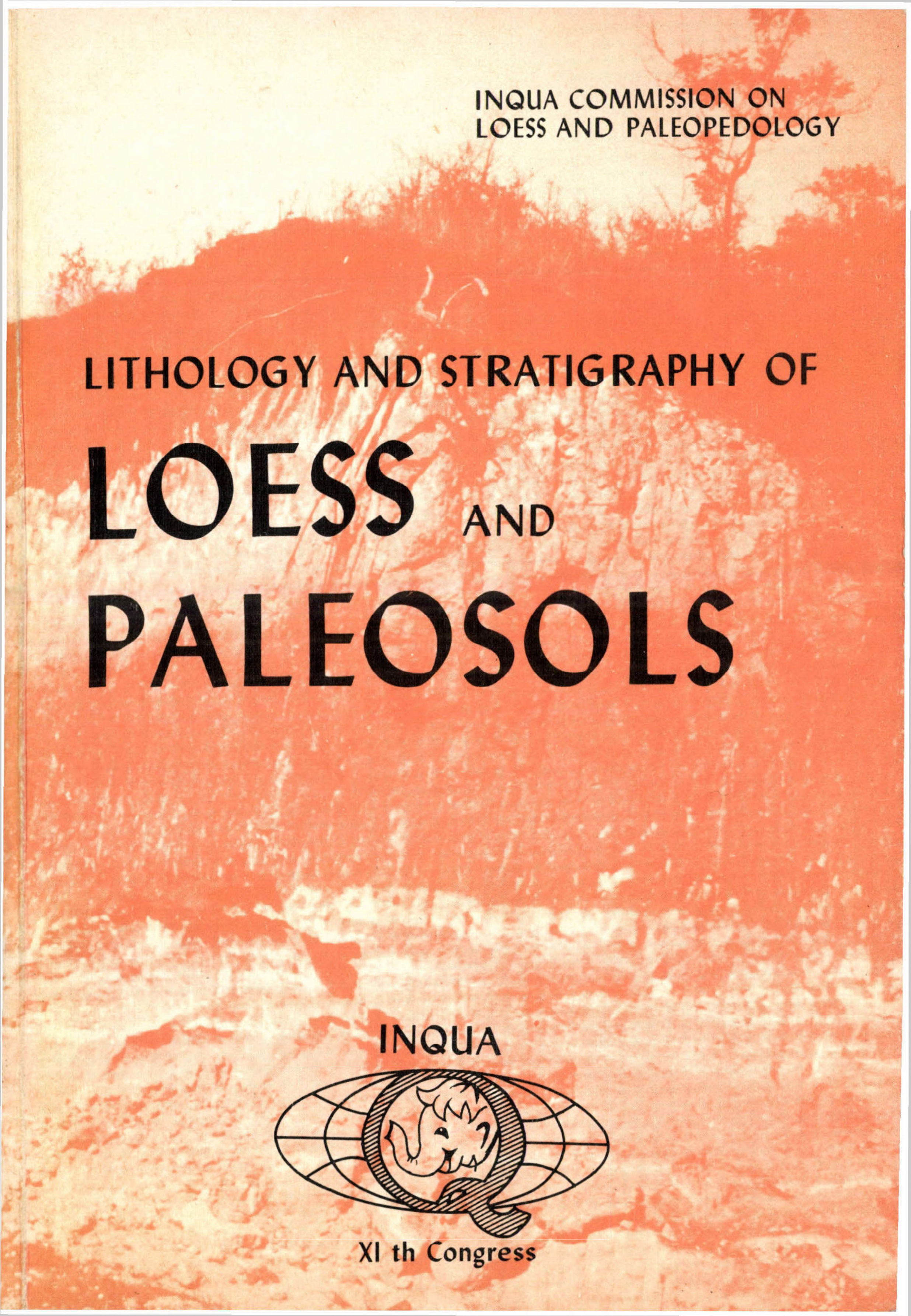
INQUA COMMISSION ON
LOESS AND PALEOPEDOLOGY



LITHOLOGY AND STRATIGRAPHY OF LOESS AND PALEOSOLS

INQUA

XI th Congress

LITHOLOGY AND STRATIGRAPHY OF LOESS AND PALEOSOLS

PROCEEDINGS OF THE SYMPOSIUM ORGANIZED BY
INQUA COMMISSION ON LOESS AND PALEOPEDOLOGY

XI th INQUA CONGRESS, MOSCOW

Edited by
MÁRTON PÉCSI

BUDAPEST, 1984

Translated by

Ottó TOMSCHEY
Béla KECSKÉS

Revised by

Edward DERBYSHIRE
Dénes LÓCZY
I.J. SMALLEY
Ottó TOMSCHEY

Technical board

Mariann FERENCZ*
Lívia KAISER
Zsuzsanna KERESZTESI
Mária KRETZOI
Margit MOLNÁR
Márta MÓROTZ
József NÉMETH
István POÓR
Erzsébet TARPAY
Györgyi TURÓCZI*
Katalin TORNALLYAY

* The texts were typed in the Hungarian Meteorological Service

Sponsored by

INQUA Commission on
Loess and Paleopedology

Published and copyright by

GEOGRAPHICAL RESEARCH INSTITUTE
HUNGARIAN ACADEMY OF SCIENCES

GEOGRAPHICAL RESEARCH INSTITUTE
HUNGARIAN ACADEMY OF SCIENCES

Theory – Methodology – Practice
Elmélet – Módszer – Gyakorlat

30.

I S S N 0139-2875
I S B N 963 7322 31 0

LITHOLOGY AND STRATIGRAPHY OF LOESS AND PALEOSOLS

PREFACE

The research of loess, one of the most important surfacial Quaternary formation gains more and more significance in soil conservation and building construction all over the world.

Apart from the important environmental and practical purposes of loess research, substantial tasks in the field of fundamental research have also come to the forefront.

A great number of engineering geologists, geomorphologists, geobotanists, geochemists, geophysicists, and pedologists have been studying the problems of loess from various aspects and the newest methods are involved in this research. All the major loess regions of the world are by now under investigation, including China, Siberia, Central Asia, East-, Central and Western Europe as well as the United States. These studies on loess provide valuable opportunity to compare and parallelize loess complexes and interbedded paleosols on a global scale.

International efforts to these purposes have been coordinated by the International Union of Quaternary Research for more than fifty years. To commemorate the semi-centennial anniversary of the first congress in Leningrad, the XI. INQUA Congress was held at Moscow in August 1982. A collection of papers presented at the joint symposium organized by Commissions on Loess and Paleopedology have been selected for publication in this volume.

Altogether 30 papers cover the fundamental topics of loess investigations. As far as the origin of loess is concerned special regard is given to the paleoenvironmental reconstruction of loess and paleosol formation, cycles in the sedimentation of loess complexes, their mineralogical composition, geochemical features and their relation to geographical zonation. Some basic contributions are given to the application of paleoclimatological, palynological, thermoluminescence, paleopedological, electronmicroscopic and paleomagnetic methods in the stratigraphy and chronology of the sequences. Some practical problems are also raised in the papers dealing with engineering-geological and agricultural utilization aspects of these deposits.

The papers of interdisciplinary nature deserve the attention of Quaternary researchers as well as experts in broad field of related sciences.

M. Pécsi

CONTENTS

Preface 7

I. MORPHOGENESIS AND CATENARY ASSOCIATIONS OF LOESS PALEOSOLS

KRIGER, N.I.: Lithoecology and energetics of loess: paleogeographic and genetic aspects 11

SHAEVICH, Ya.E.: Cyclicity of sedimentation and system pattern as factors of loess classification: an example from southwestern Siberia 17

SIRENKO, N.A.: Pliocene and Pleistocene soil formation in the Ukraine 27

SMOLIKOVÁ, L.: On the development of Pleistocene soils in Czechoslovakia 33

VAŠKOVSKÁ, E.: New stratigraphic subdivision and typology of soils of the Late Pleistocene in loess series of the Danube lowland in Czechoslovakia 39

WANG YONG-YAN – TENG ZHI-HONG – YUE LE-PING: Loess microtextures and the origin of loess in China 49

II. LITHOLOGICAL PROPERTIES OF LOESSES IN DIFFERENT CLIMATIC ZONES

BALANDIN, Yu.G.: Peculiarities of loess sequences of key sections in the Ukraine as reflections of the characteristics of the loess geosystem 61

BORSY, Z. – FÉLSZERFALVY, J. – LÓKI, J.: Electronmicroscopic investigation of the sand material from the loess exposure at Paks 71

CODARCEA, V. – BANDRABUR, T.: Mineralogical composition of loess deposits from the Trotuş-Siret-Milcov region (Romania) 87

DERBYSHIRE, E.: Granulometry and fabric of the loess at Jiuzhoutai, Lanzhou, People's Republic of China 95

KES, A.S.: Zonation and faciality of loessic deposits 105

KHALCHEVA, T.: Facial changes in the material composition of Upper Pleistocene loesses in western and eastern regions of European USSR: a case study of Volyno-Podolia and the Dnieper basin

LAUTRIDOU, J.P. – SOMME, J. – JAMAGNE, M.: Sedimentological, mineralogical and geochemical characteristics of the loesses of North-West France 121

PETROV, A.G. – KRIGER, N.I. – GOUNESHIAN, O.G. – KOZHEVNIKOV, A.D. – MIRONUK, S.G. – ZIMINA, G.A.: Geochemical loess history 133

PYE, K.: SEM investigations of quartz silt micro-textures in relation to the source of loess 139

TSAREV, P.V.: The peculiarities in the formation of the properties and the age of loess in some areas of the southern European part of the USSR 153

WEN QI-ZHONG – YANG WEI-HUA – DIAO GUI-YI – SUN FU-QING – YU SU-HUA – LIU YOU-MEI: The evolution of chemical elements in loess of China and paleoclimatic conditions during loess deposition 161

ZHENG HONG-HAN: Paleoclimatic events recorded in clay minerals in loess of China 171

III. STRATIGRAPHY AND DATING OF LOESSES AND PALEOSOLS

BOLIKHOVSKAYA, N.S.: Paleogeography of loess accumulation in the light of palynological data 185

BUTRYM, J. – MARUSZCZAK, H.: Thermoluminescence chronology of younger and older loesses 195

DODONOV, A.E.: Stratigraphy and correlation of Upper Pliocene-Quaternary deposits of Central Asia 201

PÉCSI, M.: Is typical loess older than one million years? 213

TURLO, S.I.: Pleistocene stages in the Middle Dnieper basin by evidence of spore-pollen analysis of loesses 225

URBAN, B.: Palynology of Central European loess-soil sequences 229

VEKLICH, M.F. – SIRENKO, N.A.: Interregional paleopedological Pleistocene correlation of the USSR loess regions 249

ZHANG ZONGHU: Lithological and stratigraphical analysis on loess profiles of the Loess Plateau in China 259

IV. ASPECTS OF UTILIZATION OF AREAS COVERED BY LOESSES

FRÄNZLE, O.: Loess soils as regulatory compartments in ecosystem response to pollution 273

GOUNESHIAN, O.G. – KRIGER, N.I. – KHARCHENKO, V.M. – BOTNIKOV, V.I. – ZIMINA, G.A. – KOZHEVNIKOV, A.D. – PETROV, A.G.: Principles of engineering-geological mapping of loess and loess-like rocks 283

PÉCSI, M. – ZENTAY, T. – GEREI, L. – Mrs. REMÉNYI, M.: Relationship of the geomorphological position, genetic, physical, chemical and mineralogical features of sand soils with their fertility 291

PÉWÉ, T.L.: Deposition of windblown dust in Central Arizona, USA 305

I. MORPHOGENESIS AND CATENARY ASSOCIATIONS OF LOESS PALEOSOLS

I. MORPHOGENESIS AND CATENARY ASSOCIATIONS OF LOESS PALEOSOLS

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

LITHOECOLOGY AND ENERGETICS OF LOESS: PALEOGEOGRAPHIC AND GENETIC ASPECTS

N. I. Kriger

ABSTRACT

Loess as a rock is a yellow-gray silty calcareous macroporous loam. To characterise loess as a complex system it is necessary to use supplementary features: absence of gravel and sand interbeds, cover occurrence, presence of buried soils etc. Its pecularity as a system is a geographical zonation, adaptation to the landscape, changeability under the influence of the geological activity of man. The discipline about adaptation of rocks to the environment is called lithoecology. The distribution of loess is controlled by cosmic, terrestrial and interior factors of energetic nature. Loess presents a system reacting sensitively to climatic change. There is a clear dependence of relief. Thermodynamics and geochemistry of processes in the hypergene zone explain geographically the zonal distribution of loess and its mineral composition. The distribution of porosity, moisture content and other pecularities can be regarded and explained from the viewpoint of energetics.

LOESS AS A SYSTEM

Loess can be regarded as a rock and also as a more complicated system. Loess as a rock is a yellow-gray silty calcareous macroporous loam (or loamy sand) and the rocks described by these features can have different origins. It is insufficent, however, to use only these features to describe the characteristics of loess as a complex system, because loess is a special natural body (like, for example, a soil, a glacier, or an ocean). It is necessary to use for the caharacteristics of loess as a system the following supplement features: the absence of gravel and sand interbeds, its occurrence as a landscape cover, the presence of regional interbeds of buried soils which are stratigraphically persistent, and the presence of the remains of nonaquatic organisms and the absence of aquatic ones. The major pecularities of loess as a system are its geographical zonality, its adaptation to the landscape and its changeability under the influence of technogenesis (geological activity of man). The doctrine concerning the adaptation of rocks and geological bodies to their environment is called lithoecology (KRIGER, N.I. 1965; KRIGER, N.I. – GRAVE, N.A. 1974; KRIGER, N.I. et al. 1981).

DISTRIBUTION OF LOESS

Loess and loess-like rocks are distributed in the area between latitudes 55° and 24° North. In the southern Hemisphere they do not form such a well-marked latitude zone but are found in South America and New Zealand, also in a zone of temperate climate between the latitude 24° and 45° South. The distribution of loess is conditioned by cosmic factors (solar energy), by terrestrial factors (relief of land, distribution of land and sea) and by interior factors (composition and the structural bonds in the loess substance). These factors have an energetic nature and can be expressed by radiation balance R, aridity index R/Lr (L – latent heat of evaporation, r – quantity of atmospheric precipitation), gravitational energy (compaction of rocks and displacement down a slope), and the energy of crystallochemical, colloidal, Van der Waals and other bonds.

INFLUENCE OF CLIMATE ON LOESS

The distribution of loess coincides with strictly defined climatic and landscape conditions. In the modern epoch these conditions produce steppes with values of $0 < R < 10$ Kcal/cm^2 per year; $1 < R/Lr < 3$.

The distribution of loess is a natural phenomenon on the planetary scale, in so far as the presence of loess is „forbidden" when other values of R and R/Lr are found.

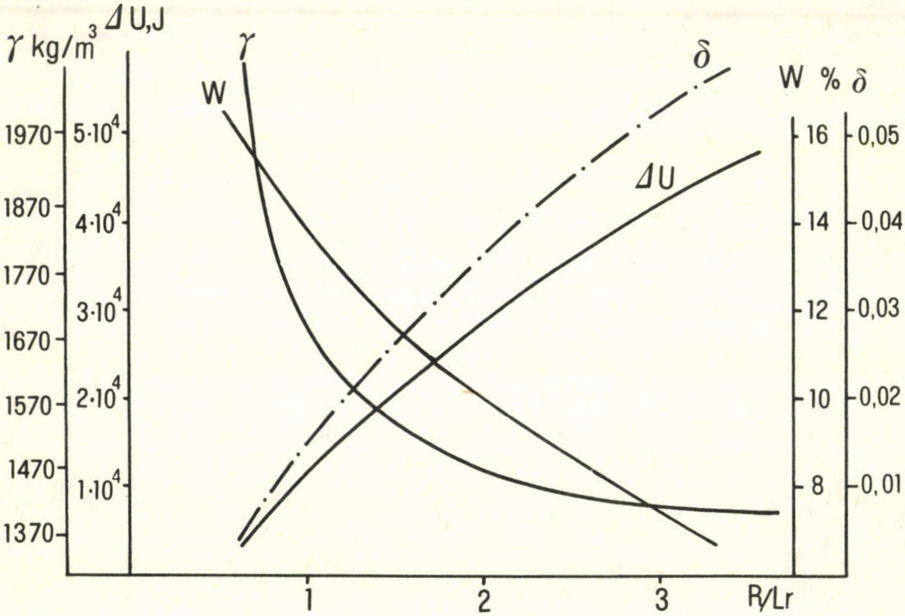


FIG. 1. Dependence of loess properties (moisture content W, relative collapsibility δ, density γ and reserves of potential gravitation energy ΔU) on radiation aridity index R/Lr.

In the Pleistocene the formation of loess was also connected with the steppes. In Europe, North Asia and North America the steppes were periglacial, when $R < 20$ and $R/Lr = 1$ (analogous to the modern zone of distribution of ice-loess deposits in the North-East of Asia). A great thickness of loess testifies to the prolonged existence of a dry climate, when values of R/Lr are relatively high. In interglacial periods the values of R/Lr are diminished, and this leads to the formation of buried soils. When $R/Lr < 1$ degradation of the loess takes place and a decrease of porosity, collapsibility and the content of soluble salts results. Loess presents a system reacting sensitively to climatic change. Thus, there is a clear dependence of the moisture content, porosity and other properties of loess and loess-like rocks on the radiation, aridity index R/Lr, climatic coefficients moisture or other similar parameters (FIG. 1).

INFLUENCE OF RELIEF ON LOESS

The main areas of loess distribution are vast plains, piedmont regions and the slopes of foothills. The covering occurrence on the interstream areas, slopes, and valley terraces is very characteristic of loess. The relief has a great influence on the composition and properties of loess. The dependence of moisture content, porosity and collapsibility of loess on altitude of areas on the mountain slopes is clearly seen (FIG. 2.).

These properties of loess like others (composition of water extract and hydrochloric acid extract, shear strength, compressibility, etc.) depend on exposure and angle of slope, character of microrelief (steppe minor depression) etc. Loess with its ability to adapt to the environment resembles a living organism or a soil.

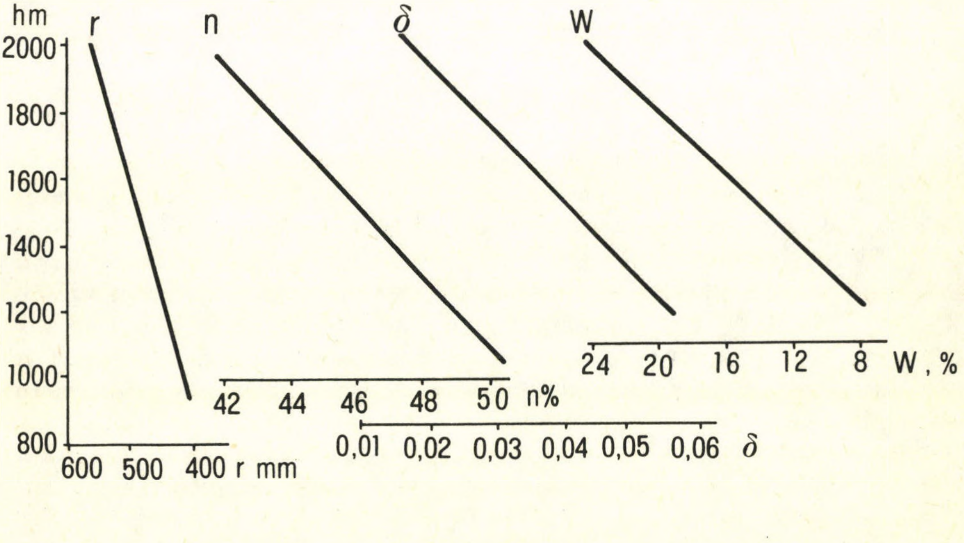


FIG. 2. Dependence of quantity of atmospheric precipitation (r) and properties of loess (porosity n, relative collapsibility δ, moisture content W) on altitude of area on north slope of Kirghiz mountain ridge

ENERGETICS OF LOESS AS A ROCK

The distribution and properties of loess are determined by the mobility of atoms, the energy of crystallochemical and other bonds in the materials, the quantity and distribution of water in the biosphere and the influx of solar energy.

These factors determine hypergene processes and in particular, create in the surrounding favourable dry conditions of soil formation and sedimentation of dust. A change of the typomorphic minerals of the hypergene zone takes place, which is influenced by the aridity of the climate. The presence of Al_2O_3 and Fe_2O_3 (laterite and bauxite) is characteristic of the forest landscape; SiO_2 (siliceous crust) – is characteristic of the African savannas, $CaCO_3$ (calcic rocks) – of the European steppes and NaCl (solonchak) – of the deserts and semi-deserts.

These listed minerals have diminishing values of crystal lattice energy; the several main values of energy according to the model of ionic crystal bonds are Al_2O_3 – 3700, SiO_2 – 3100, $CaCO_3$ – 650, $CaSO_4$ – 622, NaCl – 180 kcal/mol. This energetic peculiarity of the hypergene zone is explained by the impossibility of conservation of minerals with low energy of lattice in the soil and weathering crusts when the climate is humid, because they are thermodynamically unstable and soluble. Thus, the thermo-dynamics and geochemistry of the processes in the hypergene zone explain the geographical/zonal distribution of loess. The mineral composition of loess is also explained by the energetics of hypergenesis. The following components are present in loess: SiO_2, $CaCO_3$, $CaSO_4$, and NaCl and the crushing energy of these minerals diminishes in the same succession. It is evident that the components with low lattice energies are destroyed and carried out of the rock in the process of sedimentation, in early diagenesis and partly during epigenesis.

ENERGETICS OF LOESS AS A SYSTEM

Sedimentation and post-sedimentative compaction of loess material takes place in the gravitational field of the Earth. The porosity of clastic and dispersive rocks in this field can be regarded as an indirect characteristic of the reserves of potential energy. During the compaction of rocks (and deformation of rock grains) the potential energy transforms to kinetic and thermal energy.

The compaction of rock takes place as the pressure of sediments, accumulating from the above, increases. Density (porosity) is a function of the rock stress state. Of course other factors have an influence on the porosity; these are: granulometry, strength of the structural bonds, moisture content, and composition of the pore water. If under water deficit in arid and periglacial conditions ($R/Lr < 1$) there is formation of cemented structural bonds and the porosity decreases a little in spite of increasing pressure, there then an undercompacted rock state appears. The loess cement is unstable in water and with wetting of loess collapse takes place. Such a view of collapse is described and controlled by „Denisov's principle" (FERSMAN, A.E. 1958-1959, KRIGER, N.I. 1965, KRIGER, N.I. - GRAVE, N.A. 1974). The method of loess sedimentation (e.g. eolian, deluvial) has little influence on the compaction of the material. The existence of a „dead" (impermeable) horizon at a depth of 2-3 m where the moisture content is very low and not subject to seasonable variability is of great importance. In this horizon the undercompacted nature (collapsibility) of the rock in the arid and semi-arid areas is preserved for many tens of thousands of years.

In the presence of the dead horizon the formation of loess collapsibility under the growth of pressure of accumulating deposits can be considered as isochor thermodynamic process intristic energy increases; volume is not diminished). The potential energy of the system, which is released in the course of collapse, can be calculated according to the following formula:

$$\Delta U = \int_{0}^{h=H} P\,(h)\delta dh$$

where H – thickness of stratum, $P(h) = gsh\gamma$ – weight of rock column with an area of horizontal section s; h – height, – γ density of soil, g – acceleration of gravity, $\delta = dl/dh$ – relative collapsibility of rock, the value of possible displacement of rock grains in the course of collapse, When $S = 1$ and with average values of $\bar{\gamma}$ and $\bar{\delta}$ the potential energy is described by the following formula:

$$U = 0.5\, \bar{g}\bar{\gamma}\bar{\delta}H^2$$

This value of energy can be mapped. When $\gamma = 1500\ kg/m^3$, $\delta = 0.03$ and $H = 15$ m and with a general area of distribution of loess of 13.10^6 km^2, then the global reserves of potential energy of loess are 5.4×10^{17}J (KRIGER, N.I. 1981, KRIGER, N.I. et al 1981).

The reserves of potential energy in loess depend on the geographic environment and in particular on the radiation aridity index R/Lr.

Thus, one can conclude that the distribution of porosity, moisture content and other loess peculiarities can be considered and explained from the energetic point of view.

THE DENSITY OF LOESS

Loess belongs to a group of sensory geological bodies which react to the influence of the environment. Therefore in our epoch of the development of technogenesis as a geological process, loess is changing everywhere. The ploughing up of the ground, the artificial irrigation of the fields, the growth of urbanization and industrial construction, etc. usually brings about degradation of loess: moisture content increases, porosity diminishes, and the collapsibility disappears gradually. Loess in modern conditions is becoming extinct.

REFERENCES

DENISOV, N.Ya. 1972: Nature of strength and deformation of rocks. Moscow, Strojizdat. 280 (In Russian).

FERSMAN, A.E. 1958-1959: Izbrannye trudy. (Selected works.) Moscow, Acad. Sci. USSR. Vol. 4. 588, vol. 5. 280. (In Russian.)

KRIGER, N.I. 1965: Less, ego svoistva i svyaz' s geograficheskoi sredoi. (Loess, its characteristics and relation to the geographical environment.) Moscow, Nauka. 295.

KRIGER, N.I. 1981: Vlazhnost' i energetika lessovykh porod. (Moisture content and energy of loess rocks.) – Trudy Proizv. in.-i in-ta po inzh. izyskaniyam v stp-ve Gosstroya SSSR. Moscow, Strojizdat. 3-24.

KRIGER, N.I. – GRAVE, N.A. 1974: O kartirovanii inzhenerno-geologicheskykh svoistv gornykh porod kontinentalnogo proiskhozhdeniya. (On mapping engineering-geological characteristics of rocks of continental origin.) – Trudy Proizv. i n. -i. in-ta po inzh. izyskaniyam v stp-ve Gosstroya SSSR. 3a. 78-87.

KRIGER, N.I. – KOTELNIKOVA, N.E. – LAVRUSEVICH, S.I. – SEVOSTYANOV, V.V. 1981: Regularities of the formation of the collapse properties of loess in Central Asia and South Kazakhstan. Moscow, Nauka. 133. (In Russian.)

Address of author:
Dr.N. Kriger, Chairman of Working Group „Geotechnical properties of loess'„ PNIIIS,
Okruzhnoy proezd 18. 105058 MOSCOW – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

CYCLICITY OF SEDIMENTATION AND SYSTEM PATTERN AS FACTORS OF LOESS CLASSIFICATION: AN EXAMPLE FROM SOUTHWESTERN SIBERIA

Ya. E. Shaevich

ABSTRACT

The term ›cycless‹ is proposed to designate a cycle materially, i.e. a complex of loess strata and buried soils formed during one cycle. It is defined as ›a uniform, definitive set of loess strata and buried soils characterized by an oriented structure (morphostructure), continuous changes of the fundamental indices of composition, structural and textural features, physicomechanical properties and by closest interrelations and characteristics of the main boundaries between strata.'

The concept of the cyclicity of sedimentation and system patterns has enabled a new approach to the stratigraphy of the Krasnodubrovskaya and Kochkovskaya series of Quaternary loesses (SW-Siberia).

The fact that loess-type sediments occupy a particular position in the subaerial series is due not only to the presence of a number of specific properties in their case (e.g. liability to sagging), but also to the distinct cyclic pattern of the sequences composed of single beds and their associations. Stratification, according to the unanimous opinion of the most prominent geologists, is one of the most essential and typical characteristic of almost all sedimentary formations. Loess sediments are no exclusion to the rule in this case, either. It is all the more important to underline, as the opinion considering the loess sequences to be monotonous and non-stratified is still rather widespread. As shown by research in recent times, loess sequences show an intricate, complex and, consequently, regular multilayered structure reflecting the cyclicity of subaerial sedimentation in both space and time.

It is essential, in our opinion, to know what notion is attributed to the term ›stratum‹. Irrespective of this, however, a stratum is in every case understood as a widely distributed, common geological body.

In spite of the fact that geologists consider the origin of stratification to represent one of the basic problems in theoretical geology, the answers that could so far be given to this question have been but quite vague, nonspecific. The causes responsible for this are due to the very problem statement rather than to the non-existance of well-developed strati-accumulation schemes. The fact is that both the statement of the problem and its solution are inadequate from the viewpoint of obtaining new characteristics that might be useful both theoretically and practically. Hence the difficulty in the calibration of loess sequences, in assessing their stratification.

The fossil fauna of loesses does not allow, in most cases, to apply a paleontological method for the assessment of the stratification of the loess sequences. The same holds true of the use of floral remains, the pollen grains of plants inclusive. Archeological finds, restricted as they are to historical times, are also unimportant for reaching these goals. Attempts at using other criteria to this end, such as the degree of loess degradation, differential development of gley patterns, compaction, etc. have also proved unsuccessful. A more efficient and justified approach to loess subdivision has been the use of paleopedological methods.

As pointed out in more than two times in the literature, regional buried soils reflecting breaks in loess accumulation serve as good indices for the stratigraphic classification, calibration and correlation of loess sequences.

With a view to the prerequisites of paleopedology, we have set ourselves the aim to use the buried soils both as boundary layers and as bodies terminating particular rock strata assemblages corresponding to one cycle of sedimentation and formation of a sequence of strata. Thus it has become possible to represent a loess sequence as a system and to apply a system-structure approach to its study.

The birth of the system-structure approach was preceded by a lot of work in recent years devoted to the cyclicity of generation of subaerial rocks (KAROGODIN, Yu.N. 1980; KRIGER, N.I. 1980; MARTYNOV, V.A. et al. 1980; SHAEVICH, Ya.E. 1979, 1980). The conclusion that can already be drawn at present is that cyclicity and system pattern are closely related scientific concepts of one general and universal approach to the nature of things and phenomena.

Prior to entering into a detailed setting out let us touch, at least quite briefly, upon some notions.

Under a sedimentation cycle we understand a process (regular or interrupted) in the alternation of dynamic and other conditions and circumstances of sedimentation, a process leading to the formation of rock strata. To designate a cycle (process) materially, i.e. to designate a complex of loess strata and buried soils formed during one cycle we propose the term 'cycless'. For its definition we propose the following: 'A cycless is a uniform, definitive set of loess strata and buried soil strata characterized by an oriented structure (morphostructure), continuous changes of their basic composition indices, structure-texture features, physico-mechanical properties and by closest interrelations and characteristics of the main boundaries between the strata'. The proposed term cycless is entitled to exist, for it satisfies the requirements of term-coining such as usefulness and justification of use (virtually existing bodies of definite origin and structure), shortness, the fact of being oriented (the term-elements 'cycle' and 'loess' being used according to their primary destination), euphony and lexical potential. The term is of inter-sectorial character, for it is equally understandable to the Quaternary geologist, the geographer and the soil scientist.

International in form and content, the term in question will enable the mutual understanding of specialists speaking in different languages. As regards unambiguity there is no need to speak of it, as it never has hitherto been used by anybody with any meaning whatever. A rock strata assemblage like cycless can be figured as a system. Of course, to wish this alone is not enough, for this formation is supposed to carry the basic features of a system such as integrity, structure, hierarchy, etc.

In our interpretation an elementary loess system is an integral body with a characteristic structure of elements indivisible at the given level (rock strata and buried soils) characterized by a definite emergence, hierarchy and ordering in time.

The system approach has permitted to figure the multitude of sections of a region as a complex hierarchy system that is integrate in itself and divisible into individual integrities – elementary systems.

Now let us test the rightfulness of studying a loess sequence according to the above principles on a concrete, tangible material.

In FIG. 1 a key section exposing a 72-m-thick loess sequence is shown. All this loess rock strata assemblage can be represented as a system of a 'I' order of magnitude, as it correspond to all features of a system.

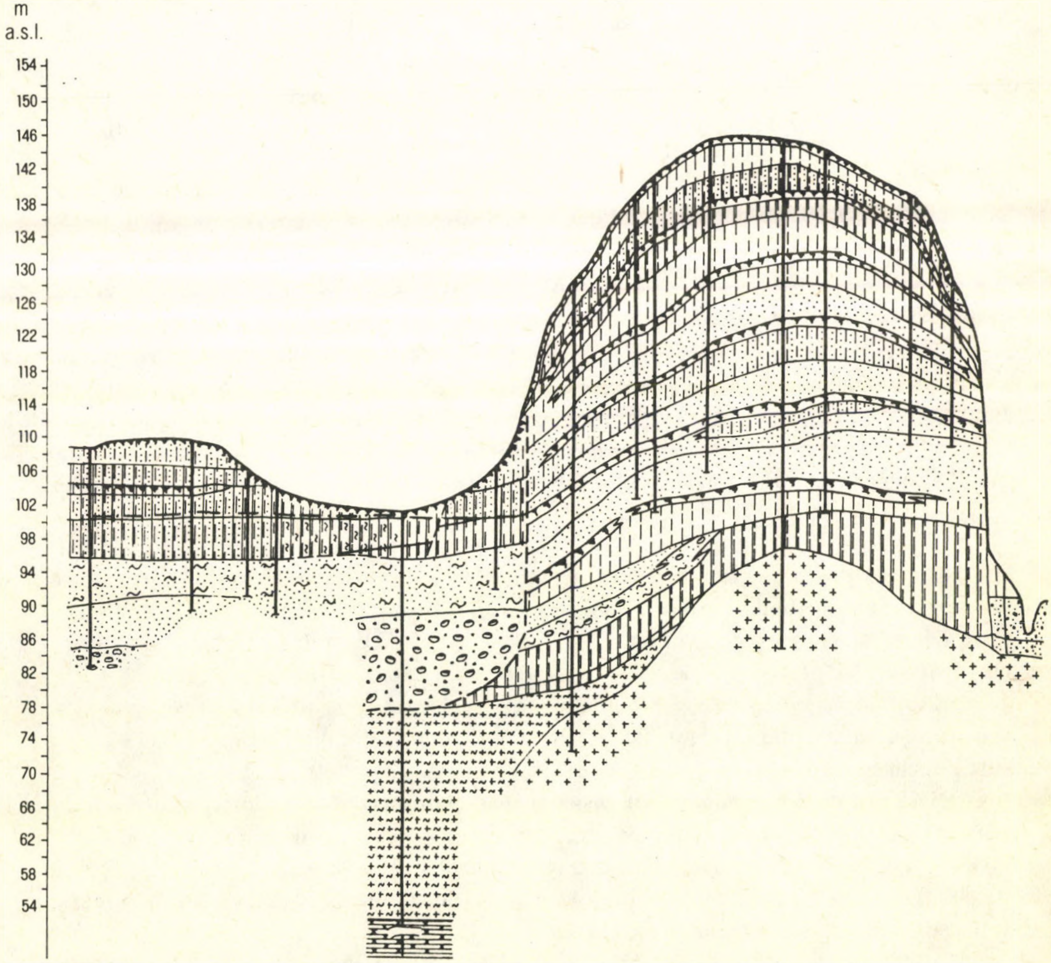


FIG. 1. Geologic-lithologic key section across the city of Novosibirsk

Let us examine now an elementary part of this system, say, the interval 6.1 to 13.6 m. Compared with the whole system, this is a subsystem of lower order. This elementary system is represented by rock strata (loam, sandy clay) and by buried soil terminating them at the top (heavy sandy clay).

Its integrity as that of a system lies in that it corresponds, firstly, to one continuous sedimentation cycle; as evident from the graphs (FIG. 2, 3, 4), its elements are characterized by an oriented structure, by the continuity and variation of the basic indices, characteristics of physico-chemical properties, a close interrelation and gentleness of the boundaries. Each of its elements, rock strata, is indivisible at the present level of knowledge. Emergence is expressed by that the fundamental feautres of this system as a whole (oriented structure, continuity of variation of the basic characteristics, character of the boundaries, etc.) are not characteristic either of the system in general or of its elements in particular (rock strata). The hierarchic nature of the system of 'I' order of magnitude being discussed means that each of its elements can be regarded as an elementary system (as it is the case with our example), but the system in question in turn is only one of the parts of a wider system (of higher order of magnitude). The hierarchic nature is manifest in another context too, being connected with the organization levels of geological bodies such as mineral, rock, formation (rock strata) bodies.

Finally, there is one more feature of the system – its being ordered in time. In a concrete case this manifests itself in that a system repeats itself in terms of composition and structure of elements. The latter feature allows us to conclude that, when studying loesses we come across not only and simply rock systems, but we have to do with cyclic systems as well.

A sequence can be divided, correctly and in a scientifically justified way, into cyclesses by making use of a complex set of genetically related features reflecting the interaction of all stages of the transformation of a sediment into a rock.

At the same time, it is necessary to select from the diversity of features the principal, diagnostic ones that will most fully and unambiguously characterize the loess deposits in the context of their cyclicity.

The specificity of the make-up and nature of variation in the vertical section of the basic compositional, textural and structural characteristics and physico-mechanical properties and particularly of the main structural feature, the granulometric composition, bears witness to the fact that (FIG. 2, 3, 4. TABLE I) any loess section, independently of the facies peculiarities manifest in the succession of the rock strata and their association, is dissected into cyclo-complexes (cyclesses) that are easy to recognize in the graphic representation, plotting, of the granulometric composition. This is how the first conclusion reads.

As proved by a number of tests, the other structural-textural features such as mineralogical and chemical composition, the physico-mechanical properties, etc., also vary both within single cyclesses and in a vertical geological section as a whole.

The boundaries, limits, of these changes coincide in most cases with the breaks and anomalies on the granulometric curve.

This testifies to a close correlation of all the indices with each other and, in particular, with the granulometric composition.

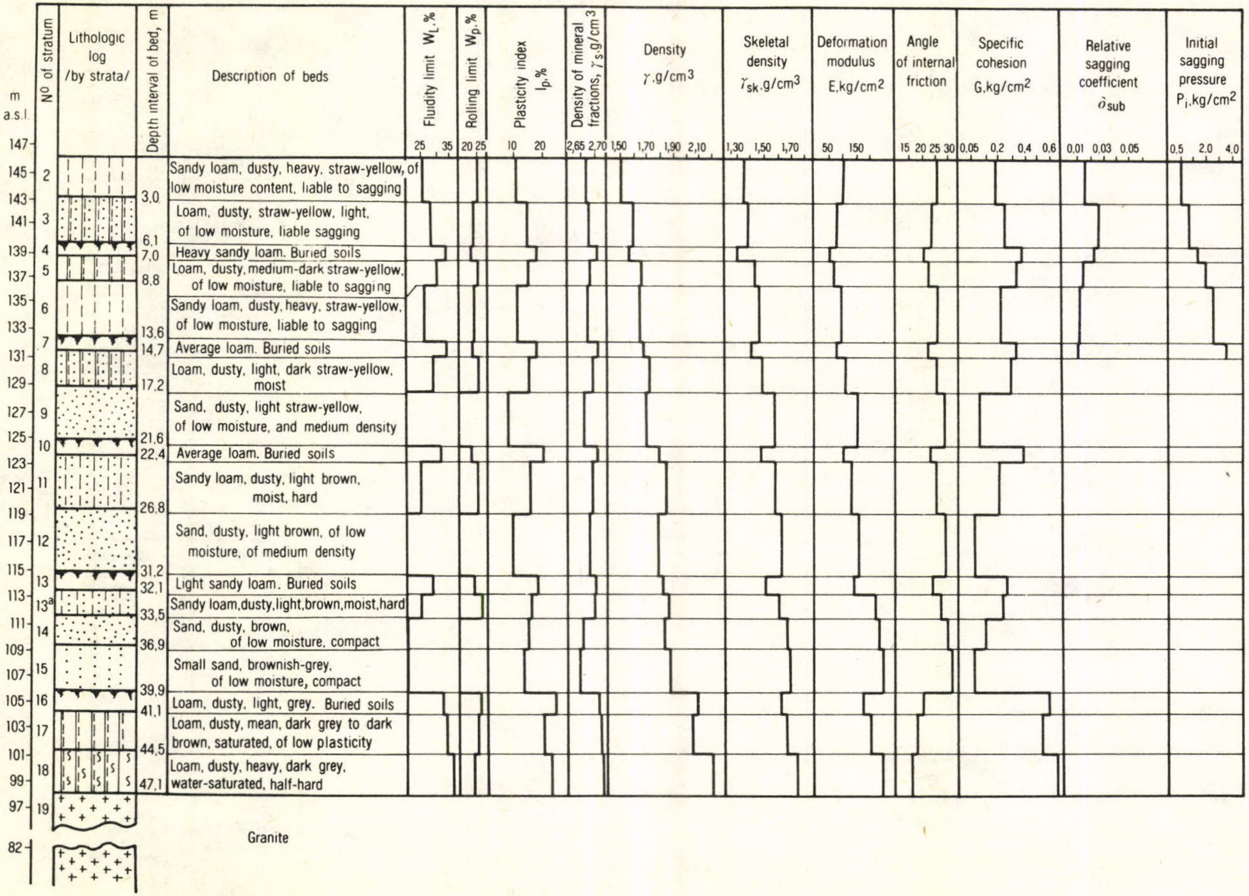


FIG. 2. Cyclicity of variation of the main physico-mechanical indices along c-15 (3)

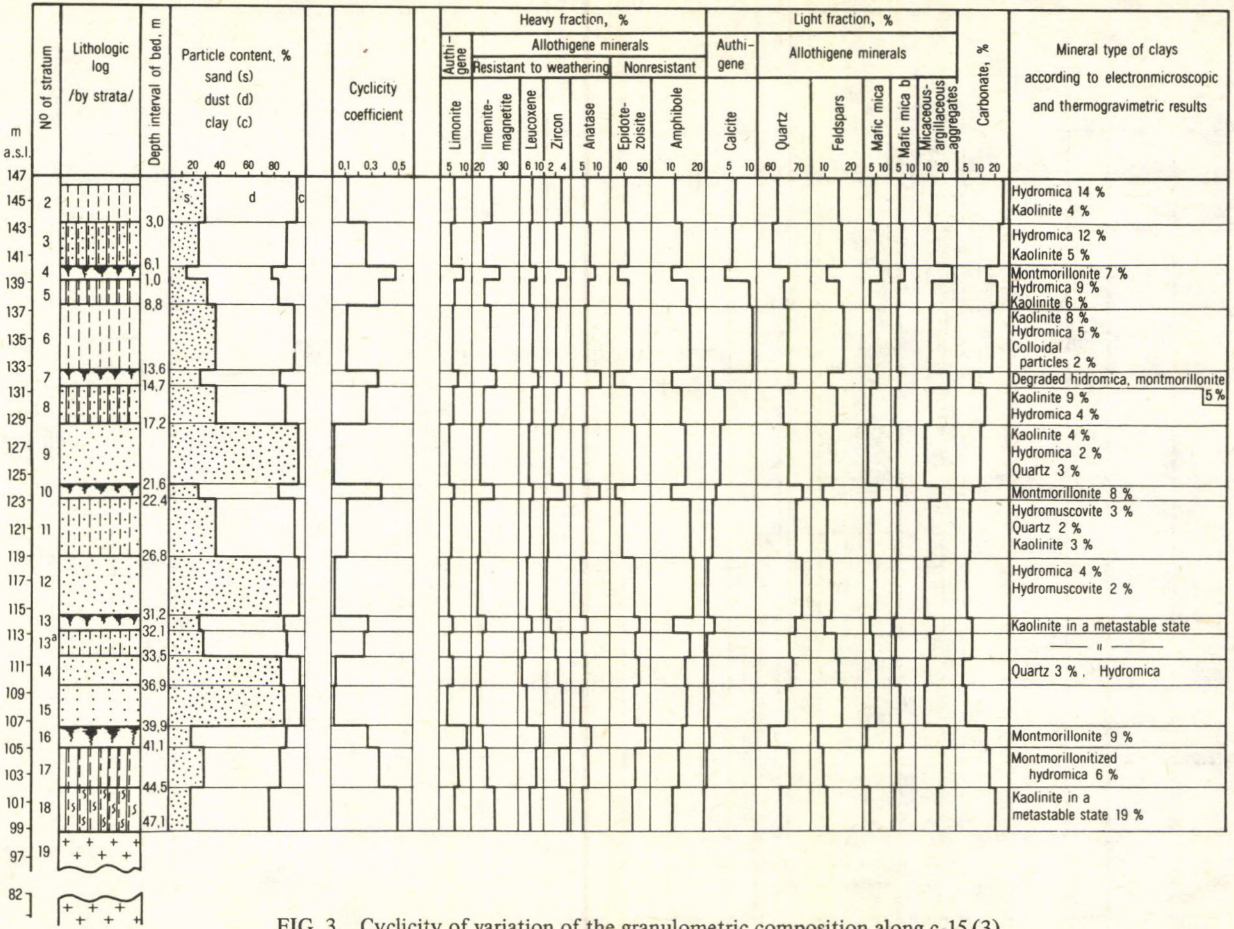


FIG. 3. Cyclicity of variation of the granulometric composition along c-15 (3)

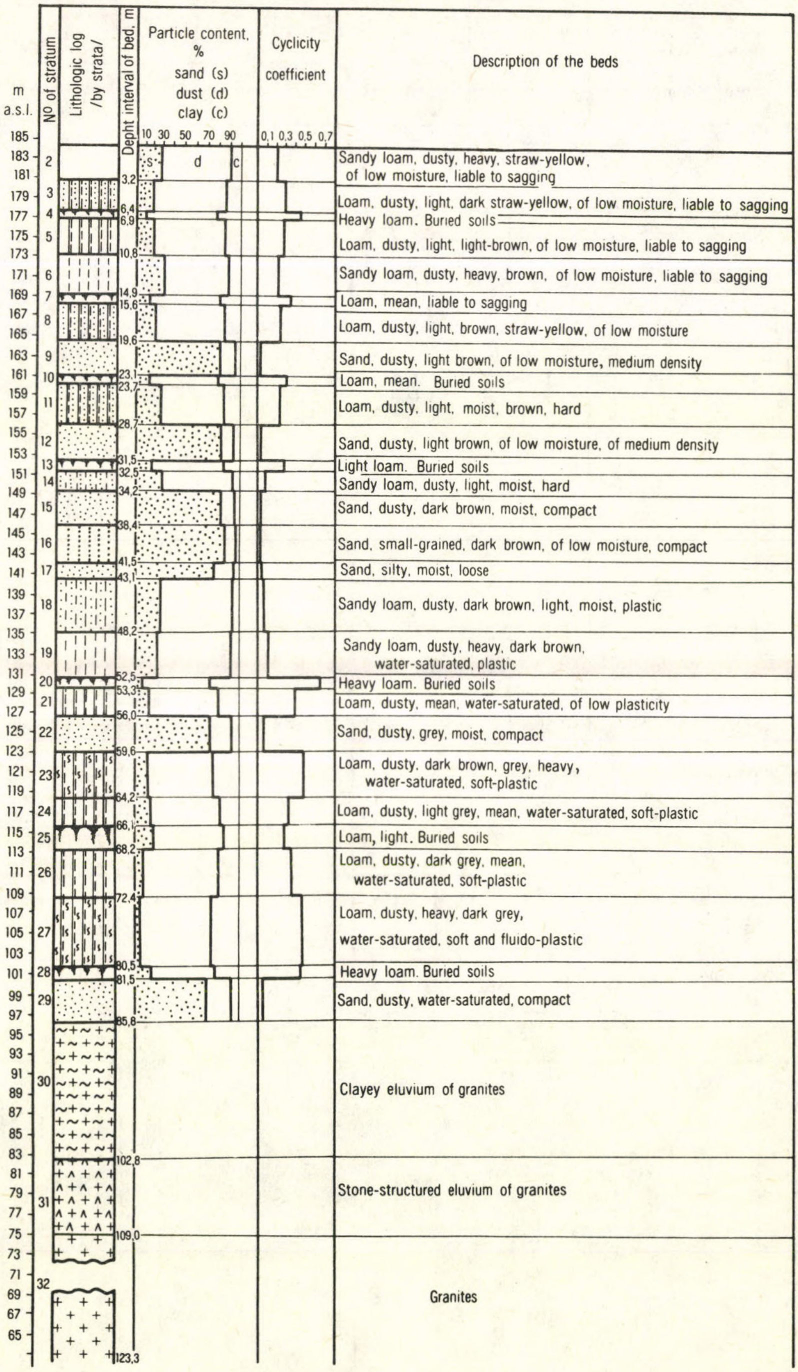


FIG. 4. Cyclicity of variation of the granulometric composition and K_c along c - 45 (1)

N^{0} of stratum	Denomination of rock stratum	N^{0} of cycless	Depth interval,m	Heavy fraction								Light fraction							Carbonate
				Heavy fraction recovery	Authigene	Allothigene minerals						Authigene	Allothigene minerals						
						Resistant to weathering				Nonresistant			Quartz	Feldspars	Rock debris	Mafic mica	Mafic mica b	Micaceous-argillaceous aggregates	
					Limonite	Ilmenite-magnetite	Leucoxene	Circon	Anatase	Epidote-zoisite	Amphibole	Calcite							
2	Heavy, sagging, sandy loam	1	0,5–3,0	4,4	6,0	25,3	5,3	2,2	7,5	41,2	10,2	7,2	63,4	15,9	3,6	4,9	2,4	12,6	18,1
3	Light, sagging loam		3,0–6,1	4,9	5,9	23,4	4,2	1,8	8,0	42,4	12,3	6,4	61,6	16,7	3,1	5,1	3,6	14,5	17,6
4	Heavy, sagging loam, buried soils	2	6,1–7,0	5,8	9,5	29,2	7,4	3,1	9,3	38,2	9,7	4,2	66,8	12,7	2,6	6,1	4,1	26,4	11,6
5	Loam of medium weight		7,0–8,8	4,1	7,0	23,4	4,3	2,0	7,4	42,5	13,8	8,7	60,3	16,1	1,9	3,4	3,0	14,1	16,3
6	Sandy loam, heavy		8,8–13,6	3,9	5,4	24,1	5,1	1,9	6,7	44,1	14,1	9,5	63,7	17,3	2,1	3,9	2,7	11,6	14,9
7	Loam of medium weight, buried soils	3	13,6–14,7	4,4	7,5	27,4	6,2	2,4	11,6	34,7	8,1	2,7	69,7	13,1	2,8	4,6	3,2	29,1	6,9
8	Light loam		14,7–17,2	3,7	5,9	23,3	5,6	1,7	7,7	43,1	11,9	4,5	65,3	15,9	2,0	4,0	1,6	10,6	11,6
9	Dusty sand		17,2–21,6	2,6	4,6	22,8	4,1	1,6	5,3	46,5	13,7	3,6	67,4	14,7	1,7	3,5	1,8	5,9	10,8
10	Loam of medium weight,buried soils	4	21,6–22,4	4,1	6,5	26,1	5,8	3,6	10,1	37,3	8,7	3,3	72,1	10,7	3,1	7,0	3,0	19,4	7,1
11	Light sandy loam		22,4–26,8	3,2	5,6	22,1	4,9	1,4	6,5	39,4	16,9	3,1	68,1	12,3	1,9	4,9	2,4	9,6	6,7
12	Dusty sand		26,8–31,2	2,1	4,1	20,6	3,8	1,3	4,7	42,7	17,1	2,1	70,1	13,1	2,1	5,1	2,1	3,1	5,4
13	Light loam, buried soils	5	31,2–32,1	3,4	5,1	21,9	5,1	1,6	7,1	42,9	10,7	3,8	69,1	12,4	1,4	3,2	1,3	9,8	6,2
14	Dusty sand		32,1–36,9	2,1	4,3	20,0	3,7	1,7	4,9	44,1	14,9	2,8	64,3	15,1	1,6	2,9	1,1	7,8	7,6
15	Small-grained sand		36,9–39,9	1,7	3,4	19,0	3,1	2,7	3,1	40,2	13,1	2,0	67,3	17,4	3,1	3,1	2,7	5,1	2,9
16	Light loam, buried soils	6	39,9–41,1	2,1	10,1	23,1	8,4	2,9	8,2	45,6	12,2	2,1	59,1	8,7	2,1	1,6	3,4	26,8	12,4
17	Medium-weight loam		41,1–44,5	1,7	8,3	24,2	7,4	2,0	6,1	39,6	11,0	1,4	64,2	9,4	2,0	0,8	1,7	21,3	13,7
18	Heavy loam		44,5–47,1	1,4	7,1	25,7	6,9	2,4	5,7	38,9	10,7	1,4	61,7	10,1	1,7	1,3	1,4	20,4	14,1

TABLE 1. Characteristic mineralogical composition of the individual cyclesses

It follows from this, that by distinguishing cyclesses in terms of the granulometric composition we make a distinction according to the other indices as well. This is the second conclusion.

The above discussion entitles us to accept the granulometric or grain composition as one of the basic diagnostic features of loess sequence subdivision. Many lithologists are inclined to think that the various combination of the granulometric fractions characteristic of a concrete rock formation reflect in a broad sense the circumstances of sedimentation.

The unquestionable diagnostic significance of the granulometric composition and the analysis of the individual fractions (sand, dust, clay fractions) have enhanced searchers to find an integral numerical criterion for the distinction of individual cyclesses in a vertical geological section.

As shown by the complex study of loess deposits, the basic fractions, having essential influence on the pattern and characteristics of loess sediments are the coarse-dust particles ($d = 0.01 - 0.05$ mm) and the clay particles ($d < 0.005$ mm).

It is the percentage of the particles $d < 0.005$ mm to the particles $d > 0.01$ to 0.05 mm that has been adopted as the so-called cyclicity coefficient (K_c).

The analysis of more than 600 values of K_c from various regions has shown this index to be correct in relation to other characteristics of the composition, the properties and also the stratigraphy of loess sediments.

As a rather consistent trend, K_c was observed to increase as the granulometric composition gets heavier. The buried soils have a cyclicity coefficient attaining 3 to 5 times or more the figure of the enclosing sediment. This is exactly what enables us to record easily the buried soils and, as already shown, to distinguish cyclesses. The granulometric properties of the individual cyclesses do not represent random alternation of lithofacies of different granulometry, but they are regularly organized complexes reflecting the interaction of the various natural factors, involved in their formation.

The analysis of the cyclicity of loess formations sheds light on two aspects of this process – the fixation of cyclicity in the vertical section and the determination of its scales in the lateral sense.

The cyclesses having been observed to be consistent both vertically and laterally over great distances (FIG.), this proves them to be of stratigraphic value. Virtually, it is the succession of the cyclesses in space and time that serves as a stratigraphic scale for the loess sequences. In our opinion, a cycless is a definite stratigraphic unit.

Let us examine now how much this approach is justified. The difficulties of loess stratification and the causes responsible for it were already pointed out.

The Soviet Stratigraphic Code has stipulated the use for the loess-like sediments of stratigraphic subdivisions that are independent and can be designated with terms of free use. The Code has stipulated the following lithostratigraphic categories for a regular usage: sequence, bed, stratum (layer), key horizon.

Without entering into details of how the Code has specified those terms, we should like to point out that all of them can find a use in loess stratigraphy.

Terms like loess sequence, rock stratum, key horizon (buried soil) need not be commented.

A bed (in the sense of the Code) is a relatively thin set of strata characterized by an identity of features . . . We already pointed out in the above that a cycless happens to be accepted as a stratigraphic category.

The use of sedimentation cyclicity and system patterns in the construction of loess sequences has enabled a new approach to representing the stratigraphy of the Krasnodubrovskaya and Kochkovskaya series of Quaternary loess deposits in the southern part of Western Siberia. So the Krasnodubrovskaya series was conventionally divided into 2 to 3 rock strata complexes. The new approach has enabled to distinguish 5 to 7 complexes (cycless) within that sequence, thus being of interest from both scientific and practical viewpoints.

REFERENCES

KAROGODIN, Yu.N. 1980: Sedimentatsionnaya tsiklichnost'. (Sedimentation cyclicity). Moscow, Nedra. 242.

KRIGER, N.I. 1980: Printsipy tsiklichnosty protsessa lessoobrazovaniya. (Principles of cyclicity of the loess generation process.) In: Tsiklichnost' formirovaniya subaeral'nykh porod. – Trudy Inst. geol. i geofiz. SO AN SSSR. 457. 34-42.

MARTYNOV, V.A. – KHRAPOV, V.S. –SHAEVICH, Ya.E. 1980: Tsiklcinost' v razrezakh Priobskoi vozvyshennoi ravniny. (Cyclicity in the sections of the Priobskaya High Plain.) – In: Tsiklichnost' formirovaniya subaeralnykh porod. – Trudy Inst. geol. i geofiz. SO AN SSSR. 457. 87-94.

SHAEVICH, Ya.E. 1979: Tsiklichnost' lessovykh porod i metod ee izucheniya na primere yuga Zapadnoi Sibiri. (Cyclicity of loess rocks and a method for studying them by the example of southern West Siberia.) – Inzhenernaya Geologiya. 1979. 2. 59-66.

SHAEVICH, Ya.E. 1980: Nekotorye voprosy terminologii i metodiki vydeleniya tsiklov subaeral'nykh porod. (Some questions of terminology and methodology for distinguishing cycles in subaeral rocks.) – In: Tsiklichnost' formirovaniya subaeral'nykh porod. – Trudy Inst. geol. i geofiz. SO AN SSSR. 457. 64-77.

Adress of author:
Ya.E. Shaevich, Geographical Research Institute for Construction Engineering (PNIIIS),
Okruzhnoy proezd 18. 105058 MOSCOW – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PLIOCENE AND PLEISTOCENE SOIL FORMATION IN THE UKRAINE

N.A. Sirenko

ABSTRACT

The article analyzes the principal regularities of Pliocene and Pleistocene soil formation in the Ukraine, its rhythm, direction, zonality, regionality. The alternation of the stages of intensive soil formation (soil series, pedocomplexes) and of sedimentation (Pliocene yellow-brown clays and Pleistocene loess-like loams) are presented. The author gives the morphogenetic characteristic of soils from eight Pliocene paleogeographical stages and from seven Pleistocene stages. The common and distinctive features in the character of the Pliocene and Pleistocene soil formation are established. The forms and types of cryogenic structures in the Pleistocene are investigated.

Paleopedology is a new science but during the last two decades it has given us numerous data about the composition, structure, paleogeographical stages and characteristics of the Earth's crust.

Paleopedology is very useful for climatostratigraphy that is considered to be the base of stratigraphic schemes of the Late Kainozoic subaerial sediments.

Specialists from the Geographical Research Institute of Ukrainian Academy of Sciences have collected many interesting data about Late Paleozoic (Carboniferous and Permian), Mesozoic (Triassic and Jurassic) and especially about Pliocene and Pleistocene soil formation.

Soil formation was continuous in the continental stages of earth history. For every time interval clear rhythms are observed. Stages of intensive soil formation (during the warm paleogeographical intervals) alternated with stages of its attenuation (during the cold and moderately cold paleogeographical intervals), that led to the alternation of soils of different genesis and complete profiles with horizons of loesses, loess-like loams, brown-coloured Pliocene clay and bluish-greenish-olive Mesozoic clay.

Each stage of soil formation is characterized by its own paleogeographical conditions, intensity and character of soil formation and sedimentation.

There are 16 paleogeographical stages (or stratigraphic horizons) (VEKLICH, M.F. 1968; VEKLICH, M.F. – SIRENKO, N.A. 1973; 1976; TABLE 1) in the continental post-Pontusian sediments of the Ukraine. Eight of them (the Ivankov, Lyubimovka, Sevastopol, Jarkov, Bogdanov, Beregovo, Kryzhanovian and Shirokino horizons) represent the major stages of intensive soil formation similar to the subtropical one. The stages of red-coloured soil formation type alternated with the stages of yellow-brown-coloured rock formation under different climatic conditions (the Belbek, Salgir, Oskol, Aidar, Kizylyar, Siver, Berezan and Ilyichevsk horizons). The Pliocene clays show traces of considerable chemical and biochemical weathering and are intercalated by 6-12 fossil soils. Unlike the red-coloured ones, they represent more moderate climatic conditions. Soils of the Lower Pliocene brown-coloured horizons, e.g. the Belbek horizon, are rather thick and are characterized by their complete profiles. But upwards soils of the brown-coloured horizons are thin and two-membered (A-C).

The Pleistocene rhythm had specific characteristics. One of them is an obvious contrast of soil processes. Seven soil horizons (the Martonosha, Lubny, Zavadovka, Kaydak, Priluki, Vitachev and Dofinovka) alternate with eight loess and loess-like loam horizons (the Priazov, Sula, Tiligul, Dnieper, Tyasmin, Uday, Bug and Prichernomorye horizons, TABLE 1). In the Tiligul, Dnieper, Bug and Prichernomorye horizons, as well as in the Pliocene clays, in the initial and final phases of sedimentary cycles there are poorly developed soils of primitive initial type. It indicates the progressive, pulsatile character of soil formation and sedimentation processes during the initial and final phases of sedimentary cycles.

Stage by stage development is characteristic for the Pliocene and especially for the Pleistocene due to the climatic alternations. Such development caused the formation of soil series (pedocomplexes) characteristic for all stages of soil formation independent of their age.

A soil series reflects conditions of old soil formation during one paleogeographical stage and corresponds to the initial, optimum and final phases of soil formation. Soil series have various structures. In some cases, especially on the high watersheds with poor sedimentation a pedocomplex may be represented by only one soil profile with a complex polygenetic structure. Sometimes a series consits of several independent soils interbedded with loess-like loam horizons that are characteristic of the Lower and Middle Pliocene in the Ukraine. Soil series of the initial and final stadials are as a rule thin and vague. Soils of the optimum stadials are the most informative from paleogeographical point of view. There are 2-6 optimum stadials in the Pliocene and 2-3 in the Pleistocene.

The analysis of the structure and characteristics of the Pliocene and Pleistocene series reveals the regular character of soil formation. From the Lower Pliocene up to the Upper Pleistocene, soil formation continued under the influence of processes of increased aridity and fall of temperature, which influenced the characteristics of fossil soils: bright-red soil of the Lower and Middle Pliocene became reddish- and brownish-cinnamon in the Upper Pliocene and Lower Pleistocene. In the Middle and Upper Pleistocene brown, grey, cinnamonish-grey colours dominate. The quantity of clays and sesquioxides decreased while quantity of carbonate, and also new formations in the south, increased.

Depending on the region, relief and position in the sequence, in the Pliocene there were several predominant soil types: in the Lower Pliocene humid-and-variable-humid-forest soil types (yellow-brown, yellow, red, red-cinnamon, leached, with lessivage and hydromorphic soils), in the Middle Pliocene predominated forest-steppe soils with different grasses, and in the Upper Pliocene forest-steppe, xerophytic-forest and meadow-

TABLE 1. Upper Kainozoic paleogeographical stages in the Ukraine

Period System	General scale	Paleogeographical stages		Subaerial sediments
		Name	Index	
ANTHROPOGENE	Modern sediments	Holocene	hl	Modern soils
	Upper Anthropogene	Prichernomorye	pc	loesses
		Dofinovka	df	soils
		Bug	bg	loesses
		Vitachev	vt	soils
		Uday	ud	loesses
	Middle Anthropogene	Priluki	pl	soils
		Tyasmin	ts	loesses
		Kaidak	kd	soils
		Dnieper	dn	loesses
	Lower Anthropogene	Zavadovka	zv	soils
		Tiligul	tl	loesses
		Lubny	lb	soils
		Sula	sl	loesses
		Martonosha	mr	soils
		Priazovye	pr	loesses
PLIOCENE	Upper	Shirokino	sh	soils
		Ilyichevsk	il	clays
		Kryzhanovian	kr	soils
		Berezan	br	clays
		Beregovo	bv	soils
		Siver	sv	clays
	Middle	Bogdanov	bd	soils
		Kizylyar	kz	clays
		Yarkov	jr	soils
		Aidar	aj	clays
		Sevastopol	st	soils
		Oskol	os	clays
	Lower	Lyubimovka	lm	soils
		Salgir	sg	clays
		Ivanovsk	iv	soils
		Belbek	bl	clays
	Lower	Pontusian stage	nv	loams

steppe soils of cinnamon and reddish-cinnamon colours prevailed. In the Middle and Upper Pliocene and partly in the Lower Pleistocene in the south sea-side regions there developed dark-coloured fused soils of montmorillonite composition.

Soil formation characteristics, as well as palynological, paleomagnetic and other data were the base for the subdivision of the Pliocene into the Lower, Middle, Upper Pliocene.

Formations of temperate subboreal climate (brown and grey forest soils of different facies, chernozem-like, chernozem, chestnut and other soils) dominate in the Pleistocene topsoils, though there are some features transitional to subtropical, and in the South, to subarid and arid subtropical character (a group of cinnamon and reddish-cinnamon, carbonate cinnamon steppish, dark-cinnamon, grey-cinnamon and other soils).

In the Pliocene and Pleistocene processes of soil formation there are 5-6 stages of higher humic content during which the lower soils of a series were formed and 6 stages with higher aridity (upper soils of the Lyubimovka, Jarkov, Bogdanov, Shirokino, Zavadovka and Dofinovka stages). This regularity is especially characteristic of the southern and south-eastern regions of the Ukraine.

Topsoils of different age had different zonal structures. Latitudinal zonation in the Pliocene was less differentiated than in the Pleistocene. Thus, red and yellow type of soil formation in the Ivanovsk times of the Lower Pliocene is seen almost everywhere in the Ukraine.

In the Upper Pliocene and Lower Pleistocene the zonal contrast of the topsoil and predominant group of cinnamon soils in central, southern and sout-eastern parts of the republic (cinnamon typical, leached, carbonic, cinnamon meadow, dark-cinnamon, reddish-cinnamon and other soils) increased. In south-western and western regions cinnamon soils were accompained by brown soils, and in the Lower Pleistocene by the chernozem-like soil formation type. In the north of the republic dark-coloured meadow and meadow-forest soils were well developed.

The clearly cut zonal structure of the topsoil is characteristic of post-Dnieper times, though in the Upper Pleistocene, especially in the Vitachev and Dofinovka periods, zonal contrast in topsoil decreased because of increased aridity.

Recently we composed and published the map-schemes of topsoils for 7 Pleistocene stages.

Beginning from the Upper Pliocene fossil soils have traces of frost deformation. There are at least 9 Pleistocene and 2 Upper Pliocene generations of cryogenic structures synchronous with loess horizons, but their intensity and dimensions are various (VEKLICH, M.F. 1969; VEKLICH, M.F. – SIRENKO, N.A. – DUBNYAK 1974; SIRENKO, N.A. 1981). The most vivid frost deformations are seen on the loess and fossil soils contact.

Forms and cryogenic structures are various in the Ukraine.

Frost deformation took place predominantly in the principal and final stages of soil formation and in the soils of the second climatic optimum where the upper and lower boundaries were deformed due to the repeated transition of melted soil to frozen one.

Forms of the residual cryogenic formations on the territory of the Ukraine show that they were produced under the influence of seasonal frost. Only during the Dnieper, Bug and Tiligul stages there might have been permafrost in the Middle Pridnieprovye. Intensive cryogenic deformation in the Lubny, Zavadovka and Vitachev horizons in indicative of this. The Bug, Uday, Tyasmin, Dnieper and Tiligul stages of loessformation were characterized by the most vivid frost regime.

Each time interval is characterised by its own group of cryogenic formation. At the same time there are zonal variants of cryogenic phenomena.

In the northern and north-western regions of the Ukraine in the Middle and Upper Pleistocene nonstructural forms of paleocryogenesis (solifluction etc.) dominated that indicate the unity of cryogenesis and humidity.

In the Middle, and especially in the Eastern regions earth veins predominated. Intensity of cryogenesis decreased to the South.

Soil formation in the Pliocene and Pleistocene was consequently subjected to repeated cycles of humidity, aridity and cryogenesis.

REFERENCES

BILENKO, D.K. 1931: Kopal'ni grunti gori Piviki. – In: Chetvertiniy period. 1-2. 75-94.

KROKOS, V.I. 1932: Instruktsiya do vivchennya chetvertinnikh pokladiv Ukraini. – In: Chetvertinniy period. 3. 17-55.

MATVIISHINA, Zh.N. 1974: Mikromorfologiya lessov i iskopaemykh pochv yuga USSR. – In: Paleogeografiya i inzhenernaya geologiya yuga Ukrainy. Kiev, Nauk. dumka. 60-64.

MAYSKAYA, Zh.N. 1974: Mikromorfologiya iskopaemykh pochv i lessov po materialam izucheniya opornykh razrezov antropogena Srednego Pridneprov'ya. – In: Paleopedologya. Kiev, Nauk. dumka. 44-56.

MOSKVITIN, A.I. 1930: Pogrebennye pochvy Prilukskogo okruga Ukrainy i vremya lessoobrazovaniya. – Bull. Moskovsk. obshch. ispytateley prirody. 8. 34. 361-372.

SIRENKO, N.A. 1974a: Antropogenovye pochvennye pokrovy ravninnoi territorii Ukrainy. – In: Paleopedologiya. Kiev, Nauk. dumka. 27-43.

SIRENKO, N.A. 1974b: Nekotorye voprosy metodiki paleopedologicheskikh issledovaniy. – In: Paleopedologiya. Kiev, Nauk. dumka. 15-27.

SIRENKO, N.A. 1975: Pleistotsenovy chornozemi Ukraini ta paleogeografichni umovi ikh utvorennya. – In: Problemy geografichnoi nauki v USSR. 2. 86-99.

SIRENKO, N.A. 1977: Pleistotsenovye iskopaemye pochvy Ukrainy. Avtoreferat diss. Kiev, Nauk. dumka. 70.

SIRENKO, N.A. 1977: Osobennosti pliotsenovogo pochvoobrazovaniya na territorii Ukrainy. – In: Paleogeografiya i ratsional'noe ispol'zovaie estestvennykh resursov. Kiev, Nauk. dumka 101-104.

SIRENKO, N.A. – KARPENKO, A.M. 1977: Opyt rekonstruktsii paleolandshaftov mezozoya Severo-Zapadnoi chasti Donbassa po paleopedologicheskim dannym. – In: Paleopedologiya. Paleolandshafty. Kiev, Nauk. dumka. 142-176.

SIRENKO, N.A. – VEKLICH, M.F. 1977: Slitye pochvy pliotsena i pleistotsena Ukrainy. – In: Paleogeograficheskie osnovy ratsional'nogo ispol'zovaniya estestvennykh resursov. Kiev, Nauk. dumka. 2. 94-97.

VEKLICH, M.F. 1968: Stratigrafiya lessovoy formatsii Ukrainy i sosednykh stran. Kiev, Nauk. dumka 240.

VEKLICH, M.F. – SIRENKO, N.A. 1973: Rozvitok gruntiv Ukraini v pizn'nomu kainozoi. Kiev, Nauk. dumka. 224.

VEKLICH, M.F. – SIRENKO, N.A. 1976: Pliotsen i pleistotsen levoberezh'ya Nizhnego Dnepra i Ravninnogo Kryma. Kiev, Nauk. dumka. 197.

VEKLICH, M.F. – SIRENKO, N.A. – DUBNYAK, V.A. 1973: Merzlotnye deformatsii antropogenovykh otlozheniy Ukrainy. – In: Mezhdunarodnaya konferentsiya po merzlotovedeniyu 3. Genezis, sostav i stroenie merzlykh tolshch i podzemnye l'dy. Yakutsk, knizhnoe izd. 58-60.

VEKLICH, M.F. – MATVIISHINA, Zh.N. – MEDVEDEV, V.V. – SIRENKO, N.A. – FEDOROV, K.N. 1979: Metodika paleopedologicheskikh issledovaniya. Kiev, Nauk. dumka. 271.

ZAMORIY, P.K. 1957: Pokhovani grunti i lesoviy tovshchi USSR. – Naukovi zapiski Kiivs'kogo univ. 15. 10. 17-21.

Adress of author:
N.A. Sirenko, Section of Paleogeography, Dept. of Geography Academy of Sciences, Ukrainian SSR
Bul. Shevchenko 60. 252032 KIEV – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

ON THE DEVELOPMENT OF PLEISTOCENE SOILS IN CZECHOSLOVAKIA

L. Smoliková

ABSTRACT

In the territory of Czechoslovakia significant pedostratigraphic units were investigated, especially those occurring in loess series, on volcanics, lacustric sediments, on the so-called solid carbonate substrates and on pronounced silicate basements.

FOSSIL SOILS IN LOESS SERIES

In loess series, mostly weakly developed soils occur, chernozems, pseudo-chernozems, illimerized soils, brown clay (Braunlehm)-like grey brown forest soils (Parabraunerdes), brown clays (Braunlehms), reddish clays (Rotlehms), pseudogleys, gley-like and panthered soils.

a) Weakly developed soils of initial pseudogley character, „arctic" brown soil (Braunerde) and pararendzina character occur in the upper sections of almost all soil complexes (pedocomplexes), thus they are of no regional stratigraphic significance. It is only the pedocomplex I ("W 2/3") which is throughout composed of these soils.

b) True chernozems occur within the interval of pedocomplexes II ("W 1/2") and III (R/W, Eem) and rarely also in pedocomplex VI (Early Holstein).

c) Polygenetic pseudo-chernozems appear within the range from pedocomplex IV (Treene, Rügen) to X (C/M, Cromer); these are associated throughout with the upper sections of the respective pedocomplexes.

d) Illimerized soils are present especially in pedocomplexes III and IV; those overlying strongly weathered soils are also present in pedocomplexes VI and VIII.

e) Brown clay (Braunlehm)-like grey brown forest soils (Parabraunerdes) (with a progressive tendency toward brown clays) occur in pedocomplexes V and CI (Late or Early Holstein) as well as in pedocomplexes IX and X.

f) The soils of brown clay (Braunlehm) and reddish clay (Rotlehm) types are present within the range from complex VII (warm Mindel time spans) to the earliest one.

g) Strongly developed pseudogleys are in the pedocomplex VI as e.g. in the Červeny kopec locality and in pedocomplex VII in the Ruženin dvur locality near Brno.

h) Strongly developed gleys are also present in pedocomplex VIII as e.g. in the Ruženin dvur near Brno.

i) Panthered soils occur still in the upper part of pedocomplex VII.

For stratigraphic purposes, the basal soils of the individual soil complexes are most significant, as they correspond to the culminating phases of warm time spans, so they indicate the intensity as well as the duration and the course of the respective warm stages. – The upper members of the soil complexes recur regularly in the other pedocomplexes, this fact being in harmony with the course of the Quaternary climatic cycle.

All fossil soils (except the weakly developed ones corresponding to slight climatic oscillations) are of polygenetic character. This polygenetic origin reflects the complex Quaternary climato-sedimentary and soil-forming cycle. It can be best evident micromorphologically, e.g. brown-clays (Braunlehms) and reddish clays (Rotlehms) were secondarily earthened and rubified to various degrees (brown clay-grey brown forest soils and brown forest soils were subsequently granulated to earthened) as well as subsequently moderately pseudogleyed and enriched in a fresh allochtonous component. Then together with the overlying humic soils these were finely re-pseudogleyed, some of them were mechanically disturbed, and all were strongly re-calcified.

The intensity of the development of brown-clay soils (plastosols) increases towards the Tertiary, but in the opposite direction it is decreasing. In Czechoslovakia, brown-clay soils have not been found so far either in the Late Middle Pleistocene, or in the Late Pleistocene. The latest warm time span of the Elster (Mindel) glacial (pedocomplex VII) is therefore the last warm interval where, these soils formed on loesses in the area in question (TABLE 1).

An analogous case is that of plastosols on other substrates, e.g. volcanics or lacustrine marls.

SOILS ON VOLCANICS

In this case relict brown clays (Braunlehm) in the České středohoři Mountains may serve as an example. These occur there e.g. on debris of olivine basalts. Based on the analysis of the malacofauna (carried out by V.LOŽEK) preserved in the direct substratum of these soils, it was found that the formation of the brown clays (Braunlehms) may be assigned here to the Cromer interglacial and it is probably younger than the final phase of the Early Pleistocene.

SOILS ON FRESHWATER MARLS

On the above mentioned substrates relict (Unětice near Prague) as well as fossil (Přezletice near Prague) soils of brown clay (Braunlehm) type were preserved. The formation of the fossiliferous lacustric marls with a rich archaeological content falls within

TABLE 1. Development of fossil soils in loess layers in Czechoslovakia

Chronology	Pedocomplex	Soil development
„W 3”	I	Weakly developed soils- initial stages of pseudogley soils, pararendzinas etc.
„W 2/3”		„Arctic” brown soil (Braunerde) consisting of loam-crumbs sands
(Stillfried B)		„Arctic” brown soil (Braunerde)
„W 2”	II	Weakly developed soils – initial stages of pseudogley soils
„W 1/2”		Pararendzina to chernozem
Stillfried A		Degraded chernozem to brown forest soil (Braunerde)
„W 1”	III	Weakly developed soils – initial stages of pseudogley soils, brown forest soils, Stillfried A (Braunerde soils) and pararendzinas consisting of loam-crumbs sands
Eem (R/W)		Chernozem
		Illimerized soil
Treene (Rügen)	IV	Weakly developed soils – initial stages of pseudogley soils and pararendzinas
		Pseudochernozem Granular to slightly earthified greybrown forest soil (Parabraunerde)
		Pseudochernozem Granular to earthified grey brown forest soil (Parabraunerde)
Late Holstein	V	Pseudochernozem Earthified brown clay-like grey brown forest soil (Braunlehm-like Parabraunerde)
		Pseudochernozem Strongly brown clay-like grey brown forest soil (Braunlehm-like Parabraunerde)
Early Holstein	VI	Pseundochernozem Earthified grey brown forest soil (Parabraunerde)
		Strongly brown cley-like grey brown forest soil (Braunlehm-like Parabraunerde) (displaying developmental tendency to brown clay (Braunlehm)

TABLE 1. Development of fossil soils in loess layers in Czechoslovakia

Chronology	Pedocomplex	Soil development
Early Holstein	VI	Pseudochernozem (or still chernozem) Strongly brown clay-like grey brown forest soil (Braunlehm-like Parabraunerde (displaying developmental tendency to brown clay (Braunlehm)
Warm intervals of Elster Glacial (M)	VII	Humous soil (or mottled soil) Earthified brown clay (Braunlehm)
	VIII	Pseudochernozem Earthified grey brown forest soil (Parabraunerde) Earthified brown clay (Braunlehm)
	IX	Pseudochernozem Brown clay-like grey brown forest soil (Braunlehm-like Parabraunerde)
Cromer Interglacial (G/M) and other warm intervals	X	Pseudochernozem (Brown clay-like grey brown forest soil (Braunlehm-like Parabraunerde) Earthy brown clay (Braunlehm)
	XI	Earthy brown clay (Braunlehm) Earthy rubefied brown clay (Braunlehm)
	XII (?)	Rubefied brown clay (Braunlehm)

the early phase of the Cromer interglacial in a broad sense and that of the brown clays (Braunlehms) into one of the culminating phases of the respective climatic optimum.

SOILS ON SOLID CARBONATES

On travertines, carbonate breccias, freshwater chalks, carbonate gravels etc., the pedostratigraphic function of interglacial soils is taken by soils belonging to the terrae calcis group. The autochthonous terra rossa occurs only on oldest substrates. The hitherto ascertained latest terra rossa falls to the Cromer interglacial. The later lst order warm intervals are represented by terra fusca which is lacking in interstadials, being not fully developed even in the postglacial. In solid carbonate sediments, rendzinas may be regarded as an equivalent of the interstadial-chernozems in loess series. These rendzinas occur commonly also as buried Holocene soils or as recent soils.

The stratigraphic position of the terra rossa is therefore analogous to the soils of brown-clay (Braunlehm) and reddish clay (Rotlehm) types on loesses, volcanics and lacustric sediments, whereas the position of terra fusca is analogous to that of illimerized soils, the position of rendzinas corresponds to that of chernozems.

SOILS ON SILICATE SUBSTRATES

For stratigraphic purposes, soils of ferretto type may be best use. Their stratigraphic position follows from their relation to earlier gravel covers as well as to later accumulations, now terrace form.

In Czechoslovakia the latest ferretto soils occur on the surface of a sandy gravel cover of Günz age. The earlier ferretto soils (e.g. on Neogene substrates) are substantially more strongly weathered, in contrast, the ferretto soils are missing on Mindel or still younger terrace gravels. These terraces of lithologically analogous composition are pedogenetically covered by soils of the podzol group, or rankers.

Ferrettos occur also as fossil and relict soils. These are always distinguished by their strongly polygenetic character. Their formation ended before the inversion of the Brunhes/Matuyama paleomagnetic field.

CONCLUSIONS

Strongly weathered soils (brown clays, reddish clays, terra rossa of Ferretto soil) formed for the last time during the warm time spans of the Mincel (Elster) glacial. Thus, they have no analogues in the Late Pleistocene. The above-mentioned soils therefore represent conspicuous indicators of the mutual separation of terrestrial rock series, the latest of the above-mentioned time spans (ending by pedocomplex VII) then represents the significant discontinuity limit in the course of the development of Pleistocene soils.

REFERENCES

BRUNNACKER, K. 1965: Schätzungen über die Dauer des Quartärs, insbesondere auf der Grundlage seiner Paläoböden. – Geol. Rundschau, 54. 1. 415-428.

FIDRICH, J. – SMOLIKOVÁ, L. 1976: Stary pleistocén v profilu B, Bečov I (Louské Středohoří). – – Archeol. Rozhledy, 28. 3-17.

HOWELL, C.F. 1966: Observations on the Earlier Phases of the European Lower Paleolithic. – Amer. Anthropologist, 68. 2. 88-201.

KUBIËNA, W.L. 1964: Zur Mikromorphologie und Mikromorhhologenese der Lössböden Neuseelands, – In: Soil Micromorphology. Amsterdam. 219-235.

LEAKEY, M.D. 1971: Olduvai Gorge. 3. Cambridge, Univ, Press.

LOŽEK, V. 1964: Ouartarmollusken der Tschechoslowakei. – Rozpr. UUG. 31. 373, 32 Tables.

MOROZOVA, T.D. 1981: Razvitie pochvennogo pokrova Evropy v pozdnem pleistotsene. Moscow. Nauka

MÜCKENHAUSEN, E. 1971: Die Entwicklung der Böden auf den saaleeiszeitlichen Ablagerungen Nordwestdeutschlands. – Acta Agralia Fennica, 123. 108-117.

SCHROEDER, D. 1978: Bodenkunde in Stichworten. Kiel, F. Hirt.

ŠIBRAVA, V. 1972: Zur Stellung der Tschechoslowakei im Korrelierungssystem des Pleistozäns in Europa. – Sbor.geol.Ved, Antropozoikum, A, 8. 85-218.

ŠIBRAVA, V. et al. 1979: Erforschung der Pleistozänablagerungen auf dem Hügel Zlaty kopec bei Prezletice (NO-Rand von Prag). I.Teil. – Sbor.geol.Věd, Antropozoikum, A, 12. 57-146.

SMOLIKOVÁ, L. 1967: Mikromorphologie der altpleistozänen Fossilböden von Červeny kopec bei Brno (Brünn). – Věst. Ustř.Ust. geol 42. 5. 369-373.

SMOLIKOVÁ, L. 1968: Polygenese der fossilen Lössböden der Tschechoslowakei im Lichte mikromorphologischer Untersuchungen. – Geoderma, 1. 315-324.

SMOLIKOVÁ, L. 1972: Zur Genese der Reliktbraunlehme im Bömischen Mittelgebirge. – Čas.Mineral. Geol. 17. 4. 383-394.

SMOLIKOVÁ, L. 1975: Reliktni braunlehm cromerského stáři v Suchdole u Prahy. – Čas.Mineral.Geol. 20. 4. 393-404.

SMOLIKOVÁ, L. 1977: Stratigraficky a paleogeograficky vyznam pud v profilu na Zlatém kopci u Přezletic. – Čas. Mineral.Geol. 22. 4. 373-382.

SMOLIKOVÁ, L. 1978: Bedeutung der Bodenmikromorphologie für die Datierung archäologischer Horizonte. – Micromorfologia de suelos. – In: Proceedings of the fifth International Working-Meeting on Soil Micromorphology. Granada. 1199-1222.

SMOLIKOVÁ, L. 1982: Zur Genese mittelpleistozäner Böden auf dem Hügel Červeny kopec bei Brno. – Věst.Ustř.Ust. geol., 53. 3. 169-178.

SMOLIKOVÁ, L. – FRIDRICH, J. 1982: Holsteinsky interglaciál na lokalitě Karlštejn v Českém krasu: paleopedologicky vyvoj a pozice paleolitické industrie. – Archeol.Rozhledy. (in press).

SMOLIKOVÁ, L. – KOVANDA, J. 1983: Die Bedeutung der pleistozänen Schichtenserie des Fundortes Ruženin Dvur (Brno-Židenice II) für die Stratigraphie des Brno-Beckens. – Sbor.geol.Věd, Antropozoikum, A (in press).

SMOLIKOVÁ, L. – LOŽEK, V. 1962: Zur Altersfrage der mitteleuropäischen Terrae calcis. – Eiszeitalter und Gegenwart, 13. 157-177.

SMOLIKOVÁ, L. – ZEMAN, A. 1979: Fossilböden im Profil von Sedlešovice und ihre Beziehung zu den Flussablagerungen. – Věst.Ustř.Ust.geol., 54, 4. 215-224.

SMOLIKOVÁ, L. – ZEMAN, A. 1982: Bedeutung der Ferretto-Böden für die Quartärstratigraphie. – Sbor.geol.Věd, Antopozoikum, A, 14. 57-94.

VELICHKO, A.A. – MOROZOVA, T.D. 1976: Osobennosti paleogeograficheskogo podkhoda pri izucheniu iskopaemykh pochv. – In: Izuchenie i osvoenie prirodnoj sredy. Moscow, Nauka.

Address of author:
Prof.Dr.L. Smoliková, Geological-Geographical Faculty,
Karls University
Albertov 6. 12843 PRAHA II. – CSSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

NEW STRATIGRAPHIC SUBDIVISION AND TYPOLOGY OF SOILS OF THE LATE PLEISTOCENE IN LOESS SERIES OF THE DANUBE LOWLAND IN CZECHOSLOVAKIA

E. Vaškovská

ABSTRACT

On the basis of the results of complex lithogeochemical and micromorphological investigation of about 50 profiles of loess series, mainly on paleopedological basis, a new stratigraphic scheme of the Late Pleistocene in the Danube lowland has been worked out. In the article mention is for the first time made of a more detailed typological characterization of fossil soils of the R/W interglacial, then of Early Würm soils (Amersfoort, Brörup and neither the presence of the Oderade is excluded), further of the $W_{2/3}$ (PK I) and Late Würm (Bölling and Alleröd). The age of some soils is determined by the C_{14} method. Two stratotype soil complexes are distinguished: the Nitra and Vyškovce complexes. The stratigraphic sequence of sediments and fossil soils is analysed in more detail as well as a partial reconstruction of paleogeographical conditions in the Danube lowland throughout the Late Pleistocene is carried out.

The geomorphological subunits distinguished in the Danube lowland: the Trnava, Nitra, Žitava, Hron and Ipel' uplands (in the sense of regional geomorphological subdivision of MAZUR,E. – LUKNIŠ, M.) were an arena of more extensive loess accumulation throughout the Quaternary (FIG.1.) The extension of loess is in close connection with hypsometric levels within the range of 110 to 300 m above sea level, higher up the loess usually grades into loess derivates, only exceptionally do loesses border on the adjacent mountains of the Little Carpathians, Považsky Inovec, Tribeč etc., where they are found in form of isolated occurrences up to an altitude of 400 m. Thickness of loess is uneven, it attains as much as 40 m. On geological maps the areal distribution of Late Pleistocene loesses is actually indicated, their thickness is also uneven (1-5-10-15 m).

The present author has carried out detailed lithochemical and micromorphological investigations of about 100 profiles of Quaternary sediments in the whole region of the West Carpathians (of Slovakia) in the course of two decades, about 50 of them were profiles of loess series and fossil soils which practically represent all uplands and their sections in the neighbourhood of the Danube lowland (FIG. 2).

The complex lithogeochemical investigation included the laboratory analyses of colour according to Munsell, grain size with calculation of Md, So and microaggregation coefficients (K micro) and the determination of granulotype (by the content of fraction < 0,01 mm), pH, $CaCO_3$, humus, fractional composition of humus with calculation of ratio of C humic acids to fulvoacids, chemical composition, exchange cations, clay minerals were established C by X-ray and DTA-analyses. Strong emphasis was laid on micromorphological studies of paleosols mainly of the character and inner structure of plasma (according to classification of BREWER, R. 1964), the skeleton, form and amount of pores, carbonates, new forms and other structural and textural properties.

Moreover, in some Late Pleistocene fossil soils the age was determined by the C_{14} method, also paleomagnetism was applied.

The obtained data of equal methods of complex study of loess series, especially with regard to paleosols, have supplied a good basis for the elaboration of new strati-

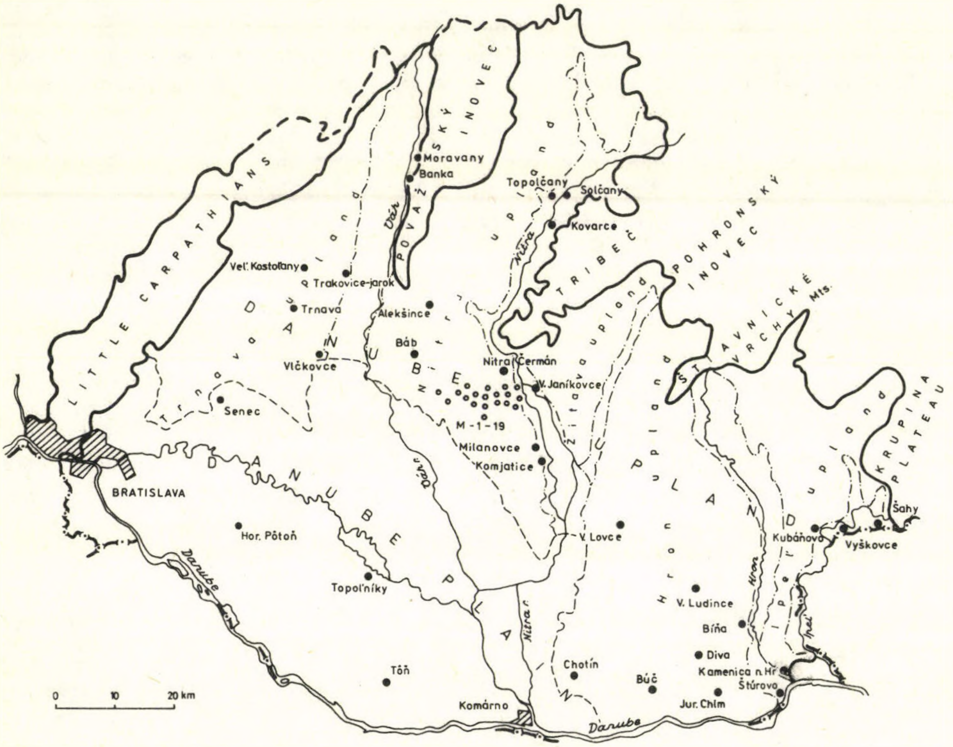


FIG. 1. Localities of lithogeochemical and micromorphological investigations of Late Pleistocene sediments and fosil soils in the Danube lowland. Compiled by E.VASKOVSKÁ, 1983.

PLEISTOCENE	YOUNG	WÜRM	LATE	LW	Dryas 3		DrIII		
					Alleröd		Al		soil formation
					Dryas 2		DrII		
					Bölling		B		soil formation
					Dryas 1		DrI		
			MIDDLE	W 2 — W 2/3 — W 3	W 3	W 3 y. ? W 3 ol.			intense loess subinterstadial accumulation
					W2/3	Denekamp ? Hengelo (Stillfried B)	D H	PK I	formation of weak initial soils
					W 2	W 2 y. ? Moershoofd W 2 ol.	M		intense loess subinterstadial accumulation
			EARLY	W 1 — W 1/2	W 1/2	? Oderade	O	PK II$_2$	weak pedogenesis
						Brörup	Br		formation of soils mainly of brownearth type, possibly also blackearth type
					W 1	W 1 y.			loess accumulation
						Ammersffoort	Am	PK II$_1$	formation of soils, mainly of blackearth subordinately of brownearth type
						W 1 ol.			very weak accumulation of loess
	RISS/WÜRM			R/W	Ém			PK III	formation of illimerized and intensively weathered brownearth soils

FIG. 2. Stratigraphy of Late Pleistocene loess and fossil soils of the Danube lowland. E.VAŠKOVSKÁ, 1983.

graphic scheme of the Late Pleistocene in the Danube lowland (FIG. 2.) which refutes the latest scheme from the region of the Danube lowland worked out by HALOUZKA, R. in HALOUZKA, R. – SCHMIDT, Z. (1979). HALOUZKA, R. established an incorrect typology and stratigraphy of fossil soils mainly in the R/W interglacial and Early Würm.

The base of the Late Pleistocene, virtually its beginning, is the R/W interglacial which is mainly indicated by fossil soils in the loess series of the Danube lowland. Their development prevailingly took place under automorphous conditions (FIG. 3.). The second less spread group is of hydromorphous soils, formed on a different substratum, on fluvial sediments (flood-plain facies) under the considerable influence of groundwater (FIG. 4).

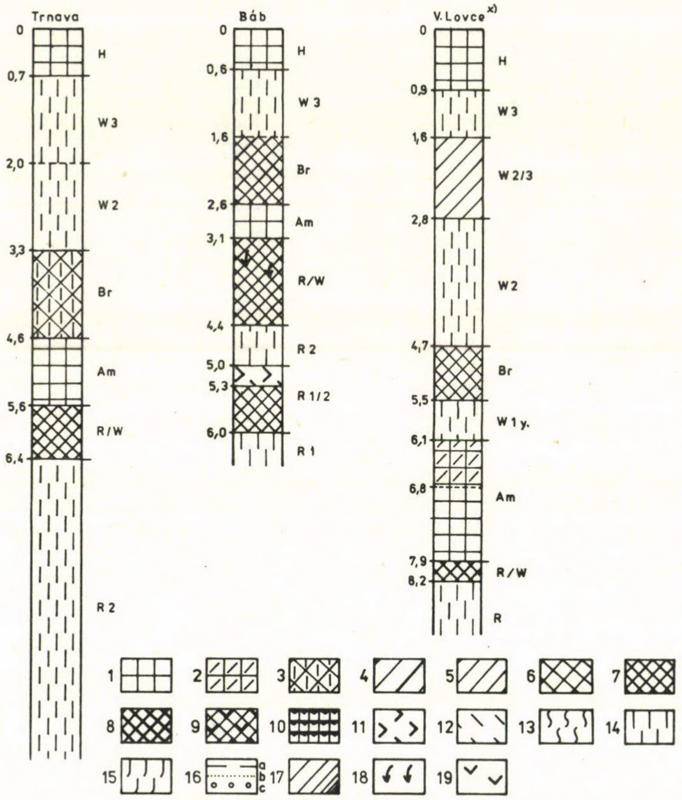


FIG. 3. Late Pleistocene loess and fossil soils of the Danube lowland. Automorphic group of soil (Nitra pedocomplex) E.VAŠKOVSKÁ, 1983 (after J.HARČAR, modified by E.VAŠKOVSKÁ). 1 = blackearth, 2 = brown earthy block earth, 3 = black earthy brownearth, 4 = weak pedogenesis, 5 = initial brownearth, 6 = brownearth, 7 = weathered brownearth, 8 = intensely weathered brownearth, 9 = gley soil, 10 = flood-plain (meadow) soil, 11 = soil sediments, 12 = wash sediments, 13 = solifluction horizon, run-off, 14 = loess, 15 = loess loam, 16 = fluvial sediments: a) loam, b) sand, c) gravel, 17 = density of hachure indicates the intensity of pedoprocess, 18 = flows of optically oriented clay, 19 = indication of gleyification.

In the frame of the first group of automorphous soil of the R/W interglacial in the Danube lowland I distinguished two types of fossil soils. The first is the illimerized soils (Parabraunerde), which I prevailingly studied at the localities of Mnešice, Trakovice, Vel'ké Kostolany, Báb, Alekšince (profile IV), Šahy, Divá, Vel'ké Ludince and possible at Kovárce and Vel'ké Lovce.

The second type of the automorphous group of soils of the R/W interglacial in the Danube lowland are the soils of brown earth type (Braunerde). Their occurrences have been observed at the following localities: Moravany, Vlačkovce, Vel'ké Lovce, Vel'ké Ludince, Kaminica and others. The R/W interglacial soils are of brown colours with various shades, they are mostly loams to clayey loams, with medium to high coefficient of microaggregation (K micro = 20-35) with a high content of particles < 0,002 mm (20-37 %), slightly calcareous ($CaCO_3$ O 1,3-3,0 %), the soils are weakly humic (0,1-0,5 % humus), mostly with the prevalance of fulvo-acids (Chk : Cfk < 1). The exchange reaction is alkalic (pH in KCl = 7,2-8,0).

Micromorphology. In the soils mainly aggregates of polysphedral forms are found, besides circular pores and channel-like forms also intergranular-composed are present. The sepic inner structure of plasma, is typical, mosepic, amnisepic and lattisepic

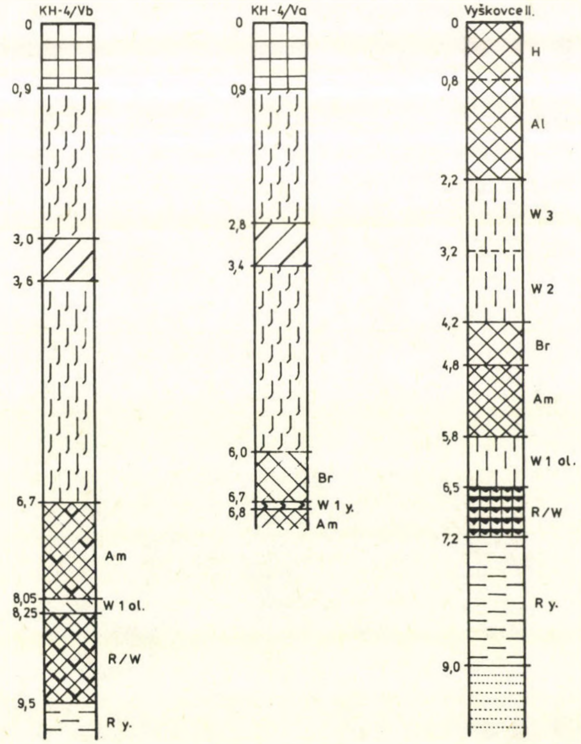


FIG. 4. Late Pleistocene loess and fossil soils in the Danube lowland. Hydromorphic group of soils (Vyškov pedocomplex) E. VAŠKOVSKÁ, 1983. Legend see to FIG.3.

and mainly vosepic separation of plasma along free spaces characteristic of illimerized soils dominate. The carbonates found in the soils are secondary: micro-crystalline calcite, spottycementing S-matrix and also present along pores; nodules and connections are rare. These soils are characterized by new forms in the shape of dark-brown organomineral flakes, concretions as well as nodules, also of angular shape, fine humified fragments and Fe - Mn radial forms of segragation.

The soils are polygenetic, besides illimerization and innersoil weathering, processes of pseudogleyification and finally recalcification also affected them.

We described the hydromorphous group of R/W interglacial soils at the localities of Vyškovce II and Kamenica - 4 (VAŠKOVSKÁ, E. in. VASS D. et al. 1980), where these soils formed on the flood-plain facies of the Late Riss terraces.

The collected facts about fossil soil at the locality of Kamenica with its typical lithogeochemical and micromorphological features unambiguously indicate that the soil typologically belongs to the gley soils with a distinct gley horizon with peculiar fragmentary microstructure, mainly in the gley horizon. The soil is characterized by a high degree of inner-soil weathering (the plasma in the soil has a sepic inner structure). The soil is polygenetic with large brown concretions, compactbordered from S-matrix and an amount of ferric and ferric-manganese hems along pores, also of radial forms, in it, finally the soil was recalcified. Under analogous, however, less hydromorphous conditions in the area of the Ipel'-ská pahorkatina upland the R/W interglacial soil formed near Vyškovce which is of the character of paleohydromorphous flood-plain (meadow) soil.

Early Würm (W_1). In the here presented new stratigraphic scheme it includes the periods: W_1 older (W_1 ol) – first stadial of the Würm glacial, then the Amersfoort (Am) interstadial (first interstadial of the Würm glacial – PK II_1), then the second stadial of the Early Würm – W_1 younger (W_1 y) and Brörup interstadial (Br) – PK II_2 and Oderade (O).

Older W_1 Stadial (W_1 ol). To the end of the R/W interglacial and at the beginning of the Würm glacial general deterioration of climate was taking place, manifest in a thin layer of loess or wash sediments of the Würm 1 ol Stadial (W_1 ol) also in the Danube lowland. The sediments from this period are preserved only at several localities in the area of Vyškovce II and then in the area of Kamenica 4.

The little thickness of W_1 ol stadial sediments or their absence at the investigated localities in the Danube lowland is due to the fact that this cold interval was short on the one hand and the first subsequent interstadial warming in the Early Würm – the Amersfoort interstadial (Am) was very intense and characterized by soil-forming processes which usually affected the total thickness of W_1 ol sediments on the other hand.

Amersfoort interstadial (Am) – PK II_1. After a short, however, very distinct cooling of climate at the beginning of the Early Würm, when the region of the Danube lowland and its broader surroundings was prevailingly characterized by loess accumulation, the first warming in the Würm glacial set in. This climatic change resulted in steppe climate in the lowland region, reflected by formation of soils dominantly of blackearth type. The intensity of soil formation was high and, as we have already mentioned in connection with the formation of the R/W interglacial soil, not only the total thickness of W_1 ol loess was affected, but quite often it was exceeded and even the rate for the R/W interglacial soil was reached, there are even cases when they practically overlap.

