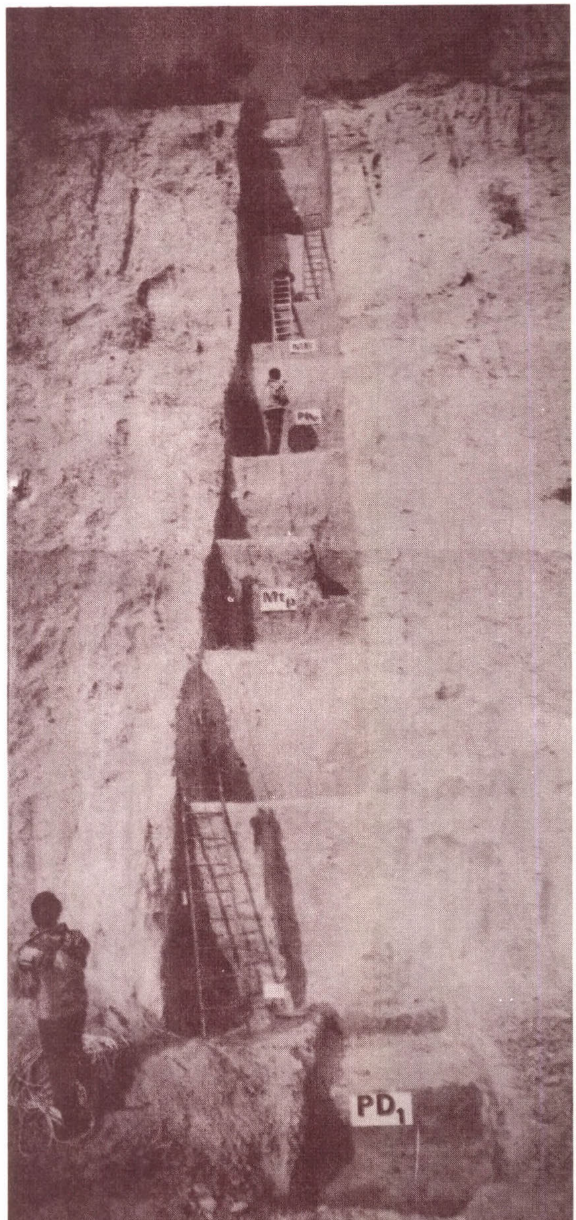
GEOGRAPHICAL RESEARCH INSTITUTE
HUNGARIAN ACADEMY OF SCIENCES

LOESS inFORM 3



BUDAPEST 1995

CONCEPT OF LOESS, LOESS–PALEOSOL STRATIGRAPHY

LOESS inFORM 3

Recommended by the Commission on Loess
of the International Union for Quaternary Research

Geographical Research Institute
Hungarian Academy of Sciences

CONCEPT OF LOESS, LOESS–PALEOSOL STRATIGRAPHY

Edited by
MÁRTON PÉCSI and
FERENC SCHWEITZER

Dedicated to the 14th INQUA Congress
Berlin, Germany, August 1995

BUDAPEST 1995
Geographical Research Institute
Hungarian Academy of Sciences

Translated by

L. BASSA
D. LÓCZY
P. MÜLLER

Technical board

Mrs. Zs. KERESZTESI, Ms. M. MOLNÁR, J. NÉMETH, I. POÓR, Mrs. M. TÁRKÁNYI, Mrs. E. GARAI

HU ISSN 0238-065X

ISBN 963 7395 69 5

Printed in Hungary

CONTENTS

PREFACE

Loess is one of the widest spread unconsolidated rocks on the Earth formed during the Quaternary, bearing fertile soils but its specific structure makes it liable to degradation and subsidence under the effect of erosion and of the land use patterns. Engineering geology and agricultural sciences deal with the practical aspects of the utilisation of loess surfaces and deposits.

Over extended areas loesses and paleosols directly superimpose each other making up sequences of considerable thickness. This configuration provides good opportunities for the reconstruction of climatic and environmental changes during the Quaternary. To understand the origin of the loess-paleosol series, their specific features, the fossils encountered in them and several other physical, chemical, geological and pedological phenomena it is indispensable to take into account and to synthesise the results of investigations carried out by the related sciences. For this reason loess research has become an increasingly interdisciplinary task.

The problem of loess has a multifold aspect and beside specific research trends comprehensive investigations are also under way. Comparative studies on loess–paleosol sequences bearing regional differences in their origin and properties is a highly complex task. Criteria, principles, methods and aspects of loess research vary by regions and workshops and the results obtained need a multifold comparison.

The series *Loess InForm* is aimed at the presentation of the more recent principles, methods and results obtained through regional investigations putting emphasis on a uniform application of criteria and terminology of loess both in the theoretical and practical contributions.

The third volume of *Loess InForm* is dedicated to the participants of A/6 pre-congress excursion of the INQUA Congress to be held in Berlin in order to inform them on the activities of the Hungarian Working Group of the Commission on Loess and Committee on Paleogeographic Atlases.

The introduction to the present volume provides a comprehensive information on the concept of loess (M. PÉCSI). The opportunities to reconstruct past climatic change based on the interpretation of loess litostratigraphy are evaluated (M. PÉCSI). Further on it is emphasised that loess series in various geological-geomorphological positions (plateaus, pediments and basins) contain different number of loess layers and paleosols developed or saved. This is a phenomena to be taken into account in the chronostratigraphic subdivision of loess-paleosol sequences (M. PÉCSI and F. SCHWEITZER). An international project has been organised recently to carry out stratigraphical analyses and to provide a new description of the Paks brickyard sequence with the best subdivision among the profiles in the middle Danube basin (M. PÉCSI-F. HELLER-F. SCHWEIT-ZER *et al.*). Phytolith analysis is considered a contribution to the paleoenvironmental investigations and to the interregional correlation of the Late Pleistocene loess-paleosol sequences in this region (S. ENGEL-DI MAURO).

Márton PÉCSI and Ferenc SCHWEITZER
editors

Loess inForm 3. 1995. pp. 9–21.
Geographical Research Institute Hungarian Academy of Sciences

CONCEPT OF LOESS: A COMPREHENSIVE INFORMATION

PÉCSI, M.

Geographical Research Institute Hungarian Academy of Sciences,
H–1388, Budapest, P.O. Box 64.

The loess concept and application of its criteria

The interpretation and classification of the mineralogical and petrological composition, fabric feature and origin of loess has been a recurring problem for a long time. It is disputable what to include into the concept of loess. On the basis of its particular features, researchers have distinguished loess from other unconsolidated subaerial deposits, but the criteria applied were not the same. Locally and occasionally, researchers emphasize some of the loess criteria which number about a dozen, while they only attribute subsidiary role to other criteria not counted among the decisive ones. The reason behind this is the fact that many loess varieties exist.

Although there have been repeated efforts to distinguish between loess and loess derivates (i.e. unconsolidated rocks similar to true or typical loess by only part of the criteria), a joint application of criteria (principles and methods) capable of drawing this distinction have not yet been tried. By now a narrower (loesses) and a broader interpretation (loess-like deposits, loess derivates) of the loess concept have developed.[1]

The formulation 'loess deposition' or 'loess accumulation' is, consequently an oversimplification. It is not the loess but its mineral mass that accumulates.

Another one-sided concept is the assumption that loess acquired all its properties, for instance, its grain size distribution, during the eolian deposition of the mineral material.

[1] For the main comprehensive criteria to define the typical loess see: PÉCSI, M. 1993. Quaternary and Loess Research. Loess inForm 2. Geographical Research Institute Hungarian Academy of Sciences, Budapest, 82 p.

To the grain size distribution and mineral composition of loess physical, chemical, biological and pedological processes jointly contributed, they are called collectively 'loessification', which takes place mainly in steppe zones with favourable conditions, as a result of seasonal pedogenesis of low intensity. In the mineral composition of loess silica, ferrous silica gel, Fe hydrosilicate, Fe carbonate, Fe hydroxide (limonite), Fe oxide, Mn, Al, Al oxide, exchangeable cations and anions are always present, partly as films on clay and as clastic grains in loess. In some loess horizons (or zones) Fe and Mn also occur in the form of aggregates (of pea or bean size and shape) or in dendritic patterns. The spots with Fe and Mn films, dispersed limonite, carbonates and humus are of considerable cementing power between grains and influence the stability of loess. Finely dispersed humus is not visible in the loess horizons (0.2–0.8 per cent), it occurs in observable amounts in the hollows of burrowing animals, while in paleosols it appears as colloids (1–2 per cent). The percentages of certain minerals (silica, Fe hydrosilicate, limonite etc.) in loess may increase under more humid climate while under dry conditions loess may be enriched in other minerals. All the above influence the formation of loess and its varieties.

Definition

According to the main criteria, typical loess is a homogeneous, unstratified, slightly diagenetized, loose silty deposit. It is usually a permeable, porous 'structured light loam', under dry conditions stable in vertical cliffs or bluffs, easily erodible by water. Colour is commonly pale yellow or buff due to its content of finely dispersed limonite (iron hydroxides). The predominant mineral constituent is quartz (40–80%), subordinately felspars, variable amounts of clay (5–20%), fine sand (5–25%) and carbonates (1–20%) occur.

It is usually assumed that the silt-sized (10–50 microns) mineral constituents were transported and deposited dominantly by wind, partly by slope wash and river flood, but loess is not just the accumulation of dust. The mineral particles of dust of any origin only become loess after the passage of a certain amount of time through diagenesis (loessification) in certain ecological environments. The *loessification* does not take place in every geographical zone, but mainly under conditions typical of semi-arid grassland (steppe) or forest steppe.

The major loess sequences consist of 1–5 meters thick, unstratified typical loess layers, alternating with very fine stratified loess-like deposits and with buried soils (paleosols), intercalated with some solifluction material, sand or coarse detritus. Several variants and facies of loess and loess-like formations are known also regionally, which together constitute the loess series. The above definition, however, is generally used for the typical loess only.

Lately, the term 'typical loess' has assumed a double meaning in its geological sense, for it implies both a well-defined lithology and a well-defined genesis, whereas in engineering practice the lithological interpretation is used without any genetic connotation. Whichever way it is defined, loess is unquestionably an Ice Age facies. No pre-Pleistocene loess is known.

Geographical distribution of loess

Loess is one of the most extensive subaeral formations of the Ice Age. It covers almost one-tenth of all land surfaces, forms a 1–200 meter thick blanket particularly in the marginal semiarid belt of the great orographic deserts, steppe, forest steppe, as well as in the forest belt of the temperate zone with the exception of land areas covered by ice-sheets during the last glaciation. Loess horizons were most typically formed simultaneously with the major glacial stages of the Quaternary period.

Loess occurs over a variety of land forms. In their largest extension loesses and loess-like deposits are encountered on plains, plateaus, pediments and major river basins and valleys such as

the North American Great Plains on prairie belt;

the Middle and Southern Russian Plains;

the basins of Lower Mississippi; Middle and Lower Danube;

the Lower La Plata; Lower Huanghe;

the Loess Plateau of China; Siberian Loess Plateau (Ob–Yenisey–Lena interfluve ridges), Columbia Plateau;

the terraced valley flanks of Middle Rhine, Lower Seine, as well as the pediments of Tien Shan, Altai and Kun-Lun Mountains.

Significant isolated areas are common:

– In Central Europe, along the middle reaches of the Vistula, Oder, Elbe, Main and their tributaries.

– In the Mediterranean zone non-typical loess varieties developed with higher clay or higher sand content and brownish–pink colour, such as in Tunis, Israel, Iran, Kashmir, Pakistan and New Zealand.

– In the loess varieties formed under oceanic climatic influence in the temperate belt, the carbonate content is low or partly absent. They are of slightly brown tint and their porosity is well below average, while the clay content is higher.

– In the cold belt, along the Yukon river in Alaska dust accumulation and loess development is observed to continue to our days. Considerable dust accumulation is recorded currently on the Loess Plateau of China, in the basins of Central Asia (e.g. Tajikistan), but soils are being formed from the dust depositing in these areas.

A special loess-like facies, the 'yedoma' loess-ice complex, occurs in larger sporadic patches in North Siberia, in the permafrost tundra zone.

The loess belts of the Earth have played a considerable role in sustaining the population and even recently these regions coincide with the densely populated areas. The loess covered surfaces bear fertile soils and 80 per cent of the corn produced in the world comes from loess regions. As a result of technical activity and agricultural land use loess is easily erodable, generally it is compacted under buildings and its durability is being degraded. Therefore, protection of loess and of its soil cover has practical significance and includes maintaining and increasing agricultural production on the one hand and establishing and ensuring the operation of economic and technical establishment, on the other.

Grain size distribution

In typical loess, which is only moderately well sorted, loosely coherent grains of 10–50 microns in diameter form the dominant grain size fraction which is also called 'loess fraction' (coarse silt or aleurite). Granulometric analyses by various methods gave 40–60 weight percentage as the average content of this fraction. The percentage of granulometric composition of non-typical loesses and loess-like deposits may be even more variable.

Characteristic grain size distribution is considered to be one of the most striking properties of loess. However, granulometric composition varies within certain limits even for *sensu stricto* typical loess. Greater differences are recorded on the grain size distribution curves of loess-like formations. These investigations are still the first approach to the lithological analysis of loesses and systematisation, classification and terminology can also be applied relying on grain size *(Tab. 1)*.

A recurring problem of the theories of loess formation is the *origin of quartz* grains of 10–50 micron size which make up the majority of loess material. Therefore, the fundamental question is how the huge amount of quartz grains of silt size had been produced.

– Many hold the view that coarse silt is the final product of physical weathering and make efforts to find experimental evidence for it. They hold *frost action* under cold glacial climates responsible for the creation of silt in amounts large enough for loess formation.

– Others emphasize *glacier grinding* that comminuted rock detritus to silt size and the resulting sediment was accumulated by meltwater in fluvioglacial deposits.

– Some scientists express the opinion that silt-size particles can also be found in sufficient amounts in river load deposited over the flood-plain during floods. Some connect this process with the transport and accumulation of fluvioglacial material.

– The concept that anticyclonal winds and rivers joined to transport the silt-size particles to deserts and to desert margins and deposited it there. This is one of the possible combinations of glacial and desert, ie. 'cold' and 'warm' loess theories.

The percentage of the finer loess particles and clay mineral grains tends to increase toward the more elevated parts of the loess-covered region on the one hand, and with increasing distance from the source of the dust, on the other. This phenomenon is attributed to the gradual decrease of the carrying capacity of the wind with increasing distance from the area of deflation. However, other factors may also be involved: e.g., loess tends to grow finer from the semiarid zones toward the more humid regions, owing to the enrichment of the clay fraction in the wetter environment. This is particularly evident in closed basins such as the Columbia River Basin of the American northwest or the Carpathian Basin of Central Europe, where sandy loess or typical loess is predominant in the central part of the basin, but changes into adobe and clayey varieties toward the basin margin.

Table 1. Systematic classification of loess-paleosol sequence based on granulometric composition and carbonate content (wt%) at Paks loess exposure in Hungary. (Estimation by the method of J. Szilárd (1985), analysis by Mrs Mária di Gléria).

Depth interval (m)	Sample	$CaCO_3$	P	AL	Ps	Estimation by the method of J. SZILÁRD (1985)
		wt%				
3.50–3.70	h_1	11.5	12.6	28.9	58.0	$Ps^{III}2^5$; s. clayey, m. loessy, s. limy sand
8.10–8.40	l_1	18.0	24.4	61.9	13.0	$AL^{IV}1^6$; s. clayey, s. sandy, m. limy loess
8.70–8.90	t_1 (MF)	15.1	37.3	47.1	15.4	$AL^{II}3^6$; m. clayey, s. sandy, m. limy loess
9.70–9.90	l_2	19.5	28.2	61.4	9.6	$AL^{IV}3^7$-h; m. clayey, h. limy loess
11.20–11.40	t_2 (BD_1)	28.9	49.0	37.3	13.1	$P^{II}3^9$; m. loessy, s. sandy clay with calcium carbonate accumulation
12.00–12.20	l_3	17.0	34.9	46.7	17.2	$AL^{II}3^6$; m. clayey, s. sandy, m. limy loess
12.60–12.75	t_3 (BD_2)	15.2	37.8	38.0	23.8	$AL^{I}3^6$; m. clayey, s. sandy, m. limy loess
13.35–13.55	l_4	13.4	38.9	46.6	13.6	$AL^{II}3^6$; m. clayey, s. sandy, m. limy loess
15.35–15.55	Ps_1	18.7	15.9	26.5	57.5	$Ps^{III}2^6$; s. clayey, m. loessy sand
20.80–21.10	l_5	22.5	27.5	55.2	16.8	$AL^{III}3^8$; m. clayey, s. sandy, +h. limy loess
21.90–22.05	t_4 (BA)	11.7	44.8	38.0	18.8	$P^{II}3^5$; m. loessy, s. sandy, s. limy clay
25.30–25.60	l_6	27.2	25.0	63.6	11.2	$AL^{IV}3^9$; m. clayey, s. sandy loess with calcium carbonate accumulation
28.35–28.55	t_5 (MB)	8.4	41.1	35.2	22.1	$P^{II}3^4$; m. loessy, s. sandy, +s. limy clay
29.45–29.75	L_1	27.2	24.4	49.2	26.0	$AL^{II}2^9$; s. clayey, m. sandy loess with calcium carbonate accumulation
30.75–30.95	t_6 (Phe)	16.5	43.0	47.3	8.3	$AL^{II}6^6$-h; s. clayey, m. limy loess
32.05–32.30	L_2	17.2	31.0	51.9	16.5	$AL^{III}3^6$; m. clayey, s. sandy, m. limy loess
35.45–35.60	t_7 (Mtp)	4.5	46.8	35.5	17.2	$P^{II}3^2$; m. loessy, s. sandy, m. leached clay
36.85–37.15	L_3	18.7	35.4	49.5	14.4	$AL^{II}3^6$; m. clayey, s. sandy, m. limy loess
40.15–40.30	t_8 (PD_1)	9.4	45.2	49.0	5.4	$AL^{II}6^4$-h; h. clayey, +s. limy loess
41.90–42.10	L_4	20.2	37.8	55.4	6.3	$AL^{III}3^7$-h; m. clayey, h. limy loess
43.35–43.55	t_9 (PD_2)	11.5	44.5	45.8	9.1	$AL^{II}6^5$-h; h. clayey, s. limy loess

t_1–t_9 = paleosols (pa); l_1–l_6 = young loess; L_1–L_4 = old loess; h_1 = humic sand; P = clay (pelite), < 10 micron; AL = aleurite (fine + course silt) 'fraction of loess', 10–50 micron; Ps = psammite (sand), > 50 micron; -h = sand content, < 10 wt%; +s = very slight; s = slight; m = medium; h = heavy; + h = very heavy. The CAPITAL-letters (e.g. AL) = the dominant grain-size class (highest wt% values) the sediment is named of; latin exponent = wt% value of the dominant grain-size class (AL^{I} = 30–40; AL^{II} = 40–50; AL^{III} = 50–60; AL^{IV} > 60%); arabic numbers = wt% value of the other two grain-size classes (1 = s/s, 2 = s/m, 3 = m/s, 4 = m/m, 5 = s/h, 6 = h/s); (+5 = < 10 wt%, s = 10–25 wt%, m = 25–40 wt%, h ≤ 40 wt%) arabic exponent = calcium carbonate content: 2 = 3–5; 4 = 7–10; 5 = 10–13; 6 = 13–19; 7 = 19–22; 8 = 22–25; 9 = > 25 wt%

Mineral and chemical composition

The *mineral composition* of loesses varies with horizons as well as with regions and simultaneously in the different grain-size classes of loesses different elements may occur in various percentages.

In the coarse medium sand fraction, *quartz* predominates (70–80 weight percentage). In the coarse and fine silt (aleurite) fraction, in addition to quartz (30–50%), micas and chlorite (4–10%) and heavy minerals (1–6%) occur.

In the granulometric composition of typical loess 10–25 weight percentage is represented by clay particles below 10 micron size.

In this pelitic fraction of loess *clay minerals* are predominant: illite (10–30%), montmorillonite (5–15%), kaolinite (1–5%), chlorite (2–10%) and vermiculite (1–2%). Within the coarse clay (0.6–2 micron) and in medium clay (0.2–0.6 micron) illite is the most important constituent (15–35%). Fine clay (< 0.2 micron) mostly contains montmorillonite–smectite (15–50%).

In non-typical loess and loess-like deposits the amount of clay particles can be remarkably larger or smaller, e.g. in the sandy loess it is 5–15 weight percentage, while for clayey loess the share of clay fraction amounts to 25–40 weight percentage. Paleosols buried in loess and clay may show even higher percentages. The differences in the quantity and quality of clay minerals in loess horizons and between loess and paleosols have been recently interpreted as indicators of cyclical climatic changes (Liu, T. 1985). Loess may have certain small amounts of pyrite (0.2–1.5%), iron oxide–hydroxide (2–3%) and also include some organic matter (0.1–0.3%).

In the coarse silt fraction about forty species of *heavy* and *light minerals* are present. Most of them are not locally formed (allogenic) minerals, thus inform about the source of the silt material. Some authigenic minerals (limonite, pyrite and calcite) developed *in situ*. Among the scientists who have analyzed heavy minerals, many have drawn attention repeatedly to the close correlation between the mineral compositions of rocks outcropping in the environs. Thus, the heavy minerals usually do not originate from a great distance.

Within individual loess profiles and also regionally there are differences of various scale in *chemical composition*. Some look for the reason in the differences of the accumulation of the original mineral material of loess. Others associate the deviation with subsequent transformations, locally differentiated weathering processes. During subsequent or simultaneous loess weathering Fe_2O_3, Al_2O_3, MgO and SiO_2 may be relatively enriched, while through leaching the amounts of CaO and Na_2O are usually reduced or concentrated in some layers, forming concretions.

Carbonate content is one of the most important and characteristic properties of loess. A certain amount of carbonate can be regarded as a criterion of (typical) loess.

'Carbonate-free loess' is not loess but loam of similar properties. The $CaCO_3/CaSO_4$ ratio is explained by the minerals of loess, which are typomorphous over the steppe zone and in its soils.

To explain the substantial *forms of carbonates* in loess (calcite and dolomite), various opinions have been put forward: (1) part of the carbonate content is *primary*, accumulated parallel with the rest of the silt mass; (2) the origin of *secondary* carbonate is partly explained by geochemical processes or is due to the activity of microorganisms. On the other hand, the Ca ions released during the weathering of felspars may combine with CO_2 from soil and groundwater to form *in situ* carbonate minerals; (3) there has been a combination of various factors acting at different times syngenetically or post-genetically during loess diagenesis.

$CaCO_3$ and $MgCO_3$ may be present in a variety of forms such as concretions of various size, typical nodules (so-called *loess dolls, Männchen, Puppen*), layers of lime accumulations such as limestone bands, and *caliche*, underlying fossil soil horizons or overlying impermeable layers, further in incrustations and membranes, granules, powdery spots. All the above-mentioned forms are secondary, due to the concentration of migrating lime-bearing solutions. Primary forms of lime include minute grains, incrustations on silt-size grain aggregates and snail shells.

The carbonate content of loess and the forms in which it is present are mainly functions of the geographical environment, particularly of atmospheric precipitation and relief. In dry regions, the lime content is generally higher, and there are more horizons of lime accumulation than in the loess areas with heavier rainfall, whereas the clay mineral content exhibits a contrary trend. In some loess areas, the carbonates may have been removed by subsequent leaching.

Lithological properties of loess and fabric of grains

The lithological properties of loess are largely controlled by the above discussed grain size distribution, mineral and chemical composition as well as by the biogenic and abiogenic processes having taken place during and after the accumulation of the mineral mass. The characteristic features of loess are colour, fabric, carbonate content, cementation, aggregation and moisture content.

1) *The colour of a typical (true) loess* is mostly yellow, pale yellow or occasionally greyish yellow. In wet condition its colour on the Munsell scale is 2.5 Y 5/4–6/4–7/4–8/3. When dry its colour is usually lighter because, for example, when dry loess bluff is long exposed to sunshine the carbonates (and the salts, too) precipitate.

Loess varieties may be of brownish yellow, brown, brownish pink or slightly yellowish pink tint. Locally and in some horizons spots caused by manganese, iron precipitations and carbonate concretions and root remnants are visible. The moderately or strongly weathered loess or loess loam are usually of darker colour than the typical loess. The colouring of loess is also influenced by various local factors.

2) Typical loess, more precisely the individual loess horizons, is characterized by the *lack of stratification.* The vertical profile of a loess sequence may comprise loess horizons of different colour and grain size composition with intercalated buried soils, sand or, locally, layers other than loess. In this sense, the *loess sequence* is subdivided into stratigraphic units or groups, *series,* even though usually there are *no sharp boundaries between layers.* Erosional hiatuses are seldom visible to the naked eye. The unstratified nature of loess means that the fabric of grains show no discernible orientation in the particular horizons. While in sedimentary rocks grains are arranged clearly in a given direction, in a loess series no such regularity can be recognised.

3) An important property of the loess fabric is the *adhesion of grains* which is due to *cohesion* and *cementation.*

Surficial energy, hygroscopic water envelope and the surface tension of capillary pressure are contributing factors to *the cohesion of grains* which is also influenced by grain structure, mineral composition, moisture content and porosity.

The *cementation of grains* is secured by a binding material which primarily is calcareous coating, i.e. calcareous contact cement around the grains and calcareous pore cement filling up the voids. Sometimes iron precipitations occur.

4) *Typical loess is characterized by high porosity.* Its void ratio may amount to 45–60 per cent. The pores between solid particles are filled by air or water.

The void ratio is largely controlled by carbonate content. Void ratio in carbonate-free loess loam is low (ca 20 per cent). The porosity of a young loess is generally higher than that of the old loess.

Loesses with high void ratio – particularly in the case of water saturation – are more liable to collapsing and sagging than those of lower porosity.

Loess is susceptible to environmental changes. Its porosity decreases with the increase of precipitation and similarly with artificial irrigation. With reduced porosity, the tendency for collapsing diminishes or ceases.

5) *The moisture content of loess* is usually 14–22 per cent and is of ephemeral nature. The amount of moisture is controlled zonally by environmental conditions. Moisture in loess profiles fluctuates seasonally at 1–3 m depth and at 10–15 m depth there is a 'dead horizon'. The moisture content within the loess profile changes with the variation of grain size and the degree of porosity, particularly on the boundaries of horizons with higher clay contents.

6) Resulting from cementation and adhesion of the finest grains the fabric of loess is characterized by the *presence of aggregates* of mostly 10–50 micron in diameter. Whereas some experts associate the formation of the aggregates partly with the deposition of grains, others explain it with diagenesis subsequent deposition. Still others doubt the

existence of aggregates in the loess, in spite of the fact that particles swell to 10–50 micron size because of $CaCO_3$ hydratation. Moreover, the adhesion of clay minerals in loess also promotes aggregate formation.

Classification and genesis

Loess has been classified according to several different points of view, but a comprehensive system is still lacking.

The most comprehensive classification is that according to *grain size distribution* in some combination with carbonate content *(Tab. 1)*. On this basis, *typical loess* is distinguished from *loess-like deposits* such as sandy loess, loess loam or adobe, clayey loess. These terms bear no genetic connotation. Loess and loess-like deposits are fairly often classified according to their genesis, mostly in some combination with a classification by grain size.

According to their orographic position and particular lithological associations, *plain loess, platform loess, hill loess* and *mountain loess* are sometimes distinguished.

A prerequisite to any genetic classification is the knowledge of the origin of loess which has, however, been a subject of heavy debates for over a century.

Opinions as to the processes resulting in the formation and accumulation of the silt fraction forming the basic parent material of loess are widely divergent. Most authors agree, however, that the process of evolution which turns the silt into loess is a diagenetic one. The diagenetic process is interpreted in a number of different ways. Some consider it a siallite–carbonate type of weathering process leading up to a loess loam enriched in alkali cations which then turns into loess owing to steppe-type pedogenic processes involving leaching of Na and K ions and enrichment of Ca and Mg carbonates. The diagenesis is contingent upon certain environmental conditions. Optimum conditions of loessification are considered to prevail in the warm steppe zone marginal to the deserts ('warm loess') and to have prevailed in the cold-steppe and wooded-steppe zones of the Pleistocene periglacial regions ('cold loess'). This is corroborated by periglacial phenomena, plant and animal remains, human artifacts, etc., preserved in the loess, and is compatible with the paleoecological conditions reconstructed from all the available evidence. Under any conditions that differ, more or less, from the steppe environment, the original silt material became turned into a *loess-like deposit* (loess derivate) such as mountain loess, a loam or adobe, clay, etc., rather than a true loess.

Whenever the optimum conditions of loess formation deteriorated, the epidiagenetic alteration of the loess took over. This way, the loess layers formed over numbers of episodes (semiarid, cold cycles) in the Pleistocene periglacial regions, and today constitute complex loess profiles, having been repeatedly altered and redeposited under a succession of different climatic phases. Their original characteristics are thus understandably difficult to reconstruct.

This is why the usual statement that typical loess is unstratified and eolian in origin cannot be taken as an unambiguous generalization. For a number of loess-like loams it is impossible to tell today whether these formations represent a syngenetic type of regional connotation or an epidiagenetic facies of loess.

The most common *syngenetic loess varieties* are the regional facies of loess, such as *brown loess, flood plain infusion loess* and *decalcified glacial loam*. The *sensu stricto epi- or postgenetically altered loesses* are classed e.g. as *reductional grey loess, rusty oxidational loess, decalcified loess, compact old loesses etc.*

Most of the almost hundred *theories of loess origin* are concerned with the developing the silt-size grains, transportation, sorting and accumulation of it. A smaller part of explanations deal with the comprehensive environmental processes of loessification. The heterogeneity of views is partly attributable to the differences in the properties of the studied loess region and partly to the variations in the methods, approaches and other circumstances of investigations.

The major and most generally favoured hypotheses are the following.

(1) In the first half of the last century loess formation was held to be a *flood-plain deposit from fluvial action*. This theory was elaborated and supported by Ch. Lyell (1834). Other explanations of loess, such as a marine or lacustrine deposit, also occurred.

(2) It was the French Virlet d'Aoust (1857) who first advocated the *eolian origin of loess*. At that time, relying on his experience in Europe, even Richthofen regarded loess a fluvial deposit and only changed his view on the origin of loess after his journey to China. However, along with the action of wind in the accumulation of loess material, Richthofen always mentioned the role of wash from runoff and rainfall in his later works.

Obruchev identified two types: '*warm*' and '*cold*' *loess* (Obruchev, V. A. 1945). In the zone of 'warm' loess he assumed dust transported by winds from deserts and accumulated in wind shadow. The mineral material of 'cold loess' was also transported by winds from the marginal areas of one-time ice-sheets, out of till and fluvioglacial deposits, to their present locations. There are both supporters and critics of this theory of cold periglacial and warm desert-margin loesses established by Obruchev.

Winds during glacial times undoubtedly played a major role in transportation of dust and sand-size grains; during the Pleistocene periglacial periods, this eolian activity covered much larger regions than today. This is confirmed also by the widespread wind-blown sand dunes, innumerable ventifacts and thin layers of volcanic ash. Although the loesses formed by eolian accumulation, particularly the typical loess of the plateaus, cover fairly vast regions, there is abundant evidence for accumulation by other sedimentary processes. These other facies occur intercalated in the loess profiles as well as independently in space.

(3) There is a long history of attempts to *combine the fluvial theory with the eolian one*. According to B. Willis (1907), the loess deposits of the Chinese Plain were accumulated by the Huanghe as fluviatile silt during the summer period and they were reworked by wind in autumn and spring.

(4) At the end of the last and early in this century some held the opinion that *sheet-wash and meltwater* played a predominant role in the accumulation of the mineral material of loess. After Richthofen this view was propagated most intensively by the Russian A. P. Pavlov. His theory is grouped with the *deluvial explanations of loess origin*.

Over the slopes of hill regions the fine material deposited by wind was redeposited by solifluction and wash by meltwater and rainwater (or their joint effect – as covered under the collective name of *derasion* by Pécsi, M., 1965). These kinds of loesses, mostly rhythmically stratified parallel to the slope, are considered to be of *eolian-nival or eolian-fluvionival origin*. Such loesses filling dells or minor valleys, are sometimes called 'valley loess'. Collectively, these deluvial-colluvial loess types appear as *derasional loess* on the loess map of Europe (Fink, J. *et al.* 1977).

