Sborník geologických věd	Antropozoikum 22	Pages 141-157	7 figs.	1 tab.	- pl.	ČGÚ Praha 1995	ISBN 80-7075-184-3 ISSN 0036-5270

Stratigraphy of the Ohře River terraces in the Most Basin

Stratigrafie terasového systému řeky Ohře v Mostecké pánvi

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Received October 31, 1993

Key words: Bohemian Massif, Most Basin, River terraces, Stratigraphy, Pliocene, Pleistocene

Tyráček, J. (1995): Stratigraphy of the Ohře River terraces in the Most Basin. - Sbor. geol. Věd, Antropozoikum, 22, 141 -157. Praha.

Abstract: The Ohře River terrace system in the Most Basin with 25 distinct accumulation terraces represents the most complete geological record of the prolonged period from the end of Tertiary and through the entire Quaternary in the Bohemian Massif. Its understanding is fundamental not only for the potential revision of currently used stratigraphical schemes of Quaternary but also for considerations on the time range of Quaternary as a separate era.

Because of the lack of fossils, the usual biostratigraphical methods cannot be used for dating and therefore a range of auxiliary and indirect methods including studies of lithology and petrology, heavy minerals, post-genetic alterations, dating of the overlying sediments and palaeomagnetic measurements have been used instead.

The terrace system shows a regular development with no pronounced environmental changes and irregularities which should demonstrate the Tertiary/Quaternary transition or to mark the position of the currently used Q/T boundary. The formation of oldest terrace has been dated to some 2.5 Ma. This correlates with the initiation of loess deposition as well as with pronounced climatic change recognized in the North Sea Basin and in deep sea sediments.

The currently used Q/T boundary (at 1.64 Ma) in the Ohře valley is placed (on the basis of the height) between the Žiželice (II_2) and the Chbany (II_3) terraces. From this results that the 7 highest terraces should correspond to the Pliocene and the remaining 18 lower terraces belong to Pleistocene. Application of such a boundary means a dramatic impact on the stratigraphical classification of the terrace systems of other rivers in the Bohemian Massif region.

The total number of 25 palaeoclimatic cycles recognized(with assumed mean duration of 100,000 years each) based upon 25 terraces surprisingly conforms to the pronounced environmental change at about 2.5 Ma and with the Gauss/Matuyama palaeomagnetic reversal (2.48 Ma). The same holds for the 18 Quaternary terraces for this number approximates the number of palaeoclimatic cycles determined in the European loess sections. The numbers may just be a coincidence but in any case they clearly represent an important contribution to the definitions of the stratigraphical schemes for the Upper Cenozoic with more precision and to more precise definition of the time range of Quaternary.

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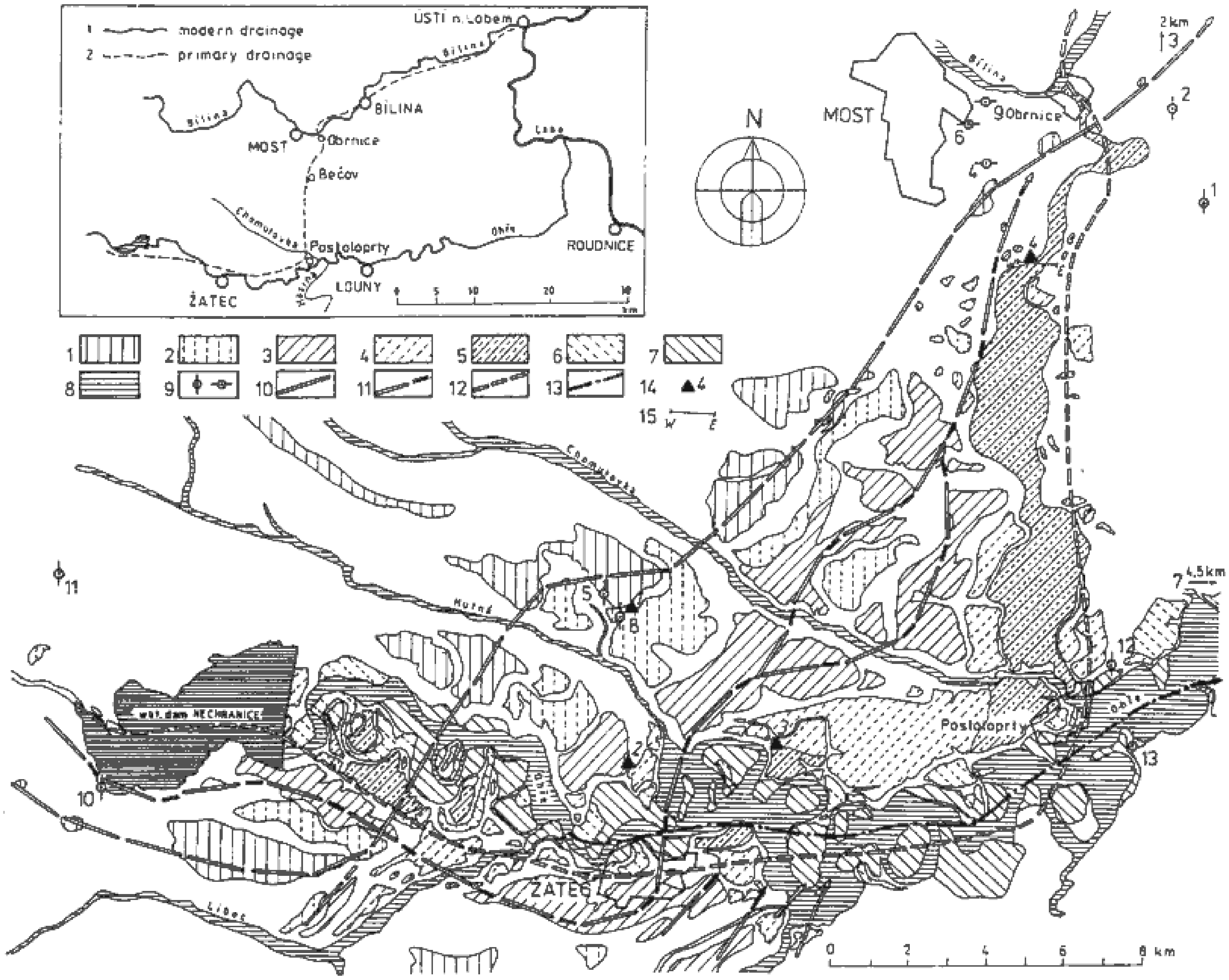
Introduction

River valleys are major zones of terrestrial deposition and fluvial sediments belong to the most sensitive sediments and provide the geological record of majority of environmental changes during the late Cenozoic. As stated many times in literature (Soergel 1939, Woldstedt 1952, Zeuner 1959, Záruba et al. 1977) river terraces play an outstanding role in Quaternary stratigraphy, regardless of the fact that opinions on their origin and development are far from being unanimous. When viewing fluvial terraces on a large scale and long term basis, it is apparent that the literature is full of contradictory statements (Fairbridge 1968) which are generally region-related. For the origin of terraces individual authors alternatingly prefer tectonic activity, differences in bedrock geology, diverse consequences of retrograde erosion, thalassostatic effects etc. Every single factor may be of course decisive in certain limited area.

Because space does not allow a full discussion of this topic here, let us focus our attention on terracing of upland rivers in the Bohemian Massif, particularly of that in the Ohře River. This represents only a minor but interesting part of a world-wide problem. Thanks to a special setting, the valley in the Most Basin preserves a complete undisturbed record of the entire period since the origin of the modern drainage pattern (Tyráček 1983). On the one hand this results from a relatively high relief which ensures repeated downcutting of streams whenever the environment permitted. On the other, was the very strong climatic impact of the Scandinavian ice sheet and the mountain glaciers in the Alps and Carpathians (and even in local Bohemian mountains) during the glacial periods. These glaciers closely embraced



1. Map of Ohře terraces (according to Balatka - Sládek 1976a - generalized)

1 - terraces of the I. group; 2 - terraces of the II. group; 3 - terraces of the III. group; 4 - terraces of the IV. group; 5 - terraces of the V. group; 6 - terraces of the VI. group; 7 - terraces of the VII. group; 8 - modern flood plain; 9 - palaeomagnetically studied localities - for details see text (a - normal polarisation, b - reverse polarisation); 10 - Ohře watercourse during Late Pliocene; 11 - Ohře watercourse during Lower Pleistocene; 12 - Ohře watercourse during Middle Pleistocene; 13 - Upper Pleistocene and modern watercourse

the inner icefree part of the Bohemian Massif thus creating a zone of very intensive periglacial conditions.

Two more factors controlled the specific development and state of preservation of the terraces in the Ohře River valley.

a) Firstly the bedrock underlying the studied sector of the valley course is the non-resistant Neogene sedimentary filling of the Most Basin. This ensures rapid adjustment of the river to new environmental conditions and a pronounced reaction to all changes in the stream dynamics, as well as to those controlled by climates.

b) Secondly it is one-sided constant shift of the stream south to southeast toward the right bank, so the river never returned to the previous course. This has resulted in a perfectly preserved terrace system, undisturbed by younger lateral erosion except by tributaries cutting cross the terrace set.

Dating the terraces

The terraces extend vertically from 5 up to 125 m above the present river and range stratigraphically from Holocene to Pliocene. The Ohře terraces have been classified using the system drawn by Balatka and Sládek (1976 a,b). These authors recognized seven terrace groups labelled I-VII in descending order which include an extraordinary high number of accumulations totalling twenty five distinct aggradational terraces, not to mention no less than ten erosional levels that reshape the original terrace surfaces. Such a high number is unknown outside this valley not only in the Bohemian Massif but in the whole periglacial region of Central Europe. It represents the richest set and has, at present, no known analogy. It perhaps represents the most complete continental records of the whole time span since the formation of the modern drainage pattern in our country.