The fossil soils of blackearth type assigned to the Amersfoort interstadial (Am) – PK II_1 are of large extension in the Danube lowland and we find them at all uplands at the localities of Trnava III, Trakovice, Vel'ké Kostolany (black earth brown earth), Báb, Alekšince (profile IV), Kovárce, Vel'ké Lovce, Biňa 1 and others.

Younger W_1 stadial (Wly). This Early Würm stadial has preserved, in the Danube lowland region in form of wash solifluction and soil sediments at several localities. The thickness of these sediments is also relatively little 0,1-0,8 m. Sediments of this period are established at the localities Trakovice, Senec, Vlčkovce, Alekšince IV, Aleksince 4, in borehole M-3, Divá, Vel'ké Ludince, Vel'ké Lovce, Buč, Kamenica and others.

W1/2 Interstadial – Brörup (Br) – PK II_2. Similar to the preceding Amersfoort interstadial the Brörup interstadial is also indicated by fossil soils in loess series in the Danube lowland region. They are mainly soils of brownearth type, which are mostly less humic, less frequently with higher humus content. These soils were found at the following localities: Trnava III, Trakovice, Vel'ké Kostolany, Moravany (MO-1), Banka, Vlčkovce, Báb, Alekšince, in boreholes (M-3, M-4, M-5, M-6, M-10, M-18), Kovárce, Vel'ké Ludince, Vel'ké Lovce, Buč, Kamenica 1, 4, Vyškovce – II etc.

The W_2 Stadial (W2) saw intense loess accumulation at all uplands and their sections bordering the Danube lowland. The thickness of loess is variable, it is up to 2,5 – 3,0 m at some localities. The loesses were studied in more detial at the following localities: Senec, Moravany, Alekšince, in borehole M-18, Divá, Vel'ké Ludince, Vel'ké Lovce, Buč, Kamenica (KH-1), Vyškovce II nad Iplom and others.

W 2/3 Interstadial – PK I. This interstadial is represented in loess series of the Danube lowland by fossil soil of brownearth type, which is mostly of initial character with frequent finds of carbon and is usually without or with a negligible content of conchylia. This soil is generally hardly distinct, found practically at all studied localities: Senec, Vlčkovce, Moravany, Komjatice, in boreholes (M-7, M-15, M-18), Divá, Vel'ké Ludince, Vel'ké Lovce, Jursky Chlm, Buč and near Kamenica 1, their age is between 22 800 – 28 300 y. B.P.

W_3 Stadial as the youngest Middle Würm stadial is of largest extension at uplands of the Danube lowland. It is represented by loesses with thicknesses up to 3,2 m. This horizon was practically found at all investigated localities: Senec, Vlčkovce, Moravany, Banka, Báb, Kovárce in boreholes (M-3, M-4, M-6, M-7, M-8, M-10, M-11, M-15, M-18), Divá, Vel'ké Ludince, Vel'ké Lovce, Buč, Kamenica 1, Vyškovce II. etc.

A short description of W-3 Stadial loess I present on the example of the locality of Senec, where loess is found below the recent soil (0,8-3,8 m), its accumulation is interrupted by weak pedogenesis at depth 2,9-3,2 m, which indicates the subinterstadial and shows aggregation in thin sections. The loess of the upper subhorizon has a high aleurite content (0,05-0,005 mm) – 72 %, of it coarse dust (0,05-0,01 mm) is 54 %. The content of clayey particles (< 0,002 mm) is 15 %. The loess has Md = 0,026, So = 1,9-2,1 and a high content of carbonates ($CaCO_3$ = 33-28 %) and a low humus content (0,18-0,25 %).

In the chemical composition of loess SiO_2 (50 %), CaO (14 %), and R_2O_3 (13 %) dominate. Among clay minerals montmorillonite and less illite are found.

Loess in thin section shows a loose microstructure, composed particles of relatively equal size of ϕ 0,015-0,055 mm, sporadically of 0,15 mm. These particles form the primary minerals of the skeleton (mainly quartz) on the one hand and microaggregates on the other hand. The microaggregates are formed by primary and secondary minerals cemented by calcite and ferric-clayey component. The loess is very porous, biospores of round, elliptical, channel-like shapes are prevailing, there are simple intergranular pores too. The carbonates are very characteristic of loess and found in various forms (form mainly part of cement of S-matrix, there are also nodules, microconcretions, seldom rhombohedrons). Micro-crystalline calcite is found in form of incrustations along pore-walls. The plasma of loess is asepic.

Late Würm (NW). Sediments and buried soils from the youngest period of the Würm are found at some localities of the Žitny ostrov island (Toň, Topolniky). In the warm period of the Late Würm – Bölling and Alleröd soil formation took place. These soils were closer investigated in the sand pit of drift sands at the locality Chotin where their age was established at 12 100 ± 600 y. B.P. (Bölling) and also at the locality Vyškovce where the soil of brownearth type is below recent soil, its age is established at 10 100 ± ± 400 y. B.P. (Alleröd).

On the basis of typifying the R/W interglacial fossil soils and Early Würm soils (Am and Br), in their spatial extension in the Danube lowland region I distinguished two pedocomplexes: the Nitra and Vyškovce pedocomplexes (FIGS. 3, 4).

The Nitra pedocomplex lies at the base of the Late Pleistocene and is mainly composed of two or three soils. The basal soil is of the R/W interglacial and typologically it is an illimerized (Parabraunerde) or brownearth type soil with distinct processes of inner-soil weathering. Above the R/W soil a soil of prevailingly blackearth type (Am) is found, which is either separated by a thin layer of W_1 ol loess sediments or lies immediately on the R/W soil and its pedoprocesses often reach down to the R/W soil. Above the Amersfoort (Am) interstadial soil on W_1 y stadial sediments a soil of mainly brownearth type, possible also more humic (Br), formed. The Nitra pedocomplex including R/W, Am and Br soils can be considered a stratotype for the automorphous group of soils in the loess series of the Danube lowland.

The Vyškovce pedocomplex also begins at the base of the R/W soil but of hydromorphous type (flood-plain meadow to gley soils), the parent material of which were loamy fluvial sediments (flood-plain facies). Higher above the R/W soil are also more humic soils of the Amersfoort (Am) interstadial, which also show hydromorphous features. Above the interstadial soil (Am) are W_1 y loess and wash deposits on which a soil of brown earth type formed, assigned to the W 1/2 Interstadial – Brörup (Br).

The Vyškovce pedocomplex is a time analogue of the Nitra pedocomplex, only with different conditions of formation the Nitra pedocomples formed in loess series in automorphous conditions whereas the Vyškovce pedocomplex in hydromorphous conditions, prevailingly of fluvial sediments.

REFERENCES

BREWER, R. 1964: Fabric and mineral analysis of soils. New York, J. Wiley. 470.

HALOUZKA, R. – SCHMIDT, Z. 1979: Brief report on the new climatic-stratigraphic interpretation of Late Pleistocene loess series in the Danube Lowland of Slowakia. – In: Project 73/1/24, „Quaternary glaciations in the northern hemisphere". Report 5. Prague. 138-145.

VAŠKOVSKÁ, E. 1970: Niektoré mikromorfologické črty fosilnej pody posledného interglaciálu v profile Nové Mestro nad Váhom (Mnešice). (Micromorphology of the last interglacial soil from the loess profile in Nové Mesto nad Váhom, Mnešice). – Geol. prace, Správy, 53. 185-188.

VAŠKOVSKÁ, E. 1981: Radiocarbon dating of Quaternary fossil soils of the West Carpathians. – In: IV. Slovakian Geological Conference. 5. Bratislava, SGU. (in Slovakian).

VAŠKOVSKÁ, E. – VAŠKOVSKY, I. – SCHMIDT, Z. 1974: Formation, structure and composition of Holocene sediments of the Žitny ostrov island, Danube lowland, Czechoslovakia. – Acta Univ. Oulensis, ser. Sci. Rev. Nat. 82, Geologica, 3.

VAŠKOVSKY, I. 1977: Kvartér Slovenska. (Quaternary of Slovakia.) Bratislava, Geol.Ustav D. Stura. 247.

VASS, D. – VAŠKOVSKY, I. – BRESTENSKÁ, E. – PRISTAŠ, J. – VAŠKOVSKÁ, E. 1980: Sprievodca po niektorych lokalitách neogéne a kvartéru Podunajskej pavny. (Guide to some Neogene and Quaternary localities of the Danube Basin). – In: Materialy XXIII. Celoštátnej geologickej konferencie Slovenskej geologickej spolocnosti. Bratislava, Geol. Ustav D. Stura. 141-152, 172-174.

Address of author:
Dr. E. Vaškovská, Geologicky ustav Dionyza Stura,
Mlynska dolina 1. BRATISLAVA – CSSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

LOESS MICROTEXTURES AND THE ORIGIN OF LOESS IN CHINA

Wang Yong-yan – Teng Zhi-hong – Yue Le-ping

ABSTRACT

On the surfaces of the quartz grains of loess mechanical microtextures are often observed such as dish-shaped pits, grooves with rounded and smooth bottom, rounded edge angles, development of pitted faces, etc. These surface microtextures resemble those of desert quartz grains, which shows that wind action is supposed to have played an important role in the transportation of loess material. As for the chemical microtextures such as silica precipitates, chemical etching and dissolution phenomena on the surface of the precipitates, they might have been subjected to weathering in situ, especially in the process of pedogenesis. Pedogenesis must not be neglected in the process of loess formation.

Broken fissures in quartz grains with sharp edges and angles may sometimes be observed which might have been formed by frost weathering during glacial periods.

Supporting-spaced and mosaic-spaced contacts are the essential relation between the coarse minerals of loess. They often coexist with each other and the mineral grains are accumulated disorderly. Such special microtextures of loess may be regarded as the result of eolian accumulation.

On the basis of the above mentioned microtextures of loess, it may be considered that the origin of loess in China is complex but the main factor of genesis is the eolian.

By scanning electron microscope, we have observed and analysed the microtexture of loess samples of various geological periods and districts from 13 sections in Shaanxi, Gansu, Qinghai and Xingjiang. The content of this work includes studying the shape of quartz grains and its surface microtexture, contact relations between the coarse minerals as well as the cementing materials and its existing state. Such data are of great significance for the discussion of the origin of loess in China.

THE SHAPE OF QUARTZ GRAINS IN LOESS

The quartz grains of loess are rather complicated in shape, their approximate shapes which are observed may be devided as follows: slate-like, irregular, triangular, baton-like, pillow-like, well-rounded, semi-rounded, cubic, pointed, etc. The slate-like shape is predominant, next are the irregular, triangular and pointed grains, and still less are the baton-like, semirounded, well-rounded, pillow-like and cubic grains, the general trend of grain shapes is that there are more edge-angle grains, and the grains of different shapes are mixed with each other disorderly. The edge angle of grains is generally obtuse due to abrasion of blown sand and sharp edge-angle grains are very few. Some sharp edge grains are characterized by fresh planes of fracture, which may be formed during the late period of transportation or after deposition. Such disorderly mixed condition of many kinds of grain shapes resembles the polymineral characteristics of loess, which may be explained by transportation of grains from one place to another and the mixing together by the wind.

We have also observed the quartz grain shapes in deserts of Mu Us, Lingwu, and Gurbantunggut under scanning electron microscope. The shapes of desert quartz grain and its quantity are almost similar to those of loess, with the only difference that the number of semi-rounded and baton-like grains is a little increased, and sometimes the pointed grains are observed. The sphericity of edges of desert grains is higher than that of loess and the area of abrasion pockmark surface is larger. Such difference was produced by different energy of abrasion. The contact area between desert sand grains rolling along the earth's surface is larger than that of suspended loess grains, and for the rolling grains, there is a higher probability to contact each other and the abrasion energy is higher. As for suspended grains drifting along the wind have lower probability to contact and little abrasion energy. Therefore, although the quartz grain shapes between desert and loess are similar, yet, owing to the difference of abrasion energy, the area and degree of abrasion between desert and loess grains are somewhat different. Above all, the similarity between quartz grains of loess and desert shows that their genetic environments are alike.

PROPERTIES OF SURFACE MICROTEXTURE OF QUARTZ GRAINS IN LOESS

The microtextures on the surface of quartz grain in loess are formed in the process of transportation and pedogenesis of loess material. On the surface of grains two types of microtexture – mechanical and chemical – are often observed.

Mechanical microtextures and wind action

The broken planes along the cleavage of quartz grain are the common microtexture with even surface and sometimes with steplike patterns (PLATE I. 1). On the concave part of fresh broken plane the conchoidal fracture is usually observed. The fresh and neat cleavage planes or clear conchoidal fracture of grains may be broken in situ during a later period and have not suffered enduring transport and abrasion. Owing to the protracted abrasion and the precipitation of SiO_2, the cleavage planes and conchoidal fracture formed in earlier period become indistinct. On the grains of fossil soil, owing to the precipitation of SiO_2 on the cleavage slices, sometimes smooth, rounded rises are produced (PLATE I, 2).

On the surface of quartz grains in loess there are some pits and grooves. Among the pits, dish-shaped ones outnumber the square pits. Generally, the pits are of rounded smooth bottom (PLATE I, 3). The pits may be formed by collisions of larger grains. If a grain was dashed by larger pointed one, a funnel dish-shaped pit may be formed and on the center of it a deeper point appears. Among the observed surfaces of grains there are some grooves with the same width, round head and round smooth bottom (PLATE I, 4). Most grooves are straight but sometimes there are also arcuate and triangular grooves. As for the formation of grooves, it is considered that when the larger pointed grain rubbed against the smaller one, the surface of the latter may be curved into a goove. With regard to the rounded and smooth bottom of grooves, it was formed by polishing of much smaller wind-blown sand. As for the grooves on the surface of quartz grains

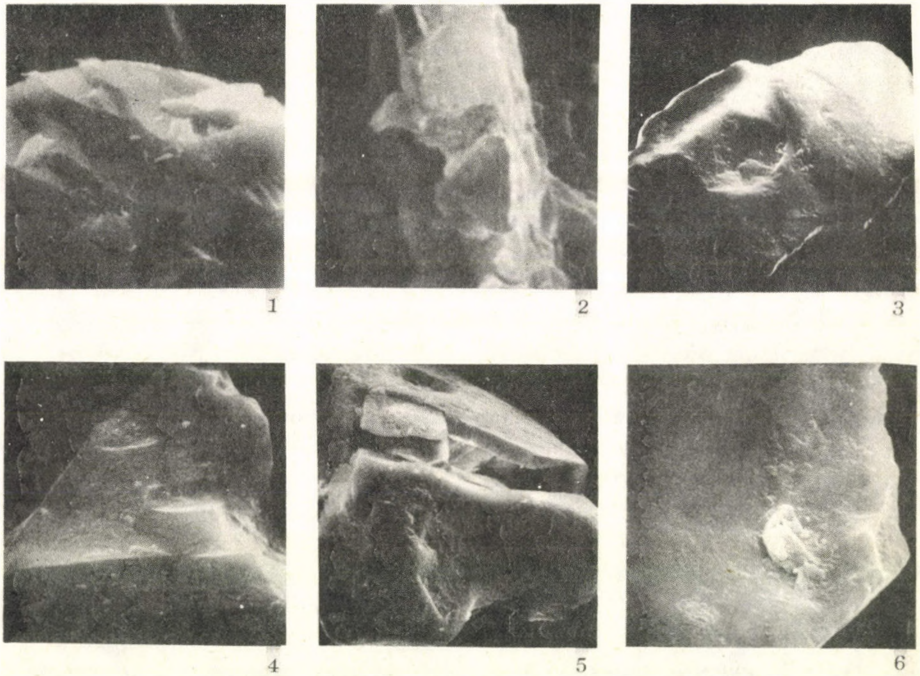


PLATE I. 1. Terraced cleavage planes and conchoidal fracture in the concave parts. Q 1/2 loess, Pingliang, Gansu. X 2,400

2. Triangular pit formed by chemical etching and SiO_2 precipitates (middle). 5th reddish brown fossil soil. Luochuan, Shaanxi. X 2,520
3. Pits formed by mechanical erosion. Q 2/1 loess, Xifeng, Gansu, X 480
4. Straight trenches on the triangular grain. Q_3 loess, Louchuan, Shaanxi. X 990
5. Broken fissure Q_3 loess, Wuqi, Shaanxi. X 640
6. SiO_2 precipited in the pits (middle right) and the surface of grain appears pockmarks (left). Q_3 loess, Xifeng, Gansu. X 972

formed by water action, their bottoms are uneven and sometimes the direction of groove bent, evidently different from grooves on the loess grain. The pits and grooves on the quartz grain surface of loess show the evident influence of wind during the transportation of loess material. There are also some broken grains in loess, some of which are completely broken and a few are partly broken. The broken fissure is generally straight (PLATE I, 5) and occasionally bent. The edges and angles of broken fissures are sharp, showing that they are new products. The broken fissure is mostly observed in loess of the western and northern parts of loess plateau and not discovered in the quartz grains of fossil soil. Such broken fissures may be formed in freezing weather during the deposition of loess materials. Sometimes the polished pockmark surface on the grains may be observed (PLATE I, 6), and it is especially clear under high magnifying microscopes.

The surface microtextures of silt quartz grains explain that the formation of material might have comprised different processes, but the wind action is supposed to have played an important role during their transportation.

The type of mechanical microtextures on the quartz grains and its appearance ratio of the above-mentioned three deserts basically resemble those on the loess grains, only the polished pockmark surfaces are relatively more common, the dish-shaped pits are increased and the clear conchoidal fracture disappears.

The similarity of these properties of surface microtexture on the loess quartz grains and on the desert grains underlines the role of wind action during the transportation of loess materials.

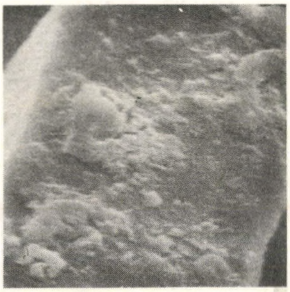
Chemical microtexture and pedogenesis

The chemical microtexture was formed during pedogenesis, basically includes silica precipitates, chemical etching and dissolution phenomena.

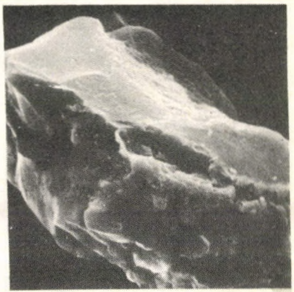
The silica precipitates are generally situated in the concave parts, pits and grooves of the surface of loess quartz grains. The silica precipitated which reveal themselves in facial distribution mostly occur on the quartz grains of fossil soil, in earlier loess and loess in the moist region to the east of Liupan Mts. The silica precipitates on the convex part of grains are in rare occurrence and sometimes only odd pieces of them may be observed. The convex part of silica precipitates sometimes appears of a smooth rounded surface (PLATE II, 7). In silica precipitates, sometimes recrystallized quartz grains (PLATE II, 8) and growth of crystals (PLATE II, 9) may be observed. Silica precipitates distributed neatly are very rare, generally they have suffered etching and dissolution. Microtexture of dissolution involves triangular pits (PLATE I, 2), round pits (PLATE II, 10) pits with lid (PLATE II, 11) and inclined pits (PLATE II, 12), If the precipitates passed through different intensity of dissolution, a stalagmite-like protrusion may be formed, if it passed through intense etching along both sides of silica precipitates ridge – or tongue-like textures (PLATE II, 8) are formed. Sometimes some laminae turn up along the edges of cleavage plane (PLATE III, 13) the slices are often obscure due to precipitation of silica and were formed by mechanical and chemical processes.

Owing to the dry climate, transportation of sand and the missing processes of pedogenesis, on the surface of desert quartz grains the occurence of silica precipitates is very rare. The chemical microtexture is closely related to the degree of pedogenesis. The older geological time, the more mature the pedogenesis and the more developed the chemical microtexture.

Among 10 quartz grains of late Pleistocene loess in Lanzhou only 4 grains provide silica precipitates, while in early Pleistocene loess of the same section, among 10 grains there are 8 grains which have silica precipitates on their surface. The loess distributed in the moist region passed through deeper pedogenesis than that in dry climate, therefore, on the surface of loess grains in the moist region, silica precipitates


7


8


9


10


11

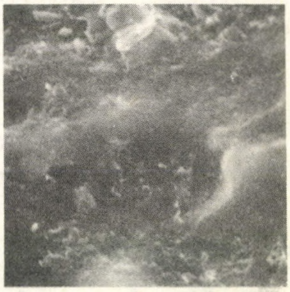

12

PLATE II. 7. Precipitation of SiO_2 on the concave part of the grain surface and rounded surface on the residual silica after dissolution. Q 1/2 loess, Jiuzhoutai, Lanzhoz. X 2,460

8. Ridge-shaped SiO_2 precipitation after etching (upper middle). Square part may be recrystallization (lower left). Q_3 loess, Luochuan, Shaanxi. X 2,400
9. Growth of crystals (middle left and middle lower). Q_2 loess, Luochuan, Shaanxi. X 630
10. Rounded pit after etching (middle and middle left) and rounded surface of high part Q 1/2 loess. Pingliang, Gansu. X 2,460
11. Etching pit with lid. Q_2 reddish brown fossil soil, Pingliang, Gansu. X 2,550
12. Inclined pits of SiO_2 precipitation after dissolution (upper left) Q 1/2 loess, Pingliang, Gansu. X 2,460

are more developed. In the loess section of Pingliang which is situated in the southern loess plateau to the east of Liupan Mts., among 50 quartz grains there are 26 grains with chemical microtexture. The above-mentioned relation between chemical microtexture and pedogenesis explains the genesis of loess, apart from its special transportation, sorting and accumulation, the original materials of loess must pass through the pedogenesis and only after the pedogenesis can the deposits of loess material be called loess.

CONTACT RELATIONSHIP BETWEEN THE COARSE MINERAL GRAINS OF LOESS AND INTERGRANULAR PORES

Under scanning electron microscope the contact relationships between coarse mineral grains of loess can be basically classified into four kinds – the supporting contact, the mosaic contact, the bag contact and dispersed distribution.

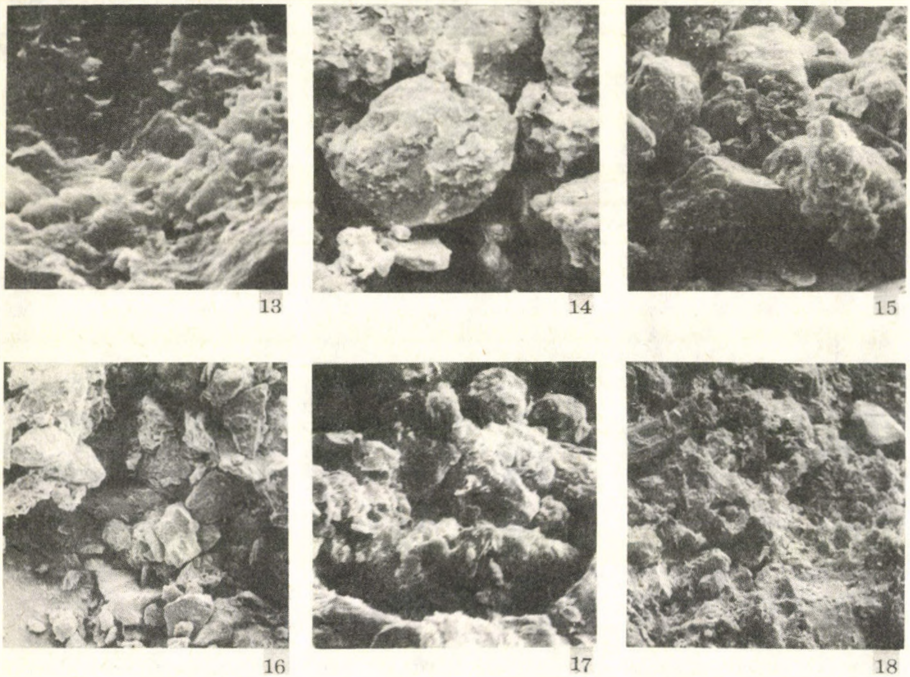


PLATE III. 13. Overturned laminae. Q 2/2 reddish brown fossil soil, Wugi, Shaanxi. X 2,220
14. Supporting contact. Q 1/2 loess, Changwu, Shaanxi. X 1,200
15. Supporting edge contact. Q_3 loess, Yongdeng, Gansu, X 540
16. Mosaic contact. Q_3 loess, Jingyuan, Gansu. X 252
17. Bag contact. Q 1/2 loess, Jingyuan, Gansu. X 1,020
18. Dispersed distribution of mineral grains. Q_3 loess, Baoji, Shaanxi. X 330

The contact area between coarse minerals of supporting contact is small. The minerals are usually point contact (PLATE III, 14) though sometimes are edge contact (PLATE III, 15). The skeleton grains support each other to form the intergranular macropores. On the micrograph the mosaic contact is observed and the skeleton grains contact each other with large contact area and present mosaic mineral arrangement (PLATE III, 16), Frequently, the longer grain interpenetrate into other grains, the larger contact area occur and the intergranular pores become smaller. The two kinds of contact do not exist alone, they often coexist in the same sample, even in the same sight. Sometimes the larger grains contact together and form a bag-like space filled up with smaller grains (PLATE III, 17). Under such condition, coexistence of supporting and mosaic contacts may appear either between the small grains or between the small and large mineral grains. In some micrographs the coarse mineral grains are not in contact with each other but separated by smaller grains or cemented materials and appearing dispersed distribution (PLATE III, 18). The supporting and mosaic contacts are the most common relationships between coarse mineral grains in loess. Statistics of appearance ratios both in districts and geological ages show the following conditions: in the early Pleistocene loess of arid district in the northern loess plateau and to the west of Liupan Mts., the supporting contact has a 65% and mosaic contact 35% share, in the middle Pleistocene loess they are 76% and 24% and in the late Pleistocene loess they are 65% and 35% respectively. The appearance ratios of supporting and mosaic contacts in middle Pleistocene loess they are 73% and 27% respectively. As for the early Pleistocene loess in this district, owing to the abundance of cemented materials, coarse grains are obscure in sight and no statistics has been made.

The above statistic data show that the contact relationships of coarse grains of loess in China resemble each other in districts and geological ages. Therefore, it could be considered that the mode of deposition of loess in China is basically the same in districts and through geological ages.

Abundance of pores is an important characteristic of loess. The pores in loess observed under scanning electron microscope are mainly intergranular micropores of about 20 microns. The shapes of these micropores are various. The percentage of micropores in the early Pleistocene loesses in regions such as Jiuzhoutai, Lanzhou is 29% of the total micropores larger than 20 microns in the whole section, in the middle Pleistocene loess the percentage is 33% and in the late Pleistocene is 38%. Owing to the filling cemented materials, the pores larger than 20 microns of loess to the east of Liupan Mts. greatly decrease in amount. Such variation of micropores shown not only in size and in quantity but also in districts and geological ages was caused under the influence of filling cemented materials instead of the difference of original pores. The total volume of intergranular micropores added to the volume of macropores larger than 20 microns often constitutes almost half of the physical volume of loess. Only when the materials of loess sink down from the air to the ground, such high porosity deposits can be formed. These micropores are preliminary pores which were formed during the accumulation of loess materials and the shapes of pores can be distinguished from those which were formed by rapid evaporation.

The supporting and mosaic contacts between the coarse grains in loess, unoriented arrangement of mineral grains, abundance of pores in different shape and size, –

– all these properties are completely different from those of the subfluvial deposits. The microtexture of early Pleistocene silt lacustrine deposits in Wuqi (PLATE IV. 19) is another case. In this deposits, the mineral grains show evidently oriented arrangement, the mineral grains contact each other in facial contact and the intergranular pores are fewer and smaller. Such microtexture apparently differs from that in loess.

EXISTING STATE OF CEMENTED MATERIALS AND PEDOGENESIS PROCESSES

Only silt deposits that have undergone pedogenesis may obtain loess features. The edogenic process is controlled by temperature, moisture, soluble salts and clay mineral.


19


20


21


22


23

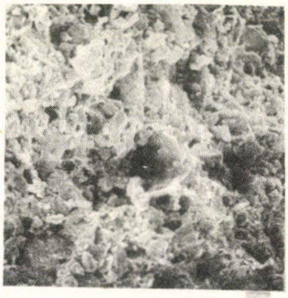

24

PLATE IV. 19. Orientation arrangement of mineral grains. Q_1 lacustrine deposit, Wugi, Shaanxi. X 330
20. Illite hydromica slices between the coarse grains. Q_3 loess, Xining, Qinghai. X 540
21. Kaolinite appears hexagonal slices (upper) and plates (lower). Q_2 loess, Jiuzhoutai, Lanzhou. X 1,453
22. Halloysite. Q_3 loess, Baoji, Shaanxi. X 528
23. Aggregate. Q_2 loess, Baoji, Shaanxi. X 330
24. Flocculent cementation. Q_2 loess, Baoji, Shaanxi. X 318

Clay minerals and soluble salts are the main cementing materials in loess and calcium carbonate and calcium sulphate are the main components of soluble salts. Calcium carbonate constitutes the largest contents in soluble salts. Generally, calcium carbonate in loess is of two types – the original and the secondary ones. The original coarse calcium carbonate minerals and original powder microcrystalline calcium carbonate were deposited together with other loess materials at the beginning. During the pedogenic process the original calcium carbonate leached, migrated and was enriched at certain horizons. The more the pedogenic process matured, the more the calcium carbonate enriched. In loess of arid region of northern loess plateau and to the west of Liupan Mts. calcium carbonate often appears to be some little slices and fragments situated in the pores between coarse minerals grains or cemented on the surfaces of them. In moist regions to the east of Liupan Mts. calcium carbonate is enriched at certain horizons forming calcium concentration beds and lithical loess. The main clay minerals in loess of northern loess plateau are illite hydromica, kaolinite and montmorillonite. Illite hydromica appears in scaleshaped fragments or belt-like plated (PLATE IV, 20), and kaolinite often appears plate-like (PLATE IV, 21). These clay minerals are often cemented on the surface of coarse grains, sometimes sandwiched between grains or extend into the macropores between the coarse grains. To the east of Liupan Mts. and in southern loess plateau, owing to leaching and concentration of calcium carbonate, the original clay minerals of loess are mixed with calcium carbonate, and become indistinct, but in loess of this region halloysite is very common (PLATE IV, 22). Between the coarse grains of loess which is younger in geological age and has insufficiently passed through pedogenic process, aggregates (PLATE IV, 23) formed by mixing of calcium carbonate and clay minerals often exsist. In older loess or loess situated in moist region, owing to the continuous supply of cementing materials, all coarse grains are cemented (PLATE IV, 24). The reason that the colour of loess in China appears light in the northwest and dark in the southeast is closely related to the degree of pedogenesis.

CONCLUSION

1. The quartz grains of loess complex in shapes and grains of various types are mixed up with each other. On the quartz grain surface, dish-like pits, grooves with smooth and rounded bottom, rounded edges and angles, polished pockmark surface are often observed which resemble the mechanical microtextures of desert quartz grains, showing the wind is the main agent in the transportation of loess material in China.

2. On some surfaces of quartz grains in loess fresh cleavage planes and conchoidal fractures, with some sharp edges and angles of grains are seen. Sometimes broken frissures on grains with sharp edges and angles are observed. These microtextures could be formed during frosts after deposition in situ and represent the cold period. Therefore, it is considered that loess formation was in the glacial period.

3. The chemical microtextures were formed during the pedogenic process. In loess to the east of Liupan Mts., expecially in the fossil soil, the chemical microtextures

were formed during the pedogenic process. In loess to the east of Liupan Mts., especially in the fossil soil, the chemical microtextues are well developed. The chemical etching and dissolution phenomena on the surface of silica precipitates are mainly in loess of this region. The existing state and degree of concentration of cementing materials are also related to the degree of pedogenesis. Therefore, the pedogenesis which produced the loess features from original loess materials must not be neglected in the formation of loess. In the discussion of loess formation usually we only pay due attention to the process of transportation of loess material yet ignored the pedogenic process. But, only after pedogenesis can the loess deposits be called loess.

4. After the transportation and deposition, most of the loess materials is stable in situ under suitable landform and pedogenesis proceeds. But sometimes due to suitable landform deposited materials may be retransported by surface water and wind to another stable place and then pedogenesis begins, but such retransported materials are uncommon that unlikely they can form the principal body of loess. However, the fact of retransportation of deposited materials by water and wind should be considered.

5. On the basis of the above-mentioned microtextures of loess grains and process of loess formation, we may come to a conclusion that the formation of loess in China is comprehensive but it is mainly of eolian origin.

REFERENCES

BARDON, L. et al. 1971: Sample disturbance in the investigation of clay structure. – Geotechnique. 12. 3. 211-228.
GAO GUORUI, 1981: Classification of loess microtextures and collapsibility. – Scientia Sinica. 24. 7. 962-970.
LU YANCHOU et al. 1976: A preliminary discussion of the origin of loess materials in China. – Geochimica. 1976. 1. 53-62.
XIE YOU–YU et al. 1980: Observation and comparison of some quartz grains. – Hydrogeology and Engineering Geology. 6.

Address of authors:
Prof. Wang Yong-yan, Teng Zhi-hong, Yue Le-ping,
Department of Geology, Northwest University
XIAN, Shensi – China

II. LITHOLOGICAL PROPERTIES OF LOESSES IN DIFFERENT CLIMATIC ZONES

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PECULIARITIES OF LOESS SEQUENCES OF KEY SECTIONS IN THE UKRAINE AS REFLECTIONS OF THE CHARACTERISTICS OF THE LOESS GEOSYSTEM

Yu. G. Balandin

ABSTRACT

Lithological, paleogeographical and engineering geological studies have been made of 28 Pleistocene key sections in the Ukraine. Ukrainian loess formations show a geosystem property in the presence of parameters of a formation, i.e. facial proximity of sequences and rather distinct lithological features of stratigraphy – horizons of loesses and buried soils developed in specific global paleogeographical conditions. Each of the Pleistocene climatic phases, including interglacials and glacials, is characterized by different elements of the lithogenetic rhythm – soils, loess-like deposits and typical loesses. The integral equation obtained for the characteristics of composition for constant properties, representing the loess geosystem as a whole, provided a basis for the interregional dependences in subsystems (sequences in Central Asia, Siberia and the Ukraine) representing the historical geological paratenesis of the types of loess soils.

In the last 15 years large-scale research, mainly by geologists of the Academy of Sciences of the Ukraine, has been devoted to the key loess sections in the Ukraine (VEKLICH, M.F. 1982, GOZHIK, P.F. et al. 1976, 1982, MOSKVITIN, A.I. 1976, REMIZOV, I. S. 1975, etc.). The present author has studied a host of sections both lithologically and paleogeographically, partly in collaboration with the Anthropogenic Geology Division of the Academy of Sciences of the Ukraine and on the basis of their publications (BALANDIN, Yu.G. – MOROZOV, S.S. 1972, BALANDIN, Yu. G. 1976a, 1976b, 1982a, etc.). Moreover, for the purpose of working out additional criteria for the interregional correlation and the clarification and assessment of the geosystem or formation features of loess sequences he has studied in detial the composition, the structural-textural characteristics and the physico-chemical properties of a series of sections developed under different geological-structural circumstances from the periglacial and extraglacial areas of the Ukraine such as the Vesternichanski, Izmail'ski and Reniyski sections on the Pleistocene Danube terraces: the Primorski section on the Pliocene terrace of the river Prut in littoral zone of the Black Sea, the Veselokutski and Novo-Kaplany sections on the Danube-Dniester Interfluvial Plateau, the Roksolanski and

Gradyanitsky sections on the terraces of the left bank of the lower reaches of the river Dniester, the Odesski, Radzel'yanski and Novo-Dimitrovichi sections on the plateau, the Krukenichi section in the Predkarpat'e, the Vitachevski, Zoryanski and other sections on the Dnieper terraces, and the Kharkovski section in eastern Ukraine.

The geological results of the study of the key sections has led to the typology of the region: loess formations in the Ukraine are characterized by the features of a regional subsystem of a higher-rank geosystem, i.e. of an independent formation, the historico-geological paragenesis of closely related genetic types (eolian-deluvial, eolian-alluvial, proluvial-alluvial, etc.) with rather satisfactorily distinct lithological features of the relevant stratigraphic subdivisions (subsystem elements) such as loess and buried soil horizons formed under peculiar zonal paleogeographic circumstances.

Hereinafter we present the characteristics of the structure of a subsystem (geological structure and the mode of superposition of strata) and of its characteristics: the structure and condition (state) of loess sequences. In this context we make comparisons with other regions and concretize interregional analogies reflected by formation-rank characteristics, i.e. by the properties of the loess geosystem as a whole.

The loess sequences of the Ukraine are characterized by a mantle- or sheet-like superposition and by a tectonic and geomorphological control of thickness and lithology. Thick and continuous sequences are developed in tectonic or denudation-controlled depressions or sags and in river valleys. At altitudes of 200 to 250 m or more the loess mantle is mosaic-patterned, poorly stratified and frequently represented only by loess-like eluvial-deluvial facies. The thickness of the Pleistocene sequences does not exceed 50 to 60 m, complete sequences being usually 20 to 35 m thick. The older loess horizons are generally less thick. Uniform ecostratigraphic and mesostructural features of the loess sequences of the Ukraine are the presence in the typical loesses of stunted forms of terrestrial, predominantly xerophilous molluscs indicating low-temperature, arid habitats. In the near-contact parts of the loess horizons and buried soils, however, the presence of hydrophilous forms is not uncommon either. They are characterized, in turn, by periglacial phenomena such as frost shattering, nivation and convective phenomena, deluvial solifluction, erosional-deluvial, eluvial and soil-generating processes (BALANDIN, Yu. G. 1976a). Palynological and archeological data are conformable to the rhythmicity of textures and the malaco-fauna in the sections studied. The granulometric and mineral composition, the microstructure (the ratio of granular and aggregate structures) and the physico-chemical activities (BALANDIN, Yu.G. 1976b, BALANDIN, Yu.G. – MOROZOV, S.S. 1972) show a rhythmic alternation in the sequences. The same holds true of the filtrational anisotropy which is due to the vertical orientation of the macropores and the cleavage cracks (which shows a downward decrease throughout the soil sections). The buried soils, as a rule, are more disperse, aggregated, carbonated, with a more strongly montmorillonitized clay fraction and with higher exchange capacity (2 to 3 times) and saturation of the exchange complex of calcium. The mesostuctures of the soil profile are typical (BALANDIN, Yu.G. 1976a, REMIZOV, I.S. 1975), STROENIE ... 1981, VEKLICH, M.F. 1975, A latitudinal and vertical conation is manifest in the distribution of genetic soil types within the loess sequences (VEKLICH, M.F. 1982). A lithological similarity is also observed in the generally loamy composition, the prevalence of dust particles, the aggregated pattern of the physical clay fractions, the similar composition of the leading mineralogical components (the light minerals of dust to sand grain size being mainly represented by quartz, feldspar and carbonate assemblages), and in the clay fraction (represented by an association of hydromica, kaolinite, montmorillonite and disperse quartz). The bulk of the clay particles are concentrated in the shells of clastogenic grains. Substantial provincial differences are felt only in the composition of the heavy minerals which, however, are present only in low amounts -0,2 to 1,0 and, very seldom up to 2% by weight or rock.

On the whole, the spatial and temporal structure of loess formation is clearly subordinated to the stages in the development of the Pleistocene natural processes.

According to the scheme developed by URMSK, there are distinguished a Holocene horizon and 14 Pleistocene horizons consisting of two members (the soil member overlying it) in the early, the middle and late Pleistocene. The seventh upper member cannot be distinguished in many cases. The horizons have been named as follows: Martonoshski, Sul'ski, Lubenski, Tiligul'ski, Zavadovski, Dnieprovski, Kaidakski, Tyasminski, Prilukski, Udaiski, Vitachevski, Bugaski, Dofinovski, Prichernomorski

$$(Q_{I}^{1}mr, Q_{I}^{2}sl, Q_{I}^{3}lb, Q_{I}^{4}tl, Q_{II}^{1}zv, Q_{II}^{2}dn, Q_{II}^{3}kd, Q_{II}^{4}ts,$$

$$Q_{III}^{1}pl, Q_{III}^{2}ud, Q_{III}^{3}vt, Q_{III}^{4}bg, Q_{III}^{4}df, Q_{III}^{4}pc).$$

In addition to paleopedological, rhythmo- and ecostratigraphic, periglacial geological methods, C^{14} and thermoluminescence techniques have also been used for the stratigraphic subdivision of the sequences. The sections have proved to be not older than 900 thousand years, the lower boundary of the Lower and Upper Pleistocene being of the order of 170 to 190 and 400 to 440 thousand years respectively. The Bugski loess is also characterized by volcanic ash interlayers observed in the sections of Roksolany and Dratuleshty in the northern Crimea. The same holds true of the Dnieprovski, Donetski and Kharkovski horizons. At Roksolany, by recent results, the ash is dated as 19 to 23 thousand years B.P. (C^{14}, Ki-1509, Ki-1510). A brown to brownish-black soil of 2 to 4.5 m thickness marks, as a rule, the Early-Middle Pleistocene boundary. Age orientations were also given by the paleomagnetic data, which fixed the Brunhes epoch and the Longchamps, Blake and Dnieprovski events as well as episodes (TRETYAK, A.N.) encompassing the Sul'ski and Tiligul'ski loesses. In our opinion, this circumstance has influenced the concept suggesting a subcompacted structural state of the loesses (BALANDIN, Yu.G. 1976b) and their resulting liability to sagging deformations. Liability to sagging with the deficiency of carbonate saturation, a wellknown feature of loesses, is another characteristic of the geosystem.

The listed methods are often insufficient for the practical correlations of loess sequences. The fact is that there is no reliable paleontological evidence, that the soils are affected by erosion, that the morphostructures are camouflaged, etc. In a number of cases, the efficiency of C^{14} and TL dating is limited owing to post-sedimentary migration and redeposition of the carbonates and silica. In such cases the features based on the study of the physico-mechanical properties of loesses and on comparing both the texture-related statistics of the composition and the characteristics and on the statistical autocorrelation models derived from studying the structure of geological analogies of interregional type, may be of help.

Investigations of this kind have been based practically on sampling the key sections (for determining their composition and properties) at 20-50 cm intervals. In the case of thin layers additional samples were taken laterally with a maximum of 5 to 6 samples recovered. This enabled us to have the minimum specimens necessary for generalizations. Complete sections are represented by 70 to 100 complex determinations of the characteristics, the total of the results obtained having been 2000. From section to section we examined the mathematical form of variation of the characteristics throughout the thickness of the horizons and the sequence as a whole. Moreover, the composition and property factors were evaluated from the viewpoint of homogeneity. The summarized results of characteristics by stratigraphic subdivisions were compared with information on the loess mantles from Bulgaria, Central Asia and Siberia (MINKOV, M., BALAEV, L.G. – TSAREV, P.V., VLJANOV, G.A., SERGEEV, E.M. – MINERVIN, A.V.) In addition, major sets of characteristic data obtained for a host of loess regions from the Ukraine, Central Asia and Siberia were used as a basis for the construction of correlation models of the dependence of the structural index property, the porosity (coefficient ϵ) on the variation of the composition of the sequences in terms of the plasticity index, I_p (FIG. 2). The results permitted us to specify more strictly the above-listed characteristics and to identify or discriminate new characteristics of the loess geosystem.

Thus elements of different characteristics of the lithogenetic rhythm such as soils, loess-like rocks and loesses proper correspond to each of the alternating Pleistocene climatic phases (within the combined interglacial-glacial epochs). Within the thickness of each rhythm there is a regular subparabolic trend of variation of the total void volume and the liability to sagging (for loads of 0.2 to 0.3 MPa), characteristics correlating with the changes in the dust particles and physical clay contents as well as with variations in the colloidal fraction of the loesses displayed by minerals of the montmorillonite, hydromica and kaolinite group. Examples of interconnection between the indices of the properties of loess sequences and their textures are given in the tabulation (TABLE 1.), where the values of δ_{sub} and ϵ are quoted for the central and contact parts of the horizons from the Primorski and Roksolanski sections) as well as in FIG. 1: Kharkovski, Novo-Dmitrovichi, Veselokutski sections (for a detailed description of their geology, see BALANDIN, Yu.G. 1982a, 1982b, GOZHIK, P.F. et al. 1976, REMIZOV, I.S. 1975). Judging by the last two, a regular, layer-by-layer differentiation of the properties is preserved throughout the sequences even in the case when both the soils and full members fall out of the section being studied. The examples and other analogous cases bear witness to the fact that the peculiarities of a horizon-by-horizon autocorrelation of the properties are paleoclimatically controlled at the level of a phase and paleogeographically controlled at that of a stage.

The featured peculiarity of the loess mantle of the Ukraine is also observed in the loess sequences of other regions of the USSR and even abroad (BALAEV, L.G. – TSAREV, P.V. 1964, MINERVIN, A.V. – SERGEEV, E.M. 1964, MINKOV, M. 1968). The fact that the properties in question are element-by-element differentiated within a layer with the maximum of subcompactness in the upper half of the layer was recorded

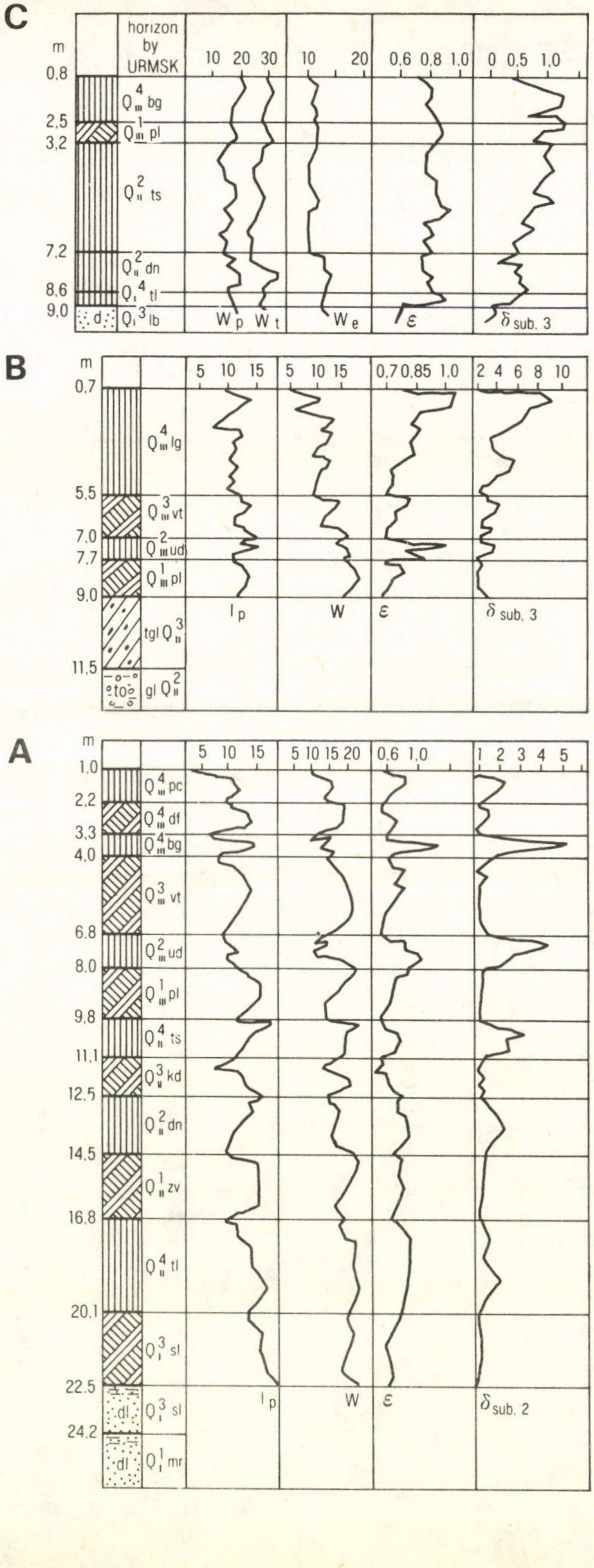


FIG 1. Stratigraphic columnar sections with diagrams showing the variation of the properties in the vertical sense within the key sections
A – Kharkov, B – Novo Dimitrovichi, C – Veselokutsk.
Indices: Ip – plasticity index (%), W – moisture (%), ϵ – coefficient of porosity, δ subcoefficient of relative sagging (%), W_p, W_t – rock failure and creep limits (%)

TABLE 1. Comparison of the characteristics
(Ip, %, ϵ, C, 10^3Pa, φ_{grad}, δ_{sub}, 2 %)
of loess horizons in the key sections at Roksolany and Primorskoe, respectively

Horizon		Roksolany					Primorskoe			
		Ip	ϵ	C	φ	δ_{sub}	Ip	ϵ	C	φ
Q_{III}	pc	10	0.85 - 0,97	16	20	5.8 - 7.0	11	0.80 - 0.86	18	18
	df	12	0.92	24	20	4.1	12	0.91	19	18
	bg	9	0.91 - 1.04	23	19	5.4 - 7.0	10	0.93 - 1.06	20	16
	vt	16	0.91	30	23	2.1	13	0.92	33	18
	ud	10	0.78 - 0.92	27	17	3.4 - 6.0	12	0.80 - 0.89	39	20
	pl	13	0.82 - 0.70	35	21	3.8	17	0.85	42	21
Q_{II}	ts	11	0.72 - 0.92	28	18	5.5 - 9.0	10	0.86 - 1.01	34	19
	kd	15	0.70 - 0.72	32	22	2.4	16	0.81	36	22
	dn	12	0.67 - 0.91	28	19	1.3 - 3.7	14	0.80 - 0.90	32	18
	zv	16	0.67	45	22	1.8	17	0.78	38	20
Q_I	tl	14	0.64 - 0.85	–	–	0.6 - 2.0	14	0.77 - 0.85	30	18
	1b	the horizon is absent					16	0.72	40	21
	sl	14	0.64	–	–	0.6 - 1.1	12	0.78	42	16
	mr	18	0.42	–	–	0.1	–	–	–	–

REMARKS:

1) C = specific cohesion, φ = angle of internal friction, shear unconsolidated, for a natural condition or state,
2) ϵ and δ_{sub} of loesses = upon values measured in the contact zones and the interior of the horizons.

in the Predkavkaz'e, on the Pritashkentskaya Plain, at Irkutsk and Krasnoyarsk. At the same time, the majority of loesses in various regions show an approximate equality of the sagging coefficient values measured in the loess parts of the rhythms. For instance, δ appr. in the loesses of the Early, Middle and Late Pleistocene sections from the Black Sea coastal region (Prichernomor'e) are close to the respective values of 4, 8, 12, in the case of Zaporozhye the respective figures are 3, 6, 11. In the loess sequences of northern Bulgaria the respective values are (3-4), 6, 11, in the North Tashkent Canal: 4, (5.5-6), (9-11.5). Such kinds of interregional analogies in the loess sequences are concealed or at least dimmed by landscape-zonation conditions only with increasing latitude and altitude. On the other hand, the general trends of variation of the properties in question with depth are usually not sharp which is explained by the specificity of loess lithogenesis taking place in Quaternary times in the stages of diagenesis when the gravity factor is of rather weak effect.

Let us quote one more peculiar feature of the loess formations of the Ukraine (a property of geosystem rank). The dependence of the physico-mechanical factors on the composition characteristics (e.g. that of ϵ on I_p) in the loess sequences of various regions in the USSR (FIG. 2) represent families of similar mathematicla descriptions (BALANDIN, Yu.G. 1980). For "ϵ – Ip" this is a combination of a branch of a parabola (for the light lithologic fractions of every region) showing an inverse linear relationship (in the case of the more disperse fractions). The mathematical inhomogeneity of the relationship is expained by the initial polygenetic pattern of the loess formations (BALANDIN, Yu.G. 1981). In accordance with the virtual I_p and the regional specificity of the field of characteristics, the equations in the series are only shifted in the diagram coordinates ($\epsilon - I_p$, FIG.2) parallel to one another. As it turned out, the equations of the type a – Ip for the individual sequences were just variants of resolution of the equation common for all sequences, an equation constructed upon cumulative values of the fields of characteristics of various sequences and they represented the geological paragenesis of faciologically related genetic types of loess to be described mathematically as ground sequences of one type.

The listed characteristics and peculiarities of loess formation (understood as having the rank of properties of the loess geosystem) contain basic information for regional engineering geological constructions and predictions or forecasts and they can be used in genetic paleoreconstructions and interregional stratigraphic correlations of loess sequences.

From the angle of system-analysis the subsystem being dealt with reflects the features of loesses as geological formations. In other words, it exhibits what is homogeneous in an inhomogeneous matrix (lithological, engeneering geological features) of discrete subdivisions (horizons) and so on, thus being a quasi-static subsystem (in the course of tens to hundreds of years rock formation processes are confined to the stages of diagenesis); an organized one (the loess features are preserved for a long time); an open one or possibly a half-open one (being liable to radical destruction or degradation in a definitive zonal landscape pattern, e.g. under the humid circumstances of high mountains), but with the ability to some kind of adaptation in the rhythmical course of the historico-geological events of the Pleistocene. In addition, as expected, the loess formations are characterized by a mathematical specificity reflecting the peculiarities of the structure and characteristics of the geosystem.

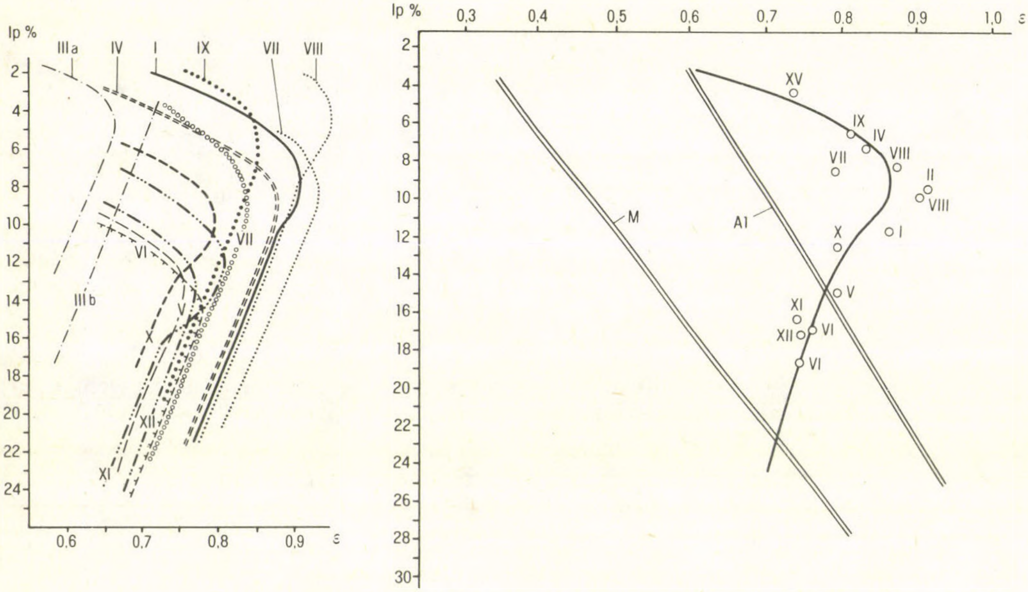


FIG. 2. Dependence of the ε fields on Ip in loesses from the following regions: I – Prichernomor'e (Black Sea Coast Zone), II – the Danube delta stretch of the former, IIIa – upper reaches of the Dniester, IIIb – environs of Zhidachev, IV – Kiev, V – left bank of the lower reaches of the Don, VI – left bank of the northern Donets, VII – Priobskoe plateau (Ob plateau), VIII – Tashkent, IX – Minusinsk, X – Irkutsk, XI – right bank on the upper reaches of the Dnieper, XII – right bank on the upper reaches of the Don, XIII – Yuzhnoukrainka, XIV – Rostov, XV – Alakol' – Balkhash region. Al – Dependence of ε on Ip upon statistics concerning the Pleistocene alluvial sequences, M – idem for the moraine formations in the European part of USSR.

REFERENCES

BALAEV, L.G. – TSAREV, P.V. 1964: Lessovye porody Tsentral'nogo i Vostochnogo Predkavkaz'ya. (Loesses of the Central and Eastern Predkavkaz.) Moscow, Nauka. 248.

BALANDIN, Yu.G. 1976a: Tekstury prikontaktovykh zon gorizontov lessovykh porod Odesskogo poberezh'ya, kak pokazatel' paleogeograficheskoi obstanovki formarovaniya lessovykh tolshch. (Textures of contact zone of loess horizons on the Odessa coast stretch as an index of the paleogeographic environment in which the loess sequences were formed.) – In: Chetvertichny period. Kiev. 16. 65-73.

BALANDIN, Yu.G. 1976b: O stratifikatsii lessovykh tolshch po pokazatel'yam svoistv. (On the stratification of loess sequences based on the indices of their properties.) – Geologiya i Razvedka, 10. 117-123.

BALANDIN, Yu.G. 1980: Printsipy teorii podobiya v matematicheskoi formalizatsii mezhregional'nykh inzhenerno-geologicheskykh analogi (na primere porod lessovoi formatsii). (Principles of the theory of similarity in the mathematical formalization of interregional engineering geological analogies (by the example of rocks of the loess formation). – In: Teoreticheskie i methodicheskie problemy povysheniya kachestva i effectivnosti inzhenerno-geologicheskikh issledovanij. Tez. dokl. Vsesoyuz. konf. T. 3. Rostov-na-Donu. 50-54.

BALANDIN, Yu.G. 1981: Otrazhenie genezisa lessovykh porod v matematicheskikh modelyakh iz svoistv. (The reflection of the genesis of loess rocks in mathematical models of their properties.) – Dokl. AN USSR. B. 9. 3-7.

BALANDIN, Yu.G. 1982a: Novoe ob osobennestyakh lessogo pokrova rayona Roksolanskogo opornogo razreza pleistotsena Ukrainy. (Some news about the peculiarities of the loess blanket of the region of the Roksolany key section of the Ukrainian Pleistocene.) – In: Materialy po izucheniyu chetvertichnogo perioda na territorii Ukrainy (k XI Kongressu INKVA). Kiev, Nauk. dumka. 19-31.

BALANDIN, Yu.G. 1982b: In: Putevoditel'ekskursii A-7, S-7. Moldaviya i Odesskaya oblast'. (Guide-book of excursions A-7, S-7.) Moscow. 46.

BALANDIN, Yu.G. – MOROZOV, S.S. 1972: O granulometricheskom sostave lessovykh porod mezhdurechiy Dunay-Dnestr-Yuzhny Bug. Khimikomineral'nykh sostav lessovykh porod Severo-zapadnogo Prichernomor'ya. (On the granulometric composition of loess rocks from the Danube-Dniester-South Bug Interfluve. Chemico-mineralogical composition of the loess rocks of the northwestern Black Sea Coast Zone.) – In: Geologiya poberezh'ya i dna Chernogo i Azovskogo morei v predelakh USSR. Kiev. 6. 21-43.

GOZHIK, P.F. – MELNIK, V.I. – SHELKOPLYAS, V.N. – TRETYAK, A.N. et al. 1976: Putevoditel' VIII Mezhdunarodnogo simpoziuma po lessovym porodam. (Guide-book for the excursions of the VIIIth International Loess Symposium) Kiev, Nauk.dumka. 71.

GOZHIK, P.F. – MELNIK, V.I. – SHELKOPLYAS, V.N. et al. 1982: Putevoditel'ekskursii A-6, S-6. Ukraina. (Guide-book for the excursions A-6 and S-6 Ukraine.) Moscow, 48.

MINERVIN, A.V. – SERGEEV, E.M. 1964: Novye dannye k resheniyu problemy lessa. (Contribution to the solution of the loess problem.) – Izvest. AN SSSR. Ser. geol. 9. 53-64.

MINKOV, M. 1968: Lestva Severna Bolgariyata. (Loesses of northern Bulgaria.) Sofia. 186.

MOSKVITIN, A.I. 1976: Opornye razrezy pleistotsena Russkoy raviny. (Pleistocene key sections of the Russian Plain.) Moscow, Nauka. 203.

REMIZOV, I.S. 1975: Putevoditel' ekskursii III sezda Geograficheskogo obshchestva USSR. (Guide-book for the IIIrd Congress of the Geographical Society of USSR). Kharkov, Oblpoligrafizdat. 70.

Stroenie i voprosy korrelyatsii chetvertichnykh otlozheniy Ukraina. (Structure and correlation problems of Ukraine's Quaternary deposits.) Kiev, Nauk.dumka. 1981. 188.

VEKLICH, M.F. 1982: Paleoetapnost' i stratotipy pochvennykh formatsiy verkhnego kainozoya. (Paleostage pattern and stratotypes of the soil formations of the Upper Cainozoic.) Kiev, Nauk. dumka. 203.

Address of author:
Yu.G. Balandin, State University, Faculty of Geography
Ul. Petra Velikogo 2. ODESSA – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

ELECTRONMICROSCOPIC INVESTIGATION OF THE SAND MATERIAL FROM THE LOESS EXPOSURE AT PAKS

Z. Borsy – J. Félszerfalvi – J. Lóki

ABSTRACT

All loess and soil layers of the Paks exposure examined by the authors contain wind-blown sand in various amounts (6-14%). Thus, this examination also confirms that in the Carpathian Basin during the Würm and Riss glaciations, mainly in the colder, drier stadials there was repeated blown sand movement in the periods of loess formation, and perhaps alternating with the latter.

The typical blown sand in the exposure appears at the depth of 29.0-31.0 m. The sand from the depth 36.70-37.41 m must be regarded, even on the basis of electronmicroscopic examinations, as aqueously transported. The material of the nearly 3 m thick coarse sand layer must have been deposited by a watercourse running from the direction of the Mezőföld towards the Danube-tisza Interfluve.

During the past one and a half decade the lithostratigraphic and chronological investigations of the loess exposure at Paks have yielded significant results, and have considerably enriched our knowledge of the evolutional conditions of the loess sequences and the fossil soils included in the former (PÉCSI, M. 1965, PÉCSI, M. 1966, PÉCSI, M. 1972, PÉCSI, M. 1975, PÉCSI, M. 1979a, 1979b, PÉCSI, M. – SZEBÉNYI, E. 1972, PÉCSI, M. – PEVZNER, M.A. 1974, PÉCSI M. et al. 1977, BORSY, Z. – FÉLSZERFALVI, J. – SZABÓ, P.P. 1979).

On the other hand, no effort has been made so far toward the detailed examination of the roundness of grains in the sand layers and in the sand fractions contained in the loess series of the exposure. It was a debated problem again which sand layer can be regarded as unequivocally fluvial, or as sediment transported and aggregated by wind.

This is why the authors decided to make an attempt, making use of the experience acquired during the study of the Quaternary deposits of the Great Hungarian Plain (BORSY, Z. – FÉLSZERFALVI, J. – LÓKI, J. 1982, BORSY, Z. – FÉLSZERFALVI, J. – LÓKI, J. 1983), at the electronmicroscopic examination and classification of the roundness of the sand material in the Paks exposure.

In the electronmicroscopic study of the roundness of grains in the sand layers embedded between the strata of the loess sequence the grains of 0.63-1.00 mm were used. In fact, most of our earlier results prove that no appropriate distinction between blown and fluvial sand can be made through the examination of grains of finer fraction (BORSY, Z. 1974).

Coarse sand can occur both in loess layers and fossil soils. Thus, samples were collected from both. In general, by the wet sieving of 1 - 2 kg material we succeeded in separating grains in suitable amounts for taking electronmicroscopic photographs.

We failed to obtain an appropriate amount of coarse sand at a depth below 37.5 m from the wall of the exposure, thus, there was no opportunity to study the lower layers of the loess sequence of Paks with our method.

– The first sample was collected from a depth of 20-25 cm (FIG. 1, SAMPLE No. 1). As proved by the electronmicroscopic photos in this sample the majority of grains are poorly rounded (PLATE I. PHOTO 1). However, there are considerable differences between the particular sand particles. Some have surfaces bearing testimony to a varied geological past. These grains were subjected, at an earlier date, to solution, then they were abraded as a result of eolian effect (PHOTO 2). Subsequently, larger breakage surfaces evolved on them which, due to eolian transport, became in places moderately coarse, or got polished. Fresh breakage patterns can also be observed on the grains, which developed either in the last phase of eolian transport or resulted from cryofracturing effects.

There are slightly rounded grains with varied textural features. The richness of patterns on these surfaces (PHOTO 3) can be partly explained by the fact that the grains were originally textured by a number of smaller steps. The variety of their surface patterns was further enhanced by the evolution of hollows due to solution, or the formation of breakage surfaces in both phases.

The presence of smaller or larger breakage patterns together with the considerable number of small-size forms resulting from solvent action is also conspicuous on grains more strongly abraded by wind (PHOTO 4).

The varied surface of the grains of the sample, the differences in their roundness suggest that the adjacent area (Mezőföld, landscape in East-Transdanubia), from where the sand grains were transported here, supplied basic material of highly varied roundness.

– With the sand grains collected from the loess of relatively high silt content from a depth of 8.25-8.30 m (FIG. 1. SAMPLE No.2) a similar phenomenon was observed as with the previous sample. The only difference being that at this level the number of rounded grains is somewhat higher (PHOTO 5). However, from these eolian transport could not wear off the steps characteristic of fluvial sand. The forms of solutional origin are frequent on these grains too, and there are several places where smaller fresh breakage surfaces are also seen.

On the less rounded grains smaller and larger breakage patterns can equally be observed (PHOTO 6). The latter may have developed mainly as a result of cryofracture, although it is possible that their evolution was also promoted by eolian transport. It is obvious from the photomicrographs that, after the larger breakage surfaces had developed on such types of grains, they were subjected to eolian effects, too.

A certain degree of similarity observed in samples No.1 and No.2 suggests that the slight amount of sand in the fraction of 0.63-1.00 mm in diameter was transported to its present location from the same source area.

– The grains of the sample collected from a depth of 11.7-11.8 m from the soil profile BD_2 (FIG. 1, SAMPLE No. 3) can be classified into three types on the basis of their roundness.

On third of the grains is well-rounded, typical blown sand (PLATE II, PHOTO 7).

Another group of the grains has been less intensively abraded by wind. The breakage surfaces characteristic of fluvial sand are conspicuous on these grains (PHOTO 8). Besides the traces of eolian transport the forms of solutional origin can also clearly be seen.

The grains of the third type (PHOTO 9) were first rounded in aqueous transport, then we subjected to eolian effects for a short time.

Characteristic of all three types are the fresh breakage patterns.

The considerable differences in the roundness of the grains indicate that wind intermixed into the original basic material of the BD_2 soils profile both typical blown sand and a material blown out from some fluvial deposit in the proximity (which had undergone repeated redeposition and abrasion of different types).

– At the depth of 12.40-12.50 m, directly bellow the soil profile BD_2 loessy sand was found (FIG. 1, SAMPLE No. 4). At this level more than 20% of the total material is constituted of typical blown sand (0.32-0.1 mm in diameter). The greater part of the sand grains examined is typical eolian sand (PHOTO 10). On the other hand, their degree of roundness is not quite uniform. There are less rounded grains as well (PHOTO 11), and the breakage patterns evolving in two phases are especially obvious on these grains. In the course of the examination of the sample it was stated that at the time when this layer evolved there must have been somewhere nearby a surface blown sand, a small part of which was intermixed into this layer.

– 18.90-19.0 m, soil profile BA, Paks (FIG. 1, SAMPLE No. 5). Only blown sand was found in the grain-size range under study. The degree of eolian abrasion on the grains is at least as high as that on the eolian dune sand in the Danube-Tisza Interfluve (PHOTO 12). The only difference is that on part of the grains smaller and larger breakage patterns evolved (PLATE· III., PHOTO 13). The larger breakage areas are the older ones. On these slight traces of eolian effect can be noticed.

This layer also gives evidence that at the time of formation there was blown sand on the surface nearby, and from there the blown sand grains were transported and later intermixed with the base material of the loess. In practice it also means that on our alluvial fans, on the fluvial terraces, where it was possible, blown sand was formed even at the beginning of the Würm glaciation. This observation is in agreement with the experience obtained in the electronmicroscopic study of the sands from the transversal boring of the Upper Pleistocene strata in the Danube-Tisza Interfluve.

– 29.44-29.54 m, upper part of soil profile Phe (FIG. 1, SAMPLE No. 6). All the studied grains of the stratum containing very fine and medium-size sand proved to be blown sand (PHOTO 14). Traces of eolian transport can clearly be seen on each grain. It can be noticed, however, that the source area from which the sand was blown out provided highly heterogeneous base material (repeatedly redeposited, in cases, subjected to strong solvent action). The remarkable differences between the grains in respect to roundness can partly be explained by this fact (PHOTO 15). Some grains are characterized by larger fracture steps, others show multiple traces of solution, in cases with smaller breakage surfaces.

LEGEND TO THE FIGURE OF THE LOESS-PROFILE

░	fine sand, blown sand
┊	loessy sand
┊	sandy loess
┆	loess
⊥ ⊥ ⊥	clayey loess
░	slope sand
⁄	loessy slope sand
⁄ ⁄	sandy slope loess
⁄ ⁄ ⁄	slope loess
▨	clayey slope loess
┄	silty sand
┄	silt
▤	clay
▥	weak humus carbonate
▥	humus carbonate
▥	steppe-type soil
▨	chernozem brown forest soil
▩	brown forest soil
▩	grey-brown podsolic soil (lessivé)
▦	red clay
┼	hydromorphic soil, medow soil
=	alluvial marshy soil
∧ Ca ∧	calcium carbonate accumulation
× × × × ×	volcanic ash
∞ ∞	loess doll
θ θ	krotovina
+ + + + +	charcoal
✻ ✻	macrofauna
〰	discontinuity of profile
⇨	areal denudation, unconformity
➡	linear dissection, unconformity
MF	Mende - Upper Soil complex
MB	Mende - Base Soil complex
BD_1-BD_2	Basaharc - Double Soil complex
BA	Basaharc - Lower Soil complex
Mtp	Paks marshy soil

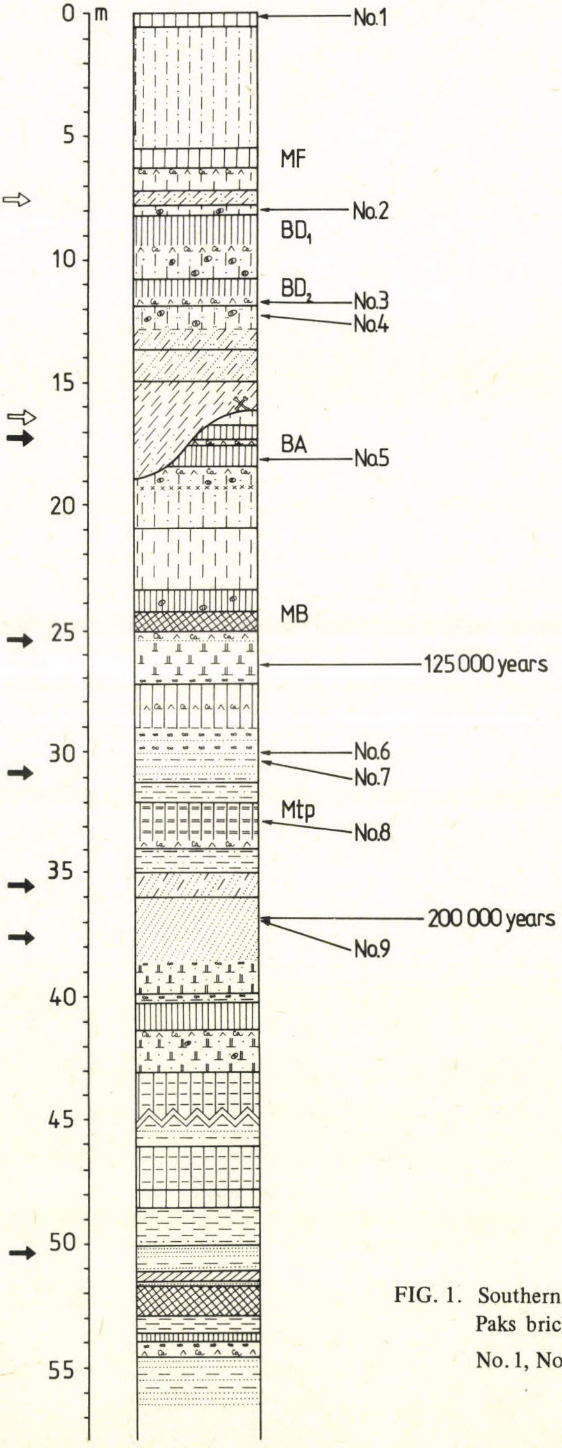


FIG. 1. Southern part of the loess profile in the Paks brickyard in 1971 (according to M. PÉCSI) No. 1, No. 2, etc. = sampling places.

PHOTO 1. Poorly rounded sand grain from the depth of 20 - 25 cm

PHOTO 2. Part of the surface of a blown sand grain with old and fresh breakage patterns. Depth: 20-25 m.

PHOTO 3. Moderately rounded sand grain with worn fracture steps along the edges, with traces of solution and fresh breakage patterns. Depth: 20-25 cm

PHOTO 4. Surface detail of a blown sand grain. Depth: 20-25 cm

PHOTO 5. Surface detail of a blown sand grain with hollows due to solution and, in places, with fresh breakage patterns. Depth: 8.25-8.30 m.

PHOTO 6. Surface detail of a blown sand grain with earlier and fresh breakage patterns.

PLATE I.

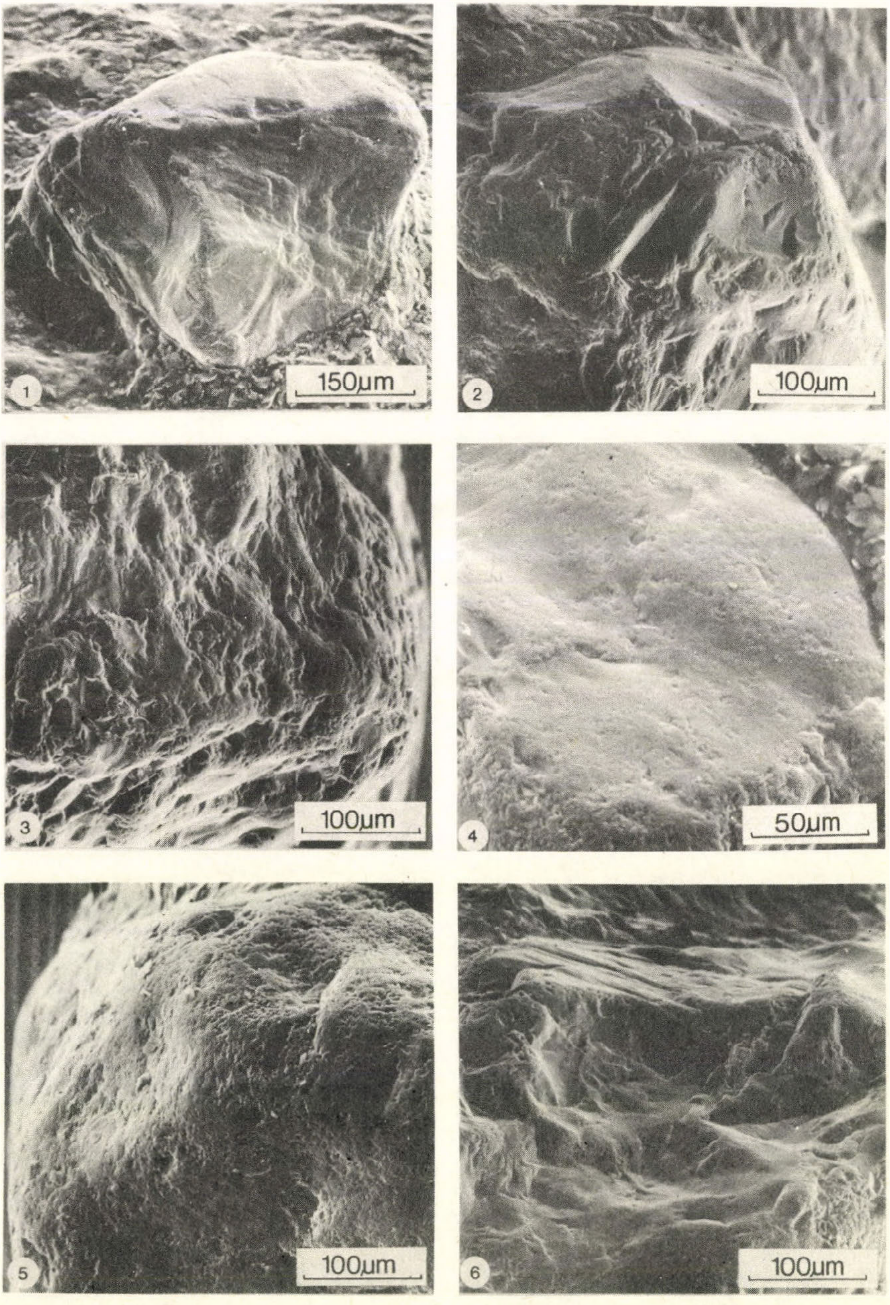


PHOTO 7. Well-rounded blown sand grain. Depth: 11.7 - 11.8 m

PHOTO 8. Surface detail of a blown sand grain. Depth: 11.7 -11.8 m.

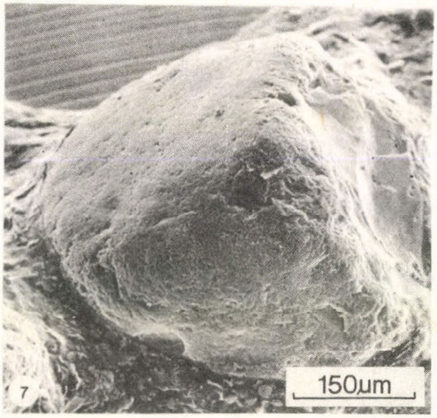
PHOTO 9. Sand grain rounded due to aqueous and eolian transport. Depth: 11.7 - 11.8 m

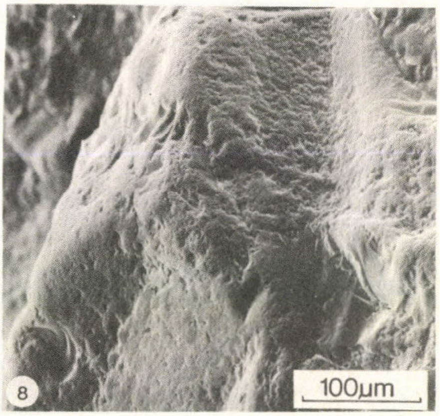
PHOTO 10. Surface detail of a blown sand grain. Depth: 12.4 - 12.5 m.

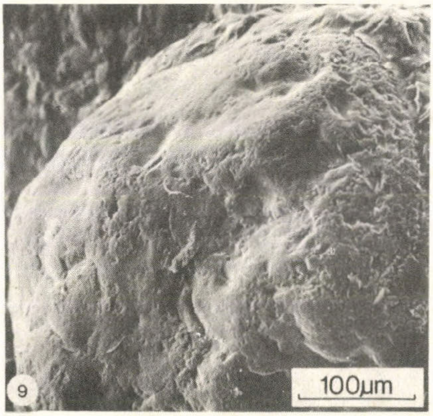
PHOTO 11. Surface detail of a blown sand grain. Depth: 12.4 -12.5 m.

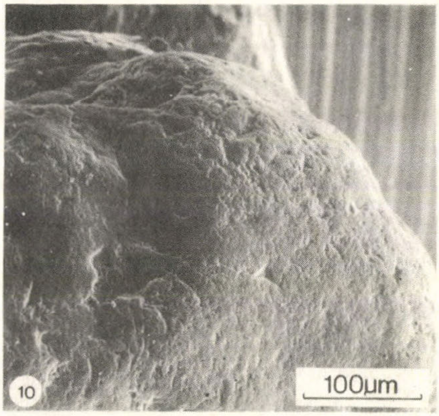
PHOTO 12. Typical blown sand grain. Depth: 18.9 - 19.0 m.

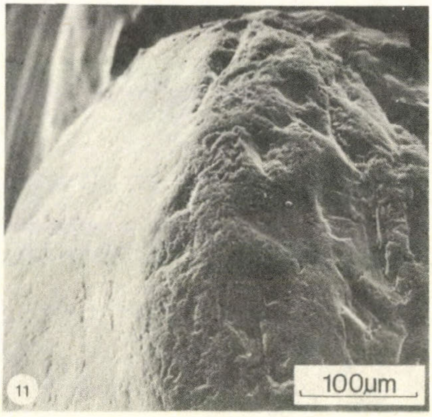
PLATE II.

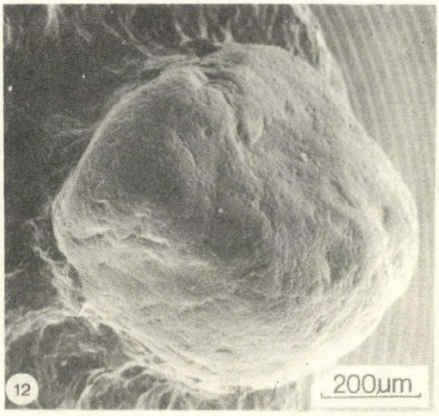












– 30.34 - 30.44 m, bottom of soil profile Phe (FIG. 1, SAMPLE No. 7). The layer containing 81% fine and medium-grain sand is a characteristic eolian deposit. In view of roundness the grains under study can be classified into two types. On the more rounded grains (PHOTO 16) the great number of depressions due to solution is conspicuous.

On the less rounded grains (PHOTO 17) the fracture steps characteristic of fluvial sand have not yet disappeared. On the grains abraded by eolian effects larger breakage surfaces evolved, which also show the traces of eolian transport.

Thus, the soil marked Phe evolved on blown sand. The occurrence of blown sand at the depth mentioned suggests that in the environs of Paks blown sand evolution took place, at least in places, in the Riss glaciation too.

– The examination of the grains collected from the depth of 32.9 - 33.0 m from the upper part of the soil segment Mtp (FIG. 1. SAMPLE 8) also yielded instructive data. All grains with a diameter 0.63 - 1.0 mm can be considered eolian sand. Their degree of roundness is, on the whole, smaller than that of the Phe segment, on the other hand, the grains fairly well show the traces of eolian transport (PHOTO 18). In addition, the larger surfaces due to breakage are conspicuous. Characteristic, in general, of the sands of the Paks loess sequence are the breakage surfaces evolved in two phases, however, in no sample have they been so obvious up to now, as in this one (PLATE IV, PHOTO 19). It is difficult to make unequivocal statements on the formation of breakage surfaces due to strong mechanical action. In their evolution some role may have also been played by cryofracturing. It is clear, anyway, that the grains were transported by wind after the development of the large breakage patterns.

– A fairly large amount of material was collected from the depth 36.7-37.41 m (FIG. 1. SAMPLE No. 9). This material was examined in wind tunnel too. This was highly justified since, after sieving, grains of 4 - 5 mm in diameter were also found in the sample. On the other hand, it could be seen even by the binocular microscope that in this sequence of layers there occurred rounded blown sand grains too. In the course of the wind tunnel experiments the largest grains were not moved by winds of 80 km/h either. This indicates that the layer also containing stripes of granule may have been deposited in this area by some watercourse.

(Aqueous transport seems to be accounted for by the special composition of the samples too. The shingle grains, rounded small lime concretions, sand grains of the most varied diameters were evenly distributed in the part examined by us, in the 0.1-0.002 mm diam sediment which made up as much as 7-10% of the layer. The material was virtually, cemented by this sediment in places. Such a load is transported by water-courses, mostly intermittent with high density bedload).

According to the lithostratigraphic examinations (PÉCSI, M. 1979a) this sand layer (h_2) in the old loess was considered fluvial. This establishment was also confirmed by the electronmicroscopic examinations.

The photos allow the statement that the roundness of the grains is of various degree, although really splintered ones cannot actually be found among them. There are rounded grains which clearly show the traces of eolian transport (PHOTO 20). On such grains large-size coarse surfaces due to eolian effect can be observed, and these are only in places interrupted by hollows due to solution or by breakage patterns.

In the case of grains classified into the following group the rounding of the edges may have started during aqueous transport (perhaps in littoral – lake or sea – environment), then continued as a result of eolian effects (PHOTO 21). Nevertheless, the steps did not disappear from their surfaces. On these grains solutional forms are also obvious and the surfaces generated by breakage. On the latter no sign of eolian effect can be seen.

It is instructive to study the grains whose edges have been worn off during aqueous transport (perhaps repeated redeposition), and whose surfaces do not reflect traces of eolian transport (PHOTO 22). The surfaces with smaller or larger steps sand fold magnifications, unequivocally prove that such grains were transported to their present-day localities by aqueous transport, in all likelihood from some Tertiary sediments.

Regarded as aqueously transported are the grains that, after some wearing-off along their edges, were subjected to strong solvent action (PHOTO 23). Later on larger breakage patterns were formed on these grains, which show no sign of eolian transport.

On the ground of the electronmicroscopic study of the grains of the sample, the final conclusion is that the material of the nearly 3 m thick coarse sand layer of the exposure may have been deposited by a watercourse that had its supply of load material from a repeatedly redeposited sediment that had been subjected to various types of abrasive effects. Through erosive effects blown sand grains may have run into the watercourse, this is why grains of eolian sand are also found in this series.

On summarizing the results the following can be stated:

All the loess and soil profiles of the exposure examined by us contained wind blown sand in larger or smaller quantities (6-14%). This indicates that at the time of the deposition of the base material of the individual loess strata there always took place some sand movement too in the vicinity.

At the time of the more intensive blown sand movement as much as over 20% sand got intermixed into the dust, deposited from the air. This can be found e.g. at the depth of 12.40-12.50 m.

The least rounded sand grains were observed in the samples collected from the depth of 20-25 cm.

Eolian sand appears at the depth of 29.0-31.0 m. The upper level of the stratum must have originally been loessy sands the majority, however, is characteristic well-classified blown sand, which was embedded as a sand blanket into the wall of the exposure.

In the sample from the depth of 36.70-37.41 m there occur sand grains with eolian abrasion. In addition, just as in all fluvial deposits of the Mezőföld, there are quite a lot of grains of aqueous transport that have undergone repeated reagglomeration, therefore, at least the edges are worn off. If the grains of 0.63-1.0 diam. are examined by binocular optical microscope, it is difficult to give a definite answer on their origin. On the other hand, in the electronmicroscopic pictures it is clearly seen that a fairly large part of the grains show no sign of eolian transport.

Adding to this that, at places, the 3 m thick layer clearly shows the signs of fluvial transport, we have no doubt that the material has been deposited by the watercourse running from the Mezőföld towards the Danube-Tisza Interfluve.

This investigation also confirms that in the Carpathian Basin, during the Würm and Riss glaciations, mainly in the colder, drier stadials, there was repeated sand movement in the periods of loess formation, perhaps in an alternating way.

PHOTO 13. Surface detail of a blown sand grain with breakage patterns. Depth: 18.9-19.0 m

PHOTO 14. Surface detail of a blown sand grain with breakage patterns and evidence of solution. Depth: 18.9-19.0 m.

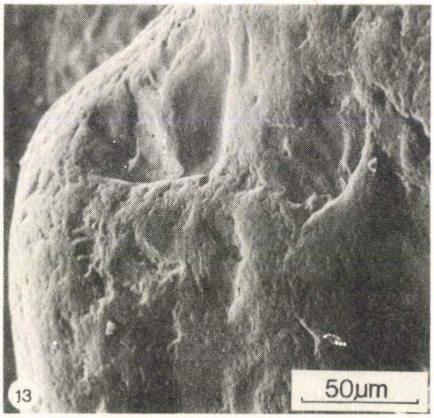
PHOTO 15. Surface detail of a blown sand grain with plenty of depressions due to solution. Depth: 29.44-29.54 m.

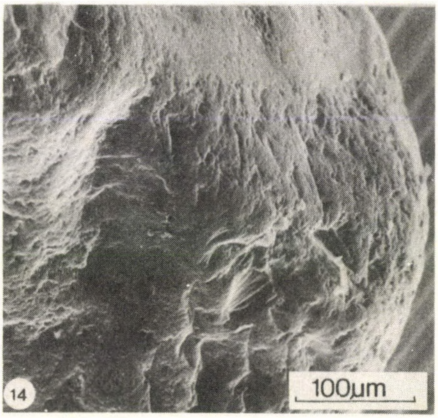
PHOTO 16. Blown sand grain with fracture steps on its surface. Depth: 29.44-29.54 m.

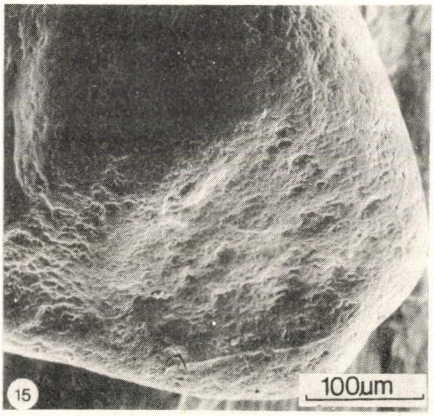
PHOTO 17. Surface detail of a blown sand grain with plenty of hollows due to solution. Depth: 30.34-30.44 m.

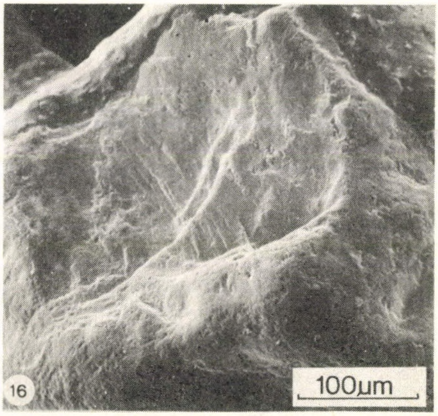
PHOTO 18. Surface detail of a blown sand grain. Depth: 30.0-30.44 m.

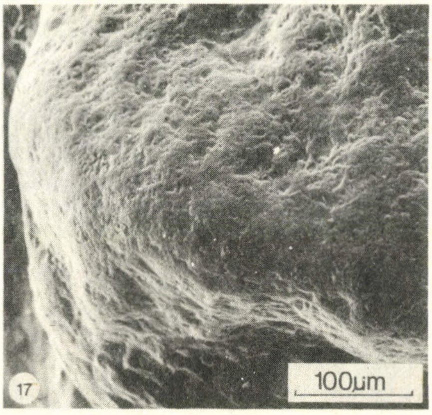
PLATE III.











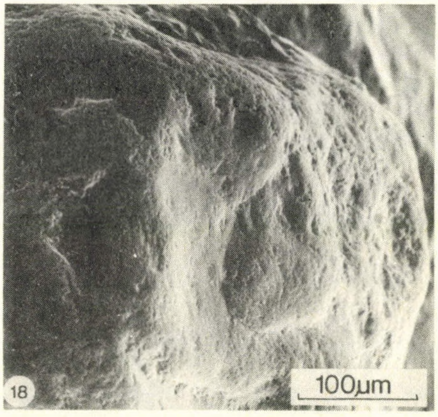


PHOTO 19. Surface detail of a blown sand grain. Depth: 32.9-33.0 m.

PHOTO 20. Surface detail of a blown sand grain with fresh breakage patterns. Depth: 32.9-33.0 m.

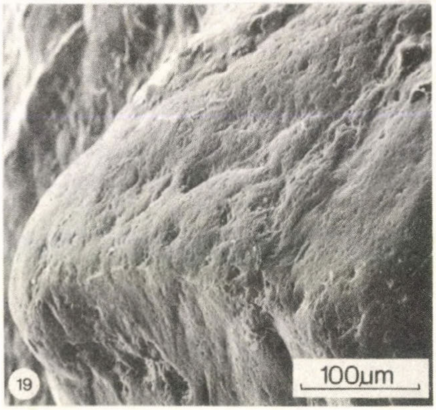
PHOTO 21. Sand grain rounded during eolian tranport. Depth: 36.7-37.41 m

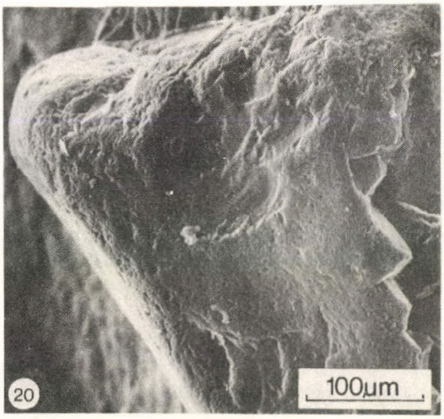
PHOTO 22. Surface detail of a sand grain abraded during aqueous and later eolian transport, with fracture steps and breakage patterns. Depth: 36.7-37.41 m

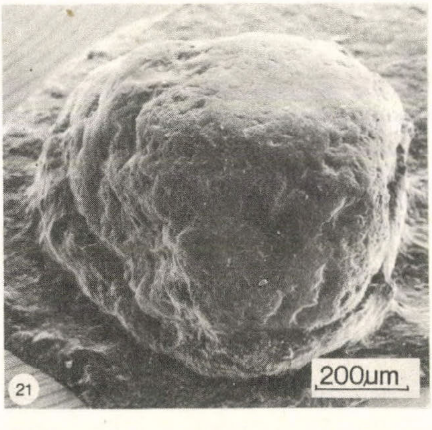
PHOTO 23. Sand grain surface detail rounded at the edges during aqueous transport. Depth: 36.7-37.41 m.

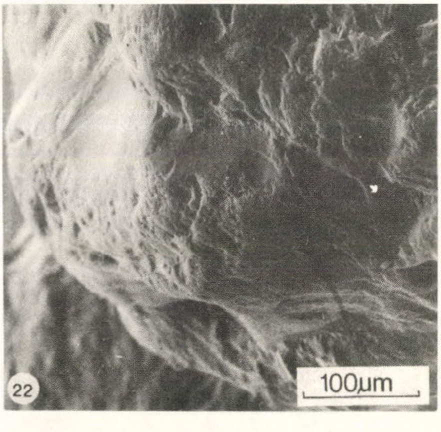
PHOTO 24. Aqueously transported sand grain with evidence of solution and fresh breakage surface. Depth: 36.7-37.41 m.

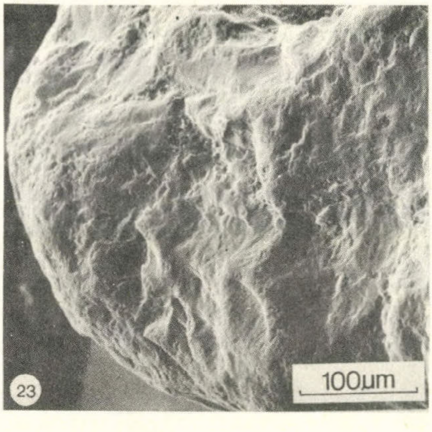
PLATE IV.

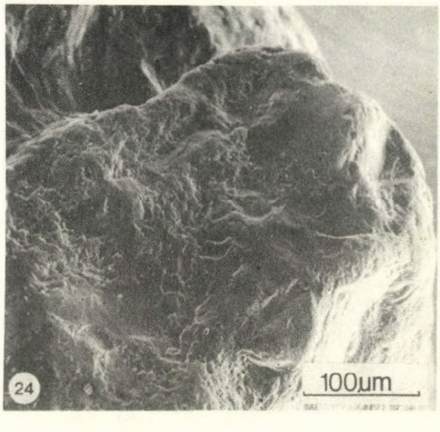

19


20


21


22


23


24

On closing our paper we express our thanks to the photographer HAPÁK, J. for his assistence in taking the electronmicroscopic photos and in preparing the prints.

REFERENCES

BORSY, Z. 1974: Folyóvízi homok vagy futóhomok? (A homokszemcsék vizsgálatának értékelése, problémái). Fluviatile or wind-blown sand. (Sand grains, problems of their study and evaluation.) – Földr. Közl. 22. 1. 1-13.

BORSY, Z. – FÉLSZERFALVI, J. – LÓKI J. 1982: A jánoshalmi MÁFI alapfúrás homoküledékeinek elektronmikroszkópos vizsgálata. (Electron microscopic investigation of the sand sediments in the core drilling of MÁFI at Jánoshalma.) – Acta Geogr. Debr. 20. 35 - 50.

BORSY, Z. – FÉLSZERFALVI, J. – LÓKI, J. 1983: A komádi alapfúrás negyedidőszaki homokrétegeinek elektronmikroszkópos vizsgálata (Elektron microscopic analysis of Quaternary sand levels in the base borehole at Komádi.). – Alföldi Tanulm. 31-58.

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

HAHN, Gy. 1977: A magyarországi löszök litológiája, genetikája – geomorfológiai és kronológiai tagolása. (Lithological, genetical, geomorphological and chronological subdivision of the Hungarian loesses.) – Földr. Ért. 26. 1. 1-28.

PÉCSI, M. 1965: A Kárpát-medencebeli löszök, löszszerű üledékek típusai és litosztratigráfiai beosztásuk. The loesses and types of loess-like sediments of the Carpathian Basin and their lithostratigraphical classification.) – Földr. Közl. 13. 4. 305 - 338.

PÉCSI, M. 1966: Lösse und lössartige Sediments im Karpaten-becken und ihre litostratigraphische Gliederung. – Petermanns Geogr. Mitt., 110. 4. 176 - 189.

PÉCSI, M. 1972: Scientific and practical significance of loess research. – Acta Geol. Acad. Sci. Hung. 16, 4. 317-328.

PÉCSI, M. 1975: A magyarországi löszszelvények litosztratigráfiai tagolása. (Lithostratigraphical subdivision of the loess sequences in Hungary.) Földr. Közl. 23. 3-4. 217-223.

PÉCSI, M. 1979a: Lithostratigraphical subdivision of the loess profiles at Paks. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 409-418.

PÉCSI, M. – PEVZNER, M.A. 1974: Paleomagnetic measurements in the loess sequences at Paks and Dunaföldvár, Hungary. (Paleomágneses vizsgálatok a paksi és a dunaföldvári löszösszletekben.) – Földr. Közl. 22. 3. 215-226.

PÉCSI, M. – SZEBÉNYI, E. 1971: Guide book for Loess Symposium in Hungary. IGU European Regional Conference, Budapest, 1-34.

PÉCSI, M. – Mrs. PÉCSI-DONÁTH, É. – SZEBÉNYI, E. – HAHN, Gy. – SCHWEITZER, F. – PEVZNER, M.A. 1977: A magyarországi löszök fosszilis talajainak paleogeográfiai értékelése és tagolása. (Paleogeographical reconstruction of fossil soils in Hungarian Loess.) – Földr. Közl. 25. 1-3. 94-134.

Address of authors:
Dr. Z. Borsy, Dr. J. Félszerfalvy, Dr. J. Lóki,
Department of Physical Geography, Kossuth L. University,
4010 Debrecen, Egyetem tér 1. – Hungary

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

MINERALOGICAL COMPOSITION OF LOESS DEPOSITS FROM THE TROTUŞ–SIRET–MILCOV REGION (ROMANIA)

V. Codarcea – T. Bandrabur

ABSTRACT

The loess deposits of this region are well developed on middle terraces, their thickness amounting to 30 m; they consist of clayey or sandy silts that exhibit 1-3 paleosols. The light fraction prevails and varies between 70-95%, while the heavy fraction consists of a greater number of mineral species but, in small amount (1.5-15%). From the heavy fraction the higher percentages are characteristic of oxides and garnets; the hornblende, epidote-zoisite, rutile, zircon, disthene, staurolite percentages decrease in the above mentioned order. There are other minerals, such as tourmaline, pyroxines, sphene, monazite, biotite, chlorite, glaucophane, antophyllite, actinolite, sillimanite, anatase, chloritoid, brookite, corundum, which occur in small amounts or even as accessory minerals. The carries is mainly represented by the Carpathian rivers which have washed all the rocks away-starting from the oldest to the most recent ones. The presence of breakes on the mineral surfaces, imply their reworking during various sedimentation cycles, with a high degree of mixture.

Our mineralogical investigations carried out in the East Romanian Plain (CODARCEA, V. – BANDRABUR, T. 1977) have been extended to the region situated in front of the East Carpathian Bend, between the rivers Siret-Trotuş and Milcov.

This region coincides partly with the piedmont zone and with the zones of the confluence terraces of the Siret and its tributaries.

The loess deposits are largely developed both in the piedmont zone and mainly on terraces, their thickness varies from a few meters in the former zone to 30 m on middle terraces.

The loess deposits of this region consist of silts, sandy or clayey silts, with 1-3 buried soils. Their upper stratigraphic position, as compared to the coarse-grained accumulations of terraces entails their assignment to the Middle Pleistocene-Holocene time interval.

Additional morphological and geological data on this region are offered by one of the authors on this occasion, too.[1]

[1] BANDRABUR, T. 1982: Morphological and Geological Aspects of the Region Situated in front of the East Carpathian Bend (Romania). XIth INQUA Congress-Moscow-gr. IV. section 18-1982.

The granulometric and mineralogical study of loess deposits implied the investigation of 50 samples, collected from 12 sections (FIG. 1).

