LOESS AND THE QUATERNARY

CHINESE AND HUNGARIAN CASE STUDIES

AKADÉMIAI KIADÓ · BUDAPEST

LOESS AND THE QUATERNARY:
CHINESE AND HUNGARIAN
CASE STUDIES
(Studies in Geography
in Hungary, 18)

The majority of the present papers were delivered as lectures at a seminar organized by the INQUA Hungarian National Comittee and Section X. (Geo- and Mining Sciences) of the Hungarian Academy of Sciences in Budapest, October 1984. Since the early 1980s the achievements of loess research in China have been internationally recognized.

In the volume comprehensive information is presented on loess in China and in Hungary as well as on the state of Quaternary research. Results achieved in several earth science fields (stratigraphy, geomorphology, paleontology, pedology and geochemistry) are summarized in a form which promotes their application in the related sciences too.

The Chinese party presented papers on the geochemical properties of loess in China and the stratigraphic interpretation of paleomagnetic data. The Hungarian contributions are concerned with the lithology, paleontology, biostratigraphy and dating of Quaternary sediments and the mineralogical composition, geochemical properties, classification and genesis of loess as well as the analysis of soils formed on loess.

The parallel papers allow certain correlations between loesses in China and Hungary. In loess profiles of China the older loess is more divided by paleosols while in Hungary it is the younger loess that manifests more stratigraphic and chronologic subdivisions than its counterpart in China.

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STUDIES IN GEOGRAPHY IN HUNGARY, 18

Research Institute of Geography
Hungarian Academy of Sciences

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CONTENTS

PREFACE

The agreement of collaboration between the Chinese Academy of Natural Sciences and the Hungarian Academy of Sciences, renewed after a long interval, enabled Chinese researchers of loess and the Quaternary to visit Hungary and to carry on an exhange of experience here for some weeks. At the same time, I had the opportunity to study the Loess Plateau in China in 1984 and to deliver lectures at seminars in the Geological Institute of the Chinese Academy (Beijing), in its Geochemical Institute (Guiyang) and in the Geological Institute of the North-West University (Xian) and outline the problems of loess research in Hungary and of the utilization of loess regions.

The majority of the present papers were delivered as lectures at the seminar organized by the INQUA Hungarian National Committee and Section X. (Geo- and Mining Sciences) of the Hungarian Academy of Sciences in the headquarters of the Academy in October 1984.

The papers are intended to present comprehensive information on loesses in China and in Hungary as well as on the state of Quaternary research. Therefore, results achieved in several fields of the earth sciences (geology, stratigraphy, geomorphology, paleontology, pedology and geochemistry) are summarized in a form which promotes their application in the related sciences too.

Until recently, in the international professional circles and in university text-books the old treatment of the topic familiar from the 'classical' literature on loess was generally found. Very few information on the most recent results of investigation in the Loess Plateau of more than 600,000 km^2 in area in China; in the world languages only a small number of papers could be read.

The Chinese loess researchers appeared again at international conferences in the early eighties. Among these conferences the most significant was the XIth Congress of the INQUA in Moscow, 1982, where numerous Chinese loess specialists took part and reported on the achievements of loess research in China. Last year these papers were published in Budapest as contributions to the symposium on Loess and Paleopedology, but this volume only appeared subsequent to the the Chinese–Hungarian loess symposium (Oct. 14th, 1984).

The Chinese party in Hungary constituted of two renowned authorities of the discipline: Dr WEN Qizhong, who studies the mineralogical–petrological and geochemical properties of the almost 200 m thick loess and of the intercalated paleosols on the Chinese Loess Plateau and Dr AN Zhisheng, a well-known expert in magnetostratigraphy, who is engaged in the chronological subdivisions of the major loess and Quaternary profiles. His lecture on the Neogene–Quaternary boundary in the Chinese Plain delivered in Budapest was highly instructive.

In recent years the Chinese Quaternary and loess researchers analyzed the major loess profiles and dated them by paleomagnetic examinations. These investigations were performed with the collaboration of Swiss and Japanese scientists. Thus, it became also possible to compare the lithostratigraphy and magnetostratigraphy of Chinese loesses with the results on the investigations of the loess formations in Hungary. In loess profiles in China old loesses are more subdivided, have more paleosols than the loess exposures in Hungary. In contrast, the young loesses in Hungary manifest more stratigraphic and chronologic subdivisions than the Malan loesses in China. The origin of these latter are dated recently at cca 110 to 120 KA in both countries, while the Lishi loess in China and the older loess series (Paks loess) in Hungary are not older than cca 1 MA by magnetostratigraphic evidence. The Wucheng formation in China and the Dunaföldvár subaerial formation in Hungary are not loess but series of variegated clays and red soils the formation of which dates back to several millions of years.

Besides stratigraphic correlations, the Hungarian participants of the Chinese–Hungarian seminar presented an overall picture of the lithological and chronological subdivisions of loess (M. PÉCSI) and the Quaternary sediments in the Great Hungarian Plain (A. RÓNAI) and of the correlation of the paleontological and biostratigrapical stages in China and in Hungary to promote the comparison of the chronological horizons of the two countries (M. KRETZOI) on the one hand, and gave comprehensive information on the clay minerals in soils formed on the loesses of Hungary (P. STEFANOVITS), on the mineralogical and geochemical properties of young loesses in Hungary (L. GEREI and É. PÉCSI-DONÁTH), on loess classification by granulometry, the lithology and genesis of loesses (Gy. HAHN) and J. SZILÁRD) and on seasonal penetration of moisture into soils on loess (P. CSORBA) on the other.

Here acknowledgements are due first of all to the authors, who undertook the task of preparation of their papers to print and to the translators and technical editors and to all who actively contributed to the publication of this volume. Finally, the effors of the Printing Office of Statistical Puslishing House in quick printing are appreciated.

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A STUDY ON THE LOWER BOUNDARY OF QUATERNARY IN NORTH CHINA–STRATIGRAPHIC SIGNIFICANCE OF THE MATUYAMA/GAUSS BOUNDARY

AN ZHISHENG

ABSTRACT

On the basis of studies on the biostratigraphy, magnetostratigraphy, paleoclimatology and sedimentology of continuous stratigraphic sequences of Pliocene-Pleistocene, the Matuyama/Gauss boundary (about 2.4 Ma), recording a big change in terms of the biological evolution and paleoclimate, is an important level throughout the geological period and can be considered as the Pliocene-Pleistocene boundary in North China. The evidences of mammalian fossils indicate that the level bearing. Equus is consistent with the Matuyama/Gauss boundary approximately. In Beijing Plain the marine bed in early Matuyama contains foraminiferal assemblage including *Globigerina bulloides* and *Hyalinea baltica* etc., and Calcareous nannofossil assemblage characterized by *Coccolithus pelagicus* and *Emiliania huxleyi* which indicates a cold water paleoecological aspect.

The 18th International Geological Congress (London, 1948) suggested to place the Plio-Pleistocene boundary at the "first indication of climatic deterioration in the Italian Neogene succession" evidenced by the marine fossil record. In recent years, the Vrica section in Calabria, Italy, was proposed as the boundary stratotype section (SELLI et al., 1977). The Plio-Pleistocene boundary stratotype is coincidence with the physical horizon (COLALONGO et al., 1981) immediately below the first appearence of the first „cold guest", *Cytheropteron testudo* at approximately 1.6 m.y. ago (TAUXE et al., 1983). However, there are many arguments on how to get an acceptable standard for determining the Plio-Pleistocene Boundary and to process data of magnetostratigraphy in the Vrica section.

C. C. YOUNG (1949) proposed that the base boundary of Pleistocene in the north of China should be placed below the Nihowan Formation with the Nihowan mammalian fauna corresponding to Villafranchian fauna of Europe. As the progress of Quaternary research in China, different viewpoints of the lower boundary of Quaternary have been suggested as follows:

(1) In the light of some uncertain data of glaciation and human evolution, to draw the boundary at the 3.5 or 3.2–3.0 m.y. ago (SUN et al., 1979; CAO et al., 1983; QIAN et al., 1983; LI and WANG, 1983).

(2) To draw the boundary at the Matuyama/Gauss boundary approximately derived from the paleomagnetic age (after the polarity time scale by MANKINEN and DALRYMPLE, 1979) of a marine bed containing *Hyalinea baltica* and other foreminifera, and the age of first indication of climatic deterioration in the north of China (AN et al., 1979; LI et al., 1979; LIU and DING, 1982).

(3) The boundary is in coincidence with the lower level of Olduvai Subchron (LI, 1977), but there are no strong evidences to support that in China.

The author attempts to discuss the suitable Plio-Pleistocene boundary to the north of China in the light of changes of various datum levels in typical continuous stratigraphic sequences of Plio-Pleistocene.

I. SEVERAL STRATIGRAPHIC SECTIONS IN THE PLIO-PLEISTOCENE

1. LOCHUAN LOESS SECTION (*Fig. 1.*)

Well developed on the loess Plateau are quite a few large-scale loess deposit basins. Among them the Heimugou section at Luochuan County of Shaanxi (35–36°N, 109–110°E) is a typical example, where loess and palaeosols occur alternatively, and there is no apparent tectonic variance. The Luochuan loess strata with a thickness of about 136m can be subdivided (from oldest to youngest) into Pliocene red clay, early Pleistocene Wucheng loess, middle Pleistocene Lishi loess and late Pleistocene Malan loess by LIU Tung-sheng et al. based on biological, lithological, and stratigraphic structure evidences. The clear erosional surfaces within loess strata have not yet observed so far (LIU et al., 1966; LIU et al., 1978). *Cathaica* snail assemblage, appearing mostly in loess layers, shows an ecological environment of dry and cold steppe. The palaeosol bearing *Metodontia* snail assemblage were formed beneath a relatively warm and humid forests or forest-steppe areas (LIU and AN, 1978).

Wucheng loess contains *Myospalax chaoyatseni, M. hsuchapinensis, M. fontanieri* and *M. arvicolinus* and other fossils. *M. omegodon,* and *Prosiphneus intermedius* have been discovered on the base of Wucheng loess and the top of underlying red clay respectively (ZHENG Shao-hua, 1984, unpublished; LIU and YUAN, 1982).

The Matuyama/Gauss Boundary is situated at the top of Pliocene red clay in Luochuan section. The upper and middle parts of the second palaeosol complex within the middle portion of Wucheng loess records the Olduvai Subchron. Estimating initial age of early Pleistocene Wucheng loess is about 2.4 m.y. ago (HELLER and LIU, 1982; LIU and AN, 1984). The base of Wucheng loess is not only a datum level that China dust loess started to accumulate, but also is a transitional level from advanced *Prosiphneus* stage represented by P. *intermedius* to the preliminary *Myospalax* stage represented by *M. omegodon.*

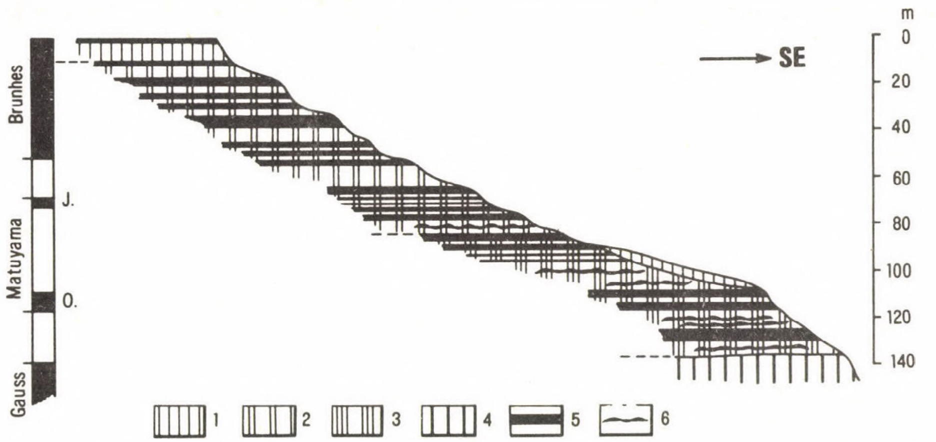

Fig. 1. Luochuan loess section
1 = Malan loess; 2 = Lishi loess; 3 = Wucheng loess; 4 = red clay; 5 = paleosol; 6 = calcareous nodule

The second palaeosol complex with the age of Olduvai Subchron are characterized by dark reddish-brown colour and well developed argillic horizon, as well as contained pollens, such as *Betula, Quercus, Rhus, Alnus* etc. Which represents an optimum climate during loess accumulation of early Pleistocene (AN Zhi-sheng, 1979; ZHOU Kun-shu et al., 1983). One of major loess layers, overlying the palaeosol complex, represents a dry-cold climate after Olduvai Subchron. An important climatic change was taken place in the loess Plateau about 1.6 m. y. ago.

2. NIHOWAN SECTION (*Fig. 2.*)

In Yangyuan and Yuxian intermontane basins in the north of Hebei, the fluviolacustrine sediments of late Cenozoic have named Nihowan Formation (BARBOUR, 1924: BARBOUR et al., 1926). It has been subdivided into two parts (HUANG et al., 1974). The upper Nihowan consists mainly of grey-yellowish sandy clay and variegated clayey sand from the base of which were discovered the Nihowan fauna (TEILHARD and PIVETEAU, 1930), such as a few Pliocene remains *Proboscidipparion sinense, Nestoritherium* sp. etc., Pleistocene elements *Bison* sp., *Equus sanmeniensis, Eucladoceros boulei, Elaphurus bifurcatus* and *Elasmotherium* sp. etc., in correspondence with the late Villafranchian fauna of Europe. Based upon the comparison between different sections, a paleomagnetic age of Nihowan fauna probably was drawn between Jaramillo and Olduvai Subchrons (LI and WANG, 1982). The lower Nihowan represented by Hongya section in margin of the basin can be subdivided into three groups (WU et al., 1980). The first one (lower portion of lower Nihowan) is composed of brownish-red sandy with sandy gravel and calcareous nodule, and contains late Pliocene fossils (WANG, 1982), as well as has an age about 3.15–3.01 m.y. (LI and WANG, 1982). The second group (middle portion of Lower Nihowan) is composed of the interbeds of greenish-yellowish silt and sandy clay with

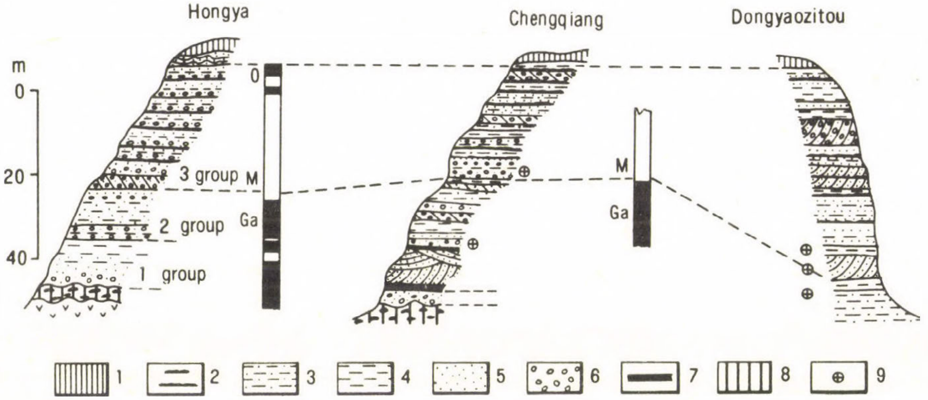

Fig. 2. A correlation of Plio–Pleistocene sections in the Nihowan Basin of North China
1 = loess; 2 = calcareous nodule or calcareous sandy layer; 3 = sandy clay–clayey sand; 4 = clay; 5 = sand; 6 = gravel; 7 = black clay; 8 = red clay; 9 = fossil location

a basal layer of sandy gravel, which formed from a fresh water lacustrine deposit. It contains coniferous tree pollens, such as *Pinus*, *Abies*, *Picea*, indicating more cold-humid climate (ZHOU et al., 1983), and has an age about 3.0–2.5 m.y. Overlying many sedimentary assemblages composed individually of gravelly, yellowish-green silt layer, and calcareous or gypseous layer constitute the third group (upper portion of lower Nihowan). The calcareous chemical deposists represent such change that the lake water became more shallow and was salified during their deposition, which indicates many times of climatic fluctuations taken place during 2.4–1.8 m.y. ago, or early Matuyama Chron. So the climate of Nihowan Basin was changed at the Matuyama/Gauss boundary obviously. Chengqiang section in the neighbourhood of Hongya is similar to Hongya section. At base gravel layer of the section, underlying calcareous deposits (upper portion of lower Nihowan), *Equus sanmeniensis* had been discovered (WU et al., 1980). According to a polarity column of Chengqiang section, the layer bearing *Equus sanmeniensis* is dated to be about 2.4 m.y. ago which may show the first appearance datum level of *Equus* in the north of China.

In the Danangou section of lower Nihowan near Chengqiang section, a new fossil horizon of Dongyaozitou was found, containing more Pliocene elements such as *Hipparion* cf. *honfenese*, *Zygolophodon* sp., *Palaeotragus*, *Autilospira* etc., and the remains of Pliocene elements *Proboscidipparion sinense,* as well as Quaternary elements such as *Lynx variablis, Nyctereutes* cf. *sinensis, Coelodonta antiquitatis, Paracamelus* sp., *Gazella sinensis* etc. (TANG et al., 1981; TANG and JI, 1983). It is earlier fauna than Nihowan fauna, and corresponds to early-middle Villafranchian fauna. The Dongyaozitou fossil horizon should be subjected to the transitional portion between the middle and upper portions of lower Nihowan near Matuyama/Gauss boundary.

3. THE SECTION OF CORE S-5 (*Fig. 3.*)

In the section of core S-5 of Shunyi County (40° 10' N, 116° 25'E) on the northeast of Beijing, the loose sediments up to a depth of 640 m is composed of fine grained sand, silt, sandy clay-clayey sand and clay, but the sediment at a depth of 640–800 m is a mottled gravel bed. The B/M boundary is placed at a depth of 160 m, and Matuyama/Gauss boundary at a depth of 468 m. At a depth of 428 m, there is a thin marine bed composed of greyish-greenish, blueyish-greyish middle-coarse sand and silt interbedded with the thin layer of sandy clay. A paleomagnetic age of the marine bed has been dated as 2.3 m. y. (AN et al., 1979). The marine bed contains more than 50 species of benthonic and planktonic foraminifera, such as *Globigerina pachyderma, G. bulloides, Hyalinea baltica, Buccella frigida, Elphidiella arctica* etc. It is postulated that during the early Matuyama Chron an extensive Beijing transgression with normal salinity took place on the Beijing Plain (AN et al., 1979; WANG and HE, 1983a). After a foraminiferal study, a calcareous nannofossil assemblage has been discovered from the same bed. There are totally eight species characterized by *Coccolithus pelagicus, Emiliania huxleyi* etc., among them *Emiliania huxleyi* and *Gephyrocapsa oceanica* should belong to Quaternary (WANG and HE, 1983a, b). The most of above mentioned foreminifera and nannofossils are indicators of a cold-water ecological environment of subarctic zone.

In Beijing Plain a cold climate about 2.3 m. y. recorded by a new datum level of the *Hyalinea baltica* appearence, and obviously cool-cold climate after Matuyama/Gauss boundary indicated by sediment characters, $CaCO_3$ content and other fossil evidences can correlate to climate records of Lochuan loess section and Nihowan Formation.

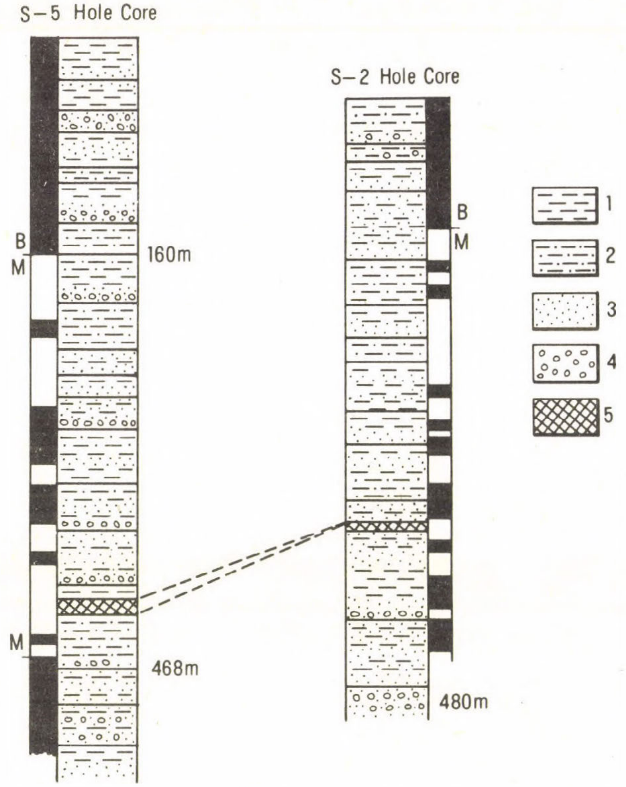

Fig. 3. Magnetostratigraphy of S-5 borehole and S-2 borehole in Beijing Plain
1 = clay; 2 = sandy clay; 3 = sand; 4 = gravel; 5 = marine bed

II. DISCUSSION OF PLIO-PLEISTOCENE BOUNDARY IN THE NORTH OF CHINA

A study on the biostratigraphy, magnetostratigraphy, paleoclimatology and sedimentology of continuous stratigraphic sequences with Plio-Pleistocene age suggests that the Matuyama/Gauss boundary or early Matuyama Chron is about 2.3–2.4 m. y. ago, recording a bigger change in terms of the biological evolution, sedimentary facies and paleoclimate than that in the end of Olduvai Subchron, is an important level throughout the geological period and may be considered as the Plio-Pleistocene boundary in the north of China.

1. The evidence of mammalian fossils

The Nihowan fauna, including advanced Pleistocene species and a few remains of Pliocene species, had been appeared since Olduvai Subchron. The first appearance level of *Equus* was placed about 2.4 m. y. ago. Dongyaozitou fauna bearing many Pliocene elements was developed about 2.5 m. y. ago. An evolutional interval from *Prosiphneus* stage to *Myospalax* stage was occurred about 2.4 m. y. ago. Consequently, a distinct alternation of the Pliocene fauna and the Pleistocene fauna was taken place in a transitional interval of geomagnetic polarity from late Gauss Chron to early Matuyama Chron.

2. The evidence of microfossils and other fossils

An appearance datum level of foreminiferal assemblage including *Globigerina bulloides, G. pachyderma, Hyalinea baltica* etc., and calcareous nannofossil assemblage characterized by *Coccolithus pelagicus, Emiliania huxleyi* are different from other observed datum levels characterized by the brackish water foraminiferal species in warm-temperate shallow water during late Cenozoic in the north of China. It represents an open sea with normal salinity and a cool-cold climate. Besides, before and after Matuyama/Gauss boundary were happened the changes of ostracod and vegetation.

3. The evidence of sedimentary facies

2.4 m. y. ago, the dust-loess accumulation had started to appear in large scale instead of Pliocene red clay. At the same time, in the Nihowan intermontane basin, the lacustrine deposit with fine grain forming in fresh water was succeeded by the calcareous deposit with coarse grain forming in shallow water, but the fine grained sediment by coarse grained sediment in Yushe Basin too (CAO et al., 1983). $CaCO_3$ content, indicating a rather dry-cold climate, was also obviously increased in fluviolacustrine sediment of Beijing Plain 2.4 m. y. ago.

In a word, a climate of rapid deterioration with an age of 2.4 m. y., in the north of China, indicates the character of dry-cold glacial climate subjected to the middle latitude area. Meanwhile, an event of biota variation was occurred at the Matuyama/Gauss boundary. It is supposed that these climatic and biological events show an important geological level placed about 2.4 m. y. ago. The level was recorded by the basal beds of Wucheng loess, calcareous sediments with coarse grain in upper portions of lower Nihowan Formation, upper Yushe Formation and Xiadian Formation, which may be regarded as the base strata of Pleistocene in the north of China temporaryly.

The geological event taken place in early Matuyama Chron would be closely connected with global climate change, and to some extent with the intense uplift of Tibet Plateau resulted from an intense uplift episode of the Himalayan Movement at the Matuyama/Gauss boundary (WANG Fu-bao, 1982).

In the north of China, the cool climate started 3.4 m. y. ago (WU, 1983). An event of colder climate was occurred between 3.5 and 2.5 m. y. (ZHOU et al., 1983). The major event of rapid climatic deterioration characterized by dry and cold climate was taken place 2.4 m. y. ago. Another event of warm or temperate and humid climate in Olduvai Subchron recorded an episode of long term climatic change. After 0.7 m. y. a tendency of dry climate has been getting more and more. All may constitute the basic pattern of long term climatic change since late Cenozoic in the north of China.

III. A CORRELATION OF PLIO-PLEISTOCENE SEQUENCES BETWEEN SEA AND LAND (*FIG. 4.*)

An attempt on a correlation of Lochuan loess section with several continental and marine sequences in the world has been made.

Continental sediments alternated with marine beds in the Osaka Group of Japan records a climatic series of Plio-Pleistocene (ITHIPARA and KAMEI). It shows that during an interval of 2.2–2.3 m. y., the climatic change from warm to cold was happened. Then many times of climatic fluctuation have been happened since 2.2–2.3 m. y.

The analysis of sedimentary facies for a bore-core of lake George in Australia of South hemisphere has reconstructed a evolutionary history of the Lake (SINGH et al., 1981). The Matuyama/Gauss boundary was consistent with the transitional interval from long dry lake to a lake in deep water. Since the Matuyama chron, the water level of lake frequently has been varied.

Loess formation of Middle Asia of U. S. S. R. developed about 2.3 m. y. ago (LAZARENKO, 1982). A terrace sequence in the lower Rhine Valley shows that the glaciation has been occurred since 2.4 m. y. approximately (BRUNNACKER et al., 1982). These facts indicate a major change of continental climate at 2.3–2.4 m. y.

Oxygen isotope and palaeomagnetic analysis of a deep sea core V28–179 shows that glacial-interglacial fluctuations have characterized Earth's climate for the past 3.2 m. y.

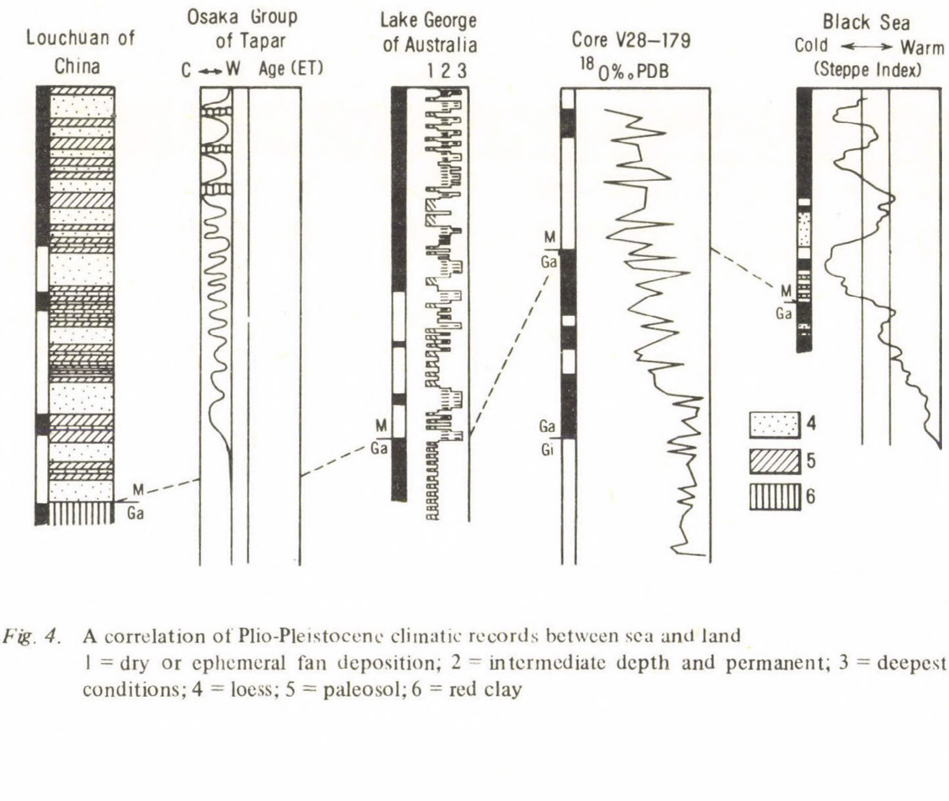

Fig. 4. A correlation of Plio-Pleistocene climatic records between sea and land
1 = dry or ephemeral fan deposition; 2 = intermediate depth and permanent; 3 = deepest lake conditions; 4 = loess; 5 = paleosol; 6 = red clay

The scale of glaciations increased about 2.5 m. y. ago (SHACKLETON and OPDYKE, 1977). The first significant cold climate took place 3.2 m. y. ago and the second intensive cold climate was appeared about 2.5 m. y. ago in the Black Sea (HSÜ and GIOVANOLI, 1979–80).

Therefore, an important level of climatic change in the late Cenozic seems to mark the beginning of Pleistocene.

A 2–3 m. y. old layer in the core E13–3 from the Antarctic Ocean with high noble metal concentrations recorded an impact event (KYTE et al., 1981), resulted from the accretion of a large extraterrestrial object, which is consistent with a major level of climate change about 2.3–2.4 m. y. ago. However, a record of the impact event should be confirmed in the future.

REFERENCES

AN Zhi-sheng–WANG Laiwen et al. 1979: Geochimica, 4. pp. 343–346.

BARBOUR, G. B. 1924; Bull. Geol. Soc. China, 3. pp. 167–168.

BARBOUR, G. B. et al. 1926: Bull. Geol. Soc. China, 5.

BRUNNACKER, K. M. et al. 1982: Quat. Res., 18. pp. 152–173.

CAO Zhaoyuan et al. 1983: Acta Geologica Sinica, 57. pp. 96–103.

COLALONGO, M. L.–PASINI, G.–SARTONI, S. 1981: Boll. Soc. Paleont. Ital. 20. pp. 99–120.

HELLER, F.–LIU Tung-sheng, 1982: Nature, 300. pp. 431–433.

HSÜ, K. J.–GIOVANOLI, F. 1979/1980: Paleogeogr. Paleoclimatol., Paleoecol. 29. pp. 75–93.

HUANG Wan-po et al. 1974: Vertebrata PalAsiatica, 12. pp. 99–108.

ITHIPARA, M.–KAMEI, T.: The 3rd Report on the Pliocene-Pleistocene Boundary in Japan.–Jap. Natl. Working Group of the IGCP Project. 41. pp. 42–50.

KYTE, F. T. et al. 1981; Nature, 292. pp. 417–420.

LAZARENKO, A. A. 1982: XI INQUA Congress, Abstracts, Vol. 1. 190 p.

LI Dingrong et al. 1979: Scientia Geologica Sinica, 4. pp. 342–349.

LI Hua-mei–WANG Jun-da, 1982: Quaternary Geology and Environment of China. China Ocean Press pp. 33–38.

LI Hua-mei–WANG Jun-da, 1983: Geochimica, 2. pp. 196–204.

LIU Tung-sheng et al. 1966: The composition and texture of loess. Science Press, pp. 9–85.

LIU Tung-sheng–AN Zhi-sheng et al. 1978: Kexue Tongbao, 23. pp. 1–9.

LIU Tung-sheng–AN Zhi-sheng, 1984: Geochimica, 2. (in press)

LIU Tung-sheng–DING Meng-lin, 1982: Quaternary geology and environment of China. China Ocean Press, pp. 1–6.

LIU Tung-sheng–YUAN Bao-ying, 1982: Research on geology (I). Cultural relics Publishing House. pp. 113–120.

LU Yan-chou–AN Zhi-sheng, 1979: Kexue Tongbao, 24. pp. 221–224.

QIAN Fang et al. 1983: Marine Geology and Quaternary Geology (3), 3. pp. 17–30.

SELLI, R. et al. 1977: Giorn. Geol., 42. pp. 181–204.

SHACKLETON, N. J.–OPDYKE, N. D. 1977: Nature, 270. pp. 216–219.

SINGH, G.–OPDYKE, N. D. –BOWLER, J. M. 1981: J. Geol. Soc. Aust. 28. pp. 435–452.

SUN Dianquing et al. 1979: Kexue Tongbao, 24. pp. 307–309.

TEILHARD de Chardin, P.–PIVETEAU J. 1930: Les mammifères fossiles de Nihovan (Chine). – Ann. Paléont. Paris, 19. pp. 1–134, Pl. 23.

TANG Yingjun et al. 1981: Vertebrata PalAsiatica, 19. pp. 256–267.

TANG Yingjun–JI Hongxiang, 1983: Vertebrata PalAsiatica, 21. pp. 245–254.

TAUXE L.–OPDYKE N. D.–PASINI, G.–ELMI, C. 1983: Nature, 304. pp. 125–129.
WANG An-de, 1982: Kexue Tongbao, 27. pp. 227–229.
WANG Fu-bao, 1982: Quaternary Geology and Environment of China. China Ocean Press, pp. 13–16.
WANG Nai-wen–HE Xi-xian, 1983a: Scientia Sinica, B–3. pp. 258–269.
WANG Nai-wen–HE Xi-xian, 1983b: Marine Geology – Quaternary Geology (3), 2. pp. 103–110.
WU Xihao, 1983: Marine Geology – Quaternary Geology (3), 2. pp. 111–121.
WU Zirong et al. 1980: Scientia Geologica Sinica, 1. pp. 87–95.
YOUNG, C. C. 1949: The Pliocene–Pleistocene boundary. – Science, 31. (11).
ZHOU Kun-shu et al. 1983: Scientia Geologica Sinica, 1. pp. 83–92.

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ON THE CORRELATION OF EURASIAN TERRESTRIAL STRATIGRAPHY IN LATE CENOZOIC TIMES (I. HIPPARION-FAUNAE)

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ABSTRACT

The vast areas of Late Genozoic terrestrial sediments in Europe, Asia, Africa and South America have given rise to local stratigraphical systems, based primarily on the successions of mammal faunae. Progress in faunal and taxonomical research in the last decades has led to sufficiently good local chronological/stratigraphical schemes to permit a broad scale intercontinental correlation at least between the European, South and East Asiatic and North American chronological/stratigraphical systems. A short account of these correlations with arguments is given. (Chronological tables.)

The framework of our chronostratigraphy is based on the biochronological sequence of marine Mollusc faunae. But vast continental sedimentary basin formations of different geological ages and the gradual narrowing of areas of marine sedimentation excluded the whole of the terrestrial realm from the direct inclusion in the "classical", malacological framework of marine stratigraphy.

The difficulties mentioned above urged for an independent terrestrial stratigraphy, a need recognised parallel with the marine stratigraphy and led to the development of a Cenozoic tetrestrial stratigraphy in the middle of the 19th century for Europe (POMEL, GAUDRY etc.), North America (MARSH, COPE) and India (the "Siwalik" of FALCONER, LYDEKKER, PILGRIM), local needs followed by a gradual elaboration of the terrestrial stratigraphy of Northern China.

Increasing knowledge of the local terrestrial, mostly mammal faunae of the late Cenozoic resulted in the possibility of broader – partly intercontinental – correlations of reasonable precision. Radiometric data also helped this work of the paleontologists and stratigraphers by measuring the duration of biochronological units.

Correlations are most readily undertaken between territories belonging to climatically continuous zones of the same hemisphere. Differences in zonation caused difficulties in the correlation of the European and Siwalian local stratigraphy. Belonging to the same climatic zonation helped the promising attempts to correlate European with North American geohistorical frameworks. This is also the situation with the North Chinese and European stratigraphical/geochronological systems which have not yet been sufficiently correlated. The aim of this brief report is to summarize the state and the perspectives of this correlation.

The most important indicators of geological contemporaneity are the sudden and dominant intrusions of new faunal elements such as the *Hipparion* or *Equus* invasions from America to Eurasia. As secondary markers indicative of environmental changes are the immigrations (infiltrations) of non-gregarious animals. In the case of this kind of immigration the occasional occurrence of these animals in the fossil record only weakens the sharpness of dates given, but do not call into question the true value of the dominant immigration. Third rank indicators are the local evolutionary stage-differences which are documented only if a statistically significant number of speciments can be counted and measured.

INDEX FORMS FOR EUROPE

The most important index forms in European-American terrestrial chronology and stratigraphy are *Hipparions* and forms of *Equus* s.l. Both invaded Eurasia from North America through the Bering strait. The fact that both reached Eurasia in masses and became suddenly dominant faunal element where they arrived, has made them firm boundary-markers in the practice of stratigraphers. But this fact has also caused errors. A flood of invaders can only give a good time mark if not weakened by other evidence. It is a d a t u m p o s t q u e m and no more. Therefore it is very dangerous to claim that when *Hipparion* is present in the fauna, it m u s t be of Early Pliocene age (Early Upper Miocene in the "new" Franco-Italian attempt to "correct" our stratigraphical concepts[1]).

[1] MAYER (the later MAYER-EYMAR) never accepted the LYELLian divisions of the Cenozoic era, he only recognized ages/stages (MAYER 1858 etc.). When establishing the Tortonian age, he confounded under this stratotaxon sediments of very different age, mainly on the basis of their "blue" colour, such as Baden-Tegel, Tortona blue clays etc. PARETO (1865) in emending MAYER's failure, restricted the Tortonian to the name-giving blue clays in the neighbourhood of Tortona and established for the Baden Tegel and corresponding sediments the denomination Serravallian. In contrast to MAYER he accepted the Lyellian stratigraphic framework and located the Serravallian at the top of Miocene and the Tortonian at the bottom of the Pliocene. MAYER – to invalidate PARETO's Serravallian – illegally restricted the Tortonian to the Baden sequence and gave to the Tortonian s.str. the new name 'Messinian. The latest French and Italian practice accepts the name and content of PARETO's Tortonian s.str., but places it on the end of the Miocene what is not correct. This false procedure is not followed here (more details in KRETZOI 1982).

Hipparion – and mutatis mutandis *Equus* – is an index form for faunal correlations, but only if other elements of the fauna do not contradict this statement, i.e. do not indicate a later age with *Hipparion.*[2]

The need to control the evidence yielded by the primary index forms with the helps of complete fauna – or at least by some secondary index forms (sporadic immigrants) – led us to the careful analysis of the entire fauna which resulted in a more or less real succession of faunal evolution, greatly confirming our dates based on first rank index forms as well as refining their documentary range.

Careful and long range comparative work on the *Hipparion* faunae and "*Elephas*"-"*Equus*"-faunae of Western and Central Europe has produced a framework for European terrestrial stratigraphical/chronological biosuccession which is used as a basis for a continental biochronology/stratigraphy of the Pliocene and Quaternary by an increasing number of European – and some American – students. The stratigraphical time-table combined with some data on faunal dynamics crucial for the establishment of the chronological change of the environment which in turn is related to important events in the history of the Earth, is given in *Table 1.*

INDEX FORMS IN THE LATE CENOZOIC OF NORTHERN CHINA

The oldest *Hipparion* faunae of the great continental basins of Kansu, Shansi, Honan and Chihli in China are restricted to the eastern strip of the mentioned sedimentary unit, namely to Honan in general and the Yüshe basin. The localities with younger *Hipparion* faunae are situated mostly in and around Kansu.