Table 1. Correlation scheme of the Ohře River terraces

ENGEL-MANN 1922	VÁNĚ 1969	BALATKA AND SLÁDEK 1976a, b		TYRÁČEK THIS PAPER			
U	VALLEY FLOOR T.	WÜRM	THALWEG T.	PLEISTOCENE	THALWEG GRAVEL		BRUNHES
	Y		VII_3 MRADICE T.		VII_3		
	U_2	RISS	VII2 TVRŠICE T.		VII2		
	U_1		VII_1 RYBŇANY T.		VII1		
O_5			VI_4 STEKNÍK T.		VI_4		
	O_5		VI3 CHOTĚNICE T.		VI3	● BŘEZNO	
			VI_2 SELIBICE T.		VI_2		
	O_{5a}		VI1 NOVÉ SEDLO T.		VI1		
O_4		PRE-RISS	V_2 NECHRANICE T.		V2		
	O_4		V1 RVENICE T.		V1	● VRBKA	
O_3		MINDEL	IV_5 BEZDĚKOV T.		IV5	● TUŠIMICE	
O_2	O_3		IV4 VELICHOV T.		IV4		
	O_2		IV3 VÝŠKOV T.		IV3	● NECHRANICE DAM	?B
O_1			IV_2 KADAŇ T.		IV2		MATUYAMA
I_2	O_1		IV1 BŘVANY HILL T.		IV1		
	I_2		III2 VIKLETICE T.		III2		
I_1	I_1		III1 BLAŽIM T.		III1		
E	E_3	GÜNZ	II3 CHBANY T.		II3	1.64 Ma	
			II_2 ŽIŽELICE T.	PLIOCENE	II2	● HRADEC T.	OLDUVAI
	E_2		II1 HRADEC T.		II1	○ MOST, LAJSNÍK	
		DONAU	I_4 PŘESKAKY T.		I4	● NEČICHY	
A	E_1 ?		I3 HRUŠOVANY T.		I3	● VYSOČANY T.	RÉUNION
			I2 VYSOČANY T.		I2	○ MOST N. TOWN	
	A		I1 VTELNO T.		I_1	○ VTELNO	
		PLIOCENE	B				

The sequence is therefore fundamental to the eventual revision of the currently used stratigraphical schemes and of course also for determining the time range of Quaternary Era.

This theoretically highly appreciated value of the detailed geological record can transform rapidly into almost invincible classification obstacle, particularly for two reasons.

1. The first problem is the definition of the time sector represented by a single aggradation terrace (from the starting erosion to the successive one), i.e. the stratigraphical range of one terrace unit (glacial, stadial?). The erosional levels do not count because they can be the results of short-lived local variations of the stream dynamics and need not be of any higher stratigraphical value.

2. The second reason ensues from the first one. If each terrace corresponds to one full climatic cycle, then in climatostratigraphical concept, the Ohře terrace system records far more stages than are allowed for in the even most detailed stratigraphical schemes, currently used (e.g. 20 glaciations in United States within the last 3.0 Ma, 19 cold substages in Europe within the last 2.5. Ma - Šibrava et al. 1986). Moreover there is practically no other to correlate our results with, because parallelization of both incompatible systems (Ohře terraces and the schemes) is almost impossible, particularly when the position of the main Pleistocene boundaries remains uncertain. Although at present the evidence for the existence of more climatic cycles, than were originally taken for granted in Soergel's (1939) "Vollgliederung", increases in number (van Donk 1976, Fink - Kukla 1977, Shackleton et al. 1990), the detailed climatostratigraphical conclusions were not applied to the stratigraphical schemes. Nevertheless, though the time for fundamental changes to the Quaternary stratigraphical charts does not seem to be appropriate, the Ohře terraces could be considered as additional evidence for any future revision.

As stated above, all Ohře terraces in the Most Basin are unfossiliferous and the usual biostratigraphical methods cannot therefore be used for dating. The classification is therefore basically altimetric, nevertheless all other applicable auxiliary and indirect methods have been used, sometimes more, sometimes less successfully, for calibration. The studies began with lithology and petrology and continued with heavy minerals, post-genetic alterations, dating of the overlying sediments and ended with palaeomagnetic investigations of both fluvial sediments and associated porcellanites.

Lithology and petrology

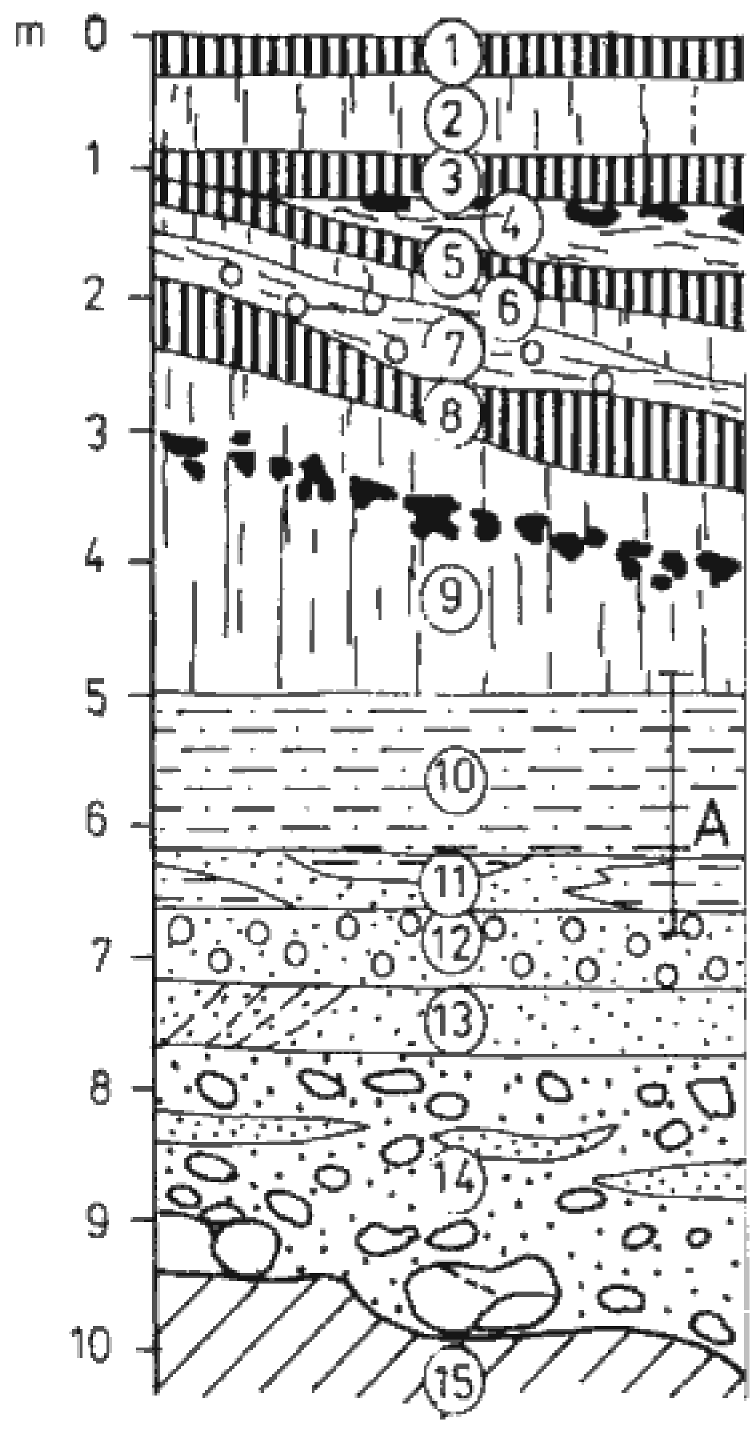
The majority of terraces was sampled and lithology and petrology were studied (Tyráček - Minaříková 1985) in an attempt to determine criteria for differentiation of individual terrace sediments or at least of terrace groups.

a) The lithology indicates rather the fluctuations of stream dynamics and environmental change than those controlled by age. The depositional style of all the identified sediment accumulations is practically the same irrespective of age. The only significant difference is that the Pliocene and Lower Pleistocene deposits are more fine-grained showing lower energy deposition without marked discharge changes. The style of deposition was, in addition, controlled by a smooth local relief and by the character of shallow braided streams. These streams shifted freely their wide valleys in the flat peneplain landscape redepositing older sediments and stripping old regolith. The relatively moderate amplitude of climatic oscillations during the preglacial period in contrast with drastic changes of the glacial Pleistocene must be of significance in determining the nature of this part of the sediment sequence.

For the younger terraces, the more frequent presence of coarse gravel or even boulders, brought by high-energy currents or ice-rafted, are typical. During these periods the sediment discharge was high and indicates a substantial input of clastics largely provided by periglacial frost action, degrading permafrost and solifluction.

However, although the lithological studies brought interesting palaeogeographical and palaeoenvironmental results, for stratigraphy are of limited value.

b) The petrological composition of the gravel is controlled by the parent rocks in the source area. Because there has been no considerable change in geology nor any change in the regional extent of the Ohře drainage basin since the Pliocene, there have been no provenance-related changes in petrology of the gravel. Despite the gravels comprising a relatively rich rock assemblage, it remains practically uniform in all levels. In some cases differences can appear even within one aggradational unit when local factors such as



2. Vysočany II - sediments overlying the Hradec Terrace
1 - dark grey to blackisch grey strongly humic clayey loam-illimerized pseudochernozem; 2 - loess with loess nodules; 3 - dark grey to greyish black clayey strongly humic loam with soil plasma skins-strongly illimerized pseudochernozem; 4 - loess-like calcareous loam with scattered gravel; 5 - fossil pseudochernozem like no. 3; 6 - loess with soft loess concretions; 7 - clayey loam with scattered pebble - solifluction layer; 8 - strongly illimerized pseudochernozem like no. 3; 9 - loess with admixture of gravel; 10 - silty overbank sediment; 11 - fluvial clayey sand with clay and silt interlayers and lenses; 12 - sandy gravel; 13 - sand; 14 - sandy gravel with large quartzite cobbles and boulders at the base of the terrace. Bed 10 to 14 represent the Hradec Terrace; 15 - sandy clay with sandy interlayers - Neogene

redeposition of older gravel, fluctuations of sediment discharge of tributaries etc. overshadow the age-controlled diversity. The results are therefore far from being unambiguous.

Heavy mineralogy

The study of heavy minerals has been applied to practically all Ohře terrace deposits. Again despite a relatively rich association, the mineral assemblage is rather monotonous and uniform in all levels. The study of heavy minerals has therefore not given results that are of stratigraphical importance (Tyráček - Minaříková 1985).

Postgenetic alterations

From the whole suite of post-sedimentary alterations, the silicification of the pebbles and intrastratal corrosion of heavy minerals are most promising.

a) Silicification proved to be one of most convincing criteria for distinguishing the Late Tertiary and Early Quaternary terraces from the remaining younger units. A marked surface silicification of pebbles, irrespective of their petrology, is analogous to the silicification described from the oldest Labe terraces and which is considered to indicate their pre-Quaternary age (Genieser 1957, Sekyra 1967). In the Ohře valley the silicification is typical of the "high level terraces group" (Tyráček et al. 1985) that incorporates terraces group I and II (Balatka - Sládek 1976b). The high terraces stratigraphically represent the Late Pliocene and the onset of Pleistocene in the present concept of the Q/T boundary (Tyráček et al. 1987).