(5) The theory about the *glacial-fluvioglacial origin of loess* also dates back to the last century (Leverett, F. 1886; Tutkovski, P. A. 1900). In this theory the fine debris comminuted by glaciers or ice-sheets was accumulated by fluvioglacial waters. Complementing this theory with the eolian and fluvial explanations of loess origin, some (Smalley, I. J. 1975) attempted to establish a complex explanation.

(6) *Loess is a product of soil formation.* L. S. Berg's (1964) theory is based on the fact that in most of the cases the traces of soil formation are recognizable in the loess, locally or by horizons, occasionally rather poorly, but elsewhere – as in the case of paleosols – more strikingly. He regards loess a periglacial dry steppe soil or a warm semiarid steppe soil respectively.

(7) According to the *polygenetic theory* (Kriger, N. I. 1965, Pécsi, M. 1965), the basic material of loess may have accumulated as the result of any of the following processes: eolian, deluvial, fluvial, proluvial, fluvioglacial, gravitational, eluvial and pedogenic. In different areas and periods, these processes may have acted in different combinations. The dust fraction constituting a substantial part of the thick loess blankets and consisting largely of typical loess was transported into its present position by eolian and deluvial processes. In the course of loessification, pedogenic and geochemical processes have undoubtedly played a decisive role.

Recently, this *environmentalistic concept of loess formation* has been put forward. Its proponents emphasize *the role of the physical environment* instead of the circumstances of sediment accumulation. According to them, the properties of loess depend on the Pleistocene and present-day geographical environments.

As an oversimplification, it is often stated in literature that the eolian theory of loess formation is hardly questioned by anyone nowadays. In reality, however, many major loess profiles appear to indicate that the mineral material was accumulated by different processes and it was affected by cyclically different paleogeographic influences.

Chronological subdivision of loess–paleosol sequences

The loess–paleosol sequences, the periglacial phenomena in some loess horizons, the sand intercalations and the traces of animal life undoubtedly allow the best opportunity for the reconstruction of Quaternary cyclical climatic and paleogeographical changes and chronology. The basic principle is that the conditions of formation should be identified, loess strata represent cold and dry climates, while paleosols indicate relatively warmer and wetter paleogeographical conditions. Thus the loess strata correspond to glacials and the paleosol horizons to interglacials or interstadials. This approach tries dating through comparison with a climatic-historical or other Quaternary chronological time-scale.

This *concept of loess–paleosol stratigraphy* is a usual approach, but it is too general. In the particular cases several other characteristics of the loess profiles, their complete bio- and lithostratigraphical composition or geomorphological position and various absolute chronological analyses also have to be taken into account.

By interruptions of the sedimentary record due to erosion, usually on uplifted loess plateaus and on foothill slopes, the loess sequence includes less stratigraphic units here than in basins which have subsided constantly over the Quaternary. The sequence of 'sediment traps' can generally be better subdivided. The erosion gaps in loess sequences represent dominantly more humid episodes, intervals of interglacial stages.

It has to be emphasized that loess–paleosol formation has not been continuous in every loess region over the last glacial cycle (ca 130–10 ka B.P.). Within some loess regions the young loess mantles were formed only during the maximum and late stages of the last glaciation (25–12 ka B.P.). The loess sequence of the Loess Plateau of China exhibit the quasi most complete stratigraphic subdivision. In some key profiles 24–37 loess horizons and an equal number of paleosols are counted. From the various chronological investigations it was believed that all the glacial and interglacial stages during the Pleistocene epoch can be identified in some Chinese loess–paleosol sequences (LIU, T. 1987, DING, Z. et al. 1991). According to this calculation the oldest loess formation has been originated 2,4 M years ago (Quaternary/Neogene boundary). But the typical loess occurs ca since 1 M years ago. Previously the formation of loess-like deposits, intercalated by variegated clays and mainly with reddish paleosols were characteristic (as on the Loess Plateau of China, in Central Asia, on the Siberian Loess Plateau, in the south Russian Plain and in some Middle European profiles below the old loess sequences, PÉCSI, M. 1993).

The paleogeographic conditions before 1 M years did not favour typical loess formation. Soil formation was predominant after and other cold spells were less marked. The deeper, older series of the exposures of these subaerial deposits usually consist of pink silt subseries alternating with or underlying red–earth paleosols, which were effected by subtropical paleoecological environment.

SELECTED REFERENCES

BERG, L. S. 1964. Loess as a Product of Weathering and Soil Formation Jerusalem, I.P.S.T., 207 p. (translated from Russian)

DING, Z.–RUTTER, N.–LIU, T.–EVANS, M.E.–WANG, Y. 1991. Climatic correlation between Chinese loess and deep-sea cores: A sructural approach. In: LIU, T. (ed.): Loess, envirinment and global change. Beijing, Science Press. 168–186.

DODONOV, A. E. 1987. Geochronology of loess in Central Asia and Quaternary events. In: PÉCSI, M.–VELICHKO, A. A. (eds.): Paleogeography and loess. (Studies in Geography in Hungary 21.) Budapest, Akadémiai Kiadó, 65–74.

FRENZEL, B.–PÉCSI, M.–VELICHKO, A.A. (eds.) 1992. Atlas of Paleoclimates and Paleoenvironments of the Northern Hemisphere, Late Pleistocene–Holocene. Budapest, Stuttgart, Geogr. Research Institute & Fischer Verlag. 153 p.

JOHNSON, W.H.–FOLLMER, L.R. 1989. Source and origin of Roxana Silt and Middle Wisconsinan Midcontinent glacial activity. Quaternary Research 31. 319–331.

KRIGER, N.I. 1965. Loess, yego svoystava i svyaz' s geograficheskoy sredoy. Moscow, Nauka. 295 p.

KRIGER, N.I.–PÉCSI, M. (eds.) 1987. Engineering geological research of loess and loess-like sediments in the USSR Budapest. Budapest, Geogr. Research Institute. 144 p. (Rich Russian references)

KUKLA, G.J. 1970. Correlation between loesses and deep-sea sediments. Geol. Fören. Stockholm Förhandl. 92. 148–180.

LEVERETT, F. 1886. The loess of western Illinois and south–eastern Iowa. Science 3, 54–55.

LIU, T. (ed.) 1985. Loess and the environment. Beijing, China Ocean Press, 251 p.

LIU, T. (ed.) 1987. Aspects of loess research. Beijing, China Ocean Press, 447 p.

LOŽEK, V. 1990. Molluscs in loess, their paleoecological significance and role in geochronology-principles and methods. Quaternary International 7–8. 71–79.

LYELL, C. 1834. Observations on the loamy deposit called 'loess' of the Basin of Rhine. Edinburgh New Philosophical Journal 17. 110–122.

OBRUCHEV, V.A. 1945. Loess types and their origin. Am. J. Sci., 243 (5).

PAVLOV, A.P. 1888. Geneticheskie tipy materikovykh obrazovaniy lednikovoy i poslelednikovoy epokhi. Izv. Geol. Kom., Moscow, 243–263.

PÉCSI, M. 1965. Genetic classification of the deposits constituting the loess profiles of Hungary. Budapest, Acta Geol. Hung. 9. (1–2) 65–84.

PÉCSI, M. 1993. Quaternary and loess research. Loess inForm 2. Geogr. Res. Inst. Hung. Acad. Sci., Budapest, 82 p. (Rich references)

PYE, K. 1987. Aeolian dust and dust deposits. London, Academic Press. 334 p.

RICHTHOFEN, F. 1877. China Vol. I. Berlin, Dietrich Reimer. 758 p.

RUSSEL, R.J. 1944. Lower Mississippi valley loess. Bull. Geol. Soc. Am., 55. 1–40.

SASAJIMA, S.–WANG, Y. (ed.) 1984. The recent research of loess in China. Stratigraphy, magnetostratigraphy, chronology, pedology, paleontology and paleoclimatology. Kyoto, Kyoto Univ. and Northwest Univ. 242 p.

SMALLEY, I.J. (ed.) 1975b. Loess: Lithology and genesis. Stroudsburg, Dowden, Hutchinson and Ross. 430 p.

SMALLEY, I.J. 1980b. Loess. A partial bibliography. Norwich, Geo Abstracts, 103 p.

TUTKOVSKII, P.A. 1900. M. Paul Tutkovskii on the origin of loess. Scottish Geographical Magazine 16. 171–174.

VELICHKO, A.A. 1990. Loess paleosol formations of the Russian Plain. Quaternary International 7–8. 103–114.

VIRLET, D'AOUST, P. Th. 1857. Observations sur un terrain d'origin météorique ou de transport aérien qui existe au Mexique, et sur le phénomène des trombes de poussière auquel itdoit principalement son origine. Geol. Soc. France, Full., 2d ser. 2. 129–139.

WILLIS, B. 1907. Research in China. Carnegie Inst. of Washington Publ. 54. 183–196, 242–256.

ZHANG, Z.–ZHANG, ZH.–WANG, YU. 1991. Loess deposit in China. Geological Publishing House, Beijing, 202. p.

Loess inForm

Informative publication about the loess investigation

Vol. 1.

N. I. KRIGER–M. PÉCSI. Engineering geological research of loess and loess-like sediments in the USSR. Budapest, 1987.
Geographical Research Institute HAS. 144 p.

Price 10 USD

Vol. 2.

M. PÉCSI. Quaternary and Loess Research. Budapest, 1993.
Geographical Research Institute HAS. 82 p.

Price 6 USD

Vol. 3.

M. PÉCSI.–F. SCHWEITZER (eds). Concept of loess, loess-paleosol stratigraphy. Budapest, 1995.
Geographical Research Institute HAS. 94 p.

Price 6 USD

ORDER FORM

Please send it back to: Geographical Research Institute Hungarian Academy of Sciences, Budapest H–1388 P.O.Box. 64. Hungary Fax: 36-1/131-79-91

Price: see above + postage surface mail 2 USD
Please send me .... copy (ies) of **Loess inForm**

Cheque to be sent to: Hungarian Nat. Bank. H-1850 Acc. name: MTA FKI. Acc. No. 232-90171-7341, indicating the title of the publication

Name...

Address...

City..Country..

Date,...Signature..

Loess inForm 3. 1995. pp. 23–30.
Geographical Research Institute Hungarian Academy of Sciences

LOESS STRATIGRAPHY AND QUATERNARY CLIMATIC CHANGE

PÉCSI, M.

Geographical Research Institute Hungarian Academy of Sciences, H–1388, Budapest, P.O. Box 64.

Introduction

The loess sequences with intercalated paleosols, the periglacial phenomena in some loess zones, the cycles of sand horizons and traces of animal life undoubtedly allow the best opportunity for the reconstruction of Quaternary climatic and paleogeographical changes. The basic principle is that the conditions of formation of a given strata should be identified for and related to the various Quaternary (climatic, litho-, bio- or chrono-stratigraphical) time-scales.

In order to date the various loess horizons in a profile, to evaluate paleogeographical events this opportunity has been made advantage of by many since long and the approaches (principles and methods) also vary. Loess stratigraphy is held to be a very suitable framework for the identification and dating of Quaternary climatic changes.

The paleogeography of the Quaternary is the subject of several disciplines – traditionally the geoscienses in a broader sense, astronomy and recently also physics, (isotopic) chemistry and archeology. This serves to underline the intricacy of loess stratigraphical analyses and the inherent difficulties.

Strongly simplified, the dates of loess sequences are established on the basis of the alternation of loess horizons and paleosols. Loesses represent cold and dry climates, while paleosols indicate relatively warmer and more humid paleogeographical conditions. Thus in the loess sequences, the loess and paleosol horizons point to glacials, interstadials or interglacials. This approach tries dating through comparison with a climatic or other Quaternary chronological time-scales.

Although correct, this approach is too general and its application has its constraints. In the particular cases several other characteristics of the layers, their stratigraphical or geomorphological position and the various time-scales also have to be taken into account.

The problems in the identification of Quaternary climates and paleogeographical changes and in loess stratigraphy are treated in this paper.

Problems in climatic reconstruction and loess stratigraphy

1) In the process of loessification, the development of loess fabric, the role of zonal, regional and partly of local environmental factors is regarded decisive (PÉCSI, M. 1990a). In the loess sequences various genetic types of loess pockets and paleosols occur and reflect different climatic and paleogeographical conditions.

During the Quaternary in the superzone of potential loess formation and distribution various paleogeographical zones (tundra steppe, cold steppe, warm steppe, forest steppe, board-leaved forest, coniferous forest and grove zones) and regions dominated (KRIGER, N. I. 1984; PÉCSI, M. 1990b; VELICHKO, A. A. 1987). As a consequence, even within a single profile the colour, grain size and mineral composition, $CaCO_3$ content, degree of weathering and fabric of loess may vary. Zonal, regional or even local variations in such loess properties may equally derive from syngenetic or postgenetic processes. For similar reasons, spatially and temporally different forms, types and subtypes of paleosols also developed.

This way loess and soil formation resulted in various spatial types in the same glacial, interstadial or interglacial phase within the various geographical zones and regions (PÉCSI, M. 1992). Although there exist major loess regions where the interglacial soils (e.g. brown forest soils) are markedly distinct from interstadial steppe soils or from other types of steppe soils, continental loess areas can also be observed in areas where the paleosols developed under interglacial and interstadial conditions (e.g. steppe or forest steppe soils) cannot be referred into different genetic types. In such cases the changes in paleoenvironments are difficult and uncertain to reconstruct (PÉCSI, M. 1991, 1993, *Tab. 1*).

The interregional correlation of paleosols is occasionally hindered by the various nomenclatures applied.

2) Among other problems, there are uncertainties concerning the dating and identification of paleoenvironments of polygenetic soils and of soil complexes consisting of double and triple soils: how many phases of soil formation they represent and how long erosional phases should be reckoned with between periods of soil formations.

– The number of loesses and paleosols in the Quaternary sequences is often closely related to the geological and geomorphological position of sediment series. In previous papers (PÉCSI, M. 1991; PÉCSI, M. and SCHWEITZER, F. 1995) it was emphasised that the frequent erosion gaps in loess profiles exclude the reconstruction of some paleoclimatic events. Particularly on uplifted loess plateaus and on foothill slopes the sequence includes less stratigraphic units than in basins which have been subsided continuously over the Quaternary. It also happens that in basins of Quaternary subsidence the number of loess, sandy and paleosol horizons is twice as high as that of the loess–paleosol units on plateaus or on foothill surfaces. The sequence of sediment traps can usually be better subdivided.

3) Under such circumstances the paleoclimatic reconstruction of loess–paleosol sequences reveals major (inter)regional variations, also in the length of the formation period.

Nevertheless, the circumspective evaluation of lithostratigraphic units provides the framework for outlining the succession of climatic changes. Important information on certain climatic types (cold and dry or cold and humid phases) may be gained from the traces of frost phenomena in the zones of cold loess, buried dells and river terraces as well as the investigation of the paleogeographic environments of various life traces etc. The time sequence of past events can be established from the lithostratigraphic framework with some probability.

What kind of timescale has to be used to correlate the paleogeographic succession of loess profiles?

1) Among the Quaternary time-scales of cyclical climatic changes – because of the different methods and approaches applied – there are major differences. The International Committee for Stratigraphic Correlation drew the Neogene–Quaternary boundary in a marine sequence (Vrica, Calabria) at 1.8 Ma. However, previous opinions and time-scales applied survive which consider the total interval of continental glaciation during the Quaternary shorter than 1 million years, while others date pre-Günz (mainly mountain) glaciation back to 2.4–3 Ma B.P., primarily relying on terrestrial paleontological evidence. Recently the Neogene–Quaternary boundary is associated with the Matuyama–Gauss paleomagnetic reversal, which is held to be identifiable in terrestrial sediments, loess–paleosol sequences.

There is still much uncertainty about which of the repeated cold and warm Quaternary climatic phases represent true continental glaciation or complete interglacial warming and about where and to what extent their paleogeographical conditions differ from the stadial or interstadial circumstances.

– Our experience shows (PÉCSI, M. 1987, 1991, 1993) that in the loess–paleosol sequences of the Pleistocene periglacial ('cold loess') zone layers which can be called true loess (i.e. not loamy clays or paleosols) do not occur before the Jaramillo paleomagnetic event (ca 1 Ma). In this period, and also prior to that, cyclic climatic changes were marked, but the conditions do not seem to have been favourable for loess formation. Over a long period soils formed superimposing each other, only separated by lighter-coloured horizons of $CaCO_3$ accumulation.

– In the zone of 'warm loesses', for instance in Central Asia and on the Loess Plateau of China these formations are mentioned as stony loess, Lishi loess or Wucheng loess series (DODONOV, A. A. 1987; LIU, T. [ed] 1987). The Wucheng formation mainly consists of alternatiing loamy clay and paleosol layers and it is underlain by true red clays superimposing each other. The subtropical red soils under the loess–paleosol sequence are dated paleomagnetically as formed in or even before the Gauss epoch (3.5–2.4 Ma).

– The red clay series underlaying the loess formation and the series of reddish-brown and variegated clays between old loesses can be traced not only in the zone of 'warm loesses' but also along the southern Pleistocene periglacial zone. From the lithological character of the horizons and from the types of paleosols a gradual transition of paleogeographic conditions (characterised by subtropical dry and humid seasons) can be observed with warm, subsequently moderately and finally with typical temperate continental climates. In this transitional period (ca 2.4–0.9 Ma) cyclical climatic changes were also characteristic with an alternating domination of dry continental and humid oceanic (monsoon) influences. It is explained by occasionally intensified overland flow that in part of the profiles soils superimpose each other.

The various interpretations of the climatic sequences of stratigraphic units in loess profiles and the concept of the longer or shorter duration of the Quaternary may cause major variations in the interregional correlation of the longer or shorter profiles. Consequently, in some cases the establishment of the sequence of climatic changes only allows a schematic correlation with some Quaternary time-scales.

2) Most of the *Quaternary time-scales* used in loess stratigraphy reflect only the time sequence of climatic changes and their impacts (e.g. the time- scale of radiation changes by Milankovich, the $0^{18/16}$ ratio in deep-sea deposits, changes of magnetic susceptibility in loess-paleosol sequences and changes of CO_2 pressure in the air bubbles of polar ice layers).

The joint consideration of the paleomagnetic time-scale and other (supplemented and revised) chronological time-scales for the Quaternary is equally indispensable as calculations about the rate of deposition. This essentially calls for the adjustment of Quaternary time-scales in order to draw realistic correlation between datings of loess profiles and events in climatic history.

3) The *climatic interpretation* of the horizons of various type and quality, cyclically repeated *in the loess profiles* indicates that in most of the loess regions repeated loess and soil formations and the corresponding climatic phases occurred during the last two 'glacial cycles'. In the loess profiles classed with Würm glacial there are 12–18 horizons

or levels of periglacial phenomena (PÉCSI, M. 1991, 1993, *Tab. 2*), it was assumed that the absolute ages of horizons which belong to the Würm glacial cycle could be determined (with good approximation) in the well-studied key loess profiles.

Some of Milankovich's followers calculated 14 to 18 climatic type changes for the last glacial cycle and also provided these data in the form of a climatic calendar (BACSÁK, Gy. 1942, 1955; BARISS, M. 1991). According to KUKLA, J.G. and LOŽEK, V. 1961, within the B loess cycle (Würm glacial), 6 climatic phases are repeated 3 times, so 18 lithological units can be identified. According to oxygen isotope stratigraphy, over the last 120 ka altogether12 major climatic changes can be recorded from marine deposition phases (5 stadials and 7 substadials). In the peat profiles of Grand Pile 20 pollen spectrum changes represent the Würm glacial (WOILLARD, G. M. 1978).

It seems probable that the *number of lithological units* formed during the Würm glacial cycle (12 to 18) and the combinations of climatic type changes calculated by various techniques (according to BACSÁK, Gy. 1942, 1955: glacial, antiglacial, subarctic and subtropical; according to BARISS, M. 1991: strongly oceanic, strongly continental, moderately oceanic and moderately continental climatic types) (12 to 20) show very similar values by loess regions (PÉCSI, M. 1993, *Tab. 2*).

Consequently, in young loesses the bio- and lithostratigraphical reconstructions indicate several repeated climatic types (not just cold and warm phases). In the younger loess profiles (cycles B and C after KUKLA, J. G. 1970) ample evidence is found for lithological and climatic changes, but their recognition and tracing in old loesses is highly problematic and as yet cannot be implemented.

4) In the lower part of *old loess cycles* mostly 1 or 2 colder and dry and 1 or 2 warmer and more humid climatic phases can be reconstructed. Their correlation with the glacials and interglacials on any time-scale is also not easy. Fixed chronological points (e.g. the Brunhes/Matuyama boundary) have to be found in the profile and one has to reckon with the erosion gaps frequent in loess profiles. The lithostratigraphy of the particular profiles has to be compared to several Quaternary timescales.

Based on tentative datings calculations and on the time-scale of radiation changes by MILANKOVICH, the trials aiming at an interregional correlation of loess profiles and at a climatic reconstruction will be over simplification.

An attempt has been made to correlate the paleosols with the climatic intervals of the solar climatic type calendar by MILANKOVICH (1930) and BACSÁK (1955) presumably favourable for soil formation. In the procedure the circumstance was taken as decisive that the Brunhes/Matuyama boundary (0.73 Ma) regularly occurs in old loess under the paleosol PD_2 in the Paks brickyard profile in Hungary (in PÉCSI, M. 1993. *Figs 1, 2 and Tab. 1*).

For the chronostratigraphical subdivision a lithostratigraphical profile was selected where probably the least number of gaps are found. No such profile could be identified where no hiatus occurred. For the same reasons the paleosols in the loess profiles are not

Table 1. Subdivision of the upper and lower series of loess in Hungary (after PÉCSI, M.)

Name	Index	Age in ka	Identification
recent soil	0	0–11.3	chernozem, locally brown earth
Upper part of young loess (Dunaújváros–Tápiósüly series)			
humous horizon 1	h_1	16–17 presumably W_3	humous horizon
humous horizon 2	h_2	27–32 pres. W_2/W_3	humous horizon
Lower part of young loess (Mende–Basaharc series)			
Mende Upper 1	MF_1	45–60 pres. W_2/W_3	forest steppe soil
Mende Upper 2	MF_2	85–105 pres. W_1/W_2	forest steppe soil
Basaharc Double 1	BD_1	120–140 pres. R_2/W_1	forest steppe soil
Basaharc Double 2	BD_2	150–170 pres. R_2/W_1	forest steppe soil
Basaharc Lower	BA	195–230 pres. R_1/R_2	forest steppe soil, locally as soil complex
Upper part of old loess series			
Mende Base 1	MB_1	280–310 pres. MR_3/MR_4	forest steppe soil
Mende Base 2 + sand in underlying layer	MB_2 + sa	320–360 pres. MR_2/MR_3	polygenetic brown earth complex
sandy humous soil of Paks	$Phe_1 + Ph_2$	360–380 (MR_1/MR_2) 440–460 (M_1/M_2)	forest steppe soil
hydromorphous soil of Paks + sand	$Mtp_1 + Mtp_2$	480–500 pres. G/M	hydromorphous soil + fluvial sand
Lower part of old loess in the Paks series			
Paks Double 1	PD_1	565–585 pres. G_1/G_2	warmer forest steppe soil (chestnut)
Paks Double 2	PD_2	600–630 pres. G_1/D_3	warmer forest steppe soil (chestnut)
Brunhes/Matuyama boundary in L_5	B/M	730 pres. Danubian glaciation (D_3)	old loess (L_5)
Paks–Dunakömlőd soil complex	PDK	750–765 pres. D_1/D_2	warmer forest steppe soil (chestnut)
old loess L_6	L_6'–L_6'''	750–900? pres. D_1 glaciation	old loess series in Paks

numbered continuously (like S_1, S_2 etc.), since their sequence – because of erosional gaps – does not always reflect the same stratigraphic or chronological position. Paleosols are marked with indices according to the locality of their best development and to their pedotypes.

Conclusions

1) The so called *loess–paleosol stratigraphic procedure* is only capable of providing *an approximative loess-chronology* with general information.

The detailed analysis of the three dimensional position of loess profiles call for a principle that under different geomorphological, geotectonic and paleoecological conditions essentially different loess-stratigraphical and chronostratigraphical sequences develop during the same geological period. Consequently, the stratigraphic units in loess profiles closely correlate with the joint influence of cyclical climatic changes and geomorphic position.

2) The Pleistocene climatic time-scale thus created essentially reflects changes on Milankovich's radiation curve. For the dating of the lithostratigraphical units of loess profiles the oxygen isotope time-scales (SPEPMAC) are increasingly used. Morever, the cold and warm intervals on Milankovich's radiation curve and on the oxygen isotope curve do not coincide with sufficient precision. Occasionally, there are considerable shifts. According to the radiation curve of Milankovich over the last one million years the environment of North Europe was favourable for soil formation on many occasions.

The number of paleosols recorded in almost complete loess profiles of Eurasia was also 8 to 10 above the B/M boundary (0.73 Ma).

Using Milankovich's climatic calendar, a new attempt was made to date the lithostratigraphical units in the loess profile of the Paks brickyard (*Table 1.* and see PÉCSI *et al.* 1995 in this volume*, pages 63–79.).

* The B/M boundary has recently been found in the upper part of paleosol PD_2.

SELECTED REFERENCES

BACSÁK, GY. 1942. Die Wirkung der skandinavischen Vereisung auf die Periglazialzone. Budapest, 86 p.

BACSÁK, GY. 1955. Pliozän- und Pleistozänzeitalter im Licht der Himmelsmechanik. Acta Geol. Acad. Sci. Hung. 3, 4. 305–346.

BARISS, M. 1991. The changing paleogeographic environment during the Upper Pleistocene at northern and mid-latitudes. In: PÉCSI, M.–SCHWEITZER, F. (eds.): Quaternary environment in Hungary. (Studies in geography in Hungary 26.) Budapest, Akadémiai Kiadó. 27–34.

DING, Z. 1991. Pedostratigraphy of Chinese loess and Quaternary climatic fluctuation. In: LIU, T. (ed.): Quaternary geology and environment in China. Beijing, Science Press. 168–172.

DODONOV, A. E. 1987. Geochronology of loess in Central Asia and Quaternary events. In: PÉCSI, M.–VELICHKO, A. A. (eds.): Paleogeography and loess. (Studies in geography in Hungary 21.) Budapest, Akadémiai Kiadó. 65–74.

KRIGER, N. I. 1984. Lithoecology and energetics of loess: paleogeographic and genetic aspects. In: PÉCSI, M. (ed.): Lithology and stratigraphy of loess and paleosols. Budapest, Geogr. Research Institute. 11–17.

KUKLA, G. J. 1970. Correlation between loesses and deep-sea sediments. Geol. Fören. Stockholm Förhandl. 92. 148–180.

KUKLA, G. J.–LOZEK, V. 1961. Loess and related deposits. In: Survey of Czechoslovak Quaternary. Czwartorzed Europy Srodkowej i Wschodniej. INQUA 6th Int. Congr., Inst. Geol. Prace 34., Warszawa. Inst. Geol. 11–28.

LIU, T. (ed.) 1987. Aspects of loess research. Beijing, China Ocean Press. 447 p.

MILANKOVITSCH, M. 1930. Mathematische Klimalehre und astronomische Theorie der Klimaschwankungen. In: KÖPPEN, W.–GEIGER, R. (eds.): Handbuch der Klimatologie I. Berlin, Gebr. Borntraeger. 1–176.

PÉCSI, M. 1987. International Loess Symposium in China. Xian Shaanxi Province, Oktober 5–16. 1985. GeoJournal. 14. 4. 435–445.

PÉCSI, M. 1990a. Loess is not just the accumulation of dust. Quaternary International 7–8. 1–21.

PÉCSI, M. 1990b. Lößverbreitung, Lößentstehung, Lößchronologie. In: LIEDTKE, H. (ed.): Eiszeitforschung. Darmstadt, Wissenschaft. Buchges. 270–284.

PÉCSI, M. 1991. Problems of loess chronology. GeoJournal 24. 2. 143–150.

PÉCSI, M. 1992. Loess of the Last Glatiation. In: FRENZEL, B.–PÉCSI, M.–VELICHKO, A. A. (eds.): Atlas of Paleoclimates and Paleoenvironments of the Northern Hemisphere, Late Pleistocene–Holocene. Budapest-Stuttgart, Geogr. Research Institute & Gustav Fischer Verlag 110–119.

PÉCSI, M. 1993. Quaternary and loess research. Loess inForm. 2. Budapest, Geogr. Research Institute. 82 p.

PÉCSI, M. 1995. The role of principles, methods in loess-paleosol investigations. GeoJournal 26. 2/3. 117-131.

PÉCSI, M.–SCHWEITZER, F. 1991. Short- and long-term terrestrial records of the Middle Danubian Basin. In: PÉCSI, M.–SCHWEITZER, F. (eds.) Quaternary environment in Hungary. (Studies in geography in Hungary 26) Budapest, Akadémiai Kiadó. 9–26.

PÉCSI, M.–SCHWEITZER, F. 1995. The lithostratigraphical, chronostratigraphical sequence of loess profiles and their geomorphological positions (Hungary). In: Loess inForm. 3. Budapest, Geogr. Research Institute (in this volume).

VELICHKO, A. A. 1987. Relationship of climatic changes in high and low latitudes of the Earth during the Late Pleistocene and Holocene. In: PÉCSI, M.–VELICHKO, A. A. (eds.): Paleogeography and loess. Pleistocene climatic and environmental reconstructions. Contribution of the INQUA Hungarian National Committee to the XIIth INQUA Congress. Ottawa, Canada, 1987. Budapest, Akadémiai Kiadó. 9–26.

WOILLARD, G. M. 1978. Grande Pile peat bog: A continuous pollen record for the last 140.000 years. Quaternary Research. 9. 1–21.

Loess inForm 3. 1995. pp. 31–61.
Geographical Research Institute Hungarian Academy of Sciences

THE LITHOSTRATIGRAPHICAL, CHRONOSTRATIGRAPHICAL SEQUENCE OF HUNGARIAN LOESS PROFILES AND THEIR GEOMORPHOLOGICAL POSITION

PÉCSI, M.–SCHWEITZER, F.

Geographical Research Institute Hungarian Academy of Sciences,
H–1388, Budapest, P.O. Box 64.

Introduction

The number of loess and paleosol levels in Quaternary sequences is often closely related to the geological and geomorphological position of the sediment series. Particularly on uplifted loess plateaus and on foothill slopes the sequence include less stratigraphic units than in basins which have been subsided constantly during the Quaternary. In basins of Quaternary subsidence the number of loess, sandy and paleosol horizons are may be twice as many as that of the loess–paleosol units on plateaus on foothill surfaces. The sequence of sediment traps can usually be better subdivided.

Under such circumstances the paleoclimatic reconstruction of loess–paleosol sequences reveals major (inter)regional differences, also in the length of the formation period.

Nevertheless, the circumspective evaluation of lithostratigraphic units provides a framework for outlining the succession of climatic changes. Important information on certain climatic types (cold and dry or cold and wetter phases) may be gained from the traces of frost phenomena in the zones of cold loess, buried dells and river terraces as well as from investigation of the paleogeographic environments of various life traces etc. The time of past events can be established from the lithostratigraphic framework with some probability.

Over identical time intervals, different litho- and chronostratigraphical sequences could evolve in different morphotectonic positions. The sedimentary sequences in basins and other sediment traps are more throroughly subdivided than on uplifted plateaux and watersheds.