Apart from this regional distinction of an older eastern and a younger western flank of the *Hipparion* faunal basin, there is a clear distinction between an older and a younger faunal complex, characterised by a number of more or less suggestive index forms. The most important macromammal forms are listed in different catalogues and check-lists (TEILHARD DE CHARDIN 1942; KURTÉN 1952; XUE w.y.)[3]

As regards the Carnivores, from among "Canids"[4] (Amphicyonids) only *Amphicyon* is mentioned from Loc. 49 and Loc. 13; the first (Shansi, Pao-te-hsien) provided a P^4 ("M1", ZDANSKY 1924) what is better to handle as enigmatic. The second find (from Loc. 13, Honan, Hsi-An-hsien) is similarly unidentifiable. On this basis Amphicyonids, indicating archaic members of Eurasiatic *Hipparion* faunae have not been unambiguously recognised in North China.

[2] Another difficulty in the anarchy is the systematic position of individual species/subspecies of both genera; more than 160 taxonal units are established for *Hipparion* and even more for *Equus* producing a situation in which no species of these genera can be distinguished with any degree of certitude. Primitive and evolved "species" lived side by side, highly evolved species can be antedated by "primitive" forms, etc. Thus it is more reasonable to use these taxa only as generic groups in the stratigraphy.

[3] Sampling practice during the first half of this century involved the collecting of only macromammal fossils and micromammal remains are accordingly extremely rare in the faunal collections of this period. It is this reason that we take only the megafauna (macromammals) into account in this comparions.

[4] True Canids are known from East Asia only from the end of Pliocene (probably Nyctereutines) and Early Pleistocene (true *Canis, Vulpes*, etc.).

Table 1. Correlations of European terrestrial biochronology

M. y.	W. Mediterranean marine stratigraphy	Terrestrial strati-graphy		Lithostra-tigraphy	Central Paratethys stratigraphy	
	Milazzium	"Quaternarium"	Toringium	Danubium	Quaternary	
	Sicilium					
1	Emilium		Biharium			
2	Calabrium		Villányium			
3	Plaisancium					
4	Zancleum - Tabianium	Barótium	Csarnótanum		"Levantium"	
5			Ruscinium			
6	Messinium	Baltavárium	Bérbaltavárium	Pannonium	Pannonium	"Unio wetzleri" horizon
7	Tortonium		Hatvanium			Congeria neumayri horizon
8			Sümegium			C. balatonica - triangularis horizon
9			Csákvárium			C. ungulacaprae horizon
10		Eppelsheimium	Rhenohassium			C. subglobosa - czjzeki horizon
11			Bodvaium			Orygoceras - L. praeponticum horizon
12			Monacium			
13	Serravallium		Oeningium	Mediterraneum	Sarmatium	
14						

Agriotheriids are worthy of inclusion in stratigraphical/biochronological speculations: we know of Agriotheriids three well distinguished evolutionary lines. The oldest, the Galeotheriines with *Galeotherium* ("*Ursavus*") is represented in Europe by fast evolving forms of small to medium size reaching from the Lower Miocene to the early late *Hipparion* faunae (Csákvárian). The second group (*Indarctos*) is known in big sized, moderately evolved forms of the late *Hipparion* faunae, while the third is composed of medium to large forms of very archaic shape (Agriotheriinae: *Agriotherium* = "*Hyaenarctos*"), all of which are of Late Pliocene to Lowermost Pleistocene age. Through this curious crossing over of evolutionary age, size and geological age, Agriotheriids may be regarded as excellent chronological indicators. Chinese Agriotheriids are represented by *Indarctos* only and all fossil specimens have come from the late *Hipparion* faunae. This is significantly congruent with our European experience and supports the earlier distinction between "*gaudryi*"-faunae and "*dorcadoides*"-faunae in the North Chinese *Hipparion* faunae (KURTÉN 1952), established originally as two different "facies" (KURTÉN, 1. c.), but recognised here as succeeding faunal stages/ages, corresponding to the European early (i.e. Eppelsheimian) and late *Hipparion* fauna (Baltavárian) respectively.

Mustelids are – partly for the reasons mentioned above – sparser in the *Hipparion* faunae and their stratigraphical value is therefore much restricted compared with forms with a more ample fossil record. This is true for the older *Hipparion* faunae of North China, from where only *Eomellivora* is known (a final – Lower Pliocene – member of the Miocene evolutionary line *Laphictis–Ischyrictis–Eomellivora/Perunium* ranging from W. Europe to N. China).

Varied Hyaenid faunae are known from the North Chinese "Pontian". They are distinct in Ictitheriines and Hyaenines, most probably parallelling wolves and foxes in Canid ethology and ecology. In European *Hipparion* faunae, *Ictitherium* appears only in the upper levels of the "Pontian", from the beginning of the Rhenohassian (Upper Eppelsheimian). They are absent from the lower part, the Bodvaian. The same also seems to apply to the true Hyaenids (*Allohyaena, Adcrocuta, Hyaenictis, Lycyaena* etc.). In the North Chinese sequence four of 88 occurrences are bound to the "*gaudryi*"-faunae, that is to the lower *Hipparion* faunae, while all others to either "transitional" or "*dorcadoides*" faunae, i.e. they are in stratigraphical sense late *Hipparion* faunae (69). But if we reexamine the occurrences of both groups in the "*gaudryi*"-faunae we can see, that one of the occurrences of *Ictitherium gaudryi* in Loc. 73 is doubtful, while the other, Loc. 12 is the only presence to be placed in the Upper Eppelsheimian (Rhenohassian) on the basis of the faunal assemblage. The occurrence of *Ictitherium hyaenoides* in Loc. Hung Kou (Wu Hsian hsien, Shansi) is far from being dated chronologically as of early *Hipparion* fauna. *Hyaena variabilis*, a primitive member of the Baltavárian *Adcrocuta* (*H. eximia*) group of the European to Near-Eastern *Hipparion* faunae is on the right place stratigraphically at Loc. 12. All other Hyaenids are suggestive of an upper (Baltavárian) *Hipparion* age.

Good examples of other stratigraphically useful forms of carnivorous animals are the Machairodontids: great Machairodontids of the group *Machairodus* appear in contemporaneous European faunae only from the Upper Eppelsheimian (Rhenohassian), as earlier *Hipparion* faunae provide only the small Machairodont forms (*Metailurus, Parapseudailurus* and characteristically *Sansanosmilus*), being anchored in the Middle to Late Miocene of Europe. In the North Chinese *Hipparion* faunal samples the great Machairodonts appear only in the upper level of the *Hipparion* faunae, whereas the small taxa already appear in the lower part. This is exactly the same chronological distribution as in Europe.

Proboscideans are so scarce in the North Chinese *Hipparion* faunae that they are not included in this chronological analysis.

Perissodactyls are of primary importance for the stratigraphy of the *Hipparion* faunae, especially the Hipparions, giving the bulk of the faunae. As gregarious invaders, they are of crucial importance for the determination of the lower boundary of the *Hipparion* age in Eurasia. Then again care must be applied when manipulating the *Hipparion* arrival in Eurasia, because:

1. The oldest (Early Eppelsheimian) "*Hipparion*" faunae do not yet yield *Hipparion;* the flood of *Hipparion* is connected with the Middle Eppelsheimian (Bodvaian) faunae, differing from the former type only in the dominant participation of *Hipparions* in the fossil records of these localities.

2. African and Siwalian *Hipparion* occurrences are not synchronous with those in Northern Eụrasia; they correspond, on the bass of faunal composition to the Early Baltavárian (Csákvárian) faunae of Europe, yielding an age of around 8–10 My.

3. Theories concerning the evolutionary lines and successions of different *Hipparion* forms have been published in large number, but the fact that more 160 specific/subspecific taxa have been erected for different *Hipparion* "forms" (the number of taxonal names for *Equus* s.l. approaches 300) based mostly on non-diagnostic fragments, caused the situation, where the only firm point in *Hipparion* taxonomy is the generic/subgeneric level. This prevents any use of *Hipparion* species/subspecies for biochronology/microstratigraphy of far reaching paleogeographical conclusions.

Tapirids are rare among the *Hipparion* faunae, but are not without stratigraphical value: the great sized *Tapirus* is only represented in the Eppelsheimian, whilst later *Hipparion* faunae produce the tiny *Tapiriscus.* Chinese Hipparion faunae are much poorer in Tapirids; the only find – *Tapirus teilhardi* from Chai-Chang-kou (Shansi) – is accompanied by a "*gaudryi*"-fauna, which corresponds to the Late Eppelsheimian (Rhenohassian) occurrence of *Tapirus priscus* in Europe (Eppelsheim, Tataros etc.).

Chalicotheriids are extremely rare in the *Hipparion* fauna of China and are therefore without stratigraphical value. In Europe *Chalicotherium,* a survivor from the Late Miocene is confined to the earlier, the Schizotheriine *Ancilotherium* to the latest (Upper) Balvárian fauna. Much later, in the Upper Pliocene–Lower Pleistocene (Ruscinian-Villányian) Chinese fossil sample only *Schizotheres* represent the family.

Rhinocerotids, though generally important for the stratigraphy, need basic taxonal revision both in Europe and Asia. We are therefore not able to draw the stratigraphical conclusions from the dates they would give after being regrouped and redetermined. Thus we must be satisfied with the – otherwise very important – statement, that the Rhinocerotids of Northern China belonging to for stocks, viz. the "*Didermocerine*", the "*Chilotherium*", the "Diceratherine" and the aberrant "*Sinotherium*"-group seem to be confined to the following ages:

The "Didermocerines", i.e. the *Stephanorhinus (orientalis)* group and the small "*Diceratherium*", are confined to the old *Hipparion* ("*gaudryi*") faunae, whilst all the Chilotheres and the ancestral Elasmotheriine *Sinotherium* are typical later forms, occurring in the "*dorcadoides*" (Baltavárian) faunae only, the former probably in the upper part of this stratigraphical group.

Artiodactyls vary in their stratigraphical/chronological significance depending on their taxonal status. If we are consequently satisfied with a separation of the fossil evidence on a generic/subgeneric level, important conclusion are to be drawn from nearly all the families of this order. Suids are likely the most conservative forms: they only allow us the supposition that *Chleuastochoerus* is dominant in the earlier, "*Microstony*" is restricted to the upper level, and lastly that "*Propotamochoerus hyotherioides*" (*?Korynochoerus*) seems to be confined to the lower part of the *Hipparion* fauna of Northern China.

Chleuastochoerus is hardly to compare with corresponding forms in Europe and "*Propotamochoerus*" also needs revision.

"*Microstonyx*" is one of the index forms of the European late *Hipparion* faunae, whilst *Korynochoerus* that of the Eppelsheimian. This correlates well with the European Suid distribution: *Korynochoerus* and *Conohyus* in the lower (Eppelsheimian) and "*Microstonyx*" in the upper levels (Baltavárian) of the *Hipparion* faunae.

Cervids also give raise to taxonomical problems and need urgent revision. The fact that *Eostyloceros* finds and the bulk of *Cervocerus* remains are bound to the earlier *Hipparion* faunae is not in contradiction with European experience, only that the sample for the later levels is too poor.

A fairly good sample is known of Giraffids from the *Hipparion* fauna of Northern China. Three groups of them are listed from this region, a *Palaeotragus*-, a *Samotherium*- and a *Honanotherium*-group. One of these three groups, the *Honanotherium* can hardly be compared with Europeans, if not with "*Giraffa*" (*Bohlinia*). *Palaeotragus* is present over the whole time-span, while *Samotherium* is limited to the late *Hipparion* faunae. Only the dominance of *Palaeotragus* in the early *Hipparion* faunae of Europe seems to contrast with the dominance of the specimens referred to *Palaeotragus* in the late *Hipparion* faunae of Northern China, whereas the exclusive presence of *Samotherium* in the late *Hipparion* faunae – as mentioned above – is not comparable with any European chronological distribution of Giraffids.

Finally Bovids, the most widely distributed group of *Hipparion* faunae in Northern China are practically focused to the spread of two *Procapra*-("*Gazella*"-) species over the whole area. One of these, i.e. *Procapra* (*Protetraceros*) *gaudryi* with brachyodont molars is the index form of the lower, whilst *P. dorcadoides* that of the upper *Hipparion* faunae in Northern China. This type of distinction is unknown in European faunae, where *Procapra* ("*Gazella*") is sporadic or absent in the earlier, but dominant in the late *Hipparion* faunae. However, if we compare the "*Gazella*"-species in Europe and Northern China we are left with the impression that European gazellas are generally more evolved than the early forms (*gaudryi*-group) in China, showing an evolutionary level comparable with that of the evolved North-East Asian forms of the *dorcadoides*-groups.

Other antelopes within the *Hipparion* fauna of Northern China are not comparable with European forms, primarily because of their more sporadic appearance and partly discussable taxonomic position. Regarding these circumstances we can only remark that "Tragocerines" are limited to the upper –and partly "transitional" – *Hipparion* faunae, whereas European forms listed under *Tragocerus* are found through both the early and late faunae. Other named antelopes like *Plesiaddax*, *Protoryx*, *Paraprotoryx*, *Prosinotragus*, *Sinotragus* are limited to the late faunal level, with *Plesiaddax depéreti* dominating in number of occurrences.

It is interesting to note that Chinese *Hipparion* faunae seem to be clearly divided faunistically by the mountain ranges crossing China from W to E into a North Chinese terrestrial red clay/loess basin and a South Chinese coal basin type, with remarkable differences in the *Hipparion* and later faunae of these two regions. Although our knowledge in respect of the *Hipparion* faunae of the coal basins is increasing from year to year, the faunal differences seem to be greater than would be the case in a normal continuous and gradual transition caused by a more southern geographical location. This contrast in the faunas is more evident when compared with that in the *Hipparion* faunae of continental Europe and the Mediterranean area. Nevertheless we can attempt to correlate the North and South Chinese *Hipparion* faunae and to insert the few known southern localities in the succession of northern faunal evolution.

Of the southern *Hipparion* faunae we consider as most important and significant that of the Shihuiba (Lufeng, Yunnan) locality – by far the richest locality in Hominoids known today – and some other, tentatively known *Hipparion* faunae as Keiyuan (Yunnan) and perhaps Shihhung (Kiangsu). The fauna of these regions show many differences compared with the great mammal assemblages of North China, although these are not so important as to make correlation hopeless.

Common to the two types of faunae is self-evidently *Hipparion*, the basis of any correlation. Other forms are more controversal. To reach a better understanding of the two faunal complexes, ancestral and modern types must be compared.

As forms giving a date post quem, we begin with the forms belonging to later faunae consisting of the following types.

Macaca sp. or any Papionid form is a typical member of the late post-*Hipparion* faunae both in Europe and the Siwaliks. Hystricids are not known in European *Hipparion*-assemblages before the Late Lower Eppelsheimian. Leporids – of hares – seem to invade Eurasia at the beginning of the Upper "Pontian" (Early Baltavárian). Machairodonts of the *Machairodus*-group – and especially *Epimachairodus* – are members of those faunal complexes beginning with the latest Eppelsheimian localities. *Chilotherium* seems to belong to the late *Hipparion* faunae in the North Chinese sample (see above). Finally *Metacervulus* or even *Antilospira* are forms of late to post-*Hipparion* faunae.

The forms enumerated above do not by themselves fix the Shihuiba fauna in the upper part of the *Hipparion* faunae, viz. the Baltavárian; they are only the most striking examples.

The most important ancestral forms which contrast with the above mentioned modern ones, are *Chalicotherium* (*Macrotherium*), lasting in Europe until the middle of the Baltavárian; *Aceratherium*, which is rare in the late *Hipparion* faunae, *Tapirus* (unless it is its dwarf form), *Korynochoerus ("Hyotherium") cf. palaeochoerus*, which only exceptionally reaches the Lower Baltavárian (Csákvárian) in Europe and "*Lophochoerus*" (*Xenochoerus*), confined to the earlier (Miocene) faunae. All these forms are very disturbing in a northern fauna, but they can be readily accepted as survivors in a fauna of a more southern biogeographical belt – such as today South China compared with the northern parts of Asia, viz. North China. All these arguments confirm the Shihuiba fauna as of early Late Baltavárian age. The importance of this dating is crucial for the position of the Hominoids in Southern China in the hominization process:

1. They are – like the Siwalik forms – not of Early, but of Late "*Hipparion* fauna" age.

2. If we consider the Siwalik great form (Kaulial Kas, Loc. 410 – GSP 15000) as ancestral to orang, the Chinese *Sivapithecus yunnanensis*, being with its broad interorbital constriction explicitly non-orang, seems to have arrived in South China not along the Subhimalayan route through the Siwaliks, but along a more northern route. This supposition is strongly supported by the fact, that Potwars–Siwaliks had no *Hipparion* before the beginning of the Nagri age (oldest absolute age date less than 10 My), implying that there was no direct faunal exchange between Southern China and India before Baltavárian/Nagrian times.[5]

[5] The early connection was accepted only under the pressure of the classical terms "Oriental" or "Indomalayan" faunal region, but these units did not exist before Late Quaternary. It was the Sino-Malayan connection that existed during the Pliocene/Early Quaternary time range, separated from the Siwalian region (KRETZOI 1938, 1964; v. KOENIGSWALD 1940; THENIUS 1972; HEINTZ – BRUNET 1982).

Whilst the period 1921–1930 was one of large-scale excavations in the red clay regions of Northern China, which produced tremendous masses of macrofossil material belonging to the Early Pliocene ("Pontian"), the years between 1931–1942 can be described as the time of intensive collecting and study of micromammal faunae. This followed the *Sinanthropus*-discovery and the large-scale excavations and description of the Early and Middle Pleistocene Sanmenian and *Sinanthropus* faunae which elucidated the environmental factors for hominization in the territories of China.

Before finishing this brief outline of the "Pontian" *Hipparion* faunae of Northern China and their comparison with contemporaneous European faunal evidence, the South Mongolian "Upper Miocene" fauna of Tung gur must be mentioned, too. The faunal list is nothing but a typical old *Hipparion* fauna – without *Hipparion*. This is exactly the case as in Europe, where the break between the Miocene and Pliocene is geological and not paleomammalogical. The brackish seas of the Western/Central Paratethys Basin disappear and a new, meso/oligohaline lake occupies the basins with an entirely new specialized Mollusc assemblage (the so-called *Congeria* faunae) which abruptly supplanted the impoverished Miocene brackized faunal complex.

The mammal forms representing the Tung gur fauna are – if not evident endemisms as *Gobicyon* and others – easily correlated with those of the European Eppelsheimian, primarily with the Early Eppelsheimian (Monacian) "*Hipparion*" faunae also without *Hipparion*.

If we accept these parallels, we can also accept the following correlations between the North Chinese and European Hipparion faunae.

On the basis of the sequence we find the first level with the Tung gur fauna, equivalent in age to the Lower Eppelsheimian (Monacian).

The second complex, characterised by the *Hipparion* flood, shows mostly the forms of a surviving Late Miocene faunal type accompanied by *Hipparion*. This can be parallelled with the Middle (Bodvaian) to Upper (Rhenohassian) Eppelsheimian of European biochronology/stratigraphy.

The third complex is a *Hipparion* fauna with a considerable number of new immigrants replacing many ancestral (Miocene) forms and showing the first great Machairodonts, varied Hyaenas and Ictitheres, Mustelids, Chilotheres, new Suids (*Microstonyx*-group), new giraffees, Cervids and an increasing variety of Bovids. This faunal type is well comparable with the late *Hipparion* faunae of Europe, i.e. with the Baltavárian time unit. A more detailed subdivision of this faunal complex is better postponed until a sedimentological revision of the localities proves this refined periodization in the field too.

A more detailed subdivision of the Baltavárian stage/age will enable us to establish a better elaborated boundary between Baltavárian and Ruscinian (Upper Pliocene) separated probably by a characteristic transition (Baltaian). The paleomagnetic record of biostratigraphically dated sediment bodies will also help in a sharp drawing of the boundaries between the stratigraphical sub-units.

The detailed grouping of the individual localities in the time table and a comparison of European with North Chinese faunal succession are given in *Table 2*.

<table>
<tr><td rowspan="4">Baltavárium</td><td colspan="2">Baltavár, Andreevka, Gökdere, Gravitelli, ?Hatunsaray-Sekisiirti, Hosszúpereszteg, Kavurca, Khirgiz Nur I, La Croix-Rousse, Velez</td></tr>
<tr><td>Hatvan, Alfacar, Galgamácsa</td><td rowspan="2">Grossulovo, Montebamboli, Halmyropotamos, Hausruck-Kobernausserwald</td></tr>
<tr><td>Sümeg, Diósd-2, Rózsaszentmárton</td></tr>
<tr><td colspan="2">Csákvár, Berislav, Biodrak, Can Llobateres, Can Trullos, Dorn-Dürkheim, ?Eldar Garkin, Eski Bayirköy, Kstellios, La Fontana, Los Aljezares, ?Mannersdorf, Novopetrovskoe, Varnitza</td></tr>
<tr><td rowspan="2">Eppelsheimium</td><td>Eppelsheim, Azambujeira moy., Bellver, Brunn-Vösendorf, ?Cerdana, Can Llobateres, Charmoille, Chabreuil, Concud-2, Fonyód 1, ?Hirsizderesi-B, Höwenegg, Inzersdorf, Kalfa, Karacahasan (=Kücükyozgat), Karain-Ürgüp, ?Mariathal, Melchingen, Montredon, Neuhausen (O Tuttlingen), Nombreville, ?Orignac, Pedregueras, Pencken, Sain-Jean-de-Bournay, Salmendingen, Seo de Urgell, Soblay, Tataros/Derna, Tuttlingen, Udabno, ?Undingen, Westhofen, Wissberg</td><td rowspan="2">Altmannsdorf, Bovila Calabui (B. Sagues), ?Bulumya, Caldes de Montbui, ?Can Aurell, ?Can Bayona, ?Carrion, ?Chai-Chang-kou, Chen-Kou-Wan, Chiao-Chia-Kou, ?Chia-Yü-Tsun, Chili loc. 66., Chingko-Hsien loc. 48., Chü-Tse-Wa, Dadasun, Delibayar Siirti, Dereikebir, Ebingen, ?El Lugarejo, Fehring, Feng-Ming-Po, Fu-Cheng-Tau, Gora Kutsai, ?Hatunsaray, Hausruck, Herzogbierbaum, ?Ho-Chien-Nao, Hsia-Yin-Kou, Hsin-An-Hsien 11, 12, 13, 27, 28, 29, 35, 57, 58, 59; Hsing-Wa-Kou, ?Hung-Kou, In-Önü, Kobernaussen-Lohesburg, Lassnitz-Höhe, ?Li-Yü-Tau, Mas d'Ocata, Mas Duran, Miao-Po, Mien-Chih-Hsien, Mistelbach, Nan-Kou 1, 2; ?Neuhausen, Paulino, Pecsenyéd, Polinya 1, 2, 3; ?Prats i Sanabastre, Pyhra, Quinta do Marmelai, Relea, Sebastopol, Süleymanli, Sung-Tsun, ?Tau-Tsun, ?Ta-Ping-Kou, Ulas, Wu-Hsiang-Hsien loc. 70, 71, 72, 73, 74, 75, 77, 78, 80, 81; Yang-kou, Yang-Lien Chuang</td></tr>
<tr><td>Rudabánya 1–7, Aveiras de Baixo, ?Berhida, Castel (or La) Bisbal, Corak Yerler, ?Drassburg, Esme-Akcaköy, Esselborn, Fertőszéplak, Gaiselberg, Gau-Weinheim, ?Hirsizderesi-A, Lassnitzhöhe-1, Monteagudo, Sabadell, ?Sogucak-Yasiören, Steinberg, Touraine (Faluns de la . . .)</td></tr>
</table>

München (Flinzsande), Azambujeira inf.. Balatonakarattya, ?Beni Mella, Diósd-1, ?Felsőtárkány, ?Hohenlöwen, ?Mikulov, ?Nyergesújfalu, Sopron, Boór-féle homoknyerö, Sopron, Kurucdomb, Akcaköy, Alas (Barranco), Aldehuela, Alfambra, ?Altan Tölü, Ananiev, Andriashovka (1), Aspe, Armavir, Avgustovka, ?Axious, Azambujeira sup., Baccinello V_{1-3}, Balcikli Dere, Barranco de la Mina, Bazaleti, Beger-2, Belka, Bilaspur Kehlor, Brunn am Gebirge, Carretera de Fornes a Arenas, Castralbo, Cenes de la Vega, Cevril, Chi-Chia-Kou, Chi-Tsu-Kou, Chiton Gol, Concud, Concud 3, Concud: Barranco de las Calaveros, Concud: Cerra de la Garita B, Cortijo de la Dehesa, Crevillente 1, 2, 3, Djebel Hamrin, Douaria, Ebic, Eggenburg, Eichkogel, Enzensdorf im Tale, Erenköy, Esme, Evcileragillari, Fu-ku-Hsien loc. 51., Garkin, Ghazgay 11, 12, 13, Grebeniki, Gura-Galbeni, Gurgenaydan, Harmancik, Ho-chü-Hsien loc. 114., Hohenwarth, Hou-Liang, Hsiao-Hung-Chü, Hsiao-Szu-Chia-Ling, Hung-Chiao-Ni-Ke-Tan, Ilhan, Jurjevka, Kainary, Kalimantsi/Kromidovo, Kayadibi, King-Yang Hsien loc. 115, 116, ?Kinik, Kizilermak, Kohfidisch, Küçükçekmece, Las Pedrizas, Libros, Lobrieu, Los Aguanaces, Los Canalisos, Lukeino, Magian, Mahmutgazi, ?Malakass-Oropos, Malang, Mancusun, Manzati, Maragheh, Masada del Valle 2, 3, 4, 5 – 6, 7; Masathy, Mitha Khatak loc. 18c, Molayan, Mollon, Mpesida, Mugla, Nagri, Nakali, Nemours, Ngorora, Novaja Jemetovka, Odessa, Olan Chorea, Olivas, Ozmaniye, Pao-Te-Hsien loc. 30, 31, 44, 108, 111, 112, 113; Pavlodar, Pei-Hou-Kou, Pena del Macho, Peralejos; Peralejos A 5, Petrovierovka, Pierola, Puente del Salobral, Ramiz-Istanbul, Rio Jatar, Saksagany, San-Ta-Kou, Şarkişla, Selçik, Shia-Shiang loc. 22., Sidi Salem, Siebenhirten, Simferopolski ray., Sinap inf. + moy., Stavropol-Kamenski, Taghar, Taginka, Tarrasa, Taşkinpaşa, Tejares de Jun, Tiraspol, Tjulkisaj, ?Torcapel, Tortajada, Tortajada A, B, C; Tsaidam, Troya (?Erenköy), Unterlaa, Valdecebro 3, 4; ?Verigenstadt, Vienne, Villalba Baja 1, 2; ?Vivero de la Rambla, Wa-Yao-Po-Kou-Nei, Wadi Hamman, ?Wadi Zra, Wien: Türkenschanze, Wiener Becken, Wolkersdorf, Yasiören, Yemliha, Zajsanskaja kotlovina
Akdere-Erkilet, Alexandr Dar, Argithan, Ayas, Azambuja/Archino, Beçin, Beçin-Kolanyaktepe, Besyol, Buzhory, Camp Berteaux, Cerro del Caleric, Chott Derid (=Tozeur), Cueva de las Tres Puertas, Djaparidze, Hüttendorf, Kalinköy, Karakeçili, Karatochok-Dagh, Kliasticy, Konnor, Krems, ?Kubanka, Kurlik, La Puebla la Almenara, ?Leopoldsdorf, Morsumkliff (=Sylt), Novocherkassk, Obertiefenbach, Oborniki, Pao-The-Hsien loc. 43, 49, 52, 109, 110; Piera (Plana del Castel), Puebla, Puerto de Vitoria, Puy-Courny, Shihuiba, Thiergarten, Tokoum, Torrentet dels Traginers, Tulcino, Valdelaguna
Abaújszolnok, ?Akin, Anjou (Faluns d'), ?Aumeister, ?Ayvacik-Gülpinar, ?Babai Khola etc., ?Basbereket, Beocsin, Bermersheim ?Bitz, ?Bugski liman, ?Chepkesin, Chinji, ?Djebel Semmene, Eggersdorf ?Farrenberg, Frohnstetten, Grosslappen, ?Heuberg, Kanatti-Chat, ?Kalkaman, ?Kavak-Dere, ?Kayadibi, Kisinev, Kisbér, Kisbucsa, ?Kolbingen, Köprübaşi, Kürpód, Lassnitz-Tunnel, ?Marian Wala, Marktl, Mochi Wala, Oshin (Lower, Upper), ?Oláhcsaholy (=Cehalut), Pero Filho, ?Pei-Ho, Ramnagar (Region), Répcekőhalom, Romhány-Világospuszta, ?San Casablancas, ?San-Chuan, Schmeien, Sopron 2, Sóskút 2, Szántóhalma, Székelyszentmihály (=Mihaileni), Trochtelfingen, ?Vasfarkasfalva, ?Villedieu, Willershausen, Willmandingen, ?Yigitler Köy

CONCLUSIONS

A detailed comparison of the *Hipparion* faunae of Europe and Northern China resulted a good intercontinental correlation between the terrestrial sedimentation of these two remote regions.

The most important results of this correlations are:

1. The North Chinese *Hipparion* faunae of the "*gaudryi*"-type are broadly contemporaneous with the European Middle-Late Eppesheimian time units. The Mongolian Tung gur fauna is probably comparable with the European Lower Eppelsheimian age (Monacian).

2. The "*dorcadoides*"-type of *Hipparion* faunae in Northern China may generally be correlated with the Baltavárian *Hipparion* fauna in Europe. The correlation of substages will be substantiated only after some taxonal revisions and comparisons have been carried out.

3. Chinese *Hipparion* faunae seem to represent two different climatic/zoogeographic provinces, i.e. the well known Northern Chinese type and the Southern one, represented primarily by the so called Lufeng fauna.

4. The Lufeng fauna is most probably a chronological parallel to the European Lower Baltavárian (Csákvárian) faunal type, and is best compared with the Siwalian Nagri fauna.

5. A correlation of the Northern Chinese "*gaudryi*"-faunae with the North American Clarendonian and consequently of the "*dorcadoides*"-faunae (or at least of the bulk of it) with the Hemphillian of the North American faunal sequence is broadly established, although substage correlation must await new evidence and – primarily – urgent taxonal revision.

REFERENCES

A more detailed bibliography is given in two articles of this list: KRETZOI, 1983; KRETZOI–PÉCSI 1982.

HEINTZ, É.–BRUNET, M. 1982: Rôle de la Téthys et de la chaine alpine asiatique dans la distribution spatio-temporelle des Cervidés. – C. R. Acad. Sc. Paris. Ser. 2. Tom. 294. pp. 1391–1394.

KOENIGSWALD, G. H. R. von, 1940: Neue Pithecanthropus-Funde 1936–1938. Ein Beitrag zur Kenntnis der Praehominiden. – Dienst v.d. Mijnbouw in Nederlandsch-Indië. Wetenschappelijke Mededeelingen. 28. pp. 1–232. Batavia.

KRETZOI, M. 1938: Die Raubtiere von Gombaszög nebst einer Übersicht der Gesamtfauna. Ein Beitrag zur Stratigraphie des Altquartärs. – Ann. Mus. Nat. Hung., Pars Miner. Geol. Palaeont. 31. pp. 88–157.

KRETZOI, M. 1964: Mammal faunae and the continental geology of India. – Acta Geol. Hung. 8. 1–4. pp. 301–312.

KRETZOI M. 1982: A Kárpát-medence felső-neozóos rétegtanának korrelációs lehetőségei. (Tentative correlation of Late Cenozoic stratigraphy in the Carpathian Basin.) – M. Földt. Int. Évi Jel. 1980-ról. pp. 407–415.

KRETZOI M. 1983: Kontinenstörténet és biosztratigráfia a felső harmadkor és a negyedidőszak folyamán a Kárpát-medencében és korrelációi. (Kontinentalgeschichte und Biostratigraphie im Jungtertiär und Quartär des Karpaten-Beckens und ihre Korrelation.) – Földr. Közlem. 31 (107). 3–4. pp. 230–240.

KRETZOI, M.–PÉCSI, M. 1982. Die Gliederung des Pliozäns und Quartärs im Pannonischen Becken. – In: Quaternary Glaciation in the Northern Hemisphere. Session Kiel, Sep. 18–23, 1980. Prague. pp. 127–149.

KRETZOI, M.–VÉRTES, L. 1965: The role of vertebrate faunae and paleolithic industries of Hungary in Quaternary stratigraphy and chronology. – Acta Geold. Hung. 9. pp. 125–144.

KURTÉN, B. 1952: The Chinese Hipparion fauna. – Soc. Sci. Fennica. Commentationes Biologicae. *13*. 4. pp. 1–82.

MAYER, K. 1858: Versuch einer neuen Klassifikation der Tertiär-Gebilde Europas. – Verh. d. Allg. Schweiz. Ges. f. d. Naturw. 42. Vers. 165–199, chron. Tabelle.

PARETO, L. 1865: Note sur les subdivisions que l'on pourrait établir dans les terrains tertiaires: de l'Appenin septentrional. – Bull. Soc. Géol. France. 2. 22. pp. 210–277.

TEILHARD DE CHARDIN, P. 1942: Chinese fossil mammals. – Publications of the Institut de Géo-Biologie, Pékin. *8*. pp. 1–142.

THENIUS, E. 1972: Grundzüge der Verbreitungsgeschichte der Säugetiere. Jena, G. Fischer. X, 345 p.

XUE XIANGXU, w.y. The Quaternary mammalian fossils in the loess area of China. pp. 112–159.

⁻DANSKY, O. 1924: Jungtertiäre Carnivoren Chinas. – Palaeont. Sinica. Ser. C. *2*. 1. pp. 1–149. 33 Taf.

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CHRONOSTRATIGRAPHY OF HUNGARIAN LOESSES AND THE UNDERLYING SUBAERIAL FORMATION

M. PÉCSI

ABSTRACT

The upper part of Young loess in Hungary is the "Dunaújváros--Tápiósüly subseries" cca. 13–26 thousand years old. The lower part of Young loess called: the "Mende–Basaharc subseries" is about 27–120 thousand years old.

The Old loess and interbedded fossil soils in Hungary are called: the "Paks subseries".

The upper part of the Paks old loess is cca. 125–210 thousand years old. The lower part of the old loess subseries contains the Brunhes–Matuyama boundary. The B/M paleomagnetic boundary (formed 0.73 million years B.P.) was reached in the loess layer between the paleosol PD_2 and PDK in both the Paks and Dunaföldvár exposures (Fig. 5, 8, 9). The loess layer of several meter thickness underlying the Paks–Dunakömlőd paleosol (PDK) is the oldest member of the Paks subseries, wich is younger than the Jaramillo paleomagnetic event.

The "mottled, gleyed reddish clay" is named Dunaföldvár formation. Below the old loess series a "non-loessic" formation of considerable thickness (25 to 30 m) follows. From a lithostratigraphic and paleopedologic point of view the "non-loessic" formation of Dunaföldvár is clearly distinct from the Paks old loess. Their marked stratigraphic boundary, in our conclusions, probably represents the Eopleistocene–Lower Pleistocene boundary (about 850 000 years B.P.).

It is also presumed that the lower limit of the Dunaföldvár formation represents the boundary between the Upper Pannonian lacustrine-inland sea formation (5.3 million years) and the Pliocene (earlier Upper Pliocene, or Levantian) terrestrial deposits.

To draw the boundary between this latter and the so-called Eopleistocene, the top of the red clay series (Dv_1) seems to be the most suitable (cca. 2.2–2.4 million years).

On the basis of its lithological characteristics, the Hungarian loess formation can be subdivided into the clearly distinct units of "young loess" and "old loess". The slightly compacted young loess of 10 m to 30 m thickness is highly calcareous and contains chernozem-like dark-brown fossil soils. The ratio of sand fraction increases towards the top of the series.

The old loess is more compact and its calcium carbonate content is lower, although the rhythmic layers with lime concretions (loess dolls) are common even within a single loess packet. Fluvial sandy lay-

ers and alluvial, paludal soils are often interbedded in the loess. Reddish-brown and ochre-red fossil soils predominate. The old loess also has an altered loamy variant.

In some sections the old loess in underlain by finely stratified pink sandy silts deposited upon the series of red clay soils and gleyed clays (at Dunaföldvár and Paks). As a separate lithostratigraphical unit this latter is named the "Dunaföldvár formation".

YOUNG LOESS AND INTERBEDDED FOSSIL SOILS

Investigating a number of sections, we found the ones at Basaharc, Mende, Dunaújváros and Tápiósüly to be the most typical and suitable for the stratigraphic subdivision of the young loess and for the correlation of the interbedded fossil soils (*Fig. 1*).

Fig. 1. Important loess exposures in Hungary

1. UPPER PART OF THE YOUNG LOESS

(The "Dunaújváros–Tápiósüly subseries", about 13 to 26 thousand years).

This 10 m thick loess sequence made up of sandy loess and loessy sand layers is the most complete subseries of the young loess known so far. In between these there are only two or three weak humus horizons (humous loess, loess serozem H_1, H_2). At the top of the first typical humous soil horizon, in a layer of only a few cm thickness, charcoal remnants of

Pinus cembra and *Larix* were found. Their radiocarbon age is 16,730 ±400 y. B.P. The occurrence on a regional basis of charcoal remnants and the traces of fire in the loess above the humous layer H_1 in some places seem to indicate extensive forest fires. These could either be due to drought of natural origin or may be attributed to the reindeer herding activity of prehistoric man living in the Magdalenian Period. Above the layer with the charcoal remnants, the 2 m thick loess overlayer, sporadically though, but contains a great number of fragments of *Rangifer tarandus* shovels.