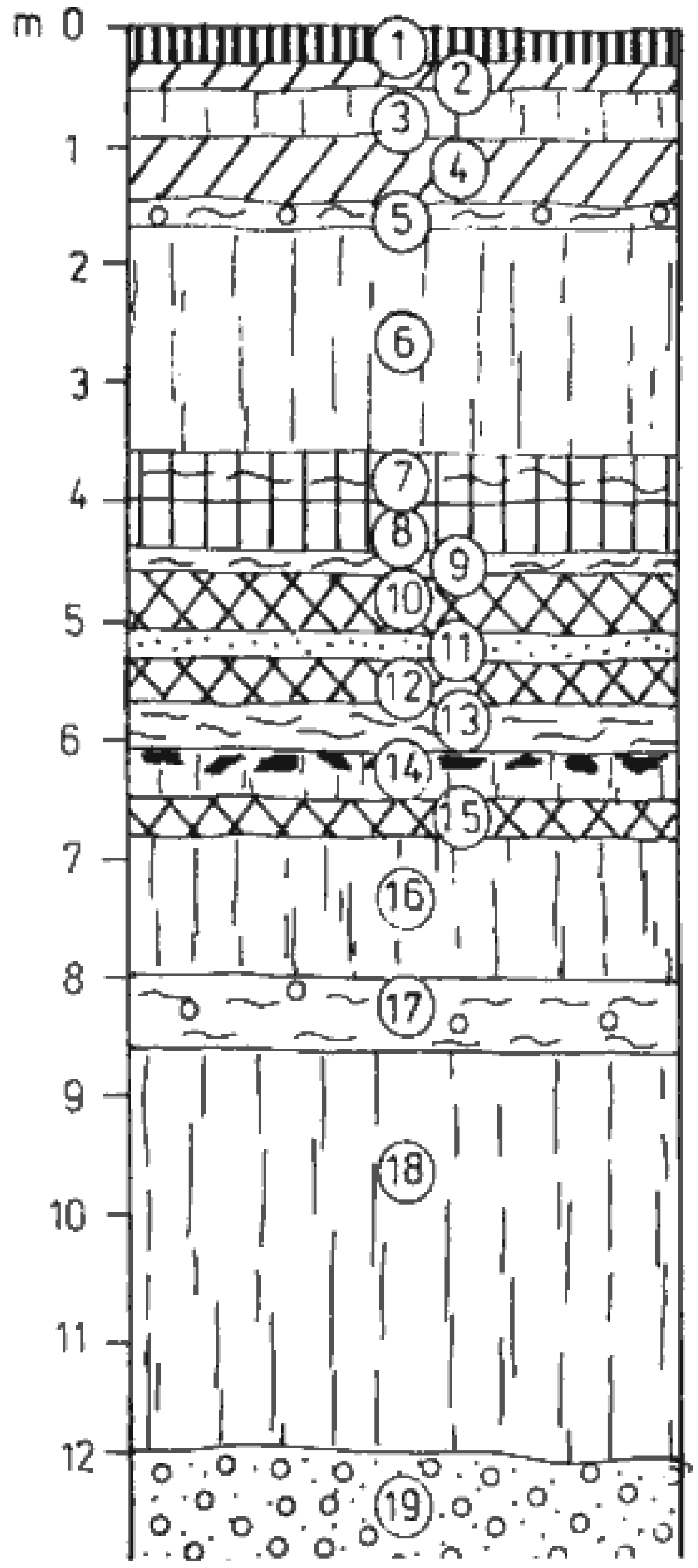
b) The corrosion of heavy mineral grains (pyroxene, amphibole, garnet) can be used to provide a major age calibration. Although the influence of local anomalies like the exposure to the weathering elements (lack of covering sediments), chemistry of the ground water and the velocity of its flow, can not be ruled out, the fundamental controlling factor of the intensity of the intrastratal corrosion is the age (Tyráček - Minaříková 1985, Tyráček et al.1985). However it only provides a coarse age calibration i.e. differentiation into Lower, Middle and Upper Pleistocene.

Dating the overlying sediments

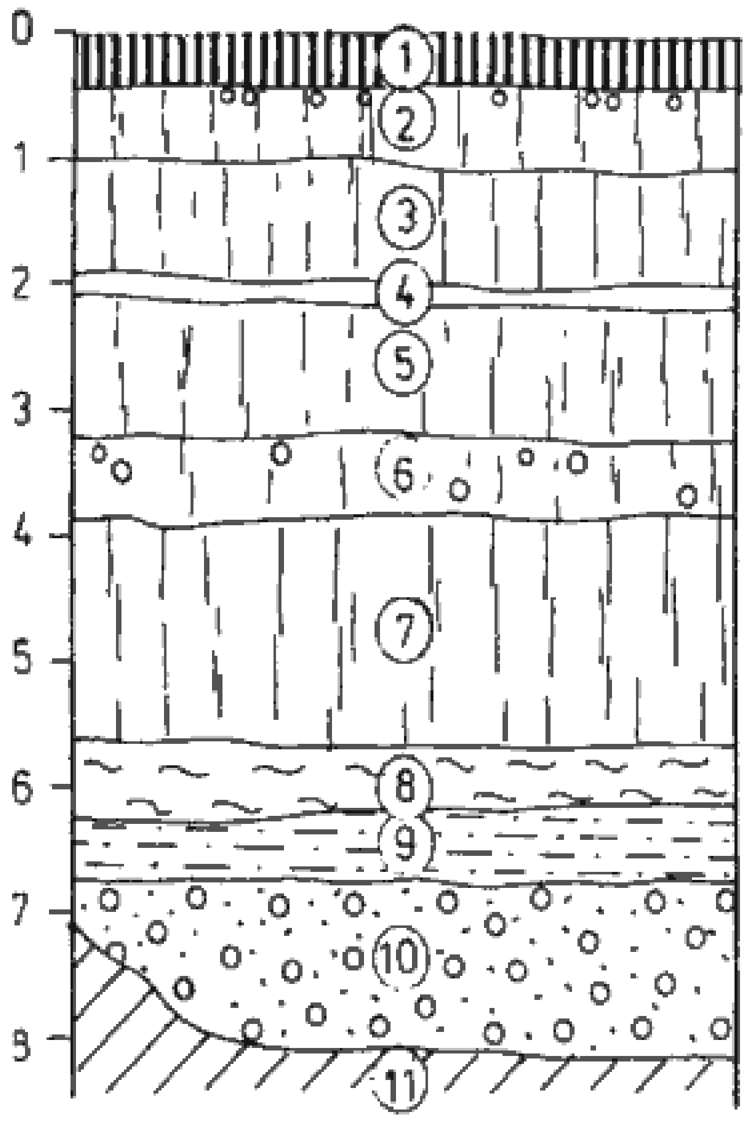
Dating the sediments overlying individual unfossiliferous terrace sediments offers one of the most suitable methods.

Theoretically the best covering sediments are the loess sequences which in morphologically convenient places form datable complexes of alternating loess blankets and fossil soils. Thank to a relatively reliable stratigraphy based on typology of fossil soils (Smolíková 1984, 1990), the overlying loess sequences can strongly support the dating of the terrace system.

Despite the fact that the Most Basin lies beyond the limits of the classical Central Bohemian loess region and that the alignment of the Ohře valley (W-E trend instead of N-S) parallel to prevailing westerly winds and therefore not favourable for loess deposition and irrespective of a chronic lack of good exposures, several localities have been found and studied. Unfortunately most exposures were documented some 10-15 years ago and since then practically all of them have become unavailable. They could not be therefore checked using modern methods, particularly by soil micromorphology. The palaeoclimatic interpretations of fossil soils in the loess sequences should be therefore considered preliminary.



3. Velichov loess sequence
1 - dark grey humic soil A horizon of a pseudochernozem; 2 - rusty brown non-calcareous loam - indistinct B horizon; 3 - loess; 4 - brownish loam - B horizon of a braunerde; 5 - clayey loam with strong gravel admixture - solifluction; 6 - loess; 7 - grey humic loam, indistinctly bedded in places-soil sediment; 8 - dark grey to greyish black strongly humic pseudochernozem; 9 - grey loam with yellowbrown streaks - soil sediments with strong admixture of loess; 10 - rusty brown loam - B horizon of parabraunerde; 11 - aeolian sand; 12 - clayey loam with visible soil plasma B horizon of an illimerized parabraunerde; 13 - humic soil sediment - unconformity (hiatus); 14 - loess capped by a marked Ca horizon; 15 - brown clayey loam with plasma skins on the surface of crumbles and fissures-illimerized soil; 16 - loess; 17 - sandy clay with gravel admixture (solifluction); 18 - loess with scattered pebbles; 19 - sandy gravel - Velichov Terrace.



4. Loess section Staňkovice manor (Staňkovice-Zámeček)
1 - A horizon of a braunerde; 2 - brown loess, partly decalcified - indistinct B horizon of a braunerde; 3 - loess; 4 - strongly calcareous whitish loess; 5 - loess like no. 3; 6 - whitish strongly calcareous loess - fossiliferous bed; 7 - loess with loess nodules; 8 - laminated calcareous loess (waterlain loess); 9 - loamy sand and silt (overbank sediment); 10 - sandy gravel (beds 9 and 10 - Rvenice Terrace).

Despite all the inaccuracies mentioned this problem is worth discussing. The information presented here is intended to introduce all localities available in the Most Basin for stratigraphical studies and to provide a foundation upon which to pursue more detailed dating.

Deposits overlying the Hradec Terrace

The Hradec Terrace (terrace II_1: Balatka - Sládek 1976b) exposed in Vysočany sand pit occurs at 94 m (surface) and 88 m (base) above the modern river. This accumulation was deposited during the Olduvai event (Tyráček et al. 1987) and is overlain by about 5 m thick sequence of loess and solifluction deposits with three intervening fossil soils. Because of the small vertical interval between this and the next higher terrace (i.e. a low bluff separating two terraces, which controls the capacity of the depositional trap), the sedimentary sequence is thin and only records a short time interval.

