pánev Basin has 24 levels. Such a system has not been found in any other Czech river valley. Low-resistant incoherent lacustrine Tertiary sediments of the Severočeská pánev Basin (sands, silts and clays) together with the tectonic uplift of this area

enabled the long-term gradual evolution of the Eger River valley. All of the Eger River terrace levels were preserved in the Mostecká pánev Basin due to the movements and meandering of its channel. These terraces are characterised by a relatively low thickness (3–7 m, locally around 10 m) and by a small vertical difference. In the main accumulation area of the Mostecká pánev Basin, 24 river terraces were identified (Balatka and Sládek 1976; Tyráček 1995; Tyráček et al. 2004). These terraces were stratigraphically classified into 7 groups (I–VII), which correspond to the main river terraces of the Elbe. In the Mostecká pánev Basin, the surface of the oldest terrace level (I₁) is situated at 125 m above the Eger River level. According to the paleomagnetic research in the Mostecká pánev Basin, the oldest Terrace I group and presumably even Terrace II₁ and II₂ are older than 1.64 Ma (Tyráček et al. 2004).

In the Mostecká pánev Basin, the river terraces appear in two separate areas: the older levels (group I–IV) have evolved on the extensive platforms outside the valley cut, while the younger levels (group V–VII), mostly smaller-scale meander terraces, are located inside the valley cut. In the downriver direction, the terrace levels show a distinct divergence (10–40 m) in the longitudinal profile. This divergence is more prominent in the case of the older terraces. In the upstream direction, both of the younger terrace groups (VI, VII) were unified with the current valley floor, while some of the accumulations of the older levels have been joined together as well. Therefore, the number of terrace levels decreases to 17 in the western part of the Mostecká pánev Basin. In the central part of the basin, the terrace groups I–V are directed north-east to the current Bílina River valley and the older terraces have distinctively shorter course than the younger levels (Balatka and Sládek, 1976). The last terrace of this paleogeographical period (V₁) has the longest course, which follows the eastern margin of the Mostecká pánev Basin and enters the České středohoří Mountains. These relics of the fluvial sediments (the surface at the relative height of 37 m) of Middle Pleistocene age have been preserved in the abandoned river valley connecting (in the hanging position) the current Eger River valley with that of the Bílina River.

The valley meanders of the various evolutionary stages are typical for the Eger River valley in the Mostecká pánev Basin, such as the entrenched or abandoned meanders, which have been formed since the Middle Pleistocene to the Holocene. In the western part of the Mostecká pánev Basin, the meander evolution is estimated to have begun at the same period as the formation of Terrace V₁. This period is characterised by intense river meandering, which was caused by the backward erosion progressing through the neovolcanites in the České středohoří Mountains. The impulse to the incision of the originally free meanders and to the evolution of the entrenched meanders was

given by the relocation of the Eger River channel from the eastern margin of the Mostecká pánev Basin to its current position in the subsidence area of the Eger fault zone, containing the less resistant sediments of Upper Cretaceous age, which took place after the sedimentation of the sandy gravel of Terrace V₁. In the eastern part of the Mostecká pánev Basin, the erosion processes were slowed-down during the Saal due to the relocation of the Eger River into the Dolnooharská pánev Basin. Therefore, the surface of the coal beds was not substantially denuded.

All of the older Eger River terraces, including the level V₁, are directed across the Mostecká pánev Basin to the north and northeast towards the Bílina River valley, which is also occupied by these terraces in its 45 km long section heading towards the Elbe valley in Ústí nad Labem. In the area of the former Eger River and the Bílina River confluence, 15 terraces have evolved. Their relative height reaches the level of the oldest Terrace I₁ at ca 95 m, while the terrace groups VI and VII are entirely missing (Balatka 1995). All 7 terrace groups were identified in the lower Bílina River valley, i.e. 15 levels. The surface of the highest Terrace I₁ is situated at 118 m. Only 12 levels of the corresponding Elbe terraces have evolved in the vicinity of Ústí nad Labem. The surface of the oldest Terrace I₁ is situated at 138 m above the river (Tab. 1).