The second humous soil horizon (H_2) was dated by the charcoal remnants of the Dunaújváros section as 20,000–22,000 radiocarbon years. In the "Dunaújváros–Tápiósüly subseries" the second humus horizon is underlain by loess layers of more or less sand content. An additional lower sandy loess (l_2) frequently contains mammoth bones and at

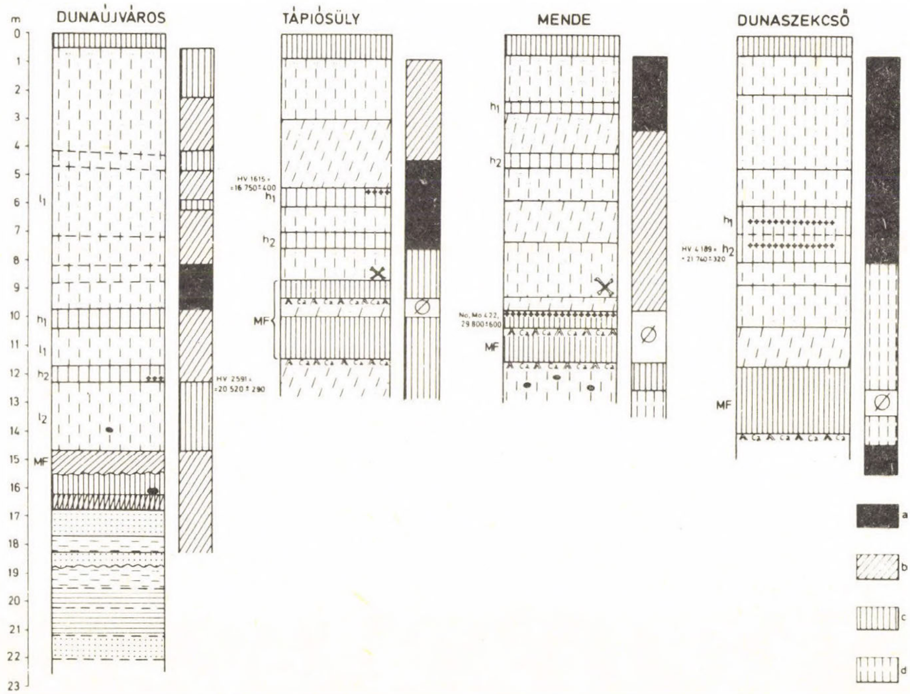

Fig. 2. The most charasteristical loess profiles of the "Dunaújváros–Tápiósüly Series"
a = snails that favour a wet and cool periglacial climate; b = snails that favour a not so wet and still cool periglacial climate; c = snails that favour relatively cold and dry periglacial climate; d = snails that favour a relatively warm and dry periglacial climate; H_1, H_2 = weak humus horizons; l_1, l_2 = number of the young loess packets
For explanation of figures see Fig. 10.

Mende the whole skeleton of a mammoth calf was also found (*Fig. 2.*). In Hungary it is the most widespread loess subseries. It was formed in a paleogeographical environment that was dominated by cold-dry loess grasslands with coniferous groves, characterized by animals living in cold forested grasslands and proper grasslands.

In the series slightly sandy loess layers alternate with more sandy loess and loessy sand. Stratified slope loesses are common, particularly in buried dells. These latter also occur in two or three layers of the loess above one-another, usually below the humous soils H_2 or H_1. By the character of strata, in addition to falling dust, blown sand, meltwater and solifluction also seem to have played a part in the accumulation of the upper part of the young loess profiles (see *Fig. 3*).

2. LOWER PART OF THE YOUNG LOESS

(The "Mende–Basaharc subseries", about 27 to 120 thousand years.)

This loess subseries is about 20 to 25 m thick and consists of four soil horizons with the enclosing loess packets (*Fig. 3, 4*). The "Mende upper" soil complex (MF) immediately underlies the Tápiósüly subseries. It is, in general, a double soil horizon. The upper part (MF_1) is a poorly developed chernozemlike soil with "krotovinas" and charcoal remnants. The latter are dated as 27,000–29,000 radiocarbon years. The lower layer is a well developed forest-steppe soil; the age of the charcoal remnants found here is 32,000 radiocarbon years. The "Mende upper" double soil represents a "warm period" of several thousand years within the youngest interstadial of the Mid-Würm. In the middle of the Mende–Basaharc series, under several metres of mostly typical loess (l_3), there is again a double soil complex.

Fig. 3.

1 = recent chernozem, locally chernozem and brown forest soil (two story profile); 2 = sandy loess, in the l_2 loess a whole skeleton of a young Mammuth was found; 3 = weak humus horizon (with charcoal); 4 = stratified loessy sand, at the lower part reindeer bone remnants occur; 5 = stratified sandy slope loess; 6 = *stratotype of Mende Upper* (MF) soil complex, it is a two story profile of forest-steppe soil. In its upper part (MF_1) there are many charcoal fragments (Picea, Larix, Pinus cembra), radiocarbon date: 29 800 ± 600, Lab. No. Mo 422; 27 200 ± 1400, Lab. No. I. 3130; 27 000 ± 1589, Lab. No. Hv 5422. The Cca horizon of MF_2 is rich in lime and carbonate concretions; 7 = typical loess, but in the lower part there is a little more sandy loess; 8 = "Basaharc double" soil complex (forest-steppe-like fossil soil) below the BD_2 there are remnants of Elephas primigenius; 9 = "Basaharc lower" fossil soil (BA) locally the uppermost part soil sediment; 10 = stratotype of Mende Base (MB) soil complex, the upper part (MB_1) is a dark steppe-like (chernozem-like) fossil soil; the lower part (MB_2) is well developed; 11 = alluvial, proluvial sand at the Tápió brook (second terrace); the Mende Base soil complex developed probably during the second half of the Riss–Würn interglacial, because the alluvial sand below that is cca 125 000 years old according to thermoluminescence data (BORSY, Z.–FÉLSZERFALVY, J.–SZABÓ, P.P. 1980). H_1, H_2 = weak humus horizons; l_1–l_5 = number of the young loess packets; l_1', l_1'', l_2' = subdivision of the main loess packets

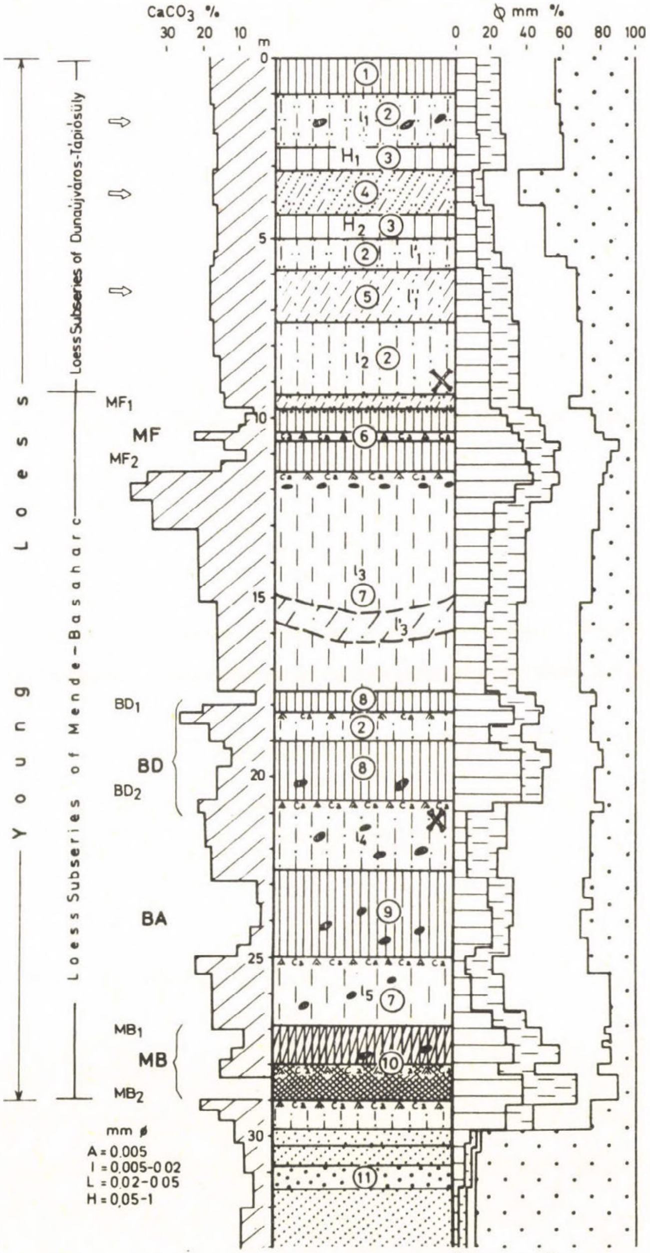

Fig. 3. Typical locality of the young loess profile at Mende near Budapest (According to PÉCSI, M.–SZEBÉNYI, E. 1971, profiling done with the cooperation of JUHÁSZ, A.–DI GLERIA, M.)

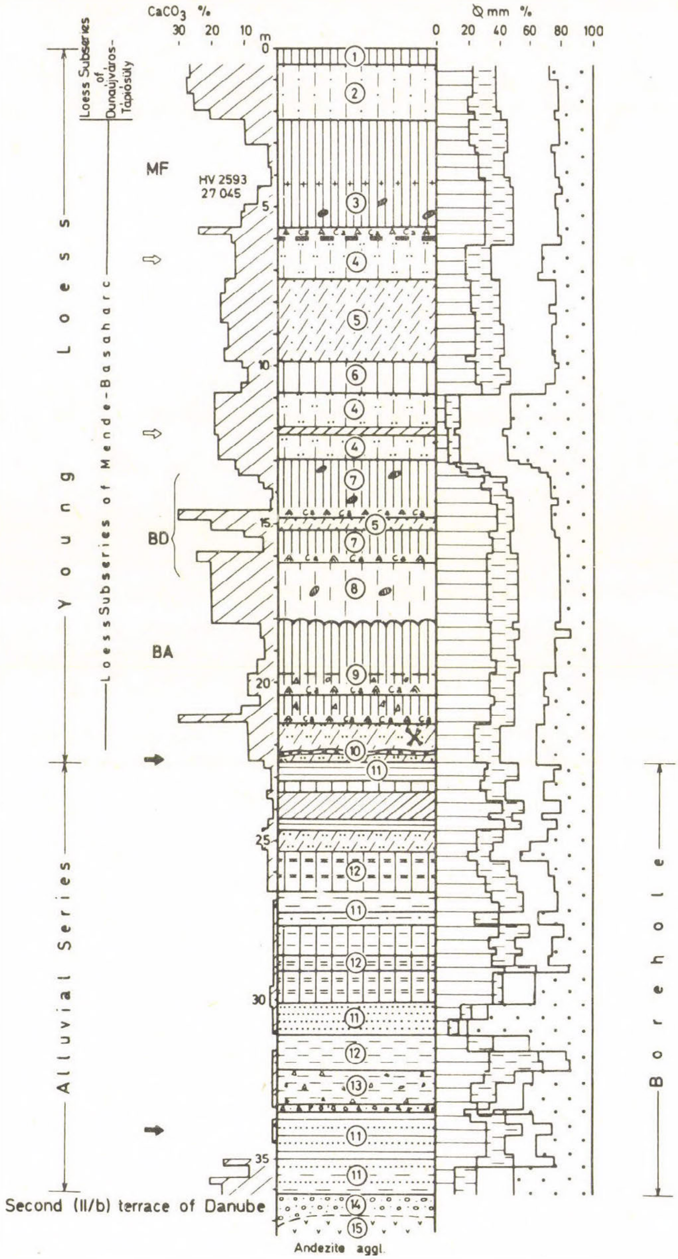

Fig. 4. Young loess profile situated on the second terrace (II/b) of the Danube (Basaharc brickyard near Visegrád) (According to PÉCSI, –SZEBÉNYI, E., profiling done with the cooperation of SCHEUER, Gy.–SCHWEITZER, F.)

The stratotype was first described at the abandoned pit of the Basaharc brickyard (PÉCSI, 1965). This "Basaharc Double" (BD) soil complex consists of chernozem-like forest-steppe soil horizons the age of which can be estimated at 40,000 to 44,000 years B.P. According to the most recent thermoluminescence investigations by BUTRYM–MARUSZCZAK (1984) the soils BD_1 and BD_2 are 37,000 to 41,000 years B.P. old (*Fig. 5*).

The third buried soil of the Mende–Basaharc subseries is the "Basaharc base" soil (BA). It is a remarkably well developed chernozem-like fossil soil of locally 1.5 to 2 m thickness. Its absolute age is estimated at 70,000 to 80,000 years B.P. and in its lower part the skull of *Ursus spaeleus* was found. The upper part of the horizon "BA" is mostly soil sediment accumulated by solifluction.

The "Mende Base" soil complex (MB) found at the base of this series is made up of two completely different soils. The upper solum MB_1 (80 to 100 cm) is a forest-steppe soil, while the lower part (80 cm) is a well developed brown forest soil (Braunerde, Parabraunerde – MB_2). This double soil was dated as having formed during the latter part of the last (Riss–Würm) interglacial (PÉCSI, 1965, 1975). The thermoluminescence analysis of samples from the Mende Base soil (BORSY et al. 1979) showed 105,000 years B.P. for their age, while BUTRYM–MARUSZCZAK (1984) found 121,000 years also by TL investigation on samples from the Paks brickyard pit. According to the measurement by BORSY et al. the age of the loess, underlying soil MB at Paks, is 125,000 years B.P. The time interval of the last (Riss–Würm) interglacial is usually given at 100,000 to 125,000 years.

In each of the loess layers (l_3, l_4, l_5) of the Mende–Basaharc subseries more or less thick (derasion) slope loess occurs.

OLD LOESS AND INTERBEDDED FOSSIL SOILS
(The "Paks subseries")

It is in the Paks profile that old loess in Hungary has been analyzed in a most detailed way, though similar sequences are also known from exposures along the bluffs at Dunaújváros and

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Fig. 4.

1 = recent soil, brown forest soil; 2 = sandy loess; 3 = dark, fossil soil complex, upper part probably soil sediment (forest-steppe-like soil complex), in the middle part of the soil B horizon numerous charcoal fragments occur (radiocarbon date 27 045 ± 880 y. B.P. Lab. HV 2593). The age of this soil complex is *likely to* be the same as the stratotype's; 4 = sandy loess, loessy sand; 5 = sandy slope loess; 6 = weak humus horizon with charcoal fragments; 7 = *stratotype of "Basaharc double" soil complex* (BD_1, BD_2) (forest-steppe-like soil complex), in the BD_1 fossil soil numerous charcoal fragments occur (radiocarbon date 32 100 ± 720 y. B.P. min. age (Lab. HV 8116); 8 = loess with krotovinas; 9 = stratotype of *"Basaharc lower" fossil soil* (forest-steppe character), below that a complete skull of an Ursus spaeleus minor was found; 10 = slope loess with unconformity caused by andesite debris; 11 = alluvial (sandy) clay, silty sand, sand; 12 = alluvial hydromorphic soils, gleyed clay; 13 = gleyed clay mixed with andesite slope debris; 14 = = terrace gravel of the Danube; 15 = altered andesite agglomerate.

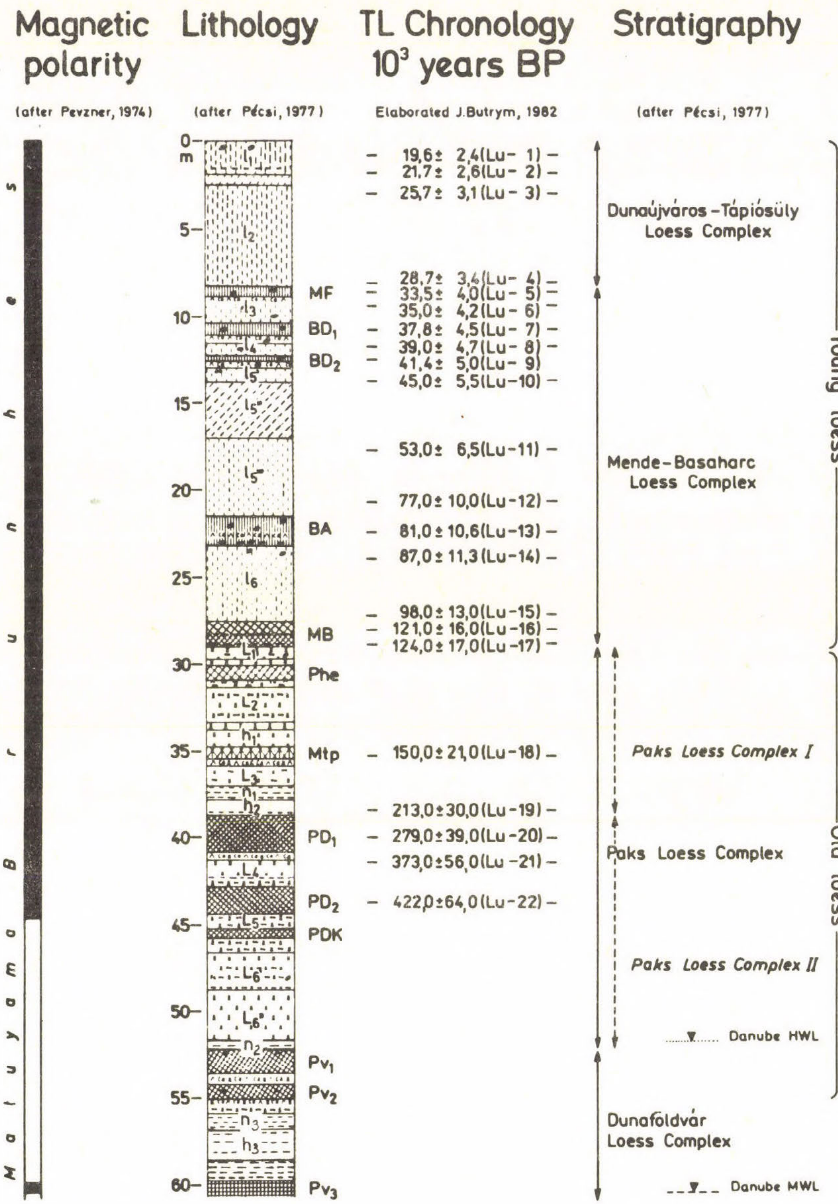

Fig. 5. Thermoluminescence chronology of the examined lithostratigraphical layers of the loess profile at Paks. Lithological and stratigraphical differentiation and the correlation with magnetic polarity diagram according to M. PÉCSI et al. (1977) and M. PÉCSI (1979), to the depth of 46 m – an exposure, 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

Dunaföldvár. The almost 25 m thick old loesses were named the "Paks series" (PÉCSI, 1975) they can be subdivided into two parts on the basis of their lithological characteristics (*Fig. 6*).

1. UPPER PART OF THE PAKS OLD LOESS (about 125 to 210 thousand years)

As presented in *Fig. 6* it is enclosed by the MB soil above and by the PD soil below and contains the old loess packets (L_1–L_3). Sand layers (S_1–S_2) represent erosional unconformities. Interlayered with the sand and silty sand beds is a well developed alluvial gleyed hydromorphous soil (Mtp in Fig. 6). In the upper part of the subseries, also upon a sand layer a weakly developed brown forest soil ("Phe") is formed.

In 1970 fragments of *Elephas throgontherii's* teeth and tusks were found (determined by D. JÁNOSSY) in the old loess horizon (L_1) above the Phe paleosol. Since the upper part of the Paks subseries may contain erosional hiatuses, thus the correlation of paleosols and loessy, sandy strata with the classic climatic phases of the Pleistocene and with the chronostratigraphical time scale becomes very difficult. It is probable, however, that the upper part of the Paks old loess represents an incomplete stratigraphical sequence of the Middle Pleistocene. As TL investigations proved the uppermost layers (L_1) of the Paks subseries are about 125,000 years old, while the lower sandy layer is (S_2) about 200,000–210,000 years old (BORSY–FÉLSZERFALVY–SZABÓ, 1979; BUTRYM–MARUSZCZAK, 1984), this period can be correlated with the penultimate glaciation (Riss – 130,000 to 190,000 years B.P.). The fluvial sand and silt (S_2, n_1) may represent the penultimate interglacial (Mindel–Riss). At the time of the accumulation of this fluvial sand, part of the old loess must have been eroded, consequently loess of Mindel glacial age is probably absent at Paks.

2. LOWER PART OF THE PAKS SUBSERIES WITH THE BRUNHES–MATUYAMA BOUNDARY

Three old loess layers build up the 15 m thick series and they are interbedded with three dark brownish-red fossil soils (Fig. 6). Situated at the bottom of the Paks exposure, the "Paks–Lower" Double Soil Complex (PD) is made up of two equally well developed 1.5 to 2.0 m thick dark brownish-red compact paleosols which enclose a 2 m thick loess bed. Calcium carbonate accumulation in the C horizons of both soils is intensive, marked by a layer rich in carbonate concretions, loess dolls. Large krotovinas are typical in the A_2 and B horizons. Genetically, the soils are probably well developed dry forest soils of Mediterranean type. The Brunhes–Matuyama paleomagnetic boundary (0.73 million years B.P.) was reached in the loess layer below the soil PD_2 – in both the Paks and Dunaföldvár exposures (PÉCSI–PEVZNER, 1974; MÁRTON, P. 1980).

Immediately below the Brunhes–Matuyama paleomagnetic boundary there follows another loess horizon of 1.5 to 2 m thickness with a reddish-brown paleosol at its base. It is observed in an exposure lying lower the Paks brickyard as well as at Dunakömlőd and

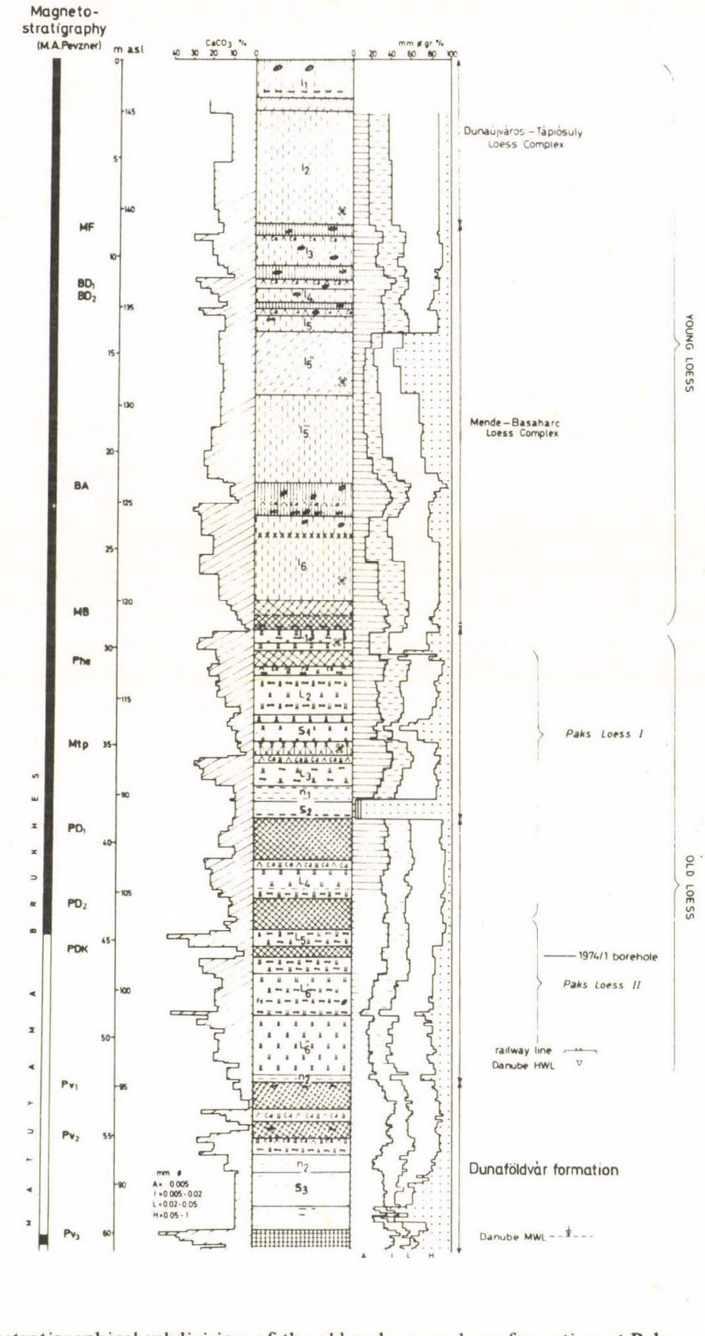

Fig. 6. Lithostratigraphical subdivision of the old and young loess-formation at Paks
The lithological and pedological analysis made by PÉCSI, M. and SZEBÉNYI, E., the paleomagnetic measurements made by PEVZNER, M.A. (Institute of Geology Acad. of Sci. USSR, 1974).

Dunaföldvár in the loess bluffs along the Danube. It was first discovered in the Paks–Dunakömlőd bluff below the Brunhes–Matuyama paleomagnetic boundary. Its first pedological description is by PÉCSI et al. (1977) and it was named the Paks–Dunakömlőd soil complex (PDK). Genetically, the 1.5–2 m thick brownish-red redbrown clayey soil is most likely a Mediterranean-type xerophylic forest soil (*Fig. 6*).

The old loess of several metre thickness underlying the Paks–Dunakömlőd paleosol (PDK) is the base member of the so-called Paks subseries and indicates its stratigraphic boundary. Below the thick old loess (L_6) in the Paks profile there is a silty sand interbedding overlying a double red paleosol. This latter is not referred to the Paks subseries. Below these layers loess strata older than them are not known from profiles in the Carpathian Basin. Similarly, in loess sections in Czechoslovakia there is only a single soil horizon and only one loess packet described below the Brunhes–Matuyama paleomagnetic boundary (KUKLA, 1970).

In the dating of the "Paks Lower Double Soils" (PD_1 and PD_2) and the Paks–Dunakömlőd fossil soil (PDK) and the whole of the lower part of the Paks subseries it is primarily the age of the Brunhes–Matuyama paleomagnetic boundary (0.73 million years) which is of major help. Furthermore, the fact that in the pink sandy sediment below the Paks old loess Jaramillo paleomagnetic event (0.9 million years) occurs, is also significant (see *Figs. 6 and 7* in PÉCSI–PEVZNER, 1974). Additional information is supplied by the most recent TL examinations by BUTRYM–MARUSZCZAK (1984), which indicate the absolute age of the PD_1 soil as 279,000 ± 30,000 years B.P., and of the PD_2 soil as 422,000 ±62,000 years B.P. It would mean more than 140,000 years' time difference between the two soil formations of identical type. The period between them appears to be too long, since no erosional hiatus is observed between the two members of this soil complex. It seems certain that the

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Fig. 6

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 ot l_2 (x) fragments of reindeer bones occur as well as locally 1 to 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 Eleph. primigenius remnants) with a thin layer of *volcanic tuffite too* in the upper part of it; MB. = "Mende-Base" fossil soil complex; the upper part of it a forest-steppe-like soil, but the lower one a well-developed brown forest soil (according to 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 occasoins; 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; S_1, S_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 chestnut, 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 = the Lowermost old loess bed, loess dolls rarely occur; n_2, n_3, S_3 = sandy clay, silty clay and sand of alluvial fan; Dv_1, Dv_2, Dv_3 = reddish, ochrered fossil soils, below the old loess (belong to the "Dunaföldvár formation")

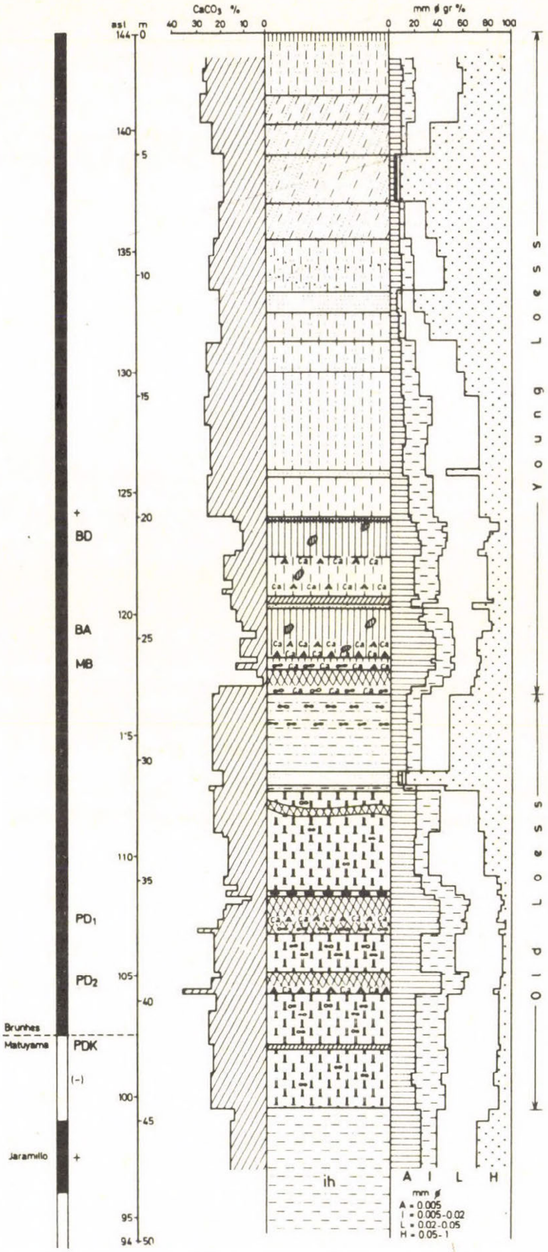

Fig. 7. Lithological, pedological profile of the open exposure No. 1. at Dunaföldvár, with paleomagnetic analysis (PÉCSI, M.–SZEBÉNYI, E.–PEVZNER, M.A.)
For explanation of figures see Fig. 10.

old loess packet (L''_6) was formed during the first real glacial (Günz?). It is still debated whether PDK and PD_2 and PD_1 can be associated with the Cromer (1–3) interglacial period between the first and the second glaciation, which is interrupted repeatedly by short cold spells alternating with longer warm periods as it had been assumed by PÉCSI (1982), or whether PD_1 and PD_2 were formed as interstadial soils within the second (Mindel) glaciation according to BUTRYM–MARUSZCZAK (1984).

THE "MOTTLED, GLEYED, REDDISH CLAY" FORMATION ("Dunaföldvár formation")

Below the old loess series a non-loessic formation of considerable thickness (25 to 30 m) follows. It is overlain by the above outlined lower part of the old loess and underlain by Upper Pannonian (Mio-Pliocene) lacustrine-marine formation. The "non-loessic" terrestrial formation is basically a mottled, gleyed-reddish clay and silty, sand clay sequence studied mainly by us in sections along the Danube between Dunaföldvár and Paks. This series of formations was earlier called the Dunaföldvár complex, or formation (PÉCSI, 1975).

At Dunaföldvár this series begins with 5 to 6 m thick, microstratified, *pale pink, slightly silty sand* (shown as "ih" in *Figs. 7. and 8.*) with rhythmically alternating thin cemented sandstone strings and concretions. Below that lies a 3 to 5 m thick *dark-grey clay meadow soil complex (Ms).* These meadow soils, as indicated in their pedological analyses, have 2 to 3 % humus, and at their bases the $CaCO_3$ content reaches 40 to 60 %. The soil profile also comprises layers with dolomitic lime concretions.

The most characteristic part of this formation is the ochre-red soil sequence with a thickness of about 10 to 15 m, known from several boreholes at Dunaföldvár (Fig. 7). Five or six reddish fossil soils were identified intercalated with thin gleyed silty-clay beds. The pedological, mineralogical and other characteristics of red paleosols have been detailed previously (PÉCSI et al. 1979). From among the red soils Dv_3, Dv_4, Dv_5 and locally Dv_6 had undergone intensive weathering (clayification). It is also typical of these soils that their $CaCO_3$ content is extremely high in the horizons B_2 and Cca of the paleosol profiles. It is presumable, therefore, that the red paleosols in the "Dunaföldvár formation" are remnants of a xerophylic forest soil formed under some Submediterranean-type climate.

The underlayer of the subaerial sequence of the Dunaföldvár formation is Upper Pannonian clay of lacustrine–inland sea origin or, a loosely cemented sandstone mostly defoliating into highly micaceous wafers as shown in the boreholes of *Fig. 8.*

Below the red soil series, in the Dunaföldvár boreholes some gleyed clay beds and silty sand are deposited in thicknesses of 5 to 6 m with repeated sand intercalations.

The meadow soil complex (Ms) above the red soil series is probably the product of some cooler climatic phase.

Based on the paleopedologic, lithostratigraphic and paleomagnetic data it may be supposed that the development of the "Dunaföldvár formation" had begun long before the Gauss epoch – it can be probably dated as far back as the early Gilbert. Its youngest deposit, the pale-pink silty sand, may become accumulated immediately after the Jaramillo event.

From a lithostratigraphic and paleopedologic point of view the "non-loessic" formation of Dunaföldvár is clearly distinct from the Paks old loess. Their marked stratigraphic

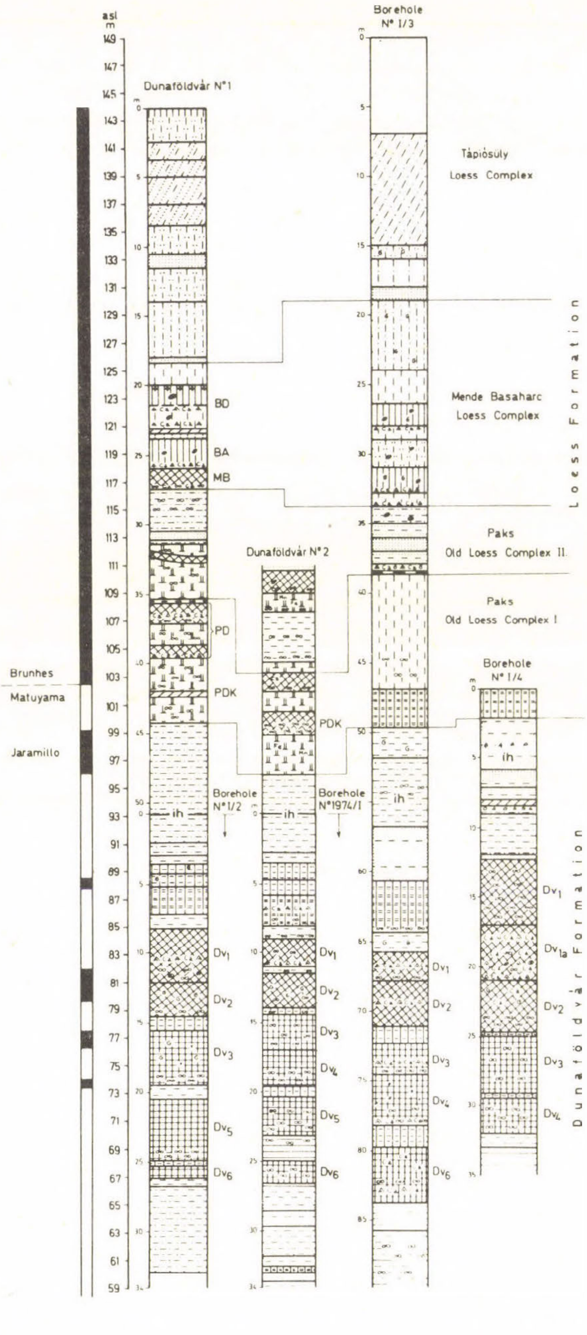

Fig. 8. Correlation of the different exposures and borehole profiles at Dunaföldvár (PÉCSI, M.–SZEBÉNYI, É.–PEVZNER, M.A.)
For explanation of figures see Fig. 10

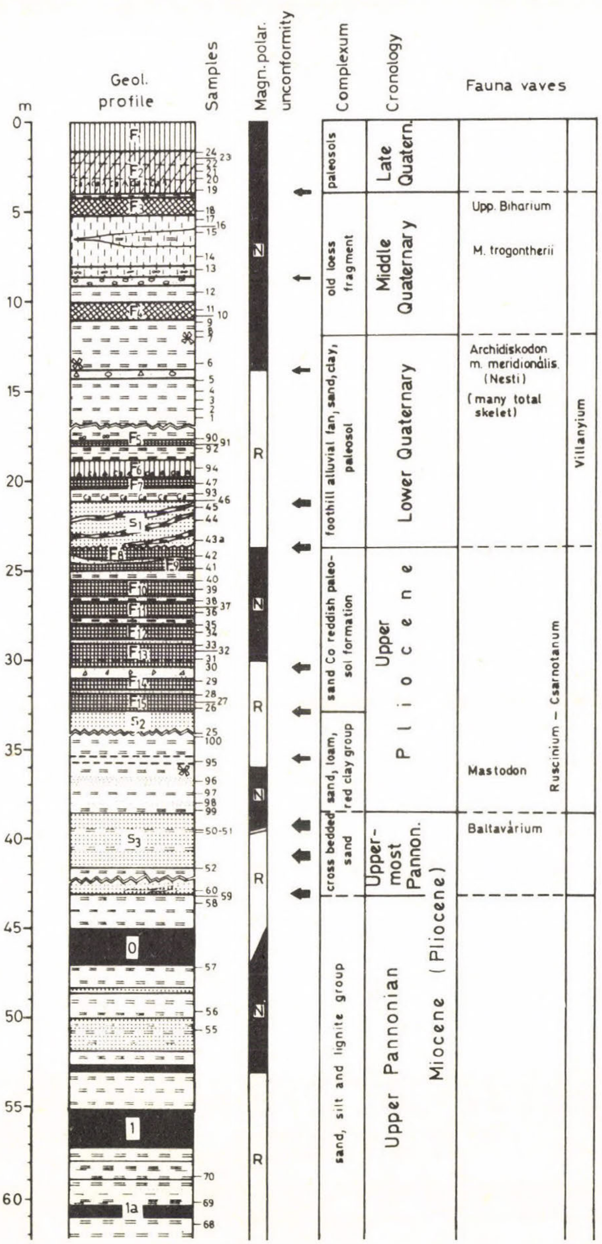

Fig. 9. Comprehensive profile of the Gyöngyösvisonta open cast lignite mine (Thorez Mine), 1981. The profile was surveyed and identified by BALOGH, J.–MÁRTON, P.–SCHWEITZER, F.–SZOKOLAI, Gy. under the guidance of PÉCSI, M.
F_1–F_{15} = paleosols; s_1–s_3 = sand; 0, 1, 1a = lignite layers
For explanation of figures see Fig. 10.

boundary, in our conclusions, probably represents the Eopleistocene–Lower Pleistocene boundary (about 850,000 years B.P.).

It is also presumed that the oldest red clay of the Dunaföldvár formation (Dv_6) represents the boundary between the Upper Pannonian lacustrine–inland sea formation (5.3 million years) and the Pliocene (earlier Upper Pliocene or Levantian) terrestrial deposits. To draw the boundary between this latter and the so-called Eopleistocene, the top of the red clay series (Dv_1) seems to be most suitable (about 2.2 million–2.4 million years old).

Red clay formation covered most of the Gauss and Gilbert paleomagnetic epochs (cca from 5.0 million to 2.4 million years). This conclusion is supported by the detailed analyses of the samples obtained from the Dunaföldvár boreholes (PÉCSI–PEVZNER, 1974) from the Vésztő and Dévaványa boreholes (RÓNAI–SZEMETHY, 1978; COOKE–HALL–RÓNAI 1979) as well as those of the overlying series of the lignite in the Gyöngyösvisonta open cast mine (KRETZOI–MÁRTON–PÉCSI–SCHWEITZER–VÖRÖS, 1982; *Fig. 9*).