The deposition in such traps in thought to start practically immediately after the space is formed or shortly after (Záruba et al. 1977). This implies that the sediments record the successive period following the aggradation of the terrace, until the trap is filled up to the brink and there is no space left (Tyráček - Kovanda 1991). Later no space for younger sediments to be deposited remains and therefore later parts of the sequence are missing without having been subsequently removed.

A schematic section (locality Vysočany II - fig. 2) shows the sedimentary sequence including the underlying Hradec Terrace. The basal coarse grained high-energy gravel passes upwards into sand and finally into silty overbank sediments. The terrace is overlain by loess the basal part of which was most probably deposited in stagnant water. The upper part of the sequence is typically terrestrial. The overlying deposits here were accumulated in a typical continental depositional trap and after its filling there was no space left for younger sediments which are totally missing. The section therefore only records a fragment of the subsequent period, succeeding the deposition of the Hradec Terrace gravel.

The fossil soils are strongly weathered and clayey with typical soil plasma coating the walls of fissures and joints. The features indicate strong chemical weathering under a warm a humid climate of typical interglacials. The surface soil is of the same character, although the plasma percolation is less well expressed and also, represents a typical interglacial (relict) soil. This section records therefore four genuine interglacials. Owing to the antiquity of the underlying Hradec Terrace, the interglacials correspond to some, more precisely unidentifiable Lower Pleistocene interglacials. In general the value of the section is relatively low, because the presence of four interglacials resting upon the terrace dated to the end of Tertiary (Tyráček 1994) does not add greatly to a more precise stratigraphical classification.

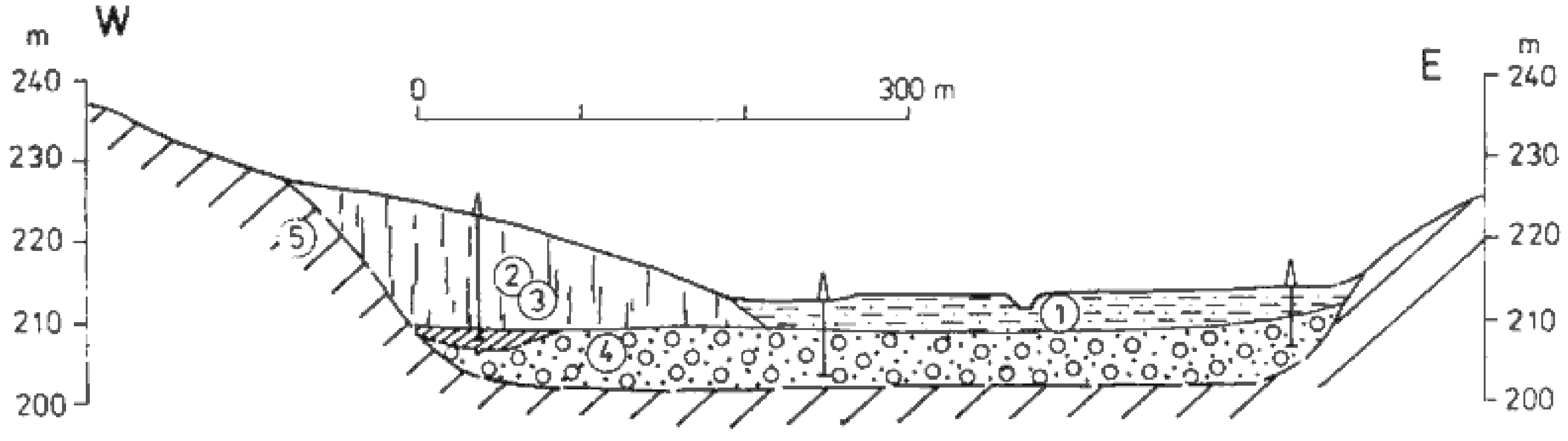
Sediments overlying the Velichov Terrace

The Velichov Terrace, i.e. the IV_4 terrace of Balatka and Sládek (1979b), stands 32 m (surface) and 28 m (base) above the river at Velichov village. Stratigraphically the whole IV group, incorporating five separate aggradation terraces, is classified into Elsterian (Mindelian).

The overlying sequence is up to 17 m thick and is represented by loess, fossil soils and soil and solifluction sediments likewise preserved in the continental depositional trap, situated on the lee-side of a marked terrace bluff. The sedimentary complex was originally exposed in two loam pits of the Žatec Astra and Velichov brick kilns. Neither of them now exists.

The section exposed in Velichov site was better developed more complete and represented a longer record (fig.3) and was therefore selected for demonstration. The top part of the section (beds 1 to 3) yields limited information. The surface chernozem is undoubtedly the product of Holocene pedogenesis. The underlying fossil soil, the B horizon of a braunerde (bed 4) is only the erosional relict of a pedocomplex (PK) which resembles the basal part of PK III even though the intensity of weathering is essentially lower. Thus suggests that its maximum age could correspond to the last interglacial (Eemian).

Of greater significance are two underlying pedocomplexes which are noted for their more complete develop-



5. Section across the abandoned Ohře valley near Stránce
1 - Holocene overbank sediments; 2 - loess and deluvio-eolian deposits undifferentiated; 3 - interglacial clayey sand; 4 - sandy gravel - Rvenice Terrace; 5 - pre-Quaternary bedrock.

ment. The younger one (beds 8 to 12) is represented by two markedly illimerized B horizons of parabraunerde type. The upper of them is topped by a strongly humic chernozem (bed 8), the lower one is represented only by B_t horizon. The structure of the pedocomplex, including the parautho-chthonous beds resembles a typical PK IV. The younger age can be excluded because the PK III is never doubled.

The older pedocomplex (beds 14 and 15) was originally also completely developed typically with two fossil soils (B horizons), separated by a loess blanket (bed 14). The existence of the upper soil is evidenced by a presence of a conspicuous Ca horizon, which usually originates at the base of a strongly weathered B horizons of parabraunerdes or braunlehms. The older pedocomplex is therefore separated from the younger unit by a striking unconformity which is indicated on the one hand by soil sediment (bed 13) and on the other by missing soil horizons, originally developed on the top of loess (bed 14).

Both older pedocomplexes indicate the existence of two genuine interglacials older than the Eemian and they can be preliminarily correlated with PK IV (Treene) and PK V (younger Holsteinian-see Smolíková 1984, 1990). A higher age, which cannot be ruled out, is limited to maximum PK VI (older Holsteinian) with respect to the soil type.

It can be therefore concluded that the Velichov Terrace pre-dates at least three interglacials and thus its Middle Pleistocene age (older Elsterian) is proved.

Sediments overlying the Rvenice Terrace

The Rvenice Terrace (V_1 sensu Balatka - Sládek 1976b) is preserved in isolated relics between the Nechranice dam and Postoloprty town. Further downstream the gravel accumulation forms a continuous infill of an old abandoned valley of the ancient Ohře River. The valley extends from Rvenice village as far as the Obrnice village, where it drains into the Bílina River (see fig. 1). The Rvenice Terrace is the last (youngest) terrace form the first developmental phase of the Ohře when the river flowed north-wards and emptied into the Bílina. In the sector between Nechranice and Postoloprty the terrace is usually overlain by loess, preserved in depositional traps. In the downstream part, between Postoloprty and the Počerady power station, the overlying sediments are missing and the gravel outcrops at the surface. Further downstream between Počerady and Obrnice the terrace passes below the Holocene deposits of the Srpina brook, that rest with a substantial hiatus upon the Middle Pleistocene gravel. The left bank in this sector is covered by deluvioaeolian and aeolian loams that partly overlie the marginal part of the Rvenice Terrace (see cross section fig. 5). Two localities in the sediments overlying the Rvenice Terrace were studied respectively at Staňkovice manor and Stránce.

Staňkovice manor section

The loess blanket is preserved on the lee-side of a bluff that separates two terrace relics located on the outer bank of an abandoned meander. The base of the higher terrace lies at the elevation 234.6 m⁺(28 m above the river) and its surface 236.5 m (30 m) and is correlated with the Bezděkov (IV_5) Terrace. The base of the lower, Rvenice Terrace (V_1) is at 227.6 m⁺ (22 m) and its surface approximately 229 m (23.5 m).

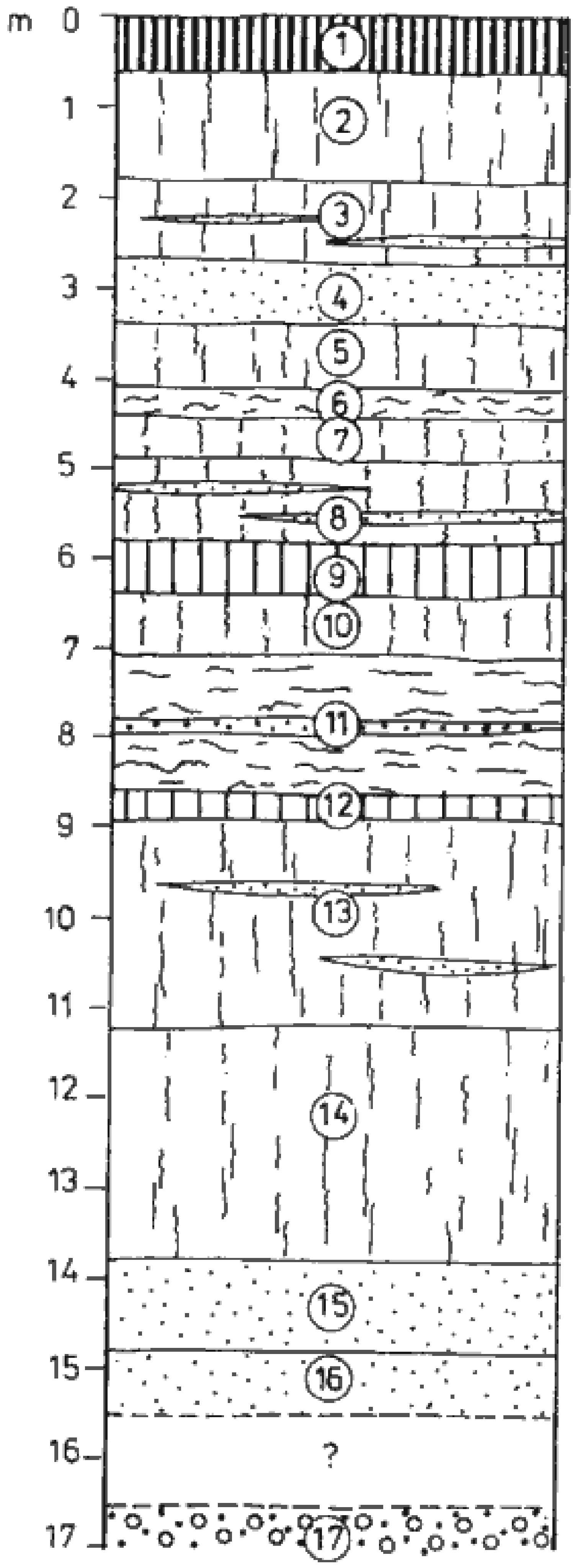
The geology of the Staňkovice locality is presented in the fig. 4. The fluvial accumulation again shows a gradation from coarse grained high-energy channel gravel into overbank silts, clayey sand and loam, typically laminated in places. The overlying sediments are composed of loess with scattered pebbles redeposited from the near by higher terrace. The loess is practically uniform except for two conspicuously lighter layers of strongly calcareous loess. Irrespective of the monotonous structure of the loess blanket which is not of great use for dating the underlying terrace,

⁺ *The altitudes were kindly provided by M. Váně who studied the Ohře terraces in detail and to whom the author wish to thank.*

the section is mentioned here because of this palaeontological and archaeological content.