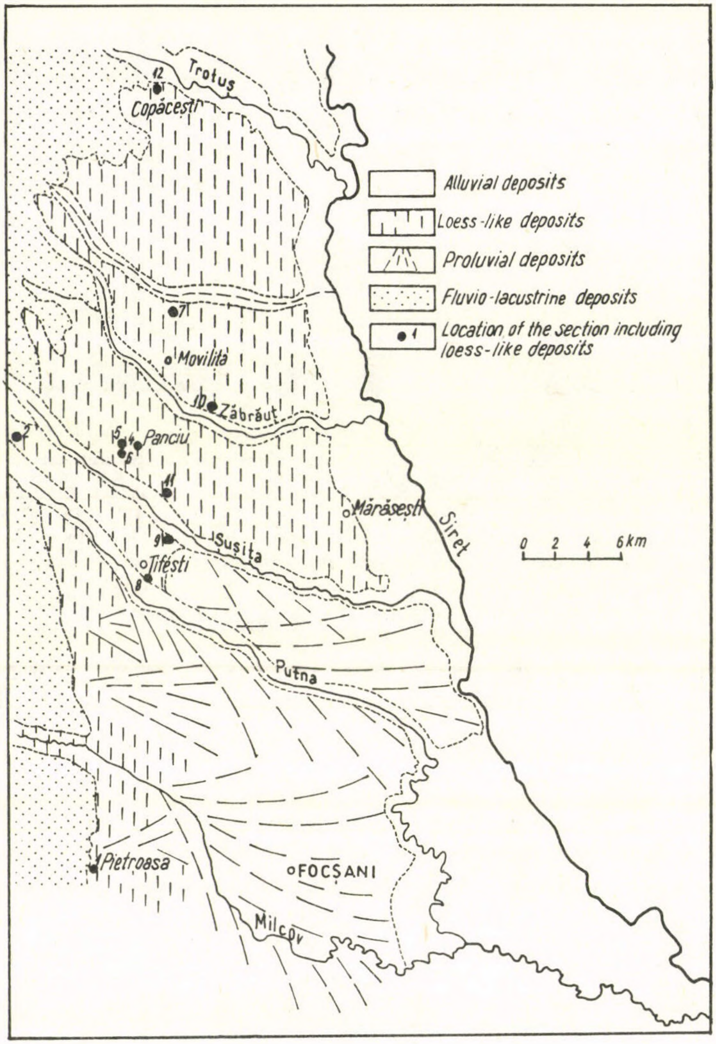


FIG. 1. Sketch presenting the location of the section including loess-like deposits

The lithological sections (FIG. 2) reveal the heterogeneous nature of the granulometric composition of loess deposits, as well as the grading from coarse sands at the base to medium-size sands and silts at the top. The same features are characteristic of the loess deposits occurring in neighbouring areas and studied by us previously.

As far as the granulometry is concerned (FIG. 3), all the investigated sections abund in the silty elements (0.5-0.005 mm) which occur in higher ratios in the terrace area (60%) as compared to the piedmont area (55%). On the whole, these values are

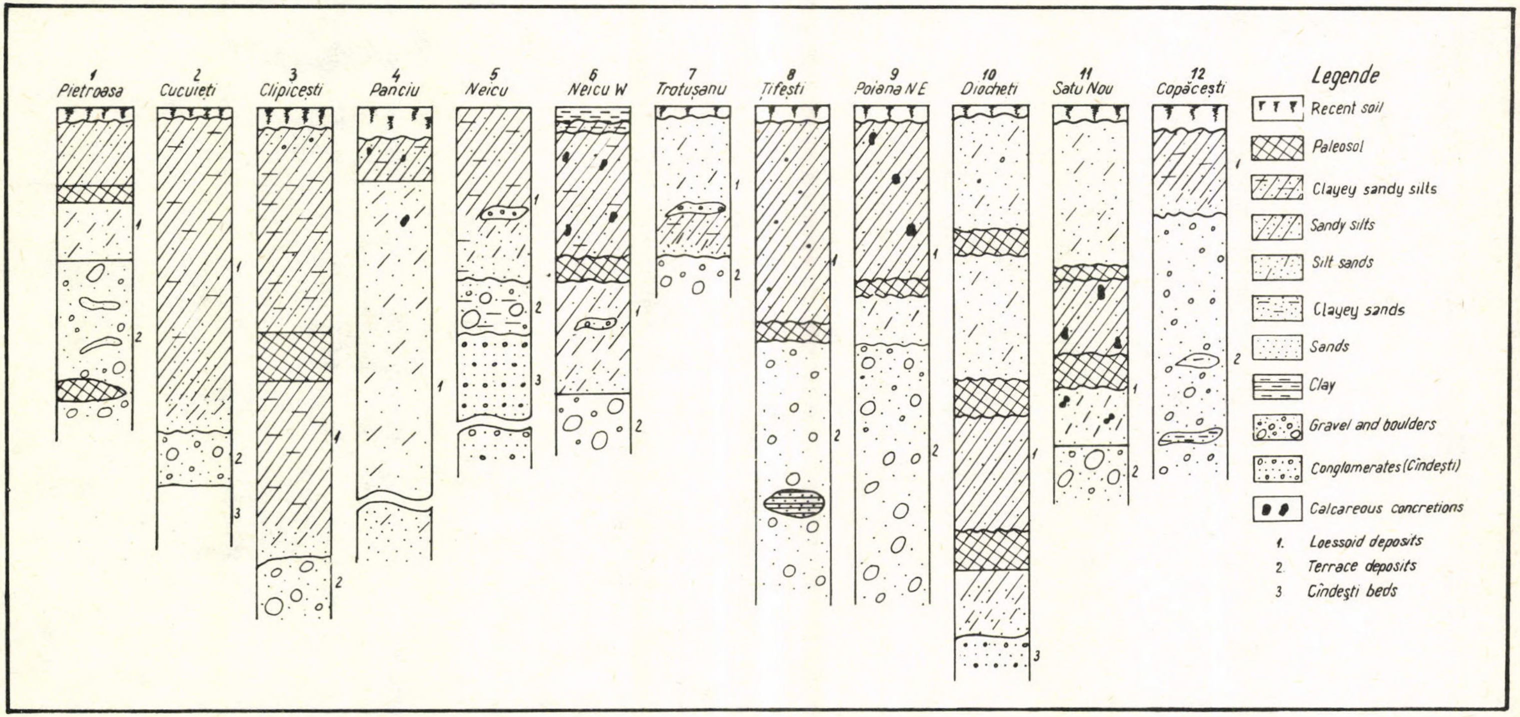


FIG. 2. Lithologic sections in the Trotuş-Milcov-Siret regions

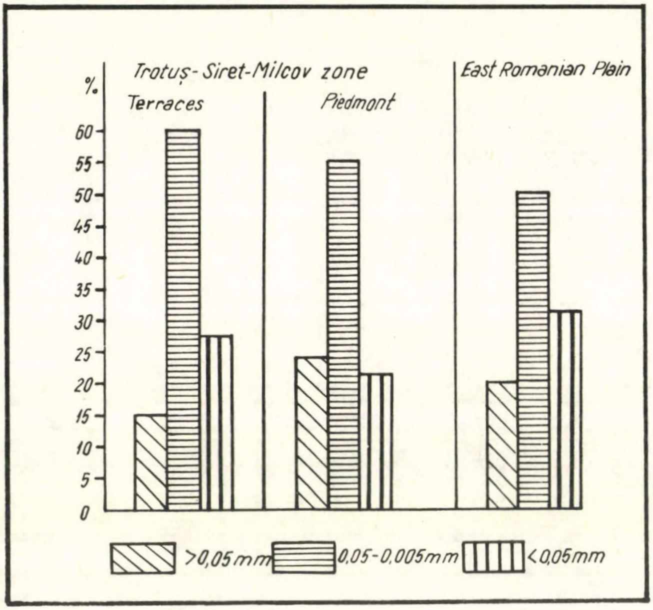


FIG. 3. Granulometric composition of loessic deposits

higher than those encountered in the East Romanian Plain (50%), on the other hand, the sandy elements (>0.05 mm) exhibit similar regional medium values (19%), which are lower in the terrace area (15%) and higher in the piedmont area (24%).

The clayey elements (< 0.005 mm) of the loess deposits occurring in this area, exhibit regional medium ratios inferior to those characteristics of the Bărăgan (24% against 31%), both on terraces (27%) and in the piedmont area (21%).

The clayey elements do constantly prevail in all the paleosoil intercalations occurring in all the lithological sections.

The mineralogical analysis of the coarse elements (>0.05 mm) points out the prevalence of the light fraction, represented by quartz, feldspars and muscovite, just like it is the case with the loess deposits from the other areas of the East Romanian Plain and Dobrogea. It varies between 75-92% (CODARCEA, V. – GHENEA, C. 1975, 1976, GHENEA, C. – CODARCEA, V. 1979).

The bulk mineralogical analyses (FIG. 4) point to increasing percentages of quartz from west to east in the Trotuş-Siret-Milcov region, similar to those mentioned for the East Romanian Plain (41% and 35% respectively).

Unlike the quartz, the muscovite prevails in this area (33%) both in the piedmont region and on terraces, as compared to the accumulations occurring in the East Romanian Plain, which do not exceed 26% (FIG. 4).

The feldspar, represented mainly by plagioclases and occasionally by orthoclasses, e.g. perthite or microcline, exhibit equal ratios for the terrace an piedmont areas (23% and 25%, respectively) on the one hand, as well as on the whole (24%) in the

Trotuş-Siret-Milcov region as compared to the East Romanian Plain (22%) (FIG. 4), on the other.

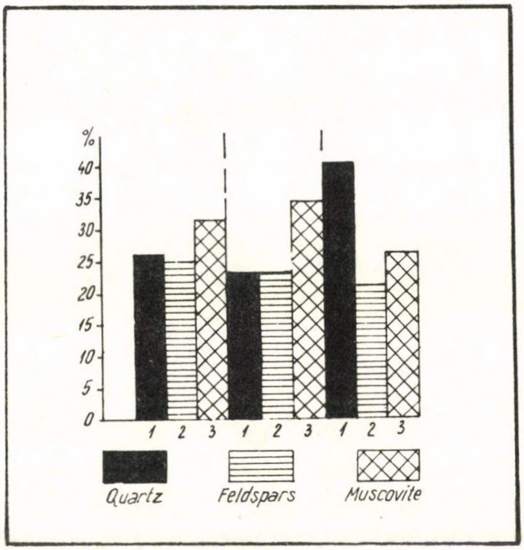


FIG. 4. Mineral composition of the light fraction

In the sandy members, the heavy fraction occurs in very small amounts (1.5 - 15%) as compared to the light fraction, these are represented mainly by oxides, garnets and hornblende, smaller amounts of epidote-zoisite, disthene-staurolite, rutile-zircontourmaline and very small or even incidental ratios of pyroxenes, sphene, monazite, brookite, anatase, glaucophane, anthophyllite, chloritoid, cordundum, sillimanite, biotite and chlorite (TABLE 1).

TABLE 1.

MINERAL COMPONENTS		Pietroasa	Cucuieți	Clipicești	Panciu	Neicu	Neicu W.	Trotusanu	Tifesti	Poiana NE	Diocheti	Satu Nou	Copăcesti	Total
Light fraction A	quartz	23.30	25,98	23,49	19.47	26,45	25.03	33.80	34,88	30,61	21,18	22,07	22.25	26,01
	feldspars	23,08	13,67	29,00	38,67	26,46	23,50	23,21	16,57	24,56	26,21	29,88	28,42	25,46
	muscovite	34,87	33,47	44,21	28,62	26,38	28.55	27.58	29,41	21,00	37,50	35,11	34,87	31,51
Heavy fraction B	garnets	25,70	19.37	33,01	23.68	26,83	23,23	27,04	26,15	23,01	28,92	19,06	31,48	25,61
	hornblende	16.54	11,78	17,15	23,11	22,05	24,01	8,17	15,24	23,28	6,28	17,16	17,87	16,91
	epidote-zoisite	2.37	3,85	4,39	1,96	3,94	5,44	3,83	2,37	3,28	3,68	8,43	4,87	4,18
	disthène	1.90	1,45	0,14	0,99	3,19	1,58	1,14	1,94	1,58	1,05	0,66	0.78	1,31
	staurolite	2,21	3.38	1,05	1,77	6,48	1,75	1,19	3,52	3,28	1,54	2,18	1.76	2,53
	rutile	6,33	15,05	10,78	8,32	2,79	6,64	18,76	15,82	9,04	10,23	8,35	8,60	10,39
	zircon	5,83	12,79	6,59	8,66	1,60	4,47	7,90	6,37	6,22	10,88	3,58	10,39	7,22
	tourmaline	1,49	1,00	1,21	0,49	—	1,67	0,53	1,25	0,73	1,38	0,76	1,17	0,92
	biotite	2,99	2,00	1,33	1,08	—	1,21	0,33	1,24	1,09	1,36	2,51	—	1,10
	chlorite	0,91	—	0,50	1,11	0,81	—	—	0,67	—	0,76	2,23	—	0.55

Both the sections from the terrace area and those from the piedmont area have constantly exhibited significant garnet ratios (25%) similar to those exhibited by the sections from Western Dobrogea and the Burnas field, but inferior to the ratios reported for the other regions of Dobrogea (35%), the southern Bărăgan (38%) and the central Bărăgan (37%) (CODARCEA, V. – GHENEA, C. 1975, 1976, CODARCEA, V. – BANDRABUR, T. 1977, GHENEA, C. – CODARCEA, V. 1979).

In the Trotuş-Siret-Milcov region, the garnets accumulate mostly within sand intercalations on terraces (32%) as against the piedmont area, where these prevail in paleosoils (30%) (FIGS. 4, 5, 6).

The green hornblende exhibits almost identical ratios (16%) both on terraces and in the piedmont areas (TABLE 1); these proportions are similar to those encountered in Dobrogea and are lower as compared to those in the south-eastern Romanian Plain, reaching 27% (FIG. 5).

The Trotuş-Siret-Milcov region is characterized by great amounts of hornblende in the silts occurring on terraces (24%) and by small amounts in sands and paleosoils. In the piedmont area, the hornblende occurs in small amounts in sands and paleosoils too

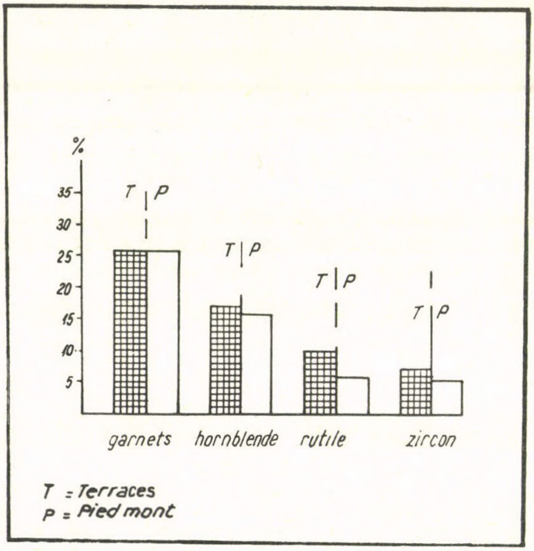


FIG. 5. Main mineral components of the heavy fraction

leading to the conclusion (in this area at least) that the hornblende amounts are equal in silts, independently of the morphological region in which they occur.

Zircon and rutile (FIGS. 5, 6) occur frequently in the loess deposits from the terraces, as compared to the piedmont area, and enter the heavy fraction by 7% and 10.39%, respectively, these proportions are obviously superior to those reported for the East Romanian Plain. As for the other minerals mentioned above, they occur in subordinate amounts.

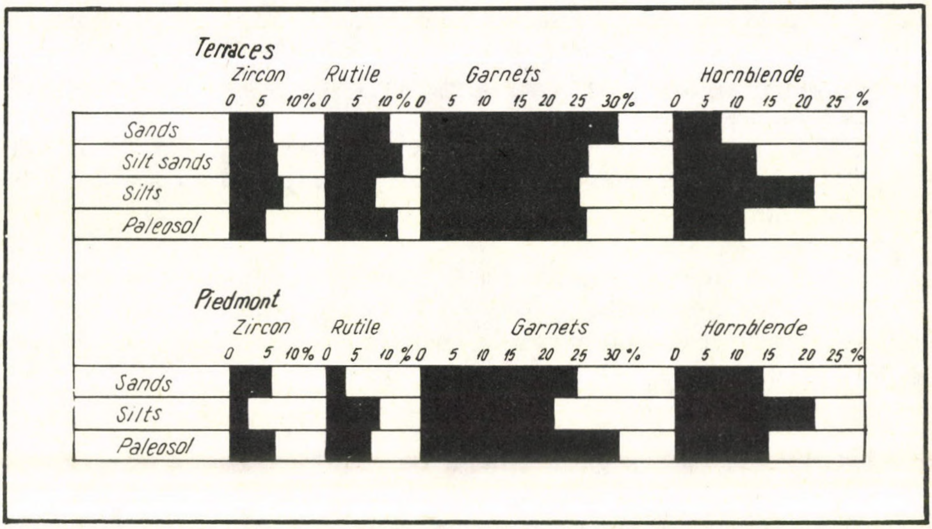


FIG. 6. Distribution of zircon, rutile, garnets and hornblende in loessic deposits from terraces and piedmont

On terraces the mineral species are more varied and occur in greater amounts due to a more intense transport of detrital material from a wider source area (situated in the hydrographic basin of the tributaries of the Siret river).

In the piedmont area, the mineral detritus is also generated by proluvial-deluvial gravitational accumulations.

We should mention another law, also pointed out by the mineralogical studies of the loess deposits from other regions of our country, according to which the low and medium-resistant minerals (hornblende and garnets) occur in great amounts, while the high-resistant ones (rutile-zircon-tourmaline-monazite) are less wide spread petrographically (occurring only as accessory minerals in primary rocks). This proportion corresponds to that mentioned for SE Europe (PÉCSI, M. 1979).

The morphoscopic features of minerals show that in the Trotuş-Siret-Milcov region, the Carpathian waters represented the transporting agent for the loess deposits, while the material was supplied by the crystalline formations, by the formations in flysh facies and by the Mio-Pliocene molasse of the Carpathian and Subcarpathian zones, which had been eroded and involved in different sedimentation cycles.

The garnets exhibit the most varied grains, represented by idiomorphic crystals, rounded or angular grains and mammilary ones. The occurrence of large and small specimens, the varied contours and mainly the breaks and scrapes on surfaces point to a mixed transport and different petrographic zones.

Rutile and zircon occur both as classical short bipyramid prisms and as rounded and broken grains, exhibiting opacitized areas, pointing to different sources and transport distances.

The occurrence of hornblende depends on the source rock, it is represented either by large prisms with well preserved contours and cleavages (granites-orthoamphibolites), or by smaller prisms broken or not, exhibiting trenchant and fringed endings (mesometamorphic schists – young eruptive). This points to a transport on long distances, most of the specimens being epidotized.

The varied morphoscopic aspects of minerals imply the occurrence of varied petrographic sources, starting from the mesometamorphic crystalline schists to the Mio-Pliocene deposits, which have been washed out and eroded by the waters that favoured the deposition of loess sediments.

There occur two paragenetic associations: garnets-hornblende and garnets-zircon-rutile. The mineralogical associations as well as their distribution point to the mixed and inhomogeneous character, while the similar mineralogical composition of loess deposits and fine-grained alluvial deposits, as well as the Carpathian and Subcarpathian sediments show that the material was supplied by these regions.

REFERENCES

CODARCEA, V. – GHENEA, C. 1975: Studii mineralogice asupra uno sedimente cuaternare în Dobrogea de S. – Dari de Seamă ale Şedintelor. 61. 1. 21-58.

CODARCEA, V. – GHENEA, C. 1976: Considerations mineralogiques sur les loess de la Dobrogea centrale et septentrionale. – Dari de Seamă ale Şedintelor. 62. l. 13-34.

CODARCEA, V. – BANDRABUR, T. 1977: Studiul geologic mineralogic al depozitelor loessoide din Cîmpia Românâ Orientală. – Dari de Seamă ale Şedintelor. 63. 1. 9-36.

GHENEA, C. – CODARCEA, V. 1979: Remarks on the loess mineralogy from Dobrogea (coarse fraction). Acta Geol. Acad. Sci. Hung. 22. 1-4. 301-305.

LITEANU, E. 1965: Contribution to the study of loess-like deposits in the Wallach Depression, Roumania. – Geol. Soc. Amer. Spec. Papers. 84. 233-245.

PÉCSI, M. 1979: Lithostratigraphical subdivision of the loess sequences in Hungary. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 367-369.

Address of authors:
Dr. V. Codarcea, T. Bandabur, Geological and Geophysical Institute,
Sosse Kiseleff, BUCUREŞTI – Romania

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

GRANULOMETRY AND FABRIC OF THE LOESS AT JIUZHOUTAI, LANZHOU, PEOPLE'S REPUBLIC OF CHINA

Edward Derbyshire

ABSTRACT

The loess at Jiuzhoutai, close to the western margin of the Loess Plateau of central China, is 335 m thick and entirely of Quaternary age, being alluvial in the lowermost 10 m. Average grain size declines with increased age and the mean sorting becomes progressively poorer. Overgrowth and cement development are also greater in the older loesses, grain shape throughout being angular to subangular. Crushed grain corners produced during salt weathering. Silt makes up over 60% by weight, up to 20% being clay grade quartz, feldspars, micas and chlorite. The microfabric consists of single grain fabric, silt-size aggregates of clay grade, fragile clay grade bridges and partially lined porewater voids. The mineralogy, grain shape, grain size, surface textures, and age range are consistent with derivation from the large, but unglaciated, central Asian deserts.

The Loess Plateau of China lies north of 34°N within the big bend of the Yellow River. It covers some 317 000 km^2 in Shanxi, Shaanxi, Gansu and Ningxia (LIU et al. 1964). The loess is at its thickest in eastern Gansu Province, the greatest known loess thickness in the world being exposed at the mountain Jiuzhoutai (2067 m), 4.5 km northwest of the city of Lanzhou.

The conventional stratigraphic subdivision of the loess of China (YAN, 1957, LIU, 1958, YAN, 1960, CHANG, 1960) is based on the type profile in the Liushu Valley, Wucheng County Shangsi, which is 121 m thick. Resting on Neogene clays, sands and gravels (containing Hipparion ssp.) is the lower, or Wucheng loess of Lower Pleistocene age. This contains 6 buried soils and is succeeded, above an unconformity, by the Lishih loess named from the type site S.S.W. of Taiyuan. This Middle Pleistocene formation is subdivided into the lower Lishih (with 15 buried soils) and the upper Lishih loess containing six buried soils or weathered horizons. A further unconformity separates the upper Lishih from the Upper Pleistocene Malan loess. A thin mantle of Holocene loess overlies this succession over wide areas.

Recent application of geomagnetic and thermoluminescence techniques to sections in the Loess Plateau indicates that the Matuyama-Brunhes boundary coincides with the Wucheng-Lishih transition (AN – WANG – LI, 1977). It has been independently confirmed (WANG – YUE – WU – CHEN – DUN, 1978) that the Wucheng loess at Luochuan shows reversed polarity with the Jaramillo normal event 20 m above the base. This also shows 14 m above the base of the Wuquanshan site in the southern suburbs of Lanzhou city. The geomagnetic chronology in the Jiuzhoutai section is not so clear. The Matuyama-Brunhes boundary occurs 105 m above the base and there are two appreciable thicknesses with normal polarity at 80 m and 58 m above the base, with a thin normal polarity layer at 44 m. Present indications are, therefore, that loess accumulation in the Jiuzhoutai section began less than 1.6 m.yr. ago (in the latter part of the Lower Pleistocene) and perhaps less than 1.2 m.yr. ago (WANG – YUE 1982). The loess of Karamaidan in the Tajikistan S.S.R., although thinner, is apparently older (2.4 m.yr.) than the basal loess at Lanzhou (PEN'KOV,A.V. – GAMOV,L.N. 1980) This raises the fundamental question of the primary causes of accumulation in different parts of the Eurasian loess belt.

At Jiuzhoutai, some 335 m of loess and loess-derived sediments rest on a fluvially planned and faulted basement of crystalline schists of the Goa Lan Group (Precambrian) and red desert sandstones of Neogene age at the level of the fourth terrace of the Yellow River. The basal Pleistocene member is an imbricated fluvial gravel about 2 m thick above which is about 10 m of finely bedded and laminated alluvial silts laid down by the Yellow River. These are succeeded by 101 m of loess of Wucheng age, overlain by the Lishih loess which totals 204 m in thickness. The maximum thickness of the Upper Pleistocene Malan loess is 34 m.

The particle size distributions of the Jiuzhoutai loesses (FIG. 1A) are predominantly in the medium and coarse silt range, with 0.5% fine sand, and clay varying from 7 to 25%. The grading envelopes of the Wucheng and Lishih formations are very similar, both lying within the much broader Malan loess envelope. The mean grain size of the Malan loess (5.2 ϕ: coarse silt) is clearly coarser than that of the underlying Lishih and Wucheng loesses (7ϕ: medium silt). Although almost all loesses sampled fall in the very poorly sorted category of FOLK, R.L. – WARD, W.C. (1957) Malan loess is distinctly better sorted than the older loesses, the co-plot of mean v. sorting coefficient (FIG. 1B) suggesting two distinct populations.

In the silt grades, quartz is the predominant mineral, usually exceeding 60%, but feldspars and micas are important subsidiary minerals. Heavy minerals average 4% of the total and include tourmaline, magnetite, epidote, hornblende and biotite. Total carbonates constitute 8-19% in the Lanzhou loess but, together with the sulphates, are generally dispersed. "Loess dolls" are rare, only small ones of $CaCO_3$ and $CaCO_4$ having been found. The palaeosols and weathering horizons in the Jiuzhoutai sections are difficult to detect by eye, as they lack the bright colours of those in the type sites of Shaanxi and Shanxi. These characteristics led WANG, WU and YUE (1978) to conclude that climates have been dry in this region throughout the past million to million and a half years. Organic contents are very low, even in the better developed palaeosols. A palaeosol analysed in the upper Wucheng loess at Jiuzhoutai displayed a gradiation with depth in both total carbonates (8.7-16.3%) and organic matter (0.8-0.44%) and a similar analysis of a palaeosol in the Lishih loess showed the same range (11.6-15% and 0.44-0.38% respectively).

The mineralogy of the clay grades (<0.002 mm) is dominated by quartz, with feldspars, calcite and illite (hydromica as ancillaries). A mixed layer clay assemblage

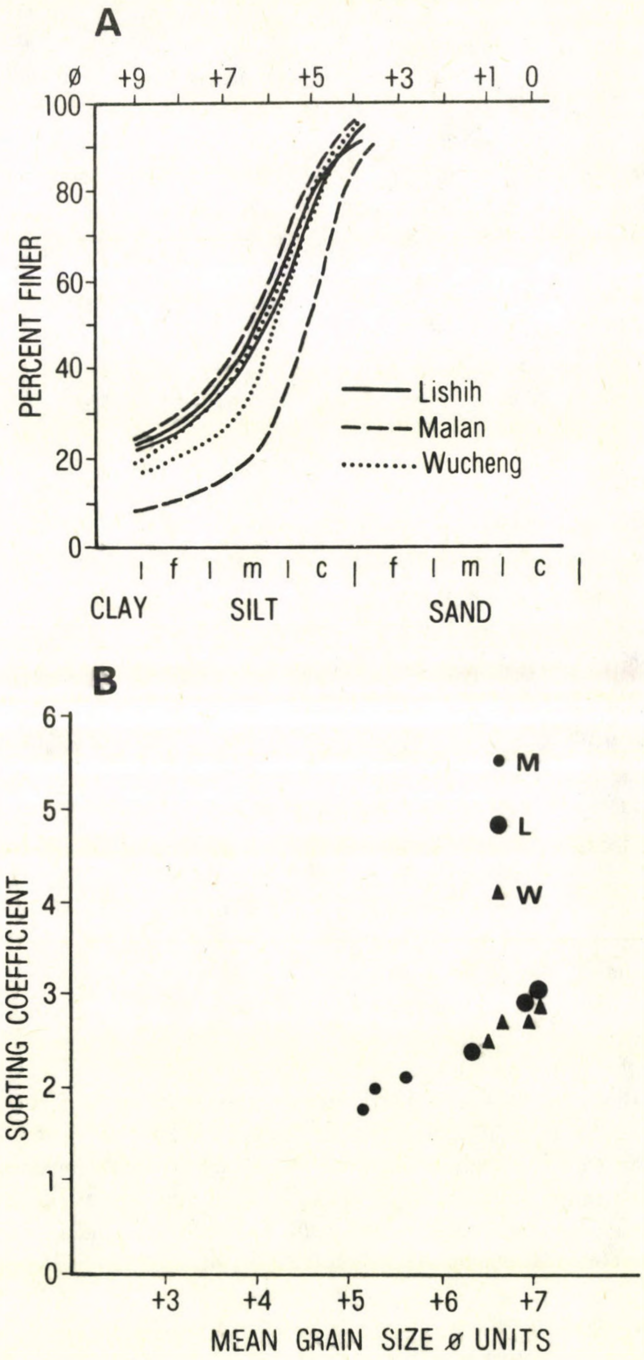


FIG. 1. A – Particle size envelopes for Malan, Lishih and Wucheng loesses at Jiuzhoutai.
B – Co-plots of mean grain size v.sorting coefficient for the Jiuzhoutai loesses.

with a broad peak at 1.4 nm is present in some samples but this does not appear to be of the smectite group. Montmorillonite, although present in tle Luochuan type section (HAN, 1982), was not detected at Jiuzhoutai. The most striking characteristic of the X-ray diffractograms of the Jiuzhoutai loess is their consistency (DERBYSHIRE, E. 1983, in press). There is, in fact no significant difference in clay grade mineralogy from Wucheng through to Malan, further reinforcing the view of WANG, WU – YU (1978), that the loess was derived from a dry, alkaline environment in which eluviation was very weak.

The Jiuzhoutai loess consists of silts of rather angular quartz, with some feldspar and mica, and minor amounts of clay-grade material, including some true clay minerals, sedimented grain-by-grain from the air. The result is a loosely-packed single-grain fabric made up of the silt "skeleton", with claygrade particles occurring as coatings, clusters and buttresses or bridges between the silts (cf. DUDLEY, J.M. 1970). The Lanzhou loess thus has a brain skeleton with essentially random disposition and some very high voids ratios (>0.8: FIG. 2A).

The character of the microfabric of the loess varies with overburden and weathering history and thus with geological age. Symmetrical silt-sized aggregates of quartz, feldspar and mica are present and probably owe their origin to deflation of flocs from desert pans and ephemeral stream courses which cover notable areas to the north of this region. Wetting and drying following deposition of the loess also induces flocculation of fines, especially with the increase in cationic concentration during decreases in pore-water content (GRIM, R.E. 1953). Clay grade aggregations of this type are drawn by the porewater menisci to the pore margins and give rise to clay bridges and coatings to be seen in loess of all ages.

Increase in compaction proportional to the overburden (normal consolidation) occurs in the loess with consequent reduction in voids ratio (VARGA, L. 1965). This "dry" compaction is essentially a process of intergranular shearing: the clay buttresses become disrupted but do not disperse. Thus, voids ratios in the Jiuzhoutai profile decrease with increasing age, from less than o.6 in the Wucheng to over 0.9 in the Malan.

A further cause of lower voids ratios (and increasing mechanical strength) is the presence of cementation. Unlike the loess in the southern and eastern parts of the Loess Plateau, in which cementation, principally of $CaCO_3$, may make up over 20% of the material, the Lanzhou loess is relatively low in carbonates. Siliceous cements are important in the older loess and X-ray diffraction has shown that iron is an accessory mineral in many inter-grain cements in the loess of Jiuzhoutai. In the Wucheng loess, silica occurs as inter-grain cements and amorphous overgrowths on silt-sized quartz and feldspar grains, significantly reducing the voids ratio and increasing the bulk strength. Clay-grade particles are held as coating by silica precipitation and as buttresses and delicate bridges between grains of silt. The fabric of the main mass of Wucheng loess just southeast of Jiuzhoutai summit at the level of Yellow River terrace 6 (2 000 m above sea level), is isotropic with abundant voids between angular, essentially clean silt grains (FIG. 2B). Silica precipitation can be seen at many grain contacts but overgrowths are not widespread. Clay grades occur mainly as clusters and buttresses. In the B-horizon of a palaeosol from the same location, precipitation of amorphous silica is widespread (FIG. 3A). It coats all silt grains and clay-grade bridges, significantly reducing porosity.

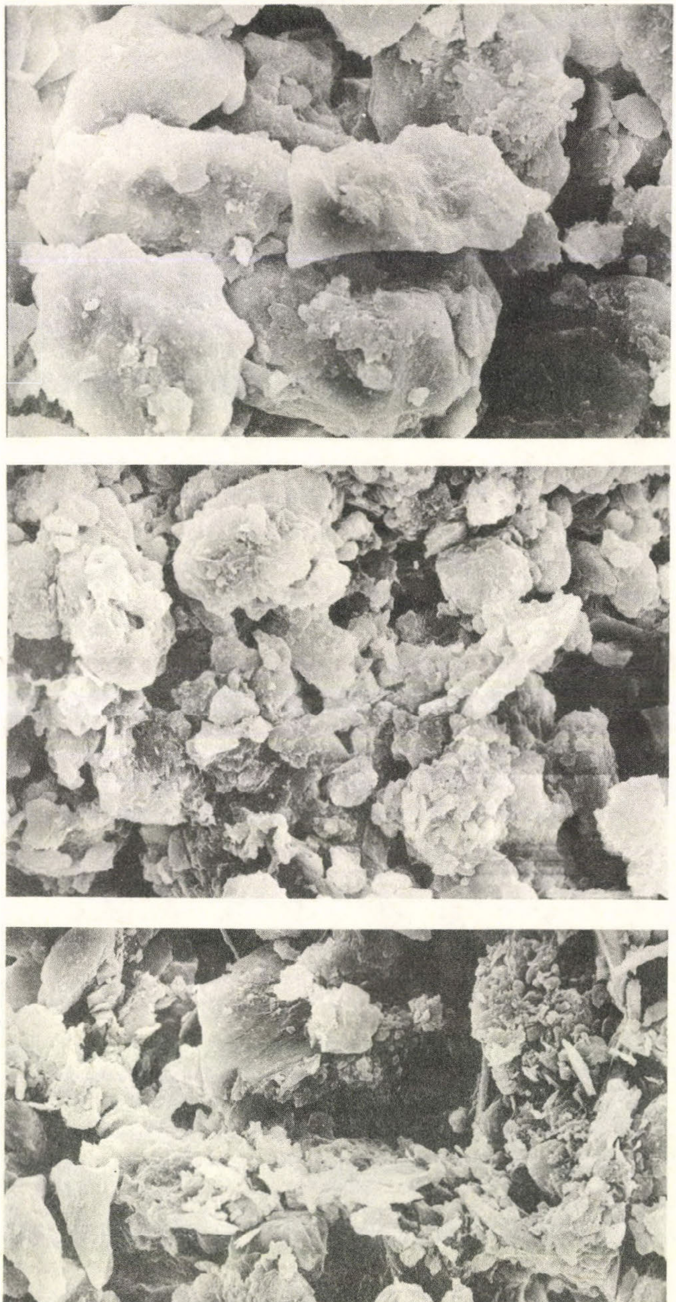


FIG. 2. Scanning electron micrographs of Malan (top), Lishih (centre) and Wucheng loesses at Jiuzhoutai. All photographs show undisturben vertical faces and are 135 nm wide

The Lishih loess at Jiuzhoutai shows similar variation. The microfabric sample from 1720 m above sea level (equivalent to Yellow River terrace 5) almost 3 km southeast of the mountain summit (FIG. 2C) shows an isotropic silt skeleton made up of rather clean, angular grains with clusters and bridges of clay-grade but few coatings and only localized examples of bridging by silicon reprecipitation (left centre of FIG. 2C). In a relict palaeosol B-horizon from the same site, however, the microfabric shows abundant clusters, buttresses and precipitates and pore-linings mainly of amorphous silica (FIG. 3B). The Malan loess has a coarser silt skeleton, higher voids ratios with clay-grade fragments making up some very delicate inter-silt bridges (FIG. 3C). Adhesion of clay platelets to silt grains is common but random: overgrowths and widespread cementation of aggregates do not occur.

When moisture contents in loess rise to saturation levels, the uncemented silts show instantaneous collapse known as hydroconsolidation. The Lanzhou loess is thus a metastable sediment and with a collapse ratio of over 10%, satisfies the collapse criteria of DENISOV, N.G. (1951) and FEDA, J. (1966).

Hydroconsolidation destroys clay buttresses, reduces the voids ratio and increases th anisotropy of the fabric (DERBYSHIRE, E. 1983, in press). This process occurs under natural conditions and much re-deposition has occurred in the Loess Plateau by colluvial and alluvial processes. Such loessic colluvium and alluvium has a distinctive microfabric, in addition to sedimentary properties such as lamination and grain sorting. The loessic colluvium from near Zhi gou men, about 14 km southeast of Lanzhou, has thin beds and laminae of silt within sandy layers dipping at 15°. These silt layers are derived from colluvial re-deposition of aeolian silt of Malan age. Their microfabrics (FIG. 3D) consist of dispersed clay and fine silt grades mantling the larger silt grains throughout. Characteristic aeolian features such as fragile clay bridges and localized clusters in the form of buttresses are absent. The microfabric of loess thus provides a menas of discriminating loess from loessic colluvium and loessic alluvium.

It has been postulated that glacial grinding is the only process capable of producing large volumes of angular silts (e.g. SMALLEY, I.J. – CABRERA, J.G. 1970) and that the Loess Plateau of China accumulated by aeolian re-deposition of glacial silts from the south (SMALLEY, I.J. 1968). On the latter point, recent re-evaluation of the evidence for Pleistocene glaciation in China (e.g. CUI, 1980, ZHENG – LI, 1981, SHI, 1982) suggests most strongly that galciers did not develop in southeast China and that, even in Tibet, ice extent was very limited. On the former point, there is accumulating evidence that weathering processes may produce large volumes of silt (e.g. RIEZEBOS, P.A. – VAN DER WAALS, L. 1974, SMALLEY, I.J. 1974). Recent laboratory experiments support the field evidence of silt production by hydration and salt crystal growth on desert plains and piedmonts (GOUDIE, A.S. – COOKE, R.U. – DOORKAMP, J.C. 1979, SPERLING, C.H.B. – COOKE, R.U. 1980, COOKE, R.U. 1981, GOUDIE, R.S. – DAY, M.J. 1981). Sand grains of York Stone treated with saturated salt solution in a simulated desert environment showed comminution and fracturing. Scanning electron microscope examination of the fragments produced in the experiments of SPERLING, C.H.B. – COOKE, R.U. (1980) show conchoidal and stepped fractures which are identical with those attributed by some authors specifically to glacial crushing (FIG. 3E). Moreover, they appear to lack the Hertzian cracks and partly-rounded corners so common on subglacially processed grains (FIG. 3F).

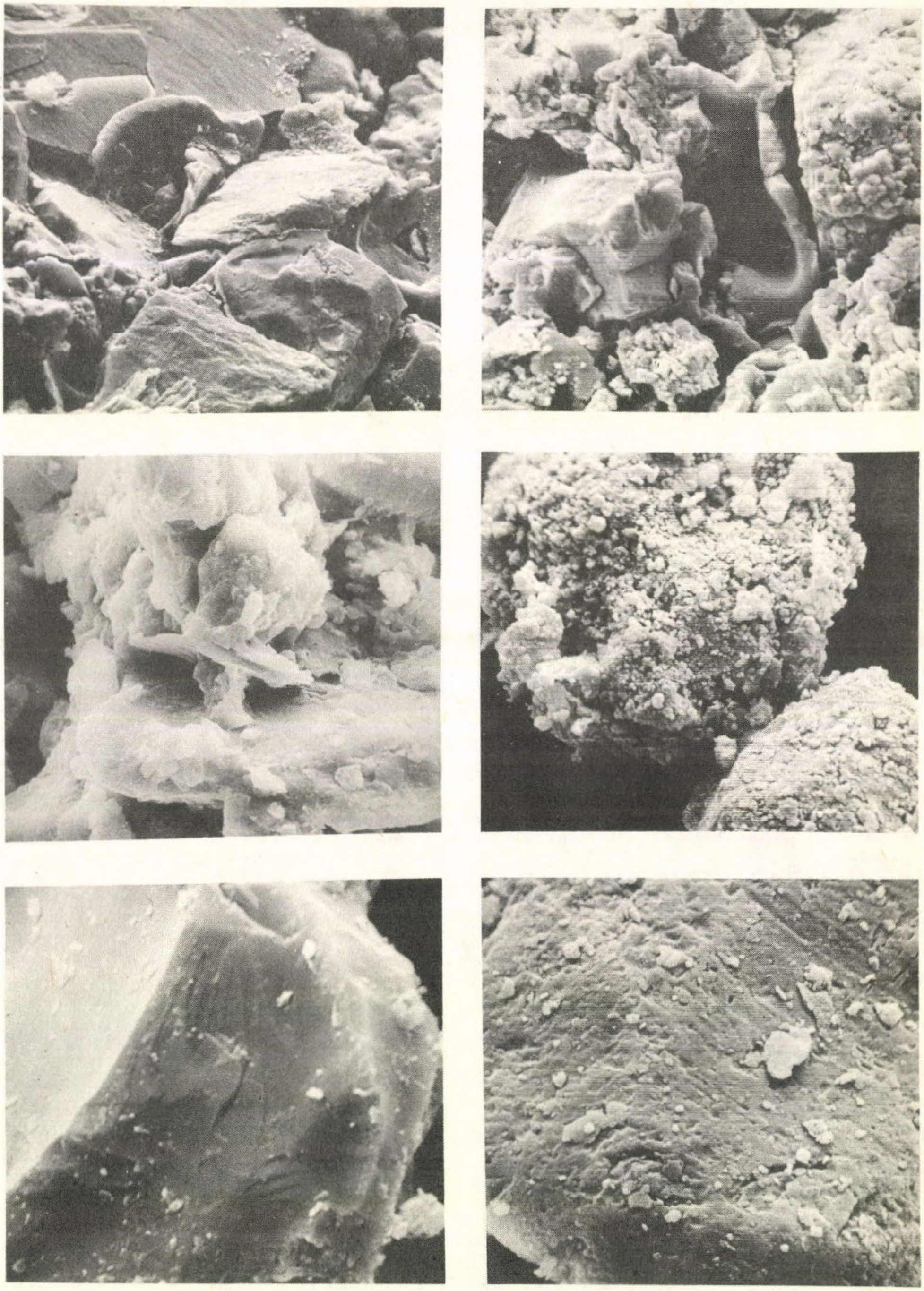


FIG. 3. Scanning electron micrographs showing the Lanzhou loess in the upper four photos (each 100 nm across) and artifically saltweathered York Stone (left) and glacially-ground coarse silt from eastern England (both c. 40 nm across)

Study of the loess at Jiuzhoutai suggests the following conclusions.

1. Particle shape, size and fabric are consistent with derivation by deflation of silts from wadis, fans and desert plains to the north and west of the Loess Plateau. The range of particle properties, including silica overgrowths and adhering platelets of clay-grade quartz are consistent with origin as desert dust described from Australia (FOLK, R.L. 1978) and the Sahara region (YAALON, D.H. 1969, WHALLEY, W.B. – SMITH B.J. 1981). A northwesterly provenance is also supported by the mineralogical studies of LIU et al. (1964, 1965, 1966). Triassic feldspathic sandstones and shales and the Neogene red sandstones which underlie the loess north of Jiuzhoutai are rich in sulphates.
2. The loess of the Lanzhou region is a product of desiccation of High Asia beginning, in the Lower Pleistocene, with the uplift by over 3 500 m in 2 million years of the Qinghai-Xizang (Tibet) Plateau and the Himalaya (LI et al. 1979). It is thus a concomitant of the essentially localized glaciation of Ouinghai-Xizang rather than a result of it.
3. The Upper Pleistocene (Malan) loess at Lanzhou is coarser-grained than the Lishih and Wucheng loess, a characteristic which appears consistent throughout the Loess Plateau.
4. Palaeosols and weathered horizons in the Lishih and Wucheng loesses show distinctive precipitation of interstitial cement, especially of amorphous silica.
5. The loess of central China, the type locality of this formation, is predominatly of aeolian origin. The microfabric of undisturbed samples of aeolian silt (loess) is quite distinctive and differs from those of silts translocated and deposited in slurries and streams (loessic colluvium and loessic alluvium).

REFERENCES

AN ZHISHENG – WANG JUNDA – LI HUAMEI, 1977: Paleomagnetic research of the Luochuan loess section. – Geochimica, 12. 239-249. (in Chinese).

CHANG, TSUNG–HU, 1980: New data on the loess deposits in China. Scientia Sinica, 9. 945-956 (in Russian).

COOKE, R.U. 1981: Salt weathering in deserts. – Proc. Geol. Assoc. 92. 1-16.

CUI ZHI-JIU, 1980: Essential features of the development of glacial landforms on Qinghai-Xizang Plateau. – Acta Geogr. Sin., 35. 137-148.

DENISOV, N.G. 1951: Settlement properties of loessial soils. Translated by KARPOFF, K.P. and H.J. GIBBS. Denver, Col. U.S. Bureau of Reclamation.

DERBYSHIRE, E. 1983: The Loess Lands. – In STODDART, D. (ed.): Physical Geography of China. Oxford (in press).

DUDLEY, J.H. 1970: Review of collapsing soils. – J. Soil Mechanics and Foundations Division of A.S.C.E., 96. 925-947.

FEDA, J. 1966: Structural stability of subsident loess soils from Praha Dejvice. – Engineering Geology. 3. 201-219.

FOLK, R.L. 1978: Angularity and silica coatings of Simpson Desert sand grains, Northern Territory, Australia. – J. Sedim. Petrol. 48. 611-624.

FOLK, R.L. – WARD, W.C. 1957, Brazos River bar. A study in the significance of grain size parameters – J. Sedim. Petrol. 27. 3-27.

GOUDIE, A.S. – COOKE, R.U. – GOORNKAMP, J.C. 1979: The formation of silt from quartz dune sand by salt weathering processes in deserts. – J. Arid Environments, 2. 105-112.

GOUDIE, A.S. – DAY, M.J. 1981: The disintegration of fan sediments in Death Valley, California, by salt weathering. – Physical Geogr. 1.

GRIM, R.E. 1953: Clay mineralogy. New York, McGraw-Hill.

HAN JIMAO 1982: A preliminary study on the clay mineralogy of the loess at Luochuan section. – In LIU DONGSHENG (ed.): Quaternary geology and environment in China. Beijing, China Ocean Press, 67-72.

LI JIJUN – WEN SHIXUAN – SHANG QUINGSON – WANG FUBAO – ZHENG BENXING – LI BING YUAN, 1979: A discussion on the period, amplitude and type of the uplift of the Qinghai-Xizang Plateau. – Scientia Sinica, 22. 1314-1328.

LIU DONG SHENG 1958: Preliminary observations on the loess of Shansi and Shensi. – Quaternaria Sinica, 1. 255-257.

LIU DONG SHENG et al. 1964: Loess on the middle reaches of the Yellow River. Beijing. Science Press, 234. (in Chinese)

LIU DONG SHENG et al. 1965: Loess deposits of China. Beijing, Science Press., 244. (in Chinese).

LIU DONG SHENG et al. 1966: Composition and texture of the loess. Beijing, Science Press, 132. (in Chinese).

PEN'KOV, A.B. – GAMOV, L.N. 1980: Paleomagnitie repery v pliocene – chetvertichnykh tolschakh yuzhnogo Tajikistanov. – In Boundary between the Neogene and Quaternary System. Moscow, "Nauka".

RIEZEBOS, P.A. – VAN DER WAALS, L. 1974: Silt-sized quartz particles: a proposed source. – Sedim. Geol. 12. 279-285.

SHI YAFENG 1982: Is there really Quaternary glaciation in the Lushan? – Problems of the Quaternary glacial deposits and landforms in China. Lanzhou, 1-6.

SMALLEY, I.J. 1968: The loess deposits and Neolithic culture of northern China. – Man, n.s. 3. 224-241.

SMALLEY, I.J. 1974: Fragmentation of granitic quartz in water. Discussion. – Sedimentology, 2l. 663-635.

SMALLEY, I.J. – CABRERA, J.G. 1970: The shape and surface texture of loess particles. – Bul. Geol. Soc. Amer. 81. 1593-1596.

SPERLING, C.H.B. – COOKE, R.U. 1980: Salt weathering in arid environments, I and II. – University of London, Bedford College Papers in Geography, 8, 9, 45 and 53.

VARGA, L. 1965: The compressibility of loess soils. – Proc. 6th Int. Conf. Soil Mech. and Found. Eng., Montreal. 395-397.

WANG YOUNG YAN – WU ZHAI BO – YUE LEPING, 1978: Constituent materials and sturctures of loess in Lanzhou and the date of its formation. – Northwest Univ. Bull. (Science Edition), 3. 1-27. (in Chinese).

WANG YONG YAN – YUE LEPING – WU ZHAI BAO – CHEN XI LING – DUN WEN, 1980: On the stratigraphic problems of the loess on the plateau north of Weihe river, Shaanxi Province in accordance with the palaeomagnetic data. – Geological Review, 26. 141-147. (in Chinese).

WHALLEY, W.B. – SMITH, B.J. 1981: Mineral content of Harmattan dust from northern Nigeria examined by scanning electron microscopy. – J. Arid Environments, 4. 21-29.

YAALON, D.H. 1969: Origin of desert loess. – In TERS, M. (ed.): Etudes sur le Quaternaire dans le Monde, Paris. INQUA. 755.

YAN, C.T. 1957: The loess of China. – Priroda. 5. 61-67. (in Russian).

YEN, C. 1960: Stratigraphy of Quaternary deposits near Po-Chi. – Quaternaria Sinica, 3. 68-103. (in Chinese).

ZHENG BEN-XING – LI JIJUN 1981: Quaternary glaciation of the Winghai-Xizang Plateau. – In Geological and ecological studies of Qinghai-Xizang Plateau. Proc. Symp. Qinghai-Xizang (Tibet) Plateau. Beijing, Science Press. 1631-1640.

Address of author:
Prof. Dr. E. Derbyshire, University of Keele, Soils Research Laboratory,
KEELE – UK

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

ZONATION AND FACIALITY OF LOESSIC DEPOSITS

A.S. Kes

ABSTRACT

Eolian and soil-formation processes are the main natural factors producing the loess and the soils of the loess red-clay formation. The deposit facies with different but quite regularly changing granulometric and mineralogical composition were formed as a result of sorting the silt in the processes of its transporting and sedimentation by the wind. The farther is the source, the finer is the soil. The soil-formation processes reflect the zonal climate and other properties of natural components. To the sediments, therefore specific properties typical of this zone are imparted. Thereby loessic deposits show zonation. The faciality and zonation of loessic deposits are expressed and traced both in space and in time. A thorough analysis of the granulometric and mineral composition of loesses, of their properties obtained as a result of soil-formation processes and peculiarities of their modern spreading are very important to the paleogeographical study of the area covered with loess red-clay formation.

The loessic deposits, spread mainly in arid, subarid and subhumid zones, have some regular characteristics which distinguish them from other deposits. They show the same properties on all continents. In addition to some unchanging properties such as colour, silty composition, presence of carbonates, typical porosity, ability to form scarps, absence of stratification, however, there are properties varying considerably from place to place and along vertical sections. The changing properties include granulometric and mineralogical composition, presence of inclusions, mainly plant and animal debris or some new forms which appeared during the process of diagenesis.

These changes are important to submit to some definite regularities combined with conditions and history of this original deposition. That necessitates a thorough and complex analysis of loessic deposits very fruitful for paleogeographic study of their regional distribution.

The examination of the granulometric composition of loess showed quite apparent variability in space in places where loess forms mantles over vast areas. These changes can be clearly observed in the direction of prevailing dust carrying winds and in different conditions e.g. on windward or leeward slopes. Such regularity is observed everywhere in Central Asia, North Caucasus, The Ukraine, Central Europe, North America etc. For instance on the plains of Central Asia loess becomes more clayey moving from the desert toward the mountains in the Ukraine and Central Europe – from the north to the south in Washington state (USA) – from south-west to the north-east and everywhere these changes coincide with the direction of presently prevailing winds or those of Pleistocene. This indicate on their facial nature.

In the piedmont plains and the mountains the loess becomes heavier with altitude. ROZANOV, A.N. (1951) examined the loesses of Soviet Central Asia and stated that light and medium loam was spread on piedmont plains and piedmonst, "the loesses of low mountains are as a rule composed of heavy loam, and the loesses of medium height mountains are of clay. Such zonal differentiation of the mechanical composition of loess is preserved everywhere in Central Asia and it is based on the regional changes". (p. 134-135). ROZANOV, A.N. explained these phenomena with hypergene processes which undoubtedly play an important role but in accordance with our data and the data obtained in other mountains these processes do not appear to be the only and are not always the determining ones.

The facial changes in loesses may be observed near large valleys where the sandy alluvium is blown off and melkozem on the watershed slopes is removed. The examination of loessical granulometric composition from one horizon of the transversal profile across such valleys shows that the farther from the river to the watershed the sample lies the heavier its composition is. Such picture have been established for the regions of the Dnieper, Don, Danube, Mississippi, Huangho and other valleys.

The aforementioned regularities are clearly observed in such classical loess countries as the Loess Province of China where loess mantles are spread over hundreds of kilometres. We analysed loess samples in two profiles there in the eastern and central parts of the Loess Province in the direction of prevailing winds from the Ordos and the Alashan deserts (the main sources of dust) southward to the mountains. The loess samples were taken from approximately the same depths and were in the similar geomorphological conditions on the crest or higher parts with similar relation to the wind watershed ouval or on the plateau surface.

Sand and clay fractions of loess have been found to change in space rather considerably and quite regularly. In the northern regions near the Ordos e.g. the loess samples contain 40-45% or sometimes more than 60% of sandy fraction, but samples from Chinlin piedmont have only 5-8%. The physical clay fraction (less then 0.01 mm) has inverse correlation changing ranging from 3-6% in the northern regions to 55-58% in the southern ones. The intermediate silt fraction changes within narrow limits: 34 to 52% (FIG. 1.). The coarse silt fraction is predominating and perhaps determining the main loess properties and makes the loesses of different geographic regions resemble to each other.

In North China loesses can be divided into four types by their mechanical composition:

1. Sandy loess with particle size less than	0.01 mm	< 10%
2. Sandy loam loess	0.01 mm	10 to 20%
3. Loam loess	0.1 mm	20 to 45%
4. Heavy loam loess	0.1 mm	> 45%

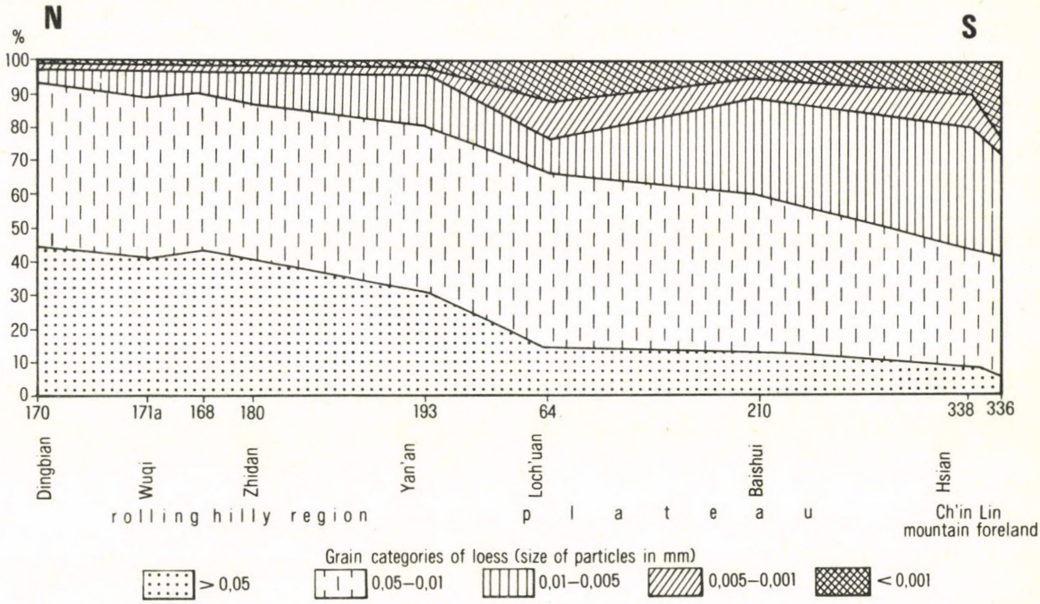


FIG. 1. Mechanical composition of yellow loess across the Loess Province (Dingbian – Hsian)

The map of loess distribution in the Loess Province (FIG. 2.) shows that the loess mantle areas occupy a well-defined zone in sublatitude direction surrounding the Ordos from the south and the east. The sandy loess zone is situated near sandy deserts, by sandy loam loess spreads to the south the loam loess is replaced sandy loam loess and, finally, near the mountains there is a zone of heavy loam.

The changes of the mechanical composition of loess coincide with prevailing wind directions and with precipitation increasing in amount to the south-east. The loam loess occupies the largest territory, the area of sandy loam loess is of half extension of the former and sandy and heavy loam loess zones cover only narrow strips stretching along the northern and southern boundaries of the Loess Province.

The mechnical composition of sandy or heavy loam loesses considerably differ from the typical one. It is doubtful, therefore, to classify these deposits as loesses is general. However, they have the same colour, porosity, carbonate inclusion and are characterized by the absence of stratification, ability to form scarps and have horizons of buried soils. The relief of sandy loess region is similar to the southern ones. There are also ravines with vertical slopes several dozens of metres high. It is of the same mantle type of deposition and correlates with other layers of loess. All these data indicate that sandy and heavy loam loesses have the same origin as the "typical" ones and relate to the same layers of genetically identical deposition.

In the sandy loess the quantity of coarse dust is equal to or less than the sandy fraction (less than 0.5 mm). The sandy fraction gradually increases to the north. Thus it is possible to observe the transition granulometric composition from loess to the thin wind-sorted sands of the South Ordos. The same can be observed for the heavy loam

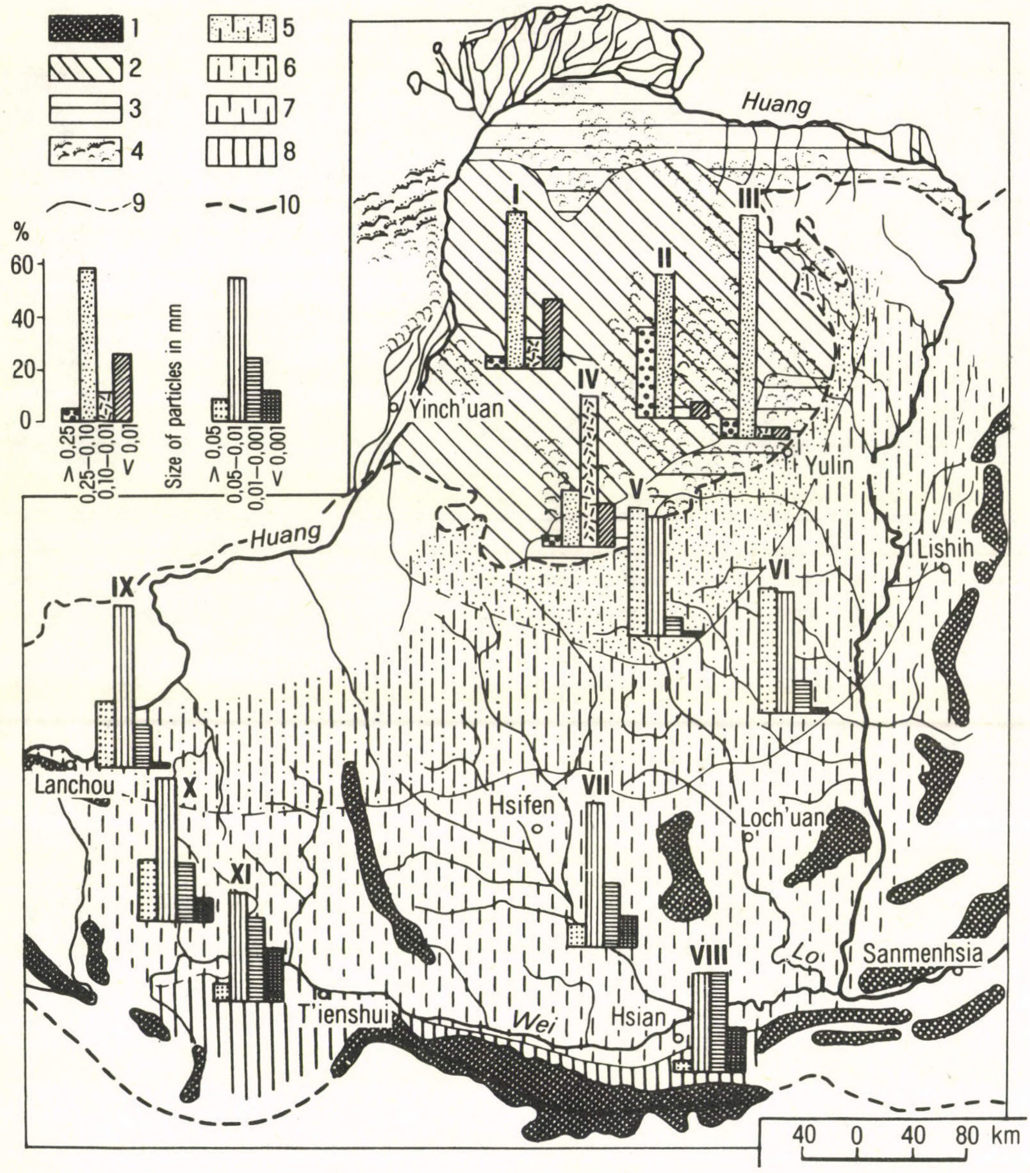


FIG. 2. Map of different kinds of loesses in the Loess Province of North China

loess. The quantity of physical clay in this loess is equal to or more than that of the coarse silt fraction and gradually increases and the heavy loam loess is replaced by the clay loess in the south.

Thus the loesses of different mechanical composition tied together by gradual transitions can be considered different facies of deposition formed by the same process changing in space and depending on the natural conditions.

The regular changes of the mechanical composition of loess in connection with its regional distribution, the coincidence of mechanical composition changes with prevailing wind direction, and the gradual transition of sandy loess to eolian sand obviously show that these changes are due to the eolian differentiation of precipitation related to the distance of the melkozem accumulation region from its source area and to the decrease of the wind velocity.

In vertical section the granulometric composition of loess also changes but not so sharply. The most essential changes are in horizons of the buried soils where the mechanical composition becomes heavier. Loesses, however, have changes of the granulometric composition on microlevel produced by the wind flow pulsation. These changes cannot be observed without special technique and have been detected by X-ray

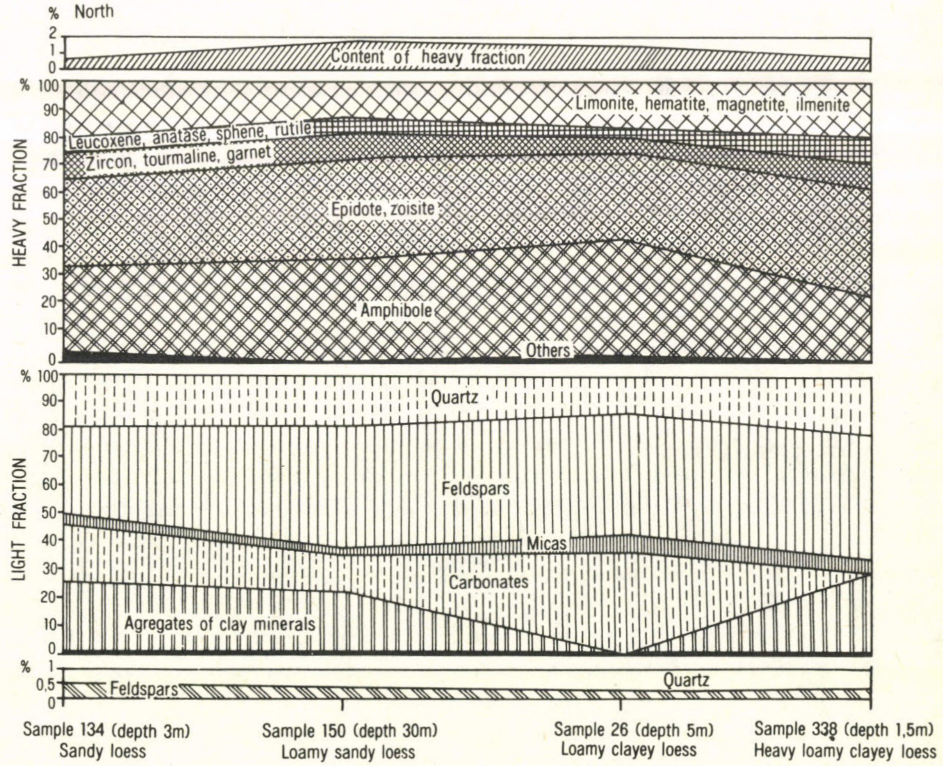


FIG. 3. Mineralogical composition of yellow loess along meridional profile across the Loess Province

radiographic tests. Having studied loesses in New Zealand by this technique, SCOTT and LEWIS (1979) noted that loess microlayers could be attributed to the effects of the melkozem brought by winds of different strength and are also due to the temporal changes of soil processes. The changes of the mineralogical composition of loess are negligible both in the vertical section and in space.

The mineralogical analysis of loess samples from the same meridional profiles of the Loess Province of China have shown only a few changes. In the heavy loam the heavy fraction contains less hornblende and the light fraction has more clay mineral aggregation (FIG. 3). This can be explained by the specific character of weathering and soil-formation processes caused by particular natural conditions and partly by the weathering products of local deposits. Few changes in mineralogical composition are worth mentioning sometimes due to the deficiency of analyses. KHALCHEVA, T.A. (1975) correctly indicated the importance of the thorough examination of not only mineralogical composition but also of the degree of weathering. Chinese loesses, however, are but poorly weathered. The weathering coefficient calculated as a relation of stable to unstable minerals varies between 0.2-0.5.

We have dealt here only with young loesses which are usually called „typical" and which were formed in the Upper Pleistocene or Holocene. But these loesses are only one of the components of a general genetic formation called Loess Red-Clay formation (KES, A.S. 1962). It contains mainly aleurite and clay without visible stratification, being of mantle-type deposition, having horizons of the buried soils and the carbonate concretions and of some characteristics specific to loesses. It indicates their similar genesis. All these deposits like the loesses consist of the dust brought by the wind accumulated on land and simultaneously reworked by soil formation processes. The common origin of all these deposits is confirmed by their regular changes of their granulometric composition in space which is the result of eolian processes.

All deposits of the Loess-Red Clay formation are characterized by regular change of mineralogical composition both in space and in time. This change is more considerable than that observed for loesses. This is the result of a longer period of formation during the Pleistocene and partly during the Pliocene. The results of the mineralogical composition analyses of the complete sections of Loess-Red Clay formation in the Loess Province of China are good examples of their changes in time. The analysis has shown that the mineralogical composition of these deposits were almost similar but the proportion of minerals considerably varies with the different layers. In the light mineral fraction the main changes occurred in carbonates which were almost absent in the buried soils and increased to 80-90 % in illuvial horizons of carbonate concretion. In the heavy fraction the main changes have been observed in the amount of hornblende decreasing from 33-41 % in the higher layer of yellow loesses to 3-8 % in the lower horizon of red clays.

Such changes in the mineralogical composition indicate more intensive weathering in the lower horizons occurring under conditions of tropical soil-formation and subsequent changes to the more arid and cold climate which is characteristic of the natural conditions of the steppes. In the background of these common changes of climate affecting all deposits of this formation, there were rather transitional climatic changes with phases of moistening, resulting in the formation of the buried soils with well developed deposits were transformed by soil- formation processes to a different extent.

The identical or similar type of the Loess-Red Clay formation structure is observed in other areas mantled by loess. In almost all cases where loess covers watersheds which kept their regime all through the Pleistocene they are underlain by brown loam, lying on red or reddish clay. The clays of Syrtovoye Zavolzh'ye are examples of such deposits. These contain the horizons (from top to bottom) yellow-brown loess loam, brown clay (DEDKOV, A.P. et al. 1961).

Similar changes in the deposits of this formation are observed in space. Under the conditions northern humid zone watersheds are mantled by brown loam and in the tropics there are red heavy loam and clay. All these similar deposits in their primary deposition should be considered as loess analogues (KES, A.S. 1966, KES, A.S. – – FEDOROVICH, B.A. 1975). Their specific zonation and faciality are due only to their eolian origin and soil formation.

A thorough analysis of all facial peculiarities of granulometric and mineralogical composition of loesses and other deposits of the Loess-Red Loam formation in combination with their properties produced by soil formation processes and with conditions of their modern distribution are very important from paleogeographic points of view concerning the regions covered by deposits of the Loess-Red Loam Formation.

REFERENCES

DEDKOV, A.P. – BURDA, V.I. – SHESTAKOV, K.A. – YASONOV, P.G. – GLEYZER, I.V. 1981: Semiarid lithogenesis and morphogenesis in the Volga region on the boundary of Pliocene and Pleistocene. – In: Klimat, rel'ef i deyatel'nost cheloveka. (Climate, relief and man activity.) Moscow, Nauka. 142-148. (In Russian).

KES, A.S. 1962: Loesses and loess-red loam deposits as eolian-soil formation. – Trudy Kommissii po izuch chetvert. perioda AN SSSR. 19. (In Russian).

KES, A.S. 1966: Eolian soil deposits, their composition, structure and peculiarity of their formation. – In: Sovremenny i chetvertichny kontinental'ny litogenez. Moscow, Nauka. 93-104. (In Russian).

KES, A.S. – FEDOROVICH, B.A. 1975: Problems of zonality and age of eolian soil melkozem (loesses and their analogues). – In: Problemy region. i obshch. paleogeogr. lessovykh i periglatsial obl. Moscow, Acad.Sci.USSR Press. 95-102. (In Russian).

KHALCHEVA, T.A. 1975: Specific of the mineralogical composition analysis of Pleistocene loessic strata of the Dnieper basin. – In: Problemy region. i obshch.paleogeogr. lessovykh i periglatsial obl. Moscow, Acad.Sci. USSR Press. 69-80. (In Russian).

ROZANOV, A.N. 1951: Grey deposit soil of Central Asia. Moscow, Acad. Sci.USSR Press. (In Russian).

SCOTT, G.L. – LEWIS, D.W. 1979: Structures in loess revealed by X-ray radiography. Bancs Peninsula. New-Zealand (Note). – N.Z. Geol. and Geophys., 22. 6.

Address of author:
Dr.A.S. Kes, Institute of Geography, Academy of Sciences of the USSR,
Staromonetny per. 29. 109017 MOSCOW – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

FACIAL CHANGES IN THE MATERIAL COMPOSITION OF UPPER PLEISTOCENE LOESSES IN WESTERN AND EASTERN REGIONS OF EUROPEAN USSR: A CASE STUDY OF VOLYNO–PODOLIA AND THE DNIEPER BASIN

T.A. Khalcheva

ABSTRACT

When determining spatial differences in Upper Pleistocene loesses we took as a basis the stability of minerals, the degree of weathering of the minerals was determined by grains morphology and by the ratio of mineral groups differing in degree of stability, i.e. by coefficients of weathering. The comparison of data on the Dnieper basin with more westward regions has shown that in the west there were an increase in the degree of weathering of minerals and a growth of the value of weathering coefficient up to 1. All these data correspond with results of palynological, faunistic, cryological and other analyses and they indicate the epoch of the Upper Pleistocene loess formation to favour weathering much more in western regions than in regions situated further to the east. Climate of that time in Volyno-Podolia was more humid.

Loess and loess-like deposits of the last Valdai (Würm) glacial epoch are widespread within the European USSR. They are distributed from the southern boundary of the fluvioglacial deposits adjoining the galcier margin in the north to the coastal Ponto-Caspian regions in the south (FIG. 1).

The Upper Pleistocene Valdai loesses are observed here in regions overlapping the distribution areas of more ancient Middle Pleistocene (Dnieper) and Lower Pleistocene (pre-Dnieper) loesses.

The loess deposits of the European USSR were studied during many years by a group of scientists from the Department of Paleogeography (Institute of Geography, USSR Academy of Sciences) under the leadership of prof. VELICHKO, A.A. The investigations were conducted on the left bank of the Dnieper, in the middle of an extended loess sequence, which was compared with the sections of Volyno-Podolia in the western regions.

According to the data of VELICHKO, A.A., the structure, composition and stratigraphy of the Upper Pleistocene loesses regularly change along a meridional section from north to south. In the north the Upper Pleistocene loess sequence is represented by one horizon. In the middle part of the profile it is well stratified and is subdivided into three horizons, among which the loess II is distinguished the best of all. In the southernmost loess zones, where the Valdai loesses overlie the thick, more ancient loess-soil series, they again are represented by a single, undivided horizon.

The mineralogical composition of loess deposits was studied by the immersion method. The most numerous, and from mineralogical aspect best represented fraction of 0.1-0.01 mm was analyzed.

The mineralogical analysis is here a part of the general paleogeographic one, which also includes the palynological, paleopedological, paleocryological and other analyses.

The mineralogical analysis was carried out in order to determine the degree of weathering of minerals in loesses. As it is known, the degree of preservation of minerals depends mainly on the climate during the period of sedimentation. According to the Ostwald's rule, 10 °C rise of temperature makes the chemical reactions go on at twofold higher rate. The investigations by GRIGORIEV, FERSMAN, SHVETSOV, RUKHIN, GLASOVSKAYA, SHUMILOVA, SIDORENKO, KAZANSKY, GINZBURG, STRA–

FIG. 1. The scheme of distribution of loess deposits in the European USSR
1 = distribution areas of loesses, 2 = sections

KNOV, etc. showed the weathering processes to be the most intensive under hot and tropical climatic conditions.

The intensity of weathering processes sufficiently decreases in the zones of moderate climate. The processes of weathering and leaching occuring here are 20-40 times slower than in the moist tropical-forest zone. The processes of chemical and physical weathering are approximately equal.

Weathering processes in the desert zone have some peculiarities. The deserts are generally characterized by a low degree of weathering. Physical weathering prevails here, while the chemical one goes on at a low rate due to the lack of moisture.

In the dry and cold regions (for instance in alpine deserts) weathering processes are similar to those in the hot deserts where the physical weathering is of great importance due to slowing down of the chemical one.

The change of climatic conditions does not equally affect the transformation of all the minerals. Such an important factor as the stability of minerals comes into force. The stability of minerals in the weathering crust depends on their chemical composition, preculiarities of their structure and character of geochemical processes which form the residual deposits.

The degree of weathering is determined by the ratio of mineral groups differing in stability. In this very case the coefficient of weathering, representing the relation of the most stable minerals (zircon and tourmaline) to the least stable one (hornblende), was used.

The evaluation of morphological peculiarities of mineral grains, the degree of preservation of their surfaces, margins, the intensity of colouring, etc. are of great importance.

The study of the mineralogical composition of the Upper Pleistocene loess horizons in the central and western regions of the Russian Plain was based on these principles.

For all the sections under study the composition of minerals in all the Valdai loess horizons has turned out to be homogeneous. The heavy fraction is extremely low (to 0.5%). But it is these minerals which are of the greatest interest for the evaluation of mineral stability. The heavy fraction includes ore minerals, those of titanium-bearing limpid group (mainly sphene, rutile, rarely brookite and anatase, tourmaline zircon, garnet, from the amphibole group mainly hornblende, from the epidote group mainly epidote, rarely zoistite, biotite, rarely kyanite, staurolite, apatite).

Quartz predominates in the light fraction. In sufficiently lesser numbers feldspars (mainly orthoclase, rarely plagioclase and microcline) as well as carbonates (calcite, rarely dolomite), muscovite and clayey-micaceous aggregates were found. Furthermore, the presence of glauconite and volcanic glass was recorded in the middle reaches of the Dnieper.

Thus, the Valdai loess sequence is homogeneous in mineralogical respect which makes it possible to suggest the absence of single strictly localized sources of wash away during the loess accumulation. Apparently the mineral mass of loesses is the remaining one after repeated redeposition and mixing of mineral from many different sources.

Before comparing the western and eastern loess regions we shall characterize the loess deposits from the Dnieper basin since they were studied in detail along the meridional profile from Smolensk to the Azov region.

On the whole the degree of weathering of the Valdai loesses does not differ much along all the loess profiles. The minerals are characterized everywhere by a great freshness. The traces of weathering in the form of accumulation of pelitic material in the fissures of junction were recorded only on the grains of unstable minerals (hornblende, epidote, feldspars). Other minerals were not practically transformed by weathering, while the most stable ones, such as zircon, tourmaline, garnet and titanium-bearing minerals (mainly rutile) looked very fresh without any traces of weathering. The mean value of weathering coefficient, i.e. the relation of quite stable minerals (zircon and tourmaline) to the unstable ones (hornblendes) is low, comprising 0.32 of the Upper Pleistocene loess (FIG. 2).

It should be•marked that in this region more ancient loess horizons have higher coefficients of weathering. These values for the Middle Pleistocene (Yarmolintsy) and Lower Pleistocene (Khorol) loesses comprise 0.70 and 1.28, respectively.

It should be mentioned that only the most representative loess horizons, those the least transformed by soil-forming processes, are under discussion. Those horizons that were changed by the superimposed fossil soils (for instance, the Lower Pleistocene pre-Dnieper loess horizons I and III) were not taken into account. The degree of weathering of minerals in these horizons increases owing to the soil-forming processes.

When following the Upper Pleistocene Valdai loess horizons from the north to the south the degree of weathering of their minerals turned out to change very little, which confirms the occurrence of similar hyperzonal conditions in all the extra-glacial region during the Valdai glaciation. However, some increase of the degree of weathering in the southern regions in comparison with the northern ones within the single hyperzone is observed (FIG. 3). It is expressed in an insufficient rise of the weathering coefficient values (from 0.19 in the north to 0.50 in the south) and in the changes of mineral grain margins, discolouring of the grains of coloured minerals). This is indicative of quite

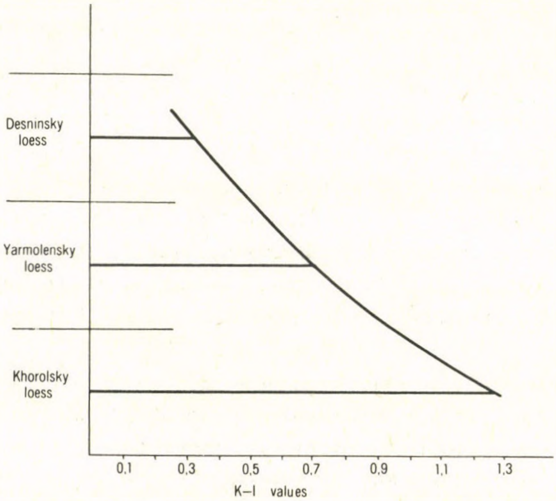


FIG. 2. Changes in the degree of weathering for loesses of different age.

small differences in the degree of transformation of the material by chemical weathering preocesses, i.e. of small-scale climatic fluctuations within the hyperzone associated with latitudinal differences.

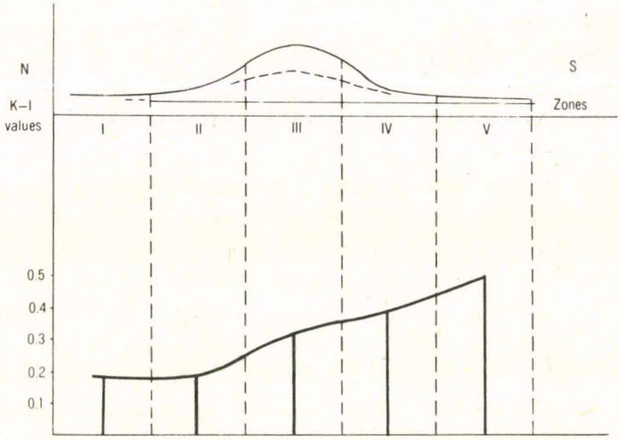


FIG. 3. Changes in the degree of weathering for the Valdai loesses from north to south

In the western regions of Volyno-Podolia the minerals of Valdai loesses are mainly the same as those from the Dnieper basin. The degree of weathering here, however, sharphly increases. The weathering coefficient rises up to about 1 (FIG. 4). Clear traces of weathering, such as accumulation of pelitic material in the fissures of junction, thinning of grain margins and discolouring of the grains of coloured minerals, are ob-

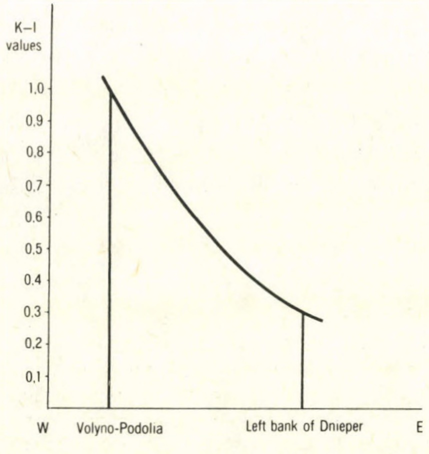


FIG. 4. Changes in the degree of weathering for the Valdai loesses from west to east

served on the particles of unstable minerals. This is the evidence of greater transformation of the Upper Pleistocene loess minerals by the chemical weathering processes in Volyno-Podolia than in the eastern regions which evidently resulted from the greater moistening of this area.

On the whole the research of mineral composition of the Valdai loesses on the Russian Plain confirms the palynological, faunal, cryological and other data available for this region and supports the suggestion that during accumulation of the loess sequence in the vast hyperzone of the extra-glacial regions the most severe, cold and dry climatic conditions occured in the Late Pleistocene compared to the older Pleistocene intervals.

This period was characterized by the accumulation of the typical loess with its peculiar granulometric composition: high degree of sorting, prevalence of silt fraction with quite insufficient admixture of coarser and finer material. In the opinion of ZEUNER, just this granulometric composition makes it possible to distinguish loess from all other types of sediments. It results from the fact that the source of loess particles must be the region with relatively arid (frosty) climate, where the physical weathering prevails over the chemical one which leads to the destruction of rocks to the silt size. Sparse vegetation cover contributed to this process. Thus the loess silt represents a certain climatic formation which resulted from the physical weathering process under the conditions of continental climate.

The extreme continental conditions contributed to the further transformation of silt into loess rock since only silt is able to assume the characteristic features of loess.

The upper Valdai loesses in all the vast extra-glacial territory of the Russian Plain are characterized by a good preservation of minerals which is indicative of the occurrence of servere conditions in this period. The latitudinal climatic changes were quite insufficient.

Some mildness of climate expressed in greater humidity was recorded only in the west region of Volyno-Podolia which led to conditions favourable for more active weathering processes.

The presence of somewhat milder conditions in the late Valdai to the west of the Russian Plain is confirmed by the data of VELICHKO, A.A. and NECHAYEV, V.P. on the study of cryogenic phenomena which proved the occurrence of rather cool but humid conditions in summer during that period. GURTOVAYA, E.E. has made the same conclusion on the basis of palynological data.

Accordingly under the conditions of the hyperzone in the extra-glacial region the climate of western portions of the Russian Plain was characterized by somewhat higher humidity.

REFERENCES

BOGUTSKY, A.B. – VELICHKO, A.A. – NECHAEV, V.P. 1975: Paleokriogennye protsessy na zapade Ukrainy v verkhnem i srednem pleistotsene. – In: Problemy region. i obshch. paleogeografii lessovykh i periglyatsialnykh oblastei. Moscow, Inst. Geogr. AN SSSR. 80-90.

GURTOVAYA, E.E. 1981: Rekonstruktsiya prirodnykh usloviy bryanskogo intervala poslednei lednikovoi epokhi dlya yugozapada Russkoi ravniny. – Doklady AN SSSR. 257. 5. 1221-1228.

KHALCHEVA, T.A. 1975: Spetsifika izucheniya mineralogicheskogo sostava lessovoi tolshchi pleistotsena basseiny Dnepra. – In: Problemy region. i obshch. paleogeografii lessovykh i periglyatsialnykh oblastei. Moscow, Inst. Geogr. AN SSSR. 69-80.

VELICHKO, A.A. 1973: Prirodny protsess v pleistotsene. Moscow, Nauka. 255.
VELICHKO, A.A. – KHALCHEVA, T.A. 1982: Pozdnepleistotsenovye lessy i ikh rasprostranenie. – In: Paleogeografiya Evropy za poslednie sto tysyach let. Moscow, Nauka.

Address of author:
Dr. T.A. Khalcheva, Institute of Geography, Academy of Sciences of the USSR,
Staromenetny per. 19. 109017 MOSCOW – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

SEDIMENTOLOGICAL, MINERALOGICAL AND GEOCHEMICAL CHARACTERISTICS OF THE LOESSES OF NORTH–WEST FRANCE

J.P. Lautridou – J. Sommé – M. Jamagne

ABSTRACT

A large extension of the loesses is found in North-West France. A marked homogeneity is evident particularly in relation to granulometry and geochemical characteristics. A type-section (at Roumare, near Rouen in Normandy) is considered and detailed analytical information is provided.

PROBLEMS OF TERMINOLOGY IN FRANCE

The term „loess" is used in a broad sense (cf. INQUA Loess Commission) to describe a silty sediment deposited in a periglacial environment in which erosion and sedimentation are dominated by wind action and specific biological processes (the loessification of LOŽEK).

On various French maps (showing geology, geomorphology, soils and surface deposits) the distinction which is sometimes made between loess and loam often corresponds to a restrictive definition of the former based either on a theoretical genetic interpretation (the idea of reworking) or a consideration of accessory criteria (calcium content for example). Moreover, the concept of „plateau loams" („limon des plateaux"), a cartographic category used to indicate the stratigraphic cômplex of loesses and associated deposits, can be criticised in that it introduces a topographic criterion which does not apply to instances where loesses completely cover the largest part of the landscape, which neglects loesses occurring as slope deposits, and which implies a reworking on slopes subsequent to deposition. The misleading nature of this cartographic concept as well as that of the colluvium (old „limons de lavage") derived from, and associated with it, should be revised because of the possible influence on basic information from geotechnical, geomorphological and soil surveys.

A. Regional segregation of loesses and paleosols according to clay ($< 2\mu m$) content. 1 = low, 2 = medium, 3 = high, R = Roumare, ME = Mesnil-Esnard, L = Lambersart (Lille), SQ = St Quentin, LH = Le Hamel

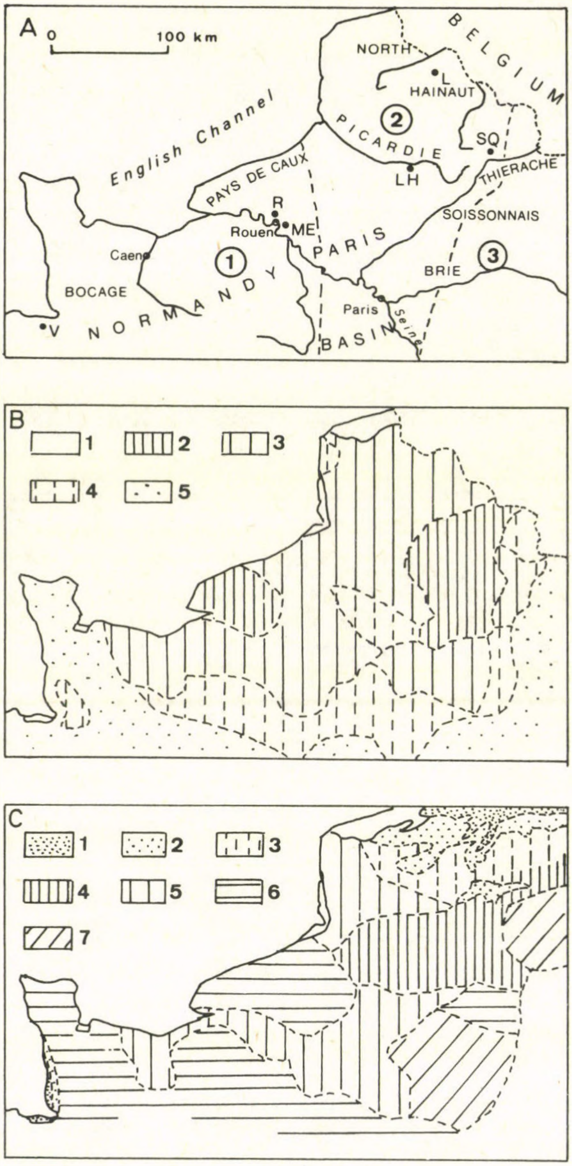


FIG. 1. Distribution of different loess types in north-west France

B. Extent and thickness of loesses. 1 = Marine Holocene, 2 and 3 = continuous cover. Thickness: 2 = greater than 5 m, 3 = less than 5 m, 4 = discontinuous cover of varying thickness, 5 = patchy distribution

C. Types of loess and eolian formations. 1 = cover sand, 2 = sand and silts (transition zone), 3 = typical cover loess (upper Weichselian) lying on (sandy) – silty formations, 4 = typical loess, 5 = typical loesses (Late Pleistocene) and ,,limons à doublets." or bedded loesses (Middle Pleistocene), 6 = ,,limons a doublets" and brown loess, 7 = clayey loess.

The loesses comprise, in fact, a large group of the class of eolian sediments which also include cover sands and transitional sandy-silty deposits. A number of different categories can be recognised according to a system of periglacial eolian zonation (FIG. 1.) These deposits possess a characteristic texture or granulometry the nature of which depends on the competence of eolian activity. The loesses are thus silty rocks (in which the silt (2. – 50 μm) fraction constitutes between 60-80% dominated by coarse silt (20 – 50 μm) and a fine sandy (50 – 80 μm) fraction. The relationship between these components is such that the ratio $\frac{20 - 50\ \mu m}{2 - 20\ \mu m}$ is always greater than 1 and is most often greater than 2.

LOESS TYPES AND THEIR DISTRIBUTION

Since north-west France belongs essentially to the loess zone which is found across the Netherlands, Belgium and norhern France, this zone comprising sandy, sandy-silty and silty components (PAEPE, R. – SOMMÉ, J. 1970), tehere is a relative homogeneity within the surface deposits. In establishing the distribution of the various loess types, recouse is made to differences in the extent of surface cover and thickness of deposits, and to facies variations.

The typical loess is easily distinguished. Distinctive characteristics are a pure silt texture (dominated by the 30 – 60 μm size fraction), a fine porous structure lacking any apparent bedding, a yellow to brown-yellow colour, and the frequent presence of $CaCO_3$ in a diffused state. The last of these characteristics permits a subdivision within the loesses, the absence of *carbonate* being either original or due to post-depositional decalcification: this subdivision can have some geographical significance (e.g.: Normandy) or, on the other hand, be unclear (e.g.: the North).

Atypical loesses are distinguished according to structural variations (bedding) and differences in texture, or can be identified by the influence of substrate, a factor not found with typical loesses (FIG. 2).

Notable within the group of bedded loesses is the noncarbonate type known as ,,limon à doublets" which is characterised by alternating brownish and yellowish beds consisting of more or less clay. Contrary to some previous statements, the ,,limons à doublets" are not formed by reworking of an original loess by meltwater or gelifluction. They are in fact loesses which have undergone decalcification during deposition, this process releasing fine clay ($< 0.2\ \mu$m) and iron which migrated into thin bands generally between 2 and 10 mm. in thickness (LAUTRIDOU, J.P. et al. 1981).

Further, periglacial meltwater has participated in the deposition of other badded loess types which belong to a large group of bedded formations having in common the same sedimentary structure i.e. multiple lines of small ice wedges, sometimes accentuated by a grading (SOMMÉ, J. 1975). These bedded silty formations can incorporate elements of the substrate (sand, flint, gelifracts).

In addition, clay content is an important distinctive criterion for the definition of paleosols (Bt) and some clayey loesses which sometimes contain more than 25% of particles smaller than 2 μm. Some systematic regional differences can be observed similar to the general differences between loesses and more clayey Weichselian and pre-Weichselian soils.

Various types of loess can be differentiated according to textural variations, coarser elements, which allow stratigraphic associations to be made, and sedimentary, structural and pedological characteristics. A further distinctive criterion is the grain size distribution curve which provides information on characteristics which are constant over long distances. This has been recognised since the 1940's, but, its precise use has been developed only by some recent detailed research. This criterion is now considered.

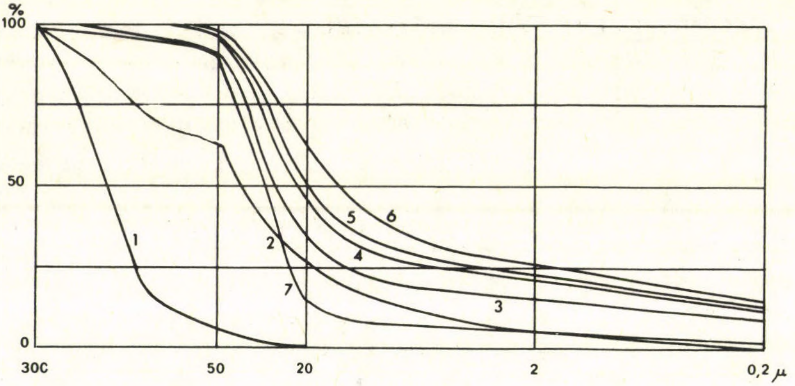


FIG. 2. Typical grain size distribution curves of wind-blown periglacial sediments
1 = cover sand, 2 = loess and sand, 3 = ,,limons à doublets" of the ,,Pays de Caux", 4 = loess of Soissonnais, 5 = loess of the North, 6 = loam of Brie, 7 = Loess of Caen

This grain size distribution curve of a loess is sigmoidal (FIG. 2) with a very straight median section (between 10 and 50 μm) indicative of a well sorted sediment of a median particle size generally between 20 and 30 μm. This sigmoid has two further characteristics: the upper (sand) portion of the curve being very limited as compared to the lower section, and the gentle gradient of the lower section, due to the large amount (sometimes more than 50%) of fine (< 0.2 μm) clay as a proportion of total clay content (LAUTRIDOU, J.P. 1979) (FIG. 3). It is necessary to emphasize the difference between calcareous and noncalcareous loesses in this respect (FIG. 3). Thus, in the North, the percentage of fine clay as a proportion of total clay content varies between 62 and 78% for non-calcareous loess as opposed to between 34 and 58% for calcareous loess, in Picardie, values vary between 40 and 56% for the former and between 32 and 42% in the case of the latter, and in Normandy, the relevant values are between 50 and 70% and 35 and 45% respectively.

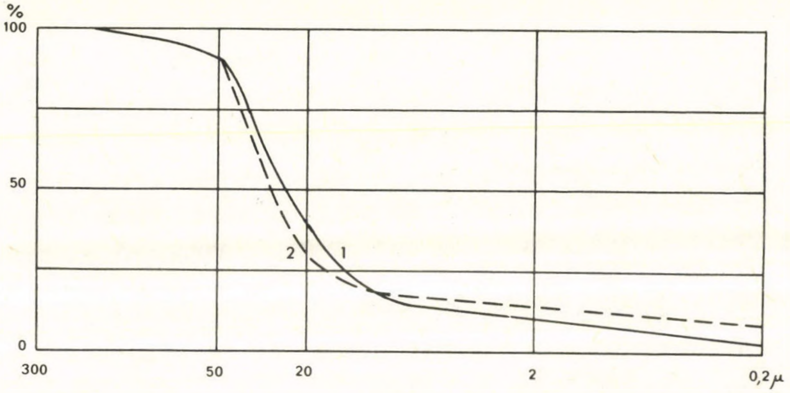


FIG. 3. Comparison of grain size distribution curves of calcareous (1) and non-calcareous (2) loesses from the „Pays de Caux"

From the point of view of granulometry, there are some notable differences between the provinces of the region under consideration (FIGS 2 and 4). For example, in the case of the superficial loesses of the North and Normandy, the latter contain less clay and are a little more sandy. The loams of Picardie, Marlois and Soissonnais resemble those of the North. However, if one considers formations adjacent to the cover loess, other regional limits become evident isolating in particular the plains of the western loamy zone of the North (SOMMÉ, J. 1977) (FIG. 1).

In relation to the clay (< 2 μm) content, a general zonation can be outlined (FIG. 1) which shows an enrichment in clay within loesses, and especially in palaesols, towards the North and the central eastern part of the Paris Basin. The case of the particularly clayey loams of Brie (FIG. 2) is due to the presence of old weathered loess generally found below outcrops. In general, the old loesses (pre-Weichselian) are non-carbonate types and contain more clay than the recent silts.

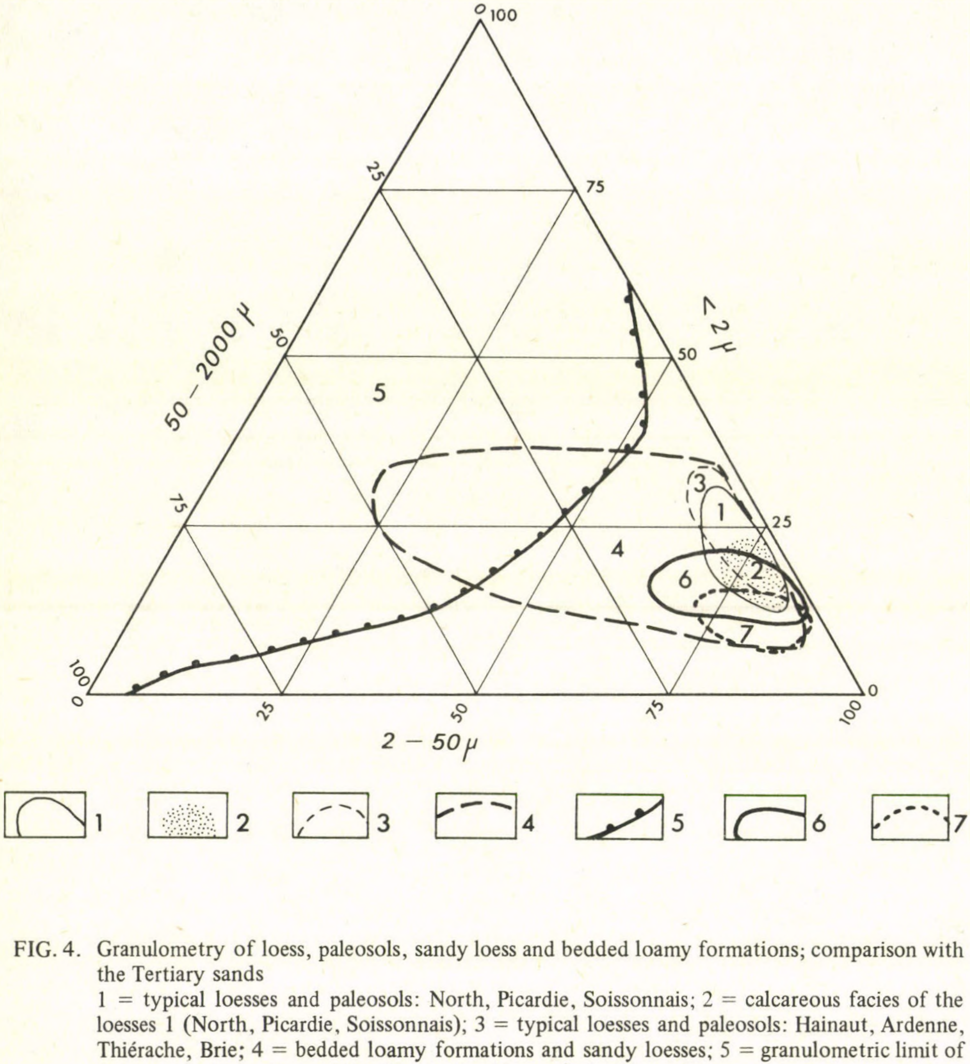


FIG. 4. Granulometry of loess, paleosols, sandy loess and bedded loamy formations; comparison with the Tertiary sands

1 = typical loesses and paleosols: North, Picardie, Soissonnais; 2 = calcareous facies of the loesses 1 (North, Picardie, Soissonnais); 3 = typical loesses and paleosols: Hainaut, Ardenne, Thiérache, Brie; 4 = bedded loamy formations and sandy loesses; 5 = granulometric limit of the tertiary formations of the North; 6 = limons à doublets of Normandy; 7 = typical calcareous loesses of Normandy

With regard to mineralogy, the sand and silt fractions are comprised essentially of angular to subrounded flat quartz grains, with a small amount of feldspar, variable amounts of muscovite and chlorite (abundant in Upper Normandy), heavy minerals, some detrital ferruginous concretions and, sometimes, calcium carbonate. The percentage of calcium carbonate is low in the West (< 12%), except around Caen (up to 20%).

It increases in the North (up to 16%), in Picardie, and in the central eastern part of the Paris Basin (between 10 and 20%). The epidote-amphibole association, which is dominant in Normandy (for Weichselian loesses) decreases progressively towards the east whilst ubiquitous heavy minerals (zircon, tourmaline, rutile) increase (regional origin). This phenomenon can be explained by the fading out towards the interior of the sediments of marine origin (floor of the English channel, fossil Seine estuaries), These being replaced by loams derived from valley alluvium and from the Seine in particular. The old loesses are different, the suite of ubiquitous minerals (zircon, tourmaline, rutile) predominating.

The < 2 μm fraction is dominated by clay minerals. Kaolinite and illite are present in smaller amounts than vermiculite and smectite, except in the Bocage region of Lower Normandy. Chlorite is also present, but irregularly: it is found especially in the Bocage region of Normandy (Baie du Mont-Saint-Michel), in the Western Picardie and in Upper Normandy.

Recent chemical analyses of loesses are few in number (JAMAGNE, M. 1973, LAUTRIDOU, J.P. in press). Silica dominates over aluminium (75 to 82% and 7 to 10% respectively). Total iron content varies between 2.5 and 3.2%, but the „limons à doublets" of the Bocage region of Normandy can contain up to 4%, similar to the oldest paleosols of Normandy and Brie. Generally the above values are quite constant.