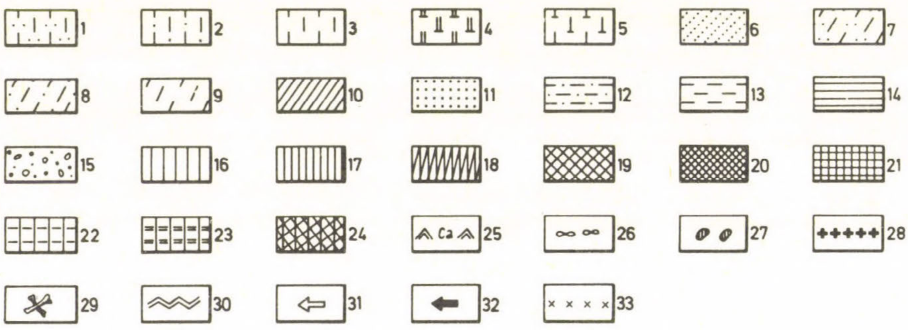

Fig. 10. General legend to the *Figs* of the Hungarian loess-profiles

1 = loessy sand; 2 = sandy loess; 3 = loess; 4 = old loess; 5 = infusion loess; 6 = slope sand; 7 = loessy slope sand; 8 = sandy slope loess; 9 = slope loess; 10 = semipedolite; 11 = fluvial-proluvial sand; 12 = silty sand; 13 = silt, gleyed silt; 14 = clay; 15 = sandy gravel; 16 = weak humus horizon; 17 = steppe-type soil, chernozem; 18 = forest soil altered by steppe vegetation; 19 = brown forest soil; 20 = grey-brown forest soil; 21 = red clay; 22 = hydromorphic soil; 23 = alluvial meadow soil; 24 = forest soil (on flood-plain); 25 = calcium carbonate accumulation; 26 = loess doll; 27 = krotovina; 28 = charcoal; 29 = macrofauna; 30 = discontinuity in profile; 31 = traces of non-linear erosion; 32 = traces of linear erosion; 33 = volcanic ash.

MF = "Mende Upper" forest-steppe Soil Complex (29 800 years B.P., Mo. 421 and HV 27 855 ± ± 599 years); BD = "Basaharc-Double" forest steppe Soil Complex; BA = "Basaharc-Lower" chernozem soil; MB = "Mende-Base" Soil Complex (brown forest soil + forest steppe soil); Phe = Paks sandy forest soil; Mtp = Paks marshy soil; PD = "Paks Lower Double" Soil Complex (brownish-red Mediterranean-type dry forest soil); PDK = Paks–Dunakömlőd brownish-red soil; Pv_1, Pv_2, Pv_3 = Paks red soils; Dv_1 – Dv_6 = Dunaföldvár red soils;

A = clay (<0.005); I = silt (0.006–0.02); L = Loess (0.02–0.05); H = sand (0.05–1.00);

n_1, n_2 = sandy silt; ih = silty sand

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. Hung. 22. pp. 451–459. – Studies on Loess. Bp. Akad. K. 1980.

BUTRYM, J.–MARUSZCZAK. H. 1984: Thermoluminescence chronology of younger and older loesses. – In: Lithology and Stratigraphy of loess and Paleosols. Budapest. Geogr. Res. Inst. Hung. Acad. Sci. pp. 195–199.

COOKE, H.B.S.–HALL, J.M.–RÓNAI, A. 1979: Paleomagnetic, sedimentary and climatic records from boreholes at Dévaványa and Vésztő, Hungary – Acta Geol. Hung. 22. pp. 89–109. – Studies on Loess. Bp. Akad. K. 1980.

KREITZOI, M.–PÉCSI, M. 1979: Pliocene and Pleistocene development and chronology of the Pannonian Basin. – Acta Geol. Hung. 22. pp. 3–33. – Studies on Loess, Budapest 1980.

KRETZOI, M.–MÁRTON, P.–PÉCSI, M.–SCHWEITZER, F.–VÖRÖS, I. 1982: Pliocene-Pleistocene piedmont correlative sediments in Hungary (based on lithological, geomorphological, paleontological analyses of the exposures in the open-cast mine at Gyöngyösvisonta). – In: Quternaty studies in Hungary. Bp. Geogr. Res. Inst. Hung. Acad. Sci. pp. 43–73.

KUKLA, J. 1970: Correlations between loesses and deep-sea sediments. – Geol. Föreningen i Stockholm Förhandligar, 92. 2. pp. 138–180.

MÁRTON, P. 1979: Paleomagnetism of the Paks brickyard exposures. – Acta Geol. Hung. 22. pp. 443–440. – Studies on Loess, Bp. Akad. K. 1980.

PÉCSI, M. 1965: Zur Frage der Typen der Löss- und lössartigen Sedimenten im Karpatenbecken und ihrer litostratigraphischen Einteilung. – Földr. Közl. 13. pp. 305–323.

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

PÉCSI, M. 1975: Lithostratigraphical subdivision of the loess sequences in Hungary. – Földr. Közl. 23. pp. 228–230.

PÉCSI, M. 1979: Lithostratigraphical subdivision of the loess profiles at Paks – Acta Geol. Hung. 22. pp. 409–418. – Studies on Loess. Bp. Akad. K. 1980.

PÉCSI, M. 1982: The most typical loess profiles in Hungary. – In: Quternary studies in Hungary. Bp. Geogr. Res. Inst. Hung. Acad. Sci. pp. 145–169.

PÉCSI, M.–PEVZNER, M.A. 1974: Paleomagnetic measurements in the loess sequences at Paks and Dunaföldvár, Hungary. – Földr. Közl. 22. pp. 215–226.

PÉCSI, M.–Mrs. PÉCSI DONÁTH, É.–SZEBÉNYI, E.–HAHN, Gy.–SCHWEITZER, F.–PEVZNER, M.A. 1977: Paleogeographical reconstruction of fossil soils in Hungarian loess. – Föld. Közl. 25. pp. 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, pedological, thermal and paleomagnetic investigation). – Acta Geol. Hung. 22. pp. 513–537. – Studies on Loess. Bp. Akad. K. 1980.

PEVZNER, M.A.–PÉCSI, M. 1980:Paleomagnetizm i stratigrafiya lessogo-pochvennykh otlozheniy Vengrii. – Byull. Komiss. po izuch. chetvertichnogo perioda. 50. pp. 24–34.

RÓNAI, A.–SZEMETHY,A. 1979: Paleomagnetic investigation of the 1110 m sediment core from Dévaványa Scientific Exploration Borehole. – In: Guide-book for Conference on the Stratigraphy of Loess and alluvial Deposits, Budapest–Szeged 1979 Hungary. Bp. Inst. Hung. Acad. Sci. pp. 63–82.

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THE QUATERNARY OF THE GREAT HUNGARIAN PLAIN

A. RÓNAI

ABSTRACT

The Great Hungarian Plain is the largest sedimentary basin in Europe, and is filled with great thicknesses of Neogene sediments.

The complex mapping of these deposits was started by the Quternary Department of the Hungarian Geological Institute in 1964, and has fallen into three parts. The first has been concerned with the superficial sediments (*Fig. 1*), the second has studied the deposits at depths of 100–1500 m by means of medium deep drilling (*Fig. 3*). While the third has looked at the pre-Pliocene geology of the basin bottom (*Fig. 4*).

Detailed paleontological studies have been devoted to determining the biostrratigraphic boundary between the Pliocene and Pleistocene (*Fig. 5*).

The Lower Pleistocene lasted from the Olduvai paleomagnetic event to the Brunhes–Matuyama reversal (1.6–0.7 million year). During the Lower Pleistocene a sedimentary sequence about 200 m thick was deposited in the three deepst local depressions (*Fig. 8*). Substantial silt and clay horizons represent the Middel Pleistocene, while more sands and some gravels were deposited during the Upper Pleistocene.

Research has also involved the elucidation of the Quaternary climatic history of the Great Plain, and has yielded remarkable results. During the 2.4 million years of the Quaternary 25 different climatic phases are indicated by pollen finds (*Fig. 5*, and 9).

During the Quaternary the maximum degree of subsidence was 700 m in the lowlands while the maximum uplift was 400 m in the mountains.

The Great Hungarian Plain, the Alföld in Hungarian, is the largest sedimentary basin in Europe, filled with Neogene sediments of great thickness. It covers an area of 100 000 km^2, has an average height about one hundred m above the sea level and most of it is as flat with micrographic differences of no more than 3–4 metres. Walking on the Plain one can distinguish three kinds of superficial deposits: wind blown sand on the hills; loess and loess-like sediments situated above the level of the actual flood-plains and gravels, sands and silty-clays on the flat alluvial areas.

The main river of the Great Plain is the Tisza. Although the Danube is four times larger than the Tisza, it flows along the western border of the Plain only a small part of which falls into its catchment area. The Tisza flows across the centre of the Plain and gathers its tributaries almost entirely from this lowland area.

Due to the combined impact of the morphology of the surface, the different kinds of rocks, the river network and the geological structure, characteristic regions have developed within the Great Plain. There are two sand-hill regions, the first between the Danube and the Tisza river and the second in the northeastern part of the Plain – the Nyírség. Some flat loess covered regions, such as the Jászság, Hajdúság and Nagykunság are situated above the actual flood-plain level, and represent the Late Pleistocene surface. The main Holocene regions are: the Danube valley between Budapest and Mohács, the Szamos plain beyond the Nyírség, the Hortobágy flood plain and the Körös basin.

The thickness of Quaternary deposits ranges from a few metres to 600–700 m and is regionally very different.

A very thoroughly prepared and *complex new mapping* of the basin's deposits was begun by the Quaternary Department of the Hungarian Geological Institute in 1964. It was aimed at meeting the various requirements of agro-geology, engineering geology, hydrogeology and the protection of the environment. Within the framework of this complex research Quaternary tectonic movements were also studied. To sum up, the target was to demonstrate the Late Neogene and Quaternary geological history of the Great Hungarian Plain, and so to add to the geological understanding of the area.

The project required that the *mapping be undertaken in three depth horizons. The first* was concerned with the superficial and near surface depositst (*Fig. 1*). It was based on

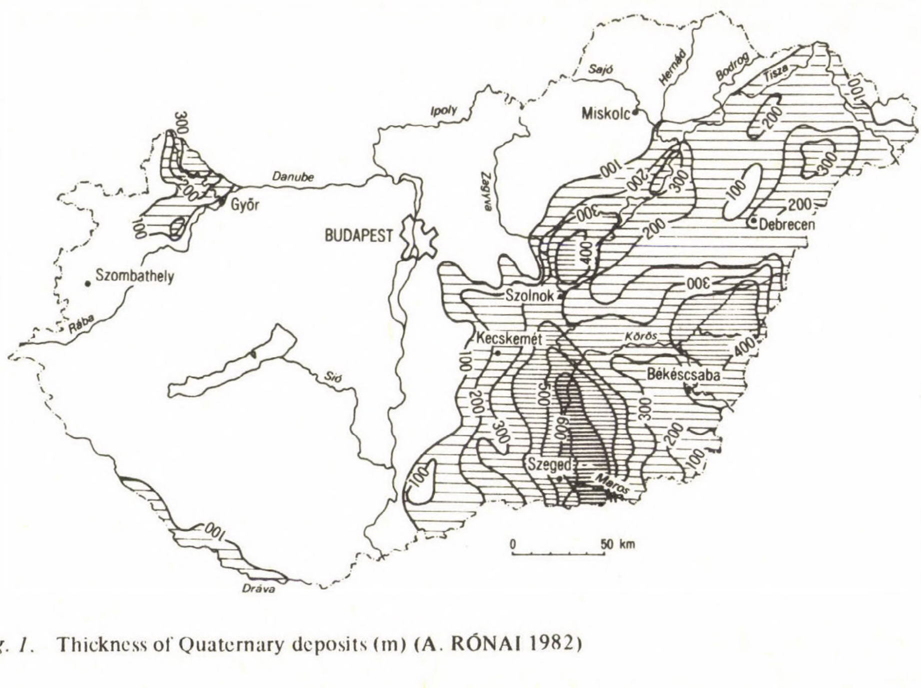

Fig. 1. Thickness of Quaternary deposits (m) (A. RÓNAI 1982)

a network shallow boreholes going down a depth of 10 metres arranged in a systematic grid fashion at distances of 1.5 km (*Fig. 2*). The field work has been carried out using 1:50 000 maps and the results published in 1:200 000 scale atlases. The various laboratory analyses and tests made it possible to plot the agrogeologic, hydrogeologic and engineering geologic potential. In accordance with these purposes some 18–20 geologic map sheets were prepared for each map square.

SHALLOW DRILLING GRID /10–20 m/

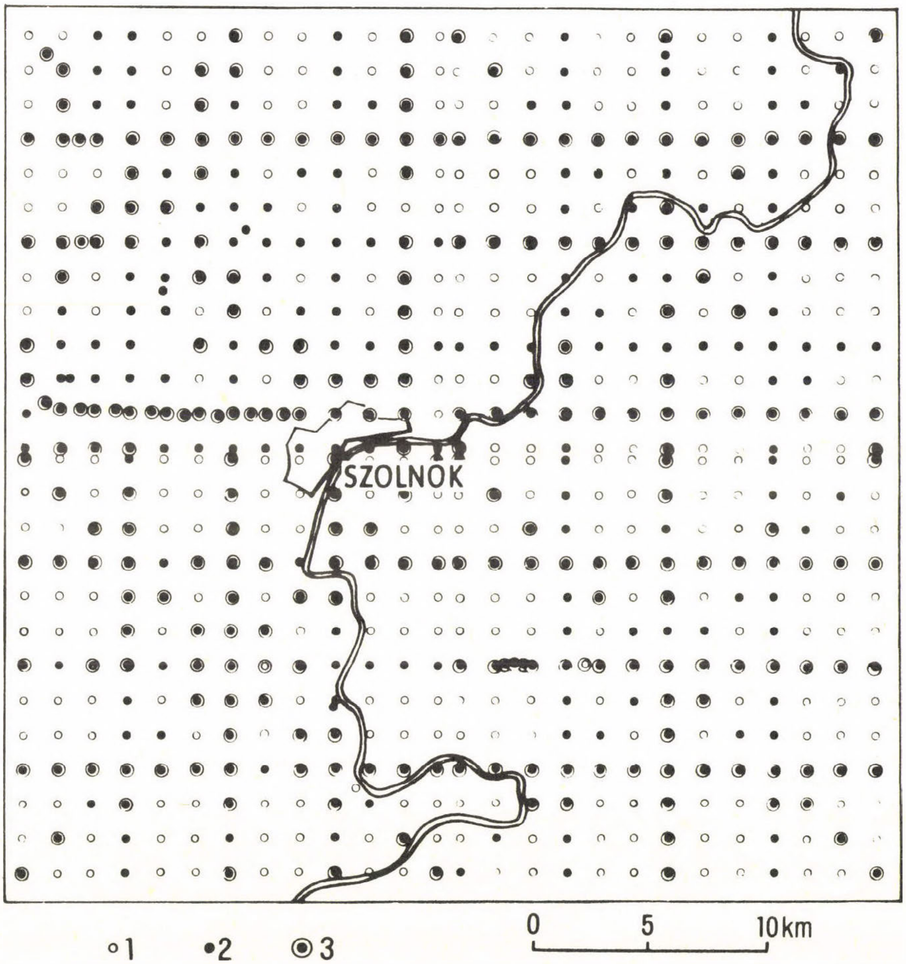

Fig. 2. An example of the arrangement of shallow boreholes
1 = Planned drilling grid; 2 = Holes actually drilled and described; 3 = Drill-holes from which cores were thoroughly analysed

The second horizon extended from 100 to 1500 metres below the surface and was studied by means of boreholes (*Fig. 3*). The aim was to discover the thickness and stratigraphy of the Quaternary deposits and to determine the Neogene–Quaternary boundary. Meanwhile the geological staff also investigated the Pliocene and Pleistocene water bearing strata with a view to establishing the best aquifers. Tectonic observations were also made on the core samples from the boreholes.

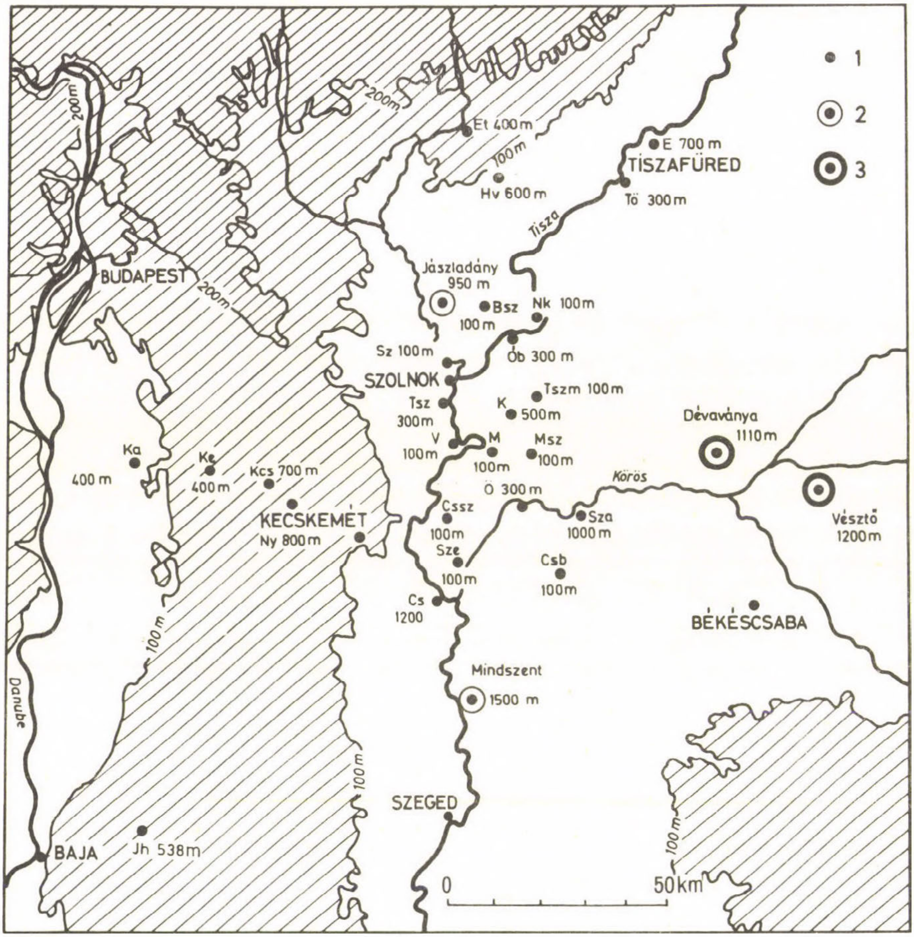

Fig. 3. Scientific key-boreholes in the Great Hungarian Plains

Bsz.: Besenyszög; Cs.: Csongrád, Csb.: Cserebökeny, Cszsz.: Cserkeszőlő, E.: Egyek, Et.: Erdőtelek, Hv.: Hevesvezekény, K.: Kengyel, Ka.: Kunadacs, Kcs.: Kecskemét, Ke.: Kerekegyháza, M.: Martfű, Msz.: Mesterszállás, Ób.: Óballa, Ö.: Öcsöd, Sz.: Szolnok, Sza.: Szarvas, Tö.: Tiszaörs. Tsz.: Tószeg, Tszm.: Törökszentmiklós. V.: Vezseny, Jh.: Jánoshalma

1 = site of boreholes with depth; 2 = boreholes treated minutely in the literature; 3 = borehole samples with paleomagnetic analysis

Cores were taken along two axes in a north-south and an east-west direction across the Great Plain (*Fig. 4*). The boreholes were later used for the construction of artesian piezzometers, i.e. check wells for the best aquifers selected. On the same spot 3–4 wells were constructed in order to measure fluctuations of water level at different depths.

The *third horizon* of the investigation was concerned with the geology of the basin bottom and with study of the sediments and rocks older than the Quaternary and Pliocene.

According to the time-table prepared in 1965, 21 years were envisaged for the accomplishment of the project. The operation has in fact, advanced systematically in accordance with the original plan and the fieldwork was broadly finished in 1983 and the laboratory tests in 1984. The completion of the final atlases is scheduled for 1985.

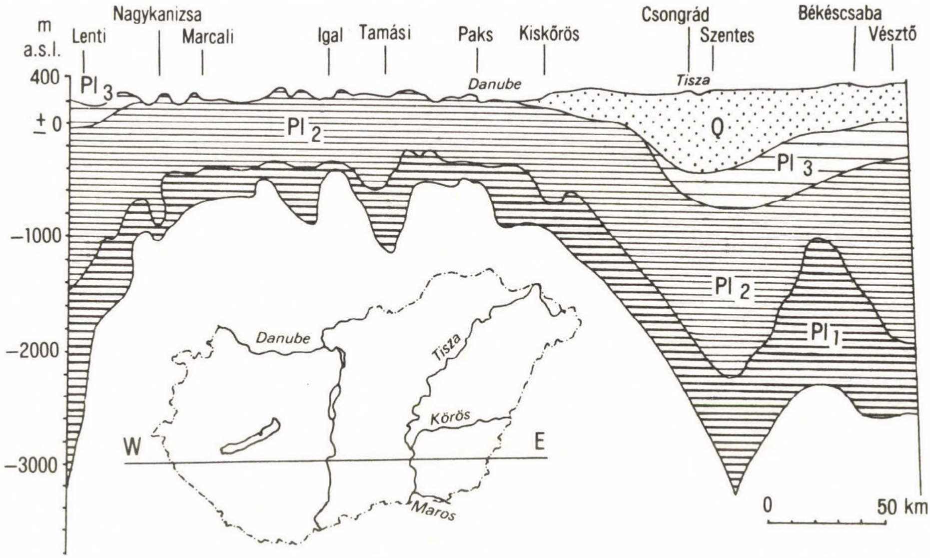

Fig. 4. W–E geological section across the Hungarian Great Plain
Q = Quaternary; Pl_3 = Uppermost Pliocene (Levantine); Pl_2 = Upper Pannonian (Pliocene); Pl_1 = Lower Pannonian (Miocene)

The geological evolution of the Pannonian Basin started in the Miocene. Parallel with the uplift of the Carpathian mountain arc the inner part of the basin began to subside. This newly developed basin was transgressed by the Pannonian Sea, a branch of the Mediterranean Tethys Sea, into which 2000–3000 metres of conglomerates, sandstones, marls and clays of marine origin were deposited. These are called the Lower Pannonian horizons.

At the end of the Miocene the outlet was closed toward the Mediterranean Sea and, as the brackish water slowly changed into fresh water, the Lower Pannonian Sea was transformed into the Upper Pannonian Lake. Subsequently during the Pliocene 1000–2000 metres of lake sediments were deposited in the basin, consisting of alternating sands, sand flour, silts and clays and merging into varietaged clays in the upper part of the sequence. These represents the uppermost part of the Pliocene series and are equated stratigraphically with the Levantine substage. At the end of the Pliocene the basin bottom emerged as dry land due to the *epirogenetic uplift* of the the whole Carpathian region. Fluvial and eolian sedimentation started in the inner part of the basin around the beginning of the Quaternary, and resulted in the accumulation of a 600–700 metres sedimentary series in the deepest parts of the basin.

Eolian sedimentation also had an important role in the mountain territories of the region. Here loess sediment is widespread and reaches a thickness of 40–50 metres. The most extensive blown sand areas are streach over the lowland.

Several types of loess sediments have been identified and mapped. Typical loess covers the hills in Trans-Danubia and the foothills of the north-eastern mountains, while sandy loess is to be found between the sand hills of the lowland and silty-clay loess on the flat surfaces of the Great Plain.

Decided differences were found in the mineralogical and chemical composition of the various types of loess. Endeavours were made to *establish correlations between source areas and mineralogical composition, and between chemical composition and the environment of sedimentation.* Samples were collected from 91 sites throughout the country and analysed in the same laboratory, but these showed that the differences found between the loess in different localities was no greater than the differences found in the several collected samples from the same exposure, or from several samples associated with the same environment.

The extreme values found in the loess samples collected were as follows:

Chemical composition of the loess samples

	maximum	minimum
SiO_2	81.5%	41.2%
Al_2O_3	5.0%	19.1%
Na_2O	0.6%	2.9%
K_2O	0.8%	3.5%
CaO	0.1%	24.3%
MgO	0.2%	8.1%
Fe_2O_3	0.9%	5.8%
FeO	0.5%	7.4%
MnO	0.0%	1.0%
TiO_2	0.2%	1.7%

Similar differences have also been found in the mineralogical composition of the samples collected.

Chronostratigraphy, biostratigraphy and lithostratigraphy are inextricably intermingled as far as limnic and fluvial deposits are concerned and the transition between limnic and fluvial sedimentation can be traced through sequences many hundreds of metres thick. There was recurrent uplift and subsidence of the surface and as a result the sedimentary environment alternated between water and dry land conditions and was repeated several times. The rivers developed large alluvial flood-plains, where the situation changed both seasonally and over several hundreds, or thousands of years. *40–50 fossil soil-horizons can be found in the 1000–1500 m deep boreholes.* Comprised of marshy-peaty soils, chernozems, forest soils and red clays in the deeper sections. Due to the abundant organic matter both the Quaternary and Upper Pliocene strata contain methane gas which cause trouble for the water supply.

The variegated silty-clays and red clays form sequences of around one thousand metres in the Kőrös-Basin. The stratigraphic division of these layers is difficult because they lack fauna and contain no lithological boundaries.

Detailed *paleontological studies* were devoted to designating the *biostratigraphic boundary between the Pliocene and Pleistocene* which had been uncertain because of the faunal sterility of the sedimentary sequences (*Fig. 5*). Nor could the cooling of the climate be proved due to the lack of pollen. Paleontological investigation could only identify two biostratigraphic units within the Pleistocene fauna, namely an Older and a Younger Pleistocene.

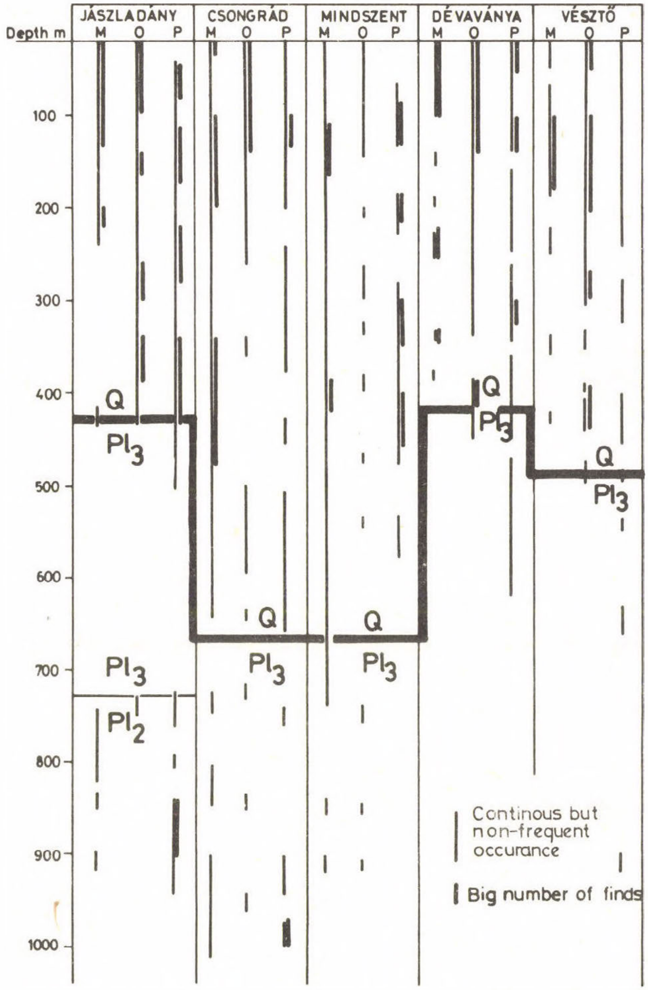

Fig. 5. Frequency of paleontological finds in key-boreholes in Hungary
1 = Continuous but non-frequent occurrence; 2 = Big number of finds; M = Mollusca; O = Ostracoda; P = Pollen

The *paleomagnetic analyses* made on the core samples of two boreholes put down in the Körös Basin constitute significant scientific achievements. This is a deep Quaternary local depression, where sedimentation was continuous during the Quaternary and where all paleomagnetic reversals and events are recorded in the cores back to 5 million years. The change from limnic to fluviatile sedimentation was synchronous with the Matuyama–Gauss reversal (2.4 mill.y.). Paleomagnetic events also contributed to the dating of internal boundaries within the Quaternary (*Figs 6, 7*).

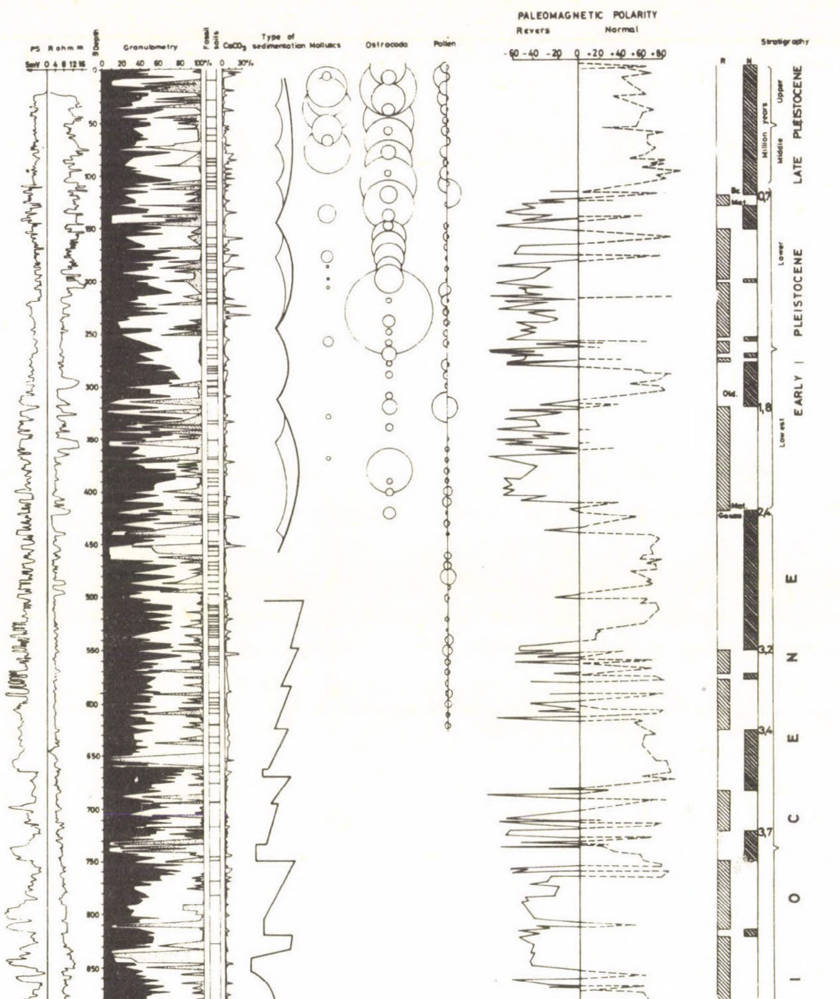

Fig. 6. Complex geological profile of the Dévaványa borehole

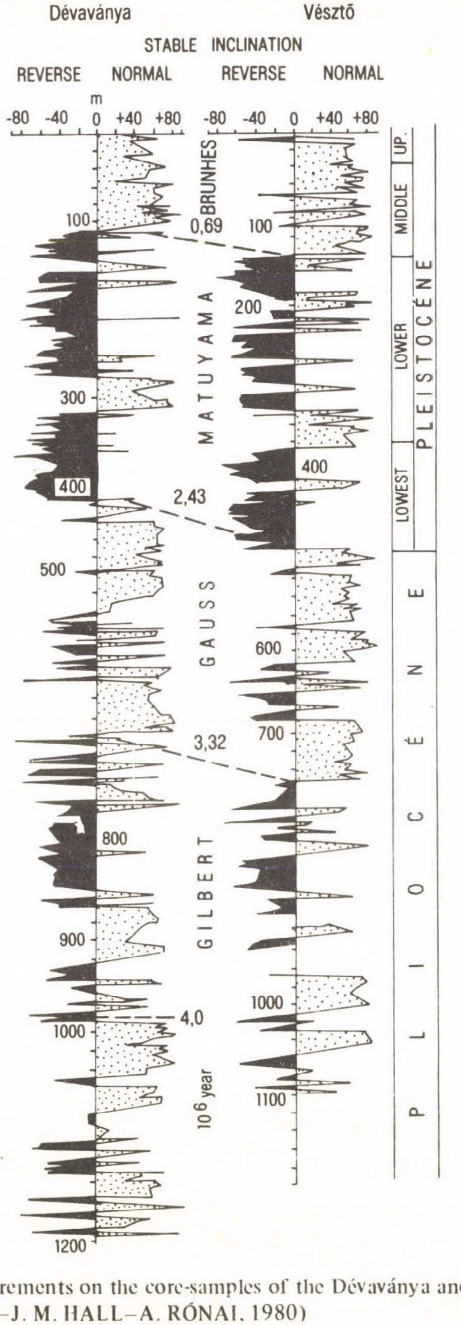

Fig. 7. Paleomagnetic measurements on the core-samples of the Dévaványa and Vésztő boreholes (By H. B. S. COOKE–J. M. HALL–A. RÓNAI, 1980)

The *granulometric cycles* within the fluvial sedimentary sequences, which can be correlated with *Quaternary tectonic movements* have been recognised as another tool for stratigraphic correlation. Pliocene tectonics can be characterised as the uniform subsidence of large areas in the Pannonian Basin. On the contrary during the Quaternary, vertical movements affecting scattered small blocks developed. During the early part of the Lower Pleistocene, which lasted from the Matuyama–Gauss paleomagnetic polarity change to the Olduvai event (2.5–1.6 mill.y.) the *climate* was moderately warm but very humid. The humidity was the decisive difference compared to the Late Pliocene climate, which was hot, dry and almost desert-like in the Carpathian Basin. During this period 100–150 metres of fluvial material was deposited in the three deepest local depressions.

The *Lower Pleistocene* lasted from the Olduvai paleomagnetic event to the Brunhes-Matuyama reversal (1,6–0,7 mill.y.). The *climate* of this period changed very often. Moderately warm, temperate and cool periods alternated several times and the humidity also changed frequently. During this phase about 200 metres of sediments were deposited in the three deepest local depressions (*Fig. 8*).

The sediments of Middle Pleistocene can hardly be differenciated from those belonging to the Upper Pleistocene. The climate of both substages was cold with a few short intervening temperate periods. There are no paleomagnetic events to set the inner boundary between these two stratigraphic units. The 700,000 years involved the last three glaciations and almost the whole time which formerly was called the Pleistocene. This is the really cold par of the Pleistocene compared with the temperate and slightly warmer climate of the lowermost Pleistocene and the Lower Pleistocene proper.

The rate of subsidence was generally slow during the Middle Pleistocene but faster in the Upper Pleistocene. Thick silts and clay horizons represent the Middle Pleistocene in the bore profiles. The sediments deposited during the Upper Pleistocene are more sandy and partly gravelly.

Holocene sediments cover the extensive *flood plains* of the rivers, and cover about one quarter of the Great Plain. The thickness of the Holocene gravels, sands and silts only exceptionally exceeds 2–4 m. In some parts of these alluvial plains big peaty layers have developed.

Detailed studies were devoted to the *Quaternary climatic history* of the Great Hungarian Plain and they have provided remarkable results. During the 2,4 million years of the Quaternary 25 climatic changes have been recorded in numerous pollen finds. The *Great Plain*, lying at the mid-point of the continent, is a *buffer territory* between the major European climate zones. The Carpathian Basin is the meeting place of the oceanic, continental, boreal and mediterranean climatic zones. The different influences alternate in the daily and seasonally weather conditions, but there are months even years during which one particular system may prevail.

The climate of the Pannonian Basin was warm and very humid during the early part of the Lower Pleistocene (*Fig. 9*). During this 800,000 years long period seven major climatic cycles have been established when temperature and humidity changed considerably. By and large this was a temperate warm climate, with diminishing warmth and growing humidity, in which oceanic influences dominated. During the Lower Pleistocene the Mediterranean in addition to the oceanic climate influence entered the Carpathian Basin. They could prevail because the Alps and Dinarides had not yet emerged properly. During the 900,000 years the Lower Pleistocene nine major climatic cycles have been established. The climate was by and large a *temperate forest climate* with warm and cool periods of increasing magnitude following on from each other. Larger changes in the seasonal distribution of the humidity are also revealed. As demonstrated by arboreal pollen, this long period was one of Mediterranean climatic cycles with hot and dry summers and mild humid winters.

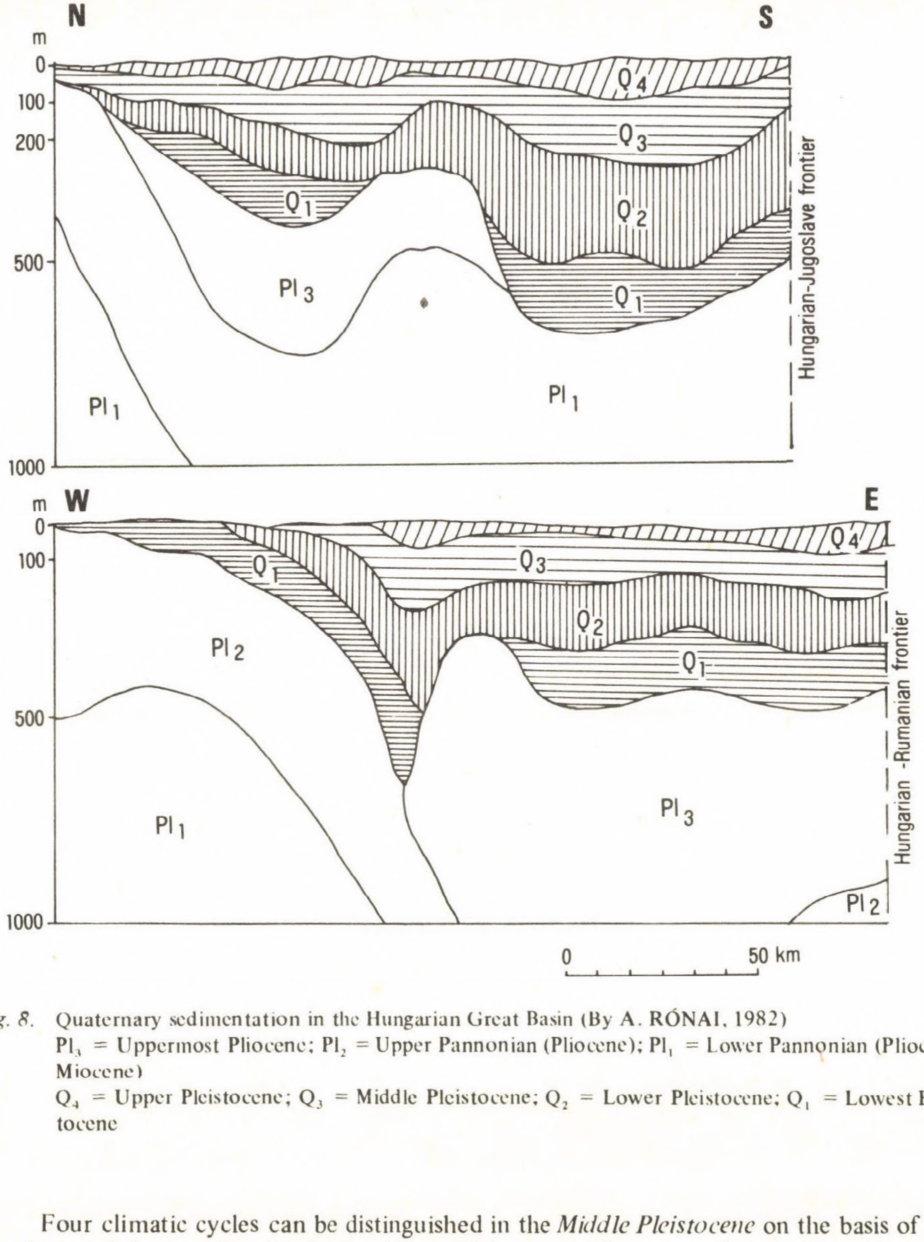

Fig. 8. Quaternary sedimentation in the Hungarian Great Basin (By A. RÓNAI, 1982)
Pl_3 = Uppermost Pliocene; Pl_2 = Upper Pannonian (Pliocene); Pl_1 = Lower Pannonian (Pliocene-Miocene)
Q_4 = Upper Pleistocene; Q_3 = Middle Pleistocene; Q_2 = Lower Pleistocene; Q_1 = Lowest Pleistocene

Four climatic cycles can be distinguished in the *Middle Pleistocene* on the basis of pollen data and four cycles also in the *Upper Pleistocene.* They were almost all cool or cold, and four were humid and six were dry. The climate on the whole resembled the Northern Scandinavian climate of today.