The results of pollen analysis (V. Vodičková 1969 unpublished) from the overbank laminites show that the pollen spectrum is dominated by arboreal (AB) taxa. The *Pinus* is most frequent while other species like *Picea, Alnus, Betula, Ulmus, Corylus, Tilia, Carya* and *Quercus*, are subordinate. Herbs (NAP) are represented only by *Asteraceae, Rosaceae* and *Rumex*. The pollen are generally poorly preserved due to their redeposition. This reworking is confirmed by occurrence of the pollen of the warm loving tree *Carya* which appears usually in Tertiary, Lower Pleistocene and in older periods of Middle Pleistocene in our country. It is never found in situ within the Upper Pleistocene sediments. Such a result cannot be therefore used for stratigraphical classification and is mentioned here just for sake of completeness and to avoid future misunderstandings.

From the lower light loess bed (No. 6), the large mammal bones present include *Mammuthus primigenius, Coelodonta antiquitatis* and cf. *Homo* (det. O. Fejfar). In the same bed stone artifacts are also found that belong to a pebble industry type and are probably Middle Palaeolithic (det. J. Fridrich).



6. Borehole Stránce

1 - dark grey humic soil - chernozem; 2 - loess; 3 - loess with sandy interlayers and lenses - deluvio-eolian sediment; 4 - calcareous eolian sand; 5 - loess; 6 - loamy sand with admixture of coarser grained and porcellanite splinters (deluvioeolian sediment); 7 - loess; 8 - alternating layers of loess and sand; 9 - initial chernozem; 10 - loess; 11 - loamy to sandy sediment with a layer of coarse grained sand - sheetwash sediment; 12 - initial chernozem; 13 - loess partly laminated with sand interlayers - niveoeolian sediment?; 14 - - ditto like 13 with coarser grained admixture; 15 - fluvial clayey sand-oxbow lake sediment; 16 - grey "muddy" sand - oxbow lake sediment; 17 - gravel of the Rvenice Terrace.

Locality Stránce

A sequence of aeolian, colluvial and fluvial deposits was recorded in a 15.5 m deep borehole, situated in a depositional trap near Stránce village at the left bank of the abandoned Ohře valley (fig. 5). The detailed description of the section is given in the explanations to the figure 6.

In the upper part of the sequence two weakly developed "initial" chernozems occur. This type of fossil soil appears very often within the Upper Pleistocene loess and is not of particular stratigraphical value because it can originate during any short-lived temperate climate oscillation.

In contrast the two basal beds (15 and 16) of clayey and muddy sand are of greater importance. This sediment, relatively rich in palynomorphs, was deposited in a small abandoned river meander. Pollen analysis of the sequence was carried out by V. Vodičková (see Tyráček in Malkovský et al. 1972) with following results: The AP is represented by *Alnus, Pinus, Betula, Corylus, Ulmus, Tilia, Carya, Picea, Ilex, Juglans, Carpinus, Evonymus* and *Quercus*. The herbs are characterized by *Potamogeton* and families *Poaceae, Cyperaceae, Rosaceae, Fabaceae, Brassicaceae* and *Ericaceae*. Sporadically the pollen of *Sparganium, Typha, Myriophyllum, Euphorbia, Vaccinium* and those of the families *Ranunculaceae, Asteraceae* and *Chenopodiaceae* appear.

This pollen spectrum represents a rich woodland and herb vegetation. The relatively well balanced assemblage was warmdemanding, particularly including species like *Carya* and *Juglans*. The assemblage in typically interglacial and was correlated with the Holsteinian. However, it is necessary to point out here that both gravel terrace aggradations i.e. Velichov and Rvenice are included in the Elsterian Stage. With respect to this interpretation the possibility that the Stránce interglacial may be an equivalent of some older, but stratigraphically close interglacial of early Middle Pleistocene, cannot be excluded.

Palaeomagnetic studies

The results of palaeomagnetic investigations, like the dating of overlying sediments, are fundamental for stratigraphical classification of the Ohře terraces. The data were obtained by using two different methods applied to two diverse types of sediment, i.e. fluvial deposits and porcellanites.

Palaeomagnetometry of fluvial sediments

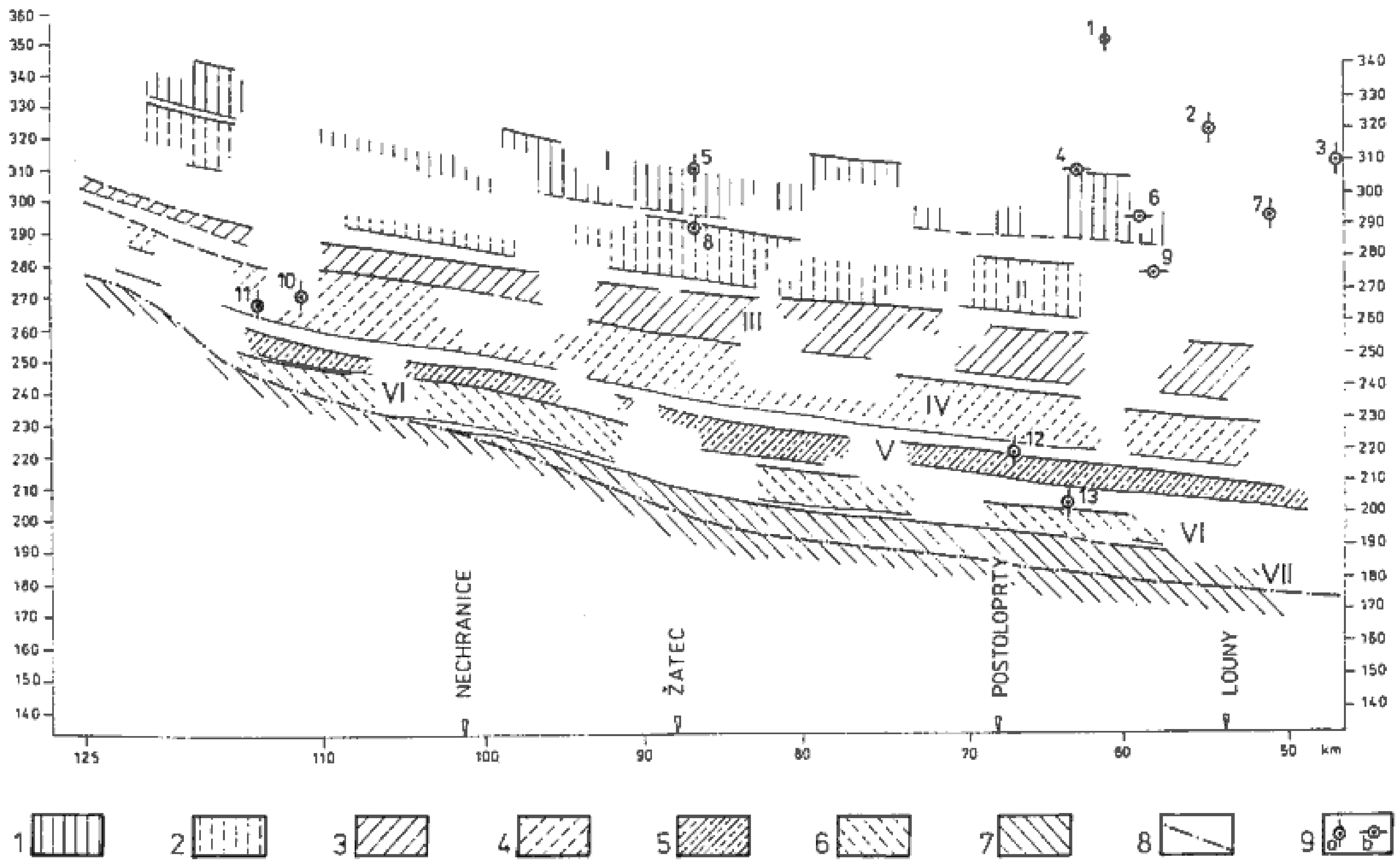
The usual method of vertical sampling of convenient fine grained sediment was used for this type of measurement. The palaeomagnetic signal was determined by application of A. C. demagnetisation fields of various intensity. The most valuable advantages of this method are on the one hand that the fluvial sediment itself is measured. On the other, the method gives a continuous curve which represents a certain time interval which in turn can be correlated with the standard profile.

In contrast this method shows several congent disadvantages and its use is limited. Firstly there is practically a complete lack of measurable silt and clay since the presence of fine-grained sediments in the high energy gravel accu-

List of measured localities

Locality		Altitude in m a.s.l.	above river	Polarity	Group
1.	Dobrčice	345-350	150-155	normal	I
2.	Svinčice	320	135	normal	
3.	Braňany-Kaňkov	310	130	normal	
4.	Vtelno	310	110	reverse	2
5.	Vysočany Terrace	308	100	normal+	
6.	Most-new town	295	105	reverse	
7.	Nečichy	295	105	normal	
8.	Hradec Terrace	290	82	normal+	
9.	Most Lajsník	275	86	reverse	
10.	Nechranice dam	270-275	22-27	normal	3
11.	Tušimice	266	15	normal	
12.	Vrbka	220	25	normal	
13.	Březno near Louny	205	12	normal	

+Palaeomagnetic signal determined from unaltered fluvial sediments. The location of palaeomagnetically measured localities is shown on the map (fig. 1) and their altimetric position in the terrace system on the longitudinal profile (fig. 7).