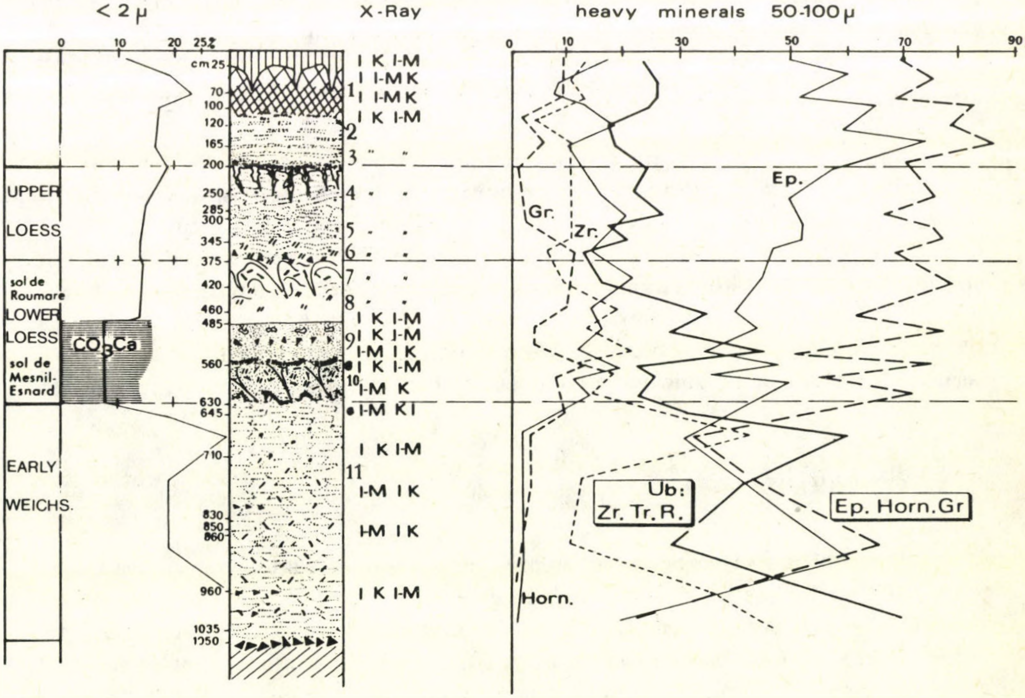


FIG.5. The type section of Roumare

Sedimentological variations are not, therefore, insignificant, the sand and clay contents in particular considerably affect geotechnical characteristics. These regional differences can only be assessed by taking into account stratigraphical and paleogeographical conditions within the context of provinces the limits of which could have varied during the course of the Pleistocene (JAMAGNE, M. et al. 1981).

THE EXAMPLE OF THE ROUMARE PROFILE

An example is afforded by the profile of Weichselian loesses found at Roumare. The site is located along the motorway between Rouen and Barentin, about 10 km west of Rouen (FIG. 1A). This profile was visited in 1975 during the excursion of the INQUA Loess Commission. The study of the profile was initiated in 1972 and has just been completed with some detailed analyses (FIG. 5,TABLES 1, 2, 3).

At a height of 130 m above sea level, the profile contains Weichselian loess, 10 m in thickness and superimposed on the Tertiary clay with flints which covers the chalk plateau of Upper Normandy. Above an old Weichselian gelifluction silt, lamellar and brown in colour (from 8.3 to 10 m), one finds the two recent loesses (lower and upper) which show classic agreement with the Normandy Pleniglacial (the Upper and Middle Pleniglacial, the Lower Pleniglacial corresponding to a hiatus). The lower loess is of the carbonate type and is enveloped by two gleyed soils (tundra gley) (VAZART, M.H. 1983): the Mesnil-Esnard soil below and the Roumare soil above (LAUTRIDOU, J.P. 1982), the latter being a hydromorphic variety of the Kesselt soil. The upper loess is a „limon à doublets".

Information on granulometry, mineralogy and chemical composition is provided in TABLES 1, 2 and 3. With regard to granulometry, the characteristics are similar to those described above, with low sand and quite high clay contents (except for the carbonate loess). Chemical analyses are similar to those for the Bocage region of Normandy and the Paris Basin, with a large amount of silica (about 80% as opposed to 8-9% aluminium and 2-3% total iron). Lastly, the heavy minerals (in the 50 – 100 µm fraction) are mainly epidote and hornblende (as is usual on the pleteaux), whilst at a very low altitude there is a noticeable increase in garnet (the epidote-amphibole-garnet suite).

CONCLUSIONS

In spite of some regional differences, it is apparent that there is some homogeneity within the loesses of North-West France. They are characterised by an average to high (14-23%) clay content (except in the low zones) a fine clay/total clay ratio greater than 40% (and often as much as 50%), a variable carbonate content (0-20%) which increases eastwards, a low sand content, a median particle size generally between 20 – 30 µm, a considerable silica and quarz content, and a large proportion of smectite-vermiculite, associated with the epidote-hornblende group which decreases in importance towards the east.

TABLE 1. Granulometry of the Roumare loams.

Depth (cm)		0-2	2-20	20-31,5	31,5-50	50-80	80-125	> 125 microns
Present soil	15	12,24	34,56	17,4	25,4	8,1	1,3	1%
	50	19,33	29,17	20,3	20,2	8,5	1,4	1,1
	85	22,8	21,3	20,3	23,5	9,3	1,4	1,4
	115	17,54	20,06	25,2	27,8	7,7	0,7	1
Limons à doublets	140	17,23	19,97	31,4	16,6	13,95	0,4	0,45
	185	17,02	16,98	19,2	20,5	25,3	0,6	0,4
	225	18,89	16,51	30,5	27,5	6,3	0,2	0,1
	295	16,59	16,11	32	33	1,9	0,4	
	340	13,4	28	34,2	23,7	1	0,3	0,3
	365	14	26	34,8	23,1	1,5	0,5	0,1
Roumare soil	420	15,8	23	19,2	33,9	7,1	1	
	470	15	28	31,7	33,3	6,3	0,7	
Loess	500	7,8	28,2	16,4	37,3	8	1,9	0,4
M. Esnard soil	600	11,92	28,88	20,7	29,8	5,3	2,6	0,8
Lamellar loams	680	30,5	18,7	16,7	25,3	6,1	1,5	1,2
	770	19,56	26,74	19,3	27,1	4,6	1,5	1,2
	880	20,28	26,22	12	32,3	8	0,6	0,6

TABLE 2. Chemical analysis of the Roumare loams and comparison with the loesses of the Bocage region of Lower Normandy (limons à doublets of Villecartier) and of the Paris Basin (Hamel, Saint-Quentin). Location Fig. 1-A

ROUMARE Depth (cm)	%									ppm.						
	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	Ba	Co	Cr	Cu	Ni	Sr	V
0,91	77,69	9,35	3,99	0,06	0,72	0,54	0,92	1,86	0,87	433	14	120	18	32	109	91
1,40	78,77	8,89	3,54	0,05	0,72	0,64	1,05	1,85	0,73	395	13	107	20	21	123	70
2,80	80,22	8,48	3,16	0,04	0,65	0,59	1,11	1,82	0,73	410	17	110	9	37	113	72
3,60	79,48	8,50	3,07	0,06	0,77	0,67	1,20	1,88	0,76	407	28	113	18	44	125	84
4,90	68,76	7,35	2,76	0,04	0,67	7,74	1,03	1,58	0,58	332	25	108	47	46	243	77
6,00	76,34	9,30	3,84	0,03	0,92	1,53	0,94	1,67	0,84	399	15	112	21	30	129	88
7,35	79,59	8,66	3,47	0,1	0,57	0,52	0,73	1,84	0,65	435	29	116	27	55	105	90
8,00	81,94	7,95	3,72	0,07	0,45	0,41	0,65	1,79	0,58	425	49	95	16	41	93	79
9,2	77,48	9,34	4,05	0,07	0,68	0,49	0,69	1,91	0,90	436	18	125	16	35	98	93
9,9	77,36	9,37	4,25	0,04	0,65	0,50	0,84	2,01	0,75	430	25	105	16	34	149	84
VILLECARTIER	82,03	8,63	3,38	0,08	0,65	0,61	1,09	2,74	0,68							
LE HAMEL 1	80,62	9,39	2,64	0,1	0,57	0,77	1,23	1,97	0,35							
ST QUENTIN	81,74	9,43	2,65	0,12	0,63	0,86	1,32	2,02	0,37							

TABLE 3. Heavy minerals of the Roumare loams (50-100 μm)

Depth (cm)		Tourmaline	Staurolite	Andalousite	Garnete	Zircon	Hornblende	Epidote	Rutile	Anatase	Topaze	Sphene	Tremolite	Glaucophane	Monazite	Disthene	Brookite	Chlorite	Biotite	Muscovite	Sillimanite	Spinel
Present Soil	15	1,7			8,7	13,7	15	47	7,7	1,3		2,3	0,3	0,3		1,3	0,3	0,3				
	50	2,3	0,7	0,3	7,7		8,3	58	4,3	1	0,3	2	0,3	0,3	0,3	1		3		0,7		
	85	8	0,3		9,7	12	6,3	51	4,7	2		1,3	0,7			1		2,7	0,3			
	115	6	0,3		6,3	9,7	9,7	51,7	4,3	2		1,7			0,3	0,3		7,3		0,3		
Limons à doublets	140	4,3			1,3	2,7	11,7	40	5	0,7		0,3	0,3		0,7	0,3		28		4,7		
	185	2,3			4,3	9,7	7,3	63	4,7	0,7		1,7						6		0,3		
	225	8,3		0,7	1,3	8	11,4	46,3	4	0,3		1,3	0,7		0,7	1		15,3	0,3	0,3		
	265	6,7	0,3		0,7	2,3	13,7	23,3	1,7	0,3		1,3				0,7		47	0,3	1,7		
	295	7			1	5	7,3	24,7	1,3	0,3	0,7							49,7	1,3	1,7		
	320	2,7		0,3	2	7	14	36,3	2	1		1	0,3			0,3		30		3		
	340	6,3	0,3		5	8,3	13,7	44	2	1		0,7			0,7			17,3	0,7			
	365	4			7	3	8	29	0,7	0,7		1,3		0,3		0,3		35		10,7		
Roumare soil	420	3,3			9,3	7	22	40	4,3	1,3		1	0,7	0,3	0,3	0,7	0,3	9,3				
	470	6,7	1,3		6	14	11,3	32	7,3	0,7		1				0,7		17,3	0,7	1		
Calcareous loess	500	8	1,7			8	10,3	30,3	2	0,3		1		3		0,7		35				
	540	9	1,3		3,7	20,7	10,7	30	10,7	0,3		1,7	0,3			0,7	0,3	10,7				
M. Esnard soil	565	4,7	0,3		12	11	16	42	5	0,7		1						7,3				
	580	2,7	0,3		7	16,7	10,7	36,3	6	1,3		0,7			0,7	0,3		16		1,3		
	615	4,3	0,3		6,7	12	12	40,7	3	1,3		1	0,3			1,3		16	1			
Lamellar loams	640	3,3	0,7		10,7	24,3	7	38,7	3,3	1,3		2,3			0,3	2,3		5,3	0,3			
	680	3,7			3,3	43,3	1,7	28,7	12,7	1,3		1				1,7		2,3				0,3
	770	24	1	1,7	3,3	12	2,3	38,3	6,7	2,7		0,7				1		5,3	0,3	0,3		
	880	9	0,7	1	1	7,7	2	50	6	1,3		1				0,7		19	0,3	0,3		
	910	9	0,7			45,3		21,7	15,3	2,3					0,7	4,3	0,3					

ACKNOWLEDGEMENT

We thank Dr J. Mc Greevy, University College of London, for the translation.

REFERENCES

COUTARD, J.P. – HELLUIN, M. – LAUTRIDOU, J.P. – PELLERIN, P. 1969: Les types de limons et leur répartition dans la Campagne de Caen. – Mem. h. – Sér. Soc. Géol. France. 5. 57-62.

JAMAGNE, M. 1972: Quelques caractéristiques fondamentales des paléosols sur loess du Nord de la France. – Pédologie. 22. 2. 198-221.

JAMAGNE, M. 1973: Contribution à l'étude pédogénétique des formations loessiques du Nord de la France. – Th. Sc. agr., Gembloux. 445.

JAMAGNE, M. – LAUTRIDOU, J.P. – SOMMÉ, J. 1981: Préliminaire à une synthese sur les variations sédimentologiques des loess de la France du Nord-Quest dans leur cadre stratigraphique et paléogéographique. – Bull. Soc. Geol. Fr. 23. 143-147.

LADRIERE, J. 1980: Etude stratigraphique de terrain quaternaire du Nord de la France. – Ann. Soc. Géol. Nord. 17. 93-149 and 205-276.

LAUTRIDOU, J.P. 1969: Rapport de la Commission de terminologie des limons. – Mém. h. – sér. Soc. géol. Fr. 5. 132-137.

LAUTRIDOU, J.P. 1968: Les loess de Saint-Romain et de Mesnil – Esnard. – Bull. Centre Géom., Caen. 2. 55.

LAUTRIDOU, J.P. 1979: Granulométrie des sédiments éolines, comparaison avec la fraction fine obtenue par gélifraction expérimentale. – 6e Réun. Ann. Sc. Terre, Orsay. Paris. Soc. Géol. Fr. 410.

LAUTRIDOU, J.P. 1982: The Quaternary of Normandy. – Bull. Centre Géom., Caen. 26. 88.

LAUTRIDOU, J.P. – GIRESSE, P. 1981: Genese et signification climatique des limons à doublets de Normandie. – Biul. Perygl. 28. 175-188.

LAUTRIDOU, J.P. – KUNTZ, G. – CLOZIER, L. – GIOT, D. 1976: Les loess des cartes géologiques à 1/50.000éme Doudeville, Saint-Saens, Yvetôt (Pays-de-Caux). – Bull. B.R.G.M. 2. 1. 1. 25-37.

LAUTRIDOU, J.P. – SOMMÉ, J. 1974: Les loess et les provinces climatosédimentaires du Pléistocene supérieur dans le Nord-Quest de la France. Essai de corrélation entre le Nord et la Normandie. – Bull. Ass. Fr. Et. Quat. 3-4. 237-241.

LOŽEK, V. 1965: Das Problem der Lössbildung und die Lössmollusken. – Eiszeitalter u. Gegenwart. 16. 61-75.

PAEPE, R. – SOMMÉ, J. 1970: Les loess et la stratigraphie du Pléistocene récent dans le Nord de la France et en Belgique. – Ann. Soc. Géol. Nord. 90. 191-201.

SOMMÉ, J. 1977: Les plaines du Nord de la France et leur bordure. Étude géomorphologique. These, Univ. Paris I. 1975, Paris, Champion. 2. 810.

SOMMÉ, J. 1978: Formations superficielles, Quaternaire et géomorphologie. Les données de la région du Nord de la France. – Hommes et Terres du Nord, Lille. 2. 5-18.

SOMMÉ, J. – PAEPE, R. – LAUTRIDOU, J.P. 1980: Principes, méthodes et systèmes de la stratigraphie du Quaternaire dans le Nord-Quest de la France et la Belgique. – Problemes de stratigraphie quaternaire en France et dans les pays limitrophes, Dijon, 1978. Suppl. Bull. Ass. Fr. Et. Quat., N.S. 1. 148-162.

VAZART, M.H. 1983: Paléodynamiques weichséliennes des provinces normande et séquanienne. Analyse micrographique de 5 coupes de loess: Roumare, Mesnil-Esnard, Iville, Mantes-la-Ville, Chaudron. 3rd cycle th. Paris 7. physical geogr. 129.

Addresses of authors:
Dr.J.P. Lautridou, Attaché de Recherches C.N.R.S. Univ. rue du Creux-au-Renard 14. CAEN–CALVADOS – France
Prof.Dr.J. Sommé, Institute of Geography,
Batiment 2 et. 6. B.P. 36 59650 VILLENEUVE d'Ascq. – France
M. Jamagne, Service d'étude des Sols et de la Carte Pédologique de France,
OLIVET – France

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

GEOCHEMICAL LOESS HISTORY

A.G. Petrov – N.I. Kriger – O.G. Gouneshian – A.D. Kozhevnikov –
S.G. Mironuk – G.A. Zimina

ABSTRACT

The peculiarity of the mineral composition of loess is the coexistence of the rather stable quartz and the more easily dissoluble carbonate. Its chemical composition depends on the lithosphere clarks of chemical elements, on the geochemical mobility of elements, and on local physical, geographical and lithogenetic conditions. The clarks of the concentration of immobile elements are lower than in the average composition of the lithosphere, the clarks of the more mobile ones are higher. The distribution of typomorphic minerals in the lithosphere conforms to geographical zonation. Loess can form in the zone, where the area of distribution of $CaCO_3$ as typomorphic minerals of the hypergene zone is determined by the values of the radiation aridity index from 0.9 to 2.5. The regularities of the distribution of typomorphic minerals in the hypergene zone is connected with the energy of strength of minerals at the atomic level and the energy of landscape derived from solar radiation.

Loess is distributed according to the law of geographical zonation and is adapted to the landscape.

Loess areas are closely connected with the nature of steppes as well as with geochemistry and physical geochemistry of the steppe landscape.

It is characteristic of loess that the constituting minerals are fairly weathered. The weathering index of loess deposits (ratio of the content of stable minerals of load fraction to the content of unstable ones) is 0.8-1.5 and 3-5 for the buried soils. It is 3-6 times less than the value of the weathering index for the Pleistocene galcial till. The peculiarity of loess composition is the coexistence of the rather stable (not leachable) quartz and the more easily dissoluble carbonate ($CaCO_3$). Under different physical and geographical conditions there are SiO_2 – 35-85%, Al_2O_3 – 9-15%, $CaCO_3$ – 5-25%, $CaSO_4 \cdot 2H_2O$ – 0.1-3.0%, easily dissoluble compounds (mainly $NaCl$) – 0.1-3.0% (by both our determinations and literary data).

The chemical composition of loess depends on the lithosphere clarks of chemical elements, on the geochemical mobility of elements, and on local physical, geographical and lithogenetic conditions. The high contents of SiO_2 and Al_2O_3 in loess are explained by the high clark of O, Si, and Al in the composition of the lithosphere.

TABLE 1 shows that clarks of the concentration of immobile elements like Si and Al in loess are lower than in the average composition of the lithosphere. On the contrary, the clarks of contrentration of more mobile elements like Ca and S are higher. It is explained by geochemical and biogeochemical conditions of the landscape favouring Ca and S accumulation: loess area coincides with calcareous landscape (steppes), S and Ca are elements accumulating under the influence of the activity of organisms. The clark of Na concentration in loess is very reduced. The reason for it is the high dissolving capacity of its compounds: the Na ion migrates even in thin water films. The high ratio of $CaCO_3$ and $CaSO_4$ in loess should be explained proceeding from regional regularities of the distribution of typomorphic minerals in the hypergene zone and in the soil cover.

TABLE 1. Chemical composition of loess

Components			Elements			Weight clark of lithosphere (according to Vinogradov)	Clark of concentration in loess
components	limits	average	elements	limits %	average %		
SiO_2	45–85	60	Si	21,0–39,7	28	29,5	0,94
Al_2O_3	9–15	11	Al	4,8–7,9	5,8	8,05	0,72
$CaCO_3$	5–25	18	Ca	2,0–10,0	7,2	2,96	2,43
$CaSO_4 \cdot 2H_2O$	0,1–4,0	1,1	S	0,16–0,644	0,177	0,047	3,77
NaCl	0,1–3,0	0,7	Na	0,039–1,179	0,275	2,50	0,11

It is known that as far as climate changes from humid to arid one, the crusts also successively change from ferruginous (forest zone) to calcareous and gypsum (steppes and savannahs) and galit ones (deserts). In FIG. 1 dependence of distribution of typomorphic minerals on radiation balance (R) and radiation aridity index (R/Lr) is seen. In this figure r is the quantity of atmospheric precipitation, and L is the latent heat of evaporation. According to this scheme there are reasons to conclude that the distribution of typomorphic minerals in the litosphere conforms to geographical zonation. Specifically, calcareous landscape or otherwise, the area of distribution of $CaCO_3$ as typomorphic minerals of hypergene zone is determined by the values of R/Lr mainly from 0.9 to 2.5. Loess can form and exist only in this zone. Under humid climate ($R/Lr < 0.9$) loess does not form because there processes of leaching occur and CaO_3 is not a typomorphic mineral. The minerals of gypsum and galit are typomorphic for the zone of arid climate of deserts. In this zone the processes of deflation and eolian replacement of silt dominate i.e. the conditions are not favourable for the formation of thick loess covers (KRIGER, N.I. 1965, 1970). It should be noted that the typomorphic minerals shown in FIG. 1 and regarded in the order of their distribution from the humid climatical zone to the arid one form a range in which every following mineral is more dissoluble and it is characterized by less stable crystallochemical bonds. Thus, the nature of the regularities of distribution of typomorphic minerals in the hypergene zone is energetic connected with energy of strength of minerals at the atomic level and the energy of landscape caused by solar radiation (KRIGER, N.I. 1980, KRIGER, N.I. – KOTELNIKOVA, N.E. – LAVRUSEVICH, S.I. – SEVOSTYANOV, V. 1981). The succession of typomorphic chemical elements (Al, Fe, Si, Ca, S and Na) corresponding to the described succession of typomorphic minerals is called the principal geochemical range of biosphere (KRIGER, N.I. – MIRONUK, S.G. 1978). We regard the described regularities of the distribution of typomorphic minerals and chemical elements as a complex energetic system, in which physical fields R and R/Lr form a kind of filter sorting atoms of different energy. This filter makes it possible for mobile atoms, ions and molecules with low energetic indices to migrate and creates a geochemical barrier for those which are characterized by higher energetic indices and low migration capacities. Described energetic system strictly determines the area of distribution of loess on the globe.

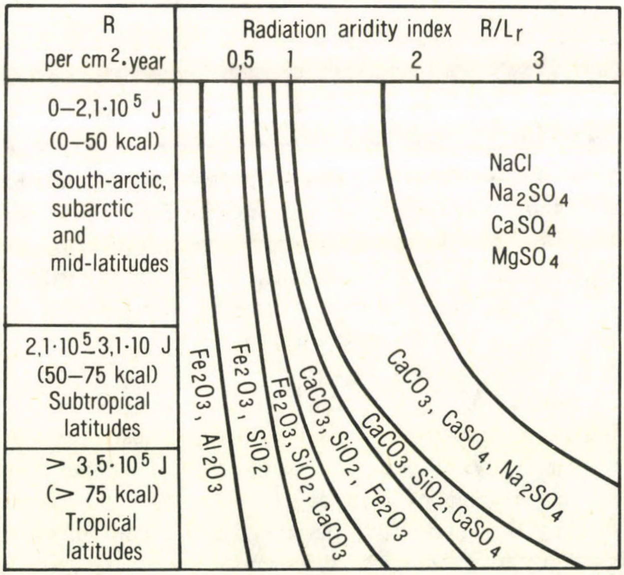


FIG 2. Typomorphic minerals of hypergene zone in the system of radiation balance R and radiation aridity index R/Lr

Not only global, but local peculiarities of the physical and geographical conditions (that is local pecularities of the system of geophysical fields) have an influence on distribution, composition and properties of loess. In FIG. 2. it is shown that the ratios of different chemical components in loess depend on the radiation aridity index R/Lr. Even little changes in the value of R/Lr affect the composition of loess: aridisation of climate leads to the increase in the quantity of dissoluble components. The radiation aridity index determines a regime of rock moisture content, which in turn has an influence on the composition and properties of rocks and on their chemical processes. As for loess it should be ascertained that the carbonate content of rocks was formed in the stage of sedimentation and early diagenesis.

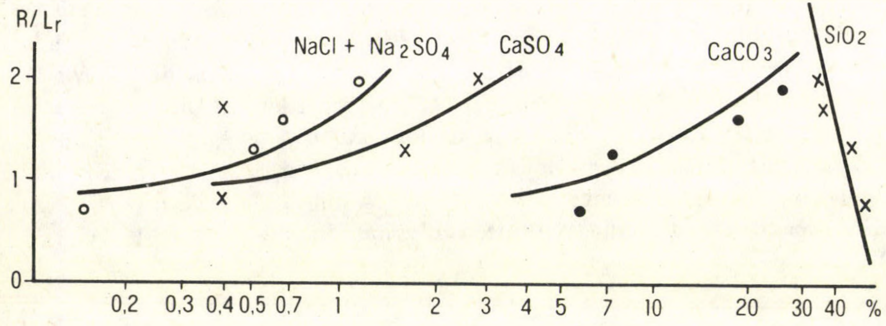


FIG. 2. Dependence of loess composition on radiation aridity index R/Lr

Distribution of $CaCO_3$ in loess sequences changed comparatively little during postsedimentational period, thus horizons of enrichment and leaching are paleogeographical and paleopedological criteria, which are of stratigraphical significance. Geochemical peculiarities of loess and specific coincidence of zones of enrichment of $CaCO_3$ and leaching with definite stratigraphical horizons testify to prolonged stability of the physical geographical situation and the little changeability of the radiation aridity index over time. With the alteration of this index the composition and properties of all the loess series change, $CaCO_3$ leaches and the geochemical pecularities of sereval horizons disappear and loess gradually digrades.

The correspodence of the quantity of comparatively little dissoluble and little mobile $CaCO_3$ content with modern value of R/Lr in each region can be regarded as evidence of constant physical geographical conditions in these regions during the Pleistocene. The absolute values of R/Lr could differ under general climatic changes, which are confirmed by the interbeds of buried soils, but the trend of plan distribution of values of R/Lr is preserved. Thus the carbonate enrichment in loess is indirect (apperent) and is in approximate dependence of the modern values of R/Lr.

As for easily dissoluble components in loess, their relation with the modern values of R/Lr is closer since even little changes of this parameter have an influence on the moisture content of loess and since even in thin water films the migration of Na^+ and Cl^- ions takes place (KRIGER, N.I. – KOTELNIKOVA, N.E. 1978).

From the above one can conclude that distribution, composition and properties of loess are closely associated with the geochemical situation which is determined by energetic fields at the global and atomic levels. The situation is favourable to the formation of loess in subaerial conditions.

REFERENCES

KRIGER, N.I. 1965: Less, ego svoistva i svyaz' s geograficheskoi sredoi. (Loess, its characteristics and relation to geographical environment.) Moscow, Nauka. 265.

KRIGER, N.I. 1970: Reasons for regularities in the distribution collapse rocks. – Trudy Proizv i n.-i. in-ta po inzh. izyskaniyam v stp-ve Gosstroya SSSR. (Proc. Research Institute of Engineering Investigations for Construction), 4. 225-264. (In Russian).

KRIGER, N.I. 1980: Vlazhnost'i energetika lessovykh porod. (Moisture content and energy of loess rocks.) – In: Inzhenerno-geologicheskie protsessy i svoistava gruntov. – Trudy Proizv. i n.-i. in-ta po inzh. izyskaniyam v stp-ve Gosstroya SSSR. (Proc. Research Institute of Engineering Investigations for Construction.) Moscow, Strojizdat. 3-24.

KRIGER, N.I. – KOTELNIKOVA, N.E. 1978: Osnovnye cherty geokhimii lessa. (Principal pecularities of loess geochemistry. (– Geokhimiya, 1978. 12. 1843-1856.

KRIGER, N.I. – MIRONUK, S.G. 1978: Regularities of loess geochemistry and geography of its collapse properties. – In: Problems of loess rocks in seismic regions. Tashkent, Fan. 50-53. (In Russian).

KRIGER, N.I. – ZAKHAROV, V.P. 1966: Engineering properties of loess as geological body. – In: Inzhenerno-geologicheskie svoistva lessovykh porod. Moscow, Nauka. 25-45. (In Russian).

KRIGER, N.I. – KOTELNIKOVA, N.E. – LAVRUSEVICH, S.I. – SEVOSTYANOV, V. 1981: Regularities of formation of collapse properties of loess rocks of Central Asia and South Kazakhstan Moscow, Nauka. 132. (In Russian).

Address of authors:
A.G. Petrov, N.I. Kriger, O.G. Gouneshian, A.D. Kozhevnikov, S.G. Mironuk, G.A. Zimina, Geographical Research Institute for Construction Engineering, (PNIIIS),
Okruzhnoy proezd 18. 105058 MOSCOW – USSR.

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

SEM INVESTIGATIONS OF QUARTZ SILT MICRO–TEXTURES IN RELATION TO THE SOURCE OF LOESS

Kenneth Pye

ABSTRACT

Scanning electron microscope examination of natural and experimentally-formed silt particles has shown that grains formed by salt weathering, frost action and mechanical crushing have similar surface features. Grains from subglacial environments in Norway were found to be qualitatively indistinguishable from supraglacial weathering debris. Features such as breakage blocks, conchoidal fractures, edge grinding and adhering clay-size particles can be produced by several different mechanisms. Silt grains formed in sub-aerial weathering environments commonly show chemical solution as well as mechanical breakage features. Quartz silt particles from unweathered loess in Central Europe, Mississippi and Tajikistan were found to display abundant mechanical breakage and limited chemical features consistent with a cryogenic origin, but at the present time it is not possible to draw definite conclusions about surface area and mode of particle formation on the basis of survace textural evidence alone.

A series of scanning electron microscope investigations has been carried out on natural and experimentally-formed quartz silt particles in an attempt to establish weather quartz grains in loess might provide micro-textural evidence of their mode of formation and source environment. SEM has been widely used to study the surface textures of sand grains, but there are few previously published investigations of silt grains. The experimental results indicate that silt grains formed by simulated salt weathering, frost action and mechanical crushing have very similar surface features. Natural silt grains collected from a subglacial environment were also found to be qualitatively indistinguishable from supraglacial weathering debris. „Adhering particles”, „breakage blocks” „conchoidal fractures” on grains in loess therefore cannot be used as evidence of glacial comminution, as some authors have previously suggested. Natural quartz silt grains collected from a saline basin in California were found to display both mechanical and chemical alteration features. Grains from a humid tropical weathering profile in Northern Australia are dominated by chemical solution features. Therefore, to some extent, the surface textures on silt grains do reflect the balance of mechanical and chemical processes in their source areas. Quartz grains from loess in Central Europe, the Mississippi

Valley and South Tajikistan were all found to show abundant mechanical breakage features supportive of a cryogenic origin.

THE LOESS SOURCE PROBLEM

Blankets of loess, defined here as wind-transported sediment consisting chiefly of silt-size particles, occur extensively in several parts of the world and have attracted scientific interest for more than a century. However, as noted by SMALLEY, I.J. (1980, p.247), „the problem of loess formation has not been solved". Although most geologists now accept that wind transport and deposition have played a critical role in the formation of loess, there is still considerable disagreement regarding the source and mode of formation of the silt particles. Several different theories of silt origin have been proposed. SMALLEY, I.J. (1966) and SMALLEY, I.J. and VITA – FINZI, C. et.al. (1968) argued that glacial grinding is probably the only natural process capable of generating large amounts of silt. The close association of many Quaternary loess formations with glaciated regions was cited as support for a genetic relationship. However, doubts about the effectiveness of glacial grinding in forming silt have been expressed (WHALLEY, W.B. 1974, 1979, WHALLEY, W.B. – KRINSLEY, D.H. 1974). According to these authors, much of the material transported and deposited by ice has not actually been eroded or crushed subglacially, but represents frost-weathered debris supplied to the glacier surfaces by slope processes. The importance of frost weathering as a mechanism of silt generation was first described in the field by ZEUNER, F.E. (1949) and has subsequently been demonstrated experimentally by MOSS, A.J. et al. (1981). Outside the glaciated regions, fluvial abrasion has been found to be an important means of particle breakage and silt production (MOSS, A.J. 1972, MOSS, A.J. et al. 1973, RIEZEBOS, P. – VAN DER WAALS,L. 1974), particularly where grains, have inherited weaknesses from the source rock environment (MOSS, A.J. 1973, MOSS, A.J. – GREEN, P. 1975). Experimental work has indicated that aeolian abrasion in desert environments is capable of producing fines, although the particles formed are generally smaller than the modal size typically found in loess (KALDI, J. et al. 1978, KRINSLEY, D.H. – MCCOY, F.W. 1978). Salt weathering in deserts has also been found to be an effective agent of silt formation (GOUDIE, A.S. et al. 1979, GOUDIE, A.S. – DAY, M.J. 1981, PYE, K. – SPERLING, C.H.B. 1982). Finally, chemical weathering processes in humid regions have recently been shown to provide a further mechanism of silt formation (NAHON, D. – TROMPETTE,R. 1982, PYE, K. 1983).

As noted by SELBY,M. (1976, 15), „in regions outside the realm of glacial influences the exact history of loess deposits is problematical. „This is well illustrated by the continuing debate as to whether the extensive loess deposits of Soviet Central Asia and China have a desert origin or are derived from a (glaciated) cold weathering mountainous environment (SMALLEY, I.J. – KRINSLEY, D.H. 1978, SMALLEY, I.J. 1980). Similar debate still surrounds the origin of loess in Nebraska and neighbouring parts of North America, which some authors (e.g. LUGN, A. L. 1962, 1968) believe was derived by aeolian reworking of weathered Tertiary Ogallala sediments during one or more arid (and possibly windier) phases of the late Pleistocene.

SCANNING ELECTRON MICROSCOPY AND QUARTZ GRAIN SURFACE TEXTURES

A technique which potentially might aid in identifying the source and mode of formation of silt in particular loess deposits is scanning electron microscopy (SEM). This technique has been applied with considerable success in studies of the environmental histories of sand grains (KRINSLEY, D.H. – DOORKAMP, F.W. 1973, MARGOLIS, S.V. and KRINSLEY, D.H. 1974, LE RIBAT,L. 1977, BULL, P.A. 1981), but to date there are few published studies of silt grains. The basic principle o the technique rests on the belief that a detrital quartz grain will display surface textural features that may be diagnostic of the processes which acted on it during formation, transportation and deposition, provided that these have not been obliterated by post-depositional modification. The clear limitations of the technique have not escaped attention (BROWN, J.G. 1973a, 1973b, SCHOLLE, P.A. – HOYT, D.E. 1973). The most serious problems are those of equifinality, that is similar surface textures may be produced by quite different processes, indeterminacy, by which the same process results in different surface features depending on, for example, crystallographic differences in the quartz grains, and superimposition of features formed in several different process environments. Several studies have also shown that post-depositional modification or obliteration of primary surface textural features can be rapid in near-surface environments (CROOK, K.A.W. 1968, CLEARY, W.J. – CONOLLY, J.R. 1971, PYE, K. 1983).

Despite these problems, however, there are numerous published examples where SEM has been successfully used, in conjunction with other techniques, to tackle problems of geological provenance (MARGOLIS, S.V. – KENNETT, J.P. 1971, KRINSLEY, D.H. – MCCOY, F.W. 1977). It is therefore worthwhile asking the question whether surface textural studies can play a similar role in loess investigations.

In this connection two main questions need to be resolved. First, do quartz silt grains formed by different mechanisms (e.g. glacial crushing, fluvial abrasion, in situ weathering) show distinctive surface features? Second, can primary depositional textures in fossil loess deposits survive post-depositional modification and be used to infer source area and mode of silt formation? It will only be possible to answer these questions satisfactorily when sufficient experimental and observational data have been accumulated. To date only a very few SEM investigations of loess have been carried out, and in the majority of these the focus of enquiry has been nature of the sediment fabric or diagenetic alteration rather than the surface features of individual grains.

PREVIOUS SEM STUDIES OF LOESS

SMALLEY, I.J. – CABRERA, J.G. (1970) published some of the first SEM observations on loess grains form Nebraska and West Germany. The grains were predominantly sub-angular with numerous adhering fine particles ($< 2\ \mu$m) which were interpreted by SMALLEY – CABRERA as glacial comminution debris. This interpretation was questioned by WARNKE, D.A. (1971) but reaffirmed by SMALLEY, I.J. – CABRERA, J.G. (1971).

Fine adhering debris was also observed on Polish loess grains by CEGLA, J. et al. (1971). These authors also concluded from SEM evidence that their loess grains had experienced considerable (presumed post-depositional) weathering and diagenesis involving precipitation of secondary silica. Further evidence of postdepositional alteration was suggested by VITA–FINZI, C. et al. (1973) and SMALLEY, I.J. et al. (1973), who noted what they thought to be authigenic dolomite on qartz grains from the Kaiserstühl loess. However, this interpretation was not substantiated by energy dispersive analysis (EDS) in the SEM or by X-ray diffraction. Further attention was drawn by SMALLEY, I.J. et al. (1973) to fracture features on quartz silt grains which they interpreted as indicating a glacial origin.

WHALLEY, W.B. (1974) pointed out that much of the material deposited in moraines and till deposits does not experience subglacial grinding but is supra-glacial debris supplied from weathered bedrock to the glacier surface by slope processes. WHALLEY presented a number of SEM micrographs which illustrated the presence of mechanical breakage features on supra-glacial grains, together with evidence of silica reprecipitation on quartz grains from moraines only a few hundred years old.

Further work (WHALLEY, W.B. – KRINSLEY, D.H. 1974, WHELLEY, W.B. 1978) suggested that quartz grains in glacial environments posses no surface textural features which are reliably diagnostic. Glacial grinding simulations by WHALLEY, W.B. (1978) succeeded in bringing about some grinding of initially sharp edges, but similar results were obtained in experiments designed to simulate high energy fluvio-glacial conditions, presumably due to collision of grains spinning at high velocity (WHALLEY, W.B. 1979).

SMITH, B.J. – WHALLEY, W.B. (1981) examined silt grains from the so-called „loess" drift of Northern Nigeria. The grains were typically found to be blocky and angular or sub-angular, with abundant evidence of secondary silica precipitation. On the balance of SEM and other evidence, it was concluded that the deposits were derived largely by aeolian reworking of alluvial and slope deposits during a more arid phase of the late Pleistocene.

WHALLEY, W.B. – SMITH, B.J. (1981) also examined grains of dust transported by Harmattan winds at the present day. Larger grains were found to be plastered with small (< 2 μm) particles of quartz, feldspar and clay minerals, in some cases cemented by secondary silica. Few mechanical breakage features and no evidence of aeolian abrasion during transport were observed. It was again concluded that the source of the bulk of the silt was bare land within the sub-Saharan zone of Northern Nigeria and neighbouring countries.

GOUDIE, A.S. et al. (1980) made a brief examination of loess grains from South Tajikistan, noting that, although some mechanical breakage features were present, the surface textures were dominated by secondary silica precipitation. No inferences were drawn concerning the origin of the material.

FURTHER SEM STUDIES

The studies summarized above provide insufficient data to answer the question whether silt grains formed by different mechanisms display distinctive morphologies and textures, and whether these can be used to identify the source of loess. Further work has been undertaken by the author in an attempt to resolve these questions. Three lines of enquiry have been pursued:

1. quartz silt grains have been formed experimentally in the laboratory by simulated weathering and abrasion processes,
2. silt grains from known modern process environments (e.g. sub-glacial, weathering profile, marginal to saline flats) have been examined,
3. silt grains collected from loess profiles in Poland, West Germany, the Mississippi Valley, and South Tajikistan have been analyzed and compared with grains from known process environments and those formed experimentally.

A fuller descripition of the experimental procedures used and of the narural materials examined will be presented elsewhere (PYE, K. – SPERLING, C.H.B. 1982, PYE, K. 1983). In the present paper only some of the more general conclusions are presented with the intention of evaluating the general potential of SEM techniques in studies of loess provenance.

SEM examination of the specimens described below was undertaken using either a Philips 501B electon microscope or a Cambridge S10 with Link EDS micro-analyzer attachment. After appropriate pre-treatment the grains were mounted on double-sided adhesive tape and sputter-coated with gold to eliminate charging. Surface features were photographed at magnifications ranging from 40X to 10 000X using accelerating voltages of 7.2kv to 30kv.

Weathering simulations were performed on two different materials, a quartzose coastal dune sand from North Queensland Australia, and polymineralic first cycle regolith from the Cairngorms, Scotland. Separate grain size fractions of these materials were subjected to thermal stress, thermal stress plus wetting and drying, sodium sulphate crystallization, and frost weathering using a climatic cabinet. A detailed description of the equipment and experimental procedure is given in PYE, K. – SPERLING, C.H.B. (1982). The objective of the thermal stress (salt weathering experiment was to establish the effectiveness of these processes in causing grain disintegration under simulated warm desert conditions (using the Wadi Dygla climatic cycle of WILLIAMS, C.B. 1923). The frost weathering simulation was aimed to approximate winter conditions in a humid maritime climate (Icelandic cycle). After 40 diurnal weathering cycles the grains and fine silt debris formed during the experiments were examined by SEM and compared with micrographs of control specimens which had not been subjected to weathering.

Samples of both types of material were also crushed mechanically with a mortar and pestle to achieve a crude approximation of the brittle fracture mechanism which might be expected at the ice-rock interface beneath a glacier. The grains so-produced were then examined by SEM and compared with the textures of grains from the initial material.

A further simple simulation of high energy fluvial abrasion, such as might be expected to occur, for example, in a gravel-transporting glacial outwash stream, was undertaken by placing samples of sieved dune sand and regolith sand in a high speed magnetic stirrer for a period of two hours. After the experiment was completed the grains were again examined by SEM.

Natural silt grains from a number of known modern process environments were analyzed under the SEM. These included subglacial grains from the base of the Nigardsbreen and Storsbreen glaciers, Norway, frost and chemically-weathered regolith derived from ademellite in the Cairngorms, Scotland, salt-weathered silt from an area adjacent to a playa lake in Death Valley, California, frost-weathered quartzite debris from the summit of Ben Arkle, Scotland, and chemically weathered quartz silt from a podzolized dune sequence in humid tropical North Queensland. The characteristics of the silt grains from the latter area are described more fully by PYE, K. (1983).

Silt grains from loess sections in West Germany, Poland, the Mississippi Valley and Soviet Central Asia have been examined in detail. Preliminary observations have also been made on loess from New Zealand, Argentina, Belgium and Southern England. In all cases the stratigraphic position level which the samples were collected was noted, since age and degree of weathering are important controls on the nature of surface textures. Some loess samples were examined without pre-treatment other than gentle disaggregation by hand. Others were shaken in a solution of sodium pyrophosphate to disperse clays, wet-sieved to separate individual grain size fractions, and treated with dilute HCl to remove carbonates. The latter procedures were found necessary to remove fine adhering debris which masked the surface of many of the larger silt grains.

SUMMARY OF RESULTS

Silt grains produced experimentally by salt action, frost weathering and mechanical crushing were found to have similar surface textures. The dominant features are sharp, angular edges, conchoidal and stepped fracture surfaces, breakage blocks, and deep cracks (FIGS. 1A – E). Prior to dispersion undertaken to allow grain size analysis, both the salt-weathered debris and frost-weathered debris contained aggregates of fine silt and clay-size particles (FIG. 1F). Morphologically these aggregates are similar to those identified in Harmattan dust by WHALLEY, W.B. and SMITH, B.J. (1981).

Most large quartz and feldspar grains in the salt and frost-weathered debris had fine particles adhering to their surfaces, held in place either by moisture or electro-static attraction. The presence of such particles therefore cannot be regarded diagnostic of sub-glacial comminution as previously suggested by SMALLEY, I.J. and CABRERA, J.G. (1970).

Sub-glacial quartz grains from Storsbreen and Nigardsbreen glaciers were observed to have similar surface features to the experimentally weathered quartz grains and to natural granitic grus grains from the Cairngorms, Scotland (FIGS. 2A and 2B). Only relatively few grains (< 10%) from the subglacial environment showed evidence of edge grinding of the type described by WHALLEY, W.B. (1978, 1979). These grains show little, if any, evidence of chemical solution, suggesting that they represent freshly crushed debris rather than material eroded from older moraines.

Natural frost-weathered grains derived from quartzite on Ben Arkle, northwest Scotland, are typically sub-angular with highly irregular breakage block surfaces and large numbers of adhering fine particles (FIGS. 2C and 2D). Some rounding of sharp edges by chemical processes is apparent. The highly irregular nature of the surfaces on

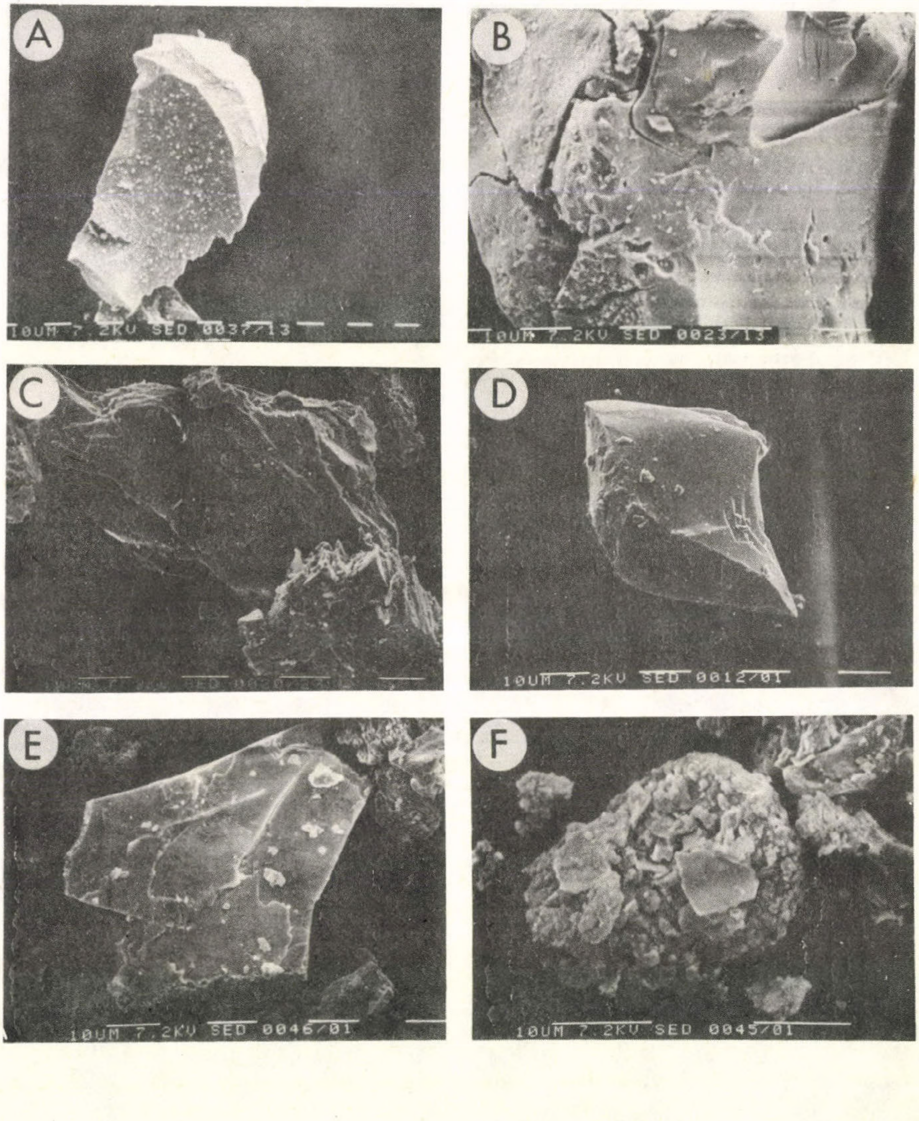


FIG. 1. (A) Angular quartz silt grain formed by experimental sodium sulphate weathering of Australian dune sand. (B) deep cracks in a coarse silt grain formed by experimental salt weathering of dune sand. (C) angular quartz silt grain (centre) and feldspar grain (lower right) formed by salt weathering of Cairngorm regolith sand. (D) angular silt grain formed by experimental frost weathering of dune snad. (E) quartz silt grain produced by frost action on regolith sand. (F) aggregate of fine quartz and feldspar grains formed by experimental frost weathering of regolith sands.

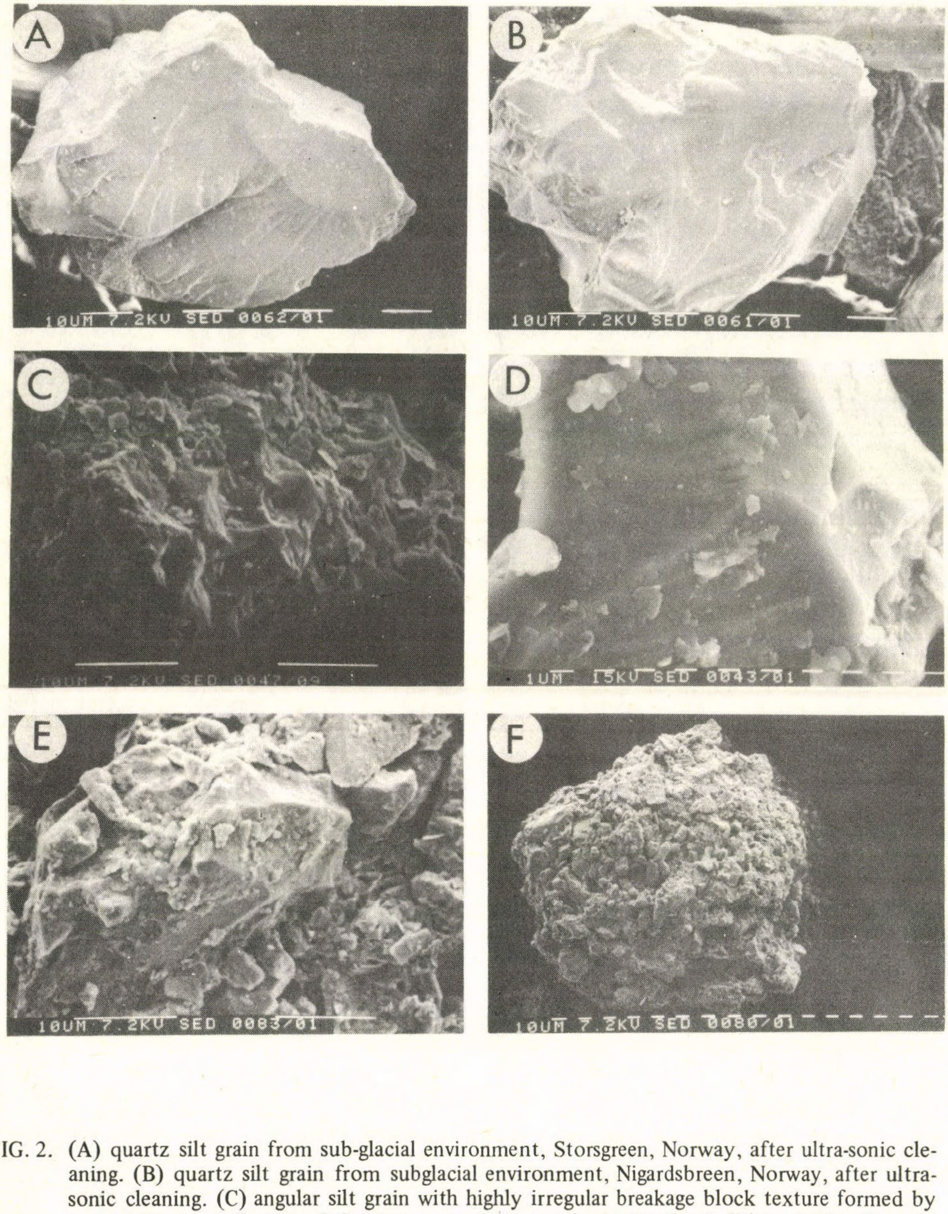


FIG. 2. (A) quartz silt grain from sub-glacial environment, Storsgreen, Norway, after ultra-sonic cleaning. (B) quartz silt grain from subglacial environment, Nigardsbreen, Norway, after ultrasonic cleaning. (C) angular silt grain with highly irregular breakage block texture formed by natural frost weathering of Cambrian quartzite, northwest Scotland. (D) part of a silt grain formed by natural frost weathering of quartzite, Northwest Scotland, showing conchoidal breakage surface and adhering clay-size quartz debris. (E) quartz silt grain from the margin of saline flats, Death Valley, California, showing presence of breakage edges which have been substantially modified by chemical action, together with numerous weakly cemented fine particles on the surface. (F) aggregate of fine silt particles from margin of saline flats, Death Valley.

these grains may reflect the fact that breakage in quartzite occurs across, rather than around, the grain. Particles produced by weathering often consist of fragments of two or more quartz grains and interstitial cement. This illustrates the point that the morphologies of particles produced by weathering may be heavily influenced by the properties of the materials from which they are formed.

Grains collected from the margin of salt flats in Death Valley, California show evidence of both mechanical breakage and chemical modification. The edges of the particles are often rounded by silica solution and reprecipitation (FIGS. 2E and F). In fresh, untreated samples, fine silt and clay-size grains cling together as aggregates (FIG. 2F). Simple immersion in distilled water commonly fails to result in disaggregation, suggesting the particles are not held together only by halite cementation. Rapid mobilization of silica is to be expected in a saline environment such as Death Valley, since experimental work has shown that the solubility of silica increases rapidly above pH 9 (SIEVER, R. 1962).

Natural quartz grains from the A horizon of a podzolic weathering profile developed in North Queensland dune sands display surface textures which are quite distinct

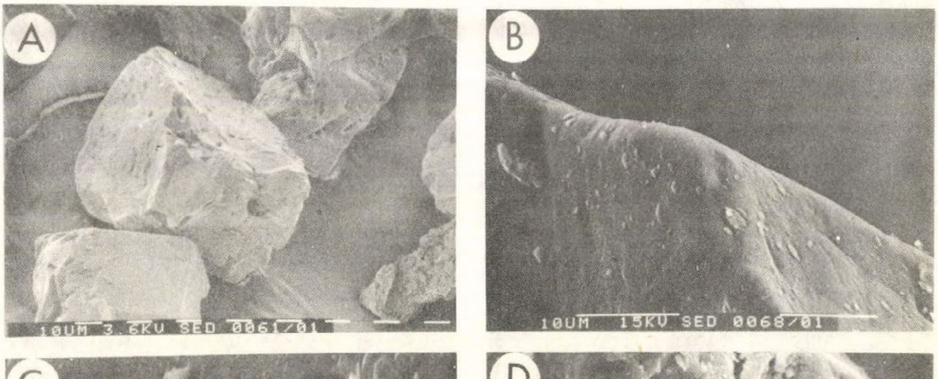


FIG. 3. (A) Sub-angular quartz silt grain from the A horizon of a tropical podzolic weathering profile, North Queensland. (B) enlargement of part of grain shown in (A), illustrating edge rounded by solution. (C) small orientated V-shaped etch pits on the surface of the grain shown in (A). (D) silt grain from a pedogenic horizon in loess at Vicksburg, Mississippi, showing surficial encrustation of clay minerals and secondary silica

from those previously described. Although the grains appear angular or sub-angular at intermediate magnifications (FIG. 3A), at higher magnifications the edges can be seem to be rounded by solution, and the grain surfaces commonly possess numerous small orientated V-shaped etch pits (FIGS. 3B and 3C). Adhering clay-size quartz particles are not common on these grains due to the efficiency of pedotranslocation processes in these podzolic profiles (see PYE, K. 1983).

The loess grains from Poland, Mississippi and Tajikistan display a variety of surface textures, but the most common features on grains from unweathered horizons are apparently the product of mechanical breakage (FIGS. 4A – D); Many grains show sharp breakage edges with little apparent post-formational rounding by solution. In horizon affected by pedogenesis, however, grains from all three areas are often encased in a pellicule of clay minerals and secondary silica (e.g. FIG. 3D). Neighbouring grains from such horizons are sometimes cemented by silica, clay minerals, carbonates or iron oxides, clearly indicating that the changes are post-depositional.

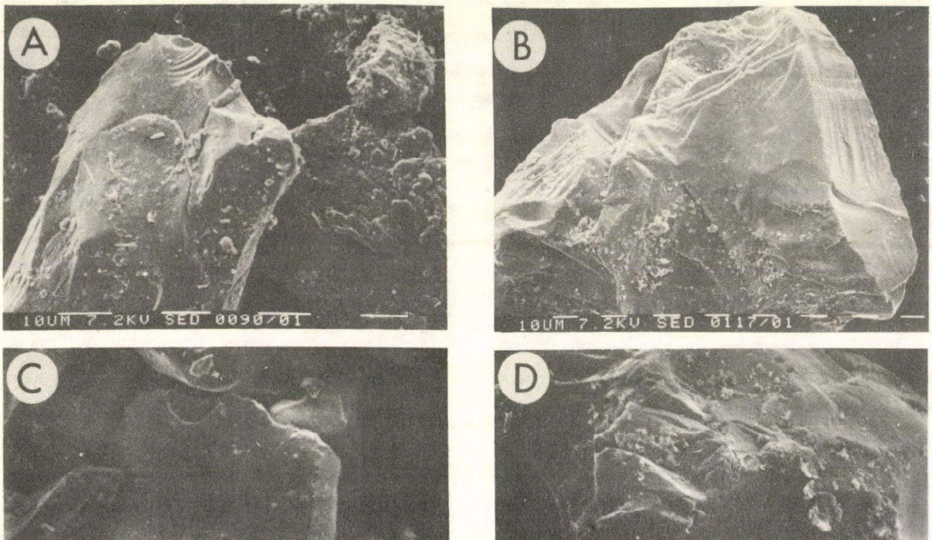


FIG. 4. (A) and (B) silt grains from loess in South Tajikistan, showing conchoidal and stepped mechanical breakage features. (C) fresh, unweathered grain from Natchez loess, Mississippi, whowing sharp edges and conchoidally fractured surfaces. (D) angular rain with breakage features from Tyszowce, southeastern Poland.

The grains shown in FIG. 4. could have been formed either by cold weathering processes (principally frost action) or glacial grinding. The near-absence of silica solution /precipitation features makes it unlikely that they were formed in a chemically active environment. A cryogenic origin is consistent with stratigraphic, distributional and dating evidence in all three areas. In Central Europe, detailed studies over many years have shown that the bulk of the loess material was derived from fluvioglacial outwash channels and ice-marginal areas during glacial phases of the late Pleistocene (MARUSZCZAK, H. 1980, SMALLEY, I.J. – LEACH, J.A. 1978, FINK, J. – KUKLA, G.J. 1977). During interglacials and interstadials, loess sedimentation slowed or ceased, allowing the development of soil horizons. Similarly, dating evidence indicates that loess sedimentation corresponded with the maximum extent of ice into the headwaters of the Mississippi and its tributaries (WILLMAN, H.B. – FRYE, J.C. 1970, SNOWDEN, J.O. – PRIDDY, R.R. 1968). In South Tajikistan the chronology and geomorphological relationships of loess deposits appear to be more complex, reflecting tectonic as well as directly climatic factors, but mineralogical and distributional evidence also point to a montane source in the glaciated Tien Shan and Pamir ranges (DAVIS, R.A. et al. 1978, DODONOV, A.E. 1979).

CONCLUSIONS AND RECOMMENDATIONS

SEM data so far available suggest that there are no microtextural features which can be regarded as strictly diagnostic of glacial deposits. Contrary to earlier suggestions, adhering surface particles, angular breakage blocks and conchoidal fractures are not only produced by glacial comminution, they can be formed by a range of mechanical breakage processes including salt crystallization and frost action. It may, however, prove possible to differentitate subglacial silt grains from supra-glacial grains and weathering debris using quantative methods of particle form analysis such as Fourier analysys (EHRLICH, R. – WEINGERG, B. 1970). Preliminary data suggest this method can be used to differentiate sand grains from different glacial sub-environments (DOWDES– WELL, J.A. 1982), and the technique might be applied to silt grains with good effect.

Textural features can be used to identify silt grains which are derived directly from mechanical environments and to distinguish them from grains derived from chemically active environments. Grains which are stored for any period of time in sedimentary deposits subject to weathering may experience rapid solution and reprecipitation of silica (for example in the upper parts of moraine or river terrace deposits). Chemical modification of silt grain textures is likely to be greatest in very humid environments, particularly where organic acids are abundant, or in alkaline desert environments.

Pre-depositional chemical alteration features on silt grains in loess may be distinguished from post-depositional features on the grounds that (a) the latter should affect all grains in a particular horizon, (b) post-depoisitional alteration usually involves corrosion of feldspars, re-distribution of carbonate and formation of authigenic clays and other minerals, and (c) pre-depositional chemical surfaces may be truncated by later breakage features, whereas post-depositional surfaces rarely are.

Because most medium and coarse silt grains in loess must first be cleaned by sonic vibration or chemical methods in order to allow examination of the underlying surface textures. Grains from weathered loess horizons should not be used for analysis of microtextures since they are likely to record only post-depositional events. In order to facilitate comparison of results it is advisable to examine a particular grain size fraction, the present author has found grains in the 20-45 μm fraction most suitable. All SEM examination should be undertaken in a systematic manner, preferable with a view to obtaining quantitative data (see BULL, 1981). Energy dispersive analysis should be used to check that all of the grains analyzed are indeed quartz.

As is the case with sand grains, studies of the surface textures of silt grains are of restricted value when used in isolation. However, used in conjunction with other techniques, such as grain size analysis and heavy mineral analysis, SEM can provide valuable supporting evidence in loess provenance studies, particularly if quantitative methods of image analysis are employed.

ACKNOWLEDGEMENTS

Financial support provided by the N.E.R.C. and Girton College is acknowledged. I thank JOHN INNES for providing samples from Norway and Scotland and DAVID NEWLING for technical assistance with the SEM.

REFERENCES

BROWN, J.E. 1973: Depositional histories of sand grains from surface textures. – Nature, 242. 396-383.

BROWN, J.E. 1972: Depositional histories of sand grains from surface textures. – Nature, 245. 31-32.

BULL, P.A. 1981: Environmental reconstruction by electron microscopy. – Prog. Phys. Geog., 5. 366-397.

CEGLA, J. – BUCKLEY, T. – SMALLEY, I.J. 1974: Microtextures of particles from some European loess deposits. – Sedimentology, 17, 129-134.

CLEARY, W.J. – CONOLLY, J.R. 1971: Embayed quartz grains in soils and their significance. – J. Sedim. Petrol, 42.899-904.

CROOK, K. A. W. 1968: Weathering and roundness of quartz sand grains. – Sedimentology, 11. 171-182.

DAVIS, R.A. – RANOV, V.A. – DODONOV, A. E. 1978: Early man in Soviet Central Asia. – Sci. Am., 92-102.

DODONOV, A.E. 1979: Stratigraphy of the Upper Pliocene – Quaternary deposits of Tajikistan (Soviet Central Asia). – Acta Geol. Acad. Scient. Hung., 22. 63-73.

DOWDESWELL, J.A. 1982: Scanning electron micrographs of quartz sand grains form cold environments examined using Fourier shape analysis. – J.Sedim.Petrol., 52. (in press).

EHRLICH, R. – WEINGERG, B. 1970: An exact method for characterization of grain shape. – J. Sedim. Petrol., 40. 205-212.

FINK, J. – KUKLA, G.J. 1977: Pleistocene climates in Central Europe: at least 17 interglacials after the Olduvai event. – Ouat-Res., 7. 363-371.

GOUDIE, A.S. – COOKE, R.U. – DORNKAMP, J.C. 1979: The formation of silt from quartz dune sand by salt weathering preocesses in deserts. – J. Arid Environs., 2. 105-112.

GOUDIE, A. S. – RENDELL, H. – BULL, P.A. 1980: The loess of Tajik SSR. – Paper presented at the Int. Islamabad Conf., June, 1980 (in press).

GOUDIE, A. S. – DAY, M.J. 1981: Disintegration of fan sediments in Death Valley, California, by salt weathering. – Phys.Geog., 1. 126-137.

KALDI, J. – KRINSLEY, D.H. – LAWSON, D. 1978: Experimentally produced aeolian surface textures on quartz sand grains from various environments. – In: Whalley, M.B. (Ed.), Scanning electron microscopy in the study of sediments. Norwich, Geoabstracts, 261-274.

KRINSLEY, D.H. – DOORNKAMP, J.C. 1973: Atlas of quartz sand surface textures. Cambridge Univ. Press, 93.

KRINSLEY, D.H. – MCCOY, F.W. 1977: Significance and origin of surface textures on broken sand grains in deep sea sediments. – Sedimentology, 24. 857-862.

KRINSLEY, D.H. – MCCOY, F.W. 1978: Aeolian sand and silt. In: Whalley, W.B. (Ed.), Scanning electron microscopy in the study of sediments. Norwich, Geoabstracts. 249-260.

LUGN, A.L. 1962: The origin and sources of loess in the Central Great Plains and adjoining areas of the central lowland. – Nebraska Univ. Stud. 26. 105.

LUGN, A.L. 1968: The origin of loesses and their relation to the Great Plains in North America. – In: SCHULTZ, C.B. – FRYE, J.C. (Ed.). Loess and related eolian deposits of the World. Nebraska, Univ.Nebraska Press. 139-182.

MARGOLIS, S.V. – KENNETT, J.P. 1971: Antarctic glaciation during the Tertiary recorded in sub-Antarctic deep-sea cores. – Science, 170. 1085-1087.

MARGOLIS, S.V. – KRINSLEY, D.H. 1974: Processes of formation and environmental occurrence of microfeatures on detrital quartz grains. – Am. J. Sci., 274. 449-464.

MARUSCZAK,H. 1980: Stratigraphy and chronology of Vistulian loesses in Poland. – Quat.Stud.in Poland, 2. 57-76.

MOSS, A.J. 1972: Initial fluviatile fragmentation of granitic quartz in water. – J.Sedim.Petrol., 42. 905-916.

MOSS, A.J. 1973: Fatigue effects in quartz sand grains. – Sedim. Teol., 10. 239-247.

MOSS, A.J. – GREEN,R.: 1975: Sand and silt grains: predetermination of their formation and properties by microfractures in quartz. – J.Geol.Soc.Aust., 22. 485-511.

SMALLEY, I.J. – LEACH, J.A. 1978: The origin and distribution of the loess in the Danube basin and associated regions of East-Central Europe – a review. – Sedim.Geol., 21. 1-26.

SMALLEY, I.J. – KRINSLEY, D.H. 1978: Loess deposits associated with deserts. Catena, 5. 53-66.

SMALLEY, I.J. – KRINSLEY, D.H. – VITA–FINZI,C. 1973: Observations on the Kaiserstühl loess. – Geol.Mag. 110. 29-36.

SMITH, S.J. – WHALLEY, W.B. 1981: Late Quaternary drift deposits of North Central Nigeria examinded by scanning electron microscopy. – Catena, 8. 345-368.

SNOWDEN, J.O. – PRIDDY, R.S. 1968: Geology of Mississippi loess. – Mississ.Geol.Surv.Bull. 111. 13-203.

VITA–FINZI, C. – SMALLEY, I.J. – KRINSLEY, D. H. 1973: Crystalline overgrowths on quartz silt particles. – J.Geol., 81. 106-108.

WARNKE, D.A. 1971: The shape and surface texture of loess particles: discussion. – Bull.Geol.Soc. Am. 82. 2357-2360.

WHALLEY, W.B. 1973: Observations on the Kaiserstühl loess. – Geol.Mag., 111. 84-86.

WHALLEY, W.B. 1978. An SEM examination of quartz grains from sub-glacial and associated environments and some methods for their characterization. – Scanning Electron Microscopy, 1. 353-360.

WHALLEY, W.B. 1979: Quartz silt production and sand grain surface textures from fluvial and glacial environments. – Scanning Electron Microscopy, 1. 547-554.

WHALLEY, W.B. – KRINSLEY, D.H. 1974: A scanning electron microscope study of surface textures of quartz grains from glacial environments. – Sedimentology, 21. 87-105.

WHALLEY, W.B. – SMITH, B.J. 1981: Mineral content of harmattan déust from northern Nigeria examined by scanning electron microscopy. – J.Arid Environs., 4. 21-30.

WILLIAMS, C.B. 1923: A short bioclimatic study in the Egyptian desert. – Ministry Agric. Egypt Techn.Sci.Serv. Bull., 29. 1-20.

WILLMAN, H.B. – FRYE, J.C. 1970: Pleistocene stratigraphy of Illinois. – Illinois State Geol.Surv. Bull., 64. 204.

ZEUNER, F.E. 1949: Frost soils on Mount Kenya, and the relation of frost soils to aeolian deposits. – J.Soil Sci., 1. 20-30.

Address of author:
K. Pye, Dept. of Earth Sciences University of Cambridge, Downing Street, CAMBRIDGE CB2 3EQ – UK

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

THE PECULIARITIES IN THE FORMATION OF THE PROPERTIES AND THE AGE OF LOESS IN SOME AREAS OF THE SOUTHERN EUROPEAN PART OF THE USSR

P.V. Tsarev

ABSTRACT

Southern regions of the USSR are featured by a continuous loess cover with a thickness of 20-70 m. The eolian factor was predominant in the transport of loess material. In submontane slopes and river valleys this material was transferred by water. According to radiocarbon dating, the upper 23 m thick loess layer is Upper Quaternary. Below Middle Quaternary deposits occur. Loess subsidence is attributed to the moisture regime of the aeration zone. Arid regions with a non-wash moisture regime of the aeration zone are characterized by the strongly subsident loess development, whereas in humid areas with a wash moisture regime of the aeration zone non-subsident loess is observed.

Loess deposits are widely spread in the southern European part of the USSR. They compose the upper part of a geological section over about 40-60% of the territory of the economically more developed areas of the European Precaucasus. The widespread loess deposits are confined to certain geological and morphostructural regions. *The loess deposits in 20 to 70 m thick continuous mantle are developed*:

(1) In the Tersko-Kumian lowland – in the central part of the depression of the same name,
(2) on the eastern slopes of the Stavropolskian uplift,
(3) on the slopes of the wide Manych river valley confined to a synclinal trough,
(4) in the central part of the Tersko-Caspian trough – in the Nadterechnian plain and the Dagestanian plain representing the surface of the high right-bank III-terrace above the floodplain of the Terek river,
(5) along the northern border of the Great Caucasus meganticlinorium – the Chechenian, Osetian and Kabardian piedmont plains,
(6) in the Alkhanchurtian intermontane valley representing the depression between the Terskian and Sunzhenskian ridges.

The loess deposits are sporadically developed:

(1) on the slopes of the Terskian and Sunzhenskian ridges – in the central part of the Tersko-Caspian trough,

(2) on high terraces above the flood-plain of the rivers (Aksai, Argun, Sunzha etc.) and on the inclined-to-the-north peneplanation plane within the eastern part of the North-Caucasus (Chernogorski monocline).

Here, the loess deposits were retained in places in the upper part of the section over the planated or slightly inclined areas. Their thickness amounts to 5-15 m.

Each area distinguished is characterized by its types of the loess deposits of a definite origin, age, composition and properties. A comparative description of the composition, state and properties of loess in the principal areas of their occurrence in the Eastern Precaucasus is given in the table compiled by the results of the author's investigations and the data from several organizations which have carried out research and surveys in this region. The amount of examined parameters for calculating the values averaged over the indices of the rock properties given in the table exceeds 100 values.

The analysis of the available data on the mode of occurrence, composition and properties of loess indicate that these deposits have passed a complex path in their formation from transportation and deposition of a loess-forming terrigenous material to gaining by it the appearance and properties of a loess deposit during the processes of diagenesis and epigenesis.

The basic factor of transportation and deposition of a loess-forming material was an eolian flow. This is confirmed by the following data:

(a) Loess deposits overlie all the landforms irrespective of their hypsometric positions that allows a sediment to be deposited only from the eolian flow.

(b) the sandy fraction gradually decreases in the composition of loess from east to west (BALAEV, L.G. – TSAREV, P.V. 1964) and the content of a clay material increases in them in the same direction. Also, the content of heavy minerals in loess was found to decrease from east to west.

This peculiarity of loess composition accounts for the fact that lighter and thinner fractions have fallen from the eolian flow as a terrigenous material was removed from the zone of evacuation (the Precaspian semidesert in the periods of the Caspian marine regression).

(c) A sedimentation stage of loess formation is confined to the epochs when a river drainage in the Eastern Precaucasus had been of a recent appearance and a terrigenous material could not come differently besides by the eolian way in most areas of the loess formation (extensive watershed spaces in the lowland part of the Precaucasus and orographically isolated areas on the slopes of the Chernye Mountains).

(d) In Loess sections on the watersheds there is no trace of an aqueous or another kind of sorting of the material (e.g. bedding).

Additional processes, in some casses, have taken part along with the eolian one in the transport and deposition of loess material. Thus a terrigenous material has arrived from a talus and by proluvial transport from the adjacent slopes of the Chernye Mountains and Peredovye ridges to the piedmont plains and intermontane valleys. This is indicative of a complex alteration of the loess deposits, layers of loam and sandy loam in the section and the presence of thin sandy and gravel interlayers in their sequences. For reasons given the loess deposits of the above-mentioned areas are related to composite eolian-talus-proluvial formations.

Also, a terrigenous material, when deposited, has partially been displaced by transport in a talus to the slope base on the river valley sides downcutting the Stavropolian Uplands and Tersko-Kumian lowland.

Until recently the age of loess of the Eastern Pre-caucasus has been only approximately determined. In the Tersko-Kumian depression the loess deposits up to 40 m thickness overlie the faunistic characterized lower Khazarian (Middle Quaternary) alluvial-marine deposits. Therefore, the age of loess here is determined as Middle – and Upper Quaternary. In those loess sections where there is a buried soil at a depth of 16-19 m, their upper part is related to Upper Quaternary age, and their lower part to Middle Quaternary. The loess deposits are of the same age on the Nadterechanian plain, where they overlie the alluvial Middle Quaternary deposits of the so-called lower Terechnian horizon.

At present, it has been seen that the loess eolian-talus deposits of the upper stage, 15-19 m thick, coming down the northern slope of the Stavropolian Uplands in the Manych river valley, ave replaced by the alluvial-talus deposits of Terrace III above the flood-plain, and downstream by the marine Khvalynian deposits. Thereby, there are good reasons to believe that all the above-mentioned complexes of deposits are of the same age, and they were formed in Upper Quaternary. A buried soil underlying the above-mentioned stage of loess is conjugated with the upper Khazarian alluvium in the Manych river valley.

The absolute age of a buried soil separating the loess deposits of the Eastern Precaucasus has been determined, at our report, by the radiocarbon procedure in the isotopic laboratory of the All-Union Research Institute of Hydrogeology and Engineering Geology. The age of a buried soil from the outcrop in the Kurp river valley on the Nadterechnian plain at a depth of 14.0-15.0 m proved to be 18 2000 ± 560 years, the age of a buried soil from the outcrop in the Kuma river valley in the area of the town of Georgievsk at a depth of 11.0-11.5 m is 16 790 ± 1660 years, the age of a buried soil from the outcrop in the Kuma river valley in the area of the town of Zelenokumsk at a depth of 22.5-23.0 m is 23 200 ± 1300 years (TSAREV,P.V. 1975).

In accordance with the latest data the time of formation of these buried soils coincides with that of different stages of the Khvalynian (Upper Ouaternary) transgression of the Caspian sea. Thus, the formation of the oldest buried soil from the outcrop in the area of the town of Zelenokumsk can be compared with the time of the early Khvalynian transgression, and the formation of a thick buried soil in the Kurp river valley is probably confined to the maximum of the Khvalynian transgression. It follows that the loess layers occuring between and superposing the characterized buried soil were formed at different stages of the recession of the Khvalynian sea and can be dated as Upper Quaternary, and the formation of loess underlaying the buried soils seems to be attributed to the second half of Middle Quaternary.

TABLE 1. A comparative characteristic of engineering properties of loess in different areas of the Eastern Precaucasus

Indices	Eastern slope of Stavropolian Uplands		Tersko-Kumian lowland		Manychian valley		Nadterechnian plain
	vQ_{III}	v-d Q_{III}	vQ_{III}	v-d Q_{III}	vQ_{II}	v-d Q_{III}	v-d-p Q_{III}
1	2	3	4	5	6	7	8
Granulometric composition; content of fractions in % >0,05 mm	$\frac{18-53}{32}$	$\frac{12-44}{24}$	$\frac{15-68}{38}$	$\frac{12-70}{34}$	$\frac{8-47}{21}$	$\frac{7-53}{23}$	$\frac{5-47}{22}$
0,05-0,005 mm	$\frac{22-74}{51}$	$\frac{34-75}{58}$	$\frac{20-62}{46}$	$\frac{15-77}{45}$	$\frac{39-86}{55}$	$\frac{22-74}{52}$	$\frac{46-85}{63}$
< 0,005 mm	$\frac{2-37}{17}$	$\frac{10-26}{18}$	$\frac{2-40}{16}$	$\frac{3-44}{21}$	$\frac{2-39}{24}$	$\frac{2-44}{25}$	$\frac{3-24}{15}$
Natural humidity, W_e, %	$\frac{7-22}{11}$	$\frac{7-18}{14}$	$\frac{4-15}{8}$	$\frac{3-16}{9}$	$\frac{9-18}{12}$	$\frac{8-20}{14}$	$\frac{4-13}{8}$
Volumetric mass Δ, g/cm^3	$\frac{1,43-1,85}{1,70}$	$\frac{1,56-1,81}{1,75}$	$\frac{1,40-1,78}{1,60}$	$\frac{1,46-1,76}{1,65}$	$\frac{1,48-1,83}{1,68}$	$\frac{1,58-1,92}{1,73}$	$\frac{1,31-1,94}{1,55}$
Volumetric mass of skeleton, δ_{sc} g/cm^3	$\frac{1,29-1,70}{1,49}$	$\frac{1,28-1,67}{1,50}$	$\frac{1,27-1,54}{1,42}$	$\frac{1,40-1,59}{1,49}$	$\frac{1,40-1,67}{1,48}$	$\frac{1,38-1.64}{1,52}$	$\frac{1,23-1,76}{1,44}$
Density, γ, g/cm^3	$\frac{2,60-2,76}{2,71}$	$\frac{2,66-2,74}{2,70}$	$\frac{2,56-2,80}{2,71}$	$\frac{2,60-2,80}{2,71}$	$\frac{2,56-2,77}{2,69}$	$\frac{2,62-2,75}{2,71}$	$\frac{2,68-2,76}{2,70}$
Plasticity W_t	$\frac{22-28}{24}$	$\frac{25-38}{30}$	$\frac{22-29}{24}$	$\frac{22-30}{26}$	$\frac{25-32}{29}$	$\frac{22-38}{32}$	$\frac{22-36}{25}$
W_p	$\frac{14-18}{16}$	$\frac{14-22}{19}$	$\frac{13-17}{16}$	$\frac{15-21}{18}$	$\frac{13-17}{16}$	$\frac{13-24}{18}$	$\frac{14-22}{17}$
W_n	$\frac{2-15}{10}$	$\frac{7-17}{12}$	$\frac{3-13}{8}$	$\frac{3-17}{9}$	$\frac{10-17}{13}$	$\frac{2-18}{15}$	$\frac{2-14}{7}$
Porosity, n, %	$\frac{40-54}{48}$	$\frac{40-49}{46}$	$\frac{41-59}{49}$	$\frac{41-53}{45}$	$\frac{39-55}{47}$	$\frac{36-53}{43}$	$\frac{39-56}{49}$
Porosity ratio, ε	$\frac{0,680-1,172}{0,923}$	$\frac{0,680-0,923}{0,840}$	$\frac{0,695-1,439}{0,962}$	$\frac{0,695-1,128}{0,818}$	$\frac{0,640-1,221}{0,887}$	$\frac{0,563-1,128}{0,755}$	$\frac{0,640-1,272}{0,962}$
Degree of water saturation, G	$\frac{0,2-0,7}{0,4}$	$\frac{0,2-0,7}{0,5}$	$\frac{0,2-0,5}{0,3}$	$\frac{0,3-0,7}{0,4}$	$\frac{0,3-0,7}{0,4}$	$\frac{0,3-0,8}{0,5}$	$\frac{0,2-0,5}{0,3}$
Shearing strength: φ, degree	$\frac{15-31}{20}$	$\frac{18-35}{22}$	$\frac{19-25}{21}$	$\frac{21-26}{23}$	$\frac{16-26}{22}$	$\frac{17-27}{23}$	$\frac{19-26}{21}$
C, kg/cm^2	$\frac{0,05-0,20}{0,12}$	$\frac{0,10-0,27}{0,15}$	$\frac{0,05-0,28}{0,17}$	$\frac{0,03-0,25}{0,16}$	$\frac{0,10-0,35}{0,18}$	$\frac{0,05-0,30}{0,16}$	$\frac{0,05-0,25}{0,12}$
Coefficient of relative subsidence:							
- with domestic loads, δd. sbd.	$\frac{0,003-0,084}{0,048}$	$\frac{0,002-0,061}{0,027}$	$\frac{0,003-0,115}{0,060}$	$\frac{0,002-0,108}{0,030}$	$\frac{0,001-0,089}{0,031}$	$\frac{0,001-0,059}{0,024}$	$\frac{0,001-0,182}{0,089}$
- with load 3 kg/cm^2, δ sbd. 3,0	$\frac{0,007-0,203}{0,095}$	$\frac{0,003-0,109}{0,065}$	$\frac{0,012-0,245}{0,114}$	$\frac{0,015-0,167}{0,055}$	$\frac{0,004-0,130}{0,081}$	$\frac{0,010-0,099}{0,050}$	$\frac{0,005-0,237}{0,105}$
Thickness of subsident stratum, m	15-20	10-15	20-30	15-20	10-15	5-12	20-30
Total value of subsidence stratum, cm	50-180	20-100	100-250	50-100	20-100	10-50	50-300

Note: The limits of changes in the indices are given in the numerator, their average values - in the nominator

Dagestanian plain	Piedmont plains			Alkhanchurtian intermontane valley	Slopes of Terskian and Sunzhenskian ridges	Slopes of Chernye mts.
	Chechenian	Osetinian	Kabardinian			
	v - d - p Q_{III}				v-d Q_{II}	vQ_{II}
9	1o	11	12	13	14	15
11-3o	9-32	1o-35	15-39 26	8-32 21	7-39 22	3-15 8
24-84	44-67	42-6o	51-62 54	52-76 64	36-71 47	29-48 4o
3-29	8-19	14-17	7-28 18	6-27 15	28-5o 31	44-63 52
7-2o 1o	7-22	11-26	8-24 13	6-21 14	6-22 4	19-32 27
1,35-1,91 1,61	1,55-1,24	1,6o-1,9o	1,36-2,oo 1,69	1,38-1,91 1,6o	1,44-1,8o 1,64	1,62-1,98 1,81
1,25-1,78 1,51	1.37-1,66	1,32-1,74	1,18-1,58 1,46	1,26-1,7o 1,47	1,28-1,65 1,46	1,28-1,6o 1,48
2,6o-2,84 2,71	2,69-2,77	2,59-2,78	2,66-2,8o 2,72	2,62-2,75 2,72	2,68-2,77 2,71	2,69-2,8o 2,73
18-36 26	22-32	23-39	24-4o 28	22-32 28	22-36 27	28-43 36
15-23 18	14-26	16-24	15-25 19	14-23 19	14-21 16	18-25 21
3-15 8	4-13	6-16	5-17 9	4-12 9	7-17 12	1o-2o 15
38-52 46	39-5o	37-49	38-55 47	36-54 48	42-53 47	41-53 48
o,619-1,1oo o,84o	o,64o-1,ooo	o,59o-o,96o	o,62o-1,12o o,887	o,56o-1,17o o,92o	o,72o-1,126 o,887	o,7o7-1,114 o,924
o,2-o,7 o,4	o,3-o,8	o,4-o,8	o,2-o,8 o,5	o,2-o,5 o,3	o,2-o,7 o,4	o,5-o,9 o,7
21-27 22	16-26	9-23	21-27 22	16-24 2o	7-2o 16	9-3o 19
o,1o-o,25 o,15	o,o9-o,38	o,o7-o,3o	o,o9-o,28 o,14	o,o5-o,3o o,15	o,o4-o,2o o,1o	o,o5-o,55 o,29
o,oo2-o,o92 o,o28	o,oo2-o,o59	o,oo2-o,o4o	o,oo3-o,o4o	o,oo4-o,123 o,o61	o,oo1-o,o89 o,o2o	o,ooo-o,o1o
o,oo3-o,165 o,o72	o,oo7-o,169	o,oo4-o,154	o,oo4-o,171	o,oo7-o,219 o,121	o,oo5-o,13o o,o52	o,oo1-o,o2o
5-1o	5-1o	4-1o	5-15	2o-3o	5-15	o-5
1o-4o	1o-5o	o-2o	1o-6o	5o-25o	5o-1oo	o-1o

As follows from the data given in the table, the relation between the loess properties and their genesis is unclearly shown. Thus the eolian loess deposits of the Tersko-Kumian plain and the loess of complex genesis of the Nadterechnian plain and the Alkhanchurtian valley are characterized by the smalles density of structure, small moisture content and the largest ability to subside. At the same time the loess deposits of eolian origin are not practically liable to subsidence on the sides of the Chernye Mountains and the loess of complex origin show low or average subsidence on the piedmont plains. These differences in the properties of loess can be explained only by the fact that a postgenetic stage of their formation proceeded under various physicogeographic, mainly climatic conditions. Based on studying the nature of the subsidence phenomena of the loess rocks in the Precaucasus L.G. BALAEV (1964) concluded that the moisture regime in the zone of aeration should be considered as one of the important factors of the formation of their strength and deformation properties. Thus, in arid regions the moisture regime in the aeration zone of loess is of an unwashed nature. Here, the atmospheric precipitation percolates to an only small depth (up to 2-5 m), and then it is completely evaporated in a dry season of the year. Under these conditions the moisture of loess rocks underlying the horizon of a seasonal moistening remains constantly low (lower than the moisture of capillary rupture), in consequence the intensity of diagenetic processes, resulting in compaction and stabilization of a rock, is greatly weakened. In developing these notions a loess deposit within the horizon with a low moisture content (so-called „dead horizon") can be assumed to retain mainly that structural type and those structural relations, which have been formed in the period of deposition and its occurrence in the zone of a seasonal change in moisture and temperature. A low density of the structure and a low strength of the structural relations are highly characteristic of loess. All that has resulted in subsidence.

In the areas with a humid climate the aqueous regime in the zone of aeration is referred to a washed type. Much atmospheric humidity percolates through the whole sequence of a terrigenous material deposited. Under the conditions of moistening the diagenetic processes in a sediment are proceeding more intensively. The initially formed weak structural relations, mostly of a condensation-crystallization nature, are destroyed and the deposit is compacted to porosity corresponding to the external pressure. Also, new structural relations of colloidchemical nature are formed instead of the destroyed structural relations, which are more stable under the conditions of moistening. Thus, in humid zones non- to low-subsident loess forms.

The formation of the major deformation and strength properties of loess rocks in the Eastern Precaucasus is represented by a somewhat simplified types. Actually, the development of thicker strata of strongly subsident loess is confined to the zones with the arid climate (Tersko-Kumian depression, Nadterechnian plain, and Alkhanchurtian valley). The thickness of a subsident stratum here attains 20-30 m and more, and a total subsidence of the surface can attain 250-300 cm with wetting the loess deposits, as this has been observed with wetting the Malo-Kabardinian, Nadterechnian, and Levoberezhnian canals.

There formed non-subsident loess rocks in the areas of the excess moistening, for example, on the sides of the Chernye Mountains.

In the areas, where the regime of the rock moisture in the zone of aeration is of a mixed nature, such as the slopes of the Stavropolian uplift and piedmont loessial plains, both subsident and non-subsident loess rocks were formed. Moreover, the regime nature of the rock moisture in the aeration zone of loess rocks here is determined by the peculiarities of the microclimate in various areas. Since the microclimate is greatly determined by the topography, the rate of subsidence of loess varies with relief. On watersheds where the regime of the rock moisture in the zone of aeration is usually unwashed, the loess rocks possessing the subsidence properties have been formed. The non-subsident loess rocks were formed in the river valleys and large beams and on the terraces under the conditions of a washed type of the moisture regime in the zone of aeration.

From the above the following conclusions can be drawn:

The subsident loess deposits in the Eastern Precaucasus, being different in origin, were formed in the Middle and Upper Quaternary period, that is convinced both by the analysis of their interrelations in the sections with other types of Quaternary rocks and the direct radiocarbon datings of the buried soil.

A comparative analysis of loess subsidence, formed under various physiogeographic conditions in the region, shows that the regime of the loess rock moisture in the zone of aeration, determining the direction and intensity of diagenetic processes, plays the main role in the fomation of the subsidence properties of these sediments.

REFERENCES

BALAEV, L.G. – TSAREV, P.V. 1964: Lessovye porody Tsentralnogo i Vostochnogo Predkavkazya. Moskva, Nauka, 247.

KAPLIN, P.A. – LEONTEV, O.K. – PARUNIN, O.B. – ROGACHEV, G.I. – SVOTOCH, A.A. – IL'ICHEV, V.I. 1972: K voprosu o vremeni khvalynskikh transgressii Kaspiya (po dannym radiouglerodnogo analyza rakovin molyuskov). – Doklady AN SSSR, 206. 1413-1416.

TSAREV, P.V. 1975: Usloviya formirovaniya inzhenerno-geologicheski svoistv lessovykh porod Vostochnogo Predkavkazjya. Sb. Sovremennye metody izucheniya fiziko-mechanicheskikh svoistv gornykh porod. – Trudy VSEGINGEO, 104, 22-29.

Address of author:
P.V. Tsarev, All-Union Research Institute of Hydrogeology and Engineering Geology
142452 MOSCOW region, Noginsk district pos Zelenyi – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

THE EVOLUTION OF CHEMICAL ELEMENTS IN LOESS OF CHINA AND PALEOCLIMATIC CONDITIONS DURING LOESS DEPOSITION

Wen Qi-zhong – Yang Wei-hua – Diao Gui-yi – Sun Fu-qing –
Yu Su-hua – Liu You-mei

ABSTRACT

Geochemical data of Luochuan loess section have been analyzed by statistic method. The results indicate that the contents of elements of Al, Fe^{+++}, Mn, Ti, K decrease from bottom upward, whereas, the contents of Ca, Sr, Si and Fe^{++} show an opposite tendency. REE content in loess lies in the range of 160-210 ppm, and their distribution patterns in different loess samples show a similarity with each other. $CaCO_3$ and Sr in paleosols were strongly leached, whereas, Al_2O_3 and Fe_2O_3 show an obvious accumulation. Meanwhile, trace elements Mn, P, Zn, Cu etc. and REE content also increase relatively in paleosols. The fluctuations of elements in 1st, 5th, 8th and 14th paleosols are especially evident, the boundaries of which are similar to those of sedimentary cycles or stratigraphic boundaries.

Periodicity in the evolution of chemical elements agrees well with those of insolation and isotopic oxygen changes in deep-sea sediments by analysis of autocorrelation coefficient and power spectrum $CaCO_3$ content, FeO/Fe_2O_3, $CaO\text{-}K_2O + Na_2O/Al_2O_3$ and Sr/Ba ratios well reflect climatic periods with the intervals of 80-100, 40-50, 20-30 thousand years, which demonstrates that the climatic variation was controlled by astronomical factors. Based on the established elemental periods loess sections are divided into sedimentary cycles and subcycles, providing important evidences for the division of climatic cycles since the Quaternary.

Evolution of chemical elements in strata can reflect the evolutionary regularity of natural conditions, also mark the evolution of the Earth (HOU DE–FENG, 1959), The regularity of the distribution, migration and accumulation of elements in loess may be used to explain the paleogeography, paleoclimatic conditions during loess deposition and the environmental variation after loess deposition as well.

The paper deals mainly with the samples taken from Luochuan section. On the basis of the past research work, the common elements (100 samples), trace elements (130 samples) and REE (23 samples) have been further analysed for loess and paleosols in this section. The common elements and trace elements are analysed by chemical analysis and atomic absorption technique, Sr and Ba by spectroscopy, and REE by neutro-activation method. All data have been analyzed statistically. Our purpose is to inquire into the evolutionary tendencies and periods of elements in loess section and their relationship with paleoclimatic conditions.

THE CIRCULATION AND RHYTHMS OF LOESS DEPOSITION

The section studied is located at Potou village 5 km from Louchuan, Shaanxi province and has a thickness of 130 m. According to the lithologic characteristics, the distribution and development of paleosols, as well as vertebrate fossils, etc., four first-order sedimentary cycles can be divided from bottom to top, moreover, there are many rhythmic variations in each sedimentary cycle. The first-order sedimentary cycles are consistent with four loess stratigraphic units. Wucheng loess, Lower Lishi loess, Upper Lishi loess and Malan loess proposed by Liu Tung-sheng et al. (LIU TUNG-SHENG – ZHANG ZONG-HU, 1962).

According to up-to-date paleomagnetic information the deposition of Wucheng loess began in the middle-late Matuyama epoch (LIU TUNG-SHENG et. al. 1978). The bottom of Lishi loess in Luochuan section lies at the boundary between the Brunhes and Matuyama epochs (0.71 my.). In addition, the 14C age of black loamy soil at the top of Malan loess is 9830 ± 1300 years[1]. These data have provided the rudiment of the time scale for the evaluation of chemical elements in the loess section.

THE CONTENT AND DISTRIBUTION OF ELEMENTS IN LOESS SECTION

From analysis, it can be seen that the average values of Si, Al, K, Ti, Zn, Co, F and RE_2O_3 approach or correspond to Clarke's value in earth crust, however, the contents of Ca, Sr, Ba and Pb are more than twice as high as Clarke's value, Cl is more than thrice as high as Clarke's, the other elements are all at lower values.

The average values of chemical compositions in Louchuan loess show similarity with those of the middle Huang He valley, which indicates that the loess is a homogeneous material. However, obvious differences exist from those of other areas over the world.

At loess strata of different ages, the variation of elements distribution is as follows: the contents of Ca, Sr, Fe^{2+} and Cl in the upper part of Malan loess are higher than

---

[1] QIAO YU–LOU et al. 1979: Radiocarbon dating of loess sediments.

TABLE 1. Texts for notable levels of elements in paleosol (and buried weathering beds)

Element / Paleosol type	Si	Al	Fe^{3+}	Fe^{2+}	Ca	Mg	K	Na	Ti	Mn	Zn	Cu	Co	Ni	Pb	Sr	Ba
Drab-brown earth	+++	+++	+++	++	+++	–	+++	++	+++	+++	+++	+	–	+++	–	+++	+++
Luvic drab soil	+++	+++	+++	+++	+++	+	++	–	+++	+++	+++	++	–	++	–	+++	–
Drab soil	+++	+++	+++	++	+++	–	+++	–	+++	+++	+++	+++	+	+++	–	+++	–
Calcareous drab soil	++	+++	+++	+	+++	–	++	–	+++	+++	+++	+	–	+++	–	++	–
Buried weathering bed (1)	+++	+++	+++	+++	+++	+++	+++	–	+++	+++	+++	–	–	+++	–	–	–
Buried weathering bed (2)	+	+++	+++	+++	+++	+++	+++	–	++	+++	+++	+	–	+++	–	++	–
Buried weathering bed (3)	–	++	+++	+++	++	+++	+++	+	++	+++	+	–	–	+++	–	+++	–
Leaching (L.) or accumulation (A.) state		A.	A.	oxidated	L.		A.	L.	A.	A.	A.	A.		A.		L.	

– no obvious differentiation ($|t| < t_{0.05}$),
\+ slightly obvious differentiation ($t_{0.05} < |t| < t_{0.01}$),
++ moderately obvious differentiation ($t_{0.01} < |t| < t_{0.001}$).
+++ strong obvious differentiation ($|t| < t_{0.001}$).

those both of lower Lishi and Wucheng loess, whereas the contents of Fe^{3+}, K and Mn show an opposite tendency. These elements are usually similar to the normal distribution or logarithmic normal distribution in loess section.

The distribution of elements is not uniform either in different classes of particles. The contents of SiO_2, TiO_2, FeO and Na_2O in clay fraction are lower than those in the whole rock, whereas the contents of Al_2O_3, Fe_2O_3 and K_2O are opposite which are higher. This is evidently due to the increase of illite content and other secondary minerals in fine grains. Moreover, to the clay fraction, about one-third of Fe_2O_3 exists in a form of free state. In addition, the contents of trace elements such as Zn, Cu, Mn, P and REE in clay fraction are also higher than those in the whole rock, which shows either replacement of elements in crystal layers of minerals, or absorption of clay might exist.

EVOLUTION OF ELEMENTS DURING LOESS WEATHERING PROCESS

Paleosols of different types (LU YAN-CHOU – AN ZHI-SHENG, 1979) and ages are found in the Luochuan section. The elements have undergone differentation and reassignation during the change from loess into paleosol. In paleosols, the contents of Al, Fe^{3+}, K, Ti, Mn, Zn, Cu, Ni and RE_2O_3 have increased to some extent compared with the parent rock of loess, whereas Ca, Fe^{2+}, Sr, etc. are lower than those in loess. Relevant ratios of oxides are lower than those in loess, too (except K_2O/Na_2O), moreover, the values of oxide ratios and Sr/Ba have progressively decreased by strong pedogenesis, whereas F/Cl value shows an opposite tendency.

By means of „t test analysis" (TABLE 1.) it has been found that paleosol was formed from loess by weathering process, and the elements of Ca, Al, Fe^{3+}, K, Si, Ti, Nm, Zn and Ni, etc. have more obvious variations than loess, but Pb, Co, Ba do not show evident variations. In addition, by analysis of relative values of oxides leaching and accumulation (WEN QI-ZHONG et al. 1981a) it has been proved that Fe_2O_3, Al_2O_3, K_2O, etc. were accumulated relatively, the sequence of accumulation is as follows: $Fe_2O_3 > K_2O > Al_2O_3 > SiO_2 > MgO$, but CaO, Na_2O, etc. were leached relatively during loess weathering. At the same time a large amount of Fe^{2+} were oxidized and reformed into Fe^{3+}. The intensity sequence of leaching is as follows: $CaO > FeO > Na_2O$, in which, the accumulation of Fe_2O_3 and the leaching of CaO are most obvious, and there exists a normal relationship between them (WEN QI-ZHONG et al. 1981b).

During loess weathering, $CaCO_3$ and Sr were strongly leached, Fe_2O_3 and Al_2O_3 show an obvious accumulation, the secondary clay minerals increased in amount, the textural properties were transformed, which made loess turn from grey-yellow or light yellow-brown bed rich in calcified layers to brown or red-brown paleosol with neutral layer rich in aluminium-silica. The frequent superpositions of loess-paleosol series in the section reflect the basis pattern of frequent, repeated climatic fluctuations from arid to humid during Quaternary. At the same time the values of oxide, F/Cl, leaching and accumulation degree, also reflect the differences of amplitudes of paleomagnetic fluctuation for each warm-humid pedogenesis during loess deposition and evolution.

THE TENDENCY AND ORIENTATION OF ELEMENT EVOLUTION IN LOESS SECTION

In order to inquire into the tendency of the evolution of chemical element contents in loess section, we have carried out the calculation by „five-term moving average analysis". From FIG. 1 it can be seen that the evolution of Si show increase to a certain extent from bottom upward, whereas Al, Fe^{3+}, K, Mn and Ti progressively decrease upward, and there are obvious increase in paleosols corresponding to the 1st, 5th, 8th, 10th layers within a general tendency of decrease.

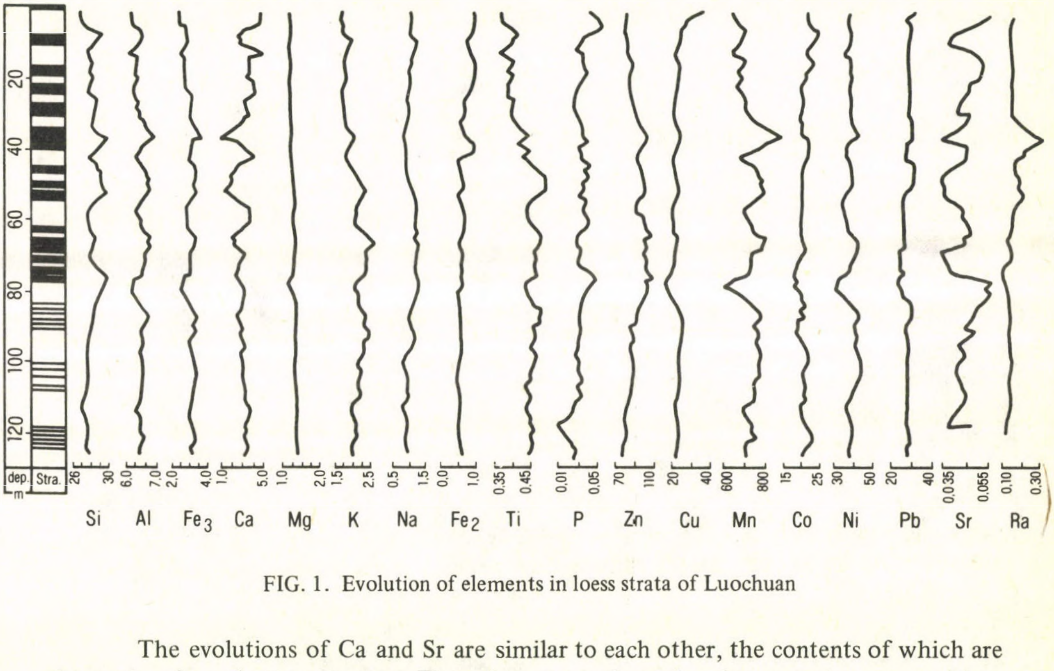


FIG. 1. Evolution of elements in loess strata of Luochuan

The evolutions of Ca and Sr are similar to each other, the contents of which are increasing from bottom to top. They show several regular decreases in a general tendency of increase, i.e. the clayey bed of paleosol has been strongly leached. And the content of Ba is in a minor fluctuation. The evolutional tendency of Fe^{2+} is similar to that of element Ca, but its fluctuation is not obvious as compared with Ca.

The evolution of Zn content is from low to high, then to low again, whereas of Cu is just the opposite. But both have shown several peaks in the above-mentioned paleosols. It shows that the fluctuations of element contents in the 1st, 5th, 8th, 10th and the 14th paleosol are especially evident, in which the boundaries are consistent with those of sedimentary cycles or stratigraphic boundaries.

The distributions of Mg, Na, Pb, Ba, Co and N contents in the loess section are comparative homogeneous so their fluctuations on evolutional curves are smaller and the curves are relatively smooth. The REE amount in loess has a range of 160 to 210 ppm, there is a tendency of progressive decrease from bottom upward (from

Wucheng to Lishi then to Malan loess). But their distribution patterns in different loess beds show a similarity among them (WEN QI–ZHONG et al. 1981a).

These evolutional tendencies of elements in loess section are related to the distribution and variation of mineral and grain components in the section, to paleoclimatic environment and conditions of geochemical media. The paleoclimatic conditions during the Wucheng loess deposition is relatively more warm-humid than those of Lishi and Malan loess deposition. The evolution of Ca, Sr, Fe^{2+} contents etc. in the loess section increase progressively from bottom to top, the contents of $CaCO_3$ also increase fluctuating in rhythms, whereas Fe^{3+}, Al, K, Mn, Ti, etc. decrease upward. It can be held that these evolutional tendencies of chemical elements in loess section are related to the climatic conditions, which have been shifting from wet to drier since the Quaternary. And these tendencies show an agreement with evolutions of animal species and sporo-pollen in loess section. All mentioned above indicate that the evolution of the paleoclimatic conditions revealed by the loess deposits has a general tendency with rhythmic fluctuation since Pleistocene, i.e. from humid forest prairie to arid desert steppe (LIU TUNG–SHENG – WEN QI–ZHONG – ZHENG HONG–HAN, 1980).

PERIODS OF ELEMENT EVOLUTION AND PALEOCLIMATIC CHANGE

It has been found that some components and ratios of elements dominated by climate, for example, $CaCO_3$, Sr/Ba, FeO/Fe_2O_3 and $CaO + K_2O + Na_2O/Al_2O_3$, etc. show periodic variations in contents of different magnitudes, and are synchronous with the loess-paleosol cycles. Accordingly, some new light have been shed on the variations of the above-mentioned element components and ratios in loess sections to be used to learn the history of climatic changes.

The climatic fluctuations vary with the lapse of time, so we regard this variation as a function of time sequence. We have used „analysis of autocorrelation coefficient (Rp) and power spectrum (Sr)" as mathematic models (RALSTON, A. – WILF, H.S. 1960, AGTERBEG, F.P. 1974). Rp and Sr obtained are drawn in FIGS. 2, 3 and each period is listed in TABLE 2. From these figures and table, the main periods may be summarized as follows: 40-50 and 20-30 thousand years. The period-terms are relatively stable, and relevant to climatic changes dominated by some factors. In order to verify this hypothesis, we have calculated, by the same mathematic model mentioned above, the insolation changes at 65°N (converting it into latitudes of those years) for the last 600 thousand years which were calculated by M. Milankovitch (YAO ZHENG–SHENG, 1959) according to astronomical hypothesis of climate and oxygen isotopic (δO^{18}) values in deep-sea sediments gained from cores $V_{12\text{-}122}$ (17°N, 74°24' W) (IMBRIE, J. et al. 1973) and $V_{28\text{-}239}$ (3°15'N, 159°E) (SHACKLETON, N.J. 1976). It seems that insolation changes or variations of oxygen isotopes (δO^{18}) of deep-sea cores from different latitudes are all stable period-terms (FIGS. 4., 5, TABLE 2) and are basically similar to the periodic variation of element components.

From these calculations and studies, several conclusions can be drawn: 1. The cycles of frequent superpositions of loess-paleosol series in Luochuan section were controlled by paleoclimate, which is synchronous to cycles of composition contents and

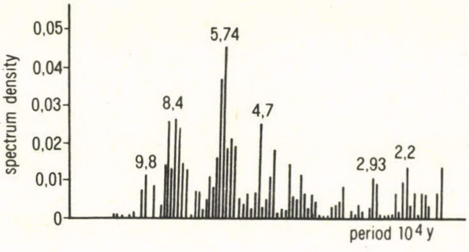


FIG. 2. Power spectrum of FeO/Fe_2O_3 ratio

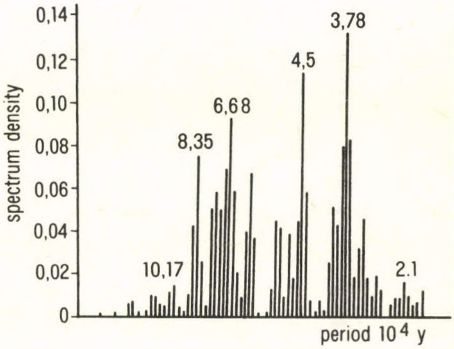


FIG. 3. Power spectrum of Sr/Ba ratio

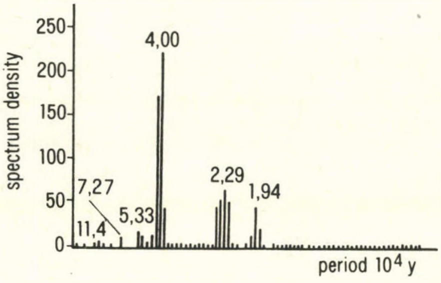


FIG. 4. Power spectrum of insolation change at 65°N

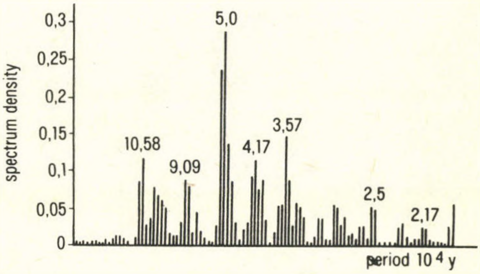


FIG. 5. Power spectrum of 0^{18} value in core $V_{28\text{-}239}$

TABLE 2. Comparison of fluctuation periods of composition contents and ratio of elements with periods of insolation changes and oxygen isotope

Time sequence	Section (10^4 yr.)	Period (10^4 yr.)						
Alternative superposition of loess-paleosol	120	12.38^{++}	8.43^{++}	4.8-4.33	3.57^{+}	2.98	2.65	2.38
	61	12.96-11.66^{++}	8.33^{++}	4.8^{+}	3.33^{+}	2.78		2.20
$CaCO_3$ content	120	11.81	7.85^{+}	4.30^{++}	3.00^{+}			2.2-1.97
	47	11.32^{+}	7.55^{++}	3.94^{++}	2.92^{+}		2.45	2.26-1.81^{+}
$CaC + K_2O + NaO/Al_2O_3$		12.86^{++}	8.18^{++}	4.50^{++}	3.67		2.50^{+}	
Sr/Ba		10.17	8.35^{+}	4.50^{+}	3.78^{++}			2.10
FeO/Fe_2O_3		9.80	8.40	5.74^{++}	2.93			2.20
Insolation change	60	11.40	7.27	5.33^{++}	4.00^{++}		2.29^{++}	1.94^{++}
Isotope oxygen (V28-239)	120	10.58^{+}	9.09	5.00^{++}	4.17^{+}	3.57^{+}	2.50	2.17
Isotope oxygen (V12-122)	46		7.50^{++}	5.19	3.75^{+}	3.07^{+}		1.90

$^{++}$The most significant, $^{+}$Significant ratios of elements dominated by climate, and they all have obviously three period-terms which are 80-100, 40-50, 20-30 thousand years, 2. These period-terms are consistent with the periods calculated by M. Milankovitch on the basis of astronomical factors, and with periods of oxygen isotopes (δO^{18}), 3. The content variations of elements governed by climatic factors can reflect the climatic periods well, which provides a new approach for studying Quaternary climatic changes in continuous continental deposits, 4. It has been further proved that climatic changes in Quaternary were controlled by astronomical factors. Establishing element periods and dividing the loess section into sedimentary cycles and subcycles by them have provided significant data for the division of climatic cycles since the Quaternary.

ACKNOWLEDGEMENTS

The authors wish to thank Prof. Liu Tung-sheng for his guiding. The analyses of common elements were made by the ninth laboratory of our institute. Sun Jing-xin and Wang Yu-gi, etc. (Institute of High Energy Physics, Academia Sinica) determined the REE value, the figures were drawn by members of the map-making group in our institute. In addition, this study has been warmly supported and helped by Mr. Zheng Hong-han, Hong Li-wen, Cheng Quing-mu and Han Jia-mao etc. We here express our sincere thanks to them all.

REFERENCES

AGTERBERG, F.P. 1974: Geomathematics. Amsterdam – London – New York, Elsevier. 363-400.

HOU DE-FENG, 1959: Geochemical concept of strata. – Scientia Geologia Sinica, 3.68-71. (in Chinese).

IMBRIE, J. et al. 1973: Paleoclimatic investigation of a late Pleistocene Caribbean deep-sea core, Comparison of isotopic and faunal methods. – Quaternary Research, 3. 1. 10-32.

LIU TUNG-SHENG – ZHANG ZONG-HU, 1962: Loess of China. – Acta Geologia Sinica, 42. 1. 1-4. (in Chinese).

LIU TUNG-SHENG et al. 1978: The geological environment of loess in China. – Kexue Tongbao, 1. 1-5. (in Chinese).

LIU TUNG-SHENG – WEN QI-ZHONG – ZHENG HONG-HAN, 1980: The paleoclimatic records in loess of China and their reflection of the ancient climatic evolution. – Proceedings of Geological Sciences for 26th Congress of I.U.G.S. Beijing, Geology Press. 78-97 (in Chinese).

LU YAN-CHOU – AN ZHI-SHENG, 1979: Investigation of variation of natural environment in loess plateau since about 700 thousand years. – Kexue Tongbao, 5. 221-224. (in Chinese).

RALSTON, A. – WILF, H.S. 1960: Mathematical methods for digital computers. New York, Wiley.

SHACKLETON, N.J. 1976: Oxygen-isotope and paleomagnetic stratigraphy of Pacific core V_{28-239} Late Pliocene to latest Pleistocene. – Geological Society of America, Memoir, 145. 449-462.

WEN QI-ZHONG et al. 1981 a: A preliminary investigation of REE in loess. – Geochimica, 2. 153-155. (in Chinese).

WEN QI-ZHONG et al. 1981 b: The ratios of oxides and relative values of weathering leaching or accumulation in loess section and their geological significance. – Geochimica, 4. 381-386. (in Chinese).

YAO ZHEN-SHENG, 1959: Climatological principle. Science Press. 361-379.

Address of authors:
Wen Qi-zhong, Yang Wei-hua, Diao Gui-yi, Sun Fu-qing, Yu Su-hua, Liu You-mei,
Institute of Geochemistry, Academia Sinica
QUEIYANG – China

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PALEOCLIMATIC EVENTS RECORDED IN CLAY MINERALS IN LOESS OF CHINA*

Zheng Hong-han

ABSTRACT

86 samples of loess and paleosol for the study of clay minerals were taken from the Heimugou loess section at Luochuan and the Nuanquangou loess section at Longxi. The results indicate that the loess and paleosols of different ages show a close similarity in their clay mineral species with illite as the dominant component, and they also contain certain amounts of chlorite, kaolinite, montmorillonite, vermiculite, halloysite and a detectable amount of mixed-layer minerals.

Some indicators, the ratio of the illite (001) reflexion peak height and width at half height (H/W value) and the ratio of (001) and (002) reflexion intensities I(001)/I(002) are adopted to discuss the loess variation in the clay mineral crystallinity after pedogenesis.

The relative amount of clay mineral species and their crystallinity are adopted as indicators showing the amplitude of climatic fluctuation and the time scale was controlled by data of biostrata, magnetostrata, radiocarbon and thermoluminescence dates. 13 climatic cycles with 26 stages have been distinguished in loess section since loess deposition. An attempt to correlate climatic events recorded in loess sections of China with glacial/interglacial in Northern Europe and the isotope oxygen stages in deep sea sediments is presented in this paper.

INTRODUCTION

Loess was early developed at the beginning of Pleistocene and loess deposition continued during Holocene in China. Good sections are widespread in regions of Gansu, Shaanxi and Shanxi provinces of North China. A loess section, composed of superimposed loess representing a cold-drought climatic condition, is an ideal geological body for the study on evolution of Quaternary climate since the deposition of the section was basically continuous, with detailed record of the climate evolution from the beginning of loess deposition.

---

* **GU XIONG–FEI, HAN JIA–MAO and DENG BING–JUN also took part in this investigation.**

It is undoubtedly an effective method to use the biogenic traces to distinguish the paleoclimatic conditions recorded in different beds during their development. However, there are many difficulties in studying the paleoclimatic records of loess strata and in the discussion of the paleoclimatic conditions for a given section due to insufficient fossils and very small content of spore-pollen in general. The minerals, especially the clay minerals, are important materials for the study of paleoclimatic conditions and of the fluctuation rule since the deposition of loess, because different clay minerals have a close similarity in their crystal structure, they can be easily changed under hypergene environment and their composition and crystallinity will reflect the characteristics of the environments they underwent.

This article is a preliminary report on the study of clay minerals and discussion of paleoclimatic conditions reflected by them both in Nuanquangou section at Longxi of Gansu and in Heimugou section at Luochuan of Shaanxi province.

CLAY MINERAL SPECIES

Luochuan and Longxi sections are developed in different geomorphological positions, the former is widespread on the loess "Yuan" area (a kind of region with an even loess topography) and the latter is developed in a basin region. Their stratigraphy shows a close similarity. The section can be subdivided into the Late Pleistocene Malan loess, the Middle Pleistocene Lishi loess and the Early Pleistocene Wucheng loess in descending order. Holocene loess is found at the top of Longxi section. The loesses of different age show disconformable contacts with each other (FIG. 1). Samples used for the examination of clay mineral were taken from each bed of the above described sections. The total number of the determined samples is 86.

X-ray powder diffraction technique was adopted in the examination of clay minerals, some of them were examined by electronmicroscope. The particle size is less than 2 μm in the clay mineral analysis. The clay minerals either in loess or paleosol samples show a close similarity, their basal reflexion peaks lie at $d = 15.5, 14, 10$ and 7.2 Å in diffraction patterns (FIG. 2). Based upon the changes of diffraction peaks after glycolated, NH_4Cl treated, heated under 550° and HCl treated, it can be judged that the reflexion at 15.5 Å is of montmorrilonite, 14 Å peak is chlorite with some vermiculite, 10 Å peak is of illite, 7.2 Å peak is an overlapped reflexion by kaolinite (001) and chlorite (002). In addition, some samples have a small amount of halloysite and mixed-layer minerals.

Given in TABLE 1. is the main mineral species and their relative amount estimated by basal reflexion intensities. This result has shown that either illite or montmorillonite content in loess is commonly less than those in paleosol, indicating that the clay minerals in paleosol changed under warmer and moister climate conditions, and some of them may be produced from other clay minerals or from detrital minerals such as feldspar.

The Luochuan section shows clearly that the older loess contains more montmorillonite and vermiculite with less illite, whereas, the younger loess shows an opposite tendency. These indicate that the paleoclimate has shifted from moist to drought since Quaternary in general, which agrees with those reflected by data of biostratigraphy and

TABLE 1. Main clay mineral species and their relative amounts in Luochuan and Longxi sections

Strata	Sediments	Amount	Clay minerals and relative amount %			
			illite,	chlorite,	kaolinite,	montmoril.
Luochuan section						
Malan 1.	Loess	3	68	12	11	9
Lishi 1. (Upper)	Loess	4	67	11	10	12
	Paleosol	6	72	8	8	13
Lishi 1. (Lower)	Loess	9	63	11	11	16
	Paleosol	8	74	7	7	13
Wucheng 1.	Loess	12	60	11	10	19
	Weathering B.	10	61	10	9	20
Longxi section						
Holocene 1.	Loess	2	56	19	13	12
	Paleosol	2	62	15	14	10
Malan 1.	Loess	1	51	22	17	10
Lishi 1.	Loess	7	62	11	12	15
	Paleosol	10	64	10	11	15
Wucheng 1.	Loess	6	69	6	8	17
	Weathering B.	3	73	5	9	13

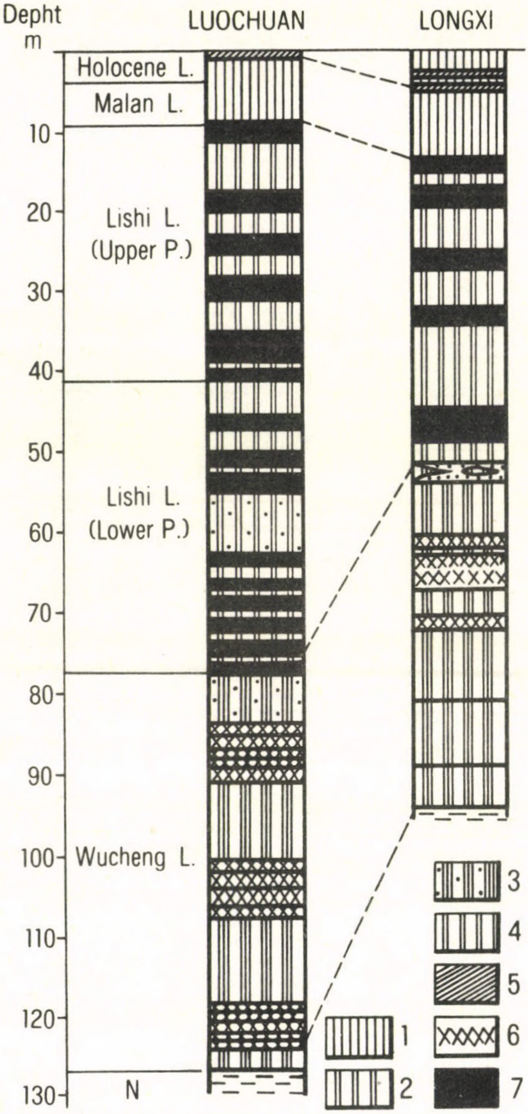


FIG. 1. Luochuan and Longxi loess sections
1 = Malan loess and Holocene loes, 2 = Lishi loess, 3 = Wucheng loess, 4 = Silt bed, 5 = Black soil, 6 = Weathering bed, 7 = Paleosol.

spore-pollen stratigraphy (LIU TUNGSHENG et al. 1964, LIU TUNGSHENG et al. 1965, SHACKLETON, N.J. et al. 1973).

CRYSTALLINITY

Illite is the most important clay mineral in loess sections, and its characteristics in different loess beds can be used to obtain information on clay minerals in deposition and reformation processes. Recently, it has been commonly accepted that illite is actually a disorder mixed-layer mineral made up to mica layers with minor expansible layers (BAILEY, S.W. 1980), in which the quantity of expansible layer decides the peak site and shape of (001) reflexion. Illite „crystallinity" was discussed by C.E. WEAVER, based upon the ratio of peak height at 10 Å to that at 10.5 Å (WEAVER, C.E. 1960)

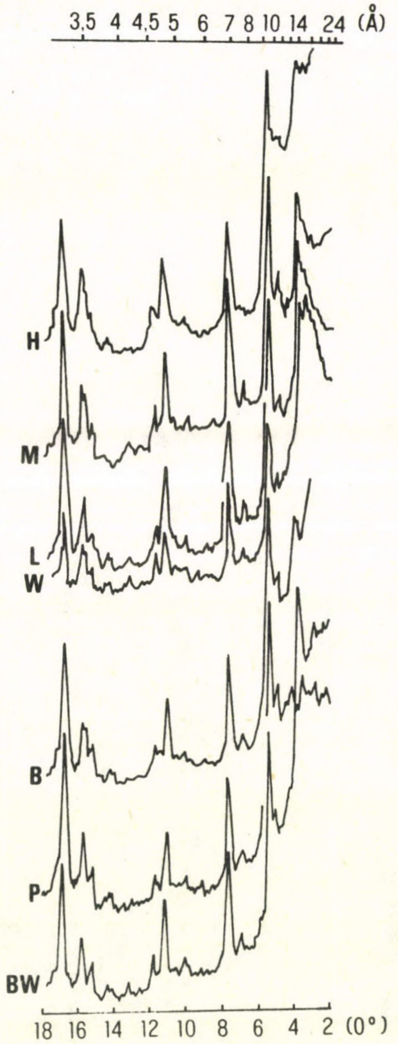


FIG. 2. X-ray diffraction patterns of clay minerals in loess and paleosol
H = Holocene loess,
M = Malan loess,
L = Lishi loess,
W = Wucheng loess,
B = Black soil,
P = Paleosol,
BW = Buried weathering bed

and the relationship between the crystallinity of illite and its formation conditions in a given geological environment was expounded by B.KUBLER in terms of the width at half height of the diffraction peak at about 10 Å (KUBLER,B. 1966). In order to show the deflection degree of illite (001) reflexion from theoretical value of mica (001) (d = 10 Å), the ratio of peak height and width at half height at about 10 Å (H/W value) was adopted to describe illite characteristic in this paper. H/W value in loess in generally greater than 25 and that in paleosol less than 20. Comparison between younger and older loess indicates that the former has a greater H/W value while the latter has a minor one. This shows that the illite in older loess and in strata which have undergone pedogenesis has worse crystallinity. In other words, they contain more expansible layers.

Another marker for illite crystallinity is I(001)/I(002), which is an indicator of mica layer characteristic. Difference of intensities between the lst and the 2nd order reflexions may be related either to iron content in its octahedral layers (GRIM, R.E. et al. 1951) or to local weathering of illite leading consequently to the decrease in K content which weaken the (002) intensity (WEAVER, C.E. 1960). It is obvious that the

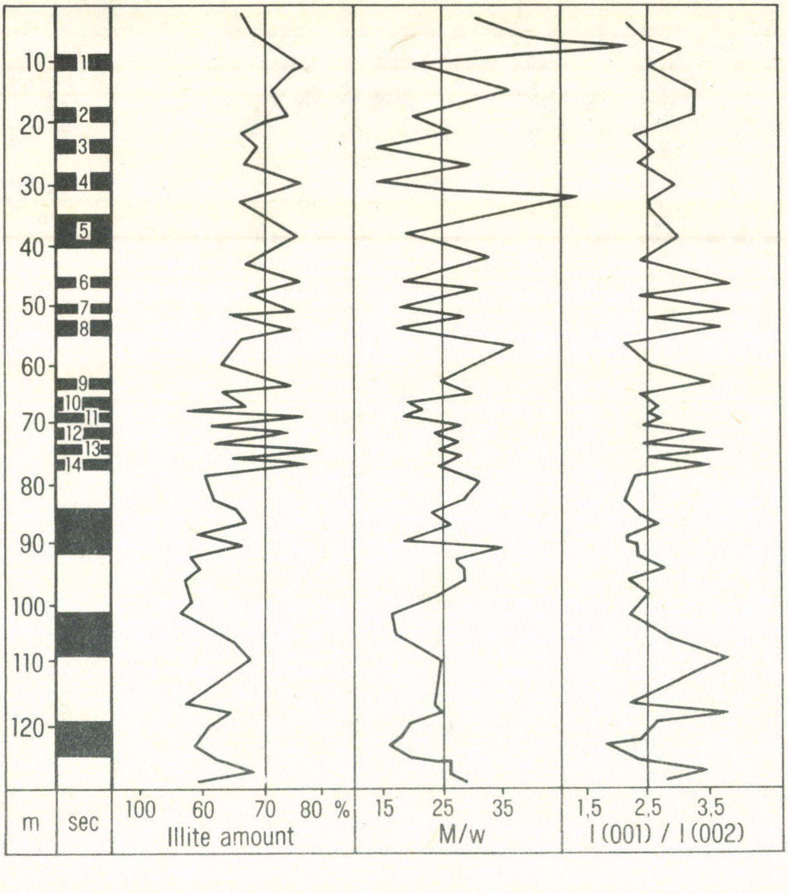


FIG. 3. Illite relative amount and its crystallinity indicators in Luochuan section of Shaanxi Province

stronger the weathering process to clay minerals, the higher its I(001)/I(002) ratio. So it can be used as an important indicator showing the difference of diagenesis level and pedogenesis degree in separated samples in the study on climate events recorded in loess section.

From the I(001)/I(002) curve of Luochuan section (FIG. 3.), it can be seen that the value of loess is in a minor fluctuation range with a value of 2.5 except for a few samples, which reflects the loess to be a homogeneous material. On the other hand, the ratio of I(001)/I(002) in paleosol has greater value of about 3.7 in general, which indicates that the pedogenesis effected deeply to interlayer ions of illite.

CLIMATE CYCLES AND SEA–LAND CORRELATION

Climate Cycles Recorded in Loess of China

1. Climate fluctuation amplitude. The data of clay minerals have shown that the variations of relative amount and crystallinity in loess sections are synchronous, the fluctuation amplitudes of different climatic events have been shown by clay minerals from various angles, for example, in Lishi loess under the 1st, 4th, 5th, 6th peleosols and upper silt beds, the crystallinity indicators show higher values, whereas, those in loess beds under 2nd and 3rd paleosols all show lower values.

In order to explore the climatic amplitude by mineral indices, the clay mineral data have been calculated into variation value for paleosols by the following formula:

$$V = (L - S) \ / L \times 100 \%$$

where V = Variation value of clay mineral indices, the greater the value, the stronger the pedogenesis, L = Determined value of clay mineral in parent material (underlying loess), S = Determined value of clay mineral indices in paleosol.

Thus, these data may better reflect the variation extent of clay minerals after pedogenesis. Following are the characteristics of paleosols observed:

a. The 3rd and the 10-11th paleosols, their relative amount of illite and I(001)/I(002) have a slight lower vatiation value. If other paleosols are representatives of interglacial fluctuations, the 3rd and the 10-11th paleosols should be products of interstadial periods.

b. The 7-8th paleosols and the 12-13-14th paleosols, their relative amount of illite and variation value of crystallinity indicators have a higher range, and constitute two soil groups with similar amplitude respectively. It seems likely that each group only represents one interglacial. Similarly, each group of weathering bed buried in Wucheng loess also can be regarded as a marker of one warmer stage respectively.

According to the characteristics of alternations of loess and paleosols in stratigraphic sections and the characteristic variation of clay minerals in loess sections climatic cycles recorded in loess sections and their characteristics can be distinguished.

2. Time control for climatic events. The chronological data available up to the present are listed in TABLE 2, which have provided a rudimentary time scale for climatic events recorded in loess sections. It was urged at a Wenner-Gren symposium in 1975 on the Middle Pleistocene that the lower boundary should be defined at the Brunhes/Matuyama reversals, while the upper boundary should be defined at the beginning of the last interglacial marine transgression (BOWEN, D.Q. 1978). The data on TABLE 2 shows that these two boundaries coincide with those between Malan/Lishi and Lish/Wucheng in loess sections of China. However, the age of development of the last paleosol at the top of Lishi loess, can be likely correlated to the 2nd phase of Eemian interglacial period in Northern Europe.

Based upon the stratigraphy and the characteristics of clay minerals in loess sections, 13 climatic cycles with 26 stages have been distinguished, in which greater amplitudes in the even-numbered stages 6, 10, 12, 16 may reflect colder condition during corresponding glaciation, whereas, greater amplitudes in the odd-numbered stages 5, 9, 11, 15, 19 may indicate stronger interglacial climatic conditions (FIG. 4.).

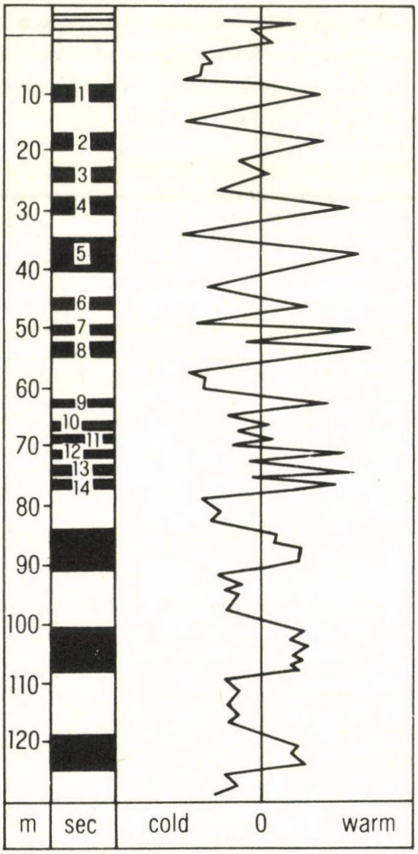


FIG. 4. Climatic curve recorded in clay minerals in Loess section

TABLE 2. Geochronological data of loess in China

Strata	Fossils[+]	Magnetostrata[++]	^{14}C and TL age (Years, B.P.)
Holocene Loess	——	——	Upper black soil at Longxi Sec. = 7,360 ± 250, Lower black soil at Longxi Sec. = 8,550 ± 300, Black soil at Luochuan Sec. = 8,000 ± 400
Malan 1.	Struthiolithus sp. Myospalax fontanieri	Blake event (?): 11-1 core and Tingjiagou sec. at Luochuan, Zaitang sec. near Beijing	Upper part of Malan loess, TL = 39,000 ± 5,000
Lishi 1.	Sinanthropus dalinensis S. lantienensis, Myospalax tingi, M. chaoyatseni, M. arvicolinis.	Brunhes/Matuyama: Luochuan, Wucheng, Longxi, Jixian, Wuquanshan at Lanzhou	——
Wucheng 1.	Hipparion sinensis, Nyclereutes sinensis, Myospalax omegodon.	Jaramillo event: Luochuan Longxi, Wuquanshan at Lanzhou	——

[+] Liu T.S. et al., 1962, 1964, 1965, Wang Y.Y. et al., 1979, Wu X. Zh. et al., 1979

[++] An Z.S. et al., 1977, Cheng G.L. et al., 1978, Li H.M. et al., 1974, 1980, Wang J.D. et al. 1980, Wang, Y.Y. et al. 1980.

TABLE 3. Tentative correlation of climatic cycles recorded in loess sections of China with glacial/interglacial periods in norhern Europe and stages of isotope oxygen in deep sea sediments

Periods	^{18}O stages* (V28-238)	Ages (kyr.,B.P.)	Gl/Intergl.**	Climatic cycles in loess of China		
			In N. Europe	Cycles,	Stages,	Loess or paleosol
Holocene	1		Post glaciation	I	1	Holocene loess at Longxi section
		13				
Late Plaistocene	2		Weichselian	II	2	Upper Malan l.
	3				3	Black soil buried in Malan loess at Jingning section
	4				4	Lower Malan l.
	5a-e		Eemian		5	1st paleosol
		128				
Middle Pleistocene	6		Warthe	III	6	Lishi l.
	7a-c		Eemian		7a-c	2nd paleosol
		240				
	8		Saalian	IV	8a-c	Lishi l./3rd paleosol/ Lishi l.
	9		Eemian		9	4th paleosol
		330				
	10		Saalian	V	10	Lishi l.
	11		Holstein		11a-e	5th paleosol
		400				
	12		Elster	VI	12	Lishi l.
	13		Holstein		13	6th paleosol
		480				
	14		Elster	VII	14	Lishi l.
	15		Cromerian		15a-c	7th pal./l./8th pal.
		570				
	16		Elster	VIII	16	Upper silt
	17		Cromerian		17	9th paleosol
		630				
	18			IX	18a-e	L./10th pal. l. 11th pal./l.
	19		Cromerian		19a-e	12th pal./l./ 13th pal./l./ 14th paleosol
		710				
Early Pleistocene	20			X	20	Lower silt
	21				21	Upper superimposed weath. bed
		810				
	22			XI	22	Wucheng l.
	23				23	Middle superimposed weath. bed
		900				
	24			XII	24	Wucheng l.
					25	Lower superimposed weath. bed
				XIII	26	Wucheng l.

* Shackleton, N.J. et al. 1973

** Bowen, D.Q., 1978, Kukla, G.J., 1977.

LAND–SEA CORRELATION OF QUATERNARY CLIMATE EVENTS

The correlation of climatic cycles recorded in the loess sections of China with glacial/interglacial periods in North Europe and stages of isotope oxygen in deep sea sediments is presented in TABLE 3. It is an attempt to apply the clay mineral indicators to stratigraphic subdivision and correlation. The purpose is to arouse more attention and interest to the study of clay minerals and the classification of climatic cycles in loess research.

REFERENCES

AN ZISHENG et al. 1977: Paleomagnetic research of the Luchuan section. – Geochimica, 2. 234-249.

BAILEY, S.W. 1980: Summary of recommenditions of AIPEA nomenclature committee on clay minerals. – American Mineralogist, 65. 1-2. 1-7.

BOWEN, D.Q. 1978: Quaternary geology. – A stratigraphic framework for multidisciplinary work. Oxford etc. Pergamon Press. XI. 221.

CHENG GUOLIANG et al. 1978: Study on paleomagnetism for several Quaternary sections of China (in press).

GRIM, R.E. et al. 1951: The mica clay minerals. – In: Brindley, G.W. (ed.), X-ray identification and crystal structure of the clay minerals. London. Min.Soc.

KUBLER, B. 1966: La cristallinite de l'illite et les zones tout a fait superieures de metamorphisme. – In: Colloque sur les Etages Tectoniques, a la Baconiere. Neuchatel, 105-122.

KUKLA, G.J. 1977: Pleistocene land-sea correlations (1), Europe. – Earth Sci. Rev., 13. 307-374.

LI HUAMEI et al. 1974: Preliminary result of research on paleomagnetism for Wucheng loess section. – Geochimica, 2.

LI HUAMEI et al. 1980: Magnetostratigraphy study for Quaternary Sediments of North China. Geology Press. (Essays of geology for international exchange, 15.)

LIU TUNGSHENG et al. 1962: Loess of China. Beijing. Science Press.

LIU TUNGSHENG et al. 1974: Loess of middle Huang He valley. Beijing, Science Press.

LIU TUNGSHENG et al. 1965: Loess deposits of China. Beijing, Science Press.

SHACKLETON, N.J. et al. 1973: Oxygen isotope and paleomagnetic stratigraphy of Equatorial Pacific core V28-238: Oxygen isotope temperatures and ice volumes on a 10^5 and 10^6 year scale. – Quaternary Res., 3. 39-55.

WANG YONGYAN et al. 1979: Discovery of Sinanthropus dalinensis fossil and the preliminary results. – J.Northwest. Univ. 3.

WANG YONGYAN et al. 1980: Exploring problems of loess subdivision from the paleomagnetic data for northern plateau of Weihe valley. – Geol. Rev. 26. 2.

WEAVER, C.E. 1960: Possible uses of clay minerals in the search for oil. – Amer. Assoc. Petrol. Geol. Bull. 44. 1505-1518.

WHITE, J.L. 1962: X-ray diffraction studies on weathering of muscovite. – Soil Science. 93. 16-21.

Address of author:
Zheng Hong-han, Institute of Geochemistry, Academia Sinica
QUEIYANG – China

III. STRATIGRAPHY AND DATING OF LOESSES AND PALEOSOLS

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PALEOGEOGRAPHY OF LOESS ACCUMULATION IN THE LIGHT OF PALYNOLOGICAL DATA

N.S. Bolikhovskaya

ABSTRACT

Palynological investigations of loess-like deposits in different regions of the USSR, carried out by the author, gave the base for the conclusion about more diverse landscape-climatic conditions of the loess accumulation than it was supposed earlier. The loess-like deposits were formed in landscapes of deserts, semideserts, steppes, forest-steppes and tundra-steppes. The landscape-climatic conditions of the formation of fossil soils are even more diverse. Loesses are characterized by the following common features:

- a presence of relict Neogene pollen in the Eopleistocene and early Pleistocene horizons,
- a high content of spores and pollen of cryophytes in loesses of the first phase of the Valdai (Würm) glaciation,
- a sharp increase of pollen of desert-steppe plants in the loess horizon of the final phase of the Valdai glaciation.

The first pollen and spores finds in loess and buried soils of the USSR were made by academician V.N. SUKACHEV and his collaborators more than 40 years ago. During the next period thanks to the works of V.P. GRICHUK, A.T. ARTYUSHENKO, N.S. BOLIKHOVSKAYA, T.D. BOYARSKAYA, V.S. VOLKOVA, R.E. GITERMAN, Z.P. GUBONINA, E.T. LOMAEVA, S.I. PARISHKURA, M.M. PAKHOMOV, G.A. PASHKEVICH and others, further geological sections of loess and loess-like sediments in many regions of the USSR were characterized by palynological data. However, up to now information about loess sediments constitutes only a small part in total paleobotanic information. It is most deficient in the stratigraphic and paleogeographical studies of the South of the USSR, but this deficiency is easily understood since the palynological analysis of loesses and paleosols involves some objective difficulties. It is to be stated, that even with the help of special methods using supersounding and other cavitation equipment, loesses considerably exceed all classical objects of palynological analysis – lacustrine, paludal and alluvial sediments in the labour-consuming character of separation of pollen and spores, in their microscopic study and in the difficulty of palynological data interpretation.

When studying the sections of loess and loess-like sediments, situated in different regions of our country, the author first of all considered soil processes participating in loess formation, which are universally recognized in the problem of loess genesis and attested by buried soil horizons. For this reason, the author's own studies and extended literature devoted to the methodical questions of the palynology of the loess-soil formations were the basis for the reconstructions of paleolandscapes. Nevertheless, some aspects of paleogeography of the epochs of loess accumulations are still vague from palynological point of view.

1. For instance, the interpretation of the so called „impoverished spectra" calls for substantiation

Generalizing the results of complex study of loess formation of East European plain, A.A. VELITCHKO (1977) came to the conclusion that climatic conditions of the epoch of Prebryansky loess horizon accumulation were cold and comparatively wet, in contrast to the extremely severe (cold and dry) epoch of Postbryansky loess accumulation. But there was no confirmation of that conclusion by palynologic data, because the same species – Alnaster fruticosus, Betula fruticosa, B. nana were indicated as significant ones for all Valdai loess horizons. As for the presence of local components of pollen spectra belonging to arcto-alpine and boreal-arctic species in the sections of loess-like formations from the second half of the Valdai age in the southern part of the extraglacial zone, it has not been marked by palynology. In a number of sections – Chekalinsky (Likhvinsky) at the upper Oka (FIG. 1), Strelitsky and Novokhopersky at the Middle Don and Veselo-Voznesensky in the Near-Azov sea region (FIG. 2) (BOLIKHOVSKAYA, N.S. 1973, 1976, BOLIKHOVSKAYA, N.S. – DOBRODEEV, O.P. 1972 etc.) joint finds of pollen and spores of Betula nana, B. fruticosa, Alnaster fruticosus, Dryas octapetala, Selaginella sibirica, Lycopodium pungens, Ephedra monosperma, E. ciliata, Salicornia herbacea etc. are connected with the Prebryansky horizon, and in the Postbryansky sediments pollens of cryophytes (Betula fruticosa, Alnaster fruticosus) were found only in the Chekalinsky section. As for the pollen of xero- and halophytes (Ephedra, species Artemisia and Chenopodiaceae) it was found in these horizons of all sections. In other words, evidence for extreme drought in the Postbryansky ages is found everywhere, while evidence for extreme cold is absent.

The analysis of modern soil samples and loess-soil horizons, formed under different conditions, helped us to specify paleogeographical reconstructions of Valdai epoch loess accumulation. Considerable changes of pollen and spores concentration and their composition in loess-soil formations, e.g. depending on edaphic and microclimatic conditions were fixed by spora-and-pollen analysis of a conjugated number of coetaneous (Valdai) sections, situated on the same slope. These data were received during the study of loess-soil profiles of Kishlyansky Yar in the central Dniestr region (BOLIKHOVSKAYA, N.S. 1981). Concentration of pollen and spores in loess horizons formed under hydromorphic conditions appeared to be four and more times as great as in the subaerial formations of the same age. Furthermore, they contained palynoflora that was richer in remnants of cryophytes: apart from the pollen of Betula nana, B. fruticosa and Alnaster

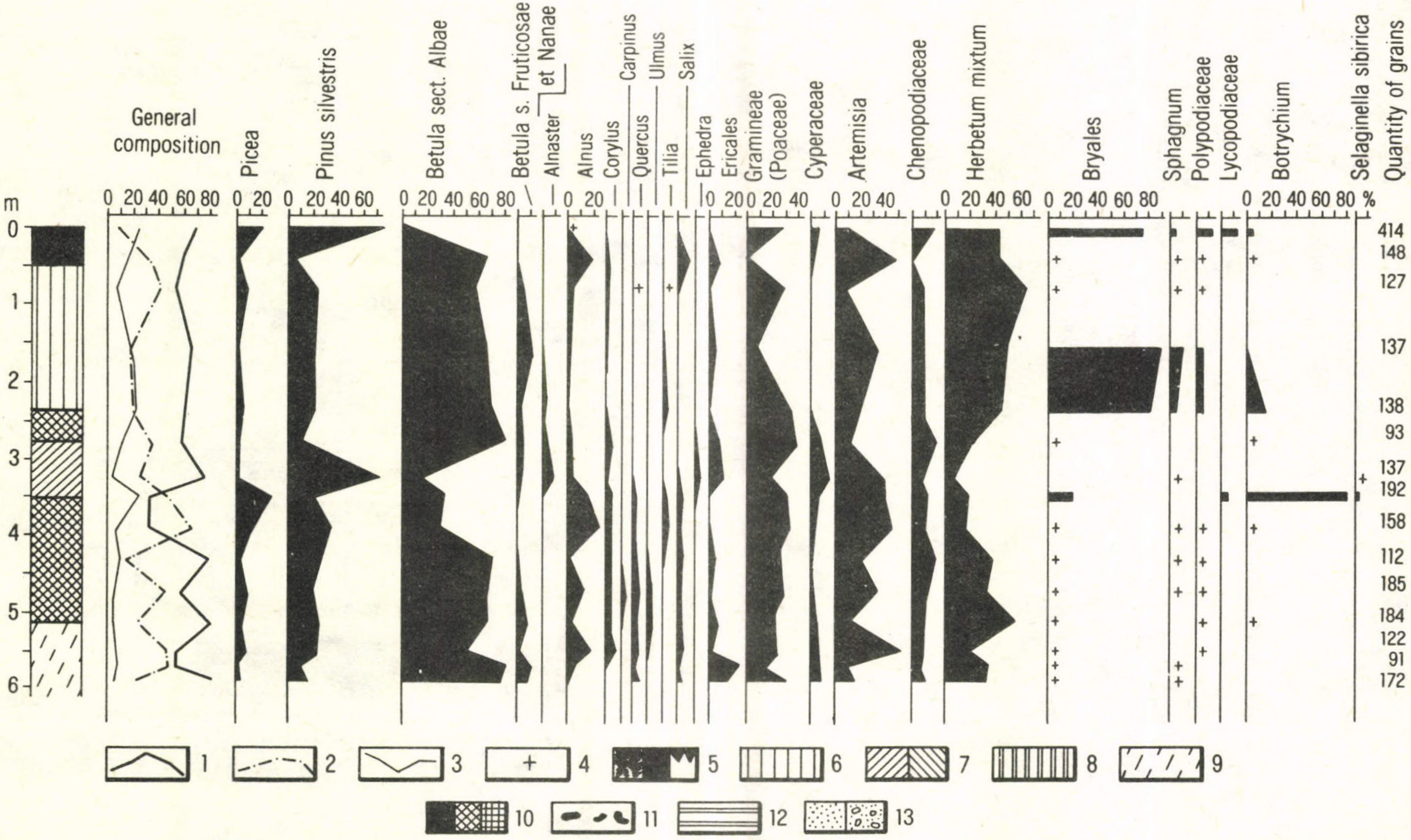


FIG. 1. Pollen diagram of the Chekalinsky (Likhvinsky) section (the upper Oka) 1 = pollen of trees and shrubs; 2 = pollen of dwarf shrubs and herbs; 3 = spores; 4 = less than 1%; 5 = modern soil; 6 = loess; 7 = loess loams; 8 = red-brown loess loams; 9 = loess loamy sand; 10 = fossil soil; 11 = holes of burrowing animals; 12 = liman clay; 13 = alluvial sediments

fruticosus they contained spores and pollen of Arctous alpina, Arctostaphyllos uva-ursi, Rubus chamaemorus, Diphazium alpinum, Selaginella selaginoides etc., and subaerial formations contained only pollen of Betula fruticosa and Alnaster fruticosus. Taking into consideration modern ecologic and phytocoenotic attachment of the mentioned cryophile herbs and shrubs and the fact, that pollen and spores of these plants are local components of spectra, it is logical to suppose that finds of cryophyte microremnants in Late-Pleistocene periglacial formations are most likely in sediments with traces of hydromorphic conditions. Even if cryophytes were members of sparse cover of herbs and shrubs of automorphic elementary landscapes, the possibility of the safe preservation of their pollen and spores was not great because of unfavourable taphonomic conditions.

This is confirmed by the result of spore-and-pollen analysis of samples from the top surface of modern soils of flood-plains, terraces, watershed plateaus and slopes,

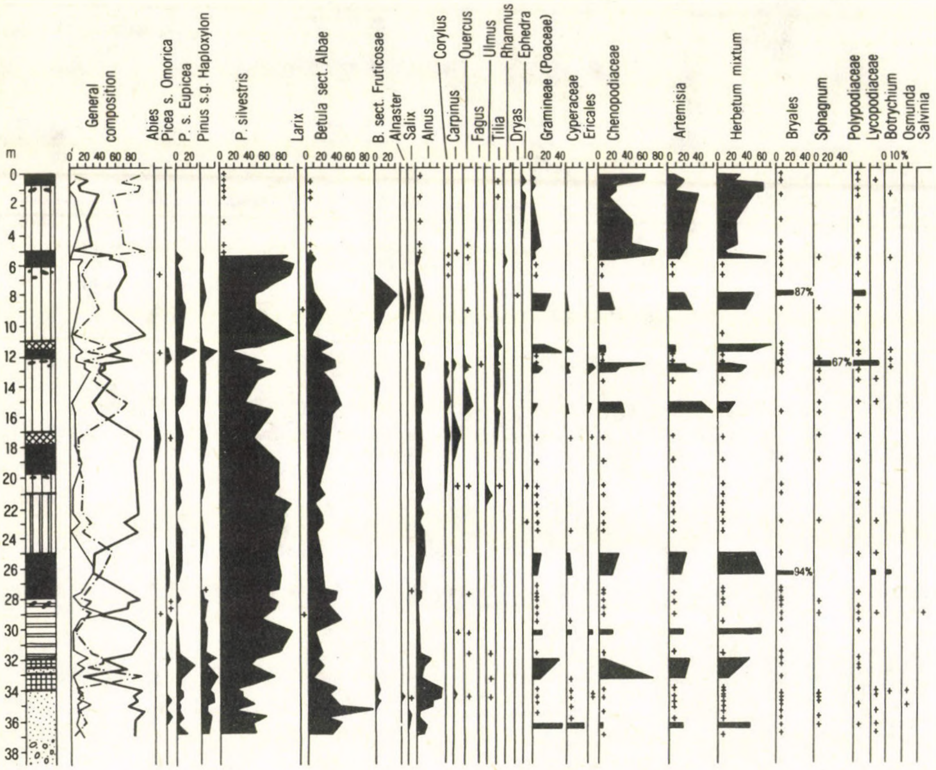


FIG. 2. Pollen diagram of the Veselo-Voznesensky section (the Azov seashore region)

depressions and elevations of microrelief, opened and forested grounds. They showed that samples from depressions of the microrelief contain great amount of grains and reliably reflect the vegetation composition of test grounds and zone type of vegetation of the surrounding areas. While in the spectra of samples from the elevations of microrelief the concentration of pollen and spores is half the amount of the content than in the previous ones and there are many grains, having undergone destruction. Everything mentioned makes it possible to conclude that most of Late-Pleistocene sections of loess of the East-European plain is characterized by ,,impoverished" spectra.

Less distorted spectra of loess sediments, containing great amounts of cryophile plant microremnants were found in the sections of North-East (BOYARSKAYA, GI–TERMAN, et al.) – one of the coldest and most continental region of the USSR. The author studied the Vorontsovsky Yar section, situated in the lower Indigirka region (BOLIKHOVSKAYA, N.S. – BOLIKHOVSKY, V.F. 1979). Palynologic data in aggregate with the results of C^{14} dating give evidence that accumulation of the 50-meter thick loess-like ,,yedoma" series took place during the Karginsky and Sartan times. The landscapes of forest-tundra and coniferous-birch sparse growth of trees were characteristic of the Karginsky interglacial (Q^3III), and during the Sartan glaciation (Q^4III) first landscapes of underbrush tundra were predominant, but subsequently the strengthening aridization caused wide expansion of steppe plots with Artemisia as edificator and led to the predomination of tundra-steppes under ultracontinental conditions. Thus, the accumulation of the analysed loesses took place under permanently cold climatic conditions, clearly fixed by high content of pollen and spores of tundra plants. The good preservation of pollen and spores, their great concentration, the presence of microremnants of Pediastrum weed indicate that loess-like deposits accumulated here in aquatic environment and experienced no considerable epigenetic transformation under subaerial conditions. The occurrence of xerophytes pollen in some horizons indicates the existence of landscape facies, which escaped alteration by water. These might be parts of flood-plains, which were free of water for a long time.

2. Another essential aspect of loess palynology is the interpretation of spectra of loess horizons containing pollen of thermophilous elements of dendroflora

For instance, the lower part of the horizon, underlying the Mikulinskaya fossil soil contains considerable amount of pollen of broad-leaved species in the following sections: Strelitsky (Carpinus – 5%, Acer – 1%, Quercus – 1%), Novokhopersky (Carpinus – 6%, Tilia – 7%) and Veselo-Vonesensky (Quercus – 9%, Tilia – 7%). Thus the question rises to what extent this pollen characterizes climatic conditions of the time of loess accumulation. Pollen of thermophilous trees did not differ from other grains by the degree of preservation and there were no microremnants of ecologically incompatible species. Loess horizons of more southern sections contain the greaterst amount of pollen of broad-leaved species. Pollen of broad-leaved species was found (e.g.) in Postmikulinsky loess-like loams of the Kishlyansky Yar and in the Novaya Etuliya section, situated in the southern part of Moldaviya. The latter includes loess-soil series, the formation of which went on through the whole Pleistocene. Here the pollen of thermophilous trees constantly appears not only in older horizons but also in loess, lying above the Bryanskaya buried soil. (The radio-carbon age of carbonates from illuvial horizon is 22700 ± \ 400 years). Its content reaches 34 % in the spectrum of the sample from the lower part of this horizon (FIG. 3). There are also single pollen grains of broad-leaved species (Quercus, or Carpinus, or Tilia) in the loess horizon, underlying the modern soil of Kishlyansky Yar and Novaya Etuliya sections, similarly preserved single pollen grains of shrubby birch are found here together with them.

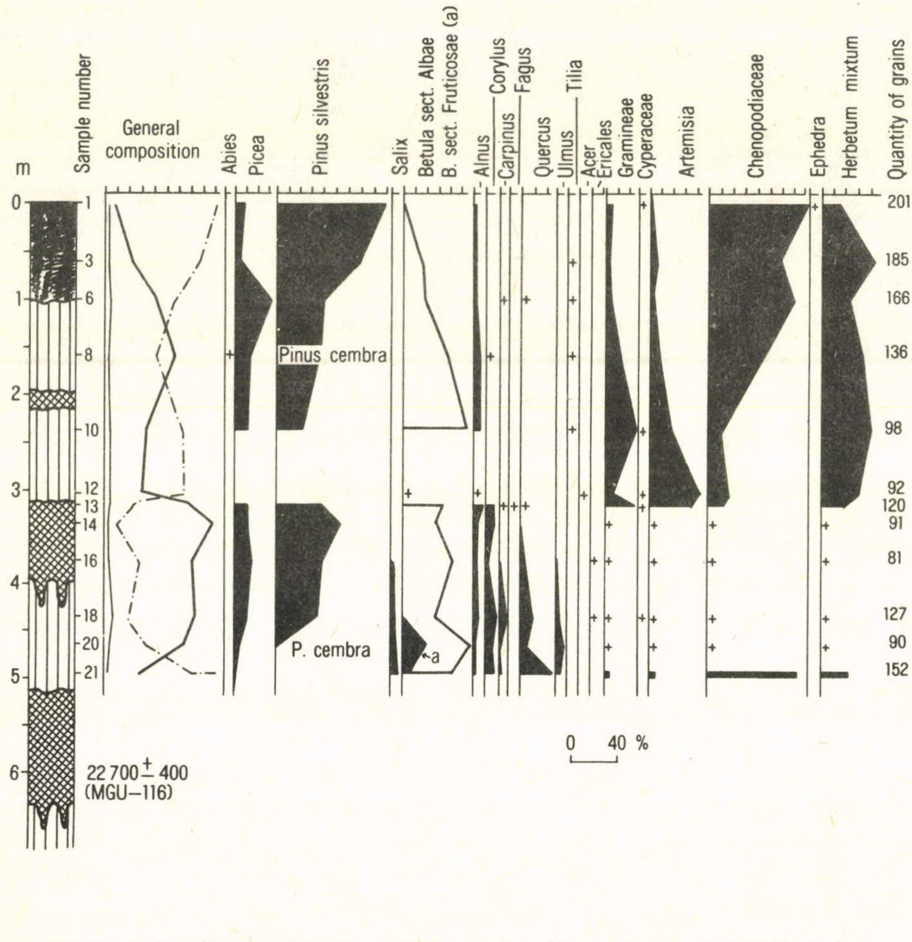


FIG. 3. Pollen diagram of the Novya Etuliya section (the southern part of Moldaviya)

Pollen of thermophilous elements was found in loess-soil series having been formed under the most warm climatic conditions in the territory of the USSR – in Central Asia. The latter was studied in the Charvak section near Tashkent (LAZARENKO,

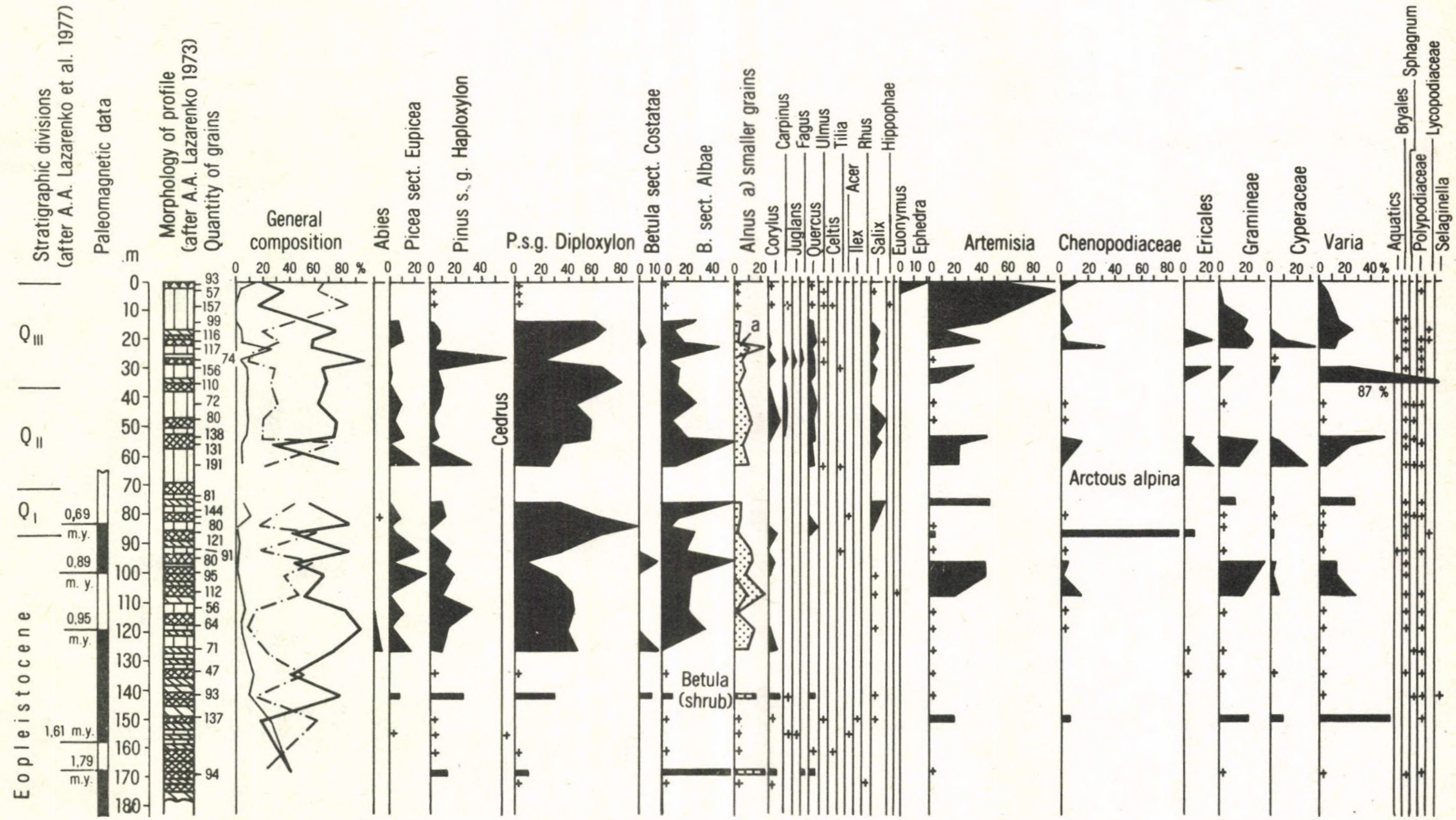


FIG. 4. Pollen diagram of the Chashmanigar section (Tadjik depression)

A.A. et al. 1981), in the Chashmanigar and Khasani (KRIGER, N.I. et al. 1980) sections in the Tadzhik depression. The palynologic characteristics of loess horizons, i.e. a 180 m thick covering series of the Chashmanigar section – one of the most complete Pleistocene section of Central Asia – are not uniform (FIG. 4). For instance in the loess mantle 7IIK (PC – pedocomplex) supremacy of pollen of trees is marked, pollen grains of Picea (22%) and Pinus s.g. Haploxylon (28%) dominating among them and rare grains of Ulmus, Tilia and Quercus have also been found. In the group of grass, the pollen grains of mesophytes are frequent, among them Ericaceae (with Arctous alpina – plant of tundra, stony scree marshes, etc., which is now absent in mountainous flora of Central Asia), Poaceae (Gramineae) and Cyperaceae. Data of pollen analysis indicate cold and wetter climate, than modern one as well as complicated structure of vegetation cover of the depression and surrounding mountains. In the spectrum of loess, lying above 2PC, a relatively great number of pollen grains similar to this of Alnaster (21%) is marked, indicating cold, but not as dry climate as the modern one. Spectra, indicating nearly general supremacy of desert and desert-steppe groups, are charcteristic of the thickest loess horizon, overlapping IPC. Apparently, spectrum of sample from the depth of 8 metres in the middle part of this loess horizon, containing single pollen grains of Carpinus, Quercus, Ulmus and Celtis, reflects a period of relative humidification (interstadial).

Now there is no reason to eliminate one or another find from the autochtonous complex of palynospectra. The possibility of introducing tree pollen into loess and loess loams from upper soil horizons is denied by methodical studies, including experimental ones, devoted to the problems palynospectra of soil formation of different natural zones (ALEKSANDROVSKY, A.L. et al. 1981, BEREZINA, N.A. 1969, ISAEVA–PETROVA, L.S. 1979 and others). These studies together with the good preservation of grains make it possible to consider them being autochtonous.

Probably, vegetable cover was mosaic-like during Valdai period loess formation in the southern part of the extraglacial zone. Besides the dominating steppe, tundra-steppe and other associations of grass and shrubs, shrub formations with Betula fruticosa and Alnaster fruticosus grew at the exposures of hard rocks and at the marshy parts, also forests of Betula s. Albae and Pinus silvestris with some broad-leaved species grew in the most favourable locations. Apparently, loess accumulation did not stop during some interstadials, although forest phytocoenoses enlarged their areas at the same time. For this reason palynospectra of loess horizons, containing a relatively great number of pollen grains of different thermophilous trees, make it possible to reveal interstadial environmental conditions even if they are not expressed as buried soils.

So palynologic studies of sections of loess-like sediments in different regions of the Soviet Union, such as the central and southern parts of the East-European plain, Central Asia and the North-East lead the author to a conclusion that landscape-climatic conditions of loess accumulation had been more diverse than it was considered before. Loess-like sediments accumulated in arid, semi-arid, steppe, forest-steppe, tundra-steppe and tundra landscapes. Landscape-climatic conditions under which buried soils formed were more diverse.

The majority of scientists, while dismembering loess-like sediments consider a priori that buried soil horizons indicate periods of relatively mild climate in comparison with the periods of loess accumulation. Palynologic data show that such assumption is not correct for all cases. Sometimes the greatest cold snap or the greatest weathering is characteristic of the periods of fossil soil formation. Cases are not rare, when formation of indivisible humus horizon of fossil soil occurred during several consecutive landscape-climatic stages, characterized by palynospectra of different types.

The features below are characteristic of loess-like sediments of the regions in question:

1. Presence of pollen of Neogene relic flora species in Eopleistocene and Early Pleistocene horizons.

2. High content of pollen and spores of cryophytes in loess-like sediments of the first part of the Valdai period on the East-European plain and of all Würm cold intervals of the Soviet North-East.

3. General sharp reinforcement of desert-steppe plants pollen role in loess horizon at the final stage of Valdai (Würm) glacial period.

Regional differences in palynology of Late Pleistocene loess-like sediments are natural. Desert and steppe spectra are characteristic of Central Asian loess, tundra and tundra-steppe spectra characterize loess-like sediments of the North-East, and steppe and forest-steppe ones characterize Moldvian and Ukrainian loess. The greatest variety of palynospectra types is characteristic of Pleistocene loess-like sediments of the East-European plain and Central Asia.

In conclusion I want to emphasize that as a result of the analysis of different factors of palynospectra of loess-soil formations it is seen that the probability of loess spectra impoverishment and distortion is the greatest in comparison with sediment spectra of other lithological types, the more the loess-like rock resembles typical loess, the greater the primary palynospectra is distorted. As for the fossil soils the degree of primary palynospectra distortment increases from humid to arid ones, from soils of subordinated landscapes to the soils of autonomous ones. Nevertheless it is necessary to point out, that the described palynospectra are objective basis for paleogeographical reconstructions and stratigraphic classification of loess series if specific conditions of formation are taken into account.

REFERENCES

ALEKSANDROVSKY, A.L. – OVSYANIKOVA, Zh.G. 1981: Palinologicheskie issledovaniya dernovo-podzolistykh i chernozemnykh pochv. – Pochvovedenie. 1981. 1. 29-39.

BEREZINA, N.A. 1969: Nekotorye faktory, opredelyayushenie formirovanie sporovo-pyl'tsevogo spektra, i ispol'zovanie sporovo-pyl'tsevogo analiza pri geobotanicheskikh issledovaniyakh. Avtoreferat kandidatskoi dissertacii, Moscow. 24.

BOLIKHOVSKAYA, N.S. 1973: Palinologicheskaya kharakteristika posledneprovskikh otlozheniy IV nadpoimennoy terrasy r. Khoper bliz g. Novokho perska. – Noveishaya tektonika, noveisie otloheniya i chelovek. Moscow, Izd. un-ta. 5. 305-319.

BOLIKHOVSKAYA, N.S. 1976: Palinologiya lessov i pogrebennykh pochv Russk ravniny. – In: Problemy obshhey fizicheskoy geografii i paleogeografii. Moscow. Izd. un-ta. 257-277.

BOLIKHOVSKAYA, N.S. 1981: Rastitel'nost' i klimat Srednogo Pridnestrov'ya v pozdnem pleistocene. Rezul'taty palinologicheskogo izucheniya otlozheniy Kishlyanskogo Yara. – In: Ketrosy, Must'erskaya stoyanka na Srednem Dnestre. Moscow. Nauka. 103-124.

BOLIKHOVSKAYA, N.S. – BOLIKHOVSKY, V.F. 1979: Iskopaemye pochvy v lessovidnykh otlozheniyakh Severo-Vostoka Evrazii. – Doklady AN SSR. 247. 2. 409-412.

BOLIKHOVSKAYA, N.S. – DOBRODEEV, O.P. 1972: Paleogeografiya pleistocena Priazov'ya po dannym sopryazheniya sporovopyl'tsevogo i paleopochvennogo analizov razreza u s. Veselo-Voznesenskogo. – Noveishaya tektonika, noveishie otlozheniya i chelovek. Moscow. Izd. un-ta. 3. 155-161.

ISAEVA–PETROVA, L.S. 1979: O vozmozhnost'i palinologicheskogo issledovaniya chernozemnykh pochv. – Izvestiya AN SSSR. ser. geograf. 1. 80-87.

KRIGER, N.I. – BOLIKHOVSKAYA, N.S. – KOTEL'NIKOVA, N.E. – LAVRUSEVICH, S.I. – SEVOST'YANOV, V.V. 1980: Paleogeograficheskie tsikly i stratigrafiya lessa Srednoj Azii i Kazakhstana. – Trudy Inst. geol. geofiz. SO AN SSSR. 457. 99-114.

LAZARENKO, A.A. – BOLIKHOVSKAYA, N.S. – SEMENOV, V.V. 1981: An attempt at a detailed stratigraphic subdivision of the loess association of the Tashkent region. – Int. Geol. Rev. 23. 11. 1335-1346.

VELICHKO, A.A: 1977: Opyt paleogeograficheskoy rekonstrukcii prirody verkhnego pleistocena dlya territorii Vostochnoy Evropy i SSSR. – Izvestiya AN SSSR, ser. geograf. 4. 28-44.

Address of author:
N.S. Bolikhovskaya, Lomonosov State University, Geographical Faculty, Dept. of Paleogeography
Leninskiye gory B-234 MOSCOW – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

THERMOLUMINESCENCE CHRONOLOGY OF YOUNGER AND OLDER LOESSES

Jerzy Butrym – Henryk Maruszczak

ABSTRACT

TL dating results prove that younger loesses at Paks are well-developed and representative for stratigraphic purposes. Older loesses are not representative for the stratigraphy of Middle and Older Pleistocene. Because of deep lithogenetic differentiation and occurence of sediment hiatuses it is difficult to distinguish horizons representing glacial cycles and interglacial periods.

In September 1980 22 samples were taken for thermoluminescence analysis from the Paks loess profile, a sequence which had been well investigated on several occasions. Samples were collected from the exposure examined by M. PÉCSI and E. SZEBÉNYI in 1977 (PÉCSI, M. 1979), which is located in the northern part of the excavation, now exploited for brick-yard purposes. Only 3 samples were taken from the highest located youngest layers in the southern, presently un-exploited part of the excavation. Thermoluminescence analysis and absolute dating have been done by J. BUTRYM in the laboratory of Physical Geography Department of the Lublin University (UMCS). Stratigraphical interpretation of the results and an attempt at parallelizing them with corrresponding data of Polish loesses have been worked out by H. MARUSZCZAK.

The thermoluminescence dating method does not differ in its assumptions from the methdos used in other laboratories (ZELLER, E.J. et al. 1957, SHELKOPLYAS, V.N. – MOROZOV, G.V. 1981). Only some modifications were introduced to simplify and state the results more precisely. The annual dose of natural radiation for samples were measured with MTS-N dosimeters (LiF: Mg, Ti), for this 10 dosimeters were inserted in each sample for 3 months. Thus the yearly dose was the mean of ten measurements. In order to measure the total natural radiation dose a fraction of 50-56 micrometers was separated and exposed to ultrasonic disintegration to get rid of the carbonate and ferruginous envelopes of the grains. Thermoluminescence measurement of samples and dosimeters were performed with TL analyser equipped with photomultiplier tube of high sensitivity type 9789 QA of the EMI firm. The total dose was calculated by comparing the natural thermoluminescence with artificially provoked one by irradiating a part of the examined sample. For artificial irradiation cobalt, ^{60}Co in Cammatron S instrument was used and a strictly determined exposing unit 15 kR was obtained. The average of 20 determined exposing unit 15 kR was obtained. The average of 20 TL measurements was accepted as the natural radiation dose expressed in rads. The absolute age of the sample was defined as the relation of the total natural dose to the yearly dose. In the measurement error due to the precision degree of measuring instruments as well as the dispersion of dosimeter sensitivity were considered, it usually amounts to 12-15% of the examined sample age. Considering theoretical assumptions – accepted in the TL method usage – this error may actually be bigger. In the present stage of investigations, however, it could not be calculated more precisely in the applied measurement technique.

The thus obtained results of absolute dating are shown in FIG. 1. presenting lithostratigraphic differentiation of Paks loesses. Three of our samples were taken from lithostratigraphical horizons which were dated earlier by TL method by Z. BORSY et al. (1979). The results for these samples obtained in two different laboratories are similar. The age of the fossil soil MB sample from Saalian/Vistulian interglacial and its direct underlayer was determined at 125,000 ± 20,000 years BP by the mentioned Hungarian authors, while according to our investigations the MB soil sample dates back to 124,000 ± ± 17,000 years BP. The age of the sandy loess under the fossil soil Mtp was determined by them at 200,000 ± 30,000 and our results for the age of the sample located 1.5 m below, that is directly above the fossil soil PD_1, amounts to 213,000 ± 30.000 years BP.

Younger loesses. TL analysis shows that these loesses were accumulated at Paks in the time interval ca 15,000 – 100,000 y. BP. Very similar data were obtained for younger loesses in Poland. In the upper part of these loesses at Paks there occur 3 interstadial fossil soils (MF, BD_1, BD_2) in the time interval 30,000 – 45,000 y.; much similar absolute age, 27,000 – 40,000 y. was determined for these soils earlier by the ^{14}C method (PÉCSI, M. et al. 1977). In the same time interval of 30,000 – 45,000 y. determined by the TL method two fossil soils are distiguished in the Polish loesses parallelized with Western European interstadials Denekamp and Hengelo (MARUSZCZAK, H. 1980a). In the lower part of the younger loesses at Paks there is one more interstadial soil – BA in the time interval 80,000 – 85,000 y. by the TL method, up to now the age of this soil has been estimated at 65,000 – 70,000 y. (PÉCSI, M. et al. 1979). In the Polish loesses of the similar interval of about 75,000 years by the TL method a fossil soil also occurs, e.g. in the profile of Komarów Górny which has been incorrrectly parallelized with the Hengelo interstadial (MARUSZCZAK, H. 1980a).

The younger Pleistocene interglacial soil, in fact a soil complex, marked by the Hungarian authors with the MB symbol („Mende-Base”), is well observed at Paks in layers about 125,000 y. old. Stratigraphically for the analogous soil complex from the Eemian interglacial, the Saalian/Vistulian of the Polish loesses, the age of mineral material was determined at 130,000 – 140,000 and more; 140,000 - 160,000 y. was determined for the Nieledew profile where this soil developed on the erosional surface of slope and not on parent accumulative surface from the end of the older loess formation period. On the basis of the TL data obtained in our laboratory it can be stated that the soil complex from the last interglacial began to develop about 125,000 – 130,000 y. BP. The end of this pedogenesis is dated at 100,000 – 105,000 y. BP.

Older loesses in the Paks profile are much differentiated formations genetically (FIG. 1) with sediment hiatuses hindering stratigraphic interpretation. The absolute age

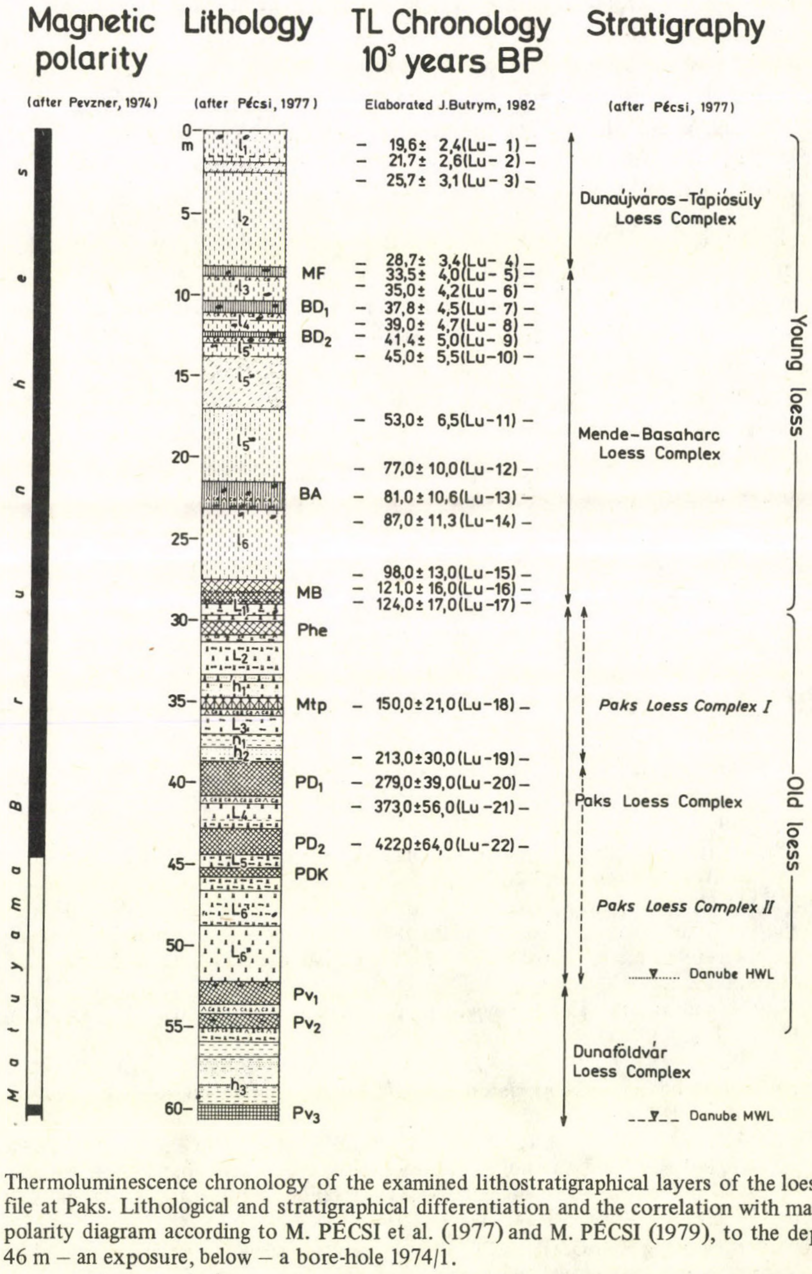


FIG. 1. Thermoluminescence chronology of the examined lithostratigraphical layers of the loess profile at Paks. Lithological and stratigraphical differentiation and the correlation with magnetic polarity diagram according to M. PÉCSI et al. (1977) and M. PÉCSI (1979), to the depth of 46 m – an exposure, below – a bore-hole 1974/1.

l_1/l_6 = younger loesses, L_1/L_6 = older loesses, h_1/h_3 = fluvial sands, n_1/n_3 = silts of these loesses is determined at 125,000 – 850,000 y. chiefly on the ground of paleomagnetic examinations (PÉCSI, M. et al. 1977, 1979). Our analyses concern the upper and middle layers of these loesses, including the fossil soil PD_2. Dating results confirm the existence of stratigraphic hiatuses in different horizons. Three from all these fossil loess soils were dated. The youngest of them is the soil Mtp dated at about 150,000 y. and it does not correspond to any of the previously investigated layers of older loesses in Poland. The much better developed 280,000 y. old soil, PD_1 corersponds to the lower soil of layers distinguished by now in the Polish loesses (MARUSZCZAK, H. 1980b), the TL age of wich is 270,000 y. The development period between the soil PD_1 and the soil PD_2 in the Paks profile was protracted as the PD_2 soil is as old as 420,000 y. The age of the PD_2 soil at Paks does not correspond to any of the Polish loess profiles.

The soil Mtp of older loess at Paks has been parallelized with Mindel/Riss interglaciation i.e. Elsterian/Saalian (PÉCSI, M. et al. 1977, PÉCSI, M. 1979). The TL dating results indicate one of the youngest Saalian interstadials as the time of its origin. The fossil soil PD_1 does not even represent the Günz/Mindel interglacial (PÉCSI, M. 1979) but one of the oldest Saalian interstadials. Chronologically the fossil soil PD_2 does not correspond to the interglacial either but most probably represents one of the interstadials of the Elsterian glaciation. Thus the TL analysis shows that in the Paks profile there is no soil from Elsterian/Saalian interglacial. In the Polish loesses, however, there is a well-developed soil of this interglacial which genetically resembles the above-mentioned soil of the last intergalacial, the Saalian/Vistulian, in the Niedelew profile the older interglacial soil developed on the layers of oldest loesses (MARUSZCZAK, H. 1960b), dated at 330,000 – 350,000 y. BP by the TL method.

REFERENCES

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

MARUSZCZAK, H. 1980a: Stratigraphy and chronology of the Vistulian loesses in Poland. – Quaternary Studies in Poland. 2. 57-76.

MARUSZCZAK, H. 1980b: Stratygrafia i chronologia lessów w Polsce (Stratigraphy and chronology of the loesses in Poland). – In: Guide-Book of field seminar „Stratigraphy and chronology of the loesses and glacial deposits of the Lower and Middle Pleistocene in SE Poland". Lublin, Univ. Marie Curie-Sklodowska. 43-54.

PÉCSI, M. 1979: Lithostratigraphical subdivision of the loess profiles at Paks. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 409-418.

PÉCSI, M. – PÉCSI–DONÁTH, É. – SZEBÉNYI, E. – HAHN, Gy. – SCHWEITZER, F. – PEVZNER, M.A. 1977: Paleogeographical reconstruction of fossil soil in Hungarian loess. – Földrajzi Közl. 101. 1-3. 94-137.

PÉCSI, M. – SZEBÉNYI, E. – PEVZNER, M.A. – HAHN, Gy. – HOCK, D. – SCHEUER, Gy. – SCHWEITHER, F. 1979: Lithological, pedological, stratigraphical and paleomagnetic analysis of the loess at Paks. – In: Guide-book for Conference... on the stratigraphy of loess and alluvial deposits. Budapest, Geogr. Res. Inst. Hung. Acad. Sci. 109-123.

SHELKOPLYAS, V.N. – MOROZOV, G.V. 1981: Primenenie termolyuminestsentnogo metoda dlya izucheniya antropogenovykh otlozheniy. Kiev, Inst. Geol. Nauk, AN Ukr. SSR.

ZELLER, E.J. – WRAY, I.L. – DANIELS, F. 1957: Factors in age determination of carbonate sediments by thermoluminescence. – Amer. Ass. Petrol. Geol. Bull. 41. 121-129.

Address of authors:
J. Butrym, H. Maruszczak, Institute of Geosciences, University Marie Curie–Sklodowska, Dept. of Physical Geography
Ul. Akademicka 12. LUBLIN – Poland

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

STRATIGRAPHY AND CORRELATION OF UPPER PLIOCENE–QUATERNARY DEPOSITS OF CENTRAL ASIA

A.E. Dodonov

ABSTRACT

The subdivision of Upper Pliocene-Quaternary deposits of Soviet Central Asia enables to identify different stratigraphic units. The paleosols or pedocomplexes and loess horizons correspond to paleoclimatic rhythms. The alluvial-proluvial suites are associated with the major erosional-aggradational cycles. The main geological boundaries were identified at the levels of 3.5, 1.8, 0.7 m.y. according to paleomagnetic and biostratigraphic data. The detailed stratigraphic correlations suggest that the climatostratigraphic units in loess-soil sequences are of wide interregional significance. However, the interregional correlation between separate horizons can be accomplished only through reliable chronostratigraphy.

The subdivision of the Upper Pliocene-Quaternary deposits of Central Asia is based on a complex of methods which make it possible to identify both the large stratigraphic units of formation or member rank and the more detailed units (horizons or climatoliths), as well as to trace the main geological boundaries.

While studying the stratigraphic succession of the Upper Pliocene and Quaternary deposits of this geologically very complicated region, we turn more and more frequently to sections of the subaquatic and subaerial types. The first type mainly consits of alluvial-proluvial accumulations, while the second are mainly loess deposits with their associated palaeosols. The stratigraphic scheme compiled by NIKIFOROVA, K.V. et al. (1980) was adopted as an initial time framework. The scheme identifies the Upper Pliocene, Eopleistocene and the Pleistocene as major series and draws geological boundaries at 3.5, 1.8 and 0.8-0.7 m.y, each of them can serve one of the variants of the Quaternary lower boundary.

Several stratigraphic schemes have been applied to the Quaternary deposits of Central Asia. There is no concensus on the time spans of the major subdivisions of the Quaternary nor on the placing of its lower boundary. Thus it is important to study the stratigraphy of Upper Pliocene-Quaternary deposits and attempt to correlate the more important sections in this vast region and in order to provide a broad interregional correlation. It is the purpose of this paper to consider some sections in the Tajik depression and in the Fergana and the Tashkent regions. These areas were characterized by predominant downwarping in the Late Cenozoic, and accumulation of thick Neogene-Quaternary molasse sediments. Distinct neotectonic modification is evident in the topography and in the structure of molasse.

The Upper Pliocene of the Central Asian regions under study is represented mostly by alluvial-proluvial sandy-pebble deposits. In southern Tajikistan the Upper Pliocene incorporates the Kuruksay suite filling the synclinal zones of the Tajik depressions. The age of the Kuruksay suite in the stratotype section of the Kuruksay river valley has been determined by means of palaeontological and paleomagnetic data as 3.5 to 2 m.y. B.P. (FIG. 1).

In western Fergana, suite C_2 and perhaps the uppermost parts of suite C_1 are correlated to the Kuruksay suite according to paleomagnetic data. Suite C_1 is represented mostly by sands and sandstones. Suite C_2 consists of alternating members of sands (sandstones) and silts. The boundary between suites C_1 and C_2 in the Kayrakkum section can be tentatively drawn along a dislocated bed of siltstones. We can also see in this section that suite C_1 is more dislocated than suite C_2 (FIG. 2. II). In the upper half of suite C_2 near the Kayrakkum reservoir some faunal remains were recognized, including Archidiskodon meridionalis Nesti. This form of ancient elephant is not younger than the Khapry faunistic complex as concluded by DUBROVO, I.A. The bone-bearing horizon with finds of a southern elephant is associated with the Gauss-Matuyama inversion. The geological boundary at about 3.5 m.y. B.P. falls within the middle part of suite C_1, this being controlled by superposition of the Gilbert-Gauss paleomagnetic inversion.

In some outcrops in the south of Tajikistan at the base of the Kuruksay suite we managed to detect an angular unconformity and washout where it rests on older rocks (FIG. 2, I). The paleomagnetic data enable us to assume that this angular unconformity occurs somewhat lower than the Gilbert-Gauss paleomagnetic inversion, i.e. approximately at the level of 3.5 m.y. At the same time, the relationship between the Kuruksay suite and the underlying Neogene molasse remains debatable. The problem involves distinguishing the Polyzak suite, drawing the boundary between the Polyzak and Kuruksay suites etc.

Subaerial deposits attributed to the Upper Pliocene are represented by red-brown loess-like silts reworked by soil processes and including well-developed red soils. Illuvial carbonate horizons in the red soils are very thick (up to 1 m), resembling calcrete.

In southern Tajikistan the Kuruksay suite correlates with high erosional-accumulation terraces, traced regionally in the foothills along the Yakhsu, Vakhsh and other rivers some 600-700 m above the thalwegs. Near Tashkent, the Nanai terrace in the Pskem river valley occupies a similar geomorphological position, being composed of alluvial-proluvial conglomerates (the so-called Nanai complex) up to 200 m thick.

The Eopleistocene in the Tajik depression is associated with the Kayrubak suite recognized for the first time in this region by LOSKUTOV, V.V. (LOSKUTOV, V.V. et al. 1971). At first neither distinct stratigraphic units nor boundaries were evident in this suite. Detailed investigations by the author togerher with paleomagnetic specialists (PEN'KOV, A.V. – GAMOV, L.N. – DODONOV, A.E. 1979) and paleontologists (VANGENGEIM, E.A., SOTNIKOVA, SHARAPOV, et al.) made possible a more precise

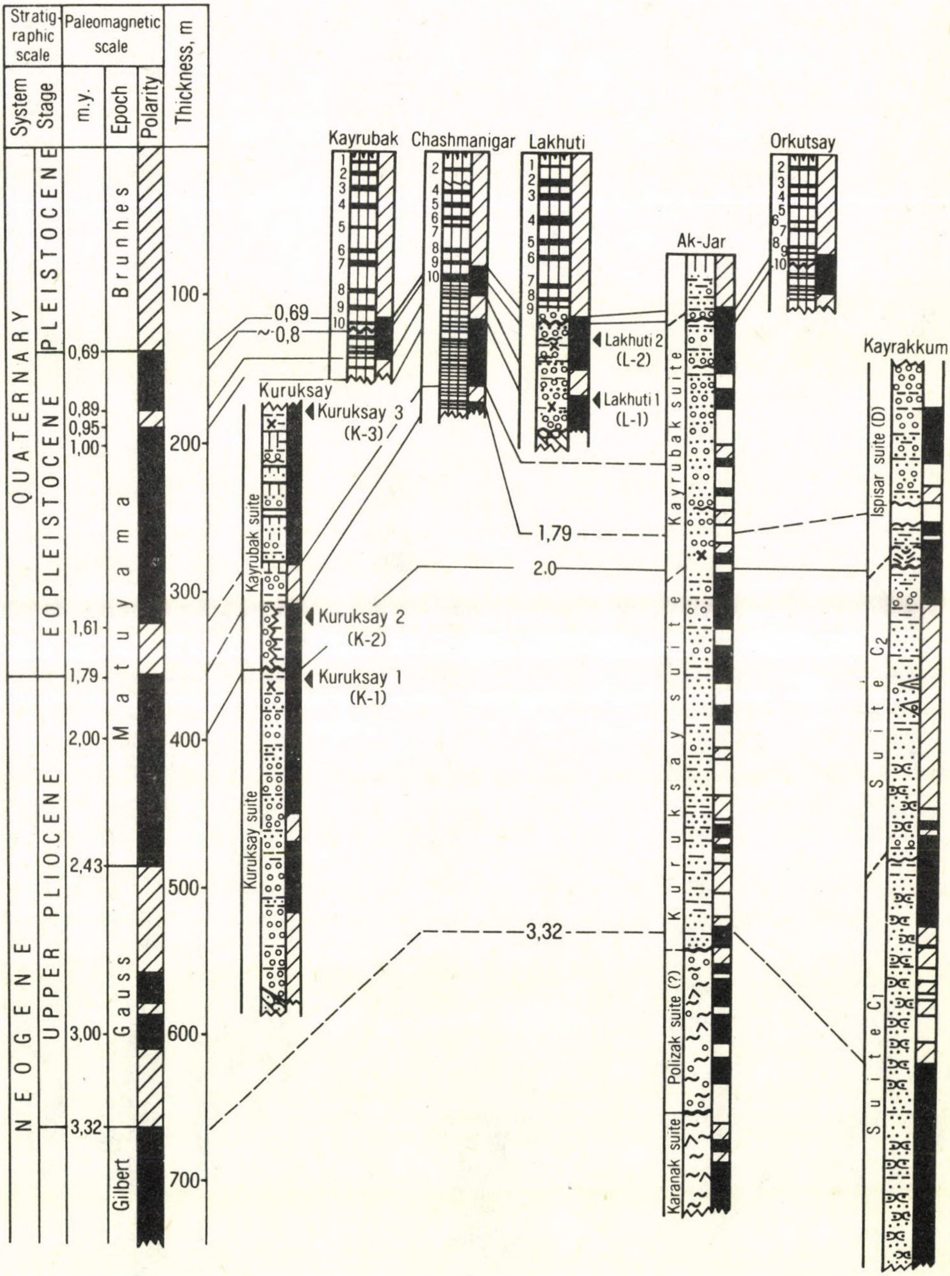


FIG. 1. Correlation scheme for the Upper Pliocene and Quaternary deposits of southern Tajikistan, western Fergana and the Tashkent region. Paleomagnetic data by PEN'KOV, A.V. and ZHIDKOV, E.I. (1977, 1978).

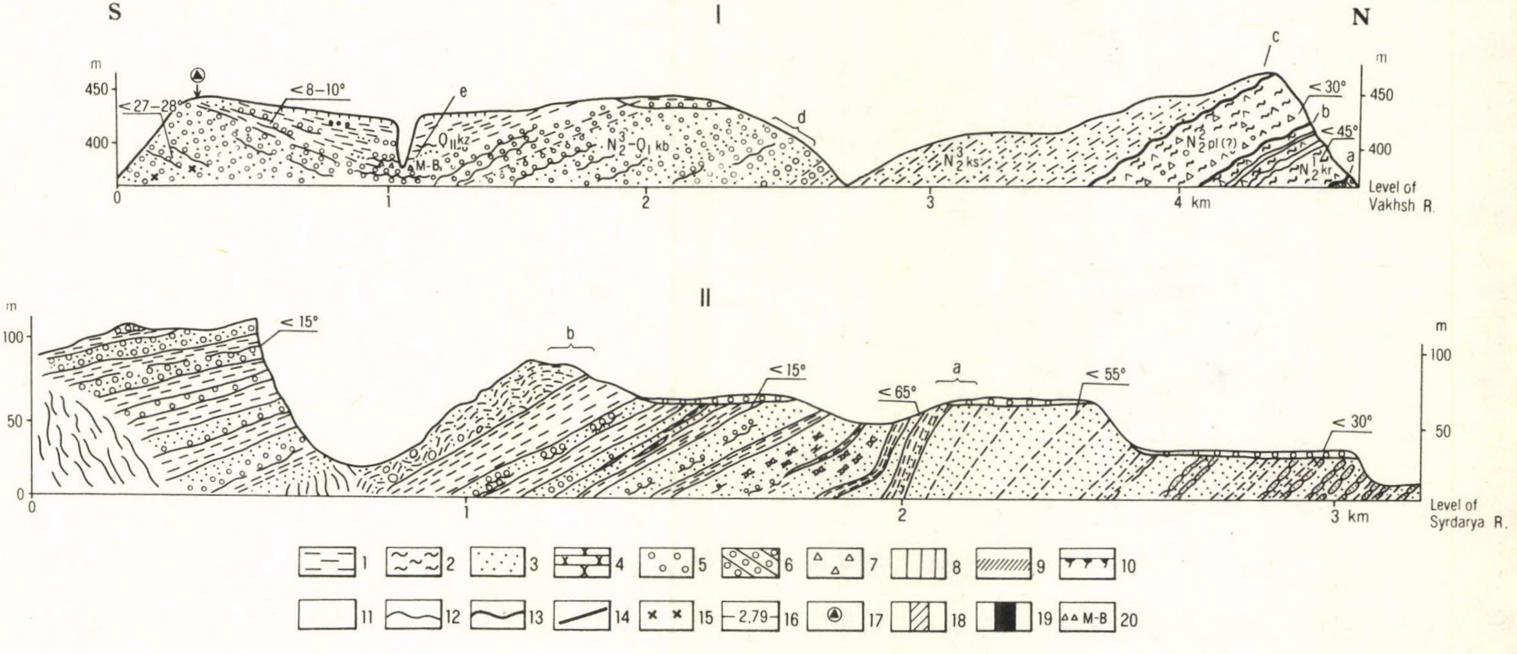


FIG. 2. Geological sections in Pliocene-Quaternary deposits. I = Ak-Jar, II = Kayrakkum. Letters show the position of the boundaries on profile I: a = at the base of Karanak suite (Lower Pliocene), b = between the Karanak and Polizak suits (Lower/Middle Pliocene), c = between the Polizak (?) and Kuruksay suites (Middle/Upper Pliocene), d = between the Kuruksay and Kayrubak suites (Upper Pliocene/Eopleistocene), e = between the Kayrubak and Kyzylsu suites (Eopleistocene/Pleistocene), profile II: a = between C_1 and C_2 suites, b = between suite C_2 and Ispisar suite. 1 = silt, 2 = siltstone, 3 = sandstone, 5 = pebbless 6 = conglomerate, 7 = rubble, rock fragments, 8 = loess, 9 = buried soil (or pedocomplex), 10 = recent soil, 11 = gypsum, 12 = erosional break, 13 = geological boundary, 14 = fault, 15 = mammalian fauna remains, 16 = correlation lines and age m.y., 17 = Paleolithic finds, 18 = normal magnetization, 19 = reversed magnetization, 20 = Matuyama/Brunhes reversal.

determination of the boundaries of the Kayrubak suite in the interval from 2-1,8 to 0.8-0.7 m.y. This corresponds to the Eopleistocene of the scale adopted. Faunistic finds in the Kayrubak suite are known mostly from the layers adjacent to the Kuruksay suite, and from the upper part of the Kayrubak suite. The fauna of the lower levels is representative of the Villafranchian in the broad sense. The composition of the fauna of the upper level (locality Lakhuti-2) it of a transitional character. Comparison with localities in Eastern Europe and Siberia suggests it is an equivalent of the transition from the Taman to the Tiraspol faunal complex. In western Fergana, the Ispisar suite belongs to the Eopleistocene. The age analogue of the Ispisar suite is suite D (the latter being distinguished by VASILKOVSKY, N.P. in 1951). Deposits of both suites are paragenetically related. Considering the geological position of the Ispisar suite and suite D, their lithological composition and space relationships, one can assume that sandy-pebble deposits of the Ispisar suite are fluvial facies of the paleo Syrdarya, whereas deposits of suite D are, on the whole, synchronous with the first proluvial sediments developed along the slopes of the valley. Both suites are slightly dislocated. In the area of the Koktyurlyuk meanders, both the Ispisar and the D suites are cut by the 70 m and 100 m terraces of the Syrdarya river. In the Kayrakkum section, the boundary between suite C_2 (Upper Pliocene) and the Ispisar suite is drawn along the bed of disharmonically dislocated silts and sands, about 20 m thick (FIG. 2, II).

Taking into account the paleomagnetic data, this member with dislocations lies in the lower part of the Matuyama zone, higher than Gauss-Matuyama inversion. As for suite D, it is characterized like the Ispisar suite, by reverse magnetization (oral communication by YEROSHKIN, A.F.).

The Eopleistocene subaerial beds of southern Tajikistan include from 25 to 28 fossil soils of red-brown and brown colour. They are conventionally grouped into 9 pedocomplexes. The thickness of the loess horizons in the Eopleistocene is insignificant. The Chashmanigar section in the eastern part of the Tajik depression in unique in its stratigraphic completeness. The complete Eopleistocene and Pleistocene subaerial sequence which outcrops here is about 170 m thick (DODONOV, A.E. – LOMOV, S.P. 1980). The paleomagnetic data on these sequences indicates the Olduvai and Jaramillo episodes and the Matuyama-Brunhes inversion (FIG. 3, II). In the subaerial sequences of the Taskent region the Eopleistocene is represented by fragments, mostly of the Upper Eopleistocene (the Orkutsay, Galvasay and some other sequences (FIG. 3, I).

In the foothills of southern Tajikistan and the Tashkent area the Eopleistocene deposits filling synclinal belts are correlated with alluvial terraces with a relative height of about 300-400 m. In southern Tajikistan such surfaces occur along the Vakhsh, Kafirnigan and Kysylsu river valleys, and in the upper course of the Chirchik river near Tashkent. These high level deposits are composed of pebble-beds, or take the form of erosional terraces without alluvial deposits.

The paleosols within the loess are the most valuable sources of Pleistocene stratigraphical data. In southern Tajikistan outcrops include those at Kayrubak, Chashmanigar, Khonoko, Lakhuti, and Karamaydan. In all these sequences the Matuyama-Brunhes inversion is found directly above the 10th soil complex. The boundary between the Eopleistocene and Pleistocene is drawn at the base of this pedocomplex: this is reinforced by the presence of an angular unconformity between the Eopleistocene and Pleistocene subaerial deposits. The boundary is traced in this fashion in all outcrops mentioned above.

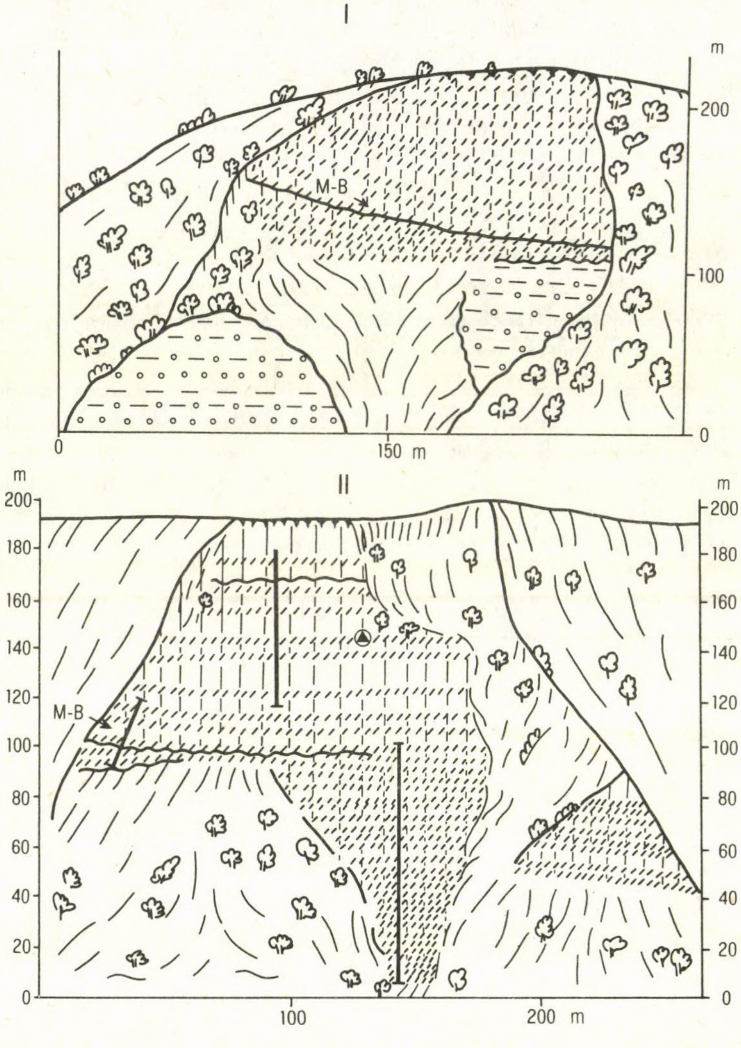


FIG. 3. Geological sections: I = outcrop Orkutsai, II = outcrop Chashmanigar.

The subdivision of the Pleistocene subaerial sequence is based on geological structure, analysis of fossil soils, paleomagnetic and thermoluminescence data and on the results of studying Paleolithic finds in the 6th and 5th complexes (DODONOV, A.E. – PEN'KOV, A.V. 1977, DODONOV, A.E. – RANOV, V.A. – PEN'KOV, A.V. 1978). The 10th, 9th and 8th soil complexes, as well as the loess horizons separating them, including the loess member above the 8th soil, were included in the Lower Pleistocene (the Vakhsh lithostratigraphic complex). The 7th and 6th pedocomplexes with loess between them and the horizon of loess above the 6th pedocomplex are regarded as Middle Pleistocene in age (the Iliak lithostratigraphic complex). The upper part of the subaerial sequence, five pedocomplexes and the associated loess horizons, belong to the Upper Pleistocene (the Dushanbe lithostratigraphic complex).

The Pleistocene buried soils in the loess mantles are correlated with the alluvial deposits making up erosion-accumulation terraces between 10 and 200-220 m high above the valley floors. There are ten terraces and Pleistocene palaeosol horizons within this altitudinal range. The terraces between 140 and 220 m (the Vakhsi complex) were classified as early Pleistocene, between 80 and 140 m (the Iliak complex) as Middle Pleistocene, and between 10 and 80 m as late Pleistocene in age (the Dushanbe complex).

The majority of Mousterian and Upper Paleolithic finds are associated with the Dushanbe terraces (RANOV, V.A. – NESMEYANOV, S.A. 1973).

In the Tashkent region the most complete loess-soil sequence is found in the Orkutsay outcrop in the Charvak basin. This sequence includes the upper part of the Eopleistocene and the Pleistocene, its stratigraphy being similar in essentials to other outcrops in southern Tajikistan. As in southern Tajikistan, the Matuyama-Brunhes inversion was recognized above the 10th soil complex and the angular unconformity was fixed at the base of this pedocomplex.

Summarizing the results of stratigraphic studies in Central Asia, we can conclude that the age framework for the last 3.5 m.y. is quite well-known, though its detailed subdivision is irregular. The most detailed scale concerns the Eopleistocene and Pleistocene. Palaeosols in the loess have provided much of the detail. The identification of climatostratigraphic subdivisions in using soil and loess horizons and tracing the climatic rhythms on the basis of well studied stages of the Pleistocene up to the base of the Eopleistocene, i.e. essentially within the last 2 m.y., generally confirms the value of using climatostratigraphic principles for subdivision of both the Pleistocene and the Eopleistocene deposits. At the same time, tracing the relationship between soil and loess horizons for that time period reveals more distinct climatic rhythms for the last 0.8 m. y. as compared to the earlier period. This is possibly a function of the relatively greater and more-distinct cooling and desiccation in the later period compared to the earlier stages. This tends to suggest that rhythmic climatic shifts, i.e. alternation of warm and cold periods, cannot be used as a firm criterion for determining the lower boundary of the Quaternary, particularly in Central Asia, where the climate had always been relatively hot. In this respect, much consideration should be given to establishing the principal geological boundaries at the dating levels 3.5, 1.8 – 2 and 0.7 – 0.8 m.y.B.P. These geological boundaries are associated with phenomena such as phases of tectonic activity, rejuvenation of the landscape, and regional changes in climate, plant life and fauna. In addition, the process of loess accumulation began in Central Asia very early in the Eopleistocene, though its initiation may possibly have taken place as far back as the Late Pliocene, at the boundary between the Eopleistocene and Pleistocene loess accumulation became more intense and gradually increased up to and including the Late Pleistocene.

Now we shall briefly touch upon interregional correlations and begin with the Pleistocene as the best studied interval of the time scale. In terms of the best known horizons within the East European plain, an analogue of the 2nd soil complex in the Central Asian loess-soil sequence appears to be the Bryansk soil, the 5th soil complex corresponds to the Mikulino interglacial horizon, and the 7th soil complex the Likhvin intergalacial horizon, etc.

As for the Alpine stratigraphical scale, we think that the five upper loess horizons separating them may represent the Würm, the Riss corresponds to two loess horizons and the 6th soil complex enclosed between them , and the Mindel may be represented by three loess horizons and the 8th and 9th soil complexes in between them.

Among the Pleistocene loess sequences of Hungary, the Paks sequences in the Pleistocene and the Mende sequence in the Upper Pleistocene sequence are the most complete. With reference to the stratigraphic data on the loess-soil deposits of Hungary (PÉCSI, M. et al. 1977, PÉCSI, M. 1979, PÉCSI, M. et al. 1979), the following correlation for the Upper Pleistocene is possible (from top downwards): the Mende-upper soil complex (MF_1-MF_2) corresponds to the 2nd soil complex of Central Asia, the Basaharc-Double soil complex (BD_1-BD_2) to the 3rd soil complex, the Basaharc-Base soil complex (BA) to the 4th soil complex, and the Mende-Base soil complex (MB) to the 5th soil complex. It is noteworthy that in the Mende sequence the Mende-Upper (MF) pedocomplex is overlain by two buried humic horizons (H_1, H_2), enclosed in loess. They have also been traced in other sequences of the Hungarian plain. These humic horizons appear to be correlated to the 1st soil complex in the loess sequences of southern Tajikistan. The age estimation of the these buried soils in the Hungarian plain provided the following results: MF_1 – 27 000-28 000 years. BD_1 – BD_2 – 42 000-45 000 y, BA – 60 000-74 000 years, and MB – about 125 000 years (BORSY, Z. et al., 1979., PÉCSI M. et al., 1979). We must emphasize the closeness between the age estimations for the soil complex MB (about 125 000 y.) and the 5th soil complex in southern Tajikistan (about 130 000 y.).

The comparative analysis of the stratigraphy of Central Asia and the northern Himalayan foothills is still disputable, although new data have been obtained lately that contribute to our knowledge. Thus, during the field conference on the Neogene/Quaternary boundary held in Chandigarh, India, in 1979, SASTRY, M.V. suggested a possible correlation of the Tatrot with the Ruscinian, the Pinjor with the Lower-Middle Villafranchian, and the Neogene/Quaternary boundary was drawn within transitional layers of the Pinjor Boulder Conglomerate (SASTRY, M.V. 1981). Recent research into the biostratigraphy and paleomagnetism of the upper Siwalik deposits (AZZAROLI, A. – NAPOLEONE, G. 1981) has shown that the Pinjor may correspond to the Lower Matuyama epoch, while the Boulder Conglomerate corresponds to its upper part. The Tatrot has been considered to lie within the Gauss paleomagnetic epoch. Other work has been devoted to the Neogene/Quaternary boundary in India (AGRAWAL, R.P. et al. 1981). The Olduvai paleomagnetic episode has been suggested for the lower boundary of the Quaternary. It was assumed that in the Siwalik zone this boundary may be drawn within the Pinjor.

We believe that the Pinjor may correspond to the Upper Pliocene (Lower-Middle Villafranchian), the Boulder Conglomerates may be Eopleistocene, and the Pleistocene/

Eopleistocene boundary may correspond to the interface between the 200-250 m high terrace complex and the Boulder Conglomerate, by analogy with the geology of the Tajikistan river valleys (DODONOV, A.E. – PEVZNER, M.A. – PEN'KOVA, A.M. 1979).

New results from the Kashmir valley (AGRAWAL, D.P. et al. 1979) allow us to assume that the upper Karewa is situated in the zone of normal polarity identified with the Lower Brunhes epoch, and that the lower Karewa corresponds to the Matuyama paleomagnetic epoch. The age of the loess mantle in the Kashmir valley with its three buried soils (A, B, C) is believed to about 100 000 years old. It should be about noted that this is the time of the most intense loess accumulation in Central Asia.

Examination of stratigraphic data on the Chinese loess sequence shows that 8 buried soil horizons exist within the Brunhes paleomagnetic epoch. The Matuyama-Brunhes reversal has been traced in loess sections to a depth of c. 52 m, and the Jaramillo episode corresponds to a depth of 70 m. Further detailed studies will make it possible to correlate more accurately the buried soils of the Loess Plateau of China with the pedocomplexes of Central Asia both in the Pleistocene and the Eopleistocene. For instance, it may be that the thick 5th buried soil in the Chinese loess sections corresponds to two typical, close soil complexes (the 6th and 7th pedocomplexes) in southern Tajikistan. The 1st pedocomplex of grey, immature soils may be omitted in the Malan loess in China may be disregarded in this correlation exercise. At present Chinese geologists draw the Neogene/Quaternary boundary along the Gauss-Matuyama reversal (2.43 m y.) that in Upper Pliocene-Quaternary sequences of China coincides with the boundary lying between the lower and upper Nihewan series. In loess sections this boundary has been assumed to lie between the Wucheng loess and underlying Red Clays (LIU TUNG-SHENG – DING MENGLIN 1982) but the Matuyama-Gauss boundary has not been detected in the loess (HELLER, F. – LIU, T. 1982).[1.] The Wucheng loess is assumed to correspond to the Central Asian loess-soil strata below the Jaramillo paleomagnetic episode.

Paleotemperature measurements of deep-sea sediments have distinguished up to 20 stages within the Brunhes paleomagnetic epoch (SHACKLETON, N.J. – OPDYKE, N.D. 1973), which may be compared to the 20 buried soil and loess horizons in the same stratigraphic interval in the Central Asia sequence. According to the Van Donk paleotemperature curve, there exist up to 18 stages within the interval between the Matuyama-Brunhes reversal and the base of the Olduvai.

Such correlation series could be continued, but this is not the main purpose of this discussion. We must emphasize something else. If our correlations are correct in the majority of cases, the conclusion is inescapable that the Late Pliocene/Quaternary was characterized by a regular and generally synchronous depositional series. The principal geological phenomena are essentially synchronous, reflecting specific geological conditions in different regions: they are fundamental for the establishment of stratigraphies and for stratigraphic correlation.

[1.] Remark by E. Derbyshire

REFERENCES

AGRAWAL, D.P. – KRISHNAMURTHY, P.V. – SHEELA KUSUMGAR – NANTIYAL, V. – ATHAVALE, R.N. – RADHAKRISHNAMURTHY, C. 1979: Chronostratigraphy of loessic and lacustrine sediments in the Kashmir valley, India. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 185-196.

AGRAWAL, D.P. – BHATT, D.K. – SHEELA KUSUMGAR – PANT, R.K. 1981: The Neogene/ Quaternary boundary in India: A review. – Proc. Indian Acad. Sci. (Earth Planet Sci.). 90. 2. 111-123.

AZZAROLI, A. – NAPOLEONE, G. 1982: Magnetostratigraphic investigation of the Upper Siwaliks near Pinjor. – Riv. Ital. Paleont. 87. 4. 739-762.

BORSY, Z. – FÉLSZERFALVI, J. – SZABÓ, P.P. 1979: Thermoluminescence dating of several layers of the loess sequences at Paks and Mende, Hungary. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 451-461.

DODONOV, A.E. – PEN'KOV, A.V. 1977: Nekotorye dannye po stratigrafii vodorazdel'nykh lessov Tadzikskoy depressii (Yuzhny Tadzhikistan). (= Some data on the stratigraphy of the watershed loesses in Tajik depression). – Bull. of the Commission on the Quaternary Research. 47. 67-76.

DODONOV, A.E. – RANOV, V.A. – PEN'KOV, A.V. 1978: Nakhodki paleolita v drevnikh pogrebyonnykh pochvakh Yuzhnogo Tadzhikistana i ikh geologisheskaya pozitsia. (= Paleolithic finds in ancient buried soils of South Tajikistan and their geological position). – Bull. of the Commission on the Quaternary Research. 48. 86-102.

DODONOV, A.E. – PEVZNER, M.A. – PEN'KOVA, A.M. 1979: Nekotorye dannye o geologicheskom stroenii i paleomagnetizme verkhnepliotsen-chetvertichnykh otlozhenyi severnoi i tsentralnoi Indii. (= Some data on geology and paleomagnetology of the Upper Pliocene/Quaternary deposits in Southern Central India). – Bull. of the Commission on the Quaternary Research. 49. 105-115.

DODONOV, A.E. – LOMOV, S.P. 1980: Stratigraficheskie i paleogeograficheskie aspekty izucheniya iskopaemykh pochv i lessov Yuzhnogo Tadzhikistana. (= Stratigraphical and paleogeographical aspects of researching buried soils and loesses in South Tajikistan). – Izv. AN SSSR. ser. geol. 8. 75-85.

HELLER, T. – LIU TUNG- SHENG: 1982: Magnetostratigraphical dating of loess deposits in China. – Nature, 300. 431-433.

LIU TUNG-SHENG – DING MENG-LIN: Pleistocene stratigraphy and Plio/Pleistocene boundary in China. Quaternary geology and environment of China. Beijing, China Ocean Press. 1-6.

LOSKUTOV, V.V. – YERSHOVA, L.N. – LIM, V.V. – KOLOTOV, V.A. 1971: O stratigrafii verkhnepliotsen-nizhnechetvertichnykh otlozhenii Tadzhikskoi depresii. (= On the stratigraphy of the Upper Pliocene – Lower Quaternary deposits of the Tajik depression). – Izv. AN Tajik SSR, otd. fiz.-mat. i geol.-khim. nauk. 2.40. 91-101.

NIKIFOROVA, K.V. – KRASNOV, I.I. – ALEKSANDROVA, L.P. et al. 1980: Khronostratigraficheskaya skhema pozdnego kainozoya evropeiskoi chasti SSSR. (= Chronostratigraphic scheme of the Late Cenozoic in the European part of the USSR). – In: Quaternary geology and geomorphology. Remote sensing. International Geological Congress, XXVIth Session. Reports of Soviet geologists. Moscow, Nauka. 65-68.

PÉCSI, M. – PÉCSI-DONÁTH, É. – SZEBÉNYI, E. – HAHN, Gy. – SCHWEITZER, F. – PEVZNER, M.A. 1977: Paleogeographical reconstruction of fossil soils in Hungarian loess. – Földr. Közl. 25. 1-3. 94-128.

PÉCSI, M. 1979: Lithostratigraphic subdivision of the loess profiles at Paks. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 409-418.

PÉCSI, M. – SZEBÉNYI, E. – PEVZNER, M.A. 1979: Upper Pleistocene litho- and chronostratigraphical type profile from the exposure at Mende. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 371-389.

PEN'KOV, A.V. – GAMOV, L.N. – DODONOV, A.E. 1976: Svodny paleomagnitny razrez verkhnepliotsen-pleistotsenovykh otlozhenyi basseina r. Kyzylsu (Yuzhny Tadzhikistan). (= Summary paleomagnetic section of the Upper Pliocene-Pleistocene deposits of the Kysylsu river basin with reference to South Tajikistan). – Izv. AN SSSR. ser. geol. 9. 33-43.

RANOV, V.A. – NESMEYANOV, S.A. 1973: Paleolit i stratigrafiya antropogena Srednei Azii. (= Paleolithic and stratigraphy of the Anthropegen of the Central Asia). Dushanbe, Donish. 160.

SASTRY, M.V.A. 1981: Status of Neogene/Quaternary boundary Field Conference, India. Proc. 1-4.

SHACKLETON, N.J. – OPDYKE, N.D. 1973: Oxygen isotope and paleomagnetic stratigraphy of Equatorial Pacific core Y 28-238: oxygen isotope temperatures and ice volumes on a 10^5 year and 10^6 year scale. – Quaternary Res. 3. 39-55.

VASILKOVSKY, N.P. 1951: K vozrastnomu raschleneniyu otlozheni severo-vostochnogo Uzbekistana. (= Age subdivision of deposits in North-Eastern Uzbekistan). – Trudy Inst. Geol. AN Usb. SSR. 6. 5-44.

Address of author:
Dr. A.E. Dodonov, Institute of Geology Academy of Sciences USSR
Pyzhevsky per. 7. 109017 MOSCOW – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

IS TYPICAL LOESS OLDER THAN ONE MILLION YEARS?

M. Pécsi

ABSTRACT

In recent years ever more characteristic loess profiles of the European and Asian loess zone have been analyzed by absolute chronological methods. For most of the repeated paleomagnetic analyses the lithologically sensu stricto true loesses are not or hardly older than the Jaramillo event (0.9 m.y.B.P.).

In certain regions this is underlain by a subaerial formation differing both petrologically and pedologically from the true loess formation. Its thickness is remarkable but uneven and it consists of the closely subsequent sequence of predominantly pale pink, reddish, brownish-reddish, sometimes gleyed clay, loam, silty clay and paleosols. The different paleosols are separated from one another by partly weathered sandy or clayey silts of similar colour. This formation differing from the loess and consisting mainly of paleosols is called „loess-like" formation or „loess derivate" by some authors. Based on the paleomagnetic investigations the formation of this group including predominently paleosols, red and mottled clays and silts can be traced back to the middle (1.8 m.y.B.P.) and early (2.4 m.y.B.P.), Matuyama respectively, or occasionally as far as the Gauss epoch (Gauss-Gilbert boundary, 3.4 m.y.B.P.).

ABSOLUTE AGE OF LOESSES IN THE CARPATHIAN BASIN

In Europe predominantly typical loess sequences of considerable thickness are found in the Middle Danube (or Carpathian) Basin. The most characteristic outcrops are found on terraces and alluvial fans along the rivers, and in some instances on Pannonian lacustrine sediments (PÉCSI, M. 1979, 1982). In the loess sequence, in addition to the typical loess and slope loess strata the fossil soils are cyclically repeated, and eolian, fluviatile and proluvial sand, lacustrine and marshy formations are also intercalated.

Based on the lithogenic and paleoecological investigation and comparison of the strata of numerous loess profiles some characteristic „loess complex" or „loess series" could be disginguished in the loess formation of the Carpathian Basin. Within this formation the loessic and non-loessic layers and the genetic types of the intercalated soils are akin to one another.

1. The young loess is most widespread on terraces, alluvial fans, piedmont surfaces, and covers the relief in a thickness of 10 to 30 m. This sequence is bipartite. The

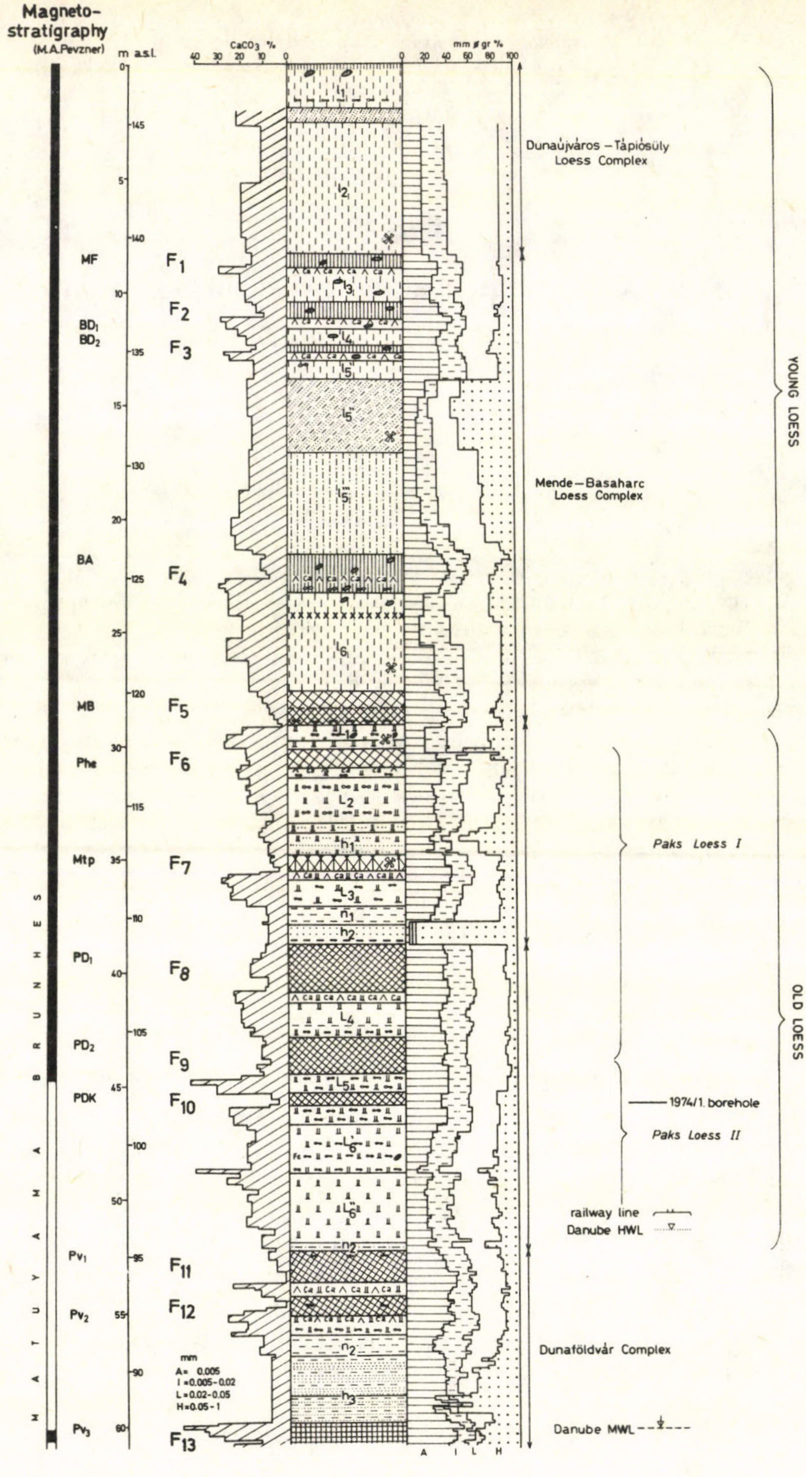


FIG. 1. Lithostratigraphical subdivision of the old and young loess-formation at Paks

youngest loess strata consist mostly of sandy loesses, loessy sands and only one or two embryonal soils, weak humus layers are found in them. The lower two-third of the young loess is composed of typical loess strata and three-four fossil soils. In these loess strata usually all the criteria characteristic of the true loesses are found, but only small loess concretions can be found (PÉCSI, M. et al. 1977, PÉCSI, M. 1979). In hilly regions the stratified slope loess („valley loess", „derasion loess") is a characteristic variety (PÉCSI, M. 1972).

– The upper part of the young loesses, the so-called „Tápiósüly Loess Complex" is 5 to 10 m thick and formed 11 to 28 t.y.B.P.

– The major part of the young loesses consists of the „Mende-Basaharc Loess Complex", 28-125 t.y.B.P., including the soil complex „MB" lying in its base (FIG. 1).

– A peculiar loess-like facies of the youngest loess is found in the Hungarian Great Plain, mainly in the wide alluvial plain of the river Tisza. Here the so-called „infusion loess" covers several ten thousand square kilometers lying on the flood-plains and on the alluvial fan situated only several metres higher than the flood-plain itself (PÉCSI, M. 1982). The thickness of these loess-like formations of variable sandy to clayey composition, is only 1 to 3 m. In the smaller part it overlies Holocene loams, while the major part of the „infuison loess" (being also called „lowland loess") is of younger Late Pleistocene age and according to radiocarbon data it was formed 18-24 t.y. B.P. also on flood-plain deposits.

FIG. 1.

l_1, l_2 = the typical youngest loess beds of the profile; between l_1, l_2 deposited sandy slope loess in a derasional valley (dell) the lower part of l_1 (+) fragments of reindeer bones occur as well as locally 1-2 humus horizons, MF = chernozem-like fossil soil of „Mende Upper", only the MF_1 remained; l_3, l_4, l_5 = young loess beds, below the fossil soil horizons (MF, BD_1, BD_2), with many krotovinas in it, BD_1, BD_2 = „Basaharc double" fossil soil complex chernozem-like locally hydromorphous meadow soil type; l_5 well-stratified sandy slope loess the loessy sand filled up the derasional valley (with Cervus sp. and Elephas primigenius fauna remnants), l_5 = sandy loess; BA = „Basaharc Lower" forest-steppe-like dark fossil soil; l_6 = the lowest young loess bed (with Elephas primigenius remnants) with a thin layer of volcanic tufite too in the upper part of it; MB = „Mende-Base" fossil soil complex, the upper part of it a forest-steppe-like soil and but the lower one a well-developed brown forest soil (according to the thermoluminescence analysis of BORSY, Z. et al. 1980 about 105 thousand years old); L_1 = old loess, sandy loess, with large „loess dolls", molars, tusks of Elephas trogontherii were found on two occasions; Phe = weakly developed sandy brown forest soil; L_2, L_3 = old loess (with 2-3 layers of „loess dolls"); Mtp = hydromorphous fossil soil (flood-plain, clayey soil) with Allohippus sp. teeth; h_1, h_2, n_1 = sand and silty clay of alluvial fan; PD_1, PD_2 = stratotype of „Paks Lower Double" fossil soil complex, with krotovinas (Submediterranean xerophile forest soil or chesnut, usually reddish brown) below the PD_2 fossil soil occurs the Brunhes-Matuyama boundary; L_4, L_5, L_6 = old loess strata, with „loess doll" layers; L_6 = lowermost old loess bed, loess dolls rarely occur; n_2, n_3 = sandy clay, silty clay and sand of alluvial fan, Dv_1, Dv_2, Dv_3 = reddish ochrered fossil soils, below the old loess (belonging to the „Dunaföldvár formation")

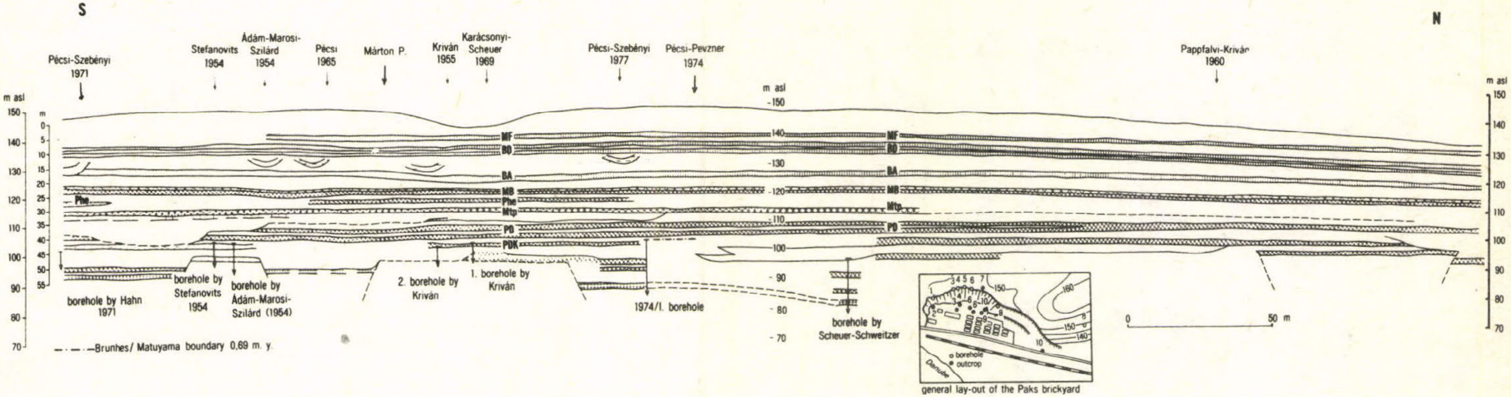


FIG. 2. Geological section of the Paks loess exposure (constructed by M. PÉCSI). Exposures and boreholes studied by other authors are also indicated.

2. The old loess can fairly well be separated from the younger one lithologycally, on the basis of its greater compaction and the intercalated fossil soils. It is characterized by layers of larger loess concretions. The old loesses occur in the greater loess profiles only, mainly in the loess bluffs along the Danube. After the best studied typical profile it is called the „Paks Loess Complex" which also consists of two different members (FIGS. 1, 2).

– In the upper part of the Paks Loess Complex sandy layers predominate. This is rather incomplete, thus its chronological assignment to the Middle Pleistocene is only possible partly considering its stratigraphic position, after the TL-investigations and its fauna content (BORSY, Z. et al. 1979, BUTRYM, J. – MARUSZCZAK, H. 1984, PÉCSI, M. 1982). The age of the sandy strata is 125-200 t.y.B.P. as shown by the TL-investigations (FIG. 1).

– Three fossil soils (PD_1, PD_2, PDK) and three old loess horizons constitute the lower part of the Paks Loess Complex, without hiatus. In the Paks profile these soils represent the paleosols No. 8-10 from up downwards in the profile (FIG. 1).

Below the paleosol No. 9 (marked by PD_2) the Brunhes-Matuyama paleomagnetic boundary could be identified (0.73 m.y.B.P.). The analyses, repeated four times in the Paks brickyard and in boreholes, revealed this significant chronostratigraphic phenomenon in the same lithostratigraphic position (MÁRTON, P. 1979, PÉCSI, M. – PEVZNER, M.A. 1974, PEVZNER, M.A. – PÉCSI, M. 1980, PÉCSI, M. 1982). Similar results were obtained at Dunaföldvár locating 20 km north of Paks where three profiles were studied from the paleomagnetic point of view (FIG. 3; PÉCSI, M. – PEVZNER, M.A. 1974, PÉCSI M. et al. 1979).

In the Paks and Dunaföldvár profiles below the Brunhes-Matuyama boundary a paleosol and a thick loess horizon of the old loess are found. Below this horizon not the loess formation, but the pale pink stratified sandy silt is found with a horizon of normal polarity probably indicating the Jaramillo event (0.9 m.y.B.P.) (FIG. 4). Similar chronological evaluation was given on the loess profiles along the Danube in Yugoslavia by MARKOVIČ–MARJANOVIČ, J. (1979).

Thus, by our investigation the real true old loesses in the Charpathian Basin are somewhat younger than one million years.

DATA ON THE ABSOLUTE AGE OF THE EURASIAN LOESS FORMATION

In Czechoslovakia KUKLA, J. (1970) determined the Brunhes-Matuyama boundary between the paleosols No. 9 and 10 in the loess profile of Červeny Kopec environs of Brno. KUKLA believed the underlying loess horizon to be the oldest loess formation cycle in Central Europe.

In Austria FINK, J. (1979) reported the old loess horizons of the Krems profile to be older than the Jaramillo event and those in the Stranzendorf profile older than the Matuyama-Gauss boundary. In the sequence of the latter the loess-like sediments predominate in addition to the paleosols. The stratigraphic position of the Krems profile is uncertain also according to FINK, J. (1979).

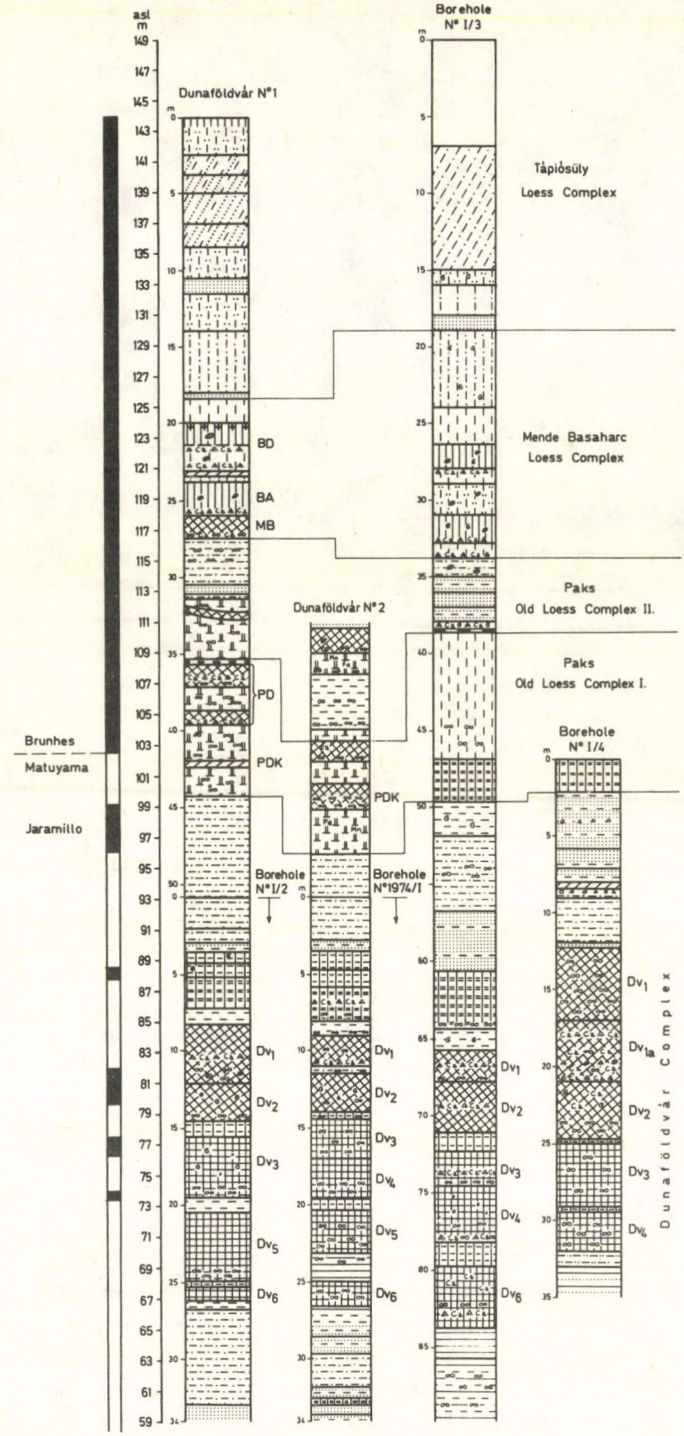


FIG. 3. Correlation of the different exposures and borehole profiles at Dunaföldvár (M. PÉCSI – E. SZEBÉNYI – M.A. PEVZNER).

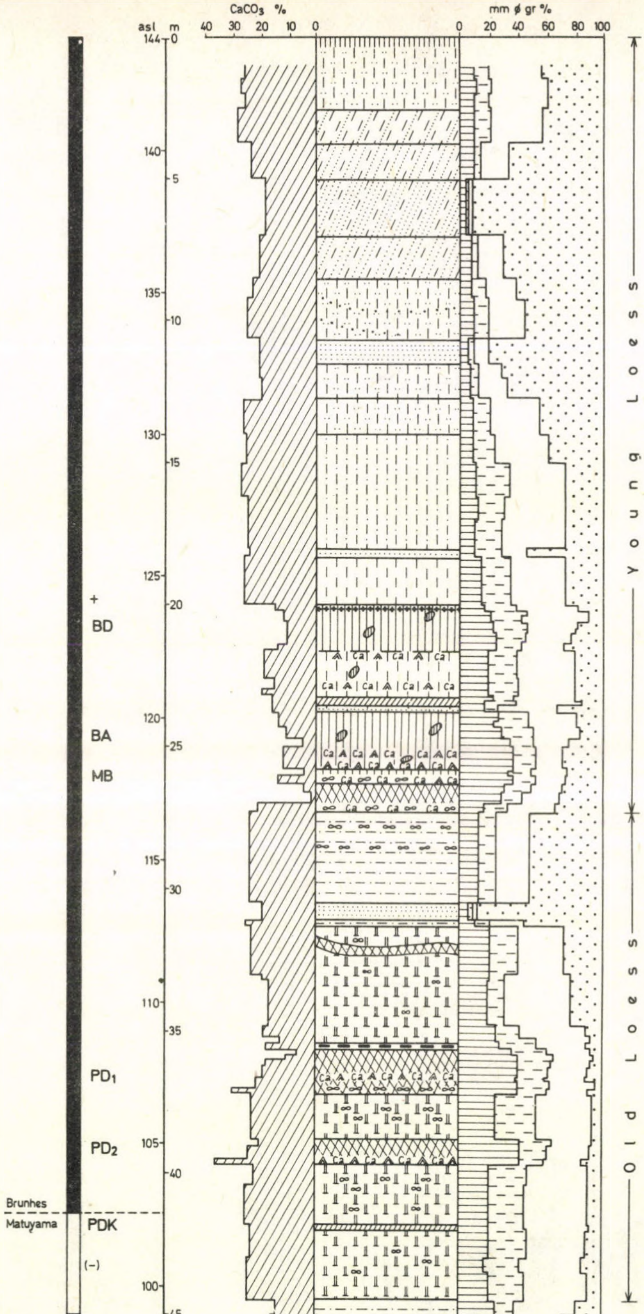


FIG. 4. Lithological and pedological profile No. 1 of the open exposure (1971) with paleomagnetic polarity information, Dunaföldvár, Kálvária Hill (M. PÉCSI – E .SZEBÉNYI – M.A. PEVZNER).

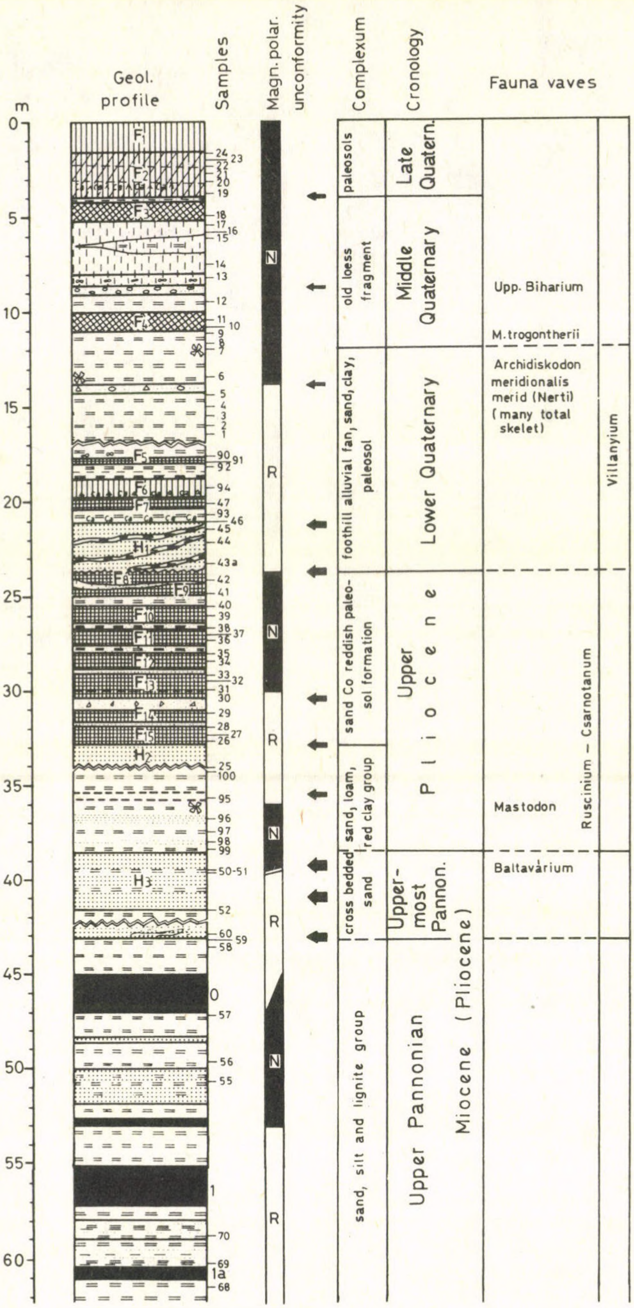


FIG. 5. Comprehensive profile of the Gyöngyösvisonta open cast lignite mine (Thorez Mine). 1981. The profile was surveyed and identified by J. BALOGH – P. MÁRTON – F. SCHWEITZER – Gy. SZOKOLAI under the guidance of M. PÉCSI

In Western Europe the Normandian loesses show normal polarity, only the lowermost paleosol of the Mesnil-Esnard profile (N^o 7) is of reverse magnetism (LAUTRIDOU, J.P. 1979).

In Eastern Europe the Ukrainian loesses are also dated as younger than one million years (VEKLICH, M.F. 1979).

In Central Asia, in Uzbekistan numerous paleomagnetic analyses were carried out in regions abounding in loess (SHERMATOV, M.Sh. – TOICHIEV, Kh. 1982). As to the paleomagnetic analyses of the young „Golodnaya Steppe Loess Complex" and of the old „Tashkent Loess Complex" neither these are older than 0.7 m.y.B.P. In our opinion the compact, pink, red-brown „stony loess" underlying the „Tashkent Loess" cannot be grouped with the loess formation in petrological sense. Neither the 65 m deep Orkutsa profile is older than the Jaramillo event, though its lower third consists of the reddish „stony loess" (SHERMATOV, M.Sh. – TOICHIEV, Kh. 1982).

In Tajikistan significant information is given by DODONOV, A.E. – PENKOV, A.V. (1977) and LAZARENKO, A.A. et al. (1977) and not exclusively on the paleomagnetic investigations of the major profiles. In the famous Karamaidan profile it has been experienced that the sensu stricto loess formation, i.e. the basis of the Kyzylsu group of about 120 m thickness hardly exceeds the B/M boundary.

The older sequence, the Kuliab group (125 m) is the series of reddish brown and brown paleosols. The individual paleosols are thick, 0.5 to 3.5 m, being separated from one another by 0.3 to 1 m thick brown and pale pink silt. The lower part of the sequence also exceeds the Gauss-Matuyama boundary, so it is older than 2.5 m.y.B.P. and it is presumed that it also includes the Gauss epoch (3.5 m.y.B.P.). Nevertheless, this latter formation is believed to be neither a loess-like formation nor a loess derivate. There is no evidence that these would be altered loesses or loesses at all. In the profiles of the Tajik depression of DODONOV, A.E. (1979) the Brunhes-Matuyama boundary falls between the paleosols No. 9 and 10. Everywhere under the paleosol No. 10 a sharp unconformity is found. Our personal experience indicates that here another lithological formation follows and the sequence of strata is transformed into the sequence of reddish soils.

In the past years in Chinese loesses were also studied in detail, paleomagnetic results and petrological descriptions were published about numerous basic profiles (HELLER, F. – LIU TUNGSHENG, 1982, ZHANG ZHONGHU 1982, LIU TUNGSHENG – DING MENGLIN 1982, WANG YONG-YAN et al. 1982). The Chinese loesses, locally exceeding the thickness of 200 m, are divided into three major groups: the uppermost is the young, Late Pleistocene Malan Loess, the second is the Middle Pleistocene Upper and Lower Lishi Loess, while the lowest is the Early Pleistocene Wucheng Loess. This latter is referred by the Chinese experts as the complex of loess-

---

FIG. 5.

F_1 = black meadow soil; F_2 = old loess with remnants of B/BC soil horizon; F_3, F_4 = brown forest soils; F_5 purplish clay soil; F_6 = greyish-brown clay with tufa detritus; F_7 = reddish clay; H_1 = alluvial sand with thin clay layers; F_8 – F_{15} = fossil soils, purple clay soils with aggregated tufa detritus; H_2, H_3 = crossbedded micaceous sand; O_1 = lignite.

like clay soils, silt loams, coarse silty clay soils which are locally underlain by (sandy) red clay. This sequence described as „loess-like" formation can be assigned to the Matuyama epoch according to paleomagnetic results. In certain profiles of the overlying Lishi loess involves also the Jaramillo event (HELLER, F. – LIU TUNG-SHENG 1982), in other cases the B/M boundary is hardly exceeded (ZHANG ZHONGHU, 1982, WANG YONG-YAN – YUE LE-PING, 1982). Consequently, the absolute age of the Chinese Lishi loess is also determined as 0.9 to 1.1 m.y.B.P.

THE MOTTLED CLAY AND RED SOIL BEARING SUBAERIAL FORMATION PRECEDING THE LOESS FORMATION

The Chinese Wucheng, and Central Asian „stony loess" , the Kuruksay and Kurubak sequences consisting of the series of pink and reddish, red-brownish clayey silty soils as well as the „Dunaföldvár formation" in the Carpathian Basin are assessed as nonloessic formations in order to distinguish them from the sensu stricto loess formation (PÉCSI, M. 1982). The formation of this subaerial group, older than the loess itself, was completed just before the Jaramillo event or somewhat later probably due to the lag in the spatial spread of consequences of the changes.

In Hungary, in the major profiles of the basin margins the subaerial sequence underlying the loess formation and differing from it both lithologically and stratigraphically was comprehended under the term the „Dunaföldvár Formation" (FIG. 3, PÉCSI, M. – PEVZNER, M.A. 1974, PÉCSI, M. et al. 1979, PÉCSI, M. 1982). Based on its lithostratigraphic position it is a Lower Pleistocene and (Upper) Pliocene formation the basis of which consists locally of red clay overlying marine-lacustrine sandy sediments of about 4-5 m.y.B.P. In the marginal parts of the basin the mottled clay formation characterized by several reddish soils is 30-40 m thick (FIGS. 3 and 5, Gyöngyösvisonta), while in the internal part of the Hungarian Great Plain it reaches several hundred meter thickness and may exceed the Gilbert and 5. epoch as shown by the paleomagnetic investigations (COOKE, H.B.S. – HALL, J.M. – RÓNAI, A. 1979). Based on paleopedologic, stratigraphic and paleomagnetic data in the foothill zones of the Great Plain margins the subaerial formation in question underlying the old loess of incomplete profiles might be of 1 to 4 m.y.B.P. (FIG. 5, KRETZOI, M. – MÁRTON, P.– PÉCSI, M. – SCHWEITZER, F. – VÖRÖS, I 1982). In this profile, being a foothill alluvial fan formation, several unconformities are observed and the red-clay complex of some m thickness forming the basis of this sequence occurs outside the studied profile.

CONCLUSION

By the litho- and magnetostratigraphic analyses carried out to the date in the significant profiles of the Eurasian loess formation the subaerial formation which can be petrologically loess is essentially not older than one million years. In the subaerial sequences accumulated before the Jaramillo event paleosols predominate which are mostly reddish soils referring to warm climate of seasonal rainfall. Usually, the paleosols overlie one another, the thin intercalated deposits were strongly altered by soil formation. Though for the more exact determination of the genetic types of paleosols further investigations are required, it can be stated that the paleoecological conditions were generally unfavourable to help the accumulated mineral substance transform into loess. For loess formation not only falling dust and silt-like deposits accumulated in other manners are needed, but it requires an appropriate climatic and ecological environment, as well. It seems that these conditions occurred on a global scale in repeated cycles in the last about one million years, nearly in the same periods of the Late Cenozoic.

REFERENCES

BORSY, Z. – FÉLSZERFALVY, J. – SZABÓ, P.P. 1979: Thermoluminescence dating of several layers of the loess sequences at Paks and Mende (Hungary). – Acta Geol. Acad. Sci. Hung. 22. 1-4. 451-459. – Studies on Loess. Budapest, Akad. K. 1980.

BUTRYM, J. – MARUSZCZAK, H. 1984: Thermoluminescence chronology of younger and older loesses. (This volume)

COOKE, H.B.S. – HALL, J.M. – RÓNAI, A. 1979: Paleomagnetic, sedimentary and climatic records from boreholes at Dévaványa and Vésztő, Hungary. – Acta Geol.Acad.Sci.Hung. 22. 1-4. 89-109. – Studies on Loess. Budapest, Akad. K. 1980.

DODONOV, A.E. 1979: Stratigraphy of the Upper Pliocene-Quaternary deposits of Tajikistan (Soviet Central Asia). – Acta Geol. Sci. Hung. 22. 1-4. 63-73. – Studies on Loess. Budapest, Akad. K. 1980.

DODONOV, A.E. (ed.) 1982: Guidebook for excursions A-11 and C-11. Uzbek SSR, Tajik SSR. INQUA XI. Congress. Moscow, 1982. 68.

DODONOV, A.E. – PEN'KOV, A.V. 1977: Nekotorye dannye po stratigrafii vodorazdel'nykh lessov Tajikskoy depressii (Yuzhny Tajikistan). (Some data on the stratigraphy of the watershed loesses in Tajik depression.) – Bull. Commiss. Quaternary Research. 47. 67-76.

FINK, J. 1979: Paleomagnetic research in the northern foothills of the Alps and in the Vienna Basin. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 125-132. – Studies on Loess. Budapest, Akad. K. 1980.

HELLER, F. – LIU TUNG-SHENG 1982: Magnetostratigraphical dating of loess deposits in China. – Nature, 300. 431-433.

KRETZOI, M. – PÉCSI, M. 1979: Pliocene and Pleistocene development and chronology of the Pannonian Basin. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 3-33. – Studies on Loess. Budapest, Akad. K. 1980.

KRETZOI, M. – MÁRTON, P. – PÉCSI, M. – SCHWEITZER, F. – VÖRÖS, I. 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: Quaternary studies in Hungary. Budapest, INQUA Hung. Nat .Comm. 43-73.

KUKLA, J. 1970: Correlations between loesses and deep-sea sediments. – Geol. Föreningen i Stockholm Förhandlingar. 92. 2. 138-180.

LAUTRIDOU, J.P. 1979: Lithostratigraphie et chronostratigraphie des loess de Haute Normandie. – Acta Geol. Acad. Sci. Hung. 22.1-4. 125-132. – Studies on Loess. Budapest, Akad. K. 1980.

LAZARENKO, A.A. – PAKHOMOV, M.M. – PEN'KOV, A.V. – SHELKOPLYAS, V.N. – GITERMAN, R.E. – MININA, E.A. – RANOV, V.A. 1977: O vozmozhnosti klimato-stratigraficheskogo raschlenenya lessovoi formatsii Srednei Azii. (On the possibility of climatic-stratigraphic differentation of loess formation of Central Asia.) – In: Late Cenozoic of North Eurasia. I. Moscow, Izd. Geol. Inst. AN SSSR. 70-32 in Russian, 133 in English.

LIU TUNG-SHENG – DING MENG-LIN 1982: Pleistocene stratigraphy and Plio/Pleistocene boundary in China. – In: LIU TUNG-SHENG (ed.), Quaternary geology and environment in China. Beijing, China Ocean Press. 1-6.

MARKOVIČ-MARJANOVIČ, J. 1979: Sédiments lacustres-fluviaux de l'Éopléistocene – base de la série des loess pléistocenes de la rive droîte du Danube en Yougoslavie. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 133-139. – Studies on Loess. Budapest, Akad. K. 1980.

MÁRTON, P. 1979: Paleomagnetism of the Paks brickyard exposures. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 443-449. – Studies on Loess. Budapest, Akad. K. 1980.

PÉCSI, M. 1972. Scientific and practical significance of loess research. – Acta Geol. Acad Sci. Hung. 16. 4. 317-328.

PÉCSI, M. 1979: Lithostratigraphical subdivision of the loess profiles at Paks. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 409-418. – Studies on Loess. Budapest, Akad. K. 1980.

PÉCSI, M. 1982: The most typical loess profiles in Hungary. – In: Quaternary studies in Hungary. Budapest, INQUA Hung. Nat. Comm. 145-169.

PÉCSI, M. – PEVZNER, M.A. 1974: Paleomagnetic measurements in the loess sequences at Paks and Dunaföldvár, Hungary. – Földr. Közlem. 22. 3. 215-226.

PÉCSI, M. – Mrs. PÉCSI, DONÁTH, É. – SZEBENYI, E. – HAHN, Gy. – SCHWEITZER, F. – PEVZNER, M.A. 1977: Paleogeographical reconstruction of fossil soils in Hungarian loess. – Földr. Közlem. 25. 1-3. 94-137.

PÉCSI, M. – SZEBÉNYI, E. – SCHWEITZER, F. – PÉCSI-DONÁTH, É. – WAGNER, M. – PEVZNER, M.A. 1979: Complex evaluation of Dunaföldvár loesses and fossil soils. (Bio- and lithostratigraphical, paleopedological, thermal and paleomagnetic investigation.) – Acta Geol. Acad. Sci. Hung. 22. 1-4. 513-537. – Studies on Loess. Budapest, Akad. K. 1980.

PEVZNER, M.A. – PÉCSI, M. 1980: Paleomagnetizm i stratigrafiya lessogo-pochvennykh otlozheniy Vengrii. – Byull. Komiss. po izuch. chet ertichnogo perioda. 50. 24-34.

SHERMATOV, M.Sh. – TOICHIEV, Kh. 1982: Route from Tashkent to the lower reaches of the Chirchik and Keles rivers. – In: Guidebook for excursion A-11 and C 11. XI. INQUA Congress, Moscow, 1982. 19-26.

VEKLICH, M.F. 1979: Pleistocene loesses and fossil soils of the Ukraine. – Acta Geol. Acad. Sci. Hung. 22. 1-4. 35-62. – Studies on Loess. Budapest, Akad. K. 1980.

WANG YONG-YAN (ed.) 1982: Loess and Quaternary geology 1976-1980. Loess Research Section, Department of Geology, Northwest University. Xian, China. 137. + Plates. (In Chinese, abstracts in English.)

WANG YONG-YAN – YUE LE-PING, 1982: Paleomagnetic stratigraphy of loess in China. – In: LIU TUNG-SHENG (ed.), Quaternary geology and environment in China. Beijing, China Ocean Press. 42.

ZHANG ZHONGHU, 1982: Lithological and stratigraphical analysis on loess profiles of the Loess Plateau in China. – Paper of Chinese Geologists submitted to XI. INQUA Congress. 1-11.

Address of author:
Prof. Dr. M. Pécsi, Geographical Research Institute, Hungarian Academy of Sciences
Népköztársaság úta 62. 1062 BUDAPEST – Hungary

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PLEISTOCENE STAGES IN THE MIDDLE DNIEPER BASIN BY EVIDENCE OF SPORE–POLLEN ANALYSIS OF LOESSES

S.I. Turlo

ABSTRACT

In the Ukraine the systematic spore-pollen investigation of loess sediments began in the sixties. During the last decade a lot of data concerning the composition and characteristics of the flatlands of the Ukraine including the Middle Dnieper region were collected. Using the spore-pollen method seven main sequences in the Middle Dnieper region were analyzed near the towns of Priluky and Chigirin and near the villages Vyazovok Rozhky, Zavadovka and Starye Kajdaki.

The data received provided the possibility to follow the development of the vegetation cover in this region throughout the Pleistocene. In the Ukraine seven warm stages were distinguished in the development of vegetation: the Martonosha, Lubny, Zavadovka, Kajdaki, Priluki, Vitachev, Dofinovka stages, and eight cold stages were determined: the Tiligul, Sula, Dnieper, Tyasmin, Uday, Bug, Prichernomorye stages.

The complete series of Lower Pleistocene sediments of the sequences in question consists of the Priazov, Martonosha, Sula, Lubny, Tiligul and Zavadovka horizons.

The spore-pollen spectra of the Priazov horizon refer to the prevalence of the grassy cover. Arboreous species occupied little areas with predominant boreal elements (pine, birch) and with rarely occurred moderate thermophilous species (oak, elm, hazel).

The more warm and humid climatic periods resulted in the alteration of the vegetation. During the Martonosha stage forest and steppe-forest type vegetation prevailed. Coniferous forests dominated with pines of Diploxylon subspecies and subordinately with pines of Haploxylon subspecies and with patches of firs and silver firs. There were many broad-leaved species: oak, hornbeam, beech, elm, lime, ash-tree, maple etc., and Tertiary relict flora elements: Pterocarya, Carya, Juglans, Rhus. Lowlands were occupied by grasses, while uplands by wormwoods, composite family etc.

As a result of the changing climate the characteristics of vegetation considerably alternated in the Sula stage. Forests disappeared, grasses became predominant. Arboreal pollen refers to the existence of the arboreal species in the valleys.

The spore-pollen spectra of the Lubny horizon show the predominance of the forest-steppe type of vegetation. The spore-pollen spectra are of forest type only in the Stajki and Vyazovok profiles. Pine and broad-leaved-pine forests were wide-spread with

the pines of Diploxylon subspecies and with the patches of the pines of Haploxylon subspecies and fir-tree. Broad-leaved species were represented by oak. hornbeam, beech, elm, maple, lime, ashtrees with patches of relict Tertiary flora: Carya, Morus, Rhus.

The Tiligul stage was represented by steppe vegetation with grasses and patches of trees and shrubbery (Pinus, Betula, Almus).

In the Middle Dnieper region the Zavadovka stage was represented by several zones: forest-steppe zone in the south, forest zone in the north (Vyazovok, Stajki). Forests consisted of pine and broad-leaved species. Broad-leaved forests occupied the most humid places. Hygrophyte trees (silver fir, fir, beech (Fagus silvatica L.) grew in valleys and balka's. Various herbs were of mesophyte character. Later the quantity of the thermophilous and hygrophyte species was reduced. The climate of the Zavadovka stage was warmer and more humid as compared with the modern climate, but more xerophyte as compared with the climate of the Martonosha and Lubny stages.

Thus, ecological conditions of the Lower Pleistocene warm phases favoured the development of forests. The vegetation of the time preserved the main features of the Pliocene.

During the Middle Pleistocene some sudden changes followed in the climate that influenced vegetation. The Dnieper glaciation was of particular influence on the development of the vegetation. Middle Pleistocene sediments consist of the Dnieper, Kajdaki, Tyasmin and Priluki horizons.

In the spore-pollen spectra of the Dnieper horizon the grass pollen is absolutely predominating. Pine (Pinus silvestris) and the shrubby forms of birch (Betula humilis, B. nana) occupy smaller areas.

Forests predominated in the Kajdaki stage. Pine was the main tree but fir and broad-leaved species also occurred (oak, maple, elm, lime etc.). Herbs were mesophyte. The forest zone was reduced to the south. In the Middle Dnieper territory there were two zones: forest and steppe-forest zones. Spore-pollen spectra of the Tyasmin horizon show the disappearence of the thermophilous species and the development of herbs indicating unfavourable climatic conditions.

The spore-pollen spectra of the Priluki horizon are the most complete. Forests of this period consisted of coniferous and broad-leaved species. The forest-tree places were covered by meadow steppe vegetation.

In the Middle Dnieper region the Upper Pleistocene sediments consist of the Uday, Vitachev, Bug, Dofinovka and Prichernomorsky horizons.

The Uday horizon was formed under cold and dry climatic conditions when steppe vegetation prevailed. Forests were uncommon and consisted of pine and birch.

In the Vitachev stage the forest-steppe landscape predominated. Forests consisted of pine, birch, fir and broad-leaved species. The climate was dry and rather warm.

In the Pleistocene the Bug stage was the coldest period. Forests almost disappeared and steppe prevailed.

In the Dofinovka stage arboreous species (oak, pine, lime) developed in the north and herbs dominated in the south, the climate was dry and cold.

The Prychernomorye stage is the period of steppe development. Trees occupied balka's, ravines and flood-plains only.

Consequently, in the Pleistocene warm periods (fossil soil forming period) the vegetation cover of the Middle Dnieper basin consisted mostly of forests. Remains of the thermophilous arboreous species characteristic of the recent Central and East European forest formation (oak, elm, hornbeam, maple etc.) were present in every soil horizon. Forest-forming species of the Lower Pleistocene warm stages have some elements of the Balkan-Caucasian flora – beech, nut-tree, wing-nut. All this confirms that the formation of soil horizons took place under warm temperate-continental conditions.

In cold periods herbs prevailed. In loess horizons the arboreous species were represented by pine, birch, alder and were of subordinate extension. Elements of thermophilous forest flora were absent. The isolated pollen of the broad-leaved species was found only in the Lower Pleistocene loesses.

REFERENCES

ARAP, R.Ya. 1972: Palinologichni doslidzhennya poverkhnevich shariv gruntu lisostepovoi chastini Ukrains'koi RSR. – Ukr. bot. zhur. 29. 4. 506-512.

ARAP, R.Ya. 1976: Sporovo-pyltsevye issledovaniya poverkhnostnykh prob pochvy rastitel'nykh zon ravninnoi chasti Ukrainy. Avtoreferat diss. Kiev. 25.

BOLIKHOVSKAYA, N.S. 1976: Palinologiya lessov i pogrebennykh pocsv Russkoi ravniny. – In: Problemy obshchei fizicheskoi geografii i paleogeografii. Moskow, MGU. 257-277.

DINESMAN, L.G. – METEL'TSEVA, E.P. 1967: Normy mlekopitayushchykh, kak obekt paleobotanicheskogo issledovaniya. – Bull. Moskov. obshch. isp. prirody, odt. biol. 70.1.

ERDTMAN, G. 1943: An introduction to pollen analysis. Waltham, Mass.

GRICHUK, V.P. 1972a: Rezul'taty paleobotanicheskogo izucheniya lessov Ukrainy i yuga Srednerusskoi vozvyshennosti. – In: Lessy, pogrebbennye pochvy i kriogennye yavleniya na Russkoi ravnine. Moscow, Nauka. 26-48.

GRICHUK, V.P. 1972b: Osnovnye etapy istoriya rastitel'nosti yugo-zapada Russkoi ravninvy v pozdnem pleistotsene. – In: Palinologiya pleistotsena. Moscow. 9-53.

GUBONINA, Z.P. 1975: Palinologicheskie issledovaniya osnovnykh gorizontov lessov i iskolaemykh pochv yuzhnoi chasti Russkoi ravniny. – Problemy paleogeografii lessovykh i periglayatsial'nykh oblastei. Moscow. 43-58.

ISAEVA-PETROVA, L.S. 1976a: Predvarite'nye rezul'taty palinologicheskogo issledovaniya pochv Tsentral'no-Chernozemnogo zapovednika. – In: Biota osnovnykh geosistem Tsentralnoi lesostepi. Moscow, Izd. IG AN SSSR. 62-73.

ISAEVA-PETROVA, L.S. 1976b: Rastitel'nost strel'tsovskoi stepi v golotsene. – Izvest. AN SSSR, Ser. geograf. 1976. 2. 75-82.

MEL'NICHUK, I.V. – PARISHKURA, S.I. 1972: O paleogeograficheskikh usloviyakh formirovaniya antropogenovykh otlozheniy rayona sz. Starye Kaidaki. – In: Voprosy geologii osadochnykh otlozheniy Ukrainy. Kiev. Nauk. dumka. 77-87.

PARISHKURA, S.I. 1967: Sporovo-pilkova kharakteristika antropogenovikh vidkladiv opornogo rozrizu v m. Priluki. – Ukr. bot. zhurn. 24. 6. 62-69.

PARISHKURA, S.I. 1968a: Izmenenie rastitel'nosti srednego Pridneprov'ya v antropogene (po palinologicheskim dannym). Avtoreferat diss. Kiev. 28.

PARISHKURA, S.I. 1968b: Palinologicheskaya kharakteristika antropogenovykh otlozheniy rayona g. Chigirin. – Geol. zhurn. 28. 6. 75-79.

PARISHKURA – TURLO, S.I. 1979: Izmeneniya rastitel'nosti vremeni lessonakopleniya na Ukraine. – Fizicheskaya geografiya i geomorfologiya. 20. 102-108.

SEREBRYANNAYA, T.A. 1975: Paleofitogeologicheskaya kharakteristika lessov iz razreza u pos. Karachizh v rayone g. Bryanska. – In: Palinologiya pleistotsena. Moscow, Nauka. 55-72.

SEREBRYANNAYA, T.A. 1978: Razvitie rastitel'nosti Srednerusskoj vozvyshennosti v golotsene. Avtoreferat diss. Moscow. 19.

VEKLICH, M.F. – ATRYUSHENKO, A.T. – SIRENKO, N.A. – DUBNYAK, V.A. – MELNICHUK, I.V. – PARISHKURA, S.I. et al. 1967: Opornye geologicheskie razrezy antropogena Ukrainy. 1. Kiev, Nauk. dumka. 107.

Address of author:
S.I. Turlo, Geographical Research Institute of the Ukrainian Academy of Sciences, Ukrainian SSR,
Bul. Shevchenko 60. 252032 KIEV – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PALYNOLOGY OF CENTRAL EUROPEAN LOESS–SOIL SEQUENCES

Brigitte Urban

ABSTRACT

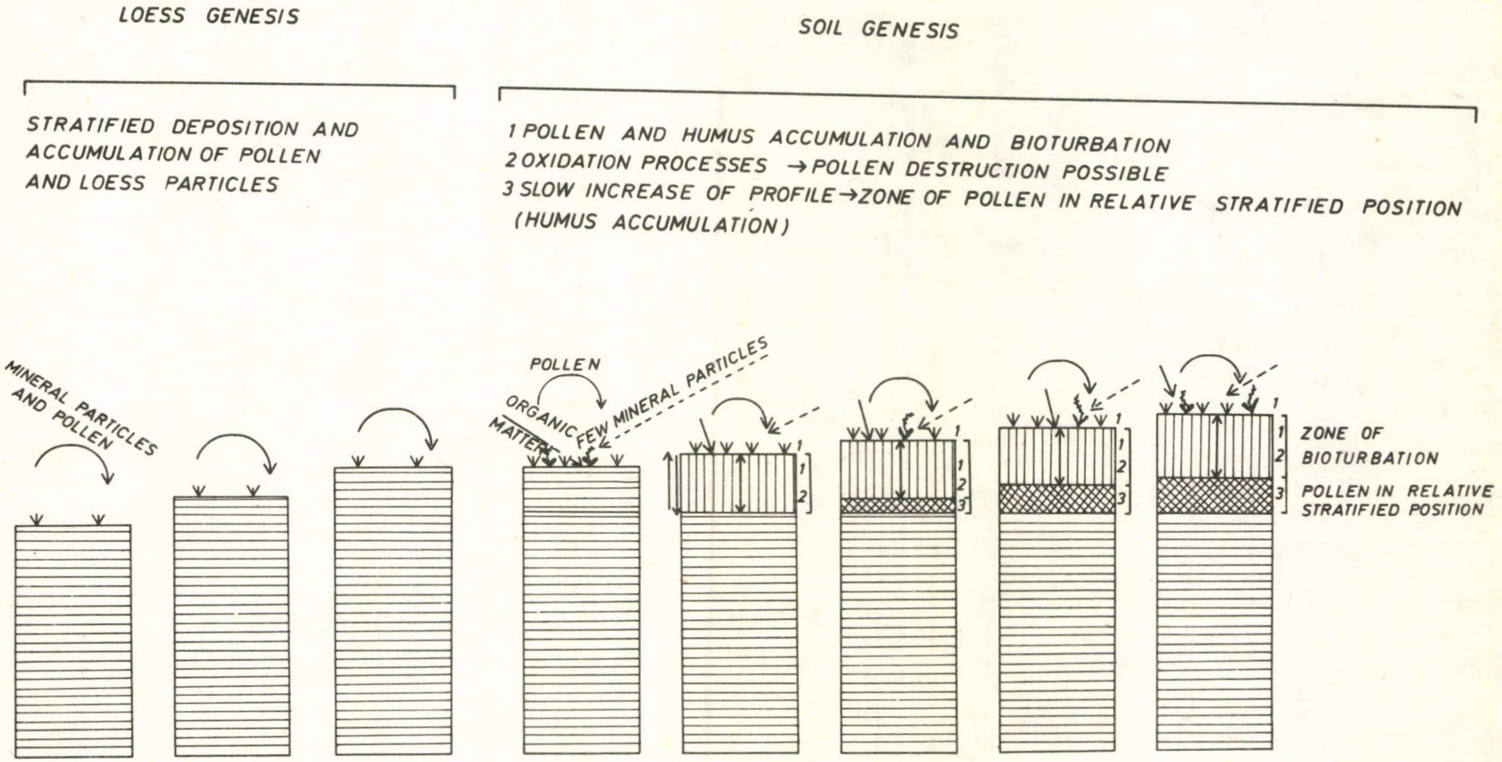
Results of palaeofloral studies of late Pleistocene loess-soil sequences at four central European localities are presented (Stillfried/Lower Austria, Dolní Veštonice/ Southern Moravia, Paks and Mende/Hungary). The palaeoenvironments during loess or soil genesis are reconstructed on the base of the pollen data.

INTRODUCTION

The results presented here are part of palaeoecological studies on the genesis of loess-soil profiles in Europe (URBAN, B. 1983), centered around the ecological conditions under which fossil and recent steppe-soils are developed.

Palynology of mineral soils has long been problematical because pollen concentration is often rather low. Sinze FRENZEL, B. (1964) developed a method of pollen concentration with heavy liquids, loess-palynology has progressed. However, several models may be constructed concerning the question of how pollen may enter a mineral soil (HAVINGA, A.J. 1962, 1963, 1974, MUNAUT, A.V. 1967, BASTIN, B. 1971). One such model (URBAN, B. 1983) (TABLE 1) assumes that during loess genesis, accumulation of mineral particles and pollen takes place in a stratified way. If the loess has been deposited under relatively dry conditions, pollen destruction would have been low. During a following period of climatic improvement in a region of continental climatic conditions, soil development would start with the creation of an A – horizon, e.g. a chernozem. In that case, as a consequence of a denser vegetation cover, more organic and less mineral material would accumulate. Bioturbation (soil mixing processes by soil organisms) would start (Zone 1, TABLE 1) and proceed downward in the profile. By adding more and more only partly demineralized organic matter and mixing it with the mineral components, the A – horizon develops during a certain time period. The lowermost part of the A – horizon, therefore, must reveal a zone (Zone 3, TABLE 1) with pollen in a relatively stratified position, as bioturbation takes place mainly in the upper parts of the A – horizon. The uppermost part of the A – horizon (A_p – horizon of recent soils) reveals a mixture of pollen of plants existing during the latest periods of soil

TABLE 1. Scheme of pollen deposition in loess and mineral soils with AC profile (e.g. chernozem)



genesis. In any case, the older sporomorphs will concentrate in the lowermost part of the profile and the younger ones in its upper part.

1. RESULTS OF PALYNOLOGICAL INVESTIGATIONS

1/1 Stillfried/Lower Austria

Stillfried is situated northeast of Vienna (FIG. 1) at the river March (Morava). The pre-Pleistocene deposits in the area consist of fluviolimnic sediments of the upper Pannonian. They are covered by a thick loess blanket, which contains a number of fossil soils. These sequences have been studied repeatedly by a number of authors, particularly FINK, J. (1956, 1962, 1969).

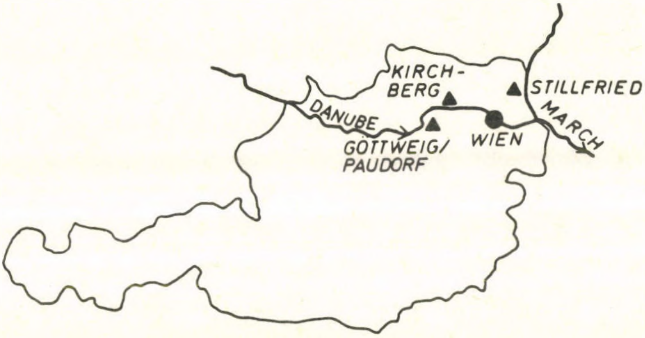


FIG. 1. Map, showing Austrian locations

The upper Pannonian sands are overlain dicordantly by Rissian loess. It carries on top the Stillfried A soil-complex, correlated with the last interglacial and the early Würmian Amersfoort and Brorup interstadials (FRENZEL, B. 1964). A light brownish-greyish horizon, termed the Stillfried B soil (FIG. 2) subdivides the Würmian loess overlying the Stillfried A soil complex. The Stillfried B soil is marked by a charcoal horizon (FIG. 2) and snails of the Columella fauna (BINDER, H. 1978). The Stillfried series ends with the Holocene soil, which is a typical chernozem (FIG. 2). FRENZEL, B. (1964) has published the pollen spectrum of one sample of the Stillfried B soil already.

The new data show, that the fossil B horizon is characterized by high amounts of Pinus silvestris (FIGS. 3 and 4) and many spores of Botrychium lunaria. The assemblage does not change in the charcoal horizon, but it changes in the overlying loess layer (FIG. 4). Pine is still the predominant tree, but higher amounts of Picea are present. As a new floral element, Selaginella selaginoides occurs, while thermophilous plants are nearly lacking.

The upper part of the youngest Würmian loess in profile STI p (FIG. 2), is characterized by high amounts of Gramineae (FIG. 4). The Gramineae-rich steppe changes into an Artemisia-Chenopodiaceae-rich Gramineae steppe at the beginning of the soil

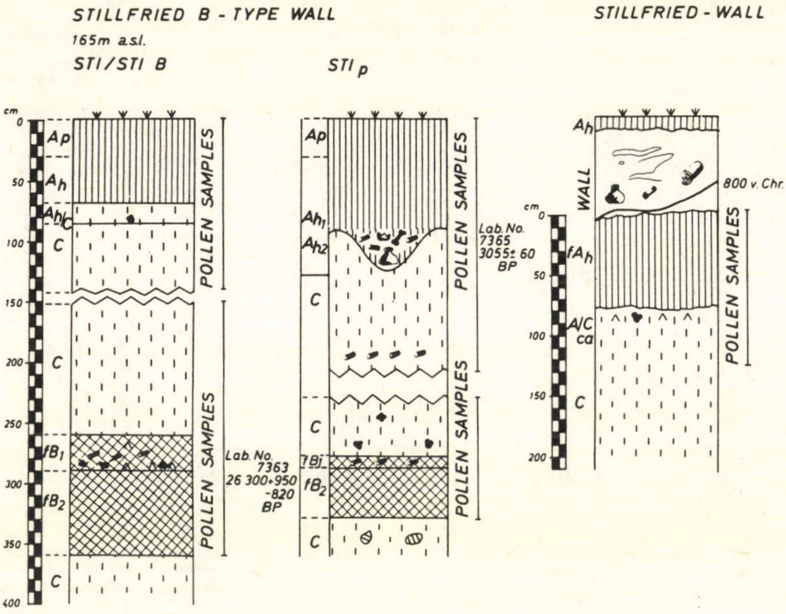


FIG. 2. Lithology of the investigated profiles at Stillfried

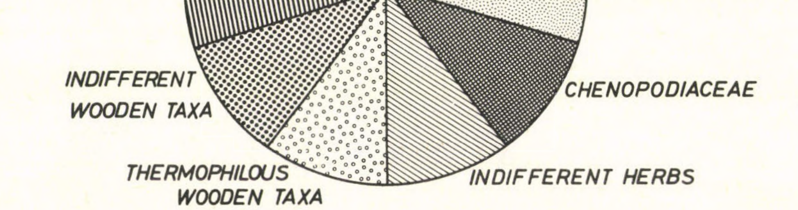


FIG. 3. Illustration of plant-sector diagrams

Steppe-elements: Compositae liguliflorae, Compositae tubuliflorae, Helianthemum, Ephedra fragilis-, distachia-Type, Polygonaceae a.s.o.

Thermophilous wooden taxa: Quercus, Ulmus, Fraxinus, Acer, Corylus, Carpinus Fagus, Juglans, Abies

Indifferent wooden taxa: Pinus, Picea, Betula, Salix, Alnus

Dwarf shrubs and tundra – elements: Juniperus, Selaginella selaginoides development of the recent chernozem (FIG. 4). The plough layer (A_p – horizon) is characterized by an increasing amount of Pinus, less Artemisia and Gramineae and a little more other steppe elements.

STi 20–30cm Ap

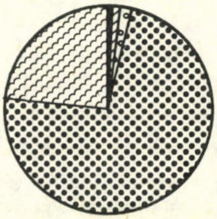
STi p 20–30 cm Ap

STi 70–80cm Ah/C

STi p 100–110cm Ah_2

STi B 20–30cm Loess (over the STi B soil formation)

STi p 185–190 cm Loess C



STi B 120–130 cm STILLFRIED – B soil formation

FIG. 4. Sector-diagrams of the Stillfried section

The sequence of Stillfried studied at the type site reveals the following trend of vegetational development (FIG. 5): the Stillfried B soil seems to have a completely different pollen spectrum, that is known from other so-called steppe soils. It contains moist-loving plants, such as Botrychium lunaria, in great number. The overlying loess contains pollen which resembles a kind of vegetation comparable to a taiga/tundra, with pine and a little spruce and high amounts of Selaginella selaginoides. The youngest Würmian loess, on the other hand, is characteristic of a relatively dry Gramineae-herb steppe. There is no evidence for a forestation of the locality studied during early or middle Holocene time. HAVINGA, A.J. (1972), however, investigated a small peat bog (Moosbrunn) surrounded by chernozems in the vicinity of Stillfried and concluded that from Boreal to Subboreal times an open forest preceeded the 'antropogenous' steppe vegetation. Obviously, organic layers mainly reveal the more local flora surrounding the bog, whereas the chernozem soil reveals such floral elements, most of it having grown in that loess-soil environment (URBAN, B. – ZAKOSEK, H. 1981).

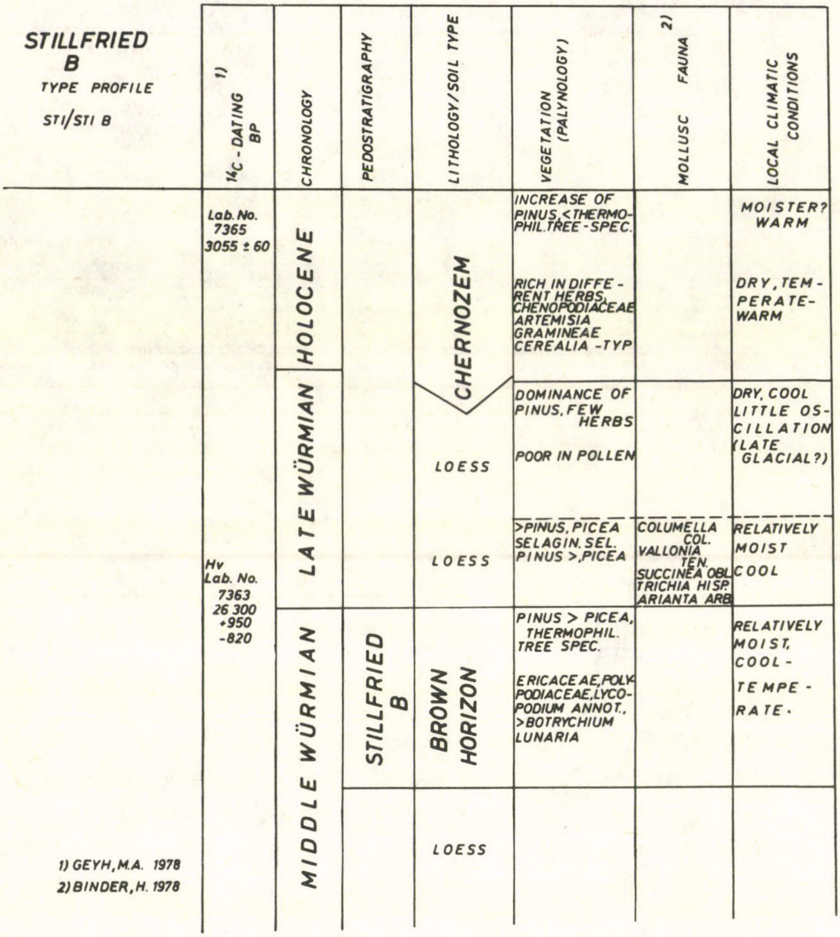


FIG. 5. Summary of palaeoecological data and interpretation of the Stillfried section

1/2 Dolní Veštonice

Dolní Veštonice is situated in southern Moravia in Czechoslovakia (FIG. 6). The locality is well known for its upper Palaeolithic industry (BRANDTNER, F. 1956, KLIMA, B. et al. 1962) which occurs in the upper part of the loess soil series.

FIG. 6. Map, showing Czechoslovakian locations

In that area, the Paleogene rocks are covered by thick loess sequences. At the base of the Dolní Veštonice section, loess of Rissian age occurs, which is overlain by a soil lessivé and three chernozěms of early Würmian age (KLIMA, B. et al. 1962, BRONGER, A. 1967, KLIMA, B. 1979) (FIG. 7).

The Rissian loess, the fossil B_t – horizon, and part of the loess interlayer on top of the soil lessivé have low pollen content. The uppermost part of the loess interlayer contains a type of vegetation rich of Gramineae. The first fossil A – horizon (profiles DV_1 and DV_2; FIG. 7) is rich in Artemisia, Gramineae and other steppe plants. On the other hand, Pinus silvestris and Pinus cembra together make up about 50% of the pollensum. The loess layer on top of the first fossil A – horizon is characterized by high amounts of taxa characteristic of an open treeless type of vegetation with steppe plants prevailing (FIG. 8). The next younger fossil A – horizon (2. f A_h; FIG. 7 and 8) contains pollen similar to the assemblage of the underlying loess. The loess layer covering this second A – horizon, however, is characterized by a conifer preponderance (FIG. 8). Pinus silvestris and Pinus cembra are the important trees, pointing to a taiga type of vegetation. During the genesis of the third fossil A – horizon (3. f A_h; FIG. 8), Pinus silvestris reaches a maximum, whereas during accumulation of the loess on top of this soil the forest retreated again.

Summarized, in the early Würmian sequence of Dolní Veštonice (FIG. 9), the 1. f A – horizon of the PK III (PK IIIb) soil complex developed under a forest steppe.

During the transition periods of loess accumulation into soil genesis e.g., an increase of Pinus cembra has been observed several times. The 2. f A – horizon is characterized by a vegetation dominated by steppe plants. The third f A – horizon is intercalated between two loess layers, the floral composition of which do not differ strongly from one another. Pine is the predominant tree, pointing to an open forest steppe. On the basis of palynological evidence, the first cooling after the last interglacial seems to have been stronger than the cold spells between the early Würmian interstadials in the investigated area.

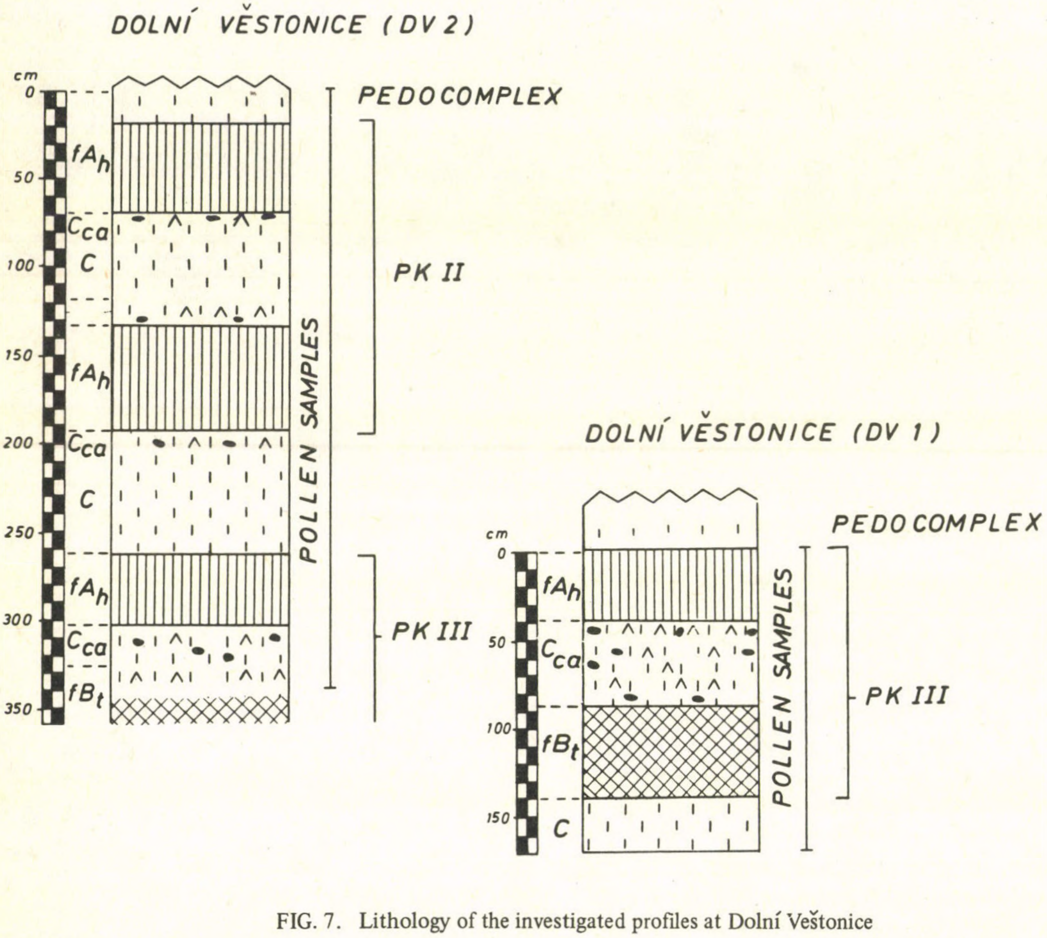


FIG. 7. Lithology of the investigated profiles at Dolní Věstonice

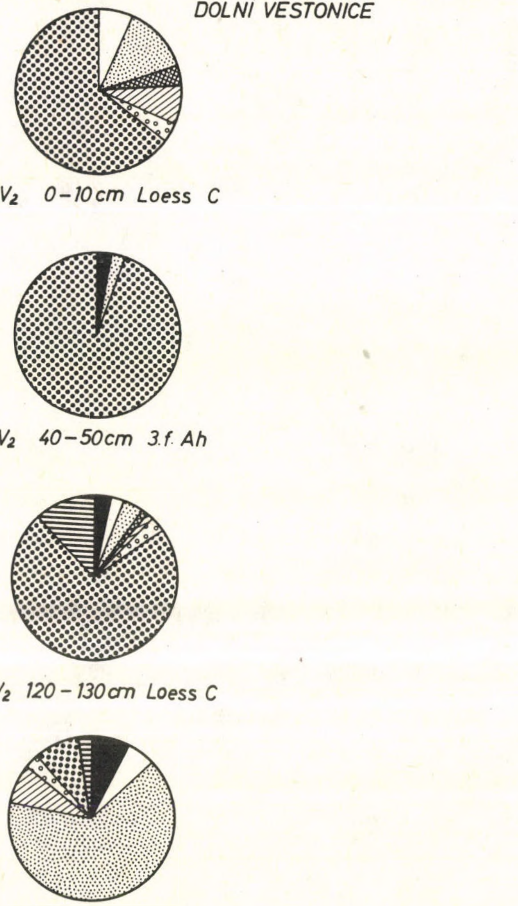


FIG. 8. Sector-diagrams of the Dolní Veštonice section

DOLNÍ VĚSTONICE

CHRONOLOGY	PEDOSTRATIGRAPHY 1)		LITHOLOGY/SOIL TYPE	VEGETATION (PALYNOLOGY)	MOLLUSC FAUNA 2)	LOCAL CLIMATIC CONDITIONS
EARLY WÜRMIAN			LOESS	PINUS (SYLV.) GRAMINEAE	PUPILLA SP.	DRY, COOL
	PK II	$PKII_b$	CHERNOZEM	PINUS (SYLV.) BETULA, CEREALIA-TYP	HELICOPSIS STRIATA, CHONDRULA TRIDENS	LESS DRY
			LOESS INTERLAYER	PINUS (CEMBRA) ARTEMISIA ASTERACEAE		DRY, COOL
		$PKII_a$	CHERNOZEM	ARTEMISIA ASTERACEAE PINUS (P. CEMBRA)		DRY, TEMPERATE
			LOESS INTERLAYER	PINUS (P. CEMBRA) CENTAUREA JACEA ASTERACEAE	REWORKED WARM-LOVING FAUNA	DRY, COOL
	PK III	$PKIII_b$	CHERNOZEM (DEGRAD.)	THERMOPHIL. TREE SPECIES, PINUS, HELIOPH. HERBS, BOTRYCH.		WARM-TEMPERATE, RELATIVELY MOIST
			LOESS INTERLAYER	POLLEN DESTRUCTION > THERMOPH. TREE SPECIES		
R.-W. INT.		$PKIII_a$	SOIL LESSIVÉ	POOR IN POLLEN		
LATE RISSIAN			LOESS	POOR IN POLLEN	COLUM. COL. PUPILLA LOES. VALLONIA TENUIL.	

1) KLIMA et al. (1962)
2) LOŽEK in KLIMA et al. (1962)

FIG. 9. Summary of palaeoecological data and interpretation of the Dolní Věstonice section

1/3 Mende and Paks/Hungary

1/3/a Mende

As shown repeatedly by PÉCSI, M. (1978, 1982) and coworkers, the profile of Mende, situated southeast of Budapest in the Gödöllő-Monor hills (FIG. 10), is the most significant profile in Hungary for subdivision of Würmian loess.

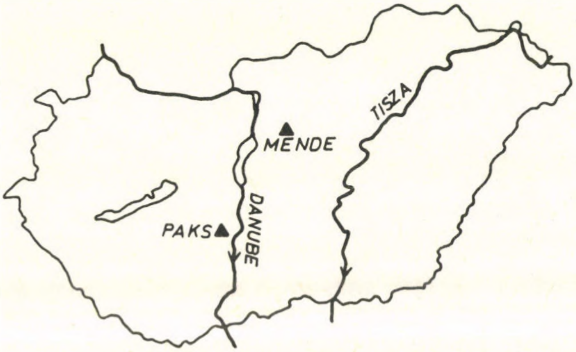


FIG. 10. Map, showing Hungarian locations

The profile of Mende contains six fossil soils (FIG. 11). The lowermost soil, Mende Base (MB), is a brown forest soil overlain by a chernozem, poor in pollen. The pollen spectrum of only one sample has been analysed (FIG. 12). As shown in FIG. 12., the sample is dominated by tree pollen, especially pine (about 90%). The MB soil is believed to correspont to the last interglacial.

The overlying loess layer l_5 (FIG. 12) is characterized by high amounts of Artemisia (up to 64%), whereas tree pollen plays a minor role. Vegetation changed rapidly during climatic deterioration after the last interglacial and the pollen flora of the oldest Würmian loess layer (l_5) points to a dry cold steppe climate. Among the rare tree species, Pinus cembra and Larix might have existed (ZOLYOMI B. 1953). Pollen spectra of soil BA (Basaharc Lower), a dark forest-steppe soil (PÉCSI, M. 1982), are still dominated by Artemisia. Pollen of Gramineae, different herbs and few tree pollen occur. The loess layer on top of soil BA, l_4, contains few pollen. On top, two chernozem-like dark soils belonging to the Basaharc Double fossil soil complex occur (BD_2 and BD_1, FIG. 11). BD_2 is dominated by pine and Betula pollen, whereas higher amouts of Tilia may indicate pollen destruction process. Gramineae play a minor role. Vegetation seems to indicate an open forest perhaps a type of a forest-steppe. A small loess interlayer (FIG. 11) is intercalated between the soils BD_1 and BD_2. It differs strongly in its pollen flora from that of the preceeding and following soil. It is characterized by high amounts of Artemisia and herbs, pointing to an open dry and cold type of steppe vegetation. During the genesis of soil BD_1 Gramineae played an important role, as well as different heliophilous herbs (Rumex, Caryophyllaceae, Rosaceae, Cruciferae a.s.o.). Pine pollen is very abundant. The loess layer on top of soil BD_1 is very rich in Gentianaceae pollen (15%), as well as in pollen of other herbs. Gramineae and Cerealia-type-Gramineae are important too. Vegetation has been rather open, with probable patches of wooden plants.

The youngest fossil soil complex (Mende Upper), consists of two chernozem-like soils, MF_1 and MF_2. The MF_2 soil, which is taken as an equivalent of the Stillfried B soil, is characterized by a dominance of tree pollen. Among these, pine, birch, alder and temperate elements play a role. Relatively high amounts of Gramineae and different herbs occur. The same holds true for the youngest soil MF_1, which is also characterized

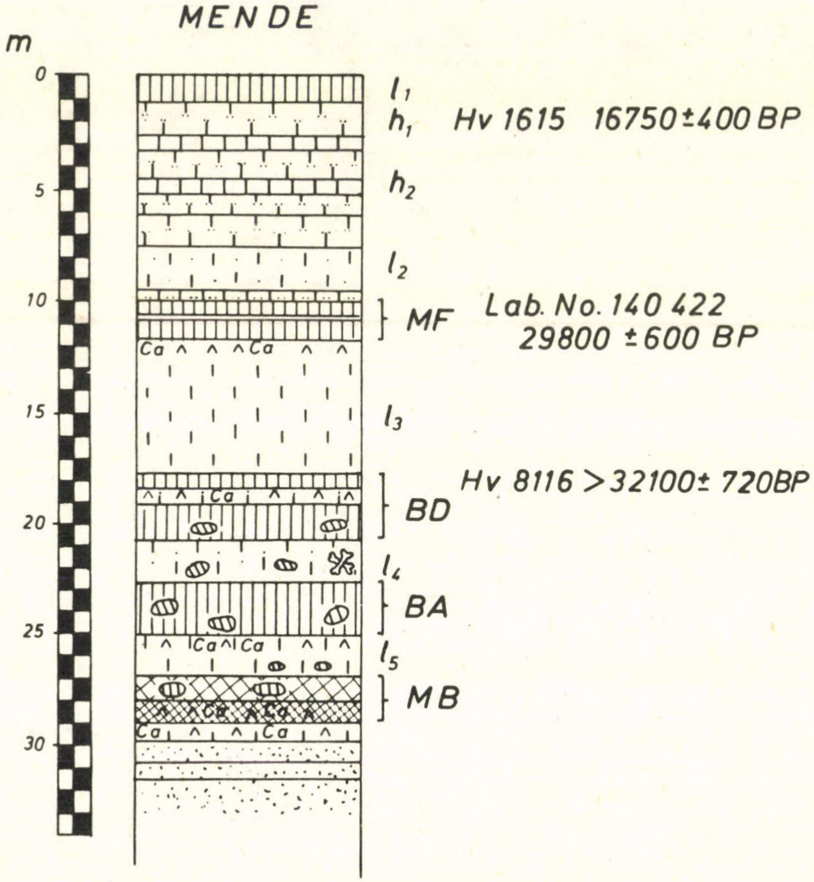


FIG. 11. Lithology of the Mende section

by tree pollen dominance in its lowermost part. The floral assemblage changes from bottom to top into a vegetation dominated by Artemisia (FIG. 12). The youngest Würmian loess unfortunately is sterile at that locality.

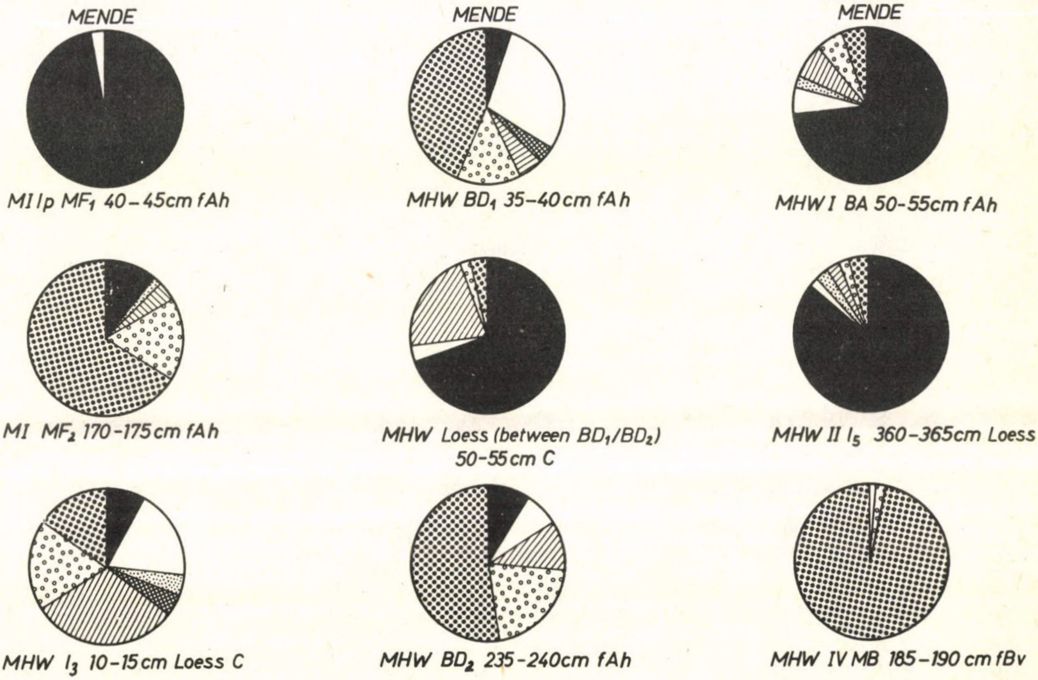
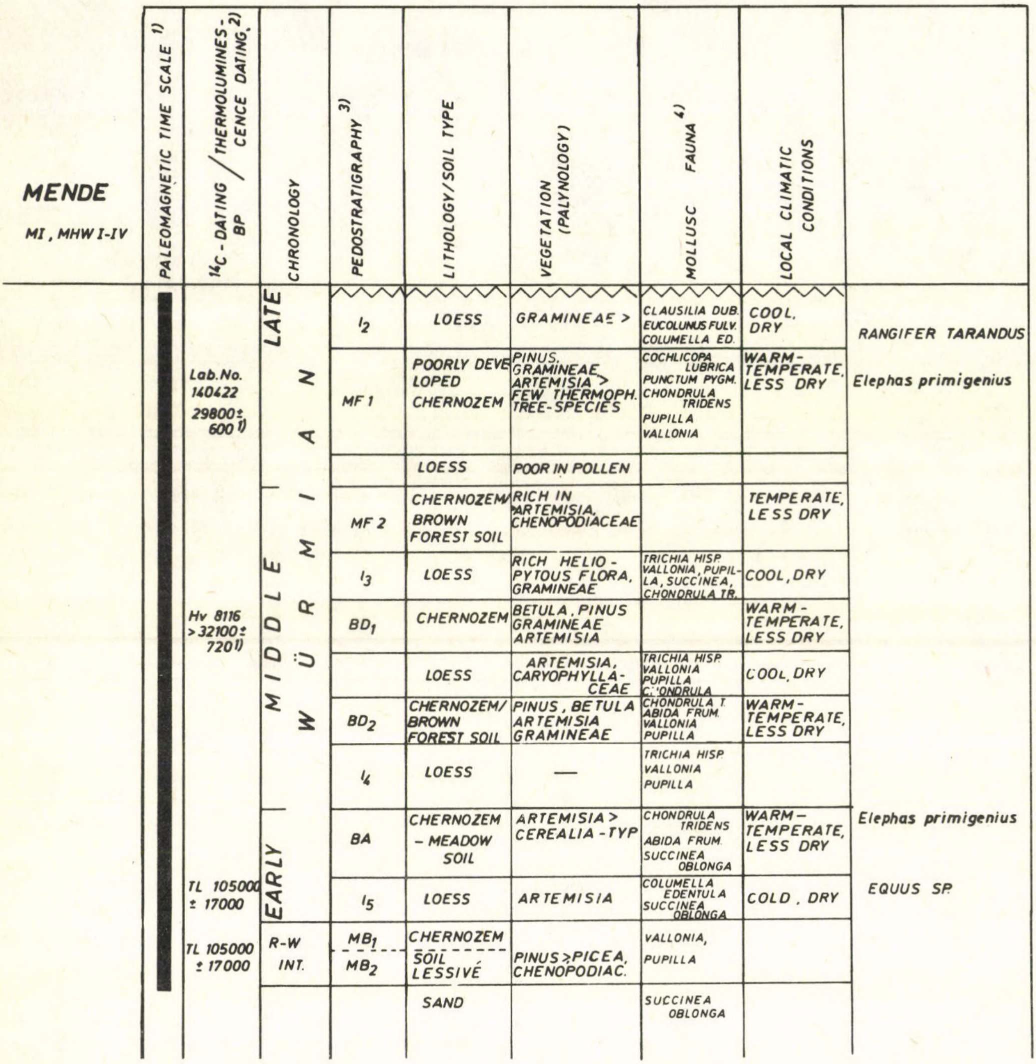


FIG. 12. Sector-diagrams of the Mende section

The described floristic results and their paleoclimatic interpretation are summarized in FIG. 13.



MENDE

MI, MHW I-IV

PALEOMAGNETIC TIME SCALE 1)	^{14}C - DATING / THERMOLUMINESCENCE DATING 2) BP	CHRONOLOGY	PEDOSTRATIGRAPHY 3)	LITHOLOGY/SOIL TYPE	VEGETATION (PALYNOLOGY)	MOLLUSC FAUNA 4)	LOCAL CLIMATIC CONDITIONS	
		LATE WÜRMIAN	l_2	LOESS	GRAMINEAE >	CLAUSILIA DUB. EUCOLUNUS FULV. COLUMELLA ED.	COOL, DRY	RANGIFER TARANDUS
	Lab.No. 140422 29800± 600 1)		MF 1	POORLY DEVELOPED CHERNOZEM	PINUS, GRAMINEAE, ARTEMISIA > FEW THERMOPH. TREE-SPECIES	COCHLICOPA LUBRICA PUNCTUM PYGM. CHONDRULA TRIDENS PUPILLA VALLONIA	WARM-TEMPERATE, LESS DRY	Elephas primigenius
				LOESS	POOR IN POLLEN			
		MIDDLE WÜRMIAN	MF 2	CHERNOZEM/ BROWN FOREST SOIL	RICH IN ARTEMISIA, CHENOPODIACEAE		TEMPERATE, LESS DRY	
			l_3	LOESS	RICH HELIOPYTOUS FLORA, GRAMINEAE	TRICHIA HISP. VALLONIA, PUPILLA, SUCCINEA, CHONDRULA TR.	COOL, DRY	
	Hv 8116 >32100± 720 1)		BD_1	CHERNOZEM	BETULA, PINUS GRAMINEAE ARTEMISIA		WARM-TEMPERATE, LESS DRY	
				LOESS	ARTEMISIA, CARYOPHYLLACEAE	TRICHIA HISP. VALLONIA PUPILLA CHONDRULA	COOL, DRY	
			BD_2	CHERNOZEM/ BROWN FOREST SOIL	PINUS, BETULA ARTEMISIA GRAMINEAE	CHONDRULA T. ABIDA FRUM. VALLONIA PUPILLA	WARM-TEMPERATE, LESS DRY	
			l_4	LOESS	—	TRICHIA HISP. VALLONIA PUPILLA		
		EARLY WÜRMIAN	BA	CHERNOZEM - MEADOW SOIL	ARTEMISIA > CEREALIA-TYP	CHONDRULA TRIDENS ABIDA FRUM. SUCCINEA OBLONGA	WARM-TEMPERATE, LESS DRY	Elephas primigenius
	TL 105000 ± 17000		l_5	LOESS	ARTEMISIA	COLUMELLA EDENTULA SUCCINEA OBLONGA	COLD, DRY	EQUUS SP.
	TL 105000 ± 17000	R-W INT.	MB_1	CHERNOZEM	PINUS ≥ PICEA, CHENOPODIAC.	VALLONIA, PUPILLA		
			MB_2	SOIL LESSIVÉ				
				SAND		SUCCINEA OBLONGA		

1) MÁRTON, P. 1979

1) PEVZNER, M.A. 1979

2) BORSY, Z. et al. 1979

3) PÉCSI, M. 1966; 1979

4) WÁGNER, M. 1979

FIG. 13. Summary of palaeoecological data and interpretation of the Mende section

1/3/b Paks

Paks is situated in the middle part of the Pannonian Basin on the right bank of the river Danube (FIG. 10). A 60 m thick sequence of loess and soils is exposed in the Paks brickyard (PÉCSI, M. 1979) (FIG. 14). To attempt a comparison with the Würmian

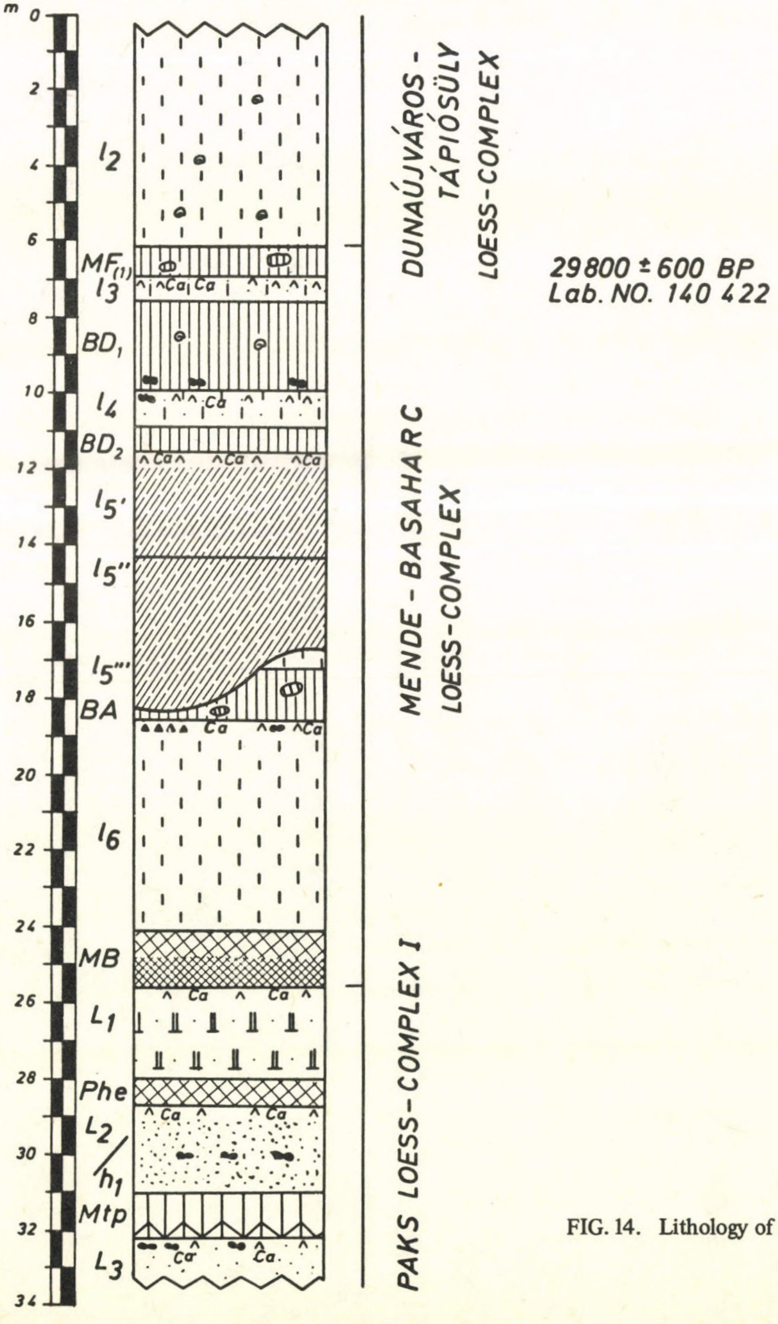


FIG. 14. Lithology of the Paks section

soils and loesses of the Mende profile, the equivalent parts of the Paks profile have been analysed, as well as the underlying older loess-soil complexes. As already shown by PASHKEVICH, G.A. (1979) for 10 samples from that exposure, pollen concentration is rather low and parts of the profile have been sterile.

The youngest (Würmian) part of the sequence has been analysed as pollen concentration has been sufficient in some of the investigated samples (FIG. 15).

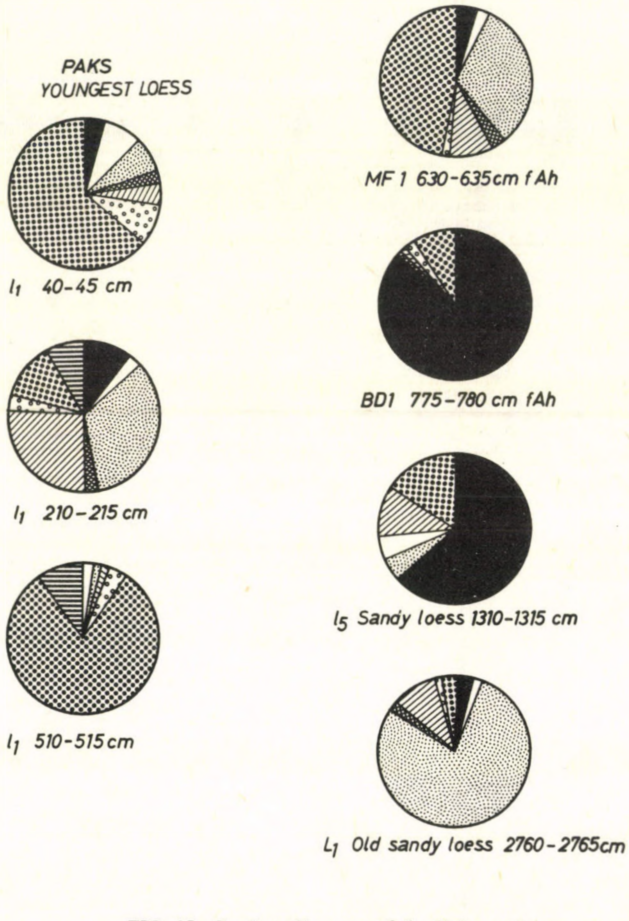
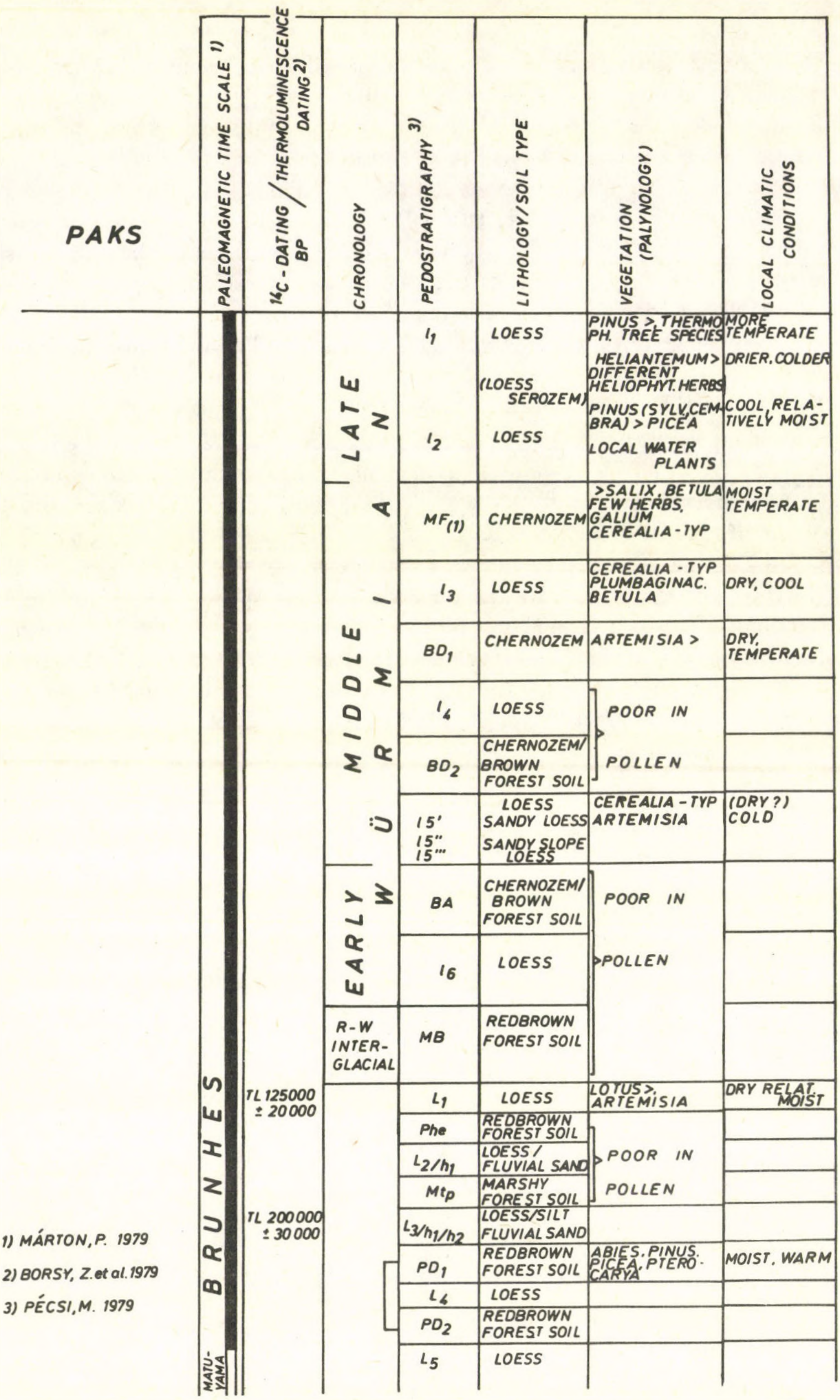


FIG. 15. Section-diagrams of the Paks section

The oldest Würmian loess (1_5) is characterized by high amounts of Artemisia and different herbs, whereas tree pollen plays a minor role. This pollen assemblage is very similar to Mende loess 1_5, pointing as well to an open landscape with steppe vegetation during early Würmian time. Among the investigated soil samples, only two samples have been chosen as an example for the vegetational assemblages. Soil BD_1 is dominated by Artemisia in the exposure of Paks (FIG. 15), pointing to a steppe type of vegetation prevailing during soil genesis. The youngest soil MF_1, on the other hand, has a similar pollen spectrum to its equivalent of the Mende series: beside high amounts of steppe plants, it is characterized by a great amount of treepollen.

The youngest Würmian loess at Paks is rich in pollen and allowed a further subdivision of that relatively homogeneous deposit (FIG. 15 and 16). The lowermost part of the loess layer 1_1 is characterized by high amounts of Pinus silvestris, Betula and of Pinus cembra. Vegetation may be described as a forest steppe. The middle part of the loess 1_1, on the other hand, shows high amounts of heliophiluous herbs and only small amounts of tree pollen. That middle part of the loess deposit may correspond to the maximum of the last glaciation (FIG. 15 and 16). Vegetation of that part of the Pannonian Basin can be described as a dry cold steppe during that time interval. A climatic amelioration can be deduced by the uppermost pollen spectra of the youngest loess. The amounts of herbs decreased and pine and other tree species started to expand. This points to late glacial climatic improvement. The type of vegetation shifted into a forest-steppe again at the end of the Würmian. Similar conditions have been described for the northern part of the Great Hungarian Plain by JÁRAI–KOMLÓDI, M. (1968) for the Allerød interstade.

A summary of all paleofloral data (also of those not discussed in this paper) and their interpretation is given in FIG. 16.



PAKS

PALEOMAGNETIC TIME SCALE [1]	^{14}C - DATING BP / THERMOLUMINESCENCE DATING [2]	CHRONOLOGY	PEDOSTRATIGRAPHY [3]	LITHOLOGY/SOIL TYPE	VEGETATION (PALYNOLOGY)	LOCAL CLIMATIC CONDITIONS
BRUNHES		LATE WÜRM	l_1	LOESS	PINUS > THERMOPH. TREE SPECIES	MORE TEMPERATE
				(LOESS SEROZEM)	HELIANTEMUM > DIFFERENT HELIOPHYT. HERBS	DRIER, COLDER
			l_2	LOESS	PINUS (SYLV, CEMBRA) > PICEA LOCAL WATER PLANTS	COOL, RELATIVELY MOIST
		MIDDLE WÜRM	$MF_{(1)}$	CHERNOZEM	> SALIX, BETULA FEW HERBS, GALIUM CEREALIA-TYP	MOIST TEMPERATE
			l_3	LOESS	CEREALIA-TYP PLUMBAGINAC. BETULA	DRY, COOL
			BD_1	CHERNOZEM	ARTEMISIA >	DRY, TEMPERATE
			l_4	LOESS	POOR IN POLLEN	
			BD_2	CHERNOZEM/ BROWN FOREST SOIL		
			15' 15'' 15'''	LOESS SANDY LOESS SANDY SLOPE LOESS	CEREALIA-TYP ARTEMISIA	(DRY ?) COLD
		EARLY WÜRM	BA	CHERNOZEM/ BROWN FOREST SOIL	POOR IN POLLEN	
			l_6	LOESS		
		R-W INTERGLACIAL	MB	REDBROWN FOREST SOIL		
	TL 125000 ± 20000		L_1	LOESS	LOTUS >, ARTEMISIA	DRY RELAT. MOIST
			Phe	REDBROWN FOREST SOIL	POOR IN POLLEN	
			L_2/h_1	LOESS / FLUVIAL SAND		
			Mt_p	MARSHY FOREST SOIL		
	TL 200000 ± 30000		$L_3/h_1/h_2$	LOESS/SILT FLUVIAL SAND		
			PD_1	REDBROWN FOREST SOIL	ABIES, PINUS, PICEA, PTEROCARYA	MOIST, WARM
			L_4	LOESS		
			PD_2	REDBROWN FOREST SOIL		
MATUYAMA			L_5	LOESS		

1) MÁRTON, P. 1979

2) BORSY, Z. et al. 1979

3) PÉCSI, M. 1979

FIG. 16. Summary of palaeoecological data and interpretation of the Paks section

CONCLUSION

In spite of methodical problems with soil palynology, establishment of former environmental conditions under which loess has accumulated or soils developed has been possible. Pollen data so far show that certain plant communities are very frequent in connection with loess or soil genesis. In some cases, description of the soil subtype by the palaeofloral data or further subdivision of a sedimentologically homogenous profile has been possible.

ACKNOWLEDGEMENTS

I am very much indebted to many collegues of the different countries where I studied loess sections. Among those I like to thank especially Prof. PÉCSI and coworkers from the Hungarian Academy of Science, Budapest, Dr. MACOUN and Dr. HAVLIČEK from the Geological Survey of Czechoslovakia and Dr. BAUER from the Institute of Geography of the University of Vienna for their help in the field and valuable discussions.

Support from Prof. ZAKOSEK, Director of the Institute of Soil Science of the University of Bonn, concerning completion of my palynological investigations of fossil and recent soils and loesses, is greatly appreciated. Last, but not least, I am very much indebted to my technical assistants R. KAHRER and C. VOSS, who helped in the field, carefully prepared the pollen samples, and helped with the pollen determination. The drawings were done with the help of G. DEDERICHS and C. VOSS.

I thank Prof. EASTERBOOK, Department of Geology, Western Washington University, who kindly reviewed the English.

Grants for palynological investigations as part of a research project on the genesis of steppe soils supported by the 'Deutsche Forschungsgemeinschaft' are greatly appreciated.

REFERENCES

BASTIN, B. 1971: Recherches sur l'evolution du peuplement végétal en Belgique duvant la glaciation de Wurm. – Acta Geogr. Lov., 9, 136.

BINDER, H. 1978: Die pleistozänen Molluskenfaunen von Stillfried an der March, Nö. – Forschungen in Stillfried, 3, 87-90.

BRANDTNER, F. 1956: Lößstratigraphie und paläolithische Kulturabfolge in Niederösterreich und in den angrenzenden Gebieten. – Eiszeitalter und Gegenwart, 7, 127-175.

BRONGER, A. 1976: Zur quartären Klima- und Landscafts entwicklung auf (paläo)-pedologischer und bodengeographischer Grundlage. – Kieler Geogr. Schriften, 45, 268.

FINK, J. 1956: Zur Korrelation der Terrassen und Lösse in Österreich. – Eiszeitalter und Gegenwart, 7, 49-77.

FINK, J. 1962: Studien zur absoluten und relativen Chronologie der fossilen Böden in Österreich. II. Wetzleinshof und Stillfried. – Arch. A, 31, 1-18.

FINK, J. 1969: Le loess en Autriche. – Bull. Assoc. Fr. pour l'Étude du Quaternaire, 17-21.

FRENZEL, B. 1964: Zur Pollenanalyse von Lössen. – Untersuchungen der Lössprofile von Oberfellabrunn und Stillfried (Niederösterreich). – Eiszeitalter und Gegenwart, 15, 5-39.

HAVINGA, A.J. 1962: Een palynologisch onderzoek van in dekzan ontwikkelde bodemprofielen. – Diss. Wageningen, 165.

HAVINGA, A.J. 1963: A palynological investigation of soil profiles developed in cover sand. – Meded. Landbouwhogeschool, 61, 93.

HAVINGA, A.J. 1972: A palynological investigation in the Pannonian climate region of Lower Austria. – Rev. Paleobot. Palynol., 14, 319-352.

HAVINGA, A.J. 1974: Problems in the interpretation of pollen diagramms of minerals of mineral soils. – Geol. en Mijnbouw, 53, 6, 449-453.

JÁRAI-KOMLÓDI, M. 1968: The Late Glacial and Holocene flora of the Hungarian Great Plain. – Ann. Univ. Sci. Budap. 9-10, 199-225.

KLIMA, B. 1979: Dolni Veštonice. – In: Guide to excursion. 6th session of the project 24 „Quaternary glaciations in the Northern Hemisphere", 65-66.

KLIMA, B. – KUKLA, J. – LOŽEK, V. – de VRIES, H. 1962: Stratigraphie des Pleistozäns und Alter des paläolithischen Rastplatzes in der Ziegelei von Dolni Veštonice (Unter Wisternitz). – Antropozoiku, 11, 93-145.

MUNAUT, A.V. 1967: Recherches paleo-écologiques en Basse et Moyenne Belgique. – Acta Geogr. Lov., 6, 191.

PASHKEVICH, G.A. 1979: Some results of the palynological investigation of the Paks loess profile. – Acta Geol. Sci. Hung. 22, 1-4, 461-465.

PÉCSI, M. 1978: Paläogeographische Forschungen und Vergleich der ungarischen und europäischen Lösse. – In: Beiträge zur Quartär- und Landschaftsforschung. Wien, H. Nagl, 413-434.

PÉCSI, M. 1979: Lithostratigraphical subdivision of the loess profiles at Paks. – Acta Geol. Acad. Sci. Hung., 22, 1-4, 409-418.

PÉCSI, M. 1982: The most typical loess profiles in Hungary. – Quaternary studies in Hungary. Budapest, Geogr. Res., Inst. Hung. Acad. Sci. 145-169.

URBAN, B. 1983: Pollenanalytische Untersuchungen holozäner und pleistozäner Schwarzerden, schwarzerdeähnlicher und mit diesen vergesellschafteter Böden Zentral- und Westeuropas. (In preparation.)

URBAN, B. – ZAKOSEK, H. 1981: Der Tschernosem von Stillfried/Niederösterreich, Westwall-Profil. – Sonderveröff. Geol. Inst. Univ. Köln, 41, 269-279.

ZÓLYOMI, B. 1953: Die Entwicklungsgeschichte der Vegetation Ungarns seit dem lezten Interglazial. – Acta Biol. Acad. Sci. Hung. 4, 3-4, 367-429.

Address of author:
B. Urban, Botanisches Institute der Universität Hohenheim Garbenstrasse 7000 STUTTGART 70 – Hohenheim – FRG

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

INTERREGIONAL PALEOPEDOLOGICAL PLEISTOCENE CORRELATION OF THE USSR LOESS REGIONS

M.F. Veklich – N.A. Sirenko

ABSTRACT

The investigations made by authors in the Don, Upper Oka, Middle Volga basins, in the Ural Foreland, in the southern part of the West Siberian plain, in some regions of Soviet Central Asia and Georgia allow to establish an interregional Pleistocene correlation of loess-soil and some other formations of these regions on the one hand, and of the territory of the Ukraine, where Pleistocene as well as Pliocene are well classified, on the other. The paleopedological is the primary method of investigation.

There are 15 Pleistocene paleogeographical stages and stratigraphical horizons corresponding to them in all the mentioned regions and in the Ukraine.

The Pleistocene soils, soil series and loess-soil strata of the same age of each of these regions and the corresponding Ukrainian regions have a number of common characteristics. Common features of soil series of the same age are clearly seen along paleogeographical zones.

Subaerial strata predominating in the loess regions consist mostly of soil formations: loesses, loess-like sediments and fossil soils.

As the band thickness, in the northern part of the loess zone loess sediments prevail in the valleys, while in the southern part fossil soils predominate.

The basic marking layers of the loess strata are represented by fossil soils and their series (pedocomplexes), that were formed during warm paleogeographical stages corresponding to the interglacials or interstadials.

Each soil series has its own structure so it is not very difficult to define the age of its stratigraphic horizon.

Fossil soils and soil series represent the formations considerably depending on the zonal, regional and local physical-geographical conditions of their temporal and spatial development.

So while using fossil soils and their series for the determination of paleogeographical stages and the age of stratigraphic horizons, for local correlation it is necessary to coordinate the fossil soil sequences with the relief characteristics, to investigate a great number of sequences in the region and to describe different fossil soil facies.

The paleogeographical and stratigraphic correlation of fossil soil formations across paleogeographical zones is possible only by means of the investigation of a great number of their sequences.

Such investigation took place on the territory of the Ukraine in the last quarter of the 20th century (VEKLICH, M.F. 1958, 1965, 1966, 1968, 1972, 1974, 1977, 1980, etc., VEKLICH, M.F. – SIRENKO, N.A: et al. 1967, 1969, 1972, 1973, 1977, 1979 etc., SIRENKO, N.A: 1972, 1973, 1974, 1975, 1977 etc. DUBNYAK, 1972, 1974 etc., MAYKAYA – MATVISHINA, 1971, 1972, 1973, 1974, 1976, 1977, 1978, 1980 etc., MELNICHUK, 1974, 1977 etc., PARISHKURA – TURLO, 1972, 1979 etc., PERE–DERIY, 1974, 1977, 1982, etc.).

As a whole 80 key-sites and almost 2 000 Pleistocene loess sequences were analyzed.

Taking into consideration the fact that the flat surface of the Ukraine extends from north to south over more than one thousand kilometres and is situated in three modern physiographic zones (southern part of the mixed forest zone, foreststeppe and steppe zone, subarid subtropics of South Crimea), the investigation laid down the foundation for paleogeographical and paleopedological correlation in east to west latitudinal, sublatitudinal directions not only in this physiographic zone but also in those adjoining it from the north and south.

It was ascertained that during the warm stages, the conditions in paleogeographical zones were similar to those in our days (NABOKIH, A.I., KROKOS, V.I., ZAMORIY, P.K. VEKLICH, M.F., SIRENKO, N.A., VELICHKO, A.A., MOROZOVA, T.D. et al.).

The paleogeographical-paleopedological correlation is easier along geographical zones than across them. In modern physiographic zones landscapes and soils are of the same character for thousands of kilometres. This is helpful when correlating the distant regions, e.g. the forest-steppe zones of the Ukraine and Western siberia.

The investigations began in 1969 in the basins of the Don, Middle Volga and Upper Oka rivers, in the Ural Foreland, in the south of the West-Siberian plain, in some regions of Soviet Central Asia and in Georgia, permitted to make interregional correlation of the Pleistocene loess-soil and of some other formations between these regions and the territory of the Ukraine. The paleopedological was the principal method of investigation. Geomorphological, paleontological, paleomagnetic and other investigation methods were also used.

All the above mentioned regions and the Ukraine (TABLE 1) have 15 paleogeographical stages and corresponding stratigraphic horizons (from the Priazov horizon to the Prichernomorskiy one). In each region the principal marking layers are represented by fossil soil series. Each horizon has its individual peculiarity.

In each of the above regions and in the corresponding regions of the Ukraine the Pleistocene soils, soil series and loess-soil strata of the same age have a number of analogous characteristics in the soil typology, in the structure, chemical and granulometric composition of soil and loess horizons, etc. All these allow to make paleopedological correlation between different regions.

The stratotype sequences of the Lihvin and Oka horizons near the village of Chekalino (the Upper Oka basin) are the index sequences of the region. The sequence has all stratigraphic horizons (from the Priazov to the Prichernomorye one: pc, bg, ud, ts, dn, tl, sl) and soil formations (df, vt, pl, kd, zv, lb).

TABLE 1. Upper Pliocene and Pleistocene stages and stratigraphy

Period/system		General scale	Paleogeographical stages, stratigraphical horizons		Age (thousand years)	Duration (thousand years)
			Name	Index		
Quaternary or Anthropogene	Pleistocene	Holocene	Holocene	hl	10	10
			Prichernomorye	pc	22	12
		Late (Upper)	Dofinovka	df	30	8
			Bug	bg	50	20
			Vitachev	vt	60	10
			Uday	ud	70	10
			Priluki	pl	100	30
			Tyasmin	ts	115	15
		Middle	Kaidaki	kd	175	60
			Dnieper	dn	250	75
			Zavadovka	zv	370	120
			Tiligul	tl	470	100
		Early (Lower)	Lubny	lb	650	180
			Sula	sl	700	50
			Martonosha	mr	920	220
			Priazov	pr	1000	80
			Shirokino	sh	1290	290
Neogene	Pliocene	Late (Upper)	Ilyichevsk	il	1400	110
			Kryshanovka	kr	1610	210
			Berezan	br	1900	290
			Beregovoye	bv	2450	530
		Middle	Siver	sv		210

TABLE 2. Interregional correlation of Pleistocene soils (northern steppe-forest zone)

Horizons	Kiev Pridnieprovye	Middle Oka river
	Predominant soil types	
hl	grey, light-grey forest soils, turf-podsolized soils	turf-podsolized, light-grey, grey forest soils
pc		
vt	poorly developed brown forest soils and brown rendzines	gleyed soils
ud		
pl	chernozem-like (pl_{b2}), brownish-grey forest soils (pl_{b1})	turf meadow chernozem-like (pl_{b2}), pseudo-gleyed (pl_{b1}) soils
ts		
kd	turf meadow, meadow-chernozem (kd_{b2}), turf-podsolized, light-grey and grey gleyed (kd_{b1})	turf, turf-gleyed, turf-podsolized, gleyed soils
dn		
	dark coloured meadow (zv_{1b2}), brown forest lessivage (zv_{1b1})	meadow, meadow-marshy (zv_{1b2}), brown forest gleyed with lessivage (zv_{1b1})
tl		
lb	chernozem-like, meadow (lb_{b2}), grey forest gleyed (lb_{b1})	light-grey forest gleyed, pseudo-gleyed (lb_{b2}, lb_{b1})
sl		
mr	dark coloured meadow, meadow-forest (mr_{b2}), brown forest gleyed (mr_{b1})	meadow, meadow-forest, marshy
pr		

TABLE 3. Interregional Correlation of Pleistocene soils (Middle Forest-steppe zone)

Horizons	Middle Pridnieprovye	Upper Don	Western Siberia
hl	leached podsolized chernozems, grey forest soils	typical chernozems, leached	leached podsolized chernozems, grey forest soils
pc			
vt	burozem-like brown soils	burozem-like brown soils	brown, gleyed, chernozem-like soils (thin)
ud			
pl	meadow steppe chernozems (pl$_{b2}$). Brown forest, brown forest steppe-like soils (pl$_{bl}$)	leached chernozems (pl$_{b2}$). Dark-grey and grey forest soils	thick leached chernozems (pl$_{b2}$), forest-steppe brown with poorly differentiated profile
ts			
kd	chernozem-like and meadow-chernozem (kd$_{b2}$), grey forest soils (kd$_{bl}$)	podsolized leached chernozems, meadow chernozem (kd$_{b2}$), grey and light-grey forest pseudo-gleyed soils	chernozem-like and meadow-chernozem (kd$_{b2}$), brown forest-steppe soils with loamy soils (kd$_{bl}$)
dn			
zv	brown forest reddish and brownish (zv$_{lb2}$), brown forest soils (zv$_{lbl}$)	brown forest carbonate soils	chernozem-like soils (zv$_{lb2}$). Brown forest podsolized grey-brown soils (zv$_{lbl}$)
tl			
lb	chernozem-like soils (lb$_{b2,3}$), brown forest with lessivage and podsolized (lb$_{bl}$)	chernozem-like (lb$_{b2,3}$) brown forest gleyed soils (lb$_{bl}$)	chernozem-like (lb$_{b2,3}$) grey forest gleyed soils (lb$_{bl}$)
sl			
mr	meadow-brown and leached with lessivage	meadow-brown and meadow-dark-brown leached soils	dark coloured forest-meadow soils
pr			

TABLE 4. Interregional correlation of Pleistocene soils (Northern steppe zone)

<table>
<tr><th>Horizons</th><th>Pridnestrovye</th><th>Middle Volga and Ural Foreland</th><th>Ob' Plateau</th></tr>
<tr><td>hl</td><td>typical humic chernozems</td><td>ordinary chernozems</td><td>ordinary chernozems</td></tr>
<tr><td>pc</td><td></td><td></td><td></td></tr>
<tr><td>vt</td><td colspan="2">dark-brown (burozem-like brown steppe-like) soils</td><td>thin chestnut soils</td></tr>
<tr><td>ud</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">pl</td><td rowspan="2">chernozems, burozem-like chernozems</td><td>burozem-like brown chernozems</td><td>leached chernozem (pl_{b2})</td></tr>
<tr><td colspan="2">forest-steppe soils with poorly differentiated profile (pl_{bl})</td></tr>
<tr><td>ts</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">kd</td><td rowspan="2">podsolized leached chernozems, meadow chernozems (kd_{b2}), brown forest podsolized pseudopodsolized (kd_{bl})</td><td>meadow chernozems (kd_{b2})</td><td>chernozems and meadow-chernozem soils (kd_{b2})</td></tr>
<tr><td colspan="2">forest steppe soils with poorly differentiated profile (kd_{bl})</td></tr>
<tr><td>dn</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">zv</td><td rowspan="2">brown and meadow-brown leached soils</td><td colspan="2">chernozem-like soils (zv_{b2})</td></tr>
<tr><td>brownish-cinnamon soils (zv_{lbl})</td><td>grey-brown soils (zv_{lbl})</td></tr>
<tr><td>tl</td><td></td><td></td><td></td></tr>
<tr><td>lb</td><td>chernozem-like ($lb_{b2,3}$), cinnamon-brown (lb_{bl}) soils</td><td>chernozem-like grey-coloured complex (lb_{b2}), meadow forest soils (lb_{bl})</td><td>thick chernozems ($b_{2,3}$), grey and grey-brown forest soil (b_1)</td></tr>
<tr><td>sl</td><td></td><td></td><td></td></tr>
<tr><td>mr</td><td>cinnamon and meadow-cinnamon complex</td><td>meadow-cinnamon leached and with carbonate</td><td>dark-coloured forest-meadow forest-meadow soils</td></tr>
<tr><td>pr</td><td></td><td></td><td></td></tr>
</table>

TABLE 5. Interregional correlations of Pleistocene soils (Southern steppe zone)

Horizons	The Crimea	The Tadzhik depression	Pritashkentskiy Region
	Predominant soils types		
hl	southern chernozems, cinnamon rock brown forest soils	cinnamon rock brown chernozems forest soils	
pc			
vt	reddish-brown soil in soil complex with solonetz soils	cinnamon carbonate, greyish-cinnamon soils	greyish-cinnamon gypsum soils
ts			
kd	ordinary partly southern chernozems	cinnamon leached soils. Brown and reddish-brown forest soils (kd_{bl})	cinnamon soils with carbonates
dn			
	cinnamon steppe-like and greyish cinnamon soils	reddish-cinnamon, leached soils	cinnamon soils with carbonates, gypsum soils
tl			
lb	dark-coloured soils of subtropical steppes and their solonetz variants ($lb_{b2,3}$), brown-cinnamon soils (lb_{b1})	reddish-cinnamon, brown-cinnamon soils	cinnamon leached soils
sl			
mr	reddish-cinnamon steppe soils in soil complex with solonetz soil	meadow-reddish-cinnamon soils, meadow soils	meadow-cinnamon solonets soils
pr			

The sequence of these horizons is similar to the sequence situated near the northern boundary of the loess formation development in the Ukraine (soil horizons, TABLE 2). The stratotype sequence of the Lihvin sediments corresponds to the Martonosha sequence, while the Oka sequences corresponds to the Priazov one.

Sometimes the complete Pleistocene sequences of the Upper Don river are characterized by mr, lb, zv, kd, pl, vt, df soil series that are similar to the pedocomplexes of the middle part of the modern Ukrainian forest-steppe zone (TABLE 3). The moraine of the right bank of the Upper Don river (Uryv – Strelitha region) is intercalated between mr and sh soil series, i.e. in the Priazov horizon.

In the Pleistocene the subaerial cover of the Middle Povolzhye and Bashkirskoye Preduralye fossil soils prevailed. Soils of the upper substages of the climatic optimum, e.g. zv_{lb2}, kd_{b2}, pl_{b2} soils and chernozem-like soils (TABLE 4), forest soils of the lower stages of the climatic optimum were considerably destroyed by the subsequent processes. Loess horizons are thin there.

All the loess horizons (even sl, ts, ud horizons, except the Prichernomorye horizon) are thicker than the Ukrainian horizons. Subaerial sands are intercalated in the loess horizons. The Kajdaki, Priluki, Vitachev, Dofinovka soil suites are similar to the soil suites of the Ukrainian northern steppe of the same age, the Martonosha, Lubny and Zavadovka soil suites are analogous to the suites of the Ukrainian forest-steppe zone.

Loess intercalations are often seen in soil series, expecially in the mr, lb and vz soil series.

In all the Pleistocene pedocomplexes (from mr to df) of the Central Asia mountain foothills fossil soils are intercalated in the loess, that is why some specialists distinguish more than seven Pleistocene pedocomplexes.

Soils of the climatic optimum (mr, lb, zv stages etc.) are similar to those of south east Ukraine, lowlands of the Crimea and Kerch peninsula (TABLE 5), but have mere southern characteristics. Steppe soils are more deserted. In the highlands of Tadzikistan the soils of the Kajdaki, Priluki and Vitachev climatic optimum are brown, but they were developed in more moderate conditions than the Lower Pleistocene soils of this region. In the foothill regions near Tashkent and Samarkand the vt-soils are reddish-brown, while the df-soils are greyish. Specialists began to investigate the Pleistocene loesssoil formation in the Ukraine more than 60 years ago, while in other loess regions this work is in its initial stage. So our attempts of paleopedological correlation has to be treated as a preliminary investigation. The paleopedological should be one of the principal methods in order to solve the problems of interregional stratigraphy.

Different soils are devided into groups on the basis of their genetic characteristics. These groups are characteristic of the individual Pleistocene paleogeographical stages and this is very useful for stratigraphy and correlation. Soil groups of different age, stituated in one or the other region, have their zonal characteristics and soil structure.

REFERENCES

BOLIKHOVSKAYA, N.S. – GLUSHANKOVA, N.I. – RENGARTEN, N.I. – SUDAKOVA, N.G. 1976: Pogrebennye pochvy Likhvinskogo (Chekalinskogo) razreza. – Bull. komiss, po izuch. chetvert. perioda, 45. 30-44.

LAZARENKO, A.A. 1980: Pogrebennye pochvy lessovoi formatsii Srednei Azii i ikh paleogeograficheskoe znahenie. – Doklady AN SSSR, 252, 1. 181-185.

MATVISHINA, Zh.N. 1982: Mikromorfologiya pleistotsenovykh pochv Ukrainy. Kiev, Nauk. dumka. 142.

MOROZOVA, T.D. 1963: Stroenie drevnykh pochv i zakonomernosti ikh geograficheskogo rasprostraneniya v razlichnye epokhi verkhnego pleistotsena. – Pochvovedenie, 1963. 12. 26-37.

PARISHKURA, S.I. 1972: Naris paleofitogeografii Ukraini v antropogeni. – In: Problemi geografichnol nauki v Ukrains'ki RSR. Kiev, Nauk. dumka. 213-227.

SIRENKO, N.A. 1974: Antropogenovye pochvennye pokrovy ravninnoi territorii Ukrainy. – In: Paleopedologiya. Kiev, Nauk. dumka. 27-43.

SIRENKO, N.A. 1975: Paleogeografiya rivninnogo Krimu v pliotseni ta pleistotseni za paleopedologichnimi dannimi. – In: Materiali do III. z'izdu geografichnogo tovaristva URSR. Kiev, Nauk. dumka. 40-42.

SIRENKO, N.A. 1977: Pleistotsenovye iskopaemye pochvy Ukrainy. Avtoreferat diss. Kiev, Nauk. dumka. 70.

SIRENKO, N.A. 1980: Osobennosti pochvo- i porodoobrazovaniya na Kerchenskom poluostrove v pliotsene i pleistotsene. – In: Fizicheskaya geografiya i geomorfologiya. Kiev, Vishcha skola. 23. 72-78.

STEPANOV,I.N. – ABDUNAZAROV, U.K. 1977: Pogrebennye pochvy v lessakh Srednei Azii i ikh paleogeograficheskoe znachenie. Moscow, Nedra. 121.

VEKLICH, M.F. 1968: Stratigrafiya lessov Ukrainy. – Sovetskaya geologiya. 1965. 6. 35-54.

VEKLICH, M.F: 1968: Stratigrafiya lessovoi formatsii Ukrainy i sosednykh stran. Kiev, Nauk. dumka 240.

VEKLICH, M.F. 1982: Paleoetapnost' i stratotipy pochvennykh formatsiy verkhnego kainozoya. Kiev, Nauk. dumka. 201.

VEKLICH, M.F. – SIRENKO, N.A. 1972: Opornye geologicheskie razrezy Ukrainy. 3. Severnoe Prichernomor'e. Kiev, Nauk. dumka. 227.

VEKLICH, M.F. – SIRENKO, N.A. 1976: Pliotsen i pleistotsen levoberezh'ya Nizhnego Dnepra i Ravninnogo Kryma. Kiev, Nauk. dumka. 187.

VEKLICH, M.F. – SIRENKO, N.A. 1977: Novoe o korrelyatsii lessovykh, morskikh i lednikovykh obrazovaniy pleistotsena. – In: Paleogeograficheskie osnovy ratsional'nogo ispol'zovaniya estestvennykh resursov. 2. Kiev, Nauk. dumka. 83-85.

VEKLICH, M.F. – SIRENKO, N.A. 1982: Mezhregional'naya paleopedologicheskaya korrelyatsiya pleistotsena lessovykh oblastei SSSR. – Tezisy dokl. XI. kongressa INQUA. 2. Moscow. 41-42.

VEKLICH, M.F. – ARTYUSHENKO, A.T. – SIRENKO, N.A. et al. 1967: Opornye geologicheskie razrezy Ukrainy. 1. Kiev, Nauk. dumka 107.

VEKLICH, M.F. – SIRENKO, N.A. – DUBNYAK, V.A. et al. 1973: Rozvitok Ukraini v pizn'omu kainozoi. Kiev, Nauk. dumka. 224.

VEKLICH, M.F. – SIRENKO, N.A. – DUBNYAK, V.A. et al. 1979: Opornye geologicheskie razrezy Ukrainy. 2. Srednee Pridneprov'e. Kiev, Nauk. dumka. 172.

VEKLICH, M.F. – SIRENKO, N.A. – MATVISHINA, Zh.N. et al. 1977: Pleistotsenovye paleolandshafty Porozhistogo Pridneprov'ya. – In: Paleogeografiya. Paleolandshafty. Kiev, Nauk. dumka. 69-112.

VEKLICH, M.F. – SIRENKO, N.A. – VOLKOV,I.A. et al. 1982: Etapy formirovaniya chetvertichnoi subaeral'noi tolshchi Ukrainy i yugo-vostochnoi chasti Zapadno-Sibirskoi ravniny. – In: Tezisy dokl. XI. kongressa INQUA. 3. Moscow. 70-71.

ZYKINA, V.S. – VOLKOV, I.A. – DERGACHEVA, M.I. 1981: Verkhnechetvertichnye otlozheniya i iskopaemye pochvy Novosibirskogo Priob'ya. Moscow, Nauka. 202.

Addresses of authors:
Prof. Dr. M.F. Veklich, Academy of Sciences Ukrainian, SSR Chkalova ul. 55/b. 252054 KIEV – USSR
Dr. M.A. Sirenko, Section of Paleogeography, Dept. of Geography Academy of Sciences, Ukrainian SSR
Bul. Shevchenko 60. 252032 KIEV – USSR

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

LITHOLOGICAL AND STRATIGRAPHICAL ANALYSIS ON LOESS PROFILES OF THE LOESS PLATEAU IN CHINA

Zhang Zonghu

ABSTRACT

A detailed study of the Quaternary loessial deposits has been carried out on three selected profiles near the counties of Pingliang, Xifeng and Wuqi, on the Loess Plateau of China. The thickness of the three profiles are 173 m, 170 m and 195 m respectively.

A detailed stratigraphic division of loess deposits in this region was made on the basis of the comprehensive study of these loess profiles. Each profile may be subdivided into several loess series, according to their lithological characters.

The paleomagnetic data of these three profiles proved that the accumulation of loess deposits had started before the Réunion event of the Matuyama epoch (about 2.4 m.y. B.P.). The results of the study of the N/Q boundary in these profiles may be used in regional stratigraphic correlation for the whole Loess Plateau.

INTRODUCTION

The stratigraphic subdivison of the Quaternary loess deposits and their boundary with the Neogene in the Loess Plateau of China have long been an interesting problem for Chinese geologists. Several experts regard the loess layer over the first fossil soil bed (Haplustalf type), which is called the „Malan Loess" in the Loess Plateau, as deposited over the whole period of the Late Pleistocene. The beginning of loess accumulation on the Loess Plateau is considered at the time about 1 m.y. B.P.

For the last several years, large amounts of investigation and research work have been carried out on the Loess Plateau. Loess profiles have been correlated and new points of view have been put forward. The paper based on the comprehensive study of three selected loess profiles, discusses the problems of stratigraphic subdivisions of loess deposits as well as the lower limit of the Quaternary system. The three selected profiles lie in three geomorphological regions with different features of development in the Quaternary geological history. 1) The profile near the Pingliang county is on the „Loess yuan" (a tablelike elevated land surrounded by deep-cut valleys) in front of the Liupanshan mountainous area, of bedrock outcrop. In the quaternary Period, the area was part of the piedmont belt of the Liupanshan Mts. 2) Another profile the Xifeng Profile in the vicinity of the Xifeng county, within the area of the largest „Loess yuan" called

„Xifeng yuan" in the central part of a post-Tertiary erosional basin. And 3) The profile near the Wuqi county is in a „Loess Mao" area (with hills and deep-cut valleys) in the northern part of the Plateau. From the end of the Tertiary until the early stage of the Middle Pleistocene, this area had been a lacustrine basin with thick lacustrine accumulations. Studies of lithological characteristics (particle size and mineral components) and paleomagnetic measurements for the three profiles permit us to approach the stratigraphic subdivision and correlation of loess deposits. We consider that the so-called „Malan Loess" belongs to the later epoch of the Late Pleistocene. Loess on the Plateau were found to deposit before the Réunion polarity event of the Matuyama Epoch about 2.4 m.y. B.P.

DESCRIPTION OF LOESS PROFILES

I. Loess profile near Pingliang

The loess profile is located at the Dazhaizi village, 30 km south of Pingliang. On the west side of Pingliang is the low mountainous area to the east of the Liupanshan Mts. where thick Tertiary series outcrop. Loess deposits of various periods from Holocene to Tertiary are exposed along the deep-cut valley. The total thickness of the loess profile is 172.4 m, within which Quaternary loess makes up 161.6 m, the remaining being the deposits of the Pliocene (FIG. 1).

From the surface of the „yuan" downward to the bottom of the valley the following loess beds are exposed:

1. Holocene, dark grey yellowish loess, intercalated with a layer of dark grey Holocene soil (dark loam) 1.0 m thick.
2. Later stage of the Late Pleistocene (Q_3^2), the so-called „Malan loess", greyish yellow, thickness 11.5 m.
3. Earlier stage of the Late Pleistocene (Q_3^1), greyish yellow loess, intercalated with four layers of fossil soil (Haplustalf soil type). The second layer is composed of two thinner ones. The total thickness of this loess series is 39.9 m.
4. Later stage of the Middle Pleistocene, fossil soil complex (burozem type), which consists of three overlapping layers of fossil soil, thickness of this complex is 5.5 m.
5. Middle Pleistocene, brownish yellow loess, intercalated with 5 thin layers of fossil soil. At the bottom of this series are two layers of silty loess-like soil. Total thickness 29.9 m.
6. Early Pleistocene, reddish-yellow loess-like clayey soil containing eight layers of calcium concretion, 13.3 m thick. The top part of the deposits is a mixture of brownish-yellow loess-like and reddish-yellow clayey materials. It represents an erosional phase in the later stage of the Early Pleistocene.
7. Early Pleistocene, reddish-yellow loess-like silty clayey soil, containing calcareous concretions. About 3.6 m thick.
8. Early Pleistocene, reddish-yellow loess-like heavy clayey soil, with calcareous concretions concentrated in the upper part and scattered in the lower part of the bed. 11.2 m in thickness. Beneath is a layer of silty loess-like clayey soil about 9.5 m thick.

9. Early Pleistocene, reddish-yellow loess-like heavy clayey soil containing minor calcareous concentrations, 8.5 m thick.
10. Early Pleistocene, reddish-yellow loess-like heavy clayey soil containing less calcareous concretions. The lower part is a layer of silty loess-like clayey soil, with a total thickness of 27.3 m.

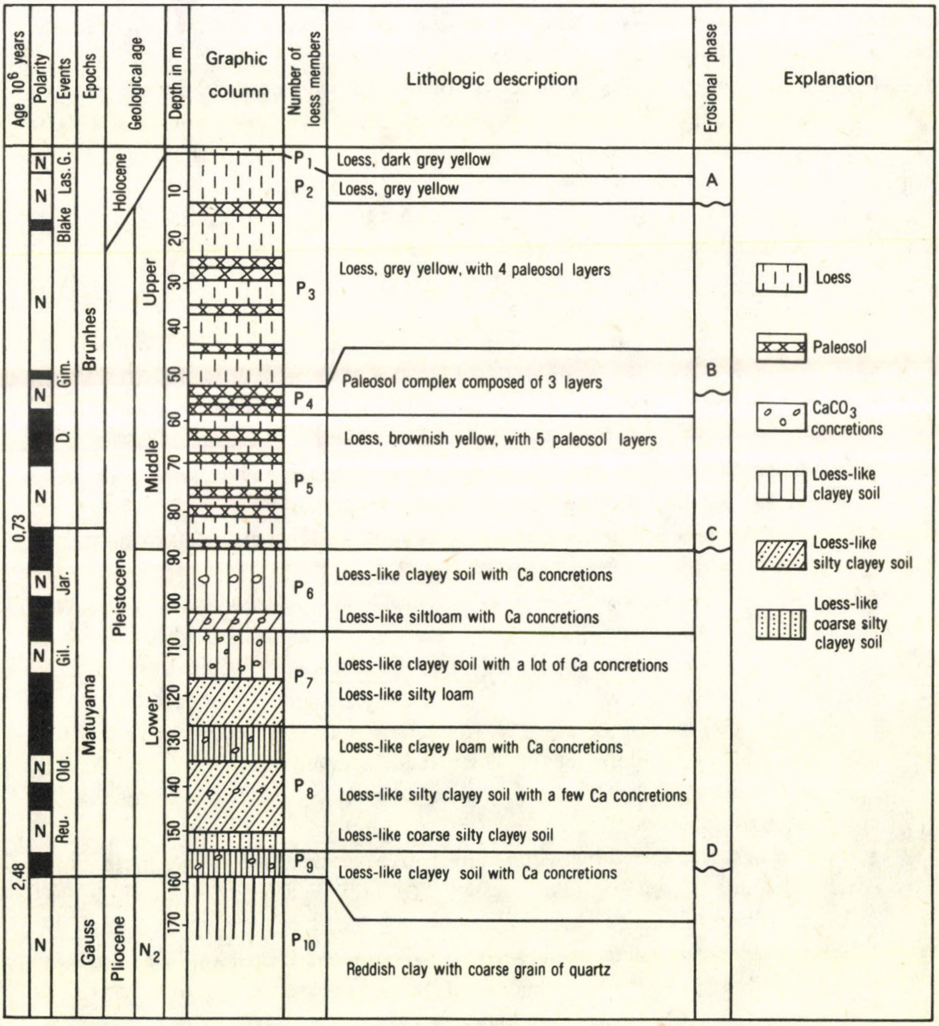


FIG. 1. Generalized profile of the loess exposure near Pingliang

11. Early Pleistocene, reddish-yellow loess-like heavy soil, interbedded with calcareous concretions. About 9.3 m thick.
12. Pliocene, light red clay, with coarse quartz grains, having a visible thickness of 10.8 m.

II. Loess profile near Xifeng

The loess profile is in the central part of the „Xifeng yuan" at the head of a deep-cut valley near Xifeng, Gansu province. After the end of the Tertiary, the „Xifeng yuan" was a great erosional basin, where loess deposits of great thickness accumulated during the Quaternary. The loess profile exposed from the top surface of the yuan to the bottom of the deep-cut valley includes Holocene, Pleistocene and Pliocene loess deposits. The total thickness of the profile is about 186.3 m, within which an interval of 179.3 m belongs to the Pleistocene, the remaining being red clay of the Tertiary. The description of the profile from the top downward is as follows (FIG. 2):

1. Holocene, grey-brownish yellow loess, with a layer of Holocene soil (dark loam) totalling 1.3 m thickness.
2. Later stage of the Late Pleistocene (Q_3^2), grey-yellow loess the so-called „Malan Loess", 10.7 m thick.
3. Early stage of the Late Pleistocene (Q_3^1), grey-yellow loess, with four layers of fossil soil (Haplustalf type), the thickness of each layer is about 1.5-3.0 m thick, totalling 34 m or so.
4. The later stage of the Middle Pleistocene, fossil soil complex of burozem type consisting of the three closely overlapping layers. The total thickness is 6.8 m. On the complex traces of erosion can be seen.
5. Middle Pleistocene, three thin layers of loess in brownish yellow colour interbedded with three layers of fossil soil, 15.7 m thick.
6. Middle Pleistocene, thick bed of loess (maximum thickness 11 m) interbedded with thin layers of fossil soil. At the bottom of the series is a bed composed of silty loess. At the contact with Early Pleistocene loess-like deposits, there is a layer of mixed sediments (about 2 m thick) composed of reddish yellow loess-like clayey soil (Early Pleistocene) and brown-yellow loess (bottom part of the Middle Pleistocene). The mixed sediments may be regarded as the mark of erosional process occuring in post Early Pleistocene times in this region. Total thickness 32.5.
7. Early Pleistocene, reddish-yellow loess-like heavy clayey soil, intercalated with degraded fossil soil. The lower part of this bed is lithologically mixed. About 13.2 m thick.
8. Early Pleistocene, reddish-brown yellow coloured loess-like clayey soil, intercalated with multiple layers of calcareous concretions, at the bottom of this bed there is another lithologically mixed layer. Total thickness 4.4 m.
9. Early Pleistocene, brownish-yellow loess-like clayey soil containing scattered calcareous concretions. At the bottom there is a mixed layer, 8.9 m thick.
10. Early Pleistocene, reddish-yellow to dark-red loess-like clayey soil containing Fe and Mn concretions, 9.5 m thick.

11. Early Pleistocene, , brownish-yellow loess-like silty clayey soil 6.7 m thick.
12. Early Pleistocene, reddish-yellow loess-like silty clayey soil with less calcareous concretions, 8.0 m thick.
13. Early Pleistocene, reddish-yellow loess-like silty clayey soil, with less calcareous concretions, 8.0 m thick.
14. Early Pleistocene, dark reddish-brown loess-like heavy clayey soil, 8.9 m thick.

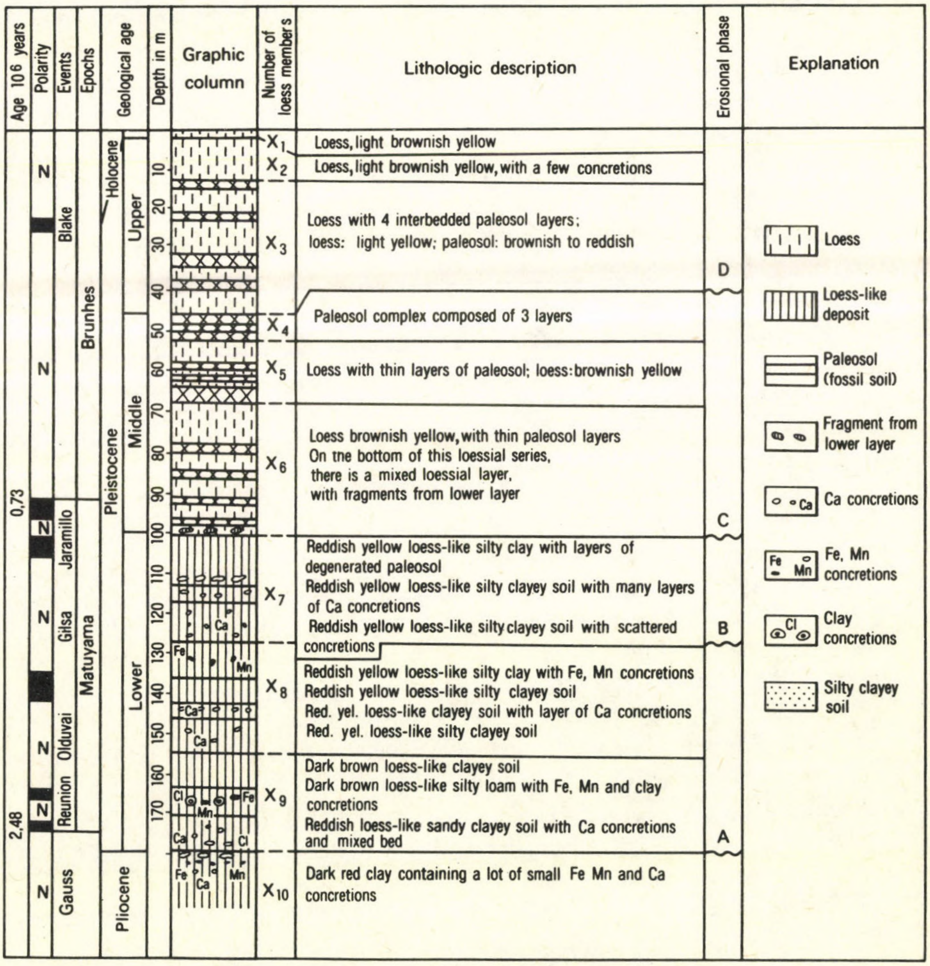


FIG. 2. Generalized profile of the loess exposure near Xifeng

15. Early Pleistocene, brownish-red loess-like heavy clayey soil with concretion of clay, iron and manganese, 6.7 m thick.
16. Early Pleistocene, reddish-yellow loess-like silty light clayey soil, with calcareous concretions. Total thickness 23.8 m. At the bottom is a lithologically mixed zone.
17. Pliocene (N_2), dark red clay with black Fe and Mn stains, containing Fe and Mn concretions and small calcareous ones. Abundant argillized Helixes have been found in it.

III. Loess profile near Wuqi

The profile is located about 20 km east of Wuqi county in Shaanxi province. In the hilly area in the upper reaches of the Lohe River, which is called „Loess Mao" by local people, the Pleistocene loess beds and Pliocene deposits are exposed from the top of „Loess Mao" down to the bottom of dissected valley. The Triassic shale and sandstone are the oldest sediments exposed in the profile (FIG. 3).

The upper part of the Pleistocene deposits in the profile is loess accumulation, and the lower part is lacustrine sediments of great thickness. The Pliocene deposits are featured by fluvial sedimentation. The region was probably a great lacustrine basin in the earlier stage of the Early Pleistocene, with an area of several hundred square kilometers. It gradually dried up in the later stages of Early Pleistocene, and finally disappeared in the Middle Pleistocene. The locality of the profile is near the centre of the ancient lake, which is now elevated up to 1545 m or so above sea level.

The total thickness of the profile is 238.5 m, in which Quaternary deposits have a thickness of 195.7 m. The sequence of the profile from upper to lower horizons is as follows:

1. Holocene, greyish yellow silty loess, 1 m thick.
2. Later stage of Late Pleistocene (Q_3^2), greyish yellow loess, 11 m thick.
3. Early stage of Late Pleistocene (Q_2^1), greyish yellow loess, intercalated with three layers of fossil soil (Haplustalf). The thickness of individual layers is about 1 m. Total thickness 29 m.
4. Later stage of Middle Pleistocene, thick bed of fossil soil (Haplustalf), 5.5 m thick.
5. Middle Pleistocene, grey-yellow in colour, thin layers of loess-like silty soil and clayey soil horizontally stratified. Underneath is loess-like silty soil with dark rusty stains. Total thickness 18.7 m.
6. Middle Pleistocene, grey-yellow loess, intercalated with four thin layers of fossil soil. In the lower part, the fossil soil contains some loess lenses. Above it the loess deposits are mixed up lithologically. Total thickness 20.4 m.
7. Early Pleistocene, loess-like heavy silty soil brownish yellow in colour, intercalated with two thin layers of fossil soil, thickness 8.4 m.
8. Early Pleistocene, clayey soil intercalated with fine sands and thin layers of clay, brownish in colour. The lower part is silty clayey soil, brownish-yellow in colour. All these layers are identified to be flood-plain deposits. Total thickness about 20.4 m.

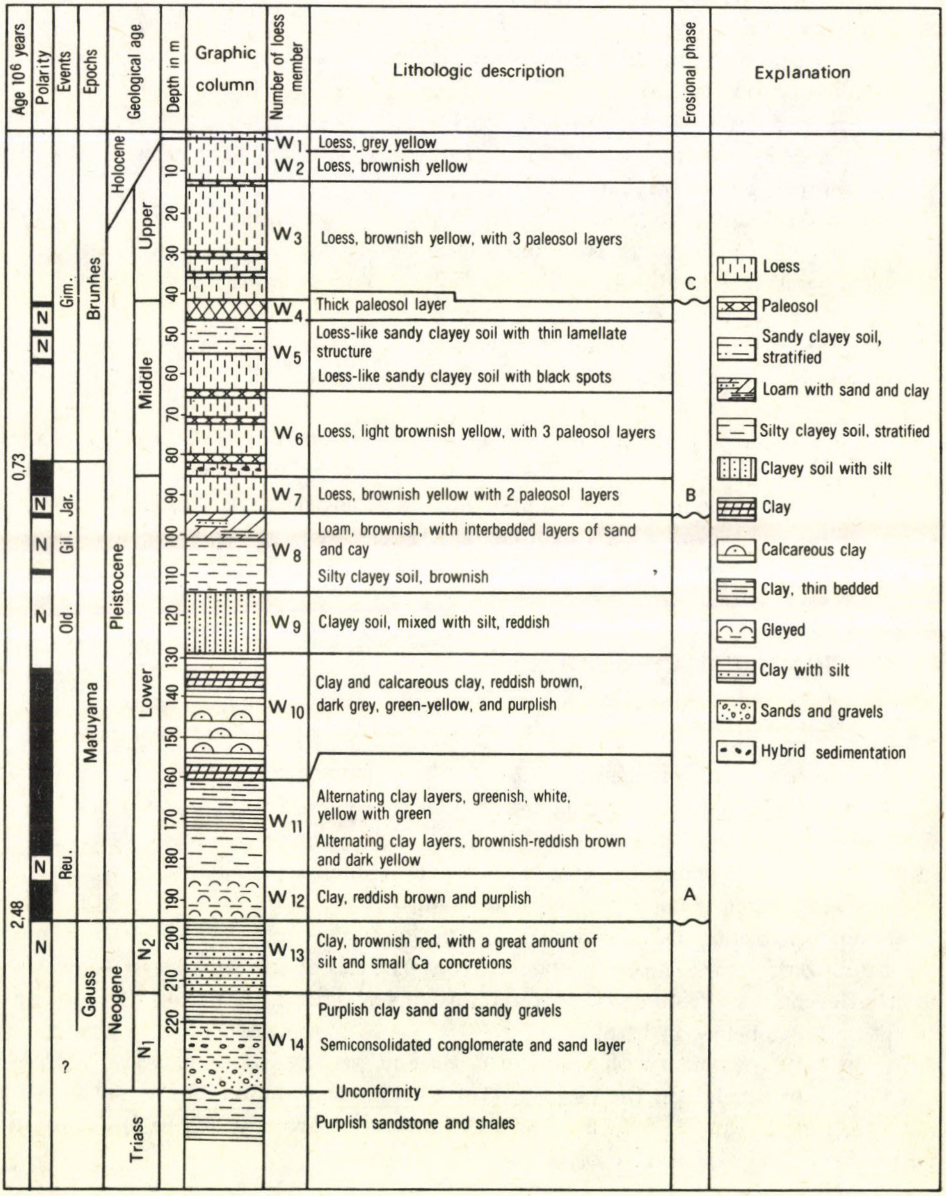


FIG. 3. Generalized profile of the loess exposure near Wuqi

9. Early Pleistocene, reddish heavy clayey soil, mixed with silt, thickness 15 m.
10. Early Pleistocene, alternating beds of clay and argillo-calcareous clay, in brown-red, dark-grey, green-yellow, pale white, purplish grey and dark brown colour. Thickness 31.3 m.
11. Early Pleistocene, in the upper part are alternating beds of clay in greyish brown colour and clay in greyish green, pale white and yellow-green colours. The lower part consists of clay in alternating colours of brownish-yellow, reddish-brown and grey-yellow. Total thickness 23 m.
12. Early Pleistocene, clay beds in alternating colours of reddish-brown and light purple. Thickness 12 m.
13. Later stage of Pliocene (N_2), brown-red clay, containing a large amount of silt and small calcareous concretions. 17.6 m thick. The Early Pleistocene clay bed in reddish-brown and pusplish colour is immediately followed by Pliocene, no sedimentary discontinuity can be observed.
14. Earlier stage of Pliocene (N_1), purplish clay, sand, and sand and gravel. Underneath are interstratified sand and semi-cemented gravel beds. Totally 25.2 m thick. The sedimentation is continuous between N_2 and N_1.
15. Triassic sandstone and shale, both in purple colour. The Early Pleistocene deposits observed in the profile have similar colours to those of the Pliocene, only the colour gradually fades with the geological time. This indicates that Pliocene accumulations and other Quaternary series are closely related to the Triassic bedrocks.

LITHOLOGICAL CHARACTERS

I. Grain size

In the three profiles, the grain size of the predominant loess particles is that of silt, 0.05-0.005 mm. In the Pingliang profile, the silt content in each layer of loess deposits is about 61.9-71.3% averaging 65.9%. In the Xifeng profile the loess deposits only contain 57-69.8% silt grains, averaging 66.3%. And in the Wuqi profile the silt grains in the loess layers ranging from 56% to 69%, averaging 63.2%.

The composition of loess has highest variation in the percentage of the fine sand-grain size (> 0.05 mm). The proportion of loess particles of such grain size in various beds at different levels from upper to lower horizons of three respective profiles is quite different as shown below in TABLE 1.

The clay components of grain size < 0.05 mm in loess profile are also different in quantity. For example in the Pingliang profile the average amount of clay particles $<$ 0.005 mm ranges from 23.8% to 37%, in Xifeng profile from 16.4% to 36%, and in Wuqi profile from 10.7% to 21.6%.

TABLE 1. Percentage of loess particles > 0.05 mm

Profile / No. of loess bed	Pingliang	Xifeng	Wuqi
	%		
1	7.2	12.4	15.9
2	12.5	6.2	27.4
3	5.7	7.5	31.0
4	3.9	5.1	12.6
5	14.9	7.6	27.3
6	3.5	8.0	–
7	4.7	1.6	–
8	0.5	7.5	–
9	2.9	13.4	18.2
10	6.5	4.1	–
(11)	(1.9 - 18.3 below)		(24)
(12)			(11.5)

According to the analysis of the grain size of loess components in the three profiles mentioned above, some conclusions can be drawn as follows:

1. As the amount of silt fraction in individual beds of loess deposits in the three profiles has very slight variation, the determinant factor of the lithological character of the loess is the amount of the fine sand fraction (> 0.05 mm) in the loess deposits.
2. Lithologically, the regularities of grain-size variation of loess in these profiles are:
   (a). Several sedimentary cyclothems, which represent the variation of the composing granular fraction in loess, are found in all these profiles. In the profiles, from bottom to top, the granular fraction in loess varies gradually from coarser to finer grain size, and in turn from finer to coarser.

   (b). In the Early Pleistocene loess deposits four cyclothems can be observed, with grain size varying from coarser to finer. Whereas in those of the Late and Middle Pleistocene four cyclothems can also be seen.

   It should be pointed out that the composition of the fossil soil intercalated in the loess beds cannot represent the original composition of the loess deposits because the fossil soil had undergone weathering and soil forming process and thus have already changed its original granular components.

   (c). The cyclothems in the profiles may be used as one of the marks of identification for the subdivision of the loess series into „lithologic members", which can be used for stratigraphic correlation between the profiles of Pingliang, Xifeng and Wuqi.

II. Mineral constituents

The analysis of the mineral constituents of loess deposits in the three profiles indicates that the heavy minerals in the loess deposits are chiefly of grain size 0.01 -0.05 mm, composing up to 90%. The remaining 10% or so has a grain size ranging from 0.05 to 0.25 mm. The heavy minerals are found to be of about twenty-six kinds, occasionally only ten kinds or more in some of the loess beds. The most enriched heavy minerals are epidote, hornblende, hematite, limonite, garnet and zircon. The light minerals mainly include quartz, feldspar and calcite. Other kinds of mineral are rare.

The distribution of mineral constituents in the loess profiles has the following characteristics:

1. All the three profiles are enriched in hematite and limonite especially the profiles of Pingliang and Wuqi. This is probably because the older rock formations before Quaternary contain higher quantities of hematite and limonite.
2. The amount of main mineral constituents varies with depth in different geological times. Therefore, the vertical variation of main mineral constituents in the loess profiles may be taken as the markers of the stratigraphic subdivision of the loess series.
3. The amounts of quartz and feldspar in loess deposits of the three profiles increase with depth from top to bottom, and larger amounts of these two minerals are found in the Tertiary strata rather than in the Quaternary loess.
4. Calcite appears in higher amount in the Pingliang profile, less in the Xifeng, and least in the Wuqi. This indicates that the loess of the individual three profiles was accumulated in different paleogeographic environments.
5. Some of the heavy minerals are very abundant in some of the loess beds, but absent in others. As a result, the distribution of mineral constituents in loess deposits is not uniform in different horizons. For example, in the Pingliang profile, zircon appears generally in small quantities in most of the loess beds, but increases abruptly in lower loess beds up to several times of even ten times or more than that of the general.

SOME SUGGESTIONS FOR THE STRATIGRAPHIC SUBDIVISION OF LOESS PROFILES

According to the lithologic characters, mineral composition and erosion phases of the loess profiles, the loess series in the profiles can be subdivided into several lithologic members. The Pingliang profile can be subdivided into ten members, nine of which belong to the Quaternary and one to the Tertiary. The Xifeng profile can be subdivided into fourteen members, of which twelve belong to the Quaternary and two to the Tertiary. Among the twelve members of the Quaternary, six are loessic deposits or loess-like accumulations, the other six are flood-plain or lacustrine deposits.

The study of the paleomagnetic stratigraphy of the three profiles has been carried out. Paleomagnetic samples were collected from the Pingliang profile with a sampling interval of 30 cm within the depth of 14 m below the ground surface. In the range between the depths of 14 m and 58 m, the sampling is spaced at 50 cm, still downward to the bottom of the profile, 100 cm. The results are presented in a combined lithological and paleomagnetic profile as shown in FIG. 3. In the Holocene loess deposits, there is a polarity drift (Gothenburg excursion during the Brunhes normal polarity epoch, about 8-10 thousand years. B.P.). The measurement of the samples collected in the upper part of the 1st loess bed from the top of the Pingliang profile indicates a magnetic anomaly, which is considered to be the Laschamp excursion of the Brunhes epoch, about 20 thousand years before present. Another remarkable polarity anomaly has been recorded in the 2nd loess bed underlying the 1st fossil soil which is considered to be the Blake event about 110 thousand years B.P. At the top of the fossil soil complex, it is recorded an obvious polarity anomaly, considered to be the Jamaica excursion of the Brunhes epoch, about 180 thousand years B.P., and underneath the complex another polarity event is recorded, corresponding to the Biwa D, about 320 thousand years B.P. In the Pingliang profile, the boundary between the Brunhes and Matuyama epoches is identified to be the lower part of the 5th lithological member P_5 (FIG. 1). And the lower limit of P_5 corresponds to the time before the end of the Matuyama. From the viewpoint of lithologic and stratigraphic characters of the loess deposits, P_5 of the Pingliang profile should be correlated with the bottom of the Middle Pleistocene series. Obviously, the Middle Pleistocene loess had already begun to deposit at the time somewhat earlier than 0.70 m.y. (the beginning of the Brunhes epoch).

In the Early Pleistocene loess deposits in the Pingliang profile, there are recorded the events in the Matuyama: Jaramillo and Gilsa-Olduvai and at the bottom part of the loess deposits, the Rèunion event is also recorded. A mixed loess-like clayey soil layer of mixed lithological characters occurring at the contact zone between the Quaternary loess beds and the Pliocene over the Tertiary system, is considered to have been formed before the Rèunion event, which represents an erosional phase that occurred at the end of the Pliocene. Beneath the mixed layer, in the Pliocene red clay, which contains a large quantity of coarse quartz grains, is recorded to be entirely of normal polarity and should be considered to be of the Gauss epoch. Thus it can be seen that the loess on the Loess Plateau began to deposit at the time of 2.4 m.y. B.P., i.e. in the period between the Gauss and Matuyama events. At the same time, paleomagnetic survey and measurement for the other two profiles were also carried out, the sampling interval being 100 cm. In both profiles were also recorded Blake, Jaramillo, and Gilsa-Olduvai events. However, the Rèunion event is recorded in both the bottom parts of the Pleistocene deposits in the two profiles (FIGS 1, 2, and 3). Though the horizons where the polarity events appear in the three profiles are slightly different, but they can generally be correlated to each other.

In short, the Quaternary loess deposits can be divided into: 1/. Early Pleistocene series, which began after the Gauss normal polarity epoch or at the beginning of the Matuyama reverse epoch, 2.4 m.y. B.P. 2/. Middle Pleistocene series, which began in late Matuyama epoch, or before the beginning of the Brunhes epoch, little earlier than 0.70 m.y. B.P. 3/. Late Pleistocene series, which began after the fossil soil complex was formed or at the end of the Jamaica excursion about 0.18 m.y. B.P., and 4/. The Holocene series, with 10 thousand years.

The stratigraphic subdivision as mentioned above may be used in stratigraphic correlation of the Quaternary deposits of the Loess Plateau.

The author would like to express his gratitude to the colleagues ZHANG PING and SHE ZHI-HUI also from the Institute of Hydrogeology and Engineering Geology for their help in his research work, and to the working staff of the laboratories of the Institute for their services and support.

Address of author:
Prof. Zhang Zonghu, Institute of Hydrogeology and Engineering Geology, Ministry of Geology
ZHENGDING, Hebei – China

IV. ASPECTS OF UTILIZATION OF AREAS COVERED BY LOESSES

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

LOESS SOILS AS REGULATORY COMPARTMENTS IN ECOSYSTEM RESPONSE TO POLLUTION

Otto Fränzle

ABSTRACT

Soils constitute particularly important regulatory compartments of ecosystems, and consequently it is the aim of the present paper to define their buffering capacities with respect to potentially toxic chemicals. On the basis of a paradigmatic description of soil moisture balance and related fluxes of chemicals a review of adsorption and retention factors of soils is given. The determination of retention factors for a set of German loess soils permits conclusions as to the relative importance of adsorption and desorption processes, hydrodynamic dispersion and soil moisture balance for their buffering capacities. Hence chemical mobility will not only depend on the inherent physical-chemical properties and the amount of the substance applied, but it is also greatly influenced by the structures of the biotope affected.

Ecosystems are environmental units comprising biocenoses and the abiotic components in a defined volume of space. They are characterized by a specific structure and function which result from the complex interactions between their components and contribute to their stability. While this latter property denotes the ability of a system to return to an equilibrium state after a limited temporary distrubance, resilience or buffering capacity as the complementary quality determines the persistence of relationships within a system and is a measure of its ability to adsorb changes of state variables and parameters. The major compartment soil is of paramount importance among the buffering components of any terrestrial ecosystem for both stability and resilience. Hence it should be considered one of the major tasks of an environmentally oriented soil science or sedimentology, respectively, to reliably define these capacities. In the context of the activities of the INQUA Loess Commission a limitation to loess soils appears appropriate. Therefore the paper first describes the basic structure of a comprehensive graph-model of the relevant relationships and defines mobility in soils as a particularly important characteristic of environmental chemicals.

1. SOIL WATER BALANCE AND FLUXES OF POTENTIALLY TOXIC SUBSTANCES

An assessment of the buffering capacity of soils requires a sufficiently detailed knowledge of the relevant physical and chemical transformation mechanisms in operation and their specific boundary conditions which comprise:

- colour, macro and microfabric of soils, horizon sequence, and chemical properties of the individual horizons
- water balance
- moisture and pH controlled cationic and anionic exchange capacities of soil horizons
- diffusion and dispersion phenomena as related to field capacity and actual soil moisture content
- microbial activity

In greater detail and precision the internal structures and manifold interrelationships of these subsystems can be depicted in a major synthetic model formulated in matrix or in graph forms, respectively. For technical reasons only two (minor) sections of it (FRÄNZLE, O. 1981) can be reproduced here. Basically they are formulated as a set of interrelated questions (cf. legend) which demand 'yes' (I) or 'no' (0) answers thus describing the fluxes of matter and energy (double arrows) through the surface and the various subhorizons of a soil in the form of cascading subsystems (FIG. 1).

Their structure is largely controlled by the regulators which can be devided into two groups. Firstly, there are the 'threshold regulators' (such as the cationic or anionic exchange capacities: KAK or AAK) which control storage decisions concerning the energy, water or toxic substances entering a subsystem. Secondly, there are 'dispositional regulators' which, although not presenting such obvious thresholds, control the disposition of energy of mass: for example, will one particular chemical be subject to solution in water, or not (LO)? After passing the regulators the fluxes of energy and mass (double arrows) may be diverted into stores of spatially and temporarily variable capacity (S_{BO}, OS, SSA, . . .). Both regulators and stores are influenced by sets of boundary conditions such as temperature (T), pH value (PH), redox potential (RED), which is depicted by means of dotted lines. It should be empasized that part of these regulators – particularly the threshold regulators – and of the boundary conditions are susceptible to human intervention, and it is one of the most important questions to reliably determine extent and consequences of such manipulations.

FIGURE 2 as an enlargement of FIGURE 1 reveals the paramount importance of adsorption and desorption processes which constitute an equilibrium. It depends primarily on the soil constituents with high specific surface and net charge, i.e. organic matter, clay minerals, and metal oxides and hydroxides. The relevant boundary conditions are: concentration and dissociation or polarity of the chemical entering the soil on the one hand, soil moisture, temperature, pH value, oxidation and reduction potentials on the other.

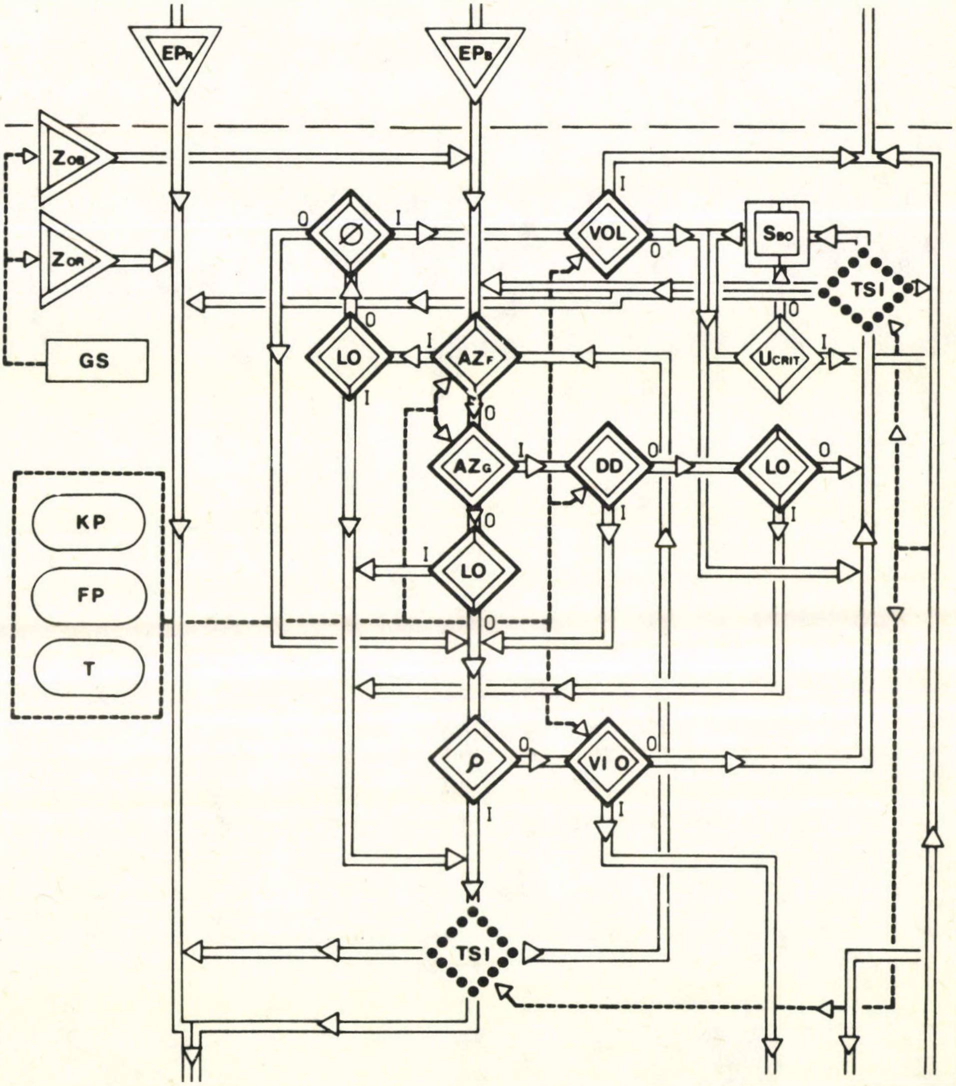


FIG. 1. Fluxes of environmental chemicals at the soil surface (extract from a comprehensive model in: FRÄNZLE 1981)

▷ Input / Output, ◇ Regulator, □ Storage element, ▭ Geomorphological boundary conditions, ⬭ Physical and chemical boundary condtions, ⁘ Transformation system, ◈ OECD Test guideline available, AZ_F = State of aggregate solid? AZ_G = State of aggregate gaseous? DD = Vapour density of substance higher than density of air? EP_B = Effective precipitation, loaded, EP_R = Effective precipitation, unloaded, FP = Melting point, GS = Geomorphological situation, KP = Boiling point, LO = Soluble in water? S_{BO} = Soil surface, T = Temperature, U_{CRIT} = Critical sheer strength exceeded? VI O = Highly viscose, high surface tension? VOL = Volatile? Z_{OB} = Incoming surface runoff, loaded, Z_{OR} = Incoming surface runoff, unloaded, ρ = Density of substance higher than density of water? ϕ = Diameter of particulate matter exceeding pore width?

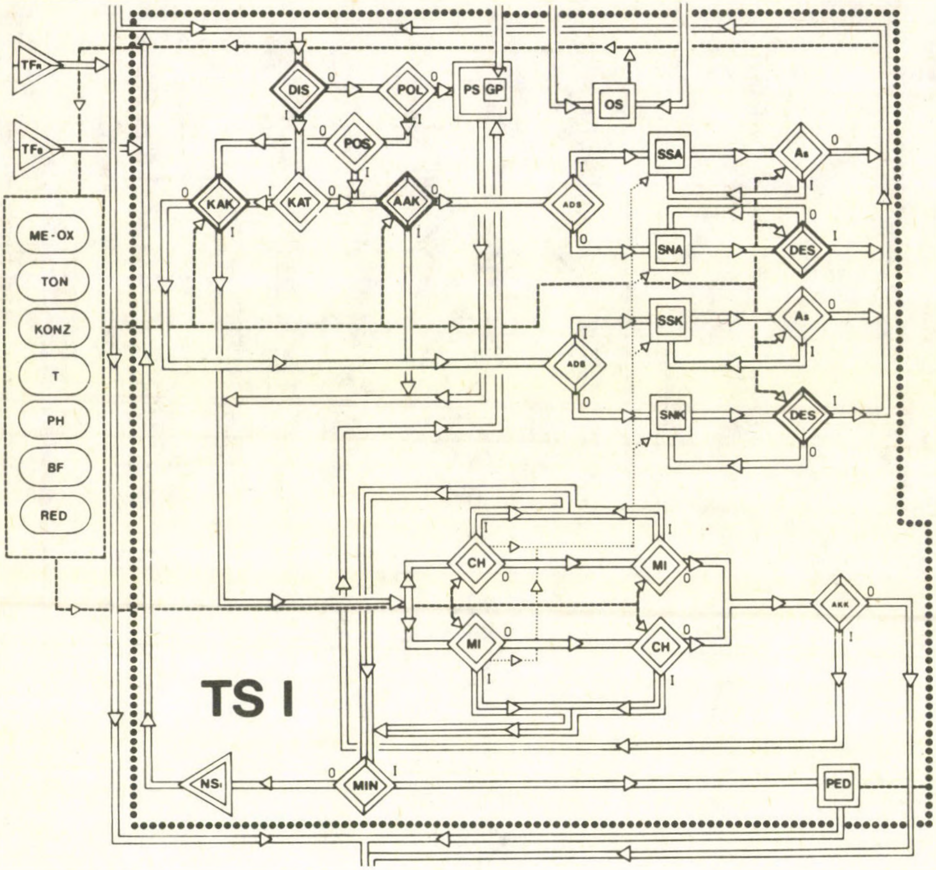


FIG. 2. Transformation operator I (TS I) (from: FRÄNZLE 1981)

▷ Input / Output, ◇ Regulator, ☐ Storage element, ⬭ Physical and chemical boundary conditions, ◈ OECD Test Guideline available, AAK = Anion exchange capacity exceeded? ADS = Adsorbed specifically? AKK = accumulated? A_S = Exchange colloids persistent? BF = Soil humidity, CH = Nonbiotically degraded? DES = Desorbed? DIS = Dissociated? GP = Major pores filled with air, KAK = Cation exhange capacity exceeded? KAT = Adsorbable due to cationic reactions? KONZ = Concentration of matrix solution, ME-OX = Metallic oxides and hydroxides, MI = Microbially degraded? MIN = Decomposed? NS_I = Newly formed toxic substances, OS = Organic matter, PED = Pedon, PH = PH value, POL = Polarized? POS = Sorption to positiv charges? PS = Porous storage, RED = Redox reactions, SNA = Nospecific adsorption in anionic form, SNK = Nonspecific adsorption in cationic form, SSA = Specific adsorption in anionic form, SSK = Specific adsorption in cationic form, T = Temperature, TF_B = Throughflow, loaded, TF_R = Throughflow, unloaded, TON = Clay mineral content and composition.

2. ADSORPTION COEFFICIENT AND RETENTION FACTOR

Since adsorption is the principal factor in leaching, a number of laboratory tests have been developed which primarily measure the effect of adsorption on leaching. The simplest index is the adsorption coefficient. Since chemicals with lower adsorption coefficients (K_{oc}) are leached to a greater degree, a ranking of a group of chemicals according to K_{oc} values is therefore a ranking of their tendency to leach. Provided the chemical undergoing adsorption migrates in cationic form the actual amount of leaching will vary from soil to soil, mainly in response to the organic carbon content. For this reason an adsorption coefficient can be defined approximately by

$$K_{oc} = \frac{\mu\text{g adsorbed / g soil organic carbon}}{\mu\text{g dissolved / g solution}} \tag{1}$$

This adsorption coefficient has the virtue of being roughly independent of any particular soil. A more precise relationship between soil adsorption and other soil properties can be established on the basis of comprehensive comparative experiments the results of which are evaluated by means of multivariate statistics. For the time being, however, data of this kind are only available for soils of the podzol and luvisol groups (FRÄNZLE, O. 1982), hence a spatial extrapolation is not yet possible.

Another quantitative index for leaching is the R_f value (i.e. retention factor) from soil thin layer chromatography as developed by HELLING, C.S. – TURNER, B.C. (1968) and HELLING, C. S. (1971).

$$R_f = \frac{1}{1 + (K_{oc})\,(\%\ oc/100)\,(d_s)\,(1/\theta 2/3 - 1)} \tag{2}$$

with θ = soil pore fraction, d_s = density of soil solid, oc = organic carbon, and K_{oc} as above (HAMAKER, J.W. 1975).

The correlation of R_f and K_{oc} data is shown in TABLE 1. The measured R_f values are from HELLING, C.S. (1971) and K_{oc} from a compilation by HAMAKER, J.W. – THOMPSON, J.M. (1972), the mobility class ratings are those assigned by HELLING, C.S. – TURNER, B.C. (1968).

The observed variability of (R_f Meas. – R_f Calc.) is probably due to uncertainty in K_{oc} drawn from investigations using many different soils. But the degree of correlation should be sufficient for a rough classification of pesticides as to relative mobility and for an evaluation of retention factors of soils.

3. RETENTION FACTORS OF GERMAN LOESS SOILS

This was accomplished by evaluating the analytical data of several hundred loess soils with regard to organic carbon, density of soil solid, and soil pore fraction (ZDECHLIK, W. 1981).

The soils were selected as a stratified sample on the basis of the 1:1 000 000 Soil Map of the Federal Republic of Germany (HOLLSTEIN, W. 1963) taking into additional account parent material and type of land use. In terms of the international nomenclature (FAO-Unesco 1972-1978) they comprise: Luvisols, Gleyic Luvisols, Gleysols, Cambisols, Luvic Chernozems, and Calcaric Regosols.

Their relevant chemical characteristics are summarized in TABLE 2.

By means of equations (1) and (2) a calculation of R_f values is possible on the basis of the individual oc, d_s, and θ data. For the test substance Diuron (3,4 dichloro phenyl – 1,1 dimethyl urea) the results are shown in TABLE 3, the differences between the mean Rf values being highly significant.

TABLE 1. Prediction of soil R_f values from adsorption coefficients (K_{oc}) and soil properties in a Hagerstown silty clay loam ($\theta = 0.5$, $d_s = 2.5$ g/cc, % oc = % om/1.724 = 1.40)

Pesticide	1/ K_{oc}	2/ Calc.	3/ Meas.	R_f Meas. – R_f Calc.	4/ Mobility Class
Chloramben	12.8	.79	0.96	.17	5
2,4-D	32	.60	0.69	.09	4
Propham	51	.49	0.51	.02	3
Bromacil	71	.41	0.69	.28	4
Monuron	83	.37	0.48	.11	3
Simazine	135	.26	0.45	.19	3
Propazine	152	.24	0.41	.17	3
Dichlobenil	164	.23	0.22	-.01	2
Atrazine	172	.22	0.47	.25	3
Chlorpropham	245	.17	0.18	.01	2
Prometone	300	.14	0.60	.46	3
Ametryne	380	.11	0.44	.32	3
Diuron	485	.09	0.24	.15	2
Prometryne	513	.09	0.25	.16	2
Chloroxuron	4,986	.01	0.09	.08	1
Paraquat	20,000	.002	0.00	-.002	1
DDT	243,000	.0002	0.00	-.0002	1
			Ave. =	.14± .27 (95% Conf.)	

1/ HAMAKER, J.W. – THOMPSON, J.M. (1972)
2/ Calculated according to equation (2)
3/ HELLING, C.S. (1971)
4/ HELLING, C.S. – TURNER, B.C. (1968)

TABLE 2. Variance statistics of selected properties of German loess soils
(n = 216 A-horizons)

	mean	variance	range	maximum
oc = org. carbon (%)	1.50	2.29	11.15	11.25
d_s = dens. soil solid (g/cm^3)	1.34	0.05	1.21	1.72
θ = soil pore fraction (%)	49.93	61.94	47.90	80.60

In horizon-wise differentiation the corresponding figures are summarized in TABLE 4, the significance level being the same as in TABLE 3.

TABLE 3. Variance analysis of R_f values of four major German loess soils and Diuron (n = 216 A-horizons)

Soil group	R_f (mean)	R_f (variance)
Luvisols	0.26	0.018
Cambisols	0.22	0.015
Gleyic Luvisols	0.20	0.010
Luvic Chernozems	0.15	0.002

TABLE 4. R_f values different subtypes of A-horizons of German loess soils with respect to Diuron (n = 216 A-horizons)

Soil group	R_f (mean)	R_f (variance)
A_h	0.17	0.004
A_p	0.18	0.006
A_1	0.32	0.018

CONCLUSION

The determination of soil leaching rates is important because they indicate how long a chemical is retained in the top soil where it is most liable to degradation or dissipation. In addition the rate of leaching is indicative of the possibility that a chemical will reach the ground water.

Leaching through soil is a complex phenomenon which is controlled by four major factors:

a. Soil adsorption is of paramount importance. The time spent by the chemical in the adsorbed condition causes it to lag behind the solvent. This chromatographic pattern is modified by the flow through soil as a porous medium.

b. Porous flow and diffusion produce a 'hydrodynamic dispersion' of the chemical. Owing to tortuous or smaller passages some of the liquid accomplishes less direct line movement than a solution taking a more direct path. In addition, the chemical may also diffuse into stagnant pores to be released slowly when the main body of chemical has passed.

c. Desorption introduces a hysteresis effect, principally through slow release of chemical from the soil matrix. Unless the water flow is extremely slow, there is a tendency for some of the chemical to trail behind the main body of liquid because the chemical cannot get off the soil fast enough.

d. The fourth factor is the pattern of rainfall and evapotranspiration which determines the infiltration into and movement of water through the soil. Chemicals are leached downward following a rain according to the rate of net precipitation, infiltration capacity, and field moisture capacity, but later, as evapotranspiration dries out the upper soil horizons, there is a compensating upward movement of water and chemical.

In view of the complex structure of 'real world' leaching field studies are difficult to analyze, and further work is urgently needed. It should aim at a quantification of the essential relationships depicted in the above graph model and pay particular attention to anionic substances. An analogous evaluation of R_f values for 2,4-D, an anionic test substance currently used for comparative leaching experiments (FRÄNZLE, O. 1982), would in fact not reveal any significant correlation with the amount of organic carbon.

As far as cationic substances are concerned or neutral ones as Diuron, the correlation with soil organic matter is highly significant (GROVER, R. 1975), and it is possible to use laboratory test results to compare the degree of leaching of one compound with another. Making appropriate allowance for the fact that leaching in soil coluns, as usually conducted, tends to overestimate the depth of penetration of a compound because of saturation flow, but also overlooks the variable fraction trailing behind the peak.

Depending on desorption rate this trailing fraction may become the main portion under field conditions.

Hence an evaluation of soil data by means of formula (2) should be restricted to chemicals displaying a neutral or cationic character under real world pH conditions. Then, however, the R_f values deduced may contribute to the assessment of the buffering capacity of soils. The corresponding mobility classes show that the environmental concentration of a chemical will not only depend on the inherent physical-chemical properties and the amount applied, but that it is also greatly influenced by the structures of the biotope in which a biotic system is exposed. Among these structures the buffering capacity of soils plays the major role.

REFERENCES

FAO – UNESCO 1972-1978: Soil map of the world. Paris.

FRÄNZLE, O. 1982: Erfassung von Ökosystemparametern zur Vorhersage der Verteilung von neuen Chemikalien in der Umwelt, Umweltforschungsplan des Bundesministern des Innern – Ökologie – Forschungsbericht 106. 02. 015.

FRÄNZLE, O. 1982: Modellversuche über die Passage von Umweltchemikalien und ihrer Metaboliten durch die ungesättigte Zone natürlicher Bodenprofile sowie durch Bodenschlämme in Laborlysimetern und im Freiland, Umweltforschungsplan des Bundesministers des Innern – Ökologie – Forschungsbericht 106. 02. 005/02.

GROVER, R. 1975: Adsorption and desorption of urea herbicides on soils. – Canad. J. Soil Sci. 55. 127.

HAMAKER, J.W. 1975: The interpretation of soil leaching experiments. – In: HAQUE, R. – FREED, V.H. (eds): Environmental Dynamics of Pesticides. New York.

HAMAKER, J.W. – THOMPSON, J.M. 1972: Adsorption. – In: GORING, C.A:I. – HAMAKER, J.W. (eds): Organic Chemicals in the Soil Environment. Marcel Dekker, Inc., N.Y.

HELLING, C.S. 1971: Pesticide mobility in soils, II: Applications of soil thin layer chromatography. – Soil Sci. Soc. Amer. Proc. 35. 737.

HELLING, C.S. – TURNER, B.C. 1968: Pesticide mobility: Determination by soil thin layer chromatography. – Science. 162. 562.

HOLLSTEIN, W. 1963: Bodenkarte der Geologischen Landesämter der Brundesrepublik Deutschland im Maβstab 1:1 Mio., Hannover.

ZDECHLIK, W. 1981: Eine regionalisierende Untersuchung der Bodenbelastbarkeit der Bundesrepublik Deutschland im Hinblick auf definierte Kohlenwasserstoffe. Unveröff. Staatsexamensarbeit. Kiel.

Address of author:
Prof. Dr. O. Fränzle, Geographisches Institut des Universitäts
Neue Universität Haus 82. Olshausenstrasse 40-60. 23 KIEL 1.– FRG

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

PRINCIPLES OF ENGINEERING–GEOLOGICAL MAPPING OF LOESS AND LOESS–LIKE ROCKS

**O.G. Gouneshian – N.I. Kriger – V.M. Kharchenko – V.I. Botnikov –
G.A. Zimina – A.D. Kozhevnikov – A.G. Petrov**

ABSTRACT

The detailed mapping of the distribution of loess and loess-like deposits is a special task. It is necessary to take into consideration the peculiarities of composition and properties of loess, the geographical zonation and local peculiarities of the landscape. Loess reacts sensitively to the effects of the geographical environment. Values of potential collapse, relative collapsibility, compressibility and other properties at different horizons are of greatest importance, thereby the concept of the engineering stratification of loess has been introduced. When prognosing changes of loess after the preriod of constructions, during the operation of buildings and structures, the authors use principles worked out on the basis of empirical data.

According to the principles worked out by POPOV, I.V. et al. 1950 and other researchers during engineering-geological mapping (mainly small scale) subordinate taxon units are distinguished successively by tectonic, geomorphological and lithological features.

Recently, besides theese regional features, it has also become the practice to account for geographical zonal peculiarities of engineering-geological conditions. The taxonomic range of geographical zonal units in some cases covers (SERGEEV, E.M. 1978) a range of regional taxons (double-range cross system of mapping) in other cases it relates to a general range of taxons (TROFIMOV, V.T. 1977). The taxonomic classification of units of engineering-geological mapping is as complex as the classification of landscape units. Therefore sometimes it is suggested that a composite system is superimposed against other taxons and accordingly related to climatical, tectonic and lithological features.

The importance of such a method is clearly seen when mapping the distribution of loess rocks covering different tectonic regions.

In this paper we deal with the detailed mapping of areas of loess and loess-like rocks, this calls for a special type of mapping.

In this case the peculiarities of composition and properties of rocks should be taken into consideration. It is also necassary to take into account not only the geographical zonation but also the local peculiarities of the landscape.

The engineering-geological mapping of loess has a number of peculiarities connected with the instability of loess properties with respect to saturation.

We suggest that the following principles represent the basis of engineering-geological mapping:

1. Large-scale engineering-geological maps are required as a basis for construction projects. It is true to note that the contents of maps can have a certain difference depending on the type of construction (POPOV, I.V. et al. 1950). Usually one suggests that a single obligatory method of engineering-geological mapping is necessary and adequate for all cases (BELYI, L.D. 1964).

Whatever extreme opinions are proposed we find that in the process of engineering-geological mapping one has always to take into account some general principles enumerated below.

2. The widespread use of I.V. POPOV's principle of mapping geological formations and geological genetic complexes supplemented with characteristics of engineering-geological rocks properties is of great interest. This principle takes into account the dependence of the properties of sedimentary rocks and associations on the paleogeographical situation at the time of sedimentation. Not ignoring the importance of this mapping principle (especially for small-scale maps) we propose that it is insufficient for the mapping of unstable geological bodies and rocks.

3. We subdivide all the rocks (and more complex geological bodies formed by them) in the superficial zone of lithosphere into inert and sensory ones.

The inert rocks (granite, gravel, sand) change but slowly under the influence of geological processes. The sensory rocks (loess, frozen rocks) react sensitively to the influence of the geographical environment, i.e. to the climate, topography, suface waters and organisms.

Therefore sensory rocks like soils are not only a part of the lithosphere, but also an inseparable part of the landscape. When working out a method and technique of engineering-geological mapping it is necessary to take into account the adaptability of the properties of sensory rocks to the present landscape. The properties of sensory rocks are changed violently during building operations and the construction process.

4. A landscape often reflects the geological structure of the area, a fact which is used in the process of landscape description or landscape geological survey. During this survey the airphoto and cosmic-photo interpretation assist in the

examination of the environment. In the areas of the distribution of sensory rocks these methods of investigation make clear the question of the retroactive influence of the landscape on these rocks.

It follows from the previous facts that mapping sensory rocks requires a special method which will account for the influence of the present geological environment on these rocks (KRIGER, N.I. 1953, KRIGER,N.I. – GRAVE,N.A. 1974).

Loess is a typical sensory geological body. Its collapse properties, porosity and easily dissoluble salt content depend on the moisture content of the rock which in its turn is a function of the geographical environment (topography, landscape, etc.). For example, FIG. 1 shows that the least moisture content and the greatest collapsibility are characteristic of loess distributed at the area of the elevated drainage divide. It follows from FIG. 2 that at the other region the distribution of collapsibility of loess, potential energy reserves and easily dissoluble salts are determined by an availability of a steppe climate. There are many such examples.

One can distinguish several types of dependence of the properties of loess and loess-like rocks on different factors of the geographical environment:

1. direct dependence, for example, dependence of moisture content on climate,
2. indirect dependence, for example, dependence of collapsibility on topography, by way of the moisture content of the loess (topography has an influence on moisture content).
3. apparent dependence. FIG. 3 makes it evident that the liquid limit of the loess (characteristic of granulometry in the precaucasian region) decreases while radiation aridity index increases, this occuring when the intensity of chemical weathering decreases. However, the granulometry of the loess was formed, on the whole, in the epoch of sedimentation of the dust and cannot depend on a recent value of the climate radiation aridity index R/Lr. The epoch of sedimentation (pleistocene) differed markedly from the current epoch. Observed dependence of the characteristic granulometry can be explained by the fact that a trend of distribution of R/Lr values in the epoch of loess dust sedimentation was analogous to the recent epoch (increase in eastern direction) even though their absolute values could be different. An epoch of buried soil formation was characterized by the more humid climate than the epoch of loess formation and that produced higher values of liquid limit of the soil horizon as compared to the loess horizon.

However, in the epoch of soil formation the aridity index increases in the eastern direction and values of liquid limit decrease in the same direction (BELYI,L.D. 1964).

In the process of engineering-geological mapping an engineer may be interested in different properties of loess and loess-like rocks. Values of potential total collapse of a loess stratum as well as relative collapsibility, compressibility and other characteristics of rocks at different horizons are of the greatest importance.

Potential collapse is a property of loess as a system because it depends on the thickness of a loess layer.

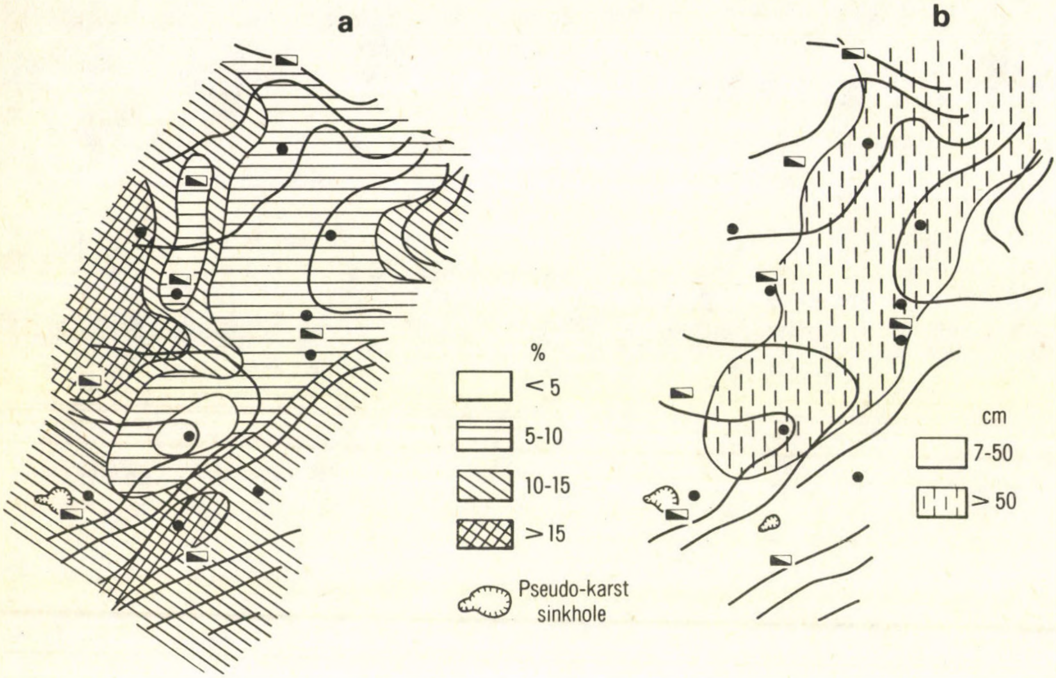


FIG. 1. Distribution of moisture content and relative collapsibility of loess on the experimental section near town of Javan (Tajikistan). a = Moisture content of loess, b = potential collapsibility

The total collapse depends on the relative collapsibility of rocks at different depths in accordance with moisture content, porosity, strength of structural bonds and with distribution of shear strength in the layer. The values of compressibility, shear strength, chemical and mineralogical composition, seismic and other properties of loess and loess-like rocks are changed at different depths and at different stratigraphical horizons.

Though these changes are not great (when the canges are great the rock ceases to be loess) they are of great practical importance. Therefore the concept of the engineering stratification of loess has been introduced.

When mapping characteristics of composition and properties of loess and loess-like rocks it is recommended that the mappers use average weighted values for all the strata of these rocks or for the first 10 metres. Moreover it should be taken into account that properties of the loess-like rocks of the upper 1-2 m usually change to some extent in different seasons of a year and sometimes it is expedient to obtain average values of characteristics for a depth of from 2 to 12 m.

The necessary requirement of engineering-geological mapping of loess and other sensory rocks and systems is their predicative character. A map of potential collapse allows the most valuable predictions to be made. Under water saturation other engineering-geological properties of loess rocks are changed (the modulus of deformation decreases and the specific cohesion varies). The addition of water to rocks is practically inevitable due to leakages from underground pipes and surface channels in areas of urban development, and regions of industrial and hydrotechnical construction.

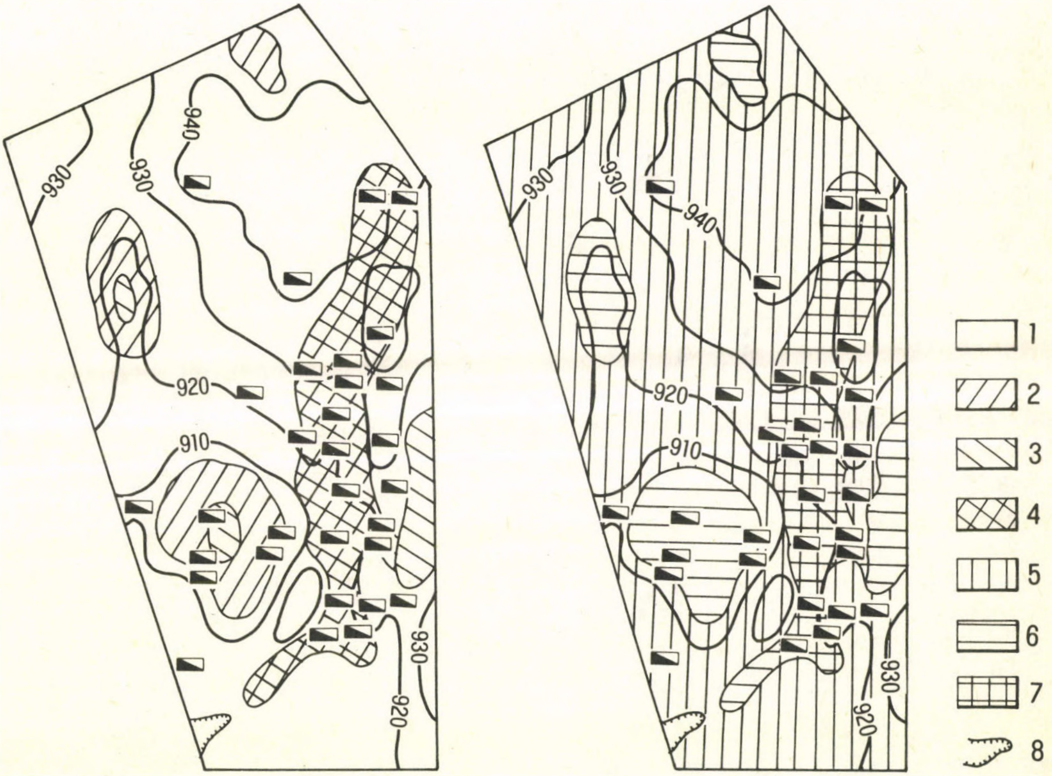


FIG. 2. Moisture content (A) and relative collapsibility (B) of loess deposits in the area of distribution of steppe minor depressions. Experimental section near town of Javan (Tadjikistan). Moisture content: 1 = (< 12%; 2 = (12-22%; 3 = (> 22% minor depression); 4 = (4-25%, area of distribution of pseudokarst). Relative collapsibility: 5 = (0.01-0.08); 6 = (⩽ 0.01); 7 = (0-0.02); 8 = (ravine)

When predicting changes of loess rocks after the construction period while the operation of building and structures is still in progress the authors take the following principles, which are worked out on the basis of empirical data. If at the base of loess strate impermeable rocks occur (e.g. clays, compact loess rock) the formation of an aquiferous horizon and a ground-water level increase as well as water accumulation in building and structure foundations would take place as a result of water loesses from the underground pipe network.

If loess is underlain by a permeable gravel then a water-bearing horizon is not formed but the moisture content of the loess rocks increases; the pore water content increases to 70-80%. If a reservoir with a large water surface area (one hectare or more) is involved then in all cases the pores of the loess rocks will be practically saturated and full of water, and thus a new aquiferous horizon is formed (KRIGER, N.I. 1976, KRIGER, N.I. – KOZHEVNIKOV, A.D. et al. 1978).

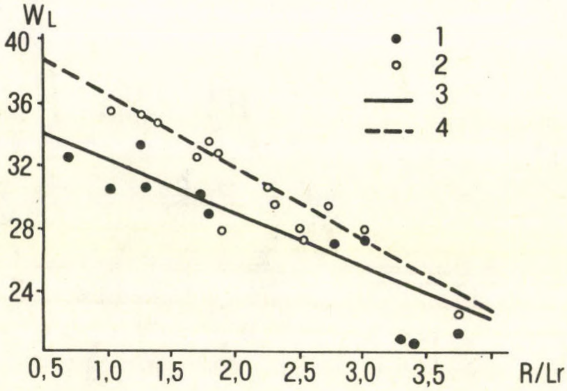


FIG. 3. Dependence of liquid limit WL of loess on radiation aridity index R/Lr in the North Caucasus.
1,3 = loess; 2, 4 = buried soils

If collapsibility at the construction area can be eliminated by a method of soaking, then the deformation modulus and shear strength of the rocks decrease to great extent. After the water is drained these parameters increase again. Draining can be described by the following equation (KRIGER, N.I. – BUINITSKY, V. F. et al. 1978) if the reservoir area is large:

$$W = W_o e^{-bt} + W_{bl}$$

where W – weight moisture, expected at a depth of h; W_{bl} – natural balance moisutre; t – time from arbitrary beginning of reading (preferably 1-2 months after the end of soaking, as such a time interval is required for draining of gravitation water); b – an empirical paramter; b – f (h); W_o – excess of moisture content over balance moisture in the moment of beginning a time reading.

An example of a predictive map of average moisture content of loess rocks of 10 m thickness in the process of drainage is shown in FIG. 4.

In this article we have considered only the principal problems related to some specific features of engineering-geological mapping of loess as a sensory geological formation.

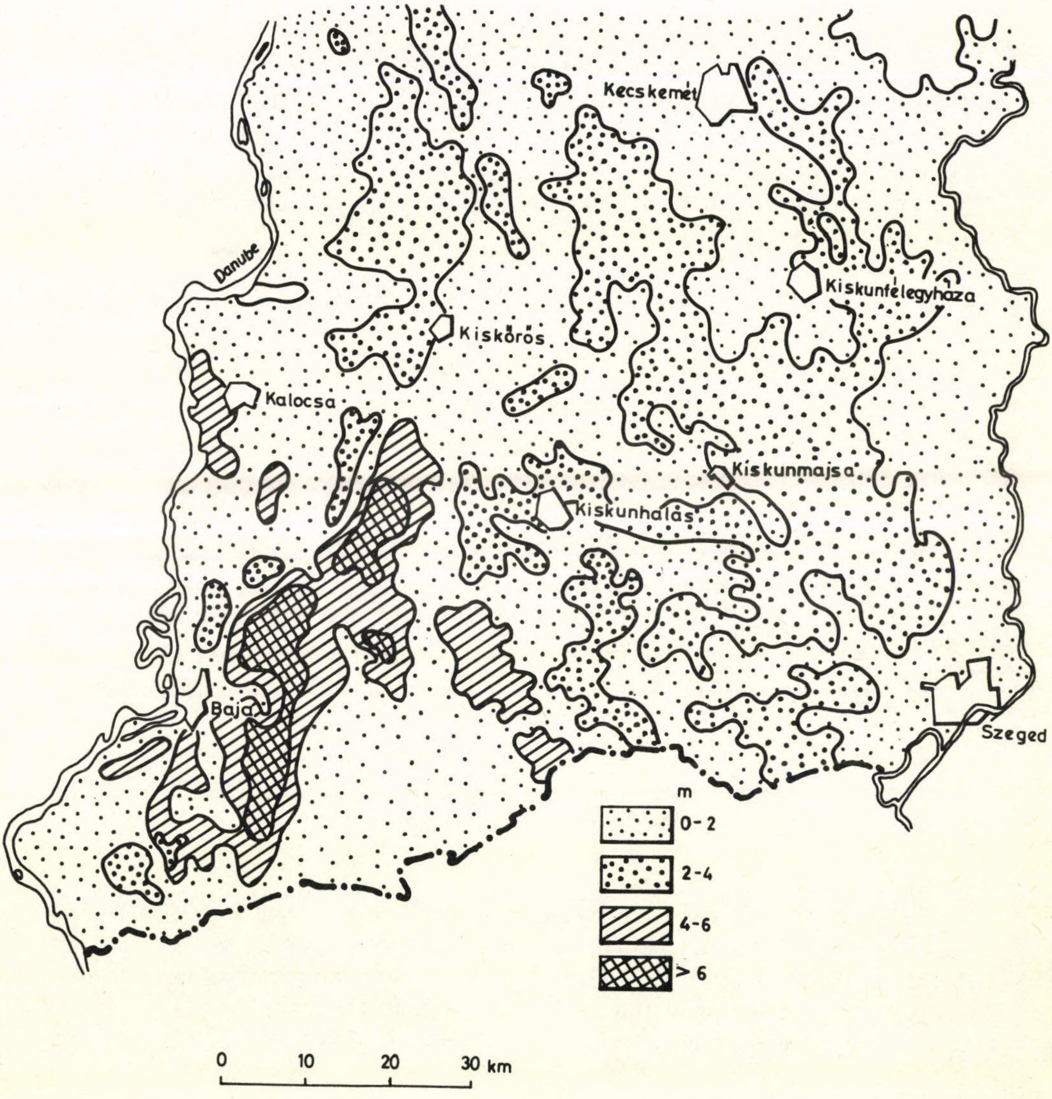


FIG. 2. Map of the depths of groundwater table in Hungary (Average of years 1956-1969)

In additon to natural parent materials, the land utilization and agrotechniques also play important role taking into account the different features of sand soils.

Irrigation is more favourable in the multi-layer humic sand soils than in sand mantles, and the effect of fertilizers is different in the various subtypes and varieties of sand soils. Thus, the relationship between the peculiarities and fertility of sand soils was supposed by authors.

Numerous references are found in the Hungarian literature on the fertility of sand soils. Out of them the elaboration of different deep-fertilizing methods are of old traditions (ANTAL, J. 1956, EGERSZEGI, S. 1953). In relation with the laminated sand melioration numerous results were obtained being useful also for the practice (LÁNG, I. 1957, 1961, LÁNG, I. – GÁTI F. 1958).

In the studied region previous geomorphological researches are also available which also took into account the ground water budget (ERDÉLYI, M. 1955, MOLNÁR, B. 1965, RÓNAI, A: et al. 1971, SÜMEGHY, I. 1952, PÉCSI, M. 1959, 1967, 1970, PÉCSI M. – ZENTAY I. – GEREI L. 1982. URBANCSEK, I. 1963).

GEOMORPHOLOGY

In the opinion of the overwhelming majority of the researchers the Danube-Tisza Interfluve is a remnant of the Pleistocene large alluvial fan of the Danube. At least from the last interglacial its surface was not affected by the Danube's erosion-accumulation activity, thus the surface consists mainly of loose permeable eolian sediments. Semi-bound sand dunes and extended thin sand mantles alternate with sandy loess and flat surfaces covered by loessic sand. In the depressions between the dunes different impermeable sediments (meadow clay, meadow limestone-dolomite, dolomitic-lime-muddy loess) are found (FIG. 1).

The deeper strata of the flat alluvial fan are built up of fluviatile sand, sandy mud and clay and subordinately eolian sediments, i.e. transformed loess-like deposits and blown sand are intercalated. In the last interglacial and in the dry periods of the Early Holocene the fluviatile sediments were redeposited by wind to considerable measures.

In our recent knowledge, in the last interglacial the Danube was active in its recent bed of N-S direction. In the last glacial the formation of blown sand and loess was characteristic in the dry surface of the alluvial fan. The prevailing NW wind blow out elongated depressions of the same direction from the sand material of the interfluve. Locally large-scale dune groups were developed, which rise above extensive flat basins by their relative height of 50 to 20 m.

The surface of the Danube-Tisza interfluve is separated into several smaller geomorphological districts of different character. Out of them the sand-mantled environment the sandy loess of the vicinity of Kecskemét falls partly within the studied areas. Here the elongated fossil sand dunes are covered by loess in a thickness of 1.5 to 2.0 m and in the flat oval small basins lying between them a chain of sodic lakes is found.

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

RELATIONSHIP OF THE GEOMORPHOLOGICAL POSITION, GENETIC, PHYSICAL, CHEMICAL AND MINERALOGICAL FEATURES OF SAND SOILS WITH THEIR FERTILITY

M. Pécsi – T. Zentay – L. Gerei – Mrs. M. Reményi

ABSTRACT

Based on 15 years of experience of the cooperative farm in the studied sand soils the following average yields of wheat could be determined:

In blown sands no agricultural cultivation was carried out because of the expected low rentability.

In humous sand soils the average yield of wheat was 2.0-2.6 t/ha in case of medium-thick humic layer and 3,0-3,5 t/ha in case of deep humic layer.

In multi-layer humous sand soils the wheat yield exceeded 4 t/ha. Accordingly, based on their fertility the sand soils of the cooperative can be classified as follows:

1. Soils of high fertility.
    a. multi-layer humous sand soils,
    b. sandy chernozem meadow soils.

2. Soils of medium fertility
    Humous sands.

3. Soils of low fertility
    a. blown sand soils,
    b. sand mantle soils

The soil acidity and the depth of groundwater below the surface were found to be disadvantageous for soil fertility. When the groundwater table is closer to the surface than one metre, this may make roots drown.

Different types of calcareous sand soils cover large areas in the Danube-Tisza Interfluve of Hungary. The fertility of these sand soils highly differs. Many subtypes and varieties are found from the infertile blown sands to the fertile humic sand soils. Their formation has been governed by the ground water budget depending on geomorphological conditions, i.e. their parent materials are responsible for their fertility.

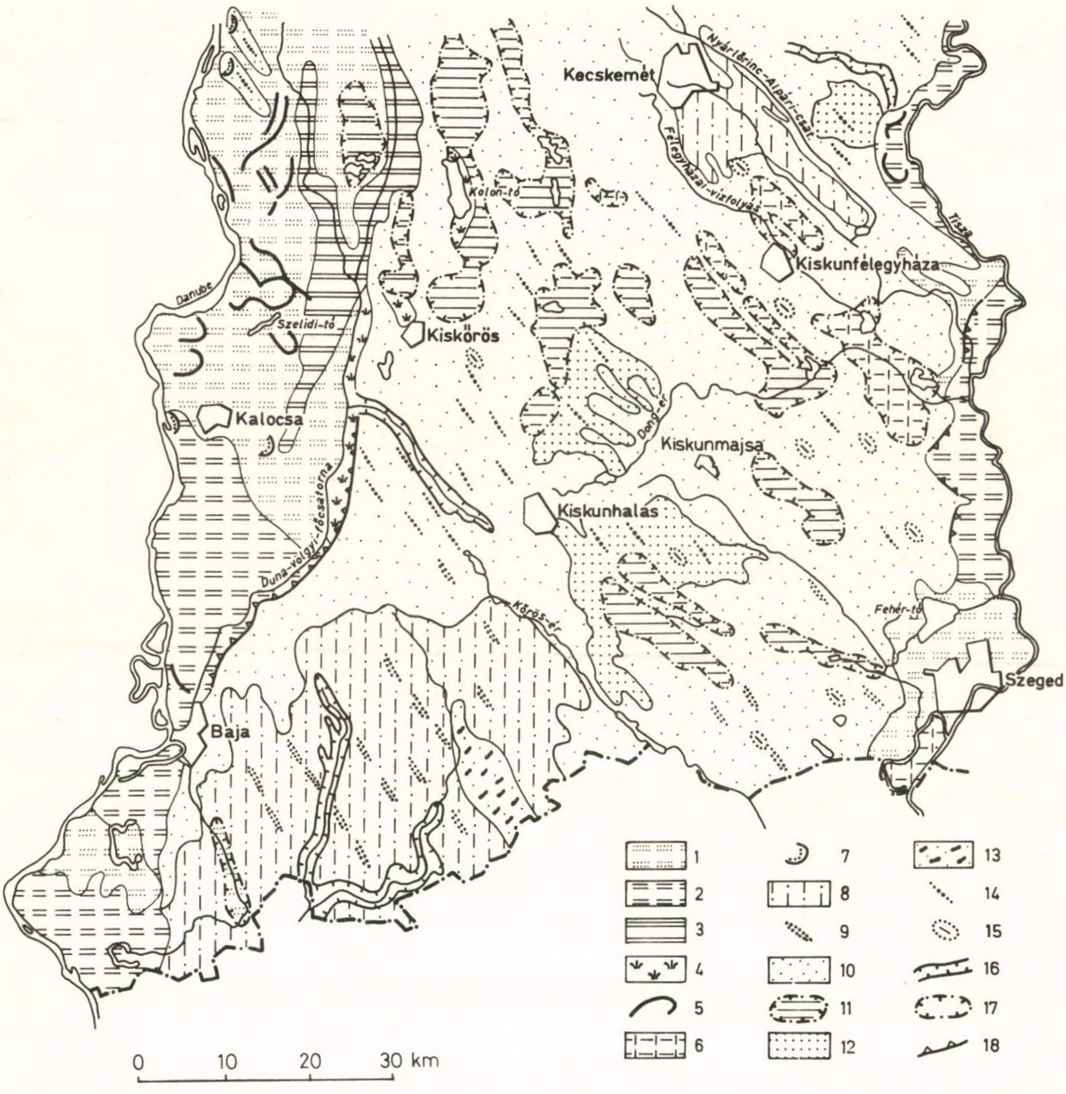


FIG. 1. Geomorphology of the study area (M.PÉCSI) 1 = high flood-plain covered by loess mud, 2 = low flood-plain with alluvial mud, 3 = salt affacted clays of the flood-plain, 4 = peaty backwaters and intra-dune depressions, 5 = filled meander of backwaters, 6 = meadow clays of the high flood-plain, 7 = bank dunes on the high flood-plain, 8 = alluvial fan covered by sandy loess, 9 = longitudinal dunes with loess cover, 10 = alluvial fan covered by blown-sand and cover sand, 11 = salt affected intra-dune depressions with calcareous muds, 12 = semi-bound surface with sand dunes, 13 = sand dunes covered by chernozems, 14 = region of stabilized sand dunes, 15 = deflation depression, 16 = erosion valley, 17 = salt affected basins and small embanked basins, 18 = inactive steep bank.

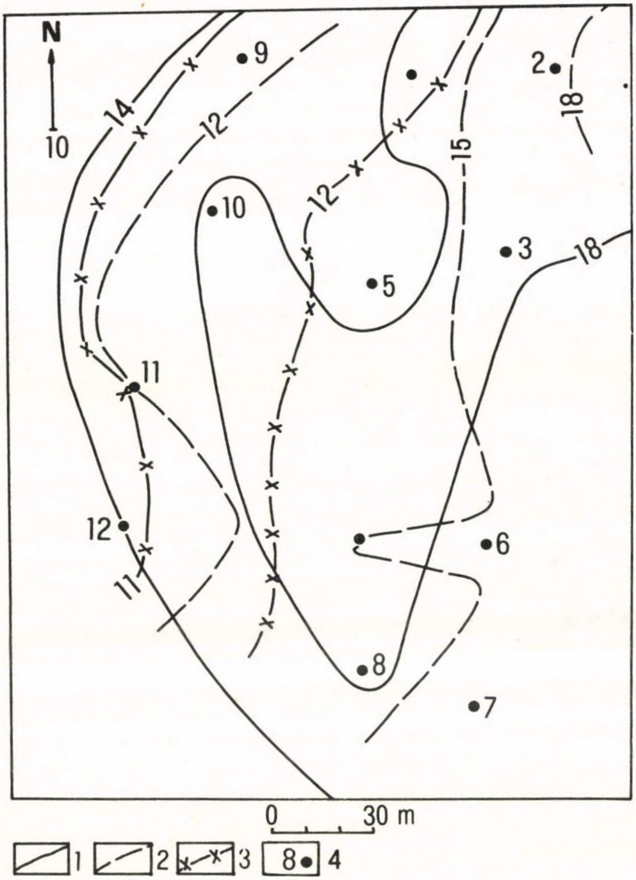


FIG. 4. Prognosis scheme of the distribution of average values of moisture content of 10 m loess series. Experimental section in the town of Doushanbe. Worked out by D.A. TOULABAEV and N.I. KRIGER. Isolines of moisture content of loess after the termination of preliminary saturation. 1 = in 0.5 year (experimental data); 2, 3 = in 5.5 and 10 years (calculated data); 4 = number of sampling site

REFERENCES

BELYI, L.D. 1964: Theoretic foundation of engineering-geological mapping. Moscow. Nauka. 168. (In Russian)

KRIGER, N.I. 1953: K metodike inzhenerno-geologicheskogo izucheniya prosadochnykh gruntov. (To methods of engineering-geological study of collapsable soils.) – Materaly po inzh. geol. 1953. 3. 96-107.

KRIGER, N.I. 1960: Engineering stratigraphy and relation of loess stratum to landscape in connection with estimation of their collapsibility. – In: Proceedings on construction on loess-like soils in Dnepropetrovsk in May 1957. Kiev, Publ. Acad. Construction and Architecture of the Ukrainian SSR. 105-117. (In Russian)

KRIGER, N.I. 1965: Less, ego svoistva i svyaz's geograficheskoi sredoi. (Loess, its characteristics and relation to geographic medium.) Moscow. Nauka. 296.

KRIGER, N.I. – GRAVE, N.A. 1974: O kartirovanii inzhenerno-geologicheskykh svoist gornykh porod kontinentalnogo proiskhozhdeniya. (On mapping engineeering-geological characteristics of rocks of continental origin.) – Trudy Proizv i n.-i. in-ta po inzh. izyskaniyam v stp-ve Gosstroya SSSR. 3a. Moscow. Stroyizdat. 78-87.

KRIGER, N.I. – BOTNIKOV, V.I. 1979: Paleogeography of Pleistocene and loess formation in the Pre-Caucasus. – Doklady AN USSR. 245. 4. 902-905.

KRIGER, N.I. – KOTELNIKOVA, N.E. – SEVOSTYANOV, V.V. 1978: Lithoecological principle of engineering-geological mapping of territories with loess-like soils development. – Engineering investigations for construction. Refer. inform. issue I (66) 8-11. (In Russian)

KRIGER, N.I. – ALESHIN, A.S: – KOZHEVNIKOV, A.D. – MINDEL, I.G. 1980: Seismicheskie kharakteristiki lessovykh porod v svyazi s geologicheskim okruzheniem i tekhnogenezom. (Seismic characteristics of loess in relation to geological environment and technogenesis.) Moscow. Nauka. 104.

KRIGER, N.I. – BUYNITSKY, V.F. – GORYUNOVA, L.A. – DZHAFAROV, R.M. – KOTELNIKOVA, N.E. 1978: Migratsiya vody pri zamachivanii i osuchenii lessovykh porod. (Water migration under flooding and drainage of loess-like soils.) -- In: Trudy Proizv. i n.-i. in-ta po inzh izyskaniyam v stp-ve Gosstroya SSSR. 57. 37-67.

KRIGER, N.I. – KOZHEVNIKOV, A.D. – KOTELNIKOVA, N.E. – LAVRUSEVICH, S.I. – SEVOSTYANOV, V.V. 1978: Variation of moisture regime and seismic characteristics of loess within an aeration zone of built-up territories. – In: Flooding of built-up territories with groundwaters and engineering protection of them. (Proc. all-union scient. – techn. conf.) Tashkent. 50-53. (In Russian)

POPOV, I.V. – KATS, R.S. – KORIKOVSKAYA, A.K. – LAZAREVA, V.P. 1950: Metodika sostavleniya inzhenerno-geologicheskikh hart. (Methods of compiling engineering-geological maps.) Moscow. Gosgeolizdat. 44. 4 maps.

SERGEEV, E.M. 1978: Inzhenernaya geologiya. (Engineering geology.) Moscow. MGU. 384.

TROFIMOV, V.T. 1977: Regularity of distance variety of engineering-geological conditions of the Western Siberian plate. Moscow. MSU. 278. (In Russian)

Address of authors:
O.G. Gouneshian, N.I. Kriger, V.M. Kharckenko, V.I. Botnikov, G.A. Zimina, A.D. Kozhevnikov, A.G. Petrov: Geographical Research Institute for Construction Engineering (PNIIILS)
Okruzhnoy proezd 18. 105058 MOSCOW – USSR

The sand region of Majsa-Dorozsma lies south-southwest of the former. Its regular monotonous ranges of NW-SE strike are varied with the intercepting dolomitic-lime-muddy flat depressions of salt affected soils.

According to data from the wells observing the seasonal variation of groundwater, in the blown sand area the groundwater table essentially follows the topography (FIG. 2).

PHYSICAL, CHEMICAL AND MINERAL PECULIARITIES OF THE STUDIED SOIL PROFILES (TABLES 1, 2, 3)

To compare the peculiarities and fertility of sand soils, the soil profiles were chosen from the sand regions of the cooperative farm in the environs of Szeged. Based on the results of the past fifteen years the chief agronomist of the cooperative farm „Polish-Hungarian Friendship" marked the fields of low, medium and high fertility.

In this paper not all the profiles but a typical one for each region of different fertility will be discussed.

PRIMORDIAL FEATURES OF SAND SOILS FROM THE POINT OF VIEW OF THEIR FERTILITY (FIG. 3)

In sandy areas of low fertility blown sand soils and sand mantles are found.

Blown sand soil. The land surface is covered by sand dunes and highly endangered by deflation. At the time of observation the depth of groundwater table was about 2.77 m, i.e. the water supply of the soil was not affected by the groundwater. The humic horizon is very thin, about 10 cm (in the underlying horizon of 17 cm thickness only a small amount of humus is found).

Down to 130 cm the profile does not contain $CaCO_3$, thus the degree of Ca-supply is insufficient.

Down to 160 cm depth the high sand fraction (92 to 95%) and the low clay fraction (2.6 to 3.6%) are responsible for the weak water holding capacity of the soil and together with the unfavourable humus conditions for the weak water and nutriment storage capacities, as well.

All these agronomically unfavourable features are responsible for the presence of primeval grass which can be utilized only as poor grazing land.

Hydromorphous soils of sand mantle

The soil consists of a fertile humic horizon overlain by an infertile humus-free (raw) sand horizon. Subsequently to its formation in the upper horizon small quantity of humus accumulated due to fertilization by organic manure. The soil surface in undulating, this relates to the movement of sand before soil strengthening. The groundwater table was found at a depth of 1.39 m; this fact considerably improves the water budget of the soil. The groundwater, which does not contain harmful salts, exerts advantageous impact on soil fertility.

TABLE 1. Physical and chemical investigations of sandy soils

Depth m	$CaCO_3$ %	H %	pH dist. w.	 KCl
0.010	0	1.29	7.8	6.9
0.10 – 0.27	0	0.43	7.8	6.9
0.27 – 1.30	0	0	7.7	6.7
1.30 – 1.50	2.57	0	7.9	–
1.50 – 1.60	2.14	0	8.0	–
1.60 – 1.94	10.72	0.86	8.4	–
1.94 – 2.77	17.15	0	8.6	–
0 – 0.08	0	0.65	7.5	6.7
0.08 – 0.79	0	0.21	7.6	6.7
0.79 – 0.96	1.70	0	7.8	6.8
0.96 – 1.35	2.56	0	8.1	–
0 – 0.17	1.29	0.65	8.1	–
0.17 – 0.28	3.00	0.43	8.3	–
0.28 – 0.69	0.86	0	8.0	–
0.69 – 1.32	10.29	0	8.5	–
0 – 0.24	0	0.43	7.8	6.9
0.24 – 0.41	0	0.21	7.6	6.8
0.41 – 0.68	0	0.11	7.6	6.8
0.68 – 0.83	0	0.21	7.8	6.9
0.83 – 1.12	0	0	8.0	–
1.12 – 1.71	16.12	0	8.5	–
0 – 0.11	0.85	1.51	8.0	–
0.11 – 0.37	2.14	1.08	8.0	–
0.37 – 0.86	1.71	0.65	8.3	–
0.86 – 1.09	35.15	0	8.5	–

Mechanical composition %				Exchangeable mg eq/100 gr			Horizon	Type
clay	silt	loess	sand	Ca	Mg	T		
3.62	1.60	2.06	92.16	4.88	1.95	13.12	A_1	Weakly humous blown-sand
2.54	1.47	0.58	94.77	0.98	0.98	3.86	A_2	
3.10	0.04	0.23	95.76	–	–	–	C	
2.63	1.25	0.84	94.62	–	–	–		
2.63	1.93	0.31	94.82	–	–	–		
13.07	4.06	2.69	79.75	–	–	–		
11.84	3.36	1.64	82.44	–	–	–		
2.73	0.79	0.61	95.17	1.95	0	3.86	A	Hydromorphous sandy soils covered by blown-sand
2.48	0.76	0.30	94.90	0.98	0	3.09	CA	
2.31	0.46	0.54	96.12	0.98	0.98	3.09	CB	
3.47	1.14	1.53	93.21	–	–	–	CC	
3.53	1.30	0.23	94.43	1.95	0.98	3.86	ASz	Hydromorphous humous sandy soil with deep humous layer
2.78	1.86	1.93	92.65	1.95	0.98	3.86	A	
3.01	0.92	0.56	94.47	1.95	0	3.09	B	
3.25	1.77	1.81	91.69	–	–	–	C	
2.36	1.97	1.03	93.86	0.98	0.98	3.86	A	Humous sandy soil with more humous layers
3.81	0.63	0.81	93.75	–	–	–	B	
5.66	1.52	1.72	89.87	1.95	0.98	6.18	CA	
5.41	1.87	2.53	89.54	–	–	–	CB	
4.40	1.13	1.09	92.70	–	–	–	CC	
4.74	1.99	1.21	91.76	–	–	–	CC	
4.95	1.09	0.77	92.98	2.93	0.98	8.49	ASz	Sandy chernozem meadow soil
5.50	2.61	0.58	90.48	2.93	0	7.72	A	
8.73	4.93	1.25	84.97	4.88	0.98	10.81	B	
22.26	7.26	3.95	64.82	–	–	–	C	

TABLE 2. Mineralogical composition of clay fractions of sandy soils

Horizon	Depth (m)	Quartz	Feldspar	Illite	Montmo-rillonite	Chlorite	Illite-Montmo-rillonite	Illite-Chlorite	Kaolinite	Type
A_1	0.00 – 0.10	5	2	48	5	15	10	10	5	Weakly humous blown-sand
A_2	0.10 – 0.27	5	2	48	5	15	10	10	5	
C	0.27 – 1.30	5	2	36	10	17	10	15	5	
	1.30 – 1.50	5	2	43	10	15	10	10	5	
	1.50 – 1.60	5	2	28	15	25	10	10	5	
	1.60 – 1.94	5	2	33	15	20	10	10	5	
	1.94 – 2.77	5	2	30	10	23	10	15	5	
A	0.00 – 0.08	7	3	50	–	20	–	20	–	Hydromorphous sandy soil covered by blown-sand
CA	0.08 – 0.79	10	3	47	–	20	–	20	–	
CB	0.79 – 0.96	8	5	37	–	20	–	30	–	
CC	0.96 – 1.35	5	3	42	15	15	–	20	–	
A_{Sz}	0.00 – 0.17	5	2	33	10	20	10	20	–	Hydromorphous humous sandy soils with deep humous layer
A	0.17 – 0.28	5	3	33	8	18	18	15	–	
B	0.28 – 0.69	5	3	40	7	15	15	15	–	
C	0.69 – 1.32	7	3	40	10	20	10	10	–	
A	0.00 – 0.24	5	2	55	10	15	–	10	3	Humous sandy soil with more humous layers
B	0.24 – 0.41	6	3	35	15	20	–	15	6	
CA	0.41 – 0.68	5	3	52	10	20	–	10	–	
CB	0.68 – 0.83	8	2	42	10	10	–	20	8	
CC	0.83 – 1.12	10	2	43	15	15	–	10	5	
A_{Sz}	0.00 – 0.11	5	2	43	–	25	–	25	–	Sandy chernozem meadow soil
A	0.11 – 0.37	5	3	52	–	20	–	20	–	
B	0.37 – 0.86	5	2	53	–	15	15	10	–	
C	0.86 – 1.09	5	2	48	–	48	15	15	–	

TABLE 3. Mineralogical composition of sandy soils

Horizon	Depth	Quartz	Mica	Feldspars		Calcite	Dolomite	Chlorite	Illite-montmorill.	Type
				Potassium	Plagioclase					
A_1	0.00 – 0.10	65	14	–	14	2	–	5	–	Weakly humous blown-sand
A_2	0.10 – 0.27	53	20	8	11	2	–	6	–	
C	0.27 – 1.30	57	17	–	18	2	–	6	–	
	1.30 – 1.50	73	7	–	13	3	–	4	–	
	1.50 – 1.60	50	12	–	25	8	–	5	–	
	1.60 – 1.94	51	11	5	11	10	6	6	–	
	1.94 – 2.77	39	10	–	18	18	5	10	–	
A	0.00 – 0.08	61	12	7	14	–	–	6	–	Hydromorphous sandy soil covered by blown-sand
CA	0.08 – 0.79	67	10	–	16	–	–	7	–	
CB	0.79 – 0.96	56	9	4	26	3	3	5	–	
CC	0.96 – 1.35	60	12	–	16	3	3	6	–	
A_{Sz}	0.00 – 0.17	57	11	5	14	2	2	9	–	Hydromorphous humous sandy soil with deep humous layer
A	0.17 – 0.28	55	9	–	27	2	2	5	–	
B	0.28 – 0.69	67	12	–	12	2	2	5	–	
C	0.69 – 1.32	47	9	–	16	13	9	6	–	
A	0.00 – 0.24	50	11	–	32	–	–	7	–	Humous sandy soil with more humous layers
B	0.24 – 0.41	53	10	–	30	–	–	7	–	
CA	0.41 – 0.68	54	18	–	23	–	–	5	–	
CB	0.68 – 0.93	50	15	–	28	–	–	7	–	
CC	0.93 – 1.12	57	12	3	18	2	2	6	–	
A_{Sz}	0.00 – 0.11	54	11	–	27	2	2	4	–	Sandy chernozem meadow soil
A	0.11 – 0.37	60	12	–	20	2	2	4	–	
B	0.37 – 0.86	57	12	–	20	–	3	8	–	
C	0.86 – 1.09	35	14	–	10	28	3	6	4	

The quantity of humus is low, but the thickness of the humic horizon is considerably greater than in blown sand soils. The degree of lime supply of the soil is low, down to 8o cm it does not contain considerable amounts of calcium carbonate. The high sand (95-96%) and low clay (2-3%) fractions are responsible for the low water holding capacity. The small amounts of inorganic and organic colloids cause the low water and nutriment storage capacities of the soil. Nevertheless, the thicker humic horizon (as compared to blown sand soils) and the better water supply produce somewhat better fertility in these soils. This accounts for the cultivation of this soil type, but the sparsely germinated autumn wheat refers to its unfavourable agronomic features.

The regions of medium fertility are characterized by hydromorphous sand soils with deep humic horizons.

Hydromorphous humous sand soil with deep humic layer. The profile is found in a flat region lying somewhat lower than its environment. The non-sodaic groundwater found at a depth of 130 cm provides good water supply. The quantity of humus is small but the humic horizon starting from the surface is deep, i.e. 69 cm. (At the base of the humic horizon the small quantity of humus cannot be identified by chemical methods but its presence unambiguously be determined.) As compared to the soils enumerated

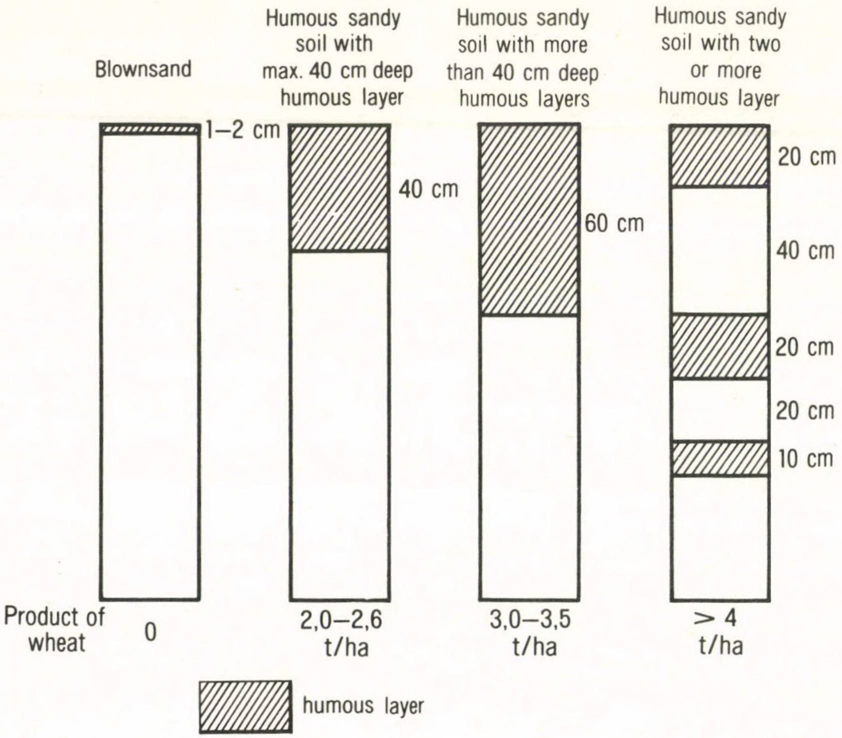


FIG. 3. Connection between productivity and types, subtypes of the sandy soils

above, the degree of lime supply of this soil is better since it contains small quantities of carbonic lime just from the surface. The high sand (92-94%) and low clay (about 3%) fractions unfavourably affect the water and nutriment storage capacities of this soil. The deep humic horizon together with the good water supply exerts advantageous effects on soil fertility. This soil can, therefore, be ranked among soils of medium fertility in the given farms. This is also indicated by the densely germinated autumn wheat in the plot represented by the profile.

In the sand regions of good fertility multilayer humous sand and sandy meadow soils were described.

Hydromorphous multilayer humous sand soil. The soil is found on the top of a slightly undulating relief. The depth of groundwater table is 1.70 m which provides favourable water supply. In the soil profile three humic horizons occur within one metre, their thicknesses being 24, 27 and 15 cm, respectively. The three humic horizons in these soils highly improve the water and nutriment storage capacities. The degree of lime supply is weak since the soil does not contain considerable amounts of calcium carbonate down to about 1 m depth. The sand fraction (90 to 94%) refers to the sandy character of the soil, but the somewhat higher amount of the clay fraction (2.36 to 5.66%) provides better water and nutriment storage capacities. This is indicated by the 6.18 mg equivalent /100 g soil absorption capacity value found in the buried CA horizon.

Consequently, in the multilayer humous sand soils the humic horizons underlying each other, the somewhat higher quantities of clay and the good water supply result in very advantageous features from the agronomic point of view. This statement has been supported by the many years' experiences of the farm.

Sandy chernozem meadow soil

The surface of the soil is flat and it lies somewhat higher than the soils above. The depth of the groundwater table is 174 cm, it exerts favourable effect on the soil's water supply and it does not contain harmful salts. The groundwater is of primordial significance in the soil formation process and it is the precursor of a meadow soil formation trend. As a result of this trend a thick (86 cm) humic layer was generated.

As compared to the previous soils, its humus content is higher, i.e. 0.65 to 1.51%. Less intensely, the chernozem soil formation process also occurs, in addition to the meadow soil formation trend. In the horizons A and B this process is marked by the apparent crumbly structure. The degree of $CaCO_3$ supply is somewhat better than in case of the former soils since it contains carbonic lime just from the surface though in small quantitaties.

In the A and B horizons the sand fractions are somewhat lower than in the other soils studied. The amounts of clay fraction is higher in these horizons, they vary between 5 and 8.7%. Due to the intense weathering during the meadow soil formation process, the clay fractions generated in thick layers highly improve the water and nutriment budget of this soil. The sandy chernozem meadow soil is a good example for the control of the soil formation process over soil fertility. In this soil type the deep humic horizon, the higher humus content and the considerably higher clay content, further the developing crumbly structure as well as the good water supply result in improved soil fertility. This statement is supported by the densely germinated autumn wheat by the many years' experience of the farm.

Consequently, in the given area the fertility of sand soils is primarily controlled by the factors below:

1. the soil types, subtypes and varieties,
2. the depth of the groundwater table,
3. the number, thickness and humus content of the humic layers,
4. the degree of $CaCO_3$ supply of the soils,
5. the quantity of the clay fraction.

CONCLUSION

1. In some soils the upper horizons are free of lime, moreover, locally exchangeable acidity is also shown. This fact may be related to the large-scale leaching in the soils.
2. In the profiles basic pH was determined in many cases besides zero lime content. The dissolution of calcite may be responsible for this. This is against the conclusion that the adsorbed Ca quantity is low in 100 g soil. Nevertheless, in the small amount of clay fraction of the sand soils small quantities of calcium may play also an important role.
3. In sand soils humus was determined in relatively small quantities. This phenomenon is caused by the aerobic conditions in the upper soil horizons which promote the rapid decomposition of humus.
4. In the surficial layers somewhat higher humus content was found also in the soils of poorer quality, than in the deeper horizons. This phenomenon can be attributed probably to the long-lasting organic fertilization and to the denser rootlet development.
5. On the basis of mineral composition alluvial layer of different origin can be distinguished.
6. In the mineral composition of the soils quartz and feldspar are predominating. The studied sand soils are relatively poor in micas.
7. In the fine disperse fraction illite predominates on the whole. The illite-chlorite mixed-layer structure occurs also in considerable amounts. This fact refers probably to hydromorphous effects.
8. In the fine disperse fractions of the studied soils the clay minerals of high adsorption capacity are present in relatively high amounts. This verifies the significant role of the fine disperse fraction in the adsorption capacity of these soils, i.e. also in their water and nutriment storage capacities, as well. This is significant also in the soils of low amounts of fine disperse fraction.
9. The water and nutriment budget of the multi-layer humic sand soils is much better than that of the blown and mantle sands. This is caused, in part at least, by the higher percentage of illite and montmorillonite in the fine disperse fraction.

REFERENCES

ANTAL, J. 1956: Aljtrágyázási és zöld aljtrágyázási kísérletek a Duna-Tisza közén. (Experiments at deep manuring and deep green manuring on the Danube-Tisza interfluve). – MTA Agrártud. Oszt. Közl. 9. 391-399.

EGERSZEGI, S. 1953: Homokterületeink termőképességének javítása „aljtrágyázással". (Erhöhung der Fruchtbarkeit von Sandböden mittels „Tiefdüngung".) – Agrokémia és Talajtan, 2. 97-108.

ERDÉLYI, M. 1955: A Duna-völgy nagyalföldi szakaszának víztároló üledékei. (Die wasserspeichernden Sedimente des Donautales in der Grossen Ungarischen Tiefebene.) – Hidrol. Közl. 35.5-6. 159-169.

LÁNG, I. 1957: Aljtrágyázott őszi gabonák zöld – levélfelületek és összlevél – festékének vizsgálata. (Untersuchung des gesamten Blattgrünhaltes bei Wintergetreide nach Untergrunddüngung.) – Agrokémia és Talajtan, 6. 69-78.

LÁNG, I. 1961: A réteges homokjavítás hatása a homoki bab terméshozamára és tápanyagfelvételére (Einfluss der Sandverbesserung mit Tiefenschichtdüngung auf Ertrag und Nährstoffgehalt der Kunbohne.) – Agrokémia és Talajtan, 10. 389-404.

LÁNG, I. – GÁTI, F. 1958: A réteges homokjavítás hatása a kukorica ásványi táplálkozására. (Der Einfluss der schichtenweisen Sandmelioration auf die mineralische Ernährung des Mais.) – MTA Agrártud. Oszt. Közl. 14, 369-382.

MOLNÁR, B. 1965: Adatok a Duna-Tisza köze fiatal harmadidőszaki és negyedkori rétegeinek tagolásához és származásához, nehézásvány összetétel alapján. (Beiträge zur Gliederung und Entstehung der jungtertiären und quartären Schichten des Donau-Theiss-Zwischenstromlandes auf Grund der Schwermineralienzusammensetzung.) – Földtani Közlöny, 95, 217-225.

PÉCSI, M. 1959: A magyarországi Duna völgy kialakulása és felszínalaktana. (Entwicklung und Morphologie des Donautales in Ungarn.) Budapest, Akad. K. 345. (Földrajzi Monográfiák, 3.)

PÉCSI, M. 1967a: Bácskai löszös hátság. A domborzat kialakulása és mai képe. (The Bácska Loess Ridge. Relief evolution and geomorphology.) – In: A dunai Alföld. Budapest, Akad. K. 244-248. (Magyarország tájföldrajza, 1).

PÉCSI, M. 1967b: Dunamenti síkság. A domborzat kialakulása és mai képe. (The Danubian Plain. Relief evolution and geomorphology.) – In: A dunai Alföld. Budapest. Akad. K. 165-176. (Magyarország tájföldrajza, 1).

PÉCSI, M. 1967c: A Duna-Tisza közi hátság. A felszín kialakulása és mai képe. (The Danube-Tisza Interfluve. Relief evolution and geomorphology.) – In: A dunai Alföld. Budapest, Akad. K. 214-221 (Magyarország tájföldrajza, 1).

PÉCSI, M. 1970: Geomorphological Regions of Hungary. Budapest. Akad. K. 45. (Studies in Geography in Hungary, 6.)

PÉCSI, M. – ZENTAI, T. – GEREI, L. 1982: Engineering Geology and the Fertility of the Sand Soils of the Southern Danube-Tisza Interfluve. – In: Quaternary Studies in Hungary. Budapest, Geogr. Res. Inst. Hung. Acad. Sci. 255-269.

RÓNAI, A. et al. 1971: Magyarázó Magyarország 200 000-as földtani térképsorozatához. L-34-XIV. Kiskunhalas. (Explanation to the 1 to 200 000 geological map series of Hungary. Budapest. MÁFI. 358.

SÜMEGHY, J. 1952: Földtani adatok a Duna-Tisza köze északi részéről. (Donées géologiques de la partie septentrionale de l'Entre-deux-fleuve Danube-Tisza.) MÁFI Évi Jel. 1948-ról. 85-96.

URBANCSEK, I. 1963: Pliocén és pleisztocén üledékek földtani szinezésének újabb lehetőségei a vízföldtani kutatásban. (New possibilities for geological levelling of Pliocene sediments in the geological research.) – Hidrol. Közl. 43.5. 392-400.

Addresses of authors:
Prof. Dr. M. Pécsi, Dr. L. Gerei, Mrs. M. Reményi,
Geographical Research Institute, Hungarian Academy of Sciences
Népköztársaság útja 62. 1062 BUDAPEST – Hungary
Dr. T. Zentay, Hungarian Geological Survey Institute
Sóhordó u. 20/b. 6721 SZEGED – Hungary

M. Pécsi (Ed.):
Lithology and Stratigraphy of Loess and Paleosols
GEOGRAPHICAL RESEARCH INSTITUTE, HUNGARIAN ACADEMY OF SCIENCES
Budapest, 1984

DEPOSITION OF WINDBLOWN DUST IN CENTRAL ARIZONA, USA*

T.L. Péwé

ABSTRACT

Windblown sediments have been deposited in many parts of the world since the creation of the continents and probably are of the same antiquitiy on other planets. Dust blown from deserts is a common phenomena that occurs with great frequency and magnitude in arid and semi-arid areas. Desert dust is often transported hundreds of kilometers, although much of the finer material is carried thousands of kilometers. It is estimated that wind-blown dust carried from deserts amounts to 500 million tons annually.

In the lower Sonoran Desert of Arizona and northern Mexico, the soil is very susceptible to deflation, and great quantities of dust are transported locally by dust devils. It is becoming increasingly evident that much dust is being transported into and within central Arizona, and is of geological importance in the study of soils, origin of caliche, and origin of desert varnish. Therefore, a local study was initiated to learn more of the characteristics, and especially the rate of deposition, of dust in Tempe, Arizona.

PHYSICAL SETTING

Geology and geography

The City of Tempe lies in the Phoenix metropolitan area of central Arizona (FIG. 1). It is adjacent to and east of the City of Phoenix in the Salt River valley, one of the many basins of the Basin and Range Physiographic Province. Typical fault-block mountains in the area project 300 to 1000 m above the basin and are composed of Precambrian metamorphic and intrusive rocks and Tertiary volcanic rocks. The essentially flat-floored basins are 1 to 100 km across and are filled with silt, sand, and gravel to depths of 300 to 2000 m.

---

* This paper is a condensation and slight modification from Péwé, E.A. – Péwé, R.H. – Journaux, A. – Slatt, R.M., 1981, Desert dust: characteristics and rate of deposition in central Arizona, in Péwé, T.L., Ed., Desert dust: origin, characteristics, and effect on man: Geological Society of Amerika Special Paper 186, 169 - 190.

The sediments in the center of the basin are mainly silt and clay, and silt is also an abundant matrix in the coarser colluvial-alluvial sediments on the flanks of the valleys. Ephemeral streams are widespread, the major perennial rivers are dammed, and water rarely runs in their riverbeds today. The Salt and Gila Rivers had, until recent decades, wide, braided active floodplains and were essentially vegetation-free in most areas. At present, however, Tamarisk gallica (Salt Cedar) chokes the Gila River floodplain, and the lower 2 km or so of the Salt River floodplain.

The largest irrigated agricultural area in Arizona is centered in the Phoenix region in the drainage of the Gila and Salt Rivers. About 1855 km^2 of the basin-floor area are cultivated, and at various times some bare, tilled soil is exposed in the region when not planted in citrus orchards or crops. The cultivated area of the Phoenix region, plus those of the Tucson and Yuma regions represent only 3.5% of the 149.230 km^2 of the sparsely vegetated Arizona desert in the Basin and Range Province. It is evident that almost all of the desert area of Arizona is represented by natural areas covered with little or no vegetation.

Dust storms

Perhaps the most important aspect of the climate pertinent to this study is the dust storm. Although dust is locally generated by thermal winds and is also stirred up by actions of man (SUCK, S. et al. 1976, GRAF, J. et al. 1976), most dust is transported

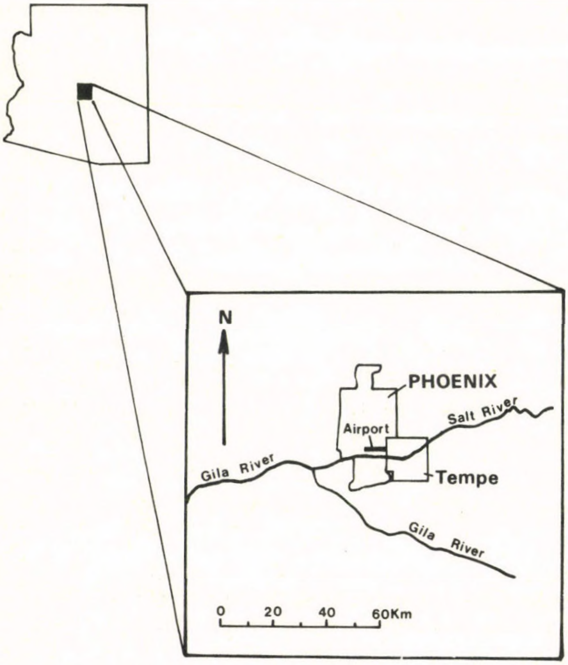


FIG. 1. Index map showing location of Tempe, Arizona, U.S.A.

and deposited by summmer dust storms. Several dust storms pass through the Phoenix area every summer, accompanied by moderate to high winds, and cause a great loss in visibility. The blinding dust storm, a real hazard, has resulted in air pollution and loss of visibility, which has resulted in many fatal highway accidents (HYERS, A.D. – MARCUS, M.G. 1981, BURRITT – HYERS, A.D. 1981).

According to IDSO, S.B. et al. (1972) about 50% of the central Arizona dust storms are true „haboobs". A haboob is the legendary dust storm of Khartoum in the Sudan and is one of the world's awesome displays of blowing dust and sand. These great dust storms form on the forward edge of cumulonimbus clouds. Strong winds are generated by the outflow of rain-cooled air, at first, dust is blown upward from the ground as independent swirls, but it soon develops to form a billowing wall of dust. The leading edge of the dust storm bulges forward to form a nose, and the upper surface slopes back and soon rises to an elevation of 2000 m to as much as 2500 m (FIG. 2). The haboobs in Sudan have an average speed of advance of about 14 m/sec, with the greatest speed about 20 m/sec. With the passage of the haboob, the air pressure, temperature, and relative humidity fluctuate considerably. Even though the common term „haboob" is not accepted by all workers (TEWFIK, M. 1976, MORALES, C. 1979), the well-known euphonious word has been imported to America and will be used in this report.

In Arizona, major dust storms occur that are of the same nature and intensity as those in Africa, according to IDSO, S.B. and others (1972). They further state that although the American dust storms are not as frequent as the Sudanese haboobs, they are equally dramatic. As many as nine major dust storms may strike the Phoenix area during the summer, but the average is 3.5/yr. (Storms are listed if visibility dropped to less than 800 m). There have been 95 dust storms of this nature recorded over the past 27 years at Phoenix Sky Harbor International Airport, 8 km west of the Tempe dust collecting site. They generally occur between June 1 and September 15. According to INGRAM, R.S. (1972), IDSO, S.B. et al. (1972), and BRAZEL, A.J. and HSU, S. (1981), most of these dust storms are caused by downdrafts from decaying stages of large thunderstorms that form over the mountain areas southeast of Tucson and northern Mexico, or over the Mogollon Rim north of Phoenix, especially during the monsoon season of July and August (FIG. 3). The dust storms documented in FIGURE 3 are those recorded at the Phoenix airport. Similar dust storms are recorded elsewhere in the Phoenix metropolitan area, but may not affect the station of the airport, for example, some serious dust storms recorded in Tempe during the study period were not recorded at the Phoenix airport. The record at the airport, however, is thought to be typical of the Phoenix region.

Most of the dust storms move into Phoenix from the east to the south. INGRAM, R.S. (1972) indicated that 69% of the documented dust storms move into Phoenix from the east, and about 35% of these dust storms are generated by thunderstorms that develop in the area south and east of Tucson. These storms move up the Santa Cruz Valley, generally at a rate of 13 to 14 m/sec. About 34% of the storms move in from the east and do not necessarily begin near Mexico. Twenty-five percent of the storms come from the north or northeast and 6% from the west. The storms that travel from the Santa Cruz Valley to the southeast generally arrive in the Phoenix area between 1700 and 2100 hours, while those from the other directions arrive between 1500 and 1900 hours. A typ-

FIG. 2. Dust cloud, a typical haboob, sweeping over the City of Phoenix, Arizona, from the south, July 16, 1971. The dust is picked up from the desert terrain in northern Mexico and southern Arizona. (Photograph by Hamilton McRae) (see IDSO and others 1972).

ical Arizona haboob that formed southeast of Tucson and moved northwest into the Phoenix area on July 16, 1971, has been well-documented by IDSO, S.B. et al. (1972) (FIG.2).

DUST IN CENTRAL ARIZONA

The dust used in this study was periodically collected by PÉWÉ, E.A. and PÉWÉ, T.L. from the roof of a house at 538 E. Fairmont Drive, Tempe, Arizona, for 450 days from April 22, 1972 to July 2, 1973 (PÉWÉ, T.L. – PÉWÉ, E.A. – PÉWÉ, R.M. 1976). The northfacing half of the roof was used. The roof is composed of rough cedar shake shingles and has an area of 131 m^2. The roof slants slightly, and the minimum height above the ground is 3 m.

After the roof was hosed off with 380 L of water, the dust fell on the roof continuously, about every 30 days the dust was washed from the roof and gutters into plastic containers with about 230 L of water hosed on the cedar shakes. After the sediments had settled into containers, the water had been removed, and the dust had dried, the quantities and compositions were recorded. Rain fell during some of the collecting periods, and this was also caught in plastic containers and added to the total water and dust from the roof for the period.

Twice during 1972, the roof has just been cleaned in the morning when a dust storm moved in over the area in the early evening. The dust was collected the next morning, therefore, we have two collecting periods of one day each that represent deposition of a single dust storm.

Physical properties of the dust

Preliminary statement. The collecting of dust from the roof at periodic intervals resulted in 15 samples. The dust samples ranged in weight from 263 g to 1330 g and represent collecting intervals of one to 56 days. The average collecting intervals was 33 days, not counting the two one-day intervals. Studies were made on the texture, chemistry, mineralogy, and clay composition of all sample.

Texture. Mechanical analyses (granulometric analyses) of the dust were made at the Center for Geomorphology in Caen, France. Analyses were made by sedimentation in water. Grains smaller than 20 μ were separated by Andresen Pipe; grains larger than 20 μ were separated by sieving. In addition to the mechanical analyses of the dust from Tempe, samples of volcanic ash from Fairbanks, Alaska, and loess from Siberia, China and New Zealand were also analyzed in the laboratory by the same method to permit reliable comparisons.

The windblown dust falls into two major size groups. Very fine-grained material is tropospherically sorted dust that moves as an aerosol, that is, a dust that remains suspended in the air until brought down by rainfall onto water and land surfaces. This dust is < 1 to 10 m in size. The other major group is dust that is transported 1 or 3 km upward in the atmosphere by winds of moderately high velocities horizontal distances of

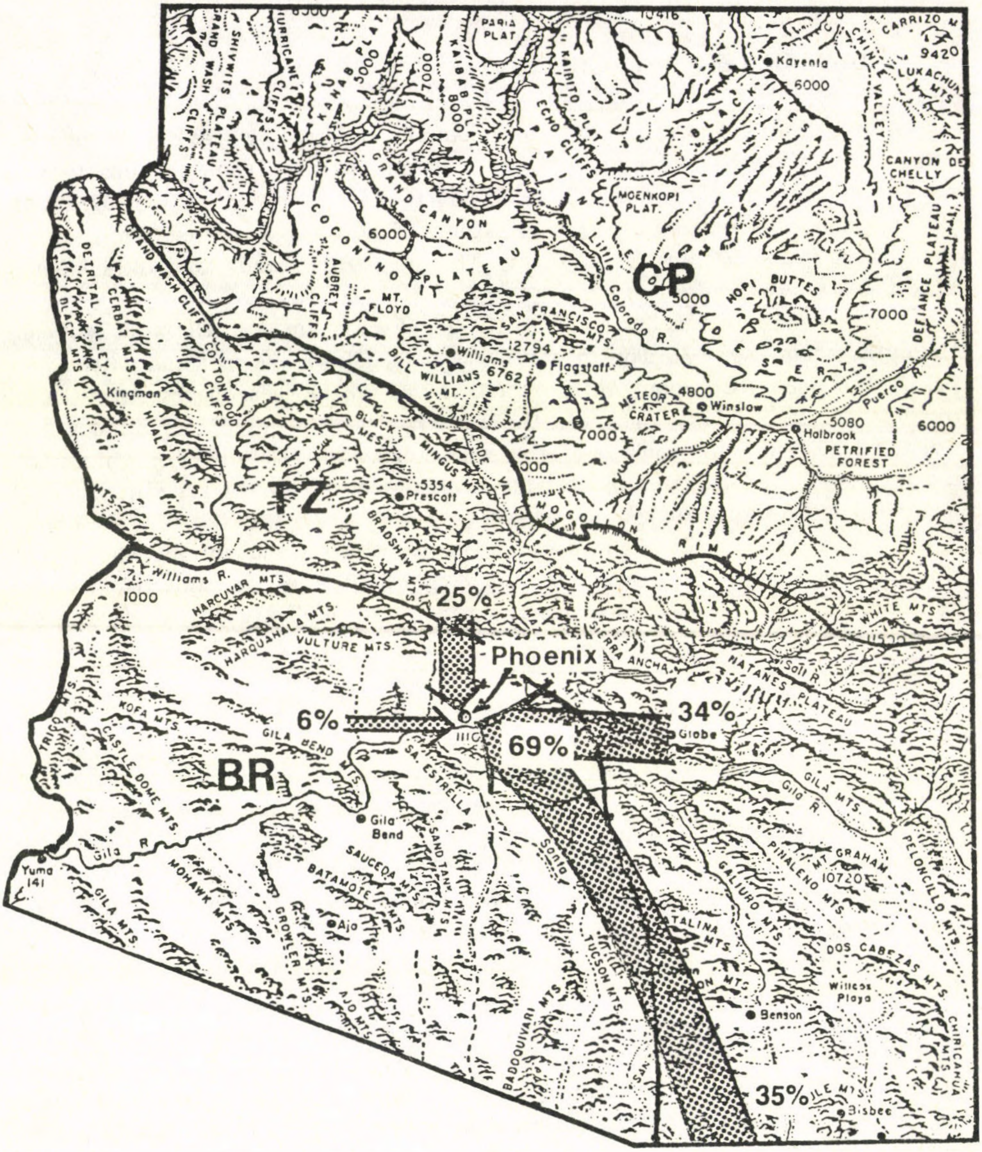


FIG. 3. Directions and percentage of dust storm entering Phoenix indicated by arrow. (Base map by RAISZ; dust storm data from INGRAM, 1972.) Physiographic provinces of Arizona: CP – Colorado Plateau, BR – Basin and Range, TZ – Transition Zone (HUNT, 1954).

lto 100 km. Ordinary, windblown dust, volcanic ash, and loess fall into this group, and the particles lie mostly between 5 and 50 μ.

The windblown desert dust considered in this report is of this second group and is well sorted (FIG.4.). Approximately 75% of the dust particles are between 0.05 and 0.005 mm in diameter. As illustrated in FIGURE 4, this size distribution of particles is similar to windblown volcanic ash and loess from various parts of the world. Mechanical analyses of the 15 dust samples from Tempe reveal curves that are practically identical one with another. Therefore, one general curve is plotted in FIGURE 4.

It has long been known that angular silt grains are characteristic of windblown dust (TWENHOFEL,W.H. 1932, p.272, CHARLESWORTH, J.K. 1957, p.513, PÉWE, T.L. 1955, p. 721). With the advent of the scanning electron microscope, the nature of loess particles was more closely revealed. According to CEGLA, J. – BUCKLEY, T. – SMALLEY, I.J. (1971), the scanning electron microscope does support the concept that the majority of dust particles are certainly angular. The grains of silt from the dust collected in Tempe are also angular, especially the minerals of low specific gravity, such as quartz.

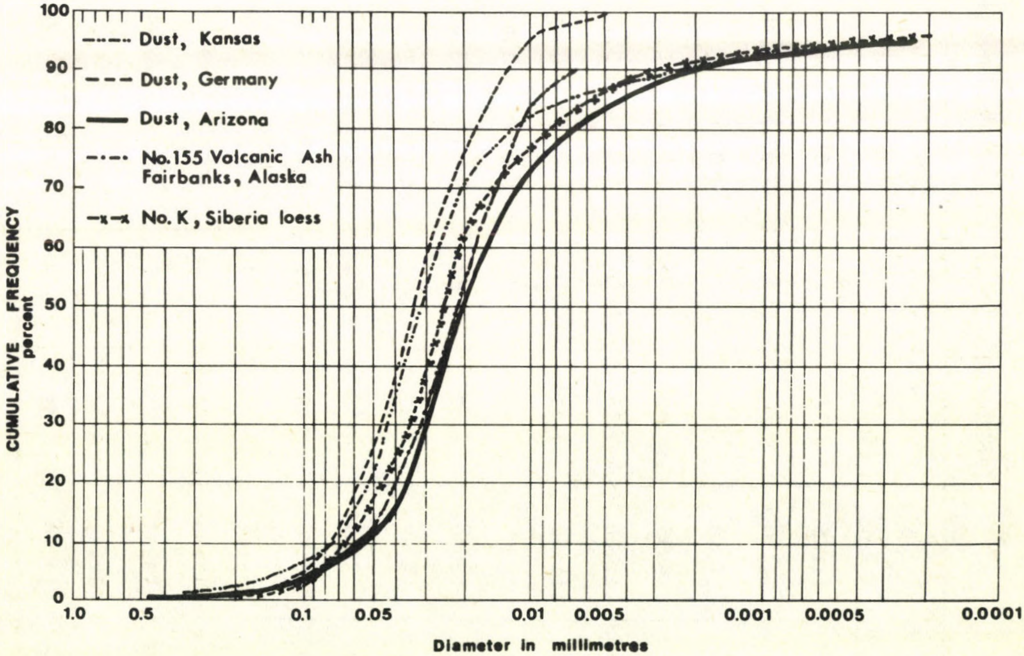


FIG. 4. Comparison of cummulative-frequence curves of modern, windblown dust from Kansas (SWINEFORD and FRYE, 1945), Germany (ZEUNER, 1949), and Arizona, and of volcanic ash from Fairbanks, Alaska (PÉWÉ, 1955) and loess from Siberia. Alaska, Siberia, and Arizona samples collected by Troy L. PÉWÉ and analyzed by Center for Geomorphology, CNRS, Caen, France.

TABLE 1. Chemical analysis of windblown dust colledted at Tempe, Arizona, U.S.A.*

Sample No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 % (Total)	TiO_2 %	MnO %	CaO %	MgO %	K_2O %	Na_2O %	H_2O %	loss on ignition %
1	57.50	11.25	4.79	0.73	0.06	2.76	3.27	3.02	1.41	2.03	11.65
2	58.90	11.10	4.84	0.86	0.07	3.18	3.20	2.93	1.60	2.01	10.55
3	56.20	11.40	5.00	0.72	0.09	2.16	3.35	2.86	1.65	2.48	14.35
4	61.80	14.35	4.60	0.80	0.07	1.92	2.89	2.56	2.04	1.79	7.10
5	60.00	11.65	5.15	0.88	0.06	3.70	3.26	2.72	2.52	2.33	8.48
6	59.00	15.00	4.75	0.74	0.06	1.74	2.95	2.81	1.87	2.13	8.64
7	55.80	14.85	4.71	0.76	0.07	1.90	2.54	2.58	1.89	2.43	11.85
8	60.10	13.30	4.60	0.82	0.09	1.40	2.83	1.77	1.98	1.98	11.72
9	58.25	13.62	4.67	0.77	0.07	0.47	3.44	2.60	2.08	2.15	11.42
10	54.00	12.95	4.60	0.72	0.06	1.63	3.44	2.69	1.93	2.44	14.20
11	57.60	10.70	4.39	0.75	0.07	1.42	2.80	2.46	2.01	2.08	13.90
12	56.30	12.55	4.46	0.24	0.07	1.69	2.71	2.40	2.28	2.04	14.95
13	56.45	12.06	4.81	0.73	0.08	2.31	3.10	2.64	2.01	2.08	12.27
14	57.85	13.30	4.95	0.77	0.07	1.93	3.07	2.67	1.93	2.09	11.10
15	55.30	12.65	4.56	0.74	0.07	1.84	2.65	2.69	1.87	2.41	15.10
16	61.60	12.70	4.67	0.87	0.06	2.15	2.73	2.66	1.76	1.81	9.00

*Analyses made at Center for Geomorphology, CNRS, Caen, France

Chemical composition. All of the 15 samples (and one grab samples from the roof gutter in 1974) were analyzed chemically at the Center for Geomorphology of the CNRS at Caen, France, under the direction of Andre Journaux. All samples average 58%-61% SiO_2 and were essentially of the same chemical composition (TABLE 1.) Trace elements were not studied, but they are present naturally and also derive from copper smelting, agricultural fertilizer, and automobile emissions.

A special analysis was made of the $CaCO_3$ content of the dust (TABLE 2). The samples ranged from about 1%-4% calcium carbonate. As with chemical analyses, 16 samples were analyzed, 15 of which were taken during the regular study period.

TABLE 2. PERCENTAGE OF $CaCO_3$ IN WINDBLOWN DUST COLLECTED AT TEMPE, ARIZONA, U.S.A.*

Sample Number	Percentage of $CaCO_3$
1	3.87
2	2.98
3	1.12
4	2.44
5	3.67
6	1.88
7	2.34
8	1.22
9	1.53
10	3.34
11	1.21
12	1.43
13	3.01
14	3.11
15	2.14
16	1.93

*Analyses made at Center for Geomorphology, CNRS, Caen, France.

Heavy mineral composition. Examination of the heavy minerals in the 16 samples was made by SLATT, R.M. Heavy minerals from washed samples were separated in tetrabromoethane (sp. gr. = 2.96). Because samples were small, size fractionation of the heavy minerals was not attempted, most of the mineral appeared to fall within the fine-

TABLE 3. Percentage of heavy minerals (mica-free basis) in windblown dust, Tempe, Arizona

Sample	Amphibole				Pyroxene		Opaques	Epidote		Others												
	Common Hornblende	Blue-green Hornblende	Tremolite/Actinolite	Brown Hornblende	Augite/Diopside	Enstatite		Epidote	Zoisite/Clinozoisite	Apatite	Alterite	Andalusite	Sillimanite	Zircon	Pale Tourmaline	Titanite	Garnet	Fluorite	Kyanite	Monazite	Staurolite	Green Tourmaline
TLP-1	20	3	7		14	4	36	3	6			2		2	1				2			
2	21	1	4		14	6	35	3	4	3	4		3				1			1		
3	32	1	11		17	1	26	2	3		4			1	2			1				
4	23	2	6		18	2	33	6	4	1	3	1		1								
5	21	3	5		18	1	37	1	6	2			1	4		1	1					
6	25	5	11		8		36	5	4	1	1		1	2	1							
7	18	3	3		15	1	36	9	3		6		1	2	1	1					1	
8	18	5	3	1	12		44	6	4	1	1		2		2							1
9	13	2	8		14	2	51	7	2					1		1						
10	20		7		13	2	42	4	3		2			4	2	1						
11	23	5	5		14	1	37	2	4	1	3		1	2			2					
12	10	7	9		8		51	8	1	1				2	1		1		1			
13	12	4	5		7	4	55	6	3		1			1	1	1						
14	17	10	8		9	2	36	6	6	1				3	1	1						
15	5	8	9		13	4	49	3	5	1	1	1	1									
$\overline{X}$	19	4	7	Tr	13	2	40	5	4	1	2	Tr	1	2	1	Tr	Tr	Tr	Tr	Tr	Tr	Tr

sand, coarse-silt size range. The heavy minerals were mounted on glass slides with Caedex, and point counts were made on each slide until a total of 100 nonmicaceous grains was determined.

Average abundances of heavier minerals are as follows (TABLE 3); *Amphibole:* common hornblende (19%), tremolite/actinolite (7%), blue-green hornblende (4%), brown hornblende (tr), *Pyroxene*: augite/diopside (14%), enstatite (2%), *Opaques:* (40%), *Epidote*: epidote (5), zoisite/clinozoisite (4%), *Others*: alerite (2%), apatite (1%), sillimanite (1%), pale tourmaline (1%), andalusite (tr), titanite (tr), garnet (tr), fluorite (tr), kyanite (tr), monazite (tr), staurolite (tr), green tourmaline (tr).

The wide variety of heavy mineral species in each sample indicates that the dust is derived from both igneous and metamorphic rocks. Most grains are fresh, angular and commonly euhedral, which along with the several species of unstable heavy minerals, suggests that sedimentary rocks are not important contributor. These features also show that the grains have minimal grain-to-grain impact. Some pyroxene and amphibole grains exhibit „cockscomb" solution features. A small number of opaque spherules of unknown composition and origin occur in each sample.

Dust deposition

By measuring dust deposition for more than one year in Tempe, it is possible to note that the range of dust deposition varies between winter and summer and is greater in the summer. Records indicate that in the winter the rate of deposition averages 0.1 to 0.15 $g/m^2/day$, but in the summer averages 0.2 to 0.4 $g/m^2/day$. The rate of deposition ranges from a low of 0.05 g/m^2 for 24 hours in the winter to as much as 3.85 g/m^2 in one hour during a summer dust storm (TABLE 4, FIG.5). Records indicate that the amount of dust falling on a square metre of surface for the year April 22, 1972, to April 21, 1973 was 53.9 g. If we were to take the year from July 2, 1972, to July 2, 1973, which was the end of the measuring period, the figure would be 54.48 $g/m^2/yr$. So, a figure of 54 $g/m^2/yr$ in this experiment would be a good average number.

There were no dust storms in Phoenix in 1973 and only three were recorgnized in Tempe during the collecting period, although four are listed for Phoenix in the summer of 1972. Also, the precipitation in the Phoenix area during the sampling year was higher than the average. The mean annual precipitation is 179 mm/yr, as measured at the Phoenix Sky Harbor International Airport, but from April 22, 1972 to April 21, 1973, the precipitation was 355 mm (NOAA, 1972; NOAA, 1973). Because of the higher precipitation and the slightly lower number of dust storms, it is thought that the amount of 54 g/m^2yr recorded in the 1972-1973 experiment is probably a little below the average.

The average annual desert dust deposition as measured in Israel by Yaalon and associates (YAALON,D.H – DAN,J. 1974; YAALON,D.H. – GANOR,E. 1975) is 50 to 200 g/m^2. GILE, L.H., HAWLEY, J.W. and GROSSMAN, R.B. (1970) measured desert dust that was trapped at elevations of 0.3 and 1 m above the desert floor in south-western New Mexico for two years. At an elevation of 0.3 m, the deposition rate was 42 to 164 $g/m^2/yr$, and at an elevation of 1 m, it was 20 to 29 g.

TABLE 4. Amount of windblown dust deposited at Tempe, Arizona, U.S.A. 1972-1973.
Precipitation measured at Sky Harbor International Airport, Phoenix, Arizona

Sampling Period No.	Date 1972-73	Days in Period	Total dust in grams	Dust in grams/day	Dust gr/ m^2/day	Precipitation in mm	Remarks
1	April 22 May 29	37	263.12	7.11	0.05	Trace 29 May	
2	May 29 May 30	1	381.29	381.29	2.89	Trace 30 May	1845--huge dust storm 29 May 1 hour duration
3	May 31 July 2	33	349.51	10.59	0.08	43.2	Several rain storms
4	July 2 July 27	25	1,222.27	48.89	0.37	18.3	Two rain storms One large dust storm
5	July 28 July 29	1	508.01	508.01	3.85	0	Small dust storms Evening 28th
6	July 30 Sept. 4	37	1,330.42	35.96	0.27	30.5	Three dust storms recorded at Phoenix airport
7	Sept. 5 Sept. 30	26	721.02	27.73	0.21	7.1	
8	Oct. 1 Nov. 2	33	500.36	15.16	0.11	111.8	
9	Nov. 3 Dec. 31	56	768.41	13.72	0.10	65.2	
10	Jan. 1 Feb. 3	34	271.11	7.93	0.06	4.8	
11	Feb. 4 March 3	28	367.68	13.13	0.10	33.0	
12	March 4 April 1	32	312.54	9.77	0.07	42.9	April 1--high level dust from California (Palm Springs)
13	April 4 April 29	26	265.27	10.20	0.08	0	
14	April 30 May 28	29	414.80	14.30	0.11	1.8	
15	May 29 July 2	35	588.82	16.82	0.13	2.5	

Most of the dust is deposited in the summer, the windiest time. Plotting the maximum wind velocity per day against dust deposition for the measured period, however, fails to reveal any correlation. PÉWÉ, R.H. did find, however, a very rough correlation of the average wind velocity per day against the amount of dust deposited. Results support the suggestion that the wind is stronger, and there are more windy days, in summer than in winter.

It is difficult to visualize 54 $g/m^2/yr$. How much is that for a whole roof, or a whole yard, or a whole swimming pool? It is about 2,2 kg/yr for a typical swimming pool. Any pool owner in Arizona will readily admit that at least that much „dirt" blows into his pool every year. The record for the measured year indicates that 0.54 t/ha/yr. were deposited in the area.

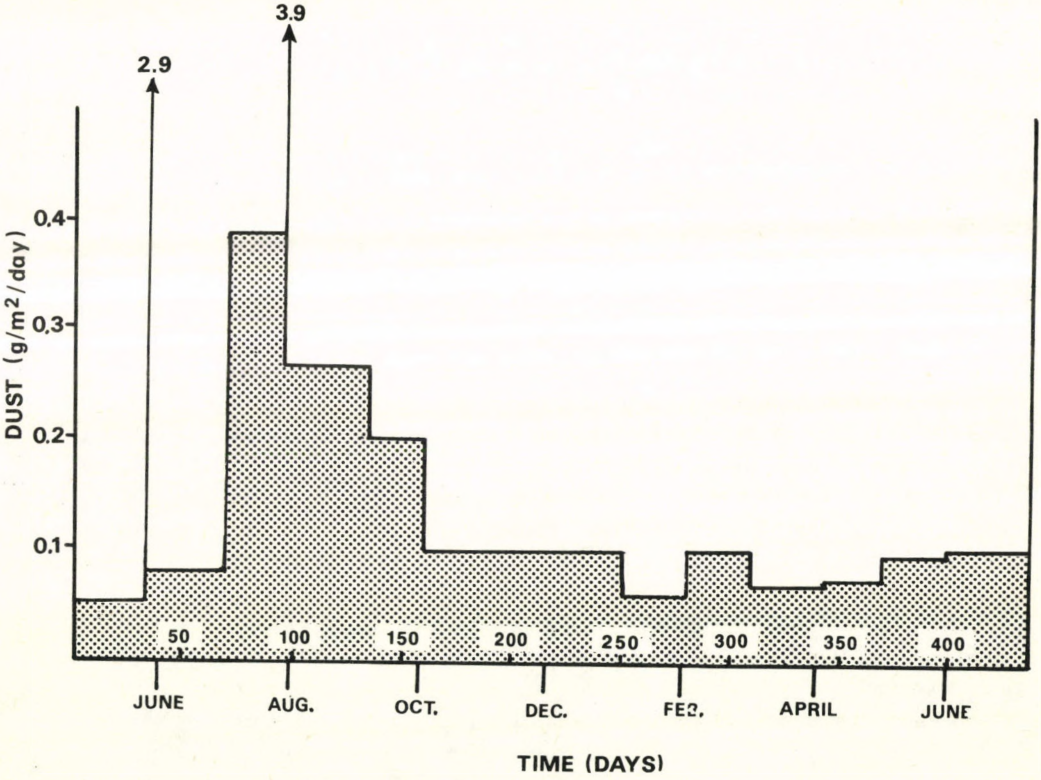


FIG. 5. Amount of windblown dust deposited at Tempe, Arizona in grams per square metre per day for measuring periods of 1 to 56 days from April 22, 1972 to July 2, 1973.

Although it is extremely speculative to extrapolate to large areas, such figures show that in one dust storm 180 t can be deposited within the city limits of Tempe, while 2720 t can be deposited in the larger city of Phoenix. For our measured year, 4500 t were deposited in the area of the city of Tempe, while 14 000 t fell on Phoenix.

GEOLOGICAL IMPLICATIONS OF THE DUST

Source of the dust

The dust deposited in the Tempe area is strikingly uniform over the year in texture and in chemical and mineralogical composition. It is essentially all mineral matter, with little tire rubber or pavement particles, even in the „nondust" season of November (GRAF, J. et al. 1976). The heavy mineral analysis indicates a source of metamorphic and igneous rocks, with little or no sedimentary rocks. Metamorphic and igneous rocks are the predominant rock types in southern Arizona (WILSON, E. D. et al 1969) and especially in the Phoenix area (SHERIDAN et al. 1970; SHANK, D.C. – PÉWÉ, T.L. 1973; POPE, C.W. 1974; CHRISTENSON, J.K. – WELSH, D.G. – PÉWÉ, T.L. 1978; SCHULTEN, C.S. – BALES, J.T. – PÉWÉ, T.L. 1979).

The analyses suggest that the dust is from the desert terrain, agricultural fields, and dry stream courses within about 50 to 200 km of Tempe, although the dust of the common haboobs moving in from the southeast is in part from southern Arizona. Even so, the soils and rocks southeast of Phoenix are similar in composition to those of the Phoenix area.

Quantity of dust

Calculations based on dust accumulation from July 2, 1972 to July 2, 1973, a year of perhaps below-normal dust accumulation, indicate by extrapolation 0.54t/ha/yr. This is extrapolated to indicate 5400 t/ha/10000 yr (or 2400 t/a/10000 yr). This is an impressive figure but is dwarfed by figures of wind-transported dust on a world-wide basis. PROSPERO, J.M. and CARLSON, T.N. (1972) estimated that 23 to 34 million t are transported through the longitude of the Barbados each year, and JUDSON, S. (1968) calculated that 54 to 330 million t of dust are delivered annually to the world's oceans. PETERSON, S.T. and JUNGE, C.E. (1971.p.312) reported that about 500 million t of windblown dust are derived annually from the continents and primarily originated from arid regions, particularly the Sahara. KES, A.S. and FEDOROVICH, B.A. (1976) reported that 20% to 75% of all the sediments on the ocean bottom are made of windblown dust.

Where is all the dust that is deposited annually in central Arizona? No loess deposits resembling those along the Mississippi, Missouri, Illinois, or Yukon Rivers, or those reported from Israel (YAALON, D.H. 1978), are known. Perhaps the source is not as localized as in these examples, or perhaps the dust is deposited but spread widely. Also, perhaps much of it is retransported by later winds or water in the absence of stabilizing grasses and forests, such as is associated with glacial loess deposition.

An enormous amount of clay- and silt-sized particles is present on the basin floors in central Arizona. On the flanks of the basins, even the coarser sediments have an abundant matrix of clay-silt sized particles – as much as 20% (SHANK, D.C. – PÉWÉ, T.L. 1973; CORDY,G.E. – HOLWAY, J.V. – PÉWÉ, T.L. 1977; CHRISTENSON, G.E.

– WELSH, D.G. – PÉWÉ, T.L. 1978). Undoubtedly, much or most of these sediments is eolian. In many areas, mineralogical studies indicate that much of the silt could not come from the adjacent bedrock slopes.

It is possible that some of the $CaCO_3$ is leached downward before some of the silt is blown farther. Also, much of the clay, manganese, and iron is locked up as desert varnish before some of the silt moves on by later winds.

No studies have been made regarding the rate and amount of deposition of windblown silt in central Arizona during the Pleistocene, especially in Wisconsin time. However, from what is known of conditions today, the desert vegetation was only slightly more restricted in Wisconsin time than at present, and much desert remained (MARTIN, P.S. – MEHRINGER,P.J. 1965). It is probable that the climate has been arid since Tertiary time (SMILEY, T.L., in press). There is little reason to believe that the rate and amount of dust deposition were much different that today. KOTTLOWSKI, F.E. COOLEY, M.E. and RUHE, R.V. (1965) believed, however, that the windblown dust was probably most common around 7000 to 3000 years ago, when conditions were drier than now.

Caliche

In the past few years, research on the origin and distribution of caliche has greatly increased, especially work on the relationship of the type and distribution of caliche in regard to land-use development and planning in the southwestern United States. It has become evident that windblown dust is important as a source of $CaCO_3$.

Caliche is a near-surface accumulation of $CaCO_3$ common to soils of low- and middle-latitude and arid and semiarid regions throughout the world. Caliche forms primarily as a result of pedogenic processes in the evaporation of water in soil voids. Early workers (BLAKE, W.P. 1902, THEIS, C.V. 1936) thought that the water rose from the water table below to evaporate and deposit $CaCO_3$. Today, it has been demonstrated that meteoric water percolates downward, carrying $CaCO_3$ in solution, but is drawn upward (or stopped in its descent) by capillary action resulting from surface evaporation. Soil permeability and the amount of rainfall also influence the depth of descent. In situ evaporation of this vadose water results in precipitation of $CaCO_3$ in soil voids. Various features develop as caliche formation progresses with time, from incipient discontinuous pebble coatings to continuous pebble coatings to interpebble fillings through a formation of a plugged horizon with overlying laminar layers. Well-developed caliche results in impermeable, indurated layers (FIG. 6, 7).

It was previously thought that the present source of the $CaCO_3$ was from the overlying or underlying sediments, although the source of $CaCO_3$ in caliche of noncarbonate sediments was given little consideration. In the past few years, thought has turned to windblown dust as a source for $CaCO_3$ in caliche (BROWN, C.N. 1956). GARDNER, R.G. (1972) showed that there is as much as 80% $CaCO_3$ in many calichified soils, and as much as two or three times more than can be accommodated in the original void space in the parent material. He believed that at least 75% of the $CaCO_3$ is from eolian dust. LATTMAN, L.H. (1973) believed that the windblown dust was major source for the $CaCO_3$ in the caliche of southern Nevada. SLACH, K.W. and SMITH, G.P. (1969) also supported the eolian origin for the source for the $CaCO_3$ in caliche. Other strong supporters of eolian origin for the source of carbonate material in the caliche are REEVES, C.C. (1970, 1976) for caliche in West Texas and eastern New Mexico, and GILE, L.H., PETERSON, F.F. and GROSSMAN, R.B. (1966) for caliche near Las Cruces, New Mexico.

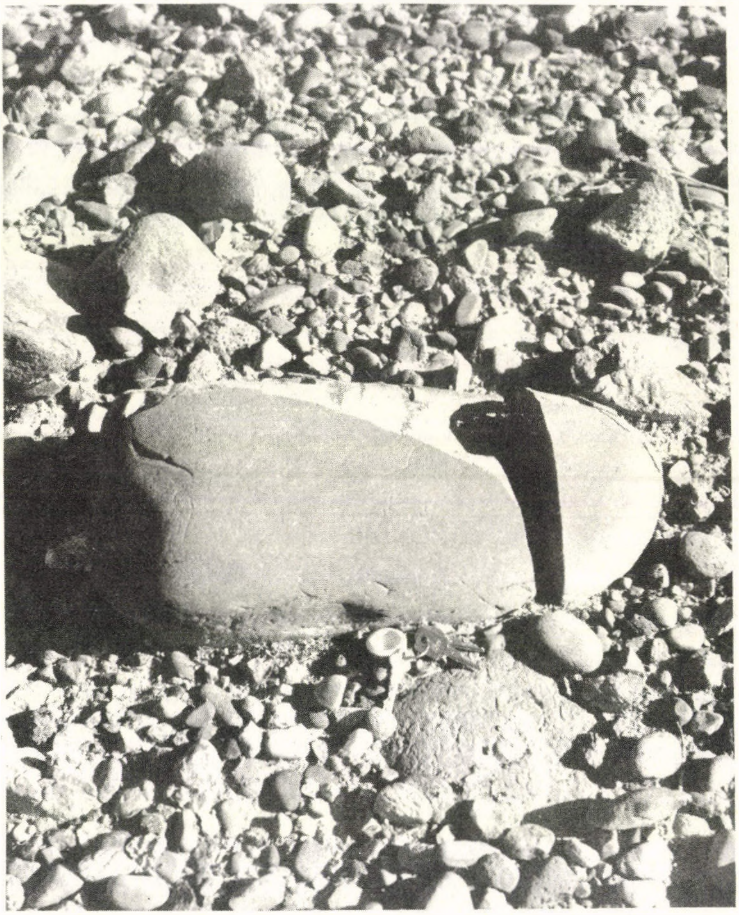


FIG. 6. Caliche-split boulder of quartzite on gravel surface of the Sawik Terrace of the Salt River near Tempe, Arizona, U.S.A. (Photograph No. 4040 by Troy L. PÉWÉ, September 17, 1977).

Quantitative data on just how much $CaCO_3$ is contributed by dust in the United States are rare. GILE, L.H., PETERSON, F.F. and GROSSMAN, R.B. (1966) caught dust in pans 0.3 m to 1 m above the ground in Las Cruces, New Mexico, for two years, and it can be concluded from their data that about 16 to 31 t/ha of carbonate may have accumulated per surface acre (36 to 69 t/ha) in the past 10000 years, although locally some areas received as much as 6,725 t/ha. WARN and COX (1951) found that at Lubbock, Texax, carbonate minerals totalled 5 to 50% of the dust. GOUDIE, A.S. (1978). p. 304) cited examples of 20% to 66% $CaCO_3$ elsewhere in the world.

FIG. 7. Salt River gravel strongly cemented by caliche. Mesa Terrace, Higley Road near the Salt River, Mesa, Arizona, U.S.A. (Photograph No. 4717 by Troy L. PÉWÉ, March 12, 1983).

Using a figure of 3% for the amount of $CaCO_3$ in the dust at Temple, it can be calculated that for the period of July 2, 1972, to July 2, 1973, 16.20 kg/ha/yr of $CaCO_3$ was deposited, or 162 t/ha/10000 yr.

Thus, a major contribution of this dust study is the demonstration that considerable $CaCO_3$ is windblown dust of central Arizona that could form caliche. The fact that strongly indurated, calichified, gravelley sediments as much as 10 m thick occur at the surface in many areas in central Arizona, and that at depth, additional thick layers of caliche exist, it is indeed necessary that considerable amounts of $CaCO_3$-bearing dust probably was available for a long time and was a main factor in the formation of the calichified surfaces that have been present for as much as 2 to 3 m.y. in the area (PÉWÉ, T.L. 1978).

Desert varnish

Desert varnish is a black to brown iron-manganese coating that forms on rocks and stones in arid regions (HUNT, C.B. 1954). It formerly was thought (MERRILL, G.P. 1898 and many others) to originate by weathering with the iron-manganese coating being obtained from the rock itself. It was later thought that the coating was from external sources such as dew, pollen, and rain, because the coating exists on rocks poor to entirely lacking in iron and manganese (ENGEL, C.G. – SHARP, R.P. 1958). Recently, it has been demonstrated that the iron-manganese coating is at least 70% clay minerals, and that the source of these fine-grained particles is in desert dust (POTTER, R.M. – ROSSMAN, G.R. 1977). Later work strongly supports the idea that windblown dust is the source of varnish materials (PERRY, R.S. – ADAMS, J.B. 1978; ALLEN, C.C. 1978; and POTTER, R.M. – ROSSMAN, G.R. 1979). ELVIDGE, C.D. (1979a) and ELVIDGE, C.D. – MOORE, C.B. (1979, 1981) have studied the desert varnish in central Arizona. They believe that dust storms deposit fine material on the exposed rock surface, after which rain falls to wet the windblown material and set up a varnish reaction. The reaction occurs in an alkaline environment where the ferromanganese coat is precipitated to cement the clay to the rock surface, thereby forming desert varnish.

Modern workers indicate that windblown clay, iron, and manganese deposited in an alkaline environment with some water over a period of a few thousand years are the necessary requirements for the formation of desert varnish. We have demonstrated that in central Arizona, a location of well-developed desert varnish (ELVIDGE,C.D. 1979b), abundant windblown dust is available (5400 t/ha/10000 yr). If 5% is taken as an average amount of the total iron oxides (Fe_2O_3-FeO) (TABLE 1), work here indicates that 2.7 g FeO are deposited m^2/yr, or 270 t FeO/ha/10000 yr (see ELVIDGE, C.D. 1979b. TABLES 5, 6 and 11). This is an enormous amount of iron falling on the rocks. Similar calculations indicate that if 0.7% of the windblown dust is MnO, then about 0.38 g/m^2/yr (3.8 t/ha/10000 yr) of MnO is deposited. C.D. ELVIDGE (oral commun., April, 1979) stated that an average heavy desert varnish coat on rocks in central Arizona has 0.5 to 23 g/m^2 of iron and manganese. Our work shown that there seems to be easily sufficient iron and manganese deposited annually by windblown dust to form the desert varnish at the rate presently hypothesized.

REFERENCES

ALLEN, C.C. 1978: Desert varnish of the Sonoran desert – optical and electron probe micro analyses. – J.Geol.86. 743-752.

BLAKE, W.P. 1902: The caliche of southern Arizona. – The American Institute of Mining Metallurgical and Petroleum and Engineers Transactions, 31. 220-226.

BRAZEL, A.J. – HSU, S. 1981: The climatology of hazardous Arizona dust storms. – In: Péwé, T.L., (Ed.), Desert dust: origin, characteristics, and effect on man: Geol.Soc.Amer.Special Paper 186. 169-190, 293-303.

BROWN, C.N. 1956: The origin of caliche on the northeast estacado, Texas. – J. Geol. 64. 1-5.

BURRITT and HYERS, A.D. 1981: Evaluation of Arizona's highway dust warning on interstate routes 8 and 10, central Arizona. – In: Péwé, T.L. (ed.) Desert Dust: origin, characteristics, and effect on man: Geol. Soc.Amer. Special Paper, 186, 169-190, 281-292.

CEGLA, J. – BUCKLEY, T. – SMALLEY, I.J. 1971: Micro textures of particles from some European loess deposits. – Sedimentology, 17. 129-134.

CHARLESWORTH, J.K. 1957: The Quaternary Era. London, Edward Arnold Publ. 513.

CHRISTENSEN, G.E. – WELSH, D.G. – PÉWÉ, T.L. 1978: Environmental geology of the McDowell mountains, Maricopa County, Arizona. – Geological Investigation Series, 1-a, b, Arizona Bureau of Geology and Mineral Technology, Tucson, scale 1: 24 000.

CORDY, G.E. – HOLWAY, J.V. – PÉWÉ, T.L. 1977: Environmental geology of the Paradise Valley quadrangle, Maricopa County, Arizona. Unpublished report, City of Scottdale, Arizona, 14 maps, scale 1 : 24 000.

ELVIDGE, C.D. 1979a: A model for desert varnish formation (abs.). Arizona-Nevada Academy of Science, 1979 Proceedings Supplement, 14, 81.

ELVIDGE, C.D. 1979b. Distribution and formation of desert varnish in Arizona. (M.S. thesis). Temple, Arizona State University, 109.

ELVIDGE, C.D. – MOORE, C.B. 1979: A model for desert varnish formation. – Geol.Soc. Amer. Abstracts with Program, 11. p. 271.

ELVIDGE, C.D. – MOORE, C.B. 1981: A model for desert varnish formation. – In Bender, G.L. (ed.): Reference handbook on North American deserts. Westport, Con., Greenwood Press.

ENGEL, C.G. – SHARP, R.P. 1958: Chemical data on desert varnish. – Geol.Soc.Amer.Bull. 69. 487-518.

GARDER, R.G. 1972: Origin of the Mormon Mesa caliche, Clark County, Nevada. – Geol.Soc.Amer. Bull. 83. 143-156.

GILE, L.H. – HAWLEY, J.W. – GROSSMAN, R.B. 1970: Distribution and genesis of soils and geomorphic surfaces in a desert region of southern New Mexico. Guidebook, Soil-Geomorphology Field Conference, Soil Sci. Soc.Amer. New Mexico State Univ. Las Cruces. 155.

GILE, L.H. – PETERSON, F.F. – GROSSMAN, R.B. 1966: Morphologic and genetic sequences of carbonate accumulation in desert soils. – Soil Sciences, 101. 347-360.

GOUDIE, A.S. 1978: Dust storms and their geomorphological implications. – J. of Arid Environments, 1. 291-311.

GRAF, J. – SNOW. R.H. – DRAFTZ, R.G. 1976: Aerosol sampling and analysis – Phoenix, Arizona. Environmental Sciences Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 135.

HUNT, C.B. 1954: Desert varnish. – Science, 120. 183-184.

HYERS, A.D. – MARCUS, M.G. 1981: Land use and desert dust hazards in central Arizona. – Geol. Soc. Amer.Special Paper, 186. 267-280.

IDSO, S.B. – INGRAM, R.S. – PRITCHARD, J.M. 1972: An American haboob. – Bull. Amer. Materol.Sec. 53. 930-935.

INGRAM, R.S: 1972: Summer dust storms in the Phoenix area. – Arizona Nat. Weather Service Technical Memorandum, Arizona 1. 14.

JUDSON, S. 1969: Erosion of the land. – American Scientists, 56. 356-374.

KES, A.S. – FEDOROVICH, B.A: 1976: Process of forming of aeolian dust in space and time. – International Geography '76, XXVI. Internat. Geog.Cong.Section 1, 174-177.

KOTTLOWSKI, F.E. – COOLEY, M.E. – RUHE, R.V. 1965: Quaternary of the Southwest. – In: Wright, A.G. – Frey, D.G. (eds.). The Quaternary of the United States. Princeton, Princeton Univ.Pr. 287-298.

LATTMAN, L.H. 1973: $CaCO_3$ cementation of alluvial fans in southern Nevada. – Geol.Soc. Amer. Bull. 84. 3013-3028.

MARTIN, P.S. – MEHRINGER, P.J. 1965: Pleistocene pollen analysis and biogeography of the southwest. – In : Wright, A.G. – Frew, D.G. (eds), The Quaternary of the United States. Princeton, Princeton Univ. Press. 433-452.

MERRILL, G.P. 1898: Desert varnish. – U.S. Geol.Surv.Bull.150. 389-391.

MORALES, C. 1979: A review of weather systems connected with dust storms in the Sudan and surrounding areas. – Rapporter och otiser, 31. Natural Geogr.Inst.,London Univ., 33.

National Oceanic and Atmospheric Administration, 1972: Climatological data – Arizona. – Environmental Data Service, 76, 4-12. 23.

National Oceanic and Atmospheric Administration, 1973: Climatological data – Arizona. – Environmental Data Service, 77, 1-4, 23.

National Oceanic and Atmospheric Administration, 1978: Local climatological data, annual summary with comparative data – Phoenix, Arizona. – Environmental Data Service, 4.

PERRY, R.S. – ADAMS, J.B. 1978: Desert varnish: Evidence for cyclic deposition of manganese. – Nature, 276. 489-491.

PETERSON, S.I. – JUNG, C.E. 1971: Sources of particulate matter in the atmosphere. – In: Mathews, W.H. – Kellop, W.W. – Robinson, G.D. (eds.) Man's impact on the climate. Cambridge, MIT Press, 310-320.

PÉWÉ, T.L. 1955: Origin of the upland silt near Fairbanks, Alaska. – Geol.Soc. Amer.Bull. 66. 699-724.

PÉWÉ, T.L. 1978: Terraces of the lower Salt River valley in relation to the late Canozoic history of the Phoenix Basin, Arizona. – In: Burt, D.M. – Péwé, T.L. (eds.), Guidebook to the geology of central Arizona. Tucson, Arizona Bureau of Geol. and Min. Technology Special Paper, 2. 1-45.

PÉWÉ, T.L. – PÉWÉ, E.A. – PÉWÉ, R.H. 1976: Rate of desert dust deposition (abs.). – J. of Arizona Acad.Sci., 11. Proc.Suppl. 95-96.

POPE, C.W. 1974: Geology of the lower Verde river valley, Maricopa County, Arizona (M.S.thesis). Tempe, Arizona State Univ. 104.

POTTER, R.M. – ROSSMAN, G.R. 1977: Desert varnish: the importance of clay minerals. – Science, 196. 1446-1448.

POTTER, R.M. 1979: The manganese and iron oxide mineralogy of desert varnish. – Chemical Geology, 25. 74-79.

PROSPERO, J.M. – CARLSON, T.N. 1972: Vertical and areal distribution of Saharan dust over the western equatorial north Atlantic Ocean. – Journal of Geophysical Research, 77. 5255-5265.

REEVES, C.C., Jr. 1970: Origin, classification, and geologic history of caliche in the southern high plains, Texas, and eastern New Mexico. – Journal of Geology, 78. 352-362.

REEVES, C.C. 1976: Caliche. Lubbock, Texas, Estacada Books. 233.

SCHULTEN, C.S. – BALES, J.T. – PÉWÉ, T.L. 1979: Environmental geology of the Tempe quadrangle, Maricopa County, Arizona. Unpublished report, City of Tempe, Arizona, 15 maps, scale 1 : 24 000.

SHANK, D.C. – PÉWÉ, T.L. 1973: Environmental geology in the Pheonix mountains (abs.). – J. of Arizona Acad.Sci. 8. 43.

SLACK, K.W. – SMITH, G.D. 1969: The new system of soil classification applied to arid-land soils. – In McGinnies, W.G. – Goldman, B.J. (eds.), Arid lands in perspective. Tucson, Univ. of Arizona Pr.Amer.Assoc. for the Advancement of Science Publications, 69-73.

SMILEY, T.L. 1984: Cenozoic climates. – In Smiley, T.L. – Nations, D. – Péwé, T.L. – Schafer, P. (eds.), Landscape of Arizona: A geologic interpretation (in press).

SUCK, S. – UPCHURCH, E. – BROCK, J. 1976: Dust transport in Maricopa County, Arizona. Environmental Sciences Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 62.

TEWFIK, M. 1976: Aspects of regional planning and rural development affacted by factors of physical environmental: dust storms and desert creep. (Ph.D. thesis). University of Lund. Sweden. 228.

THEIS, C.V. 1936: Possible effects of groundwater on the Ogalalla formation of Llano Estacado. – Journal of the Washington Acad. Sci. 26. 390-392.

TWENHOFEL, W.H. 1932: Principles of sedimentation. New York. McGraw-Hill. 272.

WILSON, E.D. – MOORE, R.T. – COOPER, S.R. 1969: Geologic map of Arizona. Ariz. Bur. of Mines and U.S. Geol. Survey, scale 1 : 500 000.

YAALON, D.H. 1978: „Geoderma" – Continental sedimentation: calcrete, desert loess and paleosols, sand dunes and eolianites. Tenth International Congress on Sedimentology, Jerusalem. 195-238.

YAALON, D.H. – DAN, J. 1974: Accumulation and distribution of loess-derived deposits in the semi-desert and desert fringe areas of Israel. – Zt. Für Geomorphologie. N. F. Suppl. 20. 91-105.

YAALON, D.H. – GANOR, E. 1975: Rates of aeolian dust accretion in the Mediterranean and desert fringe environments in Israel. – IX. Congress Internat. Sedimentol. Nice. 169-174.

Address of author:
Prof. Dr. T.L. Péwé, Arizona State University, Dept. of Geology
TEMPE, Arizona 85281 – USA

Készült az MTA Földrajztudományi Kutató Intézet házi sokszorosítóján
A kiadásért felel: Dr. Pécsi Márton intézeti igazgató
Példányszám: 800