Concerning the tectonic development of the Great Plain a certain balance between the subsidence of the basin and the uplift of the mountain rim of the Carpathian Basin can be observed. *During the Quaternary the maximum amount of subsidence was 700 m in the Lowland, while the maximum uplift in the mountains was 400 m.*

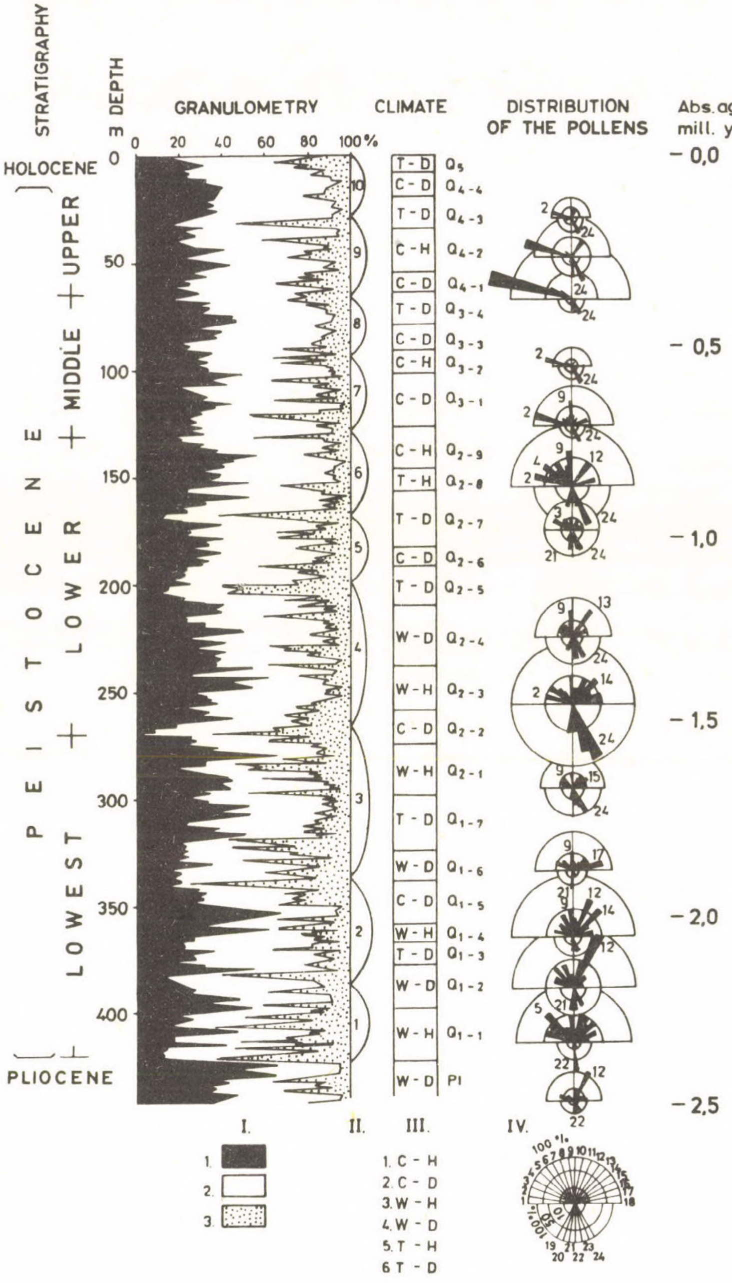

Fig. 9. Quaternary climate and sedimentation in the Hungarian Great Plain (Based upon the Jászladány Borehole)

REFERENCES

COOK, H. B. S.–HALL, J. M.–RÓNAI, A. 1979: Paleomagnetic sedimentary and climatic records from boreholes at Dévaványa and Vésztő, Hungary. – Acta Geol. Hung. 22. pp. 89–109.

FRANYÓ, F. 1977: Exploratory drillings on the Great Hungarian Plain by the Hungarian Geological Institute from 1968 to 1975. – Földr. Közl. 25. (101.) 1–3. pp. 60–71.

HAHN, Gy. 1972: The granulometric properties of the Hungarian loesses. – Acta Geol. Hung. 16. pp. 353–358.

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

PÉCSI, M.–SZEBÉNYI, E.–PEVZNER, M. A. 1979: Upper Pleistocene litho-and chronostratigraphical type profile from the exposure at Mende. – Acta Geol. Hung. 22. pp. 371–389.

RÓNAI, A. 1968: The Pliocene–Pleistocene boundary in the Hungarian Basin. – Acta Geol. Hung. 12. pp. 219–230.

RÓNAI, A. 1970: Lower and Middel Pleistocene flora in the Carpathian Basin. – Paleogeography, Paleoecology, Paleoclimatology, 8. 2–3. pp. 265–285.

RÓNAI, A. 1979: Geological mapping of the Great Hungarian Plain. – Acta Geol. Hung. 22. pp. 355–365.

RÓNAI, A. 1981a: The development of Pliocene and Quaternary depression in the Great Hungarian Plain. – In: Shoji Horie (ed): Paleolimnology of Lake Biwa and the Japanese Pleistocene. Vol. 9. Takashima, Japan. (Contribution 403.) pp. 3–25.

RÓNAI, A. 1981b: Magnetostratigraphy of Pliocene–Quaternary sediments in the Great Hungarian Plain. – Earth Evolution Sciences, Wiesbaden. 1981. 3–4. pp. 265–267.

RÓNAI, A. 1984: The development of the Quaternary geology in Hungary. – Acta Geol. Hung. 27. pp. 75–90.

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Fig. 9.

I. Granulometry 1. Clay and silt (< 0.01 mm ϕ) 2. Sand dust 3. Sand (0.1 < mm ϕ)
II. Sedimentary cycles III. Climate: 1. Cold – Humid 2. Cold – Dry 3. Warm – Humid 4. Warm – Dry 5. Temperate – Humid 6. Temperate – Dry
IV. Pollens 1. Pinus Cembra 2. Pinus silvestris 3. Larix 4. Picea 5. Abies, Tsuga 6. Salix, Betula. 7. Fagus 8. Acer 9. Quercus 10. Carpinus, Tilia, Fraxinus 11. Ulmus 12. Alnus 13. Taxodiaceae, Cupressaceae 14. Carya. Pterocarya, Nyssa 15. Gingko, Zelkova, Engelhardtia 16. Castaneae 17. Corylus, Rhus, Ilex 18. Cedrus, Palma, Pinus Haplax 19. Micophyta 20. Bryophyta 21. Pterydophyta 22. Potamogatonaceae, Cyperaceae, Nympheaceae, Typhaceae, Azolla 23. Gramineae 24. Varia

M. Pécsi (ed.):
Loess and the Quaternary
Akadémiai Kiadó
Budapest,
1985

GEOCHEMICAL CARACTERISTICS OF LOESS IN LUOCHUAN SECTION, SHAANXI PROVINCE

WEN QIZHONG–DIAO GUIYI–SUN FUQING

ABSTRACT

In recent years, we have emphatically investigated the Luochuan loess section in Shaanxi Province, which is a typical loess section (*Fig. 1*). The total thickness of this section is about 130 m. This section is composed of alternative superposition of loess and palaosols.

According to the lithic characteristics of loess, the distribution and development degree of paleosols, as well as fossil vertebrate and so on, the loess formations in Luochuan section have been divided in descending order into the Late Pleistocene Malan loess, the Middle Pleistocene upper Lishi loess and lower Lishi loess, as well as the early Pleistocene Wucheng loess (*Fig. 1*). Holocene loess has been found above the black loessial soil at the top of Malan loess.

In accordance with paleomagnetic informations up to date, the order portions of loess deposition cover nearly the complete Matuyama epoch, that is a minimum age of 2.4 Myr to the beginning of loess sedimentation (HELLER, F. and LIU Tung-Sheng 1982).

Here we would like to give a brief discussion on the geochemical caracteristics of loess in Luochuan section.

I. THE MAIN CHEMICAL COMPONENTS OF LOESS

The main chemical components of the Luochuan loess are: SiO_2 (>50%), Al_2O_3 (>10%), CaO (7.5–10,5%), and subordinately Fe_2O_3 (3–6%), FeO (0.4–1.5%), MgO (1.5–5.0%), K_2O (1.5–2.5%) and Na_2O (1.2–2.3%). There is a consistency between the chemical and mineralogical compositions of loess. By comparing the main chemical components of the

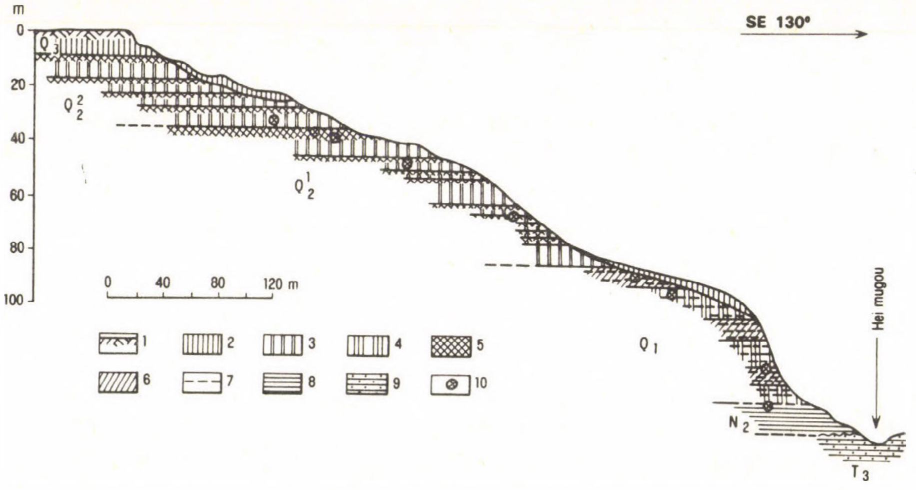

Fig. 1. Loess section of Potou village, Luochuan, Shaanxi Province
1 = dark loessial soil; 2 = Malan loess; 3 = Lishi loess; 4 = Wucheng loess; 5 = paleosol; 6 = buried weathering bed; 7 = calcareous concretion; 8 = laterite; 9 = sandstone; 10 = fossil sites

Luochuan loess with those of loesses from other areas along the middle reaches of the Huanghe River, the compositional homogeneity of the latter is similar to that reflected by the grain size and mineral compositions of the former. However, some microscopic variations are still noticed (WEN Quizhong et al., 1964). In addition, some differences are also recognized in element distribution for different grain-sized fractions.

The ratios of SiO_2/Al_2O_3, FeO/Fe_2O_3, CaO/MgO and $CaO + K_2O + Na_2O/Al_2O_3$ tend to increase in the loess section from the bottom upwards, but the ratio of K_2O/Na_2O shows an opposite tendency (*Fig. 2*). The variation curves of these ratios in the section fit the curve of $CaCO_3$.

In the process of weathering of loess, the oxides Fe_2O_3, Al_2O_3, K_2O, MgO and SiO_2 became relatively concentrated, and CaO and Na_2O were considerably leached out. The leaching value of CaO is positively correlative with the accumulating value of Fe_2O_3 (WEN Qizhong et al., 1981), but fluctuations are observed in the individual layers of loess and paleosol. According to the leaching and accumulating values for each layer of loess, the Luochuan loess can be divided into weakly weathered loess, moderately weathered loess, relatively strongly weathered loess and intensely weathered loess (WEN Qizhong et al., 1981). Furthermore, the difference in the degree of leaching and accumulation of oxides in paleosol during the process of weathering may reflect the difference in the magnitude of paleoclimatic fluctuation during the warm and wet soil-forming stages.

II. CARBONATES IN LOESS

In the loesses of different periods at Luochuan, $CaCO_3$ varies from 3.6–20.9%, averaging 11.6%. In the section from the bottom upwards, the content of $CaCO_3$ tends to increase in the manner of rhythmical fluctuation (*Fig. 2*). Non-homogeneous distribution of $CaCO_3$

is noticed in different grain-sized fractions. It is contained mainly in 0.05–0.005 mm silt grains (WEN Qizhong et al., 1964).

As to the existing forms of $CaCO_3$ in loess, two types can be distinguished in accordance with its genesis: the primary and the secondary. In terms of the characteristics of crystallization of carbonate minerals in loess, phanerocrystalline and microcrystalline $CaCO_3$ are recognized. The primary carbonate occurs in the form of detrital carbonate minerals, while the secondary carbonate has a variety of forms, such as secondary coarse-grained phenocrystal, fine-grained aggregate, dessiminated microcrystalline carbonate, pellicle, dermatic crust, pseudomycelium, and nodule. Some differences are also noticed in the coexist-

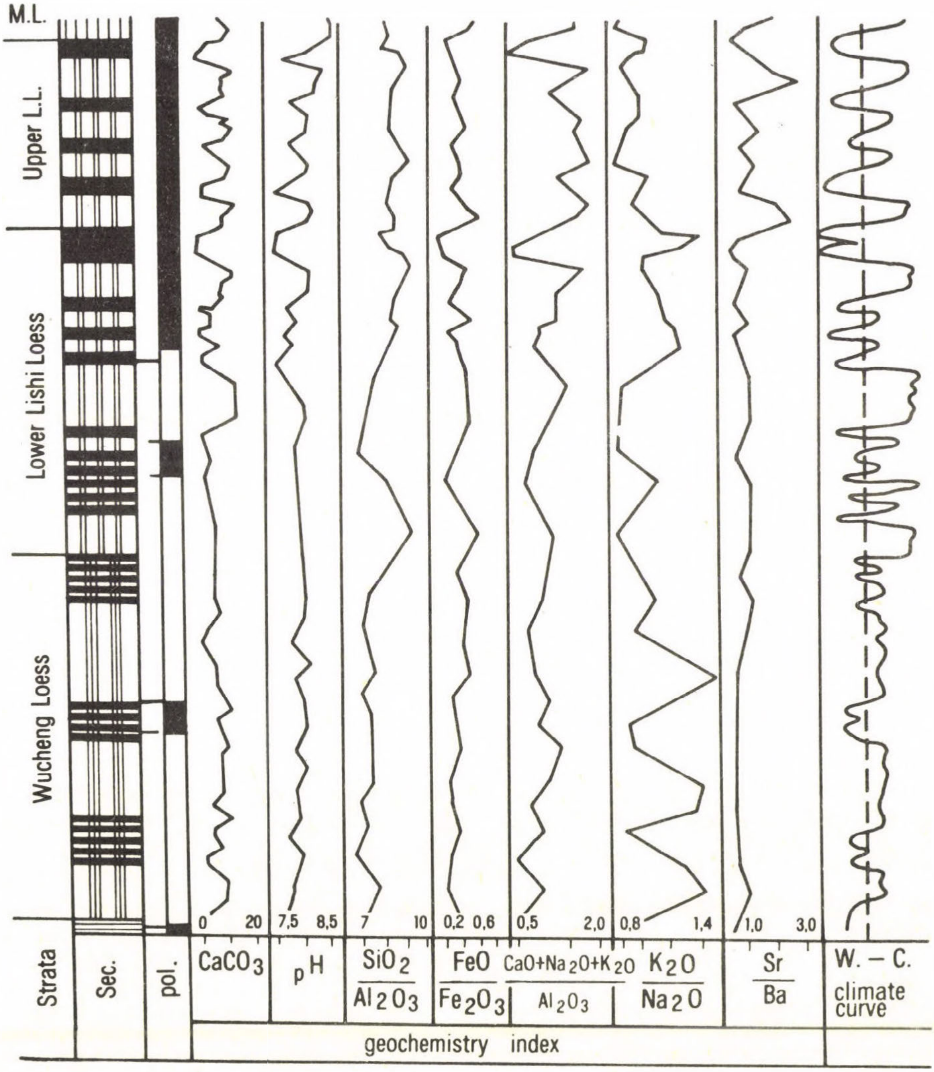

Fig. 2. The variation curves for a number of chemical elements and their ratios in the Luochuan loess section

ing form and distribution of loesses of different periods. Intercalated in the Luochuan loess section are 45 layers of carbonate concretion; there are also some differences in distribution, occurrence and trace composition for concretions in loesses of different periods (WEN Qi-zhong et al., 1964).

There is a general tendency for $CaCO_3$ to increase in the loess section from the bottom upwards (from early Pleistocene to late Pleistocene), indicating that since the Quaternary period the climate gradually became dry. Moreover, it can also be seen from the general tendency of $CaCO_3$ increase that in the periodic fluctuations on the curves the alternation of the maximum and minimum values is in coincidence with that of the loess and paleosol series. This shows that in the process of loess accumulation there took place a number of small dry cold-warm wet climatic fluctuations. In the mean time, the content of $CaCO_3$ also showed remarkable periodic variations. It seems to reflect the periodicity of climatic change since loess accumulation.

III. TRACE ELEMENTS IN LOESS

The authors centred research on the following ten trace elements: Zn, Cu, Mn, Co, Ni, Pb, P, Ti, Sr and Ba in loess samples from the Luochuan section. The results of the analysis are listed in *Table 1.* Differences in the content of these trace elements in loess depend not only on the mineral composition of loess, but also on the inherent geochemical behaviors of these

Table 1. Analyses of several trace elements in the Luochuan loess (ppm)

element	range of content	average content	standard deviation	coefficient of variation
Zn	71– 147	91	12.5	0.137
Cu	13– 34	25	3.3	0.133
Mn	486– 878	691	82.7	0.120
Co	14– 28	21	2.6	0.128
Ni	27– 50	40	4.4	0.110
Pb	15– 40	30	3.6	0.120
P	131– 742	388	113.9	0.294
Ti	3417–4676	4058	308.3	0.076
Sr	152– 288	195	34.4	0.177
Ba	500– 647	579	39.1	0.068

elements. Although different elements in loess are variable in content, some elements have certain correlations. For example, in the Malan loess distributed in the areas along the middle reaches of the Huanghe River remarkable positive correlations are shown between Zn, Cu and Mn (DIAO Guiyi et al., 1982).

In regard to their main distribution characteristics in the loess section, two broad groups of trace elements can be recognized: the first group (Co, Ni, Pb and Cu), and the second group (Zn, Mn and Ti). The 1st group elements show little difference in their content, though they are somewhat variable throughout the loess section, as justified by relatively close mean values for these trace elements in loesses of different periods. And the frequency distribution of Co and Ni displays approximately a normal distribution, demonstrating an almost homogeneous distribution of these trace elements in the loess section. Pb is relatively stable with respect to its distribution in the loess section. The 2nd group varies over a wide range relative to the 1st one, with a tendency of decrease from the bottom to the top.

The average contents of various trace elements in paleosol are all higher than those in loess, and this indicates varying degrees of enrichment of the trace elements in paleosol. More obvious enrichment of Zn, Mn and Ti is observed in paleosol, with the average content being 10% higher than that of loess layers.

IV. F/Cl RATIO IN LOESS

The F/Cl ratio in the Luochuan loess varies from 0.15 to 0.40 with a tendency of decrease form the bottom upwards (with the exception of the fluctuation of F/Cl in paleosol). The F/Cl ratio in paleosol ranges from 0.20 to 0.75, averaging 0.42. In accordance with the variation of F/Cl ratio, the pedogenesis of the brown paleosol can be divided into four stages: F/Cl < 0.3 (S_2, S_{10}, S_{12}, S_{13} in the section), typical of weak pedogenesis, 0.3–0.4 (S_6, S_7, S_9, S_{11}), of moderate pedogenesis, 0.4–0.5 (S_3, S_4, S_8, S_{14}), of relatively strong pedogenesis, and > 0.5 (S_1, S_5), of intense pedogenesis. The variation of F/Cl in the layers of paleosol in the section from the bottom upwards reflects the difference in pedogenetic intensity during warm and wet soil-forming stages.

The variation of F/Cl ratio in the Luochuan loess section is consistent with the variation of $CaCO_3$ and pH, and the distribution of SiO_2/Al_2O_3 and FeO/Fe_2O_3.

By comparing the average values of F/Cl ratio for loesses of various periods, we can see that the F/Cl ratio shows remarkable variations above and below the boundary between the Lishi and the Wucheng loess; the F/Cl values from above the boundary are greater than the average, whereas the F/Cl values from below the boundary are less than the average.

V. REE IN LOESS

The total content of RE oxides in loess varies from 160 to 210 ppm, approximate to the average of RE oxides in sedimentary rocks and in the earth's curst (*Table 2*). The content

Table 2. Comparison of ΣRE_2O_3 between loess and other rocks

Item	Loess	Alluvium	Wind-drifted sand	Chondrite*	Granite* (SiO_2 60–70%)	Sedimentary rock**	Average value of the earth's crust***
ΣRE_2C_3 (ppm)	189	130	35	6.20	290.83	212.78	235.8

*From Yu. A. BILASHOV (1976)
**From A. P. VINOGRADOV
***From E. A. LEKSIEV (1974)

of RE oxides in sand samples from the Tenger Desert is lower than that in loess by a factor of 4 or 5.

The temporal evolution of RE oxides in loess, as can be seen from the preliminary analyses of loess samples (differing in age) from the Luochuan section, shows a tendency of gradual increase in the content of RE oxides (168–203 ppm) from early to late, i. e., from the Wucheng loess to the Lishi loess and then to the Malan loess. Such a tendency is consistent with the regularities governing the increase of pH value, SiO_2/Al_2O_3, $CaO + K_2O + + Na_2O/Al_2O_3$, organic matter and $CaCO_3$ from the bottom upwards. A close relationship exists between the variation of all geochemical indices and the geological environment and palaeoclimatic fluctuation during loess deposition. The research work has revealed that at the time of deposition. the Wucheng loess underwent stronger weathering pedogenesis than the Lishi and the Malan loess, and therefore further study is needed before the problem of whether or not the REE in loess have been more or less lost by leaching can be tackled.

The REE partition features of loess are mainly reflected in the enrichment of rare-earth elements of Ce-family. Such a case is consistent with the features of low REE concentration and enrichment of LREE in the atmospherically-settled, suspended particles.

By comparing the REE content of loess with the average of the REE in 20 chondrites (*Fig. 3*), it can be seen that the REE distribution patterns of loess are obviously different from those of the chondrites, i. e., the LREE are relatively abundant in loess. The REE distribution patterns of sand samples from the Tenger Desert, though lower in total content, are similar to those of loess. Therefore, it is evident that the relative REE abundance in wind-drifted sands is similar to that in loess. Based on the REE distribution patterns in loess samples of different ages and from different localities, Holocene loess displays a remarkable positive Ce anomaly, while alluvium samples from the Hebei Plain have a negative Nd anomaly relative to the chondrites.

Similarly, the NAS-normalized REE distribution patterns of loess are similar to those of shales (*Fig. 3*), and therefore the curves established on the basis of their ratios are almost horizontal, similar to one another in shape. However, the ratios from the NAS-normalized curves are generally < 1, with the difference ranging from 0.4 to 0.8 fold. The REE distribution patterns of sand samples from the Tenger Desert are similar to those of the NAS, hence the relative abundance ratios give an extremely smooth curve. As compared with the NAS, however, the relative abundance of Nd in alluvium samples from the Hebei Plain shows an obvious negative anomaly. Additionally, the REE distribution in marine sediments is different from that in loess, and the ratios rate > 1 on the NAS-normalized curves, wherein the intermediate REE are best enriched.

From the aforementioned facts, it can be seen that the REE distribution patterns of loess in the Middle Huanghe Valley are similar to those of sand samples from the Tenger Desert, probably indicative of the cognation of source material.

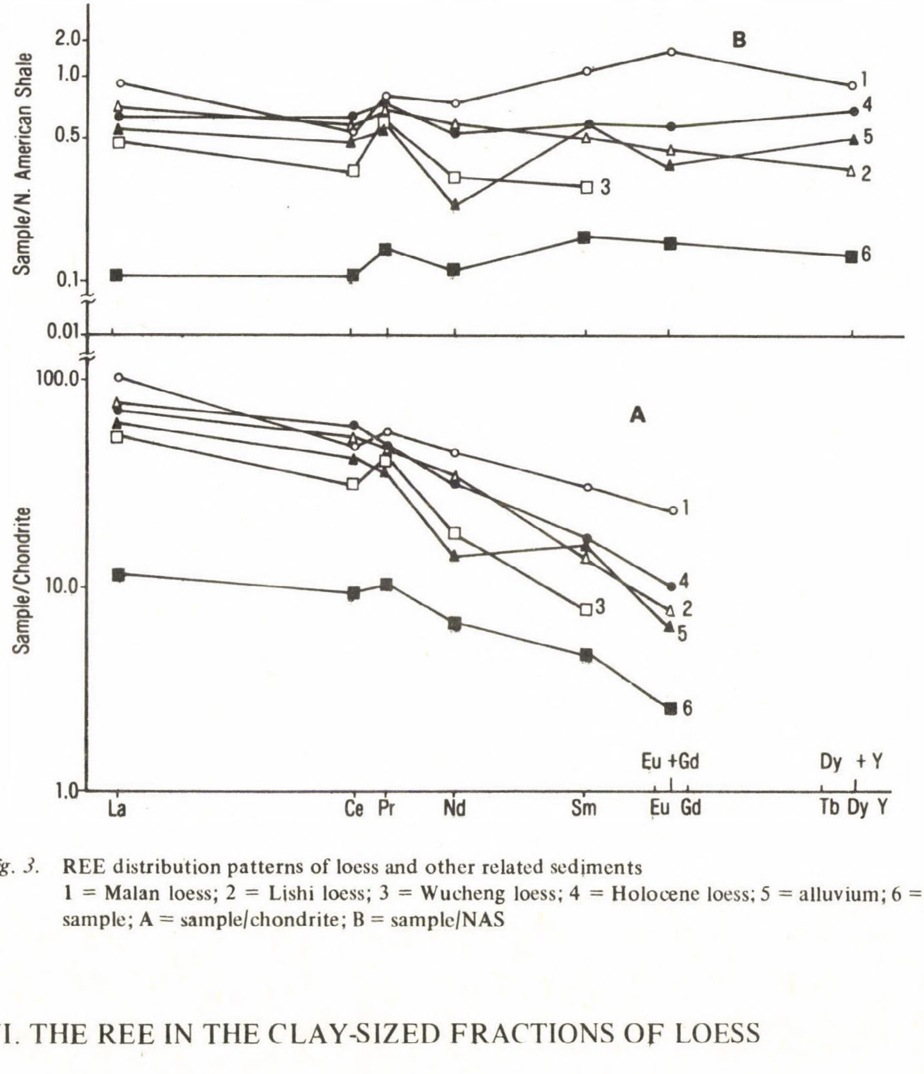

Fig. 3. REE distribution patterns of loess and other related sediments
1 = Malan loess; 2 = Lishi loess; 3 = Wucheng loess; 4 = Holocene loess; 5 = alluvium; 6 = sand sample; A = sample/chondrite; B = sample/NAS

VI. THE REE IN THE CLAY-SIZED FRACTIONS OF LOESS

As regards the REE in its clay-sized fractions, our emphasis has been placed on the investigation of the Malan loess. For comparison, analyses have been made on two additional clay samples, one from the Holocene loess in the Mt. Tomur region, and the other from the Lishi loess at Yulin. From *Table 3* it can be seen clearly that the total content of RE oxides in the

Table 3. REE distribution in loess and its clay-sized fractions and other related sediments

Sample No.	Material	Locality	Content (ppm)													
			La	Ce	Pr	Ne	Sm	Eu-Gd	Tb	Dy-Y	Ho	Er	Tm	Yb	Lu	ΣREE
74ML-095	Malan loess	Louchuan, Shaanxi	30.3	39.1	6.5	25.2	6.2	8.8	<1	31.4	<1	<1	<1	<1	<1	154
74ML-73	Lishi loess	Louchuan, Shaanxi	23.5	44.8	5.6	19.6	2.9	2.9	<1	12.4	<1	<1	<1	<1	<1	118
74ML-24	Wucheng loess	Louchuan, Shaanxi	15.7	25.2	4.8	10.9	1.6	n. d.	<1	n. d.	<1	<1	<1	<1	<1	
67	Holocene loess	Mt. Tomur, Xinjiang	20.7	47.6	5.7	17.6	3.5	3.8	<1	23.3	<1	<1	<1	<1	<1	128
35	Alluvium	Sunhe, Hebei Plain (drill core)	19.2	35.6	4.5	8.1	3.5	2.5	<1	17.6	<1	<1	<1	<1	<1	97
17	Sand	Tenger Desert	3.4	7.7	1.2	3.9	1.0	1.0	<1	4.8	<1	<1	<1	<1	<1	29
167	Clay minerals in Holocene loess	Mt. Tomur, Xinjiang	20.7	67.2	5.2	16.3	4.1	2.5	<1	19.6	<1	<1	<1	<1	<1	142
159	Clay minerals in Malan loess	Longxi, Gansu	25.2	39.1	6.4	20.8	4.6	6.0	<1	24.1	<1	<1	<1	<1	<1	132
153	Clay minerals in Lishi loess	Yulin, Shaanxi	16.8	33.0	3.2	14.6	2.9	3.6	<1	18.4	<1	<1	<1	<1	<1	99
147	Clay minerals in Malan loess	Wugong, Shaanxi	20.9	39.9	4.8	17.0	3.0	3.6	<1	22.2	<1	<1	<1	<1	<1	117
146	Clay minerals in Malan loess	Wucheng, Shanxi	23.3	55.0	7.4	18.4	5.2	4.6	<1	23.3	<1	<1	<1	<1	<1	143
141	Clay minerals in Xiashu loess	Nanjing, Jiangsu	25.2	57.0	5.8	20.0	3.8	5.3	<1	29.2	<1	<1	<1	<1	<1	152

clay-sized fraction of the Malan loess is generally within the range of 160–195 ppm. The total content of RE oxides in the clay-sized fraction of the Holocene loess in the Mt. Tomur region is higher, but that in the Lishi loess somewhat lower. Moreover, in regard to the Malan loess, itself, the spatial distribution of RE oxides in the clay-sized fraction seems to show a progressive increase in their total content from northwest to southeast, with the maximum value in the Xiashu loess.

The REE partition features of the clay-sized fraction of the Malan loess are the same as those of the whole rock of loess, both being rich in the rare-earth elements of Ce-family. The fact that the REE content in every sample is approximately the same reflects the homogeneity of material compositions of loesses (typical loess) from different localities. However, the REE partition curve for the clay-sized fraction of the Holocene loess (Eu + Gd) shows a negative anomaly. In addition, the contents of various REE in the clay-sized fraction of the Lishi loess are low as compared with those of the Malan loess, especially Pr even lower.

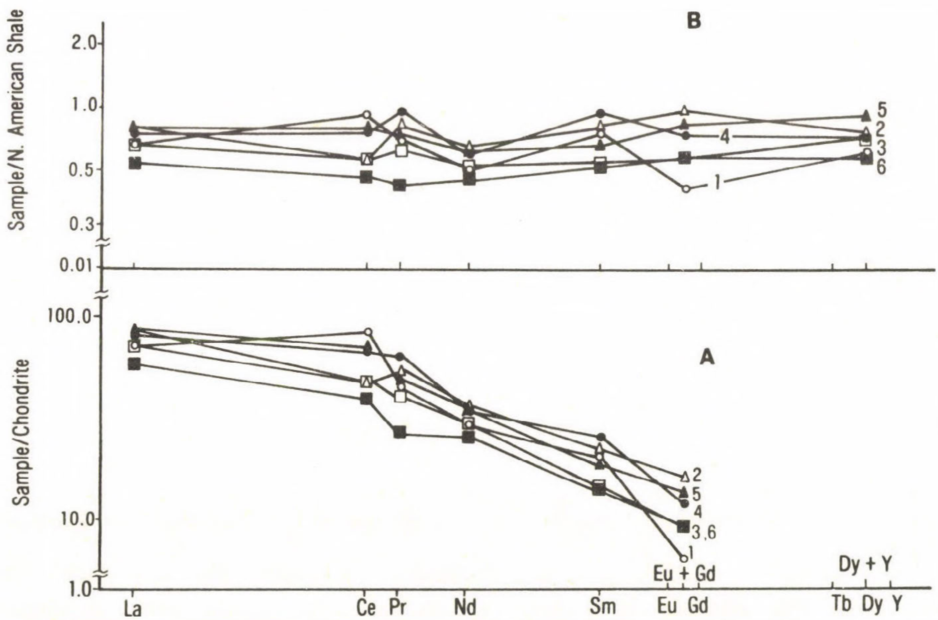

Fig. 4. REE distribution patterns of clay minerals in loess
1 = clay in Holocene loess; 2 = clay in the Malan loess (sample 159); 3 = clay in the Malan loess (sample 147); 4 = clay in the Malan loess (sample 146); 5 = clay in the Xiashu loess; 6 = clay in the Lishi loess; A = sample/chondrite; B = sample/NAS

As compared with the chondrites, the light REE in the clay-sized fractions of loess (*Fig. 4*) exhibit obvious different distribution patterns, beginning to decline from La. It can be seen precisely that the REE distribution patterns of the clay-sized fraction of loess are similar to those of continental platform clay, but different from those of marine and moraine clays. The relative abundance ratios of REE in clays to those in the NAS composite are generally < 1. The light REE distribution patterns of clay samples are nearly the same in shape, and the corresponding curves are relatively smooth. Except for samples from the Holocene loess in the Mt. Tomur region as well as from the Lishi loess at Yulin, which appear relatively low in Pr, the REE distribution patterns of the clay-sized fractions of all Malan loess samples are so close to those of the NAS that their distribution curves for the REE ratios are almost horizontal. But they are different from the REE distribution patterns of marine sedimentary clays, and the ratios of whose REE to those of the NAS are generally < 1. Marine sedimentary clays are obviously rich in intermediate REE relative to the NAS. All these are agreeable with situation encountered in the whole rock of loess.

VII. GEOCHEMICAL FEATURES OF PALEOSOL IN THE LUOCHUAN SECTION

As can be seen in *Table 4*, the average values of the major elements Si, Al, Fe, and K in paleosol are higher than those in loess, but Ca, Fe^{2+} and Na in the paleosol are lower than those in the loess.

The distribution of the elements in the paleosol section is characterized by the increase of Al, Fe and K from the bottom to the top, with the maximum peak values appearing in the clayized beds and the minimum peak values in the calcic and the parent material loess beds. On the contrary, the content of calcium carbonate is the lowest in the clayized beds, but it is remarkably enriched in the calcic and the parent-loessic beds. The trace elements Zn, Cu, Mn, Ti, Ni, and Co are higher than those in the parent material of loess. These elements are most enriched in the clayized beds.

Paleosols of different occurrences and properties may reflect the differences in pedogenetic intensity during weathering. With the enhancement of pedogenesis of paleosol, Sr/Ba and the ratios of various oxides (except for K_2O/Na_2O) tend to decrease, but the F/Cl ratio and the content of Fe_2O_3 show a tendency to increase. All these geochemical features reflect the differences in bio-climatic environment for paleosols of various types during pedogenesis.

In the process of weathering of loess into paleosol, the intense leaching-out of carbonates led to obvious accumulation of Fe_2O_3 and Al_2O_3. With the enhancement of paleosol pedogenesis, the leaching-out of CaO became more and more intense, leading to higher and higher enrichment of Fe_2O_3.

Table 4. Chemical composition of different types of paleosol in Louchuan loess section

Type	Element content (%)										Element content (ppm)								Layer order of paleosol
	Si	Al	Fe^{3+}	Fe^{2+}	Ca	Mg	K	Na	P	Ti	Zn	Cu	Mn	Co	Ni	Pb	Sr	Ba	
Dark loessial soil	26.60	6.10	2.32	0.90	6.27	1.19	1.68	1.24	0.031	0.35	73	51	530	21	33	40	–	–	So
Calcareous drab soil	28.55	7.11	3.29	0.73	2.51	1.28	2.16	1.14	0.033	0.42	95	24	703	21	43	26	370	1300	S_3, S_{10}, S_{12}
Drab soil	29.44	7.25	3.32	0.64	1.65	1.26	2.28	1.20	0.046	0.44	104	25	747	20	41	31	330	1900	S_2, S_6, S_8, S_9, S_{10}, S_{13}, S_{14}
Luvic drab soil	30.39	7.20	3.41	0.62	1.57	1.17	1.90	1.10	0.034	0.43	93	26	734	22	41	30	330	1900	S_1, S_4, S_7
Drab-brown soil	30.06	7.64	3.76	0.76	0.71	1.21	2.01	0.93	0.040	0.45	105	27	825	21	44	32	360	3400	S_1
Buried weathering bed	27.58	6.91	3.46	0.47	3.29	1.33	2.23	1.00	0.036	0.40	87	29	744	21	46	30	390	1200	
Average value of paleosols	28.77	7.04	3.24	0.69	2.67	1.24	2.04	1.10	0.037	0.42	93	30	714	21	42	32	330	1900	
Average value of loess	27.60	6.55	2.84	0.73	4.29	1.29	1.93	1.15	0.040	0.39	88	25	651	20	38	29	552	1235	
Clark value of earth crust*	29.00	8.05	4.65		2.96	1.87	2.50	2.50	0.093	0.45	83	47	1000	18	58	16	340	650	
Clark value of soil*	33.00	7.13	3.80		1.37	0.63	1.36	0.63	0.080	0.46	50	20	850	10	40	10	300	500	

*From A. P. VINOGRADOV (1962)

VIII. THE EVOLUTIONARY TREND OF CHEMICAL ELEMENTS IN THE LOESS SECTION AND PALEOCLIMATIC CHANGES

In order to explore the evolutionary trend of chemical elements in the loess section, calculations were made by using the five-term moving average analysis. It can be seen from *Fig. 5* that such elements as Ca, Sr, Fe^{2+}, etc. in the loess section show such an evolutionary tendency as to increase from the bottom to the top, and $CaCO_3$ also tends to increase in the manner of rhythmical fluctuation; Fe^{3+}, Al, K, Mn and Ti tend to decrease in the same direction. Such an evolutionary trend of the chemical elements in the loess section is related not only to the distribution of mineral components and the variation in grain size of loess, but also to the paleoclimatic environment and geochemical-medium conditions. This general tendency of the evolution of chemical elements is considered to be related to climatic changes from wetter to drier since loess accumulation.