7. Longitudinal profile of the Ohře terraces (according to Balatka - Sládek 1976b - generalized)
1 - terraces of I. group; 2 - terraces of the II. group; 3 - terraces of the III. group; 4 - terraces of the IV. group; 5 - terraces of the V. group; 6 - terraces of the VI. group; 7 - terraces of the VII. group (incl. the thalweg terrace); 8 - the gradient curve of the river; 9 - palaeomagnetically measured localities (a-normal polarity, b -reverse polarity).

mulations in the Ohře is exceptional. Therefore from the whole set of 25 terraces only two levels namely Vysočany and Hradec Terraces were found to incorporate acceptable deposits. The second more serious disadvantage is the unknown rate of deposition of the measured sediment. This depreciates the value of the resulting curve and makes the correlation with the standard profile rather uncertain. The third disadvantage is the possibility of erroneous interpretation particularly when the resulting curve is short.

In the gravel of the Vysočany Terrace a clay interbed about 1.5 thick was measured. In the Hradec Terrace, in ascending order, the top part of the fine-grained channel deposits, then the overbank silts and lastly the basal waterlain part of loess were investigated. Since the palaeomagnetic measurements were applied for the first time to fluvial sediments in this region (Tyráček et al. 1985, 1987), the data obtained have been profitable despite the limited applicability if this method.

Even though the terraces range into the high-level terrace group which as a whole belongs in the reverse Matuyama Palaeomagnetic Epoch, normal polarity was determined at both localities. They were assigned to normal events Réunion (2.14-2.01 Ma) and Olduvai (1.86-1.67 Ma). Briefly the argument was as follows (Tyráček et al. 1987):

a) Firstly is the antiquity of both terraces, since they doubtlessly correspond, in accordance with their morphostratigraphical position, to the controversial time span of the end of Tertiary and beginning of Quaternary. It means that the Normal Brunhes Epoch was ruled out because of its low age likewise the Gauss Normal Epoch because of its high age. From this follows that only normal events within Matuyama Reverse Epoch could be taken into consideration.

b) Secondly is a short time interval separating both terraces. The interpretation was therefore simple being restricted to the events mentioned because no other such a normal close couplet exists within Matuyama.

Palaeomagnetic studies of porcellanites

In the Most Basin the term porcellanite is used to refer to Neogene sediments altered caustically by naturally-induced burning of the coal seams (earth fire, Erdbrand) into orange-red, ochre-red or rich red hard rocks. The combustion of the coal was triggered by the exposure of the seam to atmospheric oxygen. Hard and colourful porcellanites, contrasting strongly with drab grey unconsolidated original Neogene sediments, rank with medium to strongly magnetic materials, which record both the direction and the intensity of the magnetic field active at the time of the caustic alteration (Krsová et al. 1989). Because the caustic alteration of the whole locality took place at the same time, there is no reason to sample vertical profiles as in sediments. From each locality 10 to 25 spot samples were taken instead randomly from suitable beds.

For the estimation of the palaeomagnetic signal the method of thermal demagnetisation was applied, i.e. the method of successive heating and cooling the sample for intervals of increasing temperature up to the maximum Curie temperature of the minerals-magnetism carriers (Krsová et al. 1989). The main advantage of this method is that the palaeomagnetic values represent mean figures and this minimizes the measurement errors and reduces the natural scatter of the data. Its main disadvantage is that the signal is obtained from different type of rock which is only related indirectly to the adjacent fluvial sediments.

The results are applicable for stratigraphical classification of terraces on the condition (Tyráček 1994) that:

1. The baking temperature in the porcellanites during the caustic alteration exceeded the Curie point of haematite.

2. The coal ignited early (i.e. from the point of view of the geology contemporaneously) after the exposure of the seam to atmospheric oxygen.

3. The rule of decreasing age with decreasing height used for the upland rivers in the Bohemian Massif is valid in this region and can be adopted for porcellanites as well.

All three conditions were satisfied.

1. High baking temperatures in porcellanites, proved on the one hand by the heating method itself used during the palaeomagnetic measurements and on the other by high sintering temperatures of brick clay (1,000-1,050 °C for porcellanites) or the melting point of coal ashes (1,187-1,308 °C for palaeoslags) gained by technological tests (Tyráček 1994) resulted in eradication of any earlier palaeomagnetic record. This means that the signal represents the prevailing geomagnetic field at the time of the fire (caustic alteration).

2. Early combustion of the exposed coal seam is indicated by mostly unaltered everlying gravel body deposited practically immediately after the formation of the rock platform (rock terrace) cut into the porcellanite. Because the erosion (represented by exposure and burning of the coal seam, caustic alteration of clays and formation of the rock terrace) and the aggradational phase belong to one Pleistocene cycle, the palaeomagnetic signal of porcellanite can be used for dating the terraces.

3. The validity of the rule of decreasing age with decreasing height of terraces in upland regions of the Bohemian Massif has been proved many times (for selection of literature see Tyráček 1994). Because the only natural agent exposing the coal seam is the valley incision (downcutting erosion) by local streams, the seams occurring at diverse altitudes were exposed, burnt and the adjacent sediments altered at different times. It means that the rule of contingency of age on the altimetric position can be likewise adopted for porcellanites. The time of the caustic alteration is recorded in the magnetic signal and can be stratigraphically interpreted.

Stratigraphical interpretation of porcellanites

Because the only factor controlling the exposure of the coal is the downcutting erosion, only 11 porcellanite localities closely-related to the terraced Ohře valley were selected for stratigraphical considerations. Two more measured localities of fluvial sediments, explicitly the Vysočany and Hradec terraces were incorporated in order to provide a complete set of data.

Because the geophysical studies can only provide an alternating normal or reverse signal, the reliability of dating based solely on palaeomagnetic values is not sufficiently detailed. In contrast the morphological position of individual localities can be quite successfully used as a fundamental tool for the calibration of the geophysical results. By using the combination of the magnetic signal and the morphostratigraphical (altimetric) position within the terrace system, the stratigraphical classification is surprisingly easy, more precise and unambiguous.

When interpreting the geophysical data using the above criteria, the set of studied localities spontaneously falls into three altitude-related groups.

1. The first group is represented by three localities Dobrčice, Svinčice and Brňany-Kaňkov which are noted for normal polarisation and lie above the high-level terrace group. This porcellanite group is correlated with the Gauss Normal Palaeomagnetic Epoch (3.40-2.48 Ma).

2. The second group of three reverse localities Vtelno, Most- New Town and Most-Lajsník is equated with the Matuyama Reverse Palaeomagnetic Epoch (2.48-0.78 Ma).

The remaining three localities, that lie within the altimetric range of the second group, fit well into this scheme despite their normal polarity. The fluvial terraces Vysočany and Hradec are correlated with normal events Réunion (2.14-2.01 Ma) and Olduvai (1.87-1.67 Ma) respectively. The porcellanites at Nečichy near Louny, showing normal polarity, also correspond stratigraphically most probably with the Réunion Event (comp. longitudinal profile-fig. 7).

3. All four youngest (lowest) porcellanite localities Nechranice dam, Tušimice, Vrbka and Březno again show normal polarity and are classified into the Brunhes Normal Palaeomagnetic Epoch (0.788 - Modern).

Discussion of some stratigraphical problems

Tertiary/Quaternary (Q/T) boundary

The currently used or better to say internationally recognized standard, but not generally accepted, Q/T (Pliocene/Pleistocene) boundary is placed at the base of Calabrian formation in Italy. This boundary is situated in the Vrica section above the top of Olduvai Event and is estimated to be some 1.64 Ma.

Application of such a boundary changes the previous classifications of the Ohře terrace system (see table 2). Accepting the mean duration of one Pleistocene climatic cycle to 100,000 years or so, the same time period should be assigned to a single aggradation terrace, which is considered to be a representative of one cycle as well. Between the dated Vysočany (I_2) and the Hradec (II_1) Terraces two more aggradation stages (terraces I_3 and I_4) were determined by Balatka and Sládek (1976b). That does not agree with the time interval separating the Réunion and Olduvai events (140.000 years). From this it follows that the Vysočany Terrace was deposited during some at present undeterminable part of Réunion. The same holds good for the Hradec Terrace and the Olduvai Event. This approach is acceptable because the palaeomagnetic events represent just changes in the magnetic field and have no impact on palaeoclimates, palaeoenvironment or on geological processes and therefore the palaeomagnetic chrons need not necessarily coincide with stratigraphical boundaries.

Because of the relatively long time span represented by the Olduvai Event (200,000 years), there is sufficient time for the successive next lower (younger) Žiželice Terrace (II_2) to be included in it. From these results it seems that the Žiželice Terrace should still be of Pliocene age. In contrast if laser-fusion 40Ar/39Ar dating (Walter et al. 1991) is taken into consideration, the age of Olduvai Subchron should be considerably greater (about 100.000 years) and the Q/T boundary should shift one terrace backward.

In view of these uncertainties which still remain, it seems safer to change the dating of two terraces only. Explicitly the Hradec terrace, dated originally (Tyráček et al. 1987) as oldest Pleistocene and the successive younger Žiželice Terrace classified by Balatka and Sládek (1976b) as Günz. Both of these units shoulds be newly classified as Pliocene. This opinion is supported by dating of the Beroun Complex (Tyráček 1991, Tyráček - Kovanda 1991) in which the Olduvai Event is also represented by two climatic cycles. In other words the currently used Q/T boundary is placed in Ohře valley between the II_2 Žiželice Terrace (Pliocene) and the II_3 Chbany Terrace (Pleistocene).

The Lower/Middle Pleistocene boundary

This boundary is mostly identified as corresponding with the Brunhes/Matuyama reversal, although is is not officially approved as non-geological in the concept of International Stratigraphic Guide (Hedberg 1976). In sedimentary sequences it is controversially correlated with the oxygen isotope stage 19 in marine sediments (warm phase). However, in the terrestrial deposits e.g. loess section in China, Červený kopec Hill, colluvial deposits in the Beroun highway section it is placed either into loess or into the fluvial gravel (cold phase). The more precise identification of this boundary suffers in many places from a lack of concrete data.