The morphostructural analysis of the tectonically disrupted terrain of the western headland of the Cretaceous Dolnooharská tabule Plateau, thus in the fault zone along the south-eastern margin of the Mostecká pánev Basin, proved the existence of the relatively young (presumably Middle Pleistocene) tectonic movements. This subsidence of the narrow rift depression floor contributed to the relocation of the Eger River to the east. Due to this relocation, which took place during the Middle Pleistocene, only terrace groups VI and VII evolved in the lower Eger River valley in the Cretaceous Dolnooharská tabule Plateau. Their surfaces are situated at 25 m above the river level. Balatka and Sládek (1976) proved the existence of the tectonically conditioned depression, which affected the sediment basis of the Eger River valley floor as well as that of the lowest terrace in the wider area of the Eger River and Elbe confluence. The thickness of its fluvial deposits reaches up to 20 m. The base of the Eger River valley floor sediments is situated in a hanging position in relation to the previously mentioned depression. There, the difference in altitude reaches more than 10 m.

6. Conclusions

Geomorphological research of the Eger valley between the Smrčiny Mountains and the western part of the Sokolovská pánev Basin was aimed at the investigation and morphogenetic evaluation of localities with river terraces and further fluvial sediments. The

whole Eger valley developed during the Neogene in morphotectonic depressions of extensive fault zones. The Chebská pánev Basin originated at the intersection of the Eger rift and the Cheb-Domažlice fault zone and its river network is incised ca 40 m into planation surfaces of the sedimentary basin. Sedimentary material in the Chebská pánev Basin reached a maximum thickness up to 400 m and these accumulations, including the Vildštejn layers of Pliocene-Pleistocene age, are disturbed by numerous faults. Both volcanic processes and frequent seismic activity in the region are associated with Late Cenozoic tectonic movements.

In the area between the Smrčiny Mountains and the Sokolovská pánev Basin the terrace system of the Eger River with following levels was identified (Table 1): the Pliocene terrace niveau B, the Cheb Terrace (I), the Hradiště Terrace (II), the Chvoječná Terrace (III), Jindřichov Terrace (IV), Nebanice Terrace (V), Chocovice Terrace (VI), Chotíkov Terrace (VII) and the recent flood plain (N). Geomorphological analysis and reconstruction of terrace flights of the Eger River enabled their inclusion in the current stratigraphical scheme of the Quaternary. It was determined to be a morphostratigraphical system of 7 river terraces of Quaternary age (Table 2). Older levels of fluvial sediments, occupying a still higher morphological position in the area between the Smrčiny Mountains and the Sokolovská pánev Basin, have been classified to the Pliocene.

A comparison of terrace flights in the longitudinal profile of the Eger River (Fig. 7) allowed the range of the Quaternary tectonic processes in the region to be specified. The Quaternary tectonics in the Smrčiny Mountains may be proven by the uplifted relics of the first terrace (Fig. 8), namely about 10 m in comparison with its level in the Chebská pánev Basin (Fig. 9). In the Chlumský práh Horst area, the oldest Pleistocene terraces (I and II), which originated during the Tiglian stage, were uplifted approximately about 15 m (Figures 7 and 10). The Terrace III, which is younger than 1.78 Ma, is uplifted about 2–4 m in this crystalline horst. In the western foreland of the Mariánské Lázně fault, an at least 8 m deep tectonic depression of the valley bottom sediments was found. This depression is also incised into the Vildštejn Formation.

The ascertained morphostratigraphy of the river accumulation terraces of Quaternary age between the Smrčiny Mountains and the western part of the Sokolovská pánev Basin is also compared to the current knowledge about the evolution of the valley and river terraces at the middle and lower stream of the Eger (Tables 1 and 2), namely in the Doupovské hory Mountains and the Mostecká pánev Basin. According to the current stratigraphical scheme of the Quaternary, the Eger River terrace system was formed mostly by the Pleistocene during the Tiglian to the Weichselian stages. The proposed morphostratigraphy of

Eger terraces River River (Table 2) can be used as a basis for their systematic radiometric dating. This procedure then allows to complete the chronostratigraphy of the formation of these fluvial landforms in the Quaternary.

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