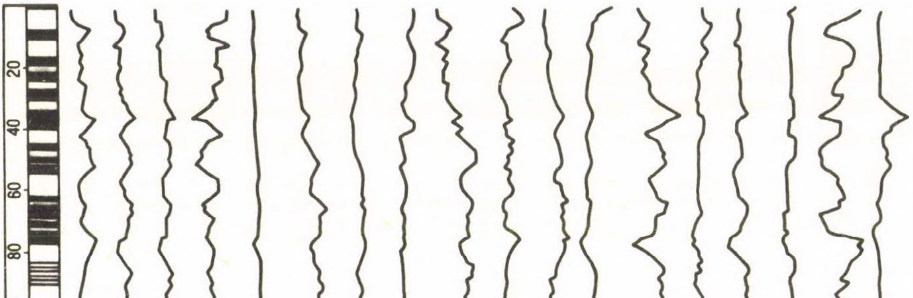

Fig. 5. The evolutionary trend of chemical elements in the Luochuan loess section (Zn, Cu, Mn, Co, Ni, Pb in ppm; the rest in %)

In this general trend of evolution, Al, Fe^{3+}, K, Mn, and Ti are remarkably increased, whereas Ca and Sr are highly decreased in paleosol layers S_1, S_5, S_{10} and S_{14}. Clearly, the variation curves for the chemical elements in these paleosol layers are of obvious fluctuation, in good coincidence with the cycle of sedimentation or the stratigraphic boundary.

The pH values for the Luochuan loess section vary from 7.5 to 8.6, indicating a weakly alkaline medium condition. As can be seen from the distribution curves, the variation of pH in the loess section is in coincidence with that of $CaCO_3$.

The Eh values for the Luochuan loess fall into the range of 420–470 mV, with an average of about 440 mV, marking an oxidating environment.

What is more, loess has a high content of $CaCO_3$, but a low content of organic matter. Amino acids present in loess are predominated by acidic ones. The Ki values in the loess section range from 6.48 to 0.65 with a tendency of increase from the bottom upwards.

The above-described geochemical indices are a clear indication that loess was deposited in arid and semiarid areas in an oxidating environment under weakly alkaline medium conditions. These indices also show that oxidation and weathering were much stronger during the accumulating stage of the Wucheng loess, 1.20–1.40 Myr ago than those during accumulation of the Lishi and Malan loesses, $1-120 \times 10^4$ y.

In the loess section, the clayized beds of paleosol are characterized by low $CaCO_3$ and pH, and relatively high Al_2O_3 and Fe_2O_3. Of the clay minerals, illite contains more montmorillonite crystal layers. At the top of paleosol are contained the fossil assemblages of terrestrial snells represented by *Metondontia hausaiensis*, which can reflect a warm-wet ecological environment. This shows that paleosol was formed in the relatively wet forest-prairie terrains under weakly acidic–weakly alkaline medium conditions.

REFERENCES

DIAO Guiyi et al. 1982: Collected works of Proc. 3rd natn. Quat. Congr. China, Scientific Press, pp. 267–268.

HELLER, F.–LIU Tung-Sheng, 1982: Nature, 300. (5891.) pp. 431–433.

WEN Qizhong et al. 1964: Problems of Quaternary geology. China, Scientific Press, 114 p.

WEN Qizhong et al. 1981: Geochimica, 4. pp. 381–384.

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ANALYSIS OF CLAY MINERALS IN HUNGARIAN LOESSES ON THE BASIS OF THE CLAY MINERAL MAP OF SOILS IN HUNGARY

P. STEFANOVITS

ABSTRACT

The clay mineral map of soils (*Fig. 2*) provided data for analysis of the the mineral composition of loess as a parent material. It was found that the ratio of illite and chlorite, and smectite and vermiculite varies from region to region. The amount of chlorite increases in the Alpine region while the ratio of smectites increases in the vicinity of andesite mountains and, in regions bordering Pannonian deposits.

In the international literature loesses are usually described by their grain size distribution, the amount and ratio of heavy minerals and the distribution of carbonates. Studies on the amounts and qualities of clay minerals are much fewer in number, although these depend partly on the rock conditions of the source area of windblown dust and partly on the diagenesis during loess formation.

In order to contribute new data to the classification of loesses, we have selected from the clay mineral map of soils, our information base, profiles in which field description indicated loess as a parent material. After evaluation regional patterns, worthy of mention were obtained.

When constructing the clay mineral map of soils a number of mineralogical, colloidical and pedological analyses were made. Here the results of x-ray diffraction examinations of oriented samples from the clay component are shown for certain representative samples. The sampling sites are mapped on *Fig. 1* and data in *Table 1*. The X-ray diffraction analyses were carried out in the Central Research Institute for Chemistry of the Hungarian Academy of Sciences, while the evaluation of curves and the disclosure of spatial relationships were undertaken by ourselves.

Comparing the information on the *figure* and in the *table*, the clay minerals in loesses appear to be different but, at the same time, individual varieties show regular regional distributions.

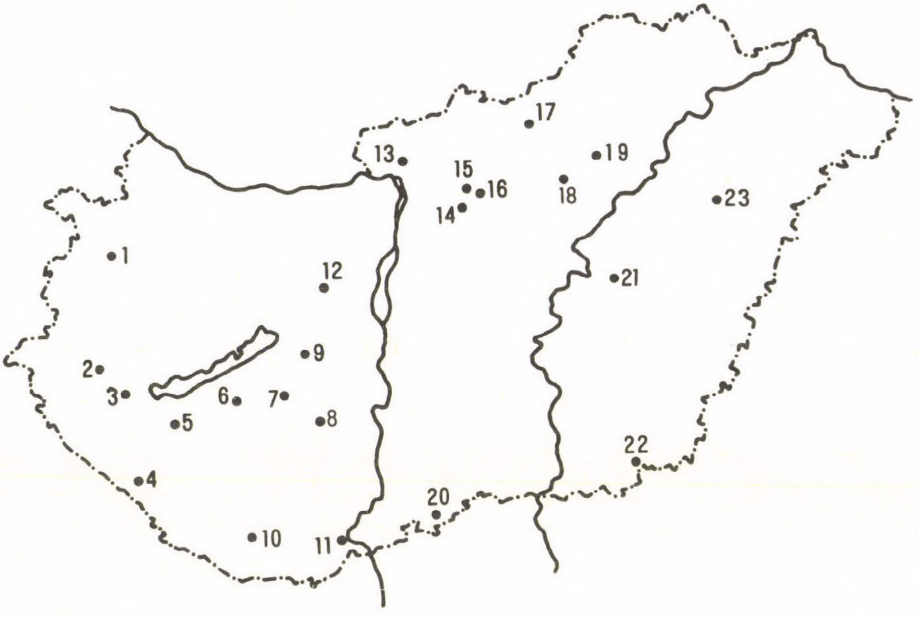

Fig. 1. Map of sampling sites (see Table 1)

The 23 loess samples enumerated in the table are representative of the major regions of the country. Of the data for the individual sites of occurrence averages were calculated for each types of clay mineral and the amounts found were assessed in relation to these averages as more or less abundant in these cases where the relativ amount was 20% above or below the average.

It can be claimed on this basis that in Transdanubia on average illite content is accompanied by much vermiculite and little chlorite and smectite (samples No. 1–5) while along the Drava river the relative amount of chlorite tends to rise (samples No. 10–11). For the loesses of Külső-Somogy a rather high chlorite and a low smectite content is characteristic (samples No. 6, 7 and 9.).

Of the very interesting profile No. 12 data from two samples are presented, for the clay mineral composition of the Pannonian horizon at depth and of the eroding loess. It is clearly seen that the Pannonian clay deposits contain 70% smectite, while the loess mantle is constituted of approximately equal amounts of illite, chlorite and smectite. This explains the higher smectite content of these loess areas where Pannonian clay is inter-mixed with the wind-blown dust matrix.

The loess in the basins and on the pediments of the North Hungarian Mountains (samples No. 13–19) usually has a higher smectite content and lesser amounts of illite owing to intermingled andesite waste.

Samples No. 20–23 representing the Great Hungarian Plain are either of average illite, chlorite and smectite contents or the deviations from the averages cannot be interpreted regionally.

Table 1. Percentages of clay minerals in the clay fraction of loesses

		I	Ka	Kl	S	V	IS	Other
1.	Sajtoskál	37	–	18	32	1	11	1
2.	Zalaegerszeg	31	–	13	28	16	11	1
3.	Pacsa	29	–	15	25	15	8	3
4.	Csurgó	33	–	12	26	18	6	5
5.	Marcali	51	–	13	8	10	11	7
6.	Karád	26	–	29	28	3	11	3
7.	Iregszemcse	38	–	26	17	6	12	1
8.	Nagyszékely	32	–	20	20	13	9	6
9.	Fürged	45	–	32	9	–	14	–
10.	Bicsérd	30	–	27	31	–	12	–
11.	Sátorhely	31	–	27	32	–	10	–
12.	Füle (loess)	28	–	22	22	12	11	5
12.a	Füle (Pannonian)	13	–	4	70	–	13	–
13.	Nőtincs	14	8	–	66	–	7	5
14.	Aszód	24	–	15	36	11	7	7
15.	Selyp	21	–	12	49	1	11	6
16.	Ecséd	19	–	30	36	4	7	4
17.	Pétervására	24	–	31	32	–	19	–
18.	Kápolna	13	–	9	67	–	11	–
19.	Bogács	22	–	–	59	2	7	10
20.	Madaras	29	–	33	31	–	7	–
21.	Kenderes	34	–	31	21	–	14	–
22.	Mezőhegyes	36	–	24	23	–	13	4
23.	Hajdúböszörmény	31	–	17	36	–	6	10
	Average	30		20	35	5	10	

I = illite; Ka = kaolinite; Kl = chlorite;S = smectite; V = vermiculite; IS = illite-smectite mixed layer minerals

The above leads to the conclusion that loesses indicate the lithology of nearby destructional hinterlands; for instance, the chlorite found in the loesses of Somogy has come from the Alps, while andesite waste and material from Pannonian deposits are detected in smectitic loesses, although environmental conditions and the nature of diagenesis have modified this variable picture even further.

As regards this latter modification, conclusions can be drawn from a comparison of the clay mineral associations of soils based on the clay mineral map of soils (*Fig. 2*). It shows that the original clay mineral composition of loess may have undergone large-scale transformation. Suffice it to draw attention to the smaller smectite ratio on the soil map in the Great Plain than would be expected from the loess composition.

The reason for this lies in chernozem soil dynamics as part of the smectite in the loess is transformed into a mica-like mineral through the adsorption of potassium. Smectites were also observed to change into chlorites and chlorites into illites. These recent processes give unambiguous evidence that the physical conditions prevailing during loess formation also influenced the composition of clay mineral associations in the loess.

In conclusion, the clay minerals in loesses yield information about the circumstances of loess formation. It was found that in the clay mineral compositions of loesses the geology of the source areas of wind-blown dust and its depositional conditions as well as the diagenesis of the deposit are all influential. In many cases local circumstances control clay mineral quality but in spite of this, over large loess tracts it is possible to discern regional regularities which promote a better understanding of the processes of loess formation.

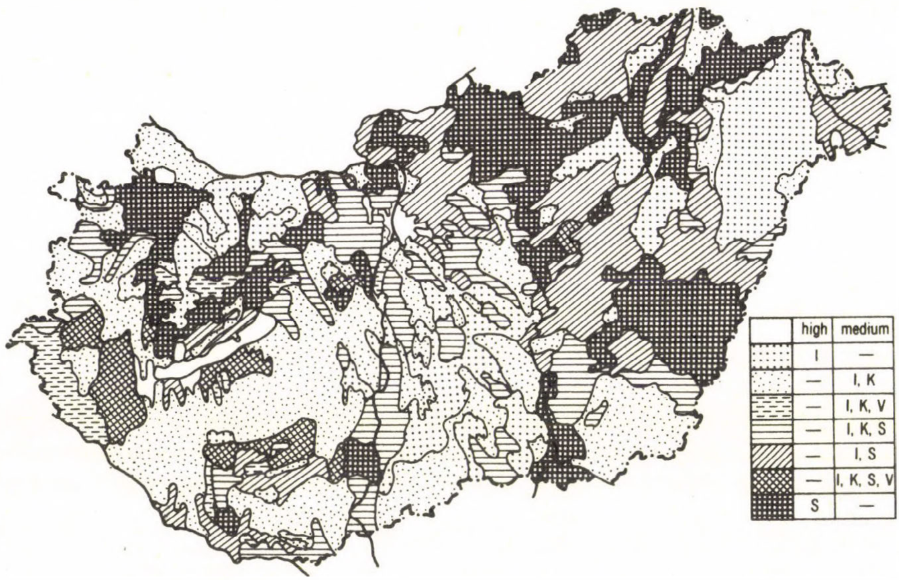

Fig. 2. Clay mineral map of soils in Hungary
I = illite; K = chlorite; S = smectite; V = vermiculite

LITERATURE

BRINDLEY, G. W.–BROWN, G. 1980: Crystal structures of clay minerals and their x-ray identification. London, Mineral. Soc.

BRONGER, A.–KALK, E. 1979: The value of mineralogical and clay mineralogical analyses of loess soils for the investigation of Pleistocene stratigraphy and paleoclimate. – Acta Geol. Hung. 22. pp. 141–152.

STEFANOVITS, P.–Mrs. L. DOMBÓVÁRI, 1985: A talajok agyagásvány társulásainak térképe. (Map of the clay mineral associations of soils.) – Agrokémia és Talajtan. (In preparation)

STEFANOVITS, P.–Mrs. P. BODOR–Mrs. L. DOMBÓVÁRI: Az ország talajagyagásvány térképének bemutatás és felhasználása a trágyázási szaktanácsadásban. (Demonstration and application of the soil clay minerals map of Hungary in consultations for fertilization.) – CIEC IX. Congress. Proceeding. Budapest, 1984. (In preparation)

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MINERALOGICAL OBSERVATIONS ON THE PAKS–DUNAKÖMLŐD LOESS PLATEAU (PROFILES SAMPLED IN 1978, 1979)

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ABSTRACT

The paper presents the results of field and laboratory investigations of two loess profiles along the Danube. The main findigs are: in the two loess profiles the sedimentary layers and fossil soils are located at similar depths but paludal processes are more intensive in the sequence below 73 m in profile measured in 1979, than in the corresponding sequence (below 62 m) in the profile observed in 1978 (GEREI et al. 1979).

MINERAL COMPONENTS OF THE STRATIGRAPHIC UNITS OF THE LOESS PLATEAU AT PAKS–DUNAKÖMLŐD (PROFILE OBSERVED IN 1978)

In the followings the results of the mineralogical analysis of samples from the borehole drilled in 1978 on the loess plateau Paks–Dunakömlőd are presented.

In the investigation of loess profiles for the characterization of individual stratigraphic units and for the establishment of their boundaries, the determination of their mineralogical composition is a useful tool for the correlation of diverse loess deposists.

On the basis of morphological, chemical and physical parameters *6 sequences could be distinguished in the borehole profile* (*Fig. 1*).

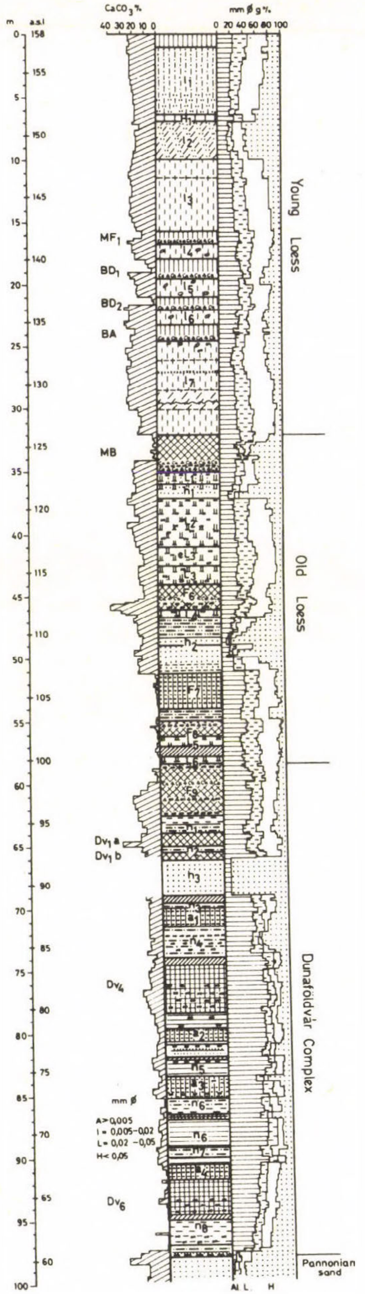

Fig. 1. Paks–Dunakömlőd section 1978
(M. PÉCSI–E. SZEBÉNYI–F. SCHWEITZER)
For explanation of symbols see Fig. 3 and of letters see the text

I. The upper part of the young loess extends from 0 to 16 m and apart from a recent humus-carbonate soil contains another humus horizon.

II. The lower part of the young loess extends from 16 to 32 m in which four chernozem soils were identified: MF_1, BD_1, BD_2 and BA.

III. The upper part of the old loess extends from 32 to 51 m and the redbrown forest soils MB and F_6 were found.

IV. The lower part of the old loess, which contains no carbonates, extends from 51 to 58.8 m containing two forest soil intercalations marked F_7 and F_8.

V. The Dunaföldvár Complex reaches from 62.6 to 97 m where red clay soils (Dv_{1a}, Dv_{1b}, Dv_4 and Dv_6) and alluvial soils (a_1, a_2, a_3, a_4) were found.

VI. Upper Pannonian sand constitutes the lowest part of the stratigraphic sequence below 97 m.

The sic stratigraphic units listed above were characterized on the basis of their feldspar, calcite, dolomite and, from among the clay minerals, montmorillonite content. The reason for the selection of these minerals is justified on the ground that they show the best correlation with different sequences (*Table 1*).

Table 1. Changes in the average feldspar, calcite, dolomite and montmorillonite content in sequences of different age

Sequences	Felspars %	Calcite %	Dolomite %	Montmorillonite %
I. Upper part of the young loess	7.0	9.0	12.0	2.6
II. Lower part of the young loess	8.4	6.6	8.3	9.3
III. Upper part of the old loess	10.3	7.1	7.4	5.3
IV. Lower part of the old loess	10.5	2.0	0.6	8.5
V. Dunaföldvár complex	5.3	10.0	1.2	9.0
VI. Pannonian sands	0	0	0	0

Summarizing the results of the analysis it can be noted that:

1. The main quantitites of each of the four minerals considered are well suited for the characterization of the various stratigraphic units in the Dunakömlőd borehole.

2. The above mentioned minerals exhibit quantitative differences in the stratigraphic units investigated.

3. In the lower part of the old loess the average amount of the four minerals, except feldspars, differed significantly from the other stratigraphic units.

4. The quantity of each of these minerals in the Pannonian sand is markedly different from the overlying sediment sequences.

MINERALOGICAL COMPOSITION OF THE FRACTION > 0.1 mm

Our aim was to describe the mineralogical composition of the various stratigraphic units of different ages from the borehole data. Accordingly a granulometric analysis of the fractions greater than 0.1 mm was also separately undertaken. In the coarse fraction those minerals mostly predominate which are related to other processes of sedimentation and are not primarily linked with soil formation (*Table 2*).

In this case the mineralogical composition of the fraction greater than 0.1 mm was determined for five complexes. The following stratigraphic units were considered: young loess, upper and lower parts of the old loess, the Dunaföldvár Complex and the Pannonian sand. Results of the investigation are presented in *Table 2.*

The stratigraphic units of the borehole record may be also characterized on the basis of the mineralogical composition of fractions greater than 0.1 mm in size.

I. The *young loess* may be distinguished from the other complexes in terms of the average amount of mica and by the presence of dolomite which occurred only here and in the upper part of the old loess.

II. *The upper part of the old loess:* it may be recognized on the basis of the quantity of mica differing from the lower part of the old loess, and by the occurrence of dolomite the amount of which differed from that found in the young loess.

III. *The lower part of the old loess* can be differentiated from the rest of the stratigraphic units by the amount of mica and by the distinctive presence of crystobalite which was collected only from this sequence.

IV. The *Dunaföldvár Complex:* it may be distinguished by the quantity of mica and by the fact that the amount of felspar was the least in this unit and no plagioclase felspar was found here.

V. *The Upper Pannonian sand* is recognized by the change in the quantity of mica compared to the overlying complex. Whereas these samples contained the smallest amounts of quartz, on the other hand, they were the only samples to contain chlorite.

It may be concluded that on the basis of the mineralogical composition of fractions greater than 0.1 mm the investigated stratigraphic units could be well distinguished from each other.

MINERALOGICAL COMPONENTS OF THE STRATIGRAPHIC UNITS IN THE PROFILE NEAR PAKS, SUERVEYED IN 1979

During the investigation of loess profiles along the Danube valley another section of about 88 m thickness was examined by authors in 1979.

On the basis of morphological, physical and chemical parameters three main complexes have been distinguished in this profile (*Fig. 2*).

I. *The Young Loess Complex* extends to a depth of 44.6 m. To 29 m depth some layers of loess, loessy sand, reworked loess, reworked deluvial loess, silty and sandy loess occur (*Fig. 2*). From 29 m to 30 m they are followed by micaceous fine sand, stratified

Table 2. Mineralogical composition by X-ray analysis of the > 0.1 mm fraction from the Dunakömlőd borehole (1978)

Stratigraphic units	Sampling depth in m	Quartz %	Chrystobalite %	Potash feldsp. %	Plagioclace %	Feldsp. %	Calcite %	Dolomite %	Mica %	Chlorite %
I. Young loess	3.0–3.50	44	–	5	10	15	10	12	19	–
Young loess	13.0–13.50	44	–	–	13	13	11	21	11	–
Young loess	28.0–28.50	57	–	–	9	9	10	15	9	–
II. Upper part of the old loess	39.0–39.50	37	–	–	12	12	29	13	9	–
Upper part of the old loess	47.25–47.60	50	–	–	14	14	10	14	12	–
III. Lower part of the old loess	54.0–55.0	55	3	–	12	12	–	–	30	–
Lower part of the old loess	55.10–55.25	57	3	3	13	16	–	–	24	–
Lower part of the old loess	58.0–58.40	60	2	12	4	16	–	–	21	–
IV. Dunaföldvár Complex	63.0–63.50	36	–	6	–	6	41	–	17	–
Dunaföldvár Complex	74.70–75.00	65	–	10	–	10	46	–	9	–
Dunaföldvár Complex	88.50–89.20	60	–	6	–	6	27	–	7	–
V. Pannonian sand	98.50–99.0	28	–	10	3	13	20	2	25	12
Pannonian sand	99.50–100.0	28	–	7	2	9	23	–	33	7

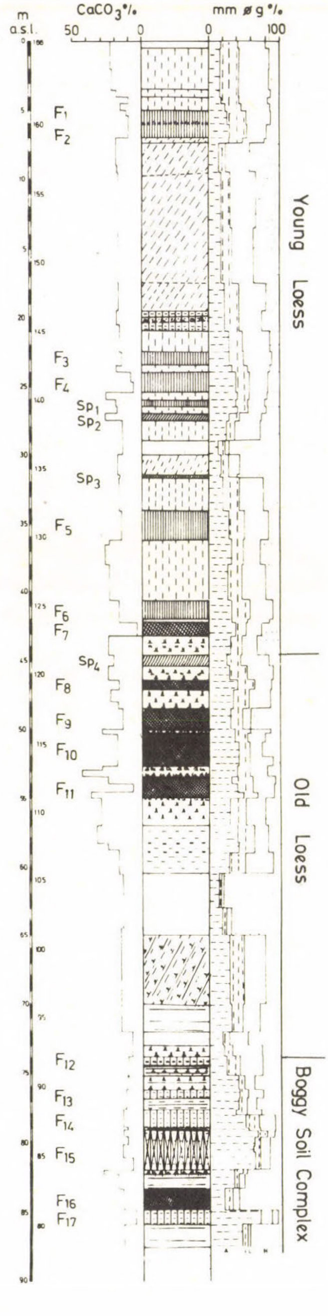

Fig. 2. Paks section 1979
For explanation of symbols see Fig. 3 and of letters see the text

sandy loess and loessy clay are present. From 43.2 m to 44.6 m there are loess layers with lime concretions.

Within the young loess series the varieties of chernozems and semipedolites are typical. The series is closed by a reddish brown forest soil. Thus, there are altogether five varieties of chernozem in the series: a coffe-brown chernozem, a greyish-brown hydromorphous chernozem, a crumbly coffe-brown chernozem, another coffe-brown chernozem and a chernozem with forest soil remains (F_1-F_2-F_3-F_4-F_5). Between 24–32 m three semipedolites were described (Sp_1 - Sp_2 - Sp_3) followed by the closing member of the series, a reddish or rust brown forest soils (F_6 - F_7).

II. *The Old Loess Complex* extends to a depth of 44.6 m to 73.8 m. The old loess appears between 47.1 m to 48.8 m and again between 55 m and 57 m. From 57 m to 70 m silty deposits with gleyed clay streaks and stratified loessy, silty clays occur. From 70 to 73.8 m yellowish-reddish variegated sand horizons are found, locally with clay.

Reddish-brown forest soils are a characteristic of this series. Also three reddish-brown forest soils (F_8 - F_9 - F_{11}) and a reddish-brown subtropical forest soil (F_{10}) were described. In the upper part of the series an ochre coloured semipedolite is found (Sp_4).

III. *A complex of boggy forest* soils occurs at depths between 73.8 and 87.6 m, where indications of paludal processes can be observed. From 73.8 m to 74.5 m paludal silty clay and grey silt are found. From 74.5 m to 76.2 m loess reappears in the forms of clayey loess and loessy sand. From 76.8 m to 87.6 m intensive paludal process is indicated by layers of iron-spotted silty sand, iron-spotted silty clay, variegated silty clayey sand and silty sand.

Grey boggy forest soils are typical of this series. In the series four grey boggy forest soils occur (a_1 - a_2 - a_3 - a_5) as well as a reddish-brown forest soil (a_4). In addition, in the lower part of the series a brownish red subtropical sand soil is found (F_{16}).

Under the sequence of boggy forest soils from a depth of 87.6 m the Pannonian sand complex follows.

In the profile altogether *17 fossil soils and 3 semipedolites were found.*

The arithmetic means of four minerals in the profile observed in 1979 at Paks were investigated in order to examine whether or not substantial differences in mineral composition exist between the various series. The four minerals were feldspar, calcite, dolomite and mica+hydromica (*Table 3*).

Table 3. Changes in the average felspar, calcite, dolomite and mica + hydromica content in the sequences of different ages

Sequences	Felspars %	Calcite %	Dolomite %	Mica + Hydromica %
I. Young loess 0.0–43.20 m	8	10	9	24
II. Old loess 43.20–75.20 m	6	17	8	21
III. Complex of boggy forest soil 75.20–87.60 m	4	16	2	17

It was found that

1. There is a striking difference between the loess series and boggy forest soil series in the distribution of feldspar, dolomite and mica+hydromica with substantially more of these three minerals in the loess than in the boggy forest soil series.

2. Comparing the younger and older loess in respect of the above three minerals, larger amounts are observed in the younger loess.

3. The distribution of calcite over the profile is in inverse relationship to the above three minerals. The smallest amount is found in the younger loess, with substantially more in the older loess and in the boggy forest soil series.

Mineral composition, in certain cases, is a good means for distinguishing between individual layers and soils. For boggy clay soils the growth in the quantity of interstratified minerals is typical.

Comparing the two loess profiles *similarities* could be observed with respect to the types and position of fossil soils and the sequences of diverse sediments.

As a *difference* it was detected that in the loess profile observed in 1979 from 73.8 to 88 m the sediments and soils show traces of intensive boggy processes. Correspondingly, in the previous profile measured in 1978 between 76 m and 85 m boggy soils are found.

Between 62.6 to 97 m of the section, observed in 1978 altough flood plain alluvial soils with some indications of reduction processes occur, these processes are less intensive than in the boggy soil series of the profile investigated in 1979.

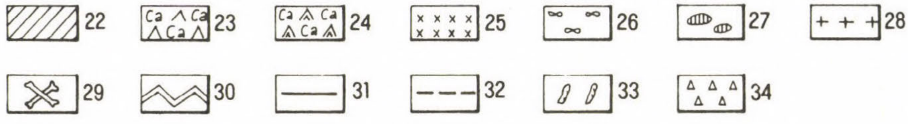

Fig. 3. Legend to figures
1 = sand; 2 = stratified sand; 3 = loess; 4 = sandy loess; 5 = loess sand; 6 = stratified loess; 7 = stratified sandy loess; 8 = stratified sandy loess; 9 = older loess; 10 = stratified older loess; 11 = silt; 12 = sandy silt; 13 = stratified silty sand; 14 = humuous layer; 15 = chernozem soil; 16 = forest soil; 17 = clay; 18 = red clay; 19 = boggy forest soil; 20 = hydromorphic soil; 21 = medow soil; 22 = semipedolite; 23 = calcium carbonate accumulation; 24 = strong calcium carbonate accumulation; 25 = volcanic ash; 26 = loess doll; 27 = krotovinen, animal burrows; 28 = charcoal; 29 = macrofauna, worm-cast; 30 = discontinuity of profile; 31 = boundaries of pack; 32 = sandstone banch; 33 = dessication fissures; 34 = detrial material;

LITERATURE

GEREI, L.–REMÉNYI, M.–PÉCSI-DONÁTH, É. 1979: Mineralogical analysis of the borehole drilled 1978 on the loess plateau of Dunakömlőd. – Acta Geol. Hung. 22. 1–4. pp. 501–511.

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ON THE MINERALOGICAL AND PETROLOGICAL PROPERTIES OF THE YOUNGER LOESS IN HUNGARY

É. PÉCSI-DONÁTH

ABSTRACT

By its stratigraphic position and geological, lithological, mineralogical and pedological nature, loess in Hungary is divided into the "younger" and "older" loess. In complete profile the younger loesses are subdivided by five forested steppe paleosols. During the last few years mineralogical and pedological investigations have been performed on type sections in several loess regions in Hungary. Most recently the loess and fossil soils in the Paks, Dunakömlőd and Mende exposures have been studied mineralogically by thermal analysis. This paper is devoted to a brief mineralogical and petrological description of the exposures and includes the results of earlier X-ray analyses together with micromineralogical, pedological and grain size composition investigations of the individual horizons.

THE YOUNGER LOESS SERIES

The younger loess series in Hungary in subdivided into the Dunaújváros–Tápiósüly (l_1-l_2) loess complex and the Mende–Basaharc (l_3-l_5) loess complex. There are extensive regions where only the former series occurs, but the presence of both the younger loess series superposed on one other is also common.

Within these two units, the younger loess series occurs in slightly varying thicknesses, but six loess packets (l_1-l_6) and five characteristic paleosols (MF_1, BD_1, BD_2, BA and MB) are generally identified.

LOESS PACKET l_1

"This is composed of several sedimentary subhorizons petrologically regarded as loess, sandy loess and loessy sand, of 2 to 5 m in thickness with numerous reindeer antlers; it is of cca 13 to 15 KA." (PÉCSI, 1985). The detailed investigation of this loess packet is based on the analysis of material from the exposures at the Paks brickyard, the Paks–Dunakömlőd borehole and the Mende brickyard.

The l_1 loess packet is characterized mineralogically and petrologically as follows (*Figs 1, 2 and 3*).

Table 1. Grain size distribution in loess packet l_1 from the Mende and Paks exposures (1971)

	Clay	Silt	Loess	Sand	Carbonate minerals
	< 0.005	0.005–0.02	0.02–0.06	0.06–1	
	per cent				
Pécsi et al. (1965)analyzed by Mrs I. Mihályi	6.2	13.1	45.6	32.1	21.16
Pécsi et al. (1979) analyzed by Mrs E. Szebényi	11.0	23.0	41.0	25.0	19.0

– The average specific weight of this loess is 2.67 g per cm^3.

– As determined by thermal and X-ray analysis, the mineral composition is as follows:

quartz:	40%	dolomite:	10 to 20% (locally calcite)
feldspars:	10%		
micas:	15% (muscovite)	pyrite:	cca 0.5%
illite:	15%	organic matter:	cca 0.5%
montmorillonite:	7%		
kaolinite:	max. 1%		

– The grain size distribution indicates that the loess fraction is less than 50 per cent and is almost equalled by the fine sand content. On this basis this loess packet is considered a sandy loess.

– Among the carbonates dolomite is predominant, while illite predominates compared to montmorillonite.

– All these seem to support the general concept that this loess packet was formed under a cold and dry climate, when clay minerals formed or accumulated in small amounts.

LOESS PACKET l_2

"This is mostly composed of sandy loess horizons of 2 to 5 metres in thickness with dell deposits (l_2', l_2", l_2'"). From its base, bone fragments of a 'young' form of *Elephas primigenius* were excavated. The age of the loess packet l_2 is 26 to 21 KA." (PÉCSI, 1985).

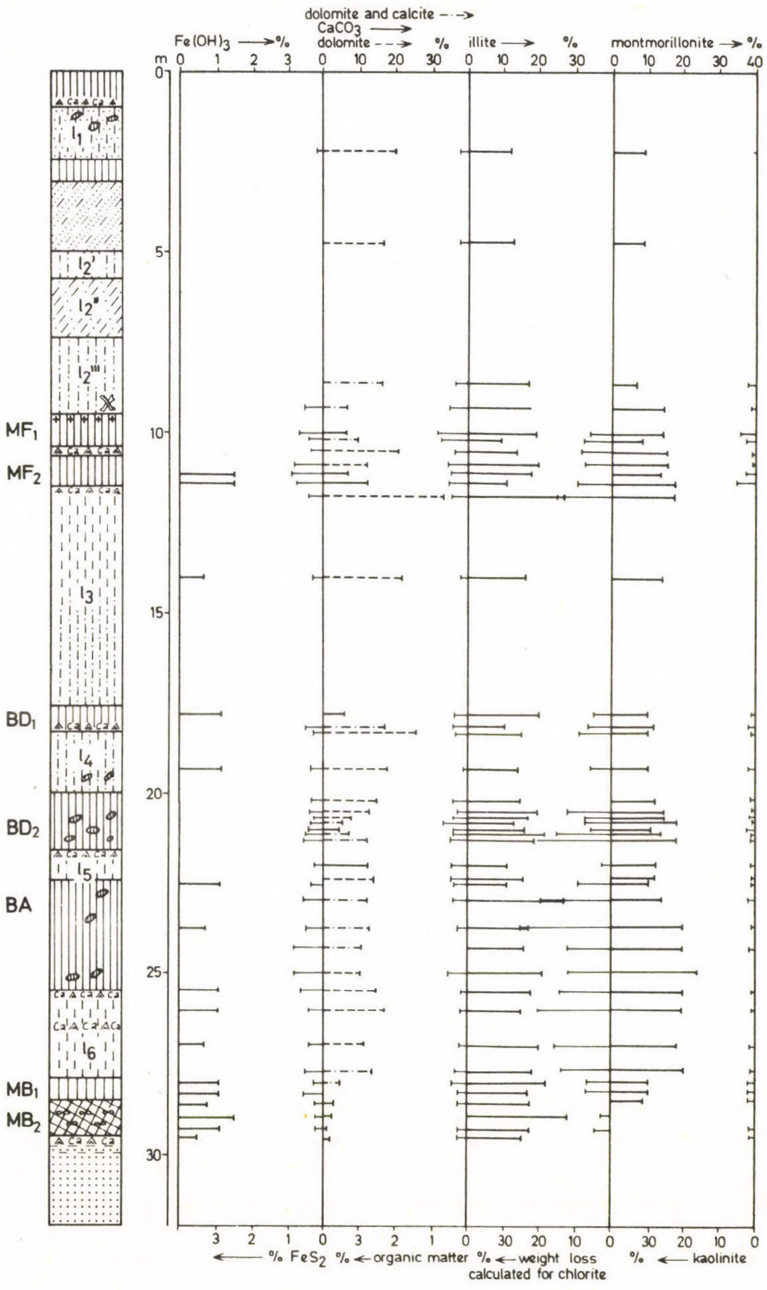

Fig. 1. Results of thermal analysis of the Mende loess profile (1976)

Table 2. Average grain size distribution in loess packet l_2 from the Mende exposures (1965 and 1968)

	Clay	Silt	Loess	Sand	Carbonate minerals
	< 0.005	0.005–0.02	0.02–0.06	0.06–1	
	per cent				
Pécsi et al. (1965) analyzed by Mrs I. Mihályi	6.6	18.0	14.4	30.7	9.51
Pécsi et al. (1968) analyzed by Mrs E. Szebényi	19.0	15.8	32.8	32.3	20.0

In this loess packet there were major differences in the proportions of the various grain size categories – even within the same exposure, depending on the exact location; only the ratio of silt fraction is stable.

– The average specific weight of this loess is 2.67 g per cm^3.

– The average mineral composition of packet l_2 as determined by thermal and X-ray analyses is as follows:

quartz:	40%	dolomite (and calcite):	14 to 17%
feldspars:	12%	iron oxihydroxide:	1 to 2%
micas:	9 to 11%	organic matter:	0.2%
illite:	16%	kaolinite:	1 to 2%
montmorillonite:	7%	few chlorite	

– The heavy mineral content of 100 g of the loess (CODARCEA, 1977) was 27 per cent garnet, 11 per cent amphibole, 2 to 5 per cent turmaline and titanite, cca. 3.5 per cent disthene, staurolite, zircon and zoisite, 5 to 6 per cent epidote and rutile, cca 2.5 per cent biotite, chloritoide, glaucophane and hypersthene.

– Differences in the grain size distribution suggest the subdivision of this loess packet into the parts l_2', l_2'', l_2''' and show that the upper part of the packet is locally more sandy and, is therefore best described as a "loessy sand" or "sandy loess".

– Among the carbonates, dolomite prevails with and average content of cca 17 per cent.

– Calcite does not occur independently, only in combination with dolomite.

– In some of the exposures, e.g. at Paks, chlorite and kaolinite are also identified, while in other places a little pyrite or iron oxihydroxide occurs.

These parameters lead to the conclusion that at the time of the genesis of this loess packet, redox conditions rose in some places, while in other places pyrite was left behind. Rock decomposition took place in acidic conditions locally and, as a result, kaolinite formed, while in other places smectite (montmorillonite) indicative of alkaline conditions accumulated.

The packet formed under variegated physico-chemical circumstances or was subject to varying effects after its accumulation. In any case, the dominance of illite over montmorillonite indicates an origin under cold and dry climatic conditions.