Placing this boundary in the Ohře terrace system at this stage of knowledge is impracticable. In valleys of other rivers in the Bohemian Massif uplands, cut into resistant bedrock, this boundary coincides with a marked change in morphology of the valley bank slopes. That is with the change from the wide open shallow valleys in the rank of the "high level terraces" into the narrow deep incised valleys of the "middle terraces group". The change in the morphology is not so clearly expressed in the Most Basin because the Ohře valley is incised into unconsolidated Neogene sediments. It would be therefore hazardous to attempt some final conclusion at present.

The Middle/Upper Pleistocene boundary

This boundary is relatively well determined. There is no doubt that in the Ohře valley two youngest terraces (Mradice and the thalweg) correspond to the Upper Pleistocene in accordance with the original dating (Balatka - Sládek 1976b). It is not impossible, however, that the whole VII group of terraces belong in the last glacial because no overlying sediments correlatable with the Eemian interglacial have been found.

Comments on the time range of Quaternary

The chronology of the Czech Quaternary is established, as elsewhere, mostly on the basis of climatic cycles. In other words this implies that the climatic oscillations are generally accepted as a guiding principle for defining of Quaternary. This approach was partly ignored by establishing the Q/T boundary at a younger level (1.64 Ma) and thus represents a fundamental but still controversial problem. The reason for this on the one hand is that the climatic implications as a major criterion is difficult to apply on the world wide scale and on the other that similar climatic oscillations typical of the pre-glacial Pleistocene also occur in certain regions during the Late Pliocene. The problem of placing the Q/T boundary is therefore not only the question of the time range of Quaternary, i.e. a simple shifting the boundary backwards, but also as stated by Šibrava (1991) "*this problem is closely related to the definition of the Quaternary itself. If the Quaternary is not defined in some way as a period characterized by well defined features, the boundary becomes difficult to draw*".

A sound definition, though needed, does not exist in the light of new data or perhaps many definitions have been invoked but none of them was generally agreed upon. It is therefore advisable that the whole set of features setting the Tertiary apart from the Quaternary should be defined and than taken into consideration when defining the new boundary. Fundamental to this are, of course, the expression of environmental changes which can be generally well characterized. But the definitions of individual factors remain in many cases inconclusive or obscure. The environmental changes mentioned here triggered new depositional styles and marked turns in palaeogeographical development. One of these was initiation of the formation of a new drainage pattern and of terrace systems. These phenomena are particularly well expressed in the Bohemian Massif uplands.

As generally known, the Neogene developmental history of the Bohemian Massif was broken by a long period of prevalent denudation. The older fluvial gravel accumulations (Hlavačov or Rakovník gravel) known from our region form up to 60 m thick unterraced fillings of old valleys and are Lower Miocene in age. They were deposited by a river discharging into a freshwater lake in the Most Basin. The E and S parts of the Bohemian Massif were drained into the Carpathian and Alpine foredeeps respectively. These rivers belonged to ancient, quite different drainage pattern which ceased to exist during Lower Miocene. Practically no demonstrable Upper Miocene and Lower and Middle Pliocene sediments are known from the Bohemian Massif uplands.

This period was truncated, for reasons not well understood at present (generally attributed to tectonic influence or unspecified general environmental change) by the formation of a modern drainage pattern accompanied by deposition of fluvial gravel arranged in terrace systems. Since the Ohře valley was formed a total of 25 distinct aggradational terraces have developed. With respect to the currently used Q/T boundary, 7 terraces representing 7 full climatic cycles, belong to the Pliocene and the remaining 18 levels fall into the Pleistocene. This means that the oldest terrace reaches stratigraphically well below the Q/T boundary. Accepting a mean duration of one full cycle (terrace) to about 100,000 years, the river should have been formed at about 2.5 million years ago.

This date approximately correlates with the beginning of loess deposition in China (Liu Tungsheng - Din Menglin 1982, Yang Zizeng et al. 1991) or in Central Asia (Dodonov 1991) as well as with the climatic change recognized in marine sediments (Berggren 1968, Gibbard et al. 1991, Shackleton et al. 1991) and surprisingly with the Gauss/Matuyama palaeomagnetic reversal.

These results add to the evidence for the requirement of lowering the Q/T boundary. Šibrava (1991) correctly states that "*it would be difficult to defend the existence of the Quaternary* (as a separate era) *knowing that more important climatic, palaeontological, palaeoenvironmental, palaeogeographical and other changes had already taken place in Pliocene*". This is particularly true when marked environmental change at about 2.5 Ma is compared with the deterioration of climate at the currently used Q/T boundary (at 1.64 Ma). The latter is considerably less pronounced (see also Kukla 1989) and conforms practically to one of the normal periodic climatic oscillations typical of pre-glacial Pleistocene.

The more or less regular development of the Bohemian Pliocene terraces and likewise the loess blankets alternating with fossil soils of about the same age, provides evidence for the similar character of the Pliocene climatic oscillations when compared with those typical of the Pleistocene. The existence of true old glacials is indicated in the temperate zone of Central Europe by finds of typical cold loess molluscs in Late Pliocene loess blankets (Kovanda et al. in print), and the long lasting complicated warm interglacials by deeply weathered fossil soils corresponding to sub-Mediterranean to subtropical palaeopedological province (Smolíková 1991).

If the first arrival of true cold climates in the temperate zone of Central Europe indicated by glacial loess as well as by cold fluvial terraces is typical of the beginning of the Quaternary, the Q/T boundary should be lowered. The best chronohorizon for world-wide correlations seems to be Gauss/Matuyama reversal (2.48 Ma). The precise identification of the geological boundary poses a quite different problem and should be located in some selected type locality in future. Although such boundaries are usually conventional, they are liable to other requirement and should be placed in accordance with the rules of the International Stratigraphic Guide (Hedberg 1976) for stratotype boundaries.

Pleistocene climatic cycle and the aggradation phases

The purpose of this part of the paper is not to deal with this topic in full extent but to draw attention to the problem of the position of fluvial processes in the Pleistocene climatic cycle. No thorough literature is therefore referred to and no details are discussed here.

Although the climatic control of alternating erosion and aggradation phases in the periglacial zone is generally accepted, their position in the Pleistocene climatic cycle is still widely discussed. Generally it can be stated here that the original simple correlations i.e. glacial=deposition and interglacial=erosion are invalid.

During the glacials in our region the environment is substantially one of arid deserts or more precisely cold arid steppes. The character of the glacial maxima is shown by cool-steppe type of terrestrial moluscs of the so called "Columella fauna" in the loess capping the terraces. The permafrost fixed the regolith during the full-glacial times and controlled thus, as well as the solid-type of precipitation, the decrease in coarse-grained load and in sediment and water discharge. No major aggradation is thought to have occurred during the glacial maxima.

During the warm and moist interglacials most of the land surface was fixed by dense vegetative cover, dominantly by deciduous forests, and the coarse-grained input was again essentially reduced. The high water stands and floods were reduced as well and the river adopted single-thread channels instead of braided stream type. The gravel load was stabilized except for local redepositions in the river channels and meanders. No major erosion as well as no major deposition could be expected during such phases.

It is apparent therefore that only transitional phases are available for pronounced stream activities in the periglacial zone uplands. The aggradation was formerly ascribed to increasing coldness (Zeuner 1959) or in other words to early glacial periods (Fairbridge 1968). During these anaglacial[+] phases (interglacial-glacial transition) the interglacial vegetation gradually disappears thus exposing the regolith to denudation. The aggradation of clastics in braided stream type of valleys starts and continues relatively far into the glacial. This accords with field observations in the Bohemian Massif where in many places the cold character of the gravel terraces (lacking palaeontological evidence) is confirmed by fluvial sediments grading up into covering loess without unconformity. In Northern Moravia the anaglacial upper accumulation of the main terrace passes laterally downstreams (basinwards) into Saalian glaciofluvial and interfingers with it (Šibrava 1964, Tyráček in Macoun et al. 1965). Later because of the continuous advance of the glacier, the glaciofluvial deposition progrades into the valleys upstream into the uplands surrounding the Ostrava Basin, and there replaces the fluvial sedimentation. The original braided streams survive the whole glacial only in the upper courses beyond the reach of glaciofluvial deposition.

This interpretation relates only to the first, anaglacial phase. The second, kataglacial phase was practically neglected. Very little has been done to elucidate the processes taking place during this time. In general it was previously considered as a main erosional phase, for some a phase such as this was theoretically needed for formation of the rock platforms of respective terraces. Only lately when there was more and more evidence coming to light on the gravel deposition during postglacials, the second phase of fluvial deposition within the same cycle was accepted.

The decaying permafrost at the end of a glacial releases huge amounts of fresh material derived by periglacial processes and vigorous solifluction provides a strong supply of local material into the valleys. The interplay of strong input of clastics and fall in the water discharge is responsible for accumulation of gravel trains forming the thalweg terrace in braided streams or pronounced fluvial and alluvial fans in morphologically convenient places. In the course of successive phases into the subsequent interglacial, the deposition gradually diminishes due to the improvement of the climate. The gradual spreading of the vegetational cover subsequently reduces the coarse-grained load and the water discharge. The rivers tend to adopt single-thread meandering courses with floodplains.

From the foregoing it is apparent that the terraces could form in both anaglacial and kataglacial phases and that they

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[+] *The terms anaglacial and kataglacial are used here respectively for warm-cold and cold-warm transitions of individual full Pleistocene climatic cycle irrespective of their status in order to eliminate endless discussions on the existence of cycles, subcycles, great and small interglacials, glacials and stadials etc. At the same time the existence of minor oscillations and irregularities accompanying each transition must be borne in mind. In this case minor variations of the climatic curve are deliberately omitted not only for sake of simplicity but also because they do not manifest themselves in the upland type of gravel accumulations or are unrecognisable in fossil free deposits.*

Stratigrafie terasového systému Ohře

(Résumé anglického textu)

Jaroslav Tyráček

Předloženo 31. října 1993

Nejvážnější překážkou studia nejmladších terestrických sedimentů a jejich datování jsou neúplné vrstvení sledy, které vyplývají ze základního znaku kvartéru, a to ze zákonitého střídání období sedimentace a eroze. Proto je zjištění dalších souvislých geologických záznamů vítaným zdrojem poznatků. Nejlepší předpoklady mají údolí řek jako hlavní zóny terestrické sedimentace, a proto jim byla vždy věnována zvýšená pozornost.