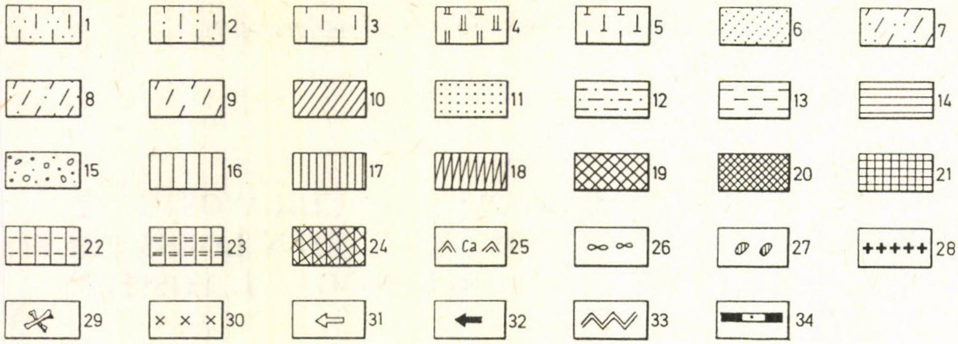


Fig. 1. Legend to the figures of this paper. 1 = loessy sand; 2 = sandy loess; 3 = loess; 4 = old loess; 5 = infusion loess; 6 = slope sand; 7 = loessy slope sand; 8 = sandy slope loess; 9 = slope loess; 10 = semipedolite; 11 = fluvial–proluvial sand; 12 = silty sand; 13 = silt, gleyed silt; 14 = clay; 15 = sandy gravel; 16 = weak humous horizon; 17 = steppe- type soil, chernozem; 18 = forest soil altered by steppe vegetation; 19 = brown forest soil; 20 = mediterranean forest steppe paleosol; 21 = red clay; 22 = hydromorphic soil; 23 = alluvial meadow soil; 24 = forest soil (on flood-plain); 25 = calcium carbonate accumulation; 26 = loess doll; 27 = krotovina; 28 = charcoal; 29 = macrofauna; 30 = volcanic ash; 31 = traces of non-linear erosion; 32 = traces of linear erosion; 33 = discontinuity in profile; 34 = calcrete horizon; MF = "Mende Upper" forest steppe Soil Complex; BD = "Basaharc Double" forest steppe Soil Complex; BA = "Basaharc Lower" chernozem soil; MB = "Mende Base" Soil Complex (chestnut + forest steppe soil); Phe = Paks sandy steppe soil; Mtp = Paks meadow soil; PD = "Paks Lower Double" Soil Complex (brownish-red Mediterranean-type chestnut soil); PDK = Paks–Dunakömlőd brownish-red soil; Pv_1, Pv_2, Pv_3 = Paks red soils; Dv_1–Dv_6 = Dunaföldvár red soils; A = clay (<0.005); I = fine silt (0.005–0.02); L = coarse silt (0.02–0.05); H = sand (0.05–1.00)

LOESS PROFILES OF PAKS IN HUNGARY

Time span covered: the Brunhes and the Matuyama epochs.

Since the mid-30s several lithostratigraphic analyses has been performed on the loess profiles of the Paks brickyard. Quarrying activities revealed considerable discrepancies within the loess–paleosol series caused by erosional gaps and sand intercalations *(Fig. 2a,b)*. Moreover, methods and concepts changed over time. As a result, the chronology of the exposure was revised and interpreted differently time by time (PÉCSI 1993).

In the section of the Paks brickyard 8 to 11 paleosols, 9 to 12 loess and loess-like layers and 2 to 3 sand interbeddings occur down to the Brunhes/Matuyama boundary. Below the B/M boundary only 2 old loess pockets and one paleosol are to be considered part of the loess series (PÉCSI, M. 1995, *Tab. 1 on page 28*). Red soils (Pv_1, Pv_2) found in the lower part of the section had been developed not on loess but on stratified sand while the lowermost red soil (Pv_3) formed on Upper Miocene (Pannonian) sand with normal paleomagnetic polarity. Obviously the formation of the latter had been preceeded by a considerable hiatus.

At the bottom of the loess series of the Paks brickyard *(Fig. 3)* the Neogene Pannonian basement is situated at an altitude 30–40 m higher than in boreholes (1978, 1979) drilled 0.5–1 km northwest *(Fig. 4)*. In the latter red and variegated clay soil series (subaerial formation) alternate with gley silt and clay layers. In this non-loessial formation the number of red soils average at 6, however, in some places 8 to 10 paleosols occur superimposing each other. In some boreholes (Paks, Dunaföldvár, Dunakömlőd, Szekszárd) heavily humified black meadow soils or gley bog soils are intercalated *(Fig. 5)*.

Within subaerial sequences developed on the under laying Neogene basement – in erosional valleys or gullies – much more (17 to 23) paleosols occur *(Fig. 6, 7)*.

SELECTED REFERENCES

ÁDÁM, L.–MAROSI, S.–SZILÁRD, J. 1954. Der Lößaufschluß von Paks. Földrajzi Közlemények 2. 3. 239–254.

BORSY, Z.–FÉLSZERFALVY, J.–SZABÓ, P. 1979. Thermoluminescence dating of several layers of the loess sequences at Paks and Mende (Hungary). Acta Geologica Acad. Sci. Hung. 22. 1–4. 451–459.

BORSY, Z.–FÉLSZERFALVY, J.–LÓKI, J. 1984. Electromicroskopic investigation of the sand material from the loess exposure at Paks. In: PÉCSI, M. (ed.): Lithology and stratigraphy of loess and paleosols. Budapest, Geogr. Research Institute. 71–86.

BRONGER, A. 1970. Zur Mikromorphologie und zum Tonmineralbestand von Böden ungarischer Lößprofile und ihre paläoklimatische Auswertung. Eiszeitalter und Gegenwart 21. 122–144.

BRONGER, A. 1979. The value of mineralogical and clay mineralogical analysis of loess soils for the investigations of Pleistocene stratigraphy and paleoclimate. Acta Geologica Acad. Sci. Hung. 22. 1–4. 141–152.

BULLA, B. 1957. Der pleistozäne Löß im Karpatenbecken I–II. Földtani Közlöny 67. 196–216, 289–309.

CODARCEA, V. 1977. Percentage distribution of heavy minerals in the loess profiles at Paks and Mohács. Földrajzi Közlemények 101. 1–3. 138–143.

FODOR, T.-NÉ–HORVÁTH ZS.–SCHEUER GY.–SCHWEITZER F. 1981. A Dunakömlőd–Paks közötti dunai magaspart mérnökgeológiai térképezése és vizsgálata. (Ingenieurgeologische Kartierung und Stabilitätsuntersuchung der Donau-Hochufers zwischen Dunakömlőd and Paks). Földtani Közlöny Budapest. 111. 258–280.

Mrs. FODOR, T.–SCHEUER, GY.–SCHWEITZER, F. 1982. Engineering geological investigations of the loess sequences along the Danube in Hungary. In: PÉCSI, M. (ed.): Quaternary studies in Hungary, Budapest, Geogr. Res. Inst. 233–243.

HAHN, GY. 1987. Chronology of the Paks loess exposures. In: PÉCSI, M. - FRENCH, H.M. (eds.): Loess and periglacial phenomena (Studies in Geography in Hungary 20). Budapest, Akad. Kiadó. 87–103.

HORVÁTH A. 1954. A paksi pleisztocén üledékek csigái és értékelésük. (Molluscs of the Pleistocene sediments of Paks and theirs evaluation). Állattani Közlöny. 44. 3–4. 171–185.

KRIVÁN, P. 1955. La division climatologique du Pleistocene en Europe Centrale et la profil de loess de Paks. Annales Inst. Geol. Publ. Hung. 43. 3. 441–512.

KORDOS, L. 1987. Climatostratigraphy of Upper Pleistocene Vertebrates and the Conditions of Loess Formation in Hungary. GeoJournal. 15. 2. 163–166.

MÁRTON, P. 1979. Paleomagnetism of the Paks brickyard exposures. Acta Geologica Acad. Sci. Hung. 22. 1–4. 433–441.

PASHKEVICH, G. A. 1979. Some Results of the Palynological Investigation of the Paks Loess Profile. Acta Geologica Acad. Sci. Hung. 22. 1–4. 461–467.

PÉCSI, M. 1972. Scientific and practical significance of loess research. Acta Geologica Acad. Sci. Hung. 16. 317–328.

PÉCSI, M. 1979. Lithostratigraphical Subdivision of the Loess Profiles at Paks. Acta Geologica Acad. Sci. Hung. 22. 1–4. 409–419.

PÉCSI, M. 1993. Quaternary and Loess Research. Loess inForm 2. – Budapest, Geogr. Research Institute. 82 p.

PÉCSI, M. 1995. The role of principles and methods in loess–paleosol investigations. GeoJournal. 36. 2–3. 117–131.

PÉCSI, M.–DONÁTH, É. 1979. Thermal investigation of the loesses and fossil soils of Paks. Acta Geologica Acad. Sci. Hung. 22. 1–4. 419–426.

PÉCSI, M.–PEVZNER, M. A. 1974. Paleomagnetic measurements in the loess sequences at Paks and Dunaföldvár, Hungary. Földrajzi Közlemények. 22. 3. 215–224.

PÉCSI, M.–SZEBÉNYI, E. (eds.) 1971. Guide-Book for Loess-Symposium in Hungary. Budapest–Dunaújváros, 15–19 August 1971. Budapest., Geogr. Research Institute. 1–34.

PÉCSI, M.–SZEBÉNYI, E.–PEVZNER, M. A.–HAHN, GY.–SCHEUER GY.–SCHWEITZER, F.–HOCK, D. 1979. Lithological, pedological, stratigraphical and paleomagnetic analysis of the loess profiles at Paks. In: PÉCSI, M. (ed.): Guide-book for Conference and Field-workshop on the Stratigraphy of Loess and Alluvial Deposits. Budapest–Szeged. 26–31. August 1979. Budapest, Geogr. Research Institute. 109–123.

PÉCSI, M.–HELLER, F.–SCHWEITZER, F.–BALOGH. J.–Mrs. BALOGH, M.–Mrs. HAVAS, J. 1995. A new loess-paleosol lithostratigraphical sequence at Paks (Hungary). In: Pécsi, M. (ed.): Loess inForm 3. Budapest, Geogr. Res. Inst. Hung. Acad. Sci. 63–79.

SCHERF, E. 1936. Versuch einer Einteilung des ungarischen Pleistozäns auf moderner polyglazialistischer Grundlage. In: Verhandlungen der III. Internationalen Quartär-Konferenz, Wien, Sept. 1936. Wien, Geologische Landesanstalt. 237–247.

STEFANOVITS P.–RÓZSAVÖLGYI J. 1962. Újabb paleopedológiai adatok a paksi szelvényről. (Weitere paläopedologische Angaben über das Bodenprofil von Paks.) Agrokémia és Talajtan. 11. 2. 143–160.

SZEBÉNYI, E. 1979. Sedimentological and Micromineralogical Analysis of the Southern Profile of Paks Loess Exposure. Studies on Loess. Acta Geologica Acad. Sci. Hung. 22. 1–4. 427–433.

SZÖŐR, GY.–BORSY, Z. 1982. Chronological evaluation of loess snails from Paks using the thermoanalytical method. In: PÉCSI, M. (ed.:) Quaternary Studies in Hungary. Budapest, Geogr. Research Institute. 22. 181–193.

URBAN, B. 1984. Palynology of Central European loess-soils sequences. In: PÉCSI, M. (ed.): Lithology and stratigraphy of loess and paleosols. Budapest, Geogr. Research Institute. 229–248.

WAGNER, M. 1979. Mollusc fauna of the Paks loess profile. Acta Geologica Acad. Sci. Hung. 22. 1–4. 433–441.

ZÖLLER, L.–WAGNER, G. A. 1990. Thermoluminescence dating of loess – recent developments. In: PÉCSI, M.–LÓCZY, D. (eds.): Loess and the paleoenvironment. Quaternary International Supplement. 7. 119–128.

ZÖLLER, L.–OCHES, E. A.–McCOY, W. D. 1994. Towards a revised chronostratigraphy of loess in Austria, with respect to key sections in Czech Republic and in Hungary. Quaternary Geochronology. (Quaternary Science Reviews). 13. 465–472.

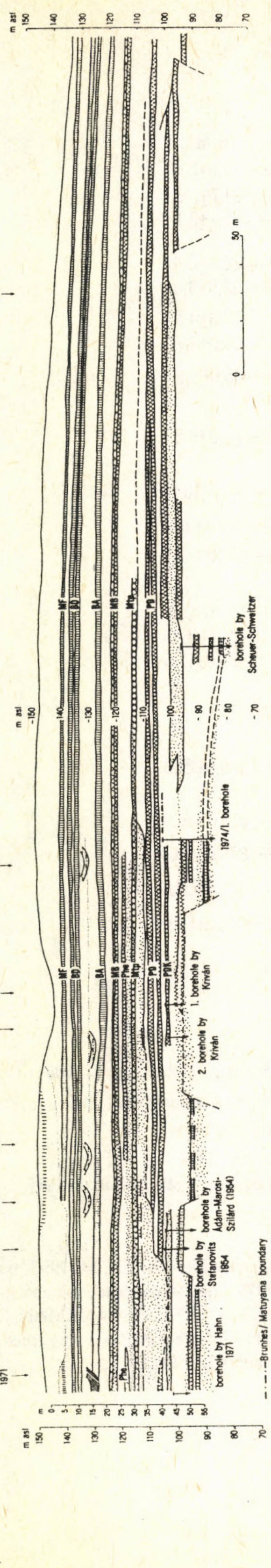


Fig. 2a. Geological section of the Paks loess exposure (compiled by PÉCSI, M.). Exposures and boreholes studied by different authors are also indicated in *Fig. 2b.*

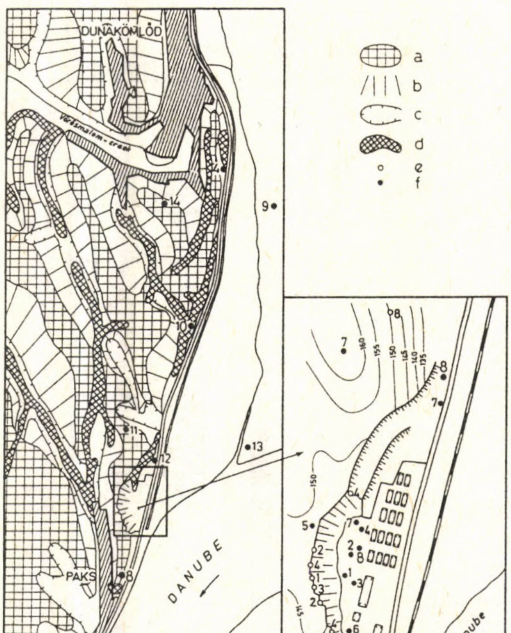


Fig. 2b. Location of profiles and boreholes around Paks – a = loess hill; b = slopes; c = valleys; d = natural exposures; e = profile; f = soil mechanical borehole; 1–L. ÁDÁM , S. MAROSI, J. SZILÁRD 1954; 2–P. KRIVÁN 1955; 3–P. STEFANOVITS–J. RÓZSAVÖLGYI 1954; 4–M. PÉCSI, 1963–77; 5–S. KARÁCSONYI, GY. SCHEUER; 6–GY. HAHN 1971; 7–M. PÉCSI, GY. SCHEUER, F. SCHWEITZER 1978; 8–S. PAPPFALVI, P. KRIVÁN 1960; 9–14 GY. SCHEUER, F. SCHWEITZER 1978–79.

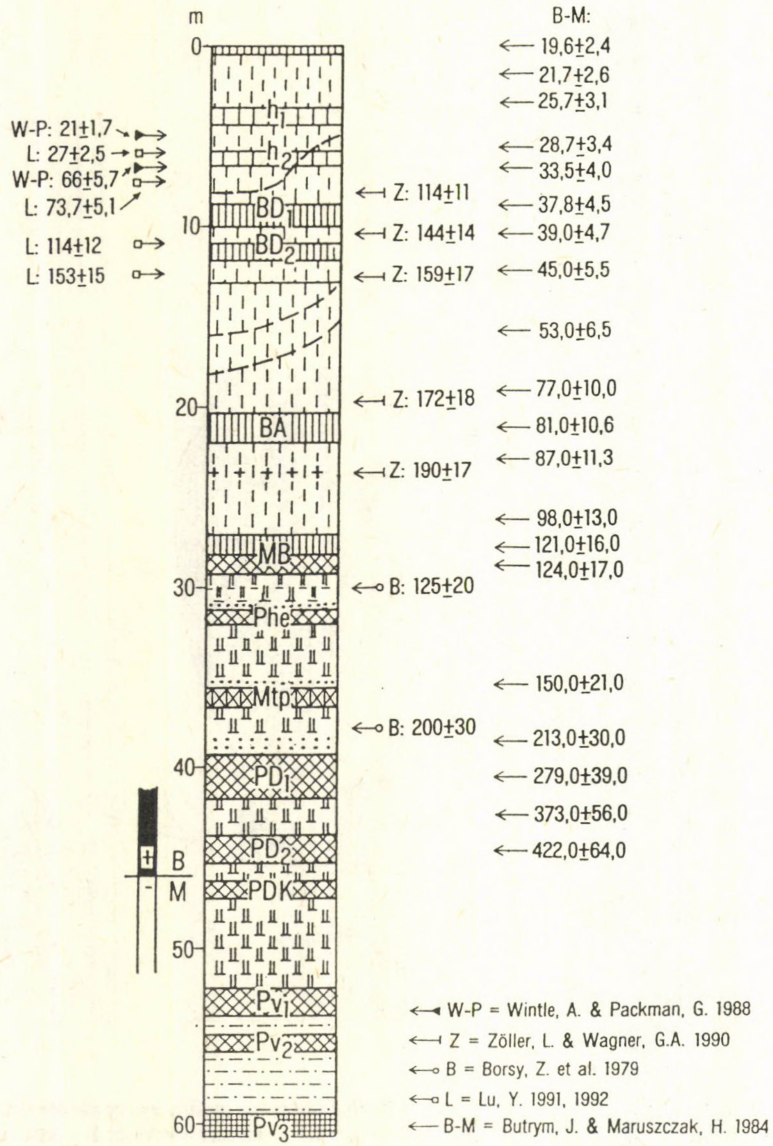


Fig. 3. Summarized geological profile of the Paks brickyard. Lithostratigraphy after PÉCSI, M. 1993, magnetostratigraphy after PÉCSI, M.–PEVZNER, M. A. 1974, MÁRTON, P. 1979, thermoluminescence analysis after BORSY, Z. et al. 1979, BUTRYM, J.–MARUSZCZAK, H. 1984, LU, Y. 1992, WINTLE, A.–PACKMAN, G. 1988, ZÖLLER, L.–WAGNER, G. A. 1990. – The results of the TL dating achived by different methods vary consideraby. The most reliable geochronological marker is the Brunhes–Matuyama boundary (0.73 Ma)

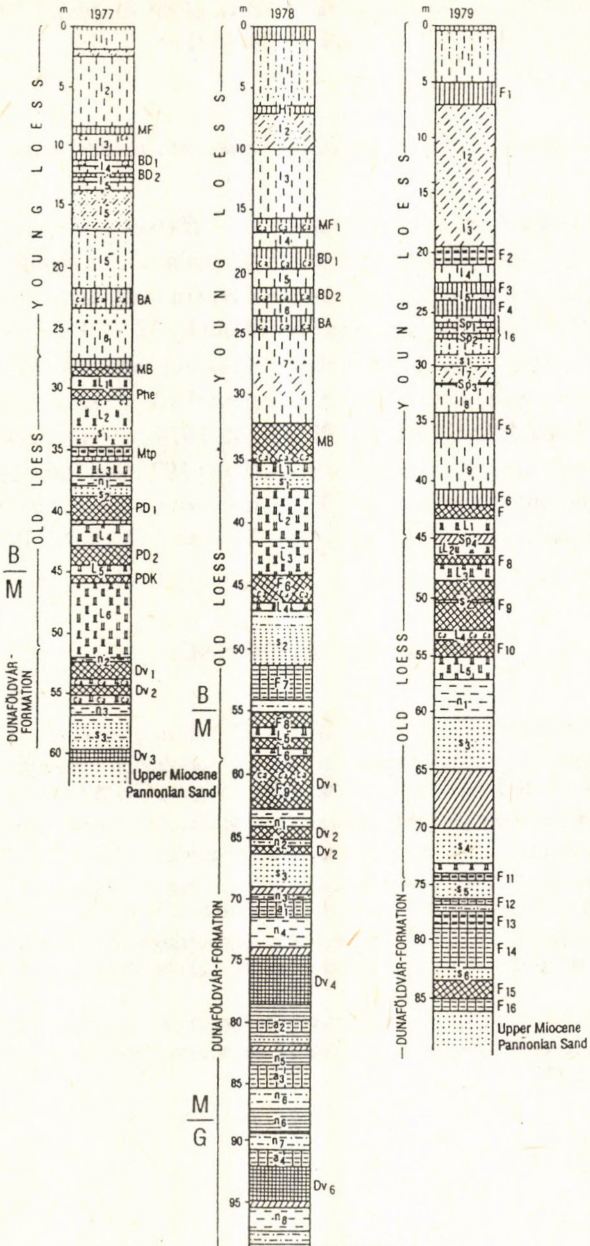


Fig. 4. Lithostratigraphy of the exposures in the Paks brickyard (Paks 1977) and of the boreholes in the vicinity of Paks (boreholes Paks 1978 and Paks 1979) (PÉCSI 1979, 1993). Paleomagnetic investigations by MÁRTON P. and PEVZNER M.A.

DUNAFÖLDVÁR LOESS–PALEOSOL SEQUENCES IN HUNGARY

Time span covered: probable Brunhes–Matuyama–Gauss epochs.

The loess exposures at the Dunaföldvár bluff (Nos I–I/4) are to be found south of the railway bridge, on the margin of the flood plain of the Danube (90 m a.s.l.). Two boreholes were deepened here at a distance of 200 m from each other with oriented core sampling. Paleomagnetic analysis was carried out by M. A. PEVZNER *(Fig. 5)*.

Below the Hungarian loess series a subaerial (and non-loessial) sequence was recognised overlying the Upper Miocene (Pannonian) lacustrine sand formation which is called the Dunaföldvár Formation (PÉCSI, M. 1979a). Geomorphological position of this sequence is similar to those found in the Paks 1978 and Paks 1979 boreholes as an upfilling of gullies and valleys cutting 35–40 m down on the surface of the Late Neogene Pannonian sand sediments (PÉCSI, M. *et al.* 1979ab, PÉCSI, M. 1993).

SELECTED REFERENCES

PÉCSI, M. (ed.) 1979a. Studies on Loess, Acta Geol. Acad. Sci. Hung. 22. Budapest, Akad. Kiadó. 555 p.

PÉCSI, M. (ed.) 1979b. Guide-book for conference and field-workshop on the stratigraphy of loess and alluvial deposits. Budapest–Szeged 26–31. August 1979. Budapest, Geogr. Research Institute. 236 p.

PÉCSI, M. 1987. The loess–paleosol and related subaerial sequence in Hungary. GeoJournal. 15. 2. 151–162.

PÉCSI, M. 1993. Quaternary and Loess research. (Loess inForm 2.) Budapest, Geogr. Research Inst. 82 p.

PÉCSI, M.–SZEBÉNYI, E. 1971. Guide-book for loess symposium in Hungary. Budapest–Dunaújváros, 15–19. August 1971. Budapest, Geogr. Research Institute. 1–34.

PÉCSI, M.–SCHEUER, GY.–SCHWEITZER, F. 1979a. Engineering geological and geomorphological investigation of landslides in the loess bluffs along the Danube. Acta Geologica Acad. Sci. Hung. 22. 327–343.

PÉCSI, M.–SZEBÉNYI, E.–SCHWEITZER, F.–PÉCSI–DONÁTH, É.–WAGNER, M.–PEVZNER, M. A. 1979b. Complex evaluation of Dunaföldvár loesses and fossil soils. Acta Geologica Acad. Sci. Hung. 22. 1–4. 513–537.

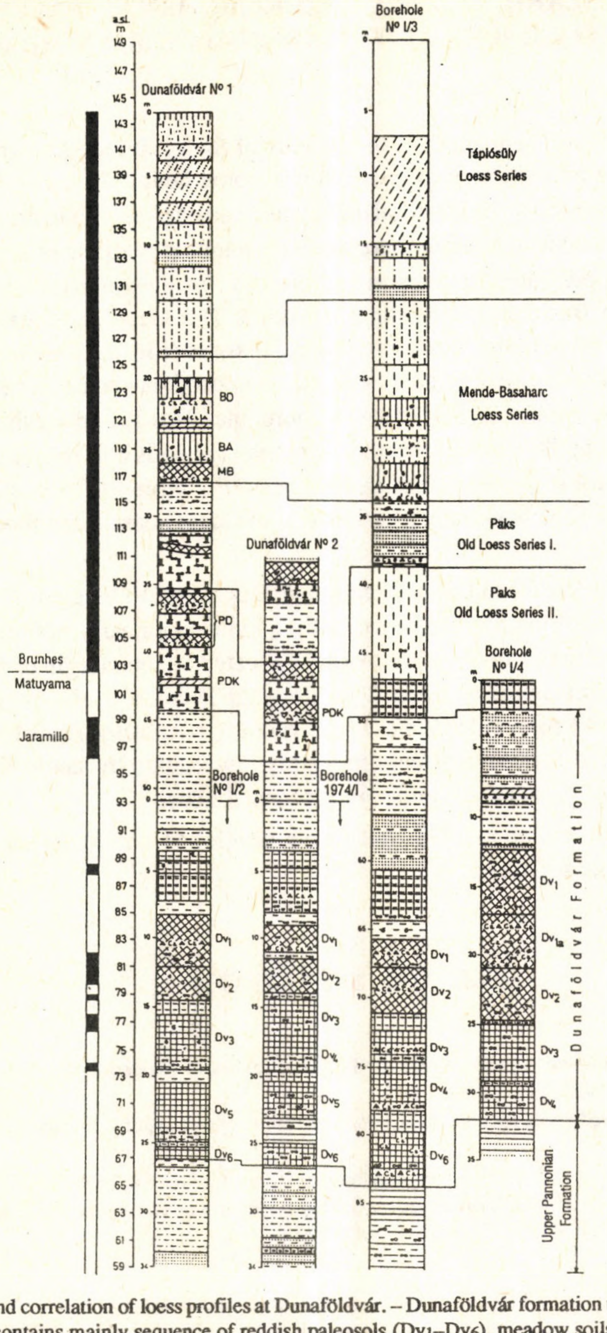


Fig. 5. Subdivision and correlation of loess profiles at Dunaföldvár. – Dunaföldvár formation underlying the young and old loess series contains mainly sequence of reddish paleosols (Dv1–Dv6), meadow soils and sand, silty sand (lithological, pedological analyses made by M. PÉCSI, E. SZEBÉNYI and F. SCHWEITZER; paleomagnetic measurement by M. A. PEVZNER). The red clays Dv5 and Dv6 probably belong to Gilbert Epoch.

SZEKSZÁRD AND DUNASZEKCSŐ, LOESS–PALEOSOL SEQUENCES IN THE TRANSDANUBIAN HILLS

Loess–paleosol sequences in the vicinity of Szekszárd are known from boreholes on a gentle slope of a 270 m high hill, situated some hundred metres from each other, on altitudes of 220–230 m. Substantial differences can be observed in the lithostratigraphy of the distinct sequences, though there are only minor elevations or depressions on the surface of the Upper Pannonian basement, the latter being situated on the margin of the Great Hungarian Basin and only slightly eroded. The loess–paleosol sequence of the borehole No 1 is 60 m thick, subdivided by 8 paleosols *(Fig. 6)*. Below it a formation of 30 m thickness is composed by paleosols superimposed on each other (F_9 through F_{18}). The two lowermost units are red clays. In boreholes Nos II and III the young and old loess series make up 80 to 90 m together while the red soils and red clays (Dunaföldvár Formation) amount to a mere 10 m in thickness (F_{15} through F_{17} and F_{11} through F_{14} respectively). The B/M boundary is assumed to the loess layer immediately below the F_8 paleosol.

South of Szekszárd in this hilly region is Dunaszekcső located *(Fig. 1)*. The loess exposure and an additional exploratory drilling indicate a nearly 100 m loess–paleosol and subaerial sequence *(Fig. 7)*. This profile is situated on the margin of the foothill zone of Mecsek Mountains in the loess bluff of along the Danube. The loess series (ca 57 m) are subdivided by 11 paleosols *(in situ)*, 3 paleosols (redeposited) and 1 sand strata. The underlying subaerial series (ca 40 m) are mainly represented by sandy silt, glayed clays and intercalated by 12 paleosols and some erosional gaps.

This profile contains 23–25 paleosols developed on Upper Pannonian (upper Miocene) lacustrine sediment.

SELECTED REFERENCES

PÉCSI, M. 1970. Geomorphological regions of Hungary (Studies in Geography in Hungary 6.). Budapest, Akadémiai Kiadó. 45 p.

PÉCSI M. 1993. Negyedkor és löszkutatás (Quaternary and Loess Research). Budapest, Akadémiai Kiadó. 375 p.

PÉCSI, M.–SCHWEITZER, F. 1991. Short- and long-term terrestrial records of the Middle Danubian Basin. In: PÉCSI, M.–SCHWEITZER, F. (eds.): Quaternary environment in Hungary. (Studies in Geography in Hungary 26.) Budapest, Akadémiai Kiadó. 9–26.

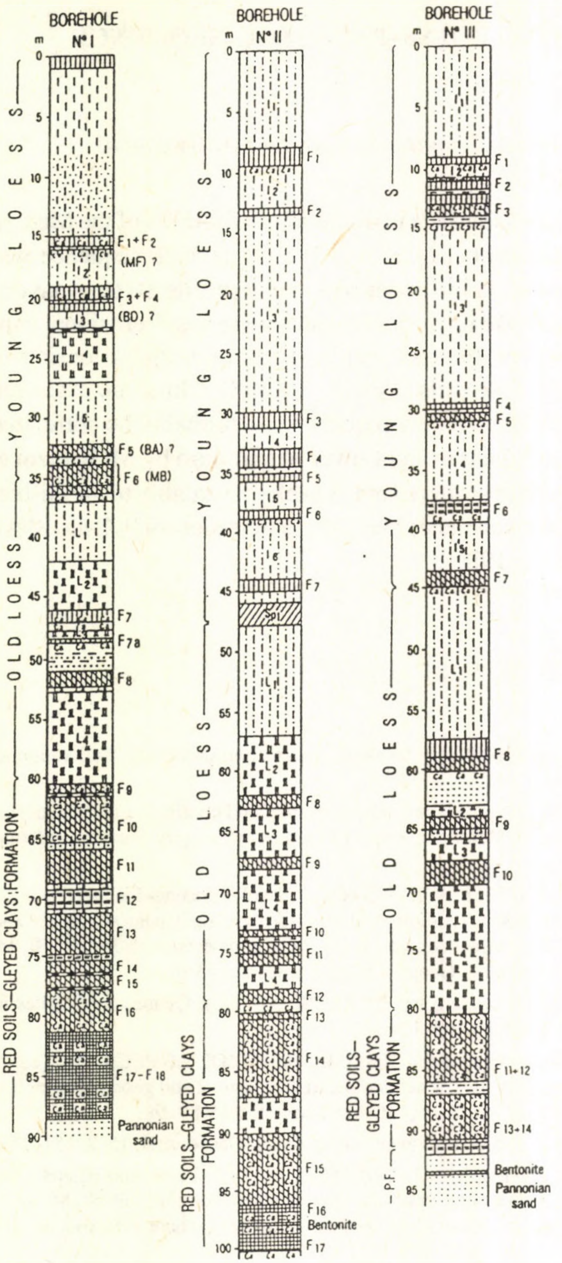


Fig. 6. Lithostratigraphical sequences at Szekszárd (in Tolna Hill Region, Hungary). Exploratory drillings N° I–III. F_1–F_{15} = paleosols; F_{16}–F_{18} = red clays; l_1–l_5 = young loess; L_1–L_5 = old loess (after PÉCSI, M., SCHEUER, GY., SCHWEITZER, F.)

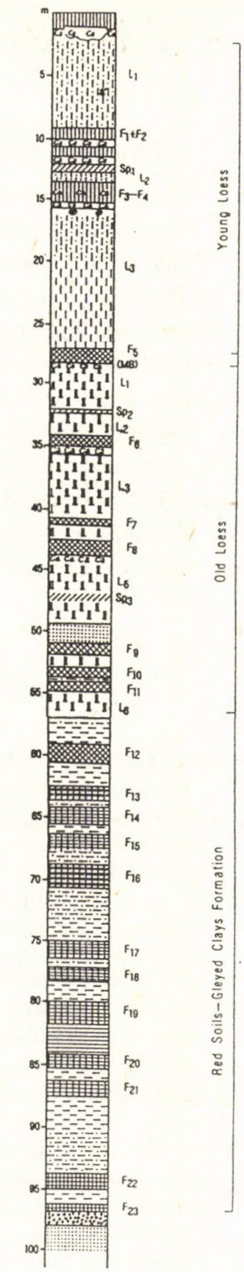


Fig. 7. Lithostratigraphical sequences at Dunaszekcső (in Tolna Hill Region, Hungary), after SCHEUER, GY. and SCHWEITZER, F.)

POSTA VALLEY AT PÉCS, LOESS–PALEOSOL SEQUENCE

Time span presumably covered: Brunhes–Matuyama–Gauss epochs

A sequence developed on the glacis surface in the southern foothills of the Mecsek Mountains, on a Pannonian sand basement *(Fig. 8., 9)*. The 60 m thick sequence was studied by a geotechnical core sampling. In the upper part of the profile 10 loess layers, 11 paleosols and 7 sand interbeddings make up the loess–paleosol series, 9 erosional gaps were identified. The lower third of the profile (between $P_{18}R$ through $P_{29}R$) consists of a sequence of red soils and sandy red clay soils (PÉCSI, M. 1985). In some cases red clays developed on wind blown sand. The red clay sequence can probably be correlated with the Pliocene Csarnóta stage (Csarnótánum and Lower Villányium by M. Kretzoi et al. 1982). Paleomagnetic evidence, though scattered reach back presumably to the Gilbert Epoch. The subaerial sequence frequently includes hiatuses. In the paleosol P_5C the Blake event probably occurs (PÉCSI, M. et al. 1987).

SELECTED REFERENCES

KRETZOI, M.–PÉCSI, M. 1979. Pliocene and Pleistocene development and chronology of the Pannonian Basin. Acta Geologica Acad. Sci. Hung. 22. 1–4. 3–33.

KRETZOI, M.–PÉCSI, M. 1982. Pliocene and Quaternary chronostratigraphy and continental surface development of the Pannonian basin. In: PÉCSI, M. (ed.): Quaternary studies in Hungary. Budapest, Geogr. Research Institute. 11–42.

KRETZOI, M.–MÁRTON, P.–PÉCSI, M.–SCHWEITZER, F.–VÖRÖS, L. 1982. Pliocene–Pleistocene piedmont correlative sediments in Hungary (based on lithological, geomorphological, paleontological and paleomagnetic analyses of the exposures in the open-cast mine at Gyöngyösvisonta). In: PÉCSI, M. (ed.): Quaternary studies in Hungary. Budapest, Geogr. Research Institute. 43–73.

PÉCSI, M. 1982. The most typical loess profiles in Hungary. In: PÉCSI, M. (ed.): Quaternary Studies in Hungary. Budapest, Geogr. Research Institute. 145–169.

PÉCSI, M. 1985. The Neogene red clays of the Carpathian Basin. In: KRETZOI, M–PÉCSI, M. (eds.): Problems of the Neogene and Quaternary in the Carpathian Basin. Geological and geomorphological studies. (Studies in Geography in Hungary 19.) Budapest, Akadémiai Kiadó. 89–98.

PÉCSI, M. 1987. The loess–paleosol and related subaerial sequence in Hungary. GeoJournal. 15. 2. 151–162.

PÉCSI, M.–GEREI, L.–SCHEUER, GY.–SCHWEITZER, F.–MÁRTON, P. 1987. Loess and paleosol sequence in Hungary reflecting cyclic climatic deterioration in the Late Cenozoic. In: PÉCSI, M. (ed.): Pleistocene Environment in Hungary. Budapest, Geogr. Research Institute. Theory–Methodology–Practice, 42. 39–57.

PÉCSI, M.–MÁRTON, P.–SCHWEITZER, F.–HAHN GY. 1985. The absolute chronology of the Plio–Pleistocene alluvial sequence overlying the pediment of the Mátra Mountains. In: KRETZOI, M.–PÉCSI, M. (eds.): Problems of the Neogene and Quaternary in the Carpathian Basin. Geological and geomorphological studies. (Studies in Geography in Hungary 19). Budapest, Akadémiai Kiadó. 109–114.

PÉCSI, M.–SCHWEITZER, F. 1991. Short- and long-term terrestrial records of the Middle Danubian Basin. In: PÉCSI, M.–SCHWEITZER, F. (eds.): Quaternary environment in Hungary. (Studies in Geography in Hungary 26.) Budapest, Akadémiai Kiadó. 9–26.

RÓNAI, A. 1977. Review on the present state of art in the knowledge Neogene–Quaternary boundary in Austria–Hungary–Czechoslovakia. Giorn. Geol. 41. 2. 213–215.

RÓNAI, A. 1985b. The Quaternary of the Great Hungarian Plain. In: PÉCSI, M. (ed.): Loess and the Quaternary. Chinese and Hungarian case studies (Studies in Geography in Hungary 18). Budapest, Akadémiai Kiadó. 51–63.

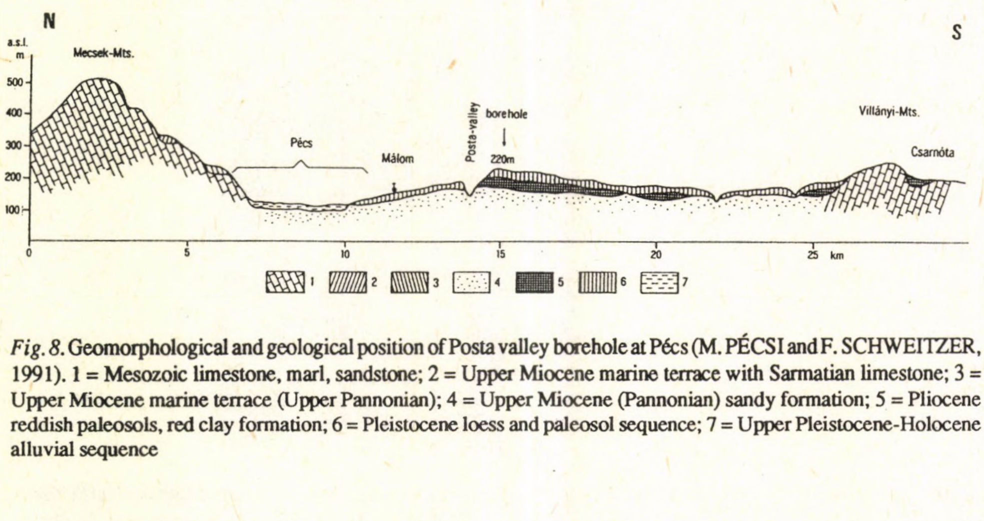


Fig. 8. Geomorphological and geological position of Posta valley borehole at Pécs (M. PÉCSI and F. SCHWEITZER, 1991). 1 = Mesozoic limestone, marl, sandstone; 2 = Upper Miocene marine terrace with Sarmatian limestone; 3 = Upper Miocene marine terrace (Upper Pannonian); 4 = Upper Miocene (Pannonian) sandy formation; 5 = Pliocene reddish paleosols, red clay formation; 6 = Pleistocene loess and paleosol sequence; 7 = Upper Pleistocene-Holocene alluvial sequence

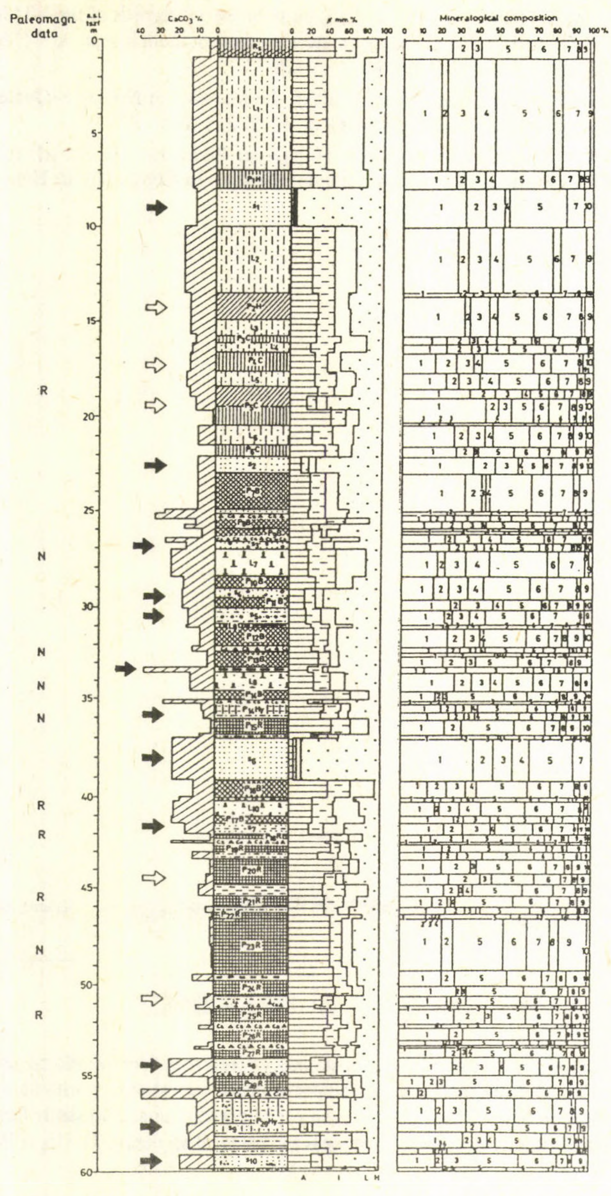


Fig. 9. Loess–paleosol sequences of Posta valley at Pécs. (Lithological, paleopedological and mineralogical analyses made by M. PÉCSI, GY. SCHEUER, F. SCHWEITZER, L. GEREI and M. REMÉNYI; paleomagnetic data by P. MÁRTON). R = reverse; N = normal polarity; L_1–L_6 = young loess; L_7–L_{10} = old loess; S_1–S_{10} = sandy layers; P_1H, P_2H = humic loess, embryonal paleosols; P_3C–P_6C = chernozem-like forest-steppe paleosols; P_8B–$P_{14}B$ = brown forest paleosols; $P_{15}R$–$P_{29}R$ = ochre-red paleosols, red clays; $P_{14}Hy$, $P_{29}Hy$ = hydromorphic meadow soils; A = clay (2–10 μ); I = fine silt (10–20 μ); L = coarse silt (20–50 μ); H = sand (50–500 μ); 1 = quartz; 2 = felspars; 3 = calcite; 4 = dolomite; 5 = micas + hydromicas; 6 = montmorillonite; 7 = chlorite; 8 = kaolinite; 9 = interstratified minerals; 10 = Al and Fe hydroxides; ➔ = significant unconformity; ⇒ = unconformity

VISONTA, QUATERNARY AND LATE NEOGENE SEQUENCE IN HUNGARY

Time span presumably covered: Brunhes–Matuyama–Gauss–Gilbert–epochs
Nos 5 and 6

A Quaternary–Late Neogene sequence is to be found in an opencast lignite mine at the foothill zone of the Mátra Mountains. Loess-like deposits and a subaerial sequence with 15 paleosols (0 to 39 m) are overlying the Upper Pannonian (Late Miocene) lignite bearing formation *(Fig. 10)*. The sequence includes many unconformities. On the basis of biostratigraphic evidence, magnetostratigraphic analyses and lithostratigraphical subdivision of the profile it is assumed that the whole sequence comprises at least 8 paleomagnetic epochs (KRETZOI, M. et al. 1982, PÉCSI, M. et al. 1985).

SELECTED REFERENCES

FRANYÓ, F. 1982. The scientific and practical significance for investigating the Quaternary fluviatile alluvial fans of the foreland of the Bükk and Mátra Mountains. In: PÉCSI, M. (ed.): Quaternary Studies in Hungary. Budapest, Geogr. Research Institute. Theory–Methodology–Practice. 24. 95–105.

JASKÓ S. 1973. A pliocénkori lignitképződés törvényszerűségei (Gesetzmäßigkeiten der Lignitbildung in Pliozän). Földtani Közlöny 103. 41–48.

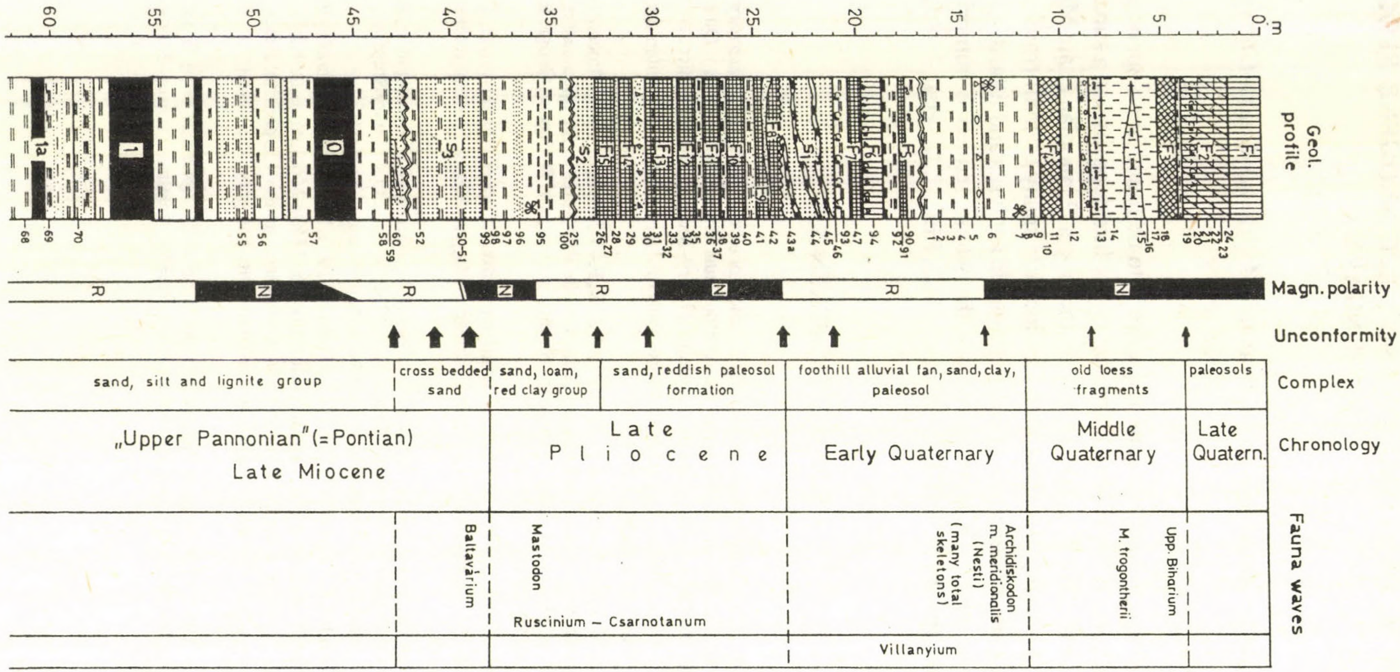
KRETZOI, M.–MÁRTON, P.–PÉCSI, M.–SCHWEITZER, F.–VÖRÖS, L. 1982. Pliocene–pleistocene piedmont correlative sediments in Hungary (Based on the Exposures in the open-cast mine at Gyöngyösvisonta). In: PÉCSI, M. (ed.): Quaternary Studies in Hungary, Budapest, Geogr. Research Institute. Theory–Methodology–Practice. 24. 43–74.

PÁLFALVI J.–RÁKOSI L. 1979. A visontai lignittelepes összlet növénymaradványai. (Pflanzenreste des lignitführenden Komplex von Visonta, N-Ungarn). Magyar Állami Földtani Intézet 1977. Évi Jelentése. 47–66.

PÉCSI, M.–DONÁTH, É.–GEREI, L.–REMÉNYI, M. 1982. Mineralogical investigation of the fossil soils of the Plio–Pleistocene piedmont sediments. In: PÉCSI, M. (ed.): Quaternary Studies in Hungary. Geogr. Research Institute. Budapest, Theory–Methodology–Practice. 24. 83–95.

PÉCSI, M.–MÁRTON, P.–SCHWEITZER, F.–HAHN, GY. 1985. The absolute chronology of the Plio–Pleistocene alluvial sequence overlying the pediment of the Mátra-Mountains. In: KRETZOI, M.–PÉCSI, M. (eds.): Problems of the Neogene and Quaternary in the Carpathian Basin. Geological and geomorphological studies. (Studies in Geography in Hungary 19) Budapest. Akadémiai Kiadó. 109–114.

SZOKOLAI, GY. 1982. Pliocene and Pleistocene formation in the open-cast mine in the Mátra foothills. Quaternary Studies in Hungary, Budapest. Geogr. Research Institute. Theory–Methodology–Practice. 24. 75–82.



Geol. profile
Magn. polarity
Unconformity
Complex
Chronology
Fauna waves
sand, silt and lignite group
cross bedded sand
sand, loam, red clay group
sand, reddish paleosol formation
foothill alluvial fan, sand, clay, paleosol
old loess fragments
paleosols
„Upper Pannonian" (= Pontian) Late Miocene
Late Pliocene
Early Quaternary
Middle Quaternary
Late Quatern.
Baltavárium
Mastodon
Ruscinium – Csarnotanum
Archidiskodon m. meridionalis (Nesti) (many total skeletons)
M. trogontherii
Upp. Biharium
Villanyium

Fig. 10. Profile of the *Visonta* open cast lignite mine at the foot of the Mátra Mountains (1982). The profile was surveyed and identified by J. BALOGH, P. MÁRTON, F. SCHWEITZER and GY. SZOKOLAI under the guidance of M. PÉCSI. The correlative sediments for pedimentation are the reddish purple fossil soils (F_7 to F_{15}) between fossil soil F_6 and sand layer S_3. The paleomagnetic measurement by P. MÁRTON (Dept. of Geophysics Eötvös L. Univ. – 0.0–1.6 m = black meadow soil; 1.6–4.5 m = old loess with remnants of B/BC soil horizon; 4.6–5.2 m = brown forest soil; 5.2–8.1 m = loess-like material, with yellow limy sandy intercalation at the base; 8.1–8.7 m = yellow limy sand with tuff detritus; 8.7–9.2 m = sand with andesite gravel and with *Equus (Allohippus) süssenbornensis*; 9.2–9.9 m = flood plain clay soil; 9.9–11.0 m = dark-grey purplish flood plain clay soil; 11.0–12.0 m = $CaCO_3$ accumulation horizon; 12.0–13.8 m = grey clay with $CaCO_3$ concretions and tuff detritus *(Mammuthus trogontherii and Bison sp.* finds*)*; 13.8–14.3 m = sand with andesite gravel *(Archidiskodon meridionalis* find); 14.3–15.3 m = clayey sand with tuff detritus; 15.3–16.7 m = grey clay flood plain soil; 16.7–17.7 m = greyish-brown clay with tuff detritus; 18.0–18.8 m = greyish brown clay with tuff detritus; 18.8–20.4 m = reddish brown clay soil; 20.4–21.1 m = limy, sandy old loess; 21.7–23.7 m = clayey sand (from 23.4 sand with tuff detritus); 23.7–25.0 m = purplish aggregated clay (with wedging of yellowish-brown tuff detritus); 25.0–25.5 m = yellowish-brownish tuff detritus; 25.5–26.4 m = purple clay soil; 26.4–26.7 m = clayey sand with tuff detritus; 26.7–27.6 m = greyish-purplish clay soil; 27.6–28.0 m = clayey sand with tuff detritus; 29.1–30.4 m = purplish clay (from 29.9 m greyish-purplish clay); 30.4–31.0 m = yellowish-brown coarse sand with tuff detritus; 31.0–31.6 m = purplish clay; 31.6–31.8 m = clay with tuff detritus; 31.8–32.3 m = purple clay with tuff detritus; 32.3–32.7 m = purple clay; 32.7–34.0 m = yellowish-brown sand with tuff detritus; 34.0–35.8 m = sandy clay with yellowish-grey purplish sand of tuff detritus and with *Zygolophodon* find; 35.8–36.6 m = crumbled clay with yellowish-grey ferrous precipitations of purplish tint; 36.6–37.1 m = coarse-grained sand with tuff detritus; 37.1–37.9 m = ferrous sandy clay; 37.9–38.5 m = sandy clay with tuff detritus with purplish tuff detritus at the base; 38.5–41.5 m = micaceous yellow sand with thin sandy clay intercalations; 41.5–42.4 m = greyish-greenish clay; 42.4–43.1 m = ochre-yellow clayey sand; 43.1–45.0 m = grey clay; 45.0–47.0 m = lignite; 47.0–48.3 m = grey clay; 48.3–48.6 m = yellowish-grey sand; 48.6–50.0 m = grey clay; 50.0–51.8 m = yellowish sandy clay; 51.8–52.7 m = grey clay; 52.7–53.0 m = lignite; 53.0–55.3 m = grey clay; 55.3–57.2 m = lignite; 57.2–58.0 m = grey clay; 58.0–59.0 m = greyish-yellowish clay; 59.0–60.5 m = grey sandy clay; 60.5–61.1 m = lignite; 61.1–62.4 m = micaceous fine-sandy clay; 62.4–69.5 m = micaceous fine-sandy mud interwoven with grey clay bands, from which water infiltrates; 69.5–75.5 m = grey clay

DÉVAVÁNYA AND VÉSZTŐ, LATE CENOZOIC SUBAERIAL SEQUENCE OF THE GREAT HUNGARIAN PLAIN

Time span covered: Brunhes–Matuyama–Gauss–Gilbert epochs and the Epoch 5

A quasi-complete sequence of Pliocene and Qaternary sediments was studied in a partial depression of the Great Hungarian Plain. At the end of the 1970s in the framework of a joint Hungarian–Canadian stratigraphic research project two exploration boreholes were drilled at Dévaványa and Vésztő *(Figs 1* and *11)* and a paleomagnetic analysis of the core samples of 1100 and 1200 m thick subaerial sequences was carried out (COOKE, HALL and RÓNAI 1979, RÓNAI 1983, 1985, 1986). The investigations revealed 5 paleomagnetic epochs *(Fig. 11)*. These boreholes did not reach the Upper Pannonian (Upper Miocene) lacustrine sediments. These records of great scientific significance has not yet been used sufficiently for chronological correlation of past climatic change events. In these boreholes as many as three times more paleosols were found than in the loess and subaerial sequences of the hills and mountain forelands over the marginal zones of the Great Hungarian Plain (PÉCSI, M.–SCHWEITZER, F. 1991).

SELECTED REFERENCES

COOKE, H. B. S.–HALL, J. M.–RÓNAI, A. 1979. Paleomagnetic, sedimentary and climatic records from boreholes at Dévaványa and Vésztő, Hungary. Acta Geologica Acad. Sci. Hung. 22. 1–4. 89–109.

PÉCSI, M.–SCHWEITZER, F. 1991. Short- and long-term terrestrial records of the Middle Danubian Basin. In: PÉCSI, M.–SCHWEITZER, F. (eds.): Quaternary environment in Hungary. (Studies in Geography in Hungary 26.) Budapest, Akadémiai Kiadó. 9–26.

RÓNAI, A. 1977. Review on the present state of art in the knowledge Neogene–Quaternary boundary in Austria–Hungary–Chechoslovakia, Giorn. Geol. 41. 2. 213–215.

RÓNAI A. 1983. A Körös-medence földtörténete a negyedkorban. (Geological history of the Körös-basin during the Quaternary.) Földtani Közlöny. 113. 1. 31–43.

RÓNAI A. 1985a. Az Alföld negyedidőszaki földtana. (The Quaternary of the Great Hungarian Plain.) Geol. Hungarica. 21. Inst. Geol. Hung. Budapestini. 7–437.

RÓNAI, A. 1985b. The Quaternary of the Great Hungarian Plain. In: PÉCSI, M. (ed.): Loess and the Quaternary. Chinese and Hungarian case studies. (Studies in Geography in Hungary 18). Budapest, Akadémiai Kiadó. 51–63.

RÓNAI A. 1986. A magyarországi kvarter képződmények kifejlődése és szerkezeti helyzete. (Quaternary formations of Hungary; geological features and structural setting.) Földtani Közlöny. 116. 1. 1–25.

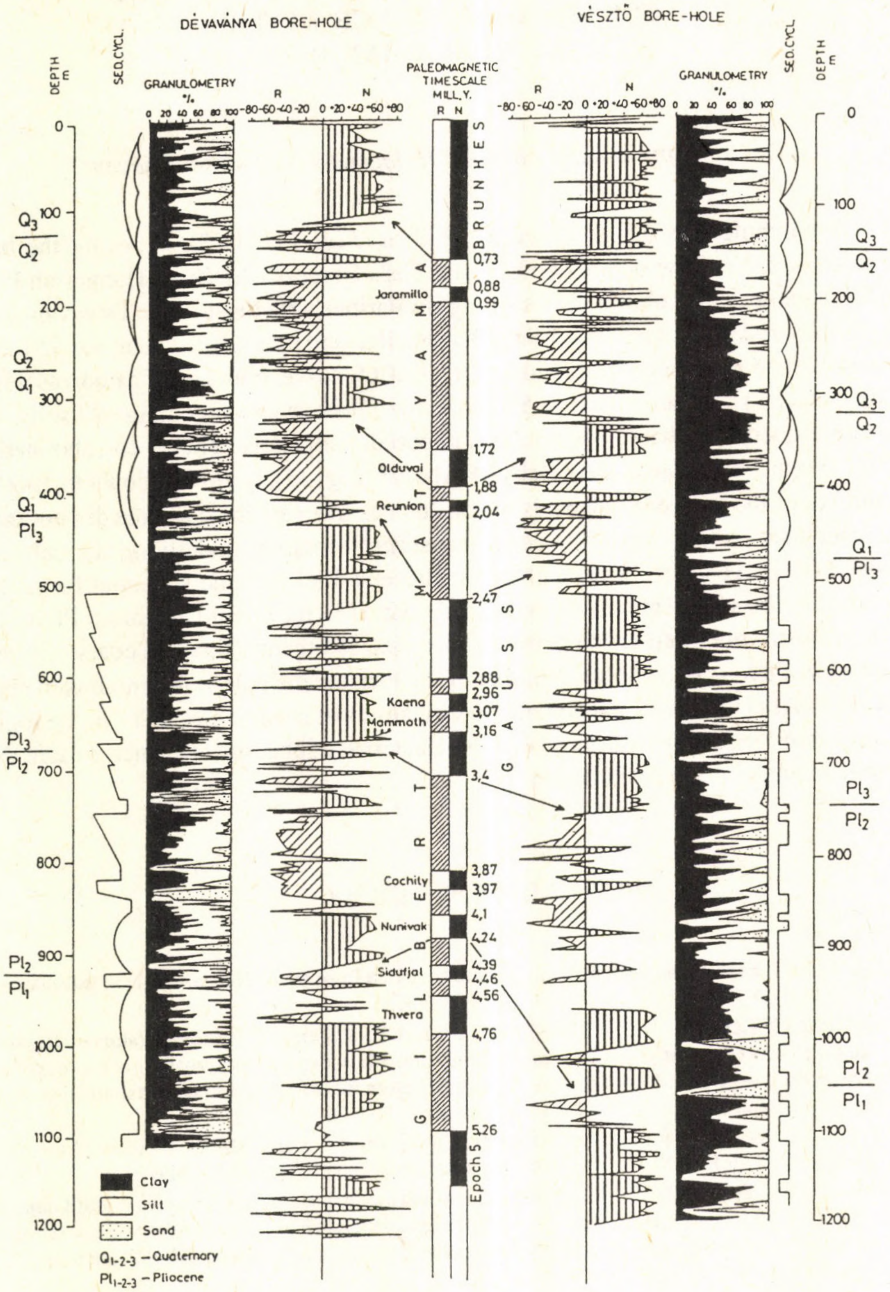


Fig. 11. Quaternary and Pliocene stratigraphy based on paleomagnetic records in Hungary (A. RÓNAI 1985b). – Source of paleomagnetic data: H. B. S. COOKE–J. M. HALL–A. RÓNAI 1979.

CSONGRÁD AND MINDSZENT, LATE CENOZOIC SUBAERIAL SEQUENCE OF THE GREAT HUNGARIAN PLAIN

Time span presumably covered: Holocene–Pleistocene–Pliocene

A borehole was drilled down to 1200 m *(Figs 1* and *12)*, exposing the basin sediments of a Neogene depression near the Tisza River on the Great Hungarian Plain. The lithostratigraphic column shows strong similarities with those of the Dévaványa and Vésztő subaerial sequences. According to a detailed and many-sided analyses 95 paleosols were found evidenced by maxima of the $CaCO_3$ curve. Number of paleosols within the Pleistocene series amounted to 55, while the Pliocene series contains 40 soils. The Pliocene sequence probably has not been exposed completely. This is corroborated by the fact that in a borehole at the nearby Mindszent *(Fig. 13)*, deepened down to 1500 m, the number of the Pliocene paleosols was as high as 67 even this borehole did not reach the Upper Pannonian (Upper Miocene) lacustrine formation underlying the subaerial sequence (RÓNAI 1985, 1986) within the Pliocene–Pleistoncene subaerial formation, developed in the sediment trap along the Tisza River in the Great Hungarian Plain. 100 to 110 paleosols are intercalated between loess-like sediments (fine and coarse silt) and sand layers of cyclic occurrence. Number of the Pleistocene paleosols amounts to about 50. A. RÓNAI (1985), who carried out investigations of several boreholes in the region and evaluated the results, registered – in the Quaternary subaerial sequence – more than 25 cyclic changes in the past climate.

SELECTED REFERENCES

FRANYÓ, F. 1977. Exploratory Drilling on the Great Hungarian Plain by the Hungarian Geol. Institute from 1968 to 1975. Földrajzi Közlemények. 101. 1–3. 60–71.

GEDEONNÉ-RAJETZKY M. 1973. A Mindszenti és Csongrádi kutatófúrások mikromineralógiai vizsgálata, különös tekintettel az anyagszállítás egykori irányaira. (Micromineralogical analysis of materials form Exploratory drilling at Mindszent and Csongrád: Determination of Paleotransportation Directions.) Magyar Állami Földtani Intézet 1971. Évi Jelentése. 169–186.

RÓNAI A. 1985. Az Alföld negyedidőszaki földtana. (English Summary: The Quaternary of the Great Hungarian Plain.) Geologica Hungarica. 21. Inst. Geol. Hung. Budapestini. 7–437.

RÓNAI A.–PAPP GY.–JÁNOS E. 1972. A Mindszenti fúrás mintáinak szemcseösszetételi grafikonja. In: RÓNAI A. (ed.): Negyedkori üledékképződés és éghajlattörténet az Alföld medencéjében. (Quartärsedimentation und Klimageschichte im Becken der Ungarischen Tiefebene (Alföld). Budapest, Magyar Állami Földtani Intézet. 56. 1. II. melléklet.

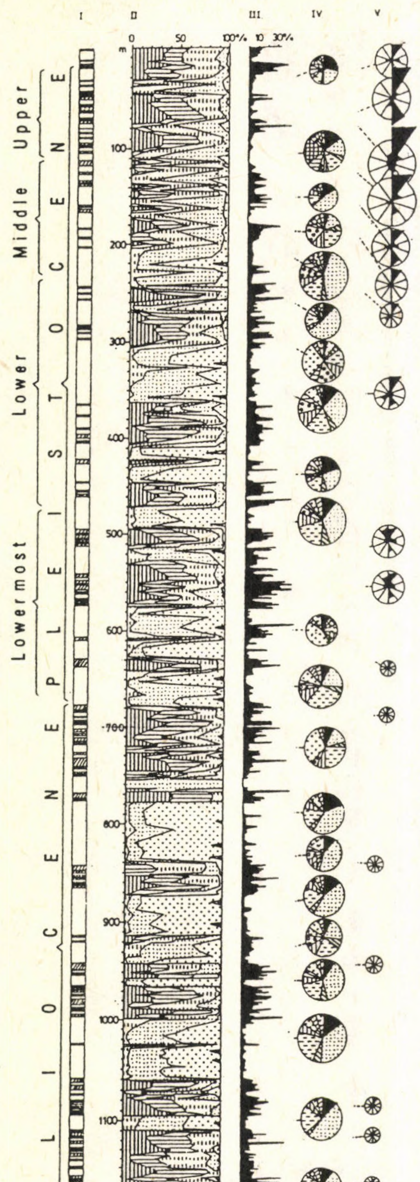


Fig. 12. Complex geological profile of the Csongrád borehole (plotted by A. RÓNAI and F. FRANYÓ, in A. RÓNAI 1985). I = Paleosols in the profile: Total number of the Pleistocene series = 55; Total number of the Pliocene series = 40. II = granulometry: 1 = clay; 2 = fine silt; 3 = coarse silt; 4 = fine sand; 5 = medium and coarse sand; 6 = gravel. III = $CaCO_3$ content. IV = heavy minerals: 1 = hematite, magnetite, ilmenite, leucoxene; 2 = garnet; 3 = disthene, staurolite, chloritoide; 4 = epidote, pistacite, piemontite, zoisite, clinazoisite; 5 = tremolite, actinolite, anthophyllite, glaucophane, sillimanite; 6 = green amphibolite; 7 = brown amphibole and lamproboli-te; 8 = hypersthene; 9 = augite; 10 = biotite; 11 = chlorite; 12 = rutile, brookite, athanase, zircon, titanite, tourmaline, apatite; 13 = limonite, pyrite, siderite, carbonates, clay minerals. V = Ostracoda finds: 1 = *Candona parallela* G. W. MÜLLER; 2 = *Candona neglecta* G. O. SARS; 3 = *Candona rostrata* BRADY-NORM; 4 = *Candona protzi* HARTWIG; 5 = *Ilyocypris gibba* RAMDOHR; 6 = *Cyclocypris laevis* O. F. MÜLLER; 7 = *Cyclocypris huckei* TRIEBEL; 8 = *Lymnocythere inopinata* BAIRD; 9 = *Lymnocythere sanctipatricii* BRADY-ROB; 10 = *Cytherissa lacustris* G. O. SARS

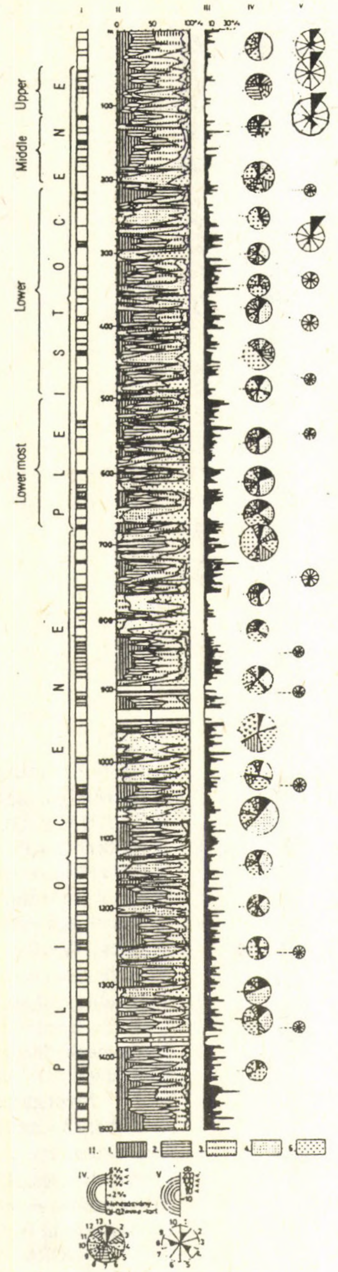


Fig. 13. Complex geological profile of the borehole of Mindszent. Plotted by A. RÓNAI and F. FRANYÓ. – I = Paleosols in the profile: Total number of the Pleistocene series: 46; Total number of the Pliocene series: 67; for further explanation see *Fig. 12*.

LATE CENOZOIC TRAVERTINE SEQUENCES ON TERRACED GEOMORPHIC SURFACES

AT DUNAALMÁS[1] *and VÉRTESSZŐLŐS*[2]

(Hungarian Upland section of the Danube Valley)

From the perspective of the reconstruction of the geomorphic evolution a highly unique terrace surface succession (fluvial terraces, foothills and marine terraces) occur along the Hungarian Upland section of the Danube valley. These geomorphological levels are covered and have been protected by travertine sequences from the subsequent denudation (*Fig. 14*, PÉCSI, SCHEUER and SCHWEITZER 1988). For the past decades a wealth of geomorphological and geological data have accumulated to subdivide these formations geologically, and, more recently beside the traditional chronological methods Th/U, ESR, ^{14}C and paleomagnetic methods have been applied for absolute dating. From the travertine horizons covering the terrace surfaces and, occasionally, from the intercalated loess and paleosol layers several mammal and mollusc fauna were determined. The travertine horizons in several places were suitable for absolute dating. Taking into consideration the geomorphological position of the terraces and the genesis of the sediments, an approximate chronology of the landform succession was summarised in *Fig. 14* and *Tab. 1*.

Upper and Middle Pleistocene travertine and terrace sequence at Vértesszőlős

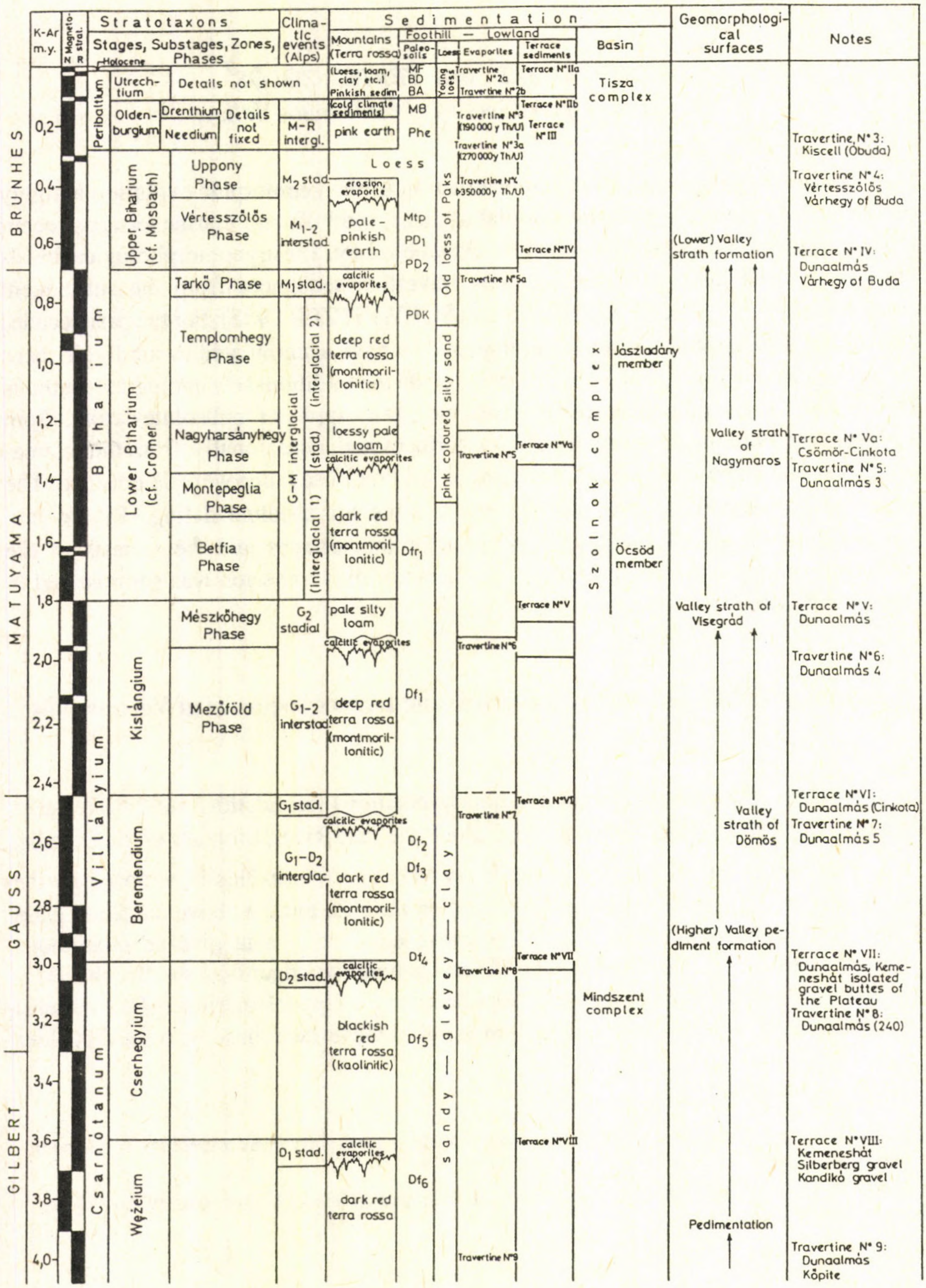
The age of the terraces in low and middle position (second, third and fifth terraces above the flood plain) was studied in detail along the Tata River, tributary of the Danube.

The Lower Paleolithic site of the Early Man at Vértesszőlős is enclosed by the horizons of the travertine sequence developed on the fifth terrace above the flood plain of the Tata River *(Figs 15, 16, 17)*. Otherwise conflicting data give an unanimous evidence on the travertine overlying the V. terrace being younger than the Brunhes/Matuyama boundary (0.73 Ma) and containing a fauna of the Upper Biharium (Mosbachium) stage (PÉCSI, M. 1990). The (cemented) material of the terrace (in some places) is older

[1] Latitude: N 47° 45', Longitude: E 18° 32', Altitude: 120–130 m a.s.l., time span covered: Pleistocene–Pliocene–Miocene

[2] Latitude: N 47° 33', Longitude: E 18° 34', Altitude of settlement: 140 m a.s.l., time span covered: Upper and Middle Pleistocene

Table 1. Correlation of the terrestrial, biostratigraphical and geomorphological history of the Upper Pliocene and Quaternary in the Carpathian Basin. M. KRETZOI–M. PÉCSI



and its normal polarity presumably preserved the Jaramillo event (PÉCSI, SCHEUER, SCHWEITZER 1988). Absolute age of the travertines on the IIb and III flood-free terraces was determined Th/U and ESR datings as 125–135 ka and 200–240 ka, respectively (HENNIG et al.). The travertine enclosing the Lower Paleolithic site was dated between 220–>350 ka by different laboratories *(Figs 16, 17)*.

Lower Pleistocene series and the Quaternary/Neogene boundary

The silt, sandy loess and paleosol horizons (D_4–D_{12}) enclosed in the travertine sequence at Dunaalmás as a lithostratigraphic unit (between T_6 and T_7, *Figs 18, 19*) all are of reversed magnetic polarity, except the lowermost D3 layer with normal polarity.

The ochre-reddish paleosol *(Fig. 19)* is rich in macro- and micromammals of Upper Villányium age (Kislángium) (JÁNOSSY 1979). Evaluating the geomorphological, stratigraphical, paleontological and paleomagnetic data, in our interpretation *the lower and lowermost Pleistocene is represented by the Dunaalmás travertine (T_6 and T_7)* (KRETZOI and PÉCSI 1979, JÁNOSSY 1990, SCHEUER and SCHWEITZER 1982, 1988). The ochre-reddish paleosol (*Fig. 19*, D_{10}–D_{11}) with rich Kislángium fauna is assumed to have formed during the Upper Villányium stage (between 2–1.4 Ma). The travertine overlying this paleosol seems to be of similar age *(Tab. 1)*. The paleosol formation indices a sedimentation gap within the travertine sequence. The underlying travertine horizons, subdivided by silt and sandy loess layers, seem to represent the initial phase of the Pleistocene. *The Q/N boundary seems to lie between the Dunaalmás travertine sequence (T_7) and the series of the underlying gravelly sand and cemented sand.*

Neogene travertine sequence underlain by delta gravels of the Danube

Thick travertine sequences in a higher geomorphological position (*Fig. 14*, T_8–T_{11}), deposited on sandy gravel and sand of delta structure, already contain Neogene mammal and mollusc fauna. The uppermost travertine sequence (T_{11a}, T_{12}, *Fig. 14*) was formed on Pannonian (Upper Miocene) lacustrine terraces (PÉCSI, SCHEUER and SCHWEITZER 1982, 1988).

CONCLUSION

In the deep-subsided basin, the number of paleosols (95–115) is about three or locally fourfold exceeds that in the subaerial sequence of the non-subsiding mountain foreland or alluvial fan surfaces.

The Plio–Pleistocene subaerial sedimentation ensuing in the Upper Miocene (Upper Pannonian) period began with red clay development on slowly subsiding basin surface and then increasing subsidence produced repeated formation of various soils and loess deposits. They are better preserved than in the sequence of the neighbouring, non-subsiding *Middle Danube Basin* margins accumulated over the same period.

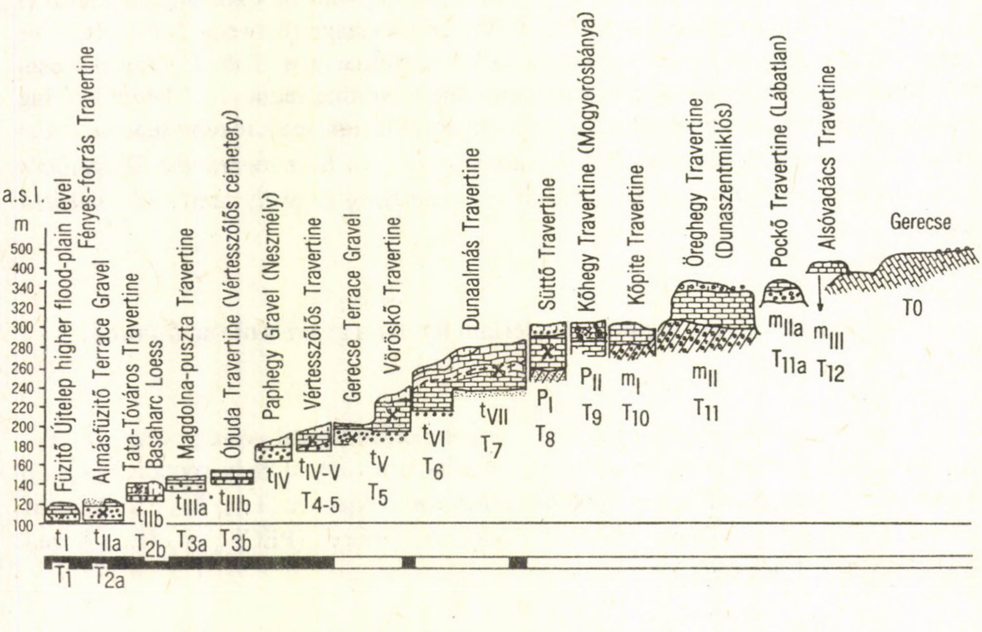


Fig. 14. Geomorphological surfaces and travertine horizons in the Gerecse foreland (M. PÉCSI–GY. SCHEUER,–F. SCHWEITZER 1988). t_I–t_{VII} = river terraces usually covered by travertines (T_1–T_7) and loess; P_I–P_{II} = Pliocene pediment surfaces covered by travertines (T_8–T_9); m_I–m_{III} = Upper Pannonian (Upper Miocene) raised beaches covered by travertines (T_{10}–T_{12}); T_0 = Paleogene-Mesozoic planation surface sculptured by Oligocene-Miocene pedimentation with sporadic gravels

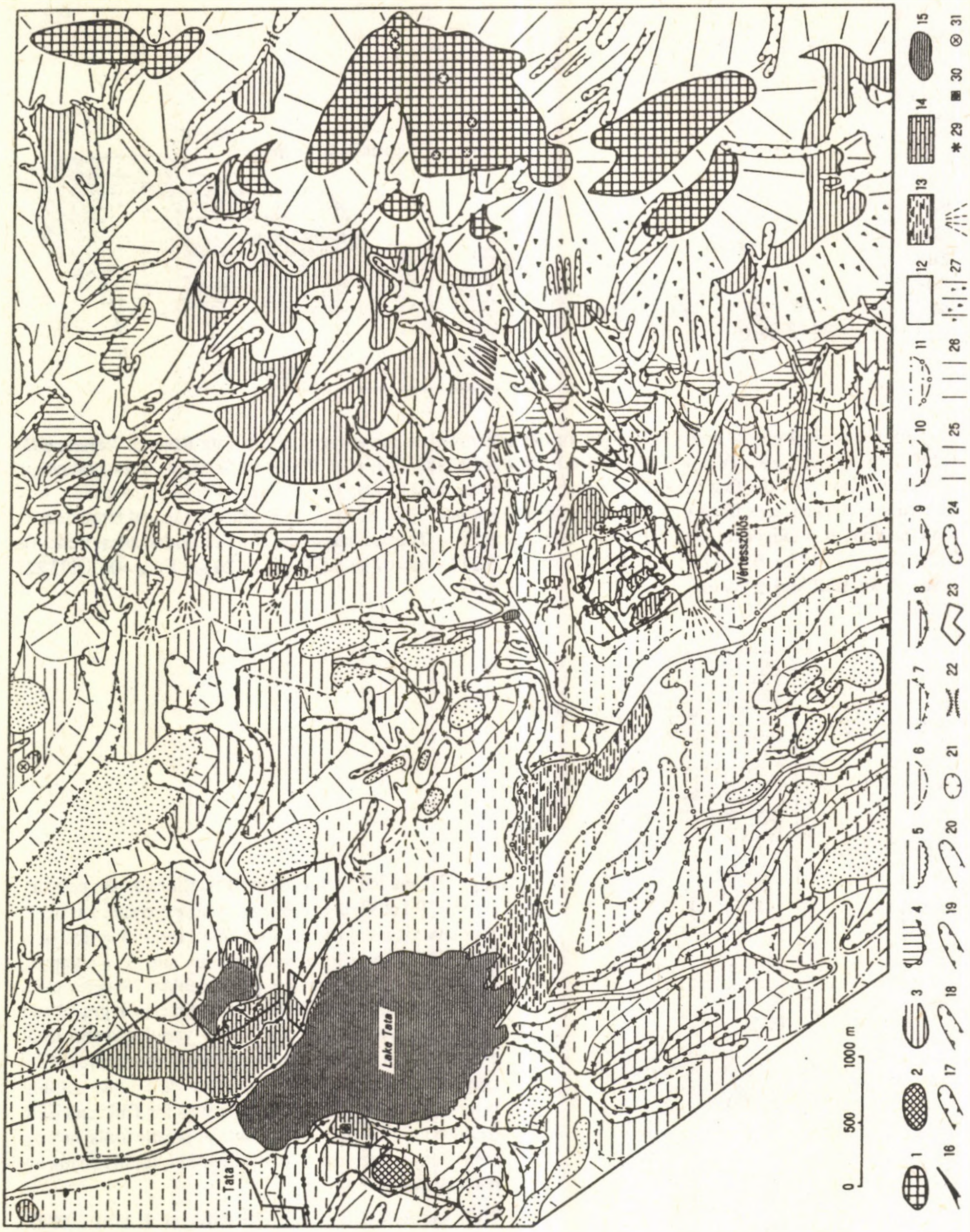


Fig. 15. Geomorphological map of the Vértesszőlős–Tata area (M. PÉCSI–F. SCHWEITZER, 1986) 1 = Summit level of Mesozoic horsts in the Gerecse Mountains; 2 = Mesozoic horst in threshold position at Tata; 3 = remnants of marine terraces; 4 = foothill surface and margin (locally two levels); 5 = terrace N° VI; 6 = terrace N° V; 7 = terrace N° IV; 8 = terrace N° III; 9 = terrace N° II/b; 10 = terrace N° II/a; 11 = higher flood-plain, terrace N° I; 12 = lower flood-plain; 13 = seasonally waterlogged flood-plain; 14 = terraces covered by travertine; 15 = natural and artificial lake; 16 = gully; 17 = karst erosional valley; 18 = erosional-derasional valley; 19 = derasional valley; 20 = flat and broad erosional valley; 21 = doline; 22 = col; 23 = settlement; 24 = open cast mine; 25 = steep slope; 26 = gentle slope; 27 = lapies slope; 28 = alluvial fan; 29 = Vértesszőlős Paleolithic site; 30 = Tata Paleolithic site; 31 = Kenderhegy Paleolithic site

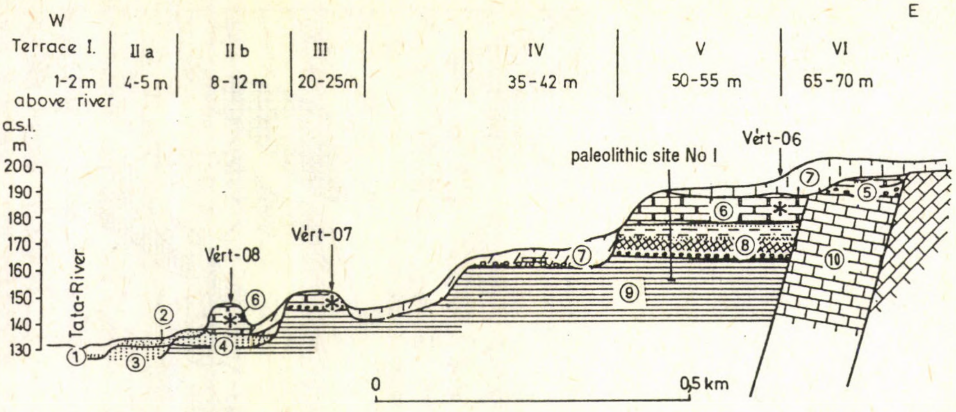


Fig. 16. Geological profile and absolute age of the travertines on the terraces of the Tata River at Vértesszőlős (PÉCSI, M.–SCHEUER, GY.–SCHWEITZER, F. 1988; HENNIG, G. J. et al. 1983). 1 = flood-plain; 2 = colluvium; 3 = sandy gravels of the first flood-free terrace; 4 = fluvial sand (tII/b); 5 = thin gravel beds (tII/b to VI); 6 = travertine cap on terraces III to VI; 7 = loess, slope loess and slope deposit; 8 = alluvial fan and terrace series with red clay; 9 = Oligocene clay, sandy clay and gravel; 10 = Triassic limestone; ✳ = Paleolithic sites. Vért. –08 Th/U 135 + 12 –11 ka, ESR 123 ± 25 ka; Vért. –07 Th/U 248 + 00 –67 ka, ESR 202 ± 20 ka; Vért. –06 Th/U 227 + 56 –37 ka, ESR 386 ± 39 ka

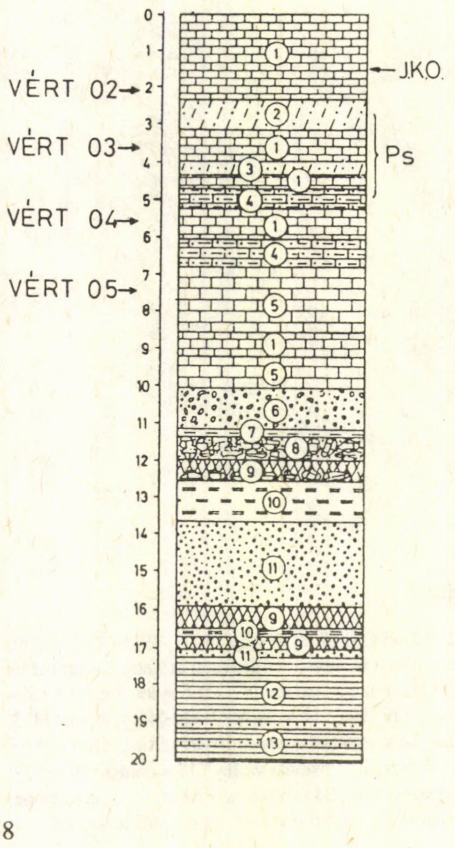


Fig. 17. Detailed profile of the travertines on the paleolithic site N° I at Vértesszőlős travertine exposure. 1 = loose, thin-layered travertine; 2 = stratified loess; 3 = fine sand with calcareous silt; 4 = calcareous silt; 5 = compact, thick-banked travertine; 6 = sandy pebble; 7 = ochre clay; 8 = local alluvial fan gravel, coarse limestone gravel and pebble; 9 = red clay paleosols; 10 = variegated terrestrial clay; 11 = fluvial sandy pebble; 12 = Oligocene clay; 13 = Oligocene clayey sand; Ps = Lower Paleolithic cultural layers; 02, 03, 04 and 05 = sample sites for Th/U and ESR datings; Ps = cultural layers contain; pebble tools, hearth, burnt bones, fragment of paleoman skul, fossils characterised by *Biharian* fauna.

Th/U and ESR dating after HENNIG, G. J. et al. (1983): 02 = Th/U 128 + 20 –12 ka^x, ESR 127 ± 13 ka^x ; 03 = Th/U 217 + 40 –8 ka^x, ESR 245 ± 25 ka^x ; 04 = Th/U 325 + ∞ –60 ka^x, ESR 172 ± 17 ka ; 05 = Th/U 350 ka, ESR 333 ± 17 ka; x = contaminated samples; J. K. O. = Th/U dating after PÉCSI, M.–OSMOND, J. K. (1973), two samples analysed on 3 occasions: 350 ka BP.

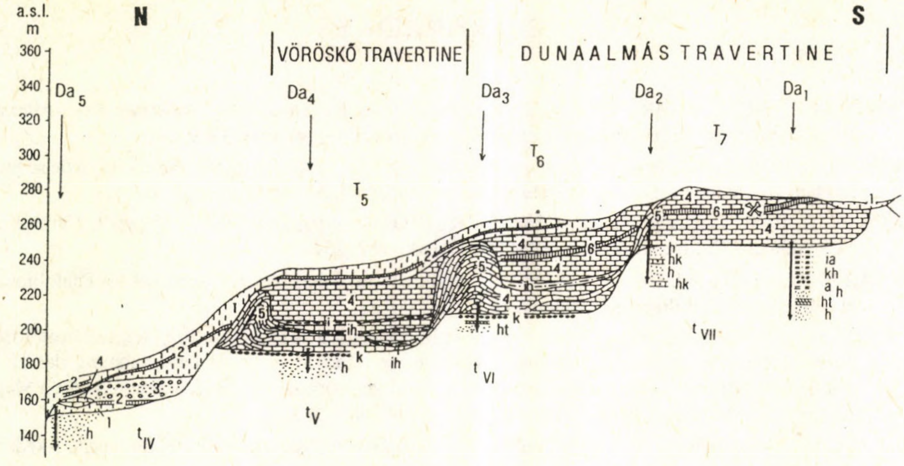


Fig. 18. The Dunaalmás Travertine (T_6–T_7). Profile of the Danube terraces (IV–VII) and the overlying travertine sequences (T_5–T_7) based on exposure and borehole data (after M. PÉCSI–GY. SCHEUER,– F. SCHWEITZER 1988). 1 = loess and slope loess; 2 = paleosols in loess; 3 = terrace gravel; 4 = travertine; 5 = terrace tetarata barriers; 6 = paleosol in travertine; Da_1–Da_5 = borehole sites; t_{IV}–t_{VII} = terraces; a = clay; ia = muddy clay; ih = muddy sand; h = sand; kh = gravelly sand; ht = hydromorphic soil; hk = sandstone; k = gravel

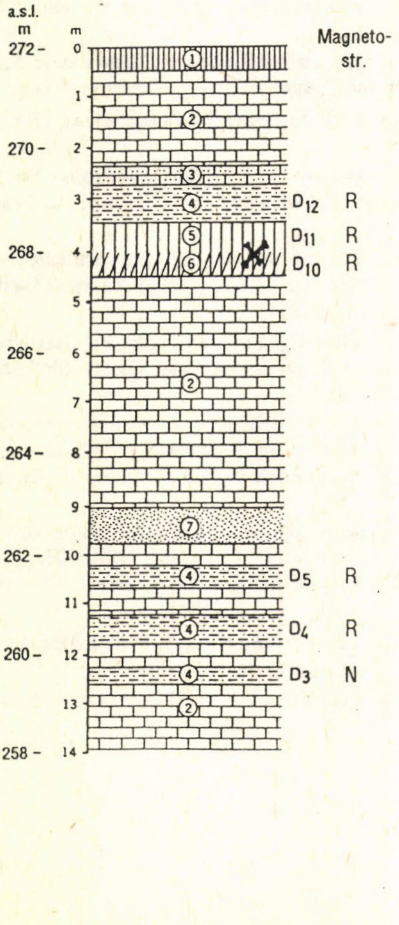


Fig. 19. The Dunaalmás Travertine (T_7). Profile drawn by SCHWEITZER, F., paleomagnetic investigations by PEVZNER, M. A. and fauna identification by JÁNOSSY, D. (1979). 1 = recent rendzina soil; 2 = travertine; 3 = calcareous silt; 4 = loess with fine sand; 5–6 = double paleosol, N^o 6 is a Lower Pleistocene ochre-red soil of Kislángian type with rich micro- and macrofauna; 7 = silty sand; D_4–D_{12} = samples for paleomagnetic analysis (all are of reverse polarity). D_3 = normal polarity

SELECTED REFERENCES

HENNIG, G. J.–GRÜN, R.–BRUNNACKER, K.–PÉCSI, M. 1983. Th–230/U–234–sowie ESR–Altersbestimmungen einiger Travertine in Ungarn. Eiszeitalter und Gegenwart. 33. 9–19.

JÁNOSSY, D. 1979. A magyarországi pleisztocén tagolása gerinces fauna alapján (The Pleistocene sequence in Hungary on the basis of the vertebrate fauna). Budapest, Akadémiai Kiadó. 207 p.

JÁNOSSY, D. 1990. Vertebrate Fauna of Site II. KRETZOI, M.–Mrs. DOBOSI V. T. (eds.): Vértesszőlős. Site, Man and Culture. Budapest, Akadémiai Kiadó. 187–231.

Mrs. JÁRAI-KOMLÓDI, M. 1973. Pollenstatistical examination of the travertine layers of the Paleolithic site at Vértesszőlős. Földrajzi Közlemények. 21. 2. 120–132.

KORMOS T.–SCHRÉTER Z. 1916. Előzetes jelentés a Budai-hegyek és a Gerecse-hegység szélén előforduló édesvízi mészkövek tanulmányozásáról. (Vorläufiger Bericht über die Untersuchung der an den Rändern des Budaer-Gebirges und des Gerecse-Gebirges vorkommenden Süsswasserkalke.) Magyar Állami Földtani Intézet 1915. Évi Jelentése. 542–544., 583–585.

KRETZOI, M.–Mrs. DOBOSI, V. T. 1990. (eds.): Vértesszőlős. Site, Man and Culture. Budapest, Akadémiai Kiadó 553 p.

KRETZOI, M.–PÉCSI, M. 1979. Pliocene and pleistocene development and chronology of the Pannonian Basin. Studies on Loess. Acta Geologica Acad. Sci. Hung. 22. 3–33.

KRETZOI, M.–VÉRTES, L. 1965a. Upper Biharian (Inter-Mindel) Pebbleindustry Occupation Site in Western Hungary. Current Anthropology. 6. 74–87.

KRETZOI, M.–VÉRTES, L. 1965b. The Role of Vertebrate Fauna and paleolithic industries of Hungary in Quaternary stratigraphy and chronology. Acta Geologica Acad. Sci. Hung. 9. 125–144.

KROLOPP, E. 1977. Middle Pleistocene mollusc fauna from Vértesszőlős composite of Prehistoric Man. Földrajzi Közlemények. 25. (101) 1–3. 204–211.

MOLDVAY, L. 1990. Sedimentological Conditions of the Vértesszőlős Pleistocene Travertine. KRETZOI, M.–DOBOSI, V.T. (eds.): Vértesszőlős. Site, Man and Culture. Budapest, Akadémiai Kiadó. 63–76.

PÉCSI, M. 1973. Geomorphological position and absolute age of the Lower Paleolithic site at Vértesszőlős, Hungary. Földrajzi Közlemények. 21. 10–119.

PÉCSI, M. 1990. Geomorphological position and absolute age of the Vértesszőlős lower paleolithe site. In: KRETZOI, M.–DOBOSI, V. T. (eds.): Vértesszőlős. Site, Man and Culture. Budapest, Akadémiai Kiadó. 27–41.

PÉCSI, M.–OSMOND, J. K. 1973. Geomorphological position and absolute age of the settlement at Vértesszőlős of the Lower Paleolithic prehistoric man in Hungary. IX. Cong. Intern. Union of Quaternary Res. Abstract. Christchurch, New Zealand, 2–10. Dec. 283–284.

PÉCSI, M.–SCHEUER, GY.–SCHWEITZER, F. 1982. Geomorphological and chronological classification of Hungarian travertines. In: PÉCSI, M. (ed.): Quaternary Studies in Hungary. Theory–Methodology–Practice 24. Budapest, Geogr. Research Institute. 113–117.

PÉCSI, M.–SCHEUER, GY.–SCHWEITZER, F.–HAHN, GY.–PEVZNER, M. A. 1985. Neogene–Quaternary geomorphological surfaces in the Hungarian Mountains. In: KRETZOI, M.–PÉCSI, M. (eds.): Problems of the Neogene and Quaternary in the Carpathian Basin. (Studies in Geogr. in Hungary 19) Budapest, Akadémiai Kiadó. 51–63.

PÉCSI, M.–SCHEUER, GY.–SCHWEITZER, F. 1988. Neogene and Quaternary Geomorphological Surfaces and lithostratigraphical units in the Transdanubian Mountains. In: PÉCSI, M.–STARKEL, L. (eds).: Paleogeography of Carpathian Regions. Budapest, Geogr. Research Institute. Theory–Methodology–Practice 47. 11–43.

SCHEUER GY.–SCHWEITZER F. 1970. Új szempontok az édesvízi mészkőösszletek képződéséhez. (New Aspects on the Formation of Travertine sequences.) Földrajzi Értesítő. 19. 381–392.

SCHEUER, GY.–SCHWEITZER, F. 1972. Paleogeographic conditions and classification of karstic springs depositing travertine. Földrajzi Értesítő. 20. 285–290.

SCHEUER, GY.–SCHWEITZER, F. 1973. The development of the Hungarian travertine sequences in the Quaternary. Földrajzi Közlemények. 22. 133–144.

SCHEUER GY.–SCHWEITZER F. 1988. A Gerecse- és a Budai-hegység édesvízi mészkőösszletei. Földrajzi Tanulmányok. 20. Budapest, Akadémiai Kiadó. 7–131.

SCHEUER, GY.–SCHWEITZER, F. 1990. Travertine Formations of the Gerecse Mountains. In: KRETZOI, M–DOBOSI, V. T. (eds.): Vértesszőlős. Site, Man and Culture. Budapest, Akadémiai Kiadó. 43–56.

SCHRÉTER, Z. 1953. Les occurrences de calcaire d'eau douce des bords des montagnes de Buda et Gerecse. Magyar Állami Földtani Intézet 1951. Évi Jelentése. 11–150.

SCHRÉTER, Z. 1953. Freshwater limestone occurrences on the margins of the Buda and Gerecse Mountains. Magyar Állami Földtani Intézet 1952. Évi Jelentése. 11–146.

SCHWARZ, H. P.–LATHAM, A. G. 1984. Uranium-series Age Determination of Travertines from the Site of Vértesszőlős, Hungary. Journal of Archeological Science. 11. 327–336.

SCHWARZ, H. P.–LATHAM, A. G. 1990. Magnetic polarity of travertine samples from Vértesszőlős. In: KRETZOI, M.–DOBOSI, T. V. (eds.): Vértesszőlős. Site, Man and Culture. 1990. Budapest, Akadémiai Kiadó. 553–555.

VÉRTES, L. 1968. Bilan des découvertes les plus importantes faites de 1963 à 1966 dans les fouilles du site paléolithique inférieur de Vértesszőlős (Hongrie). Revue Anthropologique, 12. 3–13.

National Atlas of Hungary
Budapest , 1989. 395 p.

Published by Cartographia, Budapest on behalf of the Hungarian Academy of Siences and the Ministry of Agriculture and Food

Hungary's natural endowments, population and economic life in the middle 1980s. Changes in the environment, demography, social and technical infrastructure since the 1960s. 273 map pages: 100 insert maps, 200 diagrams, 6 space images, 2 aerial photos. Legends and explanatory text on 100 pages in English and Hungarian. Supplement: Hungary's administrative map at 1:500,000 scale.
Size: 29x43 cm
Volume: 395 pages (including the explanatory text)
Main map scales for Hungary: 1:1,000,000, 1:500,000, 1:2,000,000, 1:2,500,000.

Contents by chapters:	15 maps on	15 pages
I. Introductory maps	24	7
II. Surveying and mapping	5	7
III. Relief	30	17
IV. Geology and geophysics	73	9
V. Climate	15	15
VI. Surface and groundwaters	15	15
VII. Soils	15	7
VIII. Biogeography, regions by physical factors	11	7
IX. Nature conservation and environmental protection	10	9
X. Population, settlements, housing and public utilities	76	41
XI. Health	21	7
XII. Education, culture and sport	14	7
XIII. Industry	71	35
XIV. Agriculture and food industry	184	59
XV. Transport, post and telecommunication	16	9
XVI. Internal trade, catering and services	12	7
XVII. Tourism	8	9
XVIII. Foreign trade	3	3
XIX. Regional planning	4	3

$ 160.-

Loess inForm 3. 1995. pp. 63–78.
Geographical Research Institute Hungarian Academy of Sciences

A NEW LOESS-PALEOSOL LITHOSTRATIGRAPHICAL SEQUENCE AT PAKS (HUNGARY)

PÉCSI, M.–SCHWEITZER, F.–BALOGH, J.–Mrs. BALOGH, M.–Mrs. HAVAS, J

Geographical Research Institute Hungarian Academy of Sciences
H–1388, Budapest, P.O. Box 64.

HELLER, F.

Institute für Geophysik, CH–8093 Zürich

Introduction

The world-known loess sequence of the Paks brickyard was chosen as the first stop of the field trip A/6 (Carpathian Traverse) of the Berlin XIV INQUA Congress. This section was first presented to an international audience by E. SCHERF (1936) on the occasion of the III INQUA Congress, Vienna. According to current views, SCHERF correlated the sequence, consisting of 9 paleosols, 2 embryonic soils, loess and sand layers, to the Middle European Glacial Chronology (*Fig. 1*). The section was studied by several Hungarian and foreign specialists during the past fifty years (*Fig. 1,* PÉCSI and SCHWEITZER in this volume, *Fig. 2a*).

The various interpretations of the chronology were partly the result of the above mentioned factor, partly that of the various level of recognition of the different soils, sand horizons and hiatuses within sections in different parts of the brickyard, during the long time of studies. The studied sections seldom represented the entire sequence. The sections, surveyed in details lithologically and pedologically (ÁDÁM et al. 1954, BRONGER 1976, KRIVÁN 1955, PÉCSI 1972, STEFANOVITS and RÓZSAVÖLGYI 1965, SZEBÉNYI 1979, cf. also the references of PÉCSI and SCHWEITZER in this volume), were only apparently complete during these studies.

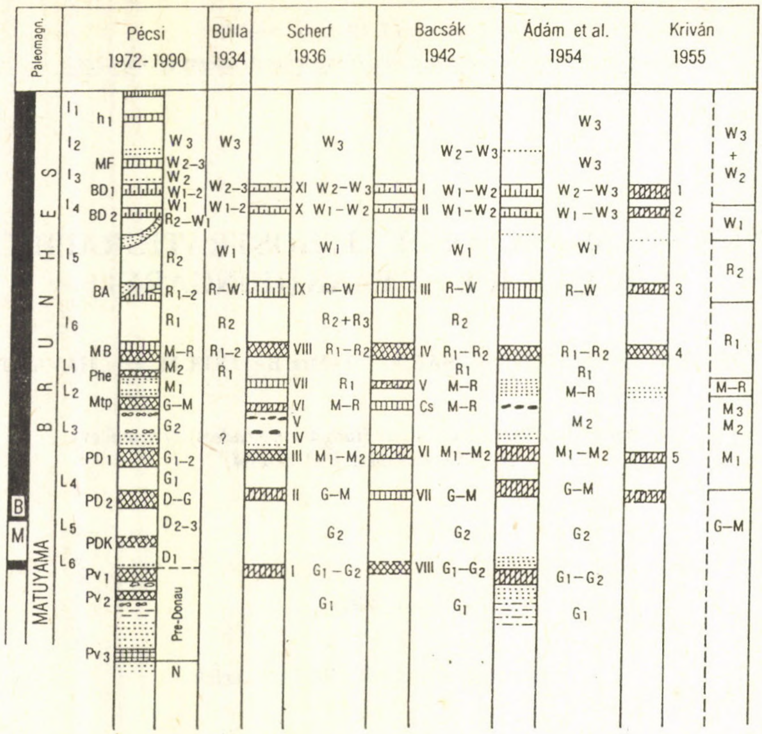


Fig. 1. Some former chronological subdivisions of loess profiles of Paks by various authors (compiled by M. PÉCSI). On the basis of the Pleistocene climatic calendar by MILANKOVITCH (1941) and BACSÁK (1942) various authors mention different amounts of loess, paleosols and sands. Even within the ca 200 m long brickyards exposure variation in the number and position of horizons is considerable.

The privatisation of the brickyard enabled us recently to look for more complete sections than those previously studied. We cleaned and densely sampled them (*Fig. 2, 3* and *Tab. 1*). The preparatory works for sampling on the section were expensive, covered mostly by Prof. Dr. F. HELLER, the head of the Geophysical Laboratory of the Zurich University. He and his colleagues accomplished the magnetostratigraphic study of the sequence. The sedimentological and pedological studies were performed by the loess team of the Geographical Research Institute of the Hungarian Academy of Sciences, and supervised by M. PÉCSI, Chairman of the INQUA Paleogeographical Atlas Committee. About one third of the costs was covered by the Loess Project, led by M. PÉCSI.

The samples taken or to be collected in the near future are analysed with various methods. This report is a preliminary one about the lithostratigraphy, palaeopedology, and magnetostratigraphy of this loess-paleosol sequence. With a support of the INQUA Hungarian National Committee, a set of palynological, geochemical, chronological, malacological, paleoclimatological and geological investigations of the samples will be conducted.

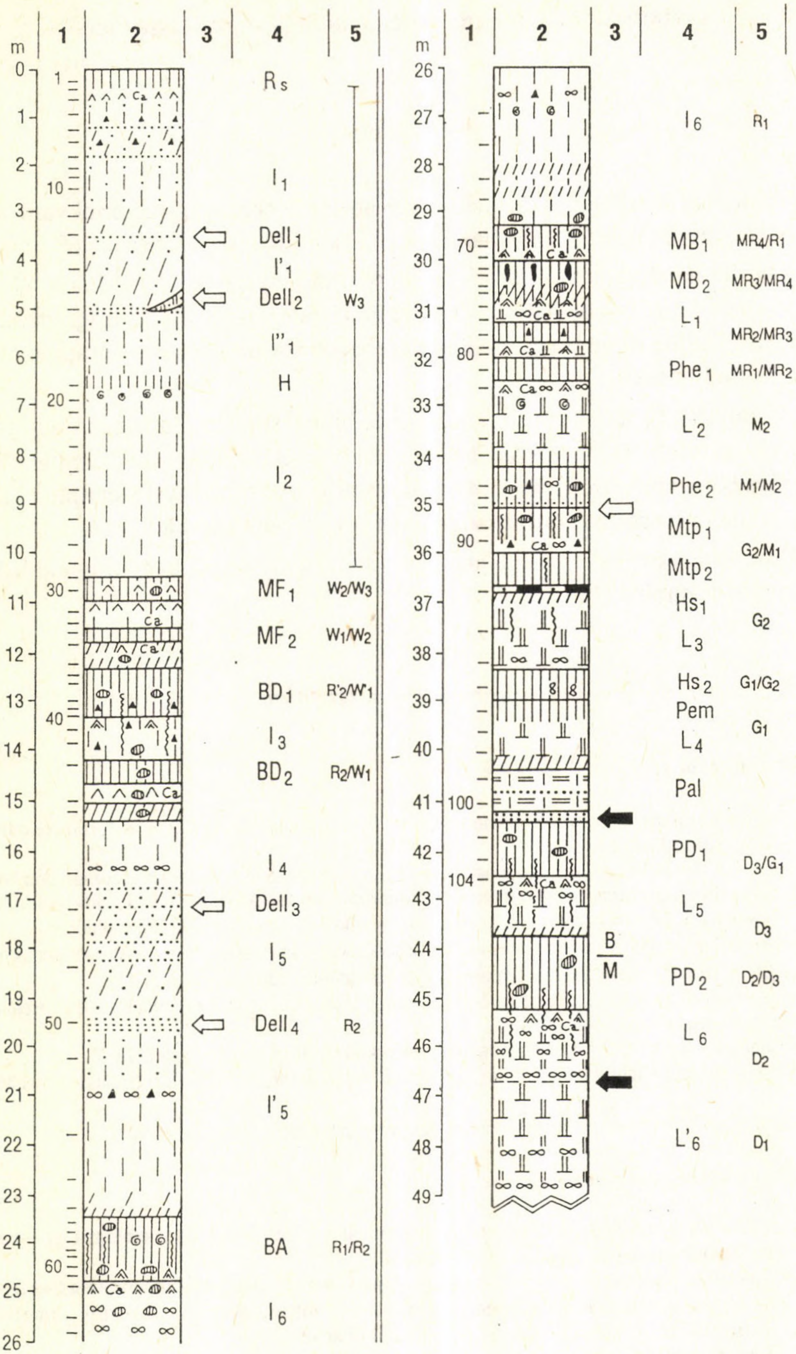


Fig. 2. Loess-paleosol sequence at Paks (1995) in Hungary. 1 = number of samples; 2 = profile; 3 = gaps; 4 = index; 5 = presumable chronology (see also *Tab. 1* on pages 72–77)

Lithostratigraphy and paleopedology of the sequence

Sampling

The studied section was cleaned at the northern corner of the brickyard wall and 20 steps were cut in the wall, each having a 2–3 m high, 2 m wide plane (*Figs 2, 3*).

– On the newly cut surface of the section the layers between 0 and 49 m were surveyed in detail macroscopically, and classified stratigraphically, petrographically and pedologically. At the same time samples were taken for magnetostratigraphic measurements in 20 cm intervals.

– A sampling has been done for sedimentological studies. During sampling another stratigraphic-pedological survey has been carried out. 104 monolithic samples, 15 x 10 cm each, has been taken from the 0–42.5 m interval. Paleosols were sampled in denser intervals, while in loess each different types of layers were sampled.

– Based on these surveys and laboratory analyses (*Tab. 1*) a pedological-lithological profile was compiled (*Fig. 2*).

Stratigraphical description

Upper part of the young loess sequence

The loess–paleosol sequence was evaluated in detail. This is given here in a concise form, completed with the data included in *Table 1* and *Fig. 2*.

The surface is covered by a zonal chernozem type soil down to 0.5 m. Carbonate accumulation horizon of this soil is developed in a usual form. Small calcretes are scattered down to 1.5 m level, into a sandy loess of a typical loess fabric. Between 1.5–2.0 m a layered sandy loess occurs with 1–2 mm thick sand intercalations.

The upper 10.5 m thick layer of the young loess (l_1) is a structured fine sandy loess, with calcareous micaelia, scattered manganese patches, small calcretes, rootprints and earthworm burrows.

Between 3–4 m there is a slightly structured fine sandy loess, with 1 to 2 mm thick sand intercalations in each 10 cm, representing layered delle infillings.

At 5 m there is a sandy delle infilling containing reworked clasts of the old loess (*Fig. 2*).

Between 6.4–6.6 m a slightly humic loess (a structured steppe embryonic soil) is intercalated with tiny snail remnants.

Between 10.0–10.5 m there are small calcretes overlying the paleosol designated MF.

Middle part of the young loess sequence

In the interval 10.5–11.1 m there is a crumby, chestnut steppe soil (MF_1), and between 11.1–11.4 a well developed accumulation horizon (calcareous loess) was found.

The MF_2 paleosol between 11.5–11.7 m is highly crumby, with numerous krotovinas in its accumulation horizon at 11.74–11.84 m. Underlying the C_{ca} layer of the MF_2 embryonic soil, at 11.85–12.27 m, there are reworked soil fragments of some cm^2 size. These fragments are remnants of an older soil.

There is a minor stratigraphical hiatus corresponding to the formation of the paleosol MF_2. In a great part of the Paks brickyard section the soils MF_1 and MF_2 are missing. The loess underlying the MF_2 paleosol is thin (max. 20 cm), probably it was partly removed by erosion.

The BD_1 paleosol is at 12.4–13.36 m, with a C_{ca} horizon. The soil is strongly crumby, greyish brown, its lower part is of dark chestnut colour, it contains rootprints, earthworm and insect burrows and krotovinas of some cm diameter.

A similar steppe paleosol BD_2 was found at 14.2–15.11 m, containing krotovinas in the accumulation horizon.

Underlying BD_2 there is a loess of some dm thickness with reworked soil fragments, and below it the first loess is encountered containing calcareous concretions of 2 to 5 cm size at 16.4–16.5 m.

Lower part of the young loess sequence

Between 16–23.1 m fine sandy loess, typical loess and loessy sand layers of various granulometry are found (Nos. 14). Intercalated at 16.83–18.57 m there are 1 to 3 cm thick sandy layers in each 10–20 cm. This is a typical layered sandy slope loess infilling a major delle. In similar position, in other parts of the Paks brickyard sections there are identical formations. Probably this (l_5) intercalation indicates a hiatus. The lower layer of the young loess (l'_5) at 20–23 m is well structured, with manganese precipitations and small calcretes. At 23 m it contains major calcareous nodules, quite similar to those found in the old loess sequence. At 22.3 and 23.3 there are some cm thick reworked soil containing loess of solifluction origin.

Between 23.3–25.1 m there is a paleosol designated BA, which is a chestnut, chocolate coloured, structured steppe soil with large (20–30 cm in diameter) krotovinas. Pale and dark brown soil fragments at 23.5–23.9 m result in a characteristic variegated colour and fabric (semipedolith).

The BA chestnut, steppe soil is strongly bioturbated by earthworms. These give a characteristic appearance to these paleosols not only in Paks but in other key loess sections in Hungary as well. The accumulation horizon of the BA soil with big calcareous concretions ("loess dolls") intrudes into the underlying old loess (l_6) as deeply as 1 m.

Between 26–29 m there is a moderately structured, compact, old loess containing mica and snail remains with small calcretes and manganese patches.

At 28.1–28.9 m the loess is intercalated by two thin embryonic soils or semipedolith horizons; this is a transitional layer to the underlying MB paleosol.

Upper part of the old loess-paleosol sequence

This sequence is characterised by densely packed paleosols.

At 29.3–30.0 m there is a strikingly crumby, chestnut paleosol, designated MB_1, with steppe type krotovinas, and earthworm burrows filled with light or dark coloured soils. Some krotovinas are brick coloured, others are filled with dark brown soil fragments, some are filled in with a mixed soil material. In the transitional level between paleosols MB_1 and MB_2, there is an accumulation horizon with vertical carbonate moduli, they are observable downward in the upper part of the paleosol MB_2.

Between 30–31.3 m there is a reddish, chestnut paleosol, in its upper level the prismatic cracks are filled with carbonate noduli and small calcretes. The clay content is 50 weight %, but clay coating is absent or poor. It contains many manganese patches. Between 20.8–31.3 m there is a horizon with large calcareous concretions. The main part of the C_{ca} of the MB_2 horizon is represented by a calcareous old loess (L_1).

At 31.37–32.6 m there is a crumby light grey steppe soil, designated Phe_1. Its upper part is a structured embryonic soil, with carbonate tubes and manganese patches. Between 31.62–32.0 m a strongly calcareous old loess was detected, which is an accumulation horizon of the upper unit of Phe_1.

The soil horizon at 32.03–32.4 m is the lower part of the paleosol Phe_1, a light brown crumby steppe soil, with many carbonate tubes and concretions. The accumulation horizon may be traced downwards in the old loess (between 32.6–33.0 m).

The old loess (L_2) at 32.6–34.2 m is well structured, with few manganese patches, carbonate tubelets, includes two horizons with big calcareous concretions (loess dolls). Its lower part is a pedified old loess, forming transition toward the paleosol Phe_2 (*Fig. 2*).

The paleosol Phe_2 is situated between 34.2–35.1 m. It is moderately crumby, rusty brown sandy forest steppe soil. Its colour gets darker downwards. This soil was formed on a sand layer, its lower part contains 52 weight % sand grains. Its boundary downwards is very sharp, an erosional hiatus is assumed here.

Two paleosols (Mtp_1 and Mtp_2) are superimposed on each other at 35.1–35.9 and 35.9–36.8 m. The upper one is a crumby steppe soil with krotovinas, its sand and clay content is equally 31 weight %. This passes to the strongly clayey soil unit Mtp_2, which is a dark brown, crumby meadow chernozem soil with many calcareous mycaelia, calcretes. Sporadically it contains rusty patches. Clay content is 47 volume %. The accumulation horizon of the Mtp_2 soil is a 30 to 40 cm thick carbonate layer (dolomitic "Ortstein").

Layered old loess (L_3) is found at 36.8–38.4 m. Its upper part is a brownish grey, strongly calcareous, crumby, pedified old loess (Hs_1), with numerous calcareous mycaelia. The entire layer is transsected with vertical earthworm burrows infilled with the soil Mtp_1.

Between 38.4–39.45 m there is a slightly pedified old loess (Hs_2), containing many manganese patches, sporadically with carbonate concretions, loess dolls. At 38.8–39.45 there is an embryonic soil (Pem) horizon, and a manganese-iron patchy old loess.

A poorly structured old loess (L_4) is situated at 39.45–40.4 m, with iron precipitations and abundant mica. At 40.1 there is a 20 cm thick residual soil brown, with many Mn and iron patches. Its lower part is intercalated with sand layers, which are probably delle type valley sediments.

At 40.4–41.2 m there is a chocolate brown valley-bottom floodplain paleosol (Paks alluvial soil, Pal), sporadically with carbonate concretions and thin sand layers.

Between 41.2–41.45 m a stratified coarse sand was found, which is slightly clayey. It is sharply delimited lithologically from the underlying PD_1 paleosol. The thickness of the sand may exceed one metre at the central part of the Paks brickyard wall. It represents a significant erosional hiatus.

Lower part of the old loess, the Brunhes/Matuyama boundary

A pale yellow old loess (L_5) was found at 41.2–43.7 m. This is moderately structured, there are grey patches due to reduction and carbonate tubelets of rootprint origin. There are big calcareous concretions in two levels as well as earthworm burrows throughout the entire layer, filled with the soil PD_1. The unit of L_5 mainly is the accumulation horizon of the PD_1 paleosol which has a chestnut steppe soil character between 41.2–42.3 m (*Tab. 1, Fig. 2*).

Between 43.7–45.2 there is a reddish chestnut steppe soil (PD_2), darkening downwards, strongly crumby, with krotovinas. The upper- and lowermost 20 cm of this soil is built of light and dark soil fragments (pedosediment). The accumulation horizon of this soil is in the underlying old loess (L_6), down to 46 m, forming two levels with big concretions. Krotovinas and earthworm burrows are filled with this soil.

A moderately structured old loess (L_6, L'_6) is situated between 45.2–48.9 m. Its one metre thick upper part is the accumulation horizon (C_{ca}) of the overlying soil (PD_2), with snails, krotovinas and concretions, down to 47.7 m. In this level there is a hiatus marked by the concretions arranged horizontally. This is the upper boundary of the L'_6 old loess. This is poorly structured, containing two levels with concretions.

This time the Paks brickyard section was surveyed down to 49 m. The underlying layers were previously studied by drillings made down from the base of the wall as well as by boreholes penetrating the sequence of the nearby loess plateau (see also PÉCSI and SCHWEITZER in this volume, *figs. 2a, b,* and *3, 4.* pages 35–37).

Conclusions, new observations

1) Previous paleomagnetic surveys (PÉCSI and PEVZNER 1974, PÉCSI et al. 1979, MÁRTON 1979) put the Brunhes/Matuyama (B/M) boundary (0.73 Ma) into the old loess below the "Paks Dupla" (PD_2) paleosol. The new susceptibility and magnetostratigraphic analysis, made by F. HELLER and his colleagues, located the B/M boundary in the PD_2 (*Fig. 3*).

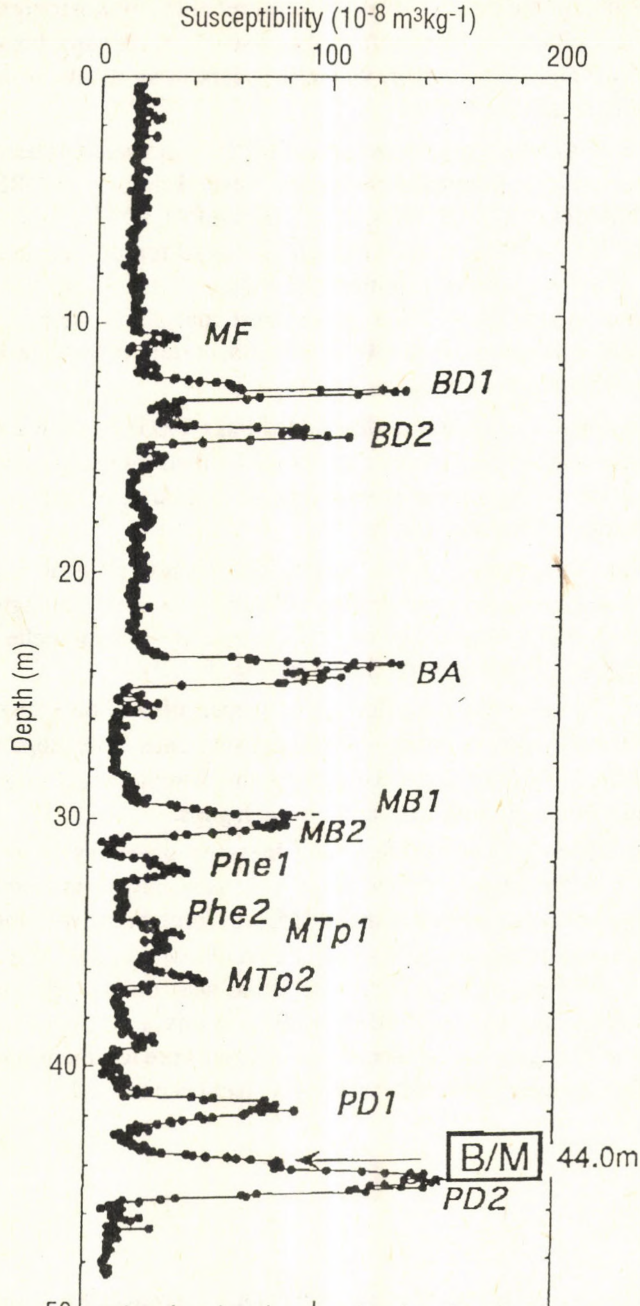


Fig. 3. Susceptibility and provisional paleomagnetic analysis at Paks 1995 profile (according FOSTER, SARTORI and HELLER)

It seems that in the Paks profiles the most reliable chronostratigraphic marker is the B/M boundary. This is further confirmed by data about the same boundary studied at Dunakömlőd-Paks and Dunaföldvár, where it occurs in an identical lithostratigraphic setting (PÉCSI et al. 1979a, 1979b).[1]

2) Material from the southern section in the Paks brickyard has been studied during the last two decades for thermoluminescence. Several authors (BORSY et al. 1979, BUTRYM and MARUSZCZAK 1984, WINTLE and PACKMAN 1988, ZÖLLER et al. 1988, 1993, and LU Y. 1993) studied the samples by different methods. These investigations resulted in various chronostratigraphical data. These results are compared with each other in this volume (page 36). E.g. the latest analysis, made by L. ZÖLLER, the BD_1 and BD_2 paleosols are 114 resp. 144 ka B.P. old, correlated with the last interglacial, using Milankovich's climatic calendar.

The above described outcrop (designated Paks 1995) is more complex than the previously studied ones, thus it is more appropriate for thermoluminescence studies. Thus a repeated study of the new samples would be of great use, perhaps allowing a more reliable chronostratigraphic subdivision.

3) The lithostratigraphy of the "Paks 1995" section point to a more complete sequence here than at the previously studied and published ones, although there are some gaps here, too (white arrows point to levels with delle erosion and delle infilling, while black arrows indicate gaps caused by linear erosion, *Fig. 2*).

It may be supposed that the paleosols are superimposed on each other in the old loess series indicate weaker or stronger erosional gaps caused by slope wash. Residual soils (eroded soils, MF_2, Phe_1, Mtp_1, Hs_2, Pem), thin resedimented soils in loess layers and some detritus of concretions may point to such gaps.

4) In the upper 10.5 m of the young loess no paleosols occur, just one thin embryonic soil (H). The upper 6 m fine sandy loess is weekly or moderately structured, the delle infillings are interstratified with sands. Loess formation, evolution of loess fabric was more effective between 6 and 10 m (l_2) than elsewhere, due to a relatively slow accumulation of minerals. A layer of similar fabric was found at the lower part of the young loess, between the paleosols BD_2 and BA. In this series, between 16–20 m the delle activity was high (erosion and accumulation), thus predominantly sandy loess was formed, loessification was weak, thin sand layers had been eroded.

[1] In the BD_2 soil in the southern section of the Paks claypit M.A. PEVZNER (1988) found reversed magnetism, but repeated measurements could not confirm this statement. Thus the position of the Blake event (125 ka) needs further studies.

Regarding the granulometry and fabric, loess layers l'_5 and l_6 may be regarded as typical loess, although there are some intercalated semipedolith horizons of solifluction origin within them. Among the old loess layers, L_2, L_5, L_6 and L'_6 show typical loess fabric (*Tab. 1*).

5) The 0.2–1 m thick C_{ca} horizons, calcareous loesses, beneath the paleosols may be regarded genetically as part of the soils rather than true loesses. Consequently, their lithostratigraphic classification is dubious, they may be classified either as part of the paleosol or of the loess.

Some paleosols (MB_1+MB_2, Phe_2+Mtp_1+Mtp_2) are superimposed upon one another and no calcareous loess occurs between them, their accumulation horizon is assumed to be situated in the underlying soil. The duration of the formation of these soilcomplexes and of the so called *double soils* (MF_1+MF_2, BD_1+BD_2) is still dubious. Their litho- and chronostratigraphic classification has not yet been resolved.

Variations within the Paks brickyard sequence have been observed for several decades. Based on these observations as well as on study of many Hungarian and foreign loess–paleosol sequences, we hold that in our section (*Fig. 2*) the formation of the double soils MF_1+MF_2 and BD_1+BD_2 were interrupted for some time, and, after a moderate erosion or reduced sedimentation the process of soil formation started again.

The formation of the polygenetic soil complex MB_1+MB_2, however, lasted for a long time, consequently, two superimposed soil units were formed, due to a change in climate during pedogenesis.

The superposition of the paleosols Phe_2+Mtp_1 must be preceded by a significant erosional hiatus, because the steppe soil Phe_2 was formed on a sandy substratum, which was deposited after an erosional period by a subsequent proluvial sand accumulation.

These three types of superimposed soils may be combined with each other (PÉCSI 1995).

In the above described section there are more paleosols than in the profile Paks/1977. In the present sequence the MF_2 and Phe1 soil residues also occur. The Pal (Paks alluvial soil) unit is newly recognised. In the old loess some pedified loess (embryonic soils: Hs_1, Hs_2 and Pem) were also identified (*Fig. 2*).

6) *Fig. 2* illustrates the chronostratigraphic subdivision of the Paks 1995 section. This is based on the observed lithostratigraphic features, on the conditions of the formation of zonal soils and loess layers, on the radiation curve of Milankovich, on the situation of the B/M boundary as well as on some other TL and paleomagnetic data. Our aim is to promote further studies about the formation and chronology of loess sequences at Paks.

Table 1. Granulometric composition, carbonate and humus content of the loess profile at Paks 1995, Hungary. (Analysed by Mrs. BALOGH, DI GLÉRIA, M. and Mrs. HAVAS, J.)

Profile	$CaCO_3$	H	N°	clay			silt		sand				P	L	Ps
				<0.002	0.002–0.005	0.005–0.01	0.01–0.02	0.02–0.05	0.05–0.1	0.1–0.2	0.2–0.5	>0.5			
m	%	%	Samp	mm Ø gr %									%	%	%
0.15–0.25	12.3	2.37	1	9.9	5.9	5.9	18.1	23.2	30.4	3.9	2.0	0.7	21.7	41.3	37.0
0.28–0.40	12.8	1.29	2	12.2	5.4	5.5	14.8	28.8	28.2	3.3	1.5	0.3	23.1	43.6	33.3
0.45–0.58	20.4		3	14.5	7.7	6.6	16.3	30.8	22.3	1.3	0.3	0.2	28.8	47.1	24.1
0.80–0.93	14.9		4	11.6	5.2	5.4	10.8	36.2	28.8	1.5	0.3	0.2	22.2	47.0	30.8
1.10–1.23	14.0		5	10.4	3.3	2.4	8.0	35.5	38.2	1.8	0.4	0.0	16.1	43.5	40.4
1.36–1.48	12.8		6	12.1	3.9	2.5	9.9	38.2	31.1	2.0	0.3	0.0	18.5	48.1	33.4
1.65–1.76	12.3		7	10.2	2.9	0.7	5.6	38.3	41.3	0.9	0.0	0.1	13.8	43.9	42.3
1.87–2.00	14.9		8	8.6	7.3	3.7	10.3	37.0	32.1	0.9	0.1	0.0	19.6	47.3	33.1
2.10–2.23	14.5		9	11.7	3.8	1.6	10.2	41.2	30.9	0.6	0.0	0.0	17.1	51.4	31.5
2.40–2.52	12.8		10	10.7	3.8	3.0	7.9	39.4	34.0	1.1	0.1	0.0	17.5	47.3	35.2
2.72–2.86	11.9		11	11.8	3.5	3.6	11.8	42.5	25.7	0.9	0.2	0.0	18.9	54.3	26.8
3.00–3.13	14.0		12	11.7	3.9	4.7	11.1	41.4	23.3	2.6	1.3	0.0	20.3	52.5	27.2
3.34–3.45	13.2		13	12.6	3.4	5.7	21.1	31.3	22.7	2.5	0.7	0.0	21.7	52.4	25.9
3.64–3.80	12.8		14	11.8	1.7	4.8	12.9	36.0	30.7	1.7	0.4	0.0	18.3	48.9	32.8
4.18–4.31	13.6		15	11.8	3.2	4.9	14.3	35.4	26.6	2.7	1.1	0.0	19.9	49.7	30.4
4.51–4.64	11.9		16	13.6	2.6	4.5	13.3	37.4	26.2	1.7	0.6	0.1	20.7	50.7	28.6
4.93–5.02	10.2		17	16.9	6.8	7.1	17.0	28.7	14.2	5.5	3.6	0.2	30.7	45.7	23.5
5.48–5.60	11.9		18	12.9	3.1	4.1	13.3	37.5	28.1	0.9	0.1	0.0	20.1	50.8	29.1

Pelite (P): < 0.002–0.01, Aleurite (L) 0.01–0.05, Psammite (Ps): > 0.05

Table 1. (continuation)

Profile	$CaCO_3$	H	N°	clay			silt		sand				P	L	Ps
				<0.002	0.002–0.005	0.005–0.01	0.01–0.02	0.02–0.05	0.05–0.1	0.1–0.2	0.2–0.5	>0.5			
m	%	%	Samp	mm Ø gr %									%	%	%
6.44–6.56	4.3	0.21	19	15.5	4.9	7.9	20.5	35.7	14.8	0.6	0.1	0.0	28.3	56.2	15.5
6.68–6.82	11.9	0.00	20	11.5	8.0	6.8	13.7	33.7	25.2	1.0	0.1	0.0	26.3	47.4	26.3
7.00–7.12	11.1		21	13.7	4.1	2.8	15.4	38.0	25.0	0.9	0.1	0.0	20.6	53.4	26.0
7.40–7.53	11.1		22	13.3	3.5	5.2	15.8	38.1	23.1	0.9	0.1	0.0	22.0	53.9	24.1
7.73–7.86	10.7		23	13.0	3.6	3.6	16.8	40.5	21.7	0.7	0.1	0.0	20.2	57.3	22.5
8.30–8.42	11.1		24	12.1	2.8	3.8	13.7	40.2	26.5	0.8	0.1	0.0	18.7	53.9	27.4
8.68–8.81	11.9		25	13.5	2.4	5.6	19.6	31.4	27.1	0.4	0.0	0.0	21.5	51.0	27.5
9.37–9.51	9.8		26	12.4	3.7	5.3	15.0	36.7	26.5	0.4	0.0	0.0	21.4	51.7	26.9
9.80–9.92	8.9		27	11.9	4.1	6.0	20.1	39.7	17.9	0.3	0.0	0.0	22.0	59.8	18.2
10.25–10.37	8.9		28	13.6	4.9	6.1	18.3	39.9	17.0	0.2	0.0	0.0	24.6	58.2	17.2
10.48–10.60	5.1	0.65	29	18.9	6.3	7.8	23.3	33.1	9.7	0.7	0.2	0.0	33.0	56.4	10.6
10.70–10.83	5.5	0.54	30	22.6	6.4	7.9	16.7	32.1	12.6	1.3	0.4	0.0	36.9	48.8	14.3
11.10–11.23	17.0	0.00	31	24.0	6.4	7.5	15.8	35.3	10.7	0.3	0.0	0.0	37.9	51.1	11.0
11.28–11.40	16.5	0.00	32	19.1	10.1	7.8	14.7	35.4	12.7	0.2	0.0	0.0	37.0	50.1	12.9
11.50–11.62	4.7	0.11	33	17.0	5.6	6.7	21.1	36.7	12.2	0.7	0.0	0.0	29.3	57.8	12.9
11.64–11.80	8.9		34	14.8	5.0	8.6	20.0	37.3	13.8	0.5	0.0	0.0	28.4	57.3	14.3
12.19–12.31	11.9	0.11	35	19.3	7.1	7.1	19.9	35.5	10.7	0.4	0.0	0.0	33.5	55.4	11.1
12.42–12.53	8.5	0.65	36	22.3	6.8	6.6	15.6	36.9	11.4	0.4	0.0	0.0	35.7	52.5	11.8

Pelite (P): < 0.002–0.01, Aleurite (L) 0.01–0.05, Psammite (Ps): > 0.05

Table 1. (continuation)

Profile	$CaCO_3$	H	N°	clay			silt		sand				P	L	Ps
				<0.002	0.002–0.005	0.005–0.01	0.01–0.02	0.02–0.05	0.05–0.1	0.1–0.2	0.2–0.5	>0.5			
m	%	%	Samp	mm Ø gr %									%	%	%
12.65–12.78	3.8	0.65	37	24.6	6.8	6.7	22.0	25.3	13.3	1.0	0.3	0.0	38.1	47.3	14.6
12.87–13.00	3.4	0.86	38	29.4	5.1	6.1	13.4	27.9	15.7	1.8	0.6	0.0	40.6	41.3	18.1
13.05–13.18	2.5	0.65	39	29.4	4.6	5.1	11.5	27.7	18.9	2.0	0.8	0.0	39.1	39.2	21.7
13.23–13.36	18.7	0.00	40	33.2	10.3	6.6	8.0	26.2	14.3	1.1	0.3	0.0	50.1	34.2	15.7
13.50–13.63	21.6	0.00	41	25.5	8.0	5.5	13.8	29.0	17.2	0.8	0.2	0.0	39.0	42.8	18.2
13.83–13.95	11.0	0.00	42	26.1	7.9	6.4	14.1	32.0	12.4	0.8	0.2	0.1	40.4	46.1	13.5
14.20–14.33	5.5	0.32	43	28.8	6.7	6.8	16.3	24.6	13.4	2.4	0.9	0.1	42.3	40.9	16.8
14.90–15.00	18.2	0.00	44	22.5	9.3	6.7	10.2	19.8	21.9	6.2	3.1	0.3	38.5	30.0	31.5
15.11–15.23	9.7	0.00	45	26.1	4.5	4.7	14.1	27.9	16.5	4.3	1.8	0.1	35.3	42.0	22.7
16.51–16.63	11.0		46	13.8	5.9	8.4	14.9	35.3	18.4	2.2	0.9	0.2	28.1	50.2	21.7
17.23–17.35	7.6		47	10.0	2.3	1.6	7.8	18.7	38.1	16.4	4.9	0.2	13.9	26.5	59.6
17.65–17.80	8.1		48	11.0	2.9	3.4	8.5	26.2	38.9	7.5	1.6	0.0	17.3	34.7	48.0
18.40–18.52	8.9		49	10.7	2.6	3.5	9.7	13.0	49.1	10.2	1.2	0.0	16.8	22.7	60.5
19.40–19.53	6.4		50	7.8	1.8	2.4	4.6	6.2	37.7	27.5	11.7	0.3	12.0	10.8	77.2
20.20–20.35	9.7		51	10.7	3.6	4.8	12.1	39.2	28.2	1.2	0.2	0.0	19.1	51.3	29.6
21.80–21.95	10.2		52	9.8	3.0	6.7	15.0	40.4	23.5	1.3	0.3	0.0	19.5	55.4	25.1
22.60–22.73	10.2		53	13.8	4.8	5.9	15.3	40.8	18.0	1.1	0.3	0.0	24.5	56.1	19.4
23.30–23.43	8.5		54	20.7	6.0	6.6	18.4	35.0	11.6	1.3	0.4	0.0	33.3	53.4	13.3

Pelite (P): < 0.002–0.01, Aleurite (L) 0.01–0.05, Psammite (Ps): > 0.05

Table 1. (continuation)

Profile	$CaCO_3$	H	N°	clay			silt		sand				P	L	Ps
				<0.002	0.002–0.005	0.005–0.01	0.01–0.02	0.02–0.05	0.05–0.1	0.1–0.2	0.2–0.5	>0.5			
m	%	%	Samp	mm Ø gr %									%	%	%
23.50–23.65	7.2	0.21	55	28.3	5.6	6.5	15.1	30.8	11.3	1.7	0.7	0.0	40.4	45.9	13.7
23.80–23.92	9.3	0.75	56	27.9	9.4	6.9	13.3	27.9	11.4	2.4	0.8	0.0	44.2	41.2	14.6
23.94–24.05	6.4	0.65	57	31.2	5.9	5.1	12.8	28.0	13.3	2.8	0.9	0,0	42.2	40.8	17.0
24.12–24.24	11.0	0.75	58	31.2	5.4	6.3	11.4	21.9	11.4	2.9	9.5	0.0	42.9	33.3	23.8
24.32–24.43	16.5	0.65	59	33.0	7.0	5.5	11.4	25.4	13.3	3.2	1.2	0.0	45.5	36.8	17.7
24.55–24.68	14.8	0.54	60	30.2	6.8	5.3	10.9	26.1	15.8	3.6	1.3	0.0	42.3	37.0	20.7
24.74–24.87	18.8	0.21	61	28.8	7.3	5.8	17.5	22.4	15.8	1.9	0.5	0.0	41.9	39.9	18.2
24.90–25.05	19.2	0.00	62	25.9	7.4	5.9	11.6	30.8	17.1	0.9	0.2	0.2	39.2	42.4	18.4
25.46–25.60	10.7		63	16.5	4.9	5.8	12.0	39.2	21.2	0.4	0.0	0.0	27.2	51.2	21.6
25.84–25.96	10.2		64	14.5	5.2	4.9	13.7	44.8	16.6	0.3	0.0	0.0	24.6	58.5	16.9
26.88–27.00	11.9		65	17.9	7.5	6.1	17.6	39.0	11.7	0.2	0.0	0.0	31.5	56.6	11.9
27.50–27.63	9.8		66	18.2	6.9	7.9	18.2	40.0	8.4	0.2	0.1	0.1	33.0	58.2	8.8
28.32–28.45	10.7	0.00	67	20.8	6.6	7.7	19.7	36.9	7.4	0.6	0.3	0.0	35.1	56.6	8.3
28.78–28.92	11.9	0.00	68	19.9	8.1	8.3	18.5	35.1	9.4	0.6	0.1	0.0	36.3	53.6	10.1
29.35–29.47	4.7	0.11	69	23.6	7.7	6.9	21.5	31.1	7.7	1.1	0.4	0.0	38.2	52.6	9.2
29.60–29.73	9.4	0.21	70	28.0	7.3	7.7	17.2	27.5	9.3	2.0	0.9	0.1	43.0	44.7	12.3
29.76–29.89	3.0	0.21	71	32.2	6.6	6.5	13.8	26.3	9.6	2.8	2.0	0.2	45.3	40.1	14.6
29.97–30.10	3.0	0.43	72	31.6	6.5	7.2	13.0	26.9	11.3	3.1	2.2	0.2	45.3	39.9	16.8

Pelite (P): < 0.002–0.01, Aleurite (L) 0.01–0.05, Psammite (Ps): > 0.05

Table 1. (continuation)

Profile	$CaCO_3$	H	N°	clay			silt		sand				P	L	Ps
				<0.002	0.002–0.005	0.005–0.01	0.01–0.02	0.02–0.05	0.05–0.1	0.1–0.2	0.2–0.5	>0.5			
m	%	%	Samp	mm Ø gr %									%	%	%
30.23–30.36	1.3	0.11	73	38.3	5.5	6.5	17.9	19.7	8.3	2.1	1.3	0.4	50.3	37.6	12.1
30.37–30.50	0.8	0.00	74	38.1	5.5	6.2	11.5	27.3	8.5	1.5	1.1	0.3	49.8	38.8	11.4
30.50–30.63	1.7	0.00	75	34.1	3.3	4.8	14.1	31.2	10.5	1.1	0.7	0.2	42.2	45.3	12.5
30.68–30.80	23.5	0.00	76	17.9	6.8	7.7	11.9	35.9	9.7	2.8	3.7	3.6	32.4	47.8	19.8
31.00–31.13	18.8		77	16.4	5.7	5.9	18.4	37.6	10.2	1.5	2.4	1.9	28.0	56.0	16.0
31.37–31.50	9.8	0.11	78	19.5	6.1	7.1	19.9	34.4	9.3	1.2	1.3	1.2	32.7	54.3	13.0
31.62–31.75	14.5	0.00	79	23.3	6.8	7.9	18.4	26.7	5.9	0.8	0.6	9.6	38.0	45.1	16.9
31.83–31.94	12.4		80	22.1	11.5	7.9	18.0	27.8	8.9	1.0	0.5	2.3	41.5	45.8	12.7
32.03–32.16	10.7	0.21	81	26.8	9.7	7.0	19.2	27.5	7.5	0.7	0.4	1.2	43.5	46.7	9.8
32.40–32.53	16.2		82	25.5	5.8	9.4	22.1	27.5	8.4	0.6	0.2	0.5	40.7	49.6	9.7
33.20–33.33	9.8		83	17.1	8.0	4.7	19.0	35.3	14.7	0.8	0.3	0.1	29.8	54.3	15.9
33.57–33.70	9.4		84	18.2	7.4	6.5	17.9	36.5	12.6	0.6	0.2	0.1	32.1	54.4	13.5
33.86–34.00	4.3	0.11	85	19.8	8.1	7.4	22.3	24.6	10.5	4.1	2.7	0.5	35.3	46.9	17.8
34.54–34.68	8.1	0.21	86	19.5	7.9	6.9	10.7	21.7	15.6	11.8	5.7	0.2	34.3	32.4	33.3
34.80–34.93	3.0	0.21	87	16.6	6.0	5.0	7.7	16.9	17.5	19.3	9.9	1.1	27.6	24.6	47.8
34.93–35.10	2.6	0.43	88	15.7	4.7	4.8	5.6	17.0	19.2	20.3	11.2	1.5	25.2	22.6	52.2
35.38–35.52	7.2	0.32	89	17.9	7.8	5.9	9.7	28.8	25.7	3.2	0.8	0.2	31.6	38.5	30.9
35.77–35.90	6.4	0.21	90	32.0	8.1	7.5	13.5	27.9	8.8	1.3	0.6	0.3	47.6	41.4	11.0

Pelite (P): < 0.002–0.01, Aleurite (L) 0.01–0.05, Psammite (Ps): > 0.05

Table 1. (continuation)

Profile	$CaCO_3$	H	N°	clay			silt		sand				P	L	Ps
				<0.002	0.002–0.005	0.005–0.01	0.01–0.02	0.02–0.05	0.05–0.1	0.1–0.2	0.2–0.5	>0.5			
m	%	%	Samp	mm Ø gr %									%	%	%
36.15–36.28	3.0	0.11	91	32.8	7.4	6.7	11.8	27.5	11.6	1.4	0.6	0.2	46.9	39.3	13.8
36.68–36.80	17.1	0.00	92	18.6	13.9	7.7	17.6	29.7	11.4	0.6	0.3	0.2	40.2	47.3	12.5
37.37–37.50	13.6		93	18.1	7.8	6.2	16.1	34.4	16.0	1.0	0.3	0.1	32.1	50.5	17.4
38.13–38.30	11.1		94	18.3	6.1	5.8	15.0	36.2	16.9	0.8	0.4	0.5	30.2	51.2	18.6
38.77–38.90	9.0	0.11	95	21.4	6.8	5.9	13.9	32.1	16.9	2.0	0.9	0.1	34.1	46.0	19.9
39.05–39.20	8.1	0.21	96	22.7	7.3	6.3	11.1	29.3	17.6	3.6	1.9	0.2	36.3	40.4	23.3
39.45–39.60	8.1		97	21.8	7.2	6.6	19.8	17.2	19.1	5.6	2.6	0.1	35.6	37.0	27.4
40.00–40.14	9.4		98	20.8	5.7	6.8	17.8	31.0	14.7	2.4	0.7	0.1	33.3	48.8	17.9
40.39–40.53	5.6	0.43	99	30.3	5.9	8.0	17.3	26.4	10.3	1.2	0.5	0.1	44.2	43.7	12.1
40.90–41.00	6.0	0.00	100	29.7	5.9	7.7	16.1	30.8	7.9	1.1	0.5	0.3	43.3	46.9	9.8
41.20–41.30	6.4	0.00	101	17.7	3.6	4.7	10.9	13.0	10.3	20.4	19.3	0.1	26.0	23.9	50.1
41.50–41.65	3.9	0.11	102	32.8	5.7	7.3	17.0	28.7	7.8	0.4	0.2	0.1	45.8	45.7	8.5
42.05–42.20	12.4	0.75	103	35.8	5.8	6.0	18.3	26.4	7.1	0.4	0.1	0.1	47.6	44.7	7.7
42.40–42.50	21.4	0.00	104	29.1	11.4	8.7	15.4	26.4	8.3	0.5	0.1	0.1	49.2	41.8	9.0

Pelite (P): < 0.002–0.01, Aleurite (L) 0.01–0.05, Psammite (Ps): > 0.05

SELECTED REFERENCES

ÁDÁM, L.–MAROSI, S.–SZILÁRD, J. 1954. A paksi löszfeltárás. (Der Lößaufschluss von Paks.) Földr. Közlem. 2. 3. 239–254. (Zusammenf. Deutsch)

BACSÁK, GY. 1942. Die Wirkung der skandinavischen Vereisung auf die Periglazialzone. Budapest, 86 p.

BACSÁK, GY. 1955. Pliozän- und Pleistozänzeitalter im Licht der Himmelsmechanik. Acta Geologica Acad. Sci. Hung. 3. 4. 305–346.

BORSY, Z.–FÉLSZERFALVY, J.–SZABÓ, P. P. 1979. Thermuluminescence dating of several layers of the loess sequences at Paks and Mende (Hungary). Acta Geologica Acad. Sci. Hung. 22. 1–4. 451–459.

BRONGER, A. 1976. Zur quartären Klima- und Landschaftsentwicklung auf (paläo)-pedologischer und bodengeographischer Grundlage. Kiel, Univ. Kiel. 268 p.

BULLA, B. 1937. Der pleistozäne Löß im Karpathenbecken. I–II. Földtani Közlöny. 67. 196–216., 289–309.

BUTRYM, J.–MARUSZCZAK, H. 1984. Thermoluminescence chronology of younger and older loesses. In: PÉCSI, M. (ed.): Lithology and stratigraphy of loess and paleosols. Bp. Geogr. Res. Inst. 195–199.

KRIVÁN, P. 1953. Die Erdgeschichtlichen Rhythmen des Pleistozänzeitalters, Acta Geologica Acad. Sci. Hung. 2. 1–2. 79–90.

KRIVÁN, P. 1955. La division climatologique du Pleistocene en Europe Centrale et la profil de loess de Paks. Annales Inst. Geol. Publ. Hung. 43. 3. 441–512.

LU, Y. 1992. TL Datierung die Lößprofile von Basaharc, Mende, Paks in Ungarn. Manuskriptdokumentation in Akad. der. Wiss. Geogr. Inst. Budapest.

MÁRTON, P. 1979. Paleomagnetism of the Paks brickyard exposures. Acta Geologica Acad. Sci. Hung. 22. 1–4. 433–441.

MILANKOVITSCH, M. 1941. Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitproblem. Belgrade, Acad. Roy. Serbe. 633 p.

PÉCSI, M. 1972. Scientific and practical significance of loess research. Acta Geol. Acad. Sci. Hung. 16. 317–328.

PÉCSI, M. 1995. The Role of Principles and Methods in Loess–Paleosol Investigations. GeoJournal. 36. 2–3. 117–131.

PÉCSI, M.–PEVZNER, M. A. 1974. Paleomagnetic measurements in the loess sequences at Paks and Dunaföldvár, Hungary. Földrajzi Közlemények 22. 3. 215–224.

PÉCSI, M.–SCHWEITZER, F. 1995. The lithostratigraphical, chronostratigraphical sequence of Hungarian loess profiles and their geomorphological position. In: Loess inForm 3. Budapest, Geographical Research Institute. 31–61.

SCHERF, E. 1936. Versuch einer Einteilung des ungarischen Pleistozäns auf moderner polyglazialistischer Grundlage. In: Verhandlungen der III. Internationalen Quartär-Konferenz, Wien, Sept. 1936. Wien, Geologische Landesanstalt. 237–247.

STEFANOVITS, P.–RÓZSAVÖLGYI, J. 1965. Beschreibung der Lössprofils bei der Ziegelei Paks. Földrajzi Közlemények. 13. (89.) 4. 357–360.

SZEBÉNYI, E. 1979. Sedimentological and Micromineralogical Analysis of the Southern Profile of Paks Loess Exposure. Studies on Loess. Acta Geologica Acad. Sci. Hung. 22. 1–4. 427–433.

WINTLE, A. G. 1987. Thermoluminescence dating of loess. Catena Supplement. 9. 103–115.

ZÖLLER, L.–WAGNER, G. A. 1988. Thermolumineszenz-Datierung an Löß–Paläoböden–Sequenzen von Nieder-, Mittel- und Oberrhein. Chemical Geology. 73. 39–62.

ZÖLLER, L.–WAGNER, G. A. 1990. Thermoluminescence dating of loess–recent developments. Quaternary International. 7–8. 119–128.

ZÖLLER, L.–OCHES, E. A.–McCOY. W. D. 1994. Towards a revised chronostratigraphy of loess Austria, with respect to key sections in Czech Republic and in Hungary. Quaternary Geochronology. (Quaternary Science Reviews). 13. 465–472.

Loess inForm 3. 1995. 79–94.
Geographical Research Institute Hungarian Academy of Sciences

CONSTRUCTING THE PALAEOVEGETATIONAL RECORD FOR THE BURIED SOILS IN THE HUNGARIAN YOUNG LOESS SEQUENCE: A VIEW FROM PHYTOLITH ANALYSIS

ENGEL-DI MAURO, S.

Department of Geography, Rutgers University, U.S.A.

Abstract

Paleoenvironmental investigations on the Hungarian Young Loess sequence (Upper Pleistocene) have been used to both infer paleoclimate and improve inter-regional correlations. These paleoenvironmental data, however, are insufficient to form the basis of such inductions. Paleovegetational and malacological studies have been scarce and results from different paleoenvironmental methods do not always agree. Moreover, these problems are compounded by numerous chronological revisions derived through various dating methods.

Phytolith analysis was applied to the Hungarian Young Loess sequence as a contribution towards the solution of these problems. Opal phytoliths were extracted from the MF and BD_1 buried soils of three Hungarian type-sites: Basaharc, Mende, and Paks. Intervening loess strata were also investigated. Because the specimens observed were highly weathered, no identification to the family level was possible. Nevertheless, vegetation community types were discernible. Previous paleoenvironmental investigations were then compared to the phytolith data obtained. The findings generally display more of an affinity towards palynological than malacological data.

According to the phytolith data, the MF soils developed under a relatively dry savannah environment. The loesses within the MF pedocomplex and between the MF and BD_1 soils were stabilised under non-arboreal vegetation. The BD_1 soils exhibit more variability. At Basaharc, it was primarily formed under non-arboreal (steppe) vegetation, while at Mende savannah prevailed. At Paks, this soil was subjected to different succeeding community types. These results complement and supplement existing paleoenvironmental records. They also aid in the interpretation of the buried soils and loesses by providing additional information on the environmental conditions responsible for their development.

Introduction

The loess exposures in the western part of the Great Hungarian Plain (Alföld) provide some of the best-preserved buried soil sequences in the world. Thus, they "are especially useful for comparative loess pedostratigraphy and, by inference, a record of major parts of the Pleistocene climatic history of southeast Central Europe" (BRONGER and HEINKELE 1989, p. 171). Still, the understanding of the Quaternary environmental history of this record remains far from satisfactory. Disagreements exist among the available palaeoecological records from which paleoclimates have been inferred. In addition, the viability of buried soil correlations has been undermined by discrepancies between different dating methods.

The principal aim of this research is to contribute new data to the paleoenvironmental and paleoecological record of Late Pleistocene buried soils in Hungary. In the process, I attempt to rectify two salient problems: (1) the scarcity and insufficient resolution of paleovegetation studies and (2) irreconciled discrepancies between paleoenvironmental interpretations. For these purposes, the method of phytolith analysis was applied for the first time to this terrestrial record at three Hungarian type localities: Basaharc, Mende, and Paks.

Phytolith analysis permits the extraction of paleobotanical data from contexts where other botanical remains are seldom preserved (ROVNER 1971). Due to this advantage, phytolith analysis has been successfully employed in a variety of paleopedological and paleoenvironmental studies in many different areas of the world since the 1950's (PIPERNO 1988). Thus, phytolith analysis can contribute to a reinterpretation of this Late Pleistocene paleoenvironmental record. The new data also provide a basis whereby previous paleoenvironmental investigations can be evaluated (and possibly reconciled). As vegetation and other factors are more clearly understood, paleoclimatic interpretations become less speculative and the foundations for buried soil correlation are commensurably secured.

The Young Loess sequence

The Young Loess sequence, "the most complete of the stratigraphic series" in Hungary (PÉCSI and HAHN 1987, p. 95), ranges in age from at least the Mid Pleistocene to the last glaciation. The sites investigated are located in Central and North-Central Hungary. They are regarded as type localities for the entire sequence (PÉCSI and HAHN 1987; PÉCSI and SCHWEITZER 1993). The soils examined in this study belong to the lower Young Loess series, also known as the Mende-Basaharc Loess Complex, which can reach a 15 to 20 m thickness (PÉCSI 1993).

The soils analysed are known as the following: the MF pedocomplex, which is manifested as soils MF_1 and MF_2 at Mende; and the BD (Basaharc Double) pedocomplex, of which only the upper BD_1 soil was sampled. These pedocomplexes form part of a series of stratotypes more or less present at all the sites investigated. The MF_1 soil is considered a "poorly developed chernozem", the MF_2 soil "a well-developed forest steppe soil", and the BD_1 soil a "forest steppe soil" (PÉCSI, 1993, pp. 327–328).

Chronology

Recent reexamination of the TL ages of some of these soils and sediments have somewhat complicated existing stratigraphic correlations. The Young Loess sequence stratotypes have received more confusing than compromising chronological revisions, however. What is certain, nonetheless, is that the soils are much more ancient than previously surmised.

Corroborated through aminostratigraphic analysis, recent TL analyses place the MF soils from Mende and Paks under the same time period (OCHES 1994, ZÖLLER *et al.* 1994). The similarity in age derived from other sites is used as the rationale whereby the MF/MF_1 soils can be confirmed as older than previously thought. Previous ^{14}C dates from all three type-sites also display approximate agreement, however. Unless all radiocarbon dates are proven to have been systematically underestimated, there appears to be no reason to consider TL dates as any more reliable. Consequently, I surmise that the earlier ^{14}C ages remain viable. As recent TL analyses indicate, MF_2 at Mende represents a much earlier soil-forming episode. This suggests an erosional hiatus between soils MF_1 and MF_2.

The newer TL results from the BD_1 soils suggest that their formation preceded the last interglacial. This evidence is further corroborated by relative ages obtained through the analysis of isoleucine racemisation from fossil gastropod shells. The amino acid geochronology constructed from the Paks exposure suggests that BD_1 could belong to the last or an even earlier Riss interstadial (OCHES 1994). ZÖLLER *et al.* (1994) further claim that the entire BD pedocomplex formed during the penultimate interglacial; however, I would argue that, given the evidence, one or both of these soils could just as likely belong to Riss interstadials.

Previous paleoenvironmental studies

Malacological analyses have been limited to the sites of Mende and Paks. The original interpretations of WAGNER (1979 a,b) need to be reassessed in accordance with recent data on gastropod ethology from LOŽEK (1990) and SZÖŐR *et al.* (1991). Hence, malacological data are presented in a reinterpreted form on *Table 1*.

Many palynological investigations have also been performed, but much of the focus has been on longer-term climatic patterns (cf. RÓNAI 1985). The work of PASHKEVICH (1979) and URBAN (1984) constitute the only palynological studies on the MF and BD soils to date. Since no loess units related to this discussion were examined by these authors, the phytostratigraphy of the Young Loess sequence remains tentative. Malacological results from loess 2 (the loess overlying BD_1) at Mende and Paks and from soil BD_1 at Paks contradict palynological findings (*Tab.1*). The micromorphological interpretation of a warmer and drier environment for soil BD_1 at Paks (BRONGER and HEINKELE 1989) also finds no support in the molluscan data. Moreover, many sediments and soils at Mende and Paks have not been subjected to such research, while the site of Basaharc has been ignored.

As a consequence of these discrepancies, palaeoclimate cannot be inferred with any degree of confidence from these soils and sediments, even though the aim of such investigations has largely concentrated on the construction of paleoclimates. The data accumulated through these and the present methods are therefore best confined to the establishment of general paleoenvironmental patterns.

Phytolith analysis

Phytoliths constitute a variety of biogenically mineralised inter- and intracellular deposits which can occur in either calcareous (druses, raphids) or siliceous (plant opal) forms. Calcareous phytoliths are more susceptible to destruction through both weathering and erosion processes and no methodology for their extraction from soils and sediments has been devised (MULHOLLAND and RAPP 1992). Consequently, the siliceous version is generally considered the more viable source of information and has become the primary focus for this type of analysis.

Such deposits develop and accumulate within various plant tissues through the absorption of soil water solutes and subsequent transpiration-controlled translocation. One of these solutes, monosilicic acid, $Si(OH)_4$, contributes to the formation of opaline silica, $SiO_2 \cdot nH_2O$. Opal phytoliths are generally composed of 4-9% H_2O, 85-95% SiO_2, and a variety of impurities. A sizable amount of the latter can be present in the form of occluded organics derived from the cytoplasm. This constituent can exceed the percentage composition of all other trace elements combined and has been successfully utilised for ^{14}C dating (WILDING 1967, WILDING *et al.* 1977).

Opal phytoliths have a refractive index (R.I.) of 1.41–1.47 and are thereby discernible from glass shards (R.I.=1.48-1.61) under a polarising microscope. Their specific gravity ranges from 1.5 to 2.3. Biogenic opal is optically isotropic and displays no birefringence (JONES and BEAVERS 1963). Solubility (3 to 10 mg/l Si) is intermediate between other amorphous silica and silica-alumina gels and quartz (BARTOLI and WILDING 1980, WILDING *et al.* 1977, pp. 519–521). Opal phytoliths can reach a maximum diameter of 1,000 μm and a minimum of 1 μm (ROVNER 1983, p. 228).

As different portions of a plant, during its life cycle, either senesce or are severed and are thereafter digested through organismal activity, these biogenic deposits are released from their inter- and intracellular loci. Subsequently, they become incorporated into the soil as mostly solitary particles along with their associated organic matter.

Eventually, the entire plant ceases to live and the remaining body is consumed, thereby contributing more phytoliths to the soil.

Generally, phytoliths survive at a wider pH range than pollen, are resistant to changes in soil pH, and are not contingent upon sexually reproductive cycles (ROVNER 1971). However phytomorphic[1] differentiation rests completely on surficial features which are susceptible to dissolution and disarticulation. Problems related to preservation therefore become salient and complicate issues of interpretation. In this study, the degree of fragmentation, corrosion, and weathering precluded any possibility of identification below the general ecosystem level. Therefore, for the purpose of this analysis, only the most basic differentiation between arboreal and non-arboreal taxa was sought.

Established criteria for morphological differentiation between arboreal and non-arboreal phytoliths already exist (GEIS and JONES 1973; WILDING and DREES 1974). For instance, temperate deciduous species appear to produce diagnostic scrolled forms, cup-shaped, and spherical phytoliths. These contrast with the generally nodular (globular) forms prevalent in herbaceous taxa (GEIS and JONES 1973; ROVNER 1971; WILDING and DREES 1973 and 1974).

Phytolith assemblages can represent both allochtonous and autochtonous phytomorphs. It becomes difficult, therefore, to estimate the extent to which the local vegetation is represented in a paleosol, especially in a zone of high eolian particulate deposition. As in the loess regions of North America, the effect of eolian transport "may normalize grass phytolith distribution over a region" (FREDLUND *et al.* 1985, p. 152) such as the Alföld. Nevertheless, phytoliths remain less susceptible than pollen to eolian transport (GEIS 1973).

Methods

All soils investigated were sampled at 10 cm intervals whenever possible, but never exceeded 20 cm. Intervening loess strata were also sampled. Soil processing followed a combination of different methods learned from G.G. FREDLUND, I. ROVNER, and B. MIDDLETON (also cf. PEARSALL 1986; ROVNER 1971).

In order to address the specificity of the forms observed in these samples, I devised a descriptive nomenclature which also relies upon an amalgam of established classification schemes. Each category was defined qualitatively according to general shape characteristics, rather than geometric proportions. I assume that surficial features have dissolved as a result of prolonged exposure to alkaline conditions derived from soil

[1] Phytomorphs are distinguishable phytolith morphological units.

recalcification. Consequently, I interpreted globular and polyhedral forms as representing partially dissolved bilobates, crosses, and/or saddles (each of which are traceable to particular *Poaceae* tribes).

Ambiguities resulting from fracture and weathering allowed only a few categories to be considered for interpretational purposes. Diagnostics for grasses were seldom present in large amounts. However, the concomitant presence of bulliforms, polyhedra, globular forms, polylobates, sinuates, and cones increases the possibility of identifying a soil as having developed under a non-arboreal community. This view is supported by the predominance of more "solid polyhedral structures" and nodular forms found in herbaceous taxa, especially the *Poaceae*. This contrasts with the "generally thin (1–2 μm) fragile plate-shaped incrustations of cell walls" and sphere-shaped phytomorphs typical of soils under forested environments (GEIS 1973; WILDING and DREES 1974, p. 295).

I defined a low phytolith content (expressed as % of sediment weight) to be % and to signify a rarefied presence of herbaceous taxa. This assumption originates from the consistent finding of high phytolith contents in tandem with the dominance of herbaceous species (TWISS *et al.* 1969). Thus, a high percentage of grass phytoliths relative to arboreal types does not entail steppe vegetation dominance if the total phytolith content is too low (FREDLUND *et al.* 1985).

Results

Summary results from both previous and present investigations are displayed on *Table 1*. Phytolith content values are shown on *Table 2*. These percentage figures are determined by dividing phytolith extract weights by their respective total oven-dried sample weights. Sums of diagnostic non-arboreal and arboreal phytomorphs counted are provided on *Table 3*. These scores are weighted by multiplying each sum value by its associated pollen content value and dividing the ensuing figure by 100. These weighted figures are designed to integrate differences in phytolith content with actual counts. By so doing, sums of diagnostic phytomorphs can be compared more easily. For instance, the high number of non-arboreal phytoliths in MF_2 (0–20 cm), Mende, can be readily noted to be much less indicative of the dominance of herbaceous vegetation when weighted with the associated phytolith content percentage (*Tab. 3*).

Following the rationale of URBAN (1984), the phytolith content of each soil can be interpreted as representing the accumulation and integration of microfossils in stratigraphical order. This approach assumes the existence through time of a landscape sufficiently stable for the soils to act as aggrading receptacles. This assumption may be justified in a depositional sequence such as this one (CATT 1990). However, values for the relative abundance of phytoliths complicate this issue (*Tab. 2*).

Table 1. Results from previous and present paleoenvironmental investigations

Soil	Age (BP)*	Basaharc		Mende		Paks	
		Previous	Present	Previous	Present	Previous	Present
$MF_{(1)}$	≈30 ka (^{14}C)	❷Forest/Steppe	Forest→Savannah	❶Warm-Moist ❷Chernozem ❸Mollisol ❹*Pinus*,↑ *Artemisia*	NAV→Savannah	❶Cold ❷Degrad. Chern. ❸Udic Haplustoll ❹50% NAP	--------
MFℓ	≈69 ka (TL)	--------	--------	--------	NAV	--------	--------
MF_2	≈85-69 ka (TL)	--------	--------	❷Forest/Steppe ❸Argiustoll ❹↑ AP	Forest	--------	--------
ℓ2	≈85 ka (TL)	---------	Sparse NAV	--------	NAV	❶Moist-Cold ❹*Cerealia*, *Betula*	NAV
BD_1	≈148-100 ka (TL)	❷Entisol? ❸Udic Haplustoll	NAV	❷Forest/Steppe ❸Argiustoll ❹↑ AP, ↑ *Poaceae*	Savannah	❶Warm-Moist ❷Forest/Steppe ❸Udic Haplustoll ❹↑ *Artemisia*	Forest→Savannah

Legend:

AP: arboreal pollen	❶Malacology	ℓ: loess
NAP: non-arboreal pollen	❷Soil Macromorphology	↑ : high percentage (predominance)
NAV: non-arboreal vegetation	❸Soil Micromorphology	→: change towards other community type
	❹Palynology	*all age estimates derived from Pécsi (1993) and Zöller et al. (1994).

Table 2. Phytolith content data (% of sediment by weight in grammes)

Stratum	Basaharc	Mende	Paks
MF1/MF	1.89*	1.22	N.S.
	1.19*	0.05	N.S.
MF loess	N.A.	0.05	N.S.
MF2	N.A.	0.01	N.S.
	N.A.	0.09	N.S.
	N.A.	0.001	N.S.
loess 2	0.96	0.17	2.13
BD1	1.74	1.60	0.30
	1.67	2.10	0.10
	0.60	N.S.	0.74

* soil MF at Basaharc is presumed to correspond with MF_1 at Mende.
N.A.= not applicable
N.S.= not sampled

The MF pedocomplex. The MF_2 soil at Mende exhibited extremely low quantities of phytoliths. The highest relative values were not consistently coincident with A horizons. Post-burial translocations may have occurred and/or contemporary ecosystem(s) may not have been sufficiently phytolith-productive. There appears to be no consistency to the value fluctuations observed and there exist too many variables, some of which cannot be addressed (e.g., pH), which may have differentially affected the different soils and loesses. (cf. FREDLUND *et al.* 1985, pp. 156–157).

At Basaharc, the MF soil contained some bulliforms[2] and a relatively high amount of spheres. Some bilobates (usually associated with *Panicoid* grasses) and polyhedra appear at the top of the soil and decrease downward. The soil may have thus mostly developed under savannah. Subsequently, it may have been predominantly influenced by steppe. This conclusion is supported by the decrease of phytolith content towards the lower part of the soil and the unchanged relatively high quantities of spheres. Weighted values also demonstrate a smaller difference between arboreal vegetation (AV) and non-arboreal vegetation (NAV) raw scores.

[2] Bulliform cells are water-storing mesophyll cells which silicify under high moisture conditions (ROVNER 1983).

Table 3. Phytolith content totals and weighted values

NAV: non-arboreal vegetation
AV: arboreal vegetation

Site	Stratum	Depth (cm)	Total NAV	Total AV	Weighted NAV	Weighted AV
Basaharc						
	MF	>50①	73	20	1.38	0.37
		50①	48	20	0.57	0.24
	loess 2	middle②	136	2	1.31	0.02
	BD1	0-20	33	0	0.57	0.00
		40-60	73	1	1.22	0.02
		70-95	64	3	0.38	0.02
Mende						
	MF1	10-20	59	17	0.72	0.21
	MF1	20-40	55	4	0.03	0.00
	MFlkö	middle②	55	0	0.03	0.00
	MF2	0-20	110	23	0.01	0.00
		20-40	64	9	0.06	0.01
		40-60	62	18	0.00	0.00
	loess 2	middle②	95	9	0.16	0.01
	BD1	0-20	64	11	1.02	0.18
		20-40	64	12	1.34	0.25
Paks						
	BD1	0-20	90	6	0.27	0.02
		30-50	60	24	0.06	0.02
		70-90	90	17	0.67	0.13

① samples extracted ≥50 cm above the MF-loess 2 boundary
② samples extracted approximately from the middle of the stratum

Soil MF_1 at Mende appears to have developed at first under a NAV and subsequently under sparse AV. This is deduced from the increase down the soil profile of bulliforms and polyhedra and the downward decrease in spheres. The higher sphere content coincides with a relatively sustained number of trichomes and polylobates and the appearance of a few cones and saddles. The phytolith content values confuse the matter, however. Very low values might suggest an increasing arboreal and/or shrub influence; but spheres decrease at the bottom of the soil (A_2 horizon), while NAV values remain relatively stable throughout.

Somewhat the inverse seems to have occurred to the MF_2 soil. The downward decrease in globular shapes correlates with similar decreases in bulliforms and cones. Spheres decrease in the middle of the solum (lower A_1 and upper A_2 horizons), but remain numerous in the upper A_1 and lower A_2 horizons. The decrease coincides with a slight increase in overall phytolith content. Trichomes are present throughout in relatively large quantities. It is possible that this soil developed under forested conditions gradually shifting towards a sparsely forested environment and thereafter reverting to a forest ecosystem. However, the very low phytolith content values indicate minimal presence of NAV throughout the development of the soil.

The loess strata. The loesses mostly formed under sparse NAV. The complete absence of spherical phytomorphs from the loess between soils MF_1 and MF_2 is quite suggestive of the presence of herbaceous taxa. The loess at Mende, between the MF and BD pedocomplexes, may have formed under an environment sufficiently humid for trees to grow, as the phytolith record attests. Alternatively, AV phytoliths may have been introduced through eolian processes.

The BD_1 soil. Ambiguous results were obtained from soil BD_1. At Mende, the extremely low amount of NAV diagnostics may indicate a forest environment. Most of the NAV phytolith assemblage is comprised by globular forms, signifying a high degree of surficial weathering. The relatively high phytolith content suggests that the soil probably developed under a savannah environment. Results from Paks indicate that the soil developed under AV and then NAV as a drier phase followed. The middle of the profile coincides with the lowest levels of NAV diagnostics and the highest levels for AV. The Basaharc evidence, however, suggests a predominance of NAV, based on the virtual absence of any spherical phytomorph. Although very few NAV diagnostics were found, the levels of crosses and saddles (associated with Chloridoid grasses) were higher than at other sites and were accompanied by high amounts of globular phytomorphs.

Discussion

Phytolith preservation was rather poor, probably as a result of recalcification from the overlying loess (BRONGER and HEINKELE 1989, p. 165). The resulting alkalinity increased dissolution rates (KAUFMAN *et al.*, 1981). But despite adverse conditions of preservation, the phytolith record reveals broad vegetation community changes through time. From the integration of this phytolith record with previous paleoecological analyses a more complete environmental picture emerges for the various buried soils and loess deposits investigated (*Tab. 1*).

The MF pedocomplex. Soil MF_1 at the Mende site probably developed under steppe and was later modified by the appearance of several arboreal taxa. This is corroborated by both malacological and palynological data. Thermophilous and hygrophilous gastropods occur with sparse thermophilous trees and a predominance of steppe. From this, a relatively humid temperate environment can be deduced. Temperatures were probably high as well. It is likely that the soil was a Udoll or Ustoll (degraded chernozem).

Soil MF_2 formed under a forest ecosystem, according to both palynological and phytolith data. This somewhat contradicts BRONGER and HEINKELE's (1989) assessment. They consider this soil to represent an Argiustoll, as a consequence of a relatively high clay content in the B horizon. Presumably, this would constitute a cambic horizon. However, no data are furnished to support this proposition. Furthermore, according to the results of PÉCSI–DONÁTH (1979), only a 1 to 2 % clay increase is documented for this purported B horizon. This suggests that despite a predominance of AV very little clay translocation occurred.

At the Mende site, in summary, aeolian processes began to dominate as the forest overlying the MF_2 soil gradually disappeared. Loess then formed under probably a sparse grass vegetation. The relative aridity which ensued may have only slightly decreased when the MF_1 soil began to form. In the north-central part of the Alföld, therefore, the more recent interstadial may have been slightly drier than the two preceding it.

Malacological and palynological studies are lacking for the Basaharc site. For soil MF, phytolith data indicate a forested environment succeeded by savannah. This agrees with the interpretation of the MF as a dark-brown forest steppe soil; but other paleoenvironmental analyses should be performed to ascertain this. Humidity values should at least have been sufficiently high for tree growth at this site. Soil MF probably continued to develop during the succeeding interstadial, contemporaneously to soil MF_1 at Mende. TL ages from ZÖLLER *et al.* (1994) corroborate this view.

This contrasts with the more southern site of Paks, where soil MF is interpreted as a Udic Haplustoll. Palynological data support this view, but the gastropods appear to be more cryophilous than thermophilous. With the aid of further phytolith analysis this contradiction could be redressed.

The loess strata. The loess intercalating the MF and BD pedocomplexes presents an interesting quandary. At Basaharc, the prevailing phytomorphs suggest a NAV, although the total phytolith content is rather low. Malacological data from Paks indicate the presence of gastropods who can withstand a high range of temperatures. Finally, at the Mende site, the loess samples exhibit some indication of the scarce presence of trees.

The high phytolith content indicates a predominance of grasses. According to the palynological data, they are mostly thermophilous. The gastropod assemblage also points to a relatively warm and humid phase. It would appear that loess formed under a prevailing steppe ecosystem with the occasional tree contributing to surface stabilisation.

The BD_1 soil. The BD_1 soils are claimed to represent the last interglacial. However, at Basaharc, this "interglacial" hypothesis finds little support. The phytolith data indicate that it formed under NAV, in contrast to the more arboreal MF soil. The BD_1 soil appears to be an AC-type, probably an Entisol. It is much thinner than the overlying MF soil, which is also interpreted as an interglacial episode (BRONGER and HEINKELE 1989; ZÖLLER *et al.* 1994). Moreover, because BD_1 retained an A horizon, erosion cannot be invoked as the source of these soil development differentials. The proponents of the "interglacial" hypothesis have yet to explain this interpretational discrepancy.

The paleoenvironmental data from Paks yield a rather confused picture. Malacological and phytolith evidence indicate a forest ecosystem, probably open, and moist warm conditions can be surmised. The high values for *Artemisia* contradict these and soil morphology appear to concur with palynological data.

The contradiction might be a function of sampling, however. Previous malacological and palynological investigations involved a single sample per soil. These sample locations within the soil profile might coincide with any of the phytolith sampling intervals. As can be seen on *Table 3*, an alternation of NAV and AV dominance occurred. The results from malacological and palynological investigations might happily coincide and agree with any one of these three phytolith sampling intervals. Of course, the opposite might just as well be the case.

At the Mende site, BD_1 probably developed under a savannah environment. This agrees with both palynological and micromorphological data and the presence of a Bt horizon postulated by BRONGER and HEINKELE (1989).

Implications. Generally, the results from phytolith analysis concur with previous paleoenvironmental data (*Tab. 1*). The exceptions at MF_1 (Mende) and BD_1 (Paks) only concern gastropod analysis. This is not surprising, as malacofauna are notoriously representative of very localised areas (cf. ROUSSEAU 1992). The agreement between palynological and phytolith data is due to their relatively similar modes of diffusion. As a differentially subsiding basin, the Alföld acts as a receptacle for the influx of allogenic particulates. Therefore, the phytolith assemblages observed, like pollen frequencies, should represent areas larger than the immediate sites investigated.

The environmental variability noted between "contemporary" soils can be explained by geomorphological and local climatic differences. These differences probably resulted from the location of these sites in different ecotones (PÉCSI 1970). Basaharc is situated just within the Transdanubian mountainous forest belt (PÉCSI and HAHN 1987), while Mende and Paks lie in a low order river valley and a subsiding floodplain respectively. Therefore, the pedomorphological and palaeobiological characteristics observed in the soils analysed should be expectedly diverse. As a consequence, the value of considering these sites as regional representatives for the Alföld is questionable[3].

As far as chronological issues are concerned, the newer TL ages for the "interstadial" MF_2 soil at Mende appear to contradict phytolith data. Though indicating the possibility of very humid conditions, the phytolith data do not support the contention that this soil developed through two interstadials (ZÖLLER *et al.* 1994). That is, the phytolith assemblage do not change appreciably within the soil.

Finally, an integration with other biostratigraphical records enables one to address several methodological problems. For instance, the prevalence of NAV phytoliths in a stratum might not indicate an actual NAV dominance (FREDLUND *et al.* 1985, p. 159). Results from earlier palynological investigations mostly concur with the phytolith record and it can thus be concluded that at these sites the underrepresentation of arboreal taxa is not a hindrance to the analyst.

Problems related to equifinality of soil morphology under different ecosystems can also be obviated. As MOFFET *et al.* (1994) reported in a study of North Dakota soils under a variety of phytocoenoses, soil morphology may reflect development under an unexpected vegetation type. An agreement between palynological and phytolith data increases the certainty of a paleoenvironmental interpretation.

Summary and conclusion

Despite the amount of attention the Hungarian loess sequence has received, many problems remain unresolved, especially those related to basic paleoenvironmental considerations. Part of the solution to this problem involves a more reliable assessment of the paleophytocoenoses partially responsible for the formation of paleosols and loess deposits. Resolving such fundamental issues will increase the viability of paleoenvironmental interpretations.

Phytolith analysis was applied for the first time to the sites of Basaharc, Mende, and Paks, where palaeobotanical studies are conspicuously incomplete. These Hungarian type localities represent the lower part of the Upper Pleistocene Young Loess sequence. The MF pedocomplex and soil BD_1 were investigated for their phytolith content. It was found that phytolith analysis complements and supplements current palaeoenvironmental data. The results demonstrate the existence of different vegetation communities co-occurring through time at each site.

[3] Alternatively, this diversity within the same period might be explained by the possibility of miscorrelation. Given the extreme fluctuations in age estimates, this hypothesis might not be so incredible.

Due to poor preservation and the absence of absolute counts, these results should be considered tentative. Nevertheless, the phytolith data generally agree with the results from other palaeobiological studies, excepting soil BD_1 at Paks and soil MF_1 at Mende. The BD_1 soil at Basaharc developed under NAV (non-arboreal vegetation) while the one at Mende formed under a savannah-type environment. At the latter site, the more locally specific malacological and phytolith data suggest a warm and moist environment tending to savannah prior to burial.

The MF pedocomplex at the Mende site consists of two soils with an intervening long erosional hiatus. Both the MF_1 soil formation and underlying loess stabilisation episodes occurred under a NAV (probably steppe) environment. The latter appears to have been a drier phase according to the type of grass assemblage noted.

Phytolith and other palaeoenvironmental records indicate a high degree of environmental diversity for soils deemed to have been developed under similar climatic conditions (cf. BRONGER and HEINKELE 1989). Current soil interpretations need to be reconciled with these data. These results also contribute indirectly to issues related to both inter-regional correlation problems and the understanding of the paleoenvironments of the Carpathian Basin. More research integrating a variety of paleoenvironmental methods will increase the possibility of describing the sets of pedogenetic variables responsible for the morphological features observed in the buried soils examined.

Acknowledgements. I wish to thank Deborah Engel-Di Mauro, without whom this research could not have been completed, Dr. Márton Pécsi and Dr. János Balogh, for their invaluable support and generosity, and Dr. Vance Holliday and Dr. Glen Fredlund for their helpful critique and advice. The samples were processed in the Pollen Lab of the Center for Climatic Research and the Geomorphology Lab of the Department of Geography at the University of Wisconsin-Madison. Microscopic analyses were performed at the latter.

SELECTED REFERENCES

(AGH: Acta Geologica Academiae Scientiarum Hungaricae; SSSAP: Soil Science Society of America Proceedings)

BARTOLI, F., and WILDING, L.P. 1980. Dissolution of Biogenic Opal as a Function of Its Physical and Chemical Properties. SSSAP 44. 873–878.

BRONGER, A., and HEINKELE, Th. 1989. Paleosol Sequences as Witnesses of Pleistocene Climatic History. Catena Supplement. 16. 163–186.

CATT, J.A. 1990. Paleopedology Manual. Quaternary International. 6. 1–85.

FREDLUND, G.G. 1993. Paleoenvironmental Interpretations of Stable CARBON, Hydrogen, and Oxygen Isotopes from Opal Phytoliths, Eustis Ash Pit, Nebraska. In: PEARSALL, D.M., and PIPERNO, D.R.

(eds.): Current Research in Phytolith Analysis: Applications for Archaeology and Paleoecology. Philadelphia, MASCA.

FREDLUND, G.G., JOHNSON, W.C., and DORT, W. 1985. A Preliminary Analysis of Opal Phytoliths from the Eustis Ash Pit, Frontier County, Nebraska. Inst. for Tert.-Quat. Studies TERQUA Symp. Ser. 1. 147–162.

GEIS, J.W. 1973. Biogenic Silica in Selected Species of Deciduous Angiosperms. Soil Science. 116(2). 113–130.

GEIS, J.W., and JONES, R.L. 1973. Ecological Significance of Biogenic Opaline Silica. In: Dindal, D.L. (ed.): Proceedings of the First Microcommunities Conference. Conf.-711018. Springfield, VA, USAEC, Nat. Tech. Information Serv.

JONES, R.L., and BEAVERS, A.H. 1963. Some Mineralogical and Chemical Properties of Plant Opal. Soil Science. 96(6). 375–379.

KAUFMAN, P.B., DAYANANDAN, P., TAKEOKA, Y., BIGELOW, W.C., JONES, J.D., and ILER, R. 1981. Silica in Shoots of Higher Plants. In: SIMPSON, TL, and VOLCANI, BE (eds.): Silicon and Siliceous Structures in Biological Systems. New York, Springer-Verlag.

LOŽEK, V. 1990. Molluscs in Loess, Their Palaeoecological Significance and Role in Geochronology – Principles and Methods. Quaternary International. 7/8. 71–79.

MOFFET, C.A., Richardson, J.L., Lura, C.L., and Arndt, J.L. 1994. Soil Development under Larch, Cottonwood, and Prairie in North-Central North Dakota. Soil Survey Horizons (Summer Issue). 48–55.

OCHES, E.A. 1994. Aminostratigraphy, Geochronology and Paleoclimatology of Central European Loess Deposits. University of Massachusetts-Amherst. Doctor of Philosophy Dissertation.

PASHKEVICH, G.A. 1979. Some Results of the Palynological Investigation of the Paks Loess Profile. AGH 22. 461–466.

PEARSALL, D.M. 1986. Palaeoethnobotany: A Handbook on Procedures. San Diego, Academic Press.

PÉCSI, M. 1970. Geomorphological Regions of Hungary. (Studies in Geography in Hungary 6) Budapest, Akadémiai Kiadó. 45 p.

PÉCSI, M. 1982. The Most Typical Loess Profiles in Hungary. In: PÉCSI, M. (ed.): Quaternary Studies in Hungary. Budapest, Geogr. Res. Inst. Hung. Acad. of Sci. 145–169.

PÉCSI, M. 1987. Type Locality of Young Loess in Hungary at Mende. In: PÉCSI, M. and VELICHKO, A. (eds.): Paleogeography and Loess. Pleistocene Climatic and Environmental Reconstructions. Budapest, Akadémiai Kiadó.

PÉCSI, M. 1993. Negyedkor és Löszkutatás. Budapest, Akadémiai Kiadó. 375 p.

PÉCSI, M., and HAHN, Gy. 1987. Paleosol Stratotypes in the Upper Pleistocene Loess at Basaharc, Hungary Catena Supplement. 9. 95–102.

PÉCSI, M. and SCHWEITZER, F. 1993. Long-Term Terrestrial Records of the Middle Danubian Basin. Quaternary International. 17. 5–14.

PÉCSI-DONÁTH, É. 1979. Thermal Analysis of the Loess from the Mende Profile. AGH 22. 391–396.

PIPERNO, D.R. 1988. Phytolith Analysis: An Archaeological and Geological Perspective. San Diego, Harcourt Brace Jovanovich Publishers.

RÓNAI, A. 1985. The Quaternary of the Great Hungarian Plain. In: PÉCSI, M. (ed.): Loess and the Quaternary. Chinese and Hungarian Case Studies. (Studies in Geography in Hungary 18) Budapest, Akadémiai Kiadó. 51–63.

ROUSSEAU, D.-D. 1992. Is Causal Ecological Biogeography a Progressive Research Program? Quaternary Science Reviews 11. 593–601.

ROVNER, I. 1971. Potential of Opal Phytoliths for Use in Paleoecological Reconstruction. Quaternary Research. 1. 343–359.

ROVNER, I. 1983. Plant Opal Phytolith Analysis: Major Advances in Archaeobotanical Research. In: Schiffer, M. (ed.): Advances in Archaeological Method and Theory. New York, Academic Press.

SZÖÖR, Gy., SÜMEGI, P., and BALÁZS, E. 1991. Malacological and Isotope Geochemical Methods for Tracing Upper Quaternary Climatic Changes. In: PÉCSI, M. and SCHWEITZER, F. (eds.): Quaternary Environment in Hungary. Budapest: Akadémiai Kiadó.

TWISS, P.C., SUESS, E., and SMITH, R.M. 1969. Morphological Classification of Grass Phytoliths. SSSAP 33, 109–115.

URBAN, B. 1984. Palynology of Central-European Loess-Soil Sequences. In: PÉCSI, M. (ed.): Lithology and Stratigraphy of Loess and Paleosols. Budapest: Geog. Inst. of the Hung. Acad. of Sciences. 229–249.

VERMA, S.D., and RUST, R.H. 1969. Observations on Opal Phytoliths in a Soil Biosequence in Southern Minnesota. SSSAP 33, 749–751.

WAGNER, M. 1979a. Mollusc Fauna of the Mende Loess Profile. AGH 22, 397–402.

WAGNER, M. 1979b. Mollusc Fauna of the Paks Loess Profile. AGH 22, 443–450.

WILDING, L.P. 1967. Radiocarbon Dating of Biogenic Opal. Science. 131. 66–67.

WILDING, L.P. 1973. Scanning Electron Microscopy of Opaque Opaline Forms Isolated from Forest Soils in Ohio. SSSAP 37. 647–650.

WILDING, L.P. 1974. Contributions of Forest Opal and Associated Crystalline Phases of Fine Silt and Clay Fractions of Soils. Clays and Clay Minerals. 22. 295–306.

WILDING, L.P., SMECK, N.E., and DREES, L.P. 1977. Silica in Soils: Quartz, Cristobalite, Tridymite, and Opal. In: DIXON, J.B., and WEED, S.B. (eds.): Minerals in Soil Environments. Madison, WI, Soil Science Society of America.

ZÖLLER, L., OCHES, E.A., and McCOY, W.D. 1994. Towards a Revised Chronostratigraphy of Loess in Austria with Respect to Key Sections in the Czech Republic and in Hungary. Quaternary Geochronology (Quaternary Science Reviews). 13. 465–472.

Studies in Geography in Hungary
Vol. 18.

Loess and the Quaternary

Chinese and Hungarian Case Studies.
Budapest, 1985. Akadémiai Kiadó. 128 p.

Edited by M. PÉCSI

On the occasion of the Chinese - Hungarian symposium on loess the scientific cooperation between the Academia Sinica and the Hungarian Academy of Sciences has enlivened after a long interval of silence. Several Chinese loess researchers and geochemists arrived to the symposium in Hungary to gather new experiences.

This volume of papers in English results from the success of the symposium and the cooperation.

In the papers the main results of the contemporary research on loess and the Quaternary in China and Hungary are summarised and, at the same time, certain correlations are allowed.

The Chinese experts of international reputation present the mineralogical, petrological and geochemical properties of the 200 m-thick loess and the intercalated paleosols on the famous loess plateau and the paleomagnetic dating and subdivisions of profiles. The Hungarian party is concerned with the chronostratigraphy of loess and Quaternary deposits in Hungary, the biostratigraphical comparison of terrestrial horizons in China and Hungary, problems of loess granulometry, its geochemical and mineralogical properties and the analysis of clay minerals in soils on loess.

$ 14.-

Studies in Geography in Hungary
Vol. 19.

Problems of the Neogene and Quaternary in the Carpathian Basin

Geological and Geomorphological Studies. Contribution to the VIIIth Congress of the Regional Committe on Mediterranean Neogene Stratigraphy Budapest, 1985.
Budapest, 1985. Akadémiai Kiadó. 128 p.

Edited by M. KRETZOI and M. PÉCSI

The volume in English is dedicated to the 8th Congress of the Regional Committee on Mediterranean Neogene Stratigraphy organized by the INQUA Hungarian National Committee in Budapest in September 1985.

There are considerable differences between the criteria for defining the Quaternary/Neogene boundary recognized in the various countries and these differences reflect various interpretation of the stratigraphical and geochronological evidence. In this respect the study of deposition rates of several hundred metres of Neogene and Quaternary sediments in the Great Hungarian Plain and of the denudation chronology of the geomorphological surfaces in the Hungarian Mountains and the correlation of results deserve special attention. Along with the application of traditional geological, paleontological, sedimentological and other methods, various new absolute dating techniques have also been used.

The value of the publication is further increased by the contributions of home and international academies, universities and other scientific institutions in the published paleomagnetic research (such as the Hungarian Academy of Sciences, the Academy of Sciences of the U.S.S.R., State Geological Survey and others). The papers in this volume are meant to promote the scientific Success of the Congress and to help the further research to define the Quaternary/Neogene boundary.

$ 14.-

Studies in Geography in Hungary
Vol. 20.

Loess and Periglacial Phenomena.

Symposium of the INQUA Commission on Loess: Lithology, Genesis and Geotechnic Definitions and IGU Commission for Periglacial Studies: Field and Laboratory Experimentation Normandy, Jersey, Brittany, Caen, August 1986.
Budapest, 1987. Akadémiai Kiadó. 311 p.

Edited by M. PÉCSI and H. M. FRENCH

The 21 papers collected in this volume reveal the close relationship between periglacial geomorphology and Quaternary research through the analyses of loess and loess-like sediments. The investigations are aimed at identifying loess and periglacial deposits by means of stratigraphical and sedimentological methods. At the 1986 symposium in Caen, France, in addition to the above topics, the particular field and laboratory experiences were also treated. The case studies from all parts of the world serve as interesting material for comparisons for geoscientists as well as for experts in engineering geology and soil mechanics.

$ 36.-

Studies in Geography in Hungary
Vol. 26.

Quaternary Environment in Hungary

Contribution of the Hungarian National Committee to the XIIIth INQUA Congress Beijing, China, August 1991
Budapest, 1991, Akadémiai Kiadó. 103 p.

Edited by M. PÉCSI and F. SCHWEITZER

In past decades a detailed subdivision of the Quaternary was carried out with special emphasis on climatic or environmental phases with the Last Glacial cycle of the Pleistocene. Most recently studies on global and regional scale of the Late Quaternary ecological changes have come to the fore.

This collection of papers gives an overview of the long- and short-term terrestrial records of the Middle Danube Basin (Hungary), of paleogeographical, environmental or climatic changes since the Last Interglacial, of the cycles of solar climatic types since the Riss Glacial, of the Upper Pleistocene events and of the vegetation history of the Great Hungarian Plain.

Relying on complex sedimentological and radiometric investigations the Holocene evolution of the Lake Balaton is described, radiometric data are given on the Holocene deposition of the Danube, a mineralogical study for dating the thin tephra layer in Hungarian loess profiles is presented, as well as mass movements on steep loess slopes occurring on agricultural land are analysed.

The contributors of the volume meant to provide information on the recent results of their investigations for the participants of the XIIIth Congress of the International Union of Quaternary Research in Beijing.

$ 15.-