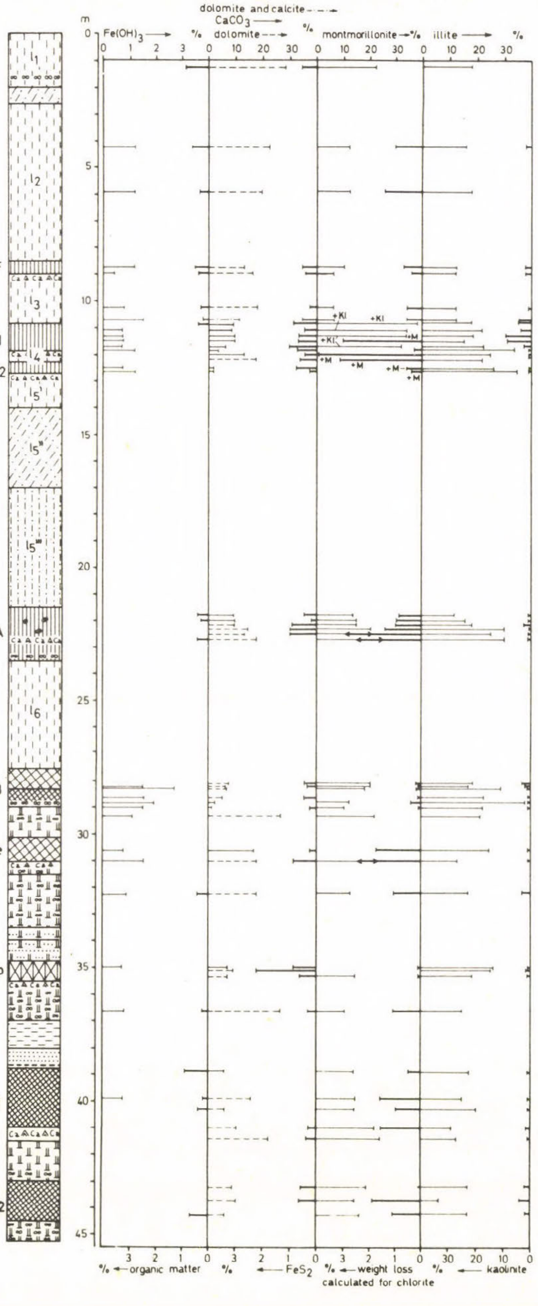

Fig. 2. DT Analysis of the loess profile (1977) at Paks brickyard (É. PÉCSI-DONÁTH)
+KI = weight loss for montmorillonite and chlorite, calculated for montmorillonite; +M = = weight loss in per cent of montmorillonite and chlorite between 600–700 °C

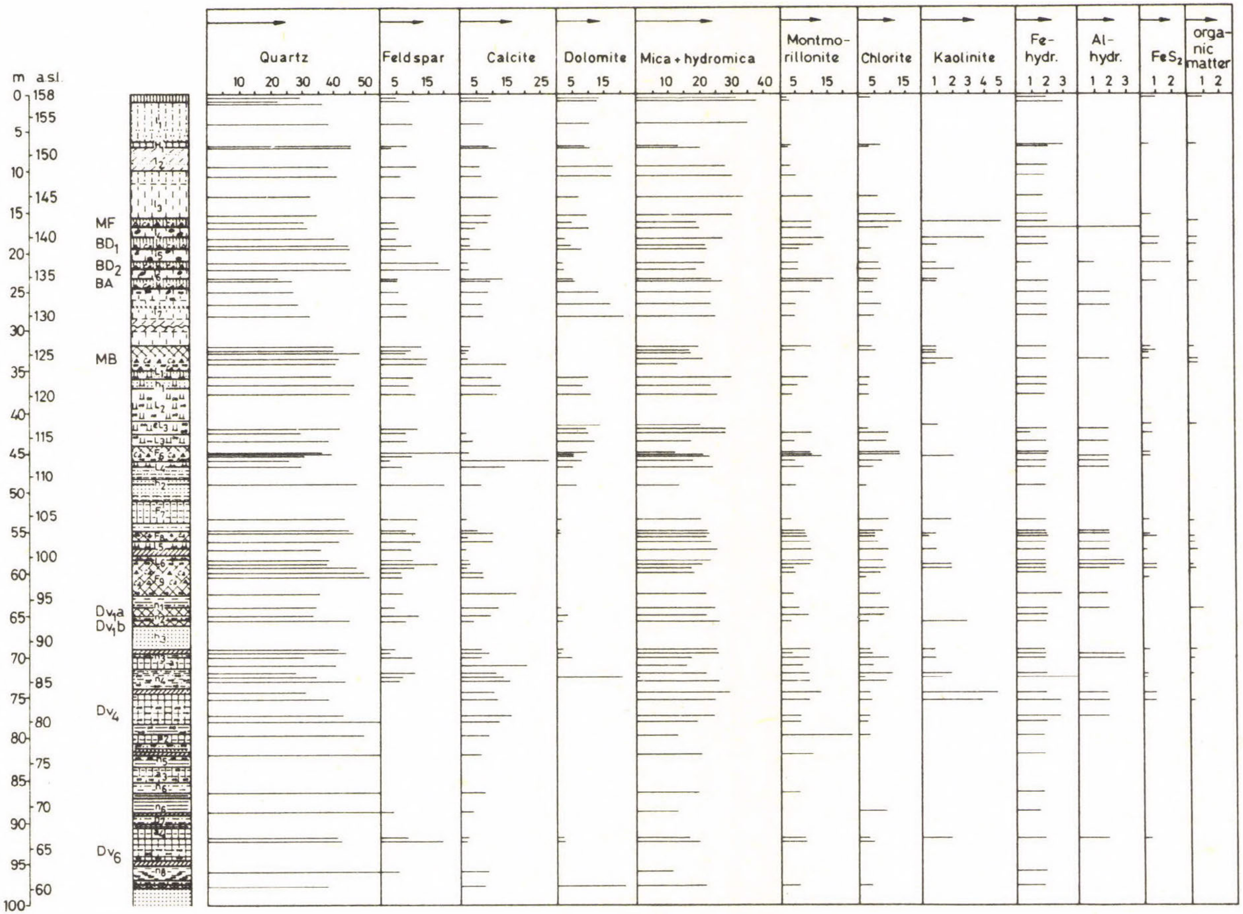

Fig. 3. The mineralogical composition (%) of the 1978 Dunakömlőd borehole section
(É. PÉCSI; DONÁTH–L; GEREI–M; REMÉNYI)

LOESS PACKET l_3

This is separated from l_2 by the MF (Mende Upper) soil complex which is composed of an upper, poorly developed forested steppe soil (MF_1) with charcoal remnants suggesting an age of 28 to 29 KA (PÉCSI, 1975) and of a lower, better developed forested steppe soil (MF_2). MF can be considered a leading horizon as it occurs in numerous exposures, although locally it is only represented by the MF_2.

"Loess packet l_3 is a typical sandy loess of 3 to 5 m thickness and fills a former dell" (PÉCSI, 1985). Its thickness is variable between paleosols MF and BD and it is thinner than l_2 at Paks.

Table 3. Average grain size distribution in loess packet l_3 from the Mende exposures (1965 and 1968)

	Clay	Silt	Loess	Sand	Carbonate minerals
	< 0.005	0.005–0.02	0.02–0.06	0.06–1	
	per cent				
Pécsi et al. (1965) analyzed by Mrs I. Mihályi	9.4	20.0	52.9	16.0	24.0
Pécsi et al. (1979) analyzed by Mrs E. Szebényi	20.0	19.0	36.0	25.0	24.0

– Average specific weight of this loess is 2.7 g per cm^3.

– The differences of graine size distribution even within a single exposure and the high proportions of 'loess' and 'sand' justify the description of this loess packet as a 'loess' or 'loessy sand' with considerable carbonate content.

– The average mineral composition as determined by thermal and X-ray analyses is as follows:

quartz:	30%	dolomite:	17%
feldspars:	7%	iron oxihydroxide:	2 to 3%
micas:	4%	organic matter:	0.2%
illite:	14%	chlorite:	7%
montmorillonite:	15%	kaolinite:	1%
pyrite:	0.1 to 0.2%		

– The average heavy mineral content of 100 g of this loess was 30 per cent garnet, 4 per cent amphibole, 1 per cent biotite and turmaline, 3.5 per cent disthene, 6 to 7 per cent epidote and zoisite, 7 per cent rutile, 3 per cent staurolite and zircon and 34 per cent magnetite: titanite and hypersthene are below 1 per cent (CODARCEA, 1977).

– The chemical analysis of the loess packet from the Mende exposure by PÉCSI et al. (1965) provided the following results:

SiO_2	39.22%
Al_2O_3	3.99%
FeO	0.6%
Fe_2O_3	1.65%

TiO_2	0.29%
MnO	0.60%
CaO	22.88%
MgO	4.12%
H_2O^-	0.58%
ignition loss	22.65%

– These various characteritics support the contention that this loess packet l_3 also formed under cold and dry climatic conditions in which the considerable accumulation of carbonates in the C soil horizon also played a role. It is a more typical loess than the previous packets.

LOESS PACKET l_4

This is separated from the l_3 by the BD_1 paleosol and is intercalated between the BD_1 and BD_2 soil complexes. Therefore, it is generally a thin horizon and has presumably been influenced by the formation paleosol BD_1.

Table 4. Average grain size distribution in the loess packet l_4 from the Mende exposure (1965 and 1968)

	Clay	Silt	Loess	Sand	Carbonate minerals
	< 0.005	0.005–0.02	0.02–0.06	0.06–1	
	per cent				
Pécsi et al. (1965) analyzed by Mrs I. Mihályi	14.3	19.0	42.5	23.4	21.0
Pécsi et al. (1979) analyzed by Mrs E. Szebényi	25.0	15.0	25.0	25.0	18.0

– Average specific weight of this loess is 2.71 g per cm^3.

– In this packet the clay content exceeds the values for the above loess packets. The ratio of 'loess' grain size fraction also is considerably higher (although not to the same degree at all sites!).

– Carbonate content is lower than in loess packet l_3.

– Average mineral composition as determined by thermal and X-ray analyses is as follows:

quartz:	33%	dolomite:	14%
feldspars:	7%	organic matter less than	1%
micas:	7%	chlorite:	3%
illite:	17%	kaolinite:	2%
montmorillonite:	10%	calcite:	5%
pyrite:	0.5%	little iron oxihydroxide	

– The heavy mineral content of 100 g of the loess packet l_4 (CODARCEA, 1977) was: 34.5 per cent garnet, 7.1 per cent amphibole, around 1 per cent turmaline and biotite, 1 per cent disthene and staurolithe, 4 to 5 per cent zoisite, epidote and clinochlor, less then 0.5 per cent titanite, hypersthene, chloritoide, sillimanite and glaucophane, 4 per cent zircon and 22 per cent magnetite.

– Dolomite and calcite are combined in the loess.

– Pyrite indicating reduction regularly occure in the exposures.

– In the exposures investigation chlorite was a significant mineral constituent.

– The occurrence of organic matter points to a close relationship with soil development.

– The chemical analysis provided the following results:

SiO_2	61.26%
Al_2O_3	10.58%
Fe_2O_3	2.79%
FeO	1.00%
TiO_2	0.41%
MnO	0.10%
CaO	7.55%
MgO	3.14%
H_2O^-	0.82%
ignition loss	8.91%

Loess packet l_4 may be termed a 'typical loess' in which the mineral matrix accumulated over a brief period of time or soon after accumulation but was later transformed by soil formation processes due to relatively humid and warm climatic conditions.

LOESS PACKET l_5

This has been deposited in variable thickness between the BD and BA paleosols, and was designated as l_4 by PÉCSI (1982) in the profile of the Mende exposure. It comprises a loess horizon of 2 to 5 m in thickness, probably dating back more than 50 KA, with the tooth remains of *Elephas primigenius,* while carbonate content is usually evenly distributed in the upper part. It reaches a maximum thickness of 8 to 9 m in the exposure in the Paks brickyard where it is intercalated between young loess horizons. It contains stratified sandy loess dell infill in its upper third.

Table 5. Average grain size distibution in the loess packet l_5 from the Mende (1965) and Paks (1977) exposures

	Clay	Silt	Loess	Sand	Carbonate minerals
	< 0.005	0.005–0.02	0.02–0.06	0.06–1	
	per cent				
Pécsi et al. (1965) analyzed by Mrs I. Mihályi	11.8	16.6	48.9	21.8	21.0
Pécsi et al (1979) analyzed by Mrs E. Szebényi	11.4	26.5	49.4	12.1	20.9

– The specific weight of this loess is 2.68 g per cm^3.

– 'Loess' and 'silt' fractions predominate.

– Average mineral composition as determined by thermal and X-ray analyses is as follows:

quartz:	21%	dolomite:	8%
feldspars:	5%	calcite:	14%
micas:	10%	organic matter:	0.2%
illite:	17%	chlorite:	5%
montmorillonite:	14%	kaolinite:	1%
pyrite:	0.2%	iron oxihydroxide:	2%

– The high clay content at the base and top of the horizon reflects weathering and soil formation.

– Average chemical composition is as follows:

SiO_2	56.85%
Al_2O_3	9.13%
FeO	0.97%
Fe_2O_3	2.77%
TiO_2	0.41%
CaO	12.08%
MgO	2.89%
MnO	0.10%
H_2O^-	0.79%
ignition loss	13.26%

LOESS PACKET l_6

The lower part of this typical loess, 2 to 5 m in thickness, is stratified slope loess with *Equus sp.* teeth (PÉCSI, 1982). Loess l_6 is deposited between the BA (Basaharc Lower) and MB (Mende Base) brown forest soil complexes. At the top of l_6 thin tuffite layers are to be found in some of the younger loess series of Hungary (KRIVÁN, 1955; KRIVÁN–RÓZSAVÖLGYI, 1964).

Table 6. Average grain size distribution in the loess packet l_6 from the Mende (1965) and Paks (1977) exposures

	Clay	Silt	Loess	Sand	Carbonate minerals
	< 0.005	0.005–0.02	0.02–0.06	0.06–1	
	per cent				
Pécsi et al. (1965) Mrs. I. Mihályi	11.4	17.9	49.5	18.0	18.0
Pécsi et al. (1979) analyzed by Mrs E. Szebényi	10.0	17.0	53.0	20.0	18.0

– The specific weight of this loess is 2.71 g per cm^3.

– Average mineral composition as determined by thermal and X-ray analyses is as follows:

quartz:	30%	dolomite:	20%
feldspars:	7%	calcite:	6%
micas:	8%	organic matter:	0.1%
illite:	17%	iron oxihydroxide:	3%
montmorillonite:	6%	kaolinite:	1%
pyrite:	0.5%	chlorite: less than 1%	

– At Paks the average heavy mineral content of 100 g of this loess was determined (CODARCEA, 1977) as 9 per cent garnet, 14 per cent amphibole, 1 per cent turmaline, 3.5 per cent disthene, 8.5 per cent zoisite, 2 per cent titanite, 6 per cent epidote, 11 per cent rutile, 5 per cent staurolite and biotite, 8 per cent zircon and 23 per cent magnetite.

– Average chemical composition is

SiO_2	52.46%
Al_2O_3	8.96%
Fe_2O_3	2.81%
FeO	0.89%
TiO_2	0.36%
MnO	0.09%
CaO	12.19%
MgO	3.68%
H_2O^-	0.59%
ignition loss	13.42%

The loess packet l_6 may be described as follows

– this thick loess series intercalated between the BA and MB soil complexes is the oldest formation in the "younger loess" of the exposures;

– in mineral composition, besides the prevalent role of dolomite, the independent occurrence of calcite is characteristic;

– in some exposures along with significant illite content, the ratio of montmorillonite is considerable;

– iron hydroxide is present in each of the exposures, which indicates highly oxidising weathering processes;

– in its grain size distribution, the higher proportions of fine grained fractions are typical (see sedimentological analyses);

– these characteristics point to somewhat more humid and warmer climatic conditions during the formation of this loess packet compared with the condition prevailing during the genesis of loess packets l_{3-1}.

REFERENCES

CODARCEA, V. 1977: Percentage distribution of heavy minerals in the loess profiles at Paks and Mohács. – Földr. Közlem. 25. (101.) pp. 138–143.

GEREI, L.–REMÉNYI, M.–PÉCSI-DONÁTH, É. 1979: Mineralogical analysis of the borehole drilled in 1978 on the loess plateau of Dunakömlőd. – Acta Geol. Hung. 22, 1–4. pp. 501–511.

KRIVÁN, P. 1955: A közép-európai pleisztocén éghajlati tagolódása és a paksi alapszelvény. (Distribution of the Central-European Pleistocene climat and the loess profile at Paks.) – M. Áll. Földt. Int. Évk. 43. 3. pp. 365–400.
KRIVÁN, P.–RÓZSAVÖLGYI, J. 1964: Andezittufit vezetőszint a magyarországi felsőpleisztocén (rissi) lösz-szelvényekből. (Andesite tuffite index horizon from Upper Pleistocene (Rissian) loess profiles in Hungary.) – Földt. Közl. 94. pp. 257–265.
PÉCSI, M. 1965a: Zur Frage der Typen der Lösse und lössartige Sedimente im Karpatenbecken und ihrer lithostratigraphischen Einteilung. – Földr. Közlem. 13. (89.) 4. pp. 305–323.
PÉCSI, M. 1965b: Der Lössaufschluss von Mende. – Földr. Közlem. 13. (89.) 4. pp. 332–338.
PÉCSI, M. 1972: Scientific and practical significance of loess research. – Acta Geol. Hung. 16. 4. pp 317–328.
PÉCSI, M. 1982: The most typical loess profiles in Hungary. – In: Quaternary studies in Hungary. Bp. Geogr. Res. Inst. Hung. Acad. Sci. pp. 145–169.
PÉCSI, M. et al. 1977: Paleogeographical reconstruction of fossil soils in Hungarian loess. – Földr. Közlem. 25. (101.) 1–3. pp. 94–137.
PÉCSI, M.–SZEBÉNYI, E.–PEVZNER, M. A. 1979: Upper Pleistocene litho- and chronostratigraphical type profile from the exposure at Mende. – Acta Geol. Hung. 22. 1–4. pp. 371–389.
PÉCSI, M. 1985: Divisions of Upper Pleistocene young loesses in Hungary. – INQUA Loess Commission Symposium, Lublin, 2 p. [MS]
PÉCSI-DONÁTH, É. 1979a: Thermal analysis of the loess from the Mende profile. – Acta Geol. Hung. 22. 1–4. pp. 391–395.
PÉCSI-DONÁTH, É. 1979b: Thermal investigations of the loesses and fossil soils of Paks. – Acta Geol. Hung. 22. 1–4. pp. 419–426.

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PROBLEMS OF THE GRANULOMETRY OF LOESS

GY. HAHN

ABSTRACT

A close relationship exists between the grain size of the loesses and the weathering and the soil forming processes. In the case of various sedimentary rocks special attention is to be paid when choosing the methods, used in measuring the sizes of grains.

It is not sufficient merely to publish grain-size distributions or composition curves of loessic sediments, but also the way of preparation, shaking, cooking, drying, etc., the stabilizer used because the slope of the curve maximum and minimum points, etc. are influenced by these factors.

The genetic and character-modifying roles of the grainsize are important. A new method has beén developed (HAHN, 1966) in order to separate the particular horizons of the loess series and to eliminate the errors of grain-size determination.

Because of the great number of the curves with the same rise, a graph grain-size for the separation of the special loessic soils or sediments has been prepared. In this way, several hundred summarizing curves can be presented without the risk of their becoming covered by one another.

Between 0.02 and 0.05 mm and between 0.05 and 0.1 mm the so-called loessic range are shown on the vertical axis and the values of the inequality degree on the horizontal one.

Using this method it is possible to separate the eolian, fluviatile, slope and solifluctional sandy loesses and fossil soil types.

The grain size properties of loesses vary world-wide but still fall within definite limits according to transportational, depositional and diagenetic conditions. The investigational techniques for loess-type sediments are different and this results in some modifications to the determination of granulometric characteristics. This paper deals with these problems.

The research activities of PÉCSI (1965) and HAHN (1972) have shown that no sharp boundaries can be drawn between certain types of loess series.

It is characteristic of such sediments that the percentage of the loess fraction (0.02–0.1 mm) is a reflection of their genesis.

The development of the loess-fraction is interpreted in various ways:

1. according of the theory of OBRUCHEV the development is due to dusty, wind-borne material, being transported on one occasion,

2. according to the observations of BERG, GANSSEN and MÜNNICHSDORFER this development is due to arid and hydratic weathering processes,

3. the theory of GRAHMAN states that loesses are formed by eolian and fluviatile transportations,

4. according to PÉCSI disintegration due to freeze/thaw activity is the main reason, while

5. others have postulated that the glacial transportation of material has produced this fraction.

Between 40 and 60 percent of loess series are made up of "rock-dust". The size characteristics of "rock-dust" (0.02–0.05 mm diameter) are considered by many experts to provide methodological limiting values with regard to conditions of transportation, and accumulation and during material testing when the characteristics may be modified.

According to BOGÁRDI (1952), in the case of particles with a diameter of between 0.05 and 0.02, mm the concentration of the flowing water does not depend on the amount of water, while below 0.02 mm the law of suspension is not valid any more, according to which the suspension is caused by an equality of the figures of buoyancy and the weight-in-the-water of the float.

KÉZDI (1959) regarded average windspeeds of 29–39 km/hour to be most appropriate for the eolian transporation of dust-sized grains.

KRIVÁN (1955) described the range of 0.02–0.1 mm, i.e. $D_2 + D_3$ as "the characteristic bulk of the loesses". The grain size of rhyolite tuff found later has been entried in this range.

MIHÁLTZ (1955) and SZTRÓKAY (1936) found that the largest ash particles transported a considerable distance from the Descabezabo volcano were 0.04 mm in size and they drew a comparison between this figure and the size of dust particles fall of Sahara origin deposited over Hungary in 1941, which ranged from 0.01–0.05 mm in diameter.

On the other hand, 58 percent of the suspended load of the Maros River fell within the range 0.01–0.05 mm diameter, according to the examinations of MEZŐSI and DONÁTH (1954).

MOLDVAY (1962) discusses the effect on speed of transport of a sharp transportation drag boundary which occurs with particles of 0.02 mm diameter in water and of 0.05 mm diameter in air. In his view, the 0.01–0.05 mm grain-size dust deposition may be deduced from:

1. air drag resulting in rapid internal sorting

2. partial lifting inertia, and

3. the original grain-size of the blown material which would not have been less than 0.01 mm in diameter.

Referring to loess, he speaks about transportation over exceptionally long distances, repeated several times and mentions that long distance transportation results in uniform deposits (below or above 0.05 mm diameter), while local flow shows a tendency to fall into the 0.01–0.02 mm and 0.02–0.05 mm franctions.

This uniform eolian composition is, however, contradicted to some degree by the results of the different grain-size distributions associated with the dust storms in Deliblát and Transdanubia in 1896 and in the Sahara in 1901, though the methods of investigation have been different.

Granulometrically loess (0.01–0.05 mm) has been related to the physical weathering (insolation and freeze/thaw action) of rocks (KRIGER, 1965). Weathering will be effective as long as temperature fluctuations are not balanced by the movement of the particles resulting from the elasticity of the material.

According to BESKOW (1930) and DÜCKER (1937), the percentage of the 0.02–0.2 mm diameter fraction is increased by the splitting of larger particles through freeze/thaw activity.

According to investigations undertaken in Hungary the boundary of block and lens freezing is at the lower boundary (0.02 mm) of the loess domain when the Allen-Hansen number is about U = 2.5. According to PÉCSI (1963, 1964), the cryo fraction in Hungary has been split down to 0.02–0.05 mm.

Since 1916 BERG has stressed the relationship between the grain-size of loess on the one hand, and the weathering and the soil forming processes on the other. The presence of $CaCO_3$ and Fe_2O_3 results in an increase in grain-size especially below and in the fraction of 0.05–0.01 mm, through a coagulating effect on smaller particles and by providing them with calcareous coating. BERG thinks it possible that the size of quartz grains is increased when silicates are present in solution, when colloidal re-crystallized gel quartz may be formed and deposited on previously existing grains of 0.02 to 0.25 mm in diameter.

TYUTYUNOV (1960) postulated that the formation of aggregate takes place under frosty conditions. According to ROZANOV (1951) the amount of microaggregates formed during the analysis of loess (preparation, shaking, etc.) is between 20 and 40 per cent of the total material.

In Hungary methods for measuring the sizes of aggregates and the grains have been studied by VENDL–TAKÁTS–FÖLDVÁRI (1935, 1936), FÖLDVÁRI (1956), UNGÁR (1957) and VENDEL (1959). Two conclusions have emerged from these works: in the case of various sedimentary rocks special attention is needed when choosing the methods, stabilizer, etc. used for measuring grain size, and the results obtained from analysis are partly dependent upon the methods of measurement that are utilised.

According to these investigations, the ATTERBERG method is not appropriate for grain-size measurement of loess because of the dissolving out of lime and its appearance in the finest fraction. It is not sufficient merely to publish grain-size distributions or composition curves of loessic sediments; the methods of preparation, shaking, cooking and drying, the stabilizer used, the values of lime and humus content present in the course of the analysis, and the duration of the particular phases, etc. should always be revealed as well. Not only are the figures for the grain-size range influenced by these factors but the same applies to the slope of the curve and the location of the maximum and minimum points. The particle-modifying role of any lime content has been examined by FARAGÓ (1938) and MIHÁLTZ (1955), and their curves have been corrected by treatment with hydrochloric acid.

It is understandable that the grain-size curve will be modified according to the methods used in the testing of materials (HAHN, 1972) also on the basis because the lower value of the shifting is 0.1 or 0.06 mm, while in the dredging the first remarkable values of reading are frequently to be found at the lower boundary (0.02 or 0.01 mm of the rock-dust). In this way, the range characteristic of loess has common figures with the joint points in the case of the two methods.

SUMMARY PRESENTATION OF GRAIN-SIZE

The genetic and character-modifying roles of grain-size are important. A new method has been developed (HAHN, 1972) in order to separate out the particular layers of a loess series and to eliminate errors in the determination of grain-size. Because of the large number of the curves with the same rise, a graph suitable for the separation of special loessic soils and sediments has been prepared. In this way, several hundred summarizing curves can be presented without the risk of them covering each other (*Fig.* 1). Two factors are used in this representation: the figures of loessic range and the range of assortment, i.e. the numerical value of the rise of the curve. There are two ways of presenting assortment: either by using the square

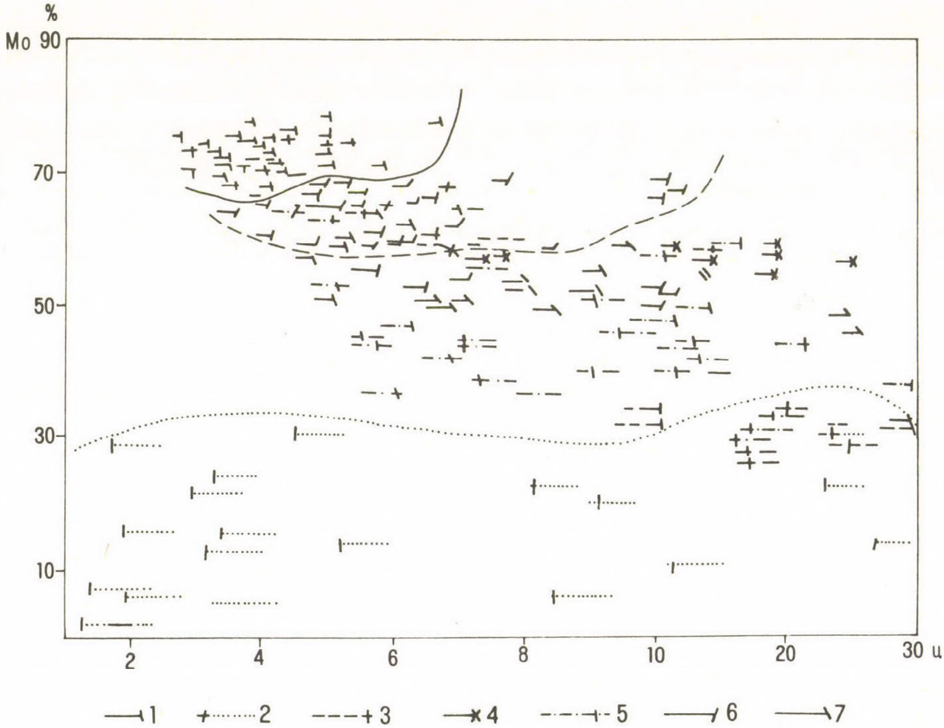

Fig. 1. Summarization of the mechanical analysis of the Hungarian loess-like sediments
1 = eolian loess; 2 = sand; 3 = tuffit; 4 = soils; 5 = fluviatile loesses; 6 = deluvial loesses; 7 = epigenetical loesses

root of the quotient of the grain diameter figures corresponding to the 25 and 75 per cent (quartile values), which gives index of assortement with the formula: $S_o = \frac{Q_1}{Q_2}$; or by employing the quotient of the values of the diameters corresponding to the 60 and 10 per cent levels, which give the degree of inequality with the formula $U = D_{60}/D_{10}$, after ALLEN–HANSEN.

The latter method is used in engineering practice. The values of the curves can be calculated by means of a simple divisions, which take more thoroughly into consideration the smaller diameter indicating the amount of the clay fraction in the case of loessic sediments. The clay content with its larger specific surface, influences the erodability of the sediment, e.g. the collapsing characteristics of the loess.

By means of vectors, we have tried to convey information not only about the amount of loessic materials but also about the percentage values of sand and clay. The limiting values of the loess range have been chosen in compliance with the KRIVÁN's survey at Paks (1955) taking account of the fraction limits of the SCHÖNHALS' index used in archeology and with regard to the generally accepted range of sand-dust (Mo).

The curve of grain distribution is divided into four sections by three vertical lines: 1. clayey and silty fractions lying between 0.0 and 0.02 mm, i.e., the D_1 value; 2. the first part (D_2) of the loessic range lying between 0.02 and 0.05 mm; 3. the second part (D_3) of the loessic range lying between 0.05 and 0.1 mm; 4. sandy sediments (D_4) made up of grains larger than 0.1 mm.

When plotting the values of each group, the figures for the second and third classes (D_2 and D_3), the so-called loessic range, that is the percentage values based on the weight of the material in the range of 0.1 mm to 0.02 mm are shown on the vertical axis, while the values of the inequality degree mentioned above are plotted on the horizontal axis. Inequality values greater that $U = 35$ are shown on the straight line on the right side of the graph.

According to this method, each of the summarizing curves is depicted by means of a point which allows separation of the particular sediment types. The range for typical loess is bordered by lines drawn to correspond to a value for the loessic range greater than 65–67 per cent and at an inequality value less than $U = 6$.

As shown in the drawing loess associated with "moist relief" are to be found around the areas mentioned above, in a long arch-shaped form. Toward the right corner of the graph are to be found the greater U-values, associated with smaller amounts of loess, and "re-washed", soaked and palustral types.

In the left hand corner and at bottom of the diagram types with low loess content and heavy assortment are shown, with unassorted sandy and wind-blown sandy loesses towards the right side, and with clay content also increasing towards the right.

We can obtain a clearer picture of the composition-curve when the quantities of the sandy, silty and clayey fractions are represented by vectors starting from the points mentioned above. The vectors result in a straight line. To the right of this line, diverging from the point representing the amount of loess and the value of U, we find the sandy range with grain-sizes larger than 0.1 mm, while to the left are the percentage values of the silty and clayey fractions with grains of less than 0.02 mm in diameter.

Our method provides a basis for the classification of loessic sediments. With the use of this method it has become possible to distinguish and to separate the eolian, fluviatile, slope and solifluctional sandy loesses and fossil soil types, described by PÉCSI (1964).

REFERENCES

BESKOW, G. 1930: Erdfliessen und Strukturböden der Hochgebirge im Lichte der Frosthebung. – Geol. Föreningen i Stockholm Förhand. 52. pp. 622–639.

BOGÁRDI J. 1952: A lebegtetett hordalék. (The suspended fluvial load.) – Mérnöki Továbbképző Intézet. Budapest, Tankönyvk. 25 p.

DÜCKER, A. 1937: Über Strukturböden im Riesengebirge. Ein Beitrag zum Bodenfrost und Lössproblem. – Deutsch. Geol. Ges. 89. pp. 113–129.

FARAGÓ M. 1938: Nagykőrös környékének felszíni képződményei. (Die oberflächlichen Gebilde der Umgebung von Nagykőrös.) – Földt. Közl. 68. pp. 144–167.

FÖLDVÁRI A. 1956: A Bakony- és Velencei-hegység löszéről. (Über die Lösse des Bakonywaldes und des Velence-Gebirges.) – Földt. Közl. 86. pp. 351–356.

HAHN, Gy. 1972: The granulometric properties of the Hungarian loesses. – Acta Geol. Hung. 16. pp. 353–358.

KÉZDI Á. 1959: Talajmechanika. (Soil mechanics.) – Budapest, Tankönyvk. 618 p.

KRIGER, N. I. 1965: Less, ego svoystva i svyaz s geograficheskoy aredoy. Moscow, Nauka. 296. p.

KRIVÁN P. 1955: A közép-európai pleisztocén éghajlati tagolódása és a paksi alapszelvény. (Distribution of the Central-European Pleistocene climate and the loess profile of Paks.) – M. Áll. Földt. Int. Évk. 43. 3. pp. 365–400.

MEZŐSI J.–DONÁTH É. 1954: A Tisza és a Maros oldott és lebegtetett anyagának vizsgálata. (Untersuchung der gelösten und schwebenden Stoffe in der Flüssen Theiss und Maros.) – Hidrol. Közl. 34. pp. 140–148.

MIHÁLTZ I. 1955: Az 1941. évi porhullás. (Über den Staubfall in Ungarn im Jahre 1941.) – Földt. Közl. 85. pp. 326–335.

MOLDVAY L. 1962: Az eolikus üledékképződés törvényszerűségei. (Gesetzmässigkeiten der Bildung von Sedimenten, die aus äolisch schwebendem Stoff abgelagert wurden.) – MTA Dunántúli Tud. Int. Értekezések. 1961–1962. pp. 37–76.

PÉCSI M. 1963: Hegylábi (pediment) felszínek a magyarországi középhegységekben. (Fussflächen in den Ungarischen Mittelgebirgen.) – Földr. Közl. 11. (87.) pp. 279–212.

PÉCSI, M. 1964: Chronological problems of the patterned soils of Hungary. – Biuletyn Peryglacjalny, 14. pp. 279–293.

PÉCSI, M. 1965: Genetic classification of the deposits constituting the loess profiles of Hungary. – Acta Geol. Hung. 9. pp. 65–84.

ROZANOV, A. N. 1951: Serozemly Srednoy Azii. Izd. AN SSSR.

SZTRÓKAY K. 1936: A Descabezado (Chile) vulkáncsoport 1932. évi kitöréséből származó vulkáni hamu kőzettani vizsgálata. (Petrographische Studien an der Asche des Vulkans Quizapu, Chile.) – Földt. Közl. 66. pp. 122–128.

TYUTYUNOV, I. A. 1960: Protsessy, izmeneniya i preobrazovaniya pochv i gornykh porod pri otritsatelnoy temperature. Izd. AN SSSR.

UNGÁR T. 1957: Üledék- és talajosztályozások összehasonlítása. (Some aspects of sediment and soil classification.) – Hidrol. Közl. 37. pp. 34–43.

VENDL A.–TAKÁTS T.–FÖLDVÁRI A. 1935: A Budapest környéki löszökről. (Studien über den Löss der Umgebung von Budapest.) – Matemat. és Természettud. Ért. 52. pp. 713–787.

VENDL A.–TAKÁTS T.–FÖLDVÁRI A. 1936: Ujabb adatok a Börzsöny hegység löszének ismeretéhez. (Über den Löss des Börzsöny Gebirges.) – Matemat. és Természettud. Ért. 54. 1. pp. 177–206.

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A NEW LITHOLOGICAL EVALUATION AND TYPOLOGY OF LOESS EXPOSURES IN TRANSDANUBIA AND ON THE DANUBE–TISZA INTERFLUVE

J. SZILÁRD

ABSTRACT

The author aims to give a new, lithologically uniform classification of loesses and loess-like deposits by weight percentages of grain distribution and evaluation of $CaCO_3$ content, and the subsequent typification of deposits on this basis. By a combination of letters and figures easily interpretable symbols are elaborated for the lithological analysis. For example $L^{II}2^6$ means medium sandy, slightly silty loess of 40–50 w% with medium $CaCO_3$ content.

On the basis of the new method it has been attempted to evaluate the loesses in Hungary. In the horizons of loess series along the Danube the analyses indicate only a minor percentage of typical loess. The detailed analyses of loess sequences in Transdanubia and on the Danube–Tisza Interfluve confirm and support with numerical data M. PÉCSI's opinion that the deeper and mainly older loess exposures present real loess series with considerable sand, silt and clay fractions. This also points to the polygenetic origin of the loess series in Hungary strongly influenced by local conditions and to the processes of subsequent transformation of loess bodies.

Loess is a special kind of deposit which has undergone soil formation of a certain degree and which covers large areas in Hungary too, mainly in Transdanubia. Loess-like deposits are also wide-spread elsewhere in Hungary. Loess regions have come to the forefront of interest because they provide favourable conditions for agriculture on the one hand and the construction and safe operation of technical establishments on loess terrains requires the comprehensive and detailed investigation of this deposit liable to compaction, collapse and rapid erosion. In Hungary, besides practical loess research, *fundamental research* including the study of material composition, origin, source area, age, stratigraphy and Quaternary history of loess and also, in broad sense, the monitoring of cyclic changes in the geographical environment arouses international interest. The numerous loess researchers abroad require the latest results of the investigation of Hungarian loess series. In the Geographical Research Institute of the Hungarian Academy of Sciences, the regular investigations of the basic loess exposures in Hungary has been going on for almost two decades. To date several internationally acknowledged achievements have been made in the description of loess series and primarily in their chronolbgical subdivisions through the application of most up-to-date methods.

A large number of data are available on the physical and chemical properties of loess and the interbedded paleosols. Information on *grain-size composition* is particularly rich. From this, acquiring a new approach, additional conclusions have been drawn and they make *the lithological classification of loesses* more precise.

1. *The first successful experimental lithological classification of Hungarian loesses based on comprehensive analyes* was presented at and approved by *the Great Hungarian Plain Congress* (MIHÁLYINÉ LÁNYI, I. 1953; KRIVÁN, P. 1953). It, however, reflects the attitude of eolian loess origin, but, nevertheless, it can serve the purposes of classification of most of the Hungarian loess varieties and loess-like deposits. At the same time, it allows us to separate loesses of common genesis by referring them into the particular fractions. This classification have been the basis of Hungarian genetic loess varieties for years and have promoted the elaboration of further classification principles.

In working out classification methods for loess and loesslike deposits and, in general, for sedimentaries, the activities of SZ. HAJÓS, M. (1954), SZÁDECZKY-KARDOSS, E. (1952), KÁDÁR, L. (1954), BÁRDOSSY, Gy. (1961), MOLDVAY, L. (1961, 1963), RÓNAI, A. (1971, 1972) and HAHN, Gy. (1977) are worth of mention. In the elaboration of the terminology of ground mechanics, the work of KÉZDI, Á. (1977) are prominent. At the geological–pedological–ground mechanical classification UNGÁR, T. (1957) made a successful attempt. He emphasized the identification and delimitation of several interval provinces of loess varieties.