Nejinak je tomu i v údolí Ohře, kde terasový systém v mostecké pánvi s 25 samostatnými akumulačními terasami představuje patrně nejúplnější terestrický záznam dlouhého časového úseku konce terciéru a celého kvartéru ve střední Evropě. Má proto zásadní význam nejen pro upřesnění stávajících stratigrafických schémat mladšího kenozoika, ale i pro úvahy o časovém rozsahu kvartéru jako samostatné éry, a s tím spojené stanovení hranice terciér/kvartér. Vzhledem k bezfosilnosti ohareckých teras nebylo možno použít obvyklé biostratigrafie, a proto byl využit celý soubor pomocných a nepřímých metod od litologie a petrologie štěrků přes těžké minerály, postgenetické alterace a hodnocení krycích sedimentů až po paleomagnetický výzkum jak vlastních fluviálních sedimentů, tak i porcelanitů.

Terasový soubor vykazuje pravidelný vývoj. V celém jeho rozsahu nebyly zjištěny žádné anomálie ani jiné důkazy, které by mohly signalizovat přechod z terciéru do kvartéru, či ze kterých by bylo možno usuzovat na pozici současně užívané hranice terciér/kvartér. Nová říční síť vznikala po dlouhém období převažující denudace (které zaujímalo celý střední a svrchní miocén a větší část pliocénu) patrně v průběhu svrchního pliocénu zhruba před 2,5 miliony let. Za celou dobu existence údolí Ohře byly prokázány dvě větší změny v paleogeografickém vývoji. První bylo přerušení procesu peneplenizace a vznik nové odvodňovací soustavy včetně údolí Ohře. Druhou nápadnou změnou byl přechod od široce otevřených mělkých údolí, reprezentovaných skupinou vysokých teras, do období intenzivní hloubkové eroze, která zafixovala toky do dnešních směrů a je dokumentována skupinou středních a spodních teras. První období je korelováno s pozdním pliocénem a tzv. preglaciálním pleistocénem, druhé, ovlivněné zejména drastickými klimatickými změnami a pohybem velkých mas kontinentálních ledovců, odpovídá glaciálnímu pleistocénu a počíná elsterským glaciálem.

Zhoršení klimatu, charakterizující dnes používanou hranici terciér/kvartér (1,64 Ma), se nijak svou intenzitou neliší od normálních periodických klimatických oscilací preglaciálního pleistocénu a nemá tedy klimatostratigrafické opodstatnění. Takto pojatá hranice se v údolí Ohře vkládá mezi žiželickou (II_2) a chbanskou (II_3) terasu. Z toho vyplývá, že do pliocénu by v dnešním pojetí náleželo celkem 7 akumulačních teras (terasy A, I_1 až I_4 a terasy II_1 a II_2 v pojetí Balatky a Sládka, 1976a, b), zatímco zbývajících 18 stupňů spadá do pleistocénu. Takto definovaná hranice leží poměrně nízko nad hladinou řek, a pokud se prokáže její platnost v širším regionu, bude znamenat zásadní změnu ve stratigrafické interpretaci terasových souborů i na ostatních řekách Českého masívu.

Podstatně výraznější změny přírodního prostředí, klimatu i paleogeografického vývoje proběhly zhruba před 2,5 miliony let, kdy vzniká nová odvodňovací soustava Českého masívu a dochází k tvorbě výškově diferencovaných teras. To je dokladem střídání období eroze a sedimentace, typického pro kvartér. Tento časový údaj zhruba odpovídá jak počátkům tvorby spraší v Číně, v centrální Asii a nakonec i v Evropě, kde nejstarší spraše (Stranzendorf) obsahují typickou studenou sprašovou faunu, tak i výrazným klimatickým změnám prokázaným v hlubokomořských sedimentech oceánů i v jižní části Severního moře. Lze jej rovněž ztotožnit i s paleomagnetickou inverzí Gauss/Matuyama (2,48 Ma).

Stanovení hranice terciér/kvartér (Q/T) by tedy v první řadě mělo vycházet z definice kvartéru jako samostatné éry. K tomu je třeba řádně definovat všechny znaky odlišující kvartér od terciéru, datovat jejich první projevy a použít tyto údaje pro definici hranice. Jedním z hlavních znaků kvartéru je zákonité střídání studených glaciálů s teplými interglaciály. První projevy skutečně drsných glaciálních podmínek v mírném klimatickém pásmu by měly počátek kvartéru určit.

Jestliže první výskyt typického studeného klimatu s permafrostem, doložený glaciálními sprašemi a studenými říčními terasami, příp. i kryogenními strukturami vyskytujícími se v pozdním pliocénu mírného klimatického pásma střední Evropy, znamená počátek kvartéru, pak je třeba tuto část terciéru do kvartéru přiřadit. V tomto případě by měla být hranice Q/T posunuta zpět až na úroveň 2,4-2,5 milionů let. Jako celosvětového korelačního chronohorizontu se může používat zmíněná inverze G/M.

S ohledem na výše uvedené skutečnosti je logičtější snížení hranice terciér/kvartér až na úroveň zhruba 2,4-2,5 milionů let. Jako celosvětového korelačního chronohorizontu se může využít zmíněné inverze G/M, i když jsme si plně vědomi, že jde o negeologické a dočasné řešení do doby než se zhodnotí vhodná typová lokalita.

Vysvětlivky k obrázkům a tabulce

1. Mapa teras Ohře (podle Balatky a Sládka, 1976b - generalizováno)
1 - terasy I. skupiny; 2 - terasy II. skupiny; 3 - terasy III. skupiny; 4 - terasy IV. skupiny; 5 - terasy V. skupiny; 6 - terasy VI. skupiny; 7 - terasy VII. skupiny; 8 - niva; 9 - paleomagneticky měřené lokality (a - normální polarizace, b - inverzní polarizace); 10 - tok Ohře ve svrchním pliocénu; 11 - tok Ohře ve spodním pleistocénu; 12 - tok Ohře ve středním pleistocénu; 13 - současný tok Ohře.

2. Vysočany II - sedimenty v nadloží hradecké terasy
1 - tmavě šedá až černavě šedá silně humózní jílovitá hlína - illimerizovaná pseudočernozem; 2 - spraš s cicváry; 3 - tmavě šedá až šedočerná jílovitá hlína silně humózní s náteky půdního plazmatu - silně illimerizovaná pseudočernozem; 4 - sprašovitá vápnitá hlína s vtroušenými valounky; 5 - fosilní pseudočernozem jako vrstva č. 3; 6 - spraš s měkkými shluky karbonátů; 7 - jílovitá hlína s vtroušenými štěrky - soliflukce; 8 - silně illimerizovaná pseudočernozem jako vrstva č. 3; 9 - spraš s příměsí štěrků; 10 - nivní silty; 11 - fluviální jílovitý písek s vložkami a čočkami jílu a siltu; 12 - písčitý štěrk; 13 - písek; 14 - písčitý štěrk s velkými valouny až balvany křemenců na bázi terasy (vrstvy 10 až 14 náležejí hradecké terase); 15 - písčitý jíl s vložkami jemnozrnných písků - neogén.

3. Cihelna Velichov
1 - tmavě šedá humózní půda - A horizont pseudočernozemě; 2 - rezavě hnědá nevápnitá hlína - B horizont; 3 - spraš; 4 - hnědavá hlína - B horizont hnědozemě; 5 - jílovitá hlína se silnou příměsí štěrků - soliflukce; 6 - spraš; 7 - šedá humózní hlína, místy nevýrazně vrstevnatá - půdní sediment; 8 - tmavě šedá až šedočerná silně humózní pseudočernozem; 9 - šedá hlína se žlutohnědými šmouhami - půdní sediment s příměsí přemístěné spraše; 10 - rezavě hnědá hlína - B horizont parahnědozemě; 11 - eolický písek; 12 - jílovitá hlína s uvolněným půdním plazmatem - B horizont illimerizované parahnědozemě; 13 - humózní půdní sediment; 14 - spraš s výrazným Ca horizontem na povrchu; 15 - hnědá jílovitá hlína s plazmatickými náteky - illimerizovaná půda; 16 - spraš; 17 - písčitý jíl s příměsí štěrků - soliflukce; 18 - spraš s vtroušenými valouny; 19 - písčitý štěrk - velichovská terasa.

4. Sprašový profil Staňkovice-Zámeček
1 - A horizont hnědozemě; 2 - hnědá spraš, zčásti dekalcifikovaná - nevýrazný B horizont hnědozemě; 3 - spraš; 4 - silně vápnitá bělavá spraš; 5 - spraš jako vrstva č. 3; 6 - silně vápnitá bělavá spraš - fosilifemí vrstva a archeologický horizont; 7 - spraš s cicváry; 8 - laminovaná vápnitá spraš sedimentovaná do vody; 9 - hlinitý písek a silt (nivní sediment); 10 - písčitý štěrk - rvenická terasa.

5. Příčný profil opuštěným údolím Ohře u Stránců
1 - holocenní povodňové sedimenty potoka Srpiny; 2 - spraš a deluvioeolické sedimenty nerozlišené; 3 - interglaciální jílovitý písek; 4 - písčitý štěrk - rvenická terasa; 5 - předkvartérní podloží - neogén.

6. Profil vrtu Stránce
1 - tmavě šedá hlína - černozem; 2 - spraš; 3 - spraš s vložkami písku; 4 - vápnitý navátý písek; 5 - spraš; 6 - hlinitý písek s příměsí hrubozrnnějších štěrků a s úlomky porcelanitů; 7 - spraš; 8 - střídání vrstviček písku a spraše; 9 - iniciální černozem; 10 - spraš; 11 - hlinitý až písčitý sediment s polohou hrubého písku - plošný splach; 12 - iniciální černozem; 13 - spraš místy laminovaná s vložkami písků - niveoeolický sediment?; 14 - dtto jako č. 13 s příměsí hrubšího písku; 15 - fluviální jílovitý písek - sediment opuštěného říčního ramene; 16 - šedý bahnitý písek - dtto jako č. 15; 17 - štěrky rvenické terasy.

7. Podélný profil terasami Ohře (podle Balatky a Sládka, 1976 b - generalizováno).
1 - terasy I. skupiny; 2 - terasy II. skupiny; 3 - terasy III. skupiny; 4 - terasy IV. skupiny; 5 - terasy V. skupiny; 6 - terasy VI. skupiny; 7 - terasy VII. skupiny včetně údolní terasy; 8 - spádová křivka řeky; 9 - paleomagneticky měřené lokality (a - normální polarizace, b - inverzní polarizace).

Tabulka 1. Korelační schéma teras Ohře.