In the further refinement of the lithological classification of loesses the *Committee on Loess Stratigraphy* of the INQUA is a major factor. Especially since the 1960s it has been a useful contributor and coordinator in the stratigraphic correlation of European loess sequences and in the genetic–lithologic classification of the particular loess varieties. As a result of international collaboration, the map entitled *'Distribution of loesses in Europe'* was published. It differentiates between typical loess, its sandy varieties, clay-loess, various 'loess derivates' (derasional–deluvial, fluvial and eluvial) as well as groups of various alluvial loess and loess-like deposits. In successful classification of modern and rich content, the group of Hungarian loess researchers led by PÉCSI, M., which is small in number, but busy in activity, has reached outstanding achievements. The above map of Europe was essentially compiled with regard to the categories and description of loess varieties in PÉCSI's map "Spread of loesses and loess-like sediments in Hungary" (1964) and to the principles of his *system of genetic loess classification* (1967).

The elaboration of a new method of evaluation is motivated by the absence of a uniform *lithological classification* of Hungarian loesses into exact categories, in spite of the intensive and up-to-date field and laboratory analyses. The enormous amount of information from analyses has been coupled with a maze of terminological inconsistencies. Differences are observed between evaluations of various approaches and for various agencies. Therefore, the need for a new lithological classification arose.

The new classifivation is *based on uniform categorization of loesses and loess-like deposits by weight percentages of grain distribution and on the evaluation of* $CaCo_3$ *content and it includes the subsequent typification of deposits on this basis.*

Table 1. A new lithological evaluation and classification for loess and loess-like deposits
a. *By weight percentage*

0–10	w%	–	clayey deposit (loess, clay etc.)
10.00–24.99	w%	slightly	silty
25.0–39.99	w%	medium	loessy
40 <	w%	strongly	sandy

The base deposit which gives the name is the one with the highest w%among the four components (weight percentage provinces)!

The weight percentage of the base deposit (e.g. loess) is indicated by Roman figures in the exponent as shown below.

L = 30 v%>
L^{I} = 30–40 v%
L^{II} = 40–50 v%
L^{III} = 50–60 v%
L^{IV} = 60 v%<

b. *By $CaCO_3$ content*

Ordinal in the exponent	w%	Grade
1	0–2.99	heavily and completely leached
2	3.0–4.99	medium leached
3	5.0–6.99	slightly leached
4	7.0–9.99	very slightly calcareous
5	10.0–12.99	slightly calcareous
6	13.0–18.99	medium calcareous
7	19.0–21.99	heavily calcareous
8	22.0–24.99	very heavily calcareous
9	25.0 <	$CaCO_3$ accumulation, concretion and loess marl

From the large amount of my own and other authors' grain size distribution data the weight percentages of the individual grain size classes were managed to be calculated by values which give an even more precise lithological description and subdivision of horizons in loess exposures and loess mantles of various size.

In order to specify the procedure further, a method for the combination of *letters* and *figures* to achieve an easily legible and interpreted *symbols* have also been elaborated by author. In the evaluation of the particular deposits, besides taking into account weight categories, $CaCO_3$ content is also considered in specific categories. Two examples are given below for the symbols:

$L^{II}2^{6}$ means medium sandy, slightly silty *loess* of 40–50 v% with medium $CaCO_3$ content. Similarly, the symbol is capable to demonstrate various *clay*, *silt* or *sand* deposits with coarser or finer deposits and their combinations. The *base deposit* (clay, silt etc.) is always *the one of the highest weight percentage*, while *subsidiary deposits* appear as attributes (sandy, loessy etc.) at the grades of *'heavily'*, *'medium'*, *'slightly'* in the function of their weight percentages.

Table 2. Varieties of clay, silt, loess and sand base deposits*

Clay				Silt				Loess				Sand			
base deposits															
No	si	l	sa	No	c	l	sa	No	c	si	sa	No	c	si	l
C1	S	S	S	Si1	S	S	S	L1	S	S	S	Sa1	S	S	S
C2	S	S	M	Si2	S	S	M	L2	S	S	M	Sa2	S	S	M
C3	M	S	S	Si3	M	S	S	L3	M	S	S	Sa3	M	S	S
C4	S	M	S	Si4	S	M	S	L4	S	M	S	Sa4	S	M	S
C5	S	M	M	Si5	S	M	M	L5	S	M	M	Sa5	S	M	M
C6	M	M	S	Si6	M	M	S	L6	M	M	S	Sa6	M	M	S
C7	M	S	M	Si7	M	S	M	L7	M	S	M	Sa7	M	S	M
C8	M	M	M	Si8	M	M	M	L8	M	M	M	Sa8	M	M	M
C9	S	S	H	Si9	S	S	H	L9	S	S	H	Sa9	S	S	H
C10	H	S	S	Si10	H	S	S	L10	H	S	S	Sa10	H	S	S
C11	S	H	S	Si11	S	H	S	L11	S	H	S	Sa11	S	H	S
C12	S	H	H	Si12	S	H	H	L12	S	H	H	Sa12	S	H	H
C13	H	H	S	Si13	H	H	S	L13	H	H	S	Sa13	H	H	S
C14	H	S	H	Si14	H	S	H	L14	H	S	H	Sa14	H	S	H
C15	S	H	M	Si15	S	H	M	L15	S	H	M	Sa15	S	H	M
C16	M	H	S	Si16	M	H	S	L16	M	H	S	Sa16	M	H	S
C17	M	S	H	Si17	M	S	H	L17	M	S	H	Sa17	M	S	H
C18	H	S	M	Si18	H	S	M	L18	H	S	M	Sa18	H	S	M
C19	S	M	H	Si19	S	M	H	L19	S	M	H	Sa19	S	M	H
C20	H	M	S	Si20	H	M	S	L20	H	M	S	Sa20	H	M	S
C21	M	M	H	Si21	M	M	H	L21	M	M	H	Sa21	M	M	H
C22	H	M	M	Si22	H	M	M	L22	H	M	M	Sa22	H	M	M
C23	M	H	M	Si23	M	H	M	L23	M	H	M	Sa23	M	H	M
C24	H	H	M	Si24	H	H	M	L24	H	H	M	Sa24	H	H	M
C25	M	H	H	Si25	M	H	H	L25	M	H	H	Sa25	M	H	H
C26	H	M	H	Si26	H	M	H	L26	H	M	H	Sa26	H	M	H
C27	H	H	H	Si27	H	H	H	L27	H	H	H	Sa27	H	H	H

Legend: c = clayey; si = silty; l = loessy; sa = sandy; S = slightly; M = medium; H = heavily (clayey, silty, sandy deposit; e.g. loess); C = clay; Si = silt; L = loess; Sa = sand (e.g. Cl = medium calcareous, slightly silty, slightly loessy, slightly sandy clay and so forth!)

*For the sake of completeness, the table includes all possible varieties. According to the assessment principles (see *Table 2*) the varieties from No. 1 to No. 11 are sufficient to describe the base deposit (e.g. loess) with three attributes (e.g. clayey or silty or sandy). It is not possible to refer it into higher categories, since weight percentages are over 100 per cent even if the lower limits of categories are summed up (at L12, for instance, S H H means slightly clayey (at least 10 w%), heavily silty (at least 40 w%) and heavily sandy (at least 40 w%) loess (at least 40.1 w%) equals 130.1 w%!). The grain distributions of loesses and loess-like deposits in the area under investigation (Transdanubia and the Danube–Tisza Interfluve) do not necessitate the amplification of the above frame (1–11), most of deposits even fall into the categories Nos 1–6.

RESULTS OF LITHOLOGICAL INVESTIGATIONS

1. On the basis of calculations by the new method it is claimed that in the Transdanubian loesses, primarily along the bluff of the Danube, the percentage of *loess fraction* in the *interbedded paleosols* is above 30 w% only in the C horizon, elsewhere it is generally around 25–31 w% and the clay fraction is predominant. Because of the numerous paleosols and partly transformed loess, *loessy clay* (LC) is a major component, particularly in the Paks profile (41.4 per cent).

The percentages of *clay* (C) and *loessy clay* (LC) are relatively high in the Dunakömlőd profile (34.1 per cent), while *sandy character* (Sa + SaL = 34.3 per cent) is most striking in the Dunaújváros profile. At this latter site the reason can be mentioned that young loess packets are more frequent on the surface (compared to old loess) than to the S. In the young loess series of this area, however, the clay fraction is generally superseded by sand. In these series the relatively low percentage of the grain size class finer than the loess fraction is explained by the lesser intensity of subsequent transformation (mainly clayification).

The *ratio between loess and the silted fraction (silt + sand)* (L/S) for all the profiles along the Danube is 0.5–0.9 and is some of the layers values below 0.4 also occur. This latter phenomenon is due not only to the increasing amount of clay, but also to the decrease of loess fraction in absolute figures. The explanation is that, first of all, loess material clayified.

2. *In the horizons of loess series along the Danube (disregarding paleosols)* the analyses indicate only *a minor percentage of typical loess* (were loess fraction is dominant over the other components), mostly only in the upper 10 m layer. In the Paks profile, for instance, no such horizon is observed. These facts are explained by the old age and the position of the mentioned loess series. (During most of the Pleistocene, they were located on the Mezőföld alluvial fan and, subsequently, with increasing relief, on more E marginal surfaces suitable for derasion valley cutting and mass movements on slopes). Thus, on flood-plain or in its neighbourhood or slope, coarse deposits were converted into fine or fine deposits mixed with coarse one and, during further alterations of facies, deposits coarser than loess (sand) accumulated.

3. The detailed analyes of loess sequences *in Transdanubia and on the Danube–Tisza Interfluve* provided evidence for the *high diversity* being the *most characteristic feature* of loesses in the area; it is manifest in the occurrence of exceptionally thin, almost *microstrata* (loess, clay, silt and sand fraction and $CaCo_3$ content). It goes back to soil formation, surface redeposition and erosion reasons of various rate as well as to the time factor. The analyses confirm and support with numerical data PECSI's opinion (1967) that the deeper and mainly older loess exposures present real *loess series* with, besides the loess fraction, considerable sand, silt and clay fractions. This also points to the *polygenetic* origin of the loess series in Hungary strongly influenced by local conditions and to the processes of *subsequent transformation* of loess bodies.

4. On the basis of *regional lithological analyses* concerning loess series, the earlier hypothesis is numerically verified that the present *form of appearance and nature* of loesses reflect the fundamental control of *local ecological (primarily climatic) of the not too remote past or even the present.*

When comparing the profiles investigated from the general aspect of the weight percentage of the *loess fraction* and of *$CaCO_3$ content,* the following order is set up. With regard to upper young loess packets, in the above respect, loesses in the *Tolna Hills* are the *first.* Second are the profiles along the Danubian bluff: at *Dunaújváros* and *Paks;* those in the *E part of the Szekszárd and Somogy Hills* as well as in *Mid-Transdanubia* and on the *Danube–Tisza Interfluve.*

In the *third* group, profiles along the middle section of the Danubian bluff (at *Dunakömlőd*), those in the *Baranya Hills* and in *W-Somogy* are contained. The high *loess fraction* ratio (above 60 w%) of loesses in the *flood-plains* in the Danube–Tisza Interfluve – and it is still open to debate to explain. This picture somewhat conforms to the present ecological setting.

With a view of the *percentages of deposit varieties* of the profiles in various regions, sediments referred to *loess base deposits* most often occur in the Szekszárd Hills (51.6%), immediately followed by the Somogy Hills (45.3 per cent). This value is lowest for the Tolna Hills (25.3 per cent), because of the numerous sandy varieties.

In *clayey* varieties (CL, LC) the Barany Hills is richest (38.8 per cent) and Mid-Transdanubia shows intermediate values. This type is not characteristic in the Tolna and Szekszárd Hills and in the Danube–Tisza Interfluve and *silty* varieties occur in their place. In sandy varieties the Tolna Hills excels (60.1 per cent), but similarly high values are typical of Mid-Transdanubia with abundant redeposited sediments; medium values are observed in the Szekszárd and Somogy profiles and those on the Danube–Tisza Interfluve.

The fraction coarser than loess in profiles is closely related to local lithological conditions. The measured increase of *sand fraction* related to the loess fraction (H/L = 1.8–3.5) in the plateau loesses of W-Somogy or along the Danube or on the Danube–Tisza Interfluve can be explained by the *coarser deposits of the alluvial fans* lying closer to the surface. The *overwhelming sand fraction* in the slope deposits of loess regions (50–70 w%; H/L = 3–6) is a concomitant of the stratigraphic properties of hill ranges. On hillslopes only the upper one-third is loess, the other two-thirds are sand in several places. During redeposition on the slope this sediment is mixed with loess and becomes dominant at the foot-slope (Tolna Hills, E-Outer-Somogy Hills; pediments, valley shoulders, some marginal parts of the Mountain Range as well as the Bársonyos, the vicinity of Pannonhalma where the percentage of stratified slope loesses approaches to 70 per cent).

The high percentages of *clayey* varieties is partly explained by the *accumulation conditions of loess basic material* and partly results from the earlier and present *ecological conditions* and by the subsequent transformation (into loam or clay) closely related to it (Baranya Hills).

In addition, other factors totally unknown or only partially revealed may have been responsible for the large-scale diversity, observed both horizontally and vertically, of loess varieties.

5. Most of the deposits regarded previously *solifluction loess* relying on the evidence of microscopic investigation (mainly in the Tolna–Szekszárd Hills) is, by our calculations, *sand deposits* (60–7) w% sand; H/L = 3–9). Solifluctional redeposition was alleviated by the fossil clay envelope (red clay or soil) of the sand grains described in several places.

REFERENCES

ÁDÁM L.–MAROSI S.–SZILÁRD J. 1959: A Mezőföld természeti földrajza. (Physische Geographie des Mezőföld.) – Földrajzi monográfiák, 2. Akad. K. Budapest. 514 p.

BÁRDOSSY Gy. 1961: Üledékes kőzeteink nevezéktanának kérdései. (Problems of nomenclature of sedimentary rocks.) – Földt. Közl. 91. 1. pp. 44–64.

HAHN Gy. 1977: A magyarországi löszök litológiája, genetikája, geomorfológiája és kronológiai tagolása. (Lithologie, Genetik, geomorphologische und chronologische Gliederung der Lösse in Ungarn.) – Földr. Ért. 26. 1. pp. 1–27.

KÁDÁR L. 1954: A lösz keletkezése és pusztulása. (The evolution and the devastation of the loess.) – Közlemények a Debreceni Kossuth Lajos Tudományegyetem Földrajzi Intézetéből. 2. pp. 1–27.

KÉZDI Á. 1977: Talajmechanika. (Soil mechanics.) Tankönyvk. Budapest. 618 p.

KRIVÁN P. 1953: A pleisztocén földtörténeti ritmusai. (Rhytms in the Pleistocene period of Earth's history.) – In: Alföldi kongresszus. Az Alföld földtani felépítésének kérdései. Akad. K. Budapest. pp. 71–81.

MIHÁLYINÉ LÁNYI I. 1953: A magyarországi löszváltozatok és egyéb hullóporos képződmények osztályozása. (Classification of loess varieties and other formations of falling dust in Hungary.) – In: Alföldi kongresszus. Az Alföld földtani felépítésének kérdései. Akad. K. Budapest. pp. 5–17.

MOLDVAY, L. 1961: On the laws governing sedimentation from eolian suspensions. – Acta Univ. Szegediensis, Ser. Min. Petrogr. 14. pp. 75–100.

MOLDVAY L. 1962: Az eolikus üledékképződés törvényszerűségei. (Gesetzmässigkeiten der Bildung von Sedimenten, die aus äolisch schwebendem Stoff abgelagert wurden.) – MTA Dunántúli Tud. Int. Értekezések, 1961–62. pp. 37–76.

PÉCSI, M. 1964: Spread of loesses and loess-like sediments in Hungary. (Map.) – In: M. PÉCSI: Ten years of physicogeographic research in Hungary. – Studies in geography. 1. Akad. K. Budapest. Fig. 12, facing page 24.

PÉCSI M. 1967: A löszfeltárások üledékeinek genetikai osztályozása a Kárpát-medencében. (Genetical classification of sediments of loess-exposures in the Carpathian Basin.) – Földr. Ért. 16. pp. 1–18.

RÓNAI A. 1971. A Tiszavölgy felszíni üledékei. (Surface sediments in the Tisza Valley.) – Hidr. Közl. 51. 8–9. pp. 368–375.

RÓNAI A. 1972: Negyedkori üledékképződés és éghajlattörténet az Alföld medencéjében. (Quartärsedimentation und Klimageschichte im Becken der Ungarichen Tiefebene.) – MÁFI Évk. 56. 421 p.

SZÁDECZKY-KARDOSS E. 1952: Ujabb irányzatok az üledékes kőzetek rendszerében. (Nouvelles tendences de la classification des roches sedimentaires.) – Földt. Közl. 82. pp. 227–236.

SZ. HAJÓS M. 1954: Üledékes kőzetek nevezéktana és leírásmódja. (Nomenclature et forme de description des roches sédimentaires.) – MÁFI Évi Jel. 1952-ről. pp. 183–188.

UNGÁR T. 1957: Üledék- és talajosztályozások összehasonlítása. (Some aspects of sediment and soil classifications.) – Hidr. Közl. 37. 1. pp. 34–43.

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SOIL MOISTURE INVESTIGATIONS ON THE LOESS-COVERED SLOPES OF THE TOKAJ AREA

P. CSORBA

ABSTRACT

An eight month-long investigation was carried out in order to determine the soil moisture characteristics of the loess-covered slopes of the Tokaj wine-district. Several soil-samples were weighted to calculate the actual moisture content, from which the chrono-isopleths of the area were drawn (*Fig. 2–6*).

The considerable variations soil-wetness in March were primarily accounted for by differences in exposure. Desiccation during spring is rapid everywhere, and the moisture content drops below 10% by the end of May. Even the largest amounts of summer precipitation hardly change the low moisture content of the subsoil. By means of chrono-isopleth data we can detect the infiltration front as it moves downslope.

Autum rainfalls soaks the layers round 1 m in depth only by the end of November.

Chrono-isopleth data give very rich information about the hydrokinetic characteristics of loess.

The Tokaj wine-district is the most famous viticultural region in Hungary. It lies at the *northern climatic fringe of vine cultivation* and the best quality grapes are grown on the steep slopes covered by loess or volcanic regolith. Resulting from the above two conditions cultivation is *endangered by a number of physico-geographical and meteorological factors.* Soil erosion is significant, serious damage is caused by drought and, at times, there are heavy frosts. Although production is more secure on the gentle slopes, the quality of grapes they produce is poorer.

Researchers from the Geographical and Meteorological Institutes of L. Kossuth University have been performing for a number of years observations and experiments that can supply useful data for the development of grapevine cultivation.

In the present paper we report on the results of investigations into soil moisture undertaken in 1979, which aimed at, answering the following questions:

1. How does soil moisture content change from desiccation in spring to permeation in autumn?
2. What are the characteristic changes that take place in soil moisture content and water movement in soils exhibiting different mechanical conditions?
3. What is the connection between the infiltration of precipitation and the humidity of deeper soil horizons?
4. How is the humidity of the soil influenced by the steepness and different exposure of slopes?
5. What is the effect of the vegetation cover?

The present work was carried out *between March 20 and November 20,* 1979. *Soil samples were taken* from Fináne-hill near Tokaj at irregular intervals, as precipitation conditions permitted, but *at least once every 3 weeks.* The 0.1–0.15 kg soil samples were collected from two altitudinal levels on the 290 m high hill which is covered with a 10–15 m thickness of typical loess. The samples were taken from four exposures, as well as from the summit of the hill at depths of 5, 10, 15, 20, 30, 40, 50, 75 and 100 cm. These were weighed on the day of sampling, and the original moisture content of the sample was calculated from the difference in weight after a few days, drying at 105 °C. Chrono-isopleths were then plotted on the basis of the sample results.

From the pedological and ecological view points the sampling sites are characterized by the following properties. Vines are grown on the summit of hill and on the eastern and southern slopes, although there are many long-abandoned plots everywhere. *The average slope angle is 25 -30°.* The western and northern slope are covered by a grass-scrub and forest-brushwood vegetation respectively. The cultivation of vines takes place on continuously eroded typical loess, in which the proportion of the *loess fraction of grain size* 0.02–0.05 mm is *50–55%,*while the silt and clay fractions amount to 30–35% *(Fig. 1). No essential difference in grain-size composition between the soils of the cultivated and recently abandoned plots was observed.* On the other hand, on the northern and western slopes, on which there has been no tillage for many decades, slow humification has begun on the loess surface. Here the silt and clay content of the near-surface soil samples reaches 40–45%. The secondary maximum of the grain-size composition curve is indicative of a slow down slope translocation of soil material.

Nevertheless the soils of the sampling area preserved the characteristics of loess everywhere, with the proportion of grains coarser than 0.05 mm never reaching 15%. The mechanical composition of the surface layer of the *northern slope* reflects recent natural ecological conditions, with *autochtonous humification* taking place in a slightly *cooler mesoclimate* on overgrown slopes.

The air temperature and precipitation data for the measurement period are denoted together with the dates of sampling on the chrono-isopleth figures. As the meteorological data show, *1979 was slightly warmer* and, especially at the end of the summer, drier than the long-term average.

Air temperature:	March–November 1931–60	: 13.9 °C
	March–November 1979	: 14.6 °C
Precipitation:	March–November 1901–40	: 506 mm
	March–November 1979	: 327 mm

The most important data that can be read from the chrono-isopleth data are as follows. The soils show *considerable differences in humidity in March,* which is primarily a result of differences in exposure, i. e. snowmelt is considerably slower in the lower air tempe-

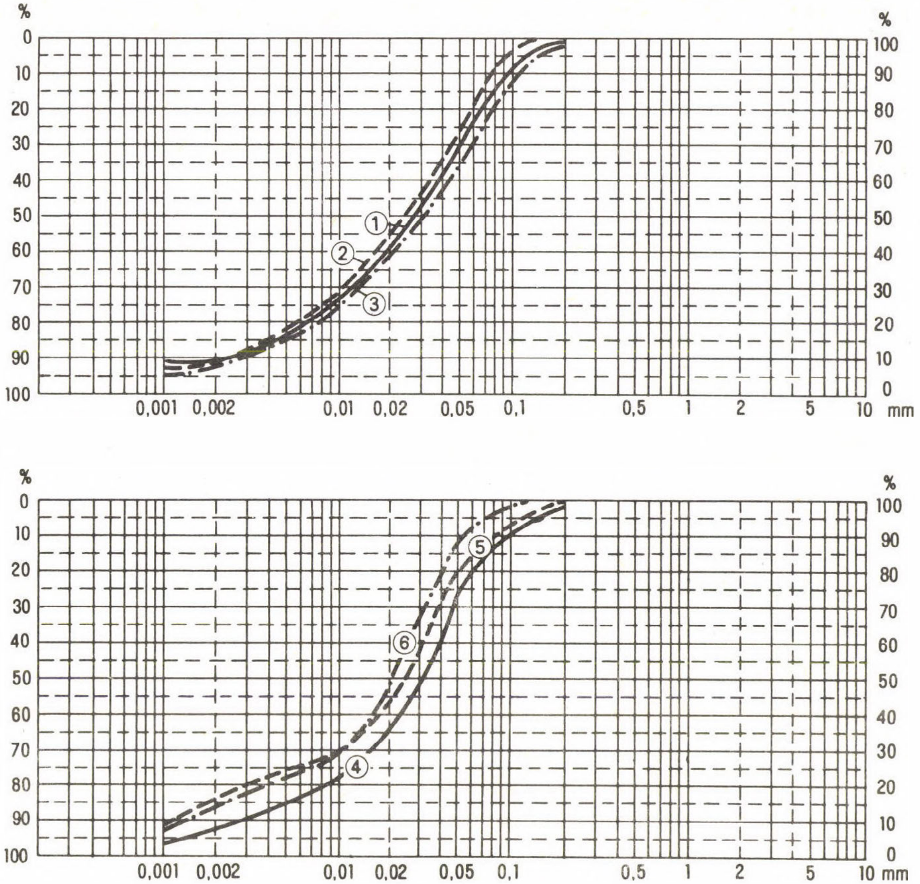

Fig. 1. Grain-size distribution of the soil-samples
1 = E-slope, 5 cm (higher altitude level);
2 = Summit of the hill, 30 cm;
3 = S-slope, 50 cm (lower altitude level);
4 = W-slope, 5 cm (higher altitude level);
5 = W-slope, 30 cm (higher altttude level);
6 = N-slope, 30 cm (lower altitude level);

ratures of the more humid northern slope, and moisture infiltration keeps these soils more humid (*Fig. 2–6*).

On the other hand *spring-time desiccation is rapid everywhere,* and *moisture content drops* by the end of May and early *June* to below 10%. It is worth mentioning that this low moisture content – at levels deeper than 20–30 cm – hardly changes until permeation begins in autumn. The low moisture content of the subsoil is uneffected even by large amounts of summer precipitation, i. e. even by 15–20 mm of a low intensity rainfall. The same conclusion can be drawn from the data obtained at the sampling site on the summit, although here precipitation occurs on a horizontal surface overgrown by tall grass.

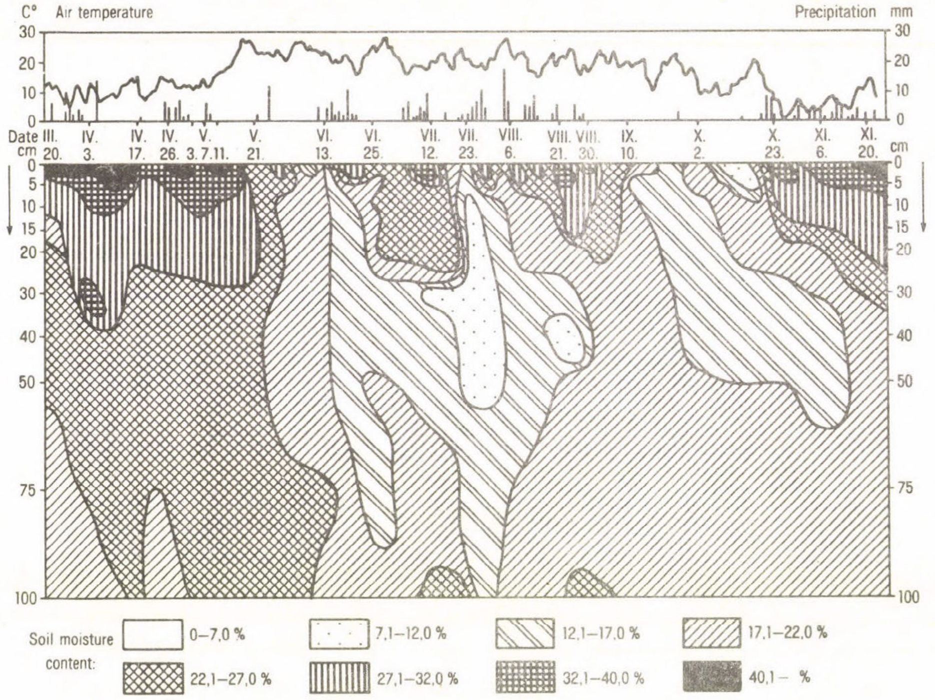

Fig. 2. Chrono-isopleth data for sampled site: N-slope, lower altitude level

Even prolonged, slow infiltration could increase humidity, by only a few per cent, and only in the upper 20–30 cm layer. *All that the summer rains can prevent is the further desiccation of the subsoil* by soaking the surface layers. In any case, the infiltration of precipitation falling on a horizontal surface shows a different dynamic to that received by *sloping terrain*, where one can easily demonstrate *the infiltration front moving downslope*. The northern slope with its more clayey soil and rich soft-stem vegetation always contains a higher moisture content, although the trend and time of springtime desiccation and autumn permeation produce chrono-isopleths similar to those of other sampling sites.

Autumn precipitation, due to a lower air temperature and therefore less moisture loss due to eveporation, initially *soaks the upper soil layers surprisingly slowly*, and a *considerable change* in the moisture content at depths of round 1 m is only brought about by in November and December, when the precipitation also contains snow.

Chrono-isopleth data provide very rich information, which have enabled the author to answer the questions posed at the outset of the investigation. It has been proved that the replacement of moisture due to a deficiency of precipitation is necessary even on loess, which is characterized by good vertical hydrokinetic properties, and that the shortage of moisture in the subsoil is greatest in September.

In other words, the *exact determination of the hydrokinetics of loess* and humified loess we can obtain data very *important for the optimization of irrigation.*

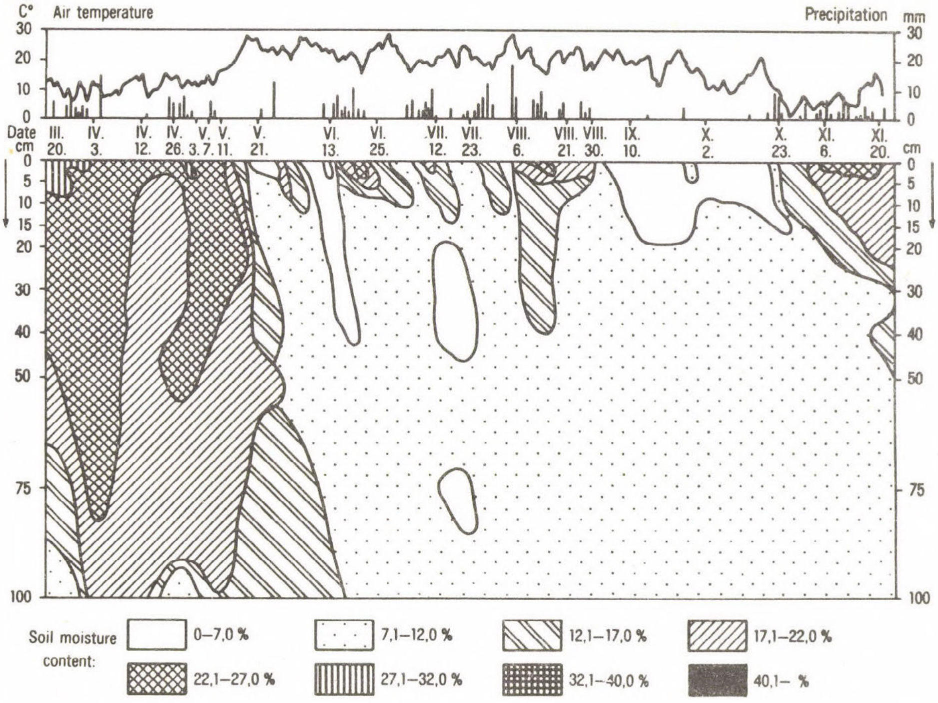

Fig. 3. Chrono-isopleth data for sampled site: top of the hill

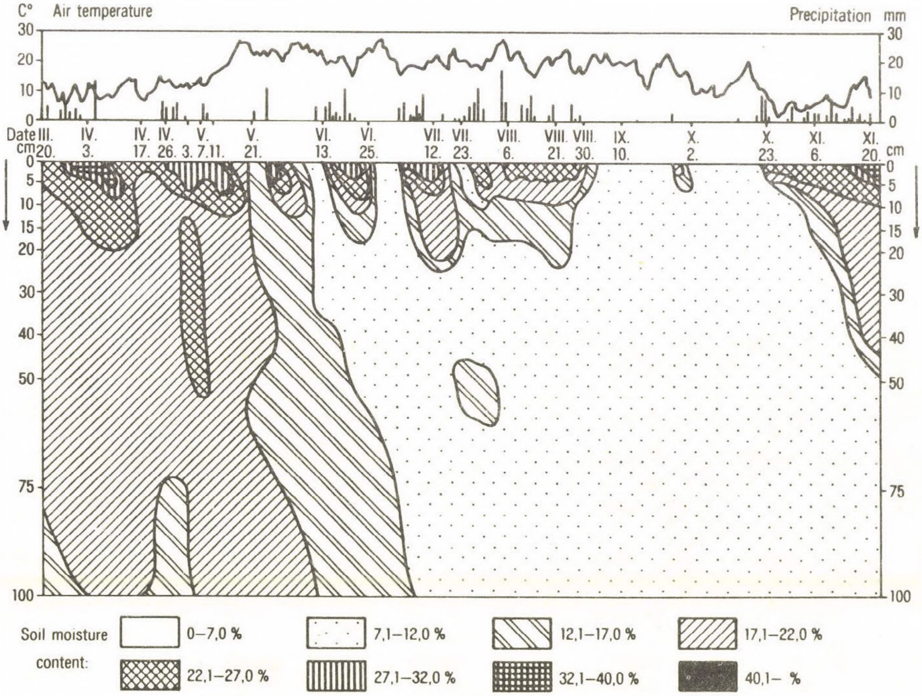

Fig. 4. Chrono-isopleth data for sampled site: W-slope, higher altitude level

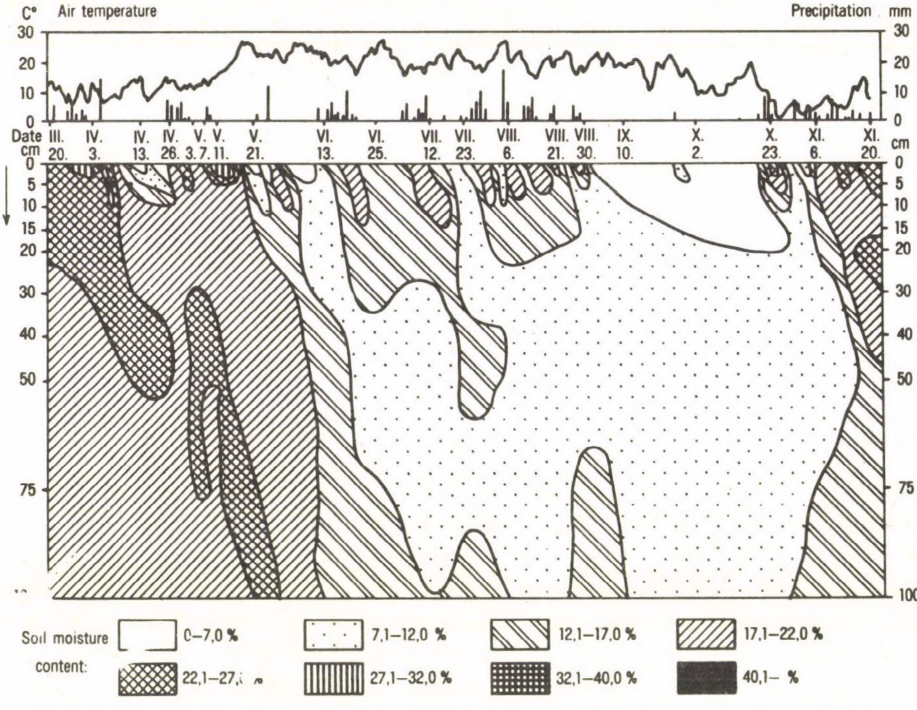

Fig. 5. Chrono-isopleth data for sampled site: E-slope, higher altitude level

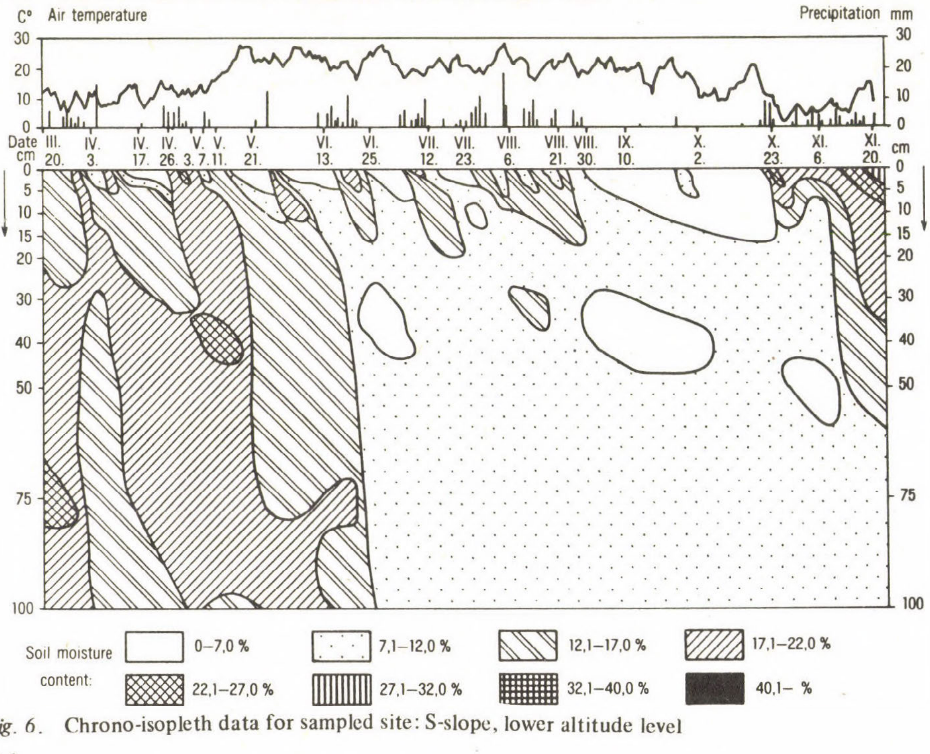

Fig. 6. Chrono-isopleth data for sampled site: S-slope, lower altitude level

REFERENCES

JUSTYÁK, J. 1967: Données sur le bilan hydrologique des vignes cultivées par irrigation. Adatok az öntözött szőlőültetvény vízgazdálkodásához. – Acta Geogr. Debrecina, 12–13. (1966–1967) pp. 114–148.

JUSTYÁK, J. 1981: A makro-, mezo- és mikroklíma néhány jellemzője Tokajhegyalján. (Einige Kennzeichen des Makro-, Meso- und Mikroklima von Tokajhegyalja. Summary in German.) – In: Einige Eigentümlichkeiten der Geoökologischen Verhälnisse des Gebietes von Tokajhegyalja. Ed: Borsod-Abaúj-Zemplén megyei Tanács. pp. 13–46.

PÉCSI, M. 1982: The most typical loess profiles in Hungary. – In: Quaternary Studies in Hungary. Geogr. Res. Inst. Hung. Acad. Sci. Budapest, pp. 145–169.

PINCZÉS, Z. 1968: Vonalas erózió a Tokaji-hegy löszén. (Linear erosion on the loess of the Tokaj Mountain.) – Földr. Közlem. 16. (92.) pp. 159–171.

PINCZÉS, Z. 1972: Die Formen der Bodenerosion und der Kampf gegen sie im Weingebiet des Tokajer Berges. – Acta Geogr. Debrecina, 10. pp. 63–70.

PINCZÉS, Z.–KERÉNYI, A.–ERDŐS-MARTON, K.–CSORBA, P. 1980: Judgement of the danger of erosion through the evaluation regional conditions. – In: Soil conservation. Ed. R. P. C. Morgan. Wiley, Silsoe, Bedford UK. pp. 87–